REPORTS OF THE BREAKOUT GROUP DISCUSSIONS

After the plenary session reports on large international programs, the workshop participants were separated into four breakout groups organized by discipline. Breakout Group 1 consisted of experts in physical/chemical oceanography and climate. Group 2 was phytoplankton, zooplankton, micronekton and benthos experts. Group 3 consisted mainly of scientists involved in fish, squid, crab, and shrimp population analyses. Group 4 was for migratory fish such as salmon and tunas, seabirds, and marine mammals. Breakout group leaders asked participants to report on national monitoring activities within each discipline and their individual reports are contained in Section II. Each group then discussed the status of the monitoring, modeling and prediction system in the North Pacific with regards to the discipline. Monitoring gaps, priority sampling and analysis activities were identified.

Breakout Group 1: Physical/Chemical Oceanography and Climate

Chairman: Richard E. Thomson
Rapporteur: James E. Overland

Participants: Steven J. Bograd, Alexander S. Bychkov, Kimio Hanawa, Makoto Kashiwai, Andrei S. Krovnin, Vyacheslav B. Lobanov, Allen Macklin, Humio Mitsudera, Yukihiro Nojiri, Fangli Qiao, Warren S. Wooster, and David Foley. Suam Kim attended part time.

Introductions and preliminary discussion

The morning session on the first day (March 7) began with each participant giving their name and affiliation, and outlining their area of research. Introduction was followed by a general discussion that attempted to define the exact goals of the breakout group in terms of the challenges presented in the workshop description. There was some uncertainty in the goals and the best approach to proceed. The initial discussion eventually centered on several main themes:

- The importance of national governments in the establishment and maintenance of time-series for observing North Pacific marine ecosystems and their biodiversity. Too often, continuation of important time-series is determined by the ability of individual scientists to secure funding and, unless the program is "institutionalized", it may end with the departure of the leading proponent of the program.
- The fundamental physical and chemical measurements needed for any long-term monitoring of the ocean. Minimum requirements are temperature and salinity from CTDs, but preferably would also include meaurements of nutrients, dissolved oxygen, beam attenuation, chlorophyll, carbonate parameters, currents, and high-frequency bioacoustics.
- Identification of "critical" time-series, such as those from coastal lighthouses and oceanic gyre sites (Station P and Station KNOT) that should be maintained to some level regardless of politics and funding constraints.
- The approaches and sensors that are needed to overcome the logistical and funding difficulties required maintaining long-term physical and chemical oceanic time-series. Newly emerging technological advanced projects, such as the proposed NEPTUNE project in the northeast Pacific, offer an opportunity for oceanographers to collect long-term, externally powered, real-time, simultaneous physical, chemical, biological and geophysical data in the open ocean.
- The degree of "value-added" information (i.e., degree of time-series interpretative) that should accompany any PICES database, and the need for a "stand-alone" document – such as a regularly updated State-of-the-Ocean Report – for managers.

Presentations on existing and proposed time-series observation programs and research

The afternoon of the first day (March 7) and the morning of the second day (March 8) were devoted to presentations by individual scientists on material they had prepared for the meeting (see Table 1 and Section II). The talks provided detailed information on existing physical/chemical databases for the North Pacific archived by American, Canadian, Chinese, Japanese, Korean, and Russian national institutions. Presentations afforded insight into past, present and future field programs for each country and associated research programs within the institutions represented by each of the participating scientists. Talks were generally informal and informative, ranging from presentations on data inventories to reports on scientific interpretation and numerical modeling. Some impressions are summarized below:

- It is clear that the major sea-going nations of the North Pacific collectively hold an impressive range of continuing (as well as recently terminated) time-series of physical and chemical data. Most participants reported on one or more oceanographic time-series (often bottle and/or CTD temperature and salinity data series) of more than 10 to 15 years duration, as well as shorter (2 to 5 year) data series from process-based studies. The latter tend to be multi-disciplinary and encompass a wide range of oceanic measurements. Much of these "untapped" data are securely stored away in the archives of various institutions. In some instances, different institutions in the same country have limited access to each other's data series.
- Most of long-term data series have been collected under the auspices of fisheries, ship navigation (e.g., ice concentrations and currents), and climate-related programs. Time-series for process-based studies are generally only a few years but encompass a broader range of physical, chemical and biological variables. Unlike the open ocean areas, there generally are sufficient data from most coastal seas to accurately define seasonal and interannual variability.
- Most of the existing datasets contain standard temperature and salinity data series from bottle/CTD casts, but many also include other oceanic parameters such as chlorophyll, beam (light) attenuation, nutrients, dissolved oxygen, carbonate parameters, current speed and direction, and zooplankton net haul time series. Sea surface temperature (SST) from satellite AVHRR imagery and SeaWIFS ocean colour are critical to examining long-term variability but are often too limited by cloud and fog for short-term process-related studies.
- Data coverage is highest within territorial seas and the continental margins of the World Ocean, and marginal at best in the offshore waters of the central Pacific, especially regions outside commercial shipping lanes.
- Data collection is now generally complemented by primitive equation biophysical modeling and box-type ecosystem productivity modeling.
- Scientists at the meeting were generally enthusiastic – albeit cautious – about sharing information on existing data sets and setting up a cooperative exchange program.

Time-series data requirements

Following the informal presentations on March 8, the group momentarily lost its direction. It was not clear how to proceed and how to address the formidable tasks set out by the convenors. The original goal of the meeting was seen by some as "analogous to climbing Mount Everest in winter without oxygen". After a brief discussion, it became clear that our goal was not to reach the peak but to set up "base camps" for future assaults on the database summit.

We decided to return to the theme of meeting which was "to review the available existing time-series and predictive models, to discuss the utility of those for assessing biodiversity and its changes, and to suggest improvements in terms of sampling and modeling strategy, and the addition of new time series observations that are not yet part of the monitoring system".

Table 1 Presenters and themes for Breakout Group 1.

