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The state of PICES science - 1999

The PICES Eighth Annual Meeting, held October 8-17, 1999, in Vladivostok, Russia, was a resounding success! We had a total of 319 scientists registered to attend the 151 oral presentations and 99 posters that were given at the meeting. Topic sessions ranged from purely physical ones such as "*Modelling and prediction of physical processes in the subarctic North Pacific: Progress since 1994*", to those dealing with environmental quality such as "*Ecological Impacts of Oil Spills and Exploration*". Interdisciplinary workshops and sessions on understanding climate variability and its effects on ecosystems began even before the main scientific meeting, with the workshops that were held as part of the PICES-GLOBEC Climate Change and Carrying Capacity Program, continued with the topic sessions on GLOBEC-related studies, and ended with the Science Board Symposium on "*The nature and impacts of North Pacific climate regime shifts*". PICES' Technical Committee on Data Exchange convened a workshop on the application of scientific visualization tools. These tools described at the workshop ranged from high-tech, expensive visualization chambers to simple, but effective use of low-tech, paper 3-D glasses, which the whole audience was able to use to view 3-D marine data.

Congratulations are in order for winners of the Best Presentation Awards at the PICES Eighth Annual Meeting. These awards are given to scientists, nominated by each PICES Scientific Committee and the Science Board, who gave the best presentation in a topic or paper session sponsored by the committee or board. Here are the 1999 winners: the BIO Award to Dr. Toru Kobari (Japan) for his paper on "*Interannual variabilities in abundance and body size of Neocalanus copepods (Crustacea: Copepoda) in the central North Pacific*"; the FIS Award to Dr. Svetlana Davidova (Russia) for her paper entitled "*Spawning of subtropical species in Peter the Great Bay in 1991-1998*"; the MEQ Award to Dr. Tatiana Orlova (Russia) for her paper on "*Harmful Algal Blooms on the Pacific Coast of Russia*"; the POC Award to Dr. Josef Cherniawsky (Canada) for his presentation on "*Long-lived meanders and eddies in the Alaskan Stream*"; the CCCC Award to Dr. Young-Shil Kang (Korea) on her paper entitled "*Long-term changes and unusual high abundance in zooplankton biomass in the South Sea of Korea*"; and the Science Board Award to Dr. Nathan Mantua (U.S.A.) for his presentation on "*Empirical indicators of climate variability and ecosystem response since 1965*".

The year of 1999 was an important one for PICES in a scientific sense because we had several "firsts" in the area of international collaborative field and laboratory work by the PICES scientific community. This year, a practical workshop was held in Vancouver Harbour by scientists of our Marine Environmental Quality Committee's Working Group 8 on Practical Assessment Methodology. This was the first time scientists from all of the PICES member countries participated in a joint field and laboratory effort. This practical workshop has set the stage for these scientists to do future collaborative work in the area of marine environmental quality (*for details see separate article in this issue*). Similarly, the Physical

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The status of the Bering Sea: January – July, 1999

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Dr. Phyllis J. Stabeno, a physical oceanographer at the Pacific Marine Environmental Laboratory (PMEL) of NOAA, conducts research focussed on understanding the dynamics of circulation of the North Pacific, Bering Sea and their adjoining shelves. She is the PMEL Director of NOAA Fishery Oceanography Coordinated Investigations (FOCI), and by applying her knowledge of physical processes to fisheries oceanography, she plays a vital role in its success. FOCI research focusses on building sustainable fishery resources in the Gulf of Alaska and Bering Sea while maintaining a healthy ecosystem. Phyllis is also a Principal Investigator on several research elements for other programs, including: Southeast Bering Sea Carrying Capacity (Coastal Ocean Program), the Bering Sea Green Belt: processes and ecosystem production (Arctic Research Initiative) and Prolonged Production and Trophic Transfer to Predators: processes at the inner front of the southeast Bering Sea (National Science Foundation). This research seeks to improve our understanding of ecosystems through the integration of physical and biological phenomena.

Observations of the eastern Bering Sea shelf continue to depict an ecosystem undergoing significant physical and biological change. Most of the observations of conditions over the southeastern Bering Sea and basin were collected as part of two funded programs: Southeast Bering Sea Carrying Capacity (a NOAA Coastal Ocean Program) and the Inner Front Program (NSF funded research). A single mooring site at the 70m isobath (56.9^{o}N, 164^{o}W), which has been occupied for five years, provides insight into the changes that have occurred during these years. Conditions at this site are representative of conditions over the southern middle shelf of the Bering Sea.

During the last three years, great interannual variability has occurred in the physical environment over the Bering Sea shelf. In 1997, sea surface temperatures were above normal, primarily as a result of weaker than normal winds in the spring and the summer (Fig. 1). Sea surface temperatures were cooler in 1998 than in 1997, and were associated with strong winds in the spring and weak winds in summer. The depth-integrated temperature in 1997 was typical of temperatures observed in the last decade. In 1998, despite the decrease in surface temperature compared to the previous year, the depth-averaged temperature was greater and closer to temperatures observed in the early 1980s. The higher than normal heat content over the southern shelf resulted from warmer initial conditions which in turn were caused by a reduction in sea ice. Although ice was present in February 1998, it retreated early and did not cool the water column to the same extent as occurred in 1997.

In contrast to these years, 1999 was markedly different. Although sea ice was not as extensive as was observed in 1995 or 1997, it arrived early over the southeastern shelf, and persisted into May. Because the ice retreated slowly, compared to the last 20 years, the water column remained cold (approximately -1^{o}C in mid-May; Fig. 1). Once the ice was gone, however, the water column began to warm at a similar rate to that observed in recent years. Because of the colder initial conditions, sea surface temperatures were unusually cool in late July and August, when the warmest sea surface temperatures are typically observed. Although conditions were cold in 1999, both sea surface temperatures and depth-averaged temperatures were still warmer than observed during the cold years before 1976.

Transport in the Bering Slope Current, which flows to the northwest along the Bering Sea shelf break, undergoes long-term variability. In 1997, transport was greater than normal (>6 x 10^6 m^3 s^{-1}). In 1998, transport weakened (~2 x 10^6 m^3 s^{-1}) and these conditions continued through the first 6 months of 1999. Mechanisms causing this shift in transport are not known. Satellite-tracked drifters also displayed a sluggish current along the eastern Bering Sea slope, with weak on-shelf transport in spring and summer.

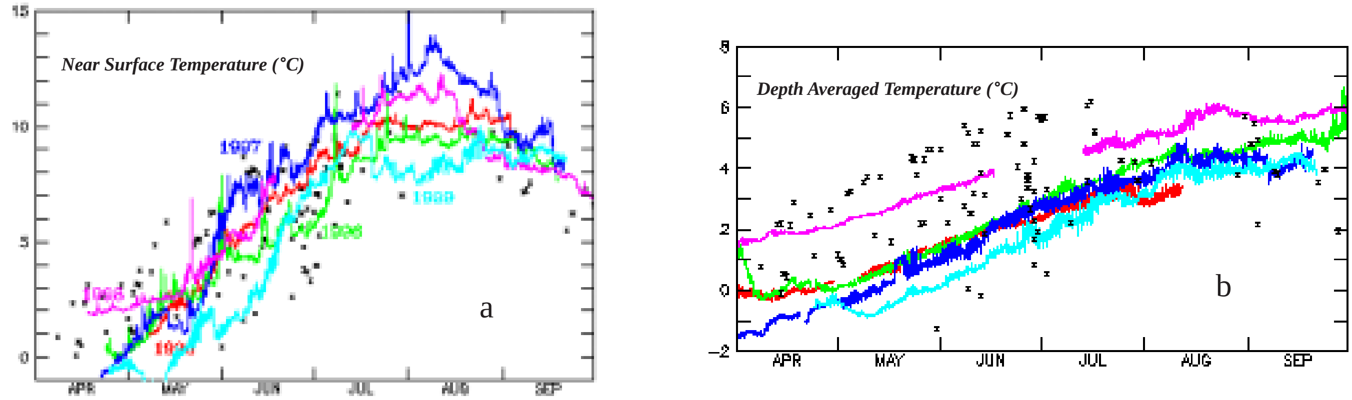

Fig. 1 (a) The seasonal sign of near surface temperature at Site 2. Data from each year when moorings were located at this location are indicated by colored lines. Data from 138 separate occupations of hydrographic stations between 1966 and 1994, in the vicinity of Site 2, are shown as Xs. (b) The depth-averaged temperature for the same data shown in panel a.

The North Pacific Ocean and the Bering Sea are influenced by large-scale atmospheric variability known as the Pacific Decadal Oscillation (PDO). It is generally recognized that a regime shift occurred in 1977, when the PDO shifted from strongly positive to negative. Speculation of a possible regime shift opposite to that which occurred in 1977 continues, but it still remains too early to be sure. ENSO events influence the PDO. The La Niña of 1998 persisted into the winter and spring of 1999, so the changes in the PDO may be a result of persistent La Niña conditions rather than a shift in the decadal patterns to pre-1977 conditions.

A coccolithophore bloom continued for an unprecedented third year over the eastern Bering Sea shelf. Coccolithophores are small, photosynthetic cells covered by calcareous plates (liths), from which light reflects giving the water its distinctive milky white color . The bloom first appeared over much of the southern Bering Sea shelf in 1997, and was observed both from space (SeaWiFS, and the space shuttle) and aboard ships. In 1998, it extended further north, and was advected into the Arctic Ocean through the Bering Strait. The earliest SeaWiFS true color image from 1999 revealed the milky white water over the shelf (Fig. 2), seaward of the ice edge. Satellite imagery does not differentiate between the live cells and free liths, which are detached from cells but remain in the water column. During early February, 1999, scientists collected samples that contained both live cells and large numbers of liths in the water column; satellite imagery from the same time revealed the distinctive color associated with coccolithophores near the ice edge (Fig. 2). Large blooms of coccolithophores in the Bering Sea do not appear until July or perhaps August. The extent of this year's bloom, and the impact of the cooler sea surface temperatures on it, will not be known until later in the year.

Significant changes in this ecosystem are of particular concern since the eastern Bering Sea provides approximately half the fish and shellfish caught in the United States and supports a large number of sea mammals. In 1997 and 1998, unexpectedly low returns of sockeye salmon occurred in the Bristol Bay fishery. This year the trend was reversed and sockeye salmon returned in large numbers. Whales continue to be seen over the middle Bering Sea shelf, which is an apparent shift from historical concentrations along the slope. The Bering Sea fur seal population on the Pribilof Islands (which accounts for ~90% of the fur seal population) has remained stable during the last few years, although this year there is some evidence of a decrease. Three to four years of observations are required to determine if a decline has occurred. The Stellar sea lion population continues its 20-year decline. Long-term changes in atmospheric forcing will undoubtedly continue to change this ecosystem.

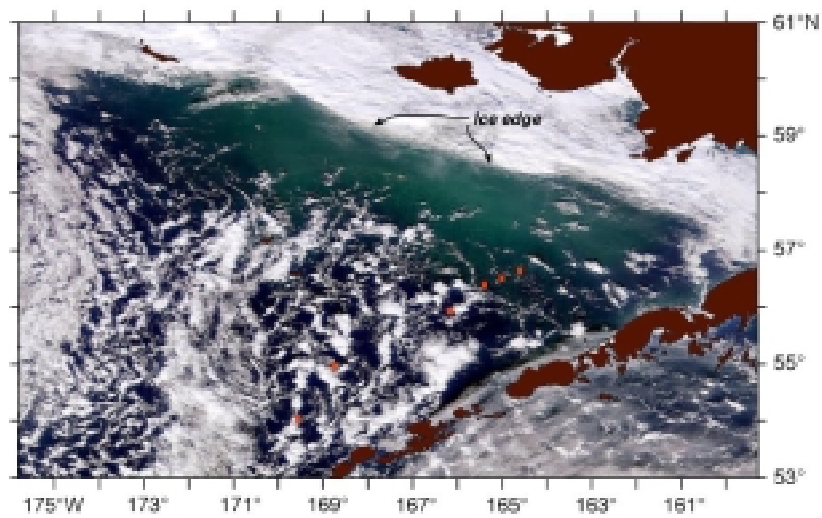

Fig. 2 SeaWiFS true color image from February 23, 1999, showing the presence of milky water near the ice edge. Both Nunivak and St. Matthew Islands (at the upper edge of the image) are in the ice field. The orange dots are where samples were taken to test for presence of coccolithophores.

The state of the western North Pacific in the second half of 1998

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Mr. Satoshi Sugimoto is Scientific Officer of the Oceanographical Division of the Climate and Marine Department at the Japan Meteorological Agency (JMA). He is working as a member of a group in charge of monitoring and forecasting sea surface temperature and sea surface current in the western North Pacific. Based on in situ *and satellite data, this group provides various oceanographical products. One of the main products is the "Monthly Ocean Report", which is published and distributed by JMA every month. Mr. Sugimoto is now involved in developing a new analysis system for sea surface and subsurface temperature to improve sea surface temperature forecasts in the western North Pacific.*

Sea surface temperature

Figure 1 shows monthly mean sea surface temperature (SST) anomalies in the western North Pacific from January to June 1999, computed with respect to JMA's 1961-90 climatology. Satellite-derived SSTs (NOAA/AVHRR) and *in situ* observations are used for the area between 20˚N and 50˚N from 110˚E to 160˚E, and only *in situ* observations are used in the other region.

It is noteworthy that positive SST anomalies exceeding +1˚C prevailed zonally along 30˚N throughout the first half of the year, and anomalies exceeding +2˚C were found primarily from 140˚E eastward in March and April (Fig. 1). The time series of regional ten-day mean SST anomalies for region C (Fig. 2) have been positive since the end of 1997.

Positive SST anomalies exceeding +0.5˚C prevailed around the Philippines from January to May, and the anomalies reduced to near normal in June. The time series for region D shows that the positive SST anomaly around +1˚C, which had continued since the beginning of 1998, came to an end in the first half of 1999. Negative SST anomalies exceeding -1˚C had prevailed around the Kuril Islands and in the northern part of the Japan Sea until April, and these anomalies became positive west of 150˚E in June.

Oyashio and Kuroshio

Figure 3 shows temperature distributions at a depth of 100 m east of Japan in February and June 1999. These charts are based on JMA's objective 100 m water temperature analysis for 0.25x0.25 degree grid point values in seas adjacent to Japan. Waters colder than 5˚C at 100 m are recognized as the Oyashio cold water. It is known that the Oyashio cold water east of Japan extends southward at its southernmost position in spring, and returns northward from summer to autumn. This spring, the coastal southward intrusion of the Oyashio cold water was restricted because of the existence of a warm eddy east of Japan from February that stayed near 39˚N (February) or 40˚N (June). Off shore intrusion of the Oyashio cold water extended southward east of the warm eddy.

The Kuroshio has maintained a non-large-meander path south of Japan since the summer of 1991.

Sea ice in the Sea of Okhotsk

The first and last dates of drift ice in sight at the meteorological stations along the coast of Hokkaido are shown in Table 1, with the location of the stations in Figure 4. The first dates of drift ice on shore and the first dates of shore lead appearance are also included. This winter, the drift ice appearance around Hokkaido is characterized by a delayed arrival and delayed retreat.

The sea ice extent in the Sea of Okhotsk was above normal (20-year averaged values from 1971 to 1990) from early December to mid-December and after mid-March. Accumulated daily sea ice extent was above normal after remaining below normal for 11 years (Fig. 5).

Drift ice in the Sea of Okhotsk flowed out into the Pacific from early February to late April (especially apparent in March), and was observed at Kushiro after 12 years' absence. Part of the drift ice flowed out into the Japan Sea from early February to mid-February, and was observed at Wakkanai after 4 years' absence.

