Big-picture synthesis requires understanding the small and "in-between" stuff – A summary of the CCCC Synthesis Symposium

By Harold P. Batchelder and Suam Kim

On April 19–21, 2006, 90 scientists from 12 countries met in Honolulu, U.S.A., at the PICES/GLOBEC *Climate Change and Carrying Capacity (CCCC) Synthesis Symposium* to discuss patterns of ocean ecosystem and productivity responses across the North Pacific to historical and recent climate variability. This symposium was organized to culminate the CCCC Scientific Program. The intent of the meeting was two-fold: (1) to establish process-based generalizations about how ecosystems have responded to climate variability through cross-regional comparisons of processes and responses, and (2) to identify issues of climate–ecosystem connectivity that remain unclear, and may be topics of future scientific efforts and programs in the North Pacific. This latter goal may be viewed as assessing what we do not yet know, and how we might incorporate those needs into the design of a future integrative scientific program of PICES. The entire symposium was held in plenary to facilitate the goals of synthesis. There were three invited overview presentations and 35 contributed presentations distributed among three theme sessions:

Theme 1: *Examination of ocean and ecosystem responses to known strong, infrequent changes in the North Pacific (regime shifts), such as those that occurred in 1977, 1989, and 1998*;

Theme 2: *Ecosystem productivity and structural responses to physical forcing, with an emphasis on shorter than interdecadal time scales, especially examining variability at interannual (El Niño–La Niña), seasonal and event time scales*;

Theme 3: *Pan-Pacific comparisons, with an emphasis on comparisons of similar species or processes from multiple coastal ecosystems and of open ocean-coastal linkages and climate connections.*

A remarkable accomplishment was that, with only one or two exceptions, all of the speakers concluded their presentations with sufficient time remaining for multiple questions from the audience. This was important for providing feedback on the work, and for stimulating broader discussion. There were contributed posters, with several dedicated discussion periods – often accompanied by copious quantities of "vittles and grog" – to allow poster presenters to interact with other scientists. Finally, Makoto Kashiwai (Japan) and John Davis (Canada) provided retrospective "Perspectives" talks, and a panel discussion was held that touched upon the successes of the CCCC Program and the synthesis symposium, and provided guidance for future research on climate and ecosystem connections. We thank Kuh Kim (Korea), David Mackas (Canada), Brenda Norcross (U.S.A.) and Manuel Barange (GLOBEC IPO) for offering their thoughts and insights during the panel discussion, and the audience for the ensuing lively exchange of ideas. This newsletter article cannot possibly do justice to all of the synthesis presentations, so proceedings of the symposium will be published as a special issue of *Progress in Oceanography*. In the meantime, we share some thoughts about the symposium, highlight a few points made, and offer a report card for the CCCC Program – based upon whether or not we have made significant progress in addressing the central scientific issues of the CCCC Program outlined a decade ago.

The mission statement of the CCCC Program describes two roles:

- To provide a strategy for determining the carrying capacity for higher trophics in the subarctic North Pacific (salmon, pollock, birds, mammals, *etc.*); and
- To develop a plan for a cooperative study of how changes in ocean conditions affect the productivity of key fish species in the subarctic North Pacific and coastal zones of the Pacific rim.

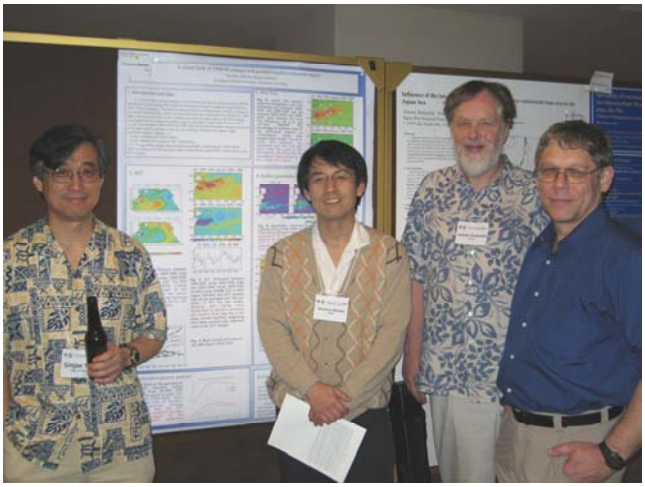
An ultimate goal of the CCCC Program is "to forecast the consequences of climate variability on the ecosystems of the subarctic Pacific." To forecast, we must understand. So a first step is to answer the following question: "How do interannual and decadal variations in ocean conditions affect the species dominance, biomass, and productivity of the key zooplankton and fish species in the ecosystems of the PICES area?" Specifically, the issues being addressed by the CCCC Program are:

