Implementation Plan

FUTURE Science Program

(***F****orecasting and* ***U****nderstanding* ***T****rends,* ***U****ncertainty and* ***R****esponses of North Pacific Marine* ***E****cosystems*)

North Pacific Marine Science Organization (PICES)

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INTRODUCTION

The basic principles of a new ten-year PICES Science Program, ***F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems* (acronym **FUTURE**) are contained in the FUTURE Science Plan that received approval by PICES leadership in February 2008. The FUTURE program evolved from the 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 providing information to a broad community in useful formats.

PICES promotes cooperative frontier marine science by providing the opportunity for collaborative comparisons of information and insights/understanding across the North Pacific, coordinating international research projects, and synthesizing results through workshops, symposiums and technical working groups.

The new program seeks to build the science capacity to understand and forecast the responses of marine ecosystems in the North Pacific to both climate change and human activities, and to determine the capacity and resilience of these ecosystems to withstand perturbations. PICES defines an ecosystem as a geographically-specified system of organisms (including biota and humans), habitat, physical components, and the processes that control its dynamics. FUTURE views that improving the reliability of forecasts of future ecosystem states requires improved understanding of processes and mechanisms behind ecosystem variations, and the near real time availability of additional data. FUTURE seeks to increase awareness of the ecological and societal importance of the North Pacific within the six PICES contracting nations, and to communicate ecosystem information and forecasts to society in ways that help informed decision making.

A new challenge to PICES in implementing FUTURE is to develop and provide interpretive products such as periodic ecosystem assessments and forecasts of expected ecosystem status to institutions and persons beyond the traditional constituencies of PICES, based on improved data synthesis and scientific insights. This will challenge the scientific community to (1) identify potential beneficiaries of ecosystem products and interact with them to clarify their needs, (2) peer review interpretive ecosystem products, including methods to quantify uncertainty, and (3) provide for routine data assimilation and product dissemination. If products are reliable and useful, recipients will develop expectations of PICES to produce and interpret 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 which impact a range of major marine species and ecological processes through a variety of physical/biological coupling mechanisms (*e.g.*, Fig. 1). At the same time, increases in human population, economic development, and continued urbanization in coastal areas are stressing marine ecosystems through chemical pollution including fertilizer effusion, 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.