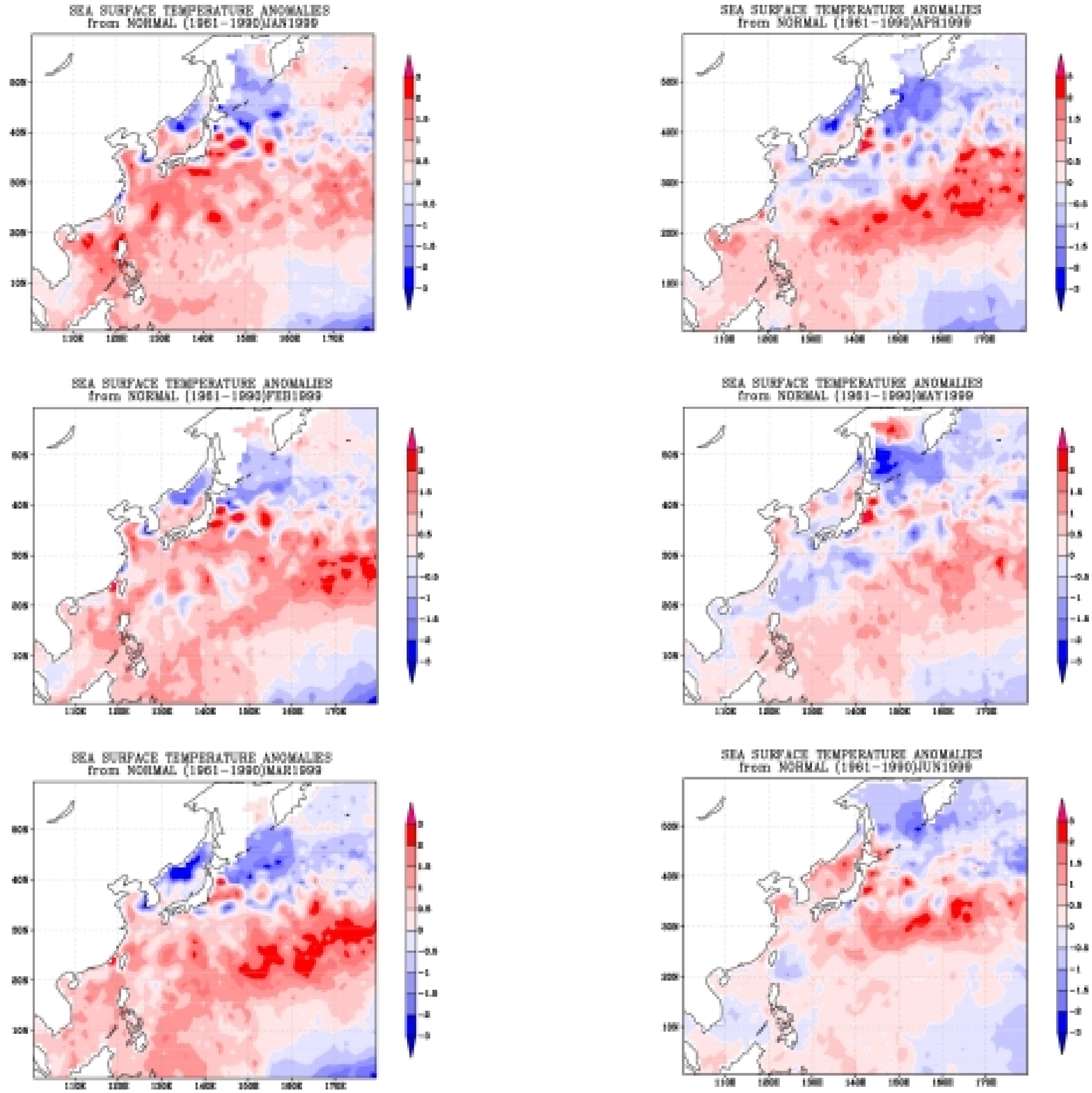
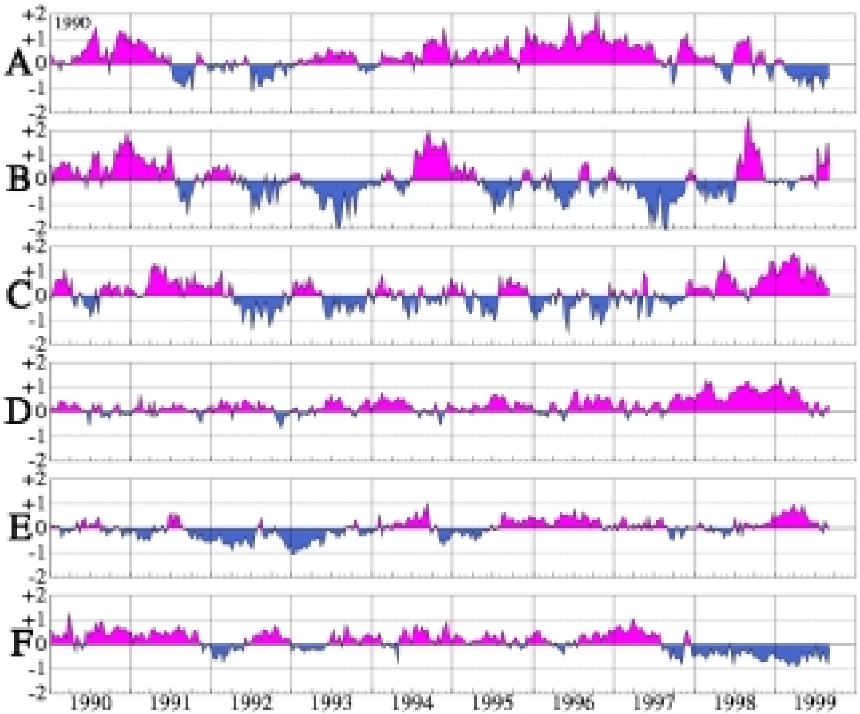


Fig. 1 Monthly mean sea surface temperature anomalies (˚C). Anomalies are departures from JMA's 1961-1990 climatology.

Table 1 The first and last dates of drift ice in sight at coastal stations in the winter of 1998/99

Station	Drift Ice First date	Last date	Period	Days	First date of drift ice on shore	First date of shore lead appearance
WAKKANAI	Feb. 11 (+4)	Feb 11 (-28)	1 (-32)	1 (-14)	#	*
KITAMIESASHI	Feb. 5 (+16)	Apr. 18 (+18)	73 (+2)	33 (-19)	Feb. 10 (+14)	Feb. 21 (-20)
OMU	Feb. 3 (+15)	Apr. 18 (+12)	75 (-3)	45 (-16)	Feb. 12 (+15)	Mar. 24 (+10)
MOMBETSU	Feb. 4 (+17)	Apr. 19 (+12)	75 (-5)	63(-1)	Feb. 12 (+13)	Apr. 9 (+23)
ABASHIRI	Jan. 13 (-4)	Apr. 18 (0)	96 (+4)	85 (+2)	Feb. 12 (+15)	Apr. 10 (+16)
NEMURO	Feb. 14 (+5)	Apr. 23 (+21)	69 (+16)	52 (+18)	Feb. 16 (+2)	*
KUSHIRO	Mar. 16 (+16)	Mar. 20 (+3)	5 (-13)	3 (*)	#	*

( ) : deviation from normal for the period from 1961 to 1990;
* : no observations or normal date is not available; # : no observations;
\+ : earlier or more than normal; - : later or less than normal



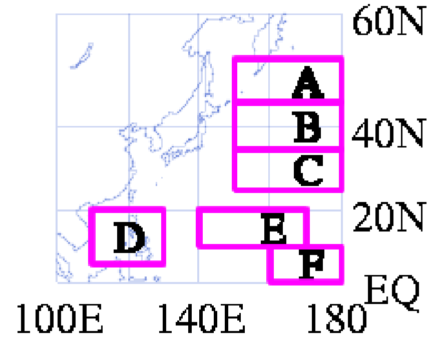


Fig. 2 *Time series of the ten-day mean sea surface temperature anomalies (˚C), computed from JMA's 1961-1990 climatology for the areas shown in the bottom panel.*

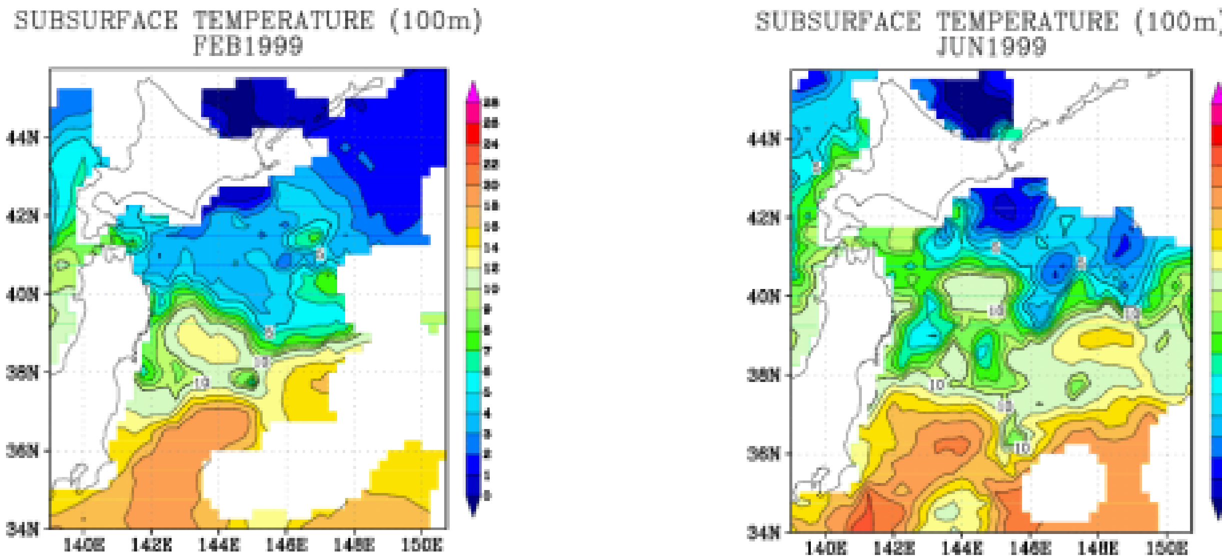


Fig. 3 *Temperature (˚C) at a depth of 100 m east of Japan in February (left) and June (right) 1999.*

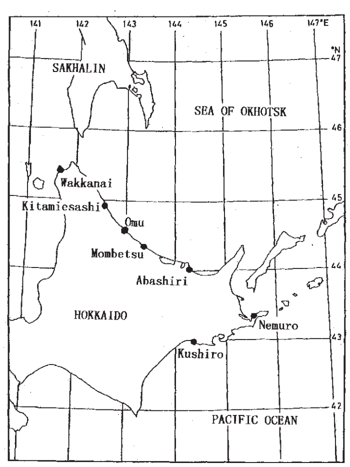


Fig. 4 *Location of the sea ice stations along the coast of Hokkaido, Japan.*

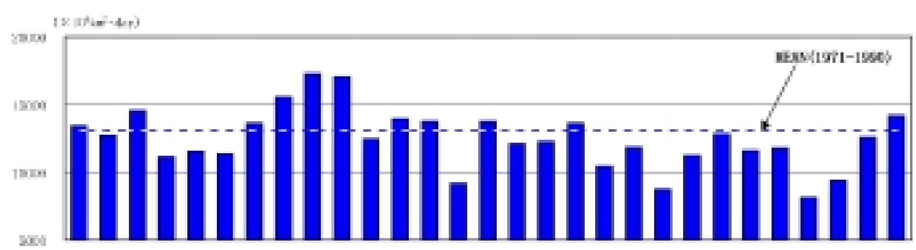


Fig. 5 *Annual accumulation of 5-days sea ice extent in the Sea of Okhotsk.*

The state of the eastern North Pacific since February 1999

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Dr. Howard Freeland is a research scientist in the Ocean Science and Productivity Division at the Institute of Ocean Sciences (Department of Fisheries and Oceans). His research interests include the climatic state of the ocean and low frequency variability. Presently he is responsible for the maintenance of Line P, a line of CTD stations that has been monitored for over 45 years between the mouth of the Juan de Fuca Strait and Ocean Station Papa at 50°N and 145°W (also known as WOCE Repeat Hydrography Line P6). Howard is also on the international science team for project ARGO which aims to deploy a global array of profiling ALACE floats to monitor the evolving state of the ocean. Examples of some products from a few profiling ALACE floats can be seen through his own web page at http://www.ios.bc.ca/ios/osap/people/freeland.htm. He is involved in various PICES activities as a member of the Physical Oceanography and Climate Committee, and Chairman of the newly formed Publication Committee.

In recent years we have witnessed some significant transitions in the climatic state of the Pacific Ocean. The 1997/98 El Niño ended in the spring of 1998, and we saw an immediate transition to moderate La Niña conditions that persisted into the spring of 1999. These events all originate in the equatorial Pacific and one useful indicator of this type of activity in the climate system is the Southern Oscillation Index, or SOI. Figure 1 shows daily values of the SOI. The solid blue line is a 30-day running mean representation. In this we see the transition in May 1998 from El Niño to La Niña-like conditions, and then in May 1999, a sharp transition back to normalcy. Of course, the SOI is only one measure of El Niño-like activity and is surely far from the whole story of activity on the equator. In fact, though this atmospheric index suggests that the equatorial Pacific has returned to normal, there is a large mass of water only about 40 metres subsurface on the equator that is substantially cooler than normal. Though conditions are normal at the surface, abnormal conditions are not far away and could be exposed very easily.

The panels of Figure 2 illustrate the evolution of temperature conditions in the eastern North Pacific Ocean during 1999. As the year progressed, the eastern North Pacific came more and more under the influence of cold anomalies. It is intriguing how these gradually penetrated into deeper waters along Line-P as the year progressed. These cold anomalies will not go away quickly, even though the La Niña forcing on the equator appears to have ended. So the consequences of La Niña will be with us for a substantial period yet.

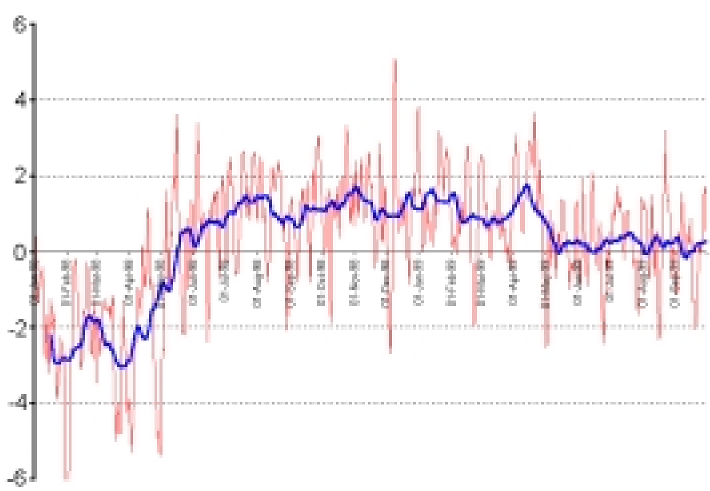

Fig. 1 The Southern Oscillation Index from January 1998 to present.

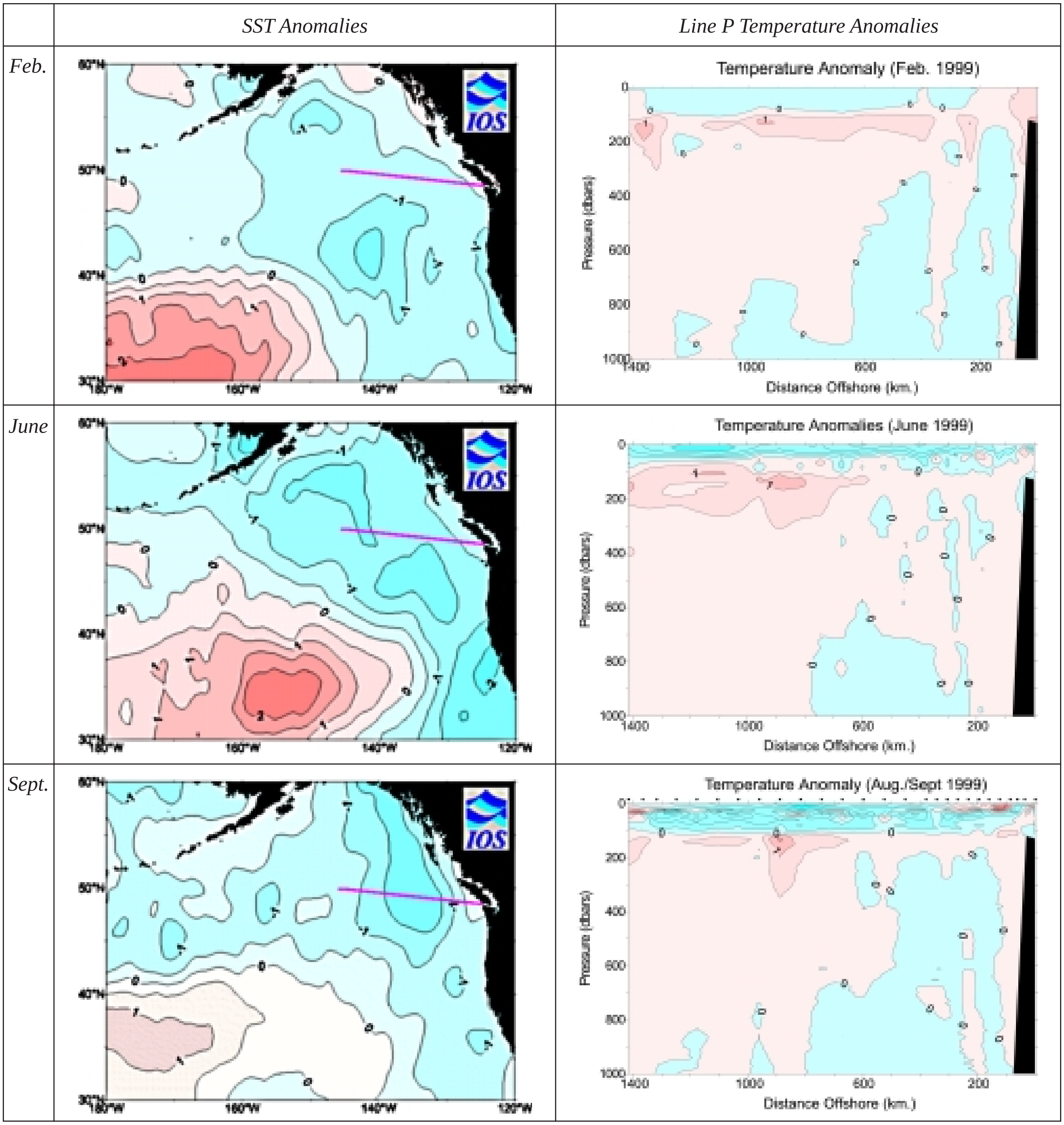

Fig.2 Sea surface temperature anomalies and temperature anomalies along Line-P for 3 representative months in 1999.

Another intriguing feature is the apparent intrusion of a warm water mass into the vicinity of Station Papa, showing in the June and September anomaly plots of Figure 2, between 600 and 1400 km offshore. It is a pity that we cannot sample more frequently along Line-P, but in this case we have data from a profiling ALACE float that has remained for more than $2^1/_2$ years. The *in situ* temperature field is shown here in Figure 3. The three near-surface warm epochs that show up clearly identify the summers of 1997, 1998 and 1999. Beneath the 1999 surface warm period, we see the abrupt arrival of this warm water mass at about the time that the El Niño conditions in the eastern North Pacific were replaced by La Niña conditions.