Presenter	Type of data series described
Bograd, Steven U.S.A.	(a) CalCOFI (1949-present) physical and biological data for the coast of California; (b) PMEL/NIMPS data server. Data on NOAA & CalCOFI websites.
Hanawa, Kimio Japan	Presented a handout of material on repeat sections. JMA repeat surveys 137°E, 155°E, 165°E. Also short coastal lines 4x per year CTD/nutrients and physics. Fisheries surveys of phyto/zooplankton along 179.5°W.
Kashiwai, Makoto Japan	Repeat lines by JFA (referred to David Welch's overhead from his talk). Has a program for distributing fisheries data. Noted the problem with data exchange among Japanese agencies.
Krovnin, Andrei Russia	Discussed monthly mean data collected by Russian fisheries agencies since 1950. Time-series exist for winter months and for ice cover in the Sea of Okhotsk. T and S data for the NW Pacific. Data are in digital form; older data in paper form.
Lobanov, Vyacheslav Russia	Pacific Oceanological Institute database (http://poi.dov.ru). Sakhalin Hydrometeorological Administration and Sakhalin Institute of Fisheries and Oceanography (SakhNIRO) sections off Sakhalin Islands continuing since the 1950s. POI studying the eddy regime off the Kuril Islands from 1990 till 2000 as an indicator of climate regimes.
Macklin, Allen U.S.A.	Indices from gridded data sets. Bering Sea ice pack data. Find an earlier transition from spring to summer. Timing of the last spring storm in the Bering Sea used for pollock predictions. North Pacific bottom pressure data at 1-minute samples collected for tsunami warnings since 1986. Alaska line 8 has 16-year data set. Pollock larvae survey = 17 years data set. Alaskan Stream work began in 1987; 7 years of current moorings. North Pacific CTDs since 1932; Sitka air temp since 1829; North Pacific index since 1899; satellite-tracked drifters 1986-2000.
McLaren, Ron Canada	Canadian meteorological program in the North Pacific. Array of 6-12 deep-drogued drifters since the mid-1980s (pressure and temperature sensors), and moored met buoys (6 m NOMADs and 3 m Discuss) measuring wind speed and direction, SST, air temperature, pressure, wave height, and wave period since late 1980s.
Mitsudera, Humio Japan/U.S.A.	Share data server with PMEL and have distributed data site at University of Hawaii. Argo implementation and remote sensing data.
Nojiri, Yukihiro Japan	Discussed measurement of carbonate parameters data in the North Pacific. Also collection of pCO_2, hydrography, DIC, and nutrient data. CO_2 and nutrients from underway sampling. 1998 began KNOT time-series. Compared time-series from Station P and Station KNOT. Station P has higher productivity in winter but to his surprise, the two are the same in summer (need to verify this). Chemists need coverage in the South Pacific on a repeated track. Has a website for T/S and CO_2 data.
Overland, James U.S.A.	Discussed NCEP (National Center for Environmental Prediction). Data from 1947- present. Used fixed physics and data assimilation to produce three-daily and monthly data files and maps.

Table 1 (continued)

Presenter	Type of data series described
Qiao, Fangli China	Presented results for a numerical model of Jiaozhou Bay. Other areas of interest include Yellow Sea area (observations), Kuroshio (have 18 years of data).
Thomson, Richard Canada	Discussed programs and data collected by the Institute of Ocean Sciences. Omitted to discuss ongoing paleooceangraphy studies examining piston, box and freeze cores from anoxic basins in British Columbia to examine histories of pelagic fish abundance, earthquake occurrences, and climate change.
Batchelder, Hal U.S.A.	Breakout group 2. US GLOBEC program: Transects off Oregon 4x per year for 6 to 7 years. Extensive CODAR array. Long-term observation program along Seward Line 1997-2005. AVHRR imagery and SeaWIFS.
Foley, David U.S.A.	Pacific basin wide TOPEX/Poseidon, SeaWIFS and measurement of wind stress, SST, wind stress curl, and chlorophyll. Websites for real-time data access.
Kim, Suam Korea	Breakout group 3. Described the 22 transects conducted around Korean Peninsula, occupying about 75 stations, plus lighthouse coastal data dating to 1965. 6 surveys per year (every other month) for T, S, nutrients, DO, zooplankton.

The following factors were addressed:

- The need to collect and process high-quality, reliable physical and chemical data of sufficient sampling frequency to define seasonal, interannual and decadal variability, and climate-scale trends.
- The need to distribute these data on a timely basis to national and international users (through joint programs if needed).
- A requirement to analyze and interpret time-series data in terms of physical and chemical dynamics of interest to biologists and political decision-makers.
- The need to provide oceanographic data for formulation, calibration and validation of numerical models of ocean/atmosphere processes and climate change.

Regional data coverage

Given its considerable observational expertise, the breakout group decided to separate the North Pacific into nine distinct oceanographic regions and then discuss the degree of coverage in each of the primary regions. A photocopy of the North Pacific was supplied by Dr. Nojiri, and group members were asked to sketch on the maps the locations and types of surveys their institutions are providing, separating these into "terminated data series" (Fig. 8) and "continuing data series" (Fig. 9).

The general conclusion is that there are considerable physical, chemical and biological data collected within the coastal domains and continental margins of the North Pacific, but a marked paucity of data series for the central Pacific and Subarctic Gyre regions. AVHRR satellite imagery and SeaWIFS are hampered by cloud cover. However, TOPEX/POSEIDON is not hampered by clouds and has been providing critical time-series data on sea level height anomalies and their propagation in the open ocean and coastal seas.

