Climate, biodiversity and ecosystems of the North Pacific

The land of Aloha welcomed over 60 participants to the workshop on the "Impact of Climate Variability on Observation and Prediction of Ecosystem and Biodiversity Changes in the North Pacific". This workshop was jointly sponsored by PICES, the International Pacific Research Center (IPRC) based in Honolulu, and the Census of Marine Life (CoML), and was held March 7-9, 2001, in Honolulu. The organizers were Vera Alexander (PICES Vice-Chairman) and Patricia Livingston (PICES Science Board Chairman). Attendees included many members of PICES Committees, Working Groups, Advisory Panels, and the PICES-GLOBEC Climate Change and Carrying Capacity Program, in addition to other members of the North Pacific marine scientific community. Representatives of many marine organizations participated, including those from CLIVAR, CoML, DBCP, GEM, GOOS, IATTC, IPHC, IPRC, and POGO.

The Census of Marine Life seeks to answer the broad question of what did live, what does live, and what will live in the oceans. This goal complements the PICES objective of advancing scientific knowledge about the ocean environment, weather and climate change, living resources and their ecosystem,s and the impacts of human activities. In order to understand past, present, and future biodiversity, we need to understand and predict climate influences on marine ecosystems.

This workshop was a first step in reviewing the goals and strategies for observing North Pacific marine ecosystems and their biodiversity in order to improve our ability to predict ecosystem change. Participants described time series that are presently available for all parts of North Pacific ecosystems, including: 1) physical/chemical oceanography and climate, 2) phytoplankton, zooplankton, micronekton and benthos, 3) fish, squid, crabs and shrimps, and 4) migratory fish, bird, and mammals. Presentations also included discussion of possible factors responsible for observed trends in the data. Predictive and explanatory models (from purely physical to coupled biophysical models) were also presented.

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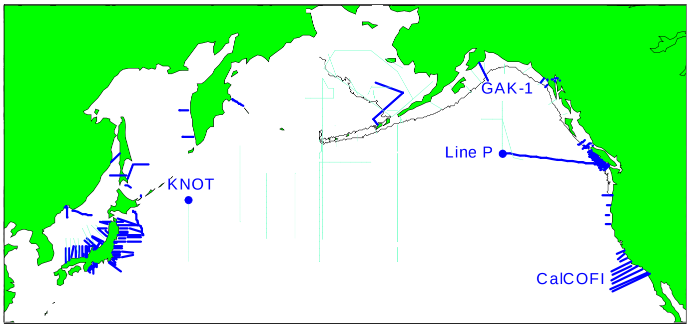

Fig. 1 All locations that are sampled at least once per year. Those sampled more frequently than once per year appear in dark blue.

Many examples of change in animal distribution, abundance, or survival in relationship to local climatic factors such as temperature or transport, or to large-scale regional climate indices were shown. It was evident from maps of where data had been collected in the North Pacific Ocean that the open ocean is less well-sampled than the shelf regions for all types of physical, chemical and biological observations (Fig. 1). For lower trophic level species such as phytoplankton and zooplankton, it appears that one of the biggest gaps was taxonomic analysis and methods for standardization/inter-comparison of sampling gears. Recommendations were made for candidate indicator species and sensitive measures of change for higher trophic level species such as fish, squid, mammals and birds. It was noted that reproductive success is one of the most sensitive indicators for these groups.

One of the main purposes of the workshop was to facilitate the compilation of data and knowledge of the status and trends of North Pacific ecosystem components into a North Pacific Ecosystem Status Report. This concept was brought to the attention of the PICES scientific community and Governing Council at the PICES Ninth Annual Meeting. A study group is now using the results and recommendations from this workshop to refine the concept and to determine how to compile such a report. The purpose of the North Pacific Ecosystem Status Report is to integrate our collective scientific knowledge of the North Pacific and its changes, and to inform the scientific community and policy- and decision-makers in the North Pacific region of ecosystem changes and the factors influencing change. Ultimately, the goal is to provide predictions of change that can be used to move towards ecosystem-based marine policy- and decision-making.

Workshop recommendations mostly dealt with the steps to be taken to produce a North Pacific Ecosystem Status Report. Many recommendations made in each of the breakout group discussions were specific to each particular group. However, some of the recommendations that were discussed in the closing plenary session covered all disciplines. One main recommendation was to include all the information regarding time series data that was identified at the workshop into the North Pacific Ecosystem Meta-database, presently maintained by U.S. researchers Allen Macklin and Bernard Megrey. The meta-database contains information about the data, but does not include the data. Compiling information on existing time series data will be very useful when structuring the North Pacific Ecosystem Status Report.

Participants recognized the need for PICES member nations to pool observational resources to provide a complete sampling program in the open ocean areas of the North Pacific. It was also recommended that PICES make formal connections with programs that are planning coordinated, technologically-advanced observation and communication systems, such as the NEPTUNE underwater observatory for the northeast Pacific. A variety of technological advancements in monitoring efforts from physics to upper-trophic level species were recommended as pilot projects for PICES scientists and groups to consider in the near future. These included putting instruments on ships-of-opportunity, putting biological sensors on buoys, improving sampling methodology for small pelagic fishes, and video monitoring of birds and mammals on continuous plankton recorder cruises.

The concept of Regional Analysis Centers (RACs) was discussed as a way for PICES to focus the work involved in producing a North Pacific Ecosystem Status Report. Two ways of viewing these centers were mentioned. One type of RAC would be an actual geographic location and building with staff assigned to it. Another type would be more of a "virtual" RAC that would rely heavily on a distributed network of scientists to contribute to the work. It seemed clear from the organization examples mentioned in discussion, that even a "virtual" RAC would still need some central support to accomplish the task.

The full report of this workshop is being compiled and is scheduled for publication before the PICES Tenth Anniversary Meeting. The North Pacific Ecosystem Status Report and Regional Analysis Center Study Group, formed by PICES in 2000, will be considering the recommendations and discussions of this workshop in order: (1) to prepare a detailed outline for the first Status Report, (2) to identify of key contributors and data sources and how the data would be synthesized into the report, (3) to estimate costs, and 4) to evaluate possible role of RACs, for consideration by the PICES scientific community. Hopefully, work can begin on compiling the North Pacific Ecosystem Status Report after PICES X.

The report was prepared by **Patricia Livingston** (Pat.Livingston@noaa.gov), Chairman of the PICES Science Board and co-convenor of the 2001 Census of Marine Life workshop in Honolulu.

The state of the western North Pacific in the second half of 2000

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Mr. Satoshi Sugimoto is a Scientific Officer 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 monthly by JMA. 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 July to December 2000, computed with respect to JMA's 1961-90 climatology. Satellite-derived SSTs (NOAA/AVHRR) as well as *in situ* observations were used for the area between 20°N and 50°N from 120°E to 160°E, and *in situ* observations are used in the other regions.

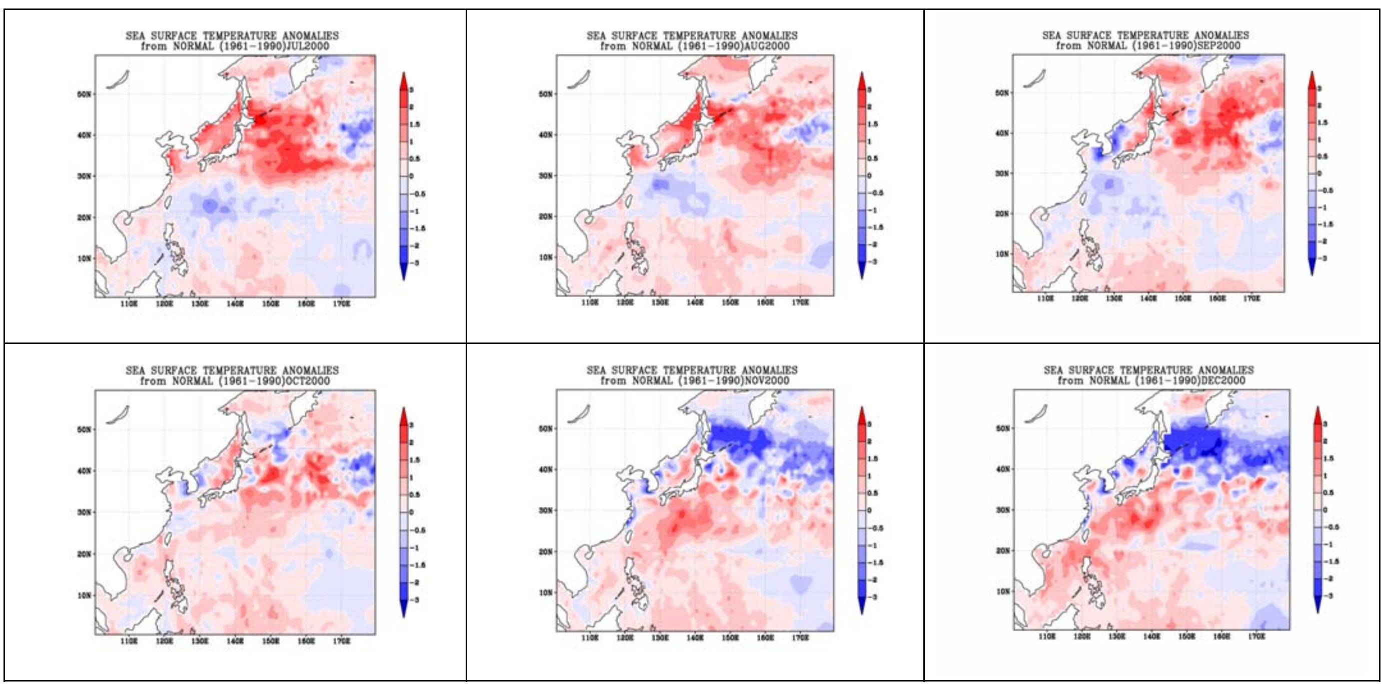


Fig. 1 Monthly mean sea surface temperature anomalies (°C) – July-September, 2000 (top row), and October-December (bottom row). Anomalies are departures from JMA's 1961-1990 climatology.

Figure 2 shows 10-day mean SST anomaly time series for the nine regions indicated below. Positive SST anomalies prevailed between 30°N and 50°N west of 170°E from July to October. After November, negative SST anomalies prevailed between 40°N and 50°N east of Japan, and positive anomalies prevailed south of Japan (Fig. 1). The SST anomaly for region 2 dropped from above +2°C in July to below –1°C in December (Fig. 2). In the equatorial Pacific, positive anomalies prevailed west of 170°E throughout the period.

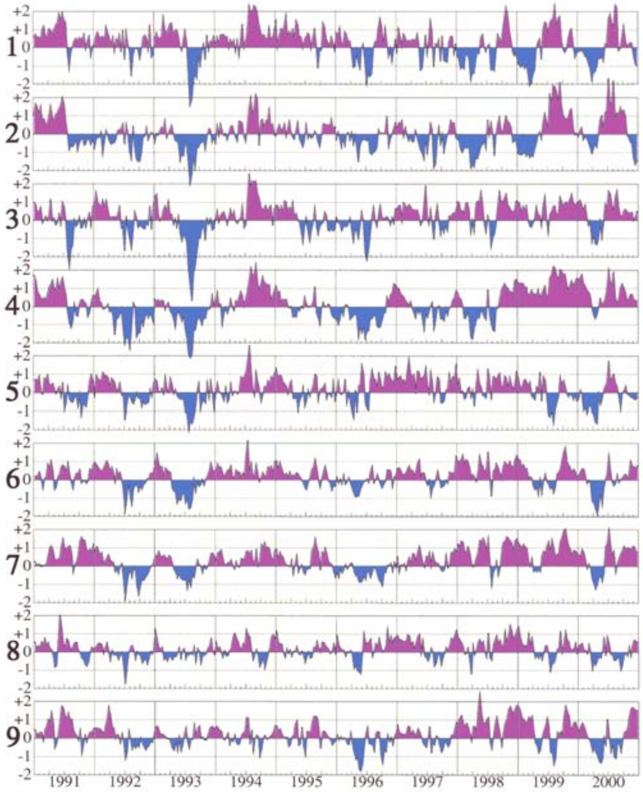
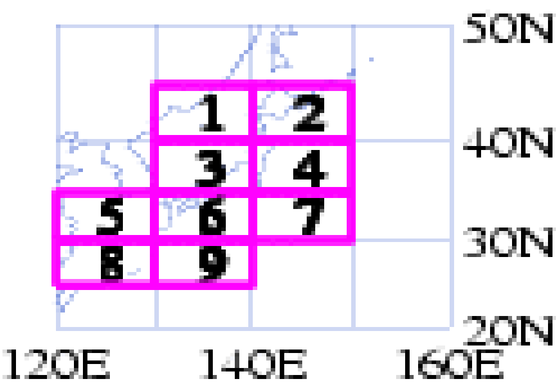


Fig. 2 Time series of the ten-day mean sea surface temperature anomalies (°C), computed from JMA's 1961-1990 climatology for the areas shown below.



Kuroshio and Oyashio

The Kuroshio meandered south of Japan throughout the period, shifting its path to and fro. The southernmost position of the meander was south of 32°N from the first 10-day period in August to the first 10-day period in October, and after the second 10-day period of December (Fig. 3).

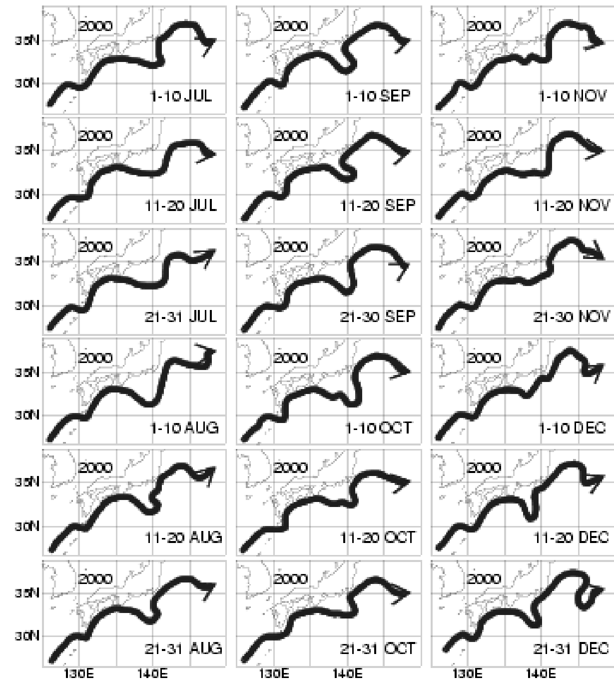


Fig. 3 Location of the Kuroshio axis from July to December 2000.

Subsurface temperature

Figure 4 shows temperature distributions at 100 m depth east of Japan for August and November 2000. These charts are based on JMA's objective 100 m water temperature analysis using a 0.25x0.25 grid points, based on *in situ* observations from ships and buoys. East of Japan, there was a warm eddy near 38.5°N, 144°E throughout the period. The Oyashio flowed southward east of the eddy before October, and the coastal branch of the Oyashio cold water was blocked by the eddy. In November, the Oyashio cold water was found just north of 40°N, reflecting its seasonal variation.

