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SCIENCE PLAN

PICES-GLOBEC '94 Workshop Steering Committee Chairman:
N.B. Hargreaves

IMPLEMENTATION PLAN

REPORT OF THE PICES-GLOBEC INTERNATIONAL PROGRAM ON CLIMATE CHANGE AND CARRYING CAPACITY

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North Pacific Marine Science Organization (PICES)
c/o Institute of Ocean Sciences, P.O. Box 6000, Sidney, B.C., Canada. V8L 4B2
pices@ios.bc.ca

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PICES-GLOBEC SCIENCE PLAN

Introduction

The North Pacific Marine Science Organization (PICES) and the Global Ocean Ecosystem Dynamics Program (GLOBEC) agreed in 1993 to jointly organize an international science program on *Climate Change and Carrying Capacity* (CCCC) in the temperate and subarctic regions of the North Pacific Ocean. A PICES-GLOBEC Workshop was organized in 1994 to develop a Science Plan during the PICES Third Annual Meeting in Nemuro, Japan. This proposed PICES-GLOBEC Science Plan is the result of this Workshop, and prior input from PICES Working Group and Science Committee members.

Activities in the CCCC Program are anticipated on two spatial scales:

1. Basin-scale studies to determine how plankton productivity and the "carrying capacity" for high trophic level, pelagic carnivores in the North Pacific change in response to climate variations.[1]

2. Regional-scale, ecosystem studies comparing how variations in ocean climate change species dominance and productivity of key plankton and fish populations in the coastal margins of the Pacific Rim, from China to California.

[1] *In accordance with discussions with the NPAFC/CSRS in November 1993 and October 1994 it would be appropriate for the salmon research component of this study to be conducted jointly with the North Pacific Anadromous Fish Commission (NPAFC).*

Background

Why is PICES interested in studying Climate Change and Carrying Capacity? The reason stems from the remarkable changes that have occurred in the North Pacific and adjacent seas in recent decades, in both the open ocean and coastal margins. Concurrent changes in atmospheric pressure and ocean temperatures indicate that in 1976 and 1977 the North Pacific shifted from one climate state, or regime, to another that has persisted through the 1980s (Trenberth 1990; Hollowed and Wooster 1992; Kerr 1992; Graham 1992; Trenberth and Hurrell 1994). Analyses of the North Pacific sea surface temperatures (SST) and atmospheric flow (Fig. 1) have identified a pattern of regime shifts in SST, the atmospheric Pacific/North American index (PNA; Fig. 2), and the southern oscillation index, lasting several years to decades. Specifically, since 1976 there has been an intensification of the Aleutian low during the winter (November through March). The centre of the low has shifted further east and is now about 4 mb deeper, on average. There have also been associated changes in wind stress curl, the corresponding Sverdrup transport, a warming over Alaska, and a cooling in the central and western North Pacific. The strength of flows in the Alaska and California Currents may also fluctuate out-of-phase (Wickett 1967; Chelton and Davis 1982; Chelton 1984; Tabata

1991). Changes in the Aleutian low also affect the distribution of sea ice in the Bering Sea (Niebauer 1989). Global modelling studies further suggest that if global warming is occurring, its effects should be most strongly developed and initially observed in high latitudes.

Although the important linkages are currently poorly understood, there is growing evidence that biological productivity in the North Pacific responds to these decadal-scale shifts in atmospheric and oceanic conditions, by alternating between periods of high and low productivity. In coastal areas, both the far eastern and California stocks of Pacific sardine peaked in abundance in the 1930s, declined significantly in the 1950s and 1960s, then began to increase synchronously in the mid-1970s (Kawasaki and Kumagai 1984; Lluch-Belda et al. 1989; Fig. 3). Large scale changes in pelagic fish production in the western Pacific (Terazaki 1989; Kawasaki 1991), and in year class synchrony in recruitment of numerous important fish stocks (Bakkala 1993; Hollowed et al. 1987; Hollowed and Wooster 1992; Beamish 1993), suggests coastal production is linked to variations in ocean climate. Paleosedimentary records indicate that these interdecadal fluctuations have been characteristic of the California Current system for the last 2000 years (Baumgartner et. al. 1992).

Between the late 1960s and mid-1970s, there was a two-fold increase in the summer biomass of zooplankton (Brodeur and Ware 1992; Fig. 4), and some higher trophic-level carnivores such as pomfret and neon flying squid (Brodeur and Ware 1994) in the eastern subarctic Pacific. Odate (1994) also reported significant fluctuations in zooplankton biomass in the Oyashio, Kuroshio and the transitional regions off the coast of Japan (Fig. 5). The combined, national catches of salmon in the North Pacific (Fig. 6) also apparently declined steadily from historic highs in the late 1930s to a low in the mid-1970s. However, by the late 1970s there was a striking increase and the combined salmon catches subsequently had risen two- to three-fold, to nearly the historic high levels for this century (Pearcy 1992; Ishida 1992; Beamish and Bouillon 1993; Hare and Francis 1994).

Significant changes in ocean climate do not affect all ecosystems or species in the same way. Conversely, it is not established that a species or ecosystem will always respond in the same way to a specific type of change in ocean climate. During any particular ocean climate regime the productivity of some species may be high, while the productivity of other species may be low. For example, major shifts in the dominant fish species have occurred among sardine, anchovy and mackerel in the Kuroshio-Oyashio Current region from the 1970s to 1980s. Productivity changes also occur in the coastal waters around the Pacific Rim, but also are not necessarily in-phase with the open ocean, or other coastal ecosystems. For example, ocean survival of Washington and Oregon coho salmon was high during the 1960s and early 1970s, then declined markedly after 1976, opposite to the pattern observed in Alaska coho (Pearcy 1992; Hare and Francis 1994). Important changes in ocean climate likely include both physical (water mass structure, nutrient fluxes, sea ice cover etc.) and biological (primary and secondary production, predator abundance and distribution, etc.) components.

In addition to the decadal-scale regime shifts, longer-term global climate change may result in substantial changes in the biological carrying capacity of the North Pacific. Several observations are consistent with this possibility. For example, coincident with the recent increase in salmon catches, the average size of adult salmon has significantly decreased in some areas of the North Pacific. The average size of adult Japanese chum has declined by about 7% in fork length and 20% in body weight from the late 1970s to the early 1980s, but has been unchanged since the early 1980s (Kaeriyama 1989; Ishida et al. 1993). The average size of Russian chum has also decreased (Ishida et al. 1993). The mean body weight of returning pink salmon in British Columbia has declined 40% since the 1950s (Ricker 1981). There is also evidence that growth and mortality of some salmon species and stocks in the high seas may vary with levels of salmon production (Krogius 1960; Peterman 1984, 1991; Ogura et al. 1991; Ishida et al. 1993). In some cases the growth rates of abundant stocks of salmon appear to be inversely related to stock size (e.g., pink salmon, Peterman 1987). Some portion of these patterns of variation may be due to the combined current abundance of salmon and other high trophic level carnivores approaching the present "carrying capacity" of the subarctic North Pacific.

By "carrying capacity" we mean how zooplankton and high trophic level carnivore species dominance and productivity respond to changes in the ocean climate. One initiative in the CCCC program will be to develop a new theoretical and mathematical framework which extends the classical, single species concept of carrying capacity into the multi-species, ecosystem domain that the CCCC Program will address. To be relevant, this extended definition must recognize that the "carrying capacity" from this point of view changes over time in response to many factors such as: abiotic conditions, spatial distribution of the population, the supply of food, and the abundance of predators. The food supply, in turn, is a function of the productivity of the prey populations, and competition for that food from both within and between predator populations. As experience has indicated, changes in the abiotic environment can affect the distributions and productivity of populations at all trophic levels.

PICES-GLOBEC Science Plan

The CCCC Program will address how climate change affects ecosystem structure, and the productivity of key biological species at all trophic levels in the open ocean and coastal North Pacific ecosystems. The physical environmental changes that have occurred in this century, particularly during the late 1970s, may provide a natural experiment for studying such questions.

At this stage, only the general scope of the proposed CCCC Program has been discussed. There will be a strong emphasis on the coupling between atmospheric and oceanographic processes, their impact on the production of the major living marine resources, and on how they respond to climate change on time scales of seasons to centuries.

The program shall focus on determining how the dynamics of the ecosystems of the subarctic Pacific respond to climate change. The program will include the following elements:

1. Employ mechanistic process studies to improve understanding and develop early recognition and prediction capabilities for regime changes.

2. Develop and employ models to guide research activities, integrate results, and improve capabilities for forecasting ecosystem responses to climate change.

3. Develop broader insights and understanding through regional comparative studies.

4. Support and coordinate CCCC Program activities with GLOBEC.INTernational and other existing and planned international (e.g. NPAFC, WOCE, JGOFS, GOOS, NOPACCS, WESTPAC, YSLME, LOICZ) and national (e.g. CalCOFI, BIOCOSMOS, GLOBEC SPACC, HUBEC, FOCI, LaPerouse) organizations and research programs in the PICES region.

The **key scientific questions** to be addressed include:

1. How do interannual and decadal variations in ocean conditions affect the species dominance, biomass, and productivity of the key zooplankton and fish species in the ecosystems of the PICES area?

2. Evidence exists for climate regime shifts in the eastern North Pacific, but it is not clear if similar shifts occur on the same time scales in the western North Pacific. Are regime shifts in the eastern and western sides of the North Pacific basin in-phase? Do they have the same or opposite sign? Methods are required for both short term detection and longer term prediction of climate regime shifts.

3. How are the open and coastal North Pacific ecosystems structured? Methods are required for both short-term detection and longer-term prediction of changes in ecosystem structure, stability and productivity. The biomass spectrum approach (Platt 1985; Boudreau and Dickie 1992; Fig. 7) may provide a useful starting point for this activity.

4. What impact do variations in flow and dynamics of eastern and western boundary currents have on the productivity of Pacific Rim coastal ecosystems? Do the strengths of the Alaska and California currents vary inversely? How are their dynamics related to those of the Kuroshio and Oyashio currents?

5. What factors affect current trends in the productivity of the North Pacific Ocean and their impacts on salmonid carrying capacity?[2] To what extent do the seasonally migrating species such as Pacific pomfret, neon flying squid and Pacific saury compete with salmonids in the subarctic Pacific?

6. What factors affect changes in biological characteristics of Pacific salmon? These characteristics include growth, size at maturity, age at maturity, ocean distribution,

survival, and abundance?[2] (This is also a critical question for all key species of the subarctic Pacific.)

7. How do responses to regime state differ among potential dominant species? How do abundances, migratory patterns, and stock-recruitment relationships change? Is the response of key species to regime change characteristic and consistent over several cycles? What limits primary production during each regime?

8. What are the causes and consequences of spatial shifts in pelagic ecosystems?

Key research activities proposed to address fundamental scientific questions include:

1. Retrospective analyses

Retrospective analyses of existing atmospheric, physical, biological and paleoceanographic data, to identify recent (and historical) changes in the subarctic Pacific. For example, plans are currently underway to:

- examine atmospheric and physical oceanographic time series in the eastern and western Pacific to determine if regime shifts occurred and if these shifts were synchronous across the North Pacific;

- examine long-term plankton and fisheries records from the eastern and western Pacific for shifts in species composition and biomass changes, and determine if these changes are synchronous on both sides of the Pacific;

- analyze plankton and high trophic level carnivore biomass data from North Pacific ecosystems to determine the average slope and intercept of the biomass spectra (Fig. 7) for different ocean regimes;

- examine the statistical evidence for a link between variations in ocean conditions, plankton, and catches of key fish stocks, and investigate the relationship between fish catches and total production, or recruitment;

- reconstruct interdecadal-through-centennial scale variability in fish populations and associated environmental changes for the past one to two millennia;

- examine historical variations in salmon growth through the analysis of their scale patterns;

- conduct comparative studies of somatic growth of fish populations around the Pacific Rim (e.g., Wada and Kashiwai 1991);

- compare the dynamics of coastal fish stocks of the North Pacific;

- examine how physical forcing affects the eastern Pacific marine mammal (e.g., harbor seals and sea lions) and

[2] *In 1993 the NPAFC agreed that ".. NPAFC and PICES could jointly examine the critical issue of the impact of change in the productivity of the North Pacific on Pacific salmon" (see NPAFC Report 1993, p.51). Key Scientific Questions #5 and #6 (above) were the two items that were specifically identified by the NPAFC as two critical issues that should be examined.*

seabird populations via changes in the abundance and availability of their food.

Other retrospective analyses will be carried out to meet program requirements.

2. Development of numerical models

This component of the program will develop models for ecosystem dynamics research and monitoring. The CCCC Program will involve scientists from countries on both sides of the North Pacific, requiring regional and ocean-basin scale models. PICES Working Group 7 (WG7) is reviewing three-dimensional circulation models of the North Pacific including nested circulation models of the marginal seas and shelf areas. PICES-GLOBEC and NPAFC member countries will be interested in developing regional food web models to couple with the nested, regional circulation models. However, reliability of results of complex nested models needs to be investigated because of the accumulation of errors. The models will be developed in close cooperation with the Ecosystem Process Studies and will also serve an important role in focusing and integrating other CCCC Program activities.

