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The 2011 Inter-sessional Science Board Meeting: A Note from Science Board Chairman

The inter-sessional Science Board meeting (ISB-2011) was held on April 29–30, 2011, in Honolulu, back to back with other three important meetings. These were: a FUTURE workshop on "*Indicators of status and change within North Pacific Marine Ecosystems*" (April 26–28), a meeting of the PICES/ICES Study Group on *Developing a Framework for Scientific Cooperation in Northern Hemisphere Science* (morning of April 29), and a meeting of the PICES Study Group on *Upgrading the PICES Strategic Plan* (May 1). I wish to thank Dr. Samuel Pooley, the former U.S. national delegate to PICES Governing Council, for inviting us to Honolulu. Thanks are also due to our colleagues from ICES (International Council for the Exploration of the Sea) and other guests who participated in the workshop, the Science Board meeting and Study Group meetings. I welcome new Committee Chairmen, Drs. Kyung-Il Chang (Physical Oceanography and Climate Committee, POC), Toru Suzuki (Technical Committee on Data Exchange, TCODE) and Atsushi Tsuda (Biological Oceanography Committee, BIO). Before continuing with my report on ISB-2011, I express my condolences to the Japanese people for the losses and damages incurred from the disastrous earthquake and tsunami that occurred on March 11. Some comfort can be drawn from the fact that all the PICES scientists and their families in Japan are safe and well.

This is an important time for FUTURE (*Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems*), the integrated science program of PICES, as it enters its second year. Last year we identified the gaps in advancing FUTURE science and planned new expert groups to fill some of these gaps. At the 2010 PICES Annual Meeting (PICES-2010), three new working groups were proposed but only one, the Working Group on *Jellyfish Blooms around the North Pacific Rim: Causes and Consequences*, was approved by Council. The other two groups were: the Working Group on *Ecosystem Responses to Multiple Stressors* and Working Group on *North Pacific Climate Variability and Change*. They aimed to tackle FUTURE Key Questions, which can be described by key words such as resilience and vulnerability of ecosystems, multiple stressors, ecosystem responses, and uncertainty in ecosystem assessment and forecasting. The reason why the proposals were turned down was that their scope and terms of reference were not clear enough. Under these circumstances, the purpose of the 3-day FUTURE Workshop, convened by Drs. Thomas Therriault (AICE-AP; Canada), Jacquelynne King (COVE-AP; Canada) and Sachihiko Itoh (Japan), was to clarify our understanding of ecological indicators as a common means to address the key words listed above. The workshop was well attended

In This Issue

ISSN 1195-2512

(55 invited participants from within and outside of the PICES community), and exciting talks and lively discussions were conducted. Through these discussions, some concepts were refined, which led to revising the terms of reference for the Working Group on *Ecosystem Responses to Multiple Stressors*. A framework was put in place to indentify ecosystem indicators and to select criteria to be used in their identification for assessing and comparing changes/impacts in North Pacific ecosystems. On the other hand, the issue of ecosystem resilience and vulnerability turned out to be a difficult one to address at this stage. These concepts are poorly defined and may require intense research in the future. You can read a detailed report on the workshop from the convenors in this issue.

ICES and PICES are two major international marine science organizations in the Northern Hemisphere, sharing many common scientific issues. In the past 10 years, there have been significant increases in reciprocal exchanges, cooperative sponsorships of scientific meetings and projects, and deeper linkages that have often developed on a case-by-case basis. Now, there is a need to build a formal framework for cooperation between ICES and PICES to serve as the basis for linkages of our science plans and longer-term strategic planning. This has resulted in forming a joint PICES/ICES Study Group on *Developing a Framework for Scientific Cooperation in Northern Hemisphere Marine Science* (SG-SP). The Study Group met for the first time at the ICES Annual Science Conference in September 2010 to initiate the discussion. In Honolulu, all SG-SP members met again to discuss how to finalize the Group's activities. They discussed the problems of establishing joint expert groups under different organizational structures and reviewed, as a model case, the progress made by the joint PICES/ICES Working Group on *Forecasting Climate Change Impacts on Fish and Shellfish* (WG-FCCIFS). As the end of its term draws near, a proposal is being made to extend WG-FCCIFS's life span and scope (more about this later). Discussions also took place on the procedures of PICES/ICES cooperation in general and how to monitor these activities. A draft SG-SP report will be prepared this summer and presented at the Annual Meetings of each Organization later this year.

The Science Board meeting dealt with various issues. The first agenda item was on interactions with other international organizations and programs that have steadily intensified in the past years. A good example is our collaboration with ICES, as mentioned above. We also discussed and approved joint activities and future plans for collaboration with IOC (Intergovernmental Oceanographic Commission of UNESCO), SCOR (Scientific Committee on Oceanic Research), IMBER (Integrated Marine Biogeochemistry and Ecosystem Research), LOICZ (Land-Ocean Interactions in the Coastal Zones), SOLAS (Surface Ocean – Lower Atmosphere Study) and GACS (Global Alliance of CPR Surveys). I expect that cooperation with these and other international organizations and programs will continue to be strengthened.

PICES, jointly with ICES and IOC, is co-sponsoring the 2nd International Symposium on "*Effects of climate change on the world's oceans*" to be held May 15–19, 2012, in Yeosu, Korea (http://www.pices.int/climatechange2012.aspx). The Chairman of the Local Organizing Committee for the symposium, Dr. Dosoo Jang (KORDI), briefed Science Board on the status of preparations for this event. He also invited PICES to review and comment on the content of the Yeosu Declaration. This Declaration is an official statement of Yeosu Ocean Expo-2012 for which the above-mentioned symposium is an opening act. The comments gathered later from Science Board were passed to the International Review Committee for the Declaration and contributed significantly to its revision.

One of the routine, but important, agenda items of ISB-2011 was for the Committees to present reports on their activities since PICES-2010. We reviewed the pursuits of each Committee's subsidiary bodies on preparation of their work plans and reports, planning of workshops, sending representatives to outside meetings, and budgetary issues. I am happy to say that all the Committees are doing well, except for a few delays.

Sinjae Yoo (back to the camera), wearing the hat of Co-Chairman at the meeting of the joint PICES/ICES Study Group on Developing a Framework for Scientific Cooperation in Northern Hemisphere Marine Science, Skyping with Anne Hollowed, Co-Chairman of the PICES/ICES Working Group on Forecasting Climate Change Impacts on Fish and Shellfish.

Capacity building has always been a high priority issue for PICES. Several events are to be sponsored by PICES in 2011–2012:

- The training workshop on "*Rapid assessment survey methodologies for detecting non-indigenous marine species*", organized jointly with IOC/WESTPAC, will take place from July 19–21, 2011, in Phuket, Thailand. Funding for this workshop is from the PICES project on "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*", supported by the Ministry of Agriculture, Forestry and Fisheries of Japan. More than 30 applications for participation have been received from 10 countries, mostly from Southeast Asia, and the list of attendees is being finalized.
- The 5th International SOLAS Summer School, a biennial, international event teaching a variety of fields, will be held from August 29 to September 10, 2011, in Corsica, France (http://solas-int.org/summerschool/welcome.html). PICES will sponsor three early career scientists (one from Canada, one from China and one from USA) to join the school.
- The NOWPAP/PICES/WESTPAC training course on "*Remote sensing data analysis*" will be organized from October 8–12, 2011, in Vladivostok, Russia (http://cearac.nowpap.org/monitoring/3rdRST/1st_Announcement.html). PICES will provide support for one guest lecturer and three trainees from the Northwest Pacific to attend the course.
- One important joint enterprise between PICES and ICES is the Early Career Scientist (ECS) conference. This is to encourage the next generation of ocean scientists from the North Atlantic and North Pacific meet early in their career to share knowledge and to build networks across disciplines and international borders. The first ECS conference was held in 2007 near Baltimore, USA. The second one titled "*Oceans of change*" will take place from April 24–27, 2012, in Majorca, Spain (http://www.ices.dk/marineworld/oceans/index.asp).

Science Board briefly discussed potential capacity building activities for 2013. In the past, PICES-sponsored summer schools have been organized in Asia (two in Korea and one in Japan), and discussions are being initiated on the possibility of holding one in North America in 2013. However, it is too early to say which side of the Pacific the school will take place, as proposals are being prepared for both sides. We will learn more about this at PICES-2011.

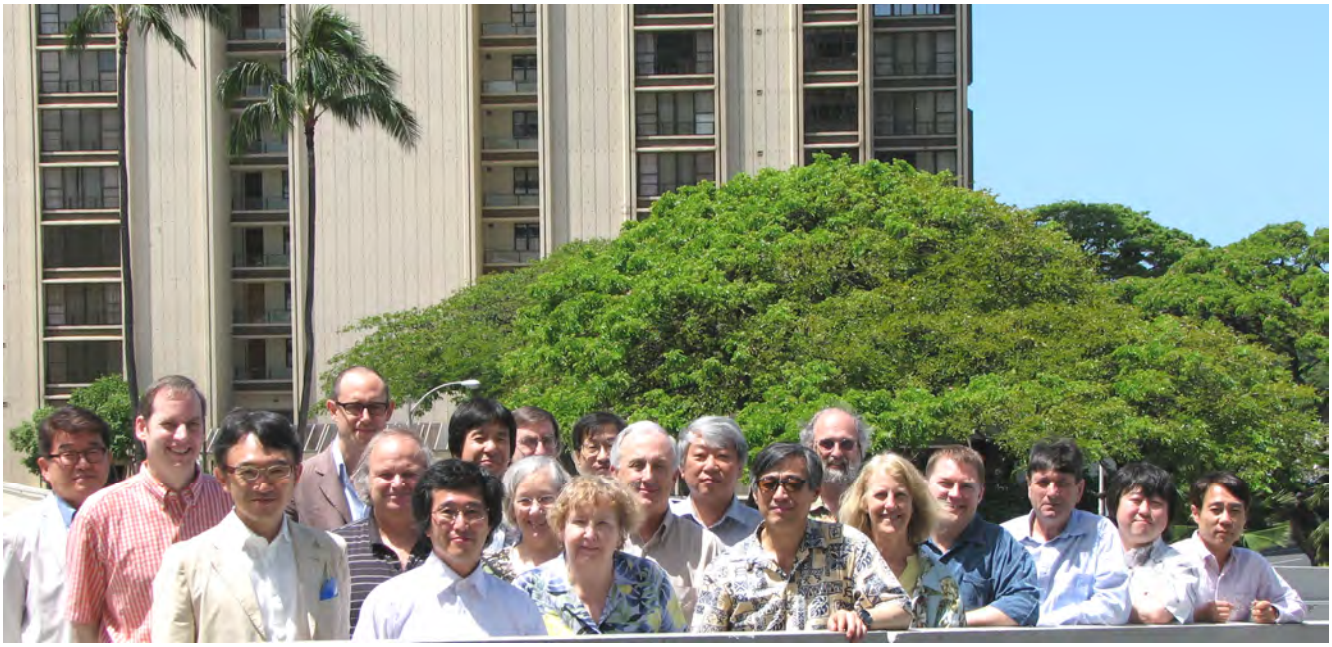
Another annual routine for Science Board is to decide on the recipients for PICES awards. Science Board met *in camera* to select a recipient for the 2011 Wooster Award (http://www.pices.int/Wooster_Award/default.aspx) and for the 2011 PICES Ocean Monitoring Service Award (POMA; http://www.pices.int/awards/POMA_award/POMA_award.aspx). The decisions were made, but we cannot reveal the names until the Opening Session at PICES-2011.

Science Board also discussed the feasibility of having a FUTURE Open Science Meeting (OSM) in the spring of 2013 as FUTURE will be nearing its mid-life by that time. It was agreed that the FUTURE Advisory Panels will look into potential themes and format for the OSM.

The Science Board meeting in session.

There were presentations on the damages from the March 11 great earthquake and tsunami in northeastern Japan and early monitoring activities on radioactive contamination. Dr. Tokio Wada, Past-Chairman of PICES, expressed his deepest thanks to all PICES member countries, PICES scientists and the Secretariat for their support in the aftermath of the destructive tsunami. He also thanked PICES and ICES for their joint donation of $55,000, and informed Science Board that the Japanese Society of Fisheries Oceanography (JSFO) was identified as the recipient of the donation that will be used as a core contribution for a PICES/ICES/JSFO fund to support the fisheries and oceanographic research in the areas affected by the Great East Japan Earthquake. Dr. Wada also stated that there was great concern about the environmental degradation in the area impacted by the tsunami, and of radioactive leakage from the Fukushima nuclear power plant into the atmosphere and ocean. Although Japanese scientists were actively monitoring the affected area, the understanding of the impact of radioactivity in the ocean and what mitigation measures to take was limited at this time. The four presentations made by Drs. Taro Ichii (Fisheries Agency of Japan), Hiroaki Saito (Fisheries Research Agency of Japan), David Detlor (NOAA, USA), and Oleg Katugin (TINRO, Russia), based on *in-situ* surveys and modeling efforts, indicated that the level of contamination in seawater and fish was insignificant at this stage, except in the vicinity of the nuclear plant. During the discussion that followed, suggestions were made for the Marine Environmental Quality (MEQ) and MONITOR Committees to consider if it is desirable/ feasible to launch a coordinated monitoring of impacts of various stressors related to tsunami and radioactive contamination. We will re-visit this issue at PICES-2011.

With Science Board being the Steering Committee for FUTURE, a half day of ISB-2011 was dedicated to various



Participants on the last day of the Science Board meeting, from left: Chul Park, Thomas Therriault, Hiroaki Saito, Emanuele Di Lorenzo, Robin Brown, Hiroya Sugisaki, Atsushi Tsuda, Alex Bychkov, Laura Richards, Vera Alexander, Tokio Wada, John Stein, Kyung-Il Chang, Sinjae Yoo (author of this article), Steve Rumrill, Pat Livingston, David Detlor, Mikhail Stepanenko, Toru Suzuki and Taro Ichii.

issues related to the program. From the FUTURE perspective, the major outcome from ISB-2011 is that at the recommendation of Science Board, Governing Council approved the two new expert groups, Working Group on *North Pacific Climate Variability and Change* and Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors* (note that the title has changed slightly), to support activities of the program. The membership for these groups is now being finalized.

I am pleased to say that there are possibly two more expert groups on the way. The first one is the joint ICES/PICES Strategic Initiative on *Climate Change and Marine Ecosystems* (SICCME). This is a sequel to the very successful WG-FCCIFS which I mentioned earlier. We envision a longer life span and a wider scope for this expert group, covering basic FUTURE elements such as the forecasting of ecosystem change and response of human society. As such, it is likely to become a Section within the PICES structure. This group will not only foster our collaboration with ICES, but will also contribute to FUTURE. One concern is how to juxtapose this group with other expert groups, maximizing complementariness while avoiding overlaps. To resolve the issue, the FUTURE Advisory Panel Chairmen will work with SICCME leadership on preparing its implementation plan. The second potential new group is the Working Group on *Human Dimensions for Environmental Change*. The Study Group on *Human Dimensions* has done a pilot study by reviewing the role of social science practices applied for decision-making in PICES member countries' marine sectors, focusing on ecosystem-based fisheries management. Based on this, they will recommend the terms of reference for the new Working Group to deal with, among other things, conducting long-term engagement and communication activities between scientists, decision makers, stakeholders, and across sectors. I expect that these two expert groups can be approved at PICES-2011 and with this, FUTURE will have a good number of workhorses.

On May 1, the Study Group on *Updating the PICES Strategic Plan* (SG-USP) met to draft revisions to the Strategic Plan. This Plan was developed and approved in 2004, and there has been an urgent need to update it in the light of changes that have taken place since then, such as the implementation of FUTURE, and to ensure that the Plan reflects the vision of all Contracting Parties for the direction of PICES over the next 5–10 years. At the end of the day, the Group nailed down most of the paragraphs. The revisions to the Plan will be finalized at PICES-2011.

Finally, PICES-2011 will be held from October 14–23, 2011, in Khabarovsk, Russia. Many interesting sessions and workshops, covering a wide range of topics, are planned. I have never visited Khabarovsk but heard it is a picturesque city at the confluence of the Amur and Ussuri Rivers in the Russian Far East. I would like to remind you that everyone needs an invitation letter from the government of Khabarovsk to obtain a Russian visa, and it is best to start the process soon. You can find information on visa and other logistics for the meeting on the PICES website. See you all in Khabarovsk!

Sinjae Yoo
Science Board Chairman

Indicators for Status and Change within North Pacific Marine Ecosystems: A FUTURE Workshop

by Jacquelynne King and Thomas Therriault

A 3-day workshop on "*Indicators of status and change within North Pacific marine ecosystems*" was held April 26–28, 2011, at the East-West Center (University of Hawaii), Honolulu, USA. The workshop was co-convened by Sachihiko Itoh (Japan), Jacquelynne King (COVE-AP; Canada), and Thomas Therriault (AICE-AP; Canada) and was very well attended, with over 50 participants, including 14 contributors. With the support of PICES, 4 invited speakers, Marta Coll Mónton (Institute of Marine Science, Spain), Jake Rice (Fisheries and Oceans Canada), Beth Fulton (Commonwealth Scientific and Industrial Research Organisation, Australia), and Sarah Gaichas (Alaska Fisheries Science Center, USA) gave provoking presentations on the three main workshop themes: (1) Ecosystem-level indicators and assessments, (2) Ecosystem resilience, and (3) Indicator uncertainty. The workshop was organized by the FUTURE Advisory Panels (AICE – *Anthropogenic Influences on Coastal Ecosystems*, COVE – *Climate, Oceanographic Variability and Ecosystems*, and SOFE – *Status, Outlooks, Forecasts, and Engagement)*, and its main goal was to impart existing approaches and concepts to the PICES community in order to provide direction on elements of the FUTURE Science Plan.

Ecosystem-level indicators and assessments

The selection and assessment of ecosystem-level indicators has been conducted by a number of collaborative programs and initiatives elsewhere, and Marta Coll Mónton provided a thorough background on the Indicator of the Seas Project (IndiSeas), which was launched in 2005 under the auspices of the EUR-OCEANS Scientific Programme as a follow-up to the SCOR/IOC Working Group 119 on *Quantitative Ecosystem Indicators*. The intent of this project was to evaluate the effects of fisheries on different marine ecosystems using a panel of ecological indicators, and to facilitate effective communication of potential ecological changes. Indicators were selected based on four criteria: (1) ecological significance (*i.e.*, are the underlying processes essential to the understanding of the functioning and structure of marine and aquatic ecosystems?); (2) measurability: availability of data required for calculating these indicators; (3) sensitivity to fishing pressure; and (4) awareness of the general public. In the IndiSeas approach, local experts play a critical role, especially interpreting indicator outputs.

Participants of the 2011 FUTURE workshop outside of the East-West Center, University of Hawaii, Honolulu, USA.

In the European Union (EU), the Marine Strategy Framework Directive has tasked Member States with developing marine strategies to achieve good environmental status by managing human pressures/drivers in order to protect and preserve the marine environment and prevent/reduce adverse inputs to the marine environment (Begoña Santos, Instituto Español de Oceanografía, Spain). Eleven descriptors of good environmental status have been identified, and ICES has been tasked to help select indicators to summarise information for management by 2012.

A pilot study in Toyama Bay, Japan, has been established to develop a new marine environmental assessment methodology which has two purposes: comprehensively assessing the marine environment and creating a suitable environment for marine life, including the restoration of degraded environments (Takafumi Yoshida, Northwest Pacific Region Environmental Cooperation Center, Japan).

In 2010, the Alaska Fisheries Science Center undertook a new approach for its annual ecosystem assessment for the eastern Bering Sea (Stephani Zador, Alaska Fisheries Science Center, USA). An interdisciplinary team of experts identified potential concerns for fishery management and endangered species issues and selected broad community-level indicators of ecosystem-wide productivity that were most informative for managers. These included the North Pacific Index, Eastern Bering Sea ice retreat, aggregate biomass indices for zooplankton, epifauna, benthic foragers, pelagic foragers, fish apex predators, fur seal pup production, thick-billed murre reproductive success, and bottom trawl disturbance.