The 9 Biophysical Domains identified for the North Pacific were identified as the:

1. California Current System (including hydrothermal venting regions)
2. Alaska Current and Gulf of Alaska System

3. Bering Sea
4. Central North Pacific
5. Sea of Okhotsk
6. Sea of Japan
7. Western Subtropical Gyre (including the Kuroshio)
8. Western Subarctic Gyre (including the Oyashio)
9. East China Sea

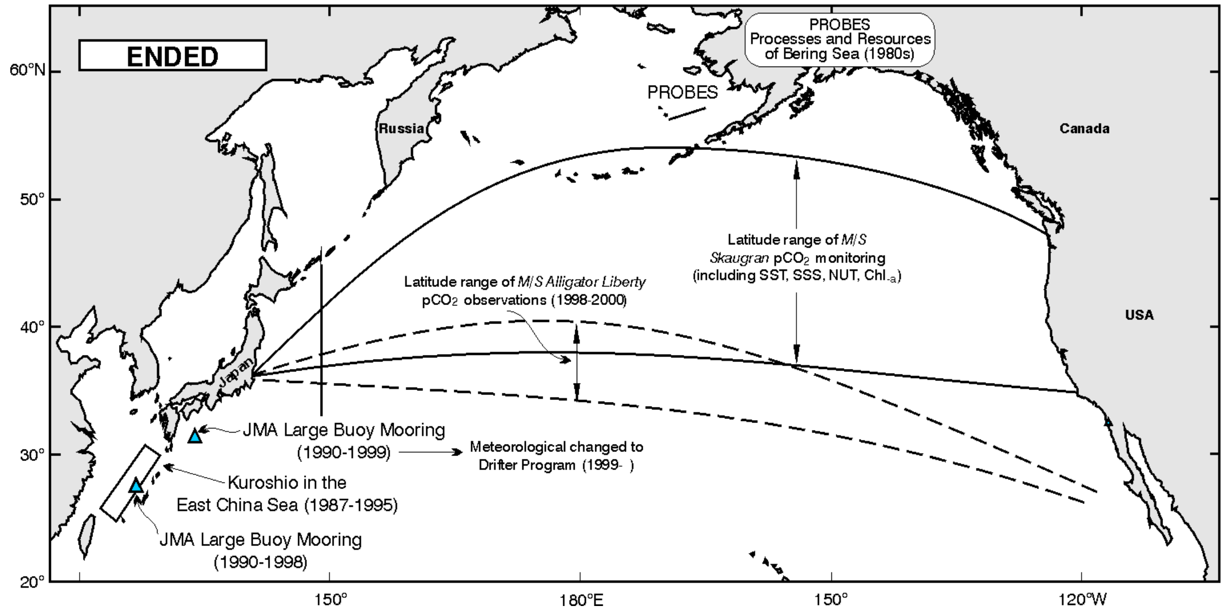

Fig. 8 Time-series observations of physical/chemical or atmospheric parameters that have been discontinued.

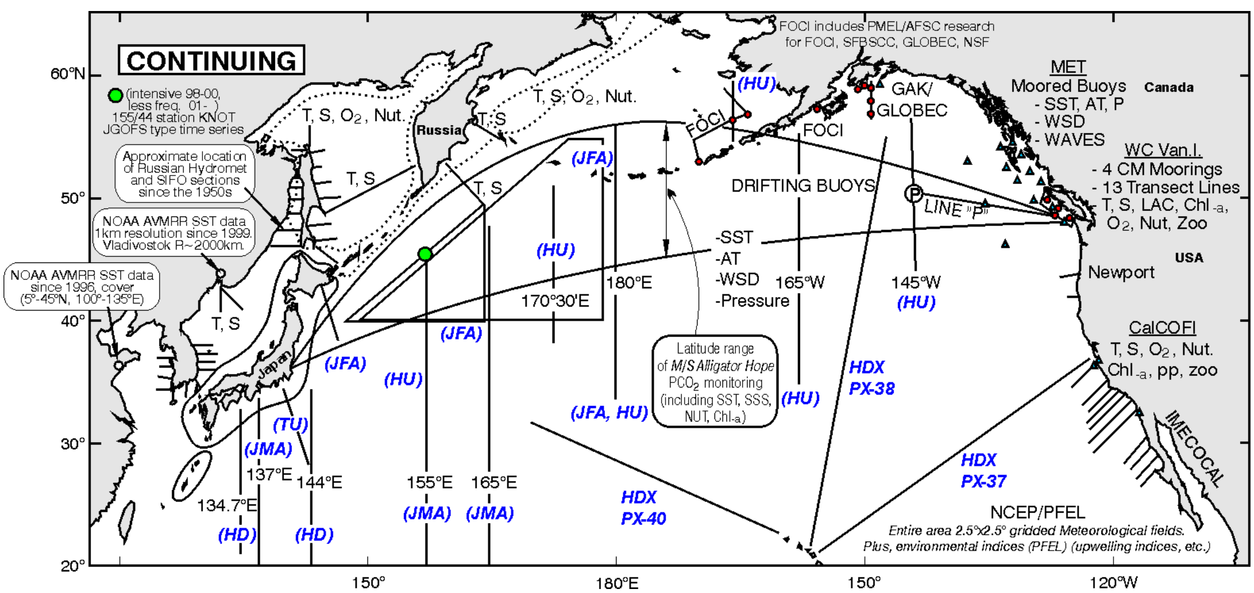

Fig. 9 Time-series observations of physical/chemical or atmospheric parameters that are continuing.

Sea of Japan

JMA (Japan) sections
NFRDI (Korea) transects
TINRO (Russia): 2 sections
SakhNIRO (Russia): semi-annual sections off Sakhalin Island
NEAR-GOOS activities

Coastal Japan

Since 1964: T, S, nutrient, chlorophyll, zooplankton

Coastal Korea

Since 1965: T, S, DO, nutrients, chlorophyll, zooplankton

Western Subarctic Gyre (and Oyashio)

HNFRI (Japan): Line A (7 years)
JMA (Japan): lines along 41.5° and 144°E; SST data composite
Station KNOT (1998-)

Western Subtropical Gyre (and Kuroshio)

JMA (Japan): lines along 137°, 155°, and 165°E
JHD (Japan): lines along 134.7° and 144°E; also G, P Lines
NIES (Japan) and IOS (Canada): Basin wide CO_2 measurements since 1995