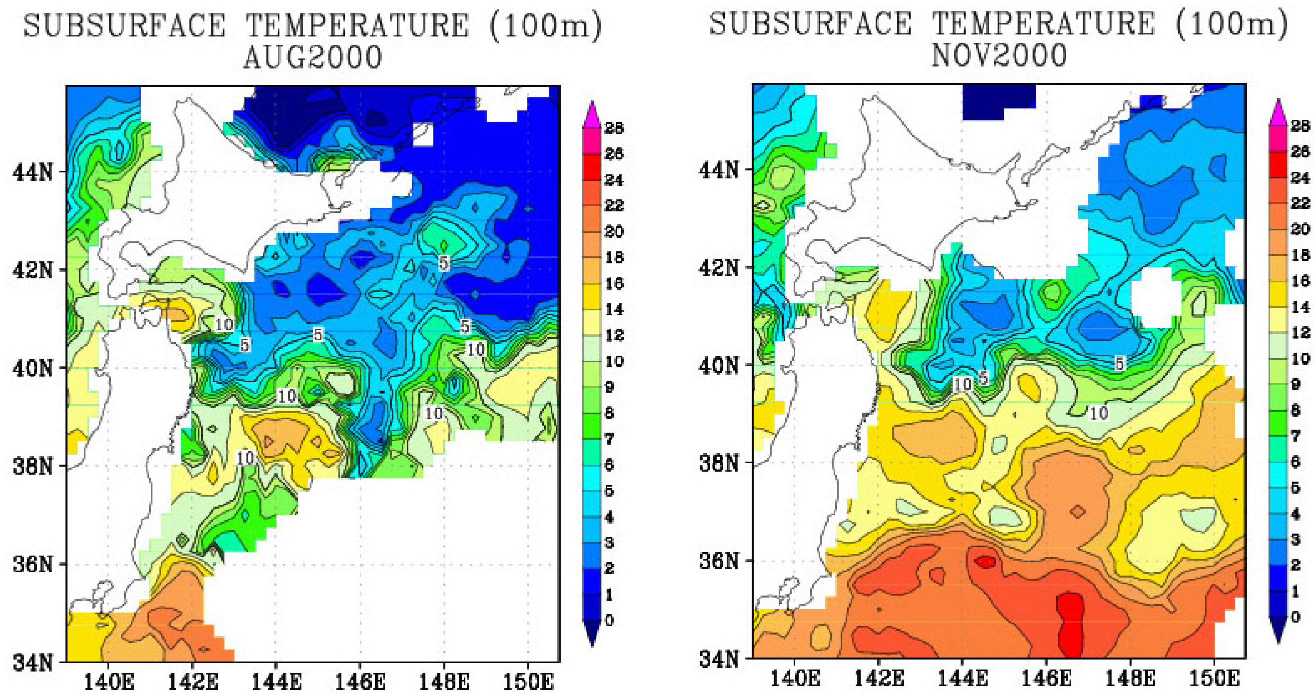


Fig. 4 *Temperature (°C) at the depth of 100 m east of Japan for August 2000 (left) and November 2000 (right).*

Carbon dioxide

JMA observed the distribution of carbon dioxide concentration (partial pressure, pCO_2 in the western North Pacific on board the R/V *Ryofu Maru* from September to November 2000. Figure 5 shows the distribution of the difference (ΔpCO_2) in pCO_2 between the surface water and the overlying atmosphere. One of the most remarkable features of this observation is that large ΔpCO_2 values of 25-66 μatm were observed in the equatorial region (156-165°E), similar to those under La Niña conditions in October 1998 and October 1999. It is considered that CO_2-rich water had been supplied to the surface due to upwelling, since the subsurface dissolved inorganic carbon concentrations in the region were also similar to those during 1998 and 1999 La Niña events.

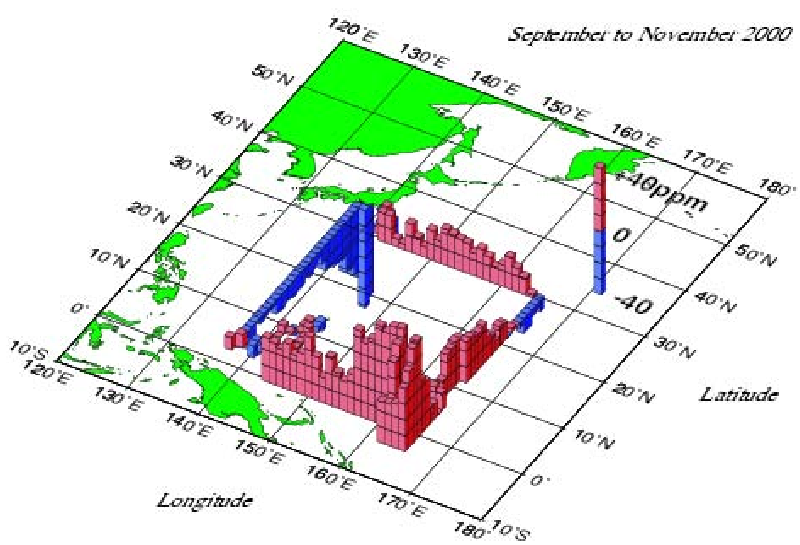


Fig. 5 *Difference in pCO_2 between the surface water and the atmosphere in September and November 2000. Red upward pillars indicate the emission of CO_2 from the ocean and blue downward pillars indicated atmospheric CO_2 absorption by the ocean.*

The status of the Bering Sea: June – December 2000

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Dr. Phyllis J. Stabeno, a physical oceanographer at the Pacific Marine Environmental Laboratory (PMEL) of NOAA, conducts research focused 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 focuses 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 collected at a single site (Site 2: 56.9°N, 164°W) over the middle shelf reveal the great year-to-year variability that characterizes the Bering Sea. This site has been occupied nearly continuously since 1995, for collecting time series of temperature, salinity, currents and fluorescence. In contrast to the warmer than normal sea surface temperatures (SST) during July and August of 1997 and 1998, SSTs during 1999 and 2000 were colder than normal (Fig. 1). In mid-August 2000, the average temperature of the water column was approximately 1° colder than in 1998, and only slightly warmer than that observed in the other four years. Depth-averaged temperatures in the fall of 2000, however, were markedly warmer than those observed in other years. During October, the average temperature of the water column was ~5°C, slightly warmer than the temperature observed in 1998. During the next two months of 2000, the water column cooled only slightly resulting in unusually warm water at Site 2. Examination of large-scale maps shows a positive SST anomaly over the whole eastern shelf of 0-2°C during December 2000. These warmer temperatures resulted from a combination of horizontal advection and atmospheric conditions.

During the summer, Site 2 at the center of the middle shelf is largely isolated from the rest of the shelf by a series of fronts. In the fall, the fronts begin to break down and cross shelf advection can modify the water column. Some evidence of increased cross shelf flow in the fall of 2000 exists from the mooring data. However, the limited number of moorings and satellite-tracked drifters deployed in 2000 makes the interpretation of the data difficult. The Bering Slope Current (BSC), which flows to the northwest along the Bering Sea shelf break, does not appear to be related to abnormally warm temperatures observed over the shelf. Transport in the BSC undergoes long-term variability. The largest observed transport was during 1997 (>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. In August 2000, the transport was average (~4 x 10^6 m^3 s^{-1}).

A clearer picture of the causes of warm ocean temperatures can be found in the atmospheric data. Air-sea interactions in the Bering Sea during the latter part of 2000 were dominated by effects associated with an unusually strong and northward-displaced Aleutian low. This represented a marked change from the summer, in which the sea level pressure (SLP) averaged about 2 mb greater than normal in the southeastern Bering Sea. The SLP anomaly map for October through December 2000 features a negative center of 10 mb in the central Bering Sea (Fig. 2). The SLP was especially low (anomalies of ~14 mb) in November and December. The consequences of these pressure anomalies for the Bering Sea included anomalous winds of 2-3 m s^{-1} from the south over the shelf in its eastern portion, and anomalous winds from the north off the Kamchatka Peninsula. The anomalous winds in the northern Bering

Sea blew from the east, and were substantially warmer than normal. These warmer than normal temperatures can also be attributed to the anomalous SLP. The mean SLP over the central Bering Sea was low because of the relatively frequent presence of cyclonic storms. These storms tend to originate well to the southwest off the east coast of Asia, and are associated with a net poleward flux of warmer air at low-levels. To a large extent, the warm December conditions observed over the northern Bering Sea resulted of the preponderance of maritime air masses originating from lower latitudes, rather than because of local wind anomalies. It is interesting to note that the SLP anomalies during the last part of 2000 are characteristic of those that tend to occur during El Niños, even though weak La Niña conditions were prevailing in the tropical Pacific.

The unusual atmospheric conditions in the fall of 2000 directly impacted the formation of sea ice over the shelf. Usually, cold winds out of the northeast freeze the seawater and advect the resulting ice southwestward across the shelf. Usually by December, much of the northern shelf is ice-covered. At the end of December 2000, however, the northern Bering Sea shelf was largely ice-free.

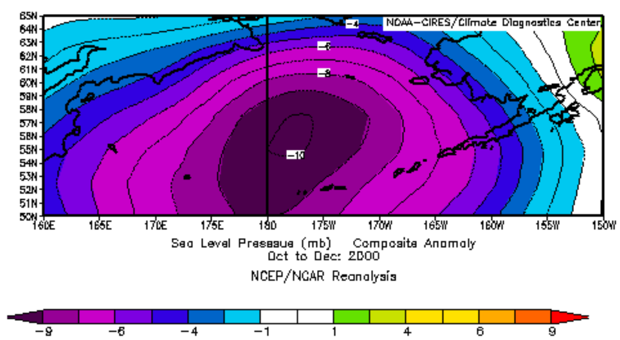

Fig. 1 Sea level pressure anomaly for October-December 2000 from the NCEP Reanalysis. Data provided by NOAA's Climate Diagnostic Center.

A series of major coccolithophore blooms have appeared over the eastern Bering Sea shelf during the last four years. 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 eastern Bering Sea shelf in 1997. During the first three years, the bloom appeared by early July, and typically reached its maximum extent in the early fall. During 2000, scientists on cruises began looking for the bloom in early July. A cruise in mid-July, sampling over the southern shelf, failed to find it. Two weeks later, however, it was observed over the middle shelf. Typically, the core of the coccolithophore blooms covers the shelf southwest of Nunivak Island. The northern and western extent, however, appear to vary each year. For example, in 1998 and 1999, the bloom was visible as far north as Bering Strait and into the Chukchi Sea. In 2000, the bloom occupied the region to the south and southwest of St. Lawrence Island and was not evident in Bering Strait. The variability in the position of the bloom is likely related to currents.

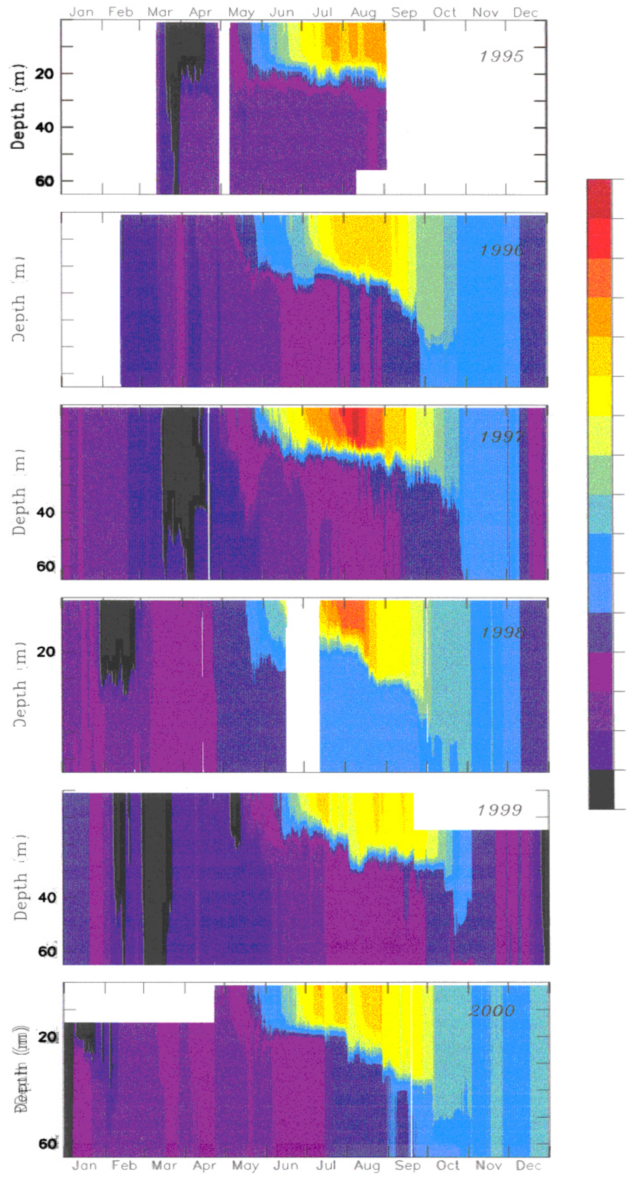

Fig. 2 Contours of temperature measured at the series of moorings deployed at Site 2 (56.9°N, 164°W). Vertical separation of temperature sensors was 3 m in the upper ~30 m and ~5-7 m in the bottom 40 m of the water column.

In general, major changes have occurred in the Bering Sea during the last decade. Presently there is evidence of an earlier transition from winter to spring. This has been evident in a more rapid retreat of the sea ice in the 1990s than previous decades, and also in an increase in the average April temperatures at 850 hPa of 3°C. Warmer conditions in spring, or delayed cooling in the fall, as was seen in 2000, could have significant impacts on the Bering Sea ecosystem.

The state of the eastern North Pacific since autumn 2000

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The southern oscillation index turned persistently positive towards the end of 2000 but has now returned to normal (Fig. 1). This pattern was quite well forecast by a variety of climate models, and these all indicate that conditions in the equatorial Pacific should remain close to normal for most of the remainder of 2001. Some models indicate that a warm episode might develop towards the end of 2001. NASA issued a warning about that possibility recently, this can be seen on the world wide web at: http://science.nasa.gov/headlines/y2001/ast06mar_1.htm?list43949.

It is much too early to suggest that this might indicate a possible 2001/02 El Niño event. The southern oscillation index is only one of the indices of climate variability in the equatorial Pacific, sea surface temperatures should also be examined. Observations in the TOGA/TAO array (http://www.pmel.noaa.gov/tao/index.shtml) indicate that surface temperatures are close to normal along most of the equatorial regions, and that subsurface temperatures are also close to normal.

Within the Gulf of Alaska, the winter of 2000/01 was dominated by a mid-Pacific warm anomaly that has been stationary since the fall of 2000 (Fig. 2). There was no sign of any significant warm anomaly appearing at the coast of N. America during the winter except for a significant warm event in Bristol Bay.

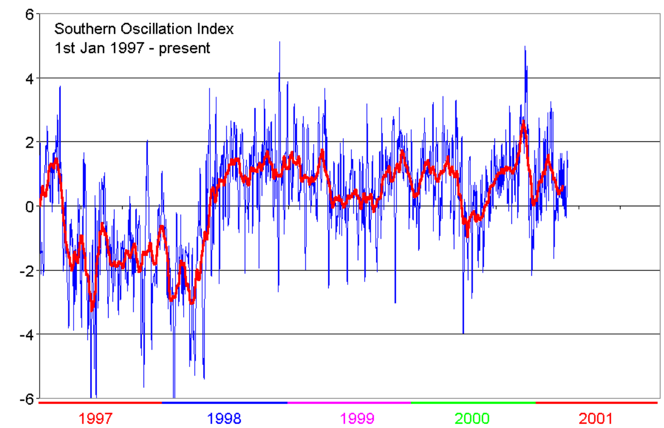

Fig. 1 Daily values of the Southern Oscillation Index (blue) and 31-day running mean (red) from January 1st 1997 to December 2001.

