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PICES Press

Newsletter of the North Pacific Marine Science Organization (Published semi-annually)

The state of PICES science – 2004

PICES "Year-in-Review" 2004

The success of PICES, now and into the future, is being built upon three pillars: scientific excellence, scientific advice, and scientific capacity.

Scientific excellence includes publications, working group activities, workshops and symposia. PICES has been very productive scientifically, with five issues of primary scientific journals on PICES topics and one scientific report being published to date in 2004. These include:

- *Marine Environmental Research 57(1-2)* (March 2004) – papers from the Marine Environmental Quality Committee's Practical Workshop (Guest editor: R. Addison);
- *Journal of Oceanography 60(1)* (February 2004) – invited papers on North Pacific JGOFS Synthesis (Guest Editors: T. Saino, A. Bychkov, C.T.A. Chen and P. Harrison);
- *Progress in Oceanography 61(2-4)* (June 2004) – papers from the PICES/CREAMS workshop on East Asian Marginal Seas (Guest editors: S. McKinnell, A. Bychkov, K.-R. Kim and M. Terazaki);
- *ICES Journal of Marine Science 61(1)* (June 2004) – papers from the 3rd International Zooplankton Symposium (published jointly with GLOBEC and ICES; Guest editors: L. Valdez, R. Harris, T. Ikeda, S. McKinnell and W. Peterson);
- *Journal of Marine Systems 50(1-2)* (September 2004) – papers from the PICES 2002 Topic Session on biophysical coupling and topography (Guest editors: J. Dower and R. Brodeur).

Three other scientific reports are expected before the end of 2004. A measure of the scientific impact of these publications is provided by the *Elsevier* publications website which, as of September 2004, indicated that of the top 25 downloaded publications from journals in which PICES has special issues, papers published by PICES occupied positions numbered 2, 3, 5, 6, 12, 16, 18, 20 in *Progress in Oceanography* and 2, 9, 11, 13, 24 in *Marine Environmental Research.*

PICES-sponsored and co-ordinated research continues to be active on the water. The Continuous Plankton Recorder project conducts meridional transects in the Northeast Pacific 5-6 times annually, and zonal transects across the North Pacific 3 times annually using commercial ship-of-opportunity vessels. And just one week prior to the PICES Thirteenth Annual Meeting, the Advisory Panel on *Micronekton sampling inter-calibration experiment* hosted a field survey off Hawaii in which they conducted inter-comparisons of systems typically used to sample micronekton in the North Pacific. Preliminary results from this survey are presented elsewhere in this Newsletter.

Another indication of PICES' scientific excellence is the North Pacific Ecosystem Status Report, which is available in pre-publication form from the PICES web site, and is expected to be published shortly. The scientific content of this report was approved by Science Board at its second inter-sessional meeting in May 2004, in Jeju, Korea. This report provides an analysis of the thirteen PICES regions in the North Pacific and a synthesis which integrates the status of all these regions. In general, although there are local and regional stresses in the marine ecosystems of the North Pacific, there have also been successes where marine populations are doing well.

The extent of scientific meetings, and the successes of the Thirteenth Annual Meeting also indicate the vibrant scientific life of PICES. Over the past year, PICES has convened or co-sponsored 19 meetings and workshops, including monitoring in the North Pacific, modelling lower trophic level production and linkages to fish, biogeochemical processes and data integration related to carbon cycling and iron enrichment experiments, and ecosystem indicators for fisheries management.

The Thirteenth Annual Meeting of PICES, held October 14-24, 2004, in Honolulu, Hawaii, hosted 403 registered participants, 11 scientific sessions, 6 workshops, and several Working Group, Task Team and Advisory Panel meetings. There were 227 oral presentations, 122 posters and 7 electronic posters. The theme of the meeting was "Beyond the continental slope - complexity and variability in the open North Pacific Ocean". Dr. Jeffrey Polovina presented the Keynote Lecture, titled "Send out the turtle fleet!", in which he described the use of radio-tagged turtles to examine oceanic habitats and migration pathways of these animals in the sub-tropical North Pacific.

This presentation was followed by the theme session for PICES XIII, which considered issues of complexity and variability in the open North Pacific. Papers dealt with causes and potential predictability of the Pacific Decadal Oscillation, with large-scale environmental monitoring of physical conditions and circulation in the North Pacific, with regime-like changes in lower and upper trophic levels of the sub-tropical North Pacific, and with classification of marine pelagic environments in the open North Pacific Ocean. Variability, on both large and small temporal and spatial scales, is a dominant feature of these sub-tropical open ocean ecosystems, which is in marked contrast to the traditional view. Other sessions (and lively discussions) were held on "Mechanisms that regulate North Pacific ecosystems: Bottom up, top down, or something else?", "Hot spots and their use by migratory species and top predators in the North Pacific", "Introduction of marine species", "Marine protected areas", "Application of global observing systems to physics, fisheries, and ecosystems", "The impacts of climate change on the carbon cycle in the North Pacific", "The impacts of large-scale climate change on North Pacific marine ecosystems", among other topics. Several workshops, which provided more time for discussion, were held both before and after the main meeting on topics that included "Scale interactions of climate and marine ecosystems" (co-sponsored with CLIVAR), "The seasonal cycle of plankton production in continental shelf waters around the Pacific Rim", and "Linking open ocean and coastal ecosystems". Brief summaries of these sessions including discussions are published in the PICES Annual Report for 2004.

Dr. Ian Perry summarizing PICES scientific achievements of 2004 at the PICES XIII Opening Session.

Dr. Jeffrey Polovina giving the Keynote Lecture at the PICES Thirteenth Annual Meeting.

The Best Paper Award during the Science Board Symposium went to Dr. Akihiko Yatsu (Japan) for his oral presentation (co-authored with Masatoshi Moku, Hiroshi Nishida, Kaoru Takagi, Norio Yamashita and Hiroshi Ito), titled "Possible ecological interactions between small pelagic and mesopelagic fishes in the Kuroshio – Oyashio Transition Zone and Kuroshio Extension in spring". Dr. Oleg Katugin received an Honourable Mention for his oral presentation (co-authored with Gennadiy Shevtsov) in the

Scientists who received Best Presentation Awards and recognition at PICES XIII. Their presentations can be found on PICES' website (just click on presentation photo on the main page http://www.pices.int.

Science Board Symposium, titled "Patterns of distribution and biology of the North Pacific oceanic squid *Berryteuthis anonychus* with implications for the species life cycle". The Best Poster Award went to Dr. Katsuya Suzuki for his poster (co-authored with Tsutomu Takagi, Shinsuke Torisawa and Kazushi Miyashita), titled "Video analysis of the schooling behavior of Japanese surfsmelt (*Hypomesus japonicus*) under light and dark conditions using a mathematical model". The Best Presentation Award from the BIO Committee went to Akinori Takasuka for his paper (co-authored with Yoshioki Oozeki, Ichiro Aoki, Ryo Kimura, Hiroshi Kubota and Takashi Yamakawa), titled "Differential optimal temperatures for growth of larval anchovy and sardine: a potential mechanism for regime shifts?" Honourable Mention from the BIO Committee went to Vladlena Gertseva for her paper (co-authored with Thomaa Wainwright and Vladimir Gertsev), titled "Juvenile salmon survival in coastal waters of the Northeast Pacific Ocean: top-down or bottom-up control?" The FIS Committee Best Presentation Award went to Scott Gende for his paper "Persistence of prey "hot spots" in southeast Alaska" (co-authored with Mike Sigler). The MEQ Committee Best Presentation Award went to Jennifer Boehme for the paper "Ballast water exchange verification using optical characteristics of dissolved organic matter" (co-authored with Mark Wells). The Best Presentation in the POC Committee went to Sabine Mecking for her paper "Age and AOU increases at the North Pacific subtropical-subpolar gyre boundary" (co-authored with Mark Warner and John Bullister). The Best Presentation Award from the TCODE Technical Committee went to Mukti Zainuddin for his electronic poster on "Spatio-temporal dynamics of albacore fishing ground and environmental conditions detected by remotely sensed satellite data" (co-authored with Katsuya Saitoh and Sei-ichi Saitoh). The Best Presentation from the CCCC Program went to Hyun-Cheol Kim for his paper (co-authored with Sinjae Yoo and Im Sang Oh) on "Relation between phytoplankton blooming and wind stress in the central Japan/East Sea".

<u>Scientific advice</u>: PICES is not designed to provide short-term, tactical, management advice, in contrast to our sister organisation ICES. However, PICES is moving to provide advice on broad issues concerning North Pacific marine systems, whether specifically requested by member nations or not. The North Pacific Ecosystem Status Report is one example of unsolicited advice. In October 2003, PICES received a formal request for advice from the United States concerning the characteristics and impacts of recent regime-like changes in the North Pacific. PICES responded by forming a 1-year Study Group (called FERRRS: *Fisheries and Ecosystem Responses to Recent Regime Shifts in the North Pacific*). The report of this Study Group was presented to the United States delegates at PICES XIII. A brief description of the findings of this group is presented elsewhere in this Newsletter; the full report and a glossy brochure with short answers to the questions posed by the United States are available on the PICES web site or from the PICES Secretariat.

<u>Scientific capacity</u>: Scientific capacity within PICES includes the willingness and commitment of the scientists and others about the North Pacific (and elsewhere) to devote time and effort to the work of PICES. It also includes a strong PICES Secretariat which, with only 4 permanent staff, is doing an outstanding job of keeping these activities going. To help a broad-based, scientific, organisation like PICES formulate a clear direction and maintain a sense of forward momentum, the Governing Council, Science Board, and scientists of PICES developed a PICES Strategic Plan (http://www.pices.int/about/PICES_strategy.pdf). The PICES mission is "*To promote and coordinate marine scientific research in the North Pacific Ocean in order to advance scientific knowledge of*

the area concerned and of its living resources." This Plan includes a strategy for PICES to achieve this mission, involving 5 themes each with specific goals:

Theme A. Advancing scientific knowledge
Theme B. Applying scientific knowledge
Theme C. Fostering partnerships
Theme D. Ensuring a modern organization supporting PICES activities
Theme E. Distributing PICES scientific information.

The Strategic Plan was developed to guide the selection of future activities of PICES. Over the past years there has been much enthusiasm for the meetings and work done by PICES, but also a sense that continuity is lacking, that issues raised as important one year, for example, to form a working group on a particular topic, are not considered the next year. Following this Strategic Plan, the next steps are to develop an Action Plan, in which each PICES Committee considers where they want to go over the next 3-5 years, what topics they want to explore, and how these fit together with topics of other Committees.

PICES has also re-organized the Climate Change and Carrying Capacity (CCCC) Program. The Basin Scale (BASS) and Regional Experiment (REX) Task Teams were concluded at this Annual Meeting, and PICES thanks their Chairmen and members for their effort and dedication. They have been replaced with a new Task Team on *Climate Forcing and Marine Ecosystem Response* (CFAME), whose objective is to synthesize regional and basin-wide studies and provide a forum for the integration and conclusion of CCCC-related hypotheses and data. The MONITOR Task Team was removed from the CCCC Program and re-formed as a Technical Committee directly under Science Board. This will provide an on-going focus on monitoring in the North Pacific, and in particular will consider the monitoring needs of the PICES region, oversee updates to the North Pacific Ecosystem Status Report, and serve as the interface between PICES and observing systems such as GOOS.

New groups that were formed at PICES XII in October 2003, and which began active work over the past year include the *Harmful Algal Bloom Section* under MEQ, Working Group 18 on *Mariculture in the 21st century - The intersection between ecology, socio-economics and production*, and the Study Group on *Ecosystem-based management science and its application to the North Pacific*. Two new groups were formed at PICES XIII in October 2004, one a Working Group (for a 3-year duration) on *Ecosystem-based management science and its application to the North Pacific* (which replaces the 1-year Study Group), and the other an Advisory Panel under the Physical Oceanography and Climate Committee on the CREAMS/PICES Program in East Asian Marginal Seas. Working Group 14 on *Effective sampling of micronekton* presented its final report at PICES XIII, which will be published shortly in the PICES Scientific Report Series. Working Group 16 on *Climate change, shifts in fish production, and fisheries management* submitted a near-final draft at this Annual Meeting and is expected to be completed by spring 2005. Working Group 17 on *Biogeochemical data integration and synthesis* is expected to publish soon their "Guide of best practices for oceanic CO_2 measurements and data reporting."

Up-coming highlights for 2005

The theme of the PICES Fourteenth Annual Meeting in Vladivostok, Russia, September 30 - October 8, 2005, will be "Mechanisms of climate and human impacts on ecosystems in marginal seas and shelf regions". Other symposia in various stages of planning (see the PICES web site for details) include:

- *Climate variability and sub-Arctic marine ecosystems*, May 16-20, 2005, in Victoria, Canada (co-sponsored with GLOBEC);
- *State of Pacific salmon and their role as indicators of the health of North Pacific ecosystems*, October 30 - November 2005, in Jeju, Korea (jointly with NPAFC);
- *Marine bioinvasions*, spring 2006 (jointly with ICES);
- *Climate variability and ecosystem impacts on the North Pacific: a basin-scale synthesis*, a PICES CCCC Symposium, April 19-21, 2006, in Honolulu, Hawaii;
- *4th Zooplankton Production Symposium*, May 28 – June 1, 2007, in Hiroshima, Japan (jointly with GLOBEC and ICES);
- *Young Scientists Conference* proposed for 2007 (jointly with ICES).

In addition, PICES is discussing what scientific issues should be the basis for the next major integrating program of PICES, after the completion of the CCCC Program. Suggestions so far include additional questions arising from the CCCC Program, possible interactions with CLIVAR on climate and North Pacific ecosystems, issues of marine biogeochemistry and food webs that would link with the new IGBP program on *Integrated Marine Biogeochemistry and Ecosystems Research* (IMBER), and ocean and ecosystem responses to high concentrations of carbon dioxide. Other ideas are welcome.

Finally, as this is the end of my 3-year term as Chairman of PICES Science Board, I welcome Dr. Kuh Kim (Korea) as the new Chairman of Science Board, and express my thanks to the Governing Council, the scientists, and in particular to the PICES Secretariat for their help and support during my term. Your support has been essential – Thank You!

R. Ian Perry
PICES Science Board Chairman
Fisheries & Oceans Canada
Pacific Biological Station,
Nanaimo, B.C., Canada V9T 6N7
E-mail: *perryi@pac.dfo-mpo.gc.ca*

2004 Wooster Award

In October 2000, PICES established a new award named in honour of Dr. Warren S. Wooster, the principal founder and first Chairman of PICES, and world-renowned researcher and statesman in the area of climate variability and fisheries production. The award is to be given annually to an individual who has made significant scientific contributions to North Pacific marine science; has achieved sustained excellence in research, teaching, administration or a combination of these in the area of the North Pacific; has worked to integrate the various disciplines of the marine sciences; and preferably someone who is or has been actively involved in PICES activities.

The award presentation ceremony took place on October 18, during the Opening Session of PICES XIII (Honolulu, U.S.A.). Dr. Ian Perry announced that **Dr. Paul H. LeBlond** was the recipient of the 2004 Wooster Award and quoted the following Science Board citation:

Dr. Paul LeBlond has had a distinguished scientific, educational and public service career, which has contributed to the marine sciences generally and specifically to many of the goals of PICES. He has authored or co-authored more than 90 primary journal publications, 20 conference proceedings, and two books spanning a wide variety of physical and biological topics, many of which link fisheries research problems with changing physical oceanographic conditions in the North Pacific Ocean. His list of contributions also includes publications under the headings of Science Education, Book Reviews, Cryptozoology, Engineering Studies, Historical, Public Services, Marine Conservation, and Fun. The section under Cryptozoology alone has over 21 publications. Dr. LeBlond has remained one of the world's leading physical oceanographers throughout his distinguished career, and has supervised over 40 graduate students. He has lectured at several universities throughout the world, including onboard a cruise ship traveling the South Pacific. Dr. LeBlond has also served PICES well, as a member and then Chairman of the Physical Oceanography and Climate Committee, Chairman of WG 7 on Modeling of the Subarctic North Pacific Circulation, *and Co-Chairman of the Scientific Steering Committee for the first major inter-sessional international conference organized by PICES entitled "Beyond El Niño". He has been the recipient of several Canadian and international marine science awards, and has been a member or chaired a number of important Canadian public marine science committees. The diversity and excellence of Dr. LeBlond's science, his significant contributions to university education and public awareness of marine problems, the recognition he has received through major awards from his peers, and his unselfish participation in national and international ecology and environmental committees, makes him a deserving candidate for this award.*

Dr. Warren Wooster provided brief remarks (photo above) on the selection of Dr. LeBlond (see Paul's biography in PICES Press Vol. 7(2), 1999) as the recipient of the 2004 Wooster Award:

I applaud the Science Board selection of Paul LeBlond to receive this award. Their citation makes the case very clear. I would like to comment on two points.

The first point relates to the interdisciplinary nature of marine science. Paul is a physical oceanographer, a species well known for avoiding involvement in messy fishery questions. But he early recognized that changes in ocean circulation and mixing had impact on fish populations and therefore has contributed actively to the work of several Canadian fishery conservation organizations. This is exactly the kind of miscegenation PICES has tried to promote!

Paul's career had been carried out in academia, at the University of British Columbia, where much of his teaching and research had been highly relevant to the work of PICES. As in the case in other member countries, such work is not done exclusively, or even principally, in government laboratories. This is evident in the makeup of delegations to PICES meetings where, for example, participation from Japan, Korea, and the US, has usually been equally divided between government and academic scientists. Academic participation from other members tends to be significantly less. Yet not all wisdom is to be found in government laboratories – as Paul might say, au contraire! I hope this point can be kept in mind by governments when identifying those to be supported for PICES participation.