The diagrams constituting Figure 2 offer a very broad-brush picture of conditions in the eastern North Pacific. When we look at the details off the coast of British Columbia, the monitoring time series indicate occasions when SST

(N.E.P. cont. on page 29)

MEQ/WG 8 Practical Workshop

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Group photo taken in front of the West Vancouver Laboratory. Left to right – Back row: Dan Lomax (U.S.A.), Colin Levings (Canada), Alexander Tkalin (Russia), Richard Addison (Canada), Terry Sutherland (Canada). 2nd row: Zhengyan Li (China), Jihyun Yun (Korea), Tatyana Belan (Russia), Bernie Anulacion (U.S.A.), Beth Piercey (Canada), Seiichi Uno (Japan), Toshihiro Horiguchi (Japan), Stelvio Bandiera (Canada). Front row: Carla Stehr (U.S.A.), John Stein (U.S.A.), Jong Jeel Je (Korea), Gina Ylitalo (U.S.A.), Tatyana Lishavskaya (Russia), Tian Yan (China), Brian Bill (U.S.A.).

Introduction

The aim of WG 8, a Working Group under the Marine Environmental Quality Committee (MEQ), is to promote the collection and exchange of information about approaches PICES member countries use to assess the biological impact of marine pollution. A Practical Workshop was held May 24 to June 7, 1999, at West Vancouver, British Columbia, towards this goal. The Workshop was developed along the lines of the earlier IOC/GEEP workshops held in Norway and Bermuda, which were co-organized by Dr. Richard F. Addison, former MEQ Chairman. The Workshop had been planned for several years, with the active participation of the involved PICES scientists at recent Annual Meetings. The focus of the field work was Vancouver Harbour, the largest port on Canada's Pacific coast. The harbour is the site for a variety of industries, and so the group thought this area might be a suitable location to study biological effects: two locations outside the harbour were presumed reference sites. The West Vancouver Laboratory of the Department of Fisheries and Oceans (DFO) located on the outer part of the harbour, was used as base of operations and sample treatment. The NOAA research vessel "*Howard W. Streeter*", based in Seattle, was the vessel used in the sample collection. PICES scientists not based in Vancouver were billeted at a nearby college in North Vancouver.

Participants, sampling, and laboratory work

Dr. Colin D. Levings, Workshop Co-Chairman, hosted the workshop and arranged for laboratory space and appropriate supplies with the invaluable assistance of Beth Piercey and Christine Elliott. Co-Chairman Dr. John E. Stein and Carla M. Stehr from the United States National Marine Fisheries Service, and other staff from Seattle, provided key planning advice, logistic support from the *Streeter*, and operated the vessel. A smaller DFO vessel based in Vancouver was used for shore collections. Representatives from all PICES countries attended, with a total of 32 scientists participating in fieldwork and/or discussions.

The workshop began with a day and a half of meetings to discuss environmental monitoring approaches that are currently being used by the PICES member countries, and to review and refine specifics of the practical workshop sampling plan. Seven days were spent on fieldwork, with the remainder of the time occupied by sample pre-treatment in the laboratories. Most of the samples were freeze dried, frozen or otherwise preserved and shipped back to the participant's home laboratories for detailed analyses.

An "operations room" was set up at the laboratory with charts, maps, and facilities to plan fieldwork. Each morning the group assembled for a short meeting to discuss the objectives for the day, to review progress and discuss new findings relevant to the workshop. Then one group of scientists would depart on the *Streeter* while another group would leave for shore collections on the small launch. Except for the first day, when a heavy westerly wind brought swells into the harbour, the weather was very good. To maintain Vancouver's reputation as a green city, there were one or two days of gentle rain.

Seven stations within Vancouver Harbour and the adjacent Strait of Georgia were sampled for sediment, benthos and intertidal invertebrates. Fish were collected by otter trawl at five of these sites to assess community structure, abundance, and biomass. Except for one trawl that yielded a huge log, skillfully removed by Captain and Biologist Dan Lomax, the trawl sampling was very successful. English sole (*Pleuronectes vetulus*) were collected for chemical and histopathological analyses. Chemical analyses included enzyme activity, body burdens of persistent organics and metals. Otoliths were obtained for age analysis and stomachs were collected for diet studies. All of the dissections of the fish were conducted aboard the *Streeter*.

A Van Veen grab was used to collect sediment for biological and chemical analyses. Five replicate grabs were obtained at each station and then sieved through a 0.5 mm screen. At the West Vancouver Laboratory, PICES scientists then sorted the animals from the mud and took the samples back to their home laboratories for detailed identification and statistical analyses to study benthic community structure. Sediment was also taken for analyses of organics and metals. A separate grab was taken for mezofauna, the smaller invertebrates which would pass through a 0.5 mm screen, as well as for sediment grain size and algae.

Clams, mussels, and algae were collected at each inter-tidal site, usually by digging with a shovel or collecting from the rocky shore. A profile of the mussel community at each station was obtained by counting and identifying the larger animals seen in a quadrat. Clams were collected for hydrocarbon analyses. Mussels and clams were collected and preserved for later analysis of hydrocarbons, lipids, metals, condition factor and toxins associated with harmful algae. Algal toxins were also tested in the laboratory with a bioassay. Snails were collected to determine frequency of sex changes, an effect related to tributyl tin used in antifouling paint. Special collections of snails were made near Victoria and north of the reference site at Gibsons because none were found in Vancouver Harbour.

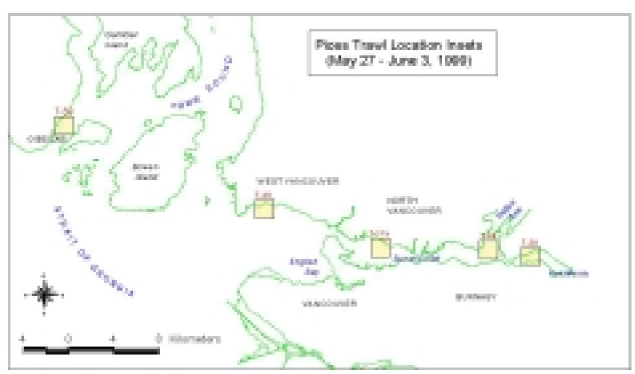
Conclusions and what is next

All participants in the Workshop thought it was a very worthwhile project, in terms of scientific advances and understanding of each country's approach to marine environmental problems. Of course there is still a lot of work to do on analyses, interpretation and reporting, but most scientists are making good progress on their projects.

Members of WG 8 met at the PICES Eighth Annual Meeting recently held in Vladivostok, to review status of data analyses, and plan for the presentation and publication of the Workshop results. There will be a special session next year at the PICES Ninth Annual Meeting in Hakodate for presentations and posters of the workshop results.

Raw data reports will be compiled and published as a PICES Scientific Report in the year 2000. In addition, peer-reviewed journal articles will be prepared, and WG 8 will approach a journal editor about publishing a special issue on the PICES Practical Workshop, tentatively named the Environmental Assessment of Vancouver Harbour: Proceedings of an International Workshop.

The research vessel "Howard W. Streeter" at anchor in the harbour while participants obtain bottom grab samples for sediment and organism collections. Yellow material in background is elemental sulfur.



Map of sampling sites within Vancouver Harbour and the adjacent Strait of Georgia.







Top row:

Mark Myers collecting tissue from English sole (Pleuronectes vetulus) *for chemical and biological analyses* (left)*;*
Tian Yan, Toshihiro Horiguchi and Seiichi Uno collecting intertidal algae and clams for analysis of contaminants (center)*;*
Colin Levings, Tatyana Belan, Alexander Tkalin, and Mark Myers sieving sediment from the bottom grab to obtain benthic animals (right)*;*

Middle row:

Colin Levings, Dan Lomax, Mark Myers, Sean Sol, and Bernie Anulacion sorting a trawl catch to enumerate fish species (left)*;*
Jong Geel Je deploying the bottom grab used for benthic sampling (center)*;*
Alexander Tkalin collecting mussels for metal analyses (right)*;*

Bottom:

Colin Levings and Dan Lomax discussing locations of sample sites in the pilothouse of the research vessel.

(cont. from page 1)

Oceanography and Climate Committee's Working Group 13 on Carbon Dioxide in the North Pacific also held a multinational technical workshop this year. Their intercalibration exercise for laboratory measurements of carbon dioxide was recognized by the IOC/JGOFS Advisory Panel on Ocean Carbon Dioxide as contributing to high quality of North Pacific carbon dioxide measurements in the future, which will allow multinational synthesis and lead to improved understanding of carbon cycle processes (*for details see Dr. Andrew Dickson's article in PICES Press No. 7 (2)*). Finally, the PICES-GLOBEC Climate Change and Carrying Capacity Program (CCCC) was successful in obtaining funding from the North Pacific Marine Research Program to perform a two-year study to initiate continuous plankton recorder (CPR) monitoring in the North Pacific (*for details see Drs. David Welch and Sonia Battens' article in this issue*). The next challenge will be to find a way to maintain this monitoring as a long-term PICES effort.

A lot of PICES scientific effort was brought to completion in 1999 by the publication of results in either the PICES Scientific Report Series, in special journal volumes, or as books. The proceedings of the 1997 Science Board Symposium on "*Ecosystem dynamics in the eastern and western gyres of the subarctic Pacific*" was published in volume 43(2-4) of Progress in Oceanography, and the final endpoint of the Science Board's Working Group 5 on the Bering Sea came with the publication of the book "*Dynamics of the Bering Sea*" by University of Alaska Sea Grant. Three volumes of the PICES Scientific Report series were produced in 1999: Number 10 has the proceedings of the 1998 Science Board Symposium on El Niño 1997-98 events, Number 11 has the proceedings of the 1998 PICES-GLOBEC CCCC Program MODEL, REX, and MONITOR workshops, and Number 12 has the proceedings of the Second PICES Workshop on the Okhotsk Sea and adjacent areas.

Several Working Groups completed their work in 1999 and will be making final preparation for publication of results in 2000. The Physical Oceanography and Climate Committee's Working Group 10 on Circulation and Ventilation in the Japan/East Sea will place their report on the PICES web site as a revisable, living document. The Fishery Science Committee's Working Group 12 on Crabs and Shrimps, and the Biological Oceanography Committee's Working Group 11 on Consumption of Marine Resources by Marine Mammals and Seabirds will also be working towards publication of their final results in the year 2000.

The PICES-GLOBEC CCCC Program continues its work on integrating and stimulating national GLOBEC research efforts in the North Pacific. The Regional Experiments (REX) Task Team is presently focusing on comparative work on herring in the North Pacific. They just completed an interesting workshop on "*Herring and Euphausiids*" and are planning a follow-on workshop for 2000, that will examine herring population trends and trophodynamics. Basin Scale Studies (BASS) Task Team has an Iron Fertilization Panel that is planning international field experiments in the subarctic North Pacific to understand the role of iron in influencing production. The MODEL Task Team is undertaking two workshops in the coming year, one to build lower trophic level models in several areas of the North Pacific and the second one to link these models to upper trophic level models. The MONITOR Task Team just completed a successful workshop to learn about the Global Ocean Observing System (GOOS) and to examine the future role of PICES in this growing international program. As an outcome of the workshop, PICES will be developing an action plan that will outline how PICES will be taking an active and leading role in the implementation of GOOS at a North Pacific level.

New collaborations and working groups will begin in the year 2000. An Advisory Panel on Continuous Plankton Recorder (CPR) survey in the North Pacific was formed, which will advise the MONITOR Task Team on the design of its CPR experiments and work. Marine mammal and bird experts now have their own Advisory Panel under the Biological Oceanography Committee (BIO). They will be providing scientific advice to BIO and CCCC, and providing leadership to marine mammal and bird scientists in the North Pacific in the area of ecosystem research. The Marine Environmental Quality Committee has just formed a Working Group to examine the ecology of harmful algal blooms in the North Pacific, and the Fisheries Science Committee has formed a Working Group to consider the implications of climate change to fisheries management. These groups will be working hard in the coming years to bring useful scientific products to the PICES community.

The PICES Science Board has approved many exciting topic sessions for next year's meeting, to be held October 20-28, 2000, in Hakodate, Japan. The details of the sessions are now being worked on in preparation for the first meeting announcement. You can look forward to a slightly different meeting format, with the Science Board Symposium taking place on the first day and much more attention being given to poster presentations. We are also beginning to plan the PICES Tenth Annual Meeting, which will be held at the site of the Secretariat in Victoria, Canada. We hope to have this Anniversary Meeting focus on the progress of PICES science in the last decade and its future direction for the coming decade.

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Michael M. Mullin – A biography

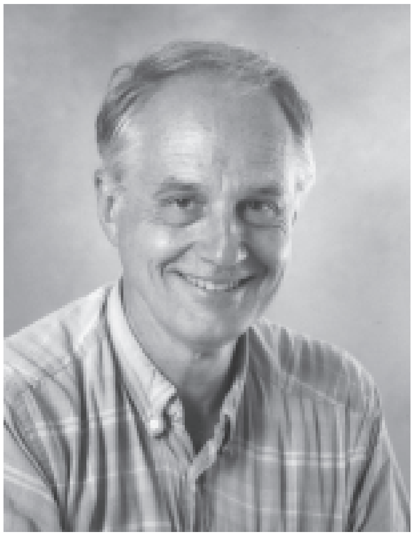

Fig. 1 Mike Mullin, 1999.

The early years

Mike Mullin was destined for a career in science from his earliest time. Born to Joseph and Alma Mullin on November 17, 1937, in the port city of Galveston, Texas, Mike was early to partake in science. From 3-18 months, he was monitored in his crib by his father, a medical researcher, as part of a study of sleep physiology (Fig. 2). Being 'wired' may seem commonplace now; in 1939, it was not.

Mike endured. He and his family moved to Chicago in the early 40's. He continued his involvement in academia at the University of Chicago Laboratory Schools. Founded in 1896, the Laboratory Schools allow a child to learn at a rate appropriate for the student, which apparently was faster than average for Mike. He graduated after 10th grade at age 15. During his Chicago childhood, Mike was a "Quiz Kid", competing on the well-known, nationally-broadcast (radio and TV) quiz show (Fig. 3). He apparently was expert in natural history. He also sang in a boys' choir with his younger brother, Mark, now headmaster of the Casady School in Oklahoma City (Fig. 4).

At the age of 15, in 1953, Mike entered the University of Chicago. The following year, he transferred to Shimer College, a rural campus of the University of Chicago, where his father had been appointed President. The liberal arts cirriculum at Chicago and Shimer was grounded in tutorials and readings from primary materials. Modern science was not covered extensively. Hence, after graduating with an A.B. degree from Shimer at age 20, he was admitted to Harvard College as a junior and completed his undergraduate science education. In Cambridge, he also met his wife-to-be, Connie, a Radcliffe student, in a church choir. Mike received a second A.B. degree (with a major in biology) in 1959. Charlie Kennel, present director of the Scripps Institution of Oceanography (SIO), was a Harvard College classmate.

Mike's scholarly association with the ocean may have begun in summer 1958, when he first worked at the Woods Hole Oceanographic Institution (WHOI). This association continued through 1964, when he received his Ph.D. from Harvard. During this period, Mike spent the academic years from 1960-1961 at SIO to broaden his studies in oceanography and statistics, as applied to ecology (Fig. 5). His first publication, with J.W. Hastings in 1962, concerned the size of small plankters. Curiously, this remains a subject of his current research, albeit now on different organisms and with modern instrumentation. The intervening years, however, have seen nearly 70 scientific publications by Mike on a range of subjects.

At Harvard and at WHOI, Mike pursued his Ph.D. under the supervision of George Clarke and Bob Conover, respectively. Grazing copepods and their food were his main focus, this being some of the first, quantitative, experimental work on this topic. It was at WHOI, as well, that Mike appears to have established his first trans-Pacific association. Makoto Omori (Tokyo University of Fisheries) was conducting Ph.D. research in the adjacent laboratory of Mary Sears at WHOI. Both graduated in 1964, Mike from Harvard and Mak from Hokkaido University. Curiously, both published their first dissertation papers in the same number of *Limnology and Oceanography* (1963, vol. 8, no. 3) and both share the same birthdate.

Mike joined the International Indian Ocean Expedition in 1964-65 as an NSF Postdoctoral Fellow, on the *R/V Anton Bruun* (Fig. 6), and did further postdoctoral research at the University of Auckland, New Zealand, studying selective feeding by calanoid copepods.

Professor and oceanographer

Following his world travels, Mike returned to the US, moved to La Jolla and SIO, and married Connie in 1964. He remains at SIO today as Research Biologist, Professor, and, since 1989, Director of the Marine Life Research Group (MLRG). At SIO, Mike developed a strong program of research and teaching and was ultimately ensnared into administration. He was Chairman of the Department of SIO during 1977-80, and Deputy Director and Dean of Academic Affairs at SIO during 1992-1996. Alternate summers from 1966 to 1978 were spent teaching zooplankton ecology with Karl Banse at the Friday Harbor Laboratory of the University of Washington, a formative environment (in a variety of dimensions) for many of his students, including Jed Hirota (Fig. 7). As Director of the MLRG, Mike has also been the UCSD representative on the three-member CalCOFI Committee.

The Food Chain Research Group (FCRG), created and led by John Strickland, was the initial research home of Mike at SIO. It was with FCRG colleagues that he investigated the plankton off La Jolla and in the North Pacific Central Gyre (Fig. 8) and the Southern California Bight.

Fig. 2 Mike in 1939, at age of 16 months, with comograph attached to his crib mattress to monitor his sleep.

Fig. 3 Mike (back and to mother's left), Alma Mullin, and Mark (to mother's right) at a Mother's Day grouping of the Quiz Kids, circa 1945.