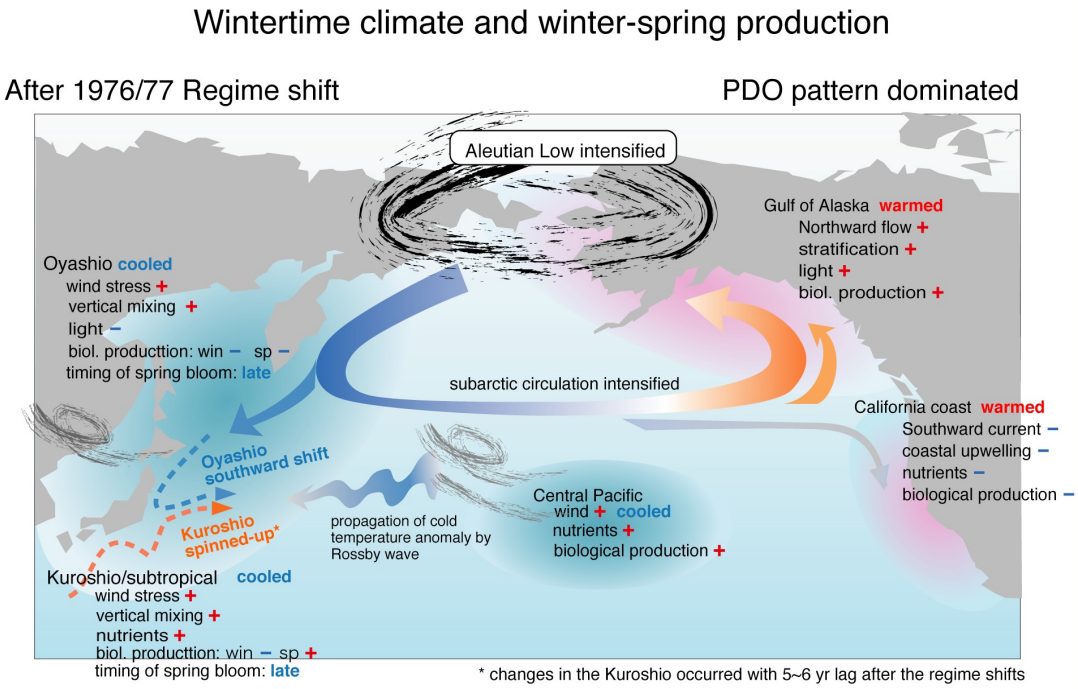

Figure 1 Response of multiple regional North Pacific ecosystems to an increase in the intensity of the northern North Pacific atmospheric circulation (Aleutian low sea level pressure field) after the 1976/1977 regime shift. Drawing by Sanae Chiba (Japan).

Ecosystem changes, such as jellyfish blooms, HABs, hypoxia and blooms of macroalgae, have appeared in coastal regions of the northwestern Pacific. Anthropogenic pressures such as eutrophication, aquaculture, fishing, and coastal development have increased for the past decades. Ecosystem changes such as community structure, productivity and biodiversity have also occurred. In many cases, these changes have resulted in economic hardship and aroused public concern in China, Korea, and Japan. Global change will interact with these local anthropogenic pressures and exacerbate future problems for PICES member countries.

According to the International Panel on Climate Change (IPCC, 2007), the earth is warming, most likely from enhanced emissions of greenhouse gases of anthropogenic origin. Over the next 30 years, natural variability will remain a large factor in 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 climate and ecosystems in the North Pacific, PICES should be a main provider of climate and ecosystem information for the 5th IPCC Report to be published in 2013.

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 scientists 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 to make the societal implications of its 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 main responsibilities:

- 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 interacting with interested institutions and other recipients.

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

Objective 1 Understanding Critical Processes in the North Pacific

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

(1) How do local and regional ecosystems respond to natural and anthropogenic forcing on all scales, and how might ecosystems change in the future?
(2) What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
(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 Scientific Steering Groups (SSG). **AICE** – ***A**nthropogenic **I**nfluences on **C**oastal **E**cosystems* – is focused primarily on human influences on coastal ecosystems, such as runoff, pollution, effects of fishing, existence of invasive species, and loss of habitat. **COV** – ***C**limate and **O**ceanographic **V**ariability* – is focused on regional (shelf) to basin scale ecosystem processes and Pacific basin teleconnections. Whereas question one is mainly the purview of COV and question three is mainly the purview of AICE, both Groups will keep all questions in mind as they pursue their activities. The second question on resilience and vulnerability is the charge of both Groups. As discussed later, the role of the Scientific Steering Groups is to provide recommendations for action, coordinate these actions among PICES Standing Committees, and synthesize results provided by Working Groups (WG).

To answer these questions, both Scientific Steering Groups will recommend priority tasks that establish new Working Groups or build on and extend existing Working Groups and other 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.

COV will be associated with the Section on *Carbon and Climate* and 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). Working Groups that explicitly focus on developing a forecast, outlook or status report, such as WG-25 on *Forecasting Climate Change Impacts on Fish and Shellfish*, will be associated with a Third Scientific Steering Group as discussed below. COV will consider 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/miss-matches between forcing and responses based on interannual versus multi-decadal environmental changes. AICE and COV Scientific Steering Groups and PICES Standing Committees will consider new potential threshold responses of ecosystems due to the combination of anthropogenic forcing and natural variability. PICES Standing Committees will utilize multiple methods to approach the research questions: retrospective analyses, model development, and process studies. Important variables and a discussion of these three methods are further outlined in Appendix 1.

Topics for new Working Groups are 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 Working Groups associated with AICE should initially consider issues such as:

- Integrated understanding of past coastal ecosystem change caused by anthropogenic forcing, especially eutrophication 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 small scale manipulation experiments;
- Understanding how continued eutrophication, 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 Working Groups associated with COV 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), food-web dynamics, and other factors.

- Evaluating how ecosystem resiliency couples with human, economic and social sustainability.

Both AICE and COV 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 Outreach

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 is 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* will also 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 Scientific Steering Group; ***S****tatus,* ***F****orecast and* ***O****utreach* (SFO). This Group will identify major sources of uncertainty and impediments to improving the skill of assessments and forecasts, and suggest research areas for priority development. SFO will recommend potential products, provide a PICES final peer review on information and interpretations, and inform potential users of the quality of information and uncertainty. Regular performance reviews 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. SFO will work with WG-25 on *Forecasting Climate Change Impacts on Fish and Shellfish*, in coordination with COV, and coordinate with the in-progress status report, *Marine Ecosystems of the North Pacific* (NPESR). PULSE (**P**ICES **U**nderstanding, **L**inking and **S**ynthesis of **E**cosystems) could exist under SFO or be under Science Board. 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) is essential.

Status Reports, Outlooks, and Forecasts

FUTURE will have three layers of products: *Status Reports, Outlooks, and Forecasts*. *Status Report*s are a web-based, 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 on the web is anticipated in spring 2010. A key question for SFO is the desired frequency of 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.

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 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 environmental surprises. SFO, MONITOR and TCODE will work jointly to ensure that all relevant data are available in a timely manner for assessment and to identify indices that exhibit utility for change detection. The timely dissemination of *Status, Outlook, and Forecast* information will primarily be via a World Wide Web site maintained by the PICES Secretariat.

Observation systems, Data management, and Dissemination

Achieving the goals of FUTURE requires that climate change, anthropogenic stressors, and ecosystem responses be measured systematically in appropriate monitoring systems. A major MONITOR requirement is to guide, coordinate and recommend best practices for timely ocean and ecosystem observations and delivery systems to support the production of *Status Reports, Outlooks, and Forecasts*.

Several 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 SFO.

Outreach: 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 civil society, 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.

This objective comprises a new activity for PICES. The current Study Group on Communication will provide guidance and recommendations on outreach activities for FUTURE. A new element in FUTURE is the human dimension. An initial effort to engage social and economic scientists will be through the proposed PULSE activity (PICES Understanding, Linking and Synthesis of Ecosystems) which is

considering methodologies for Ecosystem Based Management (EBM) or an Ecosystem Approach to Management (EAM). PULSE will provide a forum for the connection of ecosystem monitoring and status reporting of both environmental and social indicators and the subsequent interpretation of these indicators relative to their implications for policy and management options in an ecosystem context.

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 an Outreach Group established under the SFO will review information during its first year from existing sources and develop a matrix of potential applications for ecosystem status/forecasting, as well as an inventory of potential recipients. This 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 should be tailored differently for stakeholders in different North Pacific regions or Contracting Parties. The Outreach Group will collaborate with the PICES Secretariat to enhance web delivery of education and outreach developed by FUTURE. 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 and civil society 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, as diagramed in Figure 2, shows relationships between PICES Science Board, serving as the Scientific Steering Committee (SSC) for the Program; three FUTURE Scientific Steering Groups (AICE, COV and SFO); PICES Standing Committees; and affiliated Working Groups.

FUTURE Scientific Steering Committee (SSC)

The PICES Science Board, with the addition of the three FUTURE Scientific Steering Group Chairmen, serves as the SSC of FUTURE. Science Board is responsible for initiating FUTURE activities, working through the Standing Committees and their Working 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; and
- Enhancing coordination with other international science programs to facilitate information exchange and cooperation.

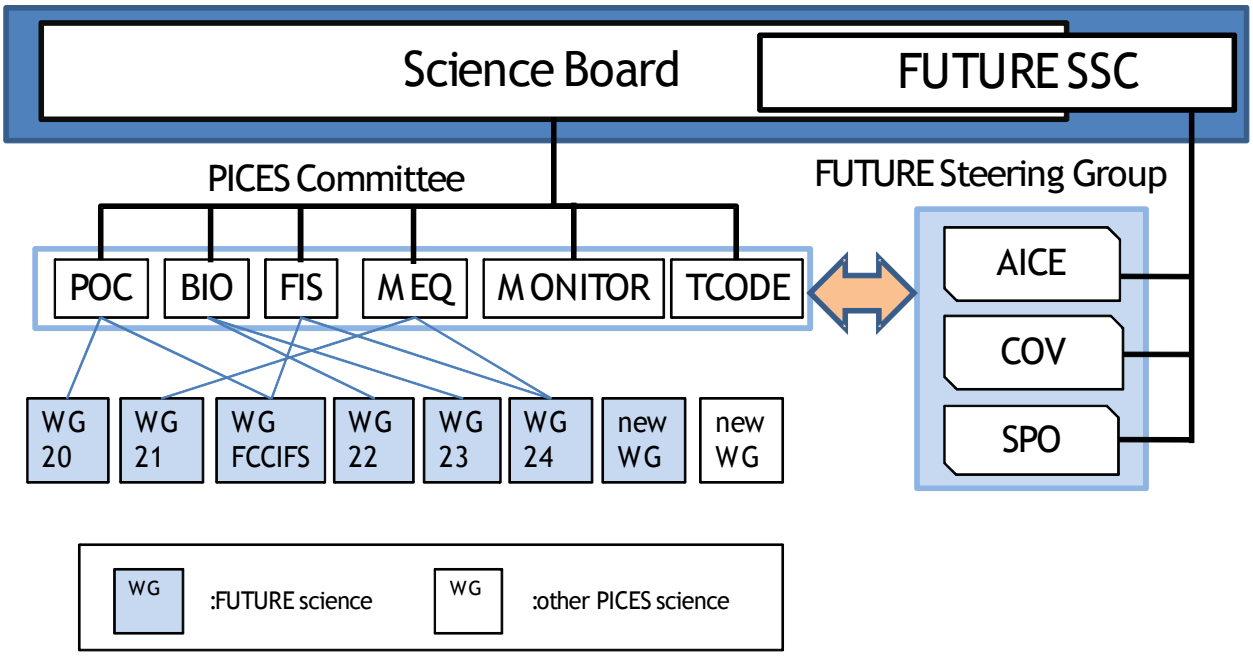

Figure 2 Structure of FUTURE.

FUTURE Scientific Steering Groups (SSG)

The three Scientific Steering Groups (AICE, COV and SFO) provide continuing direction, leadership, coordination, and synthesis within PICES toward attaining the FUTURE goal. They recommend new FUTURE products and, in coordination with Standing Committees, suggest and help develop new Working Groups. Scientific Steering Groups are relatively small groups staffed by one representative from each of the six PICES Standing (Scientific and Technical) Committees. The Vice-Chairman of a Committee or another Committee member will serve on each of the Task Teams as shown in Table 1. A Chairman is elected by each Scientific Steering Group, and will also serve as a member of the SSC.

The FUTURE Writing Team recommends that Science Board appoint interim Chairmen for the three Scientific Steering Groups as soon as the Implementation Plan is approved by Governing Council, with 1-year mandates to further the development of FUTURE during the transition period, while the Standing Committees are nominating members and the SSGs are fully staffed.

Table 1 Membership of Scientific Steering Groups (VC – Vice-Chairman, CM – Committee Member)

Committee	**AICE**	**COV**	**SFO**
BIO	VC	CM	CM
FIS	CM	VC	CM
MEQ	VC	CM	CM
POC	CM	VC	CM
MONITOR	CM	CM	VC
TCODE	CM	CM	VC

In the first year, the tasks of the Scientific Steering Groups are to:

1. Establish a list of specific FUTURE priority topics, activities and products for review by the SSC;
2. Work with the existing Working Groups and Sections associated with FUTURE to review and revise, if needed, their Terms of Reference;
3. Work with the Standing Committees, the SSC and the PICES community to identify gaps in the priorities and activities of the Working Groups and to provide recommendations to the SSC;
4. Coordinate with the Standing Committees in developing Terms of Reference for new Working Groups to be part of FUTURE; and
5. (SFO only) Coordinate with the Editors of the next version of the North Pacific Ecosystem Status Report and initiate the Outreach Working Group.

During the second and third years, PICES will carry out FUTURE, and at the end of three years, the SSGs will develop an update/addendum to the FUTURE Implementation Plan. The addendum will describe specific progress that has been achieved in answering the three major questions of FUTURE, and recommend which forecast and outlook products are most needed and suitable for further development and application.

Working Groups

The main activities of FUTURE are carried out by Working Groups recommended by the Standing Committees and initiated by the SSC following existing procedures. Current Working Groups are WG-20 through WG-25.

National Contributions

Listing the national programs that are relevant and could contribute to the goals of FUTURE is an initial requirement for the SSGs. An example from Canada is provided as Appendix 2. For most regional scale components, relevant national programs are underway or have been proposed.

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, Korea, and Japan currently have funded 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) would also be appropriate for many aspects of FUTURE.
- *Fishery Commissions*
  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 RFMO and regional fisheries councils. For FUTURE to better relate to "stakeholders", it is important that the Program be connected to national 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, is based on peer-reviewed 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.

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. How do local and regional ecosystems respond to natural and anthropogenic forcing on all scales, and how might ecosystems change in the future?
2. What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
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 the twin goals of 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 Scientific Steering Groups: one each focused primarily on the first (Anthropogenic Influences on Coastal Ecosystems, AICE) and last question (Climate and Oceanographic Variability, COV), with the second question addressed by both teams; and a Status, Forecast and Outreach Scientific Steering Group (SFO).

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, civil society, 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.

Appendix 2: An Example of a National Program which contributes to FUTURE

Canada

		1						2							3				
Region	**Canadian Projects relevant to FUTURE**	1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5
Local	The Strait of Georgia in 2030: DFO Pacific Region Ecosystem Research Initiative																		
Regional	DFO Climate Change Science Initiative																		
Basin (Global)	IPCC AR5 model (carbon & climate) development at Canadian Centre for Climate Modelling and Analysis																		
Regional	Water property and biological monitoring (Line-P and others)																		
National	International Fisheries Governance																		
Regional	Health of the Oceans																		

Numbered columns refer to the three key questions and the sub-questions identified in the FUTURE Science Plan and listed below.

1. What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
   - 1.1. What are the important physical, chemical and biological processes that underlie the structure and function of ecosystems?
   - 1.2. How might changing physical, chemical and biological processes cause alterations to ecosystem structure and function?
   - 1.3. How do changes in ecosystem structure1 affect the relationships between ecosystem components?
   - 1.4. How might changes in ecosystem structure and function affect an ecosystem's resilience or vulnerability to natural and anthropogenic forcing?
   - 1.5. What thresholds, buffers and amplifiers are associated with maintaining ecosystem resilience?
   - 1.6. What do the answers to the above sub-questions imply about the ability to predict future states of ecosystems and how they might respond to natural and anthropogenic forcing?

2. How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
   - 2.1. How has the important physical, chemical and biological processes changed, how are they changing, and how might they change as a result of climate change and human activities?
   - 2.2. What factors might be mediating changes in the physical, chemical and biological processes?
   - 2.3. How does physical forcing, including climate variability and climate change, affect the processes underlying ecosystem structure and function?
   - 2.4. How do human uses of marine resources affect the processes underlying ecosystem structure and function?
   - 2.5. How are human uses of marine resources affected by changes in ecosystem structure and function:

Such as species composition, population structure and dynamics, *etc*.?
Such as species interactions, habitat usage, biological rates and biological diversity?

2.6. How can understanding of these ecosystem processes and relationships, as addressed in the preceding sub-questions, be used to forecast ecosystem response?
2.7. What are the consequences of projected climate changes for the ecosystems and their goods and services?

3. How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?
   3.1. What are the dominant anthropogenic pressures in coastal marine ecosystems and how are they changing?
   3.2. How are these anthropogenic pressures and climate forcings, including sea level rise, affecting nearshore and coastal ecosystems and their interactions with offshore and terrestrial systems?
   3.3. How do multiple anthropogenic stressors interact to alter the structure and function of the systems, and what are the cumulative effects?
   3.4. What will be the consequences of projected coastal ecosystem changes and what is the predictability and uncertainty of forecasted changes?
   3.5. How can we effectively use our understanding of coastal ecosystem processes and mechanisms to identify the nature and causes of ecosystem changes and to develop strategies