REPORT OF SCIENCE BOARD

The Board met on October 15 (17:30-18:30) to review the order of the agenda and 19 (08:30-17:00). (See Endnote 1 for participants.)

The Chairman Dr. Makoto Kashiwai called the meeting of the 19th to order and set out the task before the Board. The Board reviewed the findings and recommendations of the Scientific Committees, TCODE, Implementation Panel for the CCCC Program and Working Groups 5 and 9; discussed implementation of decisions from 1995; discussed and recommended relationships with other organizations; discussed future perspectives for PICES; made arrangements for future activities; planned a science program for the Sixth Annual Meeting; and made recommendations to Council. Dr. Kashiwai noted that the Chairman of the FIS Committee will have completed his term of office after this meeting when the new Chairman will officially become a member of the Board.

Reports and recommendations of the Scientific and Technical Committees and the Implementation Panel

Reports of the Scientific Committees and the Implementation Panel were presented by their chairmen and are summarized below (see reports for the full text):

Fishery Science Committee (FIS) - Prof. Qi-Sheng Tang

Dr. Chang-Ik Zhang (Korea) was elected by acclamation to succeed Prof. Qi-Sheng Tang as Chairman of the FIS Committee. The Committee discussed the CCCC recommendations for 1997, and recommended that FIS be more closely connected to CCCC activities. FIS recommended that WG 12 hold a inter-sessional meeting of 4-5 day in an Asian country (to be decided). FIS made recommendations concerning PICES representation in SCOR-WG 105 activities. In connection with its scientific program, PICES should develop close relationships with regional fisheries committees.

FIS recommended that a joint topic session on “Models for linking climate and fish” for PICES VI be developed with BIO.

Physical Oceanography and Climate Committee (POC) - Prof. Paul H. LeBlond

The Physical Oceanography and Climate Committee met on October 17 and 18, 1996. Reviewing on-going business, POC first noted the need for an update on the oceanography of the Okhotsk Sea, especially in the light of recent work in the area. It is recommended that a workshop on the Sea of Okhotsk be held in the summer of 1998.

POC noted that most of the recommendations of WG 7 were being considered by TCODE and WG 9. Regarding the need for high resolution bathymetry for accurate modeling, it was recommended that a letter be drafted by the Chairman of POC for release of available data.

WG 10 Co-Chairmen, Drs. Christopher N.K. Mooers and Sang-Kyung Byun reported on progress, which was held to be very satisfactory. POC supported their plan for a workshop in Fukuoka in January 1997. A final report is to be ready for the PICES VI meeting. The PICES VI POC topic session will focus on “Circulation and ventilation of marginal and semi-enclosed seas” and will be co-convened by Drs. Mooers and Byun; it will also include a presentation on the progress of NEAR-GOOS.

POC supported the plans of CCCC task teams REX and BASS and the plan for a model workshop, with the proviso that the latter include the participation of recognized modellers.

Biological Oceanography Committee (BIO) - Prof. Patricia A. Wheeler

The Biological Oceanography Committee met on October 17 and October 18. New members were introduced; the committee recommends the re-appointment of Dr. Tsutomu Ikeda (Japan) and retention of Dr. Timothy R. Parsons (Canada) as committee members. The Committee requests the appointment of Dr. George Hunt (WG 11 Co-Chairman) to REX and Dr. Linda Jones to MODEL to maintain close connection of BIO with CCCC Task Teams. Dr. Hunt provided a summary report of the first WG 11 meeting. The Committee supports WG 11's request for a 5-day workshop prior to the PICES VI.

BIO discussed WG 9 recommendations and strongly endorses the recommendations for ecological moorings in the subarctic gyres (with retention of sampling at Station P) and also endorses annual reports on the status of the subarctic Pacific. BIO recommends the translation of figure legends and table headings for the Russian publication on Biological and Fisheries Aspects of the Okhotsk Sea.

BIO recommends two co-sponsored special topics for PICES VI: "Harmful Algal Blooms: Causes and Consequences" (with MEQ) and "Micronekton and their predators: Distributions, dynamics, and sampling problems" (with FIS).

Marine Environmental Quality Committee (MEQ) - Dr. Richard F. Addison

The MEQ Committee discussed and endorsed the report of WG 8. Following Prof. Ming-Jiang Zhou's offer to host a practical workshop at the Institute of Oceanology in Qingdao, WG 8 had developed a scientific workplan during 1996 for the workshop. Approximately 4 scientists from each of the PICES member countries will spend about two weeks working at Qingdao on assessing pollution in Jiaozhou Bay (Qingdao Harbour). Details of the workplan are appended as Annex 5 to the WG 8 Report. The cost of the Workshop will be approximately $70,000; the MEQ Committee recommended that PICES contribute $30,000 support and the balance would be found elsewhere.

The MEQ Committee reviewed the scientific presentations at its sessions and noted the large percentage of "no shows" — about 30% of speakers who submitted titles and abstracts to the scientific sessions did not attend the Annual meeting.

The Committee discussed proposals for the scientific sessions at PICES VI. Three sessions are planned: one jointly with BIO on "Harmful Algal Blooms: Causes and Consequences"; a second on "Environmental Impacts of Aquaculture", and a third for contributed papers. Members agreed to nominate convenors within a short time.

Technical Committee on Data Exchange (TCODE) - Mr. Robin Brown

TCODE met prior to and during the PICES V meeting and reviewed progress on items from PICES IV as well as additional requests that arose during PICES V. The Committee presented short reports on the Inventory of Long Time Series to the four Scientific Committees and received support for the continued expansion of this database. In addition, some other areas of interest were birds, sea mammals and contaminant entries for the inventory of long time series, inventories of real-time data sources, climatologies and useful software and analysis tools.

PICES-GLOBEC Implementation Panel Report for the CCCC program - Dr. Yutaka Nagata and Dr. Warren S. Wooster

The CCCC Workshop on Conceptual/ Theoretical Studies and Model Development was held in Nemuro, Japan on June 23-28 1996. During that workshop, meetings also took place of the Implementation Panel and its Executive Committee and of the MODEL, REX and BASS Task Teams. A report of the Workshop has been completed and should be published in the

PICES Scientific Report series. The Task Teams developed work plans, as detailed in their reports, and further discussions held by the IP/EC, and Task Teams during the present meeting led to recommendations concerning future workshops and symposia.

Working Group Reports

PICES currently has six Working Groups tasked to meet specific objectives. The Board reviewed the WG reports and recommendations. Summaries of WG reports follow:

WG 8. Practical Assessment Methodology (MEQ)

The Working Group met immediately prior to PICES V. The objective of the meeting was to review and refine the draft workplan for convening a Practical Workshop in Jaiozhou Bay, Qingdao, China, in early 1997, aimed at harmonizing approaches among PICES countries when assessing ecological impacts of pollution. (See Endnote 2 in the Report of the Marine Environmental Quality Committee for the full report.)

WG 10. Circulation and Ventilation in the Japan Sea/East Sea and its Adjacent Areas (POC)

The Working Group met immediately before PICES V to set out the task in accordance with the terms of reference. The Working Group developed a number of tasks to be undertaken and set out a tentative schedule for their accomplishment. (See Endnote 2 in the Report of the Physical Oceanography and Climate Committee for the full report.)

WG 11. Consumption of Marine Resources by Marine Birds and Mammals in the PICES Region (BIO)

The Working Group met immediately prior PICES V to develop strategies to meet the goals set out in the terms of reference. A set of regions of interest were defined within the PICES area and the Working Groups agreed to construct a tabulation of the populations of marine mammals and birds found in the area, dates of residency, energy demand, food habits and food consumption. (See Endnote 2 in the Report of the Biological Oceanography Committee for the full report.)

WG 12. Crabs and Shrimps (FIS)

The Working Group met immediately prior to PICES V. The terms of reference were reviewed and proposed changes were developed. The Working Group will develop a list of organizations and key scientific expert along with their field of interest from each Member Country. Each Working Group member was asked to bring, to the next meeting, previous published material on stock status, recent population abundance trends, and what is known or hypothesized about the causes of these fluctuations. (See Endnote 1 in the Report of the Fishery Science Committee for the full report.)

Inter-Committee (Science Board) Working Group Reports

WG 5. Bering Sea

The Working Group met in July to discuss the final report of the Group and discuss the status of the Bering Sea review volume book that is being prepared for publication. The Working Group proposed the development of a broad outline for research in the near future, in the Bering Sea, and more specific development of two areas of focus on dominant physical phenomena in the Bering Sea and the biological consequences of these phenomena. (See Endnote 2 for the full report.)

WG 9. Subarctic Pacific Monitoring

The Working Group met immediately before PICES V. Based on the seven possible monitoring initiatives outlined in their first report of the Working Group, three categories of programs were discussed; new initiatives;

continuing programs; and programs that are not yet ready for commencement of monitoring. (See Endnote 3 for the full report.)

Implementation from Decisions PICES IV

a. Participation at Scientific Meetings (95/S/3, 4)

   Science Board reviewed the value of circulating draft agendas to participants at registration and recommends that this practice be continued in future years. Science Board noted that participation in some Committee meetings can be improved. In scheduling meetings, business and scientific meetings should be spread out to allow participants to attend meetings of their choice.

   For participants to have better knowledge of what papers will be presented in scientific sessions, the Secretariat is encouraged to set a deadline two weeks before the Annual Meeting for speakers and poster presenters to confirm whether they will be able to attend.

b. Implementation Vladivostok Workshop Recommendations (95/S/3, 1)

   Science Board strongly supports the United States' proposal, concerning joint investigations in member countries' waters

c. Geographic Features of the Okhotsk Sea Region (95/S/3, 1)

   Prof. Yutaka Nagata and Dr. Vyacheslav Lobanov will co-ordinate the development of the list of geographical features of the Okhotsk Sea region, including bays, straits, and currents, in all Member States languages. Upon completion, the Secretariat will make the list available to all those who wish a copy.

d. WG 3 inventory completion (95/S/6)

   Korea and Russia will provide the Secretariat with a list of their scientists studying pelagic fishes.

e. Application PICES guidelines (95/S/9)

   Guidelines were reviewed and it was agreed that the Secretariat should continue to send them to successful oral and poster presenters for PICES VI. Committee Chairmen should encourage convenors to keep presentations within time limits.

Relations with other organizations

a. SCOR WG 105 The impact of world fisheries harvests on the stability and diversity of marine ecosystems.

   Science Board agreed that Dr. Chang-Ik Zhang, the Chairman-elect of FIS, will represent PICES in the SCOR WG 105.

b. Co-sponsorship of ICES Symposium on the Role of Physical and Biological Processes in the Recruitment Dynamics of Marine Populations.

   Dr. Dan Ware will continue to represent PICES on the Scientific Advisory Committee for this ICES Symposium.

c. Scientific Committees will aid the Secretariat to identify Organizations and Programs whose activities are of interest to PICES in order to form a closer working relationships with them.

MODEL Workshop 1998

Science Board recommends that the MODEL Co-Chairmen seek the participation of experienced modellers in the Workshop in addition to users of the results of models.

High Resolution Bathymetry

Science Board recommends that the US delegation contact the appropriate U.S. Agencies to obtain access to high resolution bathymetric data in the PICES region, for use in the PICES scientific program.

Future perspective for PICES

Science Board discussed the following recommendations for future perspectives for PICES:

1. In order to enhance the involvement of the national marine science community in PICES, members should undertake to ensure that all interested agencies and programs, both government and academic, have the opportunity to participate actively in relevant PICES activities.

2. Members should recognize their responsibility to support participation in PICES activities of their scientists, especially those appointed to scientific and technical committees, working groups, and analogous bodies as well as others who can contribute to PICES scientific programs.

3. The Science Board should review the need for standing technical committees, their terms of reference, and their membership as well as their relationship to the Science Committees and the Science Board and should forward recommendations to the Governing Council.

4. The Science Board should prepare specific guidelines for the function and duration of Working Groups.

5. The Secretariat, with the help of PICES Committees and Working Groups and of contacts in its member states and in international organizations, should identify and list national and international research programs related to ongoing activities and interests of PICES. Opportunities for collaboration with these programs should be sought, first among agencies at the national level and then by PICES through its Committees and Working Groups.

Science Board supported the principle that members recognize their responsibility to provide for the cost of participation of appointed scientists in PICES activities (see item 2). Science Board agreed to undertake items 3 and 4 and agreed to assume responsibility for item 5 with the Secretariat.

Committee Membership

Science Board recommends the following:

1. Re-appoint Dr. Tsutomu Ikeda (Japan) to BIO and retain Dr. Timothy Parsons (Canada) on BIO.
2. Appoint Dr. George Hunt (Co-Chairman of WG 11) to REX and Dr. Linda Jones to MODEL.

Biological and Fisheries Aspects of the Okhotsk Sea (printed VNIRO, Russia)

The Secretariat will contact Dr. Boris N. Kotenev to obtain the Russian figure legends and table headings from this book so that they can be translated into English. These will be made available.

Study Group

PICES should create a Study Group with members Dr. Makoto Kashiwai, Dr. Alexander Bychkov and Mr. Robin Brown to review PICES communications needs and practices. This Study Group will report to Science Board at PICES VI.

Sixth Annual Meeting

The Sixth Annual Meeting will be held in Pusan, Korea in 1997. The program will include sessions of invited and contributed papers organized by the indicated committees on the following topics:

(Science Board) BASS Symposium: *Ecosystem dynamics in the eastern and western gyres of the subarctic Pacific* (invited papers only). Co-Convenors: Richard J. Beamish (Canada), Suam Kim (Korea), Makoto Terazaki (Japan) and Warren S. Wooster (U.S.A.)

