# MONITOR WORKSHOP ON PROGRESS IN MONITORING THE NORTH PACIFIC

**(Co-convenors: Bruce A. Taft and Yasunori Sakurai)**

A 2-day MONITOR Workshop on "Progress in monitoring the North Pacific" was convened prior to the Ninth Annual Meeting in Hakodate, Japan (October 20-21, 2000). The workshop reviewed ongoing and/or planned monitoring programs in North Pacific, and the section below contains extended abstracts of papers given at the meeting. As a result of the workshop discussions, the following recommendations were made:

<u>Continuous plankton recorder field program</u>

PICES should strongly support the principal investigators in their efforts to find long-term funding support for this important monitoring program. It was pointed out that interpretation of the zooplankton data would be enhanced if ancillary environmental data were collected. Specific suggestions were: (a) the collection of sea-chest temperature data; (b) collection of sea-chest water samples for salinity determination; and (c) underway measurement of fluorescence.

<u>Ocean tracking network for the coastal ocean</u>

Participants recognize the potential scientific benefits of the acoustic monitoring array and urge that PICES promote the timely evaluation of this proposal within the community to establish proof of concept.

<u>Preservation of existing North Pacific monitoring programs</u>

a. A biophysical mooring (designated station #2) has been maintained for the last five years southwest of the Pribyloff Is. This time series data set has been used extensively to describe the variability of environmental conditions in this region. It is slated to be terminated this year. The Workshop recommends that PICES lobby in the scientific community for the continuance of this valuable time series.
b. The Japanese shipboard program in the North Pacific is in transition. The *R/V Oshoro-Maru* will not continue to occupy the Bering Sea section at 180º, and the Japan Fishery Agency (JFA) will take over this section. The 180º section is a key section with a long tradition of state-of-the-art observations. The participants recommend that PICES urge that every effort is made by JFA to provide a data set comparable in quality to the *R/V Oshoro-Maru* measurements.
c. For the last 40 years JFA has supported a prefectural monitoring program in the coastal seas of Japan. Shipboard measurements are made from the coast out to 60 nautical miles. The data are used for forecasting of coastal fishing conditions, and in addition constitutess very valuable climate data set. JFA has proposed a 50% cut in funds for this program. The Workshop recommends that PICES call for an assessment of the effects of this proposed action on climate studies in this critical region.

<u>PICES/GOOS interaction</u>

The Workshop recommends that PICES set up a Steering Group to define the direction that PICES should take in integrating their regional interests with GOOS. This Group would consider issues such as the identification of existing observing systems in the North Pacific which could contribute toward a regional PICES GOOS, new observations required to complete the system, and possible eventual establishment of a Regional Analysis Center (RAC), along the lines suggested by LMR-GOOS. The Steering Group would also comment on the possible benefits to PICES countries of providing an annual ecological assessment of the state of the North Pacific.

<u>NEAR-GOOS Planning Workshop</u>

A NEAR-GOOS Forecasting Workshop is planned to consider the future strategy for the program. In order to better serve the climate community NEAR-GOOS need to expand the types of data that they collect and archive by including chemical and biological data. It was recommended that PICES work with the workshop planners to ensure that they have the necessary expertise for a successful workshop.

Gulf Ecological Monitoring (GEM) program

It was recommended that the MONITOR Task Team always include a scientist representing GEM, as this program is a major contribution to monitoring in the PICES region.

## Continuous Plankton Recorder measurements in Subarctic Pacific

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Continuous Plankton Recorder (CPR) tows in the North Pacific were begun in March 2000, and a series of seven tows were completed in the March-August time period. The data return was apparently high and it is expected that 450 samples will be analyzed for the year. Processing of the March-May 2000 samples has been completed and preliminary analyses of these data have been carried out.

*Neocalanus plumchrus* is one of the dominant copepods of the subarctic North Pacific. It was present in the March samples from just outside Prince William Sound (PWS) south to about 41° N but with no obvious peaks. The majority of the individuals were stage 2 copepodites. April abundances were generally higher, with maximum densities between 44° - 54°N. There was a clear gradient in the apparent duration of development with most of the northern individuals still present as stage 2 copepodites whilst over 60% had reached stage 5 in the southern samples. Such a gradient might be expected, since the duration of development probably depends on temperature. These data are the first to show such a pattern in development. Preliminary analyses of the zooplankton community structure reveal distinct differences along the length of these two tows. The more “coastal” samples off PWS and California showed some similarities to each other and were clearly distinct from the more oceanic samples, however, samples within the oceanic region also showed some clustering. Further analyses will reveal the species contributing to these differences, but the fact that communities can already be identified demonstrates that the sampling resolution will be adequate to characterize regional community composition.

## Comparisons of zooplankton sampling gear

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Zooplankton collection devices cannot be calibrated - there are no absolute standards to compare the *in situ* capture or counting efficiency of various collection devices. However, comparisons of efficiency among samplers, for example total biomass or size frequency captured and retained, are useful. There are at least four types of situations where sampling equipment have been compared:

1. Multiple collection devices were used on the same project and there is a scientific need to combine the data to form indices (example - Georges Bank GLOBEC).
2. Collection devices were changed during a time series and there is a need to compare the catch before and after the change (example - Ocean Station P).
3. A collection device is being used which is based on new technology and it is important to know how it performs relative to a more traditional device (example - compare acoustic estimates with net sample collections).
4. International cooperative monitoring is undertaken and a comparison of sampling procedures used by various countries must be carried out (example- PICES CCCC Program).