A number of parameters or ecosystem components could serve as integrative indicators of ecosystem change, and at the workshop two presentations were given on this topic. The first showed how natural stable isotope levels in higher tropic-level animals could provide an integration across trophic levels of ecosystem changes (Thomas Kline, Prince William Sound Science Center, USA). Isotope records provide spatial and temporal variation due to climate change, recruitment, and growth rate. Similarly, another integrative indicator could be gelatinous zooplankton (Hiroaki Saito, Fisheries Research Agency, Japan). In the Kuroshio Extension Region, filter-feeding gelatinous zooplankton composition appears to be a potential indicator of zooplankton succession and nutrient depletion.

Irrespective of how indicators are selected, their performance must be tested, especially for application to management (Jake Rice). Indicators need to represent the true properties that they are meant to measure, track progress in meeting objectives, respond to change, and inform decision-making. Performance testing of indicators can be undertaken with retrospective modeling and analysis, scenario modeling and analysis, management strategy evaluation or formal decision analysis.

Isaac Kaplan (Northwest Fisheries Science Center, USA) highlighted that whether indicators are used to detect status and change or to make regional comparisons, the spatial scale of the underlying processes must be taken into account. Many ecosystem attribute–indicator relationships that are strong at a coast-wide scale break down at regional or local scales, and indicators must represent the processes at the appropriate spatial scale.

FUTURE workshop in session.

Ecosystem resilience

The concept of ecosystem resilience features prominently in the FUTURE Science Plan and is specified in one of the key research questions: "*What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?*". Forecasting the response of ecosystem resiliency and vulnerability to stressors could involve ecosystem indicators that measure these attributes. However, there were no contributed papers to this theme of the workshop. Beth Fulton outlined some of the difficulties in measuring ecosystem resilience and vulnerability, namely, that ecological resilience is difficult to assess and measure *a priori* and is often known only after the fact. She defined ecosystem resilience as the level of disturbance before the system changes to an alternate state. Resilience is a feature of the ecosystem controlled by internal system dynamics, such as predator–prey relationships, rather than a state of the ecosystem. A state will have variability defined in space and time, and key to resilience are thresholds, past which a system may be perturbed into an alternate state. The difficulty will be in indentifying the possible alternate states; however, it might be possible to identify threshold points based on observation or modeling. Methods of comparing current system states to threshold values include: (1) case studies of observed alternative system states (*e.g.*, anchovy *vs.* sardines), (2) experiments or active adaptive management, (3) exploration with ecosystem models,

(4) mapping alternate ecosystem habitats, (5) mapping ecotones (*i.e.*, edges of ecosystems) and species groupings at critical process spatial scales, and/or (6) measuring diversity as a surrogate for resilience. It is important to note that management can degrade an ecosystem's resilience, further complicating the issue.

Indicator uncertainty

Measuring and reporting uncertainty in indicator values is relevant when there are threshold points or reference levels, although thresholds are lacking for a number of indicators (Sarah Gaichas). Indicator uncertainty arises from field monitoring, statistical models, and mechanistic models (or combinations of all three). There are several types, or classes, of uncertainty: (1) natural variability (*e.g.*, process noise), (2) observation error (*e.g.*, sampling variability and bias), (3) model structural complexity (*i.e.*, when parameterizations outstrip data available), (4) inadequate communication between scientists, scientists and managers, managers and stakeholders, *etc*., (5) unclear management objectives, and (6) implementation or outcome uncertainty. Uncertainty must be included in indicator development, and risk tolerance levels must be included in threshold development. Communication of indicator status and change requires clear communication with stakeholders that is relevant to their interests or objectives.

Mark Dickey-Collas (IMARES, The Netherlands) presented the EU Marine Strategy Framework Directive requirement for reference points and threshold levels to be identified for the eleven descriptors of good environmental status by 2012. For some descriptors, such as commercial fish, there already exists broad consensus on suitable reference levels. However, some reference levels, such as one for biodiversity, will be difficult to determine.

Identification of reference levels in selected ecosystem indicators also is a challenge faced by the Korean National Investigation of Marine Ecosystems which is a national project to monitor and assess the status of coastal ecosystems in Korean waters (Sinjae Yoo, Korea Ocean Research and Development Institute, Korea).

Jay Peterson (Oregon State University, USA) provided an example of communicating ecosystem indicator status to the general public using a red, yellow, and green coded report card of ocean conditions that have been correlated to coho salmon survival in the northern California Current System. The visual representation is easy to follow, and supporting text conveys uncertainty in each indicator. This brings the discussion back to what level of information is needed for each end user, a question that will differ by user, highlighting the need for increased involvement by SOFE within this context for FUTURE.

Workshop outcomes and next steps

The third day of the workshop was devoted to discussion on issues surrounding: (1) how to select ecosystem-level indicators of status and change; (2) the determination of ecosystem resilience or vulnerability; (3) methods to characterize uncertainty in indicators; and (4) whether common ecosystem indicators could be selected for regional comparisons by the PICES community. The participants concluded that selecting common ecosystem indicators for regional comparisons would be premature and beyond the scope of the workshop. Instead, the workshop

Dr. Jacquelynne King (Jackie.King@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada at the Pacific Biological Station in Nanaimo, British Columbia, and an Adjunct Professor at the University of British Columbia. Jackie 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. Jackie is also Program Head of the Canadian Pacific Shark Research Lab. Within PICES, she led the Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts (2003–2004), and was a member of the Climate Forcing and Marine Ecosystem Response Task Team (2004–2009) and Working Group 16 on Climate Change, Shifts in Fish Production, and Fisheries Management (1999–2005). Jackie is currently a member of the FUTURE Advisory Panel on Climate, Oceanographic Variability and Ecosystems (COVE), the Fishery Science Committee and the PICES/ICES Working Group on Climate Change Impacts on Fish and Shellfish.

Dr. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada (DFO) at the Pacific Biological Station in Nanaimo, British Columbia. Tom is working on a number of aquatic invasive species research questions both within DFO and through the Canadian Aquatic Invasive Species Network (CAISN). He is the Principal Investigator for the Taxonomy Initiative of PICES Working Group 21 on Non-indigenous Aquatic Species (under the project on "Development of the prevention systems for harmful organisms' expansion in the Pacific Rim" supported by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan) that includes rapid assessment surveys (RAS) for non-indigenous species. Within PICES, Tom serves as Vice-Chairman of Science Board and leads the FUTURE Advisory Panel on Anthropogenic Influences on Coastal Ecosystems (AICE). He is a member of the Marine Environmental Quality (MEQ) Committee and the P/ICES Study Group on Developing a Framework for Scientific Cooperation in Northern Hemisphere Marine Science.

participants recommended that all PICES Standing Committees utilize the following common framework when identifying and calculating indicators for the common descriptors and attributes for North Pacific ecosystems:

1. identify the objective of selecting indicators;
2. identify the end user;
3. identify ecosystem attributes to be measured;
4. apply the following criteria to select the indicator for each attribute (each criterion should be weighted for relevance to the end user identified):
   - available regularly and in a timely manner applicable to the issue,
   - available as a time series,
   - statistical properties are understood and provided,
   - related to the attribute either empirically or theoretically,
   - specific to the attribute (*i.e.*, how specific is the indicator to the processes being indexed?),
   - spatial and temporal scales of the indicator are appropriate to the attribute,
   - responsive (sensitive to perturbation),
   - relevant to the objective,
   - understandable by the target audience,
   - provides a basis for comparison between ecosystems;
5. identify indicator reference levels; otherwise report on the time series' statistics (*e.g.*, current value relative to mean; trend; standard deviation);
6. test the performance of each indicator;
7. identify a suitable method of communication that is based on end user and report indicator uncertainty.

In addition to identifying a framework for selecting ecosystem indicators for use by PICES within FUTURE, workshop participants pointed out the need to create additional working groups to start tackling the difficult topics of: (1) ecosystem resilience, including metrics to measure and thresholds for comparisons, and (2) ecosystem vulnerability, especially the human dimension aspects of this topic. Lastly, at the request of Governing Council, workshop participants reviewed and revised the terms of reference for a proposed PICES Working Group on multiple stressors. Overall, the convenors were extremely happy with the workshop and its accomplishments and feel that strong guidance has been provided to PICES FUTURE science.

The convenors would like to thank all of the participants for their contributions, and the PICES Secretariat for arranging the logistics and for hosting a reception on the first day for all of us to enjoy.

PICES Calendar

- PICES/MAFF–IOC/WESTPAC Workshop on "*Rapid assessment survey methodologies for detecting marine non-indigenous species*", July 19–21, 2011, Phuket, Thailand (http://www.pices.int/meetings/summer_schools/2011_training/RAS-Workshop-description.pdf);
- 7th International Conference on "*Marine bioinvasions*" (co-sponsored by PICES), August 23–25, 2011, Barcelona, Spain (www.icmb.info/);
- 5th SOLAS Summer School (co-sponsored by PICES), August 29–September 10, 2011, Cargèse, Corsica, France (http://solas-int.org/summerschool/welcome.html);
- Joint Theme Sessions at the 2011 ICES Annual Science Conference, September 19–23, 2011, Gdansk, Poland:
  - *Atmospheric forcing of Northern hemisphere ocean gyres and their subsequent impact on the adjacent marine climate and ecosystems*;
  - *Atlantic redfish and Pacific rockfish: Comparing biology, ecology, assessment and management strategies for Sebastes* spp.;
  - *Recruitment processes: Early life history dynamics – from eggs to juveniles*;
  - *Surplus production models: Quantitative tools to manage exploited fisheries and compare the productivity of marine ecosystems*;
- International Workshop on "*Development and application of Regional Climate Models*", October 11–12, 2011, Incheon, Korea (www.pices.int/meetings/descriptions.aspx#description8);
- PICES Annual Meeting, October 14–23, 2011, Khabarovsk, Russia (www.pices.int/pices2011.aspx);
- International NPAFC-led Workshop on "*Explanations for the high abundance of pink and chum salmon and future trends*" (co-sponsored by PICES), October 30–31, 2011, Nanaimo, Canada (http://www.npafc.org/new/events/workshops/2011Workshop1stAnnouncement.pdf);
- 2nd ICES/PICES Early Career Scientist Conference on "*Oceans of change*", April 24–27, 2012, Palma de Majorca, Spain (http://www.ices.dk/marineworld/oceans/index.asp);
- 2nd PICES/ICES/IOC Symposium on "*Effects of climate change on the world's oceans*" in conjunction with Ocean Expo-2012, May 14–18, 2012, Yeosu, Korea (http://www.pices.int/climatechange2012.aspx).

2011 ESSAS Open Science Meeting
Comparative Studies of Climate Effects on Polar and Sub-polar Ocean Ecosystems: Progress in Observation and Prediction

by Kenneth Drinkwater

The GLOBEC/IMBER Regional Program on *Ecosystem Studies of Sub-Arctic Seas* (ESSAS) was established in 2005 to use a comparative approach in developing predictions of how climate variability and change affects and will affect the sustainability of goods and services obtained from the Sub-Arctic seas. ESSAS recently held its second Open Science Meeting (OSM) entitled "*Comparative studies of climate effects on polar and sub-polar ocean ecosystems: Progress in observation and prediction*", on May 22–26, 2011, in Seattle, USA. Co-sponsored by the international organizations, PICES (North Pacific Marine Science Organization), ICES (International Council for the Exploration of the Sea), IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) and GOOS (Global Ocean Observing System), as well as several U.S. marine science organizations, this symposium was attended by 195 scientists (of whom 23 were early career scientists and 28 were students) from 13 countries. There were 98 oral and 61 poster presentations. The meeting showcased the progress made in understanding the role of climate variability and change on the ecosystem structure and function within Sub-Arctic seas.

The OSM began on Sunday with a series of three 1-day workshops. The workshop on "*Biological consequences of a decrease in sea ice in Arctic and Sub-Arctic seas*" was organized by the ICES/PICES Working Group on *Forecasting Climate Change Impacts on Fish and Shellfish* (WG-FCCIFS). This workshop reviewed life history information and habitat associations to assess the risk of immigration and settlement of new biological populations in the Arctic and surrounding shelf seas in response to the retreat of sea ice. Criteria necessary to establish new species in the Arctic Ocean and surrounding areas were discussed and compared to expected conditions based on climate scenarios. Another workshop on "*Arctic–Sub-Arctic interactions*", co-sponsored by ESSAS and ASOF (Arctic–Subarctic Ocean Fluxes), brought together several disperse groups studying the fluxes between the Arctic and the Sub-Arctic and their biophysical effects. Following presentations, discussion focused upon some of our knowledge gaps, what research could be carried out to address these gaps, and how the research on these issues can be better coordinated. The workshop on "*Zooplankton life histories: Developing metrics to compare field observations and model results in order to predict climate effects*" brought together researchers interested in understanding how climate and life history patterns of zooplankton interact to produce the observed distributions and abundances of key species found throughout the boreal Sub-Arctic and Arctic seas, especially *Calanus* copepods. Two additional half-day workshops were held. The ESSAS Working Group on *Gadid–Crustacean Interactions* convened one on "*Comparative analyses of gadid and crustacean dynamics across sub-Arctic ecosystems*" to summarize and synthesize the main findings to date of their work and to discuss future directions for this Working Group. The second half-day workshop on "*Comparative analyses of marine bird and mammal responses to climate change*" focused on how to best integrate on-going and new research on marine birds and mammals into long-term PICES and ESSAS programs and objectives.

Top: The workshop on "Arctic–Sub-Arctic interactions" in session, bottom: William (Bill) Sydeman co-chairing the marine bird and mammal workshop with Co-Chairs, Yutaka Watanuki and Rolf Ream seated to his right.

The main OSM began on Monday. Instead of the usual introductory speeches by dignitaries, 8 elementary and junior high students from the Pribilof Islands of St. Paul and St. George gave a joint presentation entitled "*Discovering the Pribilof Domain*". The human inhabitants of these islands, who are mostly of Aleut descent, depend almost exclusively upon the sea for their livelihood and food. The students have been studying and conducting research into the marine ecosystem around their islands through the help of their teachers and scientist Michelle Ridgway. They attend Marine Science Camps during the summer where they have the opportunity to use some of the latest oceanographic techniques in their studies.

Students from the Pribilof Islands, Alaska, posing with award certificates and Symposium Convenor, George Hunt, Jr., scientist, Michelle Ridgway (with flowers), and teachers Tonia Kushin (fifth from right, and Juan Leon Guerrero, right).

The presentation touched upon the climate of the Pribilofs and the physical oceanography surrounding the islands, the phytoplankton and zooplankton, some of the principal fish and shellfish species and their life histories, marine mammals, and the socio-economic consequences of the fish and fisheries. During their studies of the flora and fauna, they discovered the second-known population of a new species of large brown marine algae, *Aureophycus*, near St. George Island. The students have also been working to blend traditional knowledge with conventional scientific knowledge to learn more about their marine ecosystem. The presentation was extremely interesting and given in a very professional manner. A job well done! These students also stayed for the entire meeting, presenting a poster on their work, and asking several questions of the scientists during their presentations and talking with them through the breaks.

Following the students' presentation, 6 invited speakers gave plenary talks that covered various aspects of the 3 parallel sessions that were held in the afternoon. This format of morning plenary presentations and afternoon parallel sessions continued through Wednesday. The parallel sessions covered a total of 8 separate topics:

1. Comparative studies of polar and sub-polar ecosystems
2. New observations and understanding of eastern and western Bering Sea ecosystems
3. Modeling marine ecosystem dynamics in high latitude regions
4. Nutrients, biogeochemistry and acidification in a changing climate
5. New insights from the International Polar Year (IPY) studies
6. National ESSAS Programs: Recent advances and contributions
7. Anticipating socio-economic and policy consequences of global changes in sub-polar and polar marine ecosystems
8. Interactions between Gadoids and Crustaceans: The roles of climate, predation, and fisheries.

Most of the presentations, including those of the students from the Pribilofs, are posted on the OSM website at http://www.pices.int/publications/presentations/2011-ESASS/ESSAS-2011-presentations.aspx.

Top: Plenary speakers, Anthony Lekanof, presenting with colleague, Feofaneya Rukovishnikoff, looking on; bottom left: Eddy Carmack (Fisheries and Oceans Canada), and Anthony Gaston (Environment Canada).

Awards were given for the best presentations by early career scientists. Honourable mention was given to Kristin L. Laidre (University of Washington, USA) for her talk entitled "*Climate change and baleen whale trophic cascades in Greenland*". She described tagging and tracking studies of bowhead and humpback whales off West Greenland done in conjunction with the Greenland Institute of Natural Resources. The award for the best presentation went to Joel Heath (University of British Columbia, Canada) for his talk on "*Winter ecology of*

common eiders in polynya and floe edge habitats in Eastern Hudson Bay, Nunavut". He gave a fascinating account using underwater video to help model the bioenergetics of the eiders and also described the changing environmental conditions for these birds around the Belcher Islands through changes in river runoff because of hydroelectric developments. These changes are threatening the eider populations and hence the Inuit people of the islands who depend upon them. Special awards were also given to the students from the Pribilof Islands for their presentation and participation in the OSM.

Top: George Hunt with his wife, Peggy, and young Pribilof scientist, William Lekanof. Bottom: Lots of enthusiastic conversation during the ESSAS poster session.

Sixty-one posters were on display throughout the meeting, with each covering some aspect of one of the session topics; all sessions were represented. A dedicated poster session was held on Wednesday evening during which the many participants were able to discuss the science and results behind the posters. The session with the most posters was that on results from the Bering Sea, which was bolstered by a good turnout from the local oceanographic community in Seattle. Again, awards were given for the best posters by early career scientists. Honourable mention went to Laurinda Marcello (University of Alaska, USA) for her lead on the poster entitled "*Effects of temperature and gadoid predation on snow crab recruitment: Comparisons between the Bering Sea and Atlantic Canada"*. She and her co-authors found that temperature change seems to be a more important and consistent factor controlling snow crab recruitment than that of gadoid predation. It is still unclear whether the temperature effect is through direct forcing or indirectly, *e.g.*, through temperature effects on their prey or predators. The award went to Xuehua Cui (University of Tennessee, USA) for her poster on "*Spatial distribution of groundfish in the northern Bering Sea in relation to environmental variation and feeding habitat*". Her study suggested strong linkages between physical conditions (*e.g.*, water temperature and hydrography) and biological conditions (*e.g.*, bloom status) in structuring fish communities in the northern Bering Sea.

Thursday, the last day of the OSM, was initially taken up with brief reports from each of the parallel topic sessions in order to inform all of the participants of some of the main findings under each topic. Following the reports, a special musical presentation was given by a group from Norway known as "*Science Fair*". Led by Oded Ben-Horin (vocals), with Svein Folkvord on bass and Stein Inge Brækhus on drums, they have been performing science-inspired music at scientific meetings and conferences. They performed a number of pieces, some of which were presented for the first time, based on their impressions gathered during the ESSAS OSM. In addition, two of the Pribilof students joined in to sing a song about St. George Island (in English), and then one of them sang a solo in the Aleut language about going to gather blueberries in the fall. The efforts of both *Science Fair* and the students were enthusiastically applauded and greatly appreciated.

The wrap-up to the OSM on Thursday afternoon was in the form of 3 special invited lectures. The first was by Dr. Kevin Arrigo (Stanford University, USA), who discussed the impact of climate change on lower trophic levels in polar and sub-polar seas in a talk entitled "*Phytoplankton production in the Bering Sea and Arctic Ocean: A Satellite remote sensing study*". He showed that sea surface temperatures (SSTs) in the Bering Sea have warmed over last 30 years, but there has been no trend in sea-ice cover or primary production. The exception has been the Chirikov Basin where annual primary production increased by 40% from 1998 to 2007. Dr. Arrigo speculated that in the future, a warmer, more ice-free Bering Sea is likely to be more productive than today. In the Arctic, changes in sea-ice extent and duration have resulted in a 20% increase in primary production over the last 12 years, and with reductions in sea ice, Arctic productivity could increase even more in the future. However, he noted that much work is needed before we will have reliable quantitative predictions.

The second presenter was Dr. Steve Murawski (University of South Florida, USA) who spoke on "*Understanding ecosystem processes: The key to predicting climate effects*". He noted that global patterns and ecological gradients of productivity, species richness, species distributions, and their variability form the patterns of adaptation of biodiversity to the Earth's climate, and pointed out just how complicated it will be to forecast future warming-induced impacts. Complex co-evolved dynamics defy simple

depiction with single drivers. Dr. Murawski stressed the value of the comparative approach for studying ecosystem responses to variations in ocean climate and as a powerful method for inferring biophysical processes. He went on to state that much of the "first order" science done up to now has shown just how complicated things are, and pointed the way towards a mix of comparative studies, paleoecology, and laboratory analyses that are needed to advance the field — reductionistic approaches will not reveal complex interactions. There is the need to understand how species respond not only on a taxonomic basis, but in the presence of other species, *i.e*., competitors, prey and predators. He noted the importance to assemble the global patterns of environmental information and biological data, including biological responses to environmental change, and wondered who will take on this important work.

