

Implementation Plan

FUTURE Science Program

(Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems)



North Pacific Marine Science Organization
(PICES)

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INTRODUCTION

The basic principles of a new ten-year PICES Science Program on *Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems* (acronym **FUTURE**) are contained in the FUTURE Science Plan¹ that was approved by PICES in February 2008. FUTURE evolved from research conducted by its predecessor, the PICES/GLOBEC *Climate Change and Carrying Capacity* (CCCC) Program, which had the goal of increasing understanding of climate influences on marine ecosystems. FUTURE continues a focus on understanding climate impacts on marine systems and places additional emphasis on coastal anthropogenic influences, ecosystem forecasting, and engaging a broad user community with interests in North Pacific ecological and climate information.

PICES promotes cooperative frontier marine science by providing opportunities for collaborative comparisons of information, insights, and understanding across the North Pacific, by coordinating international research projects, and by synthesizing results through workshops, symposiums and technical expert groups. FUTURE seeks to build the science capacity of its member nations to understand and forecast the responses of marine ecosystems in the North Pacific to both climate change and human activities, and to evaluate the capacity and resilience of these ecosystems to withstand perturbations. FUTURE was developed with a view that improved reliability of forecasts of future ecosystem states requires improved understanding of the processes and mechanisms behind ecosystem variations, and the availability of near-real-time data relevant to these issues. FUTURE seeks to increase awareness of the ecological and societal importance of the North Pacific within PICES Contracting Parties.

A new challenge to PICES in implementing FUTURE is to develop interpretive products for institutions and individuals beyond the traditional constituencies of the Organization. These products would include periodic ecosystem assessments and forecasts of ecosystem status, based on improved data synthesis and scientific insights. Creating these products will challenge the scientific community to: (1) identify potential beneficiaries of ecosystem products and interact with them to clarify their needs, (2) review interpretive ecosystem products, including methods to quantify uncertainty, and (3) provide for routine data assimilation and product dissemination. If the results are reliable and useful, recipients will develop expectations of PICES to make interpretations and develop these products on a routine basis. Ultimately, the utility and quality of its assessments and forecasts will reflect on PICES as an organization.

This Implementation Plan describes the initial structure necessary for FUTURE to carry out the goals of the Science Plan, and reflects consultations with the Science Board, Governing Council, and the larger PICES membership.

WHY PICES?

The North Pacific experiences large natural climate variability on all time scales. This variability impacts a range of major marine species and ecological processes through a variety of physical/biological coupling mechanisms. At the same time, increases in human population, economic development, and continued urbanization in coastal areas are stressing marine ecosystems through chemical pollution, fishing, fresh water changes, and other anthropogenic influences. The directions and interconnections among these changes indicate that the future ocean will not be the same as the past or present.

Detrimental ecosystem changes, such as jellyfish blooms, harmful algal blooms, hypoxia, and blooms of macroalgae, have appeared in coastal regions of the North Pacific. Changes in community structure,

¹ http://www.pices.int/members/scientific_programs/FUTURE/FUTURE_final_2008.pdf

productivity, and biodiversity have also occurred. In many cases, these changes have resulted in economic hardship and aroused public concern.

According to the International Panel on Climate Change (IPCC, 2007), the earth is warming, very likely from enhanced emissions of greenhouse gases of anthropogenic origin. Over the next 30 years, natural variability will remain a large factor in determining the state of the North Pacific, but the combination of natural variability and a global warming trend may alter ecosystems in unknown and non-linear ways; the recent rapid loss of sea ice in the Arctic is an example of such an abrupt response to gradual climate change. Because PICES is a leader in understanding the North Pacific, PICES should be a main provider of climate and ecosystems information, especially in the context of the 5th IPCC Report to be published in 2013–2014.