Reports were presented at the workshop by S. McKinnell (Canada) and K. Nakata (Japan), dealing with problems associated with adjusting time series to account for changes in method of measurement. At Station P early measurements were made with a NORPAC net and after 10 years of sampling, a SCOR net was used. McKinnell reported the results of over 50 comparisons of the two types of gear. These collections spanned the range of zooplankton biomass observed at Station P. He concluded that the NORPAC biomass estimates must be multiplied by approximately 1.2 to be comparable to the SCOR net when flowmeter estimates of volume filtered are unavailable (e.g. Station P 1956-1981). Another aspect of the study was that more than 40 paired comparisons were needed for adequate precision of the intercalibration. Similar problems were reported by Nakata who identified significant differences between collections made with the NORPAC, Marutoku and Long NORPAC nets - particularly at high biomass levels. Biomass was lowest with the Long NorPac net and the interpretation is that greater clogging of the Long NorPac net produced a systematic error.

The ICES Working Group on Zooplankton Ecology held a "Workshop at Sea" in 1993 to make comparisons among different zooplankton samplers. Thirty-eight scientists from eight ICES countries used two ships (*Johann Hjort* and *A.V. Humboldt*) to make simultaneous collections in a Norwegian Fjord. Net systems compared were: WP2 net, CALCOFI net, Gulf III net, Bongo net, Multi-net, LHPR, BIONESS, and MOCNESS. The data are being examined for relative efficiency for estimation of total zooplankton biomass, zooplankton size-frequency distribution and depth distribution. Manuscripts (Skjodal *et al*. unpublished) and a data CD are in preparation to describe the workshop results. Note that the workshop did not receive designated funding. All investigators participated using their own research funds.

**Recommendations**

1. PICES scientists are strongly encouraged to make their zooplankton time series internally consistent. If collection equipment changed during the time-series, then sufficient repeated paired collections should be made using the different devices so that there is a statistical basis for quantitative adjustment of the various estimates of zooplankton biomass and size frequency distribution.
2. Institutions holding long time-series should develop a strategy for dealing with anticipated instrumental changes. Changes should not be introduced until an adequate relative comparison of the sampling characteristics of the new and old instruments has been carried out.

# Monitoring zooplankton production in the Subarctic Pacific

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Most monitoring work on zooplankton involves the collection of zooplankton with a plankton net, then preserving the sample with formaldelhyde or alcohol for later analysis of biomass and/or species composition and abundance. In this note, I suggest that such efforts could easily be supplemented with experimental work on living zooplankton and with a small amount of training, experimental work could become routine and could be included in any shipboard monitoring program. By following the methods given below, one can easily estimate growth and production of adult copepods (very easy to do) and growth and production of juvenile copepods (possible but more difficult). The suggested methods can also be adapted for measurement of growth of euphausiids.

One good reason for including production measurements is as follows: analyzing a long time-series of zooplankton biomass and production, we would be able to determine if the interannual and decadal scale changes in biomass are due to changes in growth rate (i.e., production) or to other factors. For example, subarctic Pacific experienced a two-fold change in zooplankton biomass after 1977. Was this due to an overall increase in production of the subarctic or a two-fold decline in predation on zooplankton?

**Methods**

To estimate production, one must incubate animals for 24 hours in ambient seawater at some constant temperature. Female copepods are maintained in clean bottles of 500 mL or 1-liter capacity, 1 or 2 females per container for large species (such as *Calanus*) and 5-10 for small species (such as *Paracalanus*) for 24 h, during which time they will produce eggs. Adult female copepods in most cases do not grow, rather channel all energy for growth into egg production. Therefore egg production is a measure of growth. Juvenile copepods grow by moulting from one copepodite stage into another. If you know the moulting rates of a given copepodite stage, you can calculate growth, using the equations given below. Moulting rates are measured by incubating a number of juveniles of a given stage (30 or more animals per experiment) in a 1-L or 2-L container. A small number of those individuals will moult during the 24 h incubation period and those are the data used to calculate moulting rate in the equations below. If such measurements are made along with measurements of chlorophyll concentration, one will, in time, build up an understanding of relationships between secondary production that, with luck, will allow calculation of copepod production from knowledge solely of copepod biomass and chlorophyll concentration.

The basic equation used to calculate production ($P$) is

$$P = gB$$

where $g$ is growth rate and $B$ the biomass. The growth rate of juveniles is given by

$$g_i = \ln (W_i+1 / W_i) * MR$$

where $W$ is the weight of copepodite stages and $MR$ the moulting rate. The growth rate of adults is given by

$$gf = W_{eggs} / W_{female}$$

and total production is the sum of the two

$$P = (g_i B_i) + gf\,Bf$$

References below give more details on methods.

**References**

Kimmerer, W.J., and McKinnon, A.D. 1987. Growth, mortality, and secondary production of the copepod *Acartia tranteri* in Westernport Bay, Australia. Limnol. Oceanogr. 32: 14-28.

Peterson, W.T., Tiselius, P., and Kiorboe, T. 1991. Copepod egg production, smolting and growth rates and secondary production in the Skagerrak in August 1988. J. Plankton Res. 13: 131-154.