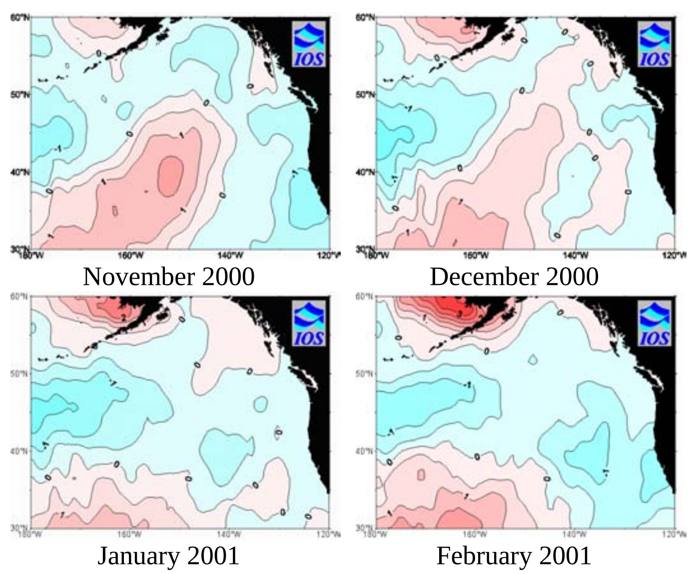

Fig. 2 Sea surface temperature anomalies in the Gulf of Alaska from fall 2000 to spring 2001. Contour interval is 0.5°C.

Korean Yellow Sea Large Marine Ecosystem Program

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The Yellow Sea is known as one of the most heavily exploited seas in the world. There are many signs that the Yellow Sea ecosystem is indeed pushed beyond its capacity in many respects. To mitigate the situation, the governments of the Republic of Korea and the People's Republic of China, with help of the United States National Oceanic and Atmospheric Administration have been seeking the financial support of the Global Environment Facility (GEF). The LME (Large Marine Ecosystem) concept was adopted as the basis of scientific efforts.

The Korean government initiated the YSLME (Yellow Sea LME) program three years ago as a pilot project for a full-fledged LME/GEF project. This project was originally conceived to run along with the GEF project. However, as the GEF project was delayed, the pilot project was conducted alone. Although the Korean YSLME program was rather limited in its scope and scale, it would still provide valuable information and experience for the future implementation of the GEF project.

Over the last three years, two cruises conducted productivity and plankton surveys and four cruises conducted trawl, hydroacoustic and pollution surveys. Coverage of these surveys was confined to the EEZ of the Republic Korea, which is roughly the east of 124°E. Below is a brief description of some major findings from these efforts.

Primary productivity

Although primary productivity is one of the fundamental properties of a marine ecosystem, that of the Yellow Sea is still uncertain on the whole since it is known to vary in a range of 11.78 - 2,694 C m^{-2} d^{-1} depending on time and space. To cope with this two-order of magnitude variability, comprehensive strategies are required.

An exercise of making maps of water column primary production using the information we have now clearly demonstrates what we need know. Estimated average daily primary production shown in Figure 1 is an example based on assumptions such as uniform surface chlorophyll values of 0.5 mg m^{-3} and homogeneous vertical structure of chlorophyll-*a*. For K(PAR), we derived an empirical relationship between Secchi depth and SeaWiFS nLw(555), then we recalculated K(PAR) from this.

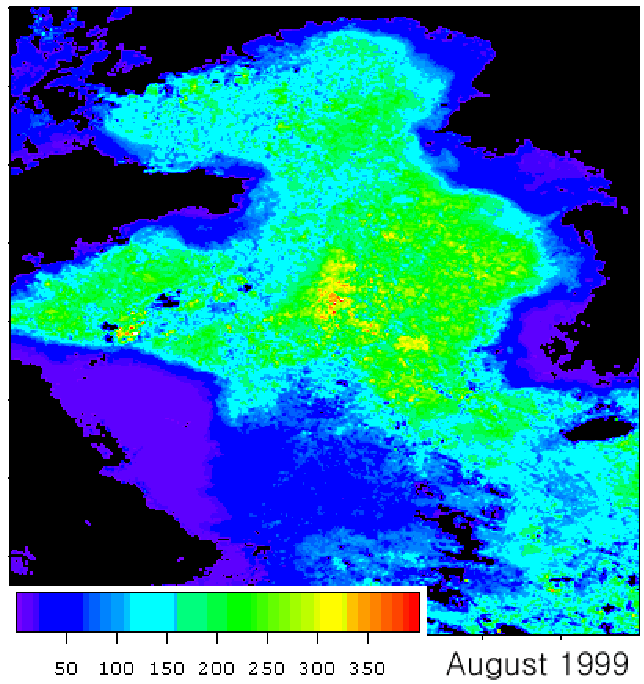

Fig. 1 Estimated average daily primary production (units: mg C m^{-2} d^{-1}) in August 1999. Monthly composite SeaWiFS data were used to calculate diffuse attenuation coefficient. Chlorophyll concentration was assumed 0.5 mg m^{-3} everywhere and vertically homogeneous.

Using the K(PAR) map and representative values of photosynthetic parameters measured during the last few years, we calculated daily water column primary production. The fact that the central open ocean region has higher productivity is unexpected, although it is logical. The pattern reflects the distribution of turbidity in the Yellow Sea. For a complete picture, more studies must be made, and first of all, we need to develop operational case 2 algorithms to retrieve chlorophyll concentration and diffuse attenuation coefficient of PAR. Such algorithms could also reveal active phytoplankton growth along the tidal front.

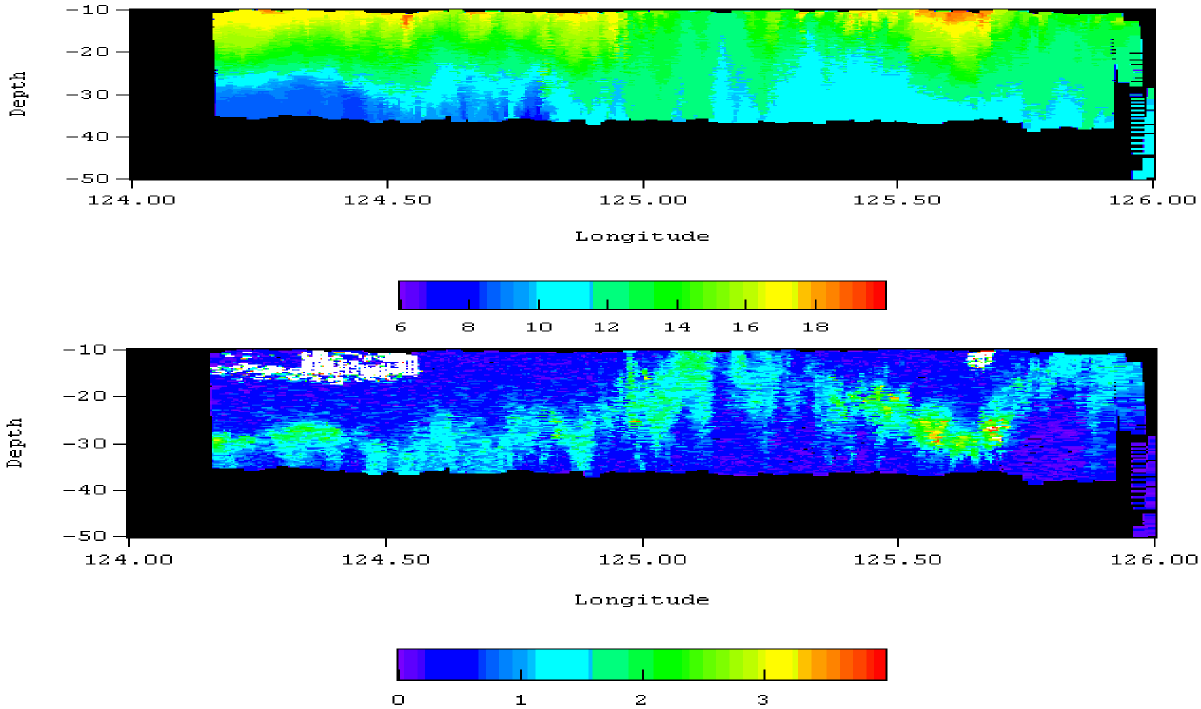

Fig. 2 Latitudinal cross-section of temperature (upper panel) and chlorophyll fluorescence (lower panel) along 34ºN.

Undulating towed body data revealed complex vertical structure in temperature and chlorophyll fluorescence (Fig. 2). The Yellow Sea Cold Water and Jeju Warm Current can be identified. A towed body survey in March showed that early blooms can occur in the frontal zone between Yellow Sea central water and the low salinity coastal water. In much of the coastal zone, water is vertically mixed permanently and turbidity is very high due to strong tides. Productivity in the tidally mixed zone and front zone needs further investigation.

Fish resources

To determine the distribution and migratory routes of some commercially important fish species, bottom trawl and acoustic surveys were conducted. The first survey was conducted in October 1998 as a pilot survey. The second and third surveys were conducted in May and August, 1999. During the May survey, trawls with accompanying hydroacoustic measurements were made at a total of 22 locations, with intervals of ~30 km, covering the region 33°N – 37°N and 124°E – 126°E. The last survey was conducted from April 10 to May 4 in 2000. Trawl tows with hydroacoustic measurements were made at a total of 26 locations.

About 100 fish species were collected during the four surveys. Based on the standardized comparison, average catches were 284, 23, 73 and 21 kg km^{-2} for the first to the fourth survey, respectively. Twenty-one

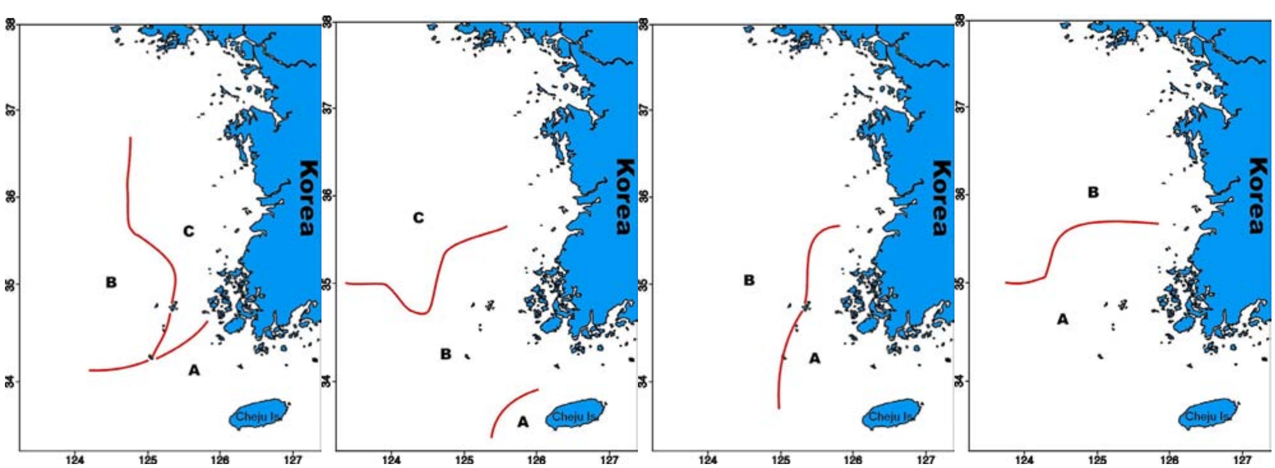

Fig. 3 Results of cluster analysis for the trawl locations and selected bottom fishes. Left to right: October 1998, May 1999, August 1999, and April 2000.

species composed the top five abundance categories either by number or by weight, which comprised 50 – 90% of the total quantity. Cluster analysis of trawl locations based on selected bottom fishes showed seasonal variation (Fig. 3). Similar patterns occurred in the springs of two different years. The October 1998 survey showed two groups: inshore (area A) and offshore (area B) consisting of four locations each. During August 1999, 19 survey locations were grouped into two clusters, 3 (area A) versus 16 (area B) with a total of 16 and 20 demersal fishes, respectively.

The distribution of backscattering coefficient, S_A, typically shows higher values in the southern part of the basin. The S_A distribution (at 38 kHz) is shown in Figure 4. High densities were observed along the west side of Jeju Island. In the other areas density was very low. In the case of the 120kHz, high densities were observed not only along the west coast of Jeju Island but also along the west coast of Heuksan Island.

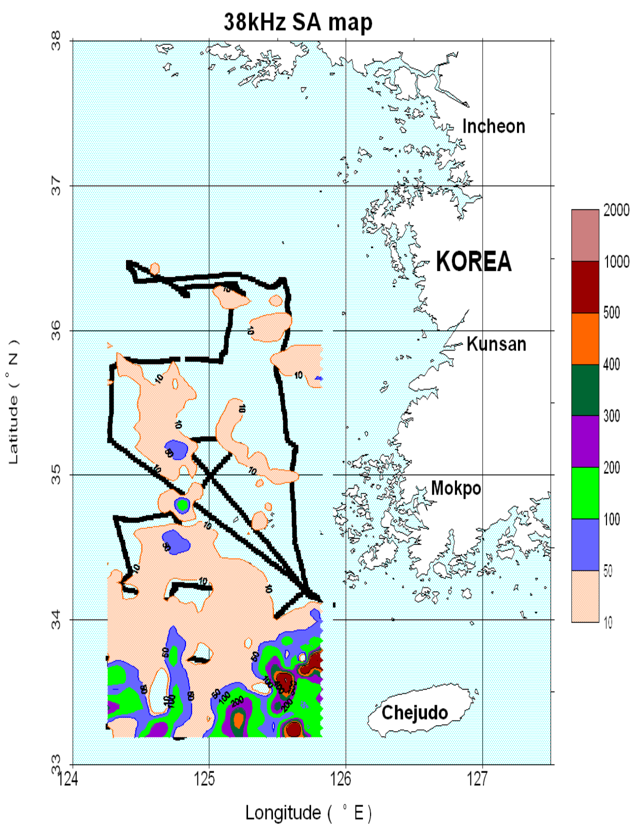

Fig. 4 Acoustic survey transects and S_A *in April 2000.*

Pollution survey

Yellow Sea surface sediments and fish samples were analyzed for a suite of: organochlorine contaminants, including pesticides and polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). PAHs in surface seawater were also analyzed. Most of the organochlorine compounds were not detected from the sediment samples. Only lindane, δ-HCH, total DDTs (TDDTs), and total PCBs (TPCBs) were consistently found in measurable amounts. Even these concentrations are much lower than the values believed to cause any biological effects.