The multi-national and multi-disciplinary structure of PICES facilitates learning and understanding by creating a forum in which scientists increase their perspectives by engaging with colleagues from a broad range of backgrounds. Understanding physical and biological processes and anticipating changes yet to come at local, regional and basin scales is an important scientific challenge. PICES is unique among international scientific organizations in coordinating North Pacific activities toward ecosystem understanding, forecasting, and dissemination for its next major multi-national program. FUTURE is the call for PICES scientists to make the societal implications of their science more explicit and accessible.

IMPLEMENTATION STRATEGY

The ultimate goal of FUTURE is *to understand and communicate the future of North Pacific ecosystems and the potential impacts from human use*. Implementation of FUTURE has two objectives:

- To increase understanding of climatic and anthropogenic impacts and consequences on marine ecosystems, with continued leadership at the frontiers of marine science;
- To develop activities that include the interpretation, clarity of presentation, peer review, dissemination, and evaluation of ecosystem products (*e.g.*, status reports, outlooks, forecasts) and establish a process for engaging interested institutions and other recipients.

To address the FUTURE goal, there is growing awareness that variability in marine ecosystems is neither simple nor linear either within or across scales, with consequences from ecological disasters to unexpected benefits. Impacts can have a mixture of local, regional, basin and global-scale causes.

Objective 1. Understanding Critical Processes in the North Pacific

Three key questions were developed by PICES scientists and adopted by the Organization as declarations of priorities for FUTURE research activities:

- (1) What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
- (2) How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
- (3) How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

The FUTURE Implementation Plan for addressing these questions is organized through two FUTURE Advisory Panels. **AICE** – *Anthropogenic Influences on Coastal Ecosystems* – is focused primarily on human influences on coastal (near-shore to continental shelf) ecosystems, such as runoff, pollution, effects of fishing, existence of non-indigenous species, and loss of habitat. **COVE** – *Climate, Oceanographic Variability and Ecosystems* – is focused on regional (shelf) to basin scale ecosystem processes and Pacific basin teleconnections. Whereas key question (2) is mainly the purview of COVE

and question (3) is mainly the purview of AICE, both Advisory Panels will keep all questions in mind as they pursue their activities. As discussed later, the role of the FUTURE Advisory Panels is to provide recommendations for action, coordinate these actions among PICES Scientific and Technical Committees, and synthesize results provided by PICES expert groups (e.g., Working Groups, Study Groups, Sections, and other Advisory Panels).

To answer the three key questions, AICE and COVE Advisory Panels will recommend priority tasks to PICES Science Board and relevant Scientific and Technical Committees that establish new PICES expert groups or build on and extend existing activities in PICES. For example, the activities of the Section on *Harmful Algal Blooms* and the activities of the Working Groups on *Non-indigenous Aquatic Species* (WG-21) and *Environmental Interactions of Marine Aquaculture* (WG-24) will form an association with AICE. AICE might consider increased nutrient loading in coastal waters as an additional activity, to be addressed by these or other expert groups, depending on AICE's priorities and decisions on the most efficient and productive approach.

COVE will be associated initially with the Section on *Carbon and Climate* and the Working Groups on *Evaluation of Climate Change Projections* (WG-20), *Iron Supply and its Impact on Biogeochemistry and Ecosystems in the North Pacific Ocean* (WG-22), and *Comparative Ecology of Krill in Continental Shelf and Oceanic Waters around the Pacific Rim* (WG-23). Expert groups that explicitly focus on developing a forecast, outlook or status report, such as the joint PICES/ICES WG on *Forecasting Climate Change Impacts on Fish and Shellfish* (WG-FCCIFS), will be primarily associated with a Third FUTURE Advisory Panel as discussed below. COVE priorities might recommend consideration of whether different species, or regional ecosystems as a whole, respond in phase or with time lags to changes in the ocean environment, and whether there are matches/mismatches between forcing and responses based on interannual versus multi-decadal environmental changes. AICE and COVE Advisory Panels may recommend study of new potential threshold responses of ecosystems due to the combination of anthropogenic forcing and natural variability. PICES Scientific and Technical Committees will utilize multiple methods to approach these research questions: retrospective analyses, model development, and process studies. Important variables and a discussion of these methods are further outlined in Appendix 1.