# Report on standardization of plankton sampling by the national institutes of the Japan Fisheries Agency

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Since 1964, national institutes of the Japan Fisheries Agency and prefectural fisheries experimental stations have conducted cooperative surveys for forecasting fishing and ocean conditions. These surveys were primarily designed to measure the distribution and abundance of eggs and larvae of pelagic fish. Plankton biomass was also a variable of interest. The measurements were made with a variety of sampling nets (Marutoku, Marunaka, NORPAC nets) so there was concern about the possibility of systematic errors in the survey results. The sampling nets differed in mesh shape and size, type of gauze material, and in the ratio of filtering area to mouth area. A working group was formed in 1993 to consider implementation of procedures to standardize the survey measurements. The working group identified the primary target organism to be fish eggs. A requirement in the standardization of the plankton sampling was that the data from the new net should be comparable to that collected in the past. They chose the Long NORPAC net for the standard net to be used in the furure, which has a ratio of the filtering area to the mouth size of 5.12 and consists of monofilament and plain weave gauze. Measurements of the collection efficiency for total biomass have shown that the Long NORPAC net values are lower compare to the Marutoku and NORPAC nets. Therefore the old measurements with the Marutoku net must be adjusted downward to be comparable to the Long NORPAC net data. Further work is needed to compare the Marunaka net with the Long NORPAC net. Further inter-comparisons for the biomass sampling efficiency of all the devices in the size range will allow a uniform time series to be constructed incorporating the old data with the new data.

## Optimal measuring conditions for plankton counters

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In marine ecological studies, one of the critical needs is the development of an accurate and automatic device which will measure the size distribution of zooplankton. Present microscope techniques are very labor intensive and often impractical. Optical plankton counters are a possible solution to this problem. Zooplankton biomass, zooplankton abundance and zooplankton biomass density have been measured by three methods and compared with those made by manual measurement under a microscope. The three automatic methods are: *in situ* optical (OPC) and electrical (EPC) plankton counters and a laboratory optical plankton counter (OPC-L). Both zooplankton abundance and biomass density measurements with OPC-L were highly correlated ($P<0.001$), when particle concentration was less than 5 counts/sec. However, there is a significant difference between samples from the Oyashio and Kuroshio regions: the relation was more variable in the Kuroshio than in the Oyashio. The plankton counter is capable of accurately reflecting differences in zooplankton abundance and biomass density and can be used under these conditions in zooplankton monitoring. Particle size distributions measured by the OPC-L are similar to those obtained by manual measurement in the size range larger than 0.5 mm under the conditions that the particle concentration passing through the OPC-L is less than 5 counts/sec, and the samples were stained. Identical samples were provided to the Scripps Institution of Oceanography (SIO) so that they could make analogous OPC-L measurements with their counter. Below 0.5 mm the SIO counts are consistently lower than the

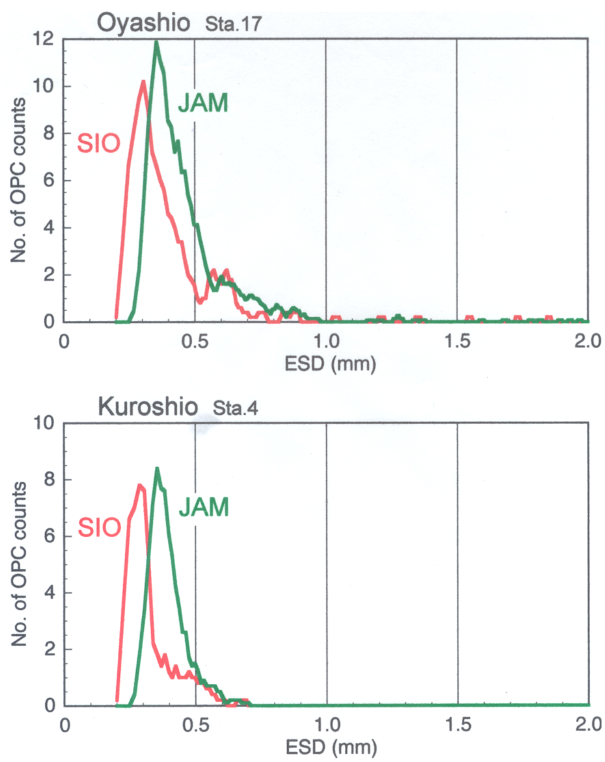


**Fig. 1** Comparison of size frequencies of the same plankton samples obtained from circulation systems equipped with OPC-L (Scripps Institution of Oceanography) and OPC-L (JAM).

Japan National Research Institute of Fisheries Science counts (Fig. 1). The source of this discrepancy is not understood. In the area of low abundance of gelatinous plankton and/or *Noctiluca*, abundance and biomass density of zooplankton measured with OPC and EPC are strongly correlated ($P<0.01$) with manual measurements, under the condition that concentrations are less than 100 particles per liter.

## Design and testing of an underwater microscope and image processing system for the study of zooplankton

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Oceanic ecosystem research needs a method to monitor the density of zooplankton at appropriate space-time scales. In order to address this need, a submersible microscope was equipped with a non-interlacing CCD camera. The target plankton for this method of measurement included Copepoda, Ploima, and Ciliata, which are the dominant species in the coastal waters around Japan. The key issues investigated for their possible influence on system performance were lens selection, camera selection, and method of illumination. Higher order local autocorrelation (HLAC) masks are used to extract features from images. Combining these with multivariate analysis, which is a two-step feature extraction method, results in a powerful tool for deriving general information from images. In our procedures a set of these features provides a 33-dimensional vector. To identify and count zooplankton, canonical correlation and discrimination analysis are performed. These procedures allow zooplankton to be counted and classified into taxonomic units. Another canonical correlation analysis is made for the sizing of the plankton. Proof of the principle experiment was obtained by using images of both preserved and living Copepoda. At this stage the limitations on the performance of the HLAC features are not clear because the number of images and the number of species is small. In the near future, a large number of plankton images will be collected, which will lead to improved algorithms for identification and counting. Future improvements in image processing may also increase the accuracy of identification because the quality of the obtained images is expected to be very high.