Organochlorine contaminants were consistently found in fish. Total PCBs were generally more concentrated in tissue than liver. Total organochlorine pesticides were also generally a little more concentrated in tissue than liver, whereas total DDTs showed rather similar concentrations. Concentrations of total polycyclic aromatic hydrocarbons in the sediments ranged from 6.0 to 111.7 ng/g dry weight. Content of high molecular weight PAHs was about two times higher than that of low molecular weight PAHs. Total PAHs were more concentrated in liver than tissue. Low molecular weight PAHs consisted of more than 90% of total PAHs in tissue and liver (96% and 95%). Concentrations of total polycyclic aromatic hydrocarbons in the seawater ranged from 144 ng/L to 819 ng/L. All target PAHs were detected in all samples. Content of low molecular weight PAHs was about three times higher than that of high molecular weight PAHs.

Heavy metals were analyzed in a similar manner. The highest concentrations of heavy metals in the surface waters were found in the northern and/or eastern part of the Yellow Sea, whereas the lowest concentrations were distributed in the southern and/or western part of this study area. Close relationships among Cu, Ni and Cd were revealed in the surface water. The metal contents in the sediments were high in the central Yellow Sea. The relationships between metals except for Pb were fairly good. The highest EF values of Pb occurred in the northeastern part of the study area and the EF distribution of Pb differed from other metals. Most of the metal levels in the surface sediments were lower than ER-L.

The average concentrations of Zn, Cr and Cu in fish muscle tissues were relatively higher than those of other metals and the order of average concentration of metals was Zn>Cr>Cu>Ni>Hg>Co>Pb>Cd. Concentrations of heavy metals in fish from the Yellow Sea were relatively low and the metal concentrations were also lower than the criteria set by Europe or Korea. For *Pseudosciaena crocea*, the correlation coefficients between Cu, Cd and Hg versus body length were 0.450, 0.405 and 0.653 respectively and the value between Hg and body weight was also high (R= 0.762). The order of mean accumulation factors of heavy metals between fish (two species) and seawater was Hg>Zn>Co>Cr>Cu>Pb> Ni>Cd

GIS Database

The Marine Geographic Information System (GIS) database was implemented to store, analyze and visualize the oceanographic data collected (Fig. 5). Coastlines and depth data in the Yellow Sea were then built into a GIS spatial database, and oceanographic data were built into a GIS attribute database.

The GIS database development tools were used with ESRI ArcView/ArcInfo GIS and MS Access database. The attribute database was designed in relation to real data and metadata. Real data are digital data obtained in the YSLME oceanographic surveys whereas metadata are the information that describe the real data. The point and grid themes from the attribute data were created using ArcView GIS, and the topology of spatial data was built using ArcInfo GIS. Using ArcView GIS, the creation of thematic maps and three-dimensional visualizations were accomplished. Also, spatial and statistical analysis functions were included for query and data modeling (Fig. 6). Through the construction of YSLME GIS database, it is possible to systematically manage oceanographic data and information. Ultimately, the YSLME GIS database will help the decision process for the conservation and development of marine environment as well as planning for the future marine research.

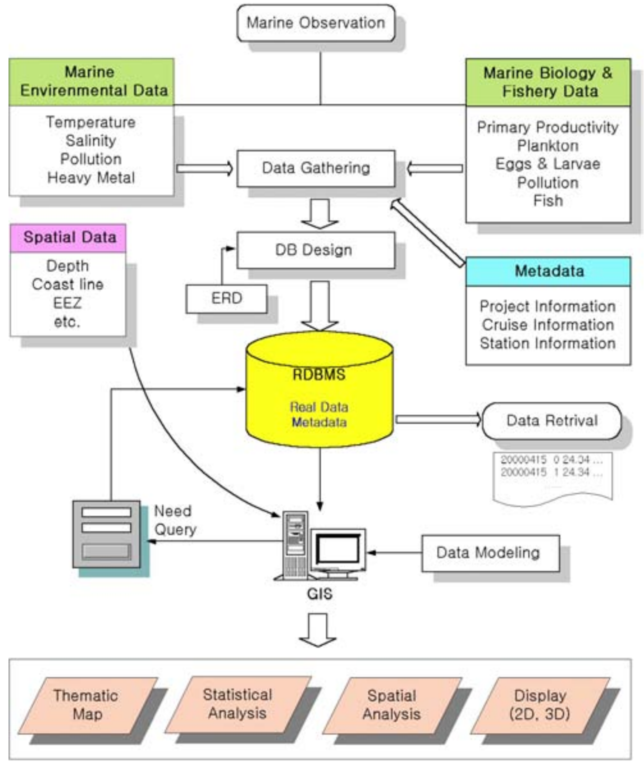

Fig. 5 Overview of the YSLME GIS database development procedures.

Future directions

The YSLME/GEF project was approved by the GEF Council in May 2000. In this program, South Korea, North Korea, and China will participate. Survey area will cover the whole Yellow Sea except for territorial seas of each nation. The range of investigation themes will also be broadened. Not only will scientific surveys be made but economics and legislative aspects will also be studied for better management of the YS ecosystem.

While sampling strategies will be improved based on our experience with the Korean YSLME program, some of the conceptual/methodological issues have to be resolved in the future. Among other things, linking and synthesis of different ecosystem properties are of fundamental importance. After all, LME is an ecosystem-based approach and requires an integrated analysis.

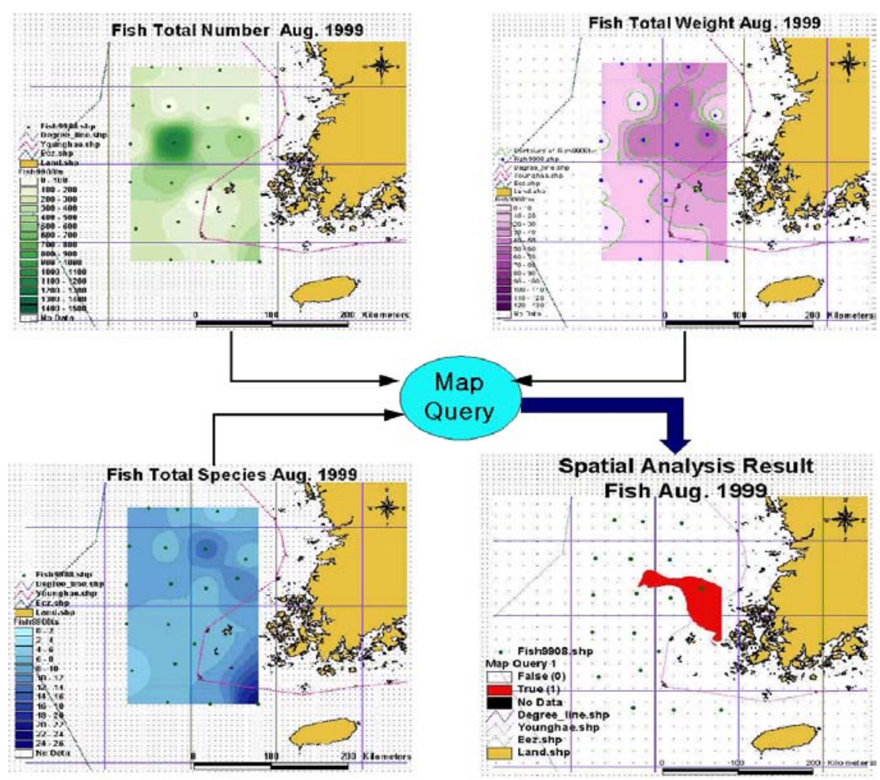

Fig. 6 An example of spatial analysis of fish data using LME GIS.

Past and on-going Mexican ecosystem research in the northeast Pacific Ocean

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Daniel Lluch-Belda is a biologist with a DS degree at the Instituto Politecnico Nacional, Mexico. He has worked at the Instituto Nacional de la Pesca (1963-1977), the Centro Interdisciplinario de Ciencias Marinas del IPN (1978-1984 and 1997-to date) and the Centro de Investigaciones Biológicas del Noroeste, SC (1984-1996). His main subjects of research have been marine mammals, shrimp fisheries, small pelagic fishes and the effect of climate change on marine resources.

Northwestern Mexico conforms the southern limits of the northeast Pacific Ocean along an extensive ecotone between the temperate California Current System and the tropical North Equatorial Countercurrent birthplace. The very peculiar extension and position of the Baja California Peninsula nearly duplicates this transition area, with mixtures of both temperate and tropical species along its west coast and in the Gulf of California, also known as the Sea of Cortés. This long, deep (to 1,500 m) inland sea features mostly a rocky, narrow continental shelf west coast, and a sandy, wider continental shelf east coast; a dynamically mixed central area results from the compressed passages between the large islands and a huge tidal flow. The west coast of the Peninsula is mostly rocky and with a narrow continental shelf, except at the Sebastián Vizcaíno Bay and the Gulf of Ulloa, that have a wider, soft-bottomed shelf. I will refer only to this area, leaving aside the rest of the Mexican seas.

Fig. 1 Subarctic Mexico.

A bit of history and institutional identification

Although there are many published records of scientific activities by foreigners back to the early 1880s both at the west coast and in the gulf, and except for some attention given to pearl fishing at the southern gulf during the early 1900s, mexican research in the area basically began during the 1940s with species descriptions by spanish immigrants such as Rioja, Caso and others, and fisheries-oriented publications by Osorio-Tafall. The first generation of mexican born marine scientists began working on the area during the 1950s, essentially looking at the shrimp fishery (Cárdenas, Chapa, Núñez, etc.) from the Instituto de Pesca del Pacífico, a privately funded research institution located in Guaymas. At the west coast, Ramírez-Granados was working on sardine fisheries biology.

The foundation of the Instituto Nacional de Investigaciones Biológico Pesqueras (INIBP, the federal institution for fisheries research) during the early 1960s greatly contributed to the expansion of marine sciences in México, through a considerably increased number of people both at their central laboratory and at a number of field stations, including Ensenada, La Paz, Guaymas and Mazatlán. By the second half of that decade, a México/FAO/UNDP fisheries development program incorporated a number of international experts and the first research vessel, the "Antonio Alzate", that followed former primitive research cruises on old fishing boats.

The 1970s saw a great expansion of marine sciences driven by an intensely emerging interest by the Federal Government that gave rise, among other things, to the adoption of the Exclusive Economic Zone. The former INIBP, transformed into a wider national fisheries institute (Instituto Nacional de la Pesca, INP), reinforced their field stations network (nowaday called Centro Regional de

Investigación Pesquera, CRIP) and incorporated the "Humboldt" and "Onjuku", two larger research vessels donated by Germany and Japan. The Navy (Secretaría de la Marina Nacional, SMN) created an oceanography section and adopted a number of ships for marine research. The Water Management branch of the federal government (Secretaría de Recursos Hidráulicos, SRH) set up a section dealing with coastal lagoons and shrimp culture, and so on. At the educational and scientific sector, a high school system was created specifically oriented to marine activities, that has evolved to a group of senior high schools (Centros de Educación en Ciencia y Tecnología del Mar, CETMAR) and university-level professional centers including graduate education, the Institutos de Ciencia y Tecnología del Mar (ITMAR), coordinated by the Unidad de Ciencia y Tecnología del Mar (UECYTM) of the public education sector of the Federal Government (Secretaría de Educación Pública, SEP).

Just looking at the northwest region, the National Autonomous University of México (UNAM) created a center for marine sciences and limnology (today the Instituto de Ciencias del Mar y Limnología, ICMyL at Mexico City), including a marine station at Mazatlán and two large, state-of-the-art research boats, the "Puma" and the "Justo Sierra". The other larger higher education institution in México, the Instituto Politécnico Nacional (IPN) created the Centro Interdisciplinario de Ciencias Marinas (CICIMAR) at La Paz. Several state universities initiated schools and institutes dealing with marine sciences, as the Universidad Autónoma de Baja California (UABC) at Ensenada, that greatly reinforced their previously created Escuela Superior de Ciencias Marinas (ESCM) and gave rise to the Instituto de Investigaciones Oceanológicas (IIO). The Universidad Autónoma de Baja California Sur (UABCS) began working on marine biology, as did the Universidad Autónoma de Sinaloa (UAS) at Mazatlán through its Escuela de Ciencias Marinas. The Universidad de Sonora (ITSON), working together with the University of Arizona, stablished a center in Puerto Peñasco. A private institution, the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM) created a unit for marine studies at Guaymas.

The National Council for Science and Technology (Consejo Nacional de Ciencia y Tecnología, CONACyT) also originated a number of research centers along the country, of which 3 have been working on marine sciences: the Centro de Investigación Científica y Enseñanza Superior de Ensenada (CICESE) that now operates the "Francisco de Ulloa" research boat, the Centro de Investigaciones Biológicas del Noroeste (CIBNOR) at La Paz, and the Centro de Investigación en Alimentos y Desarrollo (CIAD) at Hermosillo.

There are two other institutions that have become involved in marine science in later decades: the Instituto Nacional de Estadística, Geografía e Informática (INEGI) and the Comisión Nacional para el Uso y Fomento de la Biodiversidad (CONABIO).

Official coordinating and integrative initiatives at the national and regional level have been mostly slow, with a few exceptions. However, marine scientists are increasingly aware of the need for collaboration and both formal and informal relationships have been effectively developing. Active recent coordinating schemes are the networks promoted by CONACyT for aquaculture (RMA) and oceanography/fisheries (RMOP). The Mexican Academy of Sciences (Academia Mexicana de Ciencias, AMC) created an oceanographic program that worked evaluating the México-US collaboration in marine sciences and is now waiting for new initiatives.

Major research pathways

Most marine research has been focused on fisheries populations; shrimps, tuna, abalones, lobsters, small pelagic fishes, scallops, mother-of-pearl oysters and squid are among the most investigated ones. Often, from the original autoecological nature of research, wider approaches have led to habitat-wise studies, gradually incorporating other disciplines.

The ample soft-bottom continental shelf of the eastern Gulf coast and numerous associated estuaries, coastal lagoons and bays have received considerable attention given the very relevant shrimp fisheries and, in recent years, aquaculture. The offshore trawl fishery catches considerable amounts of non-shrimp species. This fact caused concern during many years and resulted in ecological research on these associations, particularly the study on the taxonomy, distribution and diversity of benthic invertebrates by UNAM for more than 20 years.

Estuaries, coastal lagoons and bays on the other hand have been subject of intense investigation not only because of their role as critical habitat for juvenile shrimp, but also for their aquacultural potential. From the tropical, warm and rainy wetlands of Sinaloa and Nayarit, traditional shrimp culture extended north to the dry and highly variable open bays of Sonora, demanding new strategies and giving rise to arid shrimp aquaculture.

While research at the tropical area has included shrimp biology and fisheries, basically by INP and UAS, mangrove structure and aquatic productivity, geochemical and pollution research, sedimentology, the impact of the effluents, and use of space in the lowlands has received attention mostly by UNAM. Dry area research directed basically to shrimp aquaculture has been mainly undertaken at northern Sonora by the UNISON and at the southern portion of the Peninsula and Sonora by CIBNOR.

Highly prized abalone and lobster fishery resources oriented research at the rocky west coast of the Peninsula extended to kelp beds, sea urchin, snails and sea cucumber populations and, since some years ago, to integral ecosystem approach and aquacultural efforts.

The very extensive collaboration between CalCOFI and INP that later extended to CICESE, CICIMAR and CIBNOR resulted in these institutions becoming deeply involved in the large area and time scales involved. Physical and chemical oceanography as well as plankton based research developed intensively in this framework. Both the California Current and the Gulf of California have been approached this way, closely linked – but not limited - to the small pelagic fish populations and fisheries investigations. Mexican involvement in tuna-related research has resulted from the country becoming a major participant in the tropical fishery and attending the complex porpoise incidental mortality issue, with very significant decline of the problem.