The following specific activities are proposed:

- develop a variety of foodweb formulations representing the appropriate dynamic ecosystem properties of interest to PICES-GLOBEC;

- embed the various formulations of foodweb models in one-dimensional mixed layer models forced by surface wind, heat and moisture exchanges typical of the subarctic Pacific, on time-scales from hours to years;

- embed mixed layer dynamics and foodweb models in the three-dimensional circulation models, and run retrospective simulations of the last 30-50 years with observed atmospheric inputs;

- develop second generation models to generate projections of physical and biological responses to possible future climate variation and large scale environmental change.

3. Ecosystem process studies

The CCCC Program will include well-resolved process studies of hypothesized linkages between target species and their environment. The process studies will be integrated closely and iteratively with the regional and basin-scale ecosystem models described in the previous section. They will also complement time series studies by allowing quicker evaluation of statistical significance, identification of important and informative intermediate variables and linkages, and verification and improvement of model structure and parameters.
The process studies will be conducted both in the open subarctic, and in selected regional, coastal ecosystems around the Pacific Rim. They will focus on how environmental conditions affect primary production; zooplankton production, distribution, and life history; food web trophodynamics (feeding, growth, reproduction and mortality rates); life history models; and the

migratory behavior of key zooplankton, micronekton, squids, fishes, marine mammals, and sea birds. Many of these topics are core components of the GLOBEC.INTernational Program.

Because many of the physical and biological changes of interest to PICES-GLOBEC occur over multi-year to interdecadal time scales, an important practical objective will be to maximize the range of environmental conditions examined in the process studies. This will be done in two ways. The first (and a very important element of the overall effort to understand how changes in ocean climate affect the production of coastal ecosystems and the population fluctuations of key species around the Pacific Rim) will be between-site comparisons among the numerous regional GLOBEC and GLOBEC-like studies ongoing or planned by Pacific Rim countries. These will include parallel and cooperative field studies comparing and contrasting the eastern and western Pacific in terms of their physical and geochemical settings, and biological characteristics of key species, including recruitment and stage specific vital rates (growth, mortality, fecundity). These measurements will be combined with parallel applications of trophodynamic and individual-based models.

Second, shorter time scale temporal variability (e.g., El Nino events) will also be studied, and the extent to which conditions and outcomes may be used as proxies or models to understand longer-term climate change will be examined. For both spatial and temporal variability, the linkage of diverse national and regional activities by cooperative process studies will provide opportunities and scientific insights which would not be gained through research conducted solely by the individual countries.

4. Development of Observation Systems

A monitoring program will be developed to collect new observational data on surface winds, upper ocean temperature and circulation, nutrient flux, phytoplankton productivity (from ocean colour sensors and *in situ* studies), zooplankton, mesopelagic micronektonic animals and higher trophic level carnivores. These data will be obtained from satellites, drifting buoys, moorings, volunteer observing ships, research vessels, and by development and implementation of required new methods and technology. Intensive multi-ship, multi-disciplinary surveys on whole ecosystem structure and dynamics, to understand biological productivity, trophic level interactions and physical biological interactions, will be developed in the Kuroshio-Oyashio transitional region. The data will be used in the numerical modelling and by other CCCC program activities. Data collection, analyses and exchange activities in the CCCC Program will also be closely linked and coordinated with survey and monitoring activities developed in other PICES and international (e.g., NPAFC) programs. It would be desirable for the CCCC Program to be coordinated with GOOS activities in the North Pacific, and to consider the use of models and experimental and statistical design tools to aid in the design of observational protocols.

Relevance and Expected Benefits of the CCCC Program

The PICES-GLOBEC International Program on *Climate Change and Carrying Capacity* will address major scientific questions and provide important benefits for the member countries. These countries are developing national GLOBEC programs, therefore, it is desirable that the PICES-GLOBEC Science Plan be developed in a timely manner to guide coordinated planning among the participating nations. The new information obtained from the CCCC Program to determine the changes in productivity of each trophic level in oceanic and coastal ecosystems will provide a stronger scientific base for rational harvesting and management of living marine resources in the North Pacific[3].

There are many important consequences of the climate regime changes that have occurred in the North Pacific during this century. For example, the current high catches of salmon in the North Pacific could change significantly when the next climate regime shift occurs. By identifying changes in productivity under different ocean climate regimes, Pacific Rim nations could respond appropriately. There are some indications that the North Pacific may have undergone another regime shift in the late 1980s making this study timely and important. Numerous studies have also found significant relationships between commercial catches or other indices of year class strength and/or recruitment (e.g., juvenile abundance) of individual stocks of marine fish and large-scale oceanic factors (e.g., El Nino events, wind stress, upwelling, temperature, salinity, primary and secondary productivity).

Major changes in species dominance and productivity have also occurred in the marginal seas around the Pacific Rim. The increases and collapses of both the Asian and California stocks of Pacific sardine populations during this century provide a striking example. These large amplitude changes in fish abundance have important economic and social effects, and appear to be linked to the general pattern of climate change in the North Pacific.

Large-scale year class synchrony in recruitment of many fish stocks in the eastern North Pacific also suggests a climate connection. Development of methods for early recognition and longer-term prediction of ocean climate regime shifts will be very valuable, and could become an important basis for more successful harvesting of short-lived species.

Scientific knowledge of the interrelationships between high trophic level carnivores and carrying capacity would be extremely useful in improving single species models, and in developing new multi-species models which could include consideration of the role of marine mammals, sea birds and non-target fish species in the ecosystem.

The linkage of local, regional, and international activities by these cooperative studies will provide unique opportunities and new scientific insights which would not be gained through

[3] *PICES itself has no fisheries management responsibility or authority. However, the scientific findings of the CCCC Program will be fully available to national and international agencies that do have that responsibility.*

research conducted solely by the individual countries.

Time Table

There is an urgent need to initiate the CCCC Program to provide international coordination between the national GLOBEC programs. Some national GLOBEC programs are anticipated to begin in late 1994 or early 1995.

The proposed schedule of activities for the CCCC Program is shown below. This schedule will be modified as the national GLOBEC programs are approved and implemented, and as appropriate linkages are established with other international organizations and programs such as NPAFC, JGOFS, WOCE and GOOS.

1995-1996: Phase 1:
Planning and Data Assimilation

- develop implementation plan
- feasibility/costing studies
- initiate planning of joint research with NPAFC
- begin compiling historic data
- begin retrospective analyses of existing data
- begin model identification and parameterization
- begin developing circulation models
- begin developing regional food web models
- begin planning observation system

1997: Start Phase 2:
Observing, Process Studies and Modelling

- complete compilation of historic data
- continue retrospective analyses
- develop new required technology
- implement required observation system
- conduct focused, international data collection surveys
- develop 3-D circulation model
- assess model and parameter uncertainty
- conduct process-oriented field and laboratory studies
- refine regional food web models
- conduct comparative ecosystem studies

2000: Start Phase 3:
Model Integration and Testing

- complete retrospective analyses
- operate observation system
- couple 3-D circulation model and regional food web models
- conduct focused, international data collection surveys
- validate ecosystem models
- develop methods to detect and predict regime shifts
- apply prognostic ecosystem models

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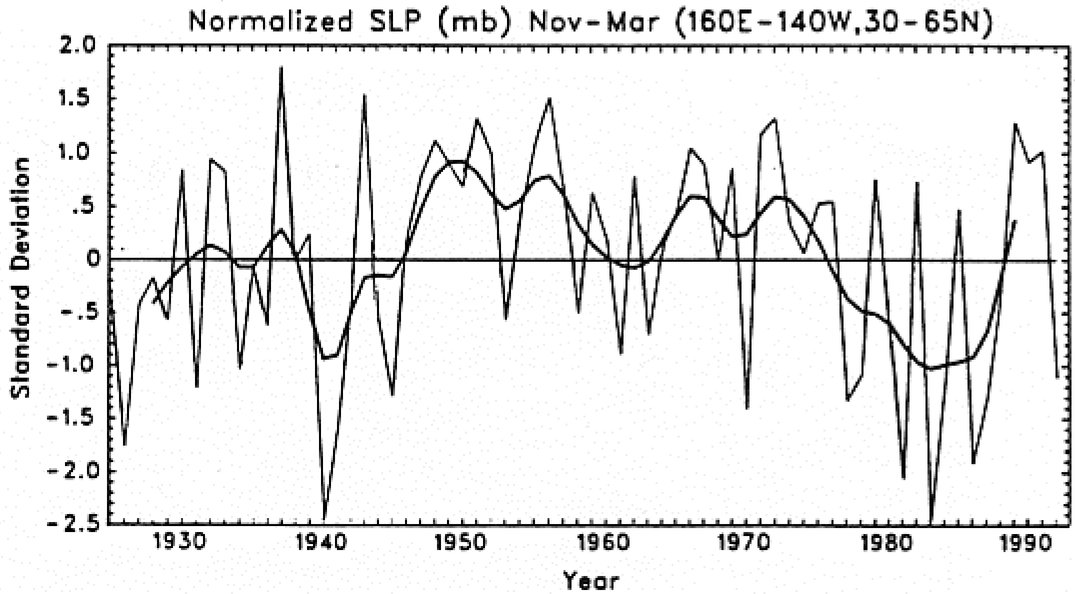

Fig. 1. Time series of mean North Pacific sea level pressures for November through March, beginning in 1925 and smoothed with a low pass filter. Source: Trenberth and Hen-ell (1994).

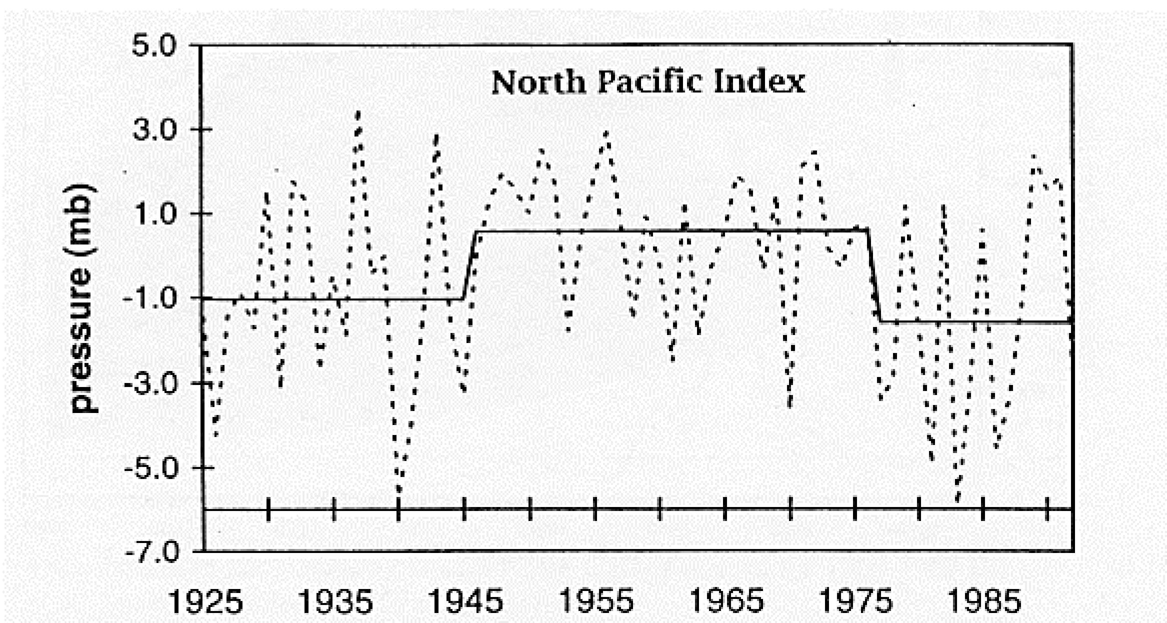

Fig. 2. Time history (dashed lines) and intervention model fit (solid line) for North Pacific Index. Source: Francis and Hare (1994).