A further topic for new expert groups under FUTURE is to understand the direct sensitivity of ecosystems to natural and anthropogenic perturbations and the trophic cascades that may result from these perturbations. Marine ecosystems respond to perturbations in various ways. The natural resilience of ecosystems can mean that responses of ecosystems to pressures are slow to be detected, and hard to link to specific causes. However, once the stress due to natural or anthropogenic sources reaches a critical level, ecosystem structure can abruptly change and in some cases changes are irreversible. Such changes or shifts in ecosystem structure and dynamics influence the goods and services humans receive. Many factors, including the role of particular species or processes in ecosystem functioning, and the amenability of various species or process to measurement, influence which species or processes are best at reflecting the pressures on an ecosystem. Identifying sensitive organisms or processes and how they reflect effects of pressures on the larger ecosystem is essential to understanding the response of ecosystems to perturbation and to accurately forecasting the future state of marine ecosystems. The sensitive organisms/processes will vary among ecosystems and among perturbations. Thus, comparisons among ecosystem responses to perturbations should provide insights to ecosystem sensitivity and resiliency, and for informing decisions on conservation measures.

The expert groups associated with AICE should initially consider issues such as:

- Integrated understanding of past coastal ecosystem change caused by anthropogenic forcing, especially hypoxia, eutrophication, chemical pollution, and fishing-related shifts in community or size structure and how societies have been affected by these changes;
- Comparing the responses of sensitive organisms to specific anthropogenic perturbations and internal

community shifts using retrospective data analysis, ecosystem models, field studies, and laboratory and manipulation experiments;

- Understanding how continued eutrophication, pollution, fishing, and other anthropogenic pressures change future coastal marine ecosystems and how these affect societies; and evaluating how societies can sustain their resilience to inevitable ecosystem changes, and which societal choices lessen the stresses placed on ecosystems.

The expert groups associated with COVE should initially consider issues such as:

- Identifying organisms and processes that are sensitive to perturbations such as: long-term trends in physical oceanography and changes in interannual (ENSO) and decadal (*e.g.*, PDO, NPGO) variability; the interaction of natural climate variability and greenhouse gas influences; and regional or short-term events such as storms and tsunamis;
- Evaluating the intrinsic resiliency of ecosystems to pressures and perturbations, and understanding how ecosystem responses may be amplified or buffered through the influence of seasonal changes in physical (*e.g.*, altered upwelling timing) and chemical conditions (*e.g.*, hypoxia, eutrophication, ocean acidification), food-web dynamics, and other factors.

Both AICE and COVE associated expert groups should initially consider:

- Understanding how natural and human perturbations cascade through ecosystems;
- The relevance of key species concepts in North Pacific marine ecosystems and their sensitivity to perturbation;
- Identifying amplifiers and buffers of perturbation effects in marine food webs and what scales and magnitudes of perturbations may induce irreversible ecosystem change;
- Understanding the mechanisms of recruitment variation in populations of commercially valuable organisms such as finfish, shellfish, shrimp, squid, kelp, *etc.*

Objective 2. Status Reports, Outlooks, Forecasts, and Engagement

The production of *Status Reports, Outlooks and Forecasts* serve two purposes. First, if they are reliable, well-documented, and sufficiently accurate, they provide opportunities for industry, government, and communities to choose or modify their actions in accordance with expected future states of nature. Secondly, *Outlooks* serve science by providing hypotheses and models of behavior/response in situations where it is not yet possible to control potentially confounding factors. Feedback and evaluation of hypotheses and models can be obtained from a wide range of sources, and are useful for developing improvements in future outlooks.

Objective 2 transforms FUTURE from research solely directed toward enhanced understanding into the realm of provision of products. Production of *Status Reports, Outlooks and Forecasts* entail associated issues of quality assurance, dissemination, and evaluation strategies. Formal predictions/forecasts of future ecosystem states is an ambitious task given the current state of climate and ocean models, the need and associated uncertainty for downscaling this information to regional ecosystems, and the complexity of ecological responses to environmental and anthropogenic forcing. Forecasting systems must rigorously address issues of uncertainty and methodology. Predictions need to be interpreted clearly, simply, and objectively. The processes of developing, assessing and disseminating forecasts will span the ten-year duration of FUTURE.

