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PICES CLIMATE CHANGE AND CARRYING CAPACITY WORKSHOP ON THE DEVELOPMENT OF COOPERATIVE RESEARCH IN COASTAL REGIONS OF THE NORTH PACIFIC

October 17-18, 1997
Pusan, Republic of Korea

Sponsored by:
PICES-GLOBEC
CCCC REX Task Team

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INTRODUCTION

The REX Task Team convened a workshop October 17 - 18, 1997. The purpose of the workshop was to review the status of national research programs and to identify areas for cooperative research experiments in support of the CCCC Program. Over 50 scientists participated in the workshop representing approximately 40 research institutions.

The workshop organizing committee recognized the need for application of the scientific method in developing regional experiments in support of the CCCC Program. Marine research programs have a legacy of resource monitoring followed by retrospective studies leading to hypothesis generation. More recently, considerable resources have been devoted towards the development of simulation models capable of integrating the synergistic influences of multiple factors. These models have been used to explore hypothetical impacts of changes in ocean conditions on marine ecosystems. Both of these approaches fail to apply the basic principles of the scientific method where scientists state their hypothesis and design and implement experiments to test the validity of their hypothesis. The absence of the scientific method in marine research is attributed to two primary factors: a) the difficulty isolating a "control" in the experimental design, and b) the difficulty in obtaining funds to conduct replicate process oriented experiments when the process of interest occurs on interannual to decadal time scales. In the REX Workshop, we examined the possibility of applying the comparative approach to answering the scientific questions posed in the Climate Change and Carrying Capacity Implementation Plan. Participants were asked to consider the possibility of designing experiments that could be conducted in distant regions of the North Pacific with the expressed intent of testing hypotheses regarding climate impacts on the carrying capacity.

The symposium began with a review of the GLOBEC and GLOBEC like research programs planned, or on-going, in each of the six PICES member nations. Subsequently, participants discussed coastal research programs in breakout sessions targeting forcing, lower trophic level response, higher trophic level response and ecosystem response. The higher trophic level response breakout sessions were further divided into four major species groups: salmon, mid-water and demersal fish, pelagic fish, and crustaceans.

Participants were asked to review the four key scientific questions presented in the CCCC Implementation Plan:

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

2. 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?

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

4. 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?

The participants were asked to develop hypotheses related to the four CCCC questions as they related to the topic of the breakout session. Participants were also asked to discuss existing or potential research approaches to test these hypotheses. The regions and target species that would be best suited for comparative research experiments were identified. Finally, the barriers to implementing the experiment were discussed.

GLOBEC CANADA - ECOSYSTEM RESPONSE TO CLIMATE VARIABILITY

David L. Mackas (Presenter)

GLOBEC Canada is a collaborative program funded for four years jointly by NSERC (Research Partnerships) and DFO (Priority Allocations, A-base). GLOBEC is designed to provide very high return on investment through more robust interpretation and management in the face of ecosystem change. The collaboration involves fifty scientists from seven universities (Memorial, Dalhousie, Laval, UQAR, Queen's, UBC and UVic), five government laboratories (NAFC, BIO, IML, IOS and PBS). Strong links exist with other national programs, e.g. in the US and Norway, and with the developing GLOBEC International effort.

GLOBEC Canada will examine how living marine resources are affected by variability of their physical environment. Marine ecosystems undergo large interannual to decadal fluctuations. These large swings affect almost every fishery, and are becoming equally apparent in time series of ocean climate and plankton indices. Their time scale is such that human impacts, in terms of economic and societal dislocation, can be very large. There is much evidence for an underlying causal connection through physical environmental forcing of variations in ocean productivity. But timely diagnosis and management response are hampered by insufficient knowledge of intermediate causal linkages. For example, low productivity and very poor recruitment of Atlantic groundfish stocks has coincided with the post-1990 cold water anomaly. Conversely, high productivity of many Pacific salmon stocks coincided with a N. Pacific atmospheric and oceanic regime that began in the mid 1970s (but there are recent physical and biological indications that the N. Pacific is now undergoing another regime shift). Understanding the reasons for these episodes of high and low productivity is essential to forecasting if and when Pacific salmon productivity will decline, and whether and when NW Atlantic groundfish will return to historic levels of productivity.

The multidisciplinary integration of field and modeling studies in GLOBEC Canada will increase this causal-level understanding. The relevance of GLOBEC includes, but is not limited to, climate change trends associated with global warming. A major focus will be naturally-forced interannual to interdecadal fluctuations and their effects on target populations through recruitment variability of individual species and changes in overall community structure. Simultaneous research programs are underway in both the Atlantic and Pacific. The dual coast effort is justified by the need for national integration and the unique characteristics of the east and west coast ecosystems. Scientific themes shared by both coasts include:

* Importance of seasonality and timing match between critical physical and biological events (shifts in these are like to be among the strongest climate change signals).

* Amount and timing of freshwater inputs, and effects on physical mixing and transport patterns.

* Importance of advective coupling among mesoscale sub-regions and between the open ocean and continental margins.

GLOBEC Canada will improve understanding of how changes in the physical environment of the ocean drive changes in the productivity and species composition and trophic structure of marine ecosystems. We know that these climate and ecosystem fluctuations exists and frequently covary, but in general we do not know how they are mechanistically linked.

GLOBEC's multidisciplinary integration of field and modeling studies will increase this cause-level understanding. The relevance of GLOBEC includes, but is not limited to, climate change trends associated with global warming. A major focus will be naturally-forced interannual to interdecadal fluctuations and their effects on target populations through recruitment variability of individual species and changes in overall community structure.

Rationale for CGLOBEC Pacific research

Pacific Ocean fish and zooplankton communities undergo large and ecologically/economically significant fluctuations over years to decades. Stock collapses and extreme failures of steady-state fisheries forecast models have tended to accompany major shifts in the marine climate. There is increasing evidence that these large changes in fishery yield are environmentally, rather than purely fishery harvest, driven. Although several important west coast fisheries are already managed using various proxy indices of ocean conditions (specific examples include Barkley Sound sockeye, Vancouver Island herring, sablefish, and hake), present indices are based on correlations with convenient proxy variables. They incorporate minimal verification through knowledge of the underlying mechanisms. Management indices based solely on hindcast correlations have a history of breaking down over time, either permanently or during specific oceanic events. Consequences are often severe: loss or major error of management advice, resulting in conservation and social crises and the loss of millions of dollars to the Canadian economy. What is needed to make the indices more reliable is understanding and quantification of the causal processes underlying the correlations.

The Pacific component will study interactions within a high nutrient and predominately pelagic ecosystem. The research will emphasize food web pathways leading to production of the most important (in commercial value and/or ecological impact) west coast finfish species: salmon, herring and hake. Target processes and species will include: alongshore and cross-shore advection, seasonal cycle of upwelling, horizontal currents and water mass boundaries (physical environment), euphausiids and copepods (zooplankton), and both adult and juvenile finfish. The conceptual model for the west coast GLOBEC program three advectively- and biologically-linked ecosystems operating at increasing spatial scales (west coast of Vancouver Island, central and north B.C. coasts, open NE Pacific Ocean). The three regions are highly interconnected. Each has important, seasonally variable, and physically-driven exchanges of nutrients and plankton with its surroundings. Each also contains large populations of migratory fish. In particular, Pacific salmon integrate, over the course of their life cycle, the consequences of ocean physical and biological processes occurring in both coastal and offshore regions. For major stocks, survival rates during marine life are known to vary six-fold (e.g. 5% to 30% for Fraser sockeye).

Project status and progress toward objectives

As of October 1997, GLOBEC Canada is halfway through the second year of a 4-year proposal cycle. This is an exciting time to be doing this research. By many indications, ocean conditions and ocean ecosystems are in an episode of strong and rapid change. For example, in the northeast Pacific, an intense developing El Niño is combining with other modes of climate variability to produce very strong positive temperature anomalies. In the northwest Atlantic, coastal ocean temperatures remain cooler than normal. Present opportunities for larger-scale examination of these events through international cooperation are excellent, especially within PICES and ICES GLOBEC programs, and bilaterally with the U.S. (their east and west coast GLOBEC programs), Japan (Japan GLOBEC), and Norway (Mare Cognitum, TASC). Within Canada, we are benefiting from idea- and data-sharing with programs such as JGOFS and OCP.

CGLOBEC includes fifteen component projects on the Atlantic and Pacific coasts (Pacific projects tabulated at the end of this report). In the first half of year two (FY9798), the projects completed remaining equipment purchase and staffing and moved into active research mode. We are on track for meeting our intended annual "milestones":

> From retrospective data, document changes over past 15-20 years in east and west coast ecosystems (water properties, currents, nutrient supply, seasonal cycles of plankton production and composition, fish growth and distribution).
>
> Intensive field process studies of circulation/ biology interactions (to be repeated in 1998-99). For west coast, spring transition of shelf edge currents, upwelling in submarine canyons, and interactions with zooplankton and fish distributions. For east coast, effect of autumn storms on bank nursery areas.

Other field sampling: In the Alaska gyre, zooplankton time series and salmonid growth and distribution. On both coasts, ongoing continental margin time series sampling.

Numerical models. Evaluation & use of physical circulation modules. Time series outputs for comparison against retrospective and process study data. Begin to embed biological modules.

Data archival and exchange. Web-based central catalog (index & metadata) with links to distributed archival sites.

Research activities fall in three main areas: retrospective statistical analyses, numerical modeling, and "time series" and "process study" field sampling.

Retrospective analyses

Retrieval of historical data into accessible databases is continuing, and interpretations of seasonal and interannual variability have been initiated. In the Pacific, multi-year average seasonal climatologies have been calculated for currents, water properties, and zooplankton biomass/composition off Vancouver Island. These are now being intercompared and used to interpret recruitment of plankton and fish. Time series of offshore and coastal wind measurements have been compared to pressure-field indices, and are being applied to models of upper ocean currents. A large interdecadal change in the life cycle timing of the N. Pacific copepod Neocalanus plumchrus was identified with data from older published data and recent JGOFS, "Strait of Georgia Salmon", and GLOBEC surveys.

Numerical Modeling

Model development is progressing well, and model applications have been initiated on both coasts. In the Pacific, a high-resolution 3-D circulation model is being developed for the Vancouver Island continental margin. Applications include coupling to a regional trophodynamic model, and examination of localized upwelling and zooplankton/fish aggregations associated with shelf-break submarine canyons. A very high resolution meteorologic model is being used to examine intensification of winds and resultant energy transfer to the ocean near coastal headlands. In the Alaska Gyre, nested NPZ, mixed layer and basin-scale circulation models are being developed to study patterns of primary and secondary production, and utilization of open ocean habitat by migrating salmon.

Field studies

1997 west coast field sampling has included four continental margin cruises (Thomson et al., Allen et al.) to deploy moorings, to maintain ongoing seasonal time series of water properties, plankton and fish distributions, and to examine shelf break upwelling/aggregation processes and effects of the spring transition on plankton and fish distributions. Spring and summer cruises in the Alaska Gyre (Welch/Perry, McKinnell/Mackas) examined salmon size-at-age, food source, and migratory route, and mesozooplankton distribution, developmental timing, and sampling methodology.

Program Integration

West and east coast regional workshops took place in October 97 (Vancouver and Halifax), and were followed by a national meeting in early January 1998.

Canadian GLOBEC Project Titles and Lead Investigators (Pacific Component)

Effects of current patterns on primary productivity and zooplankton biomass and implications on feeding patterns of larval fish - Allen, Foreman, Harrison, Mackas, Perry, Thomson, and Whiticar

Hindcast models of currents and temperatures along the British Columbia continental margin - Crawford and Cummins

Biophysical modelling for the western continental margin of Vancouver Island - Foreman, Ware, Thomson, and Harrison

Sockeye salmon migration and foraging behaviours: Acoustic tracking experiments - Hawryshyn

A coupled ocean general circulation and marine foodweb model of the subarctic Pacific - Hsieh and Denman

Gulf of Alaska zooplankton - McKinnell and Mackas

State-of-the-Ocean time series - Pacific continental margin - Thomson, Mackas, Ware, Perry, Hargreaves, Harrison, Hyatt, McFarlane, Shaw, Stull, and Gower

Zooplankton and oceanographic effects on Ocean salmon growth - Welch and Perry

ACTIVITIES OF THE CHINA-GLOBEC PROGRAM

Qi-Sheng Tang (Presenter)

The China GLOBEC program is a high priority national science program. The goal of this project is to identify how climate change and anthropogenic factors influence the dynamics of coastal sea ecosystems. The aim of this project is to predict fluctuations in ocean and its living resources. The main research activities in 1997 are on the historic data collection and analyses, designing an implementation plan, parameter estimation, and field surveys. An outline of these activities is described below.