## Status of the Census of Marine Life Program

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The Census of Marine Life is an international research program that seeks to assess and explain changes in diversity, distribution and abundance of life in the oceans. Development of the program was fostered through a series of workshops and is currently guided by an international Scientific Steering Committee (SSC) and managed by a Secretariat. The SSC is preparing a draft scientific strategy document for review by the scientific community: the overall program will be developed in cooperation with marine scientists and funding agencies from around the world. Regional assessments of marine life will address specific questions related to ocean biogeography. Ecosystems supporting extensive fishing, mid-ocean ridges, seamounts, and open-ocean pelagic environments are under consideration. An Ocean Biogeographical Information System is being developed, with several exploratory projects supported through the National Ocean Partnership Program. Other areas of interest include the History of Marine Animal Populations (HMAP) and the application of novel sampling technologies for marine populations.

# Plan to monitor migrations of key species in the North Pacific

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Many marine animals are confined to the continental shelf ecosystem for much or all of their life. For example, after entering the ocean from freshwater, Pacific salmon smolts generally move along the west coast of North America following the continental shelf (Fig. 2). Earlier work had suggested that juvenile salmon began to move off the shelf by early fall and move directly into the Gulf of Alaska (e.g. Hartt and Dell 1986). However, subsequent studies (Welch *et al.* 1998) involving an extensive sampling period, have shown that all juvenile salmon remained along the continental shelf until reaching the Aleutian archipelago (note the location of the head of the final arrow in Figure 2).

Because the continental shelf is narrow along the west coast of North America (shown in light blue), the migration corridor is restricted to a long thin region that can be monitored at many locations at relatively low cost. Marked juveniles captured during surveys indicate that most salmon swim rapidly along the continental shelf (Fig. 3). Some coho and chinook smolts remain as year-round residents of the coastal zone, while others migrate at least as far as the Aleutians islands before moving offshore.

There are some populations of Pacific salmon which move southward along the continental shelf, opposite to the general pattern of movement (Weitkamp *et al*. 1995); at present, it is not clear why they do so or which groups are involved. Identifying which groups do so is an important management issue because this may partially determine which groups experience poor marine survival. Newly developed acoustic technology is the basis of the proposed tracking program. The miniature pingers to be placed on the individual fish (body length in excess of 15 cm) are 24 mm long and have an operational life of about four months (Eveson and Welch 2000). Field tests of the acoustic receivers to be mounted on the bottom indicate that pingers can be detected at distances of perhaps 0.6-1.0 km. The receivers have a life-time of one year. Because the shelf is usually less than 20 km wide, 20-30 receivers strung across the shelf and down the slope to a depth of 0.5 km should be capable of detecting all tagged animals crossing the line (Fig. 4).

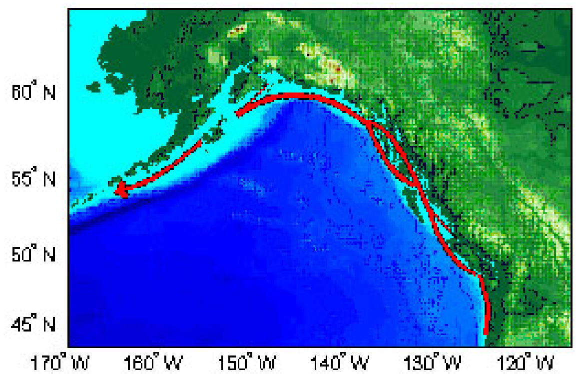


**Fig. 2** Migration path of juvenile Pacific salmon. All species (excluding steelhead) were found to remain strictly over the continental shelf (depths<200 m, shown in light blue). The only juveniles we have found off the shelf were at the far end of the Alaskan Peninsula on Dec 7th, at the start of the Aleutian Islands.

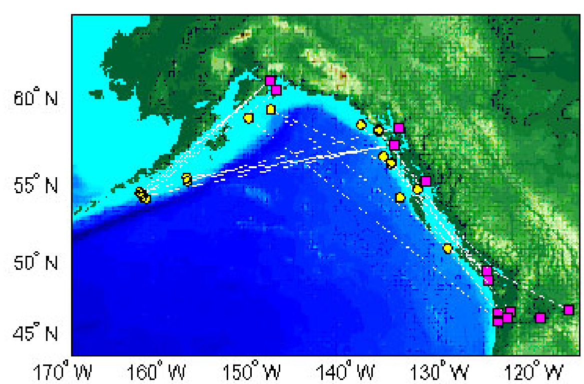


**Fig. 3** Release (squares) and recovery (circles) locations for tagged juveniles. Many of these animals travelled continuously at 1-2 BL/sec to reach the recapture points, and thus moved very rapidly out of the estuary or coastal zone around their rivers of origin.