Implementation of Objective 2 requires the establishment of a third FUTURE Advisory Panel on *Status, Outlooks, Forecasts, and Engagement* (SOFE). SOFE will recommend expert groups to identify major sources of uncertainty and impediments to improving the skill of assessments and forecasts, suggest research areas for priority development, and provide coordination of potential PICES products. SOFE will provide for a PICES final peer review on information and interpretations, and work with the PICES

Study Groups on *Communications* and on *Human Dimensions* on how to engage potential users of North Pacific ecosystem and climate information, including the quality of information and uncertainty. Regular performance reviews by Science Board and SOFE will provide an evaluation of the utility and inherent uncertainty associated with FUTURE's products. Skill and performance assessments will lead directly to improved products, and provide an early quality control check on mechanisms, linkages and model parameterizations. SOFE will work, in coordination with COVE, with WG-FCCIFS, and coordinate follow-on North Pacific Status activities with the in-progress PICES status report, *Marine Ecosystems of the North Pacific* (NPESR). Future products rely on timely, quality observations; thus a continuation of the guidance and coordination provided by the Technical Committee on Monitoring (MONITOR) and the Technical Committee on Data Exchange (TCODE) are essential.

Status Reports, Outlooks, and Forecasts

FUTURE will recommend three layers of products: *Status Reports, Outlooks, and Forecasts*. *Status Reports* are a web-based review, such as an updated version of PICES Special Publication 1, *Marine Ecosystems of the North Pacific*. This earlier publication, which included information to ca. 2003, is being updated to 2008 by an intergovernmental, multi-disciplinary team within PICES. Publication is anticipated in spring 2010. A key question for SOFE is the desired frequency of follow-on updates of the web version, with some measures requiring perhaps monthly refreshing while others only needing multiple year updates. *Forecasts* have a requirement for quantification and uncertainty measures. A special category is *Outlooks*, which are intermediate products that do not yet meet the full requirements of *Forecasts*. *Outlooks* may be categorical and can be based on limited available information coming from models or expert knowledge.

SOFE and Science Board will determine how developing *Status Reports, Outlooks and Forecasts* will be implemented within PICES. Rather than providing a full structure as part of this Implementation Plan, the writing team recommends handling ecosystem products on a case-by-case basis, with the follow on to NPESR and potential *Outlooks* from WG-FCCIFS as first candidates.

Time horizons for products include seasonal/annual status reports of key components representing the state of the marine ecosystem, the development of long-term (30–50 year) scenarios of the future of the North Pacific based on large-scale climate models and down-scaled regional models, and blended approaches for the 10–30 year time horizon. PICES needs to have an active near real-time (monthly to seasonal) observation synthesis and interpretation activity, because of the need to recognize rapid shifts and environmental surprises. The North Pacific regime shift that occurred in 1976/1977 and the recent rapid loss of sea ice in the Arctic are examples of such unexpected and abrupt environmental surprises. SOFE will consult with MONITOR and TCODE to ensure that all relevant data are available in a timely manner for assessment, and to identify indices that exhibit utility for change detection. SOFE will provide guidance on the timely dissemination of *Status, Outlook, and Forecast* information, which will primarily be via a World Wide Web site maintained by the PICES Secretariat.

Observation systems, Data management, and Dissemination

Significant events have occurred in the last decade that influence how the ocean will be studied during FUTURE. First is the emergence of new technologies for observing the ocean. Second, the assimilation of data from ocean observing systems into numerical models places greater emphasis on the timely dissemination of data and on access to high-speed computers. It will be the responsibility of MONITOR and TCODE to review existing and planned monitoring systems and data management systems, including those of the Global Ocean Observing System (GOOS), and to help facilitate the comprehensive use of new North Pacific data streams in models and assessments undertaken by FUTURE.