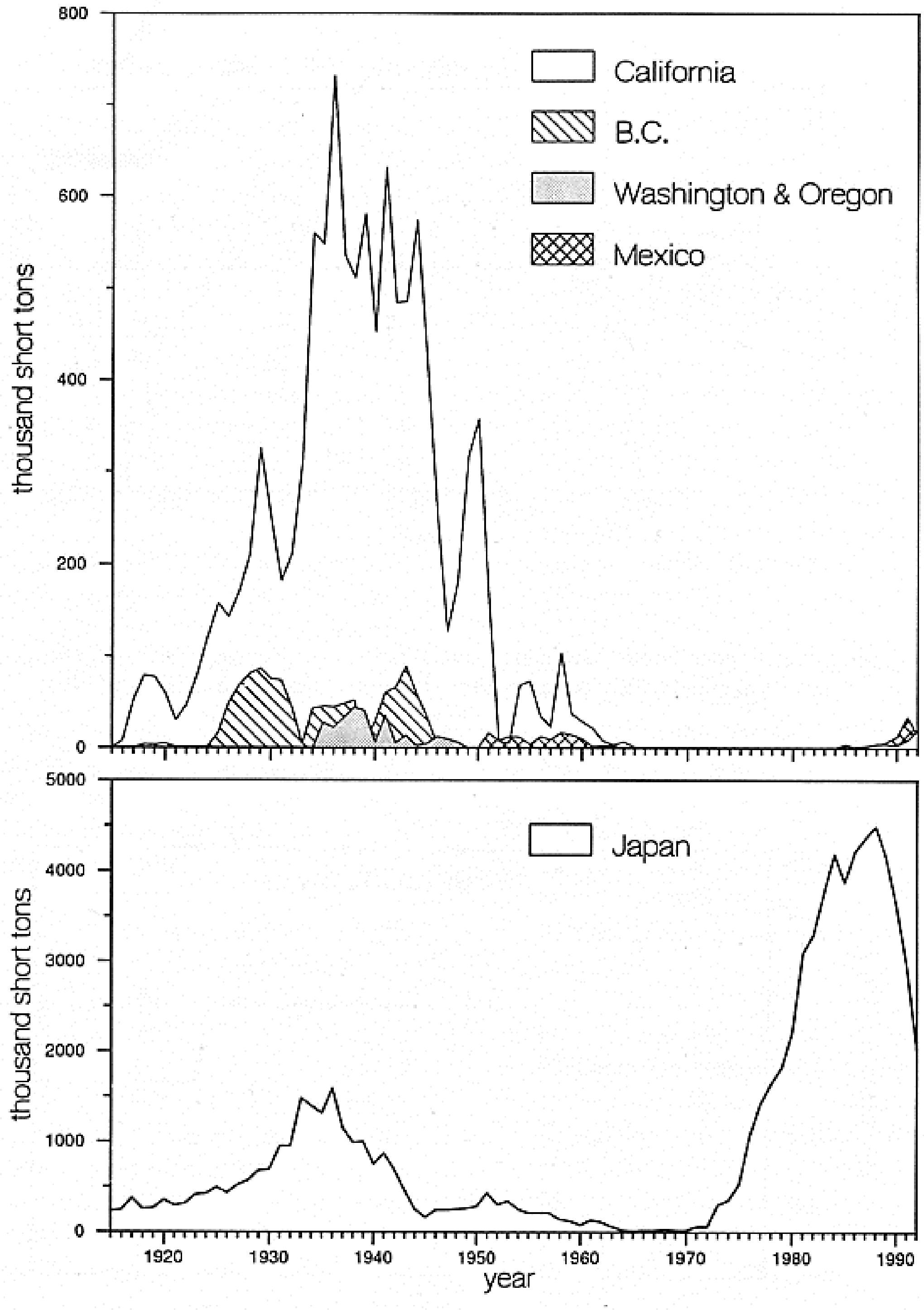

Fig. 3. Landing of Pacific sardine in the eastern Pacific (upper panel) and western Pacific Ocean (lower Panel). Source: Hargreaves, Ware and McFarlane(1994)

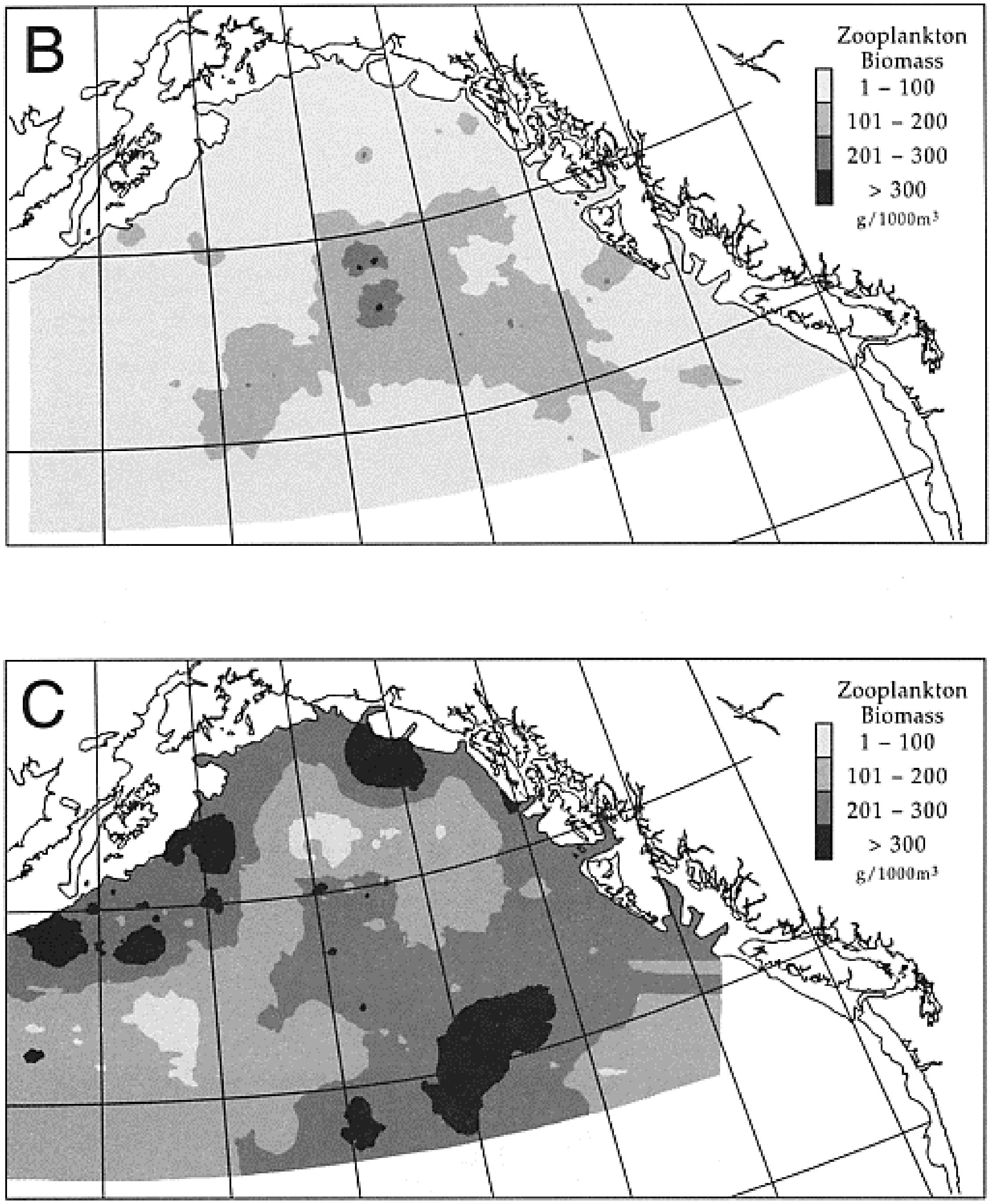

Fig. 4. Distribution of zooplankton biomass in the Gulf of Alaska for 1960-1962 (B) and 1980-1989 (C). Source: Brodeur and Ware (1992)

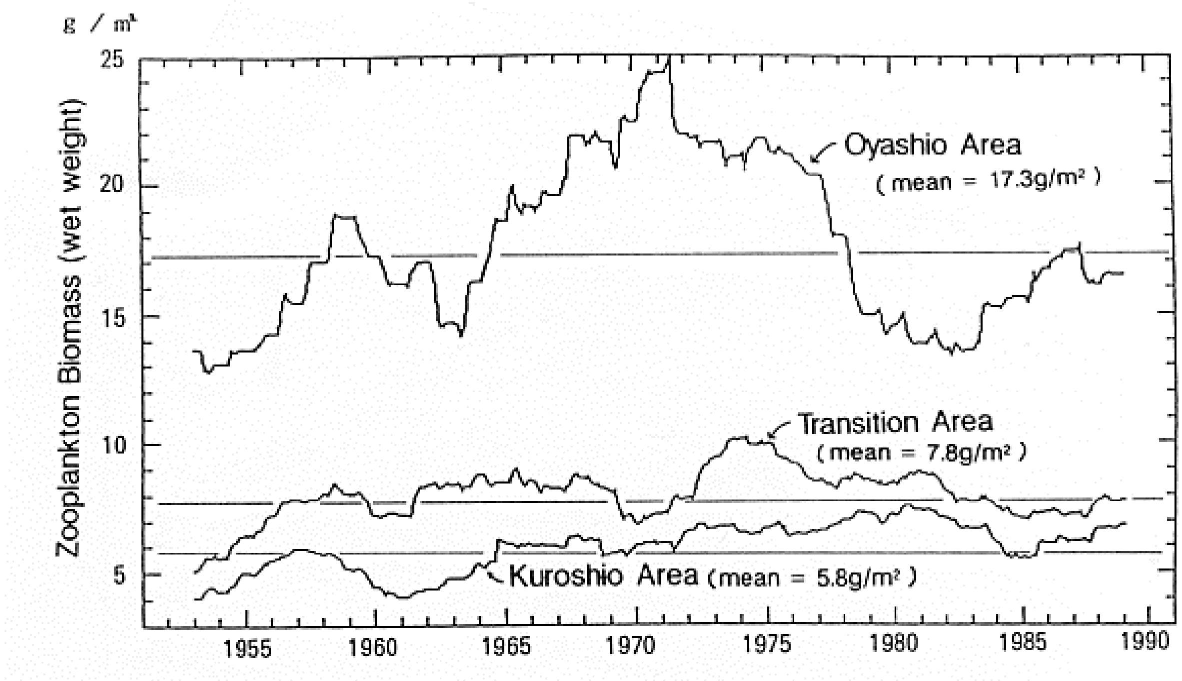

Fig. 5. Long term variability of zooplankton biomass indicate by 48 months running mean from 1951-1990. Horizontal lines show mean values of zooplankton biomass in each area. Source: Odate (1994).

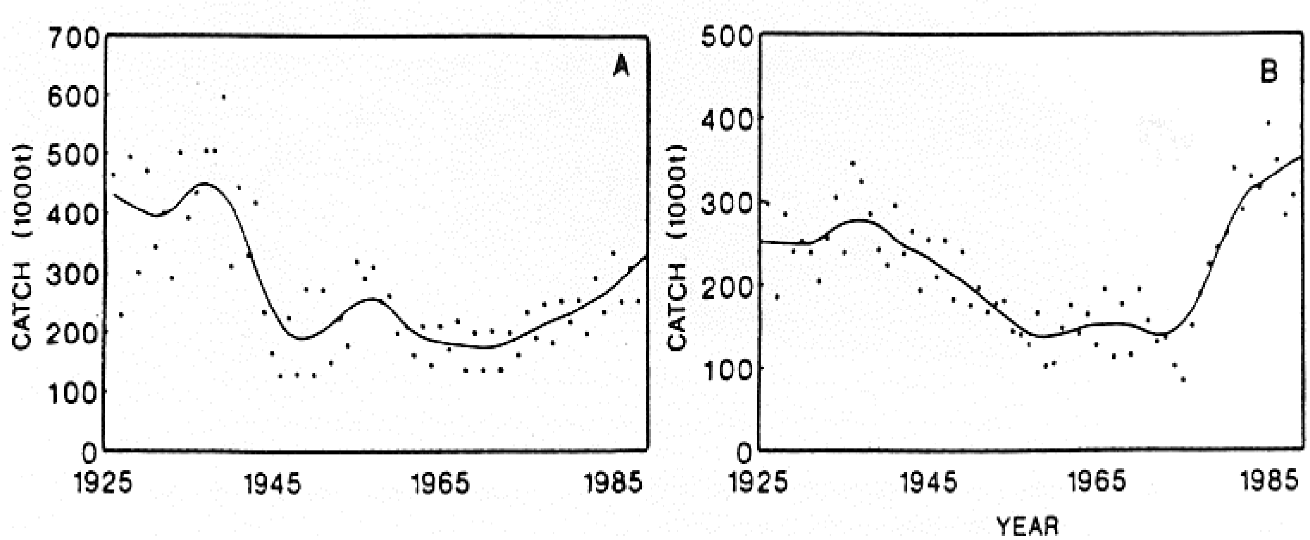

Fig. 6. Trends n catches of the combined (A) Asian and (B) North American catches of pink, chum, and sockeye salmon. Source: Beamish and Bouillion (1993).