(POC) *Circulation and ventilation of marginal and semi-enclosed seas*. Convenors: Sang-Kyung Byun (Korea) and Christopher N.K. Mooers (U.S.A.).

(BIO & FIS) *Micronekton and their predators: Distributions, dynamics and sampling problems*. Convenors: Richard D. Brodeur (U.S.A.), Kouichi Kawaguchi (Japan) and Qi-Sheng Tang (China).

(FIS & BIO) *Models for linking climate and fish*. Convenors: Michio J. Kishi (Japan), Jang-Uk Lee (Korea) and Patricia Livingston (U.S.A.).

(MEQ) *Environmental impact of aquaculture*. Convenor: Dong-Beom Yang (Korea).

(BIO & MEQ) *Harmful algal blooms: Causes and Consequences*. Convenors: Roderick Forbes (Canada) and Jae-Hyung Shim (Korea).

Future Meetings

January 1997: WG 10 Meeting (Fukuoka, Japan)
May-June 1997: MEQ Practical Workshop (Qingdao, China)
June 1997: WG 12 Meeting (Nemuro, Japan)
Immediately prior to PICES VI:
WGs 8, 9 and 11
TCODE
CCCC/IP/EC, MODEL, REX and BASS
REX Workshop
Early 1998: MODEL Workshop (California, U.S.A.)
June 1998: Okhotsk Sea Workshop (Nemuro, Japan)

SCIENCE BOARD RECOMMENDATIONS

Discussion of Scientific Committee, Working Group and the Implementation Panel reports along with other issues considered led to a set of Recommendations for presentation to Council for approval (see Appendix to Council minutes, Decisions of Council).

Scientific Program

An interdisciplinary session was organized by the Science Board. The following papers were presented and Dr. Shoshiro Minobe won the Best Presentation Award for this session.

Methods and findings of retrospective analysis. Co-Convenors: Drs. Kimio Hanawa (Japan), Steven R. Hare and Robert C. Francis (U.S.A.)

J. Anderson
Climate indicators and salmon survival.

T. Baumgartner
Reconstructing long-term histories of small pelagic fishes of the California current.

R.D. Brodeur, B.W. Frost, S.R. Hare, R.C. Francis & W.J. Ingraham Jr.
Interannual variation in zooplankton biomass in the Gulf of Alaska and covariation with California current zooplankton biomass.

W.G. Clark & S.R. Hare
Decadal scale historical changes in Pacific halibut average weight-at age.

C.C. Ebbesmeyer, R.A. Hinrichsen & W.J. Ingraham Jr.
Timing and consequences of the spring and fall wind transitions along the west coast of North America

B.P. Finney
Variations in Alaskan sockeye salmon abundance during the past 500 years determined from sediment core analysis

K. Hanawa
Retrospective analysis of the southern most position of the first intrusion of the Oyashio.

W.J. Ingraham, Jr. & C.C. Ebbesmeyer
Five decades of surface current variability in the Gulf of Alaska and Bering Sea constructed with the OSCUR model - It's time for some new indices of flow.

N. Mantua, S.R. Hare, Y. Zhang, J. Wallace & R.C. Francis
A Pacific decadal climate oscillation with impacts on salmon.

S. Minobe
An oscillation of a period 50-60 years over the North Pacific.

R.H. Parrish
Wind stress, wind curl, and circulation changes in the North Pacific, 1881-1993

J.J. Polovina
The spin-down of the subarctic and subtropical gyres in the North Pacific, 1987 to 1995, observed with the parallel ocean climate model. A response to global warming or a 20-year cycle?

Y. Sakurai
Detection of regime shift in climate change based on annual variability in distribution and catch rates of stagnant and migrant fishes in northern Japan.

D.M. Schell
Baleen isotope ratios provide a decadal record of changes in primary productivity in the Bering Sea.

G.T. Shen
Corals as climate recording systems.

D.W. Welch
Patterns of scale growth in British Columbia Pacific salmon, and its relevance to the "Climate Change and Carrying Capacity" problem

Endnote 1

Participants

Makoto Kashiwai
(Chairman, Science Board)
Patricia A. Wheeler
(Chairman, BIO Committee)
Qi-Sheng Tang
(Chairman, FIS Committee)
Richard F. Addison
(Chairman, MEQ Committee)
Paul H. LeBlond
(Chairman, POC Committee)
Chang-Ik Zhang
(Chairman-elect, FIS Committee)

Other
Robin Brown
(Chairman, TCODE)
Warren S. Wooster
(Chairman, PICES)
William G. Doubleday
(Chairman-elect, PICES)
W. Doug McKone
(Executive Secretary, PICES)
Alexander S. Bychkov
(Asst. Executive Secretary, PICES)
Gennady V. Goussev (Russia)
Boris N. Kotenev (Russia)
Satsuki Matsumura (Japan)

Endnote 2

Working Group 5: Bering Sea Final Report

This report was developed out of deliberations of the Bering Sea Working Group at the July 1996 meeting. It contains elements that were in proceedings from earlier meetings, but were further refined in July 1996. It also contains new sections.

In attendance at the meeting were: Prof. Vera Alexander, Prof. Tsutomu Ikeda, Dr. Thomas R. Loughlin, Dr. Loh-Lee Low, Prof. Yoshiaki Maita, Prof. Haruo Ogi, Prof. Kiyotaka Ohtani, Dr. James E. Overland, Prof. Albert V. Tyler (Chairman), and Prof. Terry E. Whitledge.

This report is organized into four sections:
1. A proposal of Bering Sea research concepts for the PICES Organization.
2. Some Principal Scientific Questions on Bering Sea ecosystem function.
3. Preliminary proposals for at-sea and laboratory research activities.
4. Update on the Bering Sea Review volume.

SECTION 1
A Proposal of Bering Sea Research Concepts for the PICES Organization

The Working Group proposes development of a broad outline for research in the near future in the Bering Sea, and more specific development of two areas that focus on dominating physical phenomena in the Bering Sea, and the biological consequences of these phenomena. These two areas each involve aspects of all of the Principal Scientific Questions that the WG developed at an earlier meeting. These questions were further refined at the July 1996 meeting but not changed in their basic precepts.

The subsequent development of the specified research areas is expected to evolve in a way to make use of strengths of other existing programs. Two areas of research will be outlined below in this report. WG 5 also proposed successor Working Groups that would begin the process of detailed planning for the new research. For the purposes of this report, these groups will be called: (1) the Bering Sea research compilation Working Group, (2) the Bering Sea research implementation Working Group.

The duties of the new Bering Sea research compilation working group would be to find the scope of the research plans of national agencies and universities. The developing new research pressed forward by PICES must in some sense match the scheduling of the existing agency and university programs that will be carried out regardless of the plans supported by PICES. In that way, PICES supported research may be able to draw on the cooperative help of these research efforts. The new Working Group would compile an annotated list of existing and developing programs that will be underway during the next few years, along with information of cruise planning, lab studies, and satellite data analysis with objectives, dates, geographic areas. The aim of the compendium would be to assist in planning the proposed Bering Sea research program. The group would coordinate with TCODE and WG 9 on monitoring. The compendium would contain greater detail than the National Programs listed in PICES Scientific Report No. 4. WG 5 was advised in a preliminary manner about existing programs by JAMSTEC, the Oshoro Maru of the University of Hokkaido, the programs of TINRO in Russia, the work in the eastern Bering Sea by the U.S. National Marine Fisheries Service, and the cruise plans of the RV ALPHA HELIX out of the University of Alaska Fairbanks. During its July 1996 meeting only a few details and specifics were available. We propose the following: 1) the new working group meet once, 2) participants come to the meeting with specific assignments or plans of key universities and government agencies for laboratory and at-sea research programs that will be pursued in the light of existing national interests and funding. 3) the working group would then develop a report that includes a compilation and explanation of these efforts. New PICES supported research could not afford to lose any possible use of these programs for its new directions and would likely be able to "piggy-back" its research efforts on these existing efforts. Updating of the compendium might be a planned activity of an on-going task group.

The second working group suggested by WG 5 is a research implementation Working Group. The purpose of this second group would be to follow up WG 5 and the Bering Sea research compilation working group to develop an implementation plan for a Bering Sea project. This group should coordinate with the REX Task Team of the CCCC's Program. The outline of a project called, *Bioclimatology of the Bering Sea*, will be given below.

WG 5 proposes that either one of two focal areas be developed as a PICES sponsored research project. These areas are: (1) Research on water-mass exchange, advection and mixing in the Bering Sea and the influence on bio-productivity, or (2) Research on sea ice dynamics and its influence on bio-productivity. The research problems suggested by WG 5 are detailed in Principal Scientific Questions 2, and 3 (attached). In addition, each focal area links to the other Principal Scientific Questions (Questions 1 and 4). A general conceptual model has been developed to encompass this research (Fig. 1).

The research problems of the two focal areas are not independent of one another, and are intended as research topics that can serve to generate well-knit research proposals. The suggestion by WG 5 is to focus the research programs on one of two major physical phenomena, and how these phenomena influence bio-productivity, predator prey relations and fisheries. The work should be carried out as integrated, process-oriented projects that answer questions of decadal-scale changes in physical, chemical, biological and fisheries events. The Bioclimatology Model can be expanded regarding specific forcing functions, physical-chemical responses, and ecological relationships (Fig. 2). The conceptual summary is that meteorological dynamics of atmospheric pressure change, wind and temperature (A) develop changes in sea ice formation (B), including ice residence-time and distribution, and simultaneously to influence water-mass advection and exchange (C). Both B and C in turn influence, in unique sets of processes, primary (D) and secondary productivity (E) and sensitive stages of mega-fauna of use to humans (F). Topics D, E, and F, of course, have interactions that are not given on this chart.

RESEARCH ON BIOCLIMATOLOGY OF THE BERING SEA

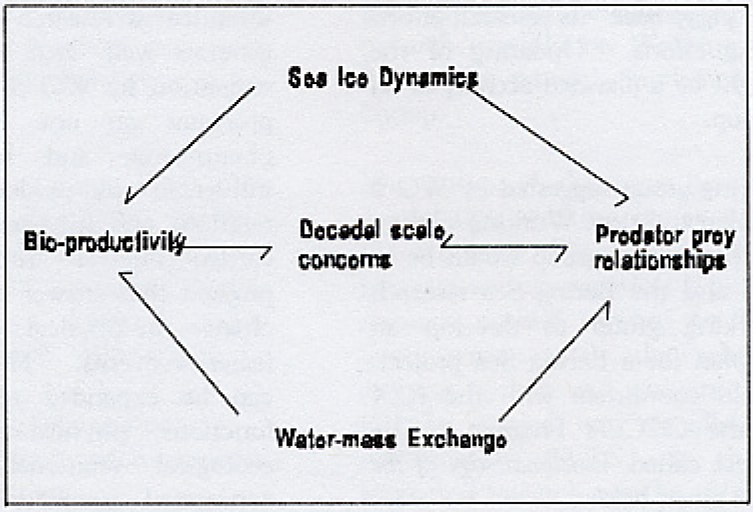

Figure 1. Bering Sea General Model for research planning

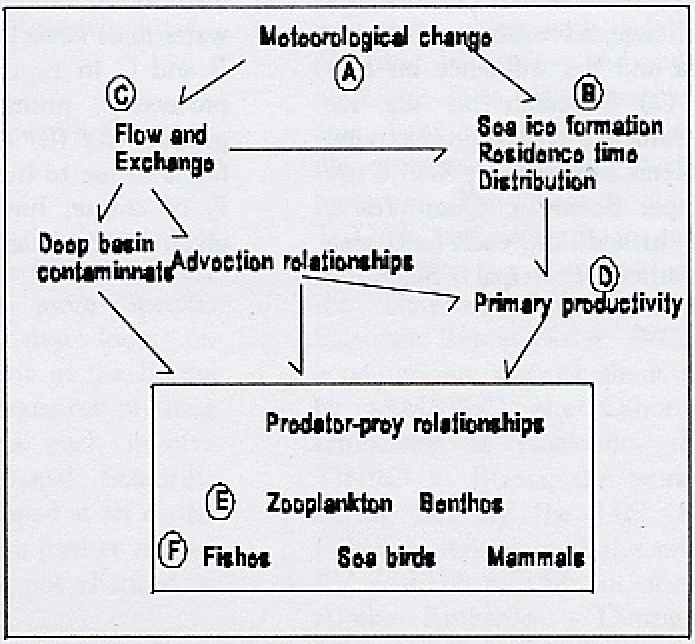

Figure 2. Summary of forcing functions and interactions for research planning

SECTION 2
Some Principal Scientific Questions on Bering Sea Ecosystem Function

Introduction

WG 5 proposes a series of research questions that it considered important for understanding the environmental and ecosystem functions of the Bering Sea. The purpose of the questions is to provide a focus for cooperative inter-national research in the region. As research progresses, it may be desirable to add additional questions or to refine the existing questions.

The WG agreed on three points which provided a common perspective for framing the scientific questions. The first point of consensus was that the abundance of animals in the Bering Sea fluctuated widely. Our work should further understanding of the nature and reasons for such fluctuations. The second point of consensus was to integrate studies of the physical and biotic environment to address biological productivity. The third point was that comparative studies of the Bering Sea and other boreal ecosystems could provide additional insights to high biological productivity in the Bering Sea.