China has initiated a research program on the Bohai prawn early life history and key processes in the habitat. As a part of this program, an egg survey covering 54 sampling stations is conducted in May. The data collected from this survey will lead to an assessment of prawns in the habitat. Physical factors such as temperature and salinity are taken. A second survey is conducted on the feeding ground in July. This survey covers 23 stations in frontal regions of the Bohai Sea. Three of these stations have 24-hour continual observation stations.

A second element of the China GLOBEC program focuses on zooplankton population dynamics and their controlling role for ecosystem productivity. In 1997, information on the vertical movement of plankton was studied by collecting continuous observations over a 48-hour period at 5 fixed locations in the Bohai Bay in June. The data were collected by both vertical plankton trawls, and benthic sampling during day and night. Nutrient samples were taken in association with this survey. Physical characteristics of the water column were obtained using a CTD

China GLOBEC also conducts studies of the trophodynamics of the food web and shifts in species dominance. In 1997, a procedure for modeling ecological growth efficiency in trophodynamic processes at higher trophic levels was developed. Larval fish were collected for analyses of food habits. Ecological growth efficiency and feeding conversion efficiencies were estimated for read sea bream, black sea bream, gobies and black tetra.

A model of the Bohai sea ecosystem is being developed by the China GLOBEC program. In support of this project, collections of benthos and geo-chemistry were made in 1997.

GLOBEC-RELATED RESEARCH PROGRAMS BY FISHERIES RESEARCH INSTITUTES OF JAPAN

Makoto Kashiwai (Presenter)

A comprehensive study of the Variation of the oceanic ENvironment and FISH populations in the Northwestern Pacific (VENFISH) is currently being conducted. This program is funded through the Agriculture, Forestry and Fisheries Research Council. The VENFISH program will be funded 1997 to 2002. This research program covers three geographical regions; Oyashio region, Transition region and Kuroshio region and can be an important component of PICES-GLOBEC / CCCC-Program. A brief overview of this program follows.

Background: The introduction of Total Allowable Catch (TAC) to the fisheries resources management in Japanese EEZ highlighted the need for improved prediction of changes in abundance of important fish resources under the effects of climate change and ecosystem interactions. Several studies showed a large influence of lower level production of the abundance of important fisheries resources such as Pacific saury and walleye pollock, and a critical importance of marine environment on the lower trophic level production. Based on these observations, the prediction of abundance of fisheries resources, presently performed using catch data and body length composition, should be and could be improved through the prediction of lower trophic level production under the effect of environmental variability.

Objective: The objective of the Program is to establish technology for precise abundance forecast of fisheries resources and to advance technology for fisheries resources management for representative fish species in the Oyashio/Kuroshio region, through developing prognostic fish production models based on elucidation of the response of fish production to variability of environment and plankton production.

Target Species: This Program identifies two target species, Pacific saury, the trans-boundary migrant of short lifetime, and Walleye pollock, the resident on Subarctic shelf of long lifetime. Thus the Program has two major components integrated by the population dynamic models for the two target species, having common feeding area of Oyashio shelf region during summer.

Program structure: The Program is structured by trophic levels and has following components:

1. Analysis of the effects of ocean environment on plankton biomass
   a. Prediction of phytoplankton biomass
      i. Field studies on the watermass structure and primary production
      ii. Development of models for phytoplankton biomass dynamics
   b. Prediction of Zooplankton biomass
      i. Responses of Zooplankton to environmental variability
      ii. Food web analysis around Zooplankton and Micronekton
      iii. Development of models for Zooplankton biomass dynamics

2. Development of technology for forecasting biomass variability of dominant fishes
   a. Responses of dominant fishes to environmental variability
   b. Development of prognostic model for fish population dynamics

Participating Institutes:

Hokkaido National Fisheries Research Institute (Kushiro)

Tohoku National Fisheries Research Institute (Shiogama)

National Research Institute of Fisheries Science (Yokohama)

Far Seas National Fisheries Research Institute (Shimizu)

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KOREAN GLOBEC AND GLOBEC-LIKE PROGRAMS

Chang-Ik Zhang

The Korean GLOBEC committee has been formally established in June 1998 as a collaborative national committee jointly by National Fisheries Research & Development Institute (NFRDI), Korean Ocean Research & Development Institute and some ocean- and fisheries- related universities such as, Pukyong National University and Seoul National University. As an initial program the Korean GLOBEC committee is developing a preliminary research project (1 year) on the title of 'Climate Changes and Abundances of Fisheries Resources in Korean Waters' as a kind of research action plan. This one-year research will be conducted mostly by Korean GLOBEC committee members, to figure out the frame, direction, and items for the GLOBEC and GLOBEC-like future research in Korea by the retrospective analyses of all historical data and results of related studies. Base upon the results of the research program, the Korean GLOBEC and GLOBEC-like researches will be much more actively conducted thereafter.

In spite of the late formation of the national GLOBEC committee in Korea, however, a number of GLOBEC-like research programs have ever been carried out and also have been being conducted currently as shown in the attached summary of ongoing research programs by region. At present, six research programs are ongoing in the Yellow Sea, three, in the East Sea/Japan Sea, and five, in the East China Sea. The major funding agencies for these programs are the Ministry of Maritime Affairs and Fisheries (MAFF), Ministry of Science and Engineering (MOST), and Korea Science and Engineering Foundation (KOSEF). Besides these programs, a lot of small researches are also carried out by universities and government research institutes.

REVIEW OF RUSSIAN GLOBEC-LIKE PROGRAMS

Vladimir I. Radchenko (Presenter)

Development of Russian GLOBEC-like programs was difficult in the early years because the research organizations within Russia were not fully integrated. It was a time when the single-objective approach predominated. Research groups were basically formed to address a single purpose and rather than multipurpose, ecosystem based, research projects. Each research group conducted routine studies and produced proposals for discrete projects for the following fiscal year. With further study, the objectives became more detailed and sub-divided.

The first multipurpose marine ecosystem research programs were undertaken by the institutes of the Russian Academy of Sciences. Dozens of large-scale expeditions were conducted annually on board of the academic fleet in diverse corners of the World Ocean. However, at this time, the Academy did not focus on higher trophic level organisms of marine ecosystems. Although these programs did not allow a description of the whole ecosystem, they provided valuable information on the relationships between physical forcing and lower trophic level response.

In early 1950s, Russian scientists attempted to relate the fish stock dynamics and climate trends which lead to the development of Dr. G. Izhevsky's system approach. This research showed statistical relationships between time series of selected fish stocks and physical factors. Dr. Izhevsyky endeavored to formalize these relationships and discovered that it was impossible to describe the single-species model adequately by mathematical means without incorporating ecosystem parameters.

Since 1980 the ecological investigations in the far-eastern seas have been carried out by the TINRO-Center. The composition, structure, inter-annual dynamics and function of the pelagic and demersal hydrobionts' communities were studied on a macro-ecosystem scale. This work was primarily undertaken by the laboratories of Applied Biocenology (i.e., ecology) and of Plankton Research in the Bering and Okhotsk Seas. The project staff consists of three dozens specialists now under the leadership of principal TINRO-Center scientist, Prof. V.P. Shuntov.

Ecosystem investigations were included as a part of fishery research and were conducted on research vessels. In 1982, the mission of first expedition was to assess demersal fishes and invertebrates on the western Kamchatka shelf in the Sea of Okhotsk. Subsequent expeditions were conducted in the Karaginsky Bay in the southwestern Bering Sea in 1983. Demersal surveys were conducted until 1983, and pelagic surveys started in 1986. Twelve expeditions with pelagic and four with demersal surveys have been completed in the Bering Sea and Kamchatka Pacific waters. In the Sea of Okhotsk and Kuriles Pacific waters, eighteen pelagic surveys and seven demersal surveys have been conducted.

Multipurpose expeditions have been conducted in the Russian far-eastern economic zone and in some international waters. These expeditions encompassed multi-disciplinary activities including: meteorological studies, hydrology, chemical sampling, fish distribution (by trawl-acoustic sampling), plankton and ichthyoplankton surveys. The distribution, migration, feeding, and physiology of nektonic organisms were all studied. Nekton was assessed mainly in the epipelagic (0-200 m) and pelagic (0-1000 m) layers, according to data of trawl surveys. Data on primary production, bacteria, and protozoa were also collected, examined, and processed onboard the research vessels in some expeditions.

The original database contains information on basic water parameters, species composition, biomass, and resources of zooplankton, nekton and benthos from more than 6200 oceanographic, plankton and trawl stations. This database includes the results of biological analyses of more than 150,000 and measurements of 1,400,000 fishes and squids. The feeding habits of tens of thousands of specimens of more than fifty nekton and nektobenthos species were studied to develop community trophic structure. These data, coupled with a thorough

review of the literature on adjacent areas allowed for the derivation of a model for energy and biomass flow through the Bering and Okhotsk Seas ecosystems. These models were presented at the PICES Workshops in Seattle in 1991 and in Vladivostok in 1995.

One of the main results of the FES-LIRES project was the prediction and further monitoring of substantial reorganization of pelagic communities of far-eastern seas that occurred since early 1990s. It was likely related to large changes in global climate and oceanographic conditions in the northern North Pacific. Changes in composition and biomass were recorded in both plankton and nekton communities.

FES-LIRES specialists analyzed the available data and developed a conceptual model of the consequences of pollock biomass decline in the far-eastern seas ecosystem (Shuntov et al., 1997). Consumer biomass reduction led to decrease of forage pressure on zooplankton communities. Then, the abundance and production of predatory plankton organisms grew in early 1990, fueled by the surplus plankton production resulting from the pollock collapse. As a consequence, the surplus plankton biomass and production decreased under the foraging pressure of planktonic predators. The food base for pelagic fishes and other high trophic level organisms worsened. Fish productivity decreased in pelagic ecosystems. At that time, the biomass of alternative nekton species begins to grow (for the northern North Pacific herring is alternative species to pollock). Herring has very high daily food ration during the feeding period and it consists of predatory zooplankton (especially chaetognaths) in more degree than the pollock ration. The decrease of predatory zooplankton biomass and production appeared in these conditions and some increase of biomass and production of unpredatory zooplankton can be expected. In late 1990s the increase of fish productivity is expected in new physical conditions and biological structure of ecosystems. However, the new level of fish productivity will be less than such level for 1980s.

Further monitoring of demersal and pelagic hydrobionts' communities is planned. Despite the financial and other difficulties the research expeditions continue in the far-eastern seas. The interesting changes in demersal communities on the western Kamchatka and Karaginsky Bay shelf zones were elucidated. It is likely related with the rate of mud sedimentation there in last years. Results of ecosystem investigations also are widely applied in the fisheries forecasting and management, in single-specific studies.

The Short-Term Fisheries Forecasting (STFF) program, encompasses all four of the PICES Central Scientific Issues. Although complex studies have been carried out in TINRO-Center since 1979, the activity has been sporadic and related to different regions. The STFF project for the Japan Sea started in 1996 and was planned for 3 or 4 years. (Unfortunately, in late 1997, the program was terminated.)

The objective of the STFF program is to identify a method for forecasting the location of pelagic fisheries for: common Japanese squid, saury, chub mackerel and sardine. To accomplish this objective, an analysis of the spatial distribution pattern of key species was performed. A set of meso-scale ecosystem blocks with flexible boundaries corresponding to types of water structure were monitored. Retrospective analysis revealed logical relationships between environmental conditions and living components of ecosystems. These relationships were formalized by statistical methods. Development of models of the seasonal factors that account for year-to-year changes should be undertaken. The components of ecosystems which are regarded to be important for the forecasting procedure include: air circulation features, water temperature, thermocline parameters, large-cell phytoplankton biomass, biomass of main zooplankton species and communities maturity, main fish and squid species population density and catches per unit effort. Thus, the result model will not be an ecosystem model on the whole, but the model of development of fisheries conditions.