Large-scale offshore and coastal oceanography dealing with ocean currents, eddies, water masses and other have been undertaken in the whole area, mostly by UNAM, CICESE, the IIO and CICIMAR. The original coverage of CalCOFI was restricted after the 1970s south of the international border; although with major gaps, this southern portion was covered afterwards by CICIMAR, IPN, UNAM and CICESE. In recent years, the IMECOCAL program (Investigaciones Mexicanas de la Corriente de California) has been covering the CalCOFI stations network.

While the major source of marine products (in terms of landings) in México, the Gulf of California sardine fishery, developed following scientific research, potential fishery resources have been explored along the years not only by national and foreign research boats, but also by fishing vessels. The “Louis Coubriere”, a French research boat, worked in the area during the late 1960s, while during the 1970s the “Bonn” and the “Wesser”, two german trawlers, sought for hake and other demersal species, all coordinated by INP. Work on kelp and its utilization has been undertaken for several years by CICIMAR, while that on pelagic red crabs has become more intense during the 1990s based on a more integrated approach by CIBNOR.

Primary productivity both *in situ* and through satellite information has been investigated mostly by CICESE, CICIMAR and CIBNOR at several locations along the west coast of the Peninsula and at the Gulf of California. In part derived from this work, research on harmful algal blooms (HABs) has been increasing considerably, while continuous monitoring for more than 20 years in the Mazatlán Bay has been kept by UNAM.

The INP took responsibility of a special effort to evaluate all fishery resources in Mexico during the last 6 years, mostly through the utilization of dynamical biomass approaches. This work resulted in a major national update and the basis for better management.

CONABIO, after effectively working mostly on land for several years, set up a number of priority marine areas for biodiversity purposes through a process of consultation.

Ecosystem studies, mostly based on ECOPATH and derived techniques are now being applied to several marine areas, from coastal lagoons to demersal, soft bottom associations. Besides description of ecosystem structure and function, the most recent research has been oriented to fisheries-ecosystem-management through formal optimization using multiple criteria involving also uncertainty and risk analysis, basically by CICIMAR.

While large-scale oceanography has been increasing by means of remote sensing, mostly by CICESE, other efforts like the Biological Action Centers (BACs) approach have been rapidly expanding. Currently both, ecosystem and BACs concepts are being boarded by scientists from CICIMAR and CIBNOR as a collaborative regional program.

Major results

As the most important fishing product in Mexico, shrimp was the first to be investigated. Through the 1950-1960s, most research effort was directed toward investigating both the offshore and coastal shrimp fisheries. Initiated by Japanese fishermen during the early 1950s, those two decades were the golden age for the offshore fishery, with landings continuously increasing. The coastal fishery, on the other hand, has a very long history and was started by natives in coastal lagoons during prehispanic times. Tapos, a unique gear, was used to catch juvenile shrimp that were developing in estuarine conditions. Species identification, life cycles, distribution, estimates of abundance, reproductive processes, recruitment age, etc., were mostly defined during those early years and have been the foundation of present knowledge.

One of the earliest applications of research involved interfering with normal siltation processes in coastal lagoons; by keeping inlets open to import shrimp larvae, catches were greatly increased.

At the onset of the 1970s, there was rather good knowledge of the Gulf’s eastern coast and shelf, but the west coast of the Peninsula was practically unknown to Mexican scientists, except for the existence of a few isolated sardine and abalone fisheries. There was only one academic institution dealing with marine science (UABC) and a few undergraduate biologists working for the federal fisheries branch. By then CalCOFI had been operative for two decades.

(cont. on page 19)

Vera Alexander

Dr. Vera Alexander is a biological oceanographer. She has contributed widely to our understanding of the ecology and the role of sea ice in biological processes in polar seas. Vera's journey through life, which led her to Alaska, began in Budapest, Hungary, where she spent winters in town and summers in a small country village, Nograd Veroce. Country life offered a fine opportunity to become attached to animals, especially horses, which characterizes her life style today.

In early childhood, Vera (left) with her sister in Budapest.

A move to a small town in Hertfordshire offered many happy days spent roaming the forests of England with her dog, Tigger, and later with her jumping pony, Cobweb 1. Then, following graduation from a rather starchy all-girls' school, it seemed time to give up on education for a while, and she and Cobweb moved to a farm in Suffolk for a year of intense farm work and riding. Then, when the opportunity to go to the United States and begin college came up, the resolve to give up scholarships weakened, since the University of Wisconsin seemed a sufficiently exciting place. The years there were very enjoyable, and switching majors from agriculture to chemistry to zoology resulted ultimately in a focus on aquatic systems. She received her M.S. degree in 1962. During these college days, the major recreational activity was mountain climbing, and several trips with the Wisconsin Hoofers Mountaineering Club to the Tetons and Canadian Rockies were undertaken.

I (John Kelley) first met Vera in the mid-1960s shortly after she joined the newly formed Institute of Marine Science (IMS) as its first graduate student. The concept of a marine sciences institute was developed by Dr. K. M. Rae and Dr. Donald Hood in the early 1960s at the Texas A&M University, and implemented at the University of Alaska campus in Fairbanks. Vera was able to participate in planning and research at IMS in those exciting years as she pursued her own research leading to a Ph.D. degree on the seasonal succession in nitrogen-limited algal blooms, and this relationship to the nitrogen cycle of a lake. She finished her doctoral studies in three years and was the first woman to be awarded a Ph.D. (one of the first of two marine science Ph.D. awardees) at the University of Alaska in 1965. Dr. Alexander might have developed her professional life elsewhere, but she fell in love with Alaska and was appointed to the faculty of IMS as an assistant professor where she remained throughout her career. As she became well known and respected in her field, she was invited to pursue her interests as a visiting professor at the University of Turku, Finland, and at the National Institute of Polar Research, Tokyo, Japan. Long-term friendships with Finnish colleagues developed while working on the circumpolar tundra during the International Biological Program. Many hours were spent with vodka, saunas, and skiing across the hills in Lappland.

A koto lesson from Fukuchi-sensei at Utsunomiya.

Experience on Wisconsin's Lake Mendota and a reservoir in Pennsylvania involved the first actual measurements of nitrogen fixation rates in aquatic systems, using N-15 as a label. This experience served her well as she added this to her interests and studies of biological oceanography of high-latitude sea ice impacted areas with emphasis on ice biology, primary production and nitrogen dynamics, as well as high-latitude limnology.

During the 15 years after joining the faculty of the IMS, she enthusiastically conducted research and trained graduate students in marine and freshwater research. She took part in the International Biological Programme (IBP) Tundra Biome study at Barrow, Alaska, and continued her studies on arctic lakes during the years after IBP. One of those pioneering research was carried out at Toolik Lake, a major tundra lake located a short distance north of the Brooks mountain range. Dr. Alexander set up her research station in a small trailer located at an abandoned construction site associated with the building of the Trans Alaska Pipeline. Toolik Lake eventually attracted other scientists and became a major ecological research site designated as a Long Term Ecological Research (LTER) site by the National Science Foundation.

Vera had broad research interests at sea and on land. At one time during the International Biological Program, comparative studies were conducted on terrestrial nitrogen fixation rates in the high alpine tundra of the Alaska Range and the wet tundra in the Barrow area. The IMS Director, Dr. Donald Hood, instructed her to give a research seminar on a marine topic. After considerable thought, the title that emerged was "Oceanography of the High Alpine Tundra". It was well received by all. Although her early interests were in marine ecology and especially the role of sea ice in biological processes in polar seas (Arctic and Antarctic), she ultimately turned her attention to the Bering Sea, where she became impressed with the extremely efficient production processes which lead to huge harvestable resources.

An account is still remembered how Vera integrated the NARL steam room. In the early 1970s, the Naval Arctic Research Laboratory (NARL) in Barrow was a hotbed of activity for the IBP Tundra Biome program. It was a different world then. NARL had a brand new H-shaped building that housed research labs in one long wing, administrative and public facilities in the shorter center section and sleeping rooms in the far wing. Only men were allowed to stay in the new building, which had flush toilets. Women were relegated to Quonset huts and other primitive buildings. NARL had a steam bath that was for men only. The male scientists and employees of the contractor running the facility could relax to their heart's content. Some of the women researchers wanted to break the gender barrier in the steam room, but didn't want to give any of the guys a heart attack or get them thrown out of camp. At the time, mixed nude saunas were common in Fairbanks, so the off-limits policy was especially rankling to those from the University of Alaska. Vera and a couple other women found the right moment to invade the steam room when some National Science Foundation (NSF) visitors came for a site visit. Surely, if they took part, the local conspirators couldn't get in trouble! One of the scientists stood guard (heart attack prevention) and Vera and the others (including some from NSF) successfully accomplished their mission. Surreptitious use of the steam room continued that year, and eventually a co-ed sauna was built.

Mother Vera with daughter, Elizabeth, and son, Graham in the birch forest of Alaska.

Dr. Alexander has a strong national and international reputation. She is Dean of the School of Fisheries and Ocean Sciences (SFOS), Director of the Coastal Marine Institute at the SFOS, and serves as University of Alaska marine representative to the National Association of Land and Sea Grant colleges. She served on the National Research Council Committee and as Treasurer on the Board of Directors of the Arctic Research Consortium of the U.S. (ARCUS). She has also served as chairman of the National Science Foundation's Committee on Ocean Sciences and is serving on the NOAA Science Advisory Board and the Ocean Research Advisory panel, and as Pollock Conservation Cooperative Research Center Director. She is a presidential appointee to the U.S. Marine Mammal Commission and one of the two United States delegates to PICES. She was elected as PICES Vice-Chairman in 1998, and re-elected for this position in 2000.

In recognition of her accomplishments the Hokkaido University awarded her an honorary Doctor of Laws degree in 2000.

In the Dean's chair at IMS, Fairbanks.

Posing with an honorary Doctor of Laws from Hokkaido University with president, Dr. Norihito Tambo (on Vera's right), and senior university dignitaries.

Research and research administration have dominated Dr. Alexander's professional life. However, she has another well-developed talent nurtured during her early years as a student in England. It was in Fairbanks that Vera was encouraged to reawaken her interest in the piano. That opportunity arose when the newly formed Fairbanks Light Opera Theater (FLOT) needed an accompanist. That led to master classes at the University of Alaska and many public recitals in Alaska and Japan. She was invited to perform during the opening ceremonies of the first International Symposium on the Okhotsk Sea and Sea Ice in Mombetsu, Hokkaido, Japan, in 1986, and again in 1991.

The Mombetsu duo: Vera at the grand piano with Willy Weeks on bass.

It must be genetic: Vera and granddaughter Celia interpret the dynamics of Rachmaninoff.

Although Dr. Alexander maintains a very robust professional schedule, she participates actively in community and many professional organizations. She was elected fellow of the American Association for the Advancement of Science (AAAS) in 1990, and is a Fellow of the Arctic Institute of North America. As a result of her extensive field research activities, she was elected as a fellow of The Explorers Club (New York) and served as chapter chairman in Alaska.

She is also active in College Rotary Club and recently served as its president. On the lighter side she was also elected as a Fellow in the Academy of Malt Scotch Whisky in 1980. Today, her household consists of three cats, a dog (again, Tigger), a 40-year old horse, which had been daughter Elizabeth's show jumper many years ago, a young Morgan mare, and a Shetland pony adopted as a yearling from the disbanded Kodiak Near Island herd.

Dr. Alexander's strong commitment to PICES is well recognized. She has consistently promoted research addressed to fisheries and ocean sciences of the North Pacific Ocean and Bering Sea.

Vera's biography was written for PICES Press by **Dr. John Kelley** who is a Professor of Marine Science in the Institute of Marine Science, School of Fisheries and Ocean Sciences at the University of Alaska Fairbanks (UAF). He has been at the UAF for 32 years where he conducted research on carbon dioxide and other trace gases in the Arctic land and seas. Current interests are in fisheries acoustics and contaminants in marine organisms. He also served as Program Manager in the Office of Polar Programs, NSF, Direct of the USN/ONR Naval Arctic Research Laboratory and Director of the NSF Polar Ice coring Office.

(cont. from page 15)

That decade was crucial for Mexican marine sciences: shrimp and abalone landings were declining, sardines were found in sizeable amounts in the Gulf, several academic and research institutions were created, and a 200 mile EEZ was adopted. An active cooperation that had been initiated by the INP and CalCOFI, and lasted several years, was jeopardized when fisheries and scientific boats entering the EEZ faced increasing problems. CalCOFI basically withdrew from the Mexican part of their grid. Although the national institutions were yet too young to effectively cover such absence, they developed strong academic relations with them.

The shrimp fishery problems were dealt with, finding a gross overinvestment problem, regulating mesh sizes and managing closed seasons to permit shrimp growth. Aquaculture for both shrimp and abalone was initiated and wide geographic projects were begun at the same time that local areas were studied. The real involvement of Mexican marine scientists in the western coast of the Peninsula began in the 1980s.

During these 20 years, we coped with issues learned mostly by the CalCOFI people and found many more. Our area turned out to be far more complicated than expected, because we have both temperate and tropical species. We learned the complexity of the California Current and of the Gulf, both areas of temperate/tropical mixing, dynamically changing along the year. It has become clear that the seasonal intrusion of tropical water is associated with low productivity, isolating massive populations like sardines in small, persistently high productivity areas. The coupling of the yearly sardine cycle to seasonal and interannual variations of the environment, particularly in the Gulf, has been possible after the effective cooperation of biologists and oceanographers.

Environmental variation between years has also been understood, and we now know that all our research effort developed during a warm period. The effects of these changes are being actively studied and are beginning to be taken in account for resource management.

By the time equilibrium yield models were becoming inadequate to understand fisheries in developed countries, Mexican scientists had caught up and were looking at alternate approaches including other population models, incorporating the effects of environmental change, and turning into ecosystem analysis. This process has resulted in about 10 institutions employing about 350 Ph. D. and 150 M. Sc. students from which 760 Master and about 85 Doctors have obtained their degrees.

North Pacific CO_2 data for the new millennium

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As the scientific study of the Global Carbon Cycle becomes an ever more international enterprise, there is a growing need for extensive and reliable oceanic CO_2 measurements which, though made at different times by different scientists from different countries around the world, are comparable and correct. The PICES Working Group 13 on CO_2 in the North Pacific (chaired by Drs. Richard Feely and Yukihiro Nojiri) has attacked this problem on two fronts. First, by improving measurement quality in the various PICES nations through a series of between-laboratory comparisons of measurement techniques followed by workshops to discuss the results (see PICES Press Vol. 7, No. 2 and Vol. 9, No. 1). Second, by working together with the PICES Technical Committee on Data Exchange (TCODE) to plan a multinational data integration/synthesis workshop aimed at achieving a detailed comparison of existing data sets for CO_2 in the North Pacific. The goal of this workshop - articulated at the first meeting of Working Group 13 in October 1998 - is to identify what needs to be done to provide for effective data exchange, i.e. including a full understanding of data quality and limitations.