In framing the questions, the WG noted that the identification of ecosystem emergent properties that contribute significantly to Bering Sea productivity as a whole would develop only upon taking a broad view of ecological interactions. The complexity of the system has to do with the number and intricacy of vital links that contribute significantly to ecosystem structure.

To stimulate international cooperative research in the Bering Sea, the working group posed four categories of questioning: 1) broad decadal change and accumulation in the basins, 2) the physics of water mass exchange, 3) sea-ice dynamics, 4) prey-predator relationships. These broad areas can serve to focus research on special environmental features and high biological productivity by member parties of PICES.

1. Decadal Scale Changes

1a. Mechanisms behind decadal scale change

Decadal and possibly centennial scale variability in atmospheric and oceanic physics has been observed; for example, in the surface pressure distribution, in ocean conditions such as sea surface temperature (SST), in sea level, and in sea ice extent. What are the mechanisms whereby these frequencies are determined for the North Pacific? To what extent can the variations be predicted; for example, when will a warm era begin and end? How would the projected global warming affect variability of this scale?

1b. Biological responses to physical-chemical forcing

Variability in atmospheric and oceanic condition appears to have a strong multi-decadal component which is reflected in the abundance of marine organisms including stocks of fish, shellfish, and piscivores. The physical environment appears to alternate between warm and cold eras. It is not known whether the biological sub-system, in response, changes continuously or whether the system varies between two or more quasi-stable states. An example could be an alteration in dominance of shelf production by benthic versus pelagic components of the ecosystem. In eastern boundary current ecosystems, sardine and anchovy dominance seem to alternate. In the Bering Sea, would pollock dominance replaced by that of some other species? Climate shifts are mediated via biological processes related to survival and productivity - processes that are influenced directly by ocean physics. Mechanisms of biological response to climate change should be examined in laboratory and at-sea research.

2. Water Mass Interchange and Formation of Deep Water

2a. Interchange between the North Pacific Ocean and the Bering Sea

What are the special features of water interchange between the North Pacific Ocean and the Bering Sea through the two deep Kamchatka and Near Straits, and the shoaler straits to the east? It is obvious that North Pacific water plays an important role in the formation of Bering Sea thermohaline structure, especially to the circulation of deep water basins. The North Pacific water masses influence the thermal regime (important to the biological production) of the Bering Sea and impacts the main features and variability (annual and longer term) of Bering Sea currents.

2b. Deep basin circulation

Do lateral and vertical input processes cause the deep Bering Sea to be a significant repository for global deep water? The deep Bering Sea is the terminus of the deep circulation in the Atlantic and Pacific Oceans as evidenced by the gradients of dissolved substances. This sink of the deep ocean flow therefore receives lateral input from other deep ocean basins and also the vertical flux of materials in the open Bering Sea. The pronounced oxygen minimum and enhanced concentrations of dissolved constituents probably results from a combination of changes in physical, chemical and biological fluxes to the deep ocean basin. Perhaps the best location to study questions concerning anthropogenic materials is the deep ocean. Both lateral and vertical input processes could be concentrating contaminants such as chlorinated organics, synthetic organics and radionuclides in the bottom waters. The deep Bering Sea is an important region to investigate the possible results of changes in global ocean circulation.

2c. Interaction between Deep Basin and Shelf Waters - biological and physical

How do the differing biological regimes and transport between the Aleutian basin and the eastern and western shelves contribute to the overall production of the Bering Sea? The Bering Sea shelf has been studied intensely through several programs but the extent of interaction of shelf and deep basin waters is not well understood. The physical transport of waters, exchange of water across the shelf break through submarine canyons and valleys, shelf break upwelling driven by winds or bathymetrically induced by flows, and the role of eddies should all be given more attention. Significant increases in primary production may result from the enrichment of nutrients through cross-shelf processes. The herbivores of the deep Aleutian basin generally are large and spawn over a February to April period, primarily independent of local phytoplankton bloom conditions. Herbivores on the shelf are small and closely linked to the blooms during May. It appears that pollock make use of both shallow and deep regions in their life cycle. How does the year to year variability in transport onto the shelf contribute to nutrient supply and larval survival? How does the year to year variability in storminess, ice cover, and air temperature regulate growth of herbivores on the shelf?

Investigation of the most intensive Bering Sea Current, the Kamchatka Current, and its relationship to water exchange with the North Pacific Ocean is recommended. The Kamchatka Current influences water mass interchange in two modes: meandering and non-meandering modes. In the meandering mode when the current moves away from the coast and does not influence coastal waters. In the non-meandering mode, it has strong influence on the onshore regime and prevents the large formations of river plumes in the Bering Sea that change vertical stratification due to weak fresh water flux from the coast. Large mesoscale eddies enhance vertical motions and change biological conditions at coastal waters. What are the relationships between the two modes, their frequencies, and other components of water balance as they relate to biological productivity?

3. Sea-Ice Dynamics

3a. Influence of ice dynamics on productivity

What are the effects of year-to-year variations in the maximum southerly extent of sea ice? Specifically, we need to know the effects on the primary production regime, including the total production during the spring bloom, timing of the spring bloom, duration and intensity. Timing of the spring bloom as determined by sea ice is important to the allocation of nutrients between the benthic and pelagic sectors.

i. What are the important effects of ice dynamics on reproductive biology of higher trophic level animals? Melting sea ice triggers an early and intense spring bloom, which may be important in satisfying the needs of higher trophic levels. (Note that APPRISE PROJECT clearly showed the importance of timing of the spring bloom and its intensity in the allocation of the products).

   The extremely low water temperatures associated with the marginal ice zone may also inhibit spawning of the shelf species that may not be tolerant of such cold water regimes (for example, pollock).

ii. What are the effects of ice dynamics on zooplankton grazing? Grazing at the ice edge appears to be depressed due to low temperatures and lack of over wintering animals. Cooney and Coyle (1985) found that copepod grazing is low and depressed whereas euphausiid grazing dominates. Thus, much of the primary production may sink to the bottom.

3b. Role of the ice edge in north-south retreat

All work on the ice edge system to date has been done either near the shelf break or near the stationary fronts. Further north over the eastern portion of the Bering Sea shelf, nutrient concentrations are lower and probably limited to the amount regenerated in situ or in the sediments. Here, in shallow waters, the residue of the brief, ice-edge spring-bloom may be quantitatively important to the primary production when it reaches the sediment surface. This question can be addressed by following the retreating ice (along with the ice edge bloom) northwards over the shelf. Remote sensing with the Sea WiFS sensor can determine the position and extent of the bloom with time. The distribution and activity of phytoplankton within the water column and over the sediment can be evaluated during the ship's return southwards.

3c. Polynyas

The Bering Sea has a number of recurrent, open-water areas along the southward-facing coasts of islands and land masses. These polynyas are recognized as very important for marine mammals and birds, at a minimum providing access to water in winter, and most likely in other ways too. The larger ones, such as the polynya in the Gulf of Anadyr and the St. Lawrence Island polynya, play an important physical role. As major sites of ice formation and export, they produce saline water that is carried south and northward. These brine waters ultimately form deep water in the North Pacific and Bering Basins. This water moves through the Bering Strait to contribute significantly to the halocline of the Arctic Ocean.

While polynyas are assumed to have distinct biological regimes, this has not as yet been examined for polynyas in the Bering Sea. These wind-formed coastal polynyas differ from those found elsewhere, with the possible exception of polynyas in the Sea of Okhotsk. The western Bering Sea polynyas are found in a region characterized by high nutrient import and high summer primary production. The interaction of the winter-early spring regime with the subsequent summer regime needs to be examined in relation to the biological consequences.

4. Biology of prey-predator relationships

4a. Natural prey-predator links

i. What are the seasonal changes in prey-predator relationships? Our present understanding of predator-prey relationships in the Bering Sea is limited to when the area is ice free. During the ice season, some top-level predatory species emigrate south to warmer waters, e.g., gray whales, northern fur seal, while others move into the area (pagophilic pinnipeds). The seasonal prey-predator links have to be identified. Impacts of seasonal predators on prey abundance and recruitment are unknown and should be a subject of priority coordinated research.

ii. What are the key nodal species in the food-web? From empirical directions and food web theory it is evident that a small number of species at an intermediate position in the food web seem to have an inordinate influence on ecosystem productivity. In the Bering Sea we need to identify the critical food-web nodes, and explore their extent and prevalence. Is there evidence for seasonal change in the nodes over annual production cycle? Do nodal species have properties in common other than their position in the food web? What are the causes and consequences of interannual variation in nodal species in food webs?

iii. Surveys and data analysis are needed on non-commercially exploited fishes, cephalopods, and other macro-invertebrates. The abundances and distributions of non-commercially exploited fishes and cephalopods in the Bering Sea are not well known. Some of these species, particularly cephalopods and meso-pelagic fishes, may be important prey and crucial links to the survival of many predatory species. The status and trend of these non-commercially important species should be determined by assessment surveys conducted in conjunction with those for commercially important fish species.

iv. Long-distance, migratory animals such as whales and seabirds enter the Bering Sea from neighboring and remote ecosystems. Some species use the region for reproduction, others as a winter area. What role do these highly mobile animals play in the transfer of energy and materials between regions?

4b. Commercial fishing as predator

What has been the effect of commercial fisheries in the Bering Sea on high-level trophic predators, particularly marine mammals and sea birds?

i. How does fishing change the food web? Commercial fisheries change the age structure and reduce the abundance of targeted species, even when managed exactly according to recommended, single-species exploitation rates. Secondary effects of this exploitation may occur through predator-prey interactions and may or may not have changed the availability of commercial and non-commercial prey for marine mammals and birds. As an example of cost-effective research, the WG proposes that historical survey data and food habits information be analyzed for evidence of changes in prey and its utilization.

ii. Comparative ecosystem studies: The Bering Sea marine mammal and seabird fauna has generally declined since the late 1960's, coincident with the increase in commercial groundfish fisheries. Conversely, pinniped populations in the California current ecosystem have significantly increased during the same period, as have commercial fisheries. A comparative approach to the study of each system will identify similarities and differences between the two systems and ultimately the mechanisms that determine marine mammal and seabird abundance and trends.

SECTION 3
Preliminary Proposals for At-Sea and Laboratory Research Activities: A Bio-Climatology Program to be Considered for Sponsorship by PICES

The proposals outlined here are preliminary and are given only as an indication of the directions of planning envisioned by WG 5. Proposals are for at-sea research programs on two major physical phenomena of the Bering Sea in relation to the Principal Scientific Questions, and biological productivity. Fleshing out of the physical, chemical, biological and fisheries aspects of these proposals would possibly be a responsibility of a new Bering Sea research implementation working group.

1. Water-Mass Interchange and Formation of Deep Water

1a. Advection and interchange of water masses

This program is keyed to Principal Scientific Question 2a on Water Mass Interchange. Recommended research measures are:

i. Pressure gauges should be deployed across the passes to measure time variability of integrated transport.

ii. Current moorings should be placed to monitor the inflow and outflow through each of the significant passes in the Aleutian Island Chain.

iii. Acoustic Doppler current profilers (ADCP) should be deployed in the passes to look at the detailed flow structure.

iv. Measures should be made of the transport of zooplankton along with temperature, nutrient and zooplankton profiles.

1b. Deep basin circulation

This program is keyed to Principal Scientific Question 2b.

i. High precision water mass identification using standard hydrographic survey instrumentation should be made. This includes a detailed water mass analysis of dissolved constituents.

ii. Special emphasis should be placed on anthropogenic tracers such as CFC's. An accelerator mass spectrometer could be used to produce ^{14}C data. Other isotopic techniques should be considered as well for aging the residence time in the deep basin.

iii. Additional studies should be undertaken as well to complete the elemental budgets of silicon and carbon, and to compare with circulation estimates using physical parameters.

1c. Interaction between deep basin and shelf waters - biological and physical

The objective is to explore the mechanism for nutrient supply onto the shelf of the eastern Bering Sea, including the interaction of vertical mixing on the slope and an unknown mechanism for intermittent flux onto the shelves. Measurements include the sequential deployment of drifters at the beginning of the Bering Sea slope Current and the Kamchatka Current, time series measurements of nutrients from in-situ instrumentation, and fluorescence sensors, as well as bottom mounted ADCP measurements for vertical profiles of mixing intensity.

2. Dynamics of Ice Formation and Influence

This program is keyed to Principal Scientific Question 3.

2a. To determine the timing and intensity of the spring bloom

Deploy fluorometers to measure the resulting rain of particulates from the plankton, sediment traps. These would be mounted on moorings near the ice edge and inside the ice during early spring.

2b. Research cruises to follow the retreat of the ice

Develop a sampling series to monitor particles and pigments in sea water via a fluorometer, and a flow cytometer. Carry out a phytoplankton species analysis, zooplankton grazing - dilution experiments and hydro-acoustics to determine the euphausiid distribution and abundance.

2c. Series of a stable isotope analyses

Using ^{15}N to determine the proportion of regenerated versus new nutrients.

2d. Ship-board surveys of benthic species abundances

Sample distribution of infauna species to confirm the role of sedimentation in enriching the bottom productivity.

2e. Remote sensing as an analysis of the spring bloom

Analyze changes in ocean color through satellite sensing. This work would include computer modeling of parameters estimated via at-sea sampling to validate the results of remote sensing and to interpolate the productivity field. Concurrent ship-board measurements should be carried out in the Navarin-Anadyr area and as well in the eastern Bering Sea region.