Fig. 4 Mike (age 8) and Mark (age 5) in choir at Christmas, 1945.

The FCRG effectively disbanded in the 1980s, although some members remained at SIO, including Angelo Carlucci, Osmund Holm-Hansen, and Farooq Azam. Mike's research in those years included the feeding, growth, production, and distribution of calanoid copepods, their role in elemental cycles, and a bit on ichthyoplankton. He participated at all levels of research (Fig. 9). It was during this time that scale, *sensu* time and space, became of interest to Mike. He also took a sabbatical as a Senior Queen's Fellow in Marine Science at the Australian Institute of Marine Science, where he worked on salp feeding.

At SIO, Mike continued research on zooplankton ecology, taught courses, and mentored Ph.D. students (~ 10), postgraduate researchers (~ 5), and numerous undergraduates. His work continued to focus on copepod ecology but expanded also to include trophodynamics and field ecology studies. Several important experiments were conducted in the SIO Deep Tank (3-m diameter, 10-m deep). At one point, wealthy landowners on Mt. Soledad, with views overlooking La Jolla Shores and SIO, were angered when floodlights, used to simulate sunlight by reflecting downward off a large mirror, shone bright in their living rooms at night. Needless to say, experimental protocol was altered. Mike's office, labs, and research programs have always provided a stimulating, if not illuminating, environment for graduate and undergraduate students, postdocs, and other colleagues.

In recent years, Mike's research has included a renewed interest in copepod egg production and its use to measure temporal and spatial variation in the California Current Region (CCR); zooplankton size distributions and their variation over decades from analysis of historical CalCOFI samples using the Optical Plankton Counter; hake larvae and its food in the CCR; and diatom-nutricline relations off Southern California. Much of Mike's work of the past decade has been oriented towards a better understanding of the environment affecting young stages of fish.

It was written of Mike in 1982,

> *"Seemingly most content are those whose aims were not stratospheric. Still as characteristically modest as in their childhood are Michael and Mark Mullin, both Quiz Kid regulars at an early age. … Mike, a biological oceanography professor at the University of California, says 'Though I have achieved at least as much professional recognition as I think I deserve, I wish I were a more original thinker on large-scale oceanographic problems*."' (Feldman, R.D., Whatever Happened to the Quiz Kids, Chicago Review Press, p. 342)

In fact, Mike has contributed significantly to studies of plankton pattern in time and space on a variety of scales, some large. His recent work has, in part, concerned the effects of El Niño on the zooplankton. Perhaps as, if not more significantly, he has acted as a guarantor of the 50-year CalCOFI time series.

Fig. 5 *Inspecting a quadrat while a student in Edward Fager's Marine Ecology course at SIO in 1961.*

Fig. 6 *Aboard the* R/V Anton Bruun *in the Indian Ocean, 1964.*

Fig. 7 *Teaching Zooplankton Ecology on the* R/V Hydah *at the Friday Harbor Labs, U. of Washington, with Karl Banse. Jed Hirota (U. of Hawaii) is shown handling a Clarke-Bumpus plankton net.*

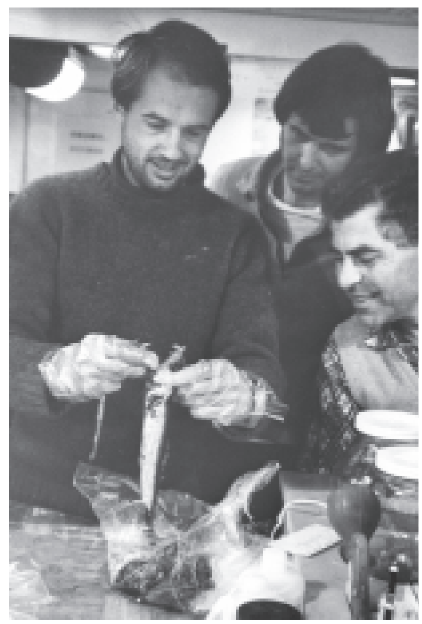

Fig. 8 *With midwater fish aboard the* R/V Thomas Washington *during Southtow XIII in the North Pacific Central Gyre, February 1973. Looking on are Jon Sharp and Ralph Lewin.*

Mike relinquished his SIO posts of Deputy Director and Dean in 1997 to become Editor-in-Chief of *Fisheries Oceanography*. This journal was conceived by Tim Parsons and first published in 1992. Under Mike's leadership, *Fisheries Oceanography* has continued to gain stature and was recently ranked 11th among fisheries and 15th among oceanography journals. Work of the PICES region is well-represented in this international journal. Mike also authored *Webs and Scales* (1993), a book based on lectures on fisheries oceanography presented at the University of Washington.

Music and family

Music is an important part of Mike's life at sea (Fig. 10) and ashore. Dave Keeling of SIO founded the UCSD Madrigal Singers in 1963. Tenor Mike became conductor in the late 60's. Usually performing *a capella* (unaccompanied by instruments), this group is now known as the La Jolla Renaissance Singers. The two-hour rehearsals are weekly at Mike and Connie's La Jolla home.

Fig. 9 Mike underwater pushing a plankton net in September 1969.

Fig. 10 Playing a makeshift pennywhistle next to a squawk box on the R/V Thomas Washington *during Tasaday XI, March 1974. Instrument crafted in ship's machine shop by Eric Shulenberger (University of Washington).*

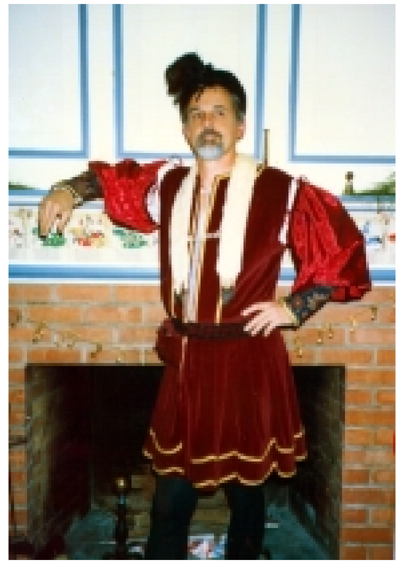

Fig. 11 Mike in costume for a La Jolla Madrigal Singers concert at the Salk Institute, December 1988.

Fig. 12 Steve, Laura, and Keith Mullin performing at home in 1976.

This is not for the faint-hearted – prospective members must try out and sight read. Performances are at Christmas, in former years at the Salk Institute and recently at the San Diego Museum of Art, and in the spring in various local venues. Members span four decades of age and have included international visitors from Germany, France, Japan, and elsewhere, as well as distinguished UCSD scientists. When Mike goes to sea, as he still does, a substitute conductor is named. A hallmark of the group is its period costume (Fig. 11). In fact, this costume has transcended the madrigal performances to the podium at UCSD, where Mike regularly lectures 100-200 undergraduates on marine ecology in full regalia (co-professor Paul Dayton does not). This appears to elicit a range of responses from the students, clearly articulated in the range of course evaluations.

Concurrent with his scientific interests, Mike has always been very involved in family life. His three children were introduced to music (Fig. 12) and science at an early age. His elder son, Stephen, once "snake-sat" a python of Paul Dayton's. Stephen Mullin, now Assistant Professor of biology at Eastern Illinois University, is carrying on the family's involvement in education to the fourth generation.

PICES, the present and the future

Mike was involved with PICES from its start in 1992. He was the first Chairman of the BIO Committee (1992-95) and served on the first PICES Science Board. Mike convened the first BIO Session on "High Resolution Paleoecological Studies in the Subarctic Pacific" at PICES II in Seattle. He has continued as a US member of BIO and he is on the Local Organizing Committee of the Beyond El Niño Conference.

Fig. 13 Aboard the R/V Toyoshio Maru *in the Inland Sea of Japan during the US/Japan Cooperative Program in Zooplankton Ecology, 1984.*

Fig. 14 Mike with Japanese schoolgirls in Kyoto 1984.

Mike has had a significant and varied involvement with scientists from other PICES countries. He has maintained his relationship with Makoto Omori over the years, hosting Mak as a Visiting Scholar, with his family, in 1975-76. He participated in the Zooplankton Symposium in Shimizu, Japan, 1984, in honor of Professors Shigeru Matoda and Martin Johnson. He was a member of a US-Japan Cooperative Science Program on zooplankton in the 1980's (Figs. 13, 14), working especially closely with Tak Onbé (retired, Hiroshima University). He joined the 4th International Copepod Conference held in Karuizawa in 1990. He mentored Shin-ichi Uye (Hiroshima University) as a visiting student and Young-Shil Kang (National Fisheries Research and Development University, Korea) as a visiting scholar. He was doctoral advisor at SIO for Dr. Hae Jim Jeong (Kunsan University, Korea).

What are some of the enduring characteristics of Mike? *Fairness*. Perhaps at times to extremes, he acts impartially, both as scientist and as administrator. *Rigor*. He is innovative yet his work is thorough, at times sufficiently so as to be difficult to read. *Responsible*. Mike honors his commitments, usually in a timely manner. MLRG has prospered under Mike's fiscal and scientific supervision and he continues to contribute vitally to CalCOFI. Bill Bartram, a graduate student of Mike's, died of cancer in 1979 near the end of his graduate work; Mike alone completed the writing of Bill's dissertation and saw it through publication in the refereed literature, with Bill as sole author. Mike acted with similar commitment when a foreign visitor to his lab was seriously injured when hit by an automobile, shepherding her through recovery. *Scholarly*. Mike has a good command of the literature and of the English language, and he puts both to good use in his advising, writing, and, particularly, as Editor of *Fisheries Oceanography*. *Wit*. Mike has his moods but, regardless, can show good humor under most circumstances. His publication titles bear witness: "How can enclosing seawater liberate oceanographers" and *Webs and Scales*.

What's next? There is no mandatory retirement age at UCSD, so it is anyone's guess. Long-term change is not greatly manifest in Mike's appearance or actions. He still bikes to and from work, conducts madrigals, lectures in costume, mentors students and postdocs, goes to sea, and researches the zooplankton. No doubt, Mike will continue to contribute importantly to PICES and the fisheries oceanography community in general.

This article is written by Dr. David Checkley, Jr., in appreciation and recognition of Dr. Michael M. Mullin's outstanding service to the Pacific Rim scientific community and PICES over many years.

David Checkley (dcheckley@ucsd.edu), is Associate Professor and Research Scientist at the Scripps Institution of Ocenaography. Dave's scientific interests are in zooplankton ecology and fisheries oceanography, with particular emphasis on the interaction of physics and biology, and non-scientific interests in family, skiing, climbing, and kites. He has known Mike Mullin for 29 years. In 1970, Dave took Zooplankton Ecology from Mike and Karl Banse at the Friday Harbor Labs. Mike was Dave's major professor at Scripps and a participant in the US/Japan Cooperative Science Program on Diel Variation in the Physiology and Behavior of Marine Zooplankton led by Dave and Professor M. Murano (Tokyo University of Fisheries). Dave is presently also a member of the Marine Life Research Group of which Mike is Director.

Acknowledgement: Connie Mullin, Lynne Talley, Makoto Omori, and Shin-ichi Uye contributed valuably to this article. Photographs were provided by Connie Mullin (Figs. 2, 3, 4, 5, 6, 7, 9, 11, 12), Elizabeth Venrick (8,10), Susan Greene (1), and David Checkley (13, 14).

Academician Vyacheslav P. Shuntov giving the Keynote Lecture at the Opening Session

Dr. John E. Stein getting great inspiration from the posters

Drs. Chang-Ik Zhang and Makoto Kashiwai enjoying Vladivostok hospitality at the Chairman's Reception at the Oceanarium

Drs. Richard J. Beamish, Olga Temnykh and Academician Vyacheslav P. Shuntov at the Opening Session

Drs. Akihiko Yatsu, Takashige Sugimoto, Masahide Kaeriyama and Yukimasa Ishida working happily at the CCCC/BASS Task Team meeting

Dr. Yutaka Nagata, Ms. Dorothy Bergamaschi and Mr. Hai-Qing Li at the Extravaganza Dinner III

50's 3-D movie show?? PICES scientists comparing different 3-D visualization tools at the TCODE Data Visualization Workshop

Dr. Tatiana Orlova receiving the MEQ Best Presentation Award from MEQ Committee Chairman, Dr. Alexander V. Tkalin

Dr. Arthur J. Miller giving his invited paper at the well-attended Science Board Symposium

P. Livingston, Y. Sakurai, G.A. McFarlane, J.M. MacDonald and G.W. Boehlert arguing about the right souvenir to bring home

Gourmet dining at the Extravaganza Dinner III at the Versailles Hotel: (from left) C. Chiu, J. Kang, H.Q. Li, V. Alexander, R.J. Beamish and D. Bergamaschi

Governing Council meeting: (front row from left) J.Y. Kim, D. Bergamaschi, H.T. Huh (Chairman), V. Alexander, P. Livingston, (back row) Q.F. Liu, A. Bychkov, H.Q. Li, W.G. Doubleday, M. Kashiwai, L.N. Bocharov, R.J. Marasco

Dr. Skip McKinnell advertises (while Ms. Christina Chiu chooses to pose) for PICES IX in Hakodate

The Chairman of the Local Organizing Committee, Dr. Alexander Kurmazov, at the end of PICES VIII

Mechanism causing the variability of the Japanese sardine population: Achievements of the Bio-Cosmos Project in Japan

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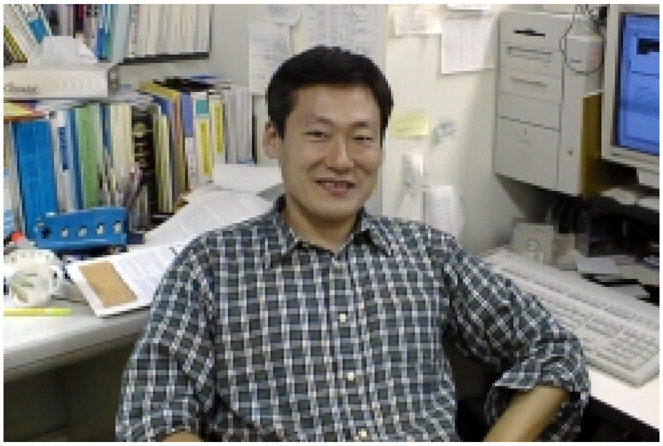

Dr. Yoshioki Oozeki was appointed Project Manager for the Japanese Sardine Recruitment Project, one of the research programs of the Bio-Cosmos Project in 1995. His research interests include fisheries oceanography and larval physiology of small pelagic fishes. He received his M.Sc (1983) and Ph.D. in Fisheries (1987) from the University of Tokyo.

The Japanese sardine *Sardinops melanostictus* has been declining in abundance since 1989 in the northwestern Pacific, and recently the population has collapsed around Japan (Fig. 1). Total catch along the Pacific coast of Japan markedly decreased from 3.46 million metric tons in 1988 to 0.15 million metric tons in 1996. A ten-year research project, named the Bio-Cosmos Project, on the population dynamics of the Japanese sardine was started in 1989, with the aim of understanding the recruitment processes of the Japanese sardine. Basic biological information had been accumulated from 1989 to 1992 on various aspects, including genetic relationships among species of the genus *Sardinops*, population structure, physiological process of maturation, egg production and spawning ecology, biological environment at the feeding grounds of adult fish, early life history and food organisms of sardine larvae. Our research activities between 1993 and 1995 focused on the population along the Pacific coast of Japan, and attempted to understand the effects of the physical and biological environment on the various life stages of the Japanese sardine from egg to adult. From 1996 to 1999, we tried to assemble two types of simulation models, an annual recruitment model and an interdecadal model, adding biological information and the results of climate change analysis.

Life history and egg production

Adult sardines migrate north in spring to feed and south in autumn to spawn (Fig. 2). Feeding grounds of adult fish are in the Oyashio area on the Pacific coast of Japan. Spawning grounds of the Japanese sardine are located along the Kuroshio Current and the area of the spawning grounds has been found to vary depending on the population size. Sardine larvae metamorphose to juveniles at the time they are entrained in the Kuroshio Current and then juveniles swim northwards along the warm water areas that separate from the Kuroshio.

Growth rates of individual fishes increased with the decreasing size of the sardine population (Fig. 3). At the same time, the age at first spawning declined from 3 to 1 year old. The spawning grounds, which expanded to areas outside of the Kuroshio current at the peak of the population, shrunk to limited areas inside of the Kuroshio current and to coastal areas. Bigger and/or older females, spawn a larger number of eggs. Egg quality, indicated by the yolk volume, however, was revealed to decrease with increasing egg quantity beyond a batch fecundity of 30,000 eggs (number of eggs in a single ovulation), although the quality increased with batch fecundity up to 30,000 eggs. The percentage of females holding mature eggs also decreased with increasing age. During the declining phase of the population, the percentage of older females increased and the number of eggs spawned from one female also increased beyond a batch fecundity of 30,000 eggs. These changes caused egg quality to decrease and the survival of hatched larvae may have been affected by the changes of egg quality.

The critical stage in the determination of year-class strength was analyzed by comparing amounts of egg, hatched larvae, first feeding larvae and 1 year old fish (Fig. 4). Significant positive relationships were observed among the abundance of eggs, yolksac larvae and first feeding larvae. No significant relationship was, however, obtained between the abundance of 1 year old fish and the other life stages. This indicated that, 1) the decrease of fry due to over-fishing of spawners was not a reason for the population of the Japanese sardine collapse and 2) the amount of recruitment was determined after the larval stage. These findings suggested that research on the juvenile stage was potentially more important in explaining population fluctuation than on the first feeding stage.