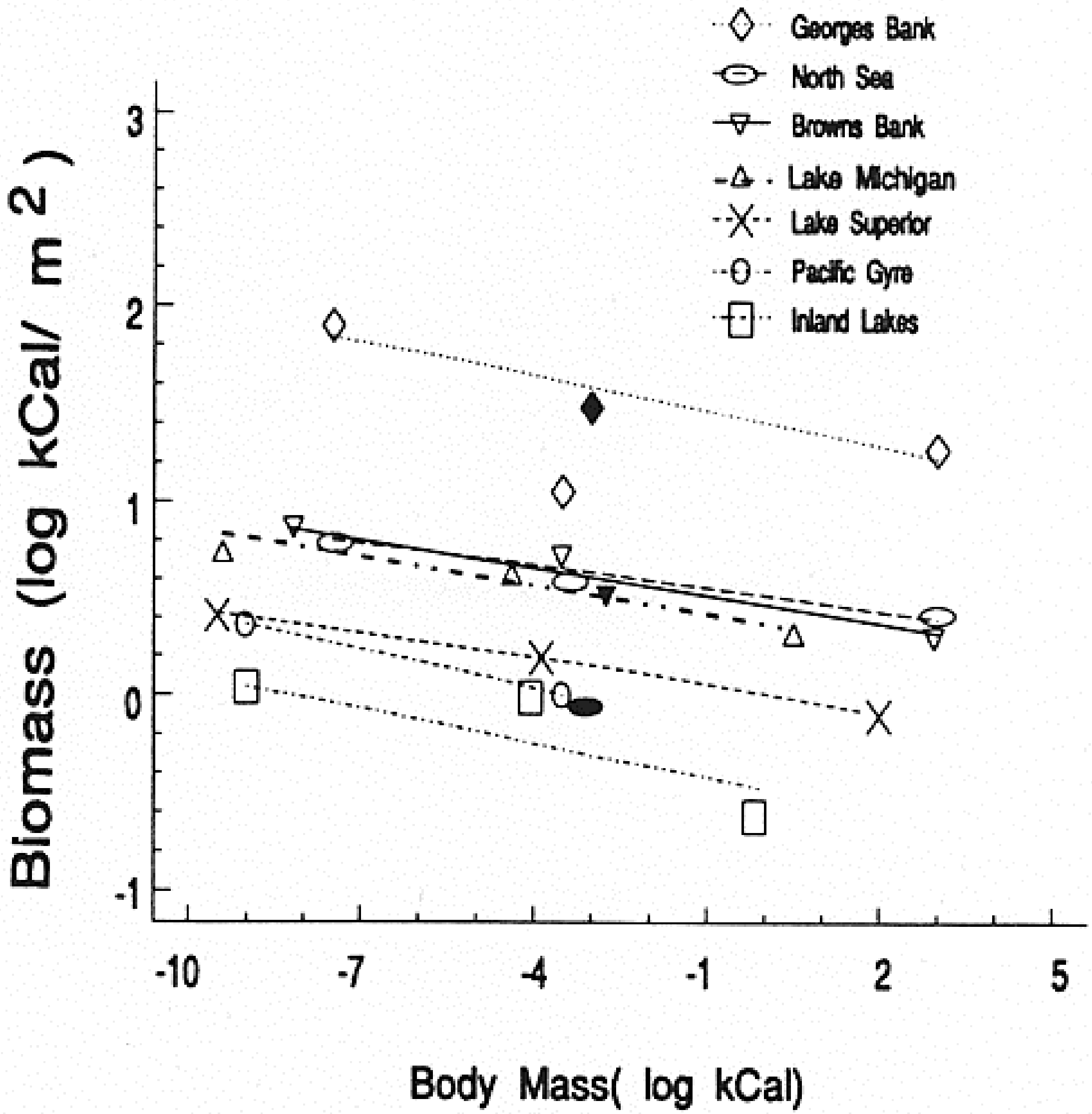

Fig. 7 Standardized biomass spectra for pelagic echosystems using summary mean points for phytoplankton, zooplankton, benthos, and fish groups. Benthos point are represented by solid symbols. The linear regression for each environment is calculated using the sum of zooplankton and benthos as the intermediate point. Source: Boudreau and Dickie (1992)

IMPLEMENTATION PLAN (PHASE 1)

Introduction

The basic description of the PICES GLOBEC-International Program on Climate Change and Carrying Capacity (CCCC) is contained in the Science Plan approved at the PICES Third Annual Meeting in October 1994. The Program will address how climate change affects ecosystem structure and the productivity of key biological species at all trophic levels in the open ocean and coastal North Pacific ecosystems. There will be a strong emphasis on the coupling between atmospheric and oceanic processes, their impacts on the production of major living marine resources, and how they respond to climate change on time scales of seasons to centuries.

As the Science Plan emphasizes, activities in the CCCC Program are anticipated on two spatial scales:

1. Basin-scale studies to determine how plankton productivity and the carrying capacity for high trophic level, pelagic carnivores in the North Pacific change in response to climate variations.

2. Regional-scale, ecosystem studies comparing how variations in ocean climate affect species dominance and fish populations in the coastal margins of the Pacific Rim, from China to California.

There is not universal agreement on the precise definitions of several important terms used in the Science Plan and the Implementation Panel considers it essential to establish a consensus on their meaning in the context of the plan.

1. In distinguishing between regional and basin scales, the former is understood to mean studies in coastal waters, generally conducted by scientists of a single country; some of these are identified as national GLOBEC programs. Basin scale refers to studies in the open ocean, generally requiring international cooperation for their conduct. The term subarctic Pacific includes the adjacent seas of the region, in accordance with terms of the PICES Convention.

2. The terms climate change and climate variation are used interchangeably to signify low frequency (seasons to centuries) fluctuations in atmospheric and oceanic conditions, both natural and man-induced.

3. Temporal scales of climate variation of particular interest to the CCCC Program are scales that have been designated quasi-biennial (2-3 years), ENSO (5-7 years), bi-decadal (about 20 years) and near-centennial (60-70 years). A major change in climate and ocean conditions in the late 1970s associated with major changes in oceanic ecosystems has been labeled a regime change; such changes are believed to occur on the bi-decadal or longer time scale.

4. Ecosystems are assemblages with distinctive food web structure of

organisms in trophic levels extending from primary producers to top predators. Such systems are forced by climate variations and human activity. Oceanic ecosystems are characteristically open so that models must account for fluxes between the ecosystems and their surroundings as well as for internal dynamics.

5. Although their definition is subjective, key species can be identified by several criteria, including their contribution to the overall biomass and/or the significance of their role in energy transfer and trophic structure. Some species are considered dominant species on the basis of the first of these criteria.

6. Productivity, the rate of the production process, is distinguished from production, the net accumulation of biomass over some specified time.

7. Carrying capacity for a given population is considered to be the limiting size of that population that can be supported by an ecosystem over a period of time and under a given set of environmental conditions.

Scientific Strategy

Central Scientific Issues

The ultimate goal of the CCCC Program is to forecast the consequences of climate variability on the ecosystems of the subarctic Pacific. To achieve this goal, the following Central Scientific Issues have been identified as a generalized restatement of the Key Scientific Questions of the Science Plan (Annex 1 shows the relation between the statements).

Physical forcing

What are the characteristics of climate variability, can interdecadal patterns be identified, how and when do they arise?

Lower trophic level response

How do primary and secondary producers respond in productivity, and in species and size composition, to climate variability in different ecosystems of the subarctic Pacific. Note that there is disagreement over the assignment of some organisms to lower or higher trophic levels.

Higher trophic level response

How do life history patterns, distributions, vital rates, and population dynamics of higher trophic level species respond directly and indirectly to climate variability?

Ecosystem interactions

How are subarctic Pacific ecosystems structured? Do higher trophic levels respond to climate variability solely as a consequence of bottom up forcing? Are there significant intra-trophic level and top down effects on lower trophic level production and on energy transfer efficiencies?

Key Research Activities

The Science Plan describes four key research activities, to which we have added a fifth, data management. The research activities described below apply to both basin and regional scales, although emphases and priorities will differ from project to project.

1. Retrospective analyses
2. Development of models
3. Process studies
4. Development of observation systems
5. Data management

These are related as indicated in Fig. 1, which suggests that retrospective studies are an important precursor to model and process studies, on which the design of observation systems will depend. The general role of PICES in these activities is to stimulate action, coordinate, and improve communication among participants. In addition, the following is noted about these activities:

1. **Retrospective analyses**: This approach is the only way whereby observed variability beyond the decadal scale can be studied. Sets of both physical and biological data are available for the region, many of which have not yet been fully analyzed. These studies are relatively low cost and are being actively conducted by many scientists. To accelerate progress, there is a need for enhanced communication among investigators and improved access to data sets. Valuable information on long time scales can be obtained from proxy, high-resloution records in sediments.
2. **Model development**: Model development is called for throughout CCCC implementation and especially in the first Phase. The activity includes conceptual/theoretical studies and has the eventual goal of a coupled atmosphere-ocean-ecosystem model. It will draw upon the findings of retrospective studies and will guide both process studies and the development of observation systems. Work on physical models is being reviewed by PICES Working Group 7. From the biological point of view, conceptual and modeling approaches will require identification of ecosystems and key species therein by several criteria, and should include an accounting of the principal elements of total system biomass.

3. **Process studies**: These include experimental approaches to study/test specific mechanisms linking ecosystem responses to environmental variability. They are very important to both regional and basin scale studies and should be essential components of national programs that contribute to the CCCC. Ideally, design of the process studies should be based on findings of retrospective and model development studies and should contribute to the design of observation systems.

4. **Observation systems**: The goal of the CCCC Program is to understand, and eventually predict, the effects of climate variation on ecosystems of the subarctic Pacific. This requires that changes in climate and in ecosystem response be measured systematically in an appropriate monitoring system, the design of

which draws on the findings of retrospective, process and model studies. It will be the responsibility of the PICES Working Group on Monitoring (WG9) to review existing and planned monitoring systems, including GOOS, and to incorporate the requirements of the CCCC Program in their recommendations for enhancement of these systems.

5. **Data management**: There is a need to enhance the availability of physical and biological data for research in the CCCC Program, through indices, inventories, compilations, and other appropriate means. Data will also be generated from CCCC process studies and observation systems, and quality control of these data (e.g., through critical examination of observational, processing, and analytical methods) is an important concern as is facilitating archiving and access to these data by scientists participating in the CCCC Program. The responsibilities of the PICES Technical Committee on Data Exchange include supporting the data management needs and recommending data management policy of the CCCC Program. This should be done in close cooperation with National Oceanographic Data Centers (NODCs) of the region and with the IOC International Oceanographic Data Exchange (IODE) program.

<u>Program components</u>

Approaches to study of Central Scientific Issues

Examples of approaches to the study of the Central Scientific Issues are given in Annex II. These encompass the various key research activities discussed earlier, and will differ from project to project.

Regional and basin scale components

On the regional scale, comparative studies of ecosystems along the continental margins of the subarctic Pacific will be of particular importance in the CCCC Program. The following regional (1-10) and basin scale (11-12) components have been identified (see Figure 2 for relative locations). First generation models have been developed for those marked *.

1. California Current System, south
2. * California Current System, Oregon to Vancouver Island
3. * Southeast, Central Alaska
4. Eastern Bering Sea
5. * Western Bering Sea/Kamchatka
6. Okhotsk Sea
7. * Oyashio/Kuroshio
8. Japan Sea/East Sea
9. Bohai, Yellow Sea
10. East China Sea
11. Western subarctic gyre
12. *Eastern subarctic gyre

National programs as of 1995, present and/or planned, are listed in Tables 1-12; programs included are national GLOBEC programs or those of equivalent scope and magnitude. Comparable international programs are also listed. The listing should be updated annually. In the case of regional scale components (Tables 1-10), comprehensive sets of programs are underway or have been proposed for most regions. National GLOBEC or other program committees should seek ways to cover gaps in coverage as well as to coordinate programs as they become active. Cooperative basin scale studies will be based to the extent possible on program material in Tables 11 and 12.

A common set of program outputs is required for successful comparison of ecosystem properties and responses to climate variability embodied in the Central Scientific Issues (i.e., physical forcing, lower and higher trophic level response, and ecosystem interactions). While such a study will be of particular importance for the regional scale components (as proposed by PICES WG3 on Coastal Pelagic Fish, PICES Scientific Report No. 1, 1993), comparison of the eastern and western subarctic gyres (components 11 and 12)is also desirable. For such comparisons, the following information is desired (Figure 3 illustrates relationships in an oceanic ecosystem):

Physical Forcing (Time series and seasonality)

- Location of major fronts/current boundaries
- Atmospheric pressure gradients (winds and storms)
- Air-sea heat exchange (insolation, cloud cover)
- Major physical features (e.g., fresh water input, ice)
- Mixed layer temperature (MLT), depth (MLD)
- Velocity of major currents
- Eddies
- Vertical and horizontal mixing, fine structure

Lower trophic levels (primary, including microbial; secondary)

- annual and seasonal productivity
- temporal and spatial pattern of plankton dynamics and nutrient fields
- Identification of major taxonomic groups
- population parameters for key species (or taxonomic groups)

Higher trophic levels and ecosystem interactions

- Abundance trends and distributions of life stages of key species and their predators and prey
- Population parameters (growth, mortality, reproduction)
- Food web structure (including diets and trophodynamic linkages of key species)
- Production and productivity structure

Program Management

Form and Function of Implementation Panel (IP)

At the Third Annual Meeting, a Scientific Steering Committee (now Implementation Panel) was established (PICES Decision 94/S/7) to initiate development of a Draft Implementation Plan, to determine how the work of PICES Scientific Committees and Working Groups can most effectively support the CCCC Program, and to identify existing or foreseen national and international research programs with which the Program can be coordinated.

Membership of the Implementation Panel was determined by the PICES Chairman in consultation with the Science Board and with the agreement of relevant national authorities. In structure, it consists of two co-chairmen, a representative of each national GLOBEC program, ex officio and liaison representatives, and three other scientists from each PICES member country (see Annex III for June 1995 membership). The Panel reports to the Science Board. The co-chairmen, Science Board chairman, and national GLOBEC representatives constitute an Executive Committee.