During the first two years the principal relations for levels "atmosphere water column", "water environment - plankton", "water environment - fish and squid", "plankton - fish and squid", "fish - squid" were found for some types of ecosystems.

Atmosphere - water column relations are asynchronic that allows too elaborate the prognostic model. The extending of these regularities on whole deep-sea part of Russian exclusive economic zone off Primorie is planned. Then, all relations should be formalized in condition of complete system of equations.

A small staff of 7 scientists belonging to the TINRO-Center laboratories of short-term fisheries forecast and of Cephalopod studies was attracted to this project. Dr. Y. Zuenko was its leader.

Far-eastern regional program on Pacific salmon marine life study ("Pacific salmon, 1997-2000") can be an example of ecosystem approaches in a single-purpose studies. It was developed in response to the necessity for improved knowledge of the life history of Pacific salmon. Main program objectives are as follow:

- Definition of Pacific salmon ecology features during the sea and ocean phases, in particular its distribution and migrations, trophic linkages, growth and maturation rates in relation with food supply state and environmental conditions, estimations of natural mortality rates for diverse salmon species, and its inter-annual dynamics.

- Survey assessment of salmon abundance immediately during anadromous run for the verification of previous forecasts of magnitude and temporal dynamics of its approaches, investigation of possibility of the pink salmon aggregations to re-distribution between regions on the last stage of migration before the spawning streams.

- Direct calculations of salmon juveniles during oceanward migrations for collection of correct information on the generation numbers and development of preliminary harvest predictions.

- Further data collection for Pacific salmon stocks differentiation, age and population structure studies for main species, in particular for definition of real ratio of abundance of wild and enhanced chum salmon stock on basic areas of feeding migration route.

For these goals, the results are applied of complex trawl surveys conducted annually in frames of the FES-LIRES project in upper epipelagic layer of far-eastern seas. Pacific waters off Kamchatka and Kurile Islands are also investigated in limits of Russian exclusive economic zone. Observations are also executed from the Russian and Japanese driftnet vessels during fishery season and in coastal zone during fisheries operations by beach and river seines.

The research activities provided by 50-60 specialists of regional institutes and divisions of TINRO-Center in frames of this regional program annually. Most of them are temporary participants of project. The database including fishery statistics, escapement data, biological information on salmon species has created at the Laboratory of Biological Forecasts in the TINRO-Center. Contacting persons are V.G. Markovtsev, head of TINRO-Center International Department and V.I. Radchenko, Deputy Director.

UNITED STATES GLOBEC AND GLOBEC-LIKE PROGRAMS

Anne Babcock Hollowed (Presenter)

There are several GLOBEC and GLOBEC like programs currently funded in the United States. The purpose of this review is to summarize the present status of national research programs and to identify areas for cooperative research experiments in support of the CCCC Program. The discussion is not a comprehensive summary of all oceanographic programs that might contribute to the CCCC Program and is limited to large, multi-investigator research programs. However, it should be understood that the some of the programs discussed below might be supplemented by collaborative research projects awarded to individual scientists. The following summary begins with programs located off the California coast and proceeds north to the Bering Sea.

Large scale research programs in the California Current South region include the California Cooperative Oceanic Fisheries Investigations (CalCOFI), the Small Pelagics Fishes and Climate Change program (SPACC), the research activities of the Southwest Fisheries Science Center (SWFSC), the Monterey Bay Aquarium Research Institute (MBARI), and research activities at University of California Davis (U.C. Davis). The CalCOFI program is jointly funded by the National Oceanic and Atmospheric Administration (NOAA), the University of California, and the California Department of Fish and Game. The CalCOFI program has collected a large suite of bio/physical data in the California Current since 1949. Current research findings are documented in the CalCOFI reports series and are easily accessible on the world wide web. The long time series has provided invaluable information on the impacts of climate on the distribution and abundance of nutrients, phytoplankton and zooplankton in the California Current. The current monitoring region is encompasses offshore transects between San Diego and Pt. San Luis.

The Small Pelagic Fishes and Climate Change (SPACC) program was developed through the International GLOBEC programs. This program proposes cooperative research on: the feeding behavior, larval distributions, foraging success (prey availability) and early life history vital rates of small pelagic fishes throughout the world. The intent of this program is to develop coupled bio/physical models. Paleo-oceanographic records will also be collected and analyzed to provide a long term retrospective perspective of population variability.

The Southwest Fisheries Science Center (SWFSC) supports fisheries research in the California Current. Target species include small pelagic species as well as groundfish. The SWFSC Tiburon laboratory conducts research on juvenile rockfish. This research project includes seasonal surveys of larval and juvenile distribution and abundance, analysis of juvenile growth rates and feeding ecology. Adult rockfish are also monitored to determined fecundity rates. Information obtained through this program is assimilated in a bio-physical model of the study region roughly located between San Francisco and Monterey Bay. The SWFSC Pacific Environmental Group (PFEG) provides retrospective studies of climate variability, access to physical oceanographic data, develops bio-physical models of the California Current system.

The California Department of Fish and Game (CDF&G) supports fisheries research in waters off the coast of California. Research programs target a variety of fish species including: small pelagic species (e.g. sardine, mackerel and pacific herring), nearshore rockfish, Pacific salmon, lingcod and market squid. Oceanic research surveys are intermittent and focused on specific research needs. Sea bird surveys are also conducted through the CDF&G as part of the oil spill response team activities. Ocean surveys planned for 1999 include a pelagic survey for adult sardine and mackerel, and a market squid survey that will utilize bottom trawl and jig gear.

The Monterey Bay Aquarium Research Institute supports a broad research plan that includes the development of advancements in remotely operated

vehicles. On-going research includes a study of biochemical responses to changes in climate and ocean circulation. This project utilizes ship board surveys, moorings and remote sensing to improve our understanding of processes influencing lower trophic level responses to climate variability.

The University of California Davis is currently involved in Dungeness crab research. The goal of this project is to understand processes influencing recruitment of Dungeness crab. This research project provides monitoring of coastal larval dispersal. Survey information is assimilated in coupled bio-physical models.

The U.S. GLOBEC Northeast Pacific research program was developed to understand the effects of climate variability and climate change on the distribution, abundance, and production of marine animals, particularly juvenile salmon and the dominant zooplankton (copepods and euphausiids) in the system. The project contrasts the response of juvenile salmon to ocean conditions in the California Current region with conditions in the northern Gulf of Alaska. The project started in 1997 and will continue for 5 to 7 years. This project includes an examination of linkages in production between Coastal Gulf of Alaska and the California Current System. The program will also focus on variability in intermediate scale features (e.g. eddies and jets) as the main physical factors influencing zooplankton dynamics. Researchers hope to relate juvenile salmon survival to interannual and inter-decadal changes in physical forcing and changes in ecosystem food web dynamics. Development of coupled 3 dimensional bio/physical models for the California Current system and Alaskan current system are currently being supported by this program.

The National Oceanic and Atmospheric Administration's (NOAA), Coastal Ocean Program supports a Pacific Northwest Coastal Ecosystem Regional Study (PNCERS). The long-term objective of the PNCERS program is to manage the Pacific Northwest Coastal Ecosystem for ecological and sociological sustainability. Short-term objectives of this program include:

- Identification of physical and human forcing factors that affect the Pacific Northwest Coastal Ecosystem (PNCE).

- Defining the relative impacts of significant forcing factors on the intrinsic and economic outputs provided by the PNCE.

- Determining the socioeconomic consequences of changing the provisioning rate and/or distribution of system outputs.

- Identify management structures and strategies (policy) which can be altered such that the PNCE functions sustainably.

The Coastal Ocean Processes (CoOP) program is a multi-diciplinary, research projects that is funded by the National Science Foundation, the Office of Naval Research and the National Oceanic and Atmospheric Administration. The CoOP program currently has a pilot project on air-sea interactions off Monterey, CA. This project focuses on air-sea gas exchange.

The Northwest Fisheries Science Center (NMFS) supports fisheries research in coastal waters of northern California, Oregon and Washington. Research encompasses a broad range of activities including monitoring of pollutants, nutrients, fisheries surveys, retrospective studies and modeling. Center staff conduct research on habitat associations, stock identification, spatial distribution and abundance. The data collected is assimilated into stock assessment models and ecosystem models to evaluate impacts of different harvest strategies. The NWFSC conducts surveys of toxic phytoplankton off the coast of Washington, Oregon and northern California using ships of opportunity. The NWFSC Newport Oregon Laboratory provides bi-weekly sampling of zooplankton distribution and abundance. Chlorophyll, zooplankton and ichthyo-plankton samples are routinely taken.

The International Pacific Halibut Commission is located in Seattle, Washington. The IPHC employs an international group of investigators who conduct research on Pacific halibut. The IPHC conducts grid surveys using longline gear in the Gulf of Alaska.

Information obtained from these surveys is assimilated into stock assessment models. Research activities of the commission include studies of changes in life history characteristics of Pacific halibut, studies of stock distribution and migratory pathways, fisheries monitoring and development of models of the functional response between stock projection success and bio/physical forcing.

The Exxon Valdez Oil Spill Trustee Council (EVOS) oversees research on the coastal ecosystem of the Gulf of Alaska. Three research projects are directly relevant to the PICES CCCC Program. The Sound Ecosystem Assessment Program (SEA) is a multidisciplinary study of the influence of biological and physical processes on production of pink salmon and Pacific herring in Prince William Sound. The Nearshore Vertebrate Predator project is focused on examination of nutrition and health indicators of top trophic level predators (marine mammals and seabirds). The Alaska Predator Ecosystem Experiment (APEX) project concentrates on the productivity of seabirds based on the availability of forage fish. Principal target species include: common murres, pigeon guillemots and black legged kittiwakes.

The Alaska Fisheries Science Center supports research on marine fish and crabs in Alaskan waters. Research activities include a broad range of activities and target species. Bottom trawl and Echo Integration Midwater Trawl (Acoustic) surveys are conducted along the west coast, Gulf of Alaska and Bering Sea. During these cruises, data is collected to evaluate habitat associations, food habits, stock identification, spatial distribution and abundance. The data collected is assimilated into stock assessment models and ecosystem models to evaluate impacts of different harvest strategies. The Fisheries Oceanography Coordinated Investigations (FOCI) program is a process oriented research program that studies the influence of environment on the abundance of various commercially important fish and shcllfish stocks in Alaskan waters and their role in the ecosystem. The primary focus of the FOCI program is the early life stages of walleye pollock and their associated ecology. The Ocean Carrying Capacity program is conducted by the AFSC, Auke Bay Laboratory. The OCC program provides funds for physical monitoring and transect surveys for juvenile salmon using a high speed net. Transects lines are broadly spaced throughout the Gulf of Alaska. The data collected by this program is used to evaluate: differences between separate salmon stocks, food habits and feeding ecology, juvenile condition, and factors influencing the distribution and abundance of juvenile salmon. The AFSC Kodiak Laboratory conducts extensive research on the distribution and abundance of Alaskan crab stocks. The Alaska Fisheries Science Center also houses the National Marine Mammal Laboratory. This research facility conducts research on marine mammals in the California Current and Alaskan waters. Ecosystem studies include monitoring cruises to evaluate foraging behavior. Observational programs (at sea, ground and air) of stock abundance and distribution.

Two government agencies conduct research on Alaskan seabirds. The United States Geological Survey supports research on Alaskan seabirds in Prince William Sound and Glacier Bay. The project supports research on the flight ranges and foraging behavior of seabirds. Research is also conducted on the relationship between foraging and reproductive success. The United States Fish and Wildlife Service monitors seabird abundance, reproductive success and food habits.

The Alaska Department of Fish and Game provides scientific support for fisheries research and management for the State of Alaska. Research activities within ADF&G encompass a wide range of activities including monitoring, modeling, and retrospective studies. Principal target species include Pacific herring, crustaceans including crab and shrimp, salmon and groundfish. Scientists within ADF&G conduct research on genetic stock identification, feeding ecology, resource modeling and habitat association. ADF&G conducts resource surveys in the coastal regions of Alaska on a routine basis.