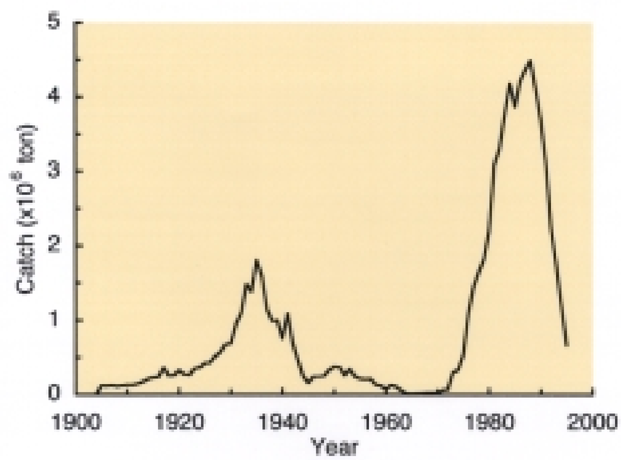

Fig. 1 *Total catch of the Japanese sardine around Japan.*

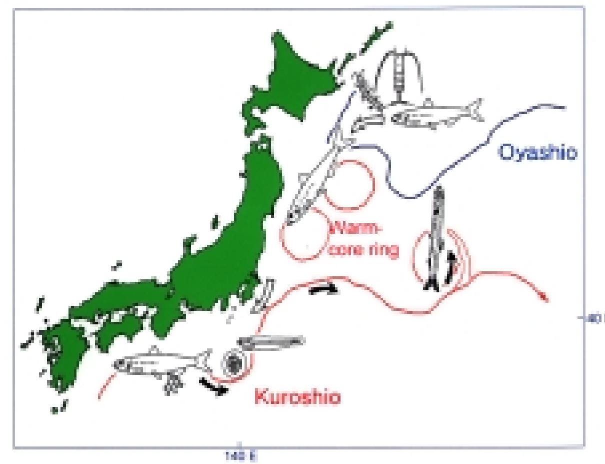

Fig. 2 *Migration pattern of the Japanese sardine along the Pacific coast of Japan.*

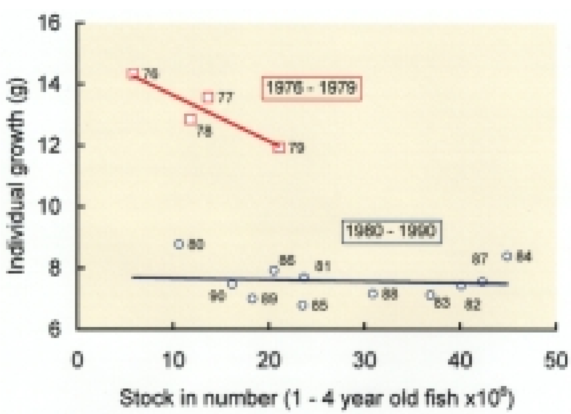

Fig. 3 *Relationships between individual growth and stock abundance of the Japanese sardine in the Oyashio region from 1976 to 1979, and 1980 to 1990. Individual growth of each year-class is indicated by the increase of body weight (g) between June and September (after Wada and Kashiwai, 1991).*

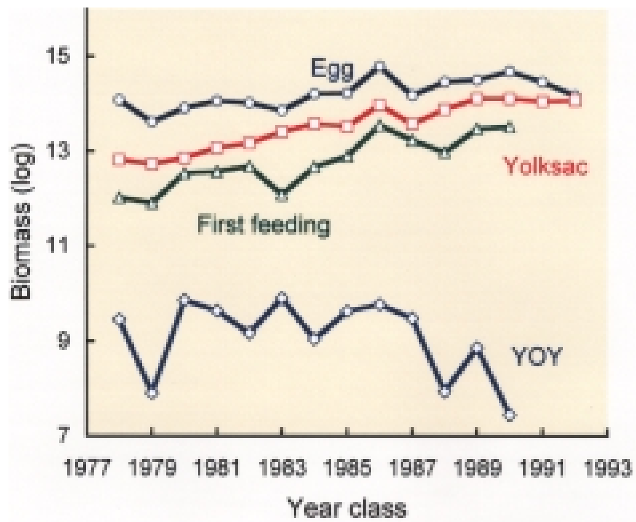

Fig. 4 *Comparison of the abundance of eggs (egg), yolksac larvae (yolksac), post first feeding larvae (feeding), and available population of young of the year (YOY) (after Watanabe et al., 1995).*

Growth and survival from larvae to juveniles

A nutritional condition scale, using RNA/DNA ratios as an indicator, showed that no larvae at the critical nutritional level (indicating starvation) were collected at sea from the coastal area to the Kuroshio region in 1993 and 1995. This indicated that starvation was not the main reason for mortality in sardine larvae. Moreover, more than 10 individuals l^{-1} of copepod nauplii were ordinarily sampled at the nursery ground of the Japanese sardine larvae, a sufficient density to sustain high levels of larval sardine survival.

Growth rates estimated from otolith increment width varied from 0.2 mm to 1.4 mm day^{-1} in SL after the first feeding and indicated a positive relationship with copepod nauplii density at sea. Growth rate variability and its effect on stage duration could be a major factor affecting recruitment levels in the case of the Japanese sardine, which has high larval growth and mortality rates and a relatively large size at metamorphosis. Food of sardine larvae was mainly copepod nauplii and high nauplii densities were observed at the frontal areas between the coastal waters and the Kuroshio current. Nutrients were provided to the surface by local upwelling at the frontal area of the Kuroshio. The increase of nutrients triggered phytoplankton blooms with subsequent high levels of copepod biomass. The amount of sunlight and the movement of the Kuroshio path also affected the phytoplankton densities. Time series of zooplankton biomass reconstructed from the data sets of sunlight and sea surface temperature showed a typical peak in 1972, which marked the start of the increase of the Japanese sardine population.

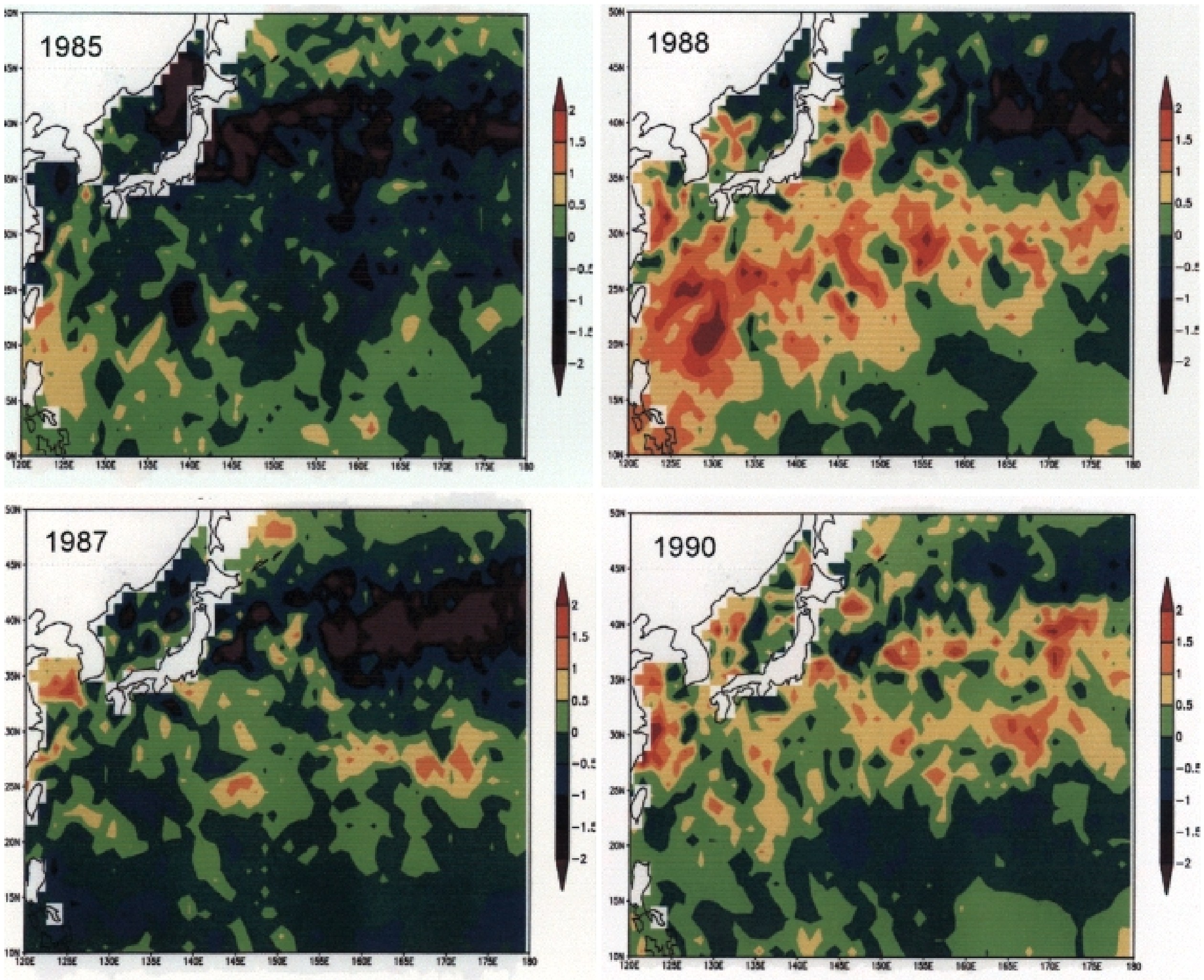

Fig. 5 *Distribution of the sea surface temperature (SST) anomaly in February in the northwestern Pacific in 1985 and 1987 (peak period of the Japanese sardine stock) and 1988 and 1990 (decreasing period of the Japanese sardine stock) (after Noto, 1997).*

Metamorphosis stage sardine larvae were sampled from the Kuroshio extension area and juveniles were also collected along the edge of warm core rings and streamers, which were separated from the Kuroshio extension. Metamorphosis from larvae to juveniles incurs a major physiological change, and the environment for larvae also concurrently changes from warm water to cold water. This process might be the key to fluctuations in the recruitment of the Japanese sardine, and the predation by other fishes might be the main cause of the mortality, because physiological changes, such as starvation and temperature changes, are thought to affect juveniles less than they affect larvae. The population size of skipjack tuna arriving in this area increased after 1988 from the data of catch per unit of effort of the pole fishery.

Effects of climate change

An increase of sea surface temperature (SST) was observed at the Kuroshio extension area (30-35˚N, 145-180˚E) in Feb - Mar 1989 - 94, which coincided with the year the Japanese sardine stock started to decrease (Fig. 5). A positive correlation was observed between the anomaly of SST in February in the Kuroshio extension area and the mortality coefficient from larvae to 1 year old fish. Retrospective analysis of zooplankton biomass from 1951 to 1988 (“Odate data”) revealed a negative correlation to SST in the Kuroshio extension. Lower winter SST might mean a thicker surface mixed layer which could provide higher nutrient levels in spring, although there is no direct evidence of this in this area.

Simulation models

In order to explain the annual recruitment success or failure, a population dynamics model was tested based on the information of growth, survival, transport, and interspecific relationships from egg to the young stage. This model required SST, estimated egg production, and

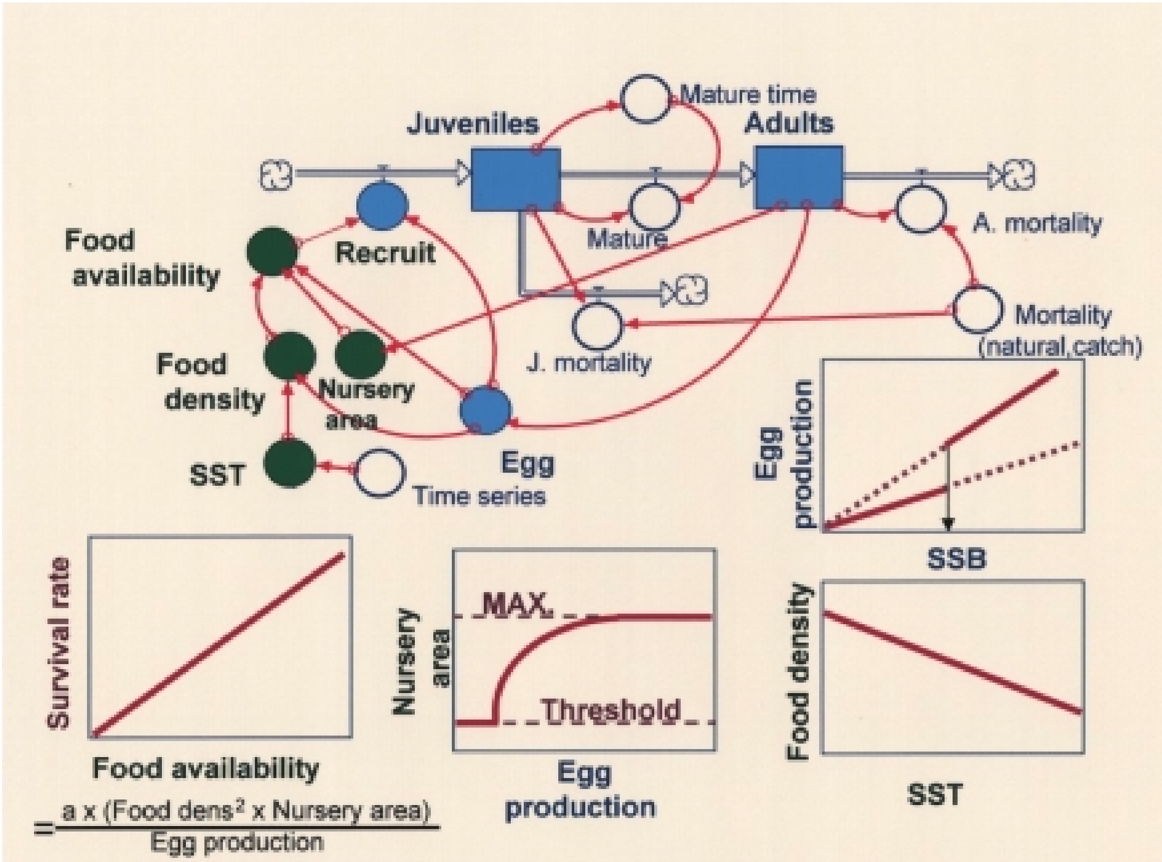

Fig. 6 Positive feedback model for explaining the process of an increasing Japanese sardine stock (after Wada and Oozeki, submitted).

the position of the Kuroshio Axis as monthly input data, and other data, such as the food density and biomass of other fish species, were also needed. After the adjustment of parameters using the data set from 1966 to 1993, the recruitment success or failure was well explained by this model and the short-term recruitment forecast is available by this model.

A positive feedback loop was proposed as a mechanism of the interdecadal fluctuation of the sardine abundance. The loop was driven by density-dependent changes in the range of distribution and food availability under the observed ocean climate changes, and the hypothesis was tested by developing a simple population dynamic model (Fig. 6). Effects of climate changes and various ecological changes observed with the fluctuation of population, such as a shift of spawning ground, expansion or reduction of the geographical area of the nursery ground, and changes in the fecundity per unit of biomass were also taken into account. Model outputs showed cyclic changes in the numbers of recruits, adults and abrupt increases and decreases of the survival rate. The relationship between egg production and number of recruits corresponded closely with the stock and recruitment relationship that was actually observed. These results suggest that the changes in food availability cause the recruitment success or failure, and the positive feedback loop sustains the population abundance at a high or a low level.

Conclusion

Accumulated biological information on the Japanese sardine and results of retrospective analysis comparing the climate change supported the construction of two types of simulation models for explaining the population fluctuation of the Japanese sardine along the Pacific coast of Japan. These models could be useful for assessing the effects of global warming on the population fluctuation of the Japanese sardine, although the models require further development. The other ideas not fully quantified and evaluated in our project, such as "top-down control" and "structural change in the small pelagic fish community", should be studied based on the knowledge from this project in the future.

Principal investigators of our project from 1996 to 1999, including Drs. R. Kimura, T. Kishida, H. Morimoto, K. Nakata, M. Noto, H. Saito, M. Shiraishi, M. Suda, H. Sugisaki, A. Tsuda, T. Wada, Y. Watanabe, and I. Yasuda, have played various vital and unique roles to reach the project goals, although citations were not listed in this article.

Climate change, global warming, and the PICES mandate – The need for improved monitoring

David W. Welch and Sonia D. Batten

Large changes have occurred in the ocean ecosystems of the PICES area in recent years. The changes in the ocean-atmosphere system affecting fish populations appear to be as large as direct effects of major commercial fisheries, so climatic changes could be as important to determining the overall sustainability of the ecosystem as the fisheries.

Existing monitoring within PICES

During the PICES Seventh Annual Meeting in Fairbanks in 1998, it became clear that the PICES community did not have a good sense of how well the North Pacific is monitored. As a result, following the meeting we worked to collect information on current monitoring efforts within the PICES region. For purposes of this paper, we define monitoring as regular systematic ocean sampling. For simplicity, we restricted our survey to ocean monitoring that is still on-going. If we plot all of the ocean sampling that is currently occurring, the map of the North Pacific and adjacent seas looks impressively well-covered (Fig. 1).

Reasonably extensive time series of data exist at Station P (since 1949), Line P (since 1956), the GAK-1 line (since 1970) and the CalCOFI grid (since 1949). However, the time of peak abundance of the dominant copepod *Neocalanus plumchrus* has shifted by approximately two months in the eastern North Pacific (Mackas 1998), emphasising the need for seasonal coverage in order to identify such changes. If we therefore restrict our definition of "monitoring" to sampling activities that re-sample the same locations two or more times per year, the picture changes dramatically (Fig. 1).