Membership and structure of the Panel are likely to evolve as implementation proceeds. In any case, a three-year rotation of members might be appropriate. Task teams and other sub-sets of the Panel will be established as needed to coordinate key research activities and to facilitate cooperative efforts. Approval to convene symposia and workshops will be sought from the Science Board and Governing Council.

Cooperation with international programs and organizations

Cooperation between CCCC and other international activities has several facets:

1. CCCC is part of GLOBEC International, a program sponsored by the Scientific Committee on Oceanic Research (SCOR), the Inter-governmental Oceanographic Commission (IOC), the International Council for the Exploration of the Sea (ICES) and the North Pacific Marine Science Organization (PICES), and proposed for sponsorship by the International Geosphere-Biosphere Program (IGBP). The relationship among these organizations and the National GLOBEC Programs is to be worked out.

2. Cooperation is envisaged with several existing international organizations in the region, including the North Pacific Anadromous Fish Commission (NPAFC), the International Pacific Halibut Commission (IPHC), and new organizations concerned with fisheries in the international area of the Bering Sea and with tuna in the North Pacific. PICES and NPAFC have agreed to examine jointly (i) the factors affecting current trends in the productivity of the North Pacific Ocean and their impacts on salmonid carrying capacity, and (ii) the factors affecting changes in biological characteristics of Pacific salmon. In order to promote this joint effort, a representative of the NPAFC is serving on the Implementation Panel Executive Committee.

3. Other international programs concerned with climate and ocean changes, including ocean fluxes (JGOFS), ocean circulation (WOCE), and monitoring systems (GOOS) can make important contributions to meeting the goals of CCCC, and close liaison, exchange of information, joint workshops, and invited participation will be sought.

Elements of support

Research efforts to be carried out under PICES auspices will be funded nationally rather than by the organization. As noted earlier, the role of PICES is to stimulate and facilitate action; to coordinate planning and, as appropriate, implementation; and to improve communication among participants. Elements of support for the CCCC Program include the following:

- PICES budget for coordinating activities, workshops, symposia,
- National GLOBEC programs related to CCCC and involving international cooperation,
- Institutional programs related to CCCC and involving international cooperation,
- National research programs related to CCCC and capable of providing ship time and data,
- International science exchange and cooperation programs with funds and other resources.

Communication, Meetings, and Publications

Because of the multiplicity of component programs, exchange of information among CCCC participants is of particular importance. Means to ensure effective communication among the component parts of the overall program include:

- special workshops to review progress and stimulate the exchange of ideas among the multi-disciplinary teams working in each component,
- establishment of task teams to address important scientific questions of broad interest to a number of program components (e.g., large scale atmospheric and oceanic forcing, integrated atmosphere-ocean-ecosystem models),
- topic sessions at annual meetings and inter-sessional symposia,
- publication of workshop and symposium papers.

PICES should play a central role in the exchange of information, including use of electronic communications to the extent possible, for example by establishing a CCCC bulletin board where early information on research activities and findings would be released. While the PICES Scientific Report series is appropriate for reporting of workshop and symposia, it may also be desirable to establish a separate CCCC Report Series. Most scientific papers resulting from CCCC will be published in the refereed scientific journals.

Time Table

The Time Table proposed in the Science Plan, repeated below, continues to be appropriate for general planning purposes:

Phase 1. Planning and Data Assimilation (1995-1996)

- develop implementation plan
- initiate planning of joint research with NPAFC
- begin compiling historic data
- begin retrospective analyses of existing data
- begin model identification and parameterization
- begin developing circulation models
- begin developing regional food web models
- begin planning observation system

Start Phase 2. Observing, Process Studies, and Modeling (1997)

- continue compilation of historic data
- continue retrospective analyses
- develop new required technology
- implement required observation system
- conduct focused international surveys
- develop 3-D circulation model
- assess model and parameter uncertainty
- conduct process-oriented field and laboratory studies
- refine regional food web models
- conduct comparative ecosystem studies

Start Phase 3. Model Integration and Testing (2000)

- complete compilation of historic data
- complete retrospective analyses
- operate observation system
- couple 3-D circulation model and regional food web models
- conduct focused international surveys
- validate ecosystem models
- develop methods to detect and predict regime shifts
- apply prognostic ecosystem models.

NATIONAL AND INTERNATIONAL PROGRAMS IN REGIONS
SUMMARY TABLES

1. California Current System, South

U.S.A.

	Retrospective	Modeling	Process	Observation
Physical Forcing	US GLOBEC; CalCOFI; SWFSC PFEG	US GLOBEC; CalCOFI; SWFSC PFEG	US GLOBEC; CalCOFI	US GLOBEC; CalCOFI
Lower Trophic Levels	US GLOBEC; CalCOFI	US GLOBEC; CalCOFI	US GLOBEC; CalCOFI	US GLOBEC; CalCOFI
Higher Trophic Levels	US GLOBEC; SWFSC; SWFSC Tiburon; SWFSC PFEG	US GLOBEC; SWFSC; SWFSC Tiburon; SWFSC PFEG	US GLOBEC; SWFSC; SWFSC Tiburon	US GLOBEC; SWFSC; SWFSC Tiburon
Ecosystem Interactions	US GLOBEC; SWFSC	US GLOBEC; SWFSC	US GLOBEC; SWFSC	US GLOBEC; SWFSC

2. California Current System, Oregon to Vancouver Island

Canada

	Retrospective	Modeling	Process	Observation
Physical Forcing	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program; Strait of Georgia Program
Lower Trophic Levels	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program; COPRA; Strait of Georgia Program
Higher Trophic Levels	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program; Starit of Georgia Program	GLOBEC Canada; La Perouse Program; Stock Assessment; Hecate Strait/ Queen Charolet Sound groundfish studies; Strait of Georgia Program
Ecosystem Interactions	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La Perouse Program	GLOBEC Canada; La perouse Program

U.S.A.

	Retrospective	Modeling	Process	Observation
Physical Forcing	SWFSC PFEG; US GLOBEC	SWFSC PFEG; US GLOBEC	US GLOBEC	US GLOBEC
Lower Trophic Levels	US GLOBEC	US GLOBEC	US GLOBEC	US GLOBEC
Higher Trophic Levels	SWFSC PFEG; AFSC; US GLOBEC	SWFSC PFEG; NWFSC; AFSC; AFSC NMML; INPHC; US GLOBEC	AFSC NMML; US GLOBEC	NWFSC; AFSC; AFSC NMML; INPHC; US GLOBEC
Ecosystem Interactions	US GLOBEC	AFSC NMML; US GLOBEC	AFSC NMML; US GLOBEC	AFSC NMML; US GLOBEC

3. Southeast, Central Alaska

U.S.A.

	Retrospective	Modeling	Process	Observation
Physical Forcing				
Lower Trophic Levels				C-LAB
Higher Trophic Levels	AFSC	AFSC; AFSC NMML; AFSC FOCI; AFSC OCC; INPHC; SEA; APEX; PWSSC	AFSC NMML; AFSC FOCI; AFSC OCC; SEA; APEX; PWSSC	AFSC; AFSC NMML; AFSC FOCI; AFSC OCC; INPHC; PWSSC
Ecosystem Interactions		AFSC NMML; AFSC FOCI; AFSC OCC; SEA; APEX; PWSSC	AFSC NMML; AFSC FOCI; AFSC OCC; SEA; APEX; PWSSC	AFSC NMML; AFSC FOCI; AFSC OCC; NBS; PWSSC

4. Eastern Bering Sea

Japan

	Retrospective	Modeling	Process	Observation
Physical Forcing				GLOBEC (Japan-US)
Lower Trophic Levels				GLOBEC (Japan-US)
Higher Trophic Levels				GLOBEC (Japan-US)
Ecosystem Interactions				

U.S.A.

	Retrospective	Modeling	Process	Observation
Physical Forcing				
Lower Trophic Levels				
Higher Trophic Levels	AFSC	AFSC; AFSC NMML; INPHC; AFSC BSFO	AFSC NMML; AFSC BSFO	AFSC; AFSC NMML; INPHC; AFSC BSFO
Ecosystem Interactions		AFSC NMML; AFSC BSFO	AFSC NMML; AFSC BSFO; NSF	AFSC NMML; AFSC BSFO

5. Western Bering Sea / Kamchatka

Japan

	Retrospective	Modeling	Process	Observation
Physical Forcing			Japan GLOBEC	Japan GLOBEC
Lower Trophic Levels			Japan GLOBEC	Japan GLOBEC; NRIFSF
Higher Trophic Levels			Japan GLOBEC	Japan GLOBEC
Ecosystem Interactions			Japan GLOBEC	Japan GLOBEC

Russia

	Retrospective	Modeling	Process	Observation
Physical Forcing	FES-LIRES	FES-LIRES		FES-LIRES
Lower Trophic Levels	FES-LIRES (zooplankton only)	FES-LIRES (zooplankton only)		FES-LIRES (zooplankton only)
Higher Trophic Levels	FES-LIRES	FES-LIRES		FES-LIRES
Ecosystem Interactions	FES-LIRES	FES-LIRES		FES-LIRES

6. Okhotsk Sea

Russia

	Retrospective	Modeling	Process	Observation
Physical Forcing	FES-LIRES	FES-LIRES		FES-LIRES
Lower Trophic Levels	FES-LIRES (zooplankton only)	FES-LIRES (zooplankton only)		FES-LIRES (zooplankton only)
Higher Trophic Levels	FES-LIRES	FES-LIRES		FES-LIRES
Ecosystem Interactions	FES-LIRES	FES-LIRES		FES-LIRES

7. Oyashio / Kuroshio

Japan

	Retrospective	Modeling	Process	Observation
Physical Forcing	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC)	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC); GOOS	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC)	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC); GOOS
Lower Trophic Levels	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC)	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC); GOOS	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC)	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC); GOOS
Higher Trophic Levels	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC)	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC)	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC)	Japan GLOBEC; BIOCOSMOS; HUBEC (Japan GLOBEC)
Ecosystem Interactions	HUBEC (Japan GLOBEC)	HUBEC (Japan GLOBEC)	HUBEC (Japan GLOBEC)	HUBEC (Japan GLOBEC)

China

	Retrospective	Modeling	Process	Observation
Physical Forcing		CJ/SCI	CJ/SCI	CJ/SCI
Lower Trophic Levels		CJ/SCI	CJ/SCI	CJ/SCI
Higher Trophic Levels		CJ/SCI	CJ/SCI	CJ/SCI
Ecosystem Interactions				

8. Japan Sea / East Sea

	Retrospective	Modeling	Process	Observation
Physical Forcing				
Lower Trophic Levels				
Higher Trophic Levels				
Ecosystem Interactions				

9. Bohai, Yellow Sea

Korea

	Retrospective	Modeling	Process	Observation
Physical Forcing	YS-LME/GEF	YS-MSP	YS-LME/KOREA YS-LME/GEF YS-MSP	YS-LME/KOREA YS-LME/GEF YS-MSP
Lower Trophic Levels	YS-LME/GEF	YS-MSP	YS-LME/KOREA YS-LME/GEF YS-MSP	YS-LME/KOREA YS-LME/GEF YS-MSP
Higher Trophic Levels	YS-LME/GEF		YS-LME/KOREA YS-LME/GEF	YS-LME/KOREA YS-LME/GEF
Ecosystem Interactions	YS-LME/GEF		YS-LME/KOREA YS-LME/GEF	YS-LME/KOREA YS-LME/GEF

China

	Retrospective	Modeling	Process	Observation
Physical Forcing		C-GLOBEC/ CCBS	C-GLOBEC/ CCBS	C-GLOBEC/ CCBS; YS-LME
Lower Trophic Levels		C-GLOBEC/ CCBS	C-GLOBEC/ CCBS	C-GLOBEC/ BIEBS; C-GLOBEC/ CCBS; YS-LME
Higher Trophic Levels		C-GLOBEC/ CCBS	C-GLOBEC/ CCBS	C-GLOBEC/ BIEBS; C-GLOBEC/ CCBS; YS-LME/ST; YS-LME
Ecosystem Interactions		C-GLOBEC/ CCBS	C-GLOBEC/ CCBS	C-GLOBEC/ CCBS

10. East China Sea

Japan

	Retrospective	Modeling	Process	Observation
Physical Forcing		MASFLEX (JGOFS and LOICZ)	MASFLEX (JGOFS and LOICZ)	MASFLEX (JGOFS and LOICZ)
Lower Trophic Levels		MASFLEX (JGOFS and LOICZ)	MASFLEX (JGOFS and LOICZ)	MASFLEX (JGOFS and LOICZ)
Higher Trophic Levels				
Ecosystem Interactions				

Korea

	Retrospective	Modeling	Process	Observation
Physical Forcing		COPEX-ECS	COPEX-ECS	
Lower Trophic Levels		COPEX-ECS	COPEX-ECS	
Higher Trophic Levels				
Ecosystem Interactions				

China

	Retrospective	Modeling	Process	Observation
Physical Forcing		China-JGOFS	China-JGOFS	China-JGOFS
Lower Trophic Levels		China-JGOFS	China-JGOFS; ECS/ST	China-JGOFS; ECS/ST
Higher Trophic Levels			ECS/ST	ECS/ST
Ecosystem Interactions				

11. Western Subarctic Gyre

Japan

	Retrospective	Modeling	Process	Observation
Physical Forcing		GOOS	Japan JGOFS	GLOBEC (Japan-US); GOOS; Japan JGOFS
Lower Trophic Levels		GOOS	Japan JGOFS	GLOBEC (Japan-US); GOOS; Japan JGOFS; NRIFSF
Higher Trophic Levels				GLOBEC (Japan-US)
Ecosystem Interactions				

Russia

	Retrospective	Modeling	Process	Observation
Physical Forcing	FES-LIRES	FES-LIRES		FES-LIRES
Lower Trophic Levels	FES-LIRES (zooplankton only)	FES-LIRES (zooplankton only)		FES-LIRES (zooplankton only)
Higher Trophic Levels	FES-LIRES	FES-LIRES		FES-LIRES
Ecosystem Interactions	FES-LIRES	FES-LIRES		FES-LIRES

12. Eastern Subarctic Gyre

Canada

	Retrospective	Modeling	Process	Observation
Physical Forcing	JGOFS Canada; High Seas Salmon; UBC Salmon Migration GLOBEC Canada	JGOFS Canada; High Seas Salmon; UBC Salmon Migration GLOBEC Canada	JGOFS Canada GLOBEC Canada	JGOFS Canada GLOBEC Canada
Lower Trophic Levels	JGOFS Canada GLOBEC Canada	JGOFS Canada GLOBEC Canada	JGOFS Canada GLOBEC Canada	JGOFS Canada GLOBEC Canada
Higher Trophic Levels	High Seas Salmon; UBC Salmon Migration GLOBEC Canada	High Seas Salmon; UBC Salmon Migration GLOBEC Canada	GLOBEC Canada	High Seas Salmon GLOBEC Canada
Ecosystem Interactions	GLOBEC Canada	GLOBEC Canada	GLOBEC Canada	GLOBEC Canada

U.S.A.