Physical Forcing – What are the characteristics of climate variability? Can interdecadal patterns be identified? How and when do they arise?

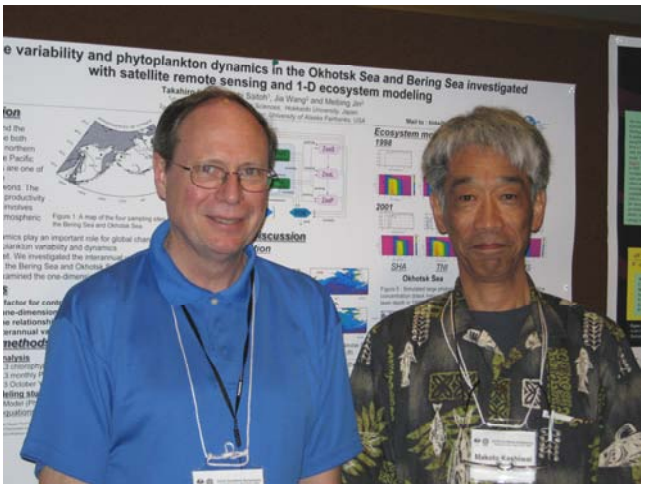
Lower Trophic Level Response – How do primary and secondary producers respond in productivity and in species and size composition, to climate variability in different ecosystems of the subarctic Pacific?

Higher Trophic Level Response – How do life history patterns, distribution, vital rates, and population dynamics of higher trophic level species respond directly and indirectly to climate variability?

Ecosystem Interactions – How are subarctic Pacific ecosystems structured? Is it solely through bottom-up forcing, or are there significant intra-trophic level and top-down effects?



Invited speakers Drs. Sinjae Yoo (Korea), Shoshiro Minobe (Japan), James Overland (U.S.A.) and David Mackas (Canada).



"Perspectives" speakers Drs. John Davis (Canada) and Makoto Kashiwai (Japan).

Panel discussion with Drs. Manuel Barange (GLOBEC IPO), Brenda Norcross (U.S.A.), David Mackas (Canada) and Kuh Kim (PICES).

One lesson learned during the symposium is that synthesis is hard to accomplish because it requires general conclusions from specific information, demands multi-disciplinary thinking and interaction, and it takes a lot of time (and money). Synthesis can be defined as the combination of separate elements of thought or process into a whole, as of simple into complex conceptions. This is in contrast to analysis, which can be defined as an examination of the component parts, each separately, of a subject. As scientists, we do the latter as a matter of routine – *e.g.*, we examine the physical ocean processes of a small piece of ocean, or the population dynamics of a single seabird colony. Conversely, it is only relatively recently, largely due to societal needs and funding agency mandates, that we have undertaken synthesis – where the physics of the ocean, the seabird population dynamics, and all of the intervening trophic patterns and processes are examined to achieve a mechanistic understanding of how climate variability is impacting seabirds or other components of marine ecosystems.