Sea of Okhotsk

TINRO (Russia): Sakhalin and Kamchatka transects, T, S, DO, nutrient, zooplankton
VNIRO (Russia): weekly SST from satellites and ships
SakhNIRO (Russia): semi-annual sections off Sakhalin Island
JMA, JHD and VNIRO: sea-ice data

Bering Sea

TINRO and KamchatNIRO (Russia): Kamchatka Current (in 1970s and 1995-); SST, winds, T, S, DO, nutrient, zooplankton, primary productivity, currents
FOCI (U.S.A.): 2 moorings and sections; sea ice
NMFS (U.S.A.): survey data

Central Pacific

Station HOT (U.S.A.): 22°N station and transect monthly along 175.5°E since 1998
Hokkaido University, HU (Japan): survey lines along 170°E, 180° and 165°W; Line P and ships of opportunity

Gulf of Alaska

FOCI (U.S.A.): Shelikof Strait since 1985; T, S, nutrient, chlorophyll, primary productivity, zooplankton, currents
GAK (U.S.A.): line since 1971, now part of US GLOBEC; CPR lines, T, S, nutrient, chlorophyll, zooplankton
IOS (Canada): La Perouse/GLOBEC lines off Vancouver Island and northern Washington State
IOS (Canada): Line P and Station P (1956-)
HU (Japan): line along 145°W
NMFS (U.S.A.): Gulf of Alaska groundfish surveys
NMFS (U.S.A.)/DFO (Canada): west coast of North America hake surveys (every 3 years)
Meteorological buoys report near real-time hourly data on wind speed and direction, wind maximum, SST, air temperature, atmospheric pressure, significant wave height, and wave period
Drifting buoys provide information on atmospheric pressure, SST, air temperature, and wind speed and direction (some buoys only)

California Current System

IOS (Canada): Station P/Line P; La Perouse/ Canadian GLOBEC programs; T, S, nutrient, chlorophyll, zooplankton
US GLOBEC: Newport Oregon line (originally in the 1960s; restarted 1996-); T, S, nutrient, chlorophyll, zooplankton
CalCOFI (U.S.A.): ongoing since 1949; T, S, nutrient, chlorophyll, primary productivity, zooplankton
Canada/U.S.A. Vents programs (focus on Juan de Fuca Ridge). T, S, currents, nutrients, zooplankton

MBARI moorings and Scripps (U.S.A.) pier time-series
IMECOCAL line off Baja (U.S.A./Mexico)
Santa Barbara Basin (U.S.A./Mexico)
Meteorological buoys report near real-time hourly data on wind speed and direction, wind maximum, SST, air temperature, atmospheric pressure, significant wave height, and wave period

East China Sea

SOA (China): five standard sections since 1960
JMA (Japan): PN line

Strait of Georgia

IOS (Canada): CTD, DO and nutrient data time-series begun in 1999

Except for the Sea of Japan

NIES (Japan): VOS CO_2 program

PICES "State-of-the-Ocean Reports" and establishment of a meta-database

The general consensus of the breakout group was that:

- PICES could provide a "virtual" site for communication of data inventory (i.e., provide information on geographical/time/type of data and data source) but should not attempt to store the data. NOAA scientists attending the meeting had considerable expertise on setting-up and maintaining a meta-database site. They should be consulted prior to and during formulation of any database site.
- PICES could provide a site for regional large-scale climate indices such as the Southern Oscillation Index, Pacific Decadal Oscillation, and Length of Day Index, and other indices.
- PICES should oversee an annual (or semiannual) report detailing the "State-of-the-Ocean" for the North Pacific which summarizes the temperature, salinity, currents, winds, primary/secondary production, fisheries productivity, carbonate parameters, and other oceanographic factors (including results of numerical modeling and theoretical studies). Several nations presently issue such status reports for their areas of interest.
- The reporting frequency should be at least annual but would prefer monthly so that seasonal cycle can be defined.
- The information should be widely distributed through as many organizations as possible. PICES should help establish a meta-database by supporting (or finding support for) existing facilities set up by NOAA on the west coast of the United States.

Breakout Group 2: Phytoplankton, Zooplankton, Micronekton, and Benthos

Chairmen: David L. Mackas and Young-Shil Kang

Participants: Vera Alexander, Harold Batchelder, Sonia D. Batten, Richard D. Brodeur, David M. Checkley Jr., Sanae Chiba, Cynthia Decker, Rita Horner, Takahito Iida, Shin-ichi Ito, Michio J. Kishi, Toru Kobari, Kosei Komatsu, Allen Macklin, Phillip R. Mundy, William T. Peterson, Sei-Ichi Saitoh, S. Lan Smith, Takashige Sugimoto, Kazuaki Tadokoro

Preliminary discussions

We began with a general discussion of the need for improved ocean observation and prediction systems. Briefly, sustained and enhanced ocean time-series are necessary because:

- The oceans are not constant (there are large changes at interannual and longer time scales);
- Some of these changes cannot yet be predicted (the ocean generates "surprises"); and
- Present time-series are insufficient for diagnosis and prediction (inadequate density

and integration among all variables and regions).

We next reviewed the specific objectives for this workshop/breakout group. These were:

- To describe what we are now doing (coverage, methodology, data management),
- To document successes and problem areas (lessons from past and present activities), and
- To develop plans for the future.

Individual presentations on existing observation and modeling programs

Most of the Breakout Group agenda (afternoon of March 7, all of March 8) was filled by a series of presentations on existing observation and modeling programs (Table 2). Extended abstracts of individual presentations can be found in Section II. The presentations provided a good overview of the lower trophic level time-series observations now being made in many parts of the North Pacific. However, there may be some important omissions. For example, our Breakout Group lacked representation from China or Russia, and also from the international community of intertidal/subtidal benthic ecologists.

Table 2 Presenters and themes for Breakout Group 2.