	Retrospective	Modeling	Process	Observation
Physical Forcing				
Lower Trophic Levels				
Higher Trophic Levels	OSU/Hokkaido	AFSC OCC	AFSC OCC	AFSC OCC
Ecosystem Interactions		AFSC OCC	AFSC OCC	AFSC OCC

NATIONAL AND INTERNATIONAL PROGRAMS IN REGIONS
DETAILED INFORMATION FROM TABLES

Canada

2. California Current System, Oregon to Vancouver Island

Program: GLOBEC Canada
Agency: GLOBEC Canada Steering Committee - funded by Department of Fisheries and Oceans (DFO)
Natural Sciences and Engineering Research Council (NSERC)
Central Scientific Issue: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activity: Retrospective, Modeling, Process, Observation studies
Funding: Proposed
Start Time: 1996
Contact: Dr. Brad deYoung, Chair
GLOBEC Canada
Dept. of Physics,
Memorial University,
St. John's, Newfoundland,
Canada. A1B 3X7

Program: La Perouse Program
Agency: DFO
Central Scientific Issue: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activity: Retrospective, Modeling, Process, Observation studies
Funding: Funded
Start Time: 1985
Contact: Dr. Dan Ware
Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.,
Canada. V9R 5K6

Program: Stock Assessments
Agency: DFO
Central Scientific Issue: HTL
Key Research Activity: Observation studies
Funding: Funded
Start Time: on-going
Contact: Dr. Mike Henderson
Department of Fisheries and Oceans
402 - 555 W. Hastings St.,
Vancouver, B.C.,

Canada. V6B 5G3

Program: Hecate Strait - Queen Charolet Sound Groundfish Studies
Agency: DFO
Central Scientific Issue: HTL
Key Research Activity: Observation studies
Funding: Funded
Start Time: on-going
Contact: Dr. Laura Richards
Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.,
Canada. V9R 5K6

Program: Cooperative Plankton Research Activity (COPRA)
Agency: DFO
Central Scientific Issue: LTL
Key Research Activity: Observation studies
Funding: Funded
Start Time: 1990
Contact: Dr. Bill Shaw
Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.,
Canada. V9R 5K6

Program: JGOFS Canada
Agency: JGOFS Steering Committee
Central Scientific Issue: Forcing, LTL
Key Research Activity: Retrospective, Modeling, Process, Observation studies
Funding: Funded
Start Time: 1995
Contact: Dr. Ken Denman
Department of Fisheries and Oceans
Institute of Ocean Sciences
Box 6000,
Sidney, B.C.,
Canada. V8L 4B2

Program: High Seas Salmon Research
Agency: DFO
Central Scientific Issue: Forcing, HTL
Key Research Activity: Retrospective, Modeling, Process, Observation studies
Funding: Funded and Proposed
Start Time: on-going
Contact: Dr. Richard Beamish, Dr. David Welch

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.,
Canada. V9R 5K6

Program: Migration of Salmon in the North East Pacific
Agency: University of British Columbia
Central Scientific Issue: Forcing, HTL
Key Research Activity: Retrospective, Modeling
Funding: Funded
Start Time: 1994
Contact: Dr. Mike Healey
Department of Oceanography
University of British Columbia
6270 University Boulevard,
Vancouver, B.C.,
Canada. V6T 1Z4

Program: Strait of Georgia Program
Agency: DFO
Central Scientific Issue: Forcing, LTL, HTL
Key Research Activity: Process, Observation studies
Funding: Funded
Start Time: 1995
Contact: Dr. Dick Beamish
Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.,
Canada. V9R 5K6

China

7. Oyashio/Kuroshio

Program: CJ/SCI (China-Japan Sub-tropical Circulation Investigation)
Agency: State Oceanic Administration
Central Scientific Issues: Forcing, LTL, HTL
Key Research Activities: Process, Modelling, Observation studies
Funding: Funded
Start time: 1995 (on-going)
Contact: Prof. Jilan Su
Second Institute of Oceanography
P.O. Box 1207,
Hangzhou,
People's Republic of China. 310012

9. Bohai, Yellow Sea

Program: C-GLOBEC/BIEBS (Basic Investigation of Ecology in the Bohai Sea)
Agency: Sciences and Technology of China
Central Scientific Issues: LTL, HTL
Key Research Activities: Observation studies
Funding: Funded
Start time: 1991-1995
Contact: Prof. Qi-Sheng Tang
Yellow Sea Fisheries Research Institute
106 Nanjing Road,
Qingdao,
People's Republic of China. 266071

Program: C-GLOBEC/CCBS (Carrying Capacity in the Bohai Sea)
Agency: National Natural Science Foundation of China (NSFC)
Ministry of Agriculture of China (MOF)
Central Scientific Issues: Forcing, LTL, HTL, EI
Key Research Activities: Process, Modelling, Observation studies
Funding: Proposed
Start time: 1996
Contact: Prof. Qi-Sheng Tang
Yellow Sea Fisheries Research Institute
106 Nanjing Road,
Qingdao,
People's Republic of China. 266071

Program: YS-LME/ST (Stock Assessment)
Agency: Ministry of Agriculture of China (MOF)
Central Scientific Issues: HLT
Key Research Activities: Observation studies
Funding: Funded
Start time: 1992 (on-going)
Contact: Prof. Qi-Sheng Tang
Yellow Sea Fisheries Research Institute
106 Nanjing Road,
Qingdao,
People's Republic of China. 266071

Program: YS-LME/China
Agency: UNDP
Central Scientific Issues: Forcing, LTL, HTL
Key Research Activities: Observation studies
Funding: Proposed
Start time: 1996

Contact: State Oceanic Administration
1 Fuxingmenwai Avenue,
Beijing,
People's Republic of China. 100860

10. East China Sea

Program: China-JGOFS
Agency: National Natural Science Foundation of China (NSFC)
Central Scientific Issues: Forcing, LTL
Key Research Activities: Process, Modelling, Observation studies
Funding: Funded
Start time: 1992-1995, 1996-1999
Contact: Prof. Dun-Xin Hu
Institute of Oceanology
7 Nanhai Road,
Qingdao,
People's Republic of China. 266071

Program: ECS/ST (Stock Assessment)
Agency: Ministry of Agriculture of China (MOF)
Central Scientific Issues: LTL, HTL
Key Research Activities: Process, Observations studies
Funding: Funded
Start time: on-going
Contact: East China Sea Fisheries Research Institute
300 Jungong Road,
Shanghai,
People's Republic of China. 200090

Japan

4. Eastern Bering Sea

Program: GLOBEC (Japan-US Cooperative Research Plan)
Agency: Faculty of Fisheries, Hokkaido University
Central Scientific Issue: Forcing, LTL, HTL
Key Research Activity: Observation studies
Funding: Proposed
Start Time: 1995
Contact: Dr. Yasunori Sakurai
Faculty of Fisheries
Hokkaido University
3-1-1 Minato-cho,
Hakodate, Hokkaido,
Japan. 041

5. Western Bering Sea/Kamchatka

Program: Japan GLOBEC
Agency: ORI, University of Tokyo
Central Scientific Issue: Forcing, LTL, HTL
Key Research Activity: Process, Observation studies
Funding: Proposed
Start Time: 1997
Contact: Prof. Kouichi Kawaguchi
ORI, University of Tokyo
1-15-1 Minamidai,
Nakano, Tokyo,
Japan. 164

Program: National Research Institute of Far Seas Fisheries (NRIFSF)
Agency: Japan Fisheries Agency
Central Scientific Issue: LTL
Key Research Activity: Observation studies
Funding: Funded
Start Time: 1994 (on-going)
Contact: Dr. Kasuya Nagasawa
National Research Institute of Far Seas Fisheries
5-7-1 Orido,
Shimizu, Shizuoka-ken,
Japan. 424

7. Oyashio/Kuroshio

Program: Japan GLOBEC
Agency: ORI, University of Tokyo
Central Scientific Issue: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activity: Retrospective, Modeling, Process, Observation studies
Funding: Proposed
Start Time: 1996
Contact: Prof. Takashige Sugimoto
ORI, University of Tokyo
1-15-1 Minamidai,
Nakano, Tokyo,
Japan. 164

Program: HUBEC (Japan GLOBEC)
Agency: Faculty of Fisheries, Hokkaido University
Central Scientific Issue: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activity: Retrospective, Modeling, Process
Funding: Funded
Start Time: 1993 (on-going)

Contact: Dr. Yasunori Sakurai
Faculty of Fisheries
Hokkaido University
3-1-1 Minato-cho,
Hakodate, Hokkaido, Japan. 041

Program: BIOCOSMOS
Agency: Japan Fisheries Agency
Central Scientific Issue: Forcing, LTL, HTL,
Key Research Activity: Retrospective, Modeling, Process, Observation studies
Funding: Funded
Start Time: 1990 (on-going)
Contact: Dr. Tokio Wada
Research Planning and Coordination Division
Nat'l Research Inst. of Fisheries Science
12-4 Fukuura 2-chome,
Kanazawa-ku, Yokohama,
Japan. 236

Program: GOOS
Agency: Ministry of Education, Science and Culture
Central Scientific Issue: Forcing, LTL
Key Research Activity: Modeling, Observation studies
Funding: Funded
Start Time: 1993 (on-going)
Contact: Prof. Keisuke Taira
ORI, University of Tokyo
1-15-1 Minamidai,
Nakano, Tokyo,
Japan. 164

10. East China Sea

Program: MASFLEX (JGOFS and LOICZ)
Agency: Science and Technology Agency of Japan
Central Scientific Issue: Forcing, LTL
Key Research Activity: Modeling, Process, Observation studies
Funding: Funded
Start Time: 1992 (on-going)
Contact: Dr. Kazuo Iseki
Seikai Nat'l Fisheries Research Institute
49 Kokubu-cho,
Nagasaki, Nagasaki-ken,
Japan. 850

11. Western Subarctic Gyre

Program: Japan JGOFS
Agency: ORI, University of Tokyo
Central Scientific Issue: Forcing, LTL
Key Research Activity: Process, Observation studies
Funding: Funded
Start Time: 1991 (on-going)
Contact: Prof. Isao Koike
ORI, University of Tokyo
1-15-1 Minamidai,
Nakano, Tokyo,
Japan. 164

Program: GLOBEC (Japan-US Cooperative Research Plan)
Agency: Faculty of Fisheries, Hokkaido University
Central Scientific Issue: Forcing, LTL, HTL
Key Research Activity: Observation studies
Funding: Proposed
Start Time: 1995
Contact: Dr. Yasunori Sakurai
Faculty of Fisheries
Hokkaido University
3-1-1 Minato-cho,
Hakodate, Hokkaido,
Japan. 041

Program: GOOS
Agency: Ministry of Education, Science and Culture
Central Scientific Issue: Forcing, LTL
Key Research Activity: Modeling, Observation studies
Funding: Funded
Start Time: 1993 (on-going)
Contact: Prof. Keisuke Taira
ORI, University of Tokyo
1-15-1 Minamidai,
Nakano, Tokyo,
Japan. 164

Program: National Research Institute of Far Seas Fisheries (NRIFSF)
Agency: Japan Fisheries Agency
Central Scientific Issue: LTL
Key Research Activity: Observation studies
Funding: Funded
Start Time: 1994 (on-going)
Contact: Dr. Kasuya Nagasawa