2f. Program on the role and formation of polynyas

This research would include research cruises using an icebreaker, combined with aircraft surveillance of the polynyas. The objective would be to investigate why these structures are critical to pinniped herds. Stomach contents and scat analysis would be carried out along with hydrographic surveys. Foraging ecology of the animals would be studied using electronic transponding tags to measure dive duration and depth along with physiological responses.

2g. To estimate the volume of brine water formation

Rate of brine formation is relevant because of strong concern about the effects on productivity of the annual formation of the "Bering Sea cold pool". Direct heat flux would be measured by deploying vertical thermistor chains in the water column to look for the sinking of surface cooled water.

2h. Dissolved constituents of polynyas

Carry out measures of the dissolved constituents, e.g., lindane and CFC'S. These would be sampled by in-situ pumps. The aim would be to investigate the role of the polynyas in the deposition and vertical transport of anthropogenic materials.

2i. Effect of drift ice on the cold pool

To estimate the effect of drift ice on the formation of southern part of cold pool, it would be valuable to measure the amount of drift ice coming on the southern shelf. An ADCP mounted upward on the bottom will measure thickness of drift ice and also currents. Deploying vertical thermistor chains will measure the thermal structure of the water column under the drift ice.

SECTION 4
Update on the Bering Sea Review Volume

THE BERING SEA: PHYSICAL, CHEMICAL, AND BIOLOGICAL DYNAMICS

A volume to be published under the auspices of PICES and edited by members of the PICES Bering Sea Working Group, Dr. Al Tyler, Chairman

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Dr. S. Gladyshev, POI, Vladivostok, Russia
Dr. J. Schumacher, PMEL, Seattle, WA, U.S.A.

1. Review of the physical characteristics of the Bering Sea by Stabeno, Gladyshev, Shumacher, and Ohthani
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14. A silica budget and renewal process for the deep Bering Sea by Whitledge and Tsunogai.
15. The influence of contact zones on chemical properties by Maslov and others. (This chapter was deleted after the July meeting in Japan; Dr. Whitledge is searching for a replacement chapter.)
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Dr. R. Beamish, Pacific Biol. Station, Nanaimo, British Columbia

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Endnote 3

Working Group 9: Subarctic Pacific Monitoring
Report of First Meeting

I. Introduction

The first meeting of the PICES Working Group 9 was held at the Pacific Marine Environmental Laboratory/NOAA in Seattle, Washington on August 1-3, 1995. Working Group members present were Drs. Ichio Asanuma and Kimio Hanawa (Co-Chairman) of Japan, Drs. Charles Miller and Bruce Taft (Co-Chairman) of the U.S.A., Dr. Lev Bocharov of Russia and Drs. David Welch and C.S. Wong of Canada. Working Group member Prof. Qi-Sheng Tang of the People’s Republic of China was unable to attend the meeting. The list of attendees is included in Appendix 1.

Terms of reference of WG 9

The primary responsibility of WG 9 is to plan “... the monitoring activities in the PICES area, including physical, biological and chemical measurements.” Monitoring here is understood to be systematic and continuous measurements taken over a sufficiently long time to measure physical and chemical climate change and the related ecosystem response.

It was decided that the first WG meeting would focus on the design of an observational system to support the PICES-GLOBEC International Program on Climate Change and Carrying Capacity (CCCC). This program addresses the question of how climate change affects ecosystem structure and productivity of key biological species at all trophic levels in the open ocean and coastal regions of the subarctic Pacific. The time scales of the relevant variability ranges from interannual (El Niño) to decadal (regime shift) to centennial. Annual variability is considered to be noise which must be properly sampled so it does not become aliased into longer climate time scales.

Previous PICES Monitoring Discussions

There was a PICES-STA Workshop on Monitoring Subarctic Pacific Ocean held in Nemuro, Hokkaido, Japan on October 22-23, 1994. Seven papers were presented and a PICES-STA pre-publication document containing drafts or abstracts of the papers is available from the PICES Secretariat. The individual papers are relevant to the work of WG 9. The Workshop did not make specific recommendations on the design of a monitoring system for the subarctic Pacific.

Another source of relevant information is the report of WG 5 of the US GLOBEC Climate Change and Carrying Capacity Planning Meeting held in Seattle, Washington April 19-20, 1995 (U.S. GLOBEC, 1995). WG 5 considered the question “What are the technological impediments to measuring the effects of climate change on the carrying capacity?” They compiled a list of technologies, noting their advantages and disadvantages, which could be used in a subarctic monitoring program.

Relation to international planning efforts

The design and implementation of the monitoring program in support of PICES will coincide with the international planning efforts which will address the need for a global climate monitoring system. The Ocean Observing System Development Panel (OOSDP) has formulated “... a conceptual design for a long-term, systematic observing system to monitor, describe, and understand the physical and biogeochemical processes that determine ocean circulation and the effects of the ocean on seasonal to decadal climate changes and to provide the observations needed for climate prediction” (OOSDP, 1995). The implementation of the recommendations of the OOSDP will be carried out under the guidance of the newly appointed Ocean Observations Panel for Climate (OOPC) (Neville Smith, Chairman). Plans for monitoring in PICES should be communicated to this Panel so that the PICES observations are well coordinated with the overall plan. It would be very difficult to obtain support at the national level for the PICES monitoring program unless it was seen to complement the Global Ocean Observing System (GOOS).

II. Existing Subarctic Monitoring Programs

In discussion of the issues of monitoring the subarctic North Pacific, a brief review of the present monitoring activities was undertaken. The list, which was created at the meeting, is not presumed to be exhaustive but could serve as a basis for producing a more complete future listing. Except for sea-level gauges, the material is organized by country supporting the monitoring. The existing sea-level gauges are dealt with in a separate section. Only programs that are presently funded, and for which there is an apparent commitment to future support, are listed.

A. Japan

1. Observations along repeat lines (coastal and offshore), *J. Fisheries Agency* (1964 --> ongoing).
   Measurements: T, S, O_2, surface current, water color, plankton; 12/yr.
   Location: 46 40-mile long sections normal to coastline of main islands of Japan.

2. Surveys of fishing and spawning grounds (commercially important species), *J. Fisheries Agency* (1970 --> ongoing).
   Measurements: fish and plankton samples, CTD or BT; 2/yr.
   Location: Japan Sea, east of Tohoku and Hokkaido, Kuroshio and adjacent areas south of Japan.

3. Meridional hydrographic sections, *J. Meteorological Agency* (1967 --> ongoing).
   Measurements: T, S, O_2, CFCs, currents, nutrients, DIC, alkalinity, dissolved organic carbon and nitrogen, zoo-/phytoplankton, pH, chlorophyll-*a*, phaeophytin, water transparency and color, marine pollution; 2/yr.
   Location: 137°; 155°E; sections extend from 33°N to the equator.

4. Meridional hydrographic section, *J. Maritime Safety Agency* (1984 --> ongoing).
   Measurements: T, S, O_2, surface current, marine pollution; 1/yr.
   Location: 144°E; section extends 33°N to equator.

5. Surveys of Kuroshio/Oyashio and Japan Sea region, *J. Maritime Safety Agency* (1956 --> ongoing).
   Measurements: T, S, O_2, surface current; 4/yr.
   Locations: sections normal to coast and meridional east of the islands; sections 200-300 km long.

6. Voluntary Observing Ship lines, *Science and Technology Agency* (1990 --> ongoing).
   Measurements: XBT; 12/yr.
   Location: south of Japan.

7. Ocean data buoy, *J. Meteorological Agency* (1970 --> ongoing).
   Measurements: 13 meteorological and oceanographic variables including ocean temperature at 1, 50 and 100 m.
   Location: Sea of Japan.

B. South Korea

Coastal transects around peninsula (???? --> ongoing).
   Measurements: T, S, O_2, surface current, water color, plankton; 12/yr.
   Locations: 40-mile sections normal to coastline.

C. Russia

At the present time there is not a Russian monitoring program in the Subarctic Pacific. There are about 17 research cruises per year in the Bering Sea, Okhotsk Sea, and off the Kamchatka Peninsula but these cruises are designed to examine processes and not long-term climate change. There is a rich data base of climatic surveys from the past period when there were 75-80 cruises per year. Work is now being done to prepare these data for international exchange.

D. U.S.A.

General

The U.S.A. has supported deployment of Expendable Bathythermograph (XBT) probes in the subarctic Pacific during the World Ocean Circulation Experiment (WOCE). The TRANSPAC measurements (PX 26) and the observations along lines PX 37 and PX 38 have been supported since 1990. It is not yet certain yet whether support will extend beyond the end of WOCE (1997). An XBT/XCTD program is under consideration as a future component of GOOS.

Alaska

1. Fisheries observer program (1989 --> ongoing).
   Measurements: adult fish and marine mammal population size and age composition (no physical data); sampling during fishing season.
   Location: Bering Sea and Gulf of Alaska.

2. Recurring fishery and CTD surveys of Bering Sea (1993 --> ongoing).
   Measurements: acoustic measurement of larval, juvenile and adult fish populations; CTD surveys of water properties (1/yr in spring).
   Location: shelf/slope region of eastern Bering Sea.

3. Array of 3 instrumented moorings (1995 --> ongoing).
   Measurements: T, S, and current profiles, SST, wind, fluorometry; hourly data.
   Location: shelf/slope region of Bering Sea.

4. Larval surveys of Shelikoff Strait (1985 --> ongoing).
   Measurements: larval pollock population size; occasional CTD casts; 1/yr in spring.
   Location: western end of Shelikoff Strait.

5. Instrumented ferry *T/V Keystone Tonsina* (1995 --> ongoing).
   Measurements: SST, SSS; 4/yr.
   Location: sea route Anchorage - Honolulu.

6. Resurrection Bay station (1970 --> ongoing).
   Measurements: CTD casts; 12/yr.
   Location: CTD station at 60°N, 149.5°W (246 m depth).

7. Monitoring of transport through passes in Aleutian Is. chain (1993--> ongoing).
   Measurements: CTD (2/yr) ; bottom pressure gauges.
   Location: Amutka and Unimak passes.

8. Alaskan Stream cross-sections (1990 --> ongoing).
   Measurements: ADCP velocity section (1-4/yr).
   Location: Shumagin Is. to Shelikoff Strait.

West Coast

There are no known monitoring activities in the area north of 35°N; CCOFI monitoring activities do not extend north of Monterrey, California.

E. Canada

1. La Perouse Program (1985 --> ????).
   Measurements: lower and higher trophic levels; ecosystem response (C, N, $Si0_4$, sediment traps); 4-5 plankton surveys per year at 10-15 sites; 5-8 CTD surveys per year with 4-5 CTD lines and 1-2 current-meter moorings.
   Location: Continental margin off southwest

Vancouver Island (48°-50°N, 125°-128°W).

2. Line P and Station P (1955 --> ongoing).
   Measurements: T, S, O_2, nutrients, chlorophyll-*a*, pCO_2, productivity, CFCs and sediment traps; 3-4 /yr.
   Location: 50°N, 145°W.

3. *M/V Skaguran* Joint Canada-Japan VOS program (1995 --> ongoing).
   Measurements: T, S, O_2, chlorophyll-*a*, nutrients, zooplankton (1996 start); 10/yr.
   Location: sea-route Vancouver-Tokyo.

4. COPRA program (1989 --> ongoing).
   Measurements: zooplankton and CTD data collected at 14 stations; total of 70-100 opportunistic samples/yr.
   Location: Vancouver Island - Queen Charlotte Sound area.

5. Lighthouse and coastal station data (1935 --> ongoing).
   Measurements: SST, SSS; daily data.
   Location: 16 sites.

6. Offshore buoys: (1986 --> ongoing).
   Measurements: SST, air T, wind velocity, atmospheric pressure; hourly data.
   Location: 14 off west coast.

F. Sea-Level Gauges

There is a subarctic N. Pacific sea-level monitoring array of 52 *operational* sea-level gauges (see list in Appendix 2). An operational sea-level gauge is defined as having submitted data to the Permanent Service for Mean Sea Level within the last four years. Coverage is weakest in the high latitudes of the northwestern Pacific where there are only three gauges north of 45°N and west of the International Date Line.

G. Satellite Coverage

Because of atmospheric conditions not all satellite sensors are useful in the subarctic N. Pacific. In particular infra-red measurement of SST and ocean color measurements are of limited applicability. Radar altimeter, scatterometer (wind velocity) and SSMI wind speed measurements are presently being made from existing platforms. Altimeter measurements are useful for climate studies up to 63°N. At higher latitudes the annual signal is significantly aliased by the tides, which reduces their usefulness for climate studies. Scatterometer and SSMI wind measurements are of good quality throughout the subarctic region. Prospects for maintaining these measurements are good, i.e., there is a sequence of planned launches of sensors through the end of the century. However, PICES should lend their support to efforts to insure continuing funding support for these vital measurements.

H. Summary

The activities, which have been singled out as components of the present monitoring of the subarctic Pacific, constitute an impressive array of measurements. The time series that have the longest duration are the sea-level measurements; 5% (21%) of the records were initiated before 1910 (1950). Hydrographic data have been systematically collected in waters adjacent to Japan since the mid-1950s. In the eastern N. Pacific Ocean Station Papa hydrographic sampling began in 1952. There is a serious lacuna of sampling in the high latitudes of the subarctic western Pacific due to the recent cessation of ocean climate measurements by the Russian far-eastern laboratories. A number of time series of measurements have been started in the mid-90s in Alaskan waters but it remains to be seen whether they will be continued long enough to contribute to climate studies.