Given the difficulty of synthesis, it was not surprising that many presentations were not successful in achieving synthesis and integration. There were exceptions, where presentations were integrative and accomplished an actual synthesis – *e.g.*, to think interdisciplinary or multi-regionally. To quote Manuel Barange of the GLOBEC International Program Office, who in his panel remarks paraphrased Robert Francis' talk, "*One could say that if a painter paints what otherwise is not there, integration and synthesis tries to extract from the observations what otherwise is not there*." Barange felt that few of the papers demonstrated integration and synthesis. We suppose, to some degree, judging the symposium's success in achieving synthesis is dependent on an individual's *a priori* expectations. One of the conveners (Batchelder) felt that most of the scientific presentations attempted to achieve synthesis, either by considering other aspects of the environment or comparing results to other regions to seek generality. In that respect, many of the presentations were "synthetic" – *e.g.*, very few were, in this convener's opinion, "reports of work in progress."

A number of recurrent themes emerged from the presentations. An emergent theme from the symposium was that "*sometimes the big picture requires that we notice and deal with the small and in-between stuff*", which is paraphrased as the title of this article. This was not a subject of a specific talk, but was mentioned by a number of presenters in the form of statements like, "think like the fish", "need to consider the life cycle specifics", "sockeye salmon life cycles are important", "time and location of spawning are important", *etc*. To paraphrase Marc Mangel (Mangel, 1993), "*Know your Organism*", you need to know the details of the biology in order to understand mechanisms that link the populations and ecosystems to climate change and variability. Brenda Norcross, in her panel remarks, listed a few themes that emerged from the 10 years of the CCCC Program. These include an increased research emphasis on: (1) larger spatial scales (ecosystem, region and basin); (2) comparisons of multiple

geographic areas or multiple stocks; and (3) less examined species groups, like jellyfish. Moreover, the CCCC Program was successful in (4) stimulating interdisciplinary work; (5) providing mechanisms and venues for coordination of scientists from different nations; and (6) supporting the establishment or continuation of sustained time series observations.

A separate assessment of themes emerging from the symposium included: (1) do not use "regime shift" as a blanket cause of something; reality is much more complicated than what can be achieved with a simple index; (2) be open-minded and seek alternative explanations to observed phenomena; (3) local forcing and conditions, which might not necessarily be described by or related to ENSO or PDO, may be more important in structuring local ecosystems than basin-scale indicators; (4) do not forget the upward trend of global warming – even the "anomalously" cool years are warm now; (5) species biology and life history are important; and (6) it is not just climate, it is also habitat. One topic that deserves more attention than it received at the symposium, if not by the CCCC Program, then by the next integrative scientific program of PICES, is that climate changes that perturb fisheries have socio-economic and cultural impacts. This is widely recognized and assumed, but there were few presentations at the symposium that focused on quantifying economic impacts. The notable exception was a presentation by Jodie Little (U.S.A.) which examined projections of biomass and revenue derived from harvested marine resources under different scenarios of climate (*e.g.*, bottom-up and top-down forcing) (**Fig. 1**). Of course, human systems are adaptive – fishers retool as needed to utilize different resources – and projections of ecosystem and economic conditions cannot be forced as if the ecological–economic interactions are static. Fluctuations in fisheries resources lead to shifting harvesting priorities and use.