The final speaker was Dr. Keith Criddle (University of Alaska Fairbanks, USA), whose presentation was entitled "*Adaptation and maladaptation: Factors that influence the fitness of fisheries and fishing-dependent communities*". Using examples from the salmon, halibut and pollock fisheries off Alaska, he showed that the fitness of fisheries and fishery-dependent communities depend on the characteristics of social, economic, and legal systems that determine who is allowed to fish and how fishing takes place, as well as the attributes of the stock. The unique legal foundations, culture, and traditions of each nation or state affect the range of viable alternative fishery governance structures. There are tradeoffs between economic efficiencies gained through management measures such as single species individual fishing quotas (IFQs) and heightened exposure to factors that affect individual stocks, associated product markets, *etc*. In contrast, generalist fleets trade reduced economic efficiency and possible losses of management precision for reduced exposure to losses associated with variations in the abundance or value of any one species. Durable individual entitlements to shares of the allowable catch increase profitability which helps fishermen adapt to modest adverse changes in stock abundance, vessel prices, and input costs, but their vulnerability to larger perturbations is increased. While catch shares increase choice and therefore, resilience from the perspective of individuals, catch shares can increase or decrease the resilience of fishery-dependent communities.

In addition to the scientific presentations and discussions, participants and some family members enjoyed a wonderful reception at the Seattle Aquarium on the waterfront on Monday evening. They were encouraged to wander through the Aquarium, and Aquarium staff were on hand to inform and answer questions. The large octopus that was very actively moving around its tank and the feeding of the seals were big hits with many of the attendees. Great food and further entertainment in the form of two local bands, as well as catching up with old friends and colleagues or meeting new ones, made for a very enjoyable evening.

During the reception at the Seattle Aquarium: Hoisting brews (top), and Michael Klages (right) making friends with a potential young scientist (bottom).

Based on numerous comments from participants, the ESSAS OSM was an overwhelming hit. Many commented on the high quality of the talks (check out the website!), the good feeling and friendly atmosphere of those who attended, the efficiency of the PICES Secretariat in running the meeting, the enjoyable time and good food at the Aquarium and during the poster session, and finally, but certainly not least, the involvement of the students from the Pribilofs and the musical session of Oded Ben-Horin and his group *Science Fair*. A big thanks to all of these people, as well as to all of the other participants and the many sponsors who helped make the meeting a big success.

The work is not complete, however; there are papers to write, review and edit. Results from the OSM will be published in several special issues of scientific journals. Papers from many of the topic sessions will appear in a special volume of the ICES *Journal of Marine Science*. This issue will be dedicated to our colleague and good friend, Dr. Bernard Megrey, a long time member of the ESSAS Scientific Steering Committee (SSC) and co-leader of the Working Group on *Modelling*, who unfortunately passed away unexpectedly last October. Papers from the workshop on gadid–crustacean interactions will appear together as a special section in *Marine Ecology Progress Series*. The papers from the session on "*New observations and understanding of eastern and western Bering Sea ecosystems*" will be published in a special issue of *Deep-Sea Research II*, and papers from the session on "*Modeling marine ecosystem dynamics in high latitude regions*" in the

Journal of Marine Systems. The latter special issue will also be dedicated to Bern, and modelling papers from some of Bern's former colleagues who did not attend the OSM will be considered for this special issue in addition to those from the meeting.

During the 2 days following the OSM, ESSAS held its annual SSC meeting. On Friday, several special invited guests attended to discuss the future direction of ESSAS science. Of particular note was the continuation of ESSAS existing Working Groups. The Working Group on *Modelling* will continue to develop an end-to-end model in conjunction with PICES and ICES scientists. They will also guide the papers submitted to the modelling session and solicited from Bern Megrey's former colleagues through the editorial process. The Working Group on *Gadid–Crustacean Interactions* will continue to complete the papers for the special issue and continue studies of predator–prey interactions through comparisons of the different Sub-Arctic regions, with a special emphasis on spatial dynamics. A new Working Group on *Arctic–Sub-Arctic Interactions* was formed. This group will seek to promote research on this important topic and will begin by holding theme sessions and workshops over the next 1 to 2 years on the role of the advection and water exchanges between the two regions on the biology. A proposal for a theme session on Arctic–Sub-Arctic interactions has been forwarded to the Ocean Sciences meeting for consideration at their February 2012 meeting in Salt Lake City, USA. Additional theme sessions for the IPY meeting in Montreal and at the 2012 PICES Annual Meeting and ICES Annual Science Conference are being considered. A Working Group on *Human Dimensions* was discussed but no firm commitment has been made, and this topic will be revisited at the next SSC meeting. The next ESSAS Annual Science Meeting and SSC meeting will be held in Hakodate, Japan, in January of 2013. The over-arching theme of this meeting will be on spatial dynamics, with sessions expected from all Working Groups as well as one already planned on human dimensions.

It was not all work, as George Hunt and his wife Peggy hosted a gathering of the SSC at their place on Friday night that included both good wine and great food. Not only did this give us time to discuss more of the science, but it also allowed us to get to know each other better and discuss other, non-scientific, issues. This SSC meeting was the last with Dr. George Hunt as Co-Chairman of ESSAS. Dr. Franz Mueter, a quantitative fisheries ecologist from the University of Alaska, Fairbanks, Juneau campus, takes over as Co-Chairman from the Pacific, and Dr. Ken Drinkwater remains as Co-Chairman from the Atlantic. All of the ESSAS SSC members wish to thank George for the untiring work he has done on behalf of ESSAS during the past 9 years, 3 years leading the push to establish ESSAS and have it recognized as a GLOBEC regional program, and 6 years as Co-Chairman from ESSAS's formal inception in 2005. Thankfully, however, George will continue to remain on the SSC as an *ex-officio* member and work toward its continued success. The SSC also wishes to welcome Franz and looks forward to working with him in the coming years.

Members of the ESSAS Scientific Steering Committee with guests, back row, from left: Yasunori Sakurai (SSC) Kenneth Drinkwater (Co-Chairman SSC), Seth Danielson (guest), Ólafur Átthórsson (SSC), and Michael Sigler (SSC). Front, from left: Enrique Curchitser (SSC), Franz Meuter (replacing George Hunt as SSC Co-Chairman at the end of the OSM), James Overland (SSC), Kai Wieland (SSC) Margaret McBride (ESSAS IPO), Jackie Grebmeier (guest), Erica Head (SSC), George Hunt (Co-Chairman SSC). Missing: Earl Dawe and Hyoung Chul Shin.

Dr. Kenneth Drinkwater (ken.drinkwater@imr.no) is a fisheries oceanographer conducting research at the Institute of Marine Research in Bergen, Norway on climate variability and its effects on the marine ecosystem, with a special interest in fish populations. He is Co-Chairman of the Scientific Steering Committee (SSC) of the IMBER regional program on Ecosystem Studies of Sub-Arctic Seas (ESSAS) and is on the SSC of IMBER and the SSG of CLIVAR.

The 5th Zooplankton Production Symposium

by Delphine Bonnet

The flyers and posters announcing the 5th International Zooplankton Production Symposium held March 14–18, 2011, in Pucón, Chile, were as majestic as the surroundings of the event. Despite the earthquake and tsunami which destroyed completely our colleagues' laboratory in Dichato and damaged the University of Concepción two years ago, Rubén Escribano, Chairman of the Local Organizing Committee, went ahead with the planning of the meeting and welcomed us to beautiful Pucón. This was the second Zooplankton Production Symposium convened outside Europe, after one in Hiroshima, Japan, in 2007. Unfortunately, the start of the symposium was overshadowed by news of the March 11 earthquake and tsunami in Japan, and Japanese colleagues were very much in the thoughts of the participants during the meeting.

A total of 293 scientists and students from 36 countries attended the symposium held at the Gran Hotel Pucón under the theme "*Population connections, community dynamics and climate variability*". The major sponsors for the event were the North Pacific Marine Science Organization (PICES), International Council for the Exploration of the Sea (ICES), and Center for Oceanographic Research in the Eastern South Pacific (COPAS). Additional funding was provided by the Global Ocean Ecosystem Dynamics (GLOBEC) project, EUR-OCEANS Consortium (EUR-OCEANS), Fisheries and Oceans Canada (DFO), Intergovernmental Oceanographic Commission of UNESCO (IOC), Institut de Recherche pour le Développement (IRD), U.S. National Marine Fisheries Service (NMFS) of NOAA, North Pacific Research Board (NPRB) and the University of Concepción. The primary sponsors were represented by three convenors: Delphine Bonnet (ICES; France), Julie Keister (PICES; USA) and Rubén Escribano (COPAS; Chile). A Scientific Steering Committee (SSC) made up of Sanae Chiba (Japan), Catherine Johnson (Canada), Angel López- Urrutia (Spain) and David Mackas (Canada) assisted with planning of scientific sessions and workshops, and recruitment of session convenors.

Artwork used in the 5th Zooplankton Production Symposium poster (painting courtesy of Alejandro Escribano, Chile).

Preparing registration in Gran Hotel Pucón.


The symposium venue – Gran Hotel Pucón (left) and the Pucón landmark – Villarica Volcano (right).

The Opening Session took place on the morning of Monday, the 14th, and included five excellent plenary talks:

- *Climate change and planktonic ecosystems: Detection, understanding and projection*, by Gregory Beaugrand (Université des Sciences et Technologies de Lille 1, France); presented by David Mackas, as Gregory Beaugrand could not attend;
- *Zooplankton role in biogeochemical cycles: Progress and prospects for the future*, by Deborah K. Steinberg (Virginia Institute of Marine Science, USA);
- *The giant jellyfish (Nemopilema nomurai) bloom in East Asian Seas: Causes, consequences and counter-measures*, by Shin-ichi Uye (Hiroshima University, Japan);
- *Modes of climate and food web variability in high latitude oceans*, by Kendra L. Daly (University of South Florida, USA);
- *Composition and succession of zooplankton communities: A global comparison*, by Torkel Gissel Nielsen (Technical University of Denmark).

On the evening of the first day, a welcome reception took place in the Ballroom of the Gran Hotel Pucón, a way of meeting many new or less new colleagues and for some others to share some old souvenirs.

Charlie Miller's former PhD students (from left to right): Jaime Gómez-Gutiérrez, Hal Batchelder, Bill Peterson and Peter Rothlisberg.

The symposium was composed of 9 theme sessions and 5 workshops. Two parallel sessions were run each day:

- **S1**: *Effects of climate variability on secondary production and community structure*, co-convened by Delphine Bonnet (France), Catherine Johnson (Canada), Angel López-Urrutia (Spain) and Anthony Richardson (Australia);
- **S2**: *Ecological interactions: Links to upper and lower trophic levels*, co-convened by Sanae Chiba (Japan) and Enric Saiz (Spain);
- **S3**: *Zooplankton life histories: Spatial connectivity, dormancy, and life cycle closure*, co-convened by Hans-Jürgen Hirche (Germany), Toru Kobari (Japan) and Jeffrey Runge (USA);
- **S4**: *Small-scale biological-chemical-physical interactions in the plankton*, convened by David Fields (USA);
- **S5**: *Zooplankton in upwelling and coastal systems*, co-convened by Jenny Huggett (South Africa) and Julie Keister (USA);
- **S6**: *Zooplankton in polar ecosystems and extreme environments*, co-convened by Carin Ashjan (USA) and Angus Atkinson (UK);
- **S7**: *Zooplankton physiology and bioenergetics*, co-convened by Maria Koski (Denmark) and Andrew Hirst (UK);
- **S8**: *The role of zooplankton in biogeochemical cycles*, co-convened by Hiroaki Saito (Japan) and Deborah Steinberg (USA);
- **S9**: *The diverse role of meroplankton in the biology and ecology of marine systems*, co-convened by Claudio DiBacco (Canada), Heidi L. Fuchs (USA) and Fabian Tapia (Chile).

The workshops were run concurrently in the morning of Day 3, and their summaries are included elsewhere in this issue:

- **W1**: *Zooplankton Individual Based Models*, co-convened by Harold Batchelder (USA) and Douglas C. Speirs (UK);
- **W2**: *Advances in genomic and molecular studies of zooplankton*, co-convened by Erica Goetze (USA),

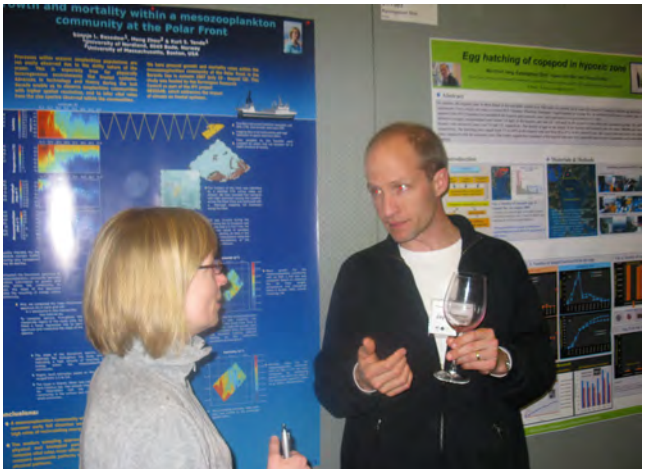
Ryuji Machida (USA) and Katja Peijnenburg (The Netherlands);

- **W3**: *Updates and comparisons of zooplankton time series*, co-convened by David Mackas (Canada) and Martin Edwards (UK);
- **W4**: *Impacts of ocean acidification on zooplankton*, co-convened by So Kawaguchi (Australia) and M. Brady Olson (USA);
- **W5**: *Automated visual plankton identification*, co-convened by Mark Benfield (USA) and Phil Culverhouse (UK).

The symposium was intensive with 159 oral presentations, including 5 plenary and 14 invited talks. Topics which did not have the chance to be elected in a session were illustrated in a General Poster Session. The 203 posters were on display during the entire symposium; two evening poster sessions were organized on Day 2 and Day 3, nicely arranged together with cheese and wine to enjoy and maximize the discussion. A last opportunity to see the posters was in the afternoon of Day 5, just before the Closing Session.

Exciting excursions were organized on Day 4 afternoon: visit of a volcano cave, canoeing, and thermal baths. The day concluded with a very enjoyable symposium dinner, which included a dramatic and colorful performance of traditional Chilean folk dances.

The symposium in session – an attentative audience.



Discussion around posters.

Some Australian colleagues enjoying the symposium dinner (top); a very enthusiastic audience for the Chilean folk dance show during the dinner (middle); Roger Harris exhibiting nimble footwork with one of the dancers (bottom).

One of the remarkable aspects of this meeting was the quality of the work of early career scientists, with some of them being honored at the Closing Ceremony. Four best talk awards were given to: Jeffrey G. Dorman (University of California at Berkeley, USA) for his presentation on "*Modeled krill distribution in the California Current from 1990–2005*", Pierre Helaouet (SAHFOS, UK) for his communication on "*Understanding populations changes in time due to niche requirements*", Rana W. El-Sabaawi (University of Victoria, Canada) for her talk on "*Interannual variability in nitrogen dynamics and zooplankton structure in the northern range of the California upwelling system*", and Sari L.C. Giering (National Oceanography Centre, UK) for her performance on "*Mesozooplankton demands exceed carbon flux in the twilight zone*". The poster session awards went to local scientist, Cristian A. Vargas (Universidad de Concepción, Chile), for his work on "*How significant are allochthonous subsidies for zooplankton production in coastal areas?*", and early career scientist, Geneviève J. Parent (Laval University, Canada), for her poster on "*Hybridization of Calanus finmarchicus and Calanus glacialis off the Canadian coast*".

Roger Harris summarizes the outcomes from the symposium (with symposium convenors, Julie Keister, Delphine Bonnet and Rubén Escribano, looking on).

As at the previous meeting in Hiroshima, Roger Harris (Plymouth Marine Laboratory, UK) gave an overview of the science presented during the Pucón symposium at the Closing Session. He noted how the long history of Zooplankton Production Symposia, extending from the first 1961 ICES symposium in Charlottenlund, through subsequent events in Plymouth (1994), Gijón (2004), Hiroshima (2007) and Pucón (2011), demonstrated the vitality and strength of our research field. Reviewing the breadth and variety of the presentations in Pucón, Roger emphasized the benefits of international collaboration and free access to data. A focus on integration, synthesis and meta-analysis, and the comparative approach should lead to significant advances being reported at the 6th International Zooplankton Production Symposium planned for 2015.

A selection of papers from the symposium will be published as a special issue of the ICES *Journal of Marine Science* in 2012. The Lead Editor for this volume is Julie Keister, and the Guest Editors are Delphine Bonnet, Sanae Chiba, Catherine Johnson and David Mackas.

Rubén Escribano giving a toast to some of the members of the Local Organizing Committee at the Welcome Reception.

As one of the convenors of this Symposium, I will remember for a long time the diverse and exciting science which was presented during the meeting, the outstanding work of many early career scientists, the increasing number of women in marine sciences, the beautiful venue surroundings, with so many active volcanoes, and finally the wonderful and hard work the Local Organizing Committee (Rubén Escribano, Pamela Hidalgo, Carmen Eliana Morales Van De Wyngard and many students) who did so much to welcome us in Pucón. The PICES Secretariat is to be thanked for providing professional assistance in the planning, development, coordination and the smooth running of the Symposium. Special thanks go to Julia Yazvenko who was unable to attend the meeting, but contributed greatly by designing and maintaining the symposium website and the database, communicating with more than 300 scientists and preparing the Book of Abstracts.

Dr. Delphine Bonnet (delphine.bonnet@univ-montp2.fr) is a lecturer and zooplankton ecologist at the University of Montpellier 2, France. Her research focuses on climate effects on zooplankton and trophic ecology, particularly on copepods and more recently on gelatinous plankton. Delphine is currently a member of the ICES Working Group of Zooplankton Ecology.

Workshop on "*Individual-Based Models of Zooplankton*"

by Harold P. Batchelder, Douglas C. Speirs and Wendy C. Gentleman

Approximately 32 modelers, experimentalists and field scientists from 11 countries met to discuss zooplankton individual-based models (IBMs) at a workshop held on March 16, 2011, during the 5th International Zooplankton Production Symposium in Pucón, Chile. Here we briefly summarize the seven presentations (one invited) and subsequent discussions. The workshop focused on new methods and current challenges in the unification of individual-level and population modeling approaches. Several topics were identified that require additional consideration and should be emphasized in future research to improve the acceptance of the individual-based approach in zooplankton ecological investigations, and to better link IBMs with population-level modeling approaches.

IBMs explicitly represent individual organisms, or quasi-individuals representing homogeneous groups of individuals, as discrete elements of a computer simulation. Individuals have their own state characteristics, such as age, size, developmental stage, and physiological condition; population-level dynamics arise as emergent properties of the interactions among individuals and between individuals and their environment. This approach contrasts with population-level models (PLMs), or aggregated mathematical models, in which population processes are described by relationships between densities of individuals, all of whom have identical (mean-state) characteristics. One of the main appeals of IBMs is that they operate at the individual level at which adaptation and evolution occurs, and provide a simple approach to capturing population heterogeneity through inter-individual variability. Stochastic processes impacting individuals can readily be incorporated into simulations. A second advantage is the ease of introducing behavioral rules, especially those relating to movement, which can be difficult to represent in PLMs in a mathematically compact way.

Wendy Gentleman (Dalhousie University, Canada) provided an invited overview of how IBMs are appropriate for advancing fundamental understanding of key issues in zooplankton ecology such as the environmental control of development timing, optimal behaviors that increase fitness, influence of transport processes on distribution and demographic processes, and the importance of individual variability in individual rate processes and experienced history. A key point noted by Wendy, and many of the other speakers and participants, is that IBMs explicitly incorporate individual variability which is fundamental to survival, fitness and eventual change in phenology and genetic structure. As was pointed out a long time ago by Gary Sharp—"*the average fish is a dead fish*"—indicating that condition-dependent growth or mortality under conditions of high mortality mean that individuals that are of average condition are destined to perish. Thus, it is only the lucky or supremely well adapted (*e.g.*, having a set of characteristics that are extreme and favorable) individuals in a population that survive. This is true for any population, such as zooplankton, in which there is high production of young, and high mortality. IBMs are ideal tools for quantifying why some individuals survive while most do not. Equally important, Wendy concluded that IBMs are a good tool for many ecologically interesting questions, but they are not the only tool and may not be appropriate for examining zooplankton community production, trophic links among multiple species assemblages, and issues where density dependence is strong. For such questions PLM approaches may be the better tool.