Presenters	**Topics**
V. Alexander	Oral presentation
H. Batchelder	U.S. GLOBEC Northeast Pacific Program observations, retrospective studies and model products
S. Batten	Continuous Plankton Recorder pilot study in the North Pacific
R. Brodeur	Micronekton data dets in North Pacific
D. Checkley	Plankton in the California Cooperative Fisheries Investigations
S. Chiba	Japan Sea time-series - qualitative study on lower trophic level ecosystem may reveal the process on climate-ecosystem interaction
R. Horner	Phytoplankton data from the Gulf of Alaska, British Columbia, and the Pacific coast of the U.S., with emphasis on harmful algal bloom species
S.-I. Ito	Time-series of the Tohoku National Laboratory
Y.-S. Kang	Monitoring system and long-term trend of zooplankton in the Korean waters
T. Kobari	180º time-series information
C. Lange (presented by R. Horner)	Scripps Pier phytoplankton time-series
D. Mackas	Canadian activities and plans for zooplankton, phytoplankton, micronekton, and benthos monitoring in the Pacific Ocean
A. Macklin	Physical and biophysical time-series originating from or used by Fisheries Oceanography Coordinated Investigations (FOCI) in the North Pacific Ocean and Bering Sea
W. Peterson	Zooplankton time-series - Oregon, Washington and N. California
S.-I. Saitoh	East-west variability of primary production in the subarctic North Pacific derived from Multi-Sensor Remote Sensing during 1996-2000
N. Shiga	Oral presentation
K. Tadokoro	Long-term variations of plankton biomass in the North Pacific

Group discussion of shared themes (characteristics, strengths and weaknesses of North Pacific time-series observation programs)

Spatial coverage and sampling frequency

For the margins of the North Pacific (inland seas, continental shelf and slope regions, boundary currents), time-series coverage ranges from poor to fair (in most high latitude and subtropical regions), and to very good (waters off Japan and Korea, the continental US and southern Canadian coasts, and some parts of Alaska).

In contrast, *open ocean regions are consistently undersampled*, except for a few variables and regions that can be sampled from satellites (e.g. ocean color in locations with low or moderate cloud cover). Seasonality of biological production and upper ocean physics is very strong in the North Pacific, but very few open-ocean programs have a sampling frequency sufficient to resolve seasonal phasing and amplitude.

Biological coverage

For mesozooplankton and phytoplankton, most North Pacific time-series provide indices of biomass (typically either wet weight, dry weight, or displacement volume for mesozooplankton; chlorophyll-*a* concentration for phytoplankton). Some time-series include additional information on taxonomic (and sometimes age/stage) composition within these categories. There was a strong consensus that *this information on biological composition has been very useful* where and when it has been available.

Unfortunately, there are fewer (and in some cases no) time-series observations for two key groups of "lower trophic level" pelagic organisms that play very important roles in oceanic food webs and geochemical cycles. Some of the conspicuous gaps:

- Very small "microbial loop" taxa such as bacteria, picoplankton and microzooplankton (some exceptions: HOTS, Station P, US GLOBEC and some Japan coastal lines);
- "Micronekton" - this category includes taxa for which quantitative sampling is very difficult: small mesopelagic fishes, shrimps, squids, and (to a lesser but significant extent) euphausiids. They are too large and agile to be well-sampled by standard zooplankton nets, but are (to date) not targeted by commercial fishing gear.

For benthic taxa, availability of time-series data drops off steeply with distance from shore. Many intertidal benthic time-series exist, but collection and use of these data is for the most part by individuals and organizations outside the PICES scientific community. This could (and should) be changed by more collaboration between biological oceanographers and intertidal ecologists.

There is much less time-series information on North Pacific sub-tidal and deep-sea benthos. One-time baseline studies have been done for a few regions (e.g., Bering Sea, southern BC continental shelf). Time-series data for large benthic epifauna are sometimes available from fisheries assessment trawl surveys (e.g., Anderson and Piatt 1999). For infauna and small benthic epifauna, breakout group members were unaware of sustained benthic time-series, except for site-specific studies of environmental perturbations in near-shore regions, and some recent repeat observations of hydrothermal vent environments.

Paleoceanography is based primarily on "benthic" sampling of chronologically stratified sediments. Comparison/intercalibration with water-column time-series from nearby regions is essential if we wish to interpret the longer time scales of ocean variability.

Duration and life expectancy of observation programs

There is a worrisome mismatch between time scales of North Pacific variability, and the typical duration of observation programs. Although this meeting has documented an increasing number of North Pacific time-series, nearly all sampling programs are either fixed duration (typically ≤ 5 years) or continue on an uncertain 'year by year' basis. Lack of long-term continuity appears to be more attributable to lack of funding agency commitment than to lack of interest and commitment by individual researchers.

Given the importance of decadal and longer time scales of climate variability, are 5-10 year fragments sufficient ingredients for a "long-term observation program"? If not, how and to whom do we convey this message? What can we offer as remedies? Can we use technology to reduce the cost per data point? From preliminary knowledge of spatial and temporal scales of variability, can we now design less detailed, but more permanent, sampling designs? What is the optimal mix of spatial lines and grids with single-point Eulerian time series?

Sensors and platforms

Existing biological oceanographic sampling programs in the North Pacific make broad use of dedicated survey cruises and satellite remote sensing. The ship-based methods used for time-series *in situ* sampling (nets, water bottles, auxiliary electronic sensors on CTDs) are generally effective, although taxonomically selective and perhaps a bit dated (see *Biological coverage* section above).

There is effective spot use of commercial ships-of-opportunity and dedicated moorings carrying sediment traps and/or optical and acoustic sensors. Promising opportunities for the future include: high frequency acoustics (we are behind fisheries scientists in standardized measurement of acoustic backscatter); supplemental "add-on" sampling that uses research vessels as ships-of-opportunity, "moorings of opportunity", "drifters of opportunity", "ocean observatories", autonomous nutrient analyzers; use of optical plankton counters (OPCs) for quick analysis of size spectrum of net samples, broader routine use of quick and simple indicators like Secchi depth.