The NOAA's Office of Atmospheric Research recently funded an Arctic Research Initiative (ARI). The focus of this study is to identify sources of natural variability within the Bering Sea and Western Arctic ecosystem. This project will also

support studies of anthropogenic influences on the Bering Sea/Western Arctic ecosystem. Surveys are conducted to monitor shelf edge processes and physical processes that control variations in productivity within the shelf edge region.

NOAA's Coastal Ocean Program supports a Southeast Bering Sea Climate Change and Carrying Capacity Regional Study (SEBSCC). The long-term objective of the SEBSCC program is to increase our understanding of the Southeast Bering Sea by documenting the role of juvenile pollock in the ecosystem. Studies are designed to evaluate the effects of climate on lower trophic level production within the Bering Sea as well as factors influencing juvenile pollock distribution and survival. Coupled 3-dimensional bio-physical models are being developed by this program.

MID-WATER AND DEMERSAL FISH BREAKOUT SESSION

Participants: Anne B. Hollowed (Co-Chairman), Steven Hare (Co-Chairman), Richard D. Beamish, James Cohen, Young Kang, Thomas C. Royer, Muneharu Tokimura, Warren S. Wooster, Chang-Ik Zhang, Vera Alexander, Richard D. Brodeur, Yutaka Isoda, Mokoto Kashiwai, Patricia Livingston (Rapporteur), Sandy McFarlane, Naonobu Shiga.

Objectives, key questions, and core hypotheses

The objectives of a coordinated research program focused on the response of mid-water and demersal fish have been outlined in the REX terms of reference, the key question posed by the CCCC implementation plan and the desirable set of program outputs identified in the CCCC implementation plan (PICES Scientific Report No. 4).

The principal mechanisms underlying higher trophic level responses to climate variability include: starvation, transport, concentration, prey suitability, prey type, and predation mortality. Hypotheses linking climate variability and higher trophic level response can be stated as follows:

1. STARVATION: Survival of mid-water and demersal fish larvae is dependent on matching hatch dates with the peak zooplankton production (i.e. the match mis-match theory). Factors that alter the timing of the spring bloom can influence the match mis-match" between first feeding larvae and prey availability.

2. STARVATION: Survival of mid-water and demersal fish larvae and juvenile fish is dependent on sustained secondary production through out the spring and summer months.

3. TRANSPORT: Survival of mid-water and demersal fish larvae depends on advection to favorable nursery grounds. Atmospherically driven shifts in large scale circulation patterns can impact recruitment success by changing larval distributions.

4. CONCENTRATION: Survival of mid-water and demersal fish larvae depends on mesoscale advection patterns that concentrate larvae and their prey. Mesoscale features such as eddies or frontal systems concentrate prey and enhance larval survival.

5. PREY SUITABILITY: Survival of mid-water and demersal fish depends on the availability of the appropriate prey species at suitable size for consumption.

6. PREDATION MORTALITY:

a. ADVECTION: Survival of mid-water and demersal fish depends on advection processes that separate larvae and juvenile fish from their predators.

b. SIZE DEPENDENT MORTALITY: Processes that enhance larval and juvenile growth rates will reduce predation mortality by reducing the time when larval or juvenile fish are vulnerable to predation.

c. PREDATOR / PREY OVERLAP: Processes that separate upper trophic levels species from juvenile midwater and demersal fish influences the amount of predation mortality.

Data requirements

The following data sets would be required to evaluate these hypotheses:

Physical Data: Sea ice extent, large-scale advection, and location and duration of mesoscale circulation features (eddies and fronts), mixing (nutrient flux).

Lower Trophic Level Data: timing of spring bloom, zooplankton distribution and abundance, zooplankton species composition, and zooplankton size distribution, surface to bottom ocean temperatures.

Higher Trophic Level Data: Ichthyoplankton distribution and abundance, larval and juvenile growth rates. Distribution and abundance of predators. Larval and juvenile prey preferences.

The availability of information for testing these hypotheses and the source of the information is summarized in Table 1. Most of the information summarized in Table 1 has only recently become available. Thus, process oriented research programs could be proposed for inter-regional comparisons. Differentiating between competing hypotheses requires a coordinated sampling scheme that utilizes comparable sampling protocols. This level of coordination should be the responsibility of individuals directly involved in the research programs. The REX Task Team could facilitate initial contacts between investigators by maintaining a list of program contacts and web sites.

Our group entertained the possibility that the rules that govern recruitment success or failure interannually, may change when a climatic regime shift occurs. A regime shift is a large scale shift in ocean properties typically associated with shifts in atmospheric forcing, that influences the species mix and/or distribution of species within an ecosystem. It was recognized that the data in support of large-scale shifts in higher trophic level distributions or abundance have not been rigorously tested.

CCCC higher trophic level response hypotheses

We identified seven hypotheses to explain perceived changes in higher trophic level abundance and distribution before and after the regime shift. These seven hypotheses are extensions of the key hypotheses introduced above.

1. The regime shift had no effect on mid-water or demersal fish production or distribution.

2. The regime shift altered the timing of the spring bloom, which altered larval survival. This is an extension of the STARVATION hypothesis.

3. The regime shift influenced advection in the North Pacific and adjacent seas, which altered larval survival. This is an extension of the mesoscale and large-scale TRANSPORT hypotheses.

4. The regime shift altered species dominance leading to differences in PREDATION mortality rates.

5. The regime shift altered the amount of suitable thermal habitat leading to shifts in feeding and spawning distributions. Shifts in spawning distributions could impact recruitment success by changing the probability of favorable advection to nursery grounds, changing the probability of successful encounters with prey of suitable size and concentration, or by changing the probability of encounters with predators. Shifts in feeding distributions could impact the prey fields within a region.

6. The regime shift influenced the frequency and intensity of storm events in the north Pacific and adjacent seas resulting in different mesoscale circulation patterns. Shifts in mesoscale circulation patterns altered survival by changing the probability of encountering mesoscale features such as eddies or frontal systems that concentrate prey and enhance larval survival. An extension of the CONCENTRATION hypothesis.

7. The regime shift changed large-scale circulation and the mixed layer depth in the North Pacific and adjacent seas. Shifts in water column properties led to changes in zooplankton production. An extension of the STARVA-TION hypothesis.

The availability of information to evaluate the seven regime shift hypotheses is summarized in Table 2. The data sets required to test the match mis-match hypothesis (e.g. shifts in the timing of the spring bloom) were available in a limited number of PICES regions (Regions 1, 2, and 4, see PICES Scientific Report #4 for definition) (Table 2). In contrast, models of large scale advection required to evaluate the impact of the regime shift on transport are available for most of the PICES regions. However, the quality of the model generated advective fields was questioned due to the limited number of field

samples taken in some regions during the late 1960s and early 1970s. Information on water column properties and storm frequency is available in most regions. Models of mesoscale circulation features required to concentrate larvae and their prey are available for Regions 1 and 2. Field samples required to evaluate long-term changes in the suitability of prey and prey diversity are only available for Region 1.

Recommendations

1. Conduct inter-regional comparative studies to evaluate the recent role of climate-variability on key processes such as: starvation, transport, concentration, prey suitability and predation mortality.

2. Ensure the data are comparable across regions to facilitate inter-regional comparisons. Principal Investigators of process oriented field programs are encouraged to contact PIs in other regions to discuss similarities and differences in sampling protocols.

3. Compare recruitment indices of fish to confirm perceived changes in higher trophic level responses to the regime shift. These studies should evaluate the frequency of strong year classes, the amplitude of strong year classes and the synchrony of strong year classes.

4. Compare adult spawning and feeding distributions before and after the regime shift.

5. Compare growth rate (length and weight) of mid-water and demersal fish before and after the regime shift.

6. Compare storm frequency and intensity and water column properties before and after the regime shift.

7. Compare large-scale advective pathways and water column properties before and after the regime shift.

8. Compare timing and intensity of the spring bloom.

Table 1. Summary of current informatin required to evaluate hypotheses regarding climate variability and mid-water or demersal fish recruitment.

Measurement	China	Korea	Japan	Russia JSES	Russia SO	Russia WB	USA BS	USA GOA	USA CCS	Canada
Phyto. dist. and abund.	F/S/M?	F/S/M?	F/S/M	F/M	F	F/S	F/S/M	F/S/M	F/S/M	F/S/M
Phyto. sust. avail.	?	F/B	F/B	F	F		F/B	F/B	F/B	F/B
Large scale advection	CM/X	CM/TN/R/X	CM/TN/R/X	CM/TN/R/X	CM/TN/R/X	CM/TN/R/X	CM/TN/R/X/D	CM/TN/R/X/D	CM/TN/R/X/D	CM/TN/R/X/D
Meso scale advection	CM/X	CM/TN/R/X	CM/TN/R/X	CM/TN/R/X	CM/TN/R/X	CM/TN/R/X	CM/TN/R/X/D	CM/TN/R/X/D	CM/TN/R/X/D	CM/TN/R/X/D
Zoop. size fraction	F/M/A/CPR	F/M/A/CPR/OPC	F/M	F/M	F/M	F	F/M/A	F/M/A	F/M/A/OPC	F/M/A
Zoop. dist. abund.	F/M	F/M	F/M	F/M	F/M	F	F/M	F/M	F/M	
Zoop. species comp.	F	F	F	F	F	F	F	F	F	F
Zoop. production	F/M	F/M	F/M	F/M	F/M	F/M	FM	F/M	F/M	F/M
Ichthyoplankton data	Fo/G	Fo/Fd/G	Fo/G/FH	Fo/Fd/G/FH	Fo/Fd/G/FH	Fo/Fd/G/FH	Fo/Fd/G/FH	Fo/Fd/G/FH	Fo/Fd/G/FH	Fo/Fd/G/FH

Legend: JSES = Japan Sea East Sea; SO = Sea of Okhotsk; WB = Western Bering Sea; BS = Bering Sea; GOA = Gulf of Alaska; CCS = California Current System. Phyto. = phytoplankton; dist. = distribution; abund. = abundance; Sust. = Sustained; Zoop. = zooplankton. F = Field sampling; S = satellite data; M = model; B = buoy; CM = coupled bio-physical models; TN = transport of nutrients; R = retrospective study; X = hydrocasts; D = Drifter; A = acoustics; CPR = continuous plankton recorder; OPC = optical plankton counter; Fo = oblique sampling; Fd = depth stratified sampling; G = growth rate; FH = food habits.

Table 2. Summary of availability of information pre and post 1997 regime shift.

Measurement	China	Korea	Japan	Russia JSES	Russia SO	Russia WB	USA BS	USA GOA	USA CCS	Canada
Phyto. dist. and abund.	Pre-regime	Starts in 1994	Starts in 1990	Starts in 1980s	Starts in 1980s	Unknown	Pre-regime	Starts in 1980s	Pre-regime	Pre-regime
Large scale advection	Unknown	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime
Storm frequency	Unknown	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime
Water column properties	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime
Zoop. Distribution							Unknown		Pre-regime	Pre-regime
Zoop. Size.									Pre-regime	Pre-regime
Zoop. species comp.									Pre-regime	Pre-regime
Recruitment indices	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime
Adult fish distributions	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime
Adult fish growth	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime	Pre-regime
Ichthyoplankton data									Pre-regime	

Legend: Pre-regime = data prior to 1977 regime shift.

CRUSTACEAN BREAKOUT SESSION

PARTICIPANTS: Robert S. Otto (WG 12 Co-Chairman, Discussion leader), Tsutomu Ikeda (BIO), David L. Mackas (BIO), Ian Perry (CCCC), Naonobu Shiga, Akira Taniguchi (BIO), Atsushi Tsuda (BIO), Sung-Yun Hong (BIO, WG 8 & 12), In-Ja Yeon (WG 12), Ling Tong (TCODE) and Rong Wang (BIO).

Introduction

Breakout Group C (crustaceans) met during the afternoon of October 17 to identify potential areas for research under the CCCC Program. In so doing the group reviewed some results of the Working Group 12 (Crabs and Shrimps) interim meeting. This provided a means to quickly identify stocks of crabs and shrimps in the PICES region and to review trends in abundance.

The group noted that crustacean issues would involve a great deal more than crabs and shrimps, particularly various planktonic groups as well as numerous benthic crustaceans for which there was little information. Discussions emphasized crabs and shrimps realizing that any planktonic crustaceans would be discussed in the context of breakout sessions for Lower Trophic Level Response and for Ecosystem Response.