Then followed a series of presentations on specific applications of IBMs to zooplankton. Gaël Dur (University of Shiga Prefecture, Japan) described an IBM development environment called MOBIDYC "Moby Dick" and its application to understanding the phenology of the egg-sac carrying copepod *Eurytemora affinis* in the Seine Estuary. MOBIDYC (**MO**delling **B**ased on **I**ndividual for **DY**namics **C**ommunities) was specifically used to investigate temperature sensitivity of reproduction and development, but included also non-specific (stage-based) mortality and predator-abundance correlated predation mortality.

Dougie Speirs (University of Strathclyde, Scotland) discussed several model approaches applied to *Calanus*

finmarchicus in the Irminger Sea region of the North Atlantic. Mismatch of the model to the data was significant when a prior tuned *C. finmarchicus* model was used without alteration to the Irminger Sea. Five parameter estimation scenarios were examined using simulated annealing to tune between 16 and 22 model parameters simultaneously—most related to mortality, which is often the least well known rate process in population and individual models. These included parameters related to background mortality rates, temperature dependence of mortality, and prey-dependent mortality.

Matteo Sinerchia (London Imperial College, UK) presented a one-dimensional (vertical) multitrophic-level IBM of diatoms (producers), copepods (herbivores), two predators on copepods—squid paralarvae (the target species of particular interest) and a generalized other consumer—and a top predator that consumes squid paralarvae. The Lagrangian Ensemble Recruitment Model (LERM) is used to explore how environmental variability at a site in the Azores (Eastern North Atlantic) influenced the planktonic ecosystem and squid recruitment. The copepod IBM is based on the Carlotti and Wolf (1998; *Fisheries Oceanography*, 7, 191–204) model for *C. finmarchicus*, which includes staged growth, diel migration, ingestion based on gut volume and passage time, and dynamic allocation of ingested carbon into protein and lipids. The squid paralarvae IBM is based on the physiology, behavior and recruitment size of *Loligo*. Top predator dynamics are implemented using abundance, size, vertical distribution and trophic interactions based on ingestion equations of squid. The coupled equations achieve near stationarity after about 15 years. Simulation results suggest that squid mortality due to predation, especially on the smallest, least mobile squid paralarvae, is the most important factor controlling annual recruitment. Survival declined with increased egg production due to increased intra-population competition for prey. At highest egg production rates, predation was an additional source of mortality, indicating an interaction between density-dependent growth and predation determining density-dependent survival.

Jeff Dorman (University of California, Berkeley, USA) described the seasonal and interannual dynamics of *Euphausia pacifica* using an individual-based bioenergetics model coupled to NPZD-ROMS simulations of the central-northern California Current for the years 1991–2008. The bioenergetics model included temperature-dependent egg development, phytoplankton and temperature-dependent growth of feeding krill, and growth-dependent egg production by adult krill. Different simulations were initialized with either only eggs or only adult krill. The seasonal pattern of monthly mean larval growth and monthly mean adult growth was similar, with peak growth occurring when the

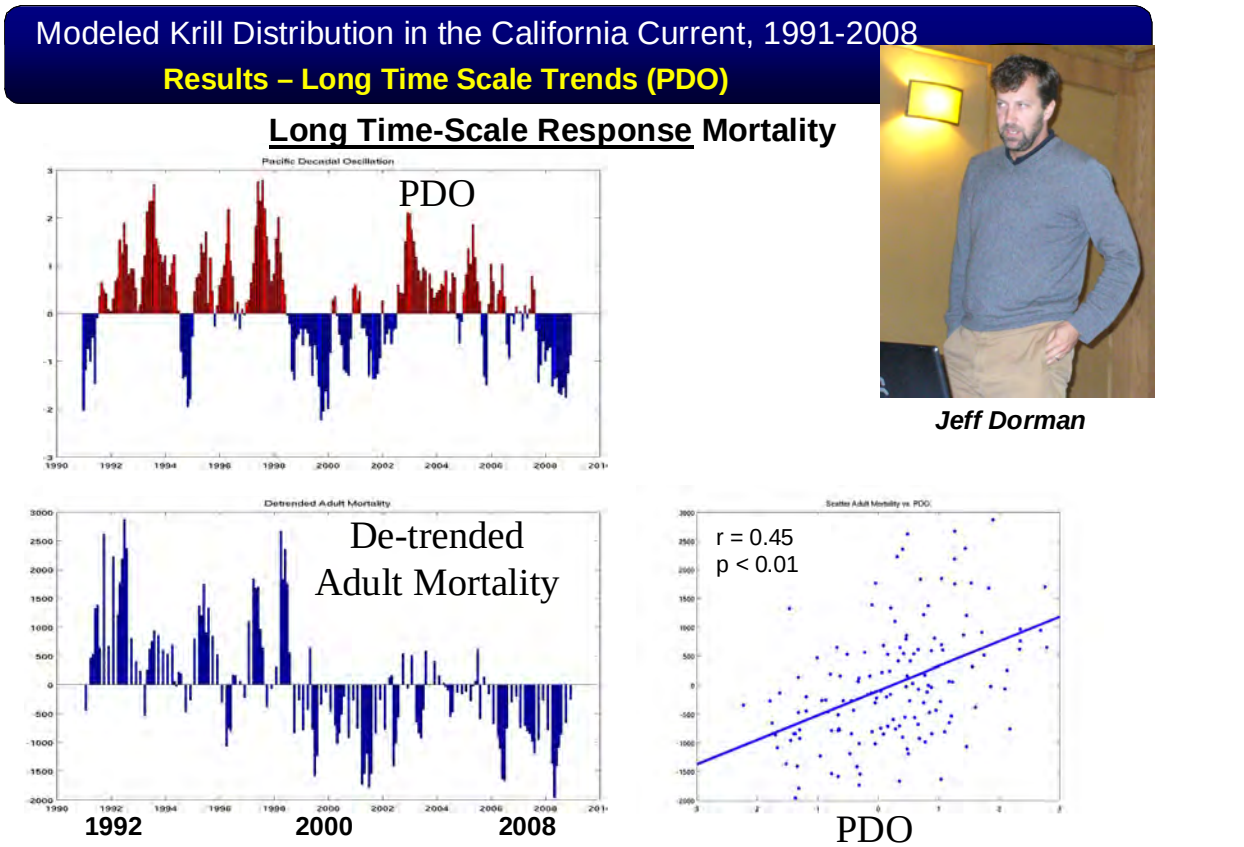
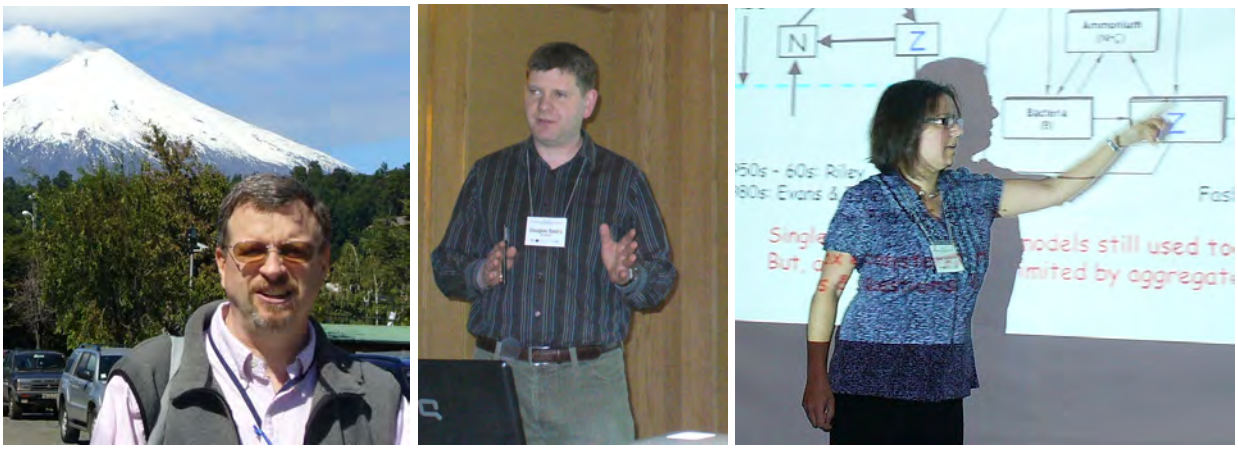


Fig. 1 Left panels show the time series of the Pacific Decadal Oscillation (PDO) and de-trended adult krill mortality from the krill IBM forced with fields from a coupled NPZD-ROMS. Lower right shows the scatter plot of adult mortality vs. PDO. Upper right is Jeff Dorman giving his talk.

population (eggs or adults) was initiated in spring (April–May; concurrent with peak phytoplankton concentration) and minimum growth in October–December (when phytoplankton is low). Conversely, monthly mean starvation was nearly uniform (but high, >60%) with start date for larvae, but variable with start date for adults, and lower (<30%), with highest mortality for adults that were initialized immediately following the spring phytoplankton bloom (*e.g.*, June–July model starts) and which experienced high offshore temperatures. Interannual variability in growth, mortality and southward advection of adult krill were negatively, positively and not significantly correlated, respectively, with variability in the Pacific Decadal Oscillation for the years 1991–2008. Wintertime abundance of krill in the region of study was positively related to Cassin's Auklet reproductive success and Chinook salmon survival. Jeff Dorman was awarded a Best Presentation Award for his talk (Fig. 1).

Brie Lindsey (Oregon State University, USA) used an IBM (with egg production, temperature-dependent stage progression and temperature- and prey-dependent feeding and metabolism) coupled to the output of an NPZD-ROMS model to identify potential *Euphausia pacifica* egg production sites and advective pathways on the central Oregon continental shelf in 2002. Total egg production rate per adult female and observed larval growth rates from the coupled model were similar to published observations from the region. Comparison of pathways of eggs and larvae from the model to cross-shelf distributions in 2002 strongly suggested that egg-laying must occur in the near shelf region to yield larvae on the shelf. Reproduction is likely also occurring off the shelf break, but the probability of those progeny developing on the shelf is low.

The final talk by Hal Batchelder (Oregon State University, USA) described an implementation of a 5-stage model of *Euphausia pacifica* into the NEMURO concentration-based ecosystem model. NEMURO (**N**orth Pacific **E**cosystem **M**odel for **U**nderstanding **R**egional **O**ceanography) has large and small phytoplankton, three feeding types of zooplankton, and tracks both nitrogen and silica through the lower trophic food web. One of the more meaningful ecosystem forecasts from climate projection scenarios is



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

Dr. Douglas Speirs (d.c.speirs@strath.ac.uk) is a Lecturer in the Department of Mathematics and Statistics at the University of Strathclyde in Glasgow, Scotland. His research is diverse, spanning mathematics, including ecosystem models of marine systems and population dynamics models of Calanus finmarchicus and insects in stream communities. Doug has participated in a number of inte-disciplinary programs, including GLOBEC, and is currently active in the EU BASIN program and the UK Ocean Acidification Program. He is on the editorial board of the Journal of Biological Systems, and is a subject matter editor for the journal Ecology.

Dr. Wendy Gentleman (wendy.gentleman@dal.ca) is an Associate Professor in Engineering Mathematics with a cross-appointment in Oceanography at Dalhousie University, Canada. Her research uses models to understand how environmental variability affects zooplankton population dynamics, as well as trophic links between primary producers, zooplankton, and their predators. This work includes analyses of assumptions inherent in model equations, improving characterization of biological processes and physical–biological coupling, and investigation of the factors controlling observed variations in zooplankton density and production. Wendy collaborates with researchers across North America and Europe, and has documented the critical roles of the grazing functional response and mortality for copepod demography and ecosystem structure. She has been actively involved with several interdisciplinary research programs (e.g., GLOBEC, JGOFS).

information on the abundance and distribution of trophically important taxa such as krill. However, predictions of abundance (or biomass density) using the IBM approach are difficult (as described in the earlier talk by Wendy Gentleman). This talk explored the extent to which some of the advantages of the IBM approaches could be incorporated into concentration-based ecosystem models. One of these is explicit recognition that different stages of the life history of an organism feed on different prey, have different mortalities and different behaviors (such as diel vertical migration amplitudes), and different growth rates. Results from 0-D and 2-D models were used to illustrate how some of these "IBM features" were included in a concentration-based model. Specifically, a stage structured algorithm that eliminates numerical diffusion (*e.g.*, rapid growth through the life history) was implemented using the mean-age model (Hu *et al*., 2008, *MEPS*, 360, 179–187). The 0-D case study illustrated the strong interaction of development rate and stage dependent mortality on the total biomass of krill in the model, with strong consequences, acting through competition for food, for other consumers in NEMURO. The 2-D NEMURO model (a vertical section across the Oregon continental shelf) revealed that the mean-age model could be implemented in a way that allowed proper mixing and advection of biomass and mean age information for krill (or other plankters) using the standard ROMS codes. Important questions in plankton population dynamics are best answered by IBMs, but other questions are better examined by concentration, stage-structured or PLM-based methods. The appropriate modeling approach depends on the specific question.

During the last hour of the workshop, a general discussion of IBMs ensued, which included tradeoffs of super-individual *vs*. individual modeling, dealing with density dependence and feedback to forcing fields (especially prey depletion), examining methods for linking IBMs with other model approaches, such as ecosystem and structured models, and the need for modelers to work more closely with observational and experimental scientists to better constrain the biological, ecological and physiological information/parameterization of models. By working together, the cycle of testing models to data will suggest new experiments and observations and identify shortcomings in the models. Finally, there is a desire to better document individual-based models to enable independent evaluation of model results. A standard for Overview, Design Concepts and Details (ODD) has been proposed for the documentation of IBMs (Grimm *et al*., 2010; *Ecological Modelling*, 221, 2760–2768).

New Book Release on the 100th Anniversary of the T/S *Oshoro Maru*

It was my great pleasure to edit the book, "100th Anniversary of the T/S *Oshoro Maru*" together with many people who have worked with the *Oshoro Maru* over the years. The book includes photos and articles depicting the rich history of the *Oshoro Maru* training ships, from the first, which was built in 1909, to the most recent, fourth ship built in 1984. The *Oshoro Maru II* was commissioned in 1927 and was replaced in 1962 by the *Oshoro Maru III*. The annual summer cruises since 1955 have allowed long-term ecosystem observations, and have advanced cooperative research among PICES member countries. The data collected during T/S *Oshoro Maru* cruises are invaluable for addressing scientific problems of the North Pacific. More than 250 scientific papers have been published using these data. Recognition of the importance of the *Oshoro Maru* monitoring program led to the receipt of the first PICES Ocean Monitoring Service Award (POMA) at PICES-2008, in Dalian, China (www.pices.int/awards/POMA_award/POMA_award.aspx).

Copies of the book are available to PICES colleagues (contact me at ssaitoh@salmon.fish.hokudai.ac.jp), but the number is limited, and they will be distributed on a first come, first served basis. They will be sent by surface mail and priority will be given to library or public use.

Sei-ichi Saitoh
Hokkaido University, Japan

Workshop on "*Advances in Genomic and Molecular Studies of Zooplankton*"

by Katja Peijnenburg, Erica Goetze and Ryuji Machida

A number of crucial questions in zooplankton ecology could benefit from a molecular or genomic approach as one component of an interdisciplinary oceanographic research program. Yet the community of zooplankton ecologists adopting molecular techniques is still small and scattered around the world. At the same time, new genetic and genomic techniques are becoming available at an unprecedented pace (Fig. 1) and with declining sequencing costs. This will open up genome-enabled science on non-model species and will provide major new research avenues in biological oceanography. Assessing the current state-of-the-field in zooplankton molecular ecology and discussing future avenues for research were the main goals of a half-day workshop held on March 16, 2011, at the 5th International Zooplankton Production Symposium in Pucón, Chile. This workshop, co-convened by the authors of this article, hosted a diverse array of topics presented as both oral (12) and poster (6) contributions, followed by an informal discussion after lunch.

One of the important central messages that emerged in both talks and discussions during the workshop is that zooplankton populations can and do evolve, in some cases quite rapidly. Our invited speaker Carol Lee (University of Wisconsin, USA) pointed out that evolutionary shifts (adaptation from ancestral marine to invasive freshwater populations) for the copepod *Eurytemora affinis* have occurred within approximately 50 years in the wild, and only 12 generations in the lab. Katja Peijnenburg (University of Amsterdam, The Netherlands) also highlighted that marine zooplankton may be particularly likely to show rapid evolution due to the larger effect of natural selection relative to genetic drift in large populations. She and her collaborators presented evidence of genetic differentiation of planktonic chaetognath and copepod populations isolated in marine lakes in Croatia over a relatively short time frame (4000–7000 years). Erica Goetze (University of Hawaii at Manoa, USA) stressed that many oceanic zooplankton species do show substantial genetic structure across their geographic range (an example is presented in Fig. 2), and that the extent of this genetic isolation varies across species. The spatial pattern of gene flow among zooplankton populations will be an important trait influencing the species capacity to adapt to environmental change. Her current work aims to test the overall hypothesis that depth habitat is a primary trait determining gene flow in the open ocean.

Another important observation from our workshop is that everywhere we look we find new species. Examples were presented by Jaime Gómez-Guttiérrez (CICIMAR, Mexico) *et al*. for ciliates, which are an important parasitoid of krill. The results from Hiroomi Miyamoto's and Erica Goetze's work also suggested cryptic and genetically divergent lineages in chaetognaths and copepods, respectively. An extreme case in chaetognaths was presented by Ryuji Machida on behalf of Hiroomi Miyamoto, who could not attend the workshop due to the unfortunate disasters that had just taken place in Japan. Miyamoto (University of Tokyo, Japan) *et al*. presented a mitochondrial phylogeny of 29 chaetognath species based on the barcoding gene Cytochrome Oxidase subunit I, showing that 14 morphological species were comprised of two or more highly divergent clades (>11%). If every mitochondrial clade is considered a phylogenetic species, then the number of species of chaetognaths may be twice that described from morphological character variation.

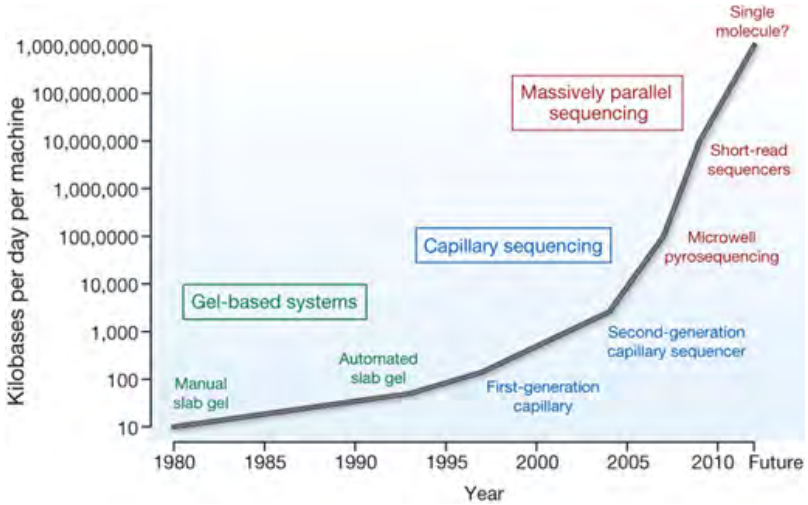


Fig. 1 Improvements in the rate of DNA sequencing over the past 30 years (from Stratton et al., 2009, Nature, 458, 719–724).