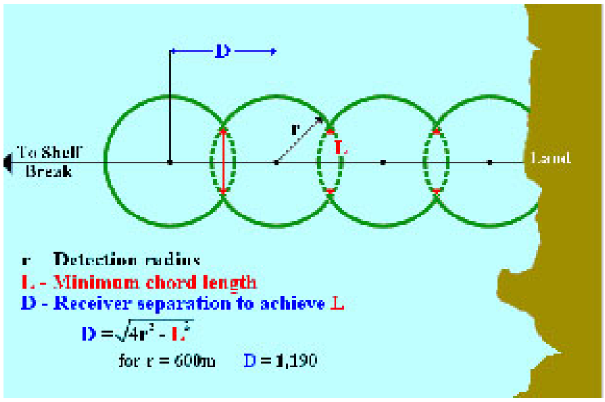


**Fig. 4** Conceptual example of a cross-shelf acoustic monitoring system. The dots indicate the location of a series of linearly aligned receivers placed on the seabed, each capable of detecting an acoustically tagged animal at a distance of r meters. The receivers would be placed D meters apart, chosen so that an animal swimming perpendicular to the array would remain within the detection area long enough to ensure reliable detection of at least one signal. For example, if the detection radius was 600 m and this minimum path length was chosen to be 150 m, the receivers could be spaced 1.2 kms apart.

The approximate cost of a single acoustic monitoring line is on the order of $50 K so that for roughly $2 M a network of 20 acoustic listening lines could be deployed that would stretch from California to the Aleutian Is. The acoustic array would provide the basis for reconstructing the movements of any animal that was tagged with a uniquely identifiable sonic tag. If initial design phase studies indicate that a credible observational program can be developed, the scientific objectives that a full-scale research program could address are listed below:

1. Determine the ocean migration pathways of multiple species of animals and their rates of migration;
2. Establish which stocks of salmon move to the offshore open Pacific or remain as coastal residents;
3. Establish the shelf feeding grounds of the shelf-resident animals;
4. Determine the period of time animals remain as residents of various sections of the coastal regime which are expected to be significantly affected by climate change; and
5. Establish movement patterns for mature and immature salmon by tagging these animals in the ocean one or more years prior to return to their natal rivers. Their movements up-river could also be tracked by placing receivers at various points in the rivers.

## Seabird monitoring and North Pacific ecosystem dynamics

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Seabirds are important constituents of marine ecosystems. Worldwide, nine families of marine birds, totaling over 300 species, are full-time participants in marine energy and nutrient cycles, deriving all their food from the sea, voiding feces in the sea, and dying at sea. Some seabirds feed almost exclusively on macro-zooplankton (e.g., auklets), while others have diets based primarily on nektonic fishes and cephalopods (e.g., murres, shearwaters and albatross).

Monitoring seabirds is important because they are sensitive biological indicators of ecosystem state, providing information on environmental change on multiple temporal and spatial scales. In addition, seabirds enjoy tremendous public support and are relatively inexpensive to study. Moreover, because marine birds are conspicuous, widespread and abundant, seabird monitoring studies yield powerful and robust numerical information to test hypotheses concerning climate change and ecosystem response. Interactions with fisheries, some positive and others negative, also provide impetus to monitor seabird populations and trophic dynamics.

There are many types of seabird monitoring strategies depending on the methodology (e.g., colony-based, wildlife telemetry, and vessel-

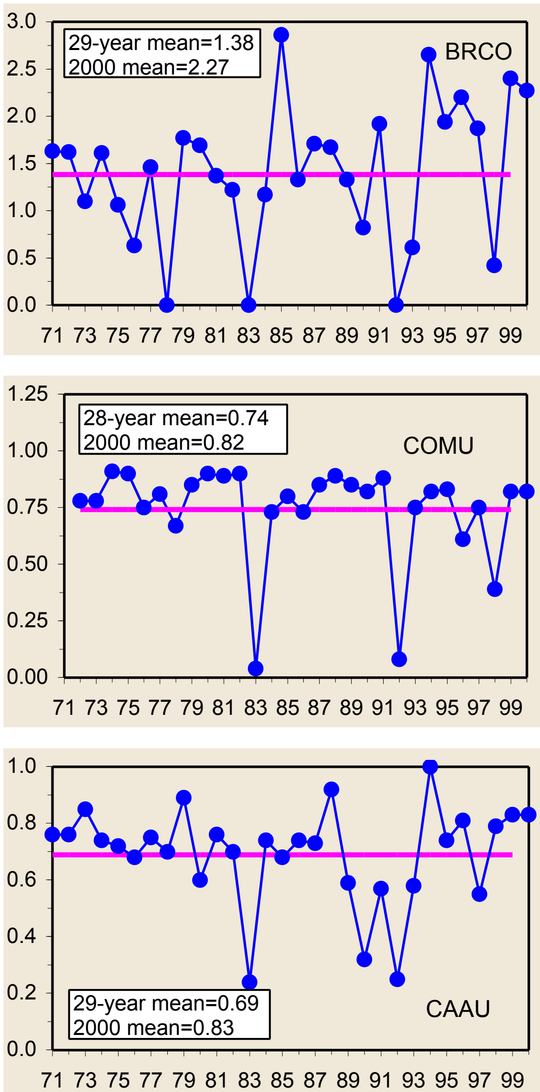


**Fig. 5** Productivity of three species of seabirds on Southeast Farallon Is., 1971-2000. Productivity is measured as the average number of chicks fledged per breeding pair.

based) and the temporal/spatial scales under consideration (e.g., short-term and long-term). Colony-based studies provide information on distribution and abundance, reproductive chronology and performance, and food habits. Similarly, shipboard monitoring of seabirds at sea provides information on distribution and abundance, and prey and oceanic habitat selection. Remote (e.g., telemetric) monitoring of seabirds at sea is a developing field that promises to reveal more information about oceanic habitat selection and predator-prey relationships on large spatial scales (e.g., basin wide). Short-term studies often provide a brief, intensive snapshot of marine bird ecology (e.g., duration / destination of a foraging trip, marine bird aggregation at a specific hydrographic feature) ideal to discern the mechanistic linkages between seabirds and their environment.