Integration with operational and diagnostic simulation models

Efforts to couple time-series observations with marine ecosystem models are expanding rapidly in the United States and Japan, somewhat less rapidly in other PICES nations. Breakout group members agreed that this is an important activity, beneficial to both data collectors and modellers. Some issues that were identified in our brief discussion:

- Most modellers of lower trophic levels use a quantification based on (pooled) biomass rather than numeric abundance. This is effective for biogeochemical applications, but may be less effective for applications involving population dynamics (survival, recruitment) of individual target species or changes in community composition.
- Neither models nor sampling can be completely detailed in every respect. Model development always involves tradeoff choices in model complexity (e.g., space and time resolution vs. community structure and diversity). There is a good discussion of this issue in the recent GLOBEC International "Report of the GLOBEC Focus 3 Working Group on Modelling and Predictive Capabilities".
- Data assimilation (the constraint of model output by ongoing observations) is proving extremely useful in meteorology and physical oceanography, but is not yet common in biological models.

Community data archival and availability

There has been ongoing, but slow, progress toward "data sharing" in biological oceanography. Compared to physical oceanographic and meteorological data (for which there is a large amount of accessible "shared" data), obstacles include the high diversity of type and quality among measured biological variables, occasional long time lags for sample workup, scientific culture, and (in a few cases) political sensitivity. More complete participation can be enforced by research funding policies. However, it is also important that data originators "buy-in" voluntarily to data sharing. This will occur if and because "community" data banks are set up in a way that the data originators find accessible and useful. Specific suggestions and problems mentioned in our group discussion:

- Metadata clearing house (A PICES node of OBIS?);
- Problem of no fixed internet address for web-access data and derived-index time-series ("URL mutation"); and

- Regional Analysis Centers (products, tools to aid formatting and analysis, site and funding vehicle for comparative analysis projects, politically neutral).

Additional gaps, problems and opportunities

Taxonomic capacity is declining, at the same time as we are learning (or re-learning) the value of species-level identification for understanding ecosystem structure and change. There is a critical need to maintain and restore access to this expertise. CoML has a clear interest and could play an important role. Suggested initiatives included:

- development of a Pacific identification clearing house;
- funding of graduate-level "taxonomic apprenticeship" programs; and
- alternative computer-based formats for identification guides.

Standardization/intercomparison of sampling methods is needed. Simplicity and constancy have merit. However, methods will differ and evolve. In cases where methods change within a time-series, there should be an adequate overlap and intercomparison period. There should also be careful choice/calibration of methods on any startup of new time-series.

Between-nation coordination and intercomparison of results (both in regions with overlapping sampling, and between separated regions) could be improved. Because of the importance of long-time scale and large spatial scale variability of marine ecosystems, there is great benefit in ensemble comparisons/contrasts among time-series from both adjoining and widely-separated ocean regions. PICES has been very effective in establishing a forum for this exchange, and a willingness of individuals and nations to participate. However, data-handling tools to facilitate collaborative analysis are not yet in place (this could be a valuable role for proposed PICES Regional Analysis Centres).

Value-added biological sampling could be conducted. Pacific monitoring programs that are now primarily focussed on physical oceanography and air-sea interaction (e.g., NEAR-GOOS, Argo) could be expanded at modest incremental cost to include biological measurements.

"State of the North Pacific" report

In the opinion of the breakout group leaders, there was general endorsement of the value of such a report, but some apprehension about capacity and infrastructure to ensure consistent and timely delivery of the proposed contents.

We concluded with a brief discussion of issues such as:

- Optimal ratio of fact to interpretation/opinion (the breakout group consensus was that some interpretation is desirable and necessary);
- Editorial/vetting structure;
- Frequency of publication/release: breakout group consensus is that there should be an annual report, possibly supplemented by less detailed releases at more frequent (quarterly) intervals;
- What contents? Suggestions follow:
  For a quarterly issue/update:
  - SeaWiFS composites
  - Real-time *in situ* data (where available)
  - CalCOFI plankton volumes, egg surveys
  - Preliminary (anecdotal) notifications of faunistic/floristic changes

  For a more extensive annual compilation and summary:
  - Pigment samples
  - Carbon chemistry
  - Plankton (phyto, microzoop, mesozoop) biomass and/or community composition (about 12-month time lag, may be possible for only a subset of samples, species)
  - Rate measurements and derived properties (e.g. productivity maps)
  - Fish larval surveys?
  - Results from recent retrospective & model analyses

Breakout Group 3: Fish, Squid, Crabs and Shrimps

Chairmen: Anne B. Hollowed and Suam Kim

Participants: Richard D. Brodeur, Cynthia Decker, Steven R. Hare, Patricia Livingston, Gordon A. (Sandy) McFarlane, Bernard A. Megrey, H. Geoffrey Moser, Yasunori Sakurai, Hiroyuki Sakano, Robert Spies, Qisheng Tang, Daniel M. Ware, AkihikoYatsu, Kees Zwanenburg

Introduction

The Fish, Squid, Crabs and Shrimps (FSCS) breakout group focused their discussion on three primary questions: What information should be examined? What is the availability of information? What is the most expeditious way to develop a PICES indices database to examine this information?

Presentations from workshop participants provided an overview of the availability of information from each of the PICES regions (see Section II for extended abstracts of individual presentations). These presentations provided strong evidence of the role of ocean variability in shifts in marine fish and shellfish community structure.

Candidate biological indicators

Collectively breakout group members supported the development of leading indicators of climate change based on four types of biological measures: shifts in production, shifts in growth or condition, shifts in distribution, and shifts in community structure.