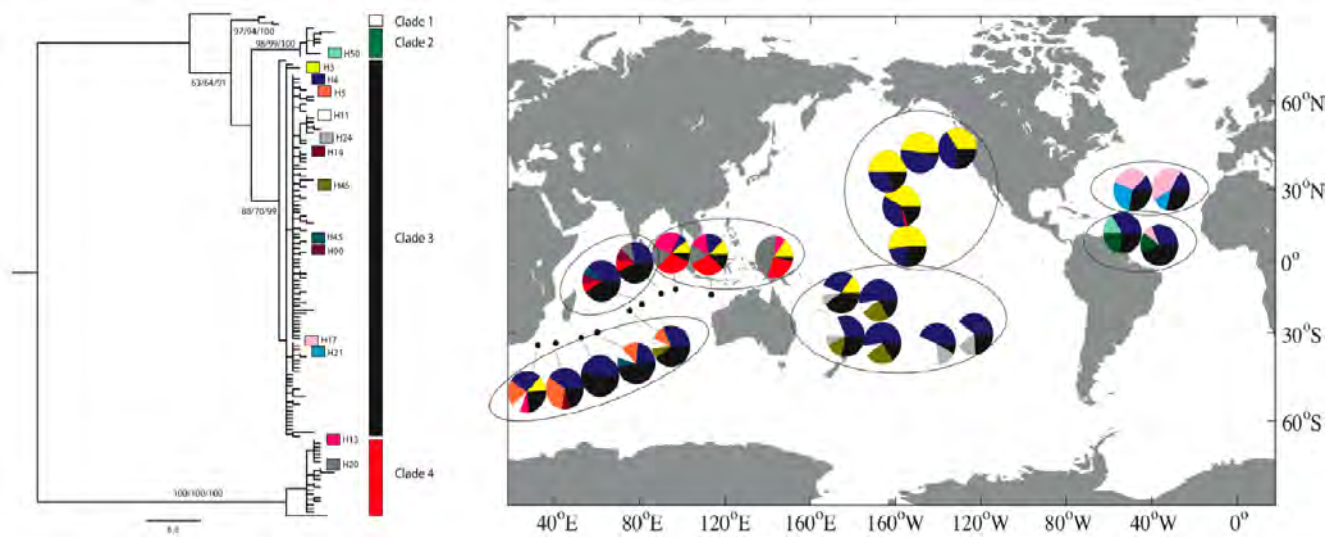


Fig. 2 Global population genetic structure in Pleuromamma xiphias, one example of an oceanic copepod species showing extensive genetic differentiation among populations in distinct pelagic provinces (sensu Longhurst, 2007). Parsimony gene tree (left) based on mitochondrial cytochrome oxidase I, with non-singleton haplotypes labelled by color. Global population structure (right) inferred from population graph, principal components, and Monmonier algorithm analyses, with pie charts illustrating haplotype frequencies (color as in gene tree), (from Goetze, unpublished).

A dynamic research area that generated a lot of interest was the new food web insights gained through application of molecular tools. Tatiana Rynearson (University of Rhode Island, USA) *et al*. identified a new trophic link in the diet of *Meganyctiphanes norvegica*, with up to 50% of the diet of this euphausiid consisting of an as yet completely unknown sediment microeukaryote. They used a new technique based on a blocking probe (PNA) and PCR with universal 18S primers in order to selectively amplify prey DNA (as opposed to krill DNA), and then combined this technique with qPCR to assess the prey spectrum of this pelagic euphausiid. Paolo Simonelli (University of Bergen, Norway) *et al*. presented data from qPCR assays of feeding rates in *Calanus* sp. and, rather surprisingly, found that experiments in the field seemed to be much more accurate than laboratory studies. qPCR-based estimates of feeding rates were compared to those estimated from conventional bottle incubation experiments. It may be that copepod digestion is more efficient in the lab or that prey cells are more resistant in the field.

Another research area well represented at the workshop was the development of new molecular tools to assess population or community-level responses to climate change. Community metagenetics is one emerging approach to studying genetic and specific diversity in bulk zooplankton samples, and could be a useful tool to rapidly assess changing zooplankton community composition. Here, nucleic acids are extracted from bulk zooplankton assemblages, and a target gene fragment is then amplified and sequenced on a massively parallel sequencer. A number of labs in Europe, North America and Asia are working to develop (or considering) this approach, but a number of methodological considerations need to be addressed before consensus can be reached on best practice techniques (*e.g*., RNA *versus* DNA, selection of the target gene or genes (Fig. 3), importance of DNA barcoding databases to be generated in parallel). During the workshop, we discussed the importance of reaching community consensus on metagenetic methods such that data generated from various research programs will be comparable on a global scale (Fig. 3).

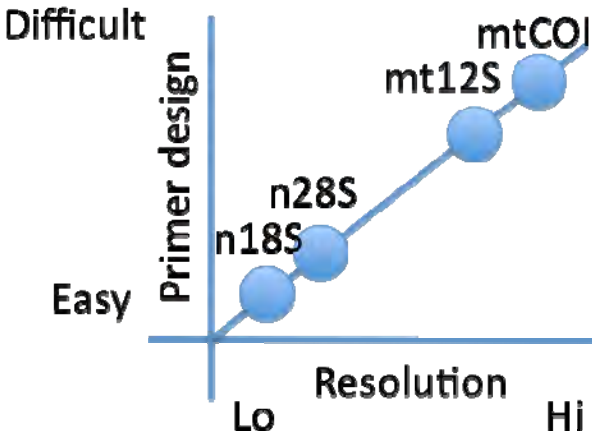


Fig. 3 The choice of a target gene for metagenetic surveys of zooplankton diversity is one important methodological consideration. There is an inherent trade-off between the taxonomic resolution possible using each gene, and the facility with which we can design truly universal primers. At the workshop it was noted that standardizing on one target gene for metagenetics would provide globally comparable datasets, but might not be possible given different research goals in programs worldwide. Four of the most likely candidate genes are included in this figure (from Machida, unpublished).

Ryuji Machida (Smithsonian Institution, USA) agreed to facilitate communication among labs conducting research in this area, and a number of scientists expressed interest in having an open policy about their method development

efforts in order to accelerate advances in this field. Studies of gene expression provide another avenue for investigating population-level responses to environmental variation (or change). Current research in this area, highlighted at the workshop by Petra Lenz (University of Hawaii at Manoa, USA) and Ebru Unal (University of Connecticut, USA) and collaborators, is focused on the development and use of a microarray in *Calanus finmarchicus.* Such a microarray allows for the simultaneous screening of many physiological processes, and identified suites of genes up- or down-regulated in response to particular types of stress, such as starvation. Mattias Johansson (Hatfield Marine Science Center, USA) also discussed the development of new molecular tools (whole mitochondrial genomes, microsatellites, reference transcriptomes) to examine euphausiid ecology and population structure in the North Pacific and beyond.

The field of zooplankton molecular ecology is on the cusp of entering a new era. Dramatically powerful new sequencing technologies now enable unprecedented access to the genome of non-model species and make possible research on a range of questions of global importance. For example, given that the distributions of marine plankton species are currently undergoing substantial change due to climate forcing (*e.g.*, Beaugrand, G., Luczak, C., and M. Edwards, 2009. Rapid biogeographical shifts in the North Atlantic Ocean. *Global Change Biology*, 15, 1790–1803), one topical research area is to understand the biological and oceanographic factors that constrain species distributions, and the ecological and evolutionary mechanisms that enable species to shift their range. What is the 'evolvability' of zooplankton species ranges, as we project into future ocean states (to 2100)? An interdisciplinary approach that integrates ecological research and genomics has the potential to determine the relative importance of natural selection *versus* neutral processes in determining zooplankton responses to climate change. Other research areas that could be advanced using new genomic techniques include looking at physiological responses to change in ocean pH (ocean acidification) and temperature, population genomic responses to environmental variation, and assessing changing genetic and specific diversity of zooplankton assemblages using metagenetic community surveys. Quantitative PCR is also likely to play an increasing role in how we assess grazing rates *in situ*, and possibly also in the enumeration of early life stages of planktonic organisms.

The creative use of new genomic technologies will be an important goal for our research community over the next 5 years. In order to be able to do this, it is very important for our community to meet regularly, share ideas, and stay up to date on what new methods work (or do not work) for addressing long-standing problems in biological oceanography.

Left photo: Erica Goetze (left) and Katja Peijnenburg (right) on the crater rim of the Villarica volcano in Pucón, Chile. Right photo: (from left to right) Ryuji Machida together with Ebru Unal, Georgina Cepeda, and Claudia Castellani in front of the Villarica volcano.

Dr. Katja Peijnenburg (K.T.C.A.Peijnenburg@uva.nl) is a molecular marine ecologist at the Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, The Netherlands. Her present postdoctoral research aims to unravel the tempo and mode of marine zooplankton evolution by examining genetic and morphometric variation in chaetognaths, calanoid copepods and pteropods.

Dr. Erica Goetze (egoetze@hawaii.edu) is a biological oceanographer in the School of Ocean and Earth Sciences and Technology at the University of Hawaii at Manoa, USA. In her current research, Erica is using molecular tools to address both population genetic and oceanographic questions in zooplankton ecology.

Dr. Ryuji Machida (ryujimachida@gmail.com) is a postdoctoral fellow at the Smithsonian National Museum of Natural History, USA. He is currently working on the application of meta-genetic, genomic, and transcriptomic analyses in marine metazoan communities, including both zooplankton and coral reef associated assemblages.

Workshop on "*Updates and Comparisons of Zooplankton Time Series*"

by David Mackas and Martin Edwards

In the four years since the 2007 International Zooplankton Production Symposium in Hiroshima, Japan, zooplankton time series data became not only more available, but also more widely used as a diagnostic tool for monitoring change in marine ecosystems. Since then, several new time series sampling programs (rich but brief in 2007) became long enough to support broader scale and more diverse analyses. SCOR Working Group 125 on *Global Comparison of Zooplankton Time Series* (2005–2008) carried out a variety of comparisons among many of the earlier and longer time series, and developed and applied new visualization and statistical tools. In addition, over this period several ocean regions experienced very strong fluctuations in climate and zooplankton composition. A half-day workshop, co-convened by the authors of this article and held on March 16, 2011, at the 5th International Zooplankton Production Symposium in Pucón, Chile, was intended to provide updates on this recent progress, and also to develop new research directions, tools, and comparisons for the future.

The workshop began with an invited talk by Jenny Huggett (Department of Environmental Affairs, South Africa) *et al.* that compared zooplankton and environmental time series from the four major eastern boundary upwelling regions (Benguela, California, northern Canary/Iberian, and Humboldt Current systems). Over the past century, all four systems have experienced long-term sea surface warming of approximately 1–2°C, overlaid by higher frequency fluctuations. Much of the ocean climate variability at interannual to decadal time scales is captured by a few dominant climate indices such as the Pacific Decadal Oscillation (PDO) and the Atlantic Multidecadal Oscillation (AMO), but signs and amplitudes of the local responses to these climate fluctuations differ among and within upwelling systems. One interesting broad generalization is that, for both temperature and zooplankton biomass, the two Pacific systems (California and Humboldt) appear to be varying in phase, while the two Atlantic systems (Iberia and Benguela) are varying inversely (Fig. 1).

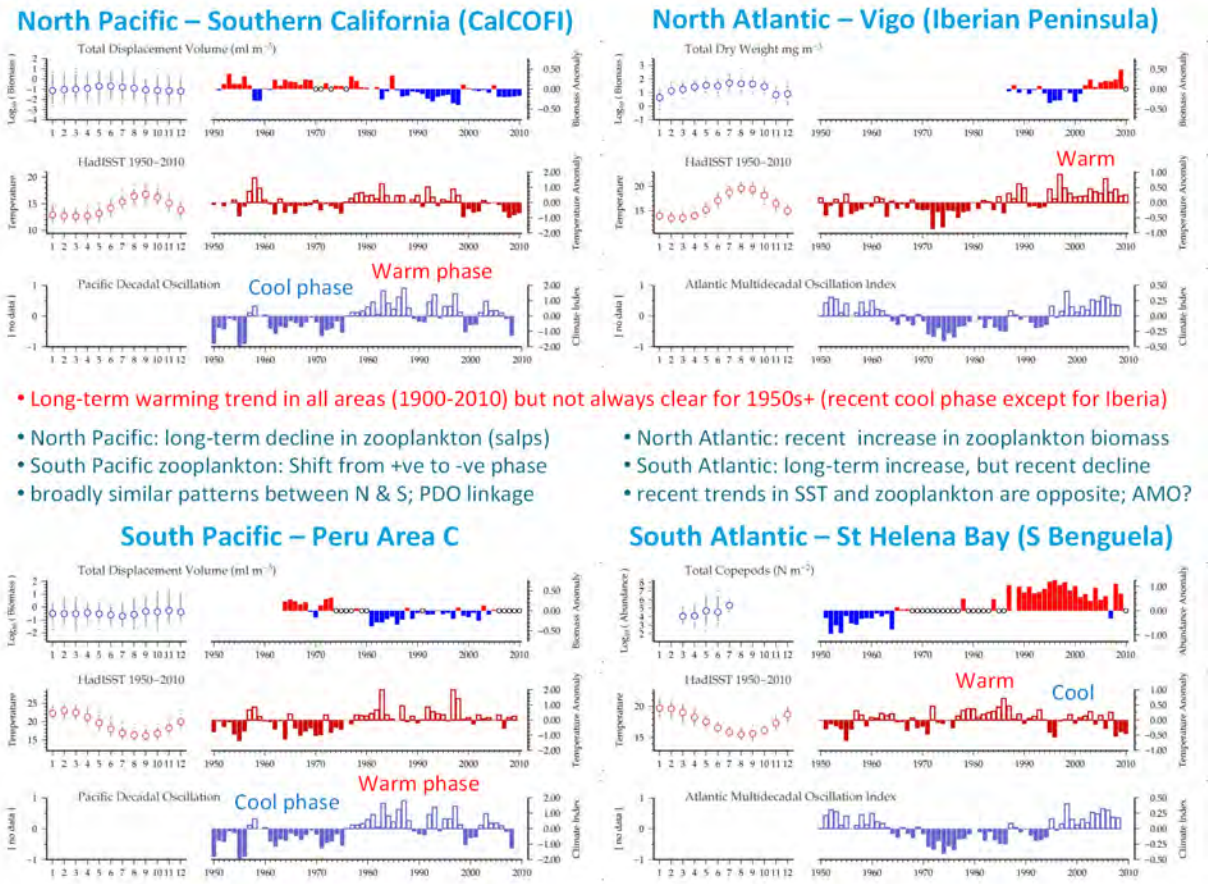


Fig. 1 Between-region comparisons of zooplankton biomass, sea surface temperature, and climate index (PDO and AMO) time series from eastern boundary upwelling regions in the Pacific (left) and Atlantic (right) from J. Huggett et al. 2011 (invited workshop presentation). Within each region, circles and error bars show average seasonal cycles, and column graphs show annual anomalies.

One exciting recent development has been a rapid increase in the amount and availability of time series data on zooplankton community composition in these systems. Many examples were shown in Dr. Huggett's talk, but one clear conclusion is that our analyses are far from complete. We have much more to learn from these data sets, and need new tools to visualize and communicate the messages they are telling us.

Other contributed papers (8 oral presentations, 2 posters) covered a range of topics:

- Between-site comparisons [Claudia Halsband-Lenk (Plymouth Marine Laboratory, UK) and Elvire Antajan (IFREMER, France) in the English Channel; Catherine Johnson (Bedford Institute of Oceanography, Canada) *et al*. along the Atlantic coast of Canada];
- New methods and tools for data visualization and interpretation [Todd O'Brien (National Marine Fisheries Service, USA); Pierre Helaouet (SAHFOS, UK) *et al*. – congratulations to Pierre for winning a "best presentation" award for this talk];
- Importance of zooplankton interannual variability to fish [Patricia Ayon (IMARPE, Peru) *et al.*] and benthos [James Highfield (Plymouth Marine Laboratory, UK) *et al*.; poster];
- Dominant time scales and dominant modes of climate connection [Fernandez de Puelles (Instituto Español de Oceanografía, Spain) and O'Brien; William Peterson (Hatfield Marine Science Center, USA) *et al*., David Mackas (Institute of Ocean Sciences, Canada); Gaël Dur (University of Shiga Prefecture, Japan; poster].

An oral presentation by Kazuaki Tadokoro (Tohoku National Fisheries Research Institute, Japan) *et al*. was cancelled (a casualty of travel disruptions following the Japan earthquake), but we look forward to seeing it soon.

By keeping all of the talks short, we were also able to include a one and a half hour group discussion of future directions and needs. This was lively and very wide-ranging, covering issues such as:

- What should we do to maintain and expand existing time series in the face of interruptions and declines in government funding levels for marine science and retirements of original investigators?
- Mechanisms and incentives for open and timely sharing of data (funding stick plus social-interaction carrot??);
- On-going issues of inter-calibration and inter-comparability of sampling designs and methods, and potential tools for between- and within-region QC/QA of biological time series data;
- International organizations, alliances, and funding mechanisms that can coordinate and support global-scale observation networks and comparative analyses. For zooplankton, we have at least a start toward these in the North Atlantic, North Pacific, and Mediterranean. Linkages are starting, but are less complete between the North Atlantic and North Pacific, and even less so between the northern and southern hemispheres. Do we need a zooplankton equivalent of the GLOBEC SPACC observation and analysis programs? Should we seek a reincarnation of SCOR WG 125 in a few years? Many think the answer is "yes" to both questions.

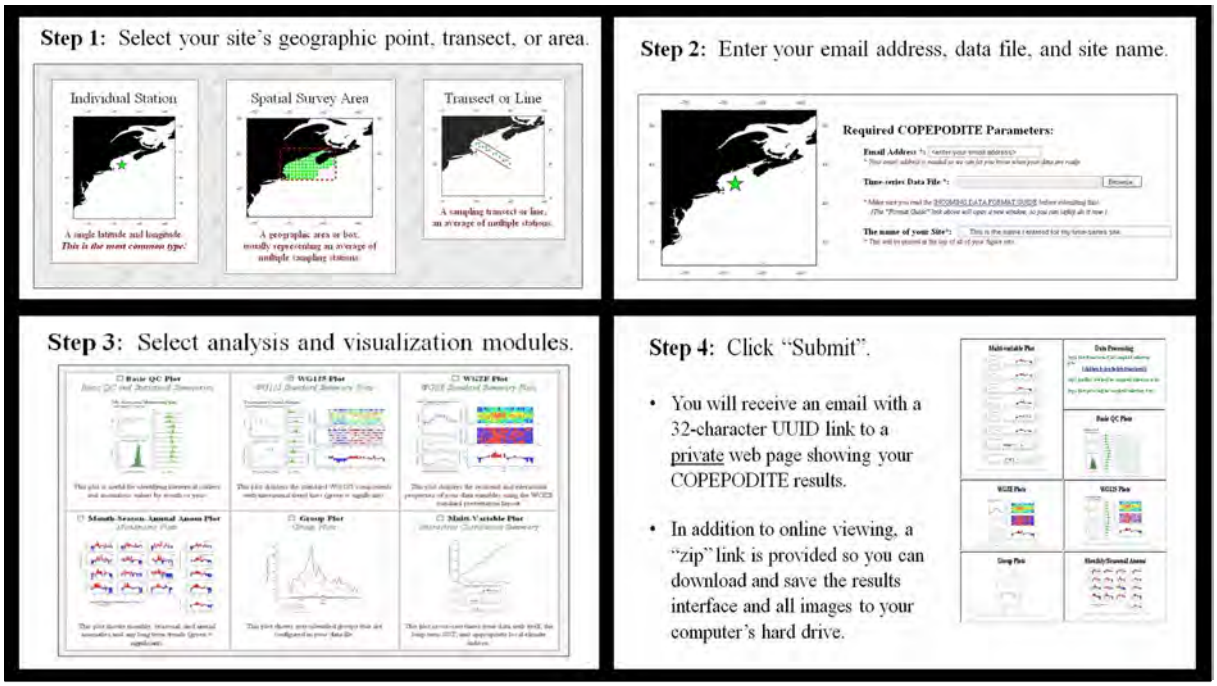


Fig. 2 Steps in using the COPEPODITE on-line tool kit (accessible at http://copepodite.org/). The application hatched on April 1, 2011, and is "powered by NAUPLIUS". What zooplanktologist could ask for more? (adapted from T. O'Brien workshop presentation).

- Because ship time gets ever more expensive and scarce, we need to find new (and maintain old) sampling methods that provide a lot of zooplankton data at low per-unit cost. Examples include the Continuous Plankton Recorder, but also the potential for unmanned observation platforms (*e.g*., gliders), and increasing use of optical, acoustic, and genomic sensors.