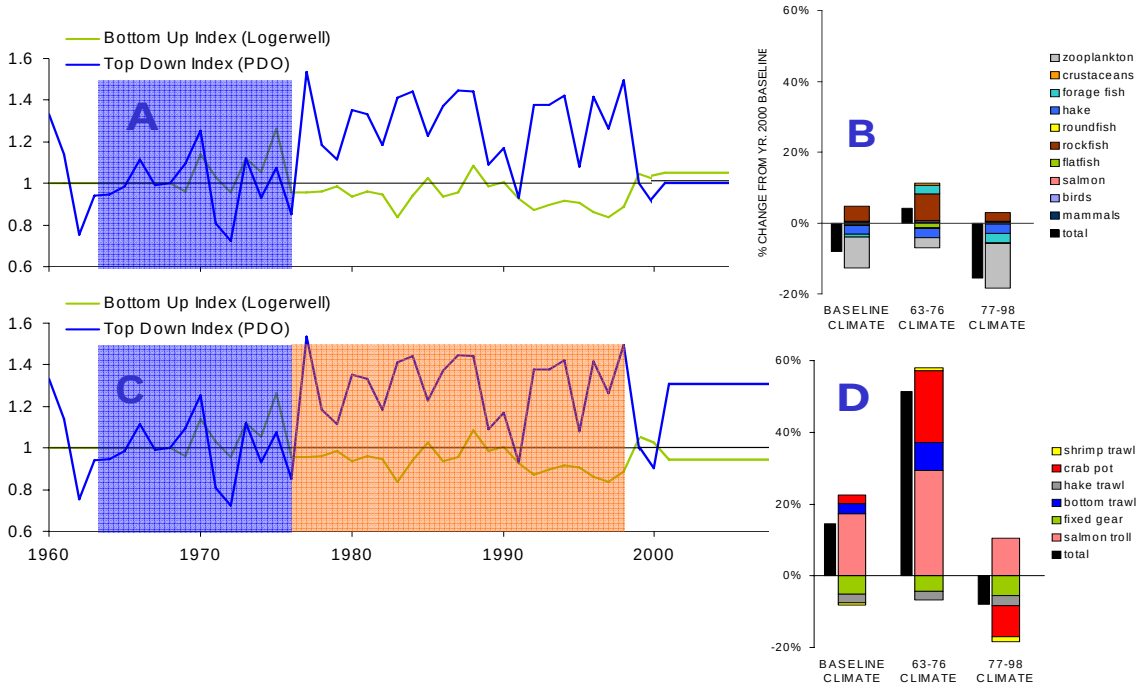


Fig. 1 Projections of California Current biomass and living marine resource-derived revenue by major fish categories for two different climate projections. Bottom-up forcing used a time series of early salmon survival (Logerwell et al.*, 2003). Top-down forcing used the PDO. Panel A is the projection scenario when forced by cold period (1963–76) conditions. Panel C is the projection scenario when forced by warm period (1977–98) conditions. Panels B and D show the percentage change of biomass and revenue, respectively, over the long-term (projections extended to 2100) under the baseline climate (1960–2000), and cold and warm scenarios, when fishing is assumed constant at 2000 levels through time. Figures are from the presentation by Jodie Little (with permission).*

James Overland (U.S.A.), in the invited talk (co-authored by Shoshiro Minobe (Japan) and Sergei Rodionov (U.S.A.)), described how regimes and regime shifts are ill- or inconsistently-defined, sometimes by statistically significant displacements in a time series, or by non-linear processes, or by external forcing. The FERRRS report (King, 2005) defined regimes as "a period of several sequential years (often a decade or more) in which the state, or characteristic behavior of the climate, the ocean conditions or an ecosystem is steady." Similarly, regime shift was defined as "a relatively rapid change (occurring within a year or two) from one decadal-scale period of a persistent state (regime) to another." This definition is of the displacement type described by Overland. Statistical displacement analysis (Rodionov, 2004) identification of regime shifts is sensitive to the parameterization of the detector, as illustrated by **Figure 2**. Two conclusions are: (1) most time series of ocean ecosystem conditions are still too short to determine the underlying model of regimes; and (2) it is important to understand the physical–biological links, and especially biological lags, in responding to physical forcing and long-term trends.