Engagement: Establish Dialogs with Recipients of Potential FUTURE Products

Requests for ecosystem information by a broad set of recipients are increasing. Governance of human activities in the sea is becoming more broadly inclusive and complex, involving many sectors of society including industries, public interest groups and the general public, as well as municipal, regional, and national levels of government, and international organizations. Moreover, many governance bodies have embraced concepts of an ecosystem approach and integrated management, which make each decision about conservation or management more complex, and perhaps more robust. Along with the greater demand for scientific and technical information needed to support policies and decisions, there is also the need for that information to be presented in timely and transparent ways. While PICES is not a policy organization, it is uniquely positioned to coordinate and provide objective scientific and technical information about the North Pacific.

Objective 2 of FUTURE comprises a new activity for PICES. The current Study Groups on *Communication* and on *Human Dimensions* will provide guidance and recommendations on engagement activities for FUTURE. It is too early in the FUTURE implementation process to fully interact with “stakeholders” that would benefit from and be targeted for FUTURE products. Instead, based on recommendations from the two Study Groups, long-term engagement and communication activities should be established in PICES. Initially user characteristics should be reviewed from existing sources. This review should be a basis for developing a matrix of potential applications for ecosystem status/forecasting, as well as an inventory of potential recipients and their communication requirements. These will be used to establish future contacts, assess status/forecast priorities of greatest interest to potential recipients, and the forms in which information and forecasts of marine ecosystems would be most useful. It should be noted that approaches and recipients often will be tailored differently for stakeholders in different North Pacific regions or Contracting Parties. This activity will collaborate with the PICES Secretariat to enhance web delivery of education and outreach. Besides the web, possible mechanisms of outreach could include research highlights, news briefs or press releases, and/or brochures.

This activity encourages individual scientists and PICES as a whole to be more involved in educating non-scientists. Initiating a dialog between the scientific community, the public, and the private sector can lead to new ideas and new directions for research.

STRUCTURE, MANAGEMENT, AND TIME SCHEDULE

The PICES Convention guides how FUTURE should be achieved. It is a function of the Governing Council “*to recommend coordinated research programs and related activities pertaining to the area concerned, which shall be undertaken through the national efforts of the participating Contracting Parties.*” The key words are “coordinated research programs”, “national efforts” and “participating.” Indeed, FUTURE is a coordinated research program whose strength is its international character. FUTURE will be implemented within a framework that recognizes the importance of national scientific contributions, as well as organizational costs for PICES. “Participating” implies that not all Contracting Parties need to be involved in all aspects of FUTURE, although FUTURE is planned to ensure that its scope is integrative and that the program’s objectives are relevant to all members.

The organizational structure of FUTURE (Figure 1) shows relationships between PICES Science Board, serving as the Scientific Steering Committee for FUTURE; three FUTURE Advisory Panels (AICE, COVE and SOFE); PICES Scientific and Technical Committees; and affiliated expert groups.