Despite the challenges described in the previous paragraph, our outlook for the future was not all pessimistic. Some of the important "good news" stories from this workshop were that:

- "Working together" does indeed work. Between-region and between-investigator collaborations started during SCOR WG 125 have remained active and on-going, and new collaborations are forming, especially among the younger generation of zooplanktologists.
- Accompanying the trends to "ecosystem approach" in fisheries and environmental management, there is increasing recognition and application of zooplankton data in cross-trophic-level research and monitoring.
- For the mechanics of data assembly and visualization of biological time series, some tasks that were formerly time consuming and potentially hit-or-miss in their capture efficiency will soon get easier. A highlight here was Todd O'Brien's description and demonstration of the new NMFS-supported online analysis and visualization toolkit COPEPODITE (a.k.a. the "**C**oastal and **O**ceanic **P**lankton **E**cology, **P**roduction, and **O**bservation **D**atabase: **I**nteractive **T**ime-Series **E**xplorer"). This allows users to upload data and produce time series results in a standard format for visualization and comparative purposes. Figure 2 shows a summary of how the tool is used. Advantages for the user include easy and reliable access to a variety of up-to-date ocean climate data, and semi-automated application of a suite of visualization tools developed by and for SCOR WG 125 and the ICES Working Group on *Zooplankton Ecology*.

Dr. David Mackas (Dave.Mackas@dfo-mpo.gc.ca) is a zooplankton ecologist, and the head of the biological oceanography and climate chemistry groups at the Institute of Ocean Sciences, Fisheries and Oceans Canada. His main research interests are zooplankton time series, spatial distributions, and links between physical and biological oceanography. Dave is active in several PICES committees and advisory panels, and was Co-Chairman of SCOR WG 125 on Global Comparison of Zooplankton Time Series. Photo on the left shows him contemplating a Fuchsia magellanica at Termas Geométricas near Pucón, and wishing his home garden looked and felt as good.

Dr. Martin Edwards (maed@sahfos.ac.uk) is Deputy Director of the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), UK. His research interests include spatial and temporal ecology, community ecology, phytoplankton blooms, non-indigenous species, and North Atlantic ecosystem changes. Martin has been a contributing author for the IPCC 4th Assessment Report on "Changes in marine ecosystems and fisheries", and the upcoming IPCC 5th Assessment Report on marine biogeography and harmful algal blooms and climate change. Photo on the left shows him kayaking in Canada.

Workshop on "*Impacts of Ocean Acidification on Zooplankton*"

by M. Brady Olson and So Kawaguchi

During the 5th International Zooplankton Production Symposium in Pucón, Chile, the authors of this article co-convened a workshop entitled "*Impacts of ocean acidification on zooplankton*". This workshop, to our knowledge, provided the first opportunity to discuss the biological effects of ocean acidification (OA) that was exclusive to zooplankton ecologists. The workshop agenda was to include, and specifically extend, the conversation on the effects of OA beyond direct acute effects on calcifying zooplankton. In particular, we solicited contributions that documented how OA sub-acutely and sub-lethally affects zooplankton biology, ecology and physiology. We were thrilled by the international participation in our workshop, having 9 oral and 4 poster presentations by scientists and students from 6 countries. Although the study of the OA effects on zooplankton is still in its infancy, this did not deter, and likely contributed to, active participation and interest from a packed audience. Workshop presentations included talks and posters ranging from field and laboratory experiments to time-series analysis showing effects of OA on the biology and ecology of microzooplankton, copepods, euphausiids, invertebrate larvae and pteropods. Although this level of taxonomic diversity and experimental scope was encouraging, it also helped to illuminate the general conclusion of the workshop: we currently, and perhaps indefinitely, are unable to make generalizations regarding the effects of OA on zooplankton. Validation of the above statement, we hope, can be found in the summation of workshop presentations below.

Brad A. Seibel (University of Rhode Island, USA), the invited speaker for this workshop, opened with an insightful talk reminding us that through synergy with hypoxic and anoxic waters, ecologists have been interested in, and have been studying the effects of, high pCO_2 conditions on ocean biota for decades. He provided evidence to show that isolating both the short- and long-term biotic responses to OA is challenging, and will remain so due to organismal plasticity, acclimation and adaptation, and multiple stressors acting in synergy with rising pCO_2. He suggested that, as a scientific discipline, our perceived understanding of the biological effects of OA is ahead of the information provided by empirical data, given the disproportionate number of reviews compared to research manuscripts. Further, he showed that much of the small yet growing body of work documenting effects of OA on zooplankton shows no discernable effect at relevant pCO_2 concentrations (IPCC IS92a CO_2 scenario), and that other environmental stressors synergistic with high pCO_2 (*e.g.*, hypoxia/anoxia) may be equally, if not more, stressful to marine organisms and worthy of our scientific attention.

Many of the talks and poster presentations showed no discernable direct effect of OA on zooplankton. M. Brady Olson (Western Washington University, USA) *et al.* demonstrated that ingestion and growth rates of micro-zooplankton acclimated to a range of pCO_2 concentrations (up to 1000 pCO_2) did not differ from ambient controls when fed phytoplankton prey grown under ambient pCO_2. When microzooplankton, in turn, were fed phytoplankton acclimated to elevated pCO_2, preliminary results indicated that microzooplankton ingestion and growth rates differed from ambient pCO_2 controls, presumably from phyto-plankton physiological or biochemical alterations in response to elevated pCO_2. This indirect effect of OA, precipitated through changes in prey state, was also seen by Cathryn Wynn-Edwards (University of Tasmania, Australia) *et al*., whose poster showed that although mortality rates of Antarctic krill were unaffected, intermolt periods, growth rates, and vitality were reduced when feeding on diatoms grown at 950 ppm CO_2. In a mesocosm experiment, Barbara Niehoff (Alfred Wegener Institute for Polar and Marine Research, Germany) *et al*. presented data indicating that no quantified metric of holo- and meroplanktonic zooplankton biology (*e.g.*, egg production, development) or ecology (*e.g.*, total abundance, species composition, sediment trappings)

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differed across eight pCO_2 treatments ranging from 180 to 1350 ppm CO_2. A poster by Kristian McConville (Plymouth Marine Laboratory, UK) *et al*. showed that even at pH 7.7 copepod feeding rate, egg production and hatching success was unaffected compared to controls. Leah Feinberg (Oregon State University, USA) *et al*. demonstrated that for *Euphausia pacifica*, egg hatching success and larval development were dependent on maternal effects rather than reduced pH, even at pH 7.2.

Other presentations showed that, indeed, increased pCO_2 appears to affect aspects of zooplankton biology. So Kawaguchi (Australian Antarctic Division, Australia) *et al*. established that while Antarctic krill larvae develop normally at pCO_2 380 and 1000 µatm, between 1000 and 2000 µatm embryo development is nearly totally halted, and James Robinson (University of Tasmania, Australia) *et al*. discovered that Antarctic krill recruitment may also suffer from elevated pCO_2. Steve Doo (Northeastern University, USA) presented a paper by Byrne *et al*. demonstrating decreased development and size in sea urchin larvae above 1000 ppm pCO_2, and Jörg Dutz (National Institute of Aquatic Resources, Denmark) *et al*. found that in addition to prey strain variability, reduced pH may play a role in hatching success of copepod eggs. Two time-series presentations showed changes in pteropod abundance, biomass, and species composition [Galbraith and Mackas (Institute of Ocean Sciences, Canada)] and shell porosity [Roger (University of Western Australia, Australia) *et al*.] across the Pacific continental shelf and in Australian tropical waters, respectively. For both studies, the degree to which these changes can be attributed to OA remains uncertain.

Following the conclusion of the formal oral presentations, we were left with twenty minutes to moderate a short, yet lively discussion. Considering the content of Seibel's talk, we began the discussion by asking the audience to what degree we should be concerned about OA and its effects on zooplankton. Have we, as a research discipline, raised the red flag too soon? That is, is OA really a threat to zooplankton that supersedes other climate stressors, and is it worthy of discipline-wide research focus? Not surprisingly, the audience was largely non-committal. Further discussion revealed several reasons for the participants' ambivalence:

- Many of the presentations in this workshop showed no discernable individual or community zooplankton response to elevated pCO_2 or decreased pH at IPCC IS92a CO_2 scenarios. Additionally, due to environmental variability (*e.g*., upwelling), diapause at depth, and ontogenetic development during ascent from great depths, many zooplankton (including larval stages) already experience pH levels well below what is predicted for surface waters in year 2100. It is difficult to comprehend a zooplankton response in these already 'corrosive' environments arising from comparatively subtle, long-term shifts in pH.
- When effects from OA were demonstrated, they occurred near, or above, the extreme pCO_2 concentrations predicted by IS92a CO_2 scenarios. It was argued that these findings cannot be dismissed as ecologically unrealistic because model projections show that depths where some zooplankton life histories occur may experience pCO_2 as high as 1400 µatm by year 2100.
- In most studies the metric used to quantify effects from OA are acute (*e.g*., mortality, morphology, embryological development, egg hatching success, alterations in community composition). By looking at obvious, discernable biological variables we may be missing subtle responses that, over time, magnify into alterations in individuals and populations that, in turn, may affect ecosystem function. It was recognized that as a research community we should focus future experiments on testing variables that will expand our knowledge of the effects of OA to less conspicuous, but equally important, changes to zooplankton biology.
- Experimental designs and pCO_2 treatment concentrations used for incubations lack formal rigor across the research community. This approach can lead to uncertainty in assigning ecological relevance of empirical findings, and handicaps our ability to characterize the impacts that OA may have on future zooplankton populations and ecosystems. Further, despite recognition that isolating single mechanisms governing biological change (*i.e*., elevated pCO_2) is important, few studies incorporate obvious variables that will change in concert with increasing pCO_2, and which may enhance or moderate the effects of elevated pCO_2 alone.
- Generating active discussion was the need to, and relevancy of, incorporating diel and seasonal variability of pCO_2 concentration into experimental designs. This is especially true for zooplankton ecologists working in temperate upwelling environments where infusion of cold, nutrient-rich water already low in pH and high in pCO_2 is chemically altered over short time scales by high phytoplankton productivity. This chemical alteration results in diel pH oscillations significantly greater than the range predicted to occur over the next century. Additionally, zooplankton ecologists working with organisms whose ontogenetic development and recruitment to surface waters begins at great depths with already low pH conditions face the pragmatic challenge of designing cross-generational experiments at wide-ranging pCO_2 concentrations.

The final point of discussion emphasized that when considering the degree to which OA may alter zooplankton biology, physiology and ecology, we need to consider how any zooplankton responses will affect adjacent trophic levels, and *vice versa*. For example, how might changes from OA to zooplankton ingestion rates, assimilation efficiencies, egesta stoichiometry, and production alter the ecology of microbial and higher-order individuals and communities? Further, how might these 'second order effects' alter basin-scale elemental cycling?

Workshop on "*Automated Visual Plankton Identification*"

by Phil Culverhouse and Mark Benfield

A half-day workshop on "*Automated visual plankton identification*" was held on March 16, 2011, at the 5th International Zooplankton Production Symposium in Pucón, Chile. The workshop, co-convened by the authors of this article, was well attended by diverse range of users of *in situ* and laboratory automated systems and, perhaps more importantly, by people who are interested in adopting these new technologies.

The speakers gave a good introduction to current uses of the computer-based image analysis technologies, with three of the speakers comparing existing and new technologies and one highlighting the development of a new semi-automatic system for high volume processing of biological sample data using ZooScan that automatically output data for use of the ecological modelling community.

The co-convenors went through a demonstration of how one can use open source software and commercially available inexpensive hardware to semi-automatically process plankton samples. This live demonstration was well received, and one participant commented that he had almost given up on the technology but was provided a new sense of purpose as a result of this workshop.

The main discussion topics were: (1) instrument inter-calibration and accuracies of systems, (2) producing a means of globally accessing analysed and labelled image data sets, and (3) the creation of standards for specimen preparation prior to image collection. The issue of training workshops and summer schools was high on the agenda, as delegates felt there was insufficient funding to support the demand for Ph.D. training in automated visual plankton identification. This type of new technology is best introduced through Ph.D. training, as students are often well placed to take up the challenges of new concepts and new work practices. It was suggested that this topic requires international support.

The workshop provided an opportunity to expand the membership in the international collaboration Research in Automated Plankton Identification (RAPID). We have started a Facebook page, but because it was made clear by some of the participants that social networking was not the preferred means of online collaboration, we will look into some alternatives.

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Dr. Mark Benfield (right; mbenfie@lsu.edu) is a Professor in the Department of Oceanography and Coastal Sciences at Louisiana State University (LSU) and a Guest Investigator in the Biology Department at the Woods Hole Oceanographic Institution, USA. His research interests include zooplankton ecology, particularly the use of in situ imaging systems combined with acoustics and nets to quantify zooplankton in fine spatial scales. He directs the Gulf SERPENT Project – a partnership between the oil and gas industry and LSU to study plankton and nekton in the mesopelagic and bathypelagic zones of the Gulf of Mexico. Mark is the current Chairman of the ICES Working Group on Zooplankton Ecology and Co-Chairman of SCOR Working Group 130 on Automatic Visual Plankton Identification. Mark received his B.Sc. from the University of Toronto, M.Sc. from the University of Natal, and a Ph.D. from Texas A&M University.

Professor Plum in the Dining Room with a Knife

by Stewart (Skip) McKinnell

In the fall of 1924, a small group of fisheries biologists from the west coast of North America came together to plan a first meeting of the *International Pacific Salmon Investigation Federation* (IPSIF) to be held in March of 1925 in Seattle, USA. Salmon biologists from California to Alaska (or at least their interests spanned that domain) met to identify priority areas of salmon research and to plan coordinated coast-wide research across political jurisdictions. It was the first self-assembly of salmon scientists on the west coast and by the end of 1925, novel insights into chinook salmon migration and abundance in coastal waters had been obtained from their tagging study. Although it occurred one week later in March (March 23–24) than in 1925, the 2011 workshop on "*Salmon ocean ecology*" in Seattle marked the 86th anniversary of that first IPSIF meeting.

It is comforting to know that most of the key questions of 1925 have been answered during the intervening 85 years. Yet some remain and foremost among these are questions about the causes of variable mortality, especially in the sea. Three years of low returns of sockeye salmon to the Fraser River from 2007–2009 was enough to trigger a federal judicial inquiry (Cohen Commission) to discover the cause. Unexpectedly high returns and high survival of sockeye salmon occurred in the adjacent Columbia River. Then in 2010, the largest return of sockeye salmon to the Fraser River since 1913 set the stage at the 2011 Seattle workshop for a special session focusing on the nature of this variability. Presentations at this part of the meeting were made by an august list of contributors: Dick Beamish, Kim Hyatt, Kristi Miller, Randall Peterman and David Welch (all Canada), and Greg Ruggerone, Kate Myers and John Williams (all USA). Topics included migration and abundance, viral infections, competition with pink salmon, survival of radio-tagged sockeye postsmolts, and patterns of co-variation. A lack of conclusive evidence for any one cause of mortality added considerably to the mystery…and motivated the title of this article, based on the 1949 board game *Clue* where the winning player must be first to correctly identify the murderer, scene of the crime, and murder weapon. The PICES role in the mystery has yet to play out.

In April of 2010, PICES was invited by the Cohen Commission to produce a report on "*The decline of Fraser River sockeye salmon in relation to marine ecology*". A team consisting of Drs. Kees Groot (Canada), Kate Myers (USA), Masahide Kaeriyama (Japan), Enrique Curchitser (USA) and Skip McKinnell (PICES) undertook the task during the summer and fall of 2010. Unfortunately, these results could not be presented at the workshop or even discussed because of the Cohen Commission's need for confidentiality until the report is presented to the court in July of 2011. A summary of the findings will appear in PICES Press after the report has been released.

Without knowing anything of IPSIF, the main organizers of the very successful 2011 workshop, Drs. Brian Beckman and Laurie Weitkamp, noted at the outset that "*Salmon biology can become myopic, constrained by physical and political boundaries. The comparative method has a long and fruitful history of helping to illustrate biological mechanisms and might be usefully employed with these [sockeye] data.*"

A Salmon Forecasting Forum has been held at each annual "*Salmon ocean ecology*" workshop since 2007 to allow salmon biologists to produce forecasts of future returns and survival from observations of juvenile salmon and the coastal ocean, and occasionally, to evaluate their performance. It did not feature prominently in Seattle, but perhaps an improved variant of it will be resurrected at the 2012 meeting that is scheduled for Oregon, the site of the most recent resurrection of the spirit of IPSIF in 1999.

Skip McKinnell (mckinnell@pices.int) is the Deputy Executive Secretary of PICES. In 2010, he was the Lead Author of the PICES Advisory Report to the Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River. It followed after his serving for two years as an author and Editor-in-Chief of the PICES North Pacific Ecosystem Status Report.

PICES and ICES on the River Elbe

by Stewart (Skip) McKinnell and Jürgen Alheit

Hamburg University might be considered by some as an unusual venue for a workshop focusing on North Pacific marine ecosystem variability, but its location highlights a continuing interest in conducting comparative studies of Northern Hemisphere oceans and climate. A search for the ultimate cause(s) of variable fish abundance demands an attention to the full range of spatial scales of the potential forces. The climate scale is large so ICES and PICES co-sponsored a workshop on "*Reaction of Northern Hemisphere ecosystems to climate events: A comparison*". It was convened during a cool but sunny week (May 2–6, 2011) by Jürgen Alheit and Christian Möllmann from ICES, and Sukgeun Jung and Yoshiro Watanabe from PICES. The focus of this workshop was an examination of time series from the northwestern North Pacific, within the context of an over-arching objective to conduct a meta-analysis of ecosystem trends and their potential drivers over the Northern Hemisphere. It followed an earlier workshop which had focused on northeastern Atlantic ecosystems.

Saskia Otto (Hamburg U. Ph.D. student) with Motomitsu Takahashi (Japan) and Sukgeun Jung (Korea) in analysis.

Yongjun Tian (Japan), Yury Zuenko (Russia), Sukgeun Jung (Korea), Motomitsu Takahashi (Japan), and Skip McKinnell (PICES) gave presentations about regional data sets from the Pacific during the first day and a half. In keeping with the workshop format, the serious work began by assembling multivariate data sets of long-term time series of physical, chemical and biological variables.

The normal challenges confronted the group as they strove to achieve a balance among the physical, chemical and biological variables. As the data originated in Japan, Republic of Korea and the Russian Federation, each with time series of variable durations, with missing years, different sampling methodologies and ecological emphasis, much of the first few days was spent trying to overcome these difficulties. Lack of balance will, for example, cause ecosystem shifts to be identified some time after they occurred when fishery statistics of long-lived animals have a significant influence on the results.

The analytical approach was to compare and contrast the results of several multivariate statistical methods with the intent to yield further insight into how ecosystems change state. For example, the rates and magnitudes of change may not be the same in the different systems, reflecting region-specific differences in the forcing factors and ecosystem responses to them. There was a general consensus among the methods and among various sub-divisions of the data that a change occurred in the climate and marine ecosystems in parts of the northwestern North Pacific between the winter of 1988/89 and that of 1992/93. The inability to specify one particular year was because different methods and data combinations produced slightly different results.

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The State of the Western North Pacific in the Second Half of 2010

by Shiro Ishizaki

Sea surface temperature

Figure 1 shows the monthly mean sea surface temperature (SST) anomalies in the western North Pacific from July to December 2010, computed with respect to JMA's (Japan Meteorological Agency) 1971–2000 climatology. Monthly mean SSTs are calculated from JMA's MGDSST (**M**erged satellite and *in-situ* data **G**lobal **D**aily **SST**), which is based on NOAA/AVHRR data, MetOp/AVHRR data AQUA/AMSR-E data, and *in-situ* observations.

Time series of 10-day mean SST anomalies are presented in Figure 2 for 9 regions indicated in the bottom panel. Positive SST anomalies exceeding +1ºC prevailed around 38ºN, 165ºE during the entire period. In particular, positive anomalies exceeding +3ºC were found there in October. From July to November, SSTs were below normal between 45ºN and 52ºN. In the equatorial Pacific, positive SST anomalies dominated west of 150ºE, while negative values were seen east of 160ºE. From August to October, SSTs were above normal in the seas around Japan. In August and September, positive SST anomalies exceeding +3ºC prevailed in regions 1, 2 and 3. In July and October, negative SST anomalies were found in the East China Sea.