Long-term seabird monitoring provides information useful to place these short-term intensive studies in perspective by interpreting their findings in a climatic context. Studies spanning several decades are ideal to detect and understand climatic change, including the phasing, intensity, and periodicity of climate change events (Fig. 5). Examples include ecosystem response to inter-annual variability, as exemplified by the El Niño/Southern Oscillation cycle, and ecosystem response to inter-decadal variability in climate, as demonstrated by changes in state of the Pacific Decadal Oscillation.

As secondary and tertiary consumers in marine ecosystems, monitoring marine bird trophic relationships provides a means of assessing major shifts in food web composition, the relative abundance of food web components, inshore and offshore movements of prey species, and bio-physical relationships for many midtrophic-level organisms. Studies have demonstrated how seabird productivity is related to inter-annual variability in coastal pelagic fish biomass, and how changes in the timing and intensity of mesoscale oceanographic events affects the apparent availability of prey to seabirds and other predators. Other important, yet difficult to obtain information concerning the age, size, and sexual characteristics of forage fishes, cephalopods, and macrozooplankton (particularly euphausiids and large copepods) may be provided by coupling studies of marine bird food habits with direct ship-board studies of these mid-trophic level organisms. Importantly, many marine birds and large predatory fishes (e.g., salmonids) occupy the same trophic positions, and may respond to changes in climate and local oceanographic factors similarly. Like predatory fishes, birds are sensitive to gradients in water characteristics (e.g., SST, thermocline depth, etc.) which promote primary productivity and aggregate prey.

Seabird monitoring has important applications for the assessment of human interactions with marine ecosystems, for example, changes in chemical and petroleum pollutants. Repeated measurements of contaminant levels in seabird tissues and eggs have revealed long-term changes in persistent organochlorine pesticides, trace metals, and petroleum products, and the introduction of new contaminants in marine ecosystems. Monitoring contaminants has highlighted the need to investigate confounding factors (e.g., oil pollution, climate change, and fisheries interactions) in relation to goals of understanding and predicting the population dynamics of many marine organisms.

As part of the Living Marine Resources (LMR) module of the Global Ocean Observing System (GOOS), one could envisage a Seabird Observation System (SOS) devised to complement other oceanographic monitoring systems and sources of information. One approach would be to augment existing marine bird time-series in both the western and eastern North Pacific Ocean, especially those longer than a decade, or those using new technologies (e.g., remote monitoring via satellite telemetry). Advantages of this approach would be the enhanced spatial and temporal coverage of well-defined large marine ecosystems at a reduced cost. There are a number of pre-existing cooperative research teams and infrastructures that could be used to promote information exchange. For example, the Seabird Monitoring Database of the Pacific Seabird Group has summarized seabird monitoring data from colonies for most of the past 30 years. This database will soon be available to the oceanographic community via the World Wide Web.

Potential new directions for seabird monitoring programs are also required. In particular, while seabirds provide an integrated and inexpensive means of monitoring both physical and biological oceanographic attributes, research is needed to calibrate the information provided by marine bird monitoring of ecosystem state and food web dynamics. We must assume that seabirds are not unbiased samplers of marine ecosystems. Research designed to couple colony, at-sea, and remote seabird monitoring with oceanographic information based on traditional shipboard sampling and remote sensing would provide information needed to calibrate marine bird datasets. Seabird observations on new research programs are also necessary to provide complementary information. For example, because seabirds forage on sub-surface prey, marine bird observations in conjunction with the PICES/Continuous Plankton Recorder (CPR) project would serve to help identify oceanographic changes that might influence variability in the plankton data. Finally, a system to monitor global contaminant levels through non-destructive predator tissue sampling would provide the oceanographic community with new information about anthropogenic impacts on marine ecosystems.

## Role of regional organizations in the design of GOOS

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Although the basic operational units for GOOS implementation are national observing systems, several regional GOOS activities have been initiated; these include EuroGOOS, MedGOOS, Africa-GOOS, Pacific-GOOS, Near-GOOS, ICES-GOOS, IOCARIBE-GOOS and Black Sea-GOOS. These regional activities have been created for various reasons: conduct ecosystem assessments, existence of common economic interests, economies of scale in operating observing systems and decentralization of GOOS administration. Groups of countries can initiate regional GOOS activities as long as they adhere to the published GOOS principles.

One model for a regional GOOS activity relevant to PICES is ICES, another intergovernmental marine science organization. In 1997, ICES recognized the opportunity to establish a regional GOOS for the North Atlantic and accordingly set up an ICES-IOC Steering Group for GOOS with the following term of reference: "prepare an action plan for how ICES should take an active role in the further development and implementation of GOOS at a North Atlantic regional level with special emphasis on fisheries oceanography".

After reviewing options for an ICES-GOOS, it was recommended that an observing system be developed with two elements: (1) an Atlantic component focused on climate; and (2) a regional component focused on ecosystem dynamics of the North Sea with emphasis on the need to improve management of fish stocks. ICES is moving toward the implementation of both components.