Dr. Vera Alexander, Chairman of PICES, and Dr. Wooster presented a commemorative plaque to Dr. LeBlond (left photo), who then made his acceptance remarks (right photo):

Madame la Presidente, distingues delegues, chers collegues! It is a great honour for me to receive the Wooster Award and to find myself in the company of previous award recipients, Michael Mullin, Yutaka Nagata and Bill Pearcy, all of whom I met and learned to appreciate at previous PICES meetings. I am also particularly delighted to be more closely associated, through this award, with our founding father, Warren Wooster, who is here with us today. Warren's child, PICES, is now holding its Thirteenth Annual Meeting: PICES is now a teen-ager! Teen-age years are a period of great turmoil in human development. I am happy to say that I can detect no such turmoil in PICES, the institution. More importantly, I detect no evidence of a more common and graver symptom of maturing institutions: the tendency to crystallize into formality, to replace youthful enthusiasm with routine and protocol. One way for an institution to retain its youthful dynamism is to attract young people to its fold, or at least to ensure that its supporters remain young-at-heart. So, in gratitude for this award, I offer two wishes. To all of you as individuals, I wish that you remain young-at-heart and full of joie-de-vivre: may you all follow in the footsteps of our founding father, who was already past usual retirement age when he gave birth to PICES. To PICES as an institution, I offer the wish of continuing youthful and dynamic success for years and years to come. Thank you again!

The late Professor Michael M. Mullin (U.S.A.), Dr. Yutaka Nagata (Japan) and Dr. William Pearcy (U.S.A.) were honoured with the Wooster Award in 2001, 2002 and 2003, respectively. A permanent plaque identifying Wooster Award winners resides at the PICES Secretariat in Sidney, British Columbia, Canada.

We are now soliciting nominations for the 2005 Wooster Award (Contact the PICES Secretariat *secretariat@pices.int* or see PICES Press Vol. 9 (1) 2001 for selection criteria and award description). **Nominations must be received no later than May 1, 2005,** and should include the following information: nominee's name, institutional affiliation and title, address, biographical resume, and statement of justification for the nomination. The award will be presented during the Opening Session of PICES XIV on October 3, 2005, in Vladivostok, Russia.

Wooster Award recipients: 2001 - Prof. Michael Mullin (U.S.A.); 2002 – Dr. Yutaka Nagata (Japan); 2003 – Dr. William Pearcy (U.S.A.); and 2004 – Dr. Paul H. LeBlond.

Micronekton - What are they and why are they important?

Richard D. Brodeur, Michael P. Seki, Evgeny A. Pakhomov and Andrey V. Suntsov

Background

Micronekton are relatively small but actively swimming organisms ranging in size between plankton (< 2 cm), which drift with the currents, and larger nekton (> 10 cm), which have the ability to swim freely without being overly affected by currents. Although there are some precise definitions based on Reynolds numbers, micronekton may be operationally defined as taxa too vagile to be caught with conventional plankton nets and too small to be retained by most large-meshed trawls. Micronekton are diverse taxonomically. The principal groups include the cephalopods (small species and juvenile stages of large oceanic species), crustaceans (including adult euphausiids, pelagic decapods and mysids), and fishes (mainly mesopelagic species and juveniles of pelagic nekton). Although not generally fished commercially because of their relatively small size and high lipid content, mesopelagic fishes represent a substantial biomass in oceanic waters and are a critical but poorly understood intermediate trophic link between the mesozooplankton and the higher trophic levels including fishes, seabirds and marine mammals. Many studies have shown that micronektonic species are a primary food source for a wide variety of harvested nektonic species.

Fig. 1 Diversity of life forms considered as micronekton.

Many micronektonic species can be found close to shore or near the sea surface (*e.g.*, Abookire *et al.*, 2002, *Fish. Bull. U.S.*, 100: 376-380), but most occur in the midwater pelagic realm mainly at the edge of, or beyond the continental shelves. Indeed, micronekton are one of the most conspicuous and ecologically-important components of the vast mesopelagic zone of the world's oceans, arguably the largest and one of the least variable ecosystems on the planet. This dark, cold, and relatively unproductive system extends from around 200 m to depths greater than 1000 m, and many of these organisms have evolved unique adaptations to this environment (Fig.1). Most mesopelagic micronektonic organisms undertake extensive vertical migrations on a daily basis, occupying the productive surface waters at night and descending to midwater during the daytime to reduce predation. Diel vertical migration of micronekton has been shown to contribute significantly to the rapid vertical transport of organic material from epipelagic to mesopelagic zones, referred to as the biological pump, where carbon fixed as living organic matter plus anthropogenic substances, such as insecticides and pollutants, are transported to deep-sea ecosystems. These micronektonic organisms in turn may be consumed by epipelagic predators in the near-surface waters, large nekton such as tunas, sharks and swordfishes that migrate dielly with the micronekton, and deep-sea fishes that migrate up to midwater. All of these predators capitalize on this vast and highly predictable food source.

Despite their importance to many consumers in the ocean, relatively scant attention has been paid to micronekton as a whole, especially compared to the primary consumer and top trophic levels that they link. Much of what is known and published in the literature was generated in the 1960s and 1970s and was not synthesized in any manner. A need was identified within the PICES community, especially among the ecosystem modelers, for a summary of the available information on micronekton in the North Pacific. In response to this, a scientific session dedicated to micronekton was held during the 1997 PICES Annual Meeting in Pusan, Korea, that brought together a large number of experts within the North Pacific region. It was at that time that a proposal was put forth to establish a PICES Working Group to assimilate knowledge of micronekton and their sampling in the North Pacific. This led to the formation of Working Group 14 (WG 14) on *Effective sampling of micronekton* which met for the first time in 2000. Initial summaries of the sampling conducted by each member nation were contained in a report presented at the PICES/CoML/IPRC workshop on "Impact of climate variability on observation and prediction of ecosystem and biodiversity changes in the North Pacific" held in Honolulu, in March 2001 (Brodeur, 2001, *PICES Sci. Rep.*, 18: 86-90). Prior to the 2000 PICES Annual Meeting in Hakodate, Japan, WG 14 co-sponsored a symposium on "Advanced techniques of sampling gear and acoustic surveys for estimation of fish abundance and behavior", the proceedings of which has since been published electronically and available from Hokkaido University (Iida, 2003). The final report of that group (Brodeur and Yamamura (Eds.), 2005, *PICES Sci. Rep.*, **30**) synthesizes what is known about the distribution, biomass, growth, reproduction, and trophic relationships of micronekton in the North Pacific Ocean and adjacent seas, with a summary of the present state of sampling of these organisms. It also attempted to identify key knowledge gaps that should be filled in the coming years.

Included in the terms of reference was a request to examine the efficacy of available micronekton sampling gears and propose new sampling devices if the available ones were not adequate for the task. One of the recommendations included in the WG 14 report is that although a number of gears are presently being used to sample micronekton in the North Pacific and other parts of the world's oceans, there has been little effort expended in comparing the relative sampling efficiency and selectivity of these gears. The merits and shortcomings of many different gear types for sampling micronekton have been discussed at length in reports and publications arising from the SCOR Working Group on *Methods of Sampling Micronekton* (Pearcy, 1981, *Biol. Oceanogr*., 2(2-4): 1-456). In most studies, only one type of gear was used so it is impossible to deduce the various biases associated with each gear. Moreover, sampling gears have become more advanced in time (see review by Wiebe and Benfield, 2003, *Prog. Oceanogr*., 56: 7-136) and the older technologies have been abandoned, often without any inter-calibration with the gears that replace them. This has hampered efforts to look at inter-decadal or even regional comparisons of micronekton composition and biomass since very often, different gears are used.

As a result of the recommendations of WG 14, PICES formed an Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) in 2002, to conduct a field study to compare micronekton sampling gears and other quantifying technologies such as acoustics and visual sampling methods, similar to that done by the International Council for the Exploration of the Sea (ICES) in the North Atlantic Ocean utilizing mainly plankton gears (Wiebe *et al.*, 2002, *ICES Coop. Res.*, 250, 25 pp). The role of MIE-AP was to oversee planning and implementation of the field program and dissemination of the results to the scientific community.

Initial field work

A preferred location is thought to be one that is known to contain high densities of all major micronektonic categories (midwater fishes, cephalopods, and crustaceans), and thus it would have to be an area that has been sampled previously to a great extent. It should also be an area that is relatively uniform over various spatial and temporal scales, and exhibits a high degree of repeatability among repeat tows taken at the same station, so that the majority of variability between tows could be ascribed to gear differences. It is desirable that the ocean conditions in the study area be relatively calm to facilitate deployment and recovery of complex gear types. Finally, the station should be in relatively deep water but also close to shore to minimize transit time. Although there are several areas within the PICES region that meet these requirements, the one recommended by MIE-AP is the area off the Hawaiian Islands. A pilot cruise was organized by the Panel to occur just prior to the PICES Annual Meeting in Honolulu to take advantage of the possibility that many potential participants would be attending the meeting. The leeward side of Oahu was chosen as the location for the experiment for several reasons including the benign weather conditions and relatively homogeneous distribution of the target taxa.

Ship time was secured on the NOAA research vessel, the *Oscar Elton Sette*, based in Honolulu, Hawaii. This vessel is over 70 m long and has the capability to tow large dual-warp trawls requiring doors as well as large and small single-warp midwater trawls. The ship also has several additional oceanographic winches equipped with conducting cable and sufficient deck space to stage several gear types. It also has advanced acoustic and oceanographic sampling capabilities needed for such a study.

An international team of experts in micronekton taxonomy and sampling and acoustics (Table 1) was assembled for the cruise, and the ship sampled continuously for seven days, alternating among three different gears (Fig. 2): a 140 m^2 pelagic Cobb trawl, a 4 m^2 Hokkaido University Rectangular Frame Trawl (HN), and a 2-m Midwater Trawl (IKMT). Sampling was conducted entirely during daylight and night periods, avoiding the crepuscular migration periods when the mesopelagic layer was in flux. Daytime

Table 1 Micronekton inter-calibration experiment cruise participants.

Organization/Institute	Name
Institute of Ocean Sciences, Fisheries & Oceans, Canada	Douglas Yelland
Earth & Ocean Sciences, University of British Columbia, Canada	Evgeny Pakhomov Larissa Pakhomova
Graduate School of Fisheries Sciences, Hokkaido University, Japan	Masayuki Abe Hiroki Yasuma
Pacific Islands Fisheries Science Center, National Marine Fisheries Service (NMFS), U.S.A.	Michael Seki (Chief Scientist) Daniel Curran Donald R. Hawn Reka Domokos
Northwest Fisheries Science Center, NMFS, U.S.A.	Richard Brodeur
Harbor Branch Oceanographic Institution, U.S.A.	Andrei Suntsov

Fig. 2 Deployment of the different sampling gears and sorting the catch.

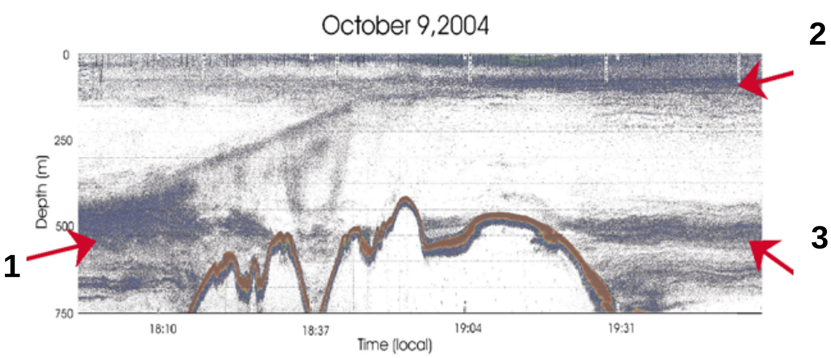


Fig. 3 An EK-60 38 kHz echogram collected from 1800-2000 h on October 9, 2004, showing the dusk migration of the scattering layer from a normal daytime depth around 550 m up to the surface, and the locations of sampling during the micronekton inter-calibration experiment. (1) Day tows ≈ 550 m, (2) Night tows ≈ 120 m, (3) One series night tows ≈ 550 m.

sampling was entirely in a deep layer (typically targeting 550 m), while nighttime sampling was mainly targeted the upper 120 m of the water column, although one series was conducted at depth to sample the non-migratory layer (Fig. 3).

Preliminary results from the cruise were presented at a MIE-AP Workshop convened prior to PICES XIII. It was found that while small sampling gears provided similar micronekton abundances, densities measured using both HN and IKT were generally significantly higher than densities obtained by Cobb trawl for main taxonomic groups sampled during the survey (Fig. 4), in part because these nets had finer mesh sizes than the Cobb trawl. The Cobb trawl, however, caught substantially larger organisms than either of the other gears due principally to its large mouth opening.

Deployment of the three types of gear resulted in a collection of approximately 43-46 species of fishes from 24-25 families. At present, these numbers exclude all representatives of the rather speciose midwater family Myctophidae, which were not identified to species at sea. The majority of fish families (21) encountered during our sampling are truly mesopelagic with only few representatives from coastal and epipelagic communities.

The quantitative composition of the entire fish collection was very uneven, with myctophids contributing close to 60% of all specimens collected. The second most abundant were in the family Gonostomatidae (largely due to abundant and ubiquitous *Cyclothone* spp.) which totals close to 38% of the total catch. The remaining families contributed less than 4% to the total fish collection.

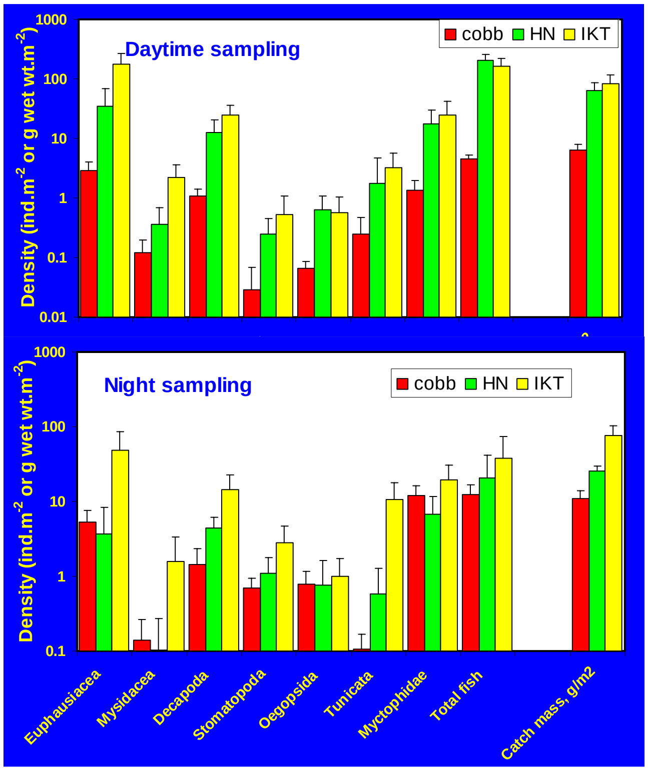


Fig. 4 Comparative catch by three sampling gears of the main taxonomic groups and overall catch biomass during day (top panel) and night (bottom panel) sampling during the inter-calibration cruise.

Based on our preliminary taxonomic treatment, we calculated basic community indices to estimate diversity, evenness and species richness (Fig. 5). As seen for densities of particular midwater groups, these indices are very similar for the HN and IKT gears. This is particularly evident for the number of species and for daytime diversity and evenness indices. Both day and night deployment of the Cobb Trawl clearly procured more species per trawl, which is also reflected in the higher diversity and evenness indices. After completing our taxonomic analysis, we expect to analyze additional data on ichthyoplankton and invertebrate abundances and species composition to complement inter-gear comparison and estimate relative catchability for each gear.

In terms of acoustics, two prominent scattering layers were observed at ~10-140 m and ~450-750 m. The surface layer was due primarily to organisms migrating to the surface at night, while the deep scattering layer was a permanent feature that may be representative of non-migratory organisms and/or organisms that migrate up from deeper water during the night (Fig. 3). The water column between the two prominent scattering layers lacked significant backscatter indicating that the water column was basically devoid of organisms outside the layers, which was verified by a single haul during daytime that fished only the upper 300 m and came back nearly empty.

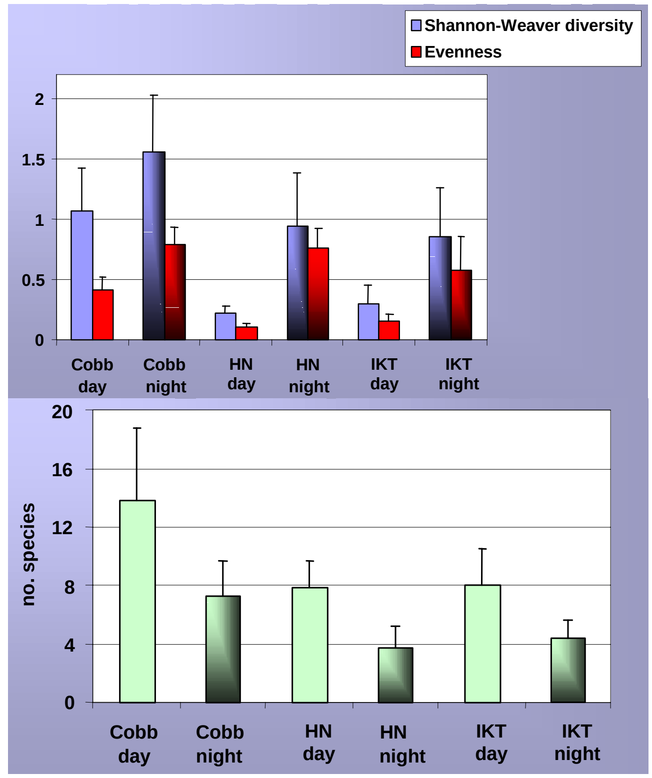


Fig. 5 Diversity and evenness indices (top panel) and total number of species (bottom panel) caught by each sampling gear by time of day.