As part of this planning activity, a pilot workshop was held earlier this year (January 22–24, 2001) at the Institute of Ocean Sciences in Sidney, British Columbia, Canada. The participants (see Table and photo) included both measurement scientists and specialists in oceanographic data from various data centers. After a brief introduction by Drs. Feely and Nojiri, a series of presentations reviewed the present status of North Pacific CO_2 data in the participating PICES member countries. Essentially, many of the recent and historic data holdings remain within individual laboratories, though steps are being undertaken to transfer the data, wherever practical, to national and international data centers.

Participants of the PICES WG 13/TCODE CO_2 Data Integration Test Workshop held January 22-14, 2001, at the Institute of Ocean Sciences, Sidney, British Columbia, Canada. Author of this article, Dr. Andrew G. Dickson (back row, second from right), is an Associate Professor-in-Residence at the Scripps Institution of Oceanography of the University of California, San Diego, and a member of WG 13 on CO_2 in the North Pacific. His research interests include the study of the oceanic carbon dioxide system as well as other aspects of ocean biogeochemistry.

Participants of the PICES WG 13/ TCODE CO_2 Data Integration Test Workshop

Canada

Institute of Ocean Sciences: *Robin Brown, John Page,* and *C.S. Wong*

Japan

Frontier Research System for Global Change: *Tsuneo Ono*
Japan Marine Science and Technology Center: *Akihiko Murata*
Kansai Environmental Engineering Center: *Koichi Goto* and , *Tomoya Sugimoto*
Marine Information Research Center: *Sachiko Oguma* and *Toru Suzuki*
National Institute for Environmental Studies: *Yukihiro Nojiri*
National Institute for Resources and Environment: *Yutaka Watanabe*

U.S.A.

Carbon Data Information & Analysis Center: *Alex Kozyr*
JISAO, University of Washington: *Christopher Sabine*
National Oceanographic Data Center: *Paulette Murphy*
NOAA Pacific Marine Environmental Laboratory: *Richard Feely*
University of California, San Diego: *Andrew Dickson*

PICES

Alexander Bychkov

However, even after such data resides at the various national data centers, integrating them into a coherent picture is a large task which will require a great deal of time and expertise. A common problem is that such data sets are often inadequately documented, making an objective assessment of their reliability very difficult. The workshop participants thus spent time working to develop draft guidelines for metadata (documentation of the methods, quality control procedures, etc.) that, it was felt, should accompany archived CO_2 data sets. Although it was recognized that in a number of cases, this information was perhaps unavailable, we believed that such guidelines would help data centers to better assess the comprehensiveness of the metadata accompanying their data products. Participants also worked to plan a CO_2 Data Integration Implementation Workshop (to be held in Japan later this year) whose goal is the integration of a limited number of presently available data sets for the North Pacific into a uniform data structure (database?) so as to better understand the technical issues involved in doing this, and to assess the usefulness of the proposed integrative approach.

However, ultimately the most important part of this pilot workshop was the opportunity it gave the various participants to articulate a long-range vision for the future of CO_2 data sets for the North Pacific, and to outline a possible mechanism for the international coordination and cooperation needed to realize these. As a result the workshop came up with a series of recommendations to PICES Working Group 13 and TCODE (see box). That aims to make the integration of both historic and future North Pacific CO_2-related data a reality.

The workshop participants recommend that the PICES Working Group 13 and TCODE:

- Work together with the data centers (JODC, NODC, CDIAC, MEDS, etc.) to compile an International North Pacific Data Inventory for CO_2 and CO_2-related data. This inventory will be available through the JODC/MIRC/IJCD web site and mirrored at the other data centers. Priority should be given to North Pacific open-ocean data; however, marginal seas will also be included.
- Encourage PICES and non-PICES countries to contribute information on their North Pacific data holdings to this inventory.
- Encourage the data centers to adopt the proposed pH, pCO$_2$, C_T, and A_T metadata guidelines.
- Prepare and distribute a list of key stations for future replicate and shore-based analysis of deep-water samples, and to encourage re-sampling these stations in future national and international North Pacific CO_2 surveys. This would aid the assessment of the quality and utility of the historical databases.
- Use the quality checked historical surface ocean pCO$_2$, data from Japan, Canada and the United States to test the live access server concept for the display and distribution of combined data sets via the internet.
- Promote the development of near real-time data exchange/data integration approaches for underway pCO$_2$, measurements in preparation for future observational programs, to ensure that timely repeated assessments of CO_2 exchange can be made.
- Support the continuation of underway pCO$_2$ inter-comparison studies to test the comparability of pCO$_2$ methods.

PICES Workshop on Higher Trophic Level Modelling

Standing (left to right): *Richard Beamish, Bernard Megrey, Daniel Ware, Kerim Aydin, Jacquelynne King, Gordon McFarlane (author of this article, E-mail: mcfarlanes@pac.dfo-mpo.gc.ca), Lan Smith, Jeffrey Polovina, Andrei Krovnin, Hiroyuki Sakano. Crouching*: *Michio Kishi and Akihiko Yatsu. Absent*: *Qisheng Tang and Makoto Kashiwai.*

The PICES BASS/MODEL Workshop to examine the feasibility of using ECOPATH/ECOSIM as a tool for modeling higher trophic level components of the Subarctic gyre ecosystems was held March 5-6, 2001, in Honolulu, U.S.A. The objectives of the workshop were to develop a common data format, to examine trophic relationships in both the Eastern Subarctic Gyre (ESA) and Western Subarctive Gyre (WSA) using ECOPATH/ECOSIM, and to examine methods of incorporating the NEMURO lower trophic level model (see PICES Press Vol. 8, No. 2, p. 18) into the analysis. The boundary areas for the two ECOPATH models coincide with PICES' definitions of the Western Subarctic (WSA) and the Eastern Subarctic (ESA), namely the regions above 45°N, bounded by the shelf breaks and divided by 165°W. The total areas for the WSA and the ESA are 2,168,000 km^2 and 3,622,000 km^2 respectively.

An ECOPATH model creates a quantitative food web using the principle of mass-balance. Each "box" in an ECOPATH model may represent a single species or a species guild. The units may vary from model to model. The following were used for the initial ESA and WSA models:

- Biomass (t/km^2)
- Production per unit biomass ($year^{-1}$)
- Consumption per unit biomass ($year^{-1}$)
- Fisheries catch ($t/km^2/year$)
- Diet matrix for each predator (% of diet by weight, shown here as trophic level).

From this information, ECOPATH calculated "Ecotrophic Efficiency" for each box, which represents the ratio of the production in each box to the biomass "demanded" by the predators and fisheries affecting that box. An Ecotrophic Efficiency > 1 indicates that more is being demanded of a box than is being produced. This quantity is a useful diagnostic tool for examining the quality of data between boxes. No fishing was included as there have been no major open ocean fisheries in the gyres since the early 1990s. This model was "mass-balanced" so that all Ecotrophic Efficiency values were < 1.

There is considerable room to improve the estimates before the model should be considered "functional." It was felt that much improvement in data quality could be accomplished by re-reviewing existing data using this preliminary ECOPATH model as a framework. Data quality was categorized as follows:

Acceptable: Generally considered to be "reasonable" estimates for model use.

General: Is consistent with known patterns for the species in question, but may be improved through re-examination of existing data, or further consultation with other researchers.

Poor: Little information for these species, or the information available to the workshop was known to be potentially inaccurate (collected outside the model domain).

N/A: No data available: estimates were derived from ECOPATH model.

Most of the estimates need to be increased from General to Acceptable before the model can be considered functional. Final data quality is a combination of two properties: the quality of each datum, and the sensitivity of the model to that input.

Bernard Megrey reviewed recent improvements to NEMURO model which included the addition of diagnostic calculations (P/B, C/B, Ecotrophic Efficiency), validation to Station Papa observed data, addition of zooplankton vertical migration, examining the effects of the microbial loop, and performing a sensitivity analysis. To be able to perform regional comparisons of model performance, several diagnostic calculations were added to NEMURO. These included Production/Biomass ratios for phytoplankton and zooplankton, Food Consumption/Biomass ratios for small, large and predatory zooplankton, and Ecotrophic Efficiency calculations.

NEMURO was parameterized for Ocean Station Papa and model results compared favourably with the data. The C/B and P/C ratios are reasonable, annual primary production from the model (149 $gC/m^2/yr$) is only 6% higher than the best current estimate (140 $gC/m^2/yr$). An f-ratio (assuming that the production of the large phytoplankton is primarily fuelled by "new" nitrogen was 0.23.

At Station Papa during spring, the large zooplankton component (ZP) should be dominated by *Calanus/Neocalanus* spp., which undergo strong ontogenetic vertical migrations. Thus, the model biomass must increase in the early spring independently of food availability/grazing. Likewise, later in the year the population must decrease by some amount to represent the descent to depth. NEMURO was modified to reflect this aspect of the biology. Model results without migration of predatory zooplankton (ZP) produce a large diatom bloom around day 73, but there is generally no spring bloom at Station Papa. With ZP migration, values of PL drop by a factor of 2 and generate more reasonable diagnostics. The estimates of Ecotropic Efficiency are not significantly affected.

Climate change patterns that produce warmer water and greater rainfall enhance water column stability. This lowers primary production by reducing or eliminating the vertical mixing that brings nutrients into the photic zone. Data from Station Papa show decreased nitrogen and reduced primary production with warmer temperatures over a period of about 25 years. These conditions change both the quantity and species composition of phytoplankton. With high nutrient concentrations, large phytoplankton that are eaten by copepods dominate the assemblage. This energy is transferred to larval and adult planktivorous fishes. Low nutrient concentrations - the phytoplankton assemblage is altered, with the microbial loop food chain being favoured over the pelagic food chain. Small nanoplankton are favoured, which are eaten by protozoans like rotifers, with secondary production generally becoming unavailable to fish.

A pragmatic approach to including the microbial food web is through the variable BetaZS (growth efficiency of Small Zooplankton, ZS) as

$$BetaZS = 0.3\ (1 + PhySn/(PhySn+PhyLn))$$

This means that the gross growth efficiency of the small zooplankton can vary between 0.3 and 0.09, and will probably average about 0.16 over the year at Station Papa. For the base model run, a constant BetaZS=0.3 was used.

Including a microbial loop had only a small impact on the standing stocks of small and large zooplankton. Predatory zooplankton were reduced by about one half, reducing potentially available biomass for fish production. These differences are due to the decreased net trophic efficiency of the system, which results when a large portion of the primary production passes through a microbial community before entering the zooplankton community.

A Monte Carlo analysis of the WSA randomly varied the input parameters and initial values by ±10% using a uniform error distribution. Principal component analysis (PCA) reduced 600 replicate sets of output parameters and initial values. Four factors explained 22% of variance in the output. The first PC was clearly related to photosynthesis of PL. It accounted for 10% of the variance and was correlated with the VmaxS, VmaxL, and PL, $N0_3$, NH_4. The second principal component was related to the zooplankton state variables, ZL and ZS.

Based on the sensitivity analysis, VmaxS, VmaxL, λP, MorZP0 and VD2N0 were estimated from observations on the A-line (off Hokkaido, Japan beyond the Oyashio) by minimizing the squared sum of differences between observed and simulated data. After estimating these parameters, the time-dependent features of each compartment of the NEMURO/FORTRAN Box model were calculated.

Argo Science Team 3rd Meeting (AST-3)

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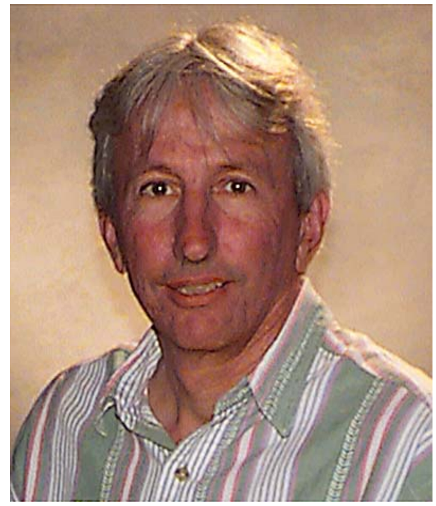


Dr. Dean Roemmich is Professor of Oceanography at the Scripps Institution of Oceanography, University of California San Diego. His research interests include large-scale ocean circulation, the role of the ocean in the climate system, and physical/biological interactions in the California Current. Recent work focuses on analysis of the heat budget of the North Pacific Ocean using High Resolution XBT/XCTD transects and TOPEX/Poseidon altimetric data. He is one of the originators of the Argo global profiling float project, chairman of the International Argo Science Team, and coordinator of the U.S. Argo Float Consortium.

At the Eighth Annual Meeting (October 1999), the PICES scientific community gave high priority to strengthening its interactions with the Climate Variability and Predictability Program (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE). It was also recommended that every effort should be made by PICES to assist in the implementation of the Argo project, which is intended to deploy 3,000 robotic floats globally and will be a key part of CLIVAR and GODAE. The profiling ALACE (Autonomous Lagrangian Current Explorer) floats and project Argo have been described previously in PICES Press (e.g., 2000: Vol. 8, No. 2 and 2001: Vol. 9, No. 1).

The International Argo Science Team was created to review national plans and commitments in order to formulate a strategy for glogal coverage for the benefit of all nations, and to provide a forum for the exchange of technical information. The third meeting of the Argo Science Team (AST-3) was held March 20-22, 2001, in Sidney, British Columbia, Canada. It was hosted by Fisheries and Oceans Canada at the Institute of Ocean Sciences, and co-sponsored by PICES. The meeting attracted 39 scientists and managers from 13 countries and 2 international organizations, Intergovernmental Oceanographic Commission (IOC) and PICES.

The substantial progress in international commitments over the past year was considered (Table 1). Committed floats now total over 900, with proposals for an average of 750 per year in the next 3 years. The geographic distribution of targeted floats was also addressed (Fig. 1). Early Argo deployments seek to quickly demonstrate the value and success of the project, while leading to global implementation as the highest priority. Early deployments are very sparse in the southern subtropics and the Southern Ocean (Fig. 1), so this must be a strong focus of subsequent efforts. Basin Implementation Meetings have been held for the Pacific Ocean (Tokyo, April 2000), and Atlantic Ocean (Paris, July 2000), with an Indian Ocean Implementation Meeting scheduled for Hyderabad, India, in late July 2001.

The Pacific Implementation Meeting focused on consensus building among the Pacific nations contributing to the Argo project, and initial plans for float deployment were discussed. There are strong commitments for float deployment in the tropical Pacific, the northern Pacific and the western subtropical North Pacific (Fig. 1). Additional attention is needed to see that adequate floats are provided for the eastern and southern portions of the Pacific basin. The total number of floats presently targeted for deployment in the Pacific is 280 by the end of 2001 and an additional 290 in 2002.