Hypotheses

The group reviewed the four key CCCC questions relative to crustaceans by considering trends in crab and shrimp stocks in each zoogeographic province and discussing hypotheses that might be considered, or potential areas for experimentation.

1. There appears to be no particular climatic or oceanographic patterns that are unique to crustaceans as opposed to finfish, further the same zoogeographic regions that have been differentiated for finfish are largely applicable, at least, to macrobenthic crustaceans. These correspond well with the 10 PICES-GLOBEC CCCC Program Components and seem to derive from large-scale oceanographic features. It is noted however that these zoogeographic provinces may change with increasing depths.

   The group noted also that there were intraspecific as well as interspecific differences in life history mechanisms that related to these regions and hence may provide natural clines or dichotomies that could be exploited for experiments. For example, in some regions euphausids may be highly seasonal in their reproduction while in others they may have protracted or aseasonal spawning. Experimentation might deal with contrasting growth and mortality between such regions.

2. Primary and secondary production in planktonic communities are translated to meroplanktonic larval stages of macrobenthic crustaceans and may be related to year-class strength through match-mis-masmatch mechanisms relating to the timing of phytoplankton blooms relative to larval release. Detritus from upper levels feeds into secondary production of benthic infauna that serve as primary food sources for crabs and shrimps as well as other epibenthic fauna. Also, many shrimps make nocturnal vertical migrations in order to feed on zooplankton.

   Physical properties of the bottom and ecological relationships within the benthos have probably not been considered very heavily in CCCC deliberations but are inescapably important relative to crabs and shrimps and other benthic crustaceans.

   The group notes that crabs and shrimps are much less mobile than finfish and hypothetically less able to adjust their times and places of spawning relative to productivity or other conditions in the euphotic zone that might affect larval survival. Hypothetically this could lead to greater variability in recruitment for crabs and shrimps as opposed to finfishes.

3. Climatic variability may affect crustacean populations directly through recruitment

processes as noted above. In much of the Gulf of Alaska and eastern Bering Sea, effects may have been mediated through predation. For example the regime shift that occurred in the late 1970s produced strong year classes of several groundfishes which in turn may have resulted in decreased shrimp abundance through predation and or competition.

Because many of the region's groundfish are long lived, there is a certain inertia in species dominance within a region. A regime shift may result from short-term climatic or oceano-graphic phenomena, but produce long-term ecological effects.

4. Top down versus bottom up control of species composition and relative abundance is likely very different between pelagic and benthic crustacean habitats.

   Most crabs and shrimps in the region have relatively long larval periods (as much as 90 days) during which they are meroplankton. It is not clear how meroplankton might be controlled or influenced by the holoplankton community through competition or predation. Interactions between the two groups certainly provide a broad topic of research and experimentation.

   Hypothetically, if both meroplankton and phytoplankton abundance were controlled by the dynamics of primary productivity then there may be a way to use information on primary productivity to model year-class success through the larval phases.

   Bottom up control may involve the rate of transfer of primary productivity to the bottom as detritus. One hypothesis is that warmer conditions are conducive to greater zooplankton abundance or diversity and greater respiration in the upper water column. Since more energy would be consumed in upper layers less could become available to lower layers or the bottom where detritus may be consumed by filter feeders that in turn become food for macrobenthic crustaceans.

   Top down control through predation occurs when changes in finfish biomass result in increases or decreases in crab and shrimp biomass. The same might be said of certain marine mammals. For example, bay populations of Dungeness crab may be controlled by sea otter predation.

Stocks and research approaches and opportunities for experimentation

Crabs

Dungeness Crab (*Cancer magister*) have cyclic populations north of central California, with peaks and troughs every 8-10 years. Landings 1970-1996: minimum 5,000 t (1974) to maximum of 26,000 t (1977). A collapse of central California stock occurred 1956-1970 with little recovery since. British Columbia landings are more consistent from year to year and do not display cyclic patterns observed in California to Washington fisheries. Alaskan landings are not in synchrony with contiguous 48 states of the U.S. or with Canada and landings may be market driven over some portions of the historical series. Since patterns differ between zoogeographic provinces, comparative studies may provide insight into mechanisms of population control.

Hypothesized environmental and ecological effects include elevated temperatures, nemertean worm predation on clutches, salmon predation on larvae, and various cyclic phenomena (cannibalism, upwelling, wind stress, geostrophic flow, fishing effort). Habitat and fishing impacts that effect stocks include dredging to maintain navigation channels and for landfills, foreign species introductions (i.e. green crab, *Carcinus maenus*, competition with Dungeness), ghost pot fishing and fishery handling of sublegal males and females. Fishery selects the largest males and there is the possibility of females not getting bred.

The list of factors used to explain changes in Dungeness crab populations is a fair sampling of factors that are thought to control crab populations in general. Additionally, predation on adults, parasitism and epizootic diseases are known to be

important in a number of king and Tanner crab populations.

Four species of king crabs are subjects of major fisheries in the PICES region. They differ in there life history characteristics and hence provide for comparative study of the effects of life history characteristics on population stability. For example, red king crab (*Paralithodes camtschaticus*) are annual spawners with relatively high fecundity and small eggs, while blue King crab (*P. platypus*) are biennial spawners with lesser fecundity and somewhat larger eggs. Both species inhabit the Pribilof Islands and other areas where their dynamics may be explored. Throughout most of the Gulf of Alaska and eastern Aleutians, red king crab populations declined in phase from the late 1970s until fisheries were closed in 1983. Populations have been at low levels and fisheries have remained closed since 1983. Populations declines soon after the well recognized regime shift of the late 1970's and offer opportunities for retrospective study as well as comparative study with Asian populations that have differing patterns of abundance over time. Comparative study of Bristol Bay and west Kamchatkan populations may be particularly instructive.

Tanner and snow crabs have broad distributions across several zoogeographic provinces and provide opportunities similar to those for king crabs.

The gazami crab (*Portunus trituburculatus*) provides the largest crab fishery in the PICES area. It is found in the Yellow and East China Sea in close association with peneid shrimps. This part of the PICES area has a more tropical fauna than the remainder of the region and provides an opportunity to compare the dynamics of crustaceans from temperate or boreal areas with tropical forms. The two faunal groups are separated only by the Korean Peninsula and hence provide a unique opportunity to study comparative effects of climatic variables.

Shrimps

Pandalid shrimps are protandric hermaphrodites and larger, older individuals that support fisheries are mostly mature females. Two species dominated trawl fisheries. Ocean pink shrimp, *P. borealis*, are distributed from northern California to British Columbia and northern pink shrimp, *P. borealis*, are distributed from British Columbia to the Bering sea. Alaskan trawl fisheries also included *P. goniurus*, *P. hypsinotus, P. platyceros* and *Pandalopsis dispar*.

Pandalid shrimp populations and fisheries in Alaska collapsed in the late 1970's and most fisheries remain closed. Very small trawl fisheries for side striped shrimp, *Pandalopsis dispar*, and pot fisheries for spot prawns, *P. platyceros*, still persist in some areas. Spot prawns also are an economically important fishery in British Columbia. The collapse of the pandalid shrimp complex in Alaska was concurrent with the late 1970's regime shift and a sharp increase in predator populations, particularly Pacific cod (*Gadus macrocephalus*) populations. Landings of ocean pink shrimp also declined sharply in the late 1970s and reached their lowest levels in 1983, but in contrast with northern pandalid shrimps, have increased since. Landings of *P. jordani* have undergone two cycles between 1970 and 1995. The recovery of *P. jordani* contrasts sharply with pandalids to the north and is a good topic for retrospective study. Pandalid shrimps occur in the western Bering Sea and in the Sea of Japan as far west as Korea providing additional possibilities.

Four species of penaeid shrimps are important in the Yellow Sea. Peneid shrimps differ from pandalids in that the are not hermaphroditic, are semilparous rather than multiparous and are short lived. Most species complete their life spans in less than two years and frequently within one year, while pandalid shrimps typically live for at least three years and frequently for 7-8 years in northern populations.

There are two stocks of the fleshy prawn, *P. chinensis*, in the Yellow Sea. The Pho Hai Bay stock in Chinese waters and the Korean coastal group both hibernate in the southern Yellow Sea during February and March but return their coastal spawning grounds in spring. The Korean coastal stock spawns April to June, and is fished from September through April. This stock provided the bulk of the Korean shrimp catch during the years 1987 to 1996. Other important peneid species (*P. japonicus*, *Metapenaeus joyneri*, *Trachypenaeus*

curvirostris) differ considerably in their life history patterns and offer opportunities for comparative studies of environmental effects on recruitment. A joint Korean-Chinese study of stock recruitment relationships in the Yellow Sea is being planned. This study would likely be profitable and has the advantages of occurring in a well defined semi enclosed body of water, and with short lived species for which results of comparative studies or experiments become available quickly.

Recommendations

1. Crusteaceans exhibit intraspecific and interspecific differences in life history traits that may be related to the characteristics of regional habitats. Compare reproductive, growth and mortality rates between region.

2. Conduct inter-regional studies of the coupling between primary and secondary production and survival of meroplanktonic larval stages and benthic prey production for macrobenthic stages.
3. In some regions, declines in crab or shrimp abundance coincide with outbursts of fish predators. Conduct inter-regional comparisons of the level of predation mortality.

4. Conduct retrospective studies of the response of Bristol Bay and west Kamchatkan populations of red King Crab to the late 1970s regime shift.

5. Pandalid shimp population trends in the Gulf of Alaska and the U.S. west coast contrast sharply and represent good candidates for a retrospective studies of bio-physical impacts on population trends.

6. There are two stocks of prawn (*P. chinensis*) in the Yellow Sea. The timing of spawning differs between these two populations providing an opportunity to evaluate spawner recruit relationships in a well defined semi-enclosed body of water.

PELAGIC FISH BREAKOUT GROUP RECOMMENDATIONS

Participants: Takashige Sugimoto (Chairman), Kenji Asano, Kimio Hanawa, Paul Harrison, Suam Kim, Jin-Yeong Kim, Michael M. Mullin (Rapporteur), Vladimir I. Radchenko, Tokio Wada.

Introduction

The discussion of this group focussed on the response of population dynamics of small pelagic fish to climate change. After reviewing the present research activities on small pelagic fish in each PICES member countries, the group examined on potential comparative studies among areas and species. The group also discussed on possible research collaboration between the member countries and new approaches we should conduct in the future studies, and provided following recommendations.

Response to climate variability

Based on discussions, it seems likely that species or groups of species of small pelagics in different regions may respond to climate change in different ways. For example, it seems that the typical pattern in the Bering Sea/ Alaska Gyre is for the abundance of several species to change in parallel (i.e. several are abundant, or rare, in the same years). In contrast, in the eastern and western boundary currents, alternation of abundance between species appears to be more typical.

The International GLOBEC Small Pelagics and Carrying Capacity (SPACC) program has initiated efforts to collect and analyze common data sets concerning the responses of sardine and anchovy (particularly) to climate change or regime shifts.

Recommendations

1. The GLOBEC SPACC efforts focusing on sardine and anchovy should be extended to include other pelagic species.

2. That comparable efforts be made to collect data on North Pacific herring and other Bering Sea / Alaska Gyre small pelagic species, together with the supporting environmental data.

3. Step b) should be followed by a larger meeting to compare the Bering Sea / Alaska Gyre and "boundary current" patterns in interannual - interdecadal variability, with supporting environmental data. This should however, be preceded by agreement on common (i.e. mutual) forms of data presentation and analysis.

4. It should be noted that the common squid could be considered a small pelagic species, but one with a different biology than finfish.

Importance of the East China Sea as a spawning ground

We understand that assessment of spawning by small pelagic species in the East China Sea is not well monitored at present, and that this area is also an important spawning ground for the common squid.

Therefore, we encourage the development of a China-Japan-Korea program of assessment of spawning (i.e. egg and larval surveys, plus environmental data) by small pelagics in the East China Sea and downstream regions of the currents for several years. Survey design should be by mutual agreement, and sampling should include techniques to assess common squid.

