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Editorial

An introduction to the PICES symposium on the ecosystem dynamics in the Eastern and Western Gyres of the subarctic Pacific

The North Pacific Marine Science Organization or PICES is an international organization that facilitates and stimulates research to improve the understanding of the dynamics of the subarctic Pacific ecosystems. PICES organized its activities by developing a science plan that drew attention to the research issues of immediate importance. The plan is called the CCCC program, which is an abbreviation for Climate Change and Carrying Capacity, and has the primary objective of identifying the impacts of climate change on the ecosystems of the subarctic Pacific. Four key scientific questions were identified relating to physical forcing, lower trophic level responses, higher trophic level responses, and ecosystem interactions. Specific research questions were: (1) what are the characteristics of climate variability and how and when do interdecadal patterns arise; (2) 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; (3) how do life history patterns, distributions, vital rates, and population dynamics of higher trophic level species respond directly and indirectly to climate variability; and (4) how are subarctic Pacific ecosystems structured? To implement the science plan PICES established four Task Teams (BASS (**BAS**in **S**tudies), REX (**R**egional **EX**periment), MODEL and MONITOR Task Teams) and is working through these teams to facilitate and co-ordinate study in the area concerned.

The **BAS**in **S**tudies Task Team was established to facilitate the exchange of information and support scientific research relating to the central subarctic Pacific Ocean. A focus for the research is the impacts of climate and climate change on the ecosystems of the oceanic subarctic Pacific in general and the Eastern and Western Gyres in particular. A difficulty with the intent to understand the linkages between climate and the ecosystems of the central subarctic Pacific is the general absence of coordinated long-term research. In a sense, this is one of the least studied areas in the North Pacific, even though the waters support important fish resources such as Pacific salmon, squid, birds, and marine mammals. It is an area that belongs to no country but the productivity and health of the ecosystems affect the economics and quality of life of all countries that surround this vast ocean.

BASS established an ambitious work plan that it recognized would require a commitment that had not existed in the past from member countries and scientists. The

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task of encouraging PICES members to pay more attention to this part of the ocean was not impossible, but it was difficult considering the priorities for freshwater and coastal studies. It was necessary to show why it made sense for nations to invest in research in an area not within their management authority, and, in some cases, to show why it was important for fisheries management to study ocean processes. Research that is relevant to responsible stewardship of marine ecosystems should anticipate the problems of the future. There is no doubt that climate and climate change impacts will be a major international management issue in the next decade. Thus, there is a reason to carry out work proposed by BASS even though it may not be immediately popular. Like all beginnings, the first step is to find out what we know and to develop insight. I think that insight is more a process that scientists carry out reclusively, but accumulating the necessary data is a group effort. BASS proposed to begin its work by organizing a symposium on the ecosystem dynamics in the Eastern and Western Gyres of the subarctic Pacific. The topics included ocean responses to climate forcing, nutrients and primary production, the structure of lower trophic levels, the structure of mesozooplankton communities, the structure of epipelagic nekton, the role of midwater fishes, and the importance of these open ocean ecosystems to marine birds and mammals. Because there was only one day for the symposium, BASS deferred some topics for future meetings such as the relationships with Pacific salmon and squid. The basin studies group expected to assemble much of the existing knowledge on the dynamics of the ecosystems in the Eastern and Western Gyres of the subarctic Pacific in this series of theme papers presented at the symposium. The intent was to compare the processes in the two gyres as well as to record existing information. Authors from North America and Asia prepared papers that were presented and discussed in the fall of 1997 at the PICES Sixth Annual Meeting in Pusan, Korea.

In the symposium, Sekine identified a linkage between the intensity and the position of the Aleutian Low Pressure System with the shifting position of the Oyashio current and subarctic circulation. A southward shift of the Oyashio current (or Aleutian Low) is also associated with changing weather over the Eurasian Continent. There is a feedback from the ocean to the southward shift that enhances the duration. Sekine noted that before 1989 there was a linkage of the enhanced Aleutian Low with the warm sea surface temperatures in the central Pacific, but after 1989 the teleconnection was weak. An association of the climate resulting from the southward shift of the enhanced Aleutian Low and the development of the anti-El Nino (La Nina) was proposed.

Minobe and Mantua found a relationship between the interannual and decadal variations in the atmospheric/ocean environment associated with the three distinct interdecadal climate regime shifts. In previous work these shifts were identified to take place in 1924/25, 1947/48 and 1976/77. In the current paper they show that during the regimes with an especially strong Aleutian low (1925–1947 and 1977–1997) there is stronger interannual North Pacific climate variability. However, the mechanism for the regime dependent modulation of interannual variability was not identified. The century scale changes of the ENSO-related teleconnection pattern are

also reported, but the interdecadal modulation of the mid-latitude North Pacific climate is not well correlated with that of the strength changes of the El Nino.

Harrison et al. and Frost and Kishi examined the processes involved in the dynamics of lower trophic levels. Harrison and colleagues showed that iron limitation is generally accepted as the micronutrient controlling the production of large phytoplankton (diatoms). The mechanisms are complicated in the winter because of co-limitation of iron and light. The sources of iron at study sites on the southern edge of the Alaska Gyre vary seasonally and are not well understood. In the spring and early summer, dust containing iron is carried from Asia in the atmosphere. In the late summer and early fall, iron may be transported horizontally in currents around the Gulf of Alaska. Frost and Kishi confined their review of numerical models to the Eastern and Western subarctic Pacific Gyres. Their focus was the seasonal and geographic variation in plankton abundance and production and the models that attempt to simulate the dynamics of these populations.