Kuroshio path

Figure 3 shows time series of the location of the Kuroshio path during the reviewed period. The Kuroshio took a non-large-meandering path off the coast to the south of Honshu Island (between 135ºE and 140ºE). In August, the latitude of the Kuroshio axis at the Izu Ridge (about 140ºE) moved southward from about 34ºN (north of Hachijo Island) to about 33ºN (around Hachijo Island). At the end of December, the Kuroshio was flowing at about 34ºN (north of Hachijo Island).

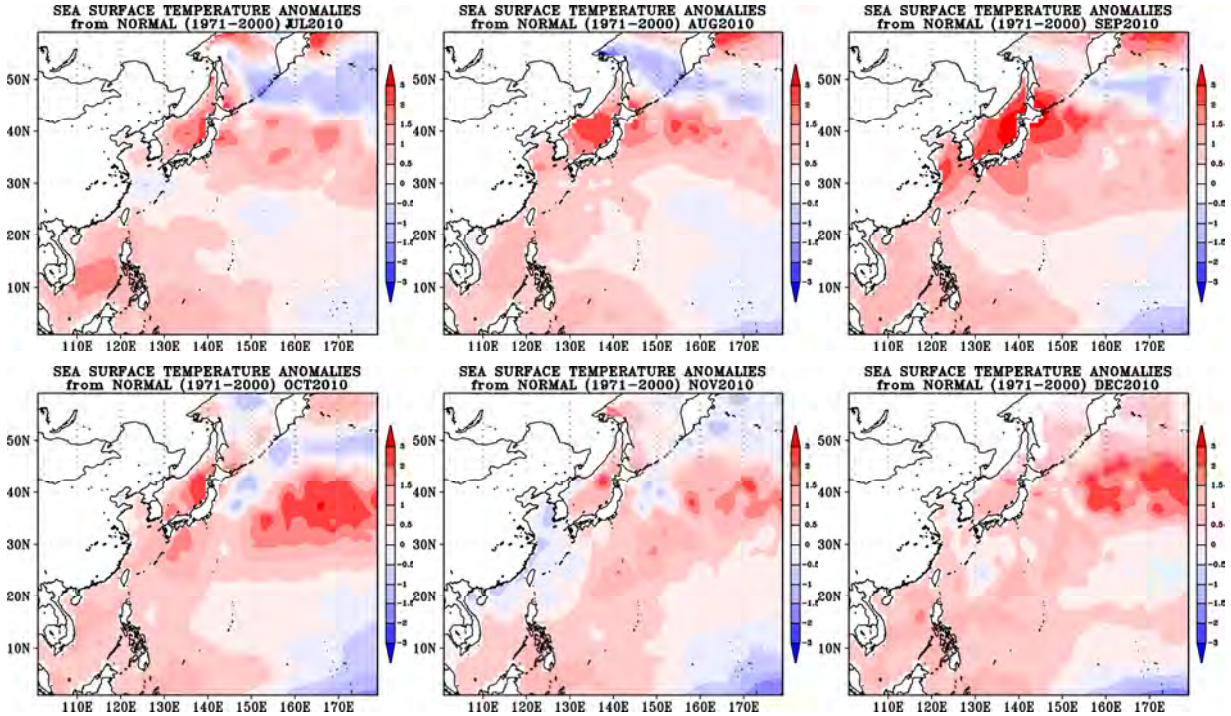

Fig. 1 Monthly mean SST anomalies (°C) from July to December 2010. Anomalies are deviations from JMA's 1971–2000 climatology.

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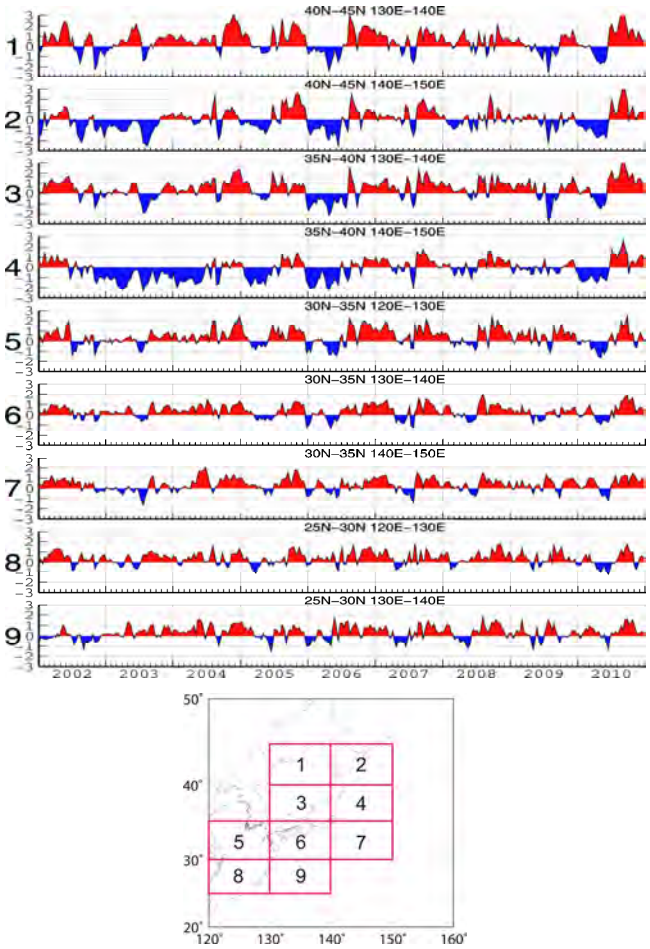

Fig. 2 Time series of 10-day mean SST anomalies (°C) averaged for the sub-areas shown in the bottom panel. Anomalies are deviations from JMA's 1971–2000 climatology.

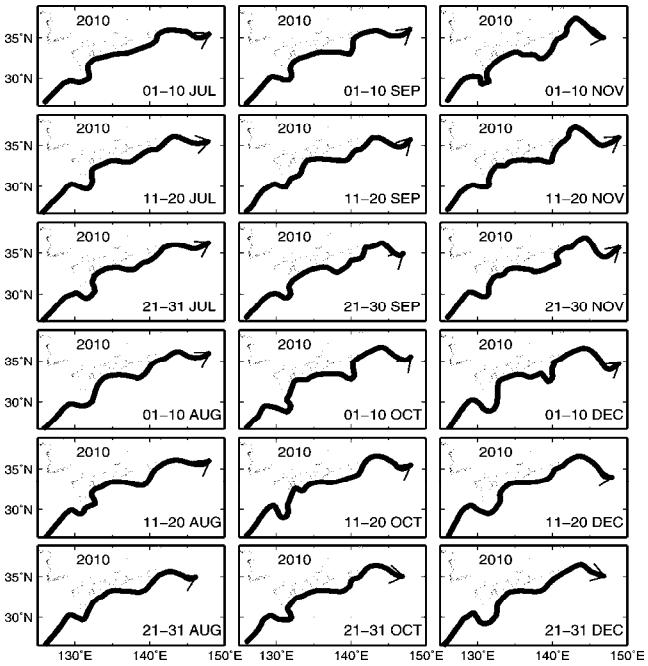

Fig. 3 Location of the Kuroshio path from July to December 2010.

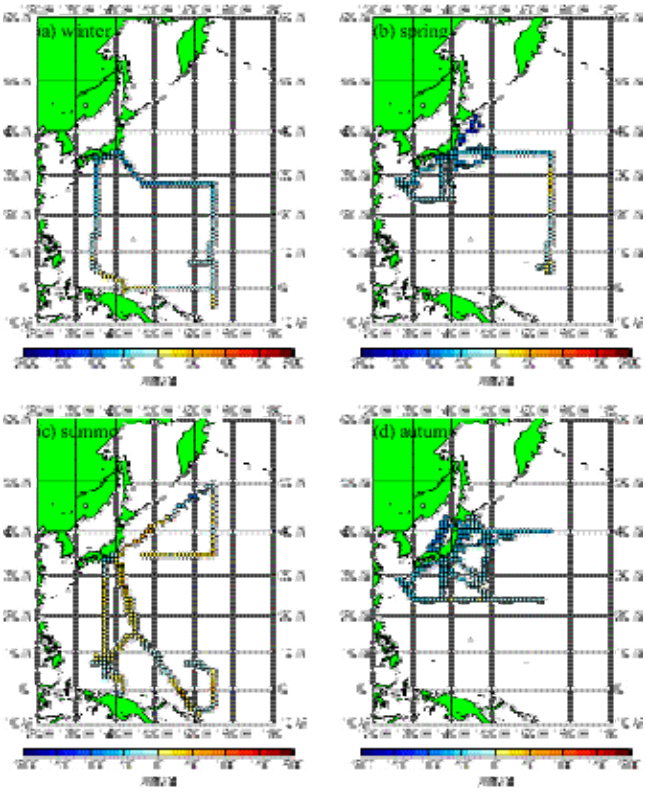

Fig. 4 Difference in CO_2 partial pressure between the ocean and the atmosphere in the western North Pacific in 2010: (a) winter (January–March), (b) spring (April–June), (c) summer (July–September) and (d) autumn (October –December).

Carbon dioxide

JMA has been conducting observations for carbon dioxide (CO_2) in the surface ocean and atmosphere in the western North Pacific on board the R/V *Ryofu Maru* and R/V *Keifu Maru*. Figure 4 illustrates the distribution of the difference in CO_2 partial pressure (pCO_2) between the surface seawater and the overlying air (denoted as ΔpCO_2) observed in the western North Pacific for each season of 2010. The sign of ΔpCO_2 determines the direction of CO_2 gas exchange across the air–sea interface, indicating that the ocean is a source (or sink) for atmospheric CO_2 in the case of positive (or negative) values of ΔpCO_2.

In the subtropical region, typically between 10–35ºN, the ocean widely acted as a CO_2 sink in the winter, spring and autumn, and as a CO_2 source in the summer of 2010 due to thermodynamically increased pCO_2 in seasonally warmed seawater. The greatest difference in pCO_2 values (–150 µatm) was found around 40ºN, 145ºE in spring, and was probably caused by enhanced biological activity. In the equatorial region, the ocean east of 150ºE acted as a weak CO_2 sink in the winter of 2010, but the region turned into a CO_2 source in the summer. In association with the La Niña event that occurred in the summer, eastern CO_2-rich surface water may have moved westward in response to strengthened easterly trade winds in the central equatorial Pacific.

The Bering Sea: Current Status and Recent Events

by Jeffrey Napp

Current status of the Bering Sea ecosystem

It was cold once again this past winter, but not as cold as in the most recent years (2009 and 2010). There were also signs that the weather may become more moderate in the near future. In some ways, the conditions during the winter of 2010/2011 were similar to 2006 (an average temperature year), although sea ice persisted later in 2011, and it was slightly colder than in 2006 (Fig. 1). During the winter of 2010/2011, sea ice extended to mooring M2 (56.87°N, 164.03°W), but was not solid (7/10 cover), and the front moved back and forth across the mooring (north and south) until April when the ice retreated. Unlike the spring of 2010, there were no sustained northerly winds in 2011 that retained ice on the middle shelf. By the end of May 2011, the ice front had retreated to St. Matthew Island. In early June, the ice cover was 2–4/10 north and west of St. Lawrence Island and 4–6/10 north and east of the island (Fig. 2). The late spring sea surface water temperatures in the southeastern Bering Sea were moderate to cold: 4–5°C over the outer shelf and 2–3°C over the middle shelf (not shown).

There have also been some changes in the coupled ocean–atmosphere systems that drive the North Pacific and marginal seas. For example, the Pacific Decadal Oscillation (PDO; 1st mode of the EOF on sea surface temperatures) changed from positive to negative in June 2010, and was moderate to strong from June to January, weakening in early 2011. On the equator, La Niña conditions weakened, and the ENSO (El Niño Southern Oscillation) index was expected to be neutral this summer. The multivariate ENSO index is still negative and has been strongly negative since July/August of 2010.

An important question to ask is — what will be the fate of the run of cold winter/spring conditions that began in 2007 and followed a string of very warm years from 2000 through 2005? The winter/spring of 2011 had a return to near average air temperatures over the southeastern Bering Sea and Alaska, and this was in sharp contrast to the cold air temperature anomalies for this season in 2010 (Fig. 3). Both years, 2011 and 2010, exhibited warm temperature anomalies in the northern Bering and Chukchi Seas that have remained an Arctic-wide feature since the beginning of the 21st century. The proximate cause of the near normal 2011 air temperatures over the southern Bering Sea was the weak pressure gradients over the southeastern Bering Sea (Fig. 4), with the position of the Aleutian Low shifted far to the west, just east of Kamchatka. This again was in sharp contrast to 2010 (and other recent cold years) when the Aleutian Low was stronger and positioned over the Gulf of Alaska (Fig. 4). The latter position favored northeasterly winds over the southeastern Bering Sea, bringing cold Arctic air into the region. Normally, a moderate El Niño (as in winter 2010) would have resulted in a warmer Bering Sea and La Niña in winter 2011, and weakening in spring would have supported cooler conditions. However, in recent years it appears that the location of the Aleutian Low had more influence on the Bering Sea in 2010 and 2011 than did the intensity of the low or the ENSO connection.

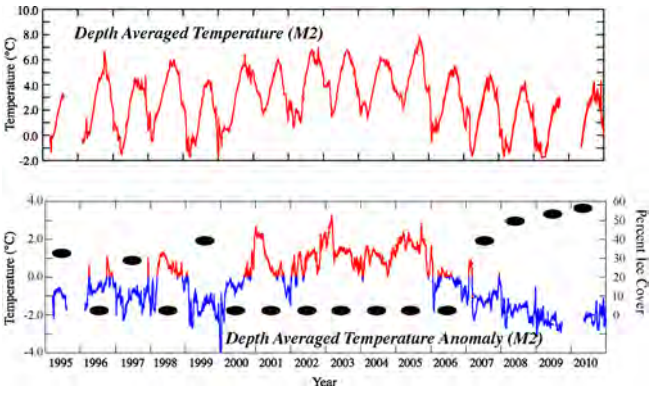

Fig. 1 Time series of water temperatures at the Bering Sea mooring M2 (56.87°N, 164.03°W). Top panel: Daily depth-averaged water column temperatures. Bottom panel: Daily temperature anomalies at M2 (blue = negative and red = positive, left ordinate) and the percent of ice cover over the mooring (ellipses, right ordinate). Figure courtesy of Phyllis Stabeno and Nancy Kachel, NOAA.

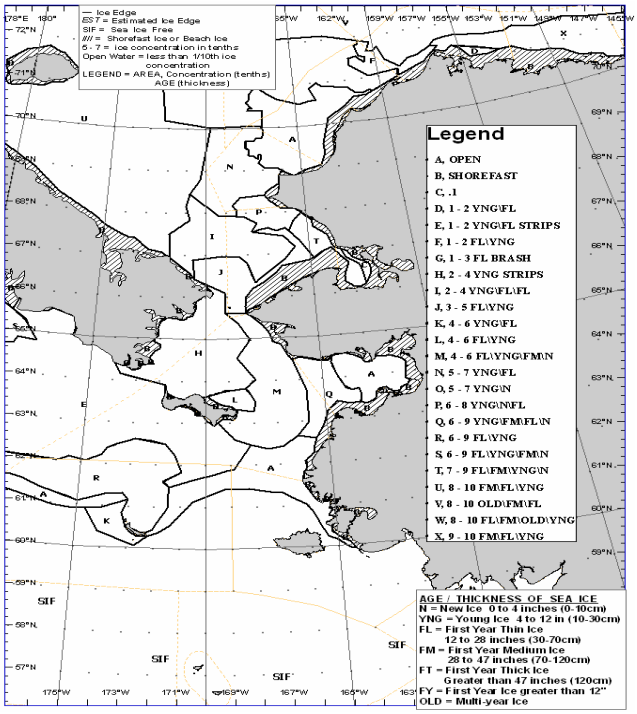

Fig. 2 Position and areal coverage of sea ice in the Bering Sea on June 2, 2011. Source: U.S. National Weather Service (http://pafc.arh.noaa.gov/ice.php).

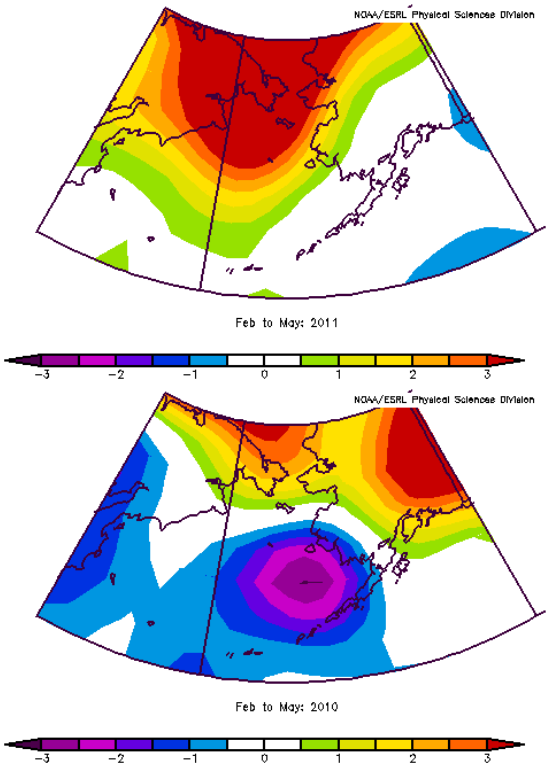

Fig. 3 Winter/spring 1000 mbar air temperature anomalies from the mean (1968–1996) over the Bering Sea for 2011 (top) and 2010 (bottom). Source: U.S. National Center for Environmental Prediction/National Center for Atmospheric Research.

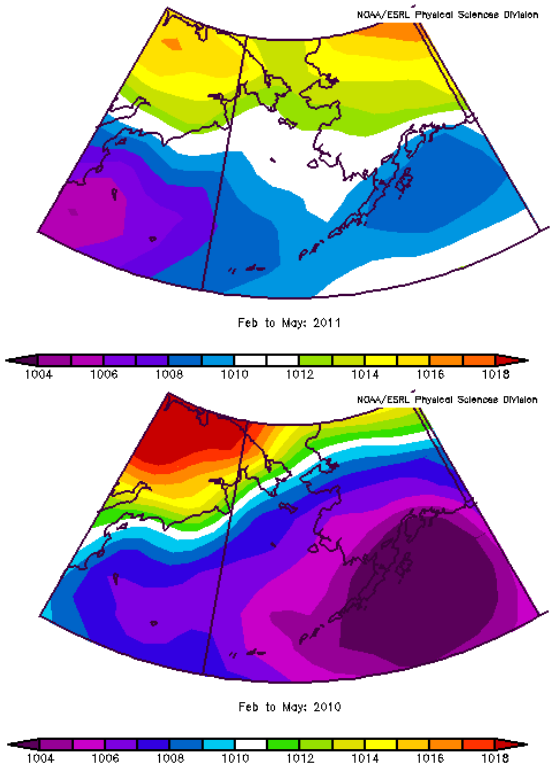

Fig. 4 Composite mean of sea level pressure (mb) for February to May 2011 (top) and 2010 (bottom). Source: U.S. National Center for Environmental Prediction/National Center for Atmospheric Research.

Arctic conditions

In the summer of 2010, the mean sea ice extent in the Arctic Ocean was 8.5×10^5 km^2, which was less than the average during the reference period of 1979–2000. However, in the spring of 2011 (April), the Bering Sea portion of the Arctic actually had more ice than average (Fig. 5). While there has been a rapid retreat of sea ice in the western Bering Sea, most of the western Arctic had been cooler than normal. A strong positive phase of the Arctic Oscillation (AO) characterized unusually low sea level pressures in much of the Arctic Ocean and drew warm air into the eastern Arctic.

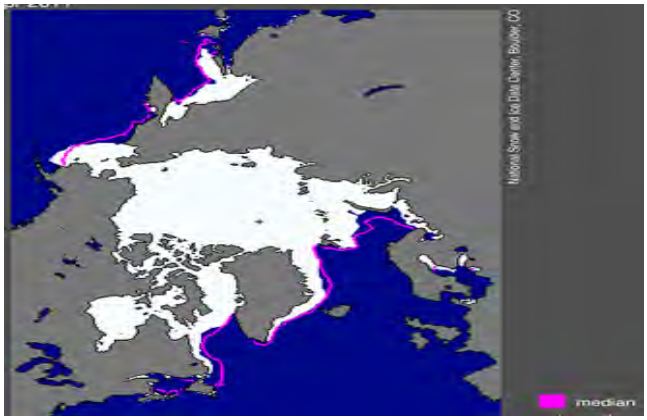

Fig. 5 Ice edge extent for April 2011 compared to median extent (pink line). Source: http://nsidc.org/arcticseaicenews/.