Future directions

Preliminary analysis from the 2004 experiment indicated that individual gears sampled different, often non-overlapping, size groups of plankton and micronekton. This appeared to be relevant for our ability to interpret the data acquired from the multiple acoustic frequencies. However, it also points out that successful inter-comparisons during future cruises requires a closer scrutiny of gear-types and net mesh sizes prior to the experiment. Adoption of a "standard" sampling gear (such as a Rectangular Midwater Trawl (RMT 1+8) or a 3-m IKMT) and mesh sizes was suggested to facilitate comparisons. Based on the success and preliminary findings of the first cruise, MIE-AP recommended conducting a second experiment within the subarctic North Pacific using a larger variety of micronektonic sampling gears. This cruise is tentatively planned for summer 2005 (or 2006, depending on ship time availability) in the Bering Sea.

Dr. Richard Brodeur (rick.brodeur@noaa.gov) is a Research Fisheries Oceanographer working in the Fish Ecology Division of the Northwest Fisheries Science Center, NOAA Fisheries, and is based in Newport, Oregon. He received his M.S. in oceanography from Oregon State University, and his Ph.D. in fisheries from the University of Washington. Following a postdoc at the Pacific Biological Station in Nanaimo, B.C., Canada, he began his career working on early life history and recruitment dynamics of walleye pollock in the Subarctic Pacific for the Alaska Fisheries Science Center. He returned to Oregon to work on habitat preferences and trophic ecology of juvenile salmon. He has published on a variety of topics ranging from satellite oceanography to fish bioenergetics to fisheries acoustics, but has focused much of his research on micronekton and nekton. Dr. Brodeur is the Co-Chairman of the PICES WG 14 on Effective sampling of micronekton*.*

Dr. Michael Seki (Michael.Seki@noaa.gov) is the Deputy Director of the Pacific Islands Fisheries Science Center located in Honolulu, Hawaii and has been with NOAA Fisheries since 1980. He has conducted studies on marine resources in the Pacific region including seabirds, sea turtles, tropical snappers, oceanic squid, tunas, and billfishes, and has authored or co-authored over 40 scientific papers on topics such as open ocean food webs (ecosystems) and the influence of the physical oceanographic environment on the distribution and abundance patterns of living marine resources. Mike received his M.S. in oceanography from the University of Hawaii, and his Ph.D. in marine environment and resources from Hokkaido University (Graduate School of Fisheries Science). Dr. Seki is the Co-Chairman of the PICES Advisory Panel on Micronekton sampling inter-calibration experiment*.*

Dr. Evgeny Pakhomov (epakhomov@eos.ubc.ca) is a Faculty in Biological/Fisheries Oceanography at the Department of Earth and Ocean Sciences of the University of British Columbia, Vancouver, Canada. His research focuses on topics ranging from species ecology, at the level from zooplankton to fish, to ecosystem structure as well as physical-biological and biochemical coupling. Recently, Evgeny has developed interests in the applications of stable isotopes (bulk and compound specific measurements) in food web studies to reconstruct trophic pathways in pelagic ecosystems. He has also published on variability and responses of marine ecosystems to climate change using stable isotopes, large-scale and retrospective analyses. Dr. Pakhomov co-chairs the PICES Advisory Panel on Micronekton sampling inter-calibration experiment*.*

Dr. Andrey Suntsov (ASuntsov@HBOI.edu) is a Postdoctoral Fellow at Harbor Branch Oceanographic Institution, Florida. After graduating from Moscow State University in 1993, he started work on oceanic ichthyoplankton/mesopelagic fishes at P.P. Shirshov Institute of Oceanology in Moscow. He entered the graduate program at the Virginia Institute of Marine Science, earning his M.S. in 1997. Andrey subsequently returned to Russia and completed his doctorate degree on ichthyoplankton in Peruvian waters in 2003. At present, Andrey is involved in the study of age and growth patterns of deep-sea fishes from the North Atlantic. His research interests encompass early life history of marine fishes, oceanic micronekton and mesopelagic biology.

Upscaling for a better understanding of climate links to ecosystems

Nathan Mantua
Department of Atmospheric Sciences
University of Washington
Box 354235, Seattle, WA
U.S.A. 98107
E-mail: nmantua@u.washington.edu

Dr. Nathan Mantua is currently the assistant director for University of Washington's Center for Science in the Earth System, and a full-time research scientist with the University Washington's Climate Impacts Group. His research includes efforts to understand the nature of climate variability, climate impacts on ecosystems, and how climate information can be used in resource management. Nate has worked at the University of Washington since 1995, and thinks that someday he would like to try his hand at the kind of blue-water field work that provides the data needed to untangle the mysteries of biophysical interactions in the Pacific. Nate has been involved with PICES serving as a member of the Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts in the North Pacific*.*

There are some obvious and major limitations in large-scale climate perspectives on biophysical interactions. Why might a vocal proponent for the importance of ENSO and the PDO for Pacific ecosystems (as I am!) believe this to be true? *First*, at the most fundamental level, all biophysical interactions must be local. A juvenile salmon in the northeast Pacific Ocean will only be influenced by an ENSO event if that tropical event somehow influences the physical or biotic environment experienced by that juvenile salmon. *Second*, large-scale climate indices generally do a poor job capturing the details of environmental changes at the scale of many (perhaps most) meaningful ecosystem interactions, and it is likely that the details of environmental events really do matter. This simple fact is by design: large-scale climate indices are developed to represent a one-dimensional perspective on large-scale aspects of climate variations, not to capture the details of local environmental changes. The PDO index, for example, is based on the monthly loadings of observed SST anomalies onto the leading EOF pattern identified in an analysis of monthly North Pacific SST variations from 1900-1993 (Zhang *et al*., *J. Climate*, 1997, 10, 1004; Mantua *et al*., *Bull. Am. Meteor. Soc.*, 1997, 78, 1069). As highlighted by Bond *et al*. (*Geophys. Res. Lett*., 2003, 30, 2183) and the commentary by McKinnell (*PICES Press*, 2004, 12, 16), the prominence of the PDO pattern varied over the period 1950-2003. In the 1990s, the PDO pattern was secondary in the total North Pacific SST variance it explained to that of the Victoria Pattern of SST variations (the 2nd EOF from an analysis of wintertime SSTs from the period 1950-2003 – see Bond *et al*. for details). In contrast, the environmental changes that influence biophysical interactions in marine ecosystems are likely to be multi-dimensional, possibly non-stationary in time, and with different elements of the key biophysical processes occurring over a variety of spatial and temporal scales.

This commentary on the limitations of large-scale climate perspectives does not aim to call for the removal of large-scale climate indices from Fishery Oceanography investigations. Instead, the objective here is to provide a climate scientist's perspective on analytical approaches for better understanding of the mechanisms for biophysical interactions, causes for local environmental and ecosystem variability, and ecosystem predictability.

A critical part of identifying and understanding the biophysical mechanisms underlying ecosystem changes is to match commensurate scales for the biotic and abiotic parameters of interest. One informative study of cross-scale issues is presented by Hallett *et al*. (Nature, 2004, 430, 71), wherein they report on investigations into the links between Soay Sheep population changes, local climate, and changes in the North Atlantic Oscillation (NAO) index. This collection of issues spans a vast range of spatial scales, from that of a small population of sheep (a few hundred animals) occupying a single catchment basin in the St. Kilda archipelago (spatial scales on the order of kms) to that of the NAO pattern that encompasses the entire North Atlantic sector. Over the period from 1985-2003, the NAO index is better correlated with Soay Sheep population variations than are indices tracking precipitation, winds, or temperatures from a meteorological station just 100 km distant. A closer inspection of the climate data reveals the source for this apparent paradox. The link between the NAO index and Soay Sheep comes with a range of different weather impacts on the limited food resources that sustain Soay Sheep in the winter season. In each case, local weather events influence wintertime mortality events for Soay Sheep; in some years it is extreme cold temperatures, in others it is high winds, and in others it is heavy precipitation events that appear as causal factors for Soay Sheep mortality events. The NAO index is modestly correlated with each of those factors, and it therefore offers a better correlation with Soay Sheep population numbers than any local one-dimensional weather index does. Important take home messages from this study are: (i) a one-dimensional view of climate (*e.g.*, temperature) is simply too narrow to identify and understand climate impacts on Soay Sheep; and (ii) that the NAO index, by itself, yields an incomplete picture for the causes of individual Soay Sheep mortality events.

In spite of the limitations provided by the NAO perspective alone, the relative risk for observing different dimensions of Soay Islands weather can be directly quantified by direct comparisons of the NAO index and Soay Islands temperature, precipitation, and wind data. Thus an understanding for NAO predictability, and the NAO link to the environmental changes of interest, offers a direct avenue for quantifying the predictability for multiple dimensions of the St. Kilda archipelago's climate. Establishing this causal chain across scales of space and time is necessary for understanding and quantifying the predictability of NAO-related Soay Sheep mortality events.

This improved understanding for climate impacts on Soay Sheep populations has come with what I would describe as an upscaling perspective on North Atlantic climate and Soay Islands biophysical interactions. In this case, upscaling refers to a study design that begins with local ecosystem measures of interest (sheep mortality records) and local weather records of interest (St. Kilda precipitation, temperature, and wind data). The mechanisms of the key biophysical interactions are established and quantified with no consideration at all for the possible links to the NAO. Yet important links to NAO variability, which is strongly suggested through the direct correlations between the NAO index and the Soay Sheep population data, becomes much more understandable by establishing the NAO influence on the local environmental parameters of interest.

The time-space scale diagram shown in Figure 1 highlights the fact that the Soay Sheep and NAO index example is quite similar to the kinds of spatial scales involved in many fishery oceanography studies aimed at linking regional ecosystem indices to large-scale climate indices. Soay Sheep populations are confined to small catchment basins (spatial scales ranging from 10's of meters to 10's of kms), and the time scales for mortality events range from hours to days. In contrast, the NAO pattern captures variations in North Atlantic sector SLPs from 100's to 1000's kms, and the NAO index varies across time scales ranging from intra-seasonal to inter-decadal (*e.g.*, see Hurrell *et al*. 2003, *Geophys. Monogr. Ser*., 134, 1).

Logerwell *et al*. (*Fish. Oceanog*., 2003, 12, 554) used an upscaling approach to develop a simple model for understanding and predicting annual variations in Oregon coho salmon marine survival variations with environmental data. The environmental model for Oregon coho survival uses 3 "local" environmental predictors: wintertime SST at a single location on the Oregon coast (a proxy for early spring water column stratification), the date of the spring transition based on coastal winds from 42ºN-48ºN and coastal sea level at Neah Bay, WA, and springtime sea level anomalies at Neah Bay, WA (a proxy for alongshore transport and coastal upwelling). Training this model on marine survival data from 1970-2001 yields a high degree of explanatory power (R^2=0.75). In contrast, direct correlations between annual indices for ENSO and PDO yield a much weaker explanatory power (R^2 = 0.008 for the Niño3.4 SST index; R^2=0.07 for the PDO index). So unlike the Soay Sheep and NAO example, the Oregon coho example is one in which the locally and regionally measured aspects of the environment offer much stronger correlations with the ecological time series of interest than one finds with a focus on only the basin-scale ENSO and PDO indices.

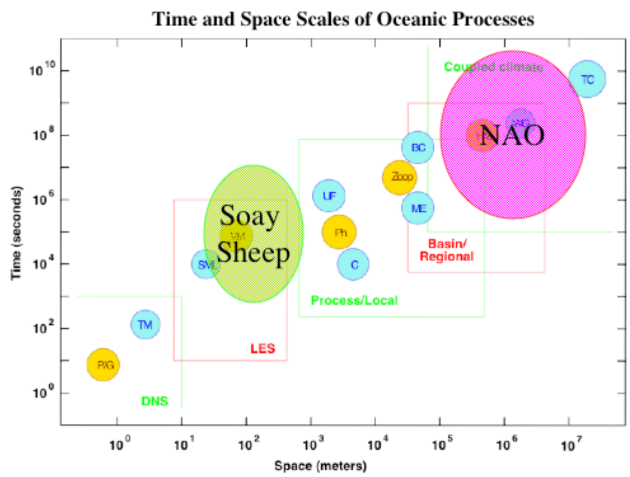


Fig. 1 *Space-time schematic highlighting some of the physical and biological processes important to fisheries oceanography studies and the relative positions of the Soay Sheep populations and NAO pattern. Physical processes (in blue) include: turbulent mixing (TM), surface mixed layer processes (SML), upwelling fronts (UF), convection (C), boundary currents (BC), mesoscale eddies (ME), and the thermohaline circulation (TC). Biological processes (in yellow) are: predation/grazing (P/G), vertical migration (VM), horizontal migration (HM), and the natural scales of aggregation for phytoplankton (Ph) and zooplankton (Zoop). The rectangular boxes in green and red show the approximate space/time scales covered by five classes of ocean and/or ocean/atmosphere models: Coupled climate, Basin/regional, Process-oriented/Local, Large-eddy simulation (LES) and Direct numerical simulation (DNS). After Mantua* et al., *2002,* Oceanography, *15, 75.*

Generally speaking, I believe that we should expect that custom-tailored environmental predictors would outperform large-scale climate indices in their ability to explain and predict ecosystem variations indexed by measurements at spatial scales smaller than 1000's of km.

In spite of scale mismatches between many climate and ecosystem indices, there are at least two good reasons to keep one eye trained on large-scale climate patterns, while the other eye focuses on the local and regional environment. *First* is the issue of predictions. The predictability for large-scale climate variations is often well researched and quantified. In the case of ENSO variability, prediction tools have been developed for over 15 years and are now used to make regularly updated forecasts for lead-times up to one year into the future. The ENSO prediction effort serves as the foundation for modern climate predictions for the extratropical North Pacific and North America, and ENSO forecasts can be used for making skillful one-year lead time PDO index forecasts (Newman *et al*. 2003, *J. Climate*, 16, 3853). *Second*, carefully developed climate indices can greatly simplify large numbers of environmental time series into a small set of meaningful large-scale climate indices. This has been common practice for nearly a century in the Pacific starting with the groundbreaking work of Sir Gilbert Walker (*e.g*., Walker and Bliss, 1932, *Mem. R. Meteorol. Soc*. 4, 53). Because there are repeatable, physically meaningful and robust spatial patterns of variability in the atmosphere and ocean, substantial fractions of the climate system's total variance can often be described with a small set of climate indices. As shown by Bond *et al*., about 48% of the North Pacific's winter-to-winter SST variance from 1950-2003 is accounted for by just two patterns of variability (30% by the PDO pattern, and 18% by the Victoria Pattern). So at the spatial scale of the entire North Pacific basin, and the temporal scales of interannual to inter-decadal variability, these two indices represent a very economical means for describing past variations in North Pacific SST.

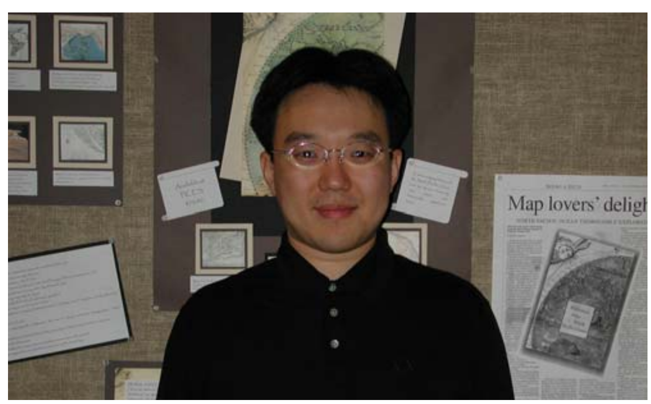
Finally, I offer yet another cautionary note on the use and utility of large-scale climate indices like those tracking variability in the PDO and Victoria SST patterns. These large-scale climate indices do not represent the actual measured value of SST at any single grid-point in the North Pacific for any particular day, week, month, season, or year. To recover the variability of SST at a single location off the coast of Oregon, for instance, one might require ten different large-scale patterns to recapture 90% of the actual variability. Such a "reconstruction" would be ridiculous if the actual data series for the location of interest is readily available.

Closing thoughts:

- A detailed understanding for the mechanisms giving rise to biophysical interactions is necessary for understanding the potential predictability of ecosystem changes.
- Large-scale climate perspectives are valuable for providing a better understanding for the long-term history of environmental and ecosystem changes.
- Once the local biophysical interactions are understood, links with large-scale climate patterns provide an avenue for quantifying the predictability of future ecosystem changes. The ability to predict ENSO variability at lead times of ~ 1 year, combined with the strong tendency for year-to-year persistence in the PDO pattern, offer two potentially valuable guidelines for predicting future large-scale climate conditions relevant to many regions and ecosystems in the North Pacific.
- In order to evaluate the possible ecosystem impacts of long-term climate changes, such as those associated with human-caused global warming, some kind of model for local biophysical impacts must be developed, and key parameters must be upscaled to the coarse spatial-scale information that is typically provided in future climate scenarios.
- Empirical studies that identify biophysical impacts from just a few decades of historical data are likely to undersample many dimensions of potentially important biophysical interactions. It is likely that such models will fail when confronted with future environmental and/or ecosystem conditions that are significantly different from those contained within the ranges of the training data.