National Research Institute of Far Seas Fisheries
5-7-1 Orido,
Shimizu, Shizuoka-ken,
Japan. 424

Korea

9. Bohai, Yellow Sea

Program: YS-LME/KOREA
Agency: MOST (Ministry of Science and Technology)
Central Scientific Issue: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activity: Process, Observation studies
Funding: Funded
Start Time: 1995
Contact: Dr. Hyung Tack Huh
Korea Ocean Res. & Dev. Inst.
Seoul, Korea. 625-400
hthuh@sri.kordi.re.kr

Program: YS-LME/GEF
Agency: UNDP
Central Scientific Issue: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activity: Retrospective, Process Observations studies
Funding: Proposed
Start Time: 1996
Contact: Dr. Hyung Tack Huh
Korea Ocean Res. & Dev. Inst.
Seoul, Korea. 625-400
hthuh@sari.kordi.re.kr

Program: YS-MSP
Agency: MOST (Ministry of Science and Technology)
Central Scientific Issue: Forcing, LTL
Key Research Activity: Modeling, Process, Observation studies
Funding: Funded
Start Time: 1995
Contact: Dr. Tong-Sup Lee
Korea Ocean Res. & Dev. Inst.
Seoul, Korea. 625-400
tslee@sari.kordi.re.kr

10. East China Sea

Program: COPEX-ECS (Coastal Ocean Processes Experiment)
Agency: MOST (Ministry of Science and Technology)
Central Scientific Issue: Forcing, LTL
Key Research Activity: Modeling, Process
Funding: Funded
Start Time: 1994
Contact: Dr. Heung-Jae Lee
Korea Ocean Res. & Dev. Inst.
Seoul, Korea. 625-400
hjlee@sari.kordi.re.kr

Russia

5. Western Bering Sea/Kamchata

Program: FES-LIRES (Ecosystem Study of Far-Eastern Seas Living Resources)
Agency: TINRO-Center (Pacific Research Fisheries Center)
Central Scientific Issue: Forcing, LTL (zooplankton only), HTL, Ecosystem interactions
Key Research Activities: Retrospective, Modeling, Observation Study (Monitoring)
Funding: Funded
Start Time: 1980
Contact: Prof. V.P. Shuntov, Principal Scientist of TINRO-Center
& V.I. Radchenko, Head of Laboratory of Applied Biocenology
TINRO-Center
4 Shevchenko Alley,
Vladivostok,
Russia. 690600
root@tinro.marine.su

6. Okhotsk Sea

Program: FES-LIRES (Ecosystem Study of Far-Eastern Seas Living Resources)
Agency: TINRO-Center (Pacific Research Fisheries Center)
Central Scientific Issue: Forcing, LTL (zooplankton only), HTL, Ecosystem interactions
Key Research Activities: Retrospective, Modeling, Observation Study (Monitoring)
Funding: Funded
Start Time: 1980
Contact: Prof. V.P. Shuntov, Principal Scientist of TINRO-Center
& V.I. Radchenko, Head of Laboratory of Applied Biocenology
TINRO-Center
4 Shevchenko Alley,

Vladivostok,
Russia. 690600
root@tinro.marine.su

11. Western Subarctic Gyre

Program: FES-LIRES (Ecosystem Study of Far-Eastern Seas Living Resources)
Agency: TINRO-Center (Pacific Research Fisheries Center)
Central Scientific Issue: Forcing, LTL (zooplankton only), HTL, Ecosystem interactions
Key Research Activities: Retrospective, Modeling, Observation Study (Monitoring)
Funding: Funded
Start Time: 1980
Contact: Prof. V.P. Shuntov, Principal Scientist of TINRO-Center
& V.I. Radchenko, Head of Laboratory of Applied Biocenology
TINRO-Center
4 Shevchenko Alley,
Vladivostok,
Russia. 690600
root@tinro.marine.su

U.S.A.

1. California Current System, south

Program: U.S. GLOBEC
Agency: U.S. GLOBEC Steering Committee -funding by: National Foundation/ National Oceanic and Atmospheric Administration
Central Scientific Issue: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, Modeling, Process, Observation studies
Funding: Proposed for retrospective and modeling
Start time: 1997
Contact: Dr. Thomas Powell
Chairman,U.S. GLOBEC Scientific Steering Committee
University of California
Department of Integrative Biology
3060 Valley Life Sciences Building #3140,
Berkeley, CA 94720-3140
U.S.A.

Program: California Cooperative Oceanic and Fisheries Investigations (CalCOFI)
Agency: Scripps Institution of Oceanography, California, Department of Fish and Game and National Marine Fisheries Service.
Central Scientific Issues: Forcing, LTL
Key Research Activities: Retrospective, Modeling, Process, Observation studies

Funding: Funded
Start time: 1949, on-going
Contact: Dr Michael Mullin
Scripps Institution of Oceanography
Marine Life Reseach Group,
La Jolla, CA 92093-0227
U.S.A.

Program: Southwest Fisheries Science Center (SWFSC)
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Retrospective, Modeling, Process, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Michael Tillman
Southwest Fisheries Science Center
P.O. Box 271,
La Jolla, CA 92038
U.S.A.

Program: Southwest Fisheries Science Center, Tiburon Laboratory
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Retrospective, Modeling, Process, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Alec MacCall
Tiburon Laboratory
Southwest Fisheries Science Center
3150 Paradise Drive,
Tiburon, CA 94920
U.S.A.

Program: Southwest Fisheries Science Center, Pacific Fisheries Environmental Group
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: Forcing, HTL
Key Research Activities: Retrospective, Modeling
Funding: Funded
Start time: on-going
Contact: Dr. George Boehlert
Southwest Fisheries Science Center
Pacific Fisheries Environmental Group
P.O. Box 831,
Monterey, CA 93942
U.S.A.

2. California Current System, Oregon to Vancouver Island

Program: Southwest Fisheries Science Center, Pacific Fisheries Environmental Group
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: Forcing, HTL
Key Research Activities: Retrospective, Modeling
Funding: Funded
Start time: on-going
Contact: Dr. George Boehlert
Southwest Fisheries Science Center
Pacific Fisheries Environmental Group
P.O. Box 831,
Monterey, CA 93942
U.S.A.

Program: Northwest Fisheries Science Center (NWFSC)
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Modeling, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Usha Varanasi
Northwest Fisheries Science Center
2725 Montlake Blvd.,
Seattle, WA 98112-2097
U.S.A.

Program: Alaska Fisheries Science Center (AFSC)
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Retrospecitve, Modeling, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. William Aron
Alaska Fisheries Science Center
7600 Sand Point Way NE,
Seattle, WA 98115
U.S.A.

Program: Alaska Fisheries Science Center (AFSC), National Marine Mammal Laboratory
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process, Observation studies
Funding: Funded

Start time: on-going
Contact: Dr. Howard Braham
Alaska Fisheries Science Center
7600 Sand Point Way NE,
Seattle, WA 98115
U.S.A.

Program: International North Pacific Halibut Commission (INPHC)
Central Scientific Issues: HTL
Key Research Activities: Modeling, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Donald McCaughran
International North Pacific Halibut Commission
P.O. Box 95009,
Seattle, WA 98145
U.S.A.

Program: U.S. GLOBEC
Agency: U.S. GLOBEC Steering Committee -funding by: National Science Foundation/ National Oceanic and Atmospheric Administration
Central Scientific Issue: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, Modeling, Process, Observation studies
Funding: Proposed for retrospective and modeling
Start time: 1997
Contact: Dr. Thomas Powell
Chairman,U.S. GLOBEC Scientific Steering Committee
University of California
Department of Integrative Biology
3060 Valley Life Sciences Building #3140,
Berkeley, CA 94720-3140
U.S.A.

3. Southeast, Central Alaska

Program: Alaska Fisheries Science Center (AFSC)
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Retrospecitve, Modeling, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. William Aron
Alaska Fisheries Science Center
7600 Sand Point Way NE,
Seattle, WA 98115
U.S.A.

Program: Alaska Fisheries Science Center (AFSC), National Marine Mammal Laboratory
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Howard Braham
Alaska Fisheries Science Center
7600 Sand Point Way NE,
Seattle, WA 98115
U.S.A.

Program: Alaska Fisheries Science Center (AFSC), Fisheries Oceanography Coordinated Investigations
Agency: Office of Atmospheric Research, NOAA
Central Scientific Issues: HTL, Ecosystem interactiona
Key Research Activities: Modeling, Process, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Art Kendall
Alaska Fisheries Science Center
7600 Sand Point Way NE,
Seattle, WA 98115
U.S.A.

Program: Alaska Fisheries Science Center (AFSC), Ocean Carrying Capacity (OCC)
Agency: Auke Bay Laboratory, NMFS, NOAA
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process, Observation studies
Funding: Funded
Start time: 1995
Contact: Dr. Michael Dahlberg
Auke Bay Laboratory
11305 Glaicer Highway,
Juneau, AK 99801-8626
U.S.A.

Program: International North Pacific Halibut Commission (INPHC)
Central Scientific Issues: HTL
Key Research Activities: Modeling, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Donald McCaughran
International North Pacific Halibut Commission
P.O. Box 95009,

Seattle, WA 98145
U.S.A.

Program: Sound Ecosystem Assessment (SEA)
Agency: The Exxon Valdez Oil Spill Trustees
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process
Funding: Funded
Start time: 1994
Contact: Dr. Ted Cooney
Institute of Marine Sciences
University of Alaska Fairbanks
Fairbanks, AK 99775-1080
U.S.A.

Program: Apex Predator Ecosystem Response (APEX)
Agency: The Exxon Valdez Oil Spill Trustees
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process
Funding: Funded
Start time: 1994
Contact: Dr. David Duffy
Department of Biology
University of Alaska, Anchorage
707 A Street,
Anchorage, AK 99501
U.S.A.

Program: National Biological Service (NBS)
Agency: United States Department of Interior
Central Scientific Issues: Ecosystem interactions
Key Research Activities: Observational studies
Funding: Funded
Start time: On-going
Contact: Dr. Scott Hatch
Alaska Fish and Wildlife Research Center
U.S. Fish and Wildlife Center
1011 E. Tudor Road,
Anchorage, AK 99503
U.S.A.

Program: Prince William Sound Science Center (PWSSC)
Agency: The Exxon Valdez Oil Spill Trustees
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process, Observational studies
Funding: Funded

Start time: 1994
Contact: Dr. Gary Thomas
Prince William Sound Science Center
P.O. Box 705,
Cordova, AK 99574
U.S.A.

Program: C-LAB
Agency: University of Alaska
Central Scientific Issues: LTL
Key Research Activities: Observational studies
Funding: Funded
Start time: 1995
Contact: Dr. Ted Cooney
Institute of Marine Sciences
University of Alaska Fairbanks
Fairbanks, AK 99775-1080
U.S.A.

4. Eastern Bering Sea

Program: Alaska Fisheries Science Center (AFSC), Bering Sea Fisheries Oceanography Coordinated Investigations
Agency: Coastal Ocean Program, NOAA
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. James Overland
Pacific Marine Environmental Laboratory
7600 Sand Point Way NE,
Seattle, WA 98115
U.S.A.

Program:
Agency: National Science Foundation
Central Scientific Issues: Ecosystem interactions
Key Research Activities: Process
Funding: Funded
Start time: on-going
Contact: Dr. George Hunt
Department of Ecology
School of Biological Sciences
University of California Irvine
U.S.A

Program: International North Pacific Halibut Commission (INPHC)
Central Scientific Issues: HTL
Key Research Activities: Modeling, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Donald McCaughran
International North Pacific Halibut Commission
P.O. Box 95009,
Seattle, WA 98145
U.S.A.

Program: Alaska Fisheries Science Center (AFSC), National Marine Mammal Laboratory
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. Howard Braham
Alaska Fisheries Science Center
7600 Sand Point Way NE,
Seattle, WA 98115
U.S.A.

Program: Alaska Fisheries Science Center (AFSC)
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Retrospecitve, Modeling, Observation studies
Funding: Funded
Start time: on-going
Contact: Dr. William Aron
Alaska Fisheries Science Center
7600 Sand Point Way NE,
Seattle, WA 98115
U.S.A.

12. Eastern Subarctic Gyre

Program: OSU/Hokkaido
Agency: OSU-NOAA
Hokkaido University
Central Scientific Issues: HTL
Key Research Activities: Retrospective
Funding: Funded
Start time: 1993 (on-going)
Contact: Dr. William Pearcy

College of Oceanography
Oregon State University
Corvallis, OR 97331-1105
U.S.A.

Program: Alaska Fisheries Science Center (AFSC), Ocean Carrying Capacity (OCC)
Agency: Auke Bay Laboratory, NMFS, NOAA
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, Process, Observation studies
Funding: Funded
Start time: 1995
Contact: Dr. Michael Dahlberg
Auke Bay Laboratory
11305 Glaicer Highway,
Juneau, AK 99801-8626
U.S.A.