Provisional terms of reference of a GOOS/PICES Scientific Steering Group (SSG) could be:

1. Determine the ways in which PICES can assist in the implementation of GOOS and advance its own interests.
2. GOOS (LMR module report) has proposed that ecosystem monitoring be designed and carried out by scientific groups familiar with particular ecosystems. The SSG should consider the desirability of PICES assuming the responsibility for reporting on the state of the North Pacific ecosystem.
3. In support of GOOS, a number of scientists in PICES have suggested setting up a Regional Analysis Center (RAC) for the North Pacific. The RAC would issue periodic assessments of the state of the North Pacific ecosystem. The SSG should make a recommendation to the Science Board as to whether or not the design of a RAC should be undertaken.
4. If the recommendation is made to proceed toward setting up a PICES RAC, the SSG should make specific recommendations on its structure, e.g. distributed (virtual) center or physical center with dedicated personnel, centers in the western and eastern Pacific or a single center, etc.
5. The SSG should report to the Science Board at PICES X.
6. Suggested membership of the SSG is David W. Welch (Canada), Warren S. Wooster (U.S.A.), Takashige Sugimoto (Japan) and Vyacheslav B. Lobanov (Russia), with Ned Cyr (GOOS) as a liaison member.

## Long-term plans of NEAR-GOOS

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NEAR-GOOS is one of the regional GOOS bodies focusing its efforts on the Northeast Asia region. Its member states are Japan, the People's Republic of China, the Republic of Korea, and Russia. These countries have agreed to a common data exchange policy under the NEAR-GOOS framework. During the last few years, the major emphasis of NEAR-GOOS has been on solving problems of data processing, archiving and creation of data products. A limited set of physical parameters has been addressed: temperature, salinity, ocean currents, winds and ocean waves. In the long term, it is expected that the NEAR-GOOS system will expand to better serve the overall goal of global ocean and climate monitoring and forecasting.

The NEAR-GOOS system operates through two different modes: a (near) real-time database and a delayed mode database. Data are kept in the real-time database for 30 days and then transferred to the delayed mode database and added to the long-term records. The databases are maintained by different agencies. The Japan Meteorological Agency (JMA) and the Japan Oceanographic Data Center (JODC) carry out the respective data aggregation at the regional level. There are a number of future developments that are envisioned:

1. At the present time other data sets are being considered for inclusion and archival: sea level, dissolved oxygen and inorganic nutrients. In addition, NEAR-GOOS will undertake to access remotely sensed variables

such as satellite altimeter sea-height, ocean-color and scatterometer wind measurements.

2. Another concern is the application of data quality standards to the submitted data. Up to the present time it has been understood that data quality has been the responsibility of the data provider. NEAR-GOOS recognizes that they must be able to provide users a statement of data quality and will begin to address ways of doing this routinely.
3. Potential users of the archived data set often have needs for specific data products. NEAR-GOOS will consider adding products based on assimilation of data into models (including forecasting models). The choices will be made in such a way that they do not compete with existing specialized agencies that support similar or more advanced systems.
4. Cooperation should not be limited to the NEAR-GOOS area. Participation in global research programs (GODAE, CLIVAR, etc.) offers valuable opportunities for the development of data applications in the NEAR-GOOS system.

NEAR-GOOS will hold a three-day workshop in August 2001, in conjunction with the Fifth IOC/WESTPAC Scientific Symposium in the Republic of Korea. The focus of the workshop will be the current status and need of ocean forecasting capacity in the NEAR-GOOS area. PICES will be asked to participate.

## Argo: Progress toward implementation

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The Argo program proposes to deploy globally an array of 3,000 profiling floats to provide real-time observations of the temperature and salinity structure of the upper layer of the ocean. The floats are designed to drift at a depth of 2,000 m and rise to the surface every 10-14 days to measure the vertical profiles of temperature and salinity. After relaying the profile data to shore via satellite, the floats will descend to 2,000 m to begin another cycle. The lifetime of a float is expected to be four years.

Argo is being planned under the auspices of the World Meteorological Organization (WMO) and Intergovernmental Oceanographic Commission (IOC). The February 7, 2000, joint IOC-WMO Circular Letter JCOMM No.00-2 states that "... it is an important component of the operational ocean observing system, as well as a major contribution to scientific research programs". International support for Argo has increased greatly over the past year. As of August 23, 2000, 11 countries (Australia, Canada, France, Germany, India, Japan, New Zealand, Korea, Spain, U.K., U.S.A.) and the European Union have proposals on file to fund 2,324 floats. Proposals for 425 floats have already been funded. In addition to these nations, China and Norway have expressed interest in providing floats.

All Argo data - both real-time and delayed-mode - will be available to anyone, with no period of exclusive use. Real-time data will be put on to the Global Telecommunications System within 12 hours of collection for use by operational forecasting agencies. Delayed-mode data, which have been scientifically quality controlled, will be accessible via the Internet within 90 days of collection. Locations and functions of Argo data centers and data exchange formats are under discussion by an Argo data-system task team.

Performance of Argo sensors has been under evaluation for several years. Provisional standards for instrument accuracy are 0.005°C for temperature, 0.01 psu for salinity and 5 db for pressure. Tests of deployment of floats from commercial vessels at full speed indicate no adverse problems, and the U.S. Navy is evaluating aircraft deployment of floats.

Since Argo floats are untethered freely drifting objects, some floats may enter the EEZs of non-participating countries. This is a particular concern of Pacific island nations. In order to address these concerns, IOC Resolution XX-6 was adopted that "...concerned coastal states must be informed in advance ….of all deployments of profiling (Argo) floats which might drift into waters under their jurisdiction (i.e. EEZs)".