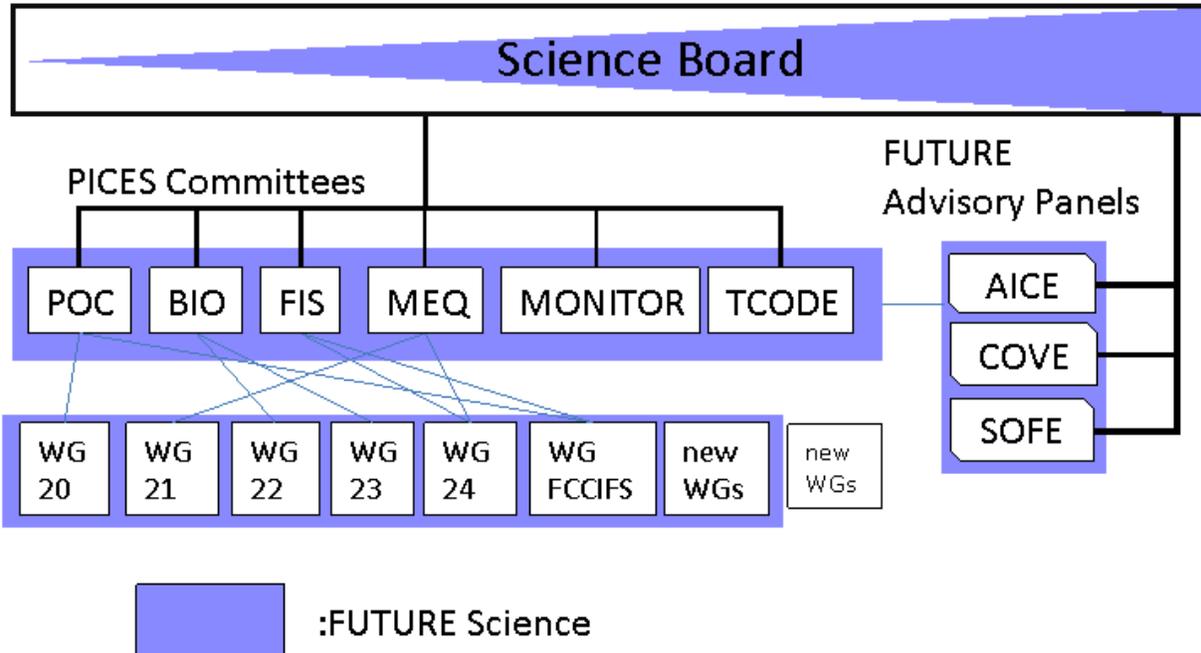


Figure 1 Structure of FUTURE.

FUTURE Scientific Steering Committee (SSC)

The PICES Science Board, with the addition of the three FUTURE Advisory Panel Chairmen, serves as the SSC of FUTURE. Science Board is responsible for initiating FUTURE activities by working through the Scientific and Technical Committees and their expert groups, and evaluating progress toward the FUTURE goal.

The major support to FUTURE by PICES leadership and its Secretariat is to coordinate and organize international activities, stimulate and facilitate actions, coordinate overall planning, and implement specific tasks such as certain outreach tasks. Support for the FUTURE Scientific Program includes:

- Convening workshops and symposia;
- Facilitating international cooperation between national and institutional research programs;
- Supporting Contracting Parties in identifying national research programs related to FUTURE that are capable of providing ship time and data;
- Enhancing coordination with other international science programs to facilitate information exchange and cooperation;
- Maintaining a website and facilitating communication products beyond the PICES community.

FUTURE Advisory Panels

Three Advisory Panels (AICE, COVE and SOFE) provide continuing direction, leadership, coordination, and synthesis within PICES toward attaining the FUTURE goal. They recommend activities to be undertaken by existing expert groups, recommend new FUTURE products and, in coordination with Scientific and Technical Committees, suggest and help to develop new expert groups. FUTURE Advisory Panels will have a membership made up of one representative on each panel from each Scientific and Technical Committee. Committees will nominate candidates for panel membership to Science Board. Science Board will select a membership from among the candidates according to the needs of FUTURE and will seek approval of the membership from Governing Council. Because of their relatively small size, a

single Chairman will be determined for each panel according to PICES Rules of Procedure. The Chairman of each FUTURE Advisory Panel will serve as a member of the Science Board.

In the first year, the tasks of the FUTURE Advisory Panels are to:

- Establish a list of specific FUTURE priority topics, activities and products for review by the Science Board;
- Work with the existing expert groups associated with FUTURE to review and revise, if needed, their Terms of Reference;
- Work with the Scientific and Technical Committees and the PICES community to identify gaps in the priorities and activities of the expert groups and to provide recommendations to the Science Board;
- Coordinate with the Scientific and Technical Committees in developing Terms of Reference for new expert groups to be part of FUTURE; and
- (SOFE only) Coordinate with the Editors of the next version of the North Pacific Ecosystem Status Report on how the Report should be updated in the future. Work with the Communication Study Group and the Study Group on Human Dimensions of Environmental Change to commence the review of user characteristics for FUTURE products.