PICES Interns

PICES offers special thanks to Mr. Gong-Gu Back (National Oceanographic Research Institute, Ministry of Maritime Affairs and Fisheries, Seoul, Korea), who will complete his internship at the Secretariat at the end of January and will returned to Korea.



We are pleased to announce that Mr. Jin-Yong Lee from the Korea Ocean Research & Development Institute (KORDI), Ansan, Korea, joined the Secretariat last November as the new PICES intern. You will have a chance to meet Jin at the upcoming "Climate variability and sub-Arctic marine ecosystems" Symposium to be held May 16-20, 2005, in Victoria, Canada. Now he is mainly involved in preparing the 2004 PICES Annual Report.

Report of the APN workshop on "Climate interactions and marine ecosystems"

Francisco E. Werner, Bernard A. Megrey and Kenneth A. Rose

A workshop on "Climate interactions and marine ecosystems" was held from October 10-13, 2004, in Honolulu, Hawaii. In attendance were scientists from Canada, the People's Republic of China, the Republic of Korea, Russia, and the United States (Fig. 1). Funding for the workshop was provided by the Asia-Pacific Network for Global Change Research (APN; http://www.apn.gr.jp/) through the award "Effects of climate on the structure and function of marine food-webs and implications for marine fish production in the North Pacific Ocean and marginal seas". Additional support for some of the workshop participants was provided by PICES and GLOBEC. The workshop took place roughly midway through the APN award, and as such the goals of the workshop were to assess achievements of the working team to date and to develop plans for the remaining six months of the project.

The project's overall hypothesis is that global climate change can alter both the structure and function of the marine ecosystem, causing changes in energy cycling, plankton composition and dynamics, and ultimately fish production. The objectives of the project include:

- to use a common marine food-web and fisheries bioenergetics modeling approach, along with long-term area-specific oceanographic and fisheries data sets, to understand the propagation of climate change effects up the marine food-web;
- to quantify its effects on energy cycling and fish growth and production in distinct geographic regions in the North Pacific; and
- to initiate a discussion of how these results can be integrated into the decision and policy making process by fisheries and resource managers.

Fig. 1 APN workshop participants. Back row: Matt Foster (U.S.A.), Shin-ichi Ito (Japan), Skip McKinnell (PICES), Alexander Leonov (Russia), Bernard Megrey (U.S.A.), Chang Ik Zhang (Korea), Jacob Schweigert (Canada), Douglas Hay (Canada), David Eslinger (U.S.A.). Front row: Harold Batchelder (PICES, CCCC), Wei Hao (China), Irina Ishmukova (Russia), Michio Kishi (Japan), Kenneth Rose (U.S.A.), Francisco Werner (U.S.A.).

Using NEMURO.FISH as a modeling framework (*PICES Scientific Report* No. 20, pp. 77-176), we focused on selected sites of the North Pacific shelf and continental margin regions. With Pacific herring as the initial target fish species, the workshop sub-hypotheses and resulting action items to be undertaken over the remaining months of the project can be summarized as follows.

Hypothesis 1: geographic variations in fish growth can be explained by differences in environmental conditions and resulting differences in lower trophic conditions.

To address this hypothesis the workshop participants:

- identified locations where data sets are available for calibration of lower trophic levels (LTLs);
- cross-referenced the LTL target list with locations that may have data on Pacific herring, sardines, anchovy, mackerel and other potential target species;
- developed a strategy for analysis of these data via a coupled LTL and fish model to address the hypothesis on geographic variability; and
- agreed to compile the available datasets with final site and target species selection to be determined depending on the quality of the various data sets.

Hypothesis 2: synchronous (or asynchronous) changes in herring growth rates across locations may be accounted for by basin-wide decadal-scale changes in environmental conditions.

The workshop participants were updated on the recent efforts of the PICES Study Group on *Fisheries and Ecosystem Responses to Recent Regime Shifts* (FERRRS). In particular, our hypothesis was reinforced by FERRRS' formal recommendation that regime shifts be considered as a concept for inclusion in ecological and management practices. With full-basin scale solutions as targets for the study of regime shifts in the longer term, an agreed target for the next six months is to implement and study the response of point LTL and coupled LTL-fish models at selected sites in the North Pacific both before and after periods associated with "regime shifts". This will allow for a measure of the possible sensitivity of the models' biological parameters to the pre- and post-regime shift conditions.

Hypothesis 3: future climate/global change scenarios may affect fish production through changes in structure of the lower trophic levels.

The study of this hypothesis requires a three-dimensional basin-scale approach that, beyond simple sensitivity studies, may fall beyond the present six-month goals of the project. Preliminary results of a basin-scale approach were presented at the PICES Thirteenth Annual Meeting (following the APN workshop) and suggested that simulations of future climate change scenarios may be available in one to two years' time. At this stage however, and guided by the basin-scale model results and other sources such as the IPCC reports, it was agreed that exploratory tests could be conducted by changing bulk parameters in the point model.

An example of calibrating NEMURO.FISH to the region off the west coast of Vancouver Island (WVCI), British Columbia is given in Figures 2 and 3. First, the lower trophic level (LTL) model without fishes was calibrated to primary and secondary production data from the region (Fig. 2). Once the LTL was calibrated, then fishes were added and dynamically linked to the prey resource provided by the LTL in such a way that consumption by fishes appeared as a mortality term for the prey species. Parameters of the fish bioenergetic model were calibrated to observed Pacific herring data. These data indicate that total biomass ranges from 2-5 g wet weight/m^2 (Fig. 3, upper panel), that a 10 year-old herring is about 200 g wet weight (Fig. 3, middle panel), and that size-at-age data, expressed in g wet weight from the model compare well to observed growth and size data (Fig. 3, lower panel). Workshop participants will be actively searching for useable data sets with which to perform similar calibrations of NEMURO.FISH to other regions of interest around the Pacific Rim. We can then effectively examine large-scale ecosystem response to climate change or regime shifts once the calibrated versions of the model are in place.

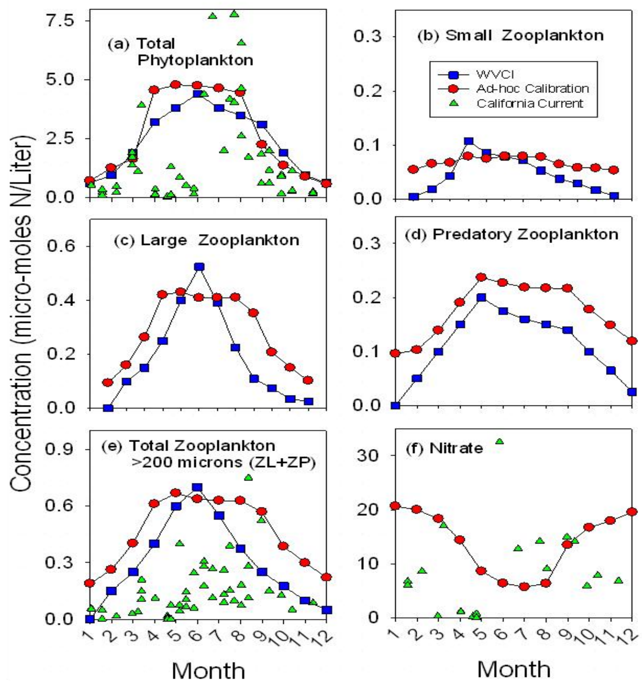


Fig. 2 Idealized coastal data set for WVCI (blue squares), field data reported for the California Current (green triangles), and model predictions from the ad-hoc calibration (red circles). Figure from Rose et al. *2004 (submitted to* Ecological Modeling*). Data from the California Current reported in Wang 1998 (Ph.D. Dissertation, University of South Alabama, Mobile) and Wainwright* et al. *(submitted to* Ecological Modeling*). Data for WVCI were assembled from a variety of sources: chlorophyll data from Richard Thomson (Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, B.C.), and zooplankton data from Stephen Romaine via the Institute of Ocean Sciences' Zooplankton Database and Donald McQueen (Aquatic Ecosystem Associates, Nanaimo, B.C.). Much of the zooplankton data reported by David Mackas (*Can. J. Fish. Aquat. Sci. *49: 903-921). WVCI calibration data was not available for nitrate. California Current data was available for total phytoplankton, total zooplankton (greater than 200 microns), and nitrate.*

The workshop's success was not only in being able to address the above scientific hypotheses, the workshop also yielded significant results and insights in the area of management – in particular as related to the communication of the present models' results to the managers – and in the area of capacity sharing.

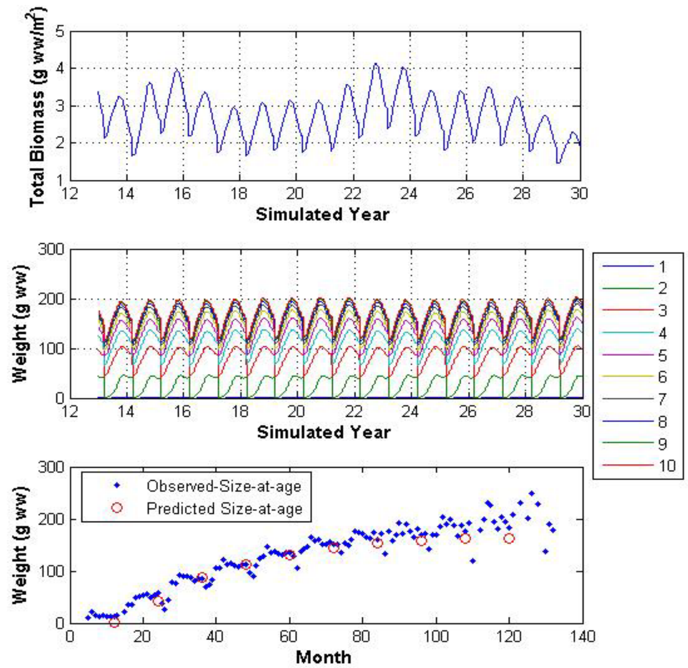


Fig. 3 Results from the calibration NEMURO.FISH to Pacific herring data (simulating 10 year classes) from the west coast of Vancouver Island, B.C. Figure from Megrey et al. 2004 (submitted to Ecological Modeling*).*

Links to management: The discussions of the relevance of the present model products to management led to the following observations: *(i)* correlations between size-at-age and fish biomass (and their fluctuations) exist; *(ii)* providing information on the size-at-age of the target fish species is a useful indicator of population health; and *(iii)* size-at-age allows us to better understand fish mortality in the context of bottom up (fishing independent) factors.

Capacity sharing: The exchange of information among the workshop participants resulted in collective gains in the following areas: *(i)* preliminary model codes were explained and distributed; *(ii)* novel quantitative methods to study model sensitivity were discussed and adopted as part of the group's approach to studies in the coming months; and *(iii)* new fish target species (*e.g.*, anchovy, sardines, etc.) were identified for future consideration and the associated data is to be made available.

Future communications: A portal will be set up to allow for ease of access of model code, data products and written material. The site will also serve as a repository of archival material.

Dr. Francisco Werner (cisco@unc.edu) is a Professor and Chairman of the Marine Sciences Department at the University of North Carolina at Chapel Hill, U.S.A., and also chairs the GLOBEC Scientific Steering Committee and the PICES MODEL Task Team. Originally from Venezuela, Cisco completed his graduate work in physical oceanography at the University of Washington in Seattle. His research includes the development of circulation of coastal ocean models and their coupling to trophodynamic inidvidual-based models of planktonic and early life stages of marine organisms.

Dr. Bernard Megrey (Bern.Megrey@noaa.gov) is a Research Fisheries Biologist with NOAA's Alaska Fisheries Science Center where he has worked since 1982. As the lead investigator for recruitment modeling studies for FOCI, he has over 20 years of experience studying dynamics of exploited North Pacific fish populations, relationships of environment to recruitment variability, and application of computer technology to fisheries research and natural resource management. His recent research has focused on developing indices of ecosystems status and health, building simulation models of marine ecosystems, and performing comparative analyses of system level characteristics of similar marine ecosystems. Bernie is a member of the PICES MODEL Task Team.

*Dr. Kenneth Rose (*karose@lsu.edu*) is a Professor with a joint appointment in the Coastal Fisheries Insitute and the Department of Oceanography and Coastal Sciences at Louisiana State University. Kenny joined the faculty of Louisiana State Unviversity in 1998, after 11 years as a research scientist at Oak Ridge National Laboratory. Kenny's research interests focus on the development and application of quantitative methods to aquatic ecosystems and fish population and community dynamics. Recent projects have centered on using individual-based and matrix projection models for fisheries management and for linking habitat quality and quantity with population health and sustainability.*

Highlights of the PICES Thirteenth Annual Meeting

Governing Council representatives at PICES XIII: (standing) J.A. Moores, T. Kishida, T. Wada, J. Fujita, Q.F. Liu, P.V. Vorobyov, L.N. Bocharov, V.A. Nazarov, G.W. Boehlert, K.O. Kim, R.M. Brown, A. Bychkov, Y.H. Chung, J.H. Kim, T. Kobayashi, W.X. Zhu, J.T. Lim; (sitting) H.T. Huh, R.J. Marasco, L. Richards, V. Alexander, L. Tirpak, C. Park.

Final countdown and getting ready to go ... The Secretariat sends a big shipment of materials to Honolulu about 10 days ahead.

Dr. Vera Alexander, Chairman of PICES, opening the Thirteenth Annual Meeting. At the head table are Ms. Yvonne Izu and Dr. Michael P. Sissenwine, and national representatives.

Dr. Ian Perry summarizing PICES achievements in 2004 before the Science Board Symposium.

A group of young Korean scientists at the Welcome Reception.

A very satisfied and well-fed bunch at the Extravaganza Dinner, held at Alan Wong's Restaurant this year.

Highlights of the PICES Thirteenth Annual Meeting

Science Board representatives at PICES XIII: M. Foreman, H. Batchelder, M. Dagg, V.I. Radchenko (outgoing Vice-Chairman, R.I. Perry (outgoing Chairman), J.E. Stein (incoming Vice-Chairman), K. Kim (incoming Chairman), I. Shevchenko, S. Kim, Y. Ishida, J.P. Zhao.

A scene at the well-attended Session on “Mechanisms that regulate North Pacific ecosystems: Bottom-up, top-down or something else?”.

Participants roam around the many poster boards at the Poster Session.

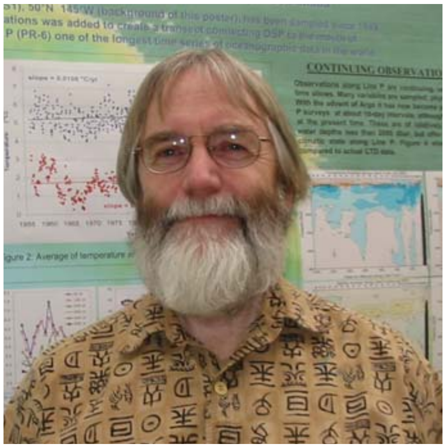
Dr. Richard Marasco was honoured at the last Governing Council meeting for his outstanding contribution to PICES as Chairman of the Financial & Administration Committee.

Governing Council representatives winding down at the Chairman’s Reception: Dr. T. Kobayashi (outgoing PICES Vice-Chairman), Mr. J. Fujita, Mr. Q.F. Liu, Drs. C. Park and T. Wada (incoming PICES Vice-Chairman).

Drs. Warren Wooster, Richard Marasco, Ms. Christina Chiu, Mrs. Darlene Marasco, Drs. Hyung-Tack Huh and Tokimasa Kobayashi enjoy a relaxing moment at the Chairman’s Reception.

Recent trends in waters of the subarctic NE Pacific – summer 2004

Frank A. Whitney
Institute of Ocean Sciences
Fisheries & Oceans Canada
P.O. Box 6000, Sidney, B.C.,
Canada. V8L 4B2
E-mail: WhitneyF@pac.dfo-mpo.gc.ca



Frank A. Whitney has led the Line P program for the past 12 years, carrying out repeat oceanographic sections for WOCE (1991-97) and hosting the Canadian JGOFS program (1992-97) on these cruises. Through this time, his main research interest has been in understanding processes which control nutrient supply to the upper ocean. He has also surveyed meso-scale eddies several times in an attempt to estimate offshore transport of coastal waters in the Gulf of Alaska. Frank has been working in oceanography on the British Columbia coast since 1969.

Warmest waters in 45 years of observations

This summer, we surveyed the warmest surface waters ever observed along Line P between 127ºW and 134ºW (Fig. 1). As a reminder, Line P is the time-series program that samples along a transect extending westward from the southern coast of British Columbia to Ocean Station Papa (OSP) at 50ºN, 145ºW (Fig. 2). Waters were as much as a degree warmer than during the strong El Niño summer of 1997 in the region called the Transition Domain, and exceeded any measurements made during the 1959 to 1981 period in which Weatherships were transiting to and from OSP every 6 weeks.

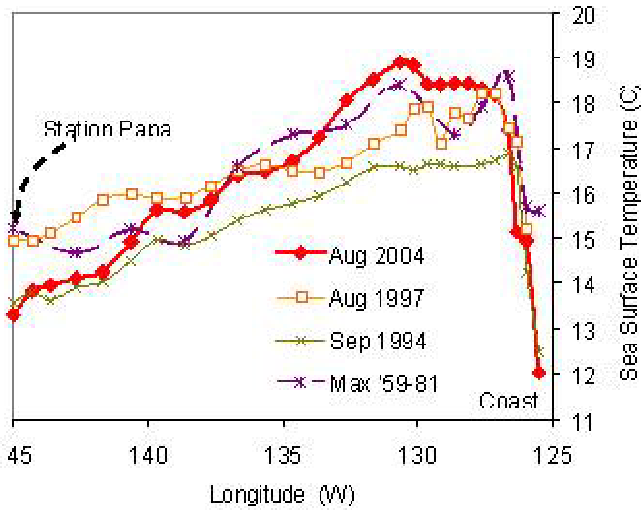


Fig. 1 SST along Line P during the warmest years of the 1990s and from the Weathership era (1956-1981).