It is often not clear what frequencies of variability can be reliably estimated from the data that are being collected. There are few long time series with sufficient time resolution to estimate the frequency spectrum and the amount of aliasing of the frequencies that could occur, i.e., interpretation of inadequately sampled high frequencies as low-frequency fluctuations. It is often difficult to use principles of array design to guide the choice of a sampling scheme because the characteristics of the variability are not well known. Riser (1995) has presented an interesting discussion of the use of statistical techniques to design observational arrays. Wherever possible these techniques should be used to evaluate the consequences of particular sampling schemes.

III. New Monitoring Initiatives in Subarctic Pacific

The WG identified a small number of observational programs that should be considered for implementation in the subarctic Pacific. Because this was the first meeting of the WG, a full discussion of these ideas was not possible. It is also recognized that it is far from an exhaustive set of proposals. At the next meeting a careful analysis of these particular ideas will take place as well as consideration of additional ideas.

A. Time Series Measurement of Primary Productivity and Zooplankton Stocks

Time-series measurements of primary productivity and zooplankton stocks in the oceanic sector of the subarctic Pacific are required to better understand the dynamics of the interaction between changes in the physical-chemical environment and the variability of plankton populations. A long data series gathered from weatherships at Ocean Station P (50°N, 145°W) from 1952 to 1981 have given us some preliminary insights into subarctic production processes in the southern reaches of the Gulf of Alaska. The weathership data show that phytoplankton stocks are nearly constant through the year with chlorophyll levels varying between relatively narrow limits of 0.15 to 0.75 mg/m^3 (Wong et al., 1995). While there is a strong annual cycle in primary productivity (measured as ^{14}C uptake), there is not an annual cycle of phytoplankton stocks. Moreover, major nutrients (NO_3, PO_4, $Si(OH)_4$) are not depleted in any season. There is some understanding of how this balance between plant growth and plant loss (primarily through grazing) operates (Miller, 1993). One of the seasonally variable features of the system is the net-caught zooplankton which are the major predators of the plants. Weathership data show annual and interannual variation; interannual differences are of the same general order (2 fold) as have been attributed to the post-1976 regime shift. There were never suitable data at Station P for showing whether variations in zooplankton stocks are related in some direct fashion to variations in primary productivity.

It is no longer considered logistically reasonable to place manned platforms at central ocean sites for oceanographic or other purposes. However, it is now possible to deploy instrumented moorings capable of providing us with well-calibrated data which are interpretable as phytoplankton standing stock, primary productivity, nutrient concentration and zooplankton biomass. Because of the severe weather encountered in the subarctic Pacific, the moorings must be large and very strongly built. High sea-states, strong winds and depths in excess of 4 km will place great demands upon the mooring technology. Nevertheless, it can be done. It would be desirable to have the time series extend over 10 annual cycles to obtain a good estimate of the annual variation. It would also be very desirable to sample through at least one climate regime shift.

Instrumented moorings can provide the following measurements:

<u>Measurement Technology</u>

1. wind velocity, air temperature anemometer, thermistor
2. temperature profiles thermistor chain
3. salinity at several depths temperature/ conductivity sensors
4. phytoplankton stock as chlorophyll, fluorescence probes chlorophyll/ phycoerythrin ratio
5. light field solar radiation/transmissometer
6. primary productivity indices flash fluorescence
7. zooplankton biomass and multifrequency acoustic sensor size distribution

Site selection is open to debate. However, a best single site might be either (1) Ocean Station P, because of its record of historical data, or (2) close to the center of the Gulf of Alaska dome (location of maximum shoaling of density isopleths). One of the disadvantages of locating the mooring at either of the above sites is that they are near the node of the Empirical Orthogonal Function of SST which best represents the subarctic El Niño response (Tanimoto et al., 1993). The implication is that the important El Niño signal may be a minimum there and difficult to measure. PICES will benefit more fully from monitoring moorings if they can be placed at a modest number of sites instead of just one. The proposed list of sites (below, locations plotted on Fig. 5) provides a comparison of the traditional Station P site with the peak of the Gulf of Alaska dome and a comparison of the variability in the east and west portions of the subarctic gyre (very different physical conditions). The western gyre is expected to have higher production rates and greater zooplankton biomass. A review of available data is needed to establish expected levels of chlorophyll, productivity and zooplankton biomass for the western gyre.

Eastern Gyre
Ocean Station P 50°N, 145°W
Gulf of Alaska dome 53°N, 150°W
Western Gyre 52°N, 165°E

Ideal moorings should telemeter data on a regular basis via satellite. This will keep the scientists continuously informed of their performance, thereby enabling timely repair visits. Data also must be recorded aboard the mooring in case a breakdown only involves the communications link. Because the moorings will be large, they will be navigational hazards, so they must be equipped with radar transponders, beacon lights and possible guard buoys. Their positions must be announced through notices to mariners on a regular basis. Development and testing of sensors and systems could be done on existing Canadian weather buoys moored near the 200 m isobath in the eastern N Pacific.

B. Heat Content and Freshwater Variability of Subarctic Pacific

Heat content

Measurement of the heat content of the upper ocean (vertical profile of temperature) provides a basis for determining a number of critical aspects of climate change in the ocean. Some examples of uses of these data are the description of the change of oceanic conditions which effect the distribution of organisms (particularly zooplankton), such as movements of water masses and ocean fronts and the depth and temperature of the mixed layer, the large-scale ocean circulation and propagation of Rossby waves (one of the primary responses of the ocean to atmospheric forcing). At the present time, the most practical way to monitor the heat content is by Expendable-Bathythermograph (XBT) measurements from Voluntary Observing Ships (VOS). The TOGA/WOCE XBT/XCTD Program Planning Committee (TWXXPPC) has undertaken to design and maintain a global VOS program to monitor the heat content variability of the world oceans on climate time scales.

The present TOGA/WOCE XBT monitoring network includes three XBT lines in the eastern N Pacific that cut across the circulation (PX 14, 37, 38, 47). These lines are especially valuable because they provide indices of the subarctic circulation and the California Current (PX 37). It is very important that the sampling along these lines extend beyond WOCE.

A region of the northern N Pacific within the PICES area, roughly from the southern Bering Sea to about 35°N, has been monitored from the early 1970s. This monitoring activity has been supported by the U.S.A. under the "TRANSPAC" program: it has been managed by NOAA and financially supported by the US Navy. The XBT data accumulated in this program have been used to describe the large-scale thermal structure and have provided many insights into the nature of the variability. For example, Rossby wave propagation was observed in the North Pacific Current (White, 1982), characteristic behavior of the paths of the Kuroshio and the Kuroshio Extension were described (Mizuno and White, 1983) and variability in the heat content of the Kuroshio Extension was shown to be associated with 1982 ENSO event (White and He, 1986).

Recently, considerable attention has been focused on the decadal and interdecadal changes of atmospheric and oceanic conditions. In the northern N Pacific a large change (regime shift) in the distribution of SST was observed in the mid-1970s (Tanimoto et al., 1993). This regime shift is clearly expressed in Fig. 1, which shows the pattern and time variation of the leading mode of the empirical orthogonal function (EOF) analysis for low-pass filtered SST fields with periods longer than 60 months. From an analysis of upper-ocean thermal data, primarily XBTs, it was found that there was a corresponding change in heat content (Watanabe and Mizuno, 1994) as well as a temperature decrease of North Pacific Central Mode Water (Yasuda and Hanawa, 1995). The XBT measurements show that the circulation was effected as well as the surface conditions.

Unfortunately the U.S. Navy stopped funding the TRANSPAC program in 1993 resulting in a decrease of the number of XBT measurements. In 1992 approximately 3,500 XBT probes were deployed in the TRANSPAC area. In subsequent years the number of XBTs deployed dropped to 2,000 in 1993 (Fig. 2) and 1,500 in 1994. If this trend continues, the density of observations will become inadequate for analysis of climate variability. TWXXPPC has already recommended the establishment of a TRANSPAC XBT pool similar to the TOGA XBT pool. PICES should support this idea.

Freshwater

In most of the subarctic region the density distribution is governed by the salinity distribution. Knowledge of the salinity distribution is required to provide accurate estimates of the geostrophic transport. In addition the salinity is a very important indicator of climate change in the ocean. In the subarctic it is influenced by the interactions of ice, ocean and atmosphere. Variability of salinity influences the formation of near-surface water masses and is a key to understanding many aspects of the circulation. For these reasons the WG 9 will consider the design of a sampling program to monitor the near-surface salinity distribution in the PICES area. Deployment of Expendable-Conductivity-Temperature-Depth (XCTD) probes on voluntary observing ship XBT lines is a possible approach to obtaining these data in the eastern Pacific.

C. Salmon Scales as Measures of Productivity

The various species of Pacific salmon spend one or more years in the ocean before returning to their home rivers to spawn. Although the precise migrations of salmon through the ocean are unknown, the annual rates of growth experienced by salmon are recorded in their scales. There are large variations in the size of salmon over time (Figs. 3a, b). These time series of growth rates index changes in the productivity of lower trophic levels which, depending on the species of salmon, reflect changes in the abundance of zooplankton and squid which cannot be obtained using conventional sampling gears.

As with any index, the interpretation of the changes in growth will require care. Although the linkage of such indices to ocean productivity may not be clearly understood, they do provide a measure of something that directly effects fish productivity.

Archives of salmon scales exist in almost all Pacific rim countries, and provide the potential to develop detailed records of ocean growth dating back many years. The scale archive for Bristol Bay, Alaska sockeye salmon extends back to about 1910, well before the last period of high salmon production in the 1930s. Although most other scale archives are of more modest length, they provide a means to index ocean productivity for the last 4 or 5 decades.

Studies of salmon scales are attractive because the relatively short life span of Pacific salmon and their precise homing ability simplifies the analysis of growth changes and provides statistical replication. However, salmon spend time in both coastal and offshore waters, and therefore integrate ocean conditions over rather large areas. The potential to use scales from other fish species should also be examined. Herring are coastal fish whose scales are readily useable, but also are rather wide-ranging. Rockfish are also coastal, and appear to be territorial and quickly return to their home territory even when displaced large distances (Carlson et al., 1972, 1995). Although, rockfish scales are difficult to age, the potential exists to measure annual rates of growth from either scales or other hard parts from fish sampled from a fixed coastal location, thereby providing an “Eulerian” measure of growth which does not confound area and time. Development of such time series would provide information on variations in ocean productivity in coastal environments similar to what the salmon time series can provide for offshore and coastal environments.

A monitoring program focussed on the growth recorded in salmon scales has several attractive features for PICES. Salmon are an important component of the fisheries of most member nations. Sampling programs already exist in most areas of the Pacific rim, and these programs can be strengthened or extended at relatively little cost. The ability to measure annual rates of growth for individual fish and individual stocks also provides a measure of statistical replication rare in oceanographic studies. Measuring approximately 80 scales per year provides a very detailed record of annual variation in growth with a statistical reliability that would be impossible to match in studies of survival. These measures of growth can then be related to changes in a wide range of oceanographic conditions, and can serve as an index of how those aspects of the productivity of the subarctic Pacific affecting salmon growth have changed over this century.

D. Electromagnetic Measurements of Transport Through Kamchatka Strait

The circulation of the Bering Sea is cyclonic. The inflow to the Bering Sea occurs through a series of passages in the Aleutian Island Chain. The deepest passage is Near Strait where the largest inflow occurs. The outflow is through the Bering Strait ($0.8\pm0.2x10^6$ m^3/s; Coachman and Aagaard, 1988) and the Kamchatka Strait between the Kamchatka Peninsula and the Komandorskii Is. ($8\text{-}24x10^6$ m^3/s; PICES Working Group 1, 1995). Thus the measurement of the transport of the East Kamchatka Strait would provide a very good indicator of the intensity of the Bering Sea circulation and is a simple measure of large-scale air-sea interaction. Because the East Kamchatka Current is the western boundary current of the Pacific subarctic gyre, and the source of water for the Subarctic and Oyashio currents, these measurements also would provide information on all the components of the western Pacific subarctic circulation.

It has been shown by Larsen (1992) that the Florida Current transport can be effectively monitored with a submarine telephone cable. These measurements provide a level of temporal resolution and spatial averaging unsurpassed by any other technique. This approach could be applied to the East Kamchatka Current or other narrow components of the circulation, such as the Alaskan Stream. It has the advantages of low operating costs, low maintenance, long-term durability (20-30 years), high temporal resolution and spatial integration. Disadvantages are high initial cost, if new cable is needed, and damage to cable by fishing activity if the inshore termination extends across the continental shelf. A program of continuing but infrequent calibration is required to monitor and correct for electrode drift. PICES should evaluate the scientific benefits of knowing the variability on climate time scales of the overall intensity of the Bering Sea circulation. The cable method is the only economical way of collecting these data.

E. Aeolian Transport of Iron into the Pacific Subarctic Gyre

PICES should consider the development of a system of observations to determine on a recurring basis the transport of iron to the subarctic Pacific. Recent research (Martin, 1991; Martin et al., 1994) strongly implicates the supply of iron as a principal limiting factor for phytoplankton productivity throughout the region, probably most strongly limiting in the east. All evidence (Donaghay et al., 1991) suggests that the main transport mechanism of iron supply to the ocean is atmospheric transport. Iron-bearing dust particles, originating from the Asian land mass, are the primary source of iron to the subarctic Pacific.