During the second and third years, the Committees and their expert groups will carry out FUTURE, and at the end of three years, the FUTURE Advisory Panels will review progress and update the Implementation Plan as needed. The update will describe progress that has been achieved in answering the three major questions of FUTURE, recommend which forecast and outlook products are most needed and suitable for further development and application, and if necessary revise the descriptions of activities undertaken by various PICES components to achieve the goal of FUTURE.

Expert Groups

The main activities of FUTURE are carried out by expert groups recommended by the Scientific and Technical Committees and initiated by the Science Board following existing procedures. Current relevant expert groups are Sections on *Harmful Algal Blooms* and on *Carbon and Climate*, Working Groups from WG-20 through WG-FCCIFS, and Study Groups on *Communications* and on *Human Dimensions*.

National Contributions

For most regional scale components, national programs that are relevant to FUTURE and could contribute to the goals of the program are underway or have been proposed. An early priority of the three Advisory Panels is to develop a summary of potential FUTURE-related activities from each Contracting Party.

Scientific Cooperation

Cooperation with other international research activities is anticipated where the interests and objectives of FUTURE are shared. It is premature to assign relationships for FUTURE beyond PICES until the Implementation Plan is established. Below are possible connections:

- *International Science Organizations and Programs*
IMBER is a scientific program that investigates the sensitivity of marine biogeochemical cycles and ecosystems to global change, on time scales ranging from years to decades. China and Japan currently have national IMBER projects. Other international programs include atmosphere–ocean interactions (CLIVAR) and monitoring systems (Argo, Jason). Collaboration with the WESTPAC, NOWPAP, and YSLME programs is important for human and coastal issues. Collaborative work with the International Council for Exploration of the Sea (ICES) is appropriate for many aspects of FUTURE.

- *Fishery and Marine Environmental Quality Agencies*
Cooperation is envisaged between PICES and existing international fisheries-related organizations, including the International Council for Exploration of the Sea (ICES), the North Pacific Anadromous Fish Commission (NPAFC), the International Pacific Halibut Commission (IPHC), the Pacific Salmon Commission (PSC), the developing North Pacific groundfish Regional Fisheries Management Organization and regional fisheries councils. For FUTURE to better relate to “stakeholders”, it is important that the Program be connected to national and regional regulatory agencies that set policy for management of marine resources, protection of water quality, and conservation of protected species.
- *Intergovernmental Panel on Climate Change*
The 5th (and possibly 6th) Assessment Report(s) of the Intergovernmental Panel on Climate Change (IPCC) will be written during the FUTURE time frame. As the 5th report, scheduled for release in 2013–2014, is based on published literature, relevant FUTURE-related research will need publication by 2011. Direct contact with IPCC section authors will be initiated as publications arise from the FUTURE activities.
- *Food and Agriculture Organization, World Bank and United Nations Ecosystem Project*
FAO, the World Bank and UNEP are planning to launch a new program focused on the implications of climate change on food resources around the world. The PICES FUTURE program will provide valuable forecasts of the implications of climate change on the availability and distribution of seafood resources in the North Pacific. These forecasts will contribute to this GLOBAL effort.

Communications among FUTURE and PICES scientists

Communications among FUTURE and PICES scientists will be facilitated by:

- Convening inter-sessional symposia to review progress and to stimulate the exchange of ideas among the multi-disciplinary teams working in different components of the program;
- Co-sponsoring activities with like-minded programs of other international organizations;
- Convening workshops to address important scientific questions;
- Convening topic and poster sessions at PICES Annual Meetings;
- Publishing workshop results in PICES Scientific Report Series;
- Publishing regularly articles in PICES Press on FUTURE scientific activities and progress;
- Publishing significant contributions in peer-reviewed scientific journals, and
- Maintaining a FUTURE website.