The maximum recorded temperature this August was 18.9ºC at station P12. Warm waters persisted northward, with 17.3ºC waters being found off the southern end of the Queen Charlotte Islands (station R6). Waters cooled to the east of R6 as they did coastward of about P4 along Line P because of upwelling on the continental shelf. Toward open ocean, temperatures likewise decreased as the high nitrate, low chlorophyll (HNLC) waters of the subarctic Pacific were approached.

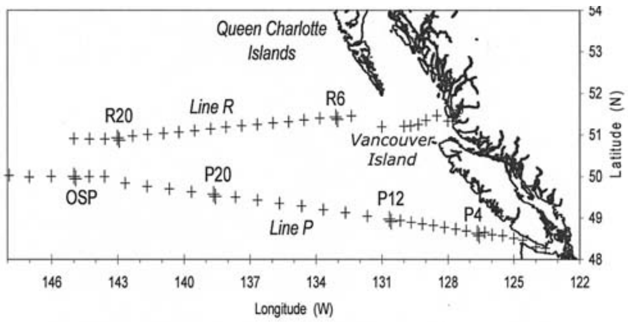


Fig. 2 Track of the August survey along Line P to Ocean Station Papa (OSP) and along line R to the southern tip of the Queen Charlotte Islands.

The Transition Domain is the region that often contains waters which are depleted of nitrate in summer, have little chlorophyll (<0.2 mg m^{-3} this August) and contain subtropical species including southern zooplankton and tuna. This summer, Moira Galbraith (Institute op Ocean sciences) found several anomalous groups of southern organisms in net tows starting at the shelf break off the BC coast and extending westward past station P12. A medusa, *Aglaura hemistoma*, which is endemic to waters south of 40ºN was abundant, as were southern euphausiids and eggs of the Pacific sardine (*Sardinops sagax*). On summer cruises, we also caught albacore tuna and saw humpback whales feeding off the shelf break in waters warmer than 16ºC. Graham Gillespie (Pacific Biological Station) reported collecting the myctophid *Symbolophorus californiensis* off Langara Island (roughly 54°10' N, 133°55' W) in September. This organism has not been found north of ~50°N previously. Through October, local people have also been finding a species of large squid that is typically found south of San Diego, California, in fishing nets and on beaches along southern British Columbia.

Marc Trudel (Pacific Biological Station) reported having caught several of these Humboldt squid (*Dosidicus gigas* Orbigny) in October off central Vancouver Island, the largest being 1.5 m long. Such oddities tend to occur during strong El Niño events. However, the Southern Oscillation Index indicated only weak El Niño conditions in 2003/04.

Sonia Batten (Continuous Plankton Recorder Program) found another consequence of the warmer surface water, the more rapid development of *Neocalanus* copepod populations. *N. plumchrus* and *N. flemingeri* typically reproduce at depth in the late winter, the early stages vertically migrate towards the surface and mature as they do so. Copepodite stages I-V are spent in the surface waters, and once CV's have accumulated enough lipid they descend again to enter diapause and over-winter at depth. Populations exist at the surface usually between February and June, peaking in biomass in May and the lipid-rich older stages are prey for a number of fish and bird species. Although the trigger for ending diapause is still unknown development through the copepodite stages is temperature-dependent. Figure 3 shows data from Continuous Plankton Recorder samples for the last 5 years. Although not all data for 2004 are available yet, it looks as though the population matured more rapidly in 2004 than any of the other years so far sampled (the line is steepest). Since peak biomass occurs when 50% of the population reaches CV (Mackas *et al.*, 1998. *Can. J. Fish. Aquat. Sci*. 55: 1878-1893), biomass would have peaked in 2004 about 3 weeks earlier than in 2000. This may have implications for predators that rely on this biomass.

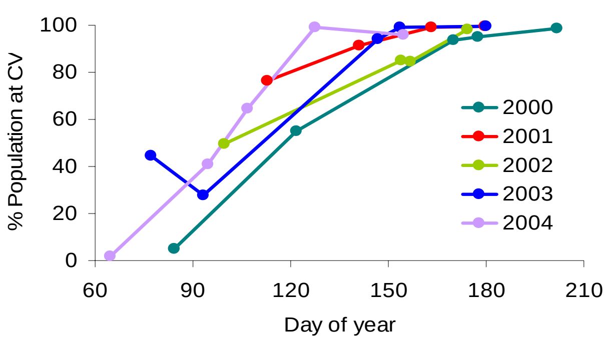


Fig. 3 *Mean proportion of the Neocalanus plumchrus/flemingeri population at stage CV (stages II to V separately counted) in each year from CPR samples collected in the eastern Gulf of Alaska.*

Decreasing oxygen in subsurface waters

For the past 17 years, nutrients and oxygen have been routinely measured onboard research vessels surveying Line P, providing a high quality data set. Several standard stations were repeatedly sampled at a frequency of ~3 times per year. One of the strongest trends in these data is for oxygen to decrease and nutrients to increase in subsurface waters. An example of this is shown for OSP (Fig. 4) where oxygen levels have declined from ~150 to ~100 µmol kg^{-1} at 200 m, and from ~90 to ~50 µmol kg^{-1} at 300 m over this observation period. Howard Freeland (IOS) has been tracking the mixed layer depth at this location (see *PICES Press*, Vol. 11 (2), July 2003), and has noted a shoaling of the surface layer over the past 4 decades. The winter mixed layer has been especially shallow in the past 2 or 3 years. Surface warming and perhaps a change in wind intensity appears to be the cause of this shoaling. A consequence of weaker mixing is evidently a decrease in the ventilation of thermocline waters (depth 100 to 400 m). This leads to declining oxygen and increasing nitrate as organic detritus is remineralized at depth.

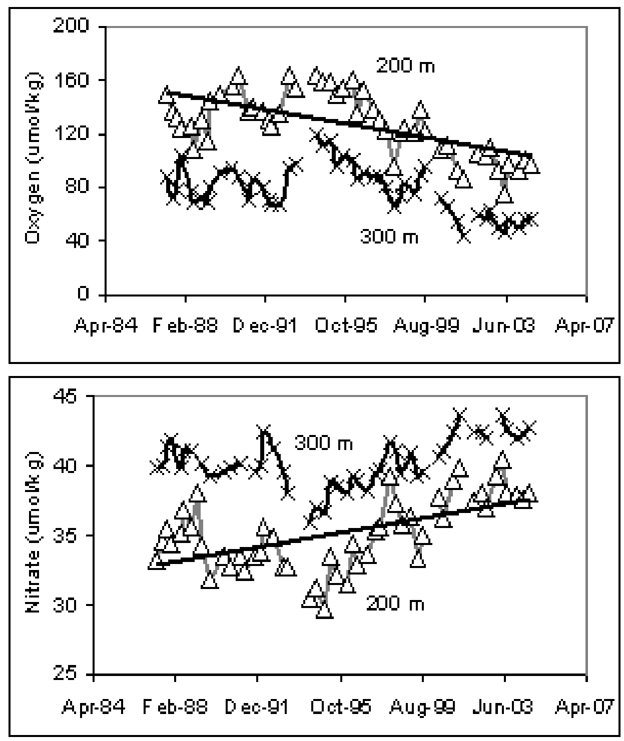


Fig. 4 *Oxygen and nitrate levels at 200 and 300 m depth at Ocean Station Papa from 1987 to 2004.*

Such declines in oxygen are a cause of concern. Hypoxia, a condition under which many marine organisms weaken or die, occurs at ~62 µmol kg^{-1}. Our data shows that hypoxia has spread upward from ~400 m to ~250 m at OSP over the past couple of decades. In addition, waters at ~200 m depth supply coastal upwelling regions with nutrient rich waters, stimulating the high primary productivity that supports rich fisheries. However, as the upwelled waters become oxygen poor and nutrient rich, coastal organisms may be stressed or killed by hypoxic conditions. Jane Huyer and colleagues (Oregon State University) have been following just such conditions along the Oregon coast. Over the past 3 years, hypoxia during the upwelling season has resulted in occasional kills of fish and crab populations. Such kills were not observed prior to 2002.

The state of the western North Pacific in the first half of 2004

Toshiyuki Sakurai
Office of Marine Prediction, Climate and Marine Department
Japan Meteorological Agency
1-3-4 Otemachi, Chiyoda-ku,
Tokyo, Japan. 100-8122
E-mail: tsakurai@met.kishou.go.jp

Mr. Toshiyuki Sakurai is a scientific officer of the Office of Marine Prediction at the Japan Meteorological Agency (JMA). He is working as a member of a group in charge of oceanic information in the western North Pacific. Using a new "Ocean Comprehensive Analysis System" (in operation since January 2001), this group produces surface and subsurface temperature, salinity and current maps with 0.25×0.25 resolution in waters adjacent to Japan. Monthly averaged fields obtained from the system are included in the "Monthly Ocean Report" published by JMA. Mr. Sakurai is now involved in developing a new daily analysis system for sea surface temperature in the global ocean, using in situ *observations and data from several satellites with infrared and microwave sensors.*

Sea surface temperature

Figure 1 shows monthly mean sea surface temperature (SST) anomalies in the western North Pacific from January to June 2004, computed with respect to JMA's 1971-2000 climatology. JMA introduced "Merged satellite and *in situ* data Global Daily SST (MGDSST)" analysis in April 2004. MGDSST is calculated from infrared sensor (AVHRR/NOAA) and microwave sensor (AMSR-E/AQUA) data, whose biases are corrected with *in situ* SSTs.

Positive SST anomalies exceeding +1ºC were found from south of Japan to around 35ºN, 165ºE in May. Positive SST anomalies exceeded +2ºC from 30ºN, 140ºE to 40ºN, 170ºE in June. Positive SST anomalies in the seas south of Japan (regions 6 and 9 of Fig. 2) and the East China Sea (region 8 of Fig. 2) have persisted for the last few years. Negative SST anomalies exceeding -1ºC were found around 37ºN, 145ºE from January through June, and around 25ºN, 175ºE in June. The negative SST anomalies in the seas east of Japan lasted from November 2002 to June 2004 (region 4 of Fig. 2).

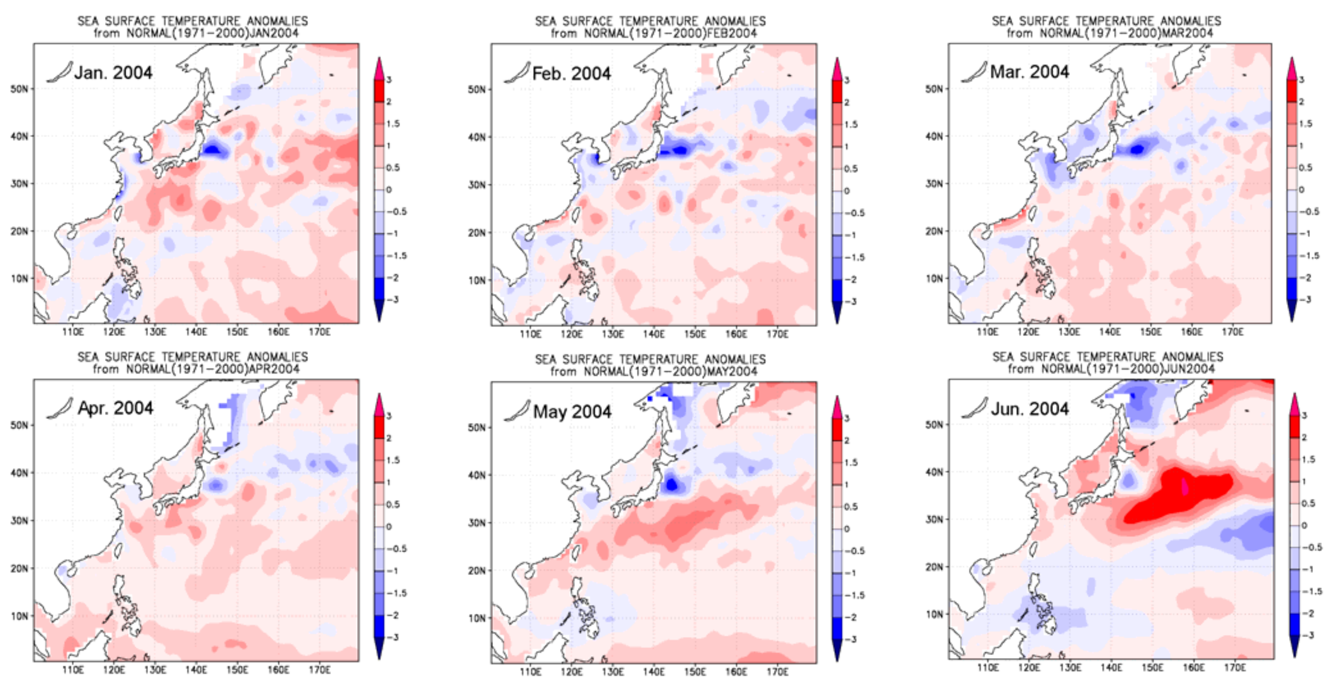


Fig. 1 Monthly mean sea surface temperature anomalies (ºC) from January to June 2004. Anomalies are deviations from JMA's 1971-2000 climatology.

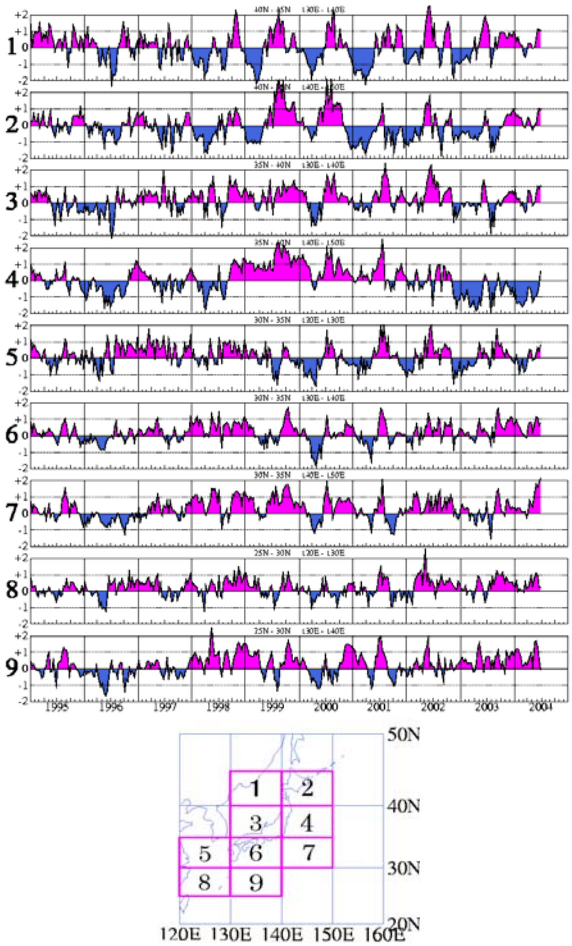


Fig. 2 *Time series of the ten-day mean sea surface temperature anomalies (ºC) from JMA's 1971-2000 climatology for the areas shown in the bottom panel.*

Kuroshio and Oyashio

In seas southeast of Kyushu, a small meander was formed in November 2003, and its scale was reduced from late February to early March. However, it rapidly developed and moved eastward from mid-March to early April, and the Kuroshio flowed far-off the coasts in the south of Shikoku after mid-April (Fig. 3).

Figure 4 shows subsurface temperature at a depth of 100 m east of Japan for March 2004. This chart is based on the numerical ocean data assimilation system (JMA's Ocean Comprehensive Analysis System).

The Oyashio cold water (area colder than 5ºC in Fig. 4) is known to extend southward at its southernmost position in the spring and return northward from summer to autumn (green line of Fig. 5). The coastal branch of the Oyashio cold water extended southward considerably in March 2004 and reached 36.5ºN, 142ºE, which was south of the climatological mean by 220 km (Fig. 4). It returned to almost the same latitude as the climatology in April and May, and extended southward again to 160 km south of the climatology in June (Fig. 5).