Production

- Annual production
  - Recruitment
  - Egg and larval surveys
  - Juvenile surveys
  - Diet composition of key predators: available for most regions
- Estimates of biomass or abundance
  - Fishery independent surveys targeting species
  - Catch statistics for target species
  - Anecdotal information
    - Bycatch in fishery independent survey
    - Bycatch in commercial fishery for other species
  - Changes in predation mortality
  - Hatch-date distributions

Growth and condition

- Annual or semi-annual measures of growth
  - Size or weight at age
  - Daily and annual growth increments
- Annual or semi-annual measures of reproductive potential
  - Fecundity
  - Maturity at age
- Annual or semi-annual measures of larval condition
  - RNA/DNA ratios
  - Stable isotopes
  - Lipid content
  - Free fatty acids
- Food habits information
  - Shifts in diet composition
  - Shifts in percent fullness

Distribution

- Distribution by life history stage
  - Range-wide by species
  - Range-wide by species by age or size
  - Index regions
    - spawning habitat
    - foraging habitat
  - Patchiness
  - Average area required to include the majority of the population (e.g. 75%)
  - Number of non-zero sets
- Migration pathways

Change in community

- Stock structure
  - Genetics
  - Parasites
  - Trace elements of otoliths
  - Morphology
- Species assemblages
- Food habits
  - Seasonal diet composition
  - Annual diet composition
- Diversity indices
  - Functional diversity
  - Species diversity
  - Average trophic level of the population

Candidate species

Upon review of the variety of biological indicators, breakout group participants realized that it would be unreasonable to suggest that each member nation should collect indices for all major species within each region. However, it might be reasonable to suggest that a smaller group of indicator species or indicator regions (in the case of community studies) would be comprehensively monitored on a regular basis (annually or semi-annually). Breakout group participants identified several candidate species for consideration in the PICES report:

- *Gadids*: walleye pollock, Pacific cod, Pacific hake
- *Small pelagics*: anchovy, Pacific sardine, chub mackerel, Pacific herring, Pacific saury, osmerids
- *Pacific salmon*
- *Sablefish*
- *Invertebrates*: common squid, selected crustaceans (e.g. king crab)
- *Rockfish* including thornyheads
- *Flatfish:* Pacific halibut, small mouthed flounders
- *Small yellow croaker*
- *Lightly exploited or non-commercial species:* sharks, myctophids
- *Commercially exploited sharks*

North Pacific Ecosystem Bio-Physical Meta-database and "State of the North Pacific" report

A major impediment to the development of the PICES "State of the Ocean" report is that it would require an infrastructure to access information from each member nation. One possible solution to this problem would be for PICES to suggest a rapid method for identifying and updating annual information from each member nation.

Dr. Megrey presented an overview of the Bering Sea Ecosystem Biophysical Metadatabase (http://www.pmel.noaa.gov/bering/mdb/). It was developed for the Bering Sea, however, it could be expanded to encompass other PICES regions. The BSEBM allows researchers to search for information by region using key words. Once a data set is identified, the user can access the data if the contributor volunteers a web-accessible link to information. In theory, the BSEBM platform could operate as a distributed database for rapid access to summarized information from each member nation. This platform would provide a possible mechanism for expediting the development of a summary of biological indicators on an annual basis. Based on this possibility the group made the following recommendations.

Recommendations

1. Workshop participants should encourage member nations to submit information on observational time series and analytical products to the North Pacific Ecosystem Bio-Physical Meta-database by the next PICES Annual Meeting.
2. A sub-group should be formed to establish protocols to facilitate searches for specific data types and indices (e.g., key word dictionary).
3. Each member nation will collect a suite of leading indicators of ecosystem patterns and trends. Time series of this sub-set of indicators will be provided to PICES.
4. PICES will require an individual to summarize this information into an annual report on the status of the North Pacific.

Remaining Questions

What are the gaps in information?

- For some transboundary species in the western Pacific, fisheries statistics are spatially limited and information is missing for some regions;
- Data is limited for non-commercially exploited species, particularly small pelagic species (e.g., myctophids, osmerids and squid) that are not well sampled by standard surveys;
- A variety of different gears and mesh sizes are needed to measure the diversity of species in the system;
- Seasonal coverage is limited which impacts our ability to evaluate the ontogenetic movements of fish.

What time-series are particularly informative for understanding or evaluating climate changes in biodiversity?

- Research survey CPUE by species;
- Bycatch data from fisheries observers - caution should be used when interpreting these data because a variety of factors influence the catch rates;
- Spatial distribution of total effort by fisheries (see caution above);
- Time-series of fish prices and associated landings;
- Species composition and catch rate from ichthyoplankton surveys.

What types of analyses or models are useful for best understanding climate related changes in biodiversity?

- Analysis of the spatial distribution of fish relative to environmental characteristics;
- Retrospective studies based on trends in stock production;
- Examine a variety of species diversity indices (e.g., slope of the size spectrum, Shannon-Wiener index, species richness) relative to a suite of environmental indices;
- Nested statistical models relating biological time series with environmental co-variates (recruitment, growth etc.);
- Changes in functional groups.

How can PICES facilitate and coordinate the collection and analysis of information for producing a North Pacific-wide ecosystem status report based on our time series and analytical products?

- Improve intra-national cooperation and coordination through symposia and workshops;
- Can TCODE members be charged with this responsibility?
- Recommend the formation of a cooperative group to enhance the exchange of information on transboundary stocks and oceanic species (e.g., Pacific pomfret and flying squid).

Breakout Group 4: Highly Migratory Fishes, Seabirds and Marine Mammals

Chairmen: Hidehiro Kato and Jeffrey J. Polovina
Rapporteur: Stewart (Skip) M. McKinnell

Participants: Richard J. Beamish, Douglas F. Bertram, Phillip R. Mundy, Robert Olson, Hiroshi Ueda, Yutaka Watanuki, David W. Welch

Time-series and their recent trends presented by species groups

Salmon

The North Pacific Anadromous Fisheries Commission (NPAFC) has agreed to provide salmon abundance information to the PICES Ecosystem Status Report. Their first contribution to the report will be prepared at the NPAFC research planning and coordinating meeting in Seattle, in March 2001. Historical catches of salmon in Canada, Japan and the United States, were reported annually to the INPFC from 1952-1992. With the creation of NPAFC in 1993, Russia became a member nation, and Russian catch statistics have been reported annually, as have hatchery release statistics. In the absence of NPAFC data, salmon experts in our breakout group noted the following:

- Coho, chinook and steelhead catches declined somewhat synchronously in the coastal northeastern Pacific during the 1990s.
- Coho and chinook abundance in the past several years show evidence of increasing in Washington/Oregon.
- High sockeye returns to the Fraser River in 2001 have been forecast.
- Alaska salmon in central/southeast have generally increased in abundance and variance in the 1990s.
- Chum/chinook survival in the Yukon River in recent years is low and certain populations have been extirpated.
- PSMFC coded wire tagging database exists from 1974 to present.
- Salmon catches in western Alaska have gone from consistently high abundance to exhibiting much higher variance.
- The Japanese salmon catch peaked in 1997 and a sharp decline occurred thereafter. Masu salmon have persisted at very low levels since the 1960s.
- National Salmon Resources Center has been established to replace the National Research Institute of the Hokkaido Salmon Hatchery.