The limited sampling is particularly noticeable in the open ocean, where apart from Line P and the new Japanese Station "KNOT", no monitoring activities are taking place. As Steele (1998) has noted, coastal zooplankton populations appear to be forced by the offshore populations (at least in the Atlantic), so it is reasonable to expect that events happening offshore will have significant impacts in the shelf region as well. It is clear, however, that the role of offshore and shelf ecosystems under climate change will not be resolved with the existing monitoring effort.

The Need for improved monitoring

It is clear from Figure 1 that the amount of monitoring of the North Pacific is fairly small. However, before advocating that greater resources be devoted to monitoring efforts, there is also an important question

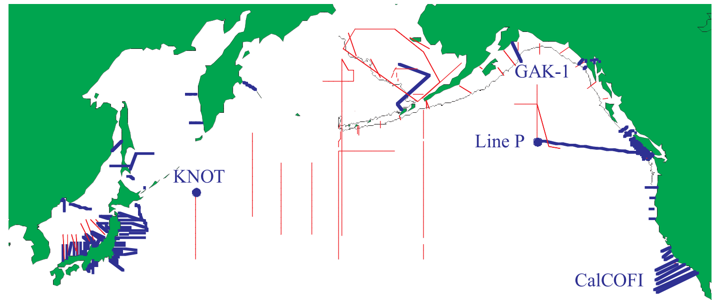

Fig. 1 All locations that are sampled at least once per year. Those sampled more frequently than once per year appear in dark blue.

concerning how to divide our efforts between process studies and more "routine" monitoring. One aspect of this issue concerns just how large the climatic changes may be in the near future from both natural fluctuations in the climate system and the additional anticipated effects of global warming.

There are a number of excellent papers demonstrating evidence for quasi-periodic oscillations in the climate system of the North Pacific with periods of roughly 20 and 50 years (e.g. Minobe, 1999; Ware 1995). In general, the oscillations have amplitudes of only a fraction of a degree Celsius, yet appear to have significant influences on the biological response of the North Pacific on similar time scales (e.g. Hare et al., 1999). There have also been suggestions that we are on the verge of another regime shift. Because we do not understand how the climate system works, there are therefore clear reasons to support both process studies and continuation of existing monitoring efforts in order to better observe what may develop. However, the projected effects of anthropogenic climate change ("global warming") may greatly change the North Pacific. In our view there is a pressing need for putting much more intensive efforts on monitoring what may happen in the region as the effects of global warming become increasingly evident.

Many people do not yet recognise just how serious the projected changes in climate may be. An excellent recent review of what is known of the climate system underlying the global warming models can be found in Ledley et al (1999). In summary, the most confident projections available from global climate models (GCMs) are for the amount of warming expected, followed by changes in precipitation (IPCC, 1996, p.6). Taking the amount of warming as a proxy for climate, big changes are anticipated. But to realise just how big these changes are likely to be, it is important to put them in a historical context.

The detailed historical record of northern hemisphere climate now extends back about 1,000 years (Mann et al., 1999). This record (Fig. 2) indicates that climate, as indexed by mean annual temperature, was stable for over 9 centuries. Approximately 100 years ago, a sharp warming trend began (see inset in Fig. 2).

The warming seen in the reconstructed temperature record (blue line) is closely matched by the instrumental record since 1902 (green line), indicating its likely reliability. However, the most serious finding from the extended climate record is that the rapid warming observed in this century is unprecedented in the last 1,000 years; northern hemisphere climate warmed by 0.68ºC over the last 100 years. The degree of observed warming is also generally consistent with the increases projected by global warming models (red line) as greenhouse gas concentrations increased in this century.

Although the warming experienced this century is unprecedented and generally consistent with forcing by increasing greenhouse gas concentrations, it is the magnitude of the projected change over the next century that is of much greater concern (red line). The projected rapid rise in temperature will shift climate far away from our previous experience.

Model projections generally suggest that we may see continuous warming of about 0.5˚C per decade over the coming century. Thus, it is conceivable that there could be as much climate change each decade as has been seen in this entire century - subsuming the amplitude of the combined bidecadal and pentadecadal oscillations which had a strong association with biological changes in the region in the past. If this warming comes to pass we will be shifting the climate of the North Pacific well away from its historical baseline. This will probably result in the climate system changing in important and unanticipated ways. It is reasonable to expect that nonlinearities in the climate system will likely increase the amplitude of these cyclical fluctuations and change the frequency that they are expressed at. For example, in very high resolution GCM simulations El Niños were found to increase in frequency (Timmerman et al., 1999). As Trenberth and Hoar (1996) note, the frequency of "El Niño-like" conditions observed in the 1990s should be expected about once every 2,000 years, so it is not unreasonable to suggest that we are already experiencing the early effects of man-made global warming.

The climate system is certainly not understood well enough to expect that we will be able to anticipate what is really likely to happen in the future. We also do not understand how the effects of "climate", loosely defined, will work their way through the ecosystem of the North Pacific, because we do not really understand how past regime shifts have developed. Thus, the projected warming, plus the evidence for past oscillations, emphasises the need for an observational framework to directly establish how lower trophic levels will respond to climate change. As the results from monitoring programs in the Atlantic demonstrate, using the Hardy Continuous Plankton Recorder (CPR) (described below), measurements of physical variables alone, such as the intensity of the North Atlantic Oscillation or sea temperature, do not always couple directly to changes in fish or zooplankton production. In addition, they have a record of suddenly breaking down (Fig. 3) without providing a mechanistic understanding of the intermediate linkages (Planque and Reid, 1998; Reid et al., 1998). Direct monitoring of the intermediate levels below the plankton is also needed to resolve what effects climate forcing will have on the ecosystem.

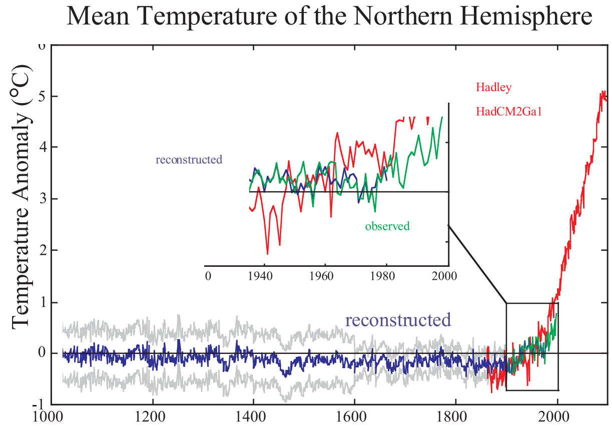

Fig. 2 *Composite figure comparing historical temperature change for the northern hemisphere. The zero line is the 1902-80 mean temperature. Climatic change in this century is unprecedented.*

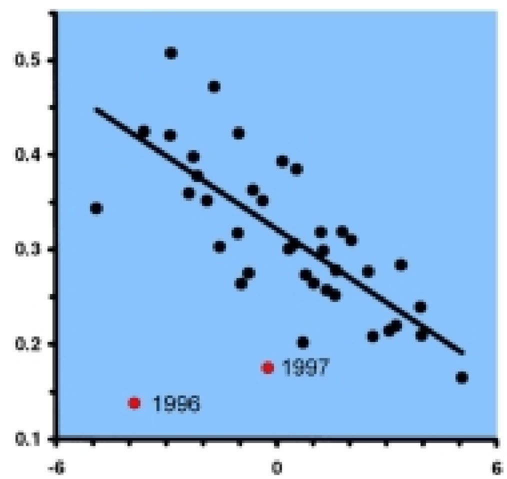

Fig. 3 *The relationship between Calanus finmarchicus and the NAO, showing how a relationship that had held for 40 years broke down in 1996 and 1997. Redrawn from Reid et al (1998).*

What do we need to monitor?

In at least some regions we know that the North Pacific is shifting towards a thinner surface mixed layer (e.g. Stn P; Freeland et al., 1997; Whitney and Freeland 1999). The eastern North Pacific has also warmed and become less saline in the last few decades. Both the warming and freshening of the surface layer stabilises the mixed layer and reduces the amount of nutrients brought up from below the permanent pycnocline. In the 1990s, nitrate limitation became a progressively more pronounced feature of the eastern North Pacific ecosystem over a much greater region along Line P (Whitney et al., 1998), and nutrient depletion has been observed in surface waters all along the shelf and slope regions as far as the Aleutian Islands (Whitney et al., 1999; Fig. 4). Unfortunately, because of the limited sampling that has taken place in the past, it is difficult to be certain to what degree nitrate limitation is a new phenomenon in the region north of Line P, although there is no question that the shift to a nitrate limited ecosystem along Line P is unprecedented.

This raises the question of what programs in the PICES area should try to monitor. There is evidence for both top-down and bottom-up forcing (e.g. Perry et al., 1998). Commercial fisheries probably provide a reasonable guide to the status of many populations, particularly as research surveys have been developed to provide independent data on the status of many important populations. The most critical need for new monitoring, therefore, seems to lie at the levels in between the atmospheric forcing (that can be reasonably measured from existing programs) and the fish populations (whose fluctuations provide much of the economic reasons for supporting the monitoring). Global warming models project that the world will be a warmer, wetter place so it is likely that the mixed layer will be even more stable in the future, further changing the ecosystem. (It has also been suggested that wind mixing of the surface mixed layer will be reduced (Hsieh and Boer 1992)).

These changes suggest that it will be important to determine what nutrients are limiting in different parts of the Pacific and the rate of depletion. Changes in both the abundance and community structure of the plant and animal plankton are likely to follow, and that will need to be related to the spatial changes in the physical and chemical properties of the surface layer. These in turn will need to be better related to the upper trophic levels. Although we tend to focus on economically important fish species, changes in the benthic community, sea birds, and marine mammals should not be ignored. As Hare and Mantua noted in their presentation at PICES VIII in Vladivostok, the biota seems to respond more sharply and clearly to climate change than do the physical variables we have chosen (often for convenience) to monitor.

The first step

In 1997, the Sir Alister Hardy Foundation conducted a trial CPR tow in the Pacific Ocean. Few problems were encountered either with the tow or the subsequent enumeration of the plankton (conducted in England). The CPR is a towed instrument which can be deployed with minimal training by commercial ship's crews, and continuously collects zooplankton on a silk mesh which is then preserved in a formalin bath. (A fuller description can be seen on the SAHFOS web site: http://www.npm.ac.uk/sahfos/introduction.html).

After a review of the preliminary findings from the 1997 work, the 1998 MONITOR Task Team meeting concluded with a recommendation that the CPR approach to wide-scale monitoring of the zooplankton should be adopted, given that it is a mature and readily deployable technology.

With this endorsement, we submitted a proposal in April 1999, to the North Pacific Marine Research Initiative program, which awarded funding for a two-year project. The objective

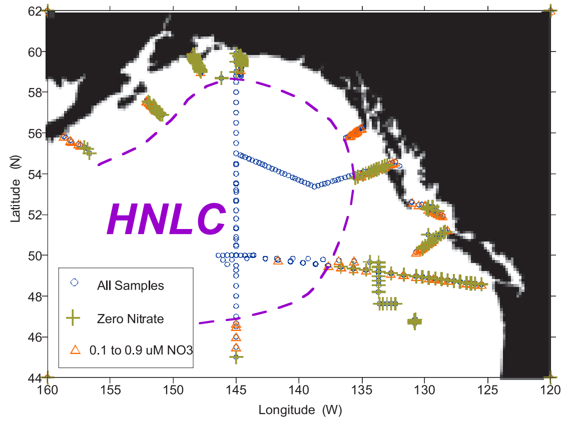

Fig. 4 *Distribution of the region of depleted nitrate in the surface mixed layer, based on mid-summer coastal surveys in 1997 and 1998, and offshore IOS surveys. The dotted line is an approximate delineation of the region of depleted nitrate, which will reduce net biological production.*

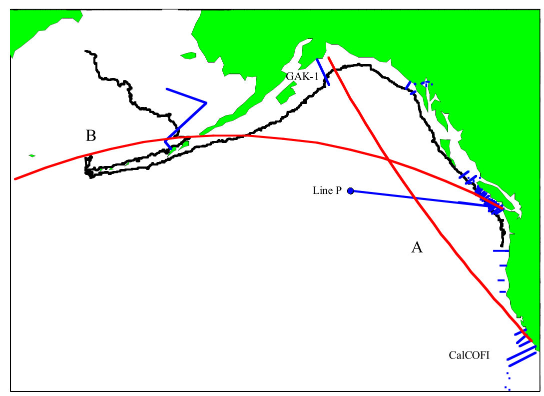

Fig. 5 *Funded CPR transects. Line A is an oil tanker route, and Line B is a container ship route. Line A will be run 5 times in 2000 and again in 2001. Line B will be run once each year.*

is to implement a pilot CPR program to collect the data necessary to determine how a major long-term monitoring initiative should be developed for the eastern North Pacific.

Two CPR routes were identified as priorities, one running north-south from Prince William Sound to California and one east-west from southern Vancouver Island on a great circle line. These lines give good spatial coverage of the Gulf of Alaska (Fig. 5). However, identifying the seasonality of the plankton is also vital. Following a meeting with the steering committee we therefore decided to run five north-south CPR tows per year (to establish seasonal variation) and one east-west tow (to establish spatial scale). The latter run will extend as far as the southern Bering Sea (Fig. 5). All samples collected in coastal/shelf environments will be analysed on these routes, providing an 18 km spatial resolution, while every fourth oceanic sample collected on the north-south tows and the single east-west tow will be enumerated, providing 72 km spacing. (The other samples will be archived). One remaining N-S tow will have alternate samples analysed (providing 36 km resolution) to try to better identify the spatial scales of patchiness. The first N-S tow will take place in March 2000, followed by tows in April, May, late June and early August. It is intended that the late June tow will be made to coincide with the E-W tow and the Line P cruise run from Victoria to Station P. This N-S tow will be the one with more detailed sample analysis to maximise the spatial information on zooplankton available for this one time period. The same sampling regime will be repeated in 2001.

The separate copepodite stages of *Neocalanus plumchrus* will be enumerated to enable extrapolation of the precise timing of the main peak of its abundance, following the work of Mackas et al. (1998). This copepod makes up much of the mesozooplankton biomass in the region, therefore, identification of its development, timing and appearance in surface waters appears to be particularly important.

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Dr. Sonia Batten (soba@wpo.nerc.ac.uk) is Deputy Director of the Sir Alister Hardy Foundation for Ocean Science, UK. Her research focus concerns the use of the CPR data, specifically mesozooplankton dynamics.

***Congratulations** go to our Chinese and Korean colleagues on developing the China GLOBEC II (1999-2004) and the Korea GLOBEC Programme (1999-2002) and getting them funded! It will be a wonderful contribution to the International GLOBEC and PICES-GLOBEC efforts. We wish you success with your research, and look forward to hearing about your progress and results at future PICES meetings.*

The new age of China-GLOBEC study

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China - GLOBEC
Global Ocean Ecosystem Dynamics

Prof. Qi-Sheng Tang is an academician of the Chinese Academy of Engineering, and Director-General of the Yellow Sea Fisheries Research Institute of the Ministry of Agriculture of China. His research fields include fisheries biology, far seas fisheries, stock enhancement and management, and carrying capacity in aquaculture. He has published over 100 papers and 6 books. Since 1984, Prof. Tang has focused on marine ecosystem study, and promoted the development of Large Marine Ecosystems (LMEs) and Global Marine Ecosystem Dynamics (GLOBEC) in China and the world. At present, Prof. Tang is continuing to study marine ecosystems and the sustainable utilization of living resources. He was the first Chairman of the PICES Fishery Science Committee (FIS) and continues to be involved in PICES activities as a member of FIS and the Executive Committee for the PICES Implementation Panel on Climate Change and Carrying Capacity Program.

China-GLOBEC II, entitled "Ecosystem Dynamics and Sustainable Utilization of Living Resources in the East China Sea and the Yellow Sea", has been approved as a Programme of the National Key Basic Research and Development Plan in the People's Republic of China, with a funding of $4.5 million for the period of 1999-2004. Nine academic institutions and about 100 scientists are involved in the Programme, and the major institutions are the Yellow Sea Fisheries Research Institute (YSFRI) of the Ministry of Agriculture, the Second Institute of Oceanography of the State Oceanic Administration, the Institute of Oceanology of the Chinese Academy of Sciences, and the Ocean University of Qingdao. Prof. Qi-Sheng Tang will serve as the Chief Scientist and Prof. Jilan Su (*sujil@zgb.com.cn*) will serve as the Scientific Advisor of the Programme.

The Programme goals are to:

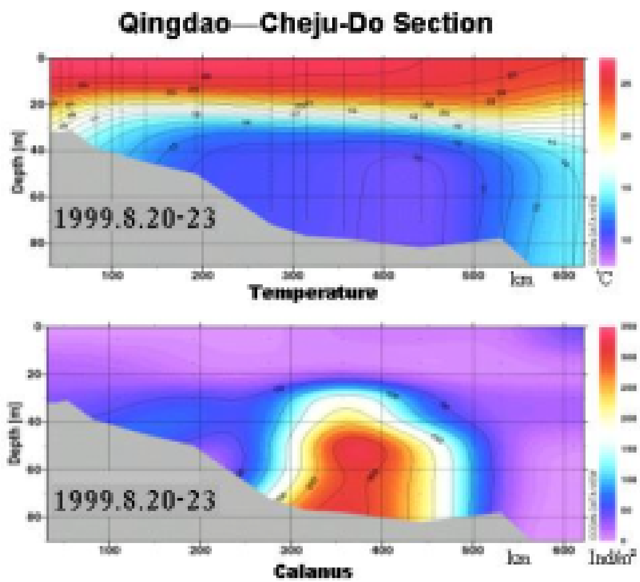
- identify key processes of ecosystem dynamics, and improve predictive and modeling capabilities in the East China Sea and the Yellow Sea;
- provide scientific underpinning for the sustainable utilization of marine ecosystems and rational management system of fisheries and other marine life.