Needs of physiological studies

Many investigations have now shown that information on rate of growth and physiological health ("condition factor") of larvae can add greatly to information on abundance and distribution in evaluating possible environmental causes of recruitment success or failure. Yet, routine preservation of samples in formalin makes them useless for many kinds of analyses.
Therefore, we recommend that egg and larval surveys by PICES nations include samples of larvae preserved in alcohol and others quick-frozen, in

addition to formalin preservation. This will permit later studies of growth, date of birth, lipid content, RNA/DNA, etc. Such additional preservation need not be done at all stations sampled, but should at minimum be done at a subset of stations chosen to represent the complete range of environmental conditions at which larvae are encountered during a cruise. Curation of such samples, and information on their availability to qualified scientists, should be considered part of each program's responsibilities.

SALMON BREAKOUT SESSION

Participants: Richard J. Beamish, Michael L. Dahlberg, Kenneth L. Denman, Bruce Frost, Brent Hargreaves (Chairman), Paul H. LeBlond (Rapporteur), Kazuya Nagasawa, Makoto Terazaki

Introduction

The discussion in this group focused on the influence of climate change on salmon within coastal areas. After reviewing the salmon research programs familiar to participants which are currently being conducted or planned by PICES member countries, the following hypotheses were identified as suitable for comparative studies and experiments.

Hypotheses

H1: The abundance of wild populations of pink, chum and sockeye salmon are not related to fisheries, as they are now managed.

H2: During periods of declining marine survival, hatchery salmon (which usually are larger than wild salmon when they enter the ocean) will gradually out compete and displace wild stocks.

H3: Wild salmon populations are significantly influenced, in terms of growth and survival, by climate variability.

H4: Ocean survival rates of salmon populations are determined by feeding conditions which they encounter during the first few months after entering the ocean.

Potential comparative studies

The following topics were identified as important areas for comparative study and experiments on salmon:

1. A particularly fruitful and appropriate area for comparative studies was thought to be the influence of ocean environment on feeding (and ultimately survival) conditions at the time of entry of salmon into the ocean and during the early stages of oceanic life.

2. Standardization of sampling gear, data collection protocols, and data analyses and presentation. If the results of the observation programs on salmon survival, growth and migration routes and migration timing in coastal areas are to be compared and contrasted, there needs to be some compatibility and consistency in the way in which samples and data are gathered, analyzed and interpreted. It is recommended that the methods used to gather salmon, zooplankton and physical oceanographic data in coastal waters should be reviewed, discussed and agreed upon.

3. Investigation and determination of the most effective and relevant scales of sampling. Under-sampling, in time or space, leads to aliasing and misinterpretation. Studies should be conducted to determine sampling scales required to describe the abundances and distributions of salmon and their food sources in coastal areas. It was noted, in particular, that sampling of juvenile salmon and associated zooplankton should be capable of documenting shifts in species and size composition which likely accompany both longer-term (e.g. decadal) and shorter-term (e.g. El Niño) changes in ocean climate.

4. Further monitoring and process studies to determine the reasons for the contrast in high return rates of hatchery chum salmon on the Pacific Ocean side of Japan, compared with the low return rates of hatchery chum on the Japan (East) Sea side of northern Japan. Documentation of food and habitat conditions on both coasts of Japan may be useful in explaining the observed consistent difference in return rate. Since salmon from both areas likely share the same rearing areas in the open Pacific, differences must arise in coastal areas, during the early sea stages.

5. Identification of the factors in coastal waters that contribute to the typically high interannual variability of survival (return) rates of wild and hatchery salmon originating in the eastern North Pacific, with the relatively constant return rate (3-4%) of Japanese hatchery chum salmon originating in the western Pacific.

6. Examination of the out-of-phase relationship between environmental variations and survival in Alaska and southern B.C., Washington and Oregon salmon stocks. A recent hypothesis by Gargett (1997: Fish. Oceanogr. 6:2, 109-117) that phytoplankton, and hence subsequently the higher trophic levels, may react to interannual variations of atmospheric forcing through the position of an "optimal stability window" deserves further examination as an explanation of the out-of-phase relationship.

7. Process studies, aimed at clarifying specific mechanisms relating to the interaction between climate or the biological environment and salmon growth and survival, may be instructive.

8. Comparative studies of the early marine survival of salmon in near shore waters of northern Japan, Russia (Kamchatka), and North America.

9. Comparative studies of the methods used to identify juvenile salmon stocks in coastal waters.

10. Comparisons of the food compositions of each species of salmon at age in coastal waters.

Some Problems and Opportunities

1. "Sleeping samples and data" ... many samples (e.g. zooplankton) and data sets are currently in archives only and have not been either analyzed or published. These data sources are potentially valuable, but necessary resources (especially manpower) in some cases are not available to make this information available.

2. Standardization of methods for sampling and data analyses.

3. Need to separate scientific questions and analyses by production type (wild versus hatchery) and species groupings (e.g. processes of feeding, survival, etc. are likely different for chinook and coho, chum, sockeye and pink salmon).

FORCING BREAKOUT SESSION

Chairman: Paul H. LeBlond; Rapporteur: Steve Hare

The discussion focussed on sampling of the environmental variables seen as important forcing components of the ecosystem. The following points were identified as being relevant and of interest to REX programs.

Sampling issues

1.1 As a general principle, sampling resolution in space and time must be adapted to the phenomena investigated. Sampling which is too coarse misses important phenomena and leads to misinterpretation; too frequent sampling is a waste of effort.

1.2 Many phenomena occur at different times from year to year; a sampling program at fixed calendar dates may miss the phenomena of interest. In such cases, intensive sampling should bracket the range of variability in timing or be adapted to the beginning of the phenomenon of interest by recognizing early signals - spawning, for example, or start of migration - which then trigger the sampling program.

1.3. Plankton distributions are heterogeneous in space; concentrations are found in physically active areas - fronts, upwelling zones - sampling protocols should recognize this fact.

Data requirements.

2.1 The lack of information on ocean bottom properties (e.g. temperature and salinity) makes it difficult to study demersal creatures.

2.2 Advection is extremely important at all trophic levels. There is a need for better information on ocean currents. TOPEX/POSEIDON satellite altimetry, now available over the internet, may help in this respect.

Processes

3.1. On-off shelf. Physical phenomena relevant in nutrient fluxes and concentrating organisms differ on and off shelf. Need to recognize these differences in experimental design and sampling.

3.2 Shelf break phenomena (internal wave generation, upwelling, canyon flows) are locally important and must be taken into account.

3.3 Land-based processes may be quite relevant and cause regional regime shifts - the Three Gorges Dam was mentioned as a potential example of a change in runoff which may affect ocean ecosystem near the mouth of the Yellow River.

3.4 Clarification required on relative roles of processes which determine upward nutrient flux in the coastal and deep ocean.

Long-term variability

Regime shifts

There remains some concern that changes labeled "regime shifts" may be artifact of data interpretation rather than an actual qualitative changes in ocean properties and circulation. There is a need to document further the details of the changes between regimes. In particular, how do regime shifts differ in coastal areas on both sides of the Pacific?

- Do strong El Niños, such as the current one, bring on regime shifts?

- Since regime shifts are long period phenomena, recognized a posteriori within larger annual and shorter-period noise, there is little hope of recognizing them as they happen unless some rapid step-like change can be recognized. It was suggested that some biological feature might be more apt for this than some physical property.

Twenty years ago, El Niño was unpredictable. Now we have six-month forecasts. Will this also happen to the lower frequency variability which we now call regime shifts?

Anthropogenic changes :

Are anthorpogenic changes confounded with natural environmental changes? How do we separate them?

LOWER TROPHIC LEVEL BREAKOUT SESSION

Participants: Tsutomu Ikeda (Chairman), Paul Harrison, David Welch, Bruce Frost, Vladimir I. Radchenko, David L. Mackas, Xian-Shi Jin, Muneharu Tokimura, Naonobu Shiga, Atsushi Tsuda, Toshiro Saino, Vera Alexander, Michael M. Mullin.

Review of key scientific questions (inventory of long-term data)

Presently available information about long-term variation of phytoplankton and zooplankton biomass in response to climate change was largely from subarctic waters. Russia scientists have been collecting data in the Okhotosk Sea, Japan Sea, eastern-western Bering Sea, but these data have not been published in English. *Oshoro Maru* cruises have sampled both the oceanic subarctic Pacific and coastal waters of Hokkaido since the late 1950s. Some limited time-series data are available from the Yellow Sea, Bohai Sea and East China Sea.

For zooplankton, long-term variation data of species level, not biomass, are available from the following locations: Station P (intermittent since 1970), northern Gulf of Alaska, off California (portions of CalCOFI time series), and both western and eastern Bering Sea. The *Oshoro Maru* zooplankton samples are in the process of being analyzed for species composition.

Data on phytoplankton species composition have been collected in the following locations: off Vancouver Island since the late 1970s, in parts of the California Current since 1949, and in the eastern and western Bering Sea in the 1990s.

It was suggested that size-fractionation may be an alternative method for species composition analysis.

Long-term variation data on microzooplankton have been collected at Station P, Line P off Canada and in the Gulf of Alaska (primarily since early 1990).

Hypotheses to be tested

1. Bottom-up/top-down control and its temporal scales (bottom-up control may be more influential than top-down control on the decadal time scale).

2. If bottom-up control is important, the dominant mechanism is:
   a) co-variation of total annual productivity of both prey and predator, or
   b) variation in seasonal match-mis-match of productivity / occurrence of predator and prey.

Comparative approach

1. Area: Eastern vs. Western Bering Sea
   Eastern vs. Western Gyre of subarctic

2. Species/Nutrients:
   Micronutrients (iron)
   Euphausia pacifica
   Phytoplankton, zooplankton community structure
   Life history pattern
   Predatory zooplankton (Chaetognaths)
   Coastal calanoid copepods in continental margins
   Neocalanus spp. in oceanic gyres and deep coastal margins.

Research barriers

Sampling methodology:

"Method inter-calibration" may be more feasible that "method standardization" for several reasons:

- maintaining continuity of local time series,
- differing requirements of different regions e.g. greenwater vs. blue water limits on mesh size,
- cost and vessel restrictions on changing gear type,
- differing requirements for different taxa. It will probably be necessary to use multiple gears to gain unbiased results over the full zooplankton size and species range.

ECOSYSTEM RESPONSE BREAKOUT SESSION

Participants: Patricia Livingston (Chairman), James Cowen, Kenneth L. Denman, Douglas E. Hay, Anne B. Hollowed, Shin-ichi Ito, Ling Tong, Allen Macklin, Sandy McFarlane, Kazuya Nagasawa, Vadim V. Navrotsky, Ian Perry, Qi-Sheng Tang, Tokio Wada, Warren S. Wooster.

PICES CCCC key question

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?

Related key questions

1. What in an ecosystem can change in response to temperature?

2. How do you distinguish between fishing effects vs. climate effects?

3. If higher trophic levels change, this provides evidence that the ecosystem has shifted – but what provides an indicator of a shift in progress?

4. How long does it take for a shift to occur?

5. Were there indicators of the shift prior to the final ecosystem pattern?

6. Can we forecast where the ecosystem is going? If so, what are the leading indicators of change?

7. Have there been changes in total productivity of the system (i.e. a shift in the carrying capacity)?

8. If ecosystems are in a constant state of flux, how do we distinguish between normal fluctuations around one equilibrium state and a shift to a new equilibrium state?

9. What is the spatial and temporal scale of physical forcing (e.g. fronts, wind fields, etc occur on many spatial scales)?

10. What are the food web flows between boxes? What does the trophic structure look like?

11. Are all North Pacific ecosystems equally sensitive to climate change?

Clearly the underlying mechanisms are critical to our ability to understand and to forecast. We need to know are there changes in species dominance (the structure of the ecosystem), plus changes in systems productivity - are there large fluctuations in either or both? This type of study must also incorporate studies of important processes at appropriate spatial and temporal scales of change.

Ecosystem hypotheses:

H1: Climate change introduces instability into the ecosystem Corollary: "Ecosystem changes in response to climate change are likely to be more dramatic at the boundaries of the system.

H2: Total system biomass remains constant through regime shifts.

H3: Changes in upper trophic level species dominance are due to changes in the prey base.

H4: Changes in upper trophic level species dominance are due to changes in spawning range.

H5: Changes in upper trophic level species dominance are due to fishing pressure.

H6: Ecosystems in the North Pacific are similar in structure and respond similarly to climate change.