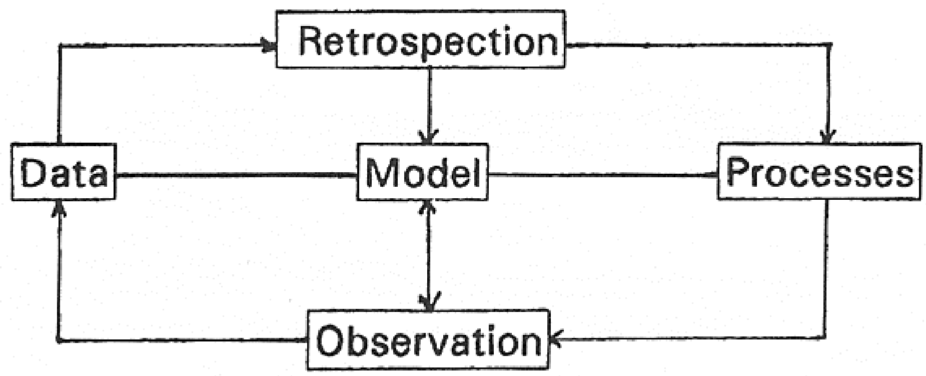

Fig. 1. Research activities PICES-GLOBEC CCCC.

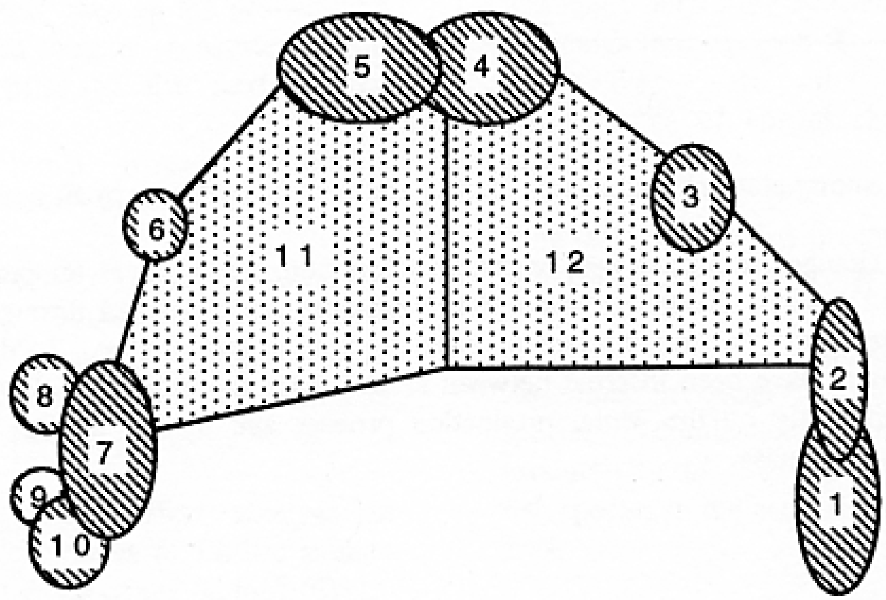

Fig. 2. PICES-GLOBEC CCCC program Components.

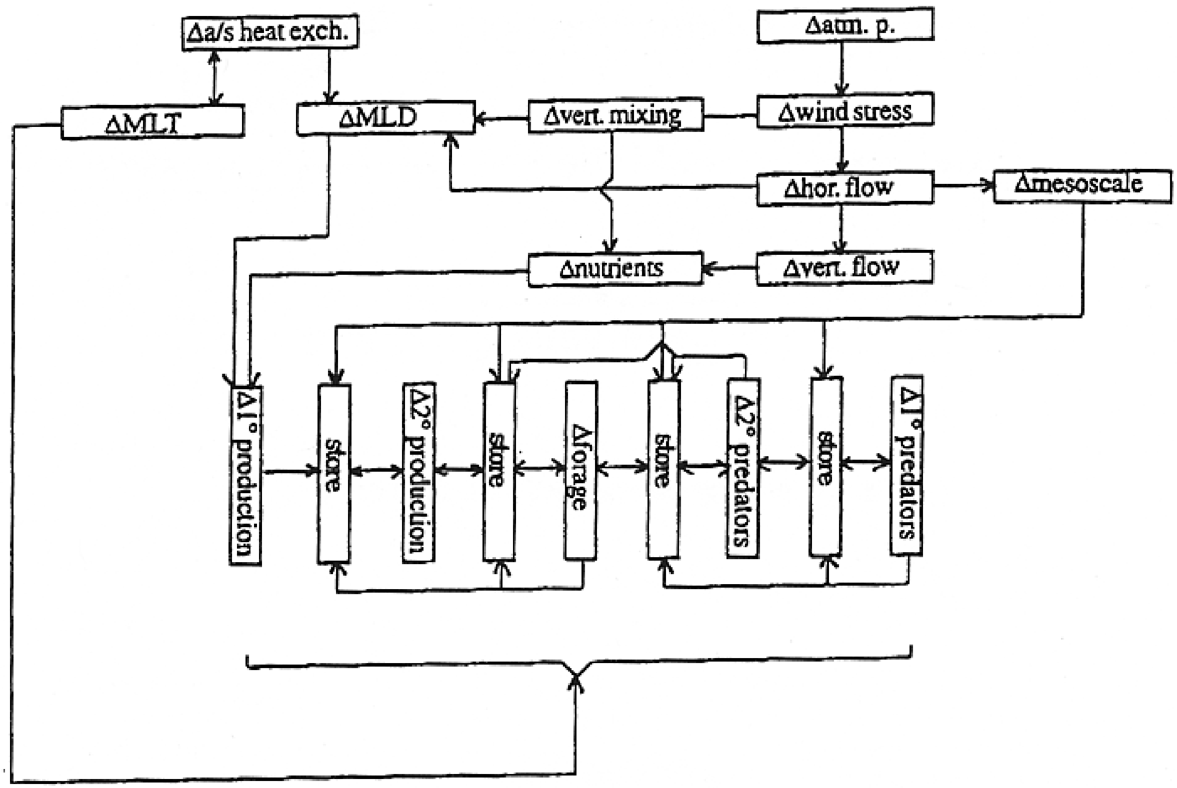

Fig. 3. Relations among elements of climate forcing and trophic structure in an oceanic ecosystem

Note that changes in air/sea heat exchange affect both mixed layer temperature (MLT) and depth (MLD) while changes in atmospheric pressure are expressed through their effects on wind stress, which in turn influences ocean circulation and mixing. In the trophic ladder, "store" boxes have been inserted between levels, since the effects of climate variation may be felt differently by the actual production process and by the storage and dispersal of accumulated biomass.

Annex 1: Relation between Central Questions and Key Scientific Questions

Forcing: What are the characteristics of climate variability, can interdecadal patterns be identified, how and when do they arise?

Are climate regime shifts in the eastern and western sides of the subarctic in phase and with the same sign? (2)

Do the strengths of the Alaska and California Currents vary inversely, and how are their dynamics related to those of the Kuroshio and Oyashio? (4)

Lower trophic level response: How do primary and secondary producers respond in productivity, and in species and size composition, to climate variability in different ecosystems of the subarctic Pacific?

What impacts do variations in flow and dynamics of eastern and western boundary currents have on the productivity of Pacific Rim coastal ecosystems? (4) [This also applies to the next Central Question]

What limits primary production during each regime? (7)

Higher trophic level response: How do life history patterns, distributions, vital rates, and population dynamics of higher trophic level species respond directly and indirectly to climate variability?

What factors affect changes in biological characteristics of Pacific salmon and other key species of the region? (6)

How do responses to regime state (abundances, migratory patterns, stock recruitment relationships) differ among potential dominant species? Is response characteristic and consistent over several cycles?

Ecosystem interactions: How are sub-arctic Pacific ecosystems structured? Do higher trophic levels respond to climate variability solely as a consequence of bottom up forcing? Are there significant intra-trophic level and top down effects on lower trophic level production and on energy transfer efficiencies?

How are open and coastal subarctic Pacific ecosystems structured? (3)

What factors affect current trends in productivity of subarctic Pacific ecosystems and their impacts on salmonid carrying capacity? To what extent do seasonally migrating species compete with salmonids in the region (5)

What are the causes and consequences of spatial shifts in pelagic ecosystems? (8)

Note that the first Key Scientific Question is a restatement of the general question:

How do interannual and decadal variations in ocean conditions affect the species dominance, biomass, and productivity of the key zooplankton and fish species in the ecosystems of the PICES area.

Annex 2: Approaches to Study of Central Questions

Forcing: What are the characteristics of climate variability, can interdecadal patterns be identified, how and when do they arise?

- Establish the pattern in space and time of atmospheric variations that have driven the interannual and decadal variations in ocean conditions.
- Establish the pattern in space and time of the interannual and decadal variations in ocean conditions, as it relates to circulation and mixing, structure, and content of heat and dissolved substances.
- Determine what measures of climate variations are most indicative of regime shifts and which criteria can be used to establish the occurrence and early detection of regime shifts.
- Construct time series of the selected measures and compare those from east and west.
- Determine available measures of the strengths of the Alaska and California Currents, assemble time series of these measures, and make comparison.
- Determine available measures of the strengths of the Kuroshio and Oyashio, assemble time series of these measures, and compare with each other and with variations in the Alaska and California Currents.
- Construct plausible hypotheses to account for observed relationships.

Lower trophic level response: How do primary and secondary producers respond in productivity, and in species and size composition, to climate variability in different ecosystems of the subarctic Pacific?

- Determine available measures of productivity of Pacific Rim coastal ecosystems, assemble time series of these measures, and determine patterns of their variations as far back as possible.
- Determine average level of primary production before and after regime shifts and identify environmental conditions that might account for any observed differences.
- Establish what changes in species dominance, biomass, and productivity of key zooplankton species have taken place.
- Conduct retrospective studies of the relation between variations in ocean conditions and in zooplankton populations

Higher trophic level response: How do life history patterns, distributions, vital rates, and population dynamics of higher trophic level species respond directly and indirectly to climate variability?

- Establish what changes in species dominance, biomass, and productivity of key fish species have taken place.
- Conduct retrospective studies of the relation between variations in ocean conditions and in fish populations.
- Establish what changes have occurred in growth, size and age at maturity, ocean distribution, survival, and abundance of salmonids and other key species of the region.
- Relate these changes to (1) changes in environmental conditions, and (2) exploitation patterns, and develop and test plausible hypotheses for the observed relationships.
- For potential dominant species, assemble existing information on abundances, migration patterns, and stock recruitment relationships before and after the most recent regime shift (e.g., compare data before and after the mid-1970s - data for several cycles may not be available).

- Identify differences in these responses among the compared species.
- Determine what spatial shifts have occurred in pelagic ecosystems.
- Relate these shifts to environmental changes and fishing patterns.
- Determine changes in ecosystem structure that accompanied these spatial shifts.

Ecosystem interactions: How are subarctic Pacific ecosystems structured? Do higher trophic levels respond to climate variability solely as a consequence of bottom up forcing? Are there significant intra-trophic level and top down effects on lower trophic level production and on energy transfer efficiencies?

- Determine the criteria to be used in defining the structure of coastal and oceanic ecosystems.
- Make tentative descriptions of present coastal and oceanic ecosystem structures based on available information.
- Compare current ecosystem structures with those present prior to the mid-1970s.
- Evaluate methods for monitoring key elements of these ecosystems in order to detect future structural changes.
- Determine working definition of "carrying capacity" and identify measures by which its magnitude for key species can be determined.
- Evaluate evidence for changes in carrying capacity for salmonids and other key upper trophic level species.
- Identify possible causes of these changes, e.g., in underlying productivity and in species dominance.
- Examine the role of seasonally migrating species, such as pomfret, neon flying squid, and saury, as competitors with salmonids for food.
- Establish relationships between circulation and ecosystem changes and develop plausible hypotheses to explain these relationships.
- Develop coupled atmosphere-ocean-ecosystem models for testing, analysis, and prediction of the relationships that appear from these studies.

Annex 3: Membership of Implementation Panel, March 1996

Chairmen:	Yutaka Nagata (Japan) Warren S. Wooster (U.S.A.)
Executive Committee:	Anne B. Hollowed (U.S.A. GLOBEC) R. Ian Perry (Canada GLOBEC) Qi-Sheng Tang (China GLOBEC, FIS Chairman) Makoto Terasaki (Japan GLOBEC) Sinjae Yoo (Korea GLOBEC) Makoto Kashiwai (Science Board Chairman) Michael L. Dahlberg (NPAFC representative)
National Members:	Richard J. Beamish (Canada) Michael A. Henderson (Canada) Daniel M. Ware (Canada) Ji-Lan Su (China) Rong Wang (China) Kasuya Nagasawa (Japan) Tokio Wada (Japan) Suam Kim (Korea) Chang Ik Zhang (Korea) Alexander I. Boltnev (Russia) Vadim V. Navrotsky (Russia) Robert C. Francis (U.S.A.) Bruce W. Frost (U.S.A.) Brenda L. Norcross (U.S.A.)
Members:	Bruce A. Taft (WG 9 Co-Chairman) Robin M. Brown (TCODE Chairman) Paul H. LeBlond (POC Chairman) Patricia A. Wheeler (BIO Chairman) Richard F. Addison (MEQ Chairman)