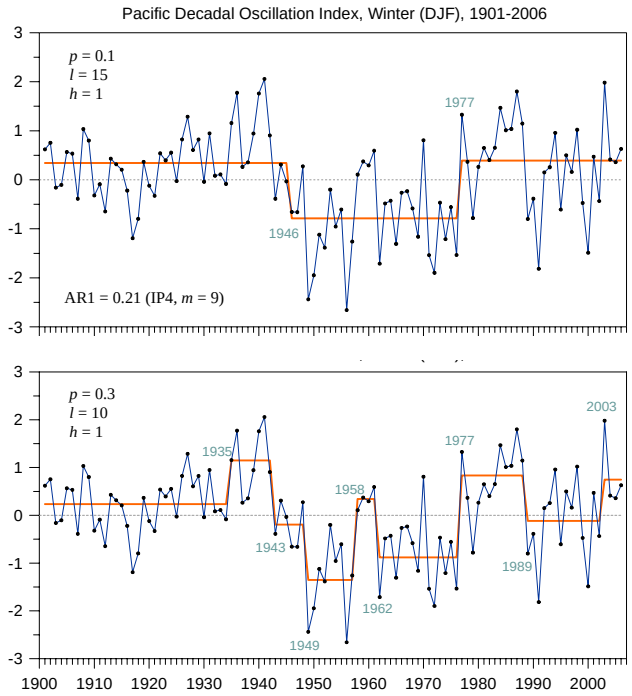


Fig. 2 Detecting regime shifts in the PDO using the displacement sequential regime detection method of Rodionov (2004). The algorithm has user-specified criteria, e.g.*, cutoff time-scale (l) that determines the minimum duration to qualify as a regime. The key concept is that there must be significant shifts in mean value relative to the within-regime variance in order to "detect" a new regime. Figure from presentation by James Overland (with permission).*

Sinjae Yoo (Korea) provided an overview invited talk for Theme 2 (co-authored by Harold Batchelder (U.S.A.)) on seasonal, interannual and event-scale changes in North Pacific ecosystems. The importance of temporal environmental variability is life-cycle scale dependent. The seasonal annual cycle is the largest amplitude signal in most regions and for most trophic levels (below fish). Spatial variations in seasonal climatology (magnitude and timing) of surface chlorophyll concentration, based on SeaWiFS data, for which comprehensive spatial data are available since 1998, indicate maximum amplitude fluctuations in continental shelf systems and high latitudes, and generally lower amplitude fluctuations in oceanic regions of the North Pacific. Fewer places have full seasonal descriptions of zooplankton biomass, but several that are described have seasonal peak biomasses corresponding with, or shortly after, peak chlorophyll concentrations (Japan/East Sea, East China Sea, Oyashio region, Alaska Coastal Current). Conversely, peak seasonal zooplankton biomass in some regions (Station P in the Gulf of Alaska, CalCOFI region) does not correspond well with peak seasonal chlorophyll concentration. For Station P, the explanation is likely related to the seasonal phenology of the large grazing copepods which peak in biomass in June, but depart surface waters to diapause at depth, enabling a slight accumulation of phytoplankton biomass in autumn.

Yoo described the interannual variability of phytoplankton biomass (surface chlorophyll) across the North Pacific for the period from 1998–2004. Several patterns of interannual variability were discerned: (1) an anti-El Niño pattern with highest chl-*a* in 1999–2002, and anomalously low chlorophyll in the other years (Southern Japan/East Sea, Alaska Coastal Current, Northern California Current); (2) an El Niño pattern opposite to that of (1), common in subarctic marginal seas (Okhotsk Sea and Bering Sea); and (3) a trend of increasing surface chlorophyll through time (Pacific subarctic regions of the Northern Japan/East Sea, Western Subarctic Gyre, Gulf of Alaska and the Pacific Subarctic Front region). Specific event-scale phenomena described were: (1) the anomalously enhanced southward flow of subarctic water into the California Current in 2001–2002, which stimulated very high phytoplankton production and had significant impacts, at multiple trophic levels, on the Oregon continental shelf ecosystems; and (2) the delayed spring transition in 2005 and its ecological impacts on zooplankton and the fish and seabirds that rely on abundant spring zooplankton prey for reproduction and/or survival.

Symposium in session.

David Witherell and Gordon Kruse discussing interesting presentations during coffee break.