2011 Bering Sea field season

The amount of sea days for the eastern Bering Sea this year will be far less than previous years. The BEST/BSIERP partnership (http://bsierp.nprb.org) has concluded its field program, and the T/S *Oshoro Maru* (Hokkaido University, Japan) will not visit the eastern Bering Sea shelf in 2011. NOAA's Alaska Fisheries Science Center (AFSC) will conduct its annual summer groundfish assessment cruises (June and July), and the U.S. Coast Guard Icebreaker *Healey* will transit through the region on its way to the 2011 Arctic West Summer Expedition. NOAA's Pacific Environmental Laboratory (PMEL) has recovered and redeployed its Bering Sea shelf moorings for the summer.

New insights into the Bering Sea ecosystem

Several new and exciting results have been published within the last year and more are on their way in a forthcoming special issue of *Deep-Sea Research II* (2012).

A synthesis article on zooplankton and fish diet shows the affect of warm and cold years on the biomass of large and small zooplankton (Coyle *et al*., 2010. *Fish. Oceanogr*., Fig. 6).

The availability of large crustacean prey in late summer corresponds with whole body energy content of age-0

walleye pollock (Fig. 7). The survival of fish through their first winter appears to be strongly related to the energy density of fish captured in a surface trawl (kJ/fish). The recruitment anomaly of age-1 eastern Bering Sea pollock is a function of the average energy density of the sampled fish (not shown). These and other data were used to revise the Oscillating Control Hypothesis (Hunt *at al*. 2011, *ICES J. Mar. Sci*.).

Recently, PICES initiated a jellyfish working group (http://www.pices.int/members/working_groups/wg26.aspx) to address concerns about increases in jellyfish in the North Pacific. The potential impact of jellyfish on marine ecosystems was recently illustrated in *Science Daily*, where a group of researchers reported that jellyfish shunt food energy away from fish and shellfish and also disrupt the carbon cycle. AFSC has been measuring jellyfish biomass in the eastern Bering Sea during two different fish assessment cruises, the summer groundfish bottom trawl and late summer/autumn surface trawl surveys. Recent data from these surveys suggest that biomass has been increasing since 2007/2008 (Fig. 8). One hypothesis for the recent increase in jellyfish biomass is the increase in large crustacean zooplankton biomass co-incident with cold conditions over the shelf.

Science meetings

The 2nd ESSAS (Ecosystem Studies of Sub-Arctic Seas) Open Science Meeting (OSM) was held May 22–26, 2011, in Seattle, USA (the OSM summary is included elsewhere in this issue). New and exciting research results about the Bering Sea were presented in the session on "*New observations and understanding of eastern and western Bering Sea ecosystems*" as well as in other topic sessions.

Future meetings in 2011/2012 that may host sessions or talks of interest to scientists working in the Bering Sea include:

- PICES Annual Meeting (October 14–23, 2011, Khabarovsk, Russia);
- Alaska Marine Science Symposium (January 23–26, 2012, Anchorage, USA);
- AGU/Ocean Sciences Meeting (February 20–24, 2012, Salt Lake City, USA);
- ICES/PICES Early Career Scientist Conference (April 24–27, 2012, Majorca, Spain);
- 2nd Symposium on "*Effects of climate change on the world's oceans*" (May 15–19, 2012, Yeosu, Korea).

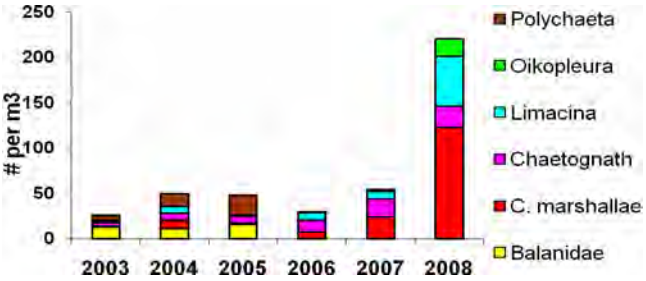

Fig. 6 Mean abundance (# per m^3) of large zooplankton within the southeastern Bering Sea shelf. Data from Bongo net tows with 505 µm mesh nets (figure courtesy of Lisa Eisner).

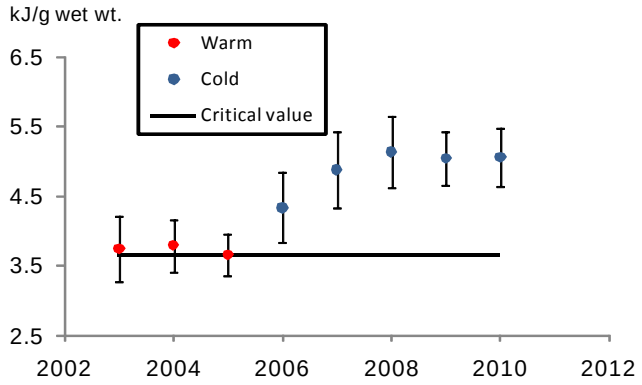

Fig. 7 Energetic status of age-0 walleye pollock during years with warm (red) and cold (blue) spring and summer sea temperatures on the eastern Bering Sea shelf. The critical value (horizontal line) is the energetic status of age-1 walleye pollock collected during spring (survived winter) in southeast Alaska (figure courtesy of Ron Heintz).

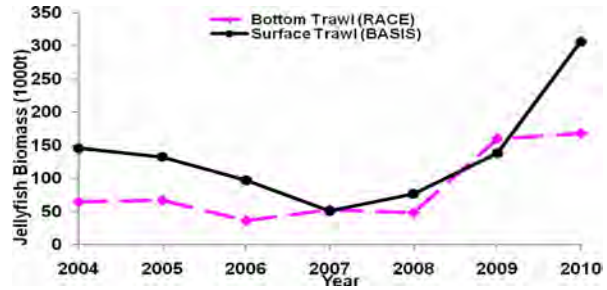

Fig. 8 Annual wet weight biomass of large jellyfish captured in fisheries trawls from the eastern Bering Sea (figure courtesy of Edward Farley).

Acknowledgements: Many thanks to the following PICESans who helped create this report: Drs. Lisa Eisner, Edward Farley, George Hunt, Jr., James Overland, and Phyllis Stabeno.

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

Northeast Pacific News

by William Crawford and Stewart (Skip) McKinnell

Temperatures of coastal waters of the northeast Pacific are very sensitive to anomalies in the direction and strength of regional winds. Prevailing currents have none of the inertia of western boundary currents such as the Kuroshio and Oyashio, and instead are driven by local winds and respond within days to changes in their direction. Wind anomalies that persist through an entire season will impose major changes in local water temperature and salinity, and even shift the composition of ecosystems. The past three winters have experienced huge shifts in wind speed and direction due to changes in intensity and position of the Aleutian Low (AL) pressure system.

Figure 1 presents maps of sea level pressure (SLP) and sea surface temperature anomaly (SSTA) for the North Pacific in February and March of 2009, 2010 and 2011. We chose to plot SLP for February because this month was the extreme of the general conditions in these winters. Normally, the AL pressure system forms in winter in the Gulf of Alaska and extends across much of the North Pacific Ocean. In 2010, AL air pressure was extremely low, falling to 994 mbar, and the system was centred in the Gulf of Alaska. By contrast, the panels of February 2009 and 2011 reveal almost no region where SLP fell below 1008 mbar, marked by a white contour in the left panels, and this contour was centred far to the west and did not even reach the Gulf of Alaska.

The temperature panels of Figure 1 reveal a classic oceanic response to ENSO (El Niño Southern Oscillation). El Niño winters in the Northern Hemisphere generally bring warm southerly winds along the west coast of Oregon to British Columbia, followed by positive SSTA. These winds are part of the cyclonic airflow around the intensified AL. By contrast, La Niña winters generally see stronger westerly winds in the subarctic northeast Pacific, due either to a weakening of the AL, or in extreme cases, as in February of 2009 and 2011, to anticyclonic flow around the rare winter extension of the North Pacific High into the Gulf of Alaska. These winds are followed by cooler waters along the west coast of U.S. and Canada. Although La Niña had diminished in the Equatorial Pacific by June 2011, SST of the eastern Gulf of Alaska remained cooler than normal.

The Aleutian Low Integral Index (ALII) is a measure of the intensity of the AL. It is formed by calculating the integral of SLP inside the 1008.5 mbar contour. Whereas the Aleutian Low Pressure Index (ALPI) is simply the area inside the 1005 mbar contour, ALII represents both the surface areal coverage and intensity of the AL by computing a "volume" of area times air pressure anomaly. The time series of ALII (Fig. 2) reveals just how extreme the past three winters have been.

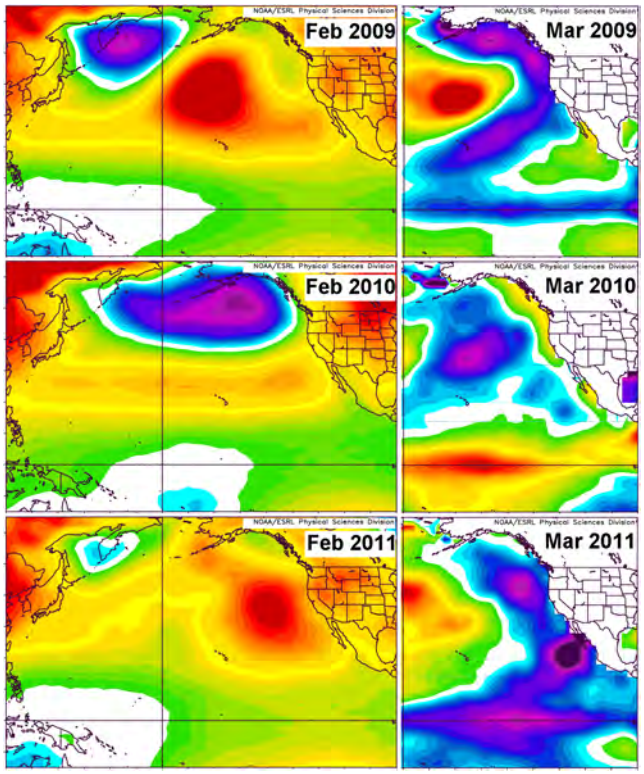

Fig. 1 Contours of sea level pressure (SLP, left) and sea surface temperature anomaly (SSTA, right) for February and March, respectively, of the past three winters. Pressure contours extend from a low of 992 mbar (purple) to 1024 mbar (red). Temperature anomalies run from –1.5°C (dark purple) to +1.5°C (red). Solid black lines denote the Equator and 180°W. Image plotted by on-line software of NOAA/ESRL Physical Sciences Division.

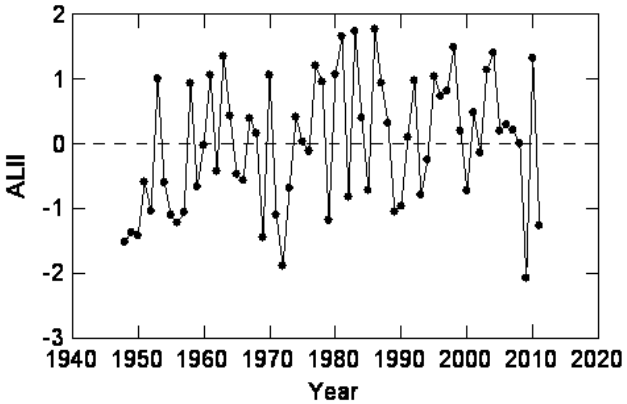

Fig. 2 Time series of the Aleutian Low Integral Index (ALPI) for December to February of winters from 1948 to 2011.

The winter of 2009 experienced the lowest ever value of ALII, followed by an extreme high in 2010 and another low in 2011. In general, ALII is high in El Niño winters and low in La Niña winters, especially since the late 1990s.

Figure 3 illustrates the changing nature of both ALII and the Oceanic Niño Index (ONI) over the winters of 1950 to 2011. ONI is determined by the anomaly of ocean surface temperature in Niño 3.4 region, which lies between 5°N and 5°S and 120°W to 170°W.

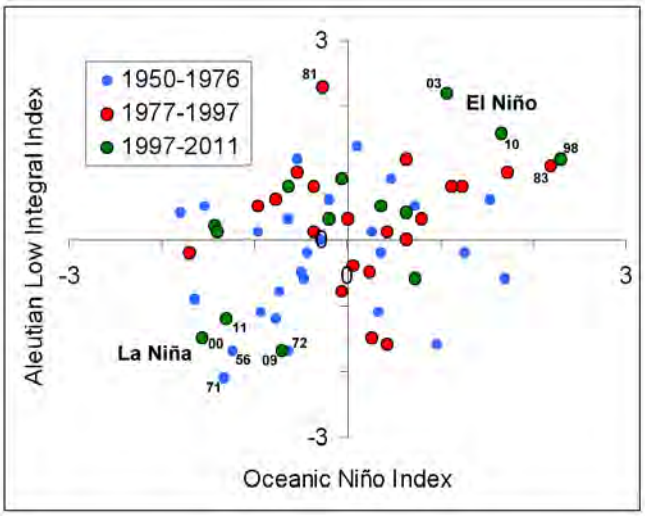

Fig. 3 Scatter plot of Aleutian Low Integral Index (ALII) and Oceanic Niño Index (ONI), each computed annually for December to February. Three eras are distinguished to reveal changes in the winter Pacific teleconnection from tropics to Gulf of Alaska. Labels indicate the last two digits of a few extreme winters.

Figure 3 reveals more negative values of both ONI and ALII from 1950 to 1976, and many more positive values from 1977 to 1997. The winters of 1976 to 1977 marked a shift in the northeast Pacific, with more intense Aleutian Lows following 1976. During the era of 1977 to 1997, only two winters had negative values for both ONI and ALII, indicating the general dominance of El Niño winters and intense Aleutian Lows. These two decades are considered to be dominated by a positive Pacific Decadal Oscillation (PDO), and the magnitude of ONI was generally a poor predictor of ALII and associated weather conditions in the Gulf of Alaska. By contrast, winters of 1950 to 1976 saw very few intense El Niño events, and no values of ALII greater than 1.2.

Green symbols of Figure 3 denote winters of 1997 to 2011. These winters cover the full range of El Niño to La Niña, with two of the most intense Aleutian Lows in the top right quadrant and three of the least intense Aleutian Lows in the bottom left quadrant. The correlation coefficient (R) between ONI and ALII for 1998–2011 is 0.66, compared to 0.24 for 1950–1977, and even lower R for 1950–1976 and 1977–1997. With such strong coupling between ONI and ALII since 1998, seasonal forecasting of winter weather along the west coast of British Columbia to Oregon has been more reliable in ENSO years.

Although the winters of 1983 and 1998 saw the most extreme warming in the ONI region, with ONI values greater than +2, these were not the winters of most intense Aleutian Lows. Instead, the more recent winters of 2003 and 2010 brought stronger Aleutian Lows whose intensity, as measured by ALII, was exceeded only in the winter of 1981.

Will these recent wide swings in ENSO and in the intensity of AL continue into future years? As of June 2011, the ensemble of El Niño models are predicting ENSO neutral conditions for the next few months, but cool surface ocean waters are still present in the eastern Gulf of Alaska. Perhaps, we may experience a "normal' winter in 2011 to 2013, with a gradual return to normal ocean temperatures.

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Dr. Skip McKinnell (right; mckinnell@pices.int) is the Deputy Executive Secretary of PICES.

PICES Advice on Marine Ecology at a Canadian Judicial Inquiry

by Stewart (Skip) McKinnell

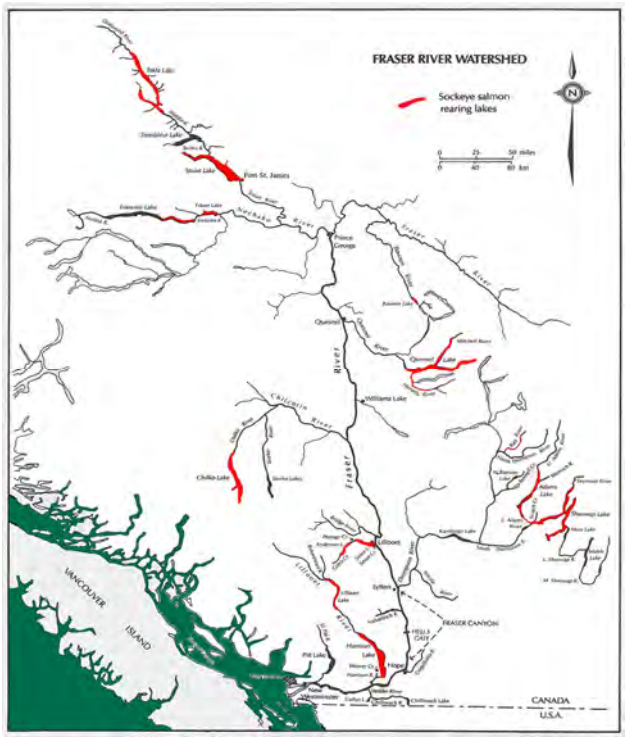

Fig. 1 Lakes (red) in the Fraser River watershed in British Columbia, Canada with sockeye salmon reproduction.

In November 2009, the Prime Minister of Canada established a commission of inquiry to discover why Fraser River sockeye salmon are not as abundant as they once were, especially from 2007 to 2009. As the investigation is being conducted by B.C. Supreme Court judge, Bruce Cohen, it has taken his name (www.cohencommission.ca). His mandate is to examine the effect of environmental changes along the Fraser River and in the ocean, the potential effects of aquaculture, predators, diseases, water temperature and other factors that may have affected the ability of sockeye salmon to reach traditional spawning grounds or to reach the ocean. He is also examining the current state of Fraser River sockeye salmon stocks and the long-term projections for those stocks to develop recommendations for improving sustainability of the sockeye salmon fishery in the Fraser River (Fig. 1), including changes to the policies, practices and procedures of the Department of Fisheries and Oceans (DFO).

Seeking to obtain advice that is produced independently of the organizations that manage and assess the fishery, 12 groups of scientists from universities and the private sector were invited to conduct research and offer their views on specific issues. The Chairman of PICES received an invitation from Mr. Cohen to develop a report on Fraser River sockeye salmon in relation to marine ecology. The invitation was accepted by the PICES Science Board at its April 2010 inter-sessional meeting in Sendai, Japan, where Skip McKinnell, Deputy Executive Secretary of PICES, was asked to lead the initiative. Work began in late June 2010 with an esteemed team of co-authors that included: Enrique Curchitser (Rutgers University), Kees Groot (DFO emeritus), Masahide Kaeriyama (Hokkaido University), and Katherine W. Myers (University of Washington). The three major objectives of the report were to: (1) provide a summary of what is known about the biology and ecology of Fraser River sockeye salmon in the ocean, (2) describe why returns were especially low in 2009, and (3) discuss the nature and cause(s) of low productivity during the last 15 years. While the report was being written last summer, an approximation of the 2010 abundance was added to the time series (Fig. 2) which invited additional comment by the authors of the report.

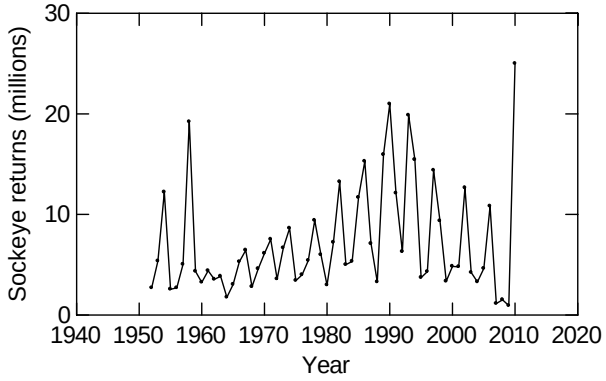

Fig. 2 Annual numbers of sockeye returning to the Fraser River.

Testimony at court on the PICES report is currently scheduled for July 2011. At press time, PICES Press was not at liberty to disclose its contents but it will be reported in a subsequent issue.

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