Seabirds

- Pacific Seabird Group and USGS have established a database of seabird time-series for the entire North Pacific and that will be accessible on the web.
- Cassin's auklet population, monitored at Triangle Island (central British Columbia) since the 1970s, has exhibited a long-term decline. However, in 1999/2000 the reproductive rate sharply increased.
- No indication of changes at Frederick Island (northern British Columbia) for the same species.
- In Japan, time-series of Black-tailed gull and slaty-back gull abundance are available since 1980, and for rhinoceros auklet and Japanese cormorant since about 1984. The data show interannual variability but no evidence of trends.
- Reproductive success of black-footed and Laysan albatrosses, measured at French Frigate Shoals since 1980, remained generally stable for both species since the early 1980s, but sharp declines have been observed in the last few years.

Marine mammals

- Whaling statistics (operational time budget, length, sex, stomach contents, blubber thickness) are available from the 1950s to 1987 through the International Whaling Commission (IWC), and since 1996, data from Japan research whaling is collected by the Japan Far Seas Laboratory in Shimizu. Systematic sighting surveys are available since 1982 from dedicated surveys, largely in the western Pacific, conducted by the National Research Institute of Far Seas Fisheries (NRIFSF), Shimizu. Also, platform-of-opportunity (POP) sighting surveys were conducted largely by U.S. researchers since the mid-1970s in the eastern Pacific. Shore-based censuses are available in specific locations (e.g., North American gray whales). Orca abundance and distribution is assessed in North American coastal waters.
- Grey whales are fully recovered after approaching near extinction. Bowhead whale monitoring has detected an increase in abundance.
- Sperm whale abundance along the coast of Japan is estimated at 170,000 animals and has been increasing 6-11% per year. Sperm whale stomach samples have the potential to sample deep water squid status.
- Minke whale population is estimated at 23,000 animals and increasing in northwestern North Pacific. Prior to 1975, their diet was mainly mackerel or some similar schooling fishes in waters off the Pacific coast of Japan. By the late 1970s, it changed to Japanese pilchard and this status continued until 1987. From 1996 onward, their diet contained an abundance of Pacific saury or anchovy.
- For pinnipeds, rookery counts are typically used to gauge abundance, but in some areas

index of thickness of blubber is available. Steller sea lion have been declining in abundance in Alaska and the south Kuril Islands. There is no abundance information prior to the 1970s.

- Hawaiian monk seals in the northwestern Hawaiian Island chain have been monitored since the early 1980s. Monk seal pup girth decreased from the mid-1980s to the mid-1990s and increased after 1998.

Tunas

- Stock assessments on tuna species in the eastern tropical Pacific are available from the mid-1970s for yellowfin, skipjack, and bigeye. Model estimates of yellowfin tuna recruitment incorporate sea surface temperature (SST). There seems to be a relationship with tropical SST anomalies leading recruitment by 6 months. Large increases of yellowfin tuna followed the recent El Niño. Data on the average weight of the catch are available since 1975.
- Bluefin tuna spawn in the western Pacific and some migrate to the eastern Pacific. Catch data are available from 1960-1998 for purse seiners in the eastern Pacific and Japanese longline fishery largely in the western Pacific, from 1952-97. Japan's Far Seas Fisheries Lab is conducting a major archival tagging study of bluefin tuna.
- North Pacific albacore catch rate time-series from US troll vessels is maintained by NMFS/SWFSC and extends from 1960 to the present. The data show a drop in the catch rates in the mid-1970s to the mid-1990s, with an increase in the late-1990s.

Models

In the North Pacific, in recent years there have been numerous ECOPATH/ECOSIM models developed covering regional as well as gyre scales. Some are used to explore both bottom-up and top down forcing. The supporting documentation for these models contains a wealth of information on marine ecosystems across the North Pacific. In the breakout group, ECOPATH/ECOSIM models were presented for the Western Pacific Transition Zone and subarctic, Prince William Sound, Northwest Hawaiian Islands, and Eastern Tropical Pacific.

Dynamic ecosystem models such as ECOSIM can be useful in understanding mechanisms or hypotheses to explain observed time-series trends as well as in identifying species to monitor.

Habitats

In addition to monitoring trends in organism abundance, it may be useful to monitor the dynamics of oceanic habitats that are important to apex species foraging, reproduction or migration. This may include location, spatial scale, and intensity of specific fronts, eddies, and upwelling regions which have been identified as critical oceanic habitat.

Discussion points

Regarding what species are well monitored, commercially exploited species have the longest time-series. Formerly commercial cetacean species have rather good time-series of absolute abundance, especially minke whale. Some seabird series are also good (30 years at Farallon Is.).

Regarding what species would be best for comparative analysis of ecosystems, Rhinoceros auklets and salmon are found all around the Pacific Rim. However, if a monitoring program is to be set up, it may be best to establish a sampling project in a region that takes all trophic levels into consideration, rather than try to use the same species throughout the region.

Regarding parameters to monitor, characteristics such as birth/death rates, fecundity, school size, age at maturity, blubber thickness, and lipid contents may be more timely indicators of climate impacts than population size, since the latter integrates many years.

PICES can facilitate the writing of an ecosystem status report and include electronic version of the data; perhaps every year. For the first report, each country might nominate people to write the report.