David Mackas (Canada) provided an overview presentation for Theme 3 (co-authored by Kazuaki Tadokoro (Japan)) on Pan-Pacific comparisons, focusing on the ecology of subarctic zooplankton. He described what was known about zooplankton ecology prior to the CCCC Program and then summarized what was learned about zooplankton ecology of the North Pacific during the Program. Briefly, the pre-CCCC knowns were: (1) average zooplankton conditions (basin-scale distributions of biomass, dominant species and their distribution, seasonal life history (phenology), prey items and predators of a few species at a few locations); (2) average environmental conditions (mean water properties, circulation, seasonal cycles and east–west contrasts); and (3) increasing awareness of the importance of (a) iron to plankton dynamics in the subarctic, (b) climate variability (regimes and ENSOs) and (c) climate trends and CO_2. Large body-sized, inter-zonal migrant copepods, especially *Neocalanus* spp., dominate the spring–summer biomass at all deep water locations in the subarctic Pacific. In addition there are a few other groups of smaller copepods, euphausiids and some "jelly" plankton that contribute to the zooplankton biomass. Despite the rather uniform east–west composition of the zooplankton fauna, there are substantial east–west contrasts in the environment (temperature, circulation, phytoplankton biomass). New zooplankton insights during the CCCC Program include: (1) quantification of how much low-frequency (regime shift and ENSO) variability of zooplankton biomass occurs; (2) knowledge of the natural history of many more zooplankton taxa (thanks largely to Japanese studies); (3) new information about within-species variability of body size and phenology, through both time and space; (4) improved knowledge about the composition of zooplankton assemblages and their variation in space and time; and (5) development of a geographically more comprehensive set of zooplankton time series across the North Pacific, and comparison of these zooplankton time series.

It was clear from the presentations made at the symposium and from recent publications that great progress has been made on coupling biological models of lower trophic levels of varying complexity (NEMURO, Individual Based Models) to physical dynamics (hydrographic structure and circulation) and to other components of the biological system, as exemplified by the coupling of NEMURO with models of growth and population dynamics of herring and Pacific saury. Recently, these coupled models are being forced by climate projections derived from IPCC (International Panel on Climate Change) assessment models to examine potential impacts of continued global warming on the ecosystems of the North Pacific.

Physical Forcing

What are the characteristics of climate variability, can interdecadal patterns be identified, how and when do they arise?

Progress and Products

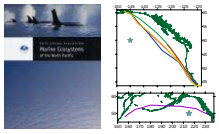
- 2000 Progress in Oceanography (North Pacific Climate Regime Shifts)
- 2005 Fisheries Ecosystem Responses Recent Regime Shifts (FERRRS) Report
- Many scientific papers on regime shifts, climate variability and posters and presentations at this symposium (*e.g.*, Overland, Schwing)

Lower Trophic Level Response

How do primary and secondary producers respond in productivity, and in species and size composition, to climate variability in different ecosystems of the subarctic Pacific?

Progress and Products

- Forthcoming Ecological Modelling special issue on NEMURO model
- Contributions to North Pacific Ecosystem Status Report
- Development of NEMURO through many workshops. Great progress on LTL and linkage to climate, including papers at this symposium (*e.g.*, Aita, Hashioki presentations)
- Activities leading to SCOR WG 125 (Global Comparisons of Zooplankton)—Mackas presentation
- New CPR program in North Pacific



Higher Trophic Level Response

How do life history patterns, distribution, vital rates, and population dynamics of higher trophic level species respond directly and indirectly to climate variability?

Progress and Products

- Linkage of NEMURO to higher trophics, esp. fish, NEMURO.FISH (e.g., Rose, Ito presentations)
- Cross-regional comparisons of species responses to climate — *e.g.*, herring, sardine, pollock (presentations by Hay, Perry, Peterman, Sydeman, Beamish poster, Takasuka, *etc.*)
- ECOSIM/ECOPATH efforts of BASS Task Team to examine differences in higher trophic food webs of eastern and western subarctic gyres.

Ecosystem Interactions

How are subarctic Pacific ecosystems structured? Is it solely through bottom-up forcing, or are there significant intra-trophic level and top-down effects?

Progress and Products

- Forthcoming Prog. Ocean. special issue on "Mechanisms that regulate North Pacific ecosystems: Bottom-up, top-down, or something else?"
- ECOSIM/ECOPATH efforts of BASS Task Team to examine differences in higher trophic food webs of eastern and western subarctic gyres.
- Iron Fertilization Experiments in Western and Eastern Subarctic Pacific that were coordinated through IFEP advisory panel.