Data requirements

The ecosystem response could be monitored using the following indices:

- Species composition
- Size structure
- Food web structures and productivity at different trophic levels
- Number of links in food webs
- Dominant species
- Fish catch composition and amount
- Change in distribution and abundance of higher trophic levels

Data requirements to address ecosystem questions:

a) Forcing:
   - Measurements of physical forcing at the appropriate spatial and temporal scales

b) Lower trophic level response:
   - Phytoplankton abundance, production and species composition
   - Planktivore (e.g. zooplankton) abundance, production, consumption rates, diet, species composition

c) Higher trophic level response:
   - Upper trophic level species abundance, production, consumption rates, diet, species composition

Recommended comparative studies

1. Compare the role of walleye pollock in the Japan Sea and Bering Sea ecosystem. Contrasting the role of walleye pollock in these two regimes could reveal important differences because the trophic linkages and production systems are likely to be different.

2. Study shifts in species dominance in different regions (e.g. competition between pollock and other species or between sardine and anchovy).

3. Compare factors influencing the distribution and survival of anadromous species because the spatial extent of the response suggests basin forcing.

4. Compare the timing and spatial extent of changes in spawning distributions, and habitat boundaries.

5. Compare or develop conceptual models that have been developed by different groups for the same (or overlapping) regions. One way to accomplish this goal would be to attempt to construct ECOPATH/ECOSIM models for each of the 10 regions. Primary and secondary production was not collected before the regime shift in many regions. However, the amount of primary and secondary production needed to balance the system could be estimated if information on upper trophic level species before and after a regime shift was available.

6. Develop ecosystem level models - coupled models looking at bottom-up and top-down processes. Fully coupled models linked to upper trophic level species is a goal but may not be a fully achievable one in the near future.

7. Compare systems with very different physical forcings and ask what level do physical forcings affect the outcome of ecosystem structure?

8. Coordinate process oriented research ongoing in PICES member nations. This may be an area that could be first initiated with a symposium on the research being performed by the GLOBEC and GLOBEC-like programs of the North Pacific.

SUMMARY OF ONGOING RESEARCH PROGRAMS BY REGION

General Environmental Data Sets: U.S.A.

Program: Gulf of Alaska Temperature/Salinity Time Series
Agency: University of Alaska
Central Scientific Issues: Forcing
Key Research Activities: Observation studies
Funding: Funded
Start time: 1970
Contact: Institute of Marine Science
University of Alaka
Fairbanks AK 99775-7220
U.S.A
http://www.ims.alaska.edu:8000/gak1/

Program: National Snow and Ice Data Center
Agency: NSF Global Change Program
Central Scientific Issues: Forcing
Key Research Activities: Observation studies
Funding: Funded
Start time: on-going
http://www-nsidc.colorado.edu/nsidc/ services.html

Program: Coastwatch Satellite Ocean Remote Sensing, California Current
Agency: National Oceanic and Atmospheric Administration
Central Scientific Issues: Forcing, LTL
Key Research Activities: Observation studies
Funding: Funded
Start Time: On-going
Contact: Operations Manager
Coastwatch West Coast Regional Node
Southwest Fisheries Science Center
P.O. Box 271
La Jolla, CA 92038
U.S.A.
http://psbsgi1.nesdis.noaa.gov:8080/hsors.htm

Program: Comprehensive Ocean Atmosphere Data Set
Agency: National Center for Atmospheric Research
Central Scientific Issues: Forcing
Key Research Activities: Observation studies
Funding: Funded
Start Time: 1946 - present
Contact: Steve Worley
Data Support Section
National Center for Atmospheric Research
P.O. Box 3000
Boulder, CO 80307
U.S.A.
303-497-1248
http://www.cdc.noaa.gov/~coads/

Program: Coastwatch Satellite Ocean Remote Sensing, Alaska
Agency: National Oceanic and Atmospheric Administration
Central Scientific Issues: Forcing, LTL
Key Research Activities: Observation studies
Funding: Funded
Start Time: On-going
Contact: Robert Robinson
Coastwatch Manager
National Weather Service- Alaska Region
222 W. 7th Ave. #23 Rm. 517
Anchorage, AK 99513-7575
U.S.A.
http://psbsgi1.nesdis.noaa.gov:8080/hsors.htm

Caifornia Current System South: U.S.A.

Program: Small Pelagic Fishes and Climate Change (SPACC)
Agency: International GLOBEC
Central Scientific Issues: Forcing, LTL, HTL Ecosystem interactions
Key Research Activities: Retrospective, modeling, Process, Observation studies
Funding:Some proposed, some funded
Start Time: on-going
Contact: John R. Hunter
Southwest Fisheries Science Center
PO Box 271, La Jolla, California 92038
U.S.A.
e-mail: john.hunter@noaa.gov

Program: Pacific Fisheries Environmental Group (PFEG), Southwest Fisheries Science Center (SWFSC)
Agency: National Marine Fisheries Service, NOAA

Central Scientific Issues: Forcing, HTL
Research Activities: Retrospective, modeling
Funding: Funded
Start Time: on-going
Contact: Geroge Boehlert
Southwest Fisheries Science Center
Pacific Fisheries Environmental Group
P.O. Box 831
Montery, CA 93942
U.S.A.
http://swfsc.ucsd.edu/swfscpg.html

Program: Southwest Fisheries Science Center (SWFSC)
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: Forcing, HTL, Ecosystem interactions
Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start Time: on-going
Contact: Michael Tillman
Southwest Fisheries Science Center
P.O. Box 271
La Jolla, CA 92038
U.S.A.
http://swfsc.ucsd.edu/

Program: Southwest Fisheries Science Center (SWFSC), Tiburon Laboratory
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start Time: on-going
Contact: Alce MacCall
Southwest Fisheries Science Center
3150 Paradise Drive
Tiburon, CA 94920
U.S.A.
http://swfsc.ucsd.edu/swfsctb.html

Program: California Cooperative Oceanic and Fisheries Investigations (CalCOFI)
Agency: Shared by three institutions: Scripps Institution of Oceanography, California Department of Fish and Game, National Marine Fisheries Service
Central Scientific Issues: Forcing, LTL
Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start Time: on-going
Contact: Tom Hayward or Michael Mullin
Scripps Institution of Oceanography
Marine Life Research Group
La Jolla, CA 92093-0227
U.S.A.
e-mail: mmullin@coast.ucsd.edu

Program: University of Santa Barbara Marine Science Institute
Agency: University of California Santa Barbara
Central Scientific Issues: Forcing, LTL
Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start Time: on-going
Contact: Steven Gaines
University of California, Santa Barbara
Santa Barbara, CA 93106-6150
U.S.A.
E-mail: gaines@lifesci.ucsb.edu

Program: Point Reyes Bird Observatory
Central Scientific Issues: HTL
Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start Time: on-going
Contact:
4990 Shoreline Highway
Stinson Beach, CA 94970
U.S.A.
e-mail: prbo@prbo.org
http://www.igc.apc.org/prbo/

Program: California Department of Fish and Game
Central Scientific Issues: HTL
Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start Time: On-going
Contact: Doyle Hanan
8604 La Jolla Shores Drive
La Jolla, CA 92037-1508
U.S.A.

e-mail: dhanan@ucsd.edu
http://www.dfg.ca.gov/dfghome.html

Program: Monterey Bay Aquarium Research Institute (MBARI)
Central Scientific Issues: Forcing, LTL
Research Activities: Process, observation studies
Funding: Funded
Start time: on-going
Contact: MBARI
P.O. Box 628,
Moss Landing, CA 95039-0628
http://www.monterey.edu/history/mabari.html

California Current North: U.S.A.

Program: CoOP Project
Agency: National Science Foundation, NSF
Central Scientific Issues: Forcing, LTL
Key Research Activities: Modeling, observation studies, process studies, retrospective studies
Funding: Funded
Start time: On-going
Contact: Michael R. Roman
Horn Point Environmental Laboratory
2020 Horn Point Road
Cambridge, MD 21613
U.S.A.
http://www.hpl.umces.edu/coop/index.htm

Program: Northwest Fisheries Science Center (NWFSC)
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, process studies, retrospective studies
Funding: Funded
Start time: On-going
Contact: Usha Varanasi, Director
Northwest Fisheries Science Center
2725 Montlake Blvd.
Seattle, WA 98112-2097
U.S.A.
http://research.nwfsc.noaa.gov

Program: Alaska Fisheries Science Center (AFSC)
Agency: ational Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, process studies, retrospective studies
Funding: Funded
Start time: On-going
Contact: James Balsiger, Director
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle, WA 98115
U.S.A.
http:/www.wrc.noaa.gov/afsc/home.html

Program: Pacific Northwest Coastal Ecosystem Regional Study (PNCERS)
Agency: Coastal Ocean Program, NOAA
Central Scientific Issues: Forcing, LTL, HTL, ecosystem interactions
Research Activities: Retrospective, modeling, process studies, observation studies
Funding: Funded
Start Time: 1997
Contact: Gregory McMurray
Department of Environmental Quality
811 SW 6th Ave
Portland, OR 97204
U.S.A.
e-mail: gregory.mcmurray@state.or.us
http://seagrant.orst.edu/~pncers

Program: U.S. GLOBEC
Agency: U.S. GLOBEC Steering Committee - funding by: National Science Foundation/ National Oceanic and Atmospheric Administration
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interacitions
Key Research Activities: Retrospective, modeling, Process, Observation studies
Funding: Funded for retrospective studies, modeling and observation studies.
Start Time: 1997
Contact: Michael Fogarty
Chairman, U.S. GLOBEC Scientific Steering Committee
University of Maryland
Center for Environmental Science
Chesapeake Biological Laboratory
Solomons, MD, 20688-0038
U.S.A.
http://www.usglobec.berkeley.edu/usglobec/

Program: International North Pacific Halibut Commission (INPHC)
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, retrospective studies, process studies
Funding: Funded
Start time: On-going
Contact: Bruce Leaman, Director
International Pacific Halibut Commission
P.O. Box 95009
Seattle, WA 98145
U.S.A.
http://www.iphc.washington.edu:80/

Program: Integrated Assessment of Climate Change, Climate Change Impacts, and Policy Response Strategies of the Pacific Northwest
Agency: NOAA Office of Global Programs
Central Scientific Issues: forcing, HTL, ecosystem studies
Key Research Activities: retrospective, modeling
Funding: Funded
Start time: 1995
Contact: Nate Mantua
Box 354235
University of Washington
Seattle, WA 98195
e-mail: mantua@atmos.washington.edu
http://www.atmos.washington.edu/~mantua/impacts/project.html

California Current North: Canada

Program: GLOBEC Canada
Agency: National Science and Engineering Research Council (NSERC) and Department of Fisheries and Oceans (DFO)
Central Scientific Issues: Response of marine ecosystems to ocean climate variability
Funding: funded
Start time: July 1996
Contact: David Mackas
Institute of Ocean Sciences
Sidney, British Columbia
Canada
MackasD@dfo-mpo.gc.ca

Southeast, Central Alaska:

Program: Alaska Fisheries Science Center (AFSC)
Agency: National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, retrospective studies, process studies
Funding: Funded
Start time: On-going
Contact: James Balsiger, Director
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle, WA 98115
U.S.A.
http:/www.wrc.noaa.gov/afsc/home.html

Program: Alaska Fisheries Science Center (AFSC), Ocean Carrying Capacity (OCC)
Agency: Auke Bay laboratory, National Marine Fisheries Service, NOAA
Central Scientific Issues: HTL, ecosystem interactions
Key Research Activities: Modeling, observation studies, process studies
Funding: Funded
Start time: 1995
Contact: Michacel Dahlberg, Laboratory Director
Auke Bay Laboratory
11305 Glaicer Highway
Juneau, AK 99801-8626
U.S.A.
e-mail: mike_dahlberg@ccgate.ssp.nmfs.gov

Program: U.S. GLOBEC
Agency: U.S. GLOBEC Steering Committee - funding by: National Science Foundation/ National Oceanic and Atmospheric Administration
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, modeling, Process, Observation studies
Funding: Funded for retrospective studies, modeling and observation studies.
Start Time: 1997
Contact: Michael Fogarty
Chairman, U.S. GLOBEC Scientific Steering Committee
University of Maryland
Center for Environmental Science

Chesapeake Biological Laboratory
Solomons, MD, 20688-0038
U.S.A.
http://www.usglobec.berkeley.edu/usglobec/

Program: International Pacific Halibut Commission (IPHC)
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, process studies, retrospective studies
Funding: Funded
Start time: On-going
Contact: Donald McCaughran, Director
International North Pacific Halibut Commission
P.O. Box 95009
Seattle, WA 98145
U.S.A.
http://www.iphc.washington.edu:80/

Program: Alaska Department of Fish and Game (ADFG)
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, process studies, retrospective studies
Funding: Funded
Start time: On-going
Contact: Frank Rue, Commissioner
1255 West 8th St.
Juneau, AK 99802-5526
U.S.A.
http://www.state.ak.us/local/akpages/FISH.GAME/adfghome.html

Program: Sound Ecosystem Assessment (SEA)
Agency: Exxon Valdez Oil Spill Trustees
Central Scientific Issues: Forcing, LTL, HTL, ecosystem interactions
Key Research Activities: Modeling, process studies
Funded: funded
Start time: 1994 - 1998
Contact: Ted Cooney, Chief Scientist
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http://www.pwssc.gen.ak.us/sea/sea.html

Program: Apex Predator Ecosystem Response (APEX)
Agency: Exxon Valdez Oil Spill Trustees
Central Scientific Issues: HTL, ecosystem interactions
Key Research Activities: Modeling, process studies
Funded: funded
Start time: 1994
Contact: David Duffy
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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: Scott Hatch
Alaska Fish and Wildlife Research Center
U.S. Fish and Wildlife Center
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Anchorage, AK 99503
U.S.A.