Because the East China Sea and the Yellow Sea are indicated as the research regions No.10 and No.9 in the PICES-GLOBEC Climate Change and Carrying Capacity Program (CCCC), China-GLOBEC II will be regarded as a contribution to providing a regional case for the PICES-GLOBEC and an example of shelf ecosystem dynamics for IGBP/SCOR/IOC-GLOBEC.

The scientific objectives of the Programme are to determine:

- impacts of key physical processes on biological production;
- cycling and regeneration mechanisms of biogenic elements;
- basic production processes and role of zooplankton in the ecosystem;
- food web trophodynamics and shifts in dominant species.

Multi-principle and comprehensive studies in field work are carried out aiming at the following key scientific questions (KSQs): energy flow and conversion of key resource species, dynamics of key zooplankton population, cycling and regeneration of biogenic elements, ecological effect of key physical processes (see Fig. 1), pelagic and benthic coupling, microbial loop contribution to the main food web.



The Programme Implementation Plan includes 12 projects:

1. Characteristics and evolution mechanism of mesoscale physical processes in high productivity areas;
2. Bottom boundary layer dynamics and its role in settling and resuspension processes in key regions;
3. Numerical models of ecosystem dynamics in key regions;
4. Cycling and regeneration of biogenic elements;
5. Interface/boundary flux of the biogenic materials and its transfer mechanism;
6. Processes studies on primary production, secondary production of heterotrophic microbes, and microplankton production;
7. Changes in community structure and biomass of zooplankton and its role in the ecosystems;
8. Population dynamics and productivity of the key zooplankton species (e.g. *Calanus sinacus*);
9. Productivity of benthos and pelagic-benthic coupling processes;
10. Characteristics of trophodynamics and modeling;
11. Dynamics of main resources population and early recruitment mechanisms of key species (e.g. anchovy);
12. Dominant species changes and important human effects on sustainable utilization of living marine resources.

(N.E.P cont. from page 8)

anomalies dropped to 3.5˚C below normal, and the lighthouse observing sites reported the lowest SST anomalies observed in 65 years.

At Ocean Station Papa we have previously reported observations of the mixed-layer depth, and the influence of climate change on that depth. Over the last 50 years, mid-winter mixed-layer depth has systematically declined, as shown in Figure 4. During the abnormally warm winter of 1997/98, we observed (in February 1998, letter B on Fig. 4) the lowest mixed-layer depth in the history of Line-P observations. The previous low value immediately followed the 1982/83 El Niño (A on Fig. 4). SST anomalies reached record lows during the winter of 1998/99, and this reduced the stability of the upper water column. The result was that the mixed layer was substantially deeper at the start of 1999 (C on Fig. 4), though only reaching the long-term average. The progressive reduction in mixed-layer has led to a progressive reduction in the supply of nutrients to the upper ocean during the deep mixing periods. This culminated in 1998, which was preceded by a winter with the lowest mixed-layer depths on record, and so the weakest mid-winter supply of nitrate to the upper ocean. Observations by Frank Whitney show that in 1999, following relatively normal mixed layers in the previous winter, the nitrate concentrations had returned close to the long-term mean conditions.

The continuation of cold conditions in the eastern North Pacific suggests that we will see an ample supply of nitrate injected into the upper layers of the ocean during the winter of 1999/2000.

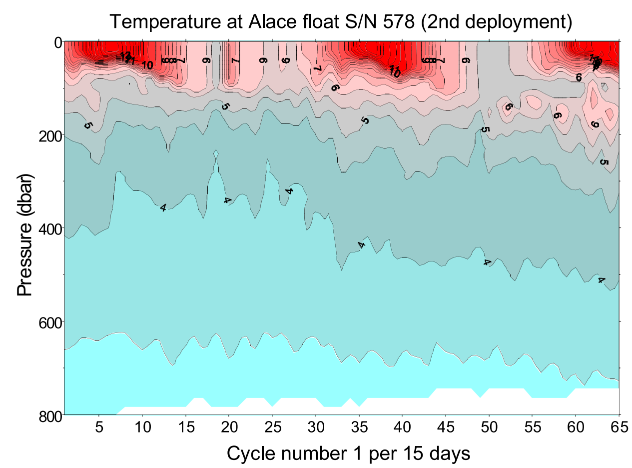


Fig. 3 Temperature measured at a profiling ALACE float which has so far spent 2.7 years near Ocean Station Papa.

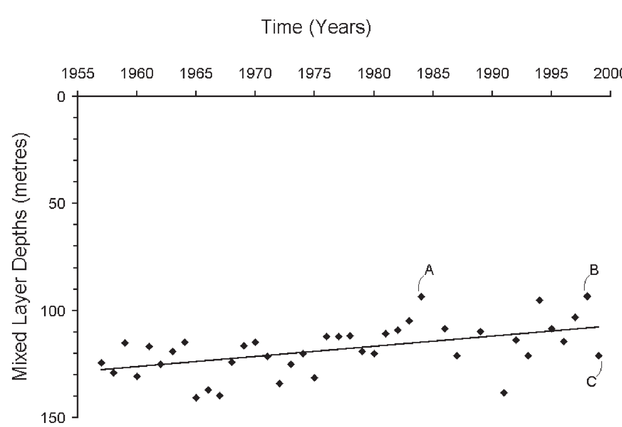


Fig. 4 Mid-winter mixed layer depth at Ocean Station Papa, from 1956 to present.

GLOBEC activities in Korean waters

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Dr. Suam Kim received his B.Sc. (1976) and M.Sc. (1979) in oceanography from the Seoul National University and got his Ph.D. in fisheries oceanography from the University of Washington in 1987. Currently Dr. Kim is Director of the Polar Research Center of the Korea Ocean Research & Development Institute (KORDI) and Chairman of Korea GLOBEC. His fields of interest include (1) the environmental factors causing the recruitment variability of fishery resources in the North Pacific and the Southern Ocean; (2) fisheries ecology, especially early life history of fish in relation to climate change; and (3) fish stock assessment. Dr. Kim represents Korea on committees of international organizations such as: PICES (Co-Chairman for Implementation Panel on CCCC Program and member of the Fishery Science Committee), GLOBEC (SSC member), CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources), and SCAR (Scientific Committee of Antarctic Research).

Introduction

Until a few decades ago, there were many diverse resident and migratory fish species in waters surrounding the Korean Peninsula. As early as the early 1970's, however, under increasing pressure from overfishing and unrestricted access to fisheries, a warning sign of drastic decreases in fish abundance was observed among some of the most commercially important fisheries. Climate and oceanic environmental changes have also exacerbated problems in Korea's fisheries resources by adversely affecting marine ecosystem structures relating to fisheries. A new management practice is urgently required for the new century, one equipped with a predictive technology regarding species replacement and their recoveries, as well as concerning population fluctuations in the marine ecosystem. Under such urgency, the Korean Society for Oceanography and the Korean Society for Fisheries Resources agreed to establish the Korea GLOBEC Committee in 1998. A total of 13 scientists were selected based on their academic specialties. They itemized on-going concerns and strategies for GLOBEC research in Korea. The Committee started its activity by conducting a small and intimate symposium in August 1999. They also plan to invite Japan GLOBEC for the joint Korea-Japan Symposium on GLOBEC in Pusan, in August 2000.

Regional data and information

Three marginal seas semi-encircle the Korean Peninsula, i.e., the East Sea/Japan Sea (referred to as the East Sea hereafter), the Yellow Sea, and the South Sea. The East Sea consists of three deep basins and a steep continental slope with narrow continental shelf whereas, the South and the Yellow Sea mostly possess very shallow continental shelves. The warm and saline water mass of the Tsushima Current, separated from the Kuroshio, is transported into the East Sea via the South Sea, and converges with the cold waters of the Liman Current in the central East Sea forming a polar front. Thus the distribution of cold and warm water fish species varies depending on the location of the polar front. Consequently, zooplankton production and fish survival might be strongly influenced by the strength of these two water masses. The Yellow Sea and the South Sea are generally influenced and occupied by the warm Tsushima Current, though seasonal cold waters and/or heavy rainfall affect local water properties of these areas. The major fish stock of these areas belongs to warm water species including anchovy and mackerel, hence their productivity may be influenced by the strength of the Kuroshio, and in turn, by El Niño.

Waters encircling the Korean Peninsula have typical regional oceanographic attributes as well as fisheries characteristics. Nevertheless, no clear information is known about meteorological events affecting climatic conditions of the Korean Peninsula including its adjacent seas. By assuming that the climate changes and environmental variability are more important than any other natural factors responsible for the fluctuation of fisheries resources (especially true for the small pelagic fish stock), the Korea GLOBEC is considering its priority focus on conducting GLOBEC research around the Korean Peninsula. Fortunately, plenty of historical data for retrospective analyses are found including temperature, precipitation, and other meteorological observations by the Meteorological Research Institute, lighthouse observations, oceanographic observations and fishery statistics by the National Fisheries Research and Development Institute. However, for the GLOBEC modeling study, a lot of laboratory work or process-oriented research are required in the future. Most of all, improved and effective political conflict-solving techniques are needed for collecting and standardizing oceanographic, fisheries and meteorological data from neighboring countries such as China, Japan, North Korea, and Russia.

Action Plan for Korea GLOBEC Programme and its structure

The Korea GLOBEC Programme, which was produced in 1999 by Korea GLOBEC Committee members, will last for three years beginning in late December 1999. For short-term results, it aims at collecting all research information that has been carried out in the past, and re-analyzing the historic data sets in relation to climate changes. Ultimately, based on the retrospective analyses, it will provide a long-term science and strategic plan for Korean waters to establish effective and reasonable conservation and sustainable measures for the fishery and ecosystem management (Fig. 1). With challenges of accomplishing these objectives, Korea GLOBEC Programme incorporated five fields of ecological study area connected interdisciplinarily as follows:

- Climate variability patterns over the Korean Peninsula;
- Climate changes and physical reactions of ocean in Korean waters
- Climate changes and other relevant responses of marine ecosystem in Korean waters
- Climate changes and fluctuation of fisheries resources
- Interaction among ecosystem components affected by changing climate conditions

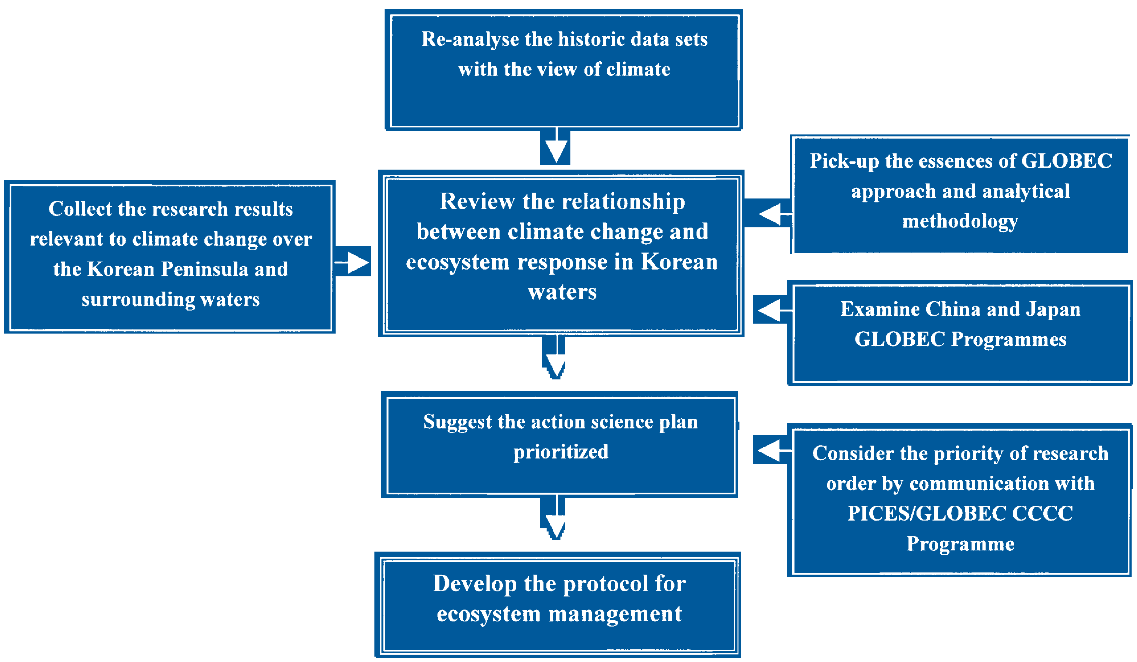

Fig. 1 Flow-chart of long-term activities to be conducted by the Korea GLOBEC Programme.

Connecting marine researches in Korea with the international GLOBEC studies

Four regional programmes, namely, Southern Ocean-GLOBEC (SO-GLOBEC), Small Pelagic Fishes and Climate Change (SPACC), Cod and Climate Change (CCC), and Climate Change and Carrying Capacity (CCCC), of International GLOBEC are strongly interrelated with fishing activities of Korea. Because Korean fishing companies were involved in krill fishing in Antarctica since 1997/98 season, and krill fishing during winter seasons has been on the increase recently, the SO-GLOBEC research which aims for winter processes including overwintering survival strategy of krill, are pertinent to the Korea Antarctic Research Programme. Moreover, in the South Sea of Korea, two small pelagic fish species (anchovy and mackerel) made up to 44% of the total fish catches in 1995, indicating its importance to the Korean fisheries. Therefore, the South Sea should be one of the study areas in SPACC programme. In addition, Korea's distant water fishing industries used to explore fisheries resources in the North Pacific and the North Atlantic Oceans. Especially, recruitment processes of demersal fish stocks such as walleye pollock are relevant to the main themes of CCC and CCCC. With emphasis, therefore, any international GLOBEC activities cannot be overlooked.

It is not clear how the El Niño events affect the marine ecosystem of the northwestern Pacific Ocean containing marine areas with the highest annual fish production among the world oceans. Recently, some Korean meteorologists, using the wavelet analysis, revealed that precipitation data in southern areas of Korea exhibit a periodic cycle similar to the El Niño and Southern Oscillation (ENSO) events (Oh and Lee, 1998). Precipitation data near the South Sea are correlated with the Southern Oscillation Index (SOI), which suggested that the occurrence and intensity of El Niño having 3.3 to 5.0 year periodic cycles since 1965.

From the satellite photographs, the SST in the South Sea became a little warmer in winters after El Niño events had occurred in the tropical ocean. The annual SOI showed a high negative correlation with the SST in December, accounting for approximately 25% of the variance in December SST. On the other hand, the SST in December revealed high correlation coefficients with anchovy catch ($r=0.419$, $p<0.05$) and mackerel catch ($r=0.436$, $p<0.05$) in the South Sea of Korea, albeit no statistically significant direct correlation were observed between SOI and fish catches. The relationship between SOI anomaly, SST anomaly in December, and fish catches is depicted in Figure 2 (Kim and Kang, in review).

Regional cooperation

Fishing overcapacity and climate change presumably have changed species composition and abundance of fish stocks in Korean waters during the last few decades. The increases in fishing activities since the 1970s have, in general, depleted fish populations, and in turn, required higher and higher fishing efforts than previous catch. Especially for demersal species, the failure of recruitment and the overall reduction of fish lengths are frequently reported. Fishes are also threatened by coastal development such as land reclamation and the construction of industrial complexes where coastal areas serve as spawning and nursery grounds for resident species. The loss of spawning grounds and the habitat degradation are making previously fertile coastal areas barren. To recover fisheries resources and rebuild stocks to achieve sustainable catch in Korean waters, it is evident that appropriately implemented fisheries research and management strategy should be considered through international cooperation and consideration. A group of Yellow Sea Large Marine Ecosystem (YSLME) scientists has agreed to establish international cooperation. GLOBEC also shares the same understanding as YSLME. YSLME's approaches to the regional co-operation, share ultimately the same purposes with GLOBEC - on how to establish ecosystem management in Korean waters. The thematic center for fisheries research and management should be established as a priority measure, and its final goal is to provide basic information for the ecosystem management including the concept of climate changes. The proposed Task Groups and their activities in new regional organization include:

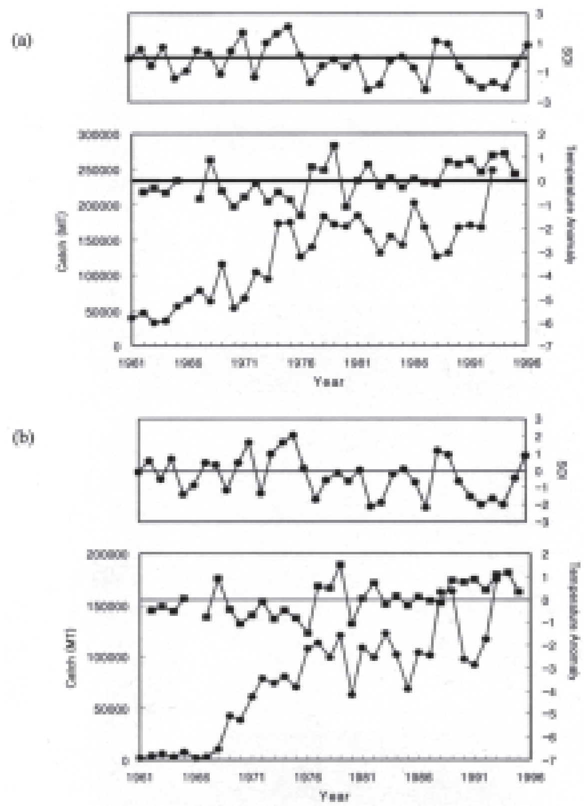

Fig. 2 Physical and biological coupling in the South Sea of Korea shown by the relationship between the annual anomaly of SOI, SST, and the annual catch of (a) anchovy and (b) mackerel from Korean waters.