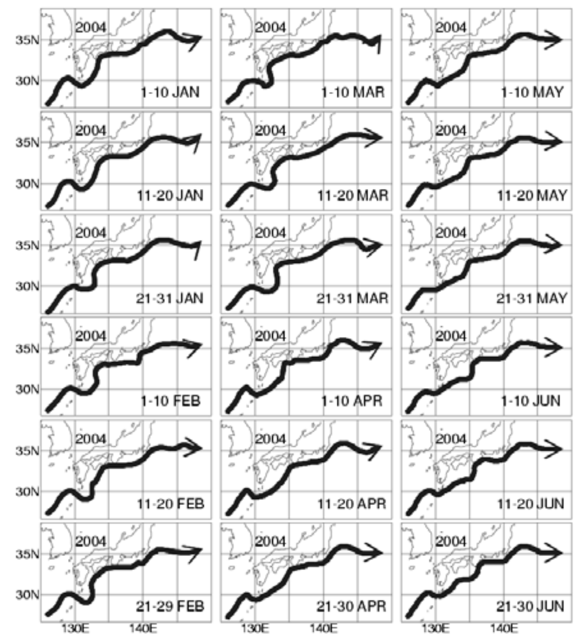


Fig. 3 *Location of the Kuroshio axis from January to June 2004.*

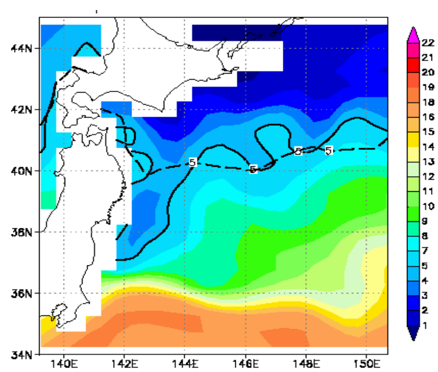


Fig. 4 *Subsurface temperature (ºC) at a depth of 100 m east of Japan for March 2004. Solid lines denote 5ºC isotherm, and dashed lines that of the climatology (30-year averaged values from 1971 to 2000).*

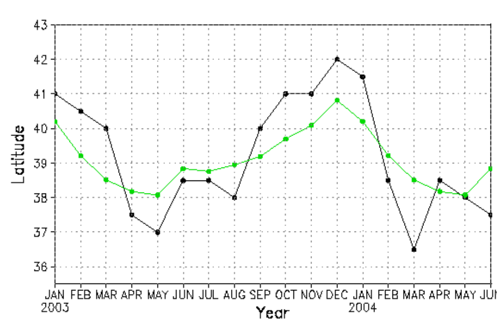


Fig. 5 *The southern-most position of the coastal branch of the Oyashio cold water from January 2003 to June 2004 (black line) and the climatology (green line, 30-year averaged values from 1971 to 2000).*

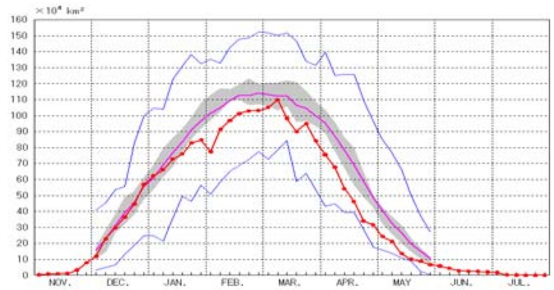


Fig. 6 Time series of sea ice extent in the Sea of Okhotsk from November 2003 to July 2004 (pink line - JMA's 1971-2000 climatology; red line – 2003-2004 analysis; blue line - maximum/minimum of sea ice extent in the period 1971-2003; grey area - within the normal range.

Sea ice in the Sea of Okhotsk

The extent of sea ice in the Sea of Okhotsk was near the climatology (30-year averaged values from 1971 to 2000) from November 2003 to mid-January 2004 (Fig. 6). After late January, it was below the climatological mean. The sea ice area reached its maximum on March 10 at 109.91$\times 10^4$ km^2, which is less than the climatology. This means that about 70% of the Sea of Okhotsk was covered with sea ice (Fig. 7). A small amount of sea ice flowed into the Pacific from mid-February to mid-April.

Fig. 7 Sea ice extent (white area) in the Sea of Okhotsk on March 10, 2004.

The Bering Sea: Current status and recent events

Jeffrey M. Napp
Alaska Fisheries Science Center
7600 Sand Point Way NE,
Seattle, WA 98115-0070, U.S.A.
E-mail: Jeff.Napp@noaa.gov

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 Fisheries Oceanography Coordinated Investigations (FOCI). His own research is focused on physical and biological processes at lower trophic levels that affect recruitment variability in fish populations. He is active as a Principal Investigator in both Bering Sea (NOAA's Bering Sea FOCI, Southeast Bering Sea Carrying Capacity) and Gulf of Alaska (FOCI, GLOBEC) Programs, and currently serves on a steering committee to organize a U.S. science initiative for the Bering Sea (BEST: Bering Sea Ecosystem STudy). Jeff is currently serving on the PICES MONITOR Technical Committee and CPR Advisory Panel.

Bering Sea observations indicate persistent warming and species impacts

Observations over the previous four years show persistent warm and ice-free conditions from late winter through summer, despite large variability in climate indices such as the Arctic Oscillation (AO) and the Pacific Decadal Oscillation (PDO). If such conditions continue, it will have an impact on the ecosystem, as Arctic species seek colder waters and subarctic species become dominant. On the southeast Bering Sea shelf (57ºN), the warmest vertically-averaged summer ocean temperatures of the decade occurred in 2001-2003 (6ºC mean temperature relative to 4ºC mean temperature in 1995-1997), and sea ice is now nearly non-existent in the southeast.

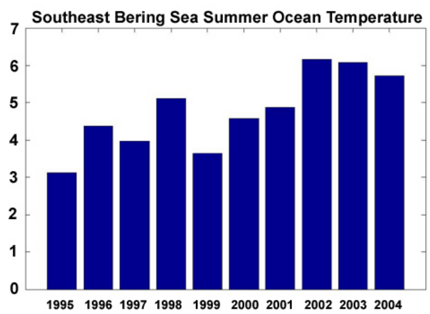


Fig. 1 Average annual summer water temperature at the Mooring 2 site in the southeast Bering Sea.

These conditions follow a major transformation, or regime shift, of the Bering Sea around 1977, which changed from a predominantly cold Arctic climate to a warmer subarctic maritime climate as part of the PDO. This shift was accompanied by a major re-organization of the marine ecosystem over the following decade. Fisheries surveys and model calculations support a shift in the importance of pollock to the ecosystem, to over 50% of the energy flow at mid-trophic levels in the 1980s from near 10% in the 1950/1960s. A major Arctic change influenced the Bering Sea began in the late 1980s, as a shift in polar vortex winds (the AO) reinforced the warm Bering conditions, especially promoting an earlier timing of spring meltback of sea ice.

Warm, ice-free conditions may favor pelagic over benthic components of the ecosystem. A cold-water amphipod is no longer found in abundance in the southeastern Bering Sea. Over the last decade, annual fisheries surveys indicate a continued decline in recruitment of fish and shellfish to cold-water stocks, such as Greenland Turbot and snow crab. The biomass of Greenland Turbot has declined to 17% of its pre-1977 peak. However, walleye pollock, which prefers warmer waters as the ice retreats, is characterized by a large, rather stable, population. Pollock biomass increased 400% following the 1977 regime shift and has generally maintained high sustained values. Pacific walrus is another species showing northward movement due to the lack of sea ice and warmer temperatures. While it is difficult to show direct causality, the timing of reductions in other marine mammals suggests some loss of their traditional Arctic habitat. Weather data beginning in the 1910s and proxy data (*e.g.*, tree rings) back to 1800 suggest that, except for a period in the 1930s, the Bering Sea was generally cool before 1977, with sufficient time for slow growing, long-lived, cold-adapted species to adjust.

It was hypothesized that the overall climate change occurring in the Arctic, as indicated by warmer atmospheric and oceanic temperatures and loss of 15% of sea ice and tundra areas over the previous two decades, is making the Bering Sea less sensitive to the intrinsic climate variability of the North Pacific. Indeed, when the waters off the west coast of the continental U.S. shifted to cooler conditions after 1998, the subarctic did not change, in contrast to three earlier PDO shifts in the 20th century.

Thus, it was projected that the Bering Sea will more likely continue on its current warm trajectory, with biomes transitioning northward at the expense of cold and ice-adapted species. A more complete discussion is in Overland and Stabeno (*EOS*, 2004, Vol. 85, No. 33) and Stabeno and Overland (*EOS*, 2001, Vol. 82, No. 29).

Coccolithophore bloom in the eastern Bering Sea

The eastern Bering Sea coccolithophore bloom, appeared once again this past summer. Dr. L. Eisner and J. Murray of NOAA's Auke Bay Laboratory spotted the aquamarine-colored water during two legs of this year's BASIS cruise which appeared to be confined to the waters above the pycnocline. These waters were found in early September between 58.13ºN, 168ºW and 59ºN and 170ºW. During the second leg of the BASIS cruise in late September, the aquamarine waters were between 59.5ºN, 172ºW and 60ºN and 173ºW. The bloom was not observed during the summer annual Hokkaido University T/S *Oshoro Maru* cruise (Dr. S. Saitoh, Hokkaido Univ., pers. comm.). Early in the summer, there were reports of reddish water between the Pribilof Islands. To my knowledge, the source of the color was never determined.

Poor recruitment of some Pribilof Island seabirds

There have been several reports of poor recruitment by diving seabirds in the Pribilof Islands this past summer. Various researchers conducting studies on and around the islands have mentioned recruitment problems with some of the species. Anomalous circulation patterns were also observed early in the summer from satellite drifters (Dr. P. Stabeno, Pacific Marine Environmental Laboratory, pers. comm.). More factual reports will be forthcoming.

Arctic Climate Impact Assessment Report

A multi-national task force of the Arctic Council, and the International Arctic Science Committee have released a report on arctic climate change and its impacts. The report was published in two sections, an overview report and a fully referenced scientific report. The 140-page overview report (available as a pdf file at http://www.acia.uaf.edu/) is meant to be a "plain language synthesis of key findings accessible to policy makers and the broader public".

Ecosystems of the Subarctic Seas (ESSAS) Symposium and BEST Science Plan

GLOBEC International and PICES are sponsoring a symposium on "Climate variability and sub-Arctic marine ecosystems" to be held May 16-20, 2005, in Victoria, B.C., Canada. The deadline for papers has already passed, but registration is still open at http://www.pml.ac.uk/globec/structure/regional/essas/symposium/annoucement.htm.
During the meeting there will be an open discussion of an implementation plan for BEST (Bering Sea Ecosystem Study). The BEST Science Plan has been published and is available on the ARCUS website at http://www.arcus.org/Bering/science_plan.html.

Many thanks to the following people who submitted information used in this report: Drs. Lisa Eisner, George Hunt Jr., James Overland, Sei-ichi Saitoh, and Phyllis Stabeno, and James Murray.

Study Group on *Fisheries Ecosystem Responses to Recent Regime Shifts* completes its mandate for the provision of scientific advice

Jacquelynne R. King
Pacific Biological Station
Fisheries & Oceans Canada
3190 Hammond Bay Road
Nanaimo, B.C., Canada. V9T 6N7
E-mail: KingJac@pac.dfo-mpo.gc.ca

Dr. Jacquelynne King is a research scientist in Groundfish Stock Assessment, at the Pacific Biological Station in Nanaimo, Canada. Her research focuses on the impacts of climatic and oceanographic variability on marine fish population dynamics and the implications for fisheries management. She has published research on a suite of disciplines including marine fish life history strategies, statistical methodology, climate impacts on ecosystems, ageing methodology, stock assessment, fish population dynamics and behavioural ecology. Dr. King is a member of the PICES WG 16 on Climate Change, Shifts in Fish Production, and Fisheries Management *and is Chair of the Study Group on* Fisheries and Ecosystem Responses to Recent Regime Shifts*.*

The North Pacific Marine Science Organization (PICES) received a formal request for scientific advice from the United States government in October 2003. The request focused on the implications of the 1998 regime shift for North Pacific fisheries. Following the strong 1997-1998 El Niño, the North Pacific climate underwent a rapid and striking transition, the persistence of which suggests that a regime shift had occurred. Previous regime shifts have had serious implications for ecosystems, and consequently for fish populations and the fishing industry. As such, the National Marine Fisheries Service requested scientific advice from PICES that addresses six specific questions:

1. Has the North Pacific shifted to a different state or regime since the late 1980s?
2. What is the nature of the new state?
3. What are the ecosystem responses?
4. How long can the shift be expected to last?
5. Is it possible to predict when the regime will shift back and what indicators should be used to determine when it happens?
6. What are the implications for the management of marine resources?

FERRRS Study Group

The PICES' Science Board established a 20-member Study Group on *Fisheries and Ecosystem Responses to Recent Regime Shifts* (FERRRS) to provide a response to the United States' request for advice. The Study Group was chaired by Jacquelynne King (Canada) and was comprised of PICES scientists from Canada (William Crawford, David Mackas, Gordon McFarlane, Jacob Schweigert), Japan (Akihiko Yatsu), People's Republic of China (Qi-Sheng Tang, Jin-Ping Zhao), Republic of Korea (Suam Kim), Russian Federation (Victor Lapko), the United States of America (Harold Batchelder, Jennifer Boldt, Anne Hollowed, Alec MacCall, Nathan Mantua, James Overland, Jeffrey Polovina, Franklin Schwing) and PICES ex-officio members (Alexander Bychkov, Stewart (Skip) McKinnell, Ian Perry).

The Study Group held its first meeting on February 9-10, 2004, in Victoria, Canada, to organize activities and outline a report that would provide the background material necessary to prepare responses to the six questions posed in the request for advice (*PICES Press*, Vol. 12 (2): 19-20).

The background material was reviewed by the Study Group at a 3-day workshop convened June 14-16, 2004, in Seattle, U.S.A. A major focus for the workshop was the description of coherent regional responses to the 1998 regime shift and development of advice on resource management approaches. Answers to the six questions were formulated.

FERRRS report

The Study Group has prepared a report which will be published as a PICES Scientific Report in January 2005, and available for download from the PICES website. The report contains an *Executive Summary* with responses to the six questions posed by the United States. It also retains the detailed scientific information used by the Study Group in formulating its advice. Chapter 2 (*Decadal-scale Climate Events*) provides information on climate-ocean indices and basin-scale events. Chapter 3 (*Coherent Regional Responses*) provides summaries of the ecosystem responses to recent regime shifts. Detailed descriptions of the observed regional responses to the 1998 basin-wide shift are provided in Appendices 1-5. Chapter 4

(*Implications for the Management of Marine Resources*) outlines the conceptual framework for the provision of scientific advice and the development of resource management policy given impacts of regime shifts on ecosystems and fish productivity.

Summary of advice

Overall the Study Group advised that a regime shift did occur in 1998, and that it appeared to have a north-south pattern of spatial variability, unlike many of the previous regimes that had an east-west pattern of spatial variability. The dominant atmospheric pressure systems over the North Pacific (the Aleutian Low and the North Pacific High) have intensified which has resulted in greater upwelling-favorable winds along much of the western United States, and greater downwelling-favorable winds of Canada and southeast Alaska. The 1998 regime shift had the greatest impact in the California Current System, less of an impact in the Gulf of Alaska, and virtually no impact in the Bering Sea. In the southern region of the eastern North Pacific and in the northern region of the western North Pacific, the biological production has improved. Although one might reasonably expect the current regime to last a decade or more, it is currently not possible to reliably predict when a regime will end because we presently lack a good understanding of the mechanisms involved in regime shifts. However, it is possible to detect regime shifts soon after they have occurred. Reliable prediction of the timing of regime shifts requires research investigating the mechanisms and triggers for regime shifts. Agencies need to develop policies with explicit decision rules and the subsequent actions to be taken when there are preliminary indications that a regime shift has occurred. These decision rules need to be included in long-range policies and plans. Stock assessment advice should indicate the potential consequences to stock viability of alternate management strategies under different levels of recruitment that would be expected in different regime periods.

Overall recommendations

Given the importance of regimes to ecological systems, the Study Group provided four recommendations for incorporating regime shift concepts into fishery management activities:

1. accept the regime concept for marine ecosystems – a wealth of historical evidence suggests regime shifts are a natural and recurring part of marine ecosystems;
2. develop and maintain a comprehensive observational program to monitor state changes in climate, ocean systems and ecosystems;
3. develop climate indices to aid ecosystem monitoring efforts, and support research efforts into linking those climate indices to predictable parts of the climate system (*e.g.*, variability in the El Niño Southern Oscillation);
4. make use of integrated stock assessments, wherein various future regime scenarios can be evaluated to assess the vulnerabilities of fisheries and ecosystems, and to conduct risk analyses for different management strategies.

PICES Calendar

- Workshop on “East Asian Seas Time Series” as part of the CREAMS/PICES project, April 21-22, 2005, Seoul, Korea
- GLOBEC/PICES Symposium on “Climate variability and sub-Arctic marine ecosystem”, May 16-20, 2005, Victoria, Canada
- Workshop on “Study of lower trophic level pelagic ecology in the subarctic Pacific Ocean”, May 23-24, 2005, Corvallis, Oregon, U.S.A.
- ICES/PICES theme sessions on “Fisheries, ecology and life history of small pelagic fish” and on “Comparing and constructing the scientific strategies and output of regional ecosystem projects” at the ICES Annual Science Conference, September 20-24, 2005, Aberdeen, Scotland
- PICES Fourteenth Annual Meeting, September 30-October 8, 2005, Vladivostok, Russia
- ORI/PICES Symposium on SEEDS-II experiment, 2 days in October 2005, Tokyo, Japan
- Workshop to build up a multi-species model extending NEMURO.FISH (potential co-sponsors: APN, IAI, IOC and FRA), September or October 2005, Japan
- NPAFC/PICES Symposium on “The status of Pacific salmon and their role in North Pacific marine ecosystems”, October 30- November 1, 2005, Jeju, Korea
- PICES/GLOBEC symposium on “Climate variability and ecosystem impacts on the North Pacific: A basin-scale synthesis”, April 19-21, 2006, Honolulu, U.S.A.
- ICES/PICES symposium on “Marine bioinvasions”, 3 days in early 2006, Boston, U.S.A.
- Symposium to celebrate the 50th anniversary of sampling along Line P and at Station PAPA, 3 days in summer 2006, Victoria, Canada
- PICES/CREAMS/WESTPAC Workshop (with training component) on “NEAR-GOOS Seas Circulation: What we know and how well can we forecast?”, summer 2006, near Vladivostok, Russia
- PICES Fifteenth Annual Meeting, October 13-21, 2006, Yokohama, Japan
- 4th International Zooplankton Production Symposium (co-sponsored by PICES, GLOBEC and ICES), May 28-June 1, 2007, Hiroshima, Japan
- PICES/ICES Young Scientist Conference, spring or summer of 2007, venue TBD

The new PICES Working Group on *Ecosystem-based management*

Glen Jamieson
Pacific Biological Station
Fisheries & Oceans Canada
Hammond Bay Road, Nanaimo, B.C.,
Canada. V8T 6N7
E-mail: JamiesonG@pac.dfo-mpo.gc.ca

Dr. Glen Jamieson is a research scientist at the Pacific Biological Station (Fisheries & Oceans Canada) who has 18 years' experience in shellfish stock assessment. His research and provision of scientific advice is currently centered in four general areas: 1) research in support of the establishment of marine protected areas (MPAs) and ecosystem-based management in British Columbia; 2) development of appropriate steward-ship and monitoring protocols; 3) evaluation of the population dynamics and responses of selected species, focusing on relatively sedentary species such as benthic invertebrates, rockfish, and lingcod; and 4) investigation and monitoring of the presence and impacts of exotic species. Glen is a member of the PICES MEQ Committee and the Chairman of the Study Group on Ecosystem-based management science and its application to the North Pacific.