Taniguchi also examined between region differences in the structure of lower trophic levels and included observations from the Bering Sea and Oyashio, and discussed implications for fish productivity. He showed that in the Gulf of Alaska, the Western subarctic Gyre, and the area south of the Aleutians, the relative biomass of microzooplankton to phytoplankton is large and nitrate levels remain high. The Bering Sea basin is intermediate between these areas and the Oyashio Region where the nitrate levels are low.

Mackas and Tsuda considered the mesozooplankton in the Eastern and Western Gyres and compared the communities in these areas with coastal communities. They reviewed evidence to show that the Western Gyre is more productive than the Eastern Gyre. New and exciting evidence is presented to show that mesozooplankton productivity has changed, possibly in response to regime changes. The changes are in biomass and in the timing of the seasonal migrations. They also showed that a large fraction of mesozooplankton production in the gyres is consumed by predators other than pelagic fish, notably mid-water micronekton.

Brodeur et al. reviewed the extensive data for upper trophic levels collected during studies of the high seas drift gill-net fishery. The fishes and other pelagic taxonomic groups such as cephalopods were shown to be highly migratory. The diversity of species was higher in the east and some species formed distinct associations.

A poorly studied component of the subarctic Pacific ecosystem is the midwater community. Beamish and colleagues reviewed studies of the midwater fishes and identified a range of species that are important in the food webs of better known and more visible marine animals. The myctophids in general, and a small number of myctophid species in particular, are exceptionally abundant. One species may eventually be shown to have one of the largest biomasses in the world.

Springer and his colleagues considered the role of marine birds and mammals in the open ocean ecosystems. Like the midwater community, these two groups of animals are poorly studied. Similar to Mackas and Tsuda, Springer et al. consider that the Western Gyre is more productive than the Eastern Gyre. A dominant group of animals is the southern hemisphere shearwaters that spend the winter in the North Pacific. Fish (including the midwater species that migrate vertically), squids and

euphausiids are key food items for most of the species of shearwaters. The Dall's porpoise appears to be the most abundant cetacean. They are distributed throughout the subarctic, north of the subarctic frontal zone. This species feeds on squid and fishes including one species of myctophid that does not migrate vertically from the midwater zone. Pacific white-side dolphins were also shown to be abundant. The abundance and diets of the other species of marine mammals were also reviewed.

A paper by Banse and English is included in the proceedings although it was not presented at the symposium. These authors use remote sensing data to compare the phytoplankton distributions between the two gyres; their paper is an important addition to the proceedings.

One objective of the symposium was to identify the key research problems. Participants concluded that it is important but difficult to quantify the interactions among trophic levels. It may be possible to carry out small-scale studies and then expand the results to larger ecosystems. In particular, information on short-term changes in the dynamics of the mixed layer is needed. Such studies need to be carried out seasonally in both the Eastern and Western Gyres. In general, how climate variations may be changing the stability of the water column needs to be examined. The role of iron, an important component of ocean productivity and photosynthesis, is not well known in the ocean. Iron chemistry and iron profiles need to be studied seasonally. Why are large diatom species dominant in the winter despite higher iron requirements and reduced light? Sources of iron and transportation mechanisms such as dust from the Gobi desert need to be studied. Why is the Western Gyre more productive than the Eastern Gyre and does iron chemistry play a role in the difference? The application of satellite technology for monitoring phytoplankton may be a method for linking iron, atmospheric circulation patterns, and resulting productivity changes.

A study of episodic events may also be a useful way to improve the understanding of physical processes. Species associations, including who eats whom, need extensive study. The waters of the subarctic Pacific are productive, but we understand very little about the dynamics of the communities. Simple studies of diets are useful and could be a standard activity of research vessels. It is the dynamics of the system in the winter that may be the key to understanding how abundance of fishes is regulated. However, a first step is the need to produce reliable biomass estimates for a number of species. Initial estimates can be 'scientific approximations', but it is important to identify key species and consider and report estimates of abundance. The midwater fish community may provide an opportunity for scientific discovery for students. Standard sampling methods could be adopted and samples could be collected and distributed among universities. Observations on sea birds and marine mammals could also be formalized so that valuable ship time can be used to improve databases. For example, marine birds are bycatch of some gill-net fisheries. These samples can provide important distribution and diet information. As the data are used by all scientists, it would be helpful to identify such opportunities and co-ordinate the funding necessary to support such studies. Birds and marine mammals may also be useful indicators of ocean ecosystem changes.

These are only a few of the research issues and some suggestions for obtaining

more information. The papers in the proceedings are the background material needed to make efficient use of the research dollars spent by the PICES member countries.

It is an exciting time to be in the aquatic sciences. Fisheries biologists are beginning to understand the need to separate fishing impacts from natural changes. Past assumptions of stable ecosystems and constant natural mortalities no longer can be the foundation of stock assessments. Instead, there is a realization that the complexities of ecosystems must be addressed and simplified in a manner that incorporates an understanding of natural processes. Understanding natural processes is also the basic principle for physical sciences. Understanding the interwoven relationships among climate, oceanography, and fisheries is a challenging topic for the scientists of PICES. It may not be among the highest priorities of national issues currently, but it most certainly will be a decade from now. The future of fisheries management has arrived and the collective knowledge and wisdom of PICES participants is an essential part of the new emphasis on protecting ecosystems. We are effective as a scientific community when we address the issues of the future before they become a crisis. Understanding how a changing climate will impact the ecosystems of the subarctic Pacific, and the Eastern and Western Gyres in particular, is a challenge of interdisciplinary and international proportion. No country can carry out the appropriate research alone; yet, each country carries out some research in these areas. Perhaps the next step is to list the most important research issues for each gyre and coordinate the appropriate sampling programs. PICES members have quickly earned a reputation for sharing information in a timely manner. It may now be time to cooperate in the planning of research in the Eastern and Western Gyres, which are areas of common interest to all citizens who live along the shores of the subarctic Pacific.

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