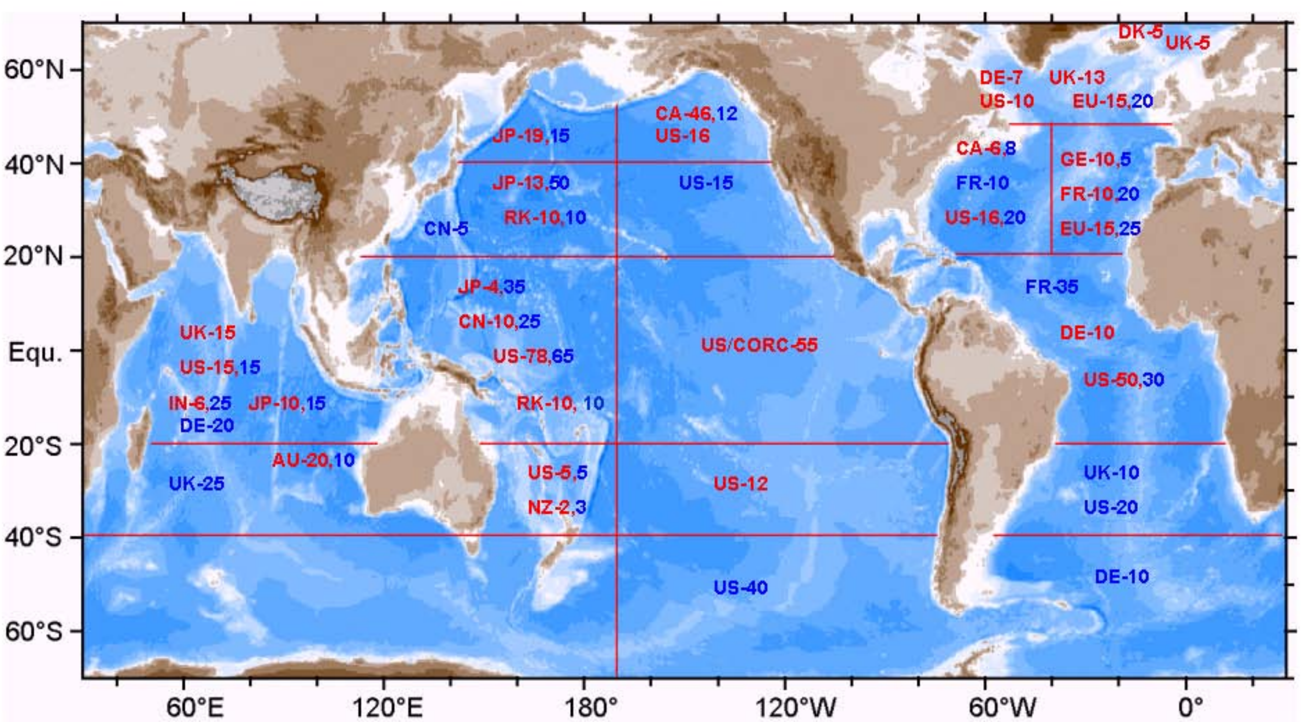
Progress in development of the Argo Data System was reported, following a meeting of Argo data managers in Brest, France, in October 2000. A standing subcommittee of the AST was formed to oversee the Data System. Immediate issues for this group are: to ensure that all Argo data are being released in near real-time via the GTS, to develop a common format to allow rapid exchange, and to disseminate Argo data, and to establish a timetable with milestones for implementation of the data system.

Technical issues relevant to the Argo array were reviewed. The most significant finding has been that of multi-year stable salinity records using Seabird CTDs, although there are not yet enough records of long duration to characterize the performance reliably. The most notable technical concern is for the viability of improved communications options that could provide fast, reliable two-way communications. While improvements are required for transmission of high quality data, the improved commercial systems presently lack financial stability. An online Argo technical forum will facilitate technical exchanges and information transfer.

Table 1. International Commitments for Argo floats. This table reflects the year in which funds are provided for floats, and takes on the order of a year until such floats are available for deployment. To achieve the global array of 3,000 Argo floats, it is necessary to provide floats at a sustained rate of 750 per year, given an average float lifetime of 4 years. A “Float Equivalent” is defined as a float—while not funded under the Argo Program— whose data are available consistent with the Argo Data Policy and provides the information equivalent to one Argo float. Additional details on this table are provided in Appendix 2.

Number of Floats by Country	Argo Funded FY99	Float Equiv's FY99	Argo Funded FY00	Float Equiv's FY00	Argo Funded FY01	Float Equiv's FY01	Proposed over next 3 years	Prop Float Equiv's over 3 yrs
Australia			10		10		90	
Canada			10		42		90	
China					10		80	
Denmark						5		
European Commission					80			
France		8	70		65		200	
Germany				18		22	100	35
India					6		150	
Japan			20		90		300	
New Zealand					2		10	
Republic of Korea					20		90	
Spain							24	
United Kingdom			13		50	5	150	40
U.S.A.	55		132	51	150	40	825	60
TOTALS	55	8	255	69	525	72	2109	135
TOTALS BY YEAR	FY99 = 63		FY00 = 324		FY01 = 597		Ave/Yr = 748	

Fig. 1 Target regions for funded floats planned for deployment by the end of calendar years 2001 (red) and additional floats for 2002 (blue). National plans shown are Australia (AU), Canada (CA), China (CN), Denmark (DK), France (FR), Germany (DE), India (IN), Japan (JP), Korea (RK), United Kingdom (UK), United States (US), and European Union (EU). Some additional floats are funded but not yet targeted and some deployment plans are tentative.



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2001 coastal ocean/salmon ecosystem event

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The third annual meeting of salmon ecosystem scientists from the northeastern Pacific was held at the Pacific Biological Station (Fisheries and Oceans Canada) in Nanaimo, B.C., from January 31 to February 1, 2001. Dramatic changes in coastal marine ecosystems following a shift from a strong El Niño in 1997/98 to a persistent La Niña thereafter motivated many of the presentations. The main theme was to improve understanding of the nature of these changes, their evolution through 2000 into 2001, and likely consequences for adult Pacific salmon returning in 2001/2002. The coastal ocean in 1999 was characterized by coastal sea surface temperatures that had not been observed since the late 1970s (see Peterson & McKinnell, PICES Press Vol. 8, No.2). These physical changes were accompanied by the return of boreal zooplankton species to British Columbia, Washington and Oregon, a declining abundance of southern species, a general increase in plankton biomass, and by some interesting shifts in fish community structure that may affect salmon directly or indirectly.

David Mackas (DFO, Sidney) reported that between 1985 and 1999, the magnitude of the zooplankton community composition anomalies were 2-3 times greater than the total biomass anomalies (see Peterson & Mackas, in this issue for details). *Neocalanus plumchrus*, a species found only in low abundance during the 1990s, increased rather dramatically in 1999. These changes were associated with the physical properties of the coastal ocean. During 1997 and 1998, nitrate disappeared from the surface waters earlier and the duration of period of depletion was longer than had been observed previously, but in 1999, the nitrate seasonal cycle approached historical norms. During most of the 1990s, poleward advection of surface waters was stronger and more persistent while southward flow in summer was weaker. This pattern reversed in mid-1998 with stronger southward flow in summer and weaker or less persistent northward flow in spring/fall. The zooplankton community changes observed in 1999 lagged the physical changes by 6 months to 1 year.

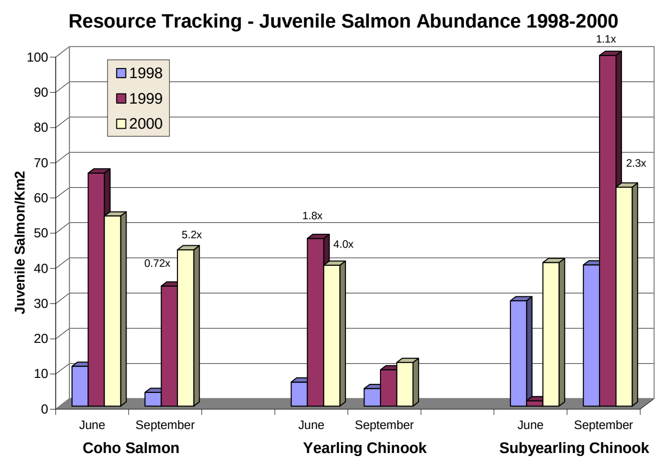

Fig. 1 Juvenile chinook and coho salmon catches in the Columbia River plume region from 1998 to 2000 (E. Casillas, NMFS).

Edmundo Casillas (NMFS, Montlake) reported that the Bonneville Power Administration (BPA) has been funding research on juvenile salmon and their coastal marine environment since 1998. These surveys discovered that coho and chinook salmon were more abundant in 1999 and 2000 than in 1998 (Fig. 1). They also found that coho salmon were found in warmer, less saline water in the Columbia River plume. Chinook salmon were also found in less saline water but there was no apparent temperature preference in June. In September, however, the chinook salmon favoured more saline water (measured at 1 m depth). There were no significant differences in coho salmon growth among years. The growth of yearling chinook increased while that of subyearling chinook decreased. Hatchery reared salmon were larger at length (better condition) than wild salmon. The mean condition factor was lower in recent years suggesting that increases in marine survival occurred because more 'marginal' fish (i.e. those that may have died in other years) have survived.

Richard Beamish and his group (DFO, Nanaimo) have found that the abundance of coho, chinook, and chum salmon in the Strait of Georgia was substantially higher in 2000 than in previous years (Fig. 2). The increases, over the 1997-1999 average were greatest for coho salmon (about 4 fold). The proportion of hatchery coho in the catch was relatively constant (as were the numbers released) suggesting that the increased abundance was due to increased survival rather than other factors. The increased abundance in the Strait of Georgia occurred one year after the increases were observed off the Columbia River.

There is enthusiasm to continue the discussion so current plans are to hold the 4th annual meeting at the Pacific Fisheries Environmental Laboratory in Pacific Grove, California, in 2002. For further information or to offer suggestions for a theme, contact mckinnell@pices.int or george.boehlert@noaa.gov.

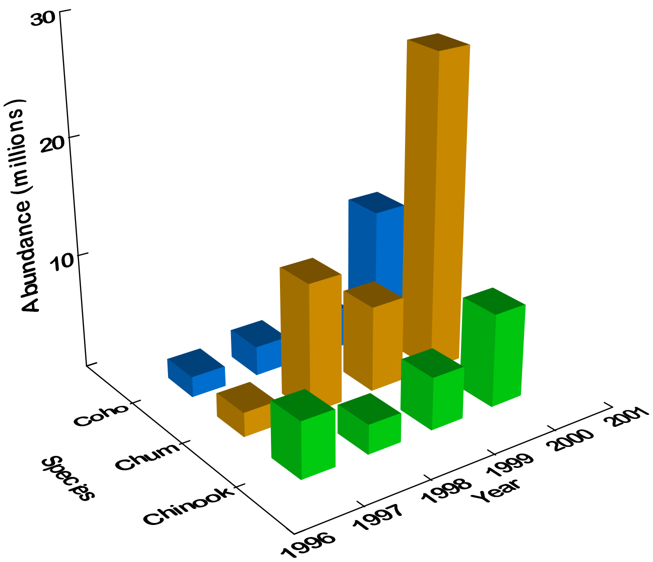

Fig. 2 *Coho, chum and chinook salmon catches in the Strait of Georgia from 1997-2000 (data from R.J. Beamish).*

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The Science Team focused on a number of issues related to international implementation:

- *The Argo Information Centre (AIC).* Float deployment notification procedures were discussed, including the necessity for float-providers to register new deployments on the AIC web site. The full-time Argo Coordinator will assist in a number of ways with Argo Implementation, with the first priority being establishment of an on-line float tracking system.
- *Capacity building/SEREAD.* It was stressed that Science Team members should participate in regional efforts aimed at building public awareness of Argo, support for Argo, and utilization of Argo data at several levels. An example was presented of an internationally supported secondary-school project in the Pacific Island nations that focuses on environmental science and Argo data.
- *Regional action groups/EEZ issues.* A discussion was held on regional cooperative efforts needed for Argo implementation, including the necessity to build broad international agreement and support for Argo float deployments within extended economic zones as well as on the high seas. An example was presented of successful regional action coordinated by the South Pacific Geosciences Commission (SOPAC) to gain support for Argo implementation in the western Pacific.
- *Float retrieval plan.* The Science Team agreed that floats should be labeled in order to facilitate retrieval of those few instruments that may wash ashore or be recovered in fishing activities. In addition, the Science Team will develop a consensus statement on the environmental impact of the Argo project.
- Members of the Science Team agreed to contribute materials for an internationally focused informational/ promotional CD.

The complete report of the Argo Science Team 3rd Meeting can be found at the AST web site (www.argo.ucsd.edu). The 4th meeting of the Argo Science Team will take place in March 2002, in Hobart, Tasmania, and will be hosted by the CSIRO. The People's Republic of China offered to host the 5th meeting tentatively scheduled for March 2003.

Shifts in zooplankton abundance and species composition off central Oregon and southwestern British Columbia

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Dr. William Peterson is an oceanographer who has been Program Manager for U.S. GLOBEC in Washington D.C., and previous scientific posts included 2 years in Monterey with NOAA, 2 years in Cape Town, South Africa with the Sea Fisheries Research Institute, and 8 years at Stony Brook, NY. His field of research is zooplankton ecology with a focus on the ecology of euphausiids off the coast of Oregon. Bill is a member of the U.S. GLOBEC SSC and serves on the U.S. GLOBEC Northeast Pacific Program Coordination Committee. He is a Co-Chairman of the PICES/REX Task Team and serves on the PICES/CCCC Implementation Panel.

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Dr. Dave Mackas is a biological oceanographer and zooplankton ecologist who works mainly on the distribution and dynamics of zooplankton populations in coastal and offshore regions of the Northeast Pacific. He has served on several PICES Committees and Working Groups, presently including BIO, MONITOR, and WG 14 on Micronekton. Despite their semi-youthful appearances and personalities, he and Dr. Peterson have been bumping professional elbows (in a friendly way) for about a quarter of a century.

It has long been known that water masses have characteristic temperature-salinity signatures (Sverdrup et al. 1942), and that these water masses are associated with the major gyre and boundary current systems. Biological oceanographers have also established that many zooplankton species have geographical distributions that correspond well with water masses, and arguably even more closely with the circulation patterns that allow reproductive closure of their life cycles. Because of close associations of many zooplankton species with water masses and water types, certain species can be used as indicators of the presence/absence of a water type, giving rise to the concept of using species as tracers (e.g. Bary 1959, McGowan 1971). Within the California Current, Fleminger (1967) classified the copepod fauna into five biogeographical types: subarctic, transitional zone, Central Pacific species, equatorial oceanic, and coastal neritic species. Coastal neritic species were further classified as boreal-temperate, temperate-subtropical and tropical. As the water goes, so go the plankton.

In the northern half of the California Current system, current speed and direction are strongly seasonal. During spring and summer, surface waters flow toward the south, driven by winds that blow equatorward. The plankton species that dominate the region are transported from the north. Prevailing winds and coastal currents reverse in the fall, usually in late October, and waters flow northward as the Davidson Current, bringing an assemblage of southern, warmer water species to coastal Oregon and British Columbia waters. Thus seasonal reversals in shelf currents generate changes in zooplankton species composition in shelf and slope waters of the southern British Columbia, Washington and Oregon coasts. The nitty-gritty details of these seasonal changes in copepod abundance and species composition in continental shelf waters off Oregon during the 1970s were described by Peterson and Miller (1977), and for the 1980's for the westcoast of Vancouver Island by Mackas (1992). In both regions, during spring and summer of the 1970s and 1980s, the copepod assemblage was dominated by boreal (subarctic) species -- *Pseudocalanus mimus*, *Calanus marshallae*, *Metridia pacifica*, *Acartia longiremis*, and *Centropages abdominalis*. During winter months they observed a minimum in the abundance of these boreal species and in total copepod abundance, but increased abundance of subtropical neritic (coastal) and/or transitional zone species such as *Calanus tenuicornis*, *Paracalanus parvus,Clausocalanus arcuicornis*, *C. pergens*, *Ctenocalanus vanus*, *Acartia tonsa* and *Corycaeus anglicus*. Off Oregon, the more southerly species dominated the winter copepod community (Peterson and Miller 1977), while off BC, their increase was to about 5-10% of the total copepod biomass (Mackas 1992).