Monitoring of the iron transport will be difficult. Concomitant measurements of velocity and iron concentration would be required at an adequate number of sites. It might be possible to use wind trajectory models in combination with measurements of airborne iron to estimate the transport of iron into the oceanic realm. If the residence time of the iron-bearing particles in the atmosphere is not too long, it might not be necessary to measure atmospheric efflux at the eastern boundary. If the efflux rate needs to be measured in the eastern Pacific, the Queen Charlotte Is. might be a suitable monitoring site. Further thought is needed regarding possible approaches. Attention should be given to monitoring variability of north Asian dust transfer, evaluating of wind trajectory models, setting up appropriate sampling schemes for airborne iron over the ocean, and searching for suitable proxy variables for the iron supply rate.

F. Voluntary Observing Ship Basin-Scale Flow-Through Measurements

Voluntary observing ships crossing the subarctic Pacific can be used to obtain time series measurements of a variety of properties important to describing and understanding climate variability. Automated instrumental packages can be used on these vessels to collect samples or to measure climate variables with minimal or no specialized technical support on board. The flow-through system takes water from the sea-chest which is continuously supplied to the automated monitoring system. In 1995 a voluntary observing ship flow-through program was begun on the Vancouver-Tokyo route under the leadership of C.S. Wong of the Institute of Ocean Sciences (Canada) and Y. Noriji of the National Institute for Environmental Studies (Japan). Measurements are being made of the following variables: T, S, chlorophyll-*a*, nitrate, pCO2, pH, total CO_2, and in the future zooplankton abundance (beginning April 1996). Sampling frequency is 10/year.

In order to increase our understanding of subarctic variability, it is necessary to sample the north-south variability as well. There are north-south shipping routes which can be used for voluntary observing ship sampling. Two crucial lines are Alaska-Hawaii and Hawaii-Seattle. These lines would cross the N Pacific Drift at 155°W and cross the southward deflected portion of the N. Pacific Drift, which is the source of the California Current. These measurements would provide critical data for a number of subarctic climate studies. For example, the contrasting physical and biological effects of El Niño events on the central Pacific (cooling) and the northeast Pacific (warming) could be documented.

The ships would have to be equipped with a seawater intake, preferably hull-mounted on the outside of the ship near the bow, and the automated monitoring system. The modules of the monitoring system would include: seawater temperature and conductivity (salinity), fluorescence, particle counting (zooplankton biomass), continuous plankton collection on sticky “mat,” nitrate, pH, pCO_2, and O_2. The shipboard data acquisition system should log GPS positions, air pressure, temperature and humidity and wind speed. Ideally the ship would also launch XBTs and XCTDs at regular intervals to obtain data on the vertical structure of the near-surface layer. The ships involved could be the same ships doing the WOCE lines PX37 and PX38. In Fig. 4 are shown the positions of the four flow-through lines, the proposed moorings (section III A) and the JGOFS HOTS time- series station (23°N, 155°W). The time series data will contribute to the interpretation of the ship-track data which provides good spatial resolution but only coarse time resolution.

G. Surface-Velocity Measurements with Satellite-Tracked Drifters

The surface-velocity measurement program (SVP) of the World Ocean Circulation Experiment involved the design and deployment of a large number of satellite-tracked drifters. The drifter has a tethered holey-sock drag element located 15 m below the surface and measures sea-surface temperature. It also can be instrumented to measure fluorescence, air pressure and conductivity (salinity).

The SVP instrument could be used to monitor the variability of the near-surface flow field in the subarctic Pacific. For example, the eastward flow into the eastern N. Pacific (N. Pacific Drift, Subarctic Current) bifurcates west of the boundary with one portion turning north into the Alaska Gyre and the other southward to form the California Current. It has been speculated that the year-to-year variability of the velocity of the incoming surface flow, the location of the bifurcation and the relative amounts of surface water contributed to the subarctic and subtropical gyres have important ecological effects within the Subarctic Gyre/California Current system (Hollowed and Wooster, 1992). Recent drifter measurements reported by van Meurs and Niiler (1995) have shown large differences between and 1987 and 1989 in the eastward component of surface flow. In Fig. 5 are shown the 250 day trajectories of 16 Argos-tracked drifters released along 145°W in 1989; in the western sector the general drift is eastward. East of 139°W the trajectories of the drifters released at the more southern latitudes show a notable southeastward trend. In Table 1 are shown the comparisons of the 1987 and 1989 geostrophic velocities in the six boxes shown in Fig. 5. The geostrophic flow is computed by subtracting the wind-driven part of the current, according to Ekman dynamics, from the measured current. It is clear that, except for the two regions closest to the coast, the 1989 currents are stronger by a factor of two than those of 1987.

A drifter experiment can be designed which will measure the climatic variability of the partitioning of water to the subarctic and subtropical gyres. This data set would describe the effects of a regime shift on the circulation and test the suggestion of Chelton and Davis (1982) that there is an out-of-phase relationship between the transports of the northern and southern deflections of water transported into the N. American boundary from the west.

The drifters are a powerful tool to study the surface circulation and should be considered as a way of monitoring the bifurcation of the flow as well as other aspects of the flow field in the PICES area.

IV. References

Carlson, H.R. and R.E. Haight, 1972. Evidence for a home site and homing of adult yellowtail rockfish, *Sebastes flavidus*. J. Fish. Res. Bd. Canada, 29, 1011–1014.

Carlson, H.R., R.E. Haight, and J.H. Helle, 1995. Initial behavior of displaced yellowtail rockfish, *Sebastes flavidus* in Lynn Canal, Southeast Alaska. Alaska Fish. Res. Bull., 2, 76–80.

Chelton, D.B. and R.E. Davis, 1982. Monthly sea-level variability along the west coast of North America. J. Phys. Oceanogr., 12, 757–784.

Coachman, L.K. and K. Aagaard, 1988. Transports through Bering Strait: annual and interannual variability. J. Geophys. Res., 93, 15,535–15,539.

Donaghay, P.L., P.S. Liss, R.A. Duce, D.R. Kester, A.K. Hanson, T. Villareal, N. W. Tindale and D.J. Gifford, 1991. The role of episodic atmospheric nutrient inputs in the chemical and biological dynamics of oceanic ecosystems. Oceanography 4: 62–70.

Hollowed, A.B. and W.S. Wooster, 1992. Variability of winter ocean conditions and strong year classes of Northeast Pacific groundfish. ICES mar. Sci. Symp. 195, 433–444.

Larsen, J.C., 1992. Transport and heat flux of the Florida Current at 27°N derived from cross-stream voltages and profiling data: theory and observations. Phil. Trans. R. Soc. Lond. A, 338, 69–236.

Martin, J.H., 1991. Iron, Liebig's law and the greenhouse. Oceanography, 4, 52–55.

Martin, J.H., et al., 1994. Testing the iron hypothesis in ecosystems of the equatorial Pacific Ocean. Nature, 371, 371, 123–129.

Miller, C.B. (ed.), 1993. Pelagic ecodynamics in the Gulf of Alaska, results from the SUPER Program. Prog. Oceanogr., 32, 1–358.

Mizuno, K. and W.B. White, 1983. Annual and interannual variability in the Kuroshio Current System. J. Phys. Oceanogr., 13, 1847–1867.

The Ocean Observing System Development Panel, 1995. Scientific design for the common module of the Global Ocean Observing System and the Global Climate Observing System: an ocean observing system for climate. Department of Oceanography, Texas A&M University, College Station, Texas, 265 pp.

PICES Working Group 1, 1995. The Okhotsk sea and Oyashio Region, PICES Report No. 2, L. D. Talley and Y. Nagata (eds.), North Pacific Marine Science Organization (PICES), 227 pp.

Tanimoto, Y., N. Iwasaka, K. Hanawa, and Y. Toba, 1993. Characteristic variations in sea surface temperature with multiple time scales on the North Pacific. J. Climate, 6, 1153–1160.

U.S. GLOBEC, 1995. Climate Change and Carrying Capacity Planning Meeting Report, Working Group 5 Report. U. California, Davis, in press.

van Meurs, P. and P.P. Niiler, 1995. The temporal variability of the large-scale geostrophic surface velocity in the North East Pacific. Manuscript in preparation.

Watanabe, T. and K. Mizuno, 1994. Decadal changes of the thermal structure in the North Pacific. Int. WOCE Newsletter, 15, 10–13.

White, W.B., 1982. Traveling wave-like mesoscale perturbations in the North Pacific Current. J. Phys. Oceanogr., 12, 232–233.

White, W.B. and Y. He, 1986. Interannual variability in the heat content of the Kuroshio Extension associated with the 1982 ENSO event. J. Phys. Oceanogr., 16, 309–321.

Wong, C.S., F.A. Whitney, K. Iseki, J.S. Page and J. Zeng, 1995. Analysis of trends in primary productivity and chlorophyll-*a* over two decades at Ocean Station P (50°N, 145°W) in the subarctic Northeast Pacific Ocean, pp. 107-117. *In* R. J. Beamish [ed.], Climate change and northern fish populations. Can. J. Fish. Aquatic. Sci., 121.

Yasuda, T. and K. Hanawa, 1995. Temporal variability of the thermal structure in the North Pacific. Part 1: Decadal change. J. Phys, Oceanogr., in review.

Table 1. Comparison of 1987 and 1989 surface geostrophic currents computed from drifter velocities and winds. The regions are defined in Fig. 6.

Region	1987		1989	
	$\|u\|$ (cm s^{-1})	θ (°)	$\|u\|$ (cm s^{-1})	θ (°)
1	3.4 ± 0.8	30.4 ± 13.6	6.0 ± 1.2	1.0 ± 10.1
2	1.6 ± 0.6	14.9 ± 23.6	4.2 ± 0.8	-6.8 ± 18.5
3	2.6 ± 1.0	0.0 ± 26.2	2.4 ± 0.9	0.0 ± 28.5
4	1.9 ± 0.8	15.5 ± 19.5	7.8 ± 1.0	11.9 ± 8.3
5	1.9 ± 0.9	34.5 ± 30.2	3.2 ± 1.0	7.4 ± 23.5
6	3.8 ± 1.3	33.3 ± 22.4	4.3 ± 1.6	24.8 ± 24.7
All	2.2 ± 0.4	24.2 ± 12.1	4.6 ± 0.5	6.2 ± 7.4

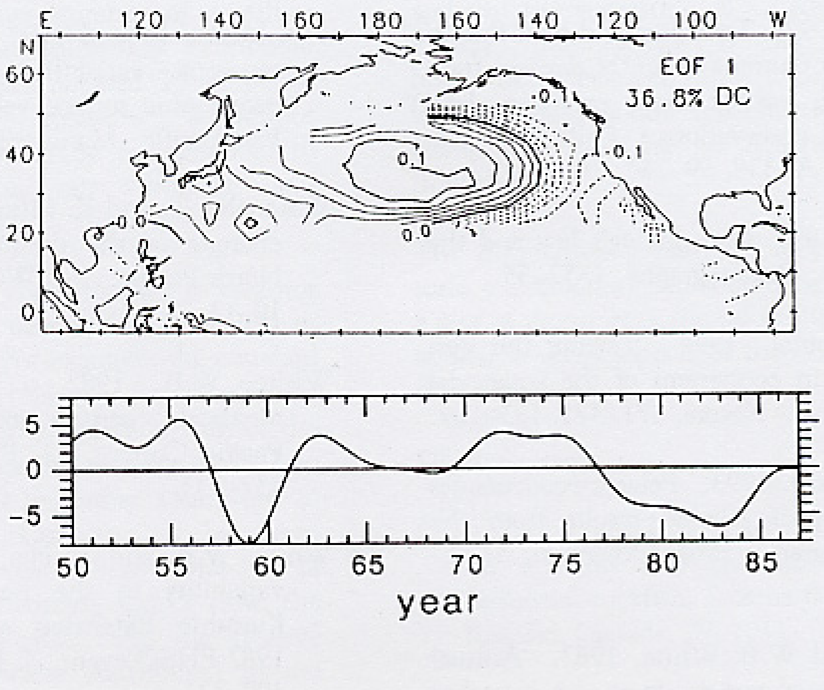

Fig. 1. Spatial and time coefficient of the leading EOF mode for low-pass filtered SST anomalies with periods longer than 60 months. After Tanimoto et al. (1993).