Since the industrial revolution, man's impact on the oceans has increased dramatically, this being especially true in recent years. In near-shore coastal areas, human population growth has led to increasing pollution and habitat modification. Fishing effects have become increasingly severe, with many, if not most, traditionally harvested populations now either fully exploited or over-fished (Garcia and Moreno, 2003). Thus far, management of these activities has been primarily sector-focused. For instance, fisheries have generally been managed in isolation of the effects of other influencing factors, and have targeted commercially important species, without explicit consideration of non-commercial species and broader ecosystem impacts. However, there is now an increasing international awareness of the cumulative impacts of sector-based activities on the ecosystem (Jennings and Kaiser, 1998; Kaiser and De Groot, 2000), and the need to take a more holistic or ecosystem-based management (EBM) approach (Anon., 1999; Kabuta and Laane, 2003; Link, 2002) to ensure the sustainability of marine ecosystems. Globally, there is an emerging paradigm shift in our approach to ocean management and usage (Sinclair and Valdimarsson, 2003).

In response to the increasing awareness to look at cumulative environmental impacts, in October 2003, the PICES Science Board established, under the direction of the Fishery Science (FIS) and Marine Environmental Quality (MEQ) Committees, the Study Group on *Ecosystem-based management science and its application to the North Pacific*, with the following terms of reference:

1) Review and describe existing and anticipated ecosystem-based management initiatives in PICES member nations and the scientific bases for them;
2) Identify emerging scientific issues related to the implementation of ecosystem-based management; and
3) Develop recommendations for a Working Group to focus on one or more of the issues identified.

The first Study Group task was to reach a common understanding of what the terms ecosystem and ecosystem-based management meant. The following definitions were agreed to:

Ecosystem: The spatial unit and its organisms and natural processes (and cycles) that is being studied or managed.

Ecosystem-based management: A strategic approach to managing human activities that seeks to ensure through collaborative stewardship the coexistence of healthy, fully functioning ecosystems and human communities [towards maintaining long-term system sustainability] by integrating ecological, economic, social, institutional and technological considerations.

Representatives from each country then submitted a summary of their country's approach to EBM, and it became immediately obvious that challenges were different between China, Japan and Korea *vs.* Russia, Canada and the United States. The greater coastal populations in the former three countries, coupled with their much longer history of full exploitation of most harvestable renewable resources, meant that EBM was, initially at least, focused on 1) minimising existing impacts, 2) rebuilding depleted stocks to more acceptable levels, and 3) in near-shore areas in particular, minimising widespread impacts in the marine environment from land runoff from both industrial and urban developments. In contrast, in the latter three countries, human coastal populations and development were generally much less, with fishing impacts and offshore oil and gas development identified as the major impacts. In many instances, relatively unimpacted, pristine habitat and biological communities still existed, and so the challenges there were often how to maintain them while permitting appropriate new economic activity to occur.

When the Study Group met at PICES XIII (Honolulu, October 2004), there was much discussion around three issues:
1) What would be an appropriate standard format to document environmental impacts and initiatives to minimise them;
2) How could the PICES region be subdivided into what the Study Group termed eco-regions; and
3) What indicators would be most appropriate to evaluate progress in achieving EBM.

While it is recognised that many human activities impact the marine environment (*e.g*., fishing, mariculture, oil and gas exploration and development, pollution from land-based activities, disruption of freshwater discharges by urbanisation, *etc*.), the most comprehensive databases (*e.g*., target species landings, bycatch and discard characteristics, habitat disruption, *etc*.) as to how these impacts are affecting marine ecosystems are related to fishing activities. Hence, much initial reporting of ecosystem impacts is likely to be focused on documenting and addressing fishery impacts. Alternate reporting formats may need to be assessed or developed that capture the ecosystem effects resulting from other human activities, and that describe how these ecosystem effects are being monitored. Ecosystem parameters already, or potentially, being monitored may capture environmental change, without linking this change back to the specific human activity, or activities, that in fact might be causing the change (*e.g*. increasing sea water temperature may be the result of many causes, some of which relate to human activities). In some cases, additional research may then be required to determine linkages. It was thus proposed by the Study Group that a standardised reporting framework that describes human activity impacts be progressively applied to all fisheries in PICES member countries, and that the adopted reporting framework be robust enough to address an increasing number of environmental and other requirements imposed by legislation, certification schemes, and consumer and community demands.

Eco-regions have been defined by Canada as "*a part of a larger marine area (eco-province) characterized by continental shelf-scale regions that reflect regional variations in salinity, marine flora and fauna, and productivity*". Biological communities between each region are somewhat different, but within a region, they are generally similar, at least on the large scale. There would obviously be differences between habitats (*e.g*., estuarine, rocky, soft substrate, *etc*.) within an eco-region, but overall, the same mix of species could be expected to occur. EBM approaches within an eco-region should thus strive to achieve the same broad conceptual objectives of trying to preserve the natural species mix, proportions across trophic levels, water quality, and so on. Since some eco-regions might transgress national boundaries, this might mean that different countries would be trying to address the same ecological objectives in their own waters within the same eco-region. The Study Group thus indicated that it would be of value to have a collective evaluation of where different eco-region boundaries are located.

It was generally agreed that while achievement of EBM was a common objective, only through monitoring could the level of progress be actually measured. For cost-effectiveness, existing monitored parameters should be first assessed as to their utility here, but it was recognised that new parameters, many associated with non-commercial species, will also have to be monitored. Different national approaches to achieving such monitoring were briefly discussed, mostly in the context of initiatives to develop a process to determine an optimal mix of parameters to monitor.

In finalising its report, the Study Group made the recommendation to its two parent Committees, FIS and MEQ, to establish a Working Group on *Ecosystem-based management*, with a 3-year duration and the following terms of reference:

- Describe and implement a standard reporting format for EBM initiatives (including more than fishery management) in each PICES country, including a listing of the ecosystem-based management objectives of each country;
- Describe relevant national marine ecosystem monitoring approaches and plans and types of models for predicting human and environmental influences on ecosystems. Identify key information gaps and research and implementation challenges;
- Evaluate the indicators from the 2004 Symposium on "Quantitative Ecosystem Indicators for Fisheries Management" for usefulness and application to the North Pacific;
- Review existing definitions of "eco-regions" and identify criteria that could be used for defining ecological boundaries relevant to PICES;
- Hold an inter-sessional workshop that addresses the status and progress of EBM science efforts in the PICES region, with the deliverable being either a special journal issue or a review article; and
- Recommend to PICES further issues and activities that address the achievement of EBM in the Pacific.

The parent Committees and Science Board accepted these recommendations, and the proposed Working Group on *Ecosystem-based management science and its application to the North Pacific* was established in October 2004. The Science Board also suggested that the full report of the Study Group be published as soon as possible in the PICES Scientific Report Series.

CO_2 data integration activity for the North Pacific

Sachiko Oguma
Graduate School of Environmental Earth Science
Hokkaido University
Hakodate, Hokkaido, Japan. 041-8611
E-mail: oguma@ees.hokudai.ac.jp

Toru Suzuki
Marine Information Research Center
Tsukiji Hamarikyu Bldg. 8F 5-3-3, Tsukiji, Chuo-ku
Tokyo, Japan. 104-0045
E-mail: suzuki@mirc.jha.jp

Dr. Sachiko Oguma was a data manager at the Marine Information Research Center (MIRC), Japan Hydrographic Association (JHA). Since April 2004, when she received her Ph.D. from Hokkaido University (Graduate School of Environmental Earth Science), Sachiko has been working for this school. Her major scientific background is physical oceanography, and her current research is on application of isotopes to water mass analysis.

Dr. Toru Suzuki is the general manager of the research division at MIRC. His current work includes integration of oceanographic data and information and development of a quality control procedure. His scientific background is physical oceanography in coastal regions. Toru is also a member of the PICES WG 17 on Biogeochemical data integration and synthesis.

As interest in greenhouse gases has increased, oceanic CO_2 observations have been actively done in many projects around the world, and lots of data have been accumulated to analyze air-sea CO_2 exchange in various temporal and spatial scales. There are some difficulties for data exchange, however, not only for CO_2 data, but also for other chemical oceanographic data. To be able to share and fully open the data, an effective data management method is crucial.

Some efforts for data exchange have been made among researchers; for example, the scientist group known as CARINA (Carbon Dioxide in the North Atlantic Ocean), has accomplished the data management for CO_2 data of the North Atlantic Ocean. For the North Pacific, a Japanese scientist group established the Inventory for Japanese Chemical oceanographic Data (IJCD) in 2000. Now IJCD data inventory is made public via the web (http://ijcd.jp/), and is partly linked with web sites with original data which can be fully opened.

PICES Working Group 13 on *CO_2 in the North Pacific* (co-chaired by Drs. Richard A. Feely and Yukihiro Nojiri) had planned to construct an international CO_2 data inventory for PICES countries as a part of data integration activity. Firstly, a PICES CO_2 Data Integration Planning Workshop was held at the Institute of Ocean Sciences (Canada) in January 2001 (see *PICES Press*, Vol. 9, No.2). At this meeting, it was recommended that PICES WG 13 and TCODE (Technical Committee on Data Exchange) work together with the data centers (JODC, NODC, CDIAC, *etc*.) and the JGOFS North Pacific Task Team to compile an international North Pacific data inventory for CO_2 and CO_2-related data. A new data inventory, PICNIC (PICES CO_2 Related Data Integration for the North Pacific), was developed following this recommendation.

The PICNIC data inventory is constructed by cruise lists, including information about observation cruises which obtained data of CO_2 and CO_2-related variables in the North Pacific. The format of the PICNIC data inventory follows that of CDIAC and IJCD; which is composed of cruise name, ship name, observation period, principal investigator, observed variables, *etc*. These components are not defined as indispensable information, however they are very important information to search the cruise individually. The cruise information registered in PICNIC are originally collected by IJCD, CDIAC and IOS, and then compiled into a common format based on the IJCD format at the Marine Information Research Center, a management office of the IJCD data inventory.

To follow-up the fruit of the January workshop, a PICES CO_2 Data Integration Implementation Workshop was held from July 31-August 2, 2001, at the Hydrographic and Oceanographic Department, Japan Coast Guard, in Tokyo (Fig. 1). The workshop aimed at (i) developing strategies for exchange of CO_2 and related data at the international level; and (ii) examining the technical issues in integrating presently available data into a uniform data structure or database.

For efficient data exchange, common formats of data and metadata for CO_2 data were discussed. The WOCE format

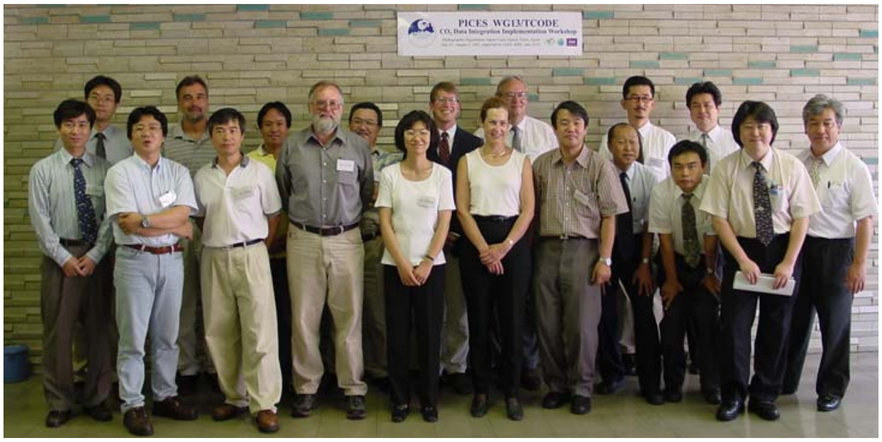


Fig. 1 *Participants of the PICES CO_2 Data Integration Implementation Workshop held July 31 - August 2, 2001, at the Japan Hydrographic Department, Tsukiji, Tokyo, Japan.*

For efficient data exchange, common formats of data and metadata for CO_2 data were discussed. The WOCE format was recommended for bottle sampling data, but there were too many model formats for underway pCO_2 data. Even in one data center, the underway pCO_2 data format is different among data sets, which were obtained by different methods and provided by different scientists. Corresponding to the difference in the data sets, classified data items were suggested: primary necessary data (date, position, seawater temperature, seawater CO_2 data), desired data (atmospheric pressure, salinity, atmospheric CO_2 data), supplemental meteorological data (atmospheric temperature, humidity, wind, wave, solar radiation), supplemental biological data (Chl-a, DO, pH, DIC, TAlk), and necessary data for global data integration (delta xCO_2 / delta fCO_2 / delta pCO_2).

As a tool to explore data in the common format, the Live Access Server (LAS) developed at the Pacific Marine Environmental Laboratory (PMEL) was introduced. LAS is a useful tool to search gridded data, such as NetCDF format data. It was agreed to use LAS as a data viewer of PICNIC. CO_2 and CO_2-related data registered in PICNIC will be converted firstly into the PICES common format, and then into the NetCDF format and mounted on LAS.

As of October 2003, 426 cruises (284 bottle sampling cruises and 214 underway pCO_2 cruises) are registered in PICNIC, and the cruise tracks of Japanese research in IJCD are shown in Figure 2. And the results of the test study of LAS using the underway pCO_2 observation data collected by the National Institute for Environmental Studies from 1995 to 2003 are shown in Figure 3.

Activities for CO_2 data integration are now continued by PICES Working Group 17 on *Biogeochemical data integration and synthesis* (co-chaired by Drs. Andrew G. Dickson and Yukihiro Nojiri). Based on the activities of WG 13 and WG 17, the PICNIC data inventory is assessable on the web (http://picnic.pices.jp/). The development of PICNIC was partly conducted by the study "Ocean Carbon Dioxide Related Substance Database for the Amount Elucidation of Anthropologic Carbon Dioxide Absorption of the Ocean" by JODC using the Global Environment Research Coordination System, Ministry of the Environment, Japan, from FY 2001-2003. To maintain the PICNIC database under international coordination will be one of our future challenges.

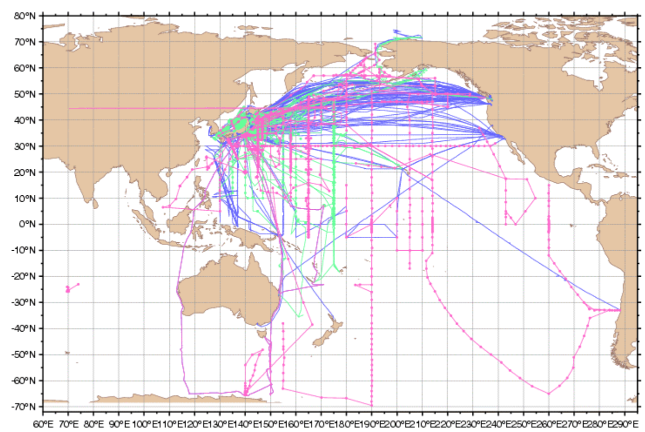


Fig. 2 *Cruise tracks of Japanese Research in IJCD.*

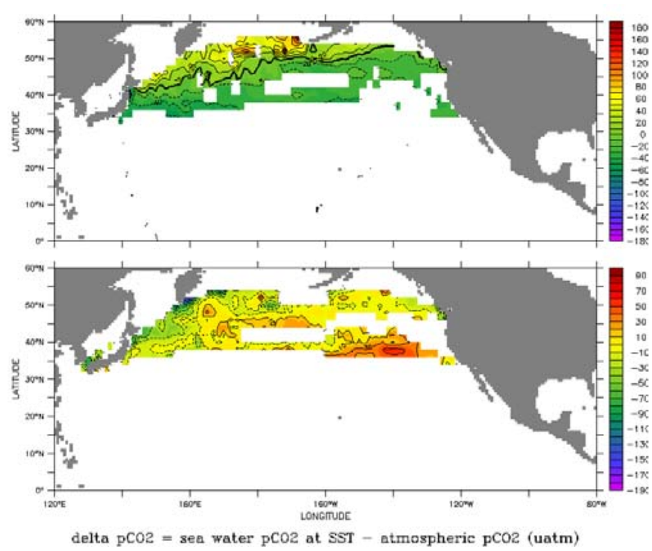
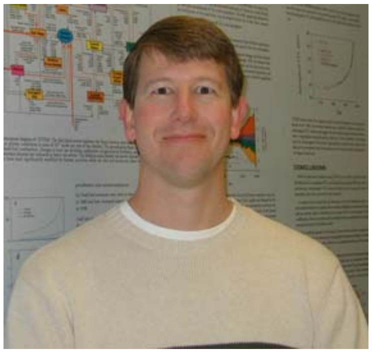


Fig. 3 *Spatial distribution of delta-pCO_2 in winter (top panel) and summer (bottom panel).*

Carbon cycle changes in the North Pacific

Christopher L. Sabine
Pacific Marine Environmental Laboratory/NOAA
7600 Sand Point Way NE
Seattle, WA 98115, U.S.A.
E-mail: chris.sabine@noaa.gov



Dr. Christopher Sabine is an oceanographer at NOAA's Pacific Marine Environmental Laboratory. His research focuses on understanding the role of the ocean in the global carbon cycle. This includes examining the air-sea exchange of CO_2 at the ocean surface and the basin-scale distributions of both natural and anthropogenic carbon in the ocean's interior, understanding multiple tracer relationships, evaluating ocean carbon cycle GCMs with data-based global carbon distributions, and examining carbonate and organic matter re-mineralization within the ocean. Chris has been heavily involved with PICES serving as a member of WG 13 and WG 17 and organizing a number of special sessions/workshops. He also sits on several international committees such as the IGBP/IHDP/WCRP Global Carbon Project (GCP) and the International Ocean Carbon Coordination Project (IOCCP), and has recently helped develop the science and implementation plans for the Ocean Carbon and Climate Change (OCCC) and the North American Carbon Program (NACP) in the United States.