Program: Prince William Sound Science Center (PWSSC)
Agency: Exxon Valdez Oil Spill Trustees
Central Scientific Issues: HTL, Ecosystem interactions
Key Research Activities: Modeling, process studies, observational studies
Funding: Funded
Start time: On-going
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P. O. Box 705
Cordova, AK 99574
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http://www.pwssc.gen.ak.us/pwssc/pwssc.html

Eastern Bering Sea: U.S.A.

Program: Alaska Fisheries Science Center (AFSC)
Agency: ational Marine Fisheries Service, NOAA
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, retrospective studies, process studies
Funding: Funded

Start time: On-going
Contact: James Balsiger, Director
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http:/www.wrc.noaa.gov/afsc/home.html

Program: Southeast Bering Sea Carrying Capacity (SEBSCC)
Agency: Coastal Ocean Program, NOAA
Central Scientific Issues: Forcing, LTL, HTL, ecosystem interactions
Key Research Activities: Modeling, observation studies, retrospective studies, process studies
Funding: Funded
Start time: 1996
Contact: James Overland
Pacific Marine Environmental Laboratory
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http:/www.pmel.noaa.gov/sebscc/home.html

Program: International North Pacific Halibut Commission (INPHC)
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, process studies, retrospective studies
Funding: Funded
Start time: On-going
Contact: Bruce Leaman, Director
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http://www.iphc.washington.edu:80/

Program: Alaska Department of Fish and Game (ADFG)
Central Scientific Issues: HTL
Key Research Activities: Modeling, observation studies, process studies, retrospective studies
Funding: Funded
Start time: On-going
Contact: Frank Rue, Commissioner
1255 West 8th St.
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http://www.state.ak.us/local/akpages/FISH.GAME/adfghome.html

Program: Collaborative Study of Prolonged Production and Trophic Level Transfer to Predators: Processes at the Inner Front of the Southeastern Bering Sea
Agency: National Science Foundation (NSF)
Central Scientific Issues: Forcing, LTL, HTL
Key Research Activities: Process studies
Funding: Funded
Start time: 1997 - 2000
Contact: George Hunt
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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: Scott Hatch
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Program: National Marine Mammal Laboratory (NMML)
Agency: AFSC, NMFS, NOAA
Central Scientific Issues: HTL, ecosystem interactions
Key Research Activities: Modeling, observation studies, retrospective studies, process studies
Funding: Funded
Start time: on-going
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Project Name: Bering Sea Impacts Study (BESIS)
Funding Agency: planning effort funded by IASC, funding requested from NSF (US), Russian Foundation for Basic Research (Russian participation), Chinese Academy of Sciences,

and agencies in Japan and elsewhere International Arctic Science Committee, IASC (main sponsor), plus other expected contributors (see Funding Status below)
Central Scientific Issues: Forcing, LTL, HTL, ecosystem interactions
Key Research Activities: Modeling, observation studies, retrospective studies, process studies
Funding: Funded
Start time: 1997
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Project Name: Arctic Research Initiative
Funding Agency: planning effort funded by IASC, funding requested from NSF (US), Russian Foundation for Basic Research (Russian participation), Chinese Academy of Sciences, and agencies in Japan and elsewhere International Arctic Science Committee, IASC (main sponsor), plus other expected contributors (see Funding Status below)
Central Scientific Issues: Forcing, LTL, HTL, ecosystem interactions
Key Research Activities: Modeling, observation studies, retrospective studies, process studies
Funding: Funded
Start time: 1997
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Western Bering Sea / Sea Okhotsk: Russia

Program: FES-LIRES (Ecosystem Study of Far-Eastern Seas Living Resources)
Agency: TINRO-Center (Pacific Scientific Research Fisheries Center)
Central Scientific Issues: Forcing, LTL (zooplankton mainly), HTL, Ecosystem interactions
Key Research Activities: Retrospective, Modeling, Observation Study (Monitoring)
Funding: Funded
Start Time: 1980
Contact: V.P. Shuntov, Principal Scientist of TINRO-Center
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Program: Pacific Salmon, 1997-2000 (Far-eastern regional program on Pacific salmon marine life study, 1997-2000)
Agency: TINRO-Center (Pacific Scientific Research Fisheries Center)
Central Scientific issues: LTL (salmon food supply), HTL (salmon and ecologically related species)
Key Research Activities: Retrospective, Modeling, Observation Study (Monitoring)
Funding: Funded
Start Time: 1997
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Program: STFF (Short-Term Fisheries Forecasting)
Agency: TINRO-Center (Pacific Scientific Research Fisheries Center)
Central Scientific Issues: Forcing, LTL, HTL
Key Research Activities: Retrospective, Modeling, Process Studies
Funding: Terminated
Start Time: 1996
Contact: Yury I. Zuenko, Section Head, Japan Sea Oceanography
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Oyashio Current System and Western Subarctic Gyre: Japan

Program: Hokkaido National Fisheries Research Insititute
Agency: Fisheries Agency, MAFF
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start time: on-going
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http://ss.hnf.affrc.go.jp/

Program: HUBEC
Agency: Faculty of Fisheries, Hokkaido University
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start time: on-going
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Kuroshio-Oyashio Transition Area: Japan

Program: Tohoku National Fisheries Research Insititute
Agency: Fisheries Agency, MAFF
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start time: on-going
Contact: Yasuaki Nakamura, Director General
3-27-5, Shinhamacho,
Shiogama 985,
Japan.
http://ss.myg.affrc.go.jp/

Program: Comprehensive study of the variation of the oceanic environment and fish populations in the north-western Pacific (VENFISH)
Agency: Tohoku National Fisheries Research Insititute, Fisheries Agency, MAFF
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions on walleye pollock and Pacific saury
Key Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start time: 1997
Contact: Kuniaki Okuda
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Kuroshio Current System: Japan

Program: National Research Insititute of Fisheries Science
Agency: Fisheries Agency, MAFF
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start time: on-going
Contact: Yoshiaki Sanbonsuga, Director General
2-12-4, Fukuura,
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http://ss.nrifs.affrc.go.jp/

Program: BIOCOSMOS
Agency: Fisheries Agency, MAFF
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions on Japanese sardine
Key Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded

Start time: 1987
Contact: Yoshioki Oozeki
2-12-4, Fukuura,
Kanazawa-ku, Yokohama 236,
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East China Sea: Japan

Program: Seikai National Fisheries Research Insititute
Agency: Fisheries Agency, MAFF
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start time: on-going
Contact: Hiroshi Hatanaka, Director General
49, Kokubucho,
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http://www.snf.affrc.go.jp/

Japan Sea/East Sea: Japan

Program: Japan Sea National Fisheries Research Insititute
Agency: Fisheries Agency, MAFF
Central Scientific Issues: Forcing, LTL, HTL, Ecosystem interactions
Key Research Activities: Retrospective, modeling, process, observation studies
Funding: Funded
Start time: on-going
Contact: Minoru Fujimoto, Director General
1-5939-22, Suidoucho,
Niigata 951,
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http://ss.jsnf.affrc.go.jp/

Yellow Sea: Korea

Program: Ministry of Maritime Affairs and Fisheries (MAFF)
Agency: NFRDA, West Sea Fisheries Research Institute
Central Scientific Issue: HTL, Ecosystem interactions, Red Tide
Key Research Activity: Retrospective, Process, Observation studies
Funding: Funded
Start Time: 1921
Contact: Dr. Jin-Yeong Kim
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West Sea Fisheries Research Institute
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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
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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
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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
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Program: Korea Science and Engineering Foundation (KOSEF)
Agency: Pukyong National University
Central Scientific Issue: Forcing, LTD, HTL, Ecosystem interactions
Key Research Activity: Retrospective, Process, Observation studies
Funding: Funded
Start Time: 1997 (on-going)
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Program: Ministry of Maritime Affairs and Fisheries (MAFF)
Agency: Pukyong National University (PKNU), NFRDA
Central Scientific Issue: LTH, HTL
Key Research Activity: Retrospective, Process, Observation studies
Funding: Proposed
Start Time: 1998
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Japan Sea/East Sea: Korea

Program: Ministry of Maritime Affairs and Fisheries (MAFF)
Agency: NFRDA, East Sea Fisheries Research Institute
Central Scientific Issue: HTL, Ecosystem interactions, Red Tide
Key Research Activity: Retrospective, Process, Observation studies
Funding: Funded
Start Time: 1921
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Program: Korea Science and Engineering Foundation (KOSEF)
Agency: Pukyong National University
Central Scientific Issue: Forcing, LTD, HTL, Ecosystem interactions
Key Research Activity: Retrospective, Process, Observation studies
Funding: Funded
Start Time: 1997 (on-going)
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Program: Ministry of Maritime Affairs and Fisheries (MAFF)
Agency: Pukyong National University (PKNU), NFRDA
Central Scientific Issue: LTH, HTL
Key Research Activity: Retrospective, Process, Observation studies
Funding : Funded
Start Time : 1998
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East China Sea: Korea

Program: Ministry of Maritime Affairs and Fisheries (MAFF)
Agency: NFRDA
Central Scientific Issue: HTL, Ecosystem interactions
Key Research Activity: Observation studies
Funding: Funded
Start Time: 1995
Contact: Mr. Cha-Soo Park
National Fisheries Res. and Dev. Institute
Coastal and Offshore Resources Division

#408-1, Shirang-Ri, Kijang,
Pusan 619-900, Korea.

Program: Ministry of Maritime Affairs and Fisheries (MAFF)
Agency: NFRDA, South Sea Fisheries Research Institute
Central Scientific Issue: HTL, Ecosystem interactions
Key Research Activity: Retrospective, Process, Observation studies
Funding: Funded
Start Time: 1921
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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
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Program: Korea Science and Engineering Foundation (KOSEF)
Agency: Pukyong National University
Central Scientific Issue: Forcing, LTD, HTL, Ecosystem interactions
Key Research Activity: Retrospective, Process, Observation studies
Funding: Funded
Start Time: 1997 (on-going)
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Program: Ministry of Maritime Affairs and Fisheries (MAFF)
Agency: Pukyong National University (PKNU), NFRDA
Central Scientific Issue: LTH, HTL
Key Research Activity: Retrospective, Process, Observation studies
Funding : Funded
Start Time : 1998
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Bohai Sea: China

Program: Bohai Sea Program
Agency: National Natural Science Foundation of China. Conducted by State Oceanic Administration, Minstry of Agriculture, Academia Sincia and Universities.
Central Scientific Issues: Forcing, LTL, HTL, ecosystem response
Key Research Activities: Retrospective, Modeling, Observation Study (Monitoring)
Funding: Funded
Start Time: 1996 - 2000
Contact: Dr. Qi-Sheng Tang, Director
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