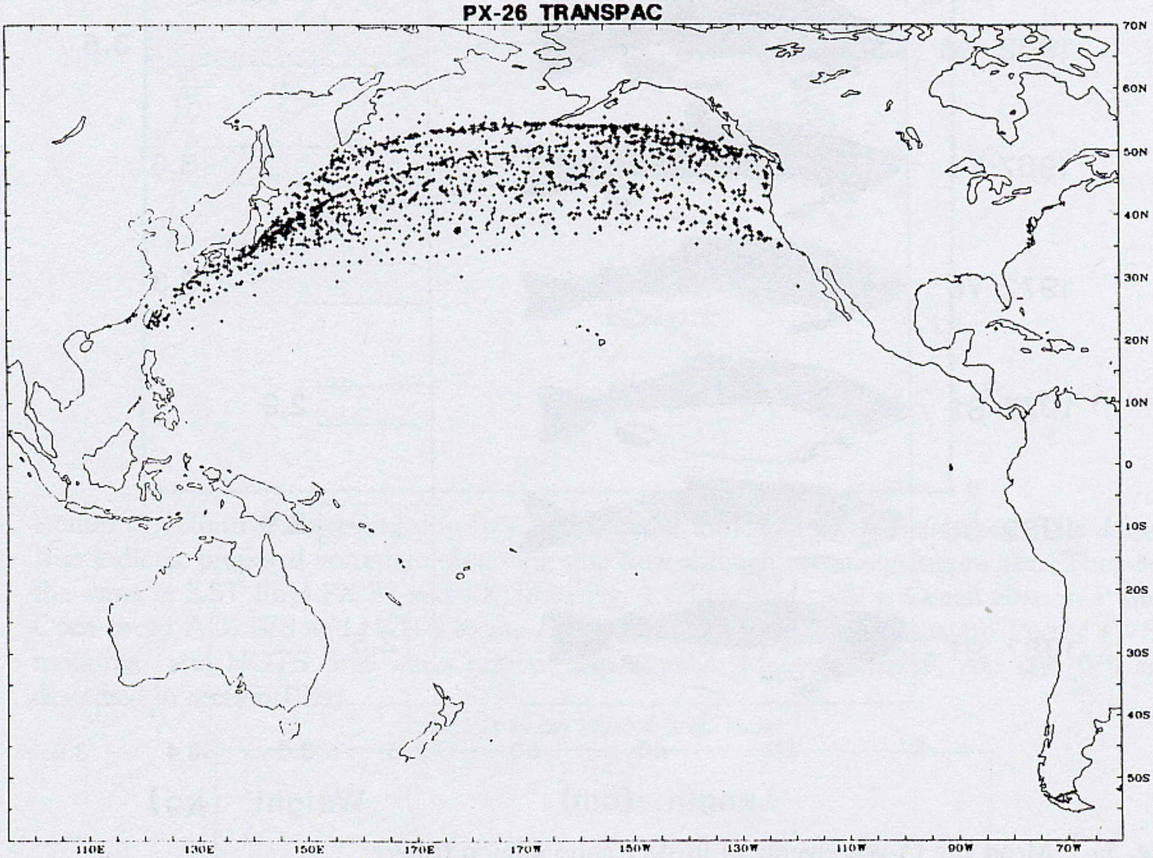

Fig. 2. XBT observational points made in 1993 in the PX-26 (TRANSPAC) area. In this year, approximately 2,000 XBTs were dropped.

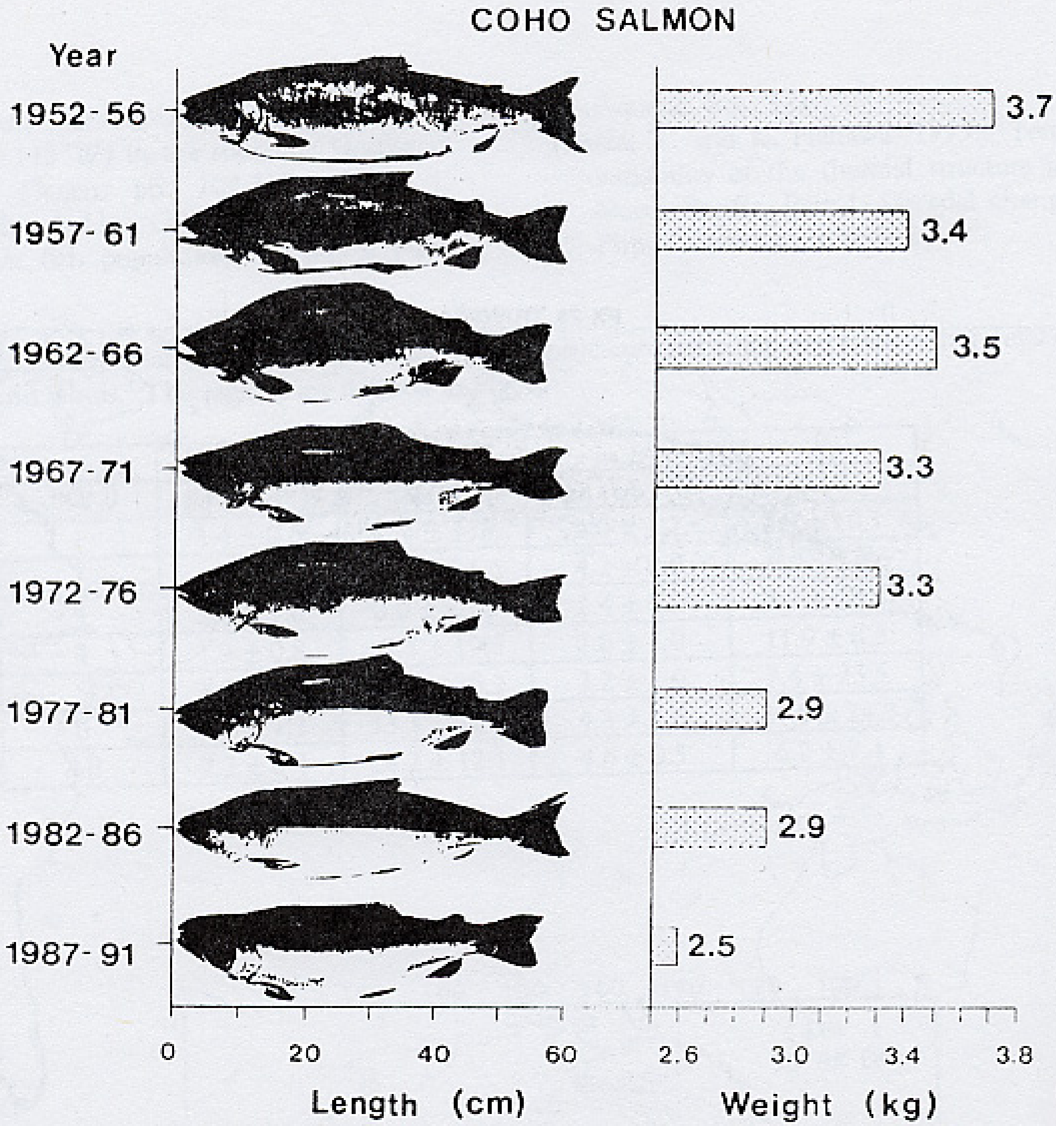

Fig. 3a. Mean size (5-year averages) in B.C. coho salmon fishery.

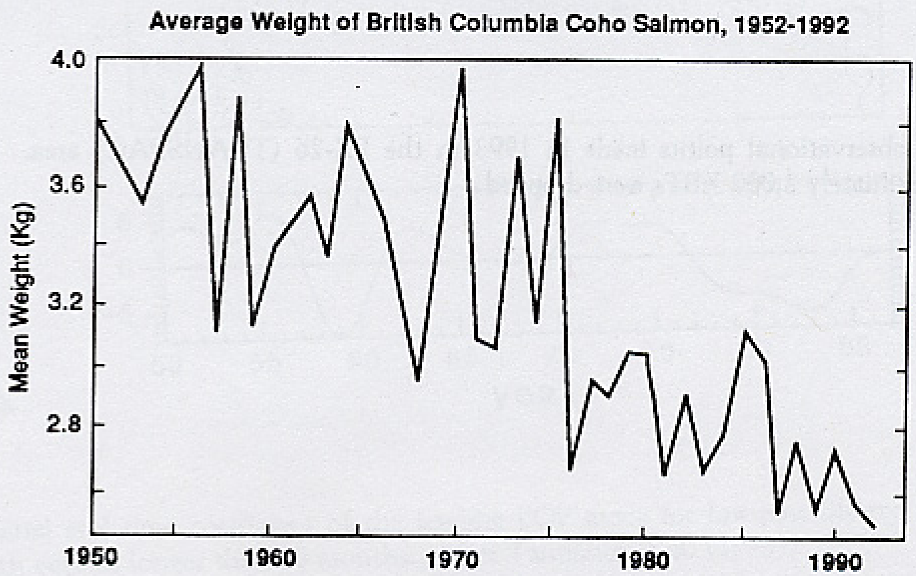

Fig. 3b. Annual variation in average size of B.C. seine-caught coho salmon.

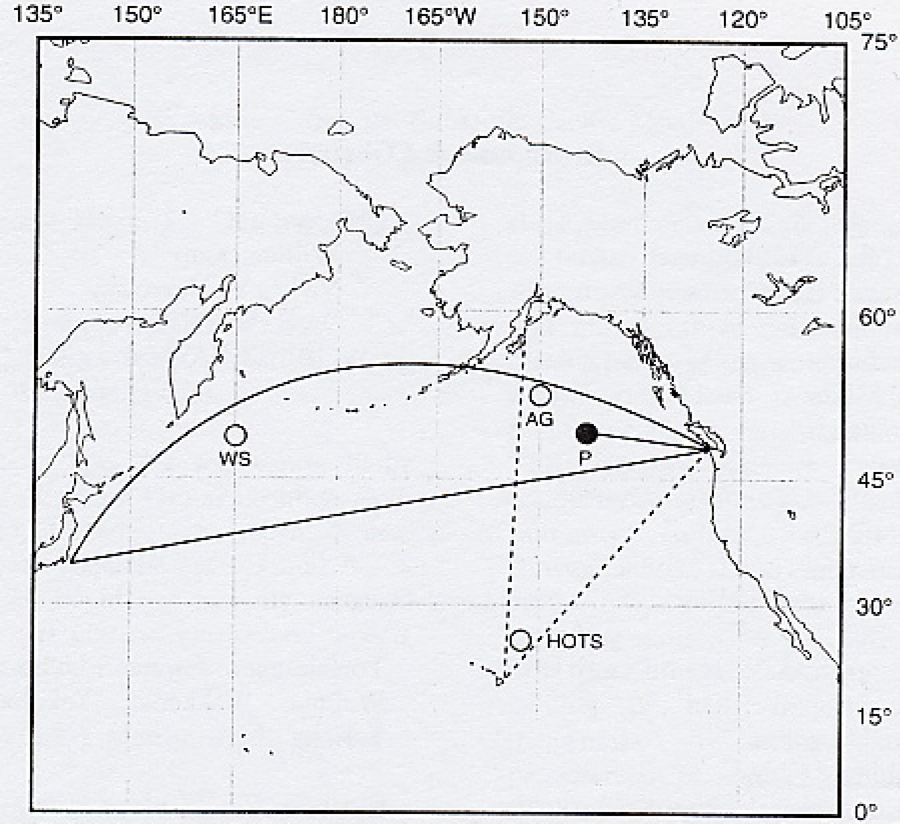

Fig. 4. Routes of volunteer observing ship R/V *Skaguran* are indicated by the *solid lines*. The *dashed lines* indicate proposed volunteer observing ship flow-through measurements routes. They are the same as XBT lines PX 37 and PX 38 in Fig. 1. The *filled circle* is Ocean Station P site. *Open circles* AG, WS and HOTS locate Alaska Gyre (AG) mooring; western Pacific (WS) mooring; and HOTS time series station, respectively. Mooring sites P, AG and WS are described in section IIIA.

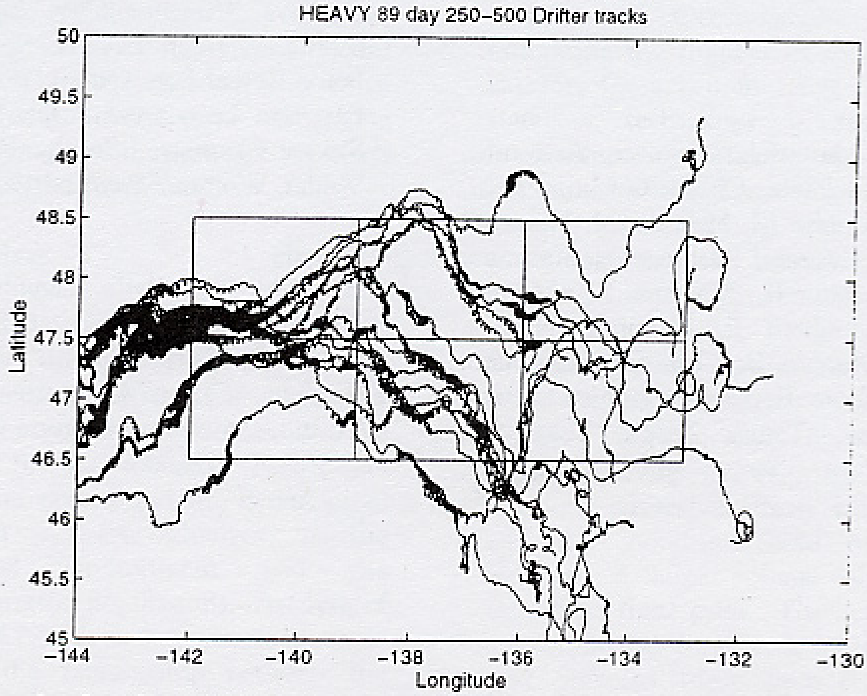

Fig. 5. Drifter tracks for the 1989 deployment (Days 250-500) (van Meurs and Niiler, 1995). Region 1 is the top left corner of the rectangle, region 4 bottom left corner, region 3 top right corner, and region 6 bottom right corner.

Appendix 1

Participants and Observers

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- Kimio Hanawa (Co-Chairman)
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- Lev N. Bocharov
- Charles B. Miller
- David W. Welch
- C. S. Wong

Observers
- William Karp
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- W. S. Wooster
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Appendix 2

Sea-Level Gauges

All gauges are north of 35°N and south of the Bering Straits.