PICES has played a major role in advancing our understanding of the North Pacific carbon cycle over the last six years. In 1998, PICES Working Group 13 was established to promote collaborative carbon cycle research among the PICES member nations, to conduct international CO_2 inter-comparison studies, and to help the development of strategies for international data exchange. By 2001, WG 13 had conducted six workshops on topics ranging from comparisons of dissolved inorganic carbon (DIC) and total alkalinity (TA) techniques to North Pacific data integration.

In 2002, a new Working Group (WG 17) was established to continue the progress started with WG 13. In addition to conducting an inter-comparison study of pCO_2 systems and developing a handbook of recommended methods, WG 17 has also helped to facilitate the synthesis and interpretation of North Pacific carbon cycle data. The latest contributions to this effort were a workshop held this summer and a follow-up session at PICES XIII in Honolulu this October. This article outlines the approach used to encourage collaboration at the workshop, some of the intriguing results and recommendations for future research.

Background

Studies of the ocean's role in the uptake and storage of anthropogenic CO_2 and modulation of future atmospheric CO_2 levels are critical for understanding the global carbon cycle and for the prediction of future climate change. The North Pacific is an important sink region for atmospheric carbon dioxide in the ocean and, consequently, plays a significant role in controlling the long-term fate of CO_2 on Earth. Some biogeochemical processes relating to the oceanic CO_2 system are unique to the North Pacific. For example, the fact that the North Pacific is the final destination of deep water circulation means that high levels of preformed nutrients and DIC are brought into the region. In addition, the strong equatorial upwelling in the Pacific brings high CO_2 waters to the surface making the southern portions of the North Pacific a large natural source of CO_2 to the atmosphere.

Evidence is accumulating that there is substantial variability in the cycling of carbon and related biogeochemical elements over a wide range of time-scales, including inter-annual and decadal scales which have been the focus of many climate change studies. Most of these studies, however, have been limited in time, space or number of parameters examined, preventing a full appreciation of the scale and magnitude of the changes. Numerous studies have been conducted in the North Pacific, but a lack of coordinated approaches has hampered our ability to fully appreciate the regional to basin-scale dynamics of the system. For example, Emerson *et al.* (2001) and Ono *et al.* (2001) both detected increases in apparent oxygen utilization (AOU) in the North Pacific Ocean, but examined different regions, depth zones and time periods using differing approaches that made it difficult to determine whether the signals were coherent across the North Pacific. Keller *et al.* (2002) examined a larger area and also found AOU changes, but indicated that compensating changes in the opposite direction may be found on deeper surfaces. Large variability has also been observed in North Pacific carbon measurements and other parameters (Feely *et al.,* 1997*;* Chavez *et al.,* 1999*;* Feely *et al.,* 1999, 2002, 2004; Karl, 1999; Karl *et al.,* 2001).

Recognizing the need to synthesize this diverse array of studies, the North Pacific Carbon Cycle Workshop was organized in Seattle in the summer of 2004. The workshop was sponsored by NOAA's Office of Global Programs with contributions from PICES, the Global Carbon Project, and the University of Washington's Program on Climate Change. The organizing committee of R. Feely (PMEL), N. Gruber (UCLA), R. Key (Princeton), C. Sabine (PMEL) and J. Sarmiento (Princeton) proposed that rather than simply organizing another meeting where participants come and listen to talks then return to their home institutions to continue their individual research, the workshop should be designed to encourage the synthesis of individual studies and create an environment of collaboration. The format for this workshop brought together modelers and observationalists representing different biogeochemical and physical specialties and different regional expertise to combine their latest model runs and data sets into a common format determined in preparation for the meeting. The goal of this meeting was to encourage real-time exchange and development of ideas among scientists who do not regularly collaborate, but have a common interest (*i.e.*, North Pacific), with the objective of generating synthesis publications that draw from the unique perspective of each participant. This way we can develop an understanding that could not be easily achieved by any individual.

A three-step approach

The workshop was organized using a three-step approach with active coordination, communication and collaboration among the participants before, during, and after the actual meeting. First, the workshop organizers contacted a team of international and diverse scientists that were interested in contributing data and new research to a collaborative study. To help focus the group, participants were divided into three Task Groups (TG) centered on one of three fundamental questions:

(1) How are air-sea CO_2 fluxes in the North Pacific affected by interannual, decadal and long-term variability?
(2) How and why are the North Pacific distribution patterns of carbon, nutrients and oxygen in the water column changing with time? and
(3) what are the requirements for detecting a climate change signal in the North Pacific carbon cycle?

Prior to the meeting, an e-mail discussion was initiated to assess the state of our knowledge on the identified topic and to define the relevant data sets, model results and analysis approaches that could be used to improve this understanding. Data and model results were collected and made available to all the participants through the World Wide Web. Each Task Group established a common framework and guidelines for the presentation of data with specific data-analysis goals. The standardization of approaches/formats and communication prior to the meeting allowed speakers to prepare presentations that could be more easily compared to other presentations at the workshop held on June 2-4, 2004, at the Harbor Steps Conference Center in downtown Seattle (Fig. 1). For example, several participants showed model results at specific locations where direct measurements were also presented. A significant amount of meeting time was spent in Task Groups discussing the similarity and differences of the various studies and considering follow-up analyses that could be used to address intriguing findings. Approximately half of the meeting time was spent in plenary to ensure that all of the participants were well informed of the progress and findings of the Task Groups, and to look for synergies and investigate cross-cutting issues between the three topics. Individual participants from one Task Group were frequently asked to come speak with other Task Groups to maximize everyone's contribution. By the end of the meeting, a total of 14 synthesis manuscripts were identified to work on.

Fig. 1 Participants of the North Pacific Carbon Cycle Workshop outside the Harbor Steps Conference Center in Seattle, June 2-4, 2004.

After the Seattle meeting, participants were encouraged to continue the interactions over e-mail, and to develop the collaborative manuscripts synthesizing the results of the workshop. A Topic Session on the North Pacific carbon cycle was organized at PICES XIII to provide an opportunity for many of the participants to meet together again and share the results of their collaborative interactions with the broader PICES community. A majority of 18 oral presentations in the session and several posters were related to the June workshop, including an invited talk by Nicolas Gruber outlining the motivation behind the workshop and some of the key results. Although many of the workshop participants were familiar with PICES, this was the first time some of the participants had experienced a PICES Annual Meeting. Results were presented from most of the synthesis manuscripts outlined at the workshop, suggesting that great progress had been made since June. The synthesis manuscripts generated from this workshop are being assembled into a special journal volume on the North Pacific carbon cycle, and should be published in 2005.

Air-sea fluxes

Many new ideas were introduced and examined as a result of the preparatory discussions. For example, as a part of TG 1 on *air-sea fluxes*, Taro Takahashi (LDEO) showed data suggesting that at least three different pCO_2 trends can be observed on decadal scale in the North Pacific surface water. Data along the west coast of North America and the eastern sub-polar North Pacific region appear to show a steady increase in surface water pCO_2 that roughly tracks the atmospheric CO_2 increase for the last couple of decades. Data sets from the equatorial Pacific and subtropical regions around Hawaii indicated that in the 1980s surface water pCO_2 was increasing at a slower rate than atmospheric CO_2. In the early to mid-1990s, however, the rate appears to have changed such that today, surface water pCO_2 is growing faster than the atmosphere (*e.g.*, Fig. 2). By contrast, some regions such as the western sub-polar North Pacific actually show decreasing surface pCO_2 values over the last few decades. Modeling studies indicate that shifts in the Pacific Decadal Oscillation (PDO) can influence the air-sea fluxes and, in some cases, have helped to explain some of the changes observed in the data. For example, pCO_2 changes in the equatorial and tropical Pacific coincide with a slowdown in meridional circulation during the 1990s that may have been driven by a PDO regime change.

Water column changes

Many of the presentations and much of the discussion in TG 2 on *changes in the biogeochemistry of the water column* focused on the general observation that dissolved oxygen seems to have decreased in the thermocline over large regions of the North Pacific in the last few decades. The apparent increase in the consumption of oxygen resulting from the decomposition of organic matter could stem from either a slowdown in the meridional circulation or an increase in organic matter fluxes from the euphotic zone. Modeling work conducted in this area suggests that changes in circulation are generally sufficient to account for the observed changes, but additional studies are needed to confirm this. Decomposition of organic matter increases dissolved inorganic carbon (DIC) while it consumes dissolved oxygen. The observed changes in DIC, however, are significantly larger than the changes expected based on Redfield stoichiometry suggesting that the anthropogenic signal is an important, identifiable component of the decadal DIC changes (*e.g.*, Fig. 3).

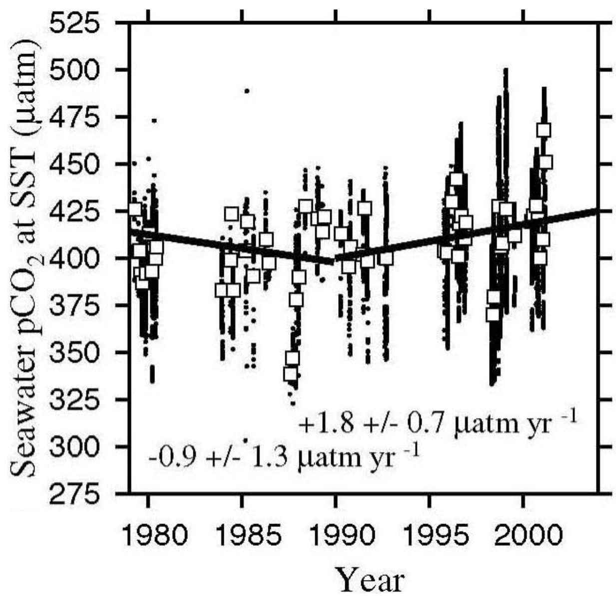


Fig. 2 pCO_2 at SST in surface seawater during non–El Niño periods in the Niño 3.4 area (5°N to 5°S, 120°W to 170°W). The measured values are indicated with dots and the monthly mean values with open squares. The monthly values are used for estimating the decadal mean by linear regression: -0.9±1.3 µatm year^{-1} for the pre–phase shift decade and +1.8±0.7 µatm year^{-1} for the post-phase shift decade. The uncertainties are expressed in terms of 1 SD for six mean rates of change evaluated by using each of the phase shift years of 1987, 1988, 1989, 1990, 1991, and 1992 (adapted from Takahashi et al.*, 2003).*

Detecting climate change

TG 3 was a cross-cutting group tasked with addressing the question of how to distinguish a climate change signal from natural variability. This question is extremely difficult to answer, particularly given the fact that our biogeochemical records tend to be much shorter than historical records of climate or fisheries. The group focused on outlining the questions that need to be considered and how to begin answering these questions:

- What are the observed magnitudes of natural variability?
- What are the anticipated magnitudes and patterns of change resulting from long-term climate change?
- When do we expect to be able to distinguish climate change from the natural variability?
- What is required to properly attribute observed changes to climate change (*e.g.*, better constraint on effects of natural modes of variability)?

Although we cannot properly answer these questions at the moment, the outcomes of this workshop will help us to address the first two of these questions. Several complications in the North Pacific make detection of climate change difficult. High variability in the tropics, Bering Sea, and Kamatchatka regions currently hinder our interpretation of long-term climate trends. With most data series collected since 1980, the recent shift in the Pacific Decadal Oscillation (PDO) complicates our ability to attribute observed changes to long-term climate change. Longer and less patchy time series data are essential, as well as the development of uniform detection approaches. Synthesis studies are needed for a wide variety of geochemically relevant parameters including DIC, alkalinity, oxygen and nutrients which may provide us with a better understanding of carbon speciation changes in the water column. We need to utilize models to provide a link between physical forcing mechanisms, water column changes and surface ocean expression. These studies will help us to better understand the physical, chemical and biological changes in the Pacific that will produce the major oceanic feedbacks for climate change. The group promoted the idea of adopting the formal detection and attribution approach for studying the ocean in a manner similar to the "optimal fingerprint analysis" approach that has been used for climate (*e.g.*, Hasselmann, 1997). The group is developing a specific set of model sensitivity runs and data analyses that can be used to assess when a climate change signal will become detectable in the North Pacific. The protocols will be posted on the web and available for anyone that wishes to participate in this exercise. For more information on the workshop results and future directions, visit the workshop web site at http://www.pmel.noaa.gov/ co2/NP/.

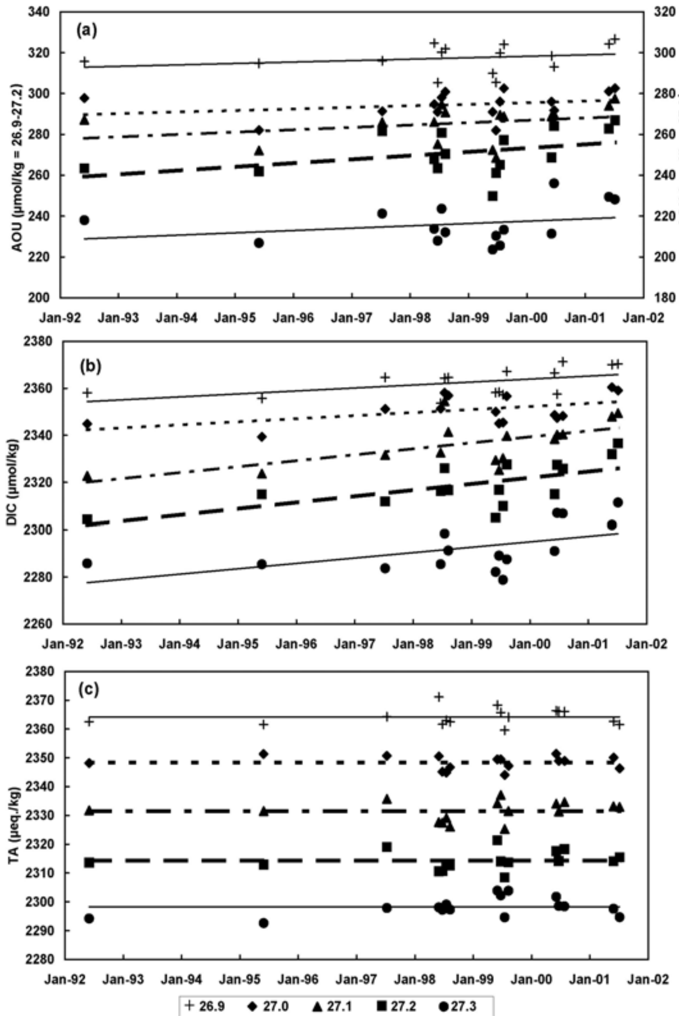


Fig. 3 Decadal changes of (a) AOU, (b) DIC and (c) TA on the 26.9 σ_θ (ave. 230 m; solid circles), 27.0 σ_θ (ave. 300 m; solid squares), 27.1 σ_θ (ave. 380 m; solid triangles), 27.2 σ_θ (ave. 490 m; solid diamonds) and 27.3 σ_θ (ave. 630 m; plus) surfaces at Station KNOT in the western sub-arctic Pacific observed during the period from 1992 to 2001. Lines indicate linear regressions of parameters on the respective density surfaces and show significant increases in AOU and DIC, but not TA. From the work of Wakita et al. as presented by Sabine et al., 2004.

Conclusions

The model of the North Pacific Carbon Cycle Workshop promotes the level of collaboration necessary to address large-scale complex environmental issues that can benefit from the coordinated efforts of a variety of scientific perspectives. This workshop was much more than a meeting. It is the first step in a long-term framework for future studies of the North Pacific Ocean. One of the exciting aspects of this workshop was that it brought together an international contingent of researchers that had a common interest, but were not regularly collaborating. PICES has been a model organization for facilitating collaborations such as these and, hopefully, will continue to promote interdisciplinary studies. Understanding the carbon cycle in the North Pacific, however, only provides us with part of the picture. Global understanding of carbon cycling in the ocean and atmosphere, and ultimately, the detection of climate change, will depend on the propagation of collaborative research efforts like this one to other oceanic regions.

Collaboration and communication aids in establishing standard collection methods as well as the exchange and comparison of data and results. Our challenge for the next decade will be to continue to find ways to bring observationalists and modelers together to allow for greater synthesis of global data and results.

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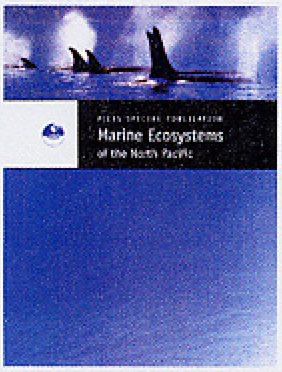

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