SUMMARY

FUTURE addresses the understanding needed to answer three questions for the North Pacific:

- (1) What determines an ecosystem’s intrinsic resilience and vulnerability to natural and anthropogenic forcing?
- (2) How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
- (3) How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

FUTURE also places a new emphasis on ecosystem forecasting and providing this information in a transparent manner to a broad community, while maintaining PICES’ traditional leadership at the frontiers of marine science. The Implementation of FUTURE proposes three small coordinating Advisory Panels: one focused primarily second question (Climate, Oceanographic Variability, and Ecosystems, COVE), one on the third question (Anthropogenic Influences on Coastal Ecosystems, AICE) with the first

question addressed by both Panels, and a Status, Outlook, Forecasts, and Engagement Advisory Panel (SOFE).

In addition to scientific literature and PICES publications, FUTURE has three layers of products: *Status Reports, Outlooks, and Forecasts*. *Status Reports* provide timely information on current conditions relative to historical information. *Forecasts* are quantitative products with associated uncertainty measures. *Outlooks* are products that do not yet fully meet the requirements of *Forecasts*. When these products are successful, member countries, management institutions, the general public, and North Pacific science at large will receive new benefits such as timely, increased ecosystem information for understanding the impacts of human activities in the sea, the development of new resources, and the management of the human impacts to ensure traditional and new uses of resources are sustainable in a changing ocean. New expectations of PICES will arise, requiring PICES to produce, interpret, peer-review, and evaluate products on a routine basis. The utility and quality of FUTURE research and products will reflect well on PICES as an Organization.

REFERENCE

IPCC, 2007. *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by Solomon S. *et al.*, Cambridge Univ. Press, Cambridge, U.K. and New York, 996pp.

Appendix 1: Important Variables and Methods

Ecosystem elements of significant interest to FUTURE include:

- Physical Forcing (Time series and seasonality)
 - Location of major fronts/current boundaries
 - Atmospheric pressure gradients (winds and storms)
 - Air-sea heat exchange (insulation, cloud cover)
 - Major physical features (e.g., fresh water input, ice)
 - Mixed layer temperature (MLT), depth (MLD)
 - Velocity of major currents
 - Eddies
 - Vertical and horizontal mixing, fine structure
- Lower trophic levels (primary, including microbial; secondary)
 - Annual and seasonal productivity
 - Temporal and spatial pattern of plankton dynamics and nutrient fields
 - Identification of major taxonomic groups
 - Population parameters for key species (or taxonomic groups)
- Higher trophic levels and ecosystem interactions
 - Abundance trends and distributions of life stages of key species and their predators and prey
 - Population parameters (growth, mortality, reproduction)
 - Food web structure (including diets and trophodynamic linkages of key species)
 - Production and productivity structure

Retrospective analyses

Retrospective studies increase knowledge of how and why marine ecosystems have varied in the past. Their results serve as benchmarks to judge current and future states of nature, and the data used and generated by these studies provide a basis of comparison for ecosystem models of all kinds. The resurrection of newly discovered physical, chemical and biological data in archives continues to provide opportunities to answer longstanding scientific questions that relate to FUTURE. Some potential products use the information and properties contained in historical time series as a basis for statistical models and forecasts.

Model development

Development of numerical and statistical models, along with their testing and validation, will occur throughout FUTURE's implementation. The activity includes conceptual/theoretical studies, but has an eventual goal of several coupled atmosphere-ocean-ecosystem models at different spatial scales. From the biological point of view, conceptual and modeling approaches require identification of ecosystems and key species by several criteria, and include an accounting of the principal elements of total system biomass, productivity and movement. A priority of FUTURE is to understand cross-scale interactions.

Process studies

These are experimental approaches to study/test specific mechanisms linking ecosystem responses to environmental variability and external forcing factors. For example, there still remain many unknown processes in marine sciences such as: vertical mixing, eddy and intermediate-deep circulations, air-sea interactions and long-term variation mechanisms, chemical properties such as trace metals and greenhouse materials and their interactions with biology in chemical and biogeochemical oceanography, plankton behavior, marine food webs and fish recruitment, and physiological-ecological responses to the environment.