Fig. 3 Summary of progress and products resulting from CCCC investigations directed at each of the major CCCC scientific issues described in the text. An overall conclusion is that the CCCC-stimulated studies have improved understanding of climate–ecosystem interactions in the North Pacific, but that not all questions and issues have been resolved.

Overall, the Symposium on "*Climate variability and ecosystem impacts on the North Pacific: A basin-scale synthesis*" was a success. Some of the progress and products of the PICES CCCC Program are summarized in **Figure 3**. Of course, we have not accomplished all that we set out to do at the inception of the Program, and there is room for improvement in achieving a synthesis. The co-conveners of the symposium (and co-authors of this article) hope that many of the presentations from the symposium will be prepared as manuscripts and submitted for consideration in the symposium proceedings in *Progress in Oceanography*.

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Dr. Harold (Hal) Batchelder (hbatchelder@coas.oregonstate.edu) is a professor (senior researcher) at Oregon State University, and the Executive Director of the U.S. GLOBEC Northeast Pacific Regional Coordinating Office. Previously he served for 6 years as the Scientific Director of the National U.S. GLOBEC Steering Committee Office. Hal is Co-Chairman of the Climate Change and Carrying Capacity Program of PICES. His research uses models to examine the interactions of plankton populations and physical flow fields, using in particular Lagrangian–Eulerian approaches that allow coupling of complex biological states and behaviors with lower trophic levels.

Dr. Suam Kim (suamkim@pknu.ac.kr) received his B.Sc. (1976) and M.Sc. (1979) in Oceanography from the Seoul National University and his Ph.D. in Fisheries Oceanography from the University of Washington in 1987. Currently he is a professor of the Pukyong National University, Busan, Korea. He served as the Director of the Polar Research Center of the Korea Ocean Research and Development Institute (KORDI) and Chairman of Korea GLOBEC. His areas of interest include fisheries ecology (especially recruitment variability focusing on early life histories of fish in relation to oceanic/climate changes) and fish stock assessment using the egg production method. Suam has represented Korea on several international organizations such as PICES (Co-Chairman for the CCCC Program and member of the Fishery Science Committee), GLOBEC (SSC member), and CCAMLR (Vice-Chairman of the Scientific Committee).

PICES Calendar

- Workshop on "*Model-data inter-comparison for the Japan/East Sea*" and Summer school on "*Ocean circulation and ecosystem modeling*" (co-sponsored by PICES, SNU and KORDI), August 21–25, 2006, Busan, Korea;
- ICES/PICES theme sessions on "*Large-scale changes in the migration of small pelagic fish and the factors modulating such changes*" and on *operational oceanography* (title TBD) at the ICES Annual Science Conference, September 2006, Maastricht, Netherlands;
- PICES Fifteenth Annual Meeting, October 13–21, 2006, Yokohama, Japan;
- International Conference on "*The Humboldt Current system: Climate, ocean dynamics, ecosystem processes and fisheries*" (co-sponsored by IMARPE, IRD, NASA, FAO, GLOBEC, ICES, PICES and IMBER), November 27–December 1, 2006, Lima, Peru;
- 5th International Conference on "*Marine bioinvasions*", (co-sponsored by ICES, PICES and the U.S. National Sea Grant College Program), May 21–24, 2007, Cambridge, U.S.A.;
- 4th International Zooplankton Production Symposium on "*Human and climate forcing of zooplankton populations*" (co-sponsored by PICES, ICES and GLOBEC), May 28–June 1, 2007, Hiroshima, Japan;
- PICES/ICES Young Scientists Conference, June 26–29, 2007, Baltimore, U.S.A.;
- PICES Sixteenth Annual Meeting, October 26–November 4, 2007, Victoria, Canada;
- International Symposium on "*Effects of climate change on the world's oceans*" (co-sponsored by ICES, PICES, IOC, GLOBEC, SCOR and WCRP), May 19–23, 2008, Gijón, Spain;
- PICES Seventeenth Annual Meeting, October 16–26, 2008 (tentative), Dalian, China.