People's Republic of China
Dalian, Laohutan, Newchwang, Qinhuangdao, Shijiusuo, Tanggu, Yantai

South Korea
Anhung, Gadeog Do, Kojong, Kunsan/outer port, Pohang, Pusan, Sogcho, Ulsan, Yosu

North Korea
Wonsan

Japan
Abashiri III, Aburatsubo Aomori, Asamushi, Awa Sima, Ayukawa, Choshi-Gyoko, Esashi, Fukaura, Hachinohe III, Hakodate I, Hanasaki II, Kamaisi II, Iwasaki, Kashiwazaki, Katsuura, Kawasaki, Kushiro II, Maizuru III, Mikuni, Miyako II, Monbetu II, Muroran, Nagoya, Nezugaseki, Ofunato II, Oga, Ogi, Ominato, Onahama, Oshoro II, Saigo, Shimizu-Minato, Sibaura, Soma, Tajiri, Tappi, Tokyo II, Tomakomai, Toyama, Uchiura, Urakawa II, Wajima, Wakkanai, Yokohama, Yokosuka, Yosioka

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Canada
Bamfield, Bella Bella, Campbell River, Fulford Harbour, New Westminster, Patricia Bay, Point Atkinson, Port Alberni, Port Hardy, Port Renfrew, Queen Charlotte City, Steveston, Tofino, Vancouver, Victoria

Working Group 9: Subarctic Pacific Monitoring
Report of Second Meeting

Report of Second Meeting - October 11-12, 1996

Participants: Bruce A. Taft (U.S.A.) Co-Chairman; C. Miller (U.S.A.); C.S. Wong (Canada); D. Welch (Canada).

The discussion at WG 9-2 was hampered by the absence of Working Group members from the western Pacific countries (Japan, Korea, Russia, People's Republic of China). A number of issues could not be fully explored with the members present, particularly aspects of climate variability in the western Pacific.

I. Status of WG 9-1 Monitoring Initiatives

At WG 9-1 seven possible PICES monitoring initiatives were outlined. Most of our discussion at WG 9-2 was focused on the further development of these ideas and the assessment of their readiness to be forwarded to the Science Board for consideration of implementation. Summaries of our discussion of each topic follow with a few recommendations for Science Board consideration. They are divided into three categories: new initiatives; continuing programs; and programs that are not yet ready for commencement of monitoring.

A. New Initiatives

1. Ecosystem monitoring moorings

Time-series measurements of primary production and zooplankton stocks in the oceanic sector of the subarctic Pacific are required to better understand the dynamics of the interaction between changes in the physical-chemical environment and the variability of plankton populations. Analysis of the Station PAPA data has provided some insight in to the relationship between the response of the plankton communities to the atmospheric forcing (Miller, 1993). However, there were never suitable data at PAPA to show whether variations in zooplankton stocks are related in some direct fashion to variations in primary productivity. Moored time series will provide these data. Long-term moored measurements of the wind velocity and vertical distributions (down to the pycnocline) of a number of ocean variables would be obtained. The ocean variables are temperature, conductivity (salinity), dissolved inorganic nutrients (nitrate, silicate), chlorophyll (phytoplankton stock), solar radiation, primary productivity indices and zooplankton stock. Sampling must cover the range of time scales from diurnal to decadal (regime shifts) to avoid aliasing of high frequencies into lower frequencies. Technology exists for moored measurement of most of these variables. The most serious shortcomings are in the measurement of zooplankton stocks. Acoustic methods of measurement of zooplankton concentration are currently under development but there renain serious systematic errors (pteropod problem). The optical plankton counter (OPC) developed at the Bedford Institute of Oceanography is capable of estimating the number of zooplankton by size category for a certain range of species. The state of technology is such that useful measurements of a sufficient number of the key variables can be made now and there is real promise of continuing improvement of the technology that can be incorporated into the evolving suite of measurements.

PICES ecosystem monitoring moorings should be located at the centers of the Alaska Gyre (53°N, 150°W) and the western Pacific Subarctic Gyre (52°N, 165°E). At these locations advective effects will be minimized and the moorings could be presumed to represent a large volume of water in the interior of these gyres. The oceanographic and meteorological conditions in the two sites are very different (deep pycnocline and higher primary productivity and zooplankton biomass in the west). Comparison of the biological and physical relationships in the two situations will provide needed insight in to how the dynamics can be modified by significant changes in the parameters of the system. The BASS Task Team, in their June 1996 meeting, strongly recommended that PICES place high priority on the installation of the two ecosystem monitoring moorings. It also should be noted that the draft of the US GLOBEC West Coast Implementation Plan shows a mooring near the center of the Alaska Gyre which appears to be very similar to the PICES ecosystem monitoring mooring. PICES should encourage US GLOBEC to implement this mooring. The corresponding mooring in the western Pacific should be provided by the PICES countries.

Recommendation - PICES undertakes to implement the ecological monitoring moorings in the Alaska Gyre and western Pacific Subarctic Gyre.

2. Measurement of E. Kamchatka Current transport by undersea cable

The general circulation of the Subarctic Pacific is thought to consist of two clearly separated cyclonic subarctic gyres: Alaska Gyre and western Pacific Gyre (Ohtani, 1991). In the intervening area between the gyres (165 E to 175 W) the Alaskan Stream flows westward adjacent to the Aleutians and south of the Stream lies the Subarctic Current. Flow into the Bering Sea occurs through a series of passages in the Aleutian Arc; the largest inflow typically occurs in the Near Strait. Outflow occurs through the Kamchatka Strait (range of 8-24 Sv) and the Bering Strait (range of 0.6-1.0 Sv). The southward flow through the Kamchatka Strait is an excellent index of the magnitude of the exchange of water between the North Pacific and the Bering Sea. Variations in the amount of water that enters the Bering Sea will affect the water- mass characteristics and the residence time of water in the Bering Sea. The E. Kamchatka Current is the source of water flowing southward in the Oyashio Current. Understanding the climatic variability of the Subarctic Pacific would be greatly aided by knowing how the intensity of the Bering Sea cyclonic circulation varies on annual, interannual and decadal time scales.

Instead of measuring the entire basin-scale Bering Sea circulation it is sufficient to measure over the 100 km width of Kamchatka Strait. The Strait is an ideal site to measure the intensity of the Bering Sea circulation with an electromagnetic cable. The technique, which has been used successfully for 14 years in the Florida Current (Larsen, 1992), resolves all the energetic time scales and gives a measure of the total (net) transport so that it is insensitive to fluctuations in the cross-stream flow structure. Under the conditions usually met in western boundary currents, the voltage difference induced in the cable by the water transport is linearly related to the transport. In the Florida Strait the *rms* error in daily volume transport is 0.7 Sv. A cable would be deployed across the deep portion of the Strait with an acoustic data link on the shallow inshore side. Data will be reported at regular intervals to a ship that visits the site. An array of current meters will have to be set in the Strait to provide a two-year calibration data set to establish the relationship between induced voltage and transport. Follow-up calibration to check for drift of the system will have to be done every three years. The cable has an expected lifetime of <u>thirty years</u>.

Costs (exclusive of shiptime costs) are estimated as follows: installation $500K; moored array $600K (one time); long-term drift calibration $200K (every third year); and annual maintenance and data analysis $100K.

Recommendation - PICES undertake implementation of installation of a conducting cable across Kamchatka Strait to measure transport of the E. Kamchatka Current.

B. Continuing Programs

1. Voluntary observing ship flow-through measurements program

At the present time a program of surface measurements are made on a vessel which traverses a route from Tokyo-Vancouver (RT) ten times per year. The following measurements are made: T, S, pCO_2, pH, chlorophyll-a, inorganic nitrate and silicate and total CO_2. Possibly zooplankton abundance will be added in the future. With these sections it has been possible to document recent changes (1995-1996) in the northeast Pacific, i.e. progressive westward shift with time in area of low nutrients off west coast of Canada that is associated with low salinity. It has been demonstrated that such changes cannot be documented without a basin-scale observational program with sufficient spatial and temporal coverage. The VOS program is the only way to obtain these data. North-south variability also needs to be sampled and attempts are being made to find funds and vessels to do the Hawaii-Alaska and Hawaii-Seattle routes. Setting up these lines would provide comparative data on the Subtropical and Alaska Gyres and sample the N. Pacific Drift and the southward deflected portion of the N. Pacific Drift that feeds in to the California Current. Once the ships are identified the funding will be sought.

2. Heat content and freshwater variability of subarctic Pacific.

Measurements of the heat content in the subarctic Pacific has a long history. Measurements were begun in the 1960s and there was a stable level of about 5,500 observations collected annually on east-west routes in the subarctic Pacific in the late 1980s. These measurements have been used in a number of studies that include demonstration of Rossby wave propagation in the N. Pacific Drift (White, 1982) and detection of climate change in the subarctic (Levitus, 1995). In 1993 the number of observations dropped to 2,000 annually because of withdrawal of US Navy funding. There is concern that sampling is now subcritical. A design study needs to be done to establish the sampling density that is adequate for subarctic climate heat content studies. During the next year WG 9 should establish how this will be done. It probably should be done in the context of the design of the global XBT sampling program rather than within WG 9.

There is no VOS salinity sampling program in the subarctic Pacific. Salinity is a very important indicator of climate change; it is determined by the interactions of ice, ocean, land runoff and atmosphere. Variation of salinity influences geostrophic flow, gravitational stability and convective processes contributing to the formation of near-surface water masses. The WG should determine what is the logical way to develop a strategy for measurements of the large-scale variability of salinity. One possibility is to undertake the study itself; however, this is a major task and may lie beyond the resources of WG 9.

3. Salmon scales as measures of productivity

Salmon scales can be used to monitor fish growth. Looking at it in another way the salmon scales are indicators of the environmental conditions the fish encountered at sea. The permanent record of amount of growth achieved in different years at sea presents an opportunity to monitor high-seas climate change. Because salmon are relatively short-lived animals with high growth rates and simple life histories, variations in the ocean environment affecting growth should cause relatively large changes in body size and therefore can be readily measured. Presumably abundance of food is the critical variable affecting growth with temperature providing a second-order effect. The analysis of existing salmon scales is now underway and will continue. Further modest investments to standardize collection techniques and scale measurements should be made. Collections from additional areas should be initiated to expand the monitoring coverage.

Budget: Technician salary $29K; Equipment purchase $25K.

C. Programs Under Discussion

1. Role of iron in determining primary production

There is an accumulating body of evidence that the trace iron ion plays a critical role in determining the level of primary production in the ocean (see for example Martin et al., 1994).

The source of iron for the ocean appears to be the atmosphere. Iron is added to the atmosphere when aerosol content increases. Flux into the ocean occurs primarily as a result of rain. It does not appear to be possible to directly measure the flux into the ocean because the distributions of rain and aerosol over the ocean are poorly known. The WG will investigate whether there may be some time-series data on aerosol content (Fe concentration) of the air at the boundary of the N. Pacific that could be analyzed for interannual and decadal variability of the aerosol source. Measurement of iron content of ocean water is technically difficult. In the foreseeable future it will not be possible to make measurements from moorings. The WG was encouraged that IOS (Sydney) will begin to make iron measurements on the PAPA hydrographic section (3 times per year). Iron measurements should be incorporated on hydrographic sections planned in the PICES area so that a data set can be acquired which documents the time and space scales of the variability of iron.

2. Surface-velocity measurements with satellite-tracked drifters

The surface-velocity program of the World Ocean Circulation Experiment employs the use of calibrated surface drifters to measure the near-surface velocity (at 15 m). The drifters can be instrumented to measure fluorescence, temperature, conductivity and barometric pressure.

The WG will consider possible uses of drifter technology to monitor features of the subarctic circulation to describe and understand the processes of climate change. One example is the study of the relation between the eastward flow in the N. Pacific Current and the variability of the eastern boundary currents (Alaska Current, California Current). Chelton and Davis (1982) have shown that the sea level along the eastern boundary covaries from Mexico to Alaska. This can be interpreted as evidence that the N. Pacific Drift bifurcates and the amount of water deflected north and south varies out of phase with the sea level. This interpretation seems to be at variance with the recent analysis of three years of TOPEX altimeter data (Strub, in preparation). Strub suggests that on seasonal and interannual time scales the flows of the two gyres are out of phase and seem to be unrelated to variability of the inflow from the offshore region. The WG will consider more fully the use of drifters in the monitoring program at the 1997 meeting.

II. Interaction of PICES WG 9 with Planning Process of GOOS

The WG discussed the need for some connection between our activities and the planning of the Global Ocean Observing System (GOOS). It was recognized that it will be important that PICES perspectives be considered in the formulation of the observing system. During the next year the Co-chairman (B. Taft) will investigate how this might best be done. In particular the advisability of direct PICES participation in these discussions will be considered. Written communications alone may not be effective.

III. Stimulation of Discussion of Monitoring within PICES

The WG felt that the dialogue between itself and the broad PICES community could be strengthened. It was our vision that we would be the focus of development of monitoring ideas but that input would be received from other scientists. The WG is small and most of the ideas considered so far represent the scientific interests of the WG membership. Ways to draw in other ideas need to be encouraged. One possibility to promote communication would be to have a session on the state of the Subarctic Pacific at the annual meeting. For example, there is some evidence that a climatic shift may be taking place now. It would be desirable to follow its development or demise. The discussion of the observed changes will focus attention on how well the system is being observed. We expect that useful ideas about improving the monitoring system would arise in the ensuing discussion.

RECOMMENDATION - In planning the next PICES annual meeting, the Science Board provide a session on the "State of the Subarctic Pacific".