We learned from subsequent work in the 1990s, that there is also considerable interannual-to-decadal-scale variability in zooplankton community structure in the northern California Current. The seasonal pattern described above began to break down in the early 1990s, starting a dramatic shift in species composition (Fig 1). The spring-summer abundance of the boreal copepod species declined off both central Oregon and off southwestern British Columbia, while subtropical neritic and transitional zone species (*Paracalanus*, *Ctenocalanus*, and *Clausocalanus* species) became increasingly common in continental shelf waters of both regions. Moreover, the warm water copepods persisted throughout the year to at least 1998, for a total of six years. How can this be? The conventional wisdom is that the presence of warm water species over the extended period of 1992-1998 is explained by persistent El Niño conditions throughout most of this period. This trend to a more southerly copepod community reversed quite suddenly in 1999 -- the ecosystem reverted back to the patterns seen in the 1970s and 1980s, with boreal neritic species dominating the copepod assemblages, and southern subtropical neritics being common only during winter months. The story is not just about copepods! Dramatic changes in euphausiid and pelagic fish species composition also occurred in the 1990s in the northern California Current. The coastal euphausiid *Thysanoessa spinifera* became less abundant in shelf waters off Oregon and in Barkley Sound (Tanasichuk 1998), and the more oceanic euphausiid species, *Euphausia pacifica*, became common in shelf waters. In addition, warm-water pelagic fishes such as juvenile sardines, jack mackerel and Pacific mackerel became common in continental shelf waters, and the northward-migrating Pacific whiting (hake) population appeared earlier each year since 1992, to the point that in 1998, the migrants reached southeast Alaska. There is evidence that hake were spawning off both the Oregon and British Columbia coasts in the 1990s.

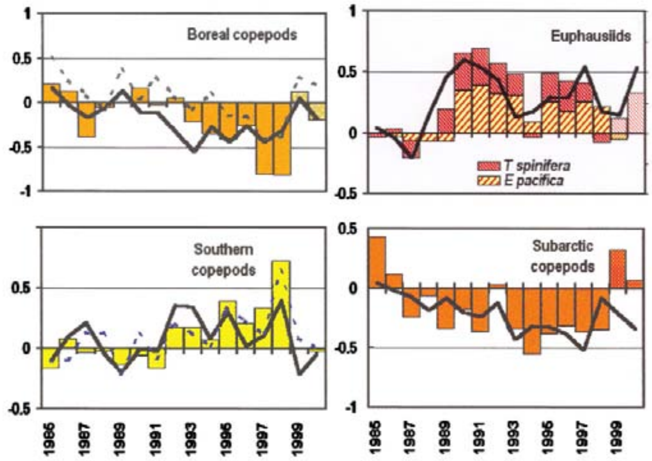

Fig. 1 1985-2000 zooplankton anomaly timeseries for the southern B.C. continental margin (adapted from Mackas et al. 2001 to include 2000 data). Annual anomalies (coloured bar graphs) are averaged within year and within major species groups, and are logarithmic in scale: an anomaly of 1.0 (-1.0) means that species within the group were on average 10 fold more (less) abundant than their seasonal norm. Lines are regression fits against 1985-1998 local (dashed) and large-scale (solid) climate indices.

Ecosystem structure began to change again in late 1998 and early 1999, with the near disappearance of most of the subtropical neritic copepods from shelf waters in summer, a return of *Thysanoessa spinifera* to shelf waters, a decline in numbers of warm water pelagic fish, and a hake migration that did not reach as far north as British Columbia in 2000. The PDO changed sign (to negative) in 1999, suggesting that the changes in zooplankton community structure and fish distribution coincided with a shift in climate. By the spring and summer of 2000, the continental margin copepod community was once again composed almost entirely of species that are boreal/subarctic in origin, the euphausiid *Euphausia pacifica* was found only in offshore waters, mackerel had disappeared from shelf waters, no juvenile sardines were found (although adults remained somewhat common), and perhaps most significantly, large numbers of anchovies had returned to the area and were again spawning in the Columbia River plume. The latter point is significant because large numbers of anchovies have not been seen since the 1977 regime shift. These collective observations beg the

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The CLIVAR - Pacific Workshop

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Dr. John Gould directs the WCRP's WOCE and CLIVAR projects offices. John is a physicist and physical oceanographer who started his working life with John Swallow, the inventor of the neutrally buoyant float that provides the underpinning technology for Argo. His research focussed almost entirely on the North Atlantic, its circulation and influence on climate. He was recently co-editor of a book "Ocean Circulation and Climate - Observing and Modelling the Global Ocean", published by Academic Press, that documents the present state of physical oceanography and the advances made in the 1990s during WOCE.

In February 2001, 50 climate scientists met at the International Pacific Research Center in Honolulu to review our knowledge of the climate of the Pacific sector and to start to plan a strategy for sustained atmospheric and ocean observations, process studies and numerical modelling that will work towards achieving CLIVAR's objectives.

The World Climate Research Programme's project on Climate Variability and Predictability (CLIVAR) seeks to better understand the variability of the physical climate system on a range of timescales as short as seasonal/interannual and extending to issues of anthropogenic climate change. Through that understanding, and the use of observations and models, will come assessments of the extent to which various climate phenomena are predictable, and hence, where appropriate, better climate predictions. Thus in the Pacific, CLIVAR builds on the earlier Tropical Ocean Global Atmosphere project that has led to an ENSO prediction capability. These objectives are described in the CLIVAR Implementation Plan published in 1998 that can be downloaded from http://www.clivar org. The plan focuses on a framework of global observations and modelling activities embedded within which are Principal Research Areas (PRAs) highlighting particular climate phenomena and regions such as ENSO, Monsoons and the Southern Ocean.

However, implementation often needs a regional focus that encompasses all timescales and phenomena. It was for this purpose that the CLIVAR Pacific regional workshop was held. Plenary talks were interspersed with working group sessions that started to identify important modelling and observational activities, to document activities already under way and those critical gaps in our knowledge for which new resources need to be sought.

The conclusions from the meeting are too lengthy to be adequately documented here. A report has been prepared by Dr. Robert Weller who was instrumental in driving forward the planning for the workshop. One recommendation from the meeting was that CLIVAR should have an implementation panel for the Pacific sector. This recommendation was endorsed by the CLIVAR Scientific Steering Group at its annual meeting in May 2001, and proposed terms of reference and membership of the panel are now being refined. The panel should be in place by July 2001.

CLIVAR is concerned with the coupled ocean-atmosphere physical climate system. That system influences, and is influenced by, variability in the terrestrial and marine biosphere. In this latter area collaboration among CLIVAR and the IGBP core projects (GLOBEC, JGOFS and PAGES) will clearly be needed - both on scientific and on logistical/resources issues (for instance in making best use of ship time and in developing appropriate data management systems). For the Pacific, PICES will be an important means of fostering this collaboration.

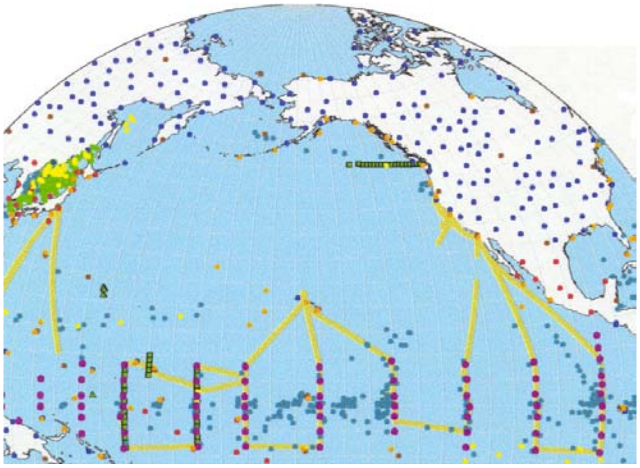

Fig. 1 CLIVAR-relevant sampling in the North Pacific sector since 1999.

PICES dialogue with Mexican scientists

At the PICES Eighth Annual Meeting (October 1999, Vladivostok), Governing Council adopted the resolution reflecting an interest in having Mexico accede to the PICES Convention. Following initial contacts between PICES and Mexican scientists for the purpose of facilitating the incorporation of Mexico to the North Pacific Marine Science Organization, particularly the attendance of Dr. Sergio Hernández Vázquez (CIBNOR) at the PICES Ninth Annual Meeting in Hakodate, Japan, PICES representatives Dr. Vera Alexander (Vice-Chairman), Ms. Patricia Livingston (Chairman of the Science Board), Dr. Warren Wooster (Founder and first Chairman) and Dr. Alexander Bychkov (Executive Secretary) met with Mexican scientists and officials during May 2-3, 2001, at CIBNOR (La Paz, México). The purpose was to present information on the history, structure, objectives and procedures of the Organization to a wider array of potential Mexican participants.

An open meeting was attended by a number of scientists from Mexican marine research institutions, and later the officials and some invited scientists met with PICES representatives in a working session. Mexican officials included Dr. Mario Martínez García, Director of CIBNOR (Centro de Investigaciones Biológicas del Noroeste, SC - *Northwest Biological Research Center*), who hosted the meeting; Dr. Guillermo Compeán Jiménez, President of INP (Instituto Nacional de la Pesca - *National Fisheries Institute*); Lic. Ricardo Belmontes Acosta (Director de Políticas y Acuerdos Pesqueros Internacionales; Secretaría de Agricultura, Ganadería, Pesca y Alimentación - *Director of International Affairs, Ministery of Agriculture, Livestock, Fisheries and Food*); Lic. Clara Morán (Subdirectora de Asuntos Multilaterales, Consejo Nacional de Ciencia y Tecnología – *Deputy Director of Multilateral Affairs, National Council of Science and Technology*); Dr. Javier Mendieta, Director of CICESE (Centro de Investigación y Educación Superior de Ensenada – *Center for Scientific Research and Higher Education of Ensenada*), Dr. Francisco Arreguín Sánchez, Director of CICIMAR (Centro Interdisciplinario de Ciencias Marinas del Instituto Politécnico Nacional – *Interdisciplinary Center for Marine Sciences, National Politechnical Institute*), Dr. Federico Páez, representing the Director of the Instituto de Ciencias del Mar y Linología, Universidad Nacional Autónoma de México – *Institute of Marine Science and Limnology, Mexican National Autonomous University*), Dr. Antonina Ivanova, Directora de Investigación Interdisciplinaria y Postgrado - *Director of Interdisciplinary Research and Graduate Education, Autonomous University of Baja California Sur*) and Dr. Jaime Farber Lorda (Coordinador de la Red Mexicana de Oceanografía y Pesca – *Coordinator of the Mexican Network of Oceanography and Fisheries*). Other scientists and representatives included Drs. Sergio Hernández Vázquez and Salvador E. Lluch Cota (CIBNOR), Drs. Gerardo López Lemus and Luis Fletcher (INP) and Dr. Daniel Lluch Belda (CICIMAR).

There was a general consensus of interest in the potential accession of México to PICES. Three main lines of action were adopted:

- Mexican officials will further explore the interest of other governmental agencies involved and the formal procedures to be followed;
- Mexican scientists will be encouraged to participate in PICES activities, beginning with the PICES Tenth Annual Meeting to be held October 5-13, 2001, in Victoria, Canada;
- PICES and Mexican participants will explore the possibility of organizing a special symposium during the spring of 2002 at La Paz, locally hosted by CIBNOR and CICIMAR. It was proposed that the symposium will examine recent advances in understanding the dynamics of marine ecosystems in high gradient regions of the Asian and North American coastal zones and in the open Pacific.

(cont. from page 29)

question: *are we witnessing another climate regime shift?* or *is this simply the manifestation of an extended La Niña*? The notion that we may have switched to a cool-and-highly-productive continental margin regime (California Current), and a cool-and-low-productivity regime in the oceanic subarctic Pacific, is supported by information gleaned from PICES IX -- the Japanese sardine population has pulled back to the waters of southern Honshu, the Japanese anchovy is increasing in numbers, and the central Pacific Ocean appears to have become more stratified. Changes in the Pacific Northwest and elsewhere all point in the same direction -- a new climate regime.

Now we could of course be very wrong in our guess because most PICES scientists agree that it takes at least five years before we can be sure that a regime shift has taken place. But, whatever! The changes that we have witnessed in the past year or two are exactly the kinds of changes that one would expect from a regime shift, so we should be able to study events of the years 1999/2000 and beyond just as if they were a regime shift. If we can all pool our data and ideas, we may be able to test existing "regime shift hypotheses" and perhaps even come up with a mechanistic explanation for their cause(s).

PICES Tenth Annual Meeting

October 5-13, 2001

Victoria, British Columbia, Canada

Ten years of PICES science: Decadal-scale scientific progress and prognosis for a regime shift in scientific approach (Science Board Symposium/S1)

Plankton size classes, functional groups, and ecosystem dynamics: causes and consequences (BIO Topic Session/S2; co-sponsored by JGOFS)

Migrations of key ecological species in the North Pacific Ocean (FIS Topic Session/S3)

Coastal ocean physical processes responsible for biological productivity and biological resources distribution (POC Topic Session/S4)

Mesoscale eddies, rings, and meanders and their biological implications (POC/BIO/FIS Topic Session/S5)

Sediment contamination - the science behind remediation standards (MEQ Topic Session/S6)

Physical oceanography to societal valuation: assessing the factors affecting coastal environments (MEQ Topic Session/S7)

Emerging issues for MEQ: a 10-year perspective (MEQ Topic Session/S8)

Physical-biological interactions during harmful algal blooms (MEQ/BIO/POC Topic Session/S9)

A decade of variability in the physical and biological components of the Bering Sea ecosystem: 1991-2001 (CCCC Topic Session/S10)

Results of GLOBEC and GLOBEC-like program (with emphasis on possible 1999 regime shift) (CCCC Topic Session/S11)

Temporal variations in size-at-age for fish species in coastal areas around the Pacific Rim (REX Workshop/W1)

Data management methods and issues for the 21st century (TCODE Workshop/W5) and Regional and National Data Centres (TCODE Electronic poster session/S12)

Upcoming PICES Publications in 2001

PICES Scientific Report No. 16. Data Report of the Practical Workshop on Vancouver Harbour (final report of WG 8).

PICES Scientific Report No. 17. PICES-GLOBEC Program on Climate Change and Carrying Capacity: 2000 Annual Report.

PICES Scientific Report No. 18. Report on PICES/CoML/IPRC Workshop on Impact of climate variability on North Pacific Ecosystems.

PICES Scientific Report No. 19. Final Report of WG 12 on Crabs and Shrimps.

Progress in Oceanography 49: 2-4. Beyond El Niño: climate variability and marine ecosystems from the tropics to the arctic (Guest Eds. McKinnell, Brodeur, Hanawa, Hollowed, Polovina and Zhang).

PICES Secretariat News

Dr. Jung Hwa Choi, from Pukyong University in Pusan joined the Secretariat in mid-May as a PICES Intern. His first few weeks were very helpful to the Secretariat in editing the backlog of PICES publications. He is photographed here with his wife and daughter at the graduation

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