- Data Management: exchanging fisheries data, creating fine-scale data reporting system, operating observer programme, etc.
- Scientific Investigation: developing cooperative scientific surveys, workshops, etc.
- Capacity Building: training and exchanging of young scientists, etc.
- Fisheries and Ecosystem Management: conducting annual meetings for stock assessment and analyses, making decisions on conservation measures, etc.

Hopefully by addressing the issues in fisheries, and implementing strong measures and newly developed fisheries management practices will rebuild and replenish Korea's fisheries resources for continuing benefit from Korean waters.

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Oh, J.-H. and Lee, Y.H. 1998. Climate jump in precipitation data over Korean Peninsula. In: Proceedings of the 1st workshop on climate changes and fisheries resources. Eds. Zhang, C.I., Kim, S. and Oh, J.-H., Pukyong National University. 1-25 pp. (in Korean).

Aspects of the Global Ocean Observing System (GOOS)

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Dr. Colin Summerhayes has been Director of the GOOS Project Office at the IOC Secretariat since March 1997. He was Director of the UK's Institute of Oceanographic Sciences (IOS) at Wormley, which he moved to Southampton to become part of the new Southampton Oceanography Centre (SOC) in 1995. He then became the Deputy Director of the SOC. Before that, Dr. Summerhayes spent 12 years in the oil business as a research scientist, research and operations manager for British Petroleum in the UK and for EXXON in Houston, Texas, following scientific research appointments at Woods Hole Oceanographic Institution, the University of Cape Town, the New Zealand Oceanographic Institute, and the Imperial College, London. He holds MSc and DSc degrees (from Victoria University in New Zealand) in marine geology, and a PhD (from Imperial College) in marine geochemistry, and has published over 100 research papers and reports including a recent textbook on Oceanography. Dr. Summerhayes regards his three main assets as "optimism, perseverance, and a sense of humour".

GOOS is a response to the demands of UNCED's Agenda 21. It is designed to provide descriptions of the present state of the sea and its contents, and forecasts of these for as far ahead as possible, for a wide range of users, and to meet the needs of the Framework Convention on Climate Change by underpinning forecasts of changes in climate. It is not solely operational, but includes work to convert research understanding into operational tools. If it is designed and managed well, GOOS should provide IOC and its partners (WMO, UNEP and ICSU) with the ability to convert research results into useful products to meet societal needs. During the past year, a major achievement was the creation of the GOOS Initial Observing System, which unites the main global observing sub-systems supported by the IOC, WMO and (in the case of coral reefs) the IUCN, and includes measurements from ships, buoys, coastal stations and satellites. Routine systematic, long-term measurements of relevant ocean properties made by these means are essential to underpin accurate forecasts of the changes in ocean conditions, that in turn provide essential input to the numerical models used to forecast storms and climatic events like El Niño, thereby helping countries to plan ahead to reduce impacts. Improving the system requires funding to maintain and extend the observational network, to improve the numerical models used to process data, and to improve the methods by which the data are assimilated into models. The Tropical Atmosphere-Ocean (TAO) array of buoys in the tropical Pacific, which underpins El Niño forecasts and is part of the GOOS Initial Observing System, proved its worth by providing even more accurate forecasts than before of the 1997-98 El Niño. Retrospective analyses of the data show that the first indications of the event appeared in subsurface data from the buoys. A conference sponsored by IOC and WMO in Guayaquil in November 1998, called for more investment in Pacific observing systems to improve El Niño forecasts. Japan is taking over management of the western part of the TAO array, replacing the ATLAS buoys with more TRITON buoys at 12 sites.

The GOOS Initial Observing System unites the main global observing sub-systems supported by the IOC, WMO and (in the case of coral reefs) the IUCN, and includes measurements from ships, buoys, coastal stations and satellites. It includes:

- the Ship of Opportunity programme (SOOP) making upper ocean measurements;
- the Voluntary Observing Ship (VOS) programme of the WMO, making marine meteorological measurements;
- the Global Sea Level Observing System (GLOSS) and its network of tide-gauges;
- the Global Coral Reef Monitoring Network (GCRMN);
- the Global Temperature and Salinity Profile Programme (GTSPP) for providing high quality data from the upper ocean;
- the Data Buoy Cooperation Panel (DBCP), for various kinds of data from buoys;
- the Tropical Atmosphere-Ocean (TAO) array of buoys for monitoring El Nino;
- NOAA's operational satellites and the Global Telecommunications System of the WMO, for transmitting information;
- the Continuous Plankton Recorder (CPR) Survey, managed by SAHFOS (Sir Alister Hardy Foundation for Ocean Science);
- the International Bottom Trawl Survey (ITBS), of the North Sea, from ICES (International Council for the Exploration of the Sea); and
- time series stations 'S' and Bravo.

The 4th Conference of the Parties (COP) to the Framework Convention on Climate Change, which took place in Buenos Aires in 1998, agreed on the URGENT need to improve the quality, coverage and management of GOOS, especially to increase the number of ocean observations, particularly in remote locations, reinforcing the need for GOOS pilot projects like the Global Ocean Data Assimilation Experiment (GODAE), the main GOOS pilot project, designed to demonstrate the power of integrating satellite and *in situ* data, the power of model assimilation, and the value of a global system capable of working in real-time. GODAE is needed for open ocean analyses and forecasts, and to establish boundary forcing for regional models to improve forecasting in coastal systems. To feed the requirements of GODAE, and to provide global coverage for the first time of upper ocean temperature and salinity, the OOPC also began development of the ARGO programme, which is a GODAE (therefore GOOS) pilot project. ARGO will use 3000 profiling floats rising from ~2000m to the surface every 14 days, each one collecting 100 CTD profiles over a 4-year period, for a total of 300,000 profiles that together provide full global coverage of the ocean interior for the first time. Added to satellite data from the ocean surface, these profiles will underpin models of ocean behaviour and of climate. Profiles will cost around $100 each, which is comparable with the cost of XBT profiles. At present, funding for GODAE is mostly from space agencies, including NOAA, and now supports a GODAE Office in Melbourne.

GOOS is now part of an Integrated Global Observing Strategy (IGOS) involving the major space-based and *in situ* systems for global observations of the Earth in an integrated framework aimed at enabling better observations to be derived in a more cost-effective and more timely fashion by building on the strategies of existing international global observing programmes. The two main regional programmes of GOOS continue to be EuroGOOS in Europe, and NEAR-GOOS in the Northeast Asian region. Highlights for EuroGOOS include the attraction of 15 million ecus from the European Commission into pre-operational research projects to develop the skills and capabilities to implement GOOS; these projects include the Mediterranean Forecasting Project. Highlights for NEAR-GOOS include a doubling of its data holdings, a significant increase in contributors to NEAR-GOOS, and a significant increase in data exchange. New regional GOOS programmes with a coastal focus include MedGOOS, PacificGOOS, Black-Sea-GOOS, and CaribbeanGOOS. MedGOOS was initiated in November 1997, and its first substantial workshop is planned for Rabat, November 1999, to address the benefits and costs of implementing GOOS in the Mediterranean Sea. PacificGOOS was initiated in February 1998, and its first substantial workshop is planned for Noumea, in spring 2000, to initiate planning for long-term monitoring and observing in the region's coastal seas. The Black Sea Regional Committee of the IOC has launched a Black Sea GOOS pilot project. The Intra-American Seas Initiative meeting in Miami in October 1998, proposed developing Caribbean GOOS to maximise the efficiency of observations for understanding complex processes in the region. This challenge was subsequently addressed at the IOCARIBE meeting in April 1999, in association with a Caribbean GOOS Capacity Building Workshop, and IOCARIBE-GOOS was born there.

At the national level, many IOC Member States are now planning or collecting their own coastal observations following GOOS Principles. This is exciting news, as the implementation of GOOS at the national level will facilitate the essential integration of data from neighbouring states as GOOS develops. At an Initial GOOS Commitments Meeting in July in Paris, 17 of IOC's Member States offered concrete contributions to GOOS from within their national observing systems, as yet another mechanism for helping GOOS to grow. Design advice for the implementation of GOOS was published in the "Strategic Plan and Principles", and "The GOOS 1998, a Prospectus for GOOS". These documents help IOC Member States to appreciate the costs and benefits of GOOS, and to see how they may participate in it.

GOOS Panels

The Coastal Panel of GOOS is meeting twice a year with the aim of publishing a strategic plan and implementation design in the year 2000. The focus of the Coastal Panel of GOOS (or C-GOOS) is: to determine the major issues and needs identified by the user community; and to address those issues and meet those needs by designing an integrated, multi-disciplinary, coastal observing system for detecting and predicting change in coastal ecosystems and environments. The issues include such things as: eutrophication due to nutrient enrichment, toxic contamination, habitat loss, saltwater intrusion, flooding and storm surges, harmful algal blooms, sea level rise, and safe navigation.

The Living Marine Resources (LMR) Panel of GOOS held its first session in March 1998. The Panel agreed that systematic measurements are required of ecosystems and processes that affect them, in order to detect patterns and trends of living marine resources. The Panel tabulated the ecosystem components and conditions for which information is required as a function of time and space. It also identified the basic monitoring products that are required. The Panel agreed to undertake a series of retrospective experiments in areas where regime shifts have occurred, with the objective of determining to what extent ecosystem changes might have been predicted from the measurement programmes that were in place. The report on the first session of the Panel has been published as GOOS Report 54. At a subsequent meeting, the design for an LMR GOOS was refined, but it will not be complete until the year 2000.

The Ocean Observing Panel for Climate (OOPC) is responsible for the Climate Module of GOOS and the ocean component of GCOS. During 1998, the OOPC focussed on identifying the steps and fostering organizational structure that must be considered to convert design of an ocean observing system into reality. Both the satellite and *in situ* measurement technologies have been developing rapidly. The spectacular performance of the TOPEX/POSEIDON altimeter, the vastly improved global wind fields provided by the NSCATT scatteromer, and the increased lifetimes and reliability of profiling floats forced a revisit of the original observing system design for ocean climate published in the final report of the Ocean Observing System Development Panel in March of 1995. This exercise resulted in modification of several of that report's recommendations and priorities and provided the basis for a course of action to develop an OOPC Implementation Plan starting with sections for a Surface and Marine Data Sub-Programme, and for a special set of permanent moored surface reference sites.

GOOS is rapidly moving from planning to implementation. The demand for and momentum of GOOS are rapidly increasing. The balance now covers the full spectrum of user interests. IOC Member States are encouraged to implement GOOS as soon as possible, and to help to build the capacity of developing nations. Much of the development of GOOS will take place through regional initiatives. A new link is the one with ICES. Perhaps the time has come for dialogue with PICES about the mutual benefits that might come from a PICES-GOOS association.

For more information about GOOS, see the following web sites:
http://ioc.unesco.org/goos
http://www.soc.soton.ac.uk/OTHERS/EUROGOOS/
http://ioc.unesco.org/goos/neargoos.htm.
http://WWW.BoM.GOV.AU/bmrc/mrlr/nrs/oopc/godae/homepage.html (GODAE):
http://WWW.BoM.GOV.AU/bmrc/mrlr/nrs/oopc/godae/Argo_Design.html (ARGO)

PICES thanks Dr. Chang-Ik Zhang (Korea) for his service to PICES as Chairman of the Fishery Science Committee (FIS) since 1996. Dr. Zhang has led the Committee's activities, which included, among many things, the development of a Strategic Plan for FIS. He will continue to contribute to PICES as a member of FIS and Executive Committee of the CCCC Implementation Panel. At the same time, PICES welcomes Dr. Douglas E. Hay (Canada) as the new FIS Chairman and wishes him a successful term. Dr. Hay first appeared in PICES in 1994, as a member of the Working Group on Coastal Pelagic Fish (WG 3) and in 1997, he was appointed to the FIS Committee.

Dr. Chang-Ik Zhang received his B.Sc. (1976) and M.Sc. (1981) in fisheries biology from the Jeju National University and the National Fisheries University at Pusan respectively. He got his Ph.D. in fisheries ecology from the University of Washington in 1987. He is Professor and Chairman (since March 1, 1998) of the Department of Marine Production Management of the Pukyang National University, Pusan, Korea. His fields of interest are fisheries ecology, fish population dynamics and stock assessment, and fishery management. Dr. Zhang is the author of four books (1991, 1994, 1998 and 1999) in fisheries ecology and management, and the winner of the Most Significant Paper Award from the American Fisheries Society in 1991, and the Best Paper Award from the Korean Cooperation of Science and Technology in 1993, and from the Korean Fisheries Society in 1994. He is deeply involved in PICES activities, first as a member, and since 1996, as Chairman of FIS. Dr. Zhang also serves as a member of SCOR Working Group 105 on The Impact of World Fisheries Harvests on the Stability and Diversity of Marine Ecosystems.

Dr. Douglas E. Hay was spawned and incubated in Manitoba, and spent his juvenile rearing period in mountainous habitats of western Canada. Pre-recruitment years were characterized by prolonged schooling behaviour that was interrupted by a one-year migration to the Gulf of Alaska and Bering Sea as an observer for the International Pacific Halibut Commission. Then he began schooling again completing a B.Sc. in zoology at the University of British Columbia. This coincided, approximately, with the onset of sexual maturity and marriage. Short experimental migrations were made to work for the groundfish program at the Pacific Biological Station, followed by a period as assistant curator at the UBC Institute of Fisheries Museum. These activities preceded a second period of intense schooling behaviour at UBC, where he completed an MSc and Ph.D. in Zoology and lectured in the biology of fishes. With Ph.D. work nearly completed he spent a year grazing as a Visiting Professor at the University of Victoria. Then an intense spawning migration took him to the east to the University of Western Ontario as an Assistant Professor in zoology. There, successful spawning and incubation produced a little Hay. Several years later a second spawning migration took him to Halifax, Nova Scotia, to work for a large consulting firm in projects ranging from analyses of bycatch and impacts of proposed Liquified Natural Gas and nuclear plants. In Halifax he completed a second successful spawning and incubation of a second little Hay. Homing migration to western Canada was completed in 1977, when he joined the Pacific Biological Station as a research scientist. There he has worked on many aspects of the biology and assessment of Pacific herring, including a variety of tasks concerned with the early life history, habitat impacts, trophic biology and juvenile rearing behaviour of herring, smelts and little Hays.

PICES Ninth Annual Meeting

October 20-28, 2000
Hakodate, Hokkaido, Japan

Subarctic Gyre processes and their interaction with coastal and transition zones: physical and biological relationships and ecosystem impacts. (Science Board Symposium)

Prey consumption by higher trophic level predators in PICES regions: implications for ecosystem studies. (BIO Session)

Recent progress in zooplankton ecology in PICES regions. (BIO/CCCC Session)

Short life-span squid and fish as keystone species in North Pacific marine ecosystems. (FIS Session)

Large-scale circulation in the North Pacific. (POC Session)

North Pacific carbon cycling and ecosystem dynamics. (POC/BIO Session)

Recent findings and comparisons of GLOBEC and GLOBEC-like programs in the North Pacific. (CCCC Session)

Environmental assessment of Vancouver Harbour: results of an International Workshop. (MEQ Session)

Science and technology for environmentally sustainable mariculture in coastal areas. (MEQ Session)

Progress in monitoring the North Pacific. (MONITOR Workshop)

Trends in herring populations and trophodynamics. (REX Workshop)

Strategies for coupling higher and lower trophic level marine ecosystem models. (MODEL Workshop)

Development of a conceptual model of the Subarctic Pacific Basin Ecosystem(s). (BASS Workshop)

The basis for estimating the abundance of marine birds and mammals, and the impact of their predation on other organisms. (BIO/MBMAP Workshop)

North Pacific CO_2 data synthesis. (Symposium/Workshop) (Oct. 18-21, 2000, Tsukuba, co-sponsored by PICES and JST/CREST)

Designing the iron fertilization experiment in the Subarctic Pacific. (IFEP Workshop) (Oct. 19-20, 2000, Abiko, co-sponsored by PICES and CRIEPI)

PICES Secretariat News

Congratulations to Dr. Stewart (Skip) M. McKinnell who has been selected as the new Assistant Executive Secretary of PICES, effective September 7, 1999.

The latest Secretariat family photo: (from left to right) Skip McKinnell (Assistant Executive Secretary), Christina Chiu (Administrative Assistant), Christie McAlister (Secretary), Alexander Bychkov (Executive Secretary). This photo was taken in November 1999, outside the Secretariat office at the Institute of Ocean Sciences, Sidney, Canada.

PICES Publications in 1999

Dynamics of the Bering Sea: A summary of the physical, chemical, and biological characteristics, and a synopsis of research on the Bering Sea (Eds. Loughlin, T. R. and Ohtani, K.) Alaska Sea Grant, AK-SG-99-03, Fairbanks, 838 pp.

Ecosystem Dynamics in the Eastern and Western Gyres of the Subarctic Pacific (Guest eds. Beamish, R. J., Kim, S., Terazaki, M., and Wooster, W. S.). Progress in Oceanography 43:(2-4).

PICES Scientific Report No. 10. Proceedings of the 1998 Science Board Symposium on the Impacts of the 1997/98 El Niño Event on the North Pacific Ocean and its Marginal Seas, 131 pp.

PICES Scientific Report No. 11. PICES-GLOBEC International Program on Climate Change and Carrying Capacity: Summary of the 1998 MODEL, MONITOR and REX Workshops and Task Team Reports, 88 pp.

PICES Scientific Report No. 12. Proceedings of the Second PICES Workshop on the Okhotsk Sea and Adjacent Areas, 203 pp.

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