EDITORIAL

An introduction to the Beyond El Nino conference: climate variability and marine ecosystem impacts from the tropics to the Arctic

The North Pacific Marine Science Organization (PICES) was established in 1992 during a period of rapid growth of interest in large-scale climate variability and its effects on marine ecosystems. At its inaugural annual meeting in 1992 in Victoria, Canada, PICES convened an international symposium on climate variability and fisheries production (Beamish, 1995). Since then, PICES symposia have continued to foster exchanges of new ideas about how marine ecosystems respond to environmental variation. Perhaps the most significant concept to emerge from the mid-1990s was that of regime shifts (Hare, Minobe, & Wooster, 2000). These are low frequency, high amplitude changes in community composition, species abundance and trophic structure that occur abruptly and concurrently with changes in the North Pacific climate system. An important role for PICES is in providing a forum for ongoing dialogue among scientists of the Pacific Rim.

The Beyond El Nino conference held in March 2000 in La Jolla, California gave an opportunity for scientists and representatives of Pacific fisheries organizations (Inter-American Tropical Tuna Commission, IATTC; International Pacific Halibut Commission, IPHC; Interim Scientific Committee for Tuna and Tuna-like Species, ISC; and the North Pacific Anadromous Fish Commission, NPAFC) and SCOR (Scientific Committee on Ocean Research), to discuss recent advances on topics such as climate regimes and other related developments. The objective of this conference was to consider the current state of knowledge of climate and marine ecosystem variability on all temporal scales. Whereas the intense 1997-1998 El Nino had temporarily diverted attention to that scale of variability, a major objective of the Beyond El Nino conference was to focus on scales of variability beyond those of El Ninos. The conference was led by a Steering Committee of Drs Warren S. Wooster, Paul H. LeBlond (co-chairs), Robin L. Allen, Bruce M. Learman, Loh-Lee Low and Michael F. Tillman who organized the conference into 4 daily sessions, each with its own complement of co-convenors. Initially, 144 abstracts were submitted for presentation at the conference. Authors wishing to have their work considered for publication in this volume were invited to submit manuscripts at the conference. Forty manuscripts were submitted, 32 of which were selected with lead authors from 12 countries. An encapsulation of the key findings of each paper by the Guest Editors follows.

1. Evidence of variability (Convenors: Richard J. Beamish, Richard D. Brodeur & Kimio Hanawa)

The first session considered new evidence of changes in climate and ecosystems on time scales from interannual to millennial. The session attracted 64 abstracts, of which 16 were presented orally and, of those submitted, nine are included in this volume. Lin et al. describe long-term variations in the physical environment along the coast of the Bohai Sea using data collected from 1960-1997. They found that annual mean air temperature, sea surface temperature (SST) and sea surface salinity (SSS) all showed increasing trends. They point out that these changes seem to have an important influence on the ecosystem in the Bohai Sea. Hong et al. investigate the relationship between the ENSO
(El Niño/Southern Oscillation) events and SST in the East/Japan Sea using 49 years of data. They conclude that the SST field in the East/Japan Sea varies synchronously with ENSO events. Alexander et al. examine the 're-emergence mechanism' in the North Pacific using both observed SSTs and SSTs reconstructed from an ocean data assimilation system. They conclude that recurring SST and SSS anomalies (observed and simulated) in several regions of the Central North Pacific have been especially strong in the northern part of the basin. Using a 40-year (1961-2000) hydrographic data set from coastal Oregon, Smith et al. examine the relationship between the ENSO signal and the phase of PDO (Pacific Decadal Oscillation) in this region. They suggest that warming/cooling cycles in the coastal ocean off Oregon result from the influence of ENSO but are modulated by the PDO. Royer et al. estimate coastal freshwater discharge from 1931-1999 in the northern Gulf of Alaska using a simple hydrological model. They find a high correlation between freshwater discharge and hydrographic properties at a coastal site near Seward, Alaska and propose an hypothesis linking the PDO with coastal freshwater discharge and subsequent salmon production in Alaska. The paper by Sugimoto et al. delves into the relationship between the monsoons that affect the Asian continent and ENSO in the tropical Pacific. They also discuss how Los Ninos influence climate in the western Pacific and provide some varied examples of how ENSO affects different trophic levels ranging from plankton to benthic corals to pelagic fishes. On slightly smaller spatial scales, Limsakul et al. analyze data on physical oceanographic conditions, nutrients, phytoplankton, and zooplankton to examine the interplay between physics and biological production. They find that winter wind-stress in the subtropical gyre off Japan has been related to the Asian monsoons over the latter half of the 20th century. They observe that increased wind stress deepens the mixed layer and hence affects lower trophic levels. An analysis of the changes occurring in the coastal ecosystem off the west coast of Canada is the focus of a contribution by McFarlane and Beamish. Using as a case study the reappearance of Pacific sardine (Sardinops sagax) to this ecosystem after an absence of about 50 years, they conclude that significant changes in climate have occurred, particularly following the regime shift, that occurred in 1989, and made the coastal ocean off Canada more suitable for sardines. Off Canada, other species such as Pacific hake (Merluccius productus) also showed positive responses, while some groundfish and salmonid species had shown coincident declines in the 1990s. Expanding the comparison, Parsons and Lear review papers on climate/fisheries interactions in the North Atlantic Ocean, focusing on studies of the role of the North Atlantic Oscillation (NAO). They trace how the NAO affects temperature and salinity patterns in the North Atlantic and how these have affected zooplankton production. Finally, they discuss how climate variability is affecting fisheries resources in the region, showing that there is an apparent inverse effect of the NAO on eastern and western Atlantic stocks.

2. Ecosystem consequences (Convenors: Anne B. Hollowed, Daniel Liuch-Beida & Yasunori Sakurai)

Thirty-two abstracts were contributed to this session, which addressed a broad range of impacts of climate forcing on marine systems from plankton to fishes and seabirds. Seven of these are included in this volume. In aggregate, bottom-up forcing is apparent in the plankton, whereas the response of fish and seabirds has been less predictable because
of the complexity of pathways for energy transfer. At large spatial scales coherent patterns of association with the cadence of climate forcing have appeared. Dr Jake Rice revisits the ecological principles that form the foundation for our current thinking regarding the consequences of ecosystem perturbation. He explores the ecosystem consequences of climate variability by examining responses of five biological processes: growth, reproduction, feeding and the avoidance of predation, shifts in state, and competition. This paper is important because it reminds us that debates regarding processes underlying ecosystem variability are not new, and that by revisiting these debates occasionally, it provides a foundation for rethinking the conceptual basis that underpinnings of ecosystem models of marine ecosystems. Papers by Goes et al. and Leonard et al. focus on impacts of shifts in ocean conditions on lower trophic levels. Both studies illustrate the large-scale impact of ENSO on productivity in the North Pacific. Goes et al. introduce a novel method for estimating nitrate and new production from remotely sensed data, showing that ENSO has a negative effect on phytoplankton production along the west coast and Gulf of Alaska. In contrast, ENSO conditions are followed by a southward extension of cold nutrient rich Oyashio waters off Asia resulting in enhanced phytoplankton production. Consistent with these findings, Leonard et al. have utilized shipboard and satellite observations to investigate the spatial and interannual variability in phytoplankton production in the subtropical North Pacific. Their analysis reveals that ENSOs are associated with increases in chlorophyll. These studies identified that eddy-like features may contribute to increased production. Both demonstrated the importance of new tools in tracking basin scale responses to atmospheric forcing. Papers by Hollowed et al. and Roy and Reason explore the responses of marine fish to large-scale ocean variability at latitudinal and longitudinal scales. Hollowed et al. compare the PDO and ENSO with time series of marine fish production. Their paper traces the northwards progression of El Ninos and identifies the presence of Nino North events along a latitudinal gradient extending from the west coast of North America to the Bering Sea. The study provides evidence that gadid populations have low autocorrelation in their production time series with strong year-classes more prevalent in years of Nino North. Piscivorous flatfish stocks and salmon appear to have highly autocorrelated production that is associated with the PDO. Roy and Reason examined the transmission of ENSO forcing along a longitudinal gradient. Their study traces the influence of ENSO on oceanic conditions in West Africa. They noted that oceanic conditions in West Africa accounted for most of the interannual variability in several marine fish stocks, and they suggested that ENSO events in the Pacific Ocean may be used to predict large-scale changes in West Africa. These papers suggested that Pacific climate variability might explain a large component of the variability of dominant fish species, which in turn may explain coherent patterns of fish production in some of the world's oceans. At still higher trophic levels, Sydeman et al. and Bertram et al. examined the influence of large-scale physical forcing on the reproductive performance of seabirds. They suggested that the impact of ocean forcing on the timing of marine production may explain shifts in seabird reproductive performance, demonstrating the complexity of pathways linking climate, ocean forcing, marine production, and fish. In aggregate, the contributions to this session recognized that the ecosystem consequences of climate variability can be detected at scales much larger those previously anticipated.

While the previous sessions reported on a wide spectrum of physical and biological variability, the intent of this session was to investigate mechanisms that produced this variability. Historically, much of the focus of biological oceanography has been on mechanisms that may account for variability in phytoplankton, for example, the roles of vertical mixing and stratification in regulating physical mechanism to regulate nutrient supplies or light levels, or zooplankton grazing as a biological mechanism in controlling phytoplankton standing stock or more recently the role of iron as a chemical or catalytic mechanism influencing primary productivity. Often the consequences of variability in higher trophic levels has received little attention and has often been assumed to track phytoplankton variability through bottom-up forcing. While this may be important in marine ecosystems, an understanding of the dynamics of higher trophic level species must also consider their complex behavior and unique habitat. This approach received considerable attention in this session with six papers proposing mechanisms to account for variation at high trophic levels by focusing on aspects of their life history, behavior, or habitat. A total of 24 abstracts were submitted to the session, eight of which are included in this volume.

Pierce discusses mechanisms that may be responsible for decadal-scale variability in the ocean. Those decadal-scale SST patterns that are reflected in the PDO suggest there is a coupled ocean-atmosphere feedback process. However Pierce shows that low frequency variation in the PDO can also arise from atmospheric white noise forcing an ocean with a longer 'memory'. Current data and models do not enable us to distinguish between these two mechanisms. Subbotina et al. examine the spectral characteristics of mid to high latitude coastal sea level variation along the west coast of North America to investigate the role of ocean and atmospheric forcing mechanisms. Los Ninos amplify sea level fluctuations, but this enhanced variability results from atmospheric teleconnections operating through changes in sea level pressure and/or wind stress rather than via direct oceanic propagation. Bakun notes a number of paradoxes in the dynamics of pelagic fish species, and proposes a mechanism based on schooling behavior and affinity for specific water masses to explain these paradoxes. He challenges fisheries scientists to consider novel ideas about how and why populations may be varying. Several papers examined how the dynamics of key ocean habitats may cause biological variation. Polovina et al. used ocean color data to describe a dynamic basin-scale front that serves as forage and migration habitat for upper trophic level fauna. They suggested that the dynamics of this major feature may affect foraging success and migration patterns. Frontal meanders create regions of ocean convergence and productivity where food webs can develop. Logerwell et al. examined the importance of eddies as habitat for Pacific sardines. They used a bioenergetics model and at-sea surveys to determine the distribution of sardine larvae and to estimate that sardine production within eddies accounted for 88% of all sardine production in the Southern California Bight. In the third habitat paper, Lehodey constructs an index of forage habitat for skipjack tuna (Katsuwonus pelamis) based on temperature and chlorophyll distribution. He uses a model to show that the basin-scale spatial dynamics of skipjack tuna can be explained by the spatial variation of the modeled forage habitat. The model reproduces the observed eastward shift in skipjack tuna abundance in response to ENSO. Beamish and Mahnken argue that Pacific salmon (Oncorhynchus spp.) must reach a critical size before a critical time during their first year
if they are to survive winter conditions. Juvenile salmon growth rate is considered to be a function of available food, which in turn is proposed to vary in response to climatic factors. Thus this mechanism links climate and salmon population dynamics through a size and time window rather than via a linear relationship. Radchenko et al. described recent cooling in the western Bering Sea and the associated ecosystem impacts that included reductions in zooplankton biomass and shifts in salmon migration patterns. The roles of atmospheric and oceanic circulation in the cooling are discussed. Rogachev et al. discussed the role of strong lunar fortnightly tidal mixing as a mechanism responsible for physical and biological variation at Kashevarov Bank in the Sea of Okhotsk. In summer, fortnightly tidal mixing provides nutrients to the stratified surface water resulting in enhanced chlorophyll and zooplankton densities. In winter, tidal mixing draws relatively warmer mid-depth water to the surface to create a polynya that appears and disappears coherently with the fortnightly vertical mixing.

4. Fisheries implications (Convenors: Steven R. Hare, Chang-Ik Zhang & David W. Welch)

Situated at the top of the food web, human predators rely on the upward flux of desirable mass and stored energy to appear in their gear. In the ongoing debate about the relative roles of fisheries and the environment in regulating fisheries production, the role of climate has recently achieved a level of consideration that has rarely been seen during the past century. Of 24 abstracts submitted to this session on the implications of climate variability for fisheries managers, seven are included in this volume. Zhang and Lee described how environmental variation in marine ecosystems near Korea is being incorporated into assessments of the status and recruitment of horse mackerel (Trachurus japonicus). Ishida et al. review published information on archaeological remains of salmon and warmer water shellfish in Japan, which indicate previous warm climates and possible shifts in the zoogeographical limits of salmon species. They establish that Pacific salmon (Oncorhynchus spp.) can survive warmer temperatures than currently prevail in northern Japan. However, the significance of the results with respect to the effects of future global warming on distribution of chum salmon (O. keta) in Japan remains unclear. Nagasawa uses a correlation between tree ring data and coastal SST to reconstruct a long time series of coastal SST data in Japan. He compares this with Pacific herring (Clupea pallasi) recruitment variability on decadal scales. More than one third of the abstracts submitted to this session originated in Spanish speaking countries, particularly Mexico and Chile, and three were included in the volume. Arcos et al. showed that the 1997 El Nino had a greater effect on the more southerly stocks of jack mackerel (T. symmetricus), although temperature also impacted their more northerly nursery area. Yaddz et al. describe the impact of El Nino on the pelagic fish populations off northern Chile on a long-term basis illustrating the alternation between anchovies (Engraulis ringens) and sardines in fishery catch time-series. They present a useful overview of the small pelagic fishery of northern Chile, together with an exploratory analysis of interaction with environment, including analyses of oceanographic variables for the region related to abundance and distribution of fish resources. Nevarez-Martínez et al. explain the observed variability of the sardine population in the Gulf of California through environmental effects. They hypothesize that the distribution and abundance of sardine can be predicted from SST and upwelling in the Gulf of California. In years when
SST is not too high and upwelling is moderate, sardine abundance and catches will be good. In the final paper in the volume, King et al., suggest a way of integrating multivariate data on fisheries and climate variability into a 'report card', which may be more meaningful to fisheries managers. Considering sablefish (*Anoplopoma fimbria*) as an example, they expand consideration of the role of decadal-scale climate variability in their assessment of stock status and future expectations for sablefish recruitment.

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S.M. McKinnell, R.D. Brodeur, K. Hanawa, A.B. Hollowed, J.J. Polovina, C.-I. Zhang

*North Pacific Marine Science Organization, c/o Institute of Ocean Sciences, PO Box 6000, Sidney, BC, V8L 4B2, Canada*

*E-mail address: mckinnell@pices.int*

**References**