The International Argo Science Team (IAST) was created to review national plans and commitments in order to formulate a strategy for global coverage for the benefit of all nations. Current members of the Team are U.S.A., Japan, Canada, Korea, China, Australia, New Zealand, E.U., Germany, France, U.K. and India. The third IAST meeting will take place at the Institute of Ocean Sciences, Sidney, Canada, in March 2001.

## Regional model of a long-term marine science program: Gulf of Alaska Monitoring (GEM)

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In 1999, the Exxon Valdez Trustee Council dedicated a fund, expected to be $120 M by October 2002, to support a program of research and monitoring in the northern Gulf of Alaska in perpetuity. The goal of the program is to promote use of living marine resources through increased understanding of the ways in which natural and human factors cause changes in these resources. The Trustee Council invites the scientific community of PICES to participate in planning and implementing the program.

The entry point for those who wish to participate is the draft GEM program document that describes the policies of the Trustee Council, and the scientific background for the northern Gulf of Alaska and related ecosystems (available on the web at www.oilspill.state.ak.us). Drawing on the expertise of many concerned scientists and the scientific literature, the draft program provides the scientific basis for regional monitoring in terms of North Pacific and global climate and oceanographic processes. The program document advances a conceptual foundation of how geophysical and human factors cause changes in the abundances of living marine resources through impacts on availability of food, amount of habitat and extent of removals by activities such as fishing. Long-term monitoring is expected to be a large part of the program, based on experience and research on a large-scale ecological disaster - the 1989 Exxon Valdez oil spill. Lessons learned during the decade following the oil spill point out that understanding the sources of changes in living marine resources, whether natural or influenced by human activities, requires a solid historical context. Comments on the program document and suggestions for monitoring activities are open until October 2001, which is the target date for completion of the review now underway by the USA National Research Council's Polar Research Board. The NRC review and other peer-review comments will be used to produce the first call for proposals under GEM in late winter 2002. Initial implementation is expected in October 2002, with further consideration of proposals for funding at regular intervals thereafter.

It is emphasized that the process of developing the scientific basis for GEM is now ongoing. For example, as part of the process of encouraging cross-disciplinary cooperation in the design of GEM, a workshop was held in Anchorage in October 2000, to exchange ideas on monitoring and research in the northern Gulf of Alaska. Teams of scientists from geophysical and biological sciences met with policymakers and stakeholders to develop responses to specific examples for monitoring and research in the region. Results from the workshop indicate broad support among scientists for long-term monitoring of physical and biological processes in order to understand and evaluate change in living marine resources. Specific recommendations from the workshop will be incorporated into the process of developing the first invitation for proposals in 2002. To receive a summary of the workshop sessions or to be put on the mailing list for future information and activities, please contact gem@oilspill.state.ak.us.

The proper development of the regional GEM program has important consequences for PICES, and for other international marine scientific organizations. An important lesson learned in the aftermath of the oil spill was that coordination among researchers, integration of data acquisition operations, and synthesis of results across disciplines are essential to make cost-effective progress in understanding change. PICES has been established to promote international cooperation, integration and synthesis for the same purposes. The Trustee Council has studied national and international scientific programs to find additional models essential to the development of a regional monitoring program. The approaches of the Global Ocean Observing System (GOOS) and the Global Ocean Ecosystem Dynamics (GLOBEC) have been found to be fully consistent with the policies established by the Trustee Council for GEM. GOOS seeks to define a core set of physical and biological variables essential to understanding changes that can be adapted to local user needs. GLOBEC has focused on understanding physical forcing of primary and secondary productivities in relation to production of higher trophic level organisms such as fish. These aspects of GOOS and GLOBEC are to be incorporated into the development of the GEM program.

## Seasonal variability of temperature/salinity structure on repeated sections in the Okhotsk Sea

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Physical processes in the Okhotsk Sea have a strong influence on regional climate. In order to understand the role of external factors on water mass structure, measurements of water characteristics on a variety of space and time scales are needed. Seasonal variations of water properties on two quasi-zonal hydrographic sections (central and southern Okhotsk Sea) have been estimated for three periods: spring (May-June), summer (July-September) and autumn (October-November).

The temperature structure is characterized by a thermocline (strongest in summer and weakest in fall) in the surface layer, a temperature minimum layer at about 100 m (coolest in summer) and warmer temperatures at depth. Seasonal temperature variability is strongest near the Sakhalin and Kamchatka coasts. On the southern section, the depth of the core layer thermocline is 75-100 m, and deeper off Kamchatka than off Sakhalin. Negative temperatures at the core are confined to west of 151°E, 150°E and 148°E respectively, in spring, summer and fall. Under the cold layer seasonal temperature variations are small.

Salinity increases monotonically with depth. On the sections the largest seasonal variation of salinity in both surface and subsurface waters occurs near the two boundaries. On the northern section, the freshest water, due to Amur River runoff and melting, is found in the spring off Sakhalin (21-24 psu). In summer, on the northern section the salinity off Sakhalin increases to 23-24 psu and the low salinities spread to 150 m and to the east. Off Kamchatka salinity varies from 31.6 to 32.0 psu over the three seasons. In the southern Okhotsk Sea, close to the Sakhalin coast, the average surface salinity varies from 32.0-32.3 psu in spring, to 31.1-31.9 psu in summer and to 30.0-30.5 psu in fall.

These results might be considered as the first approximation to the seasonal variation of temperature and salinity in the central and southern Okhotsk Sea and could serve as a baseline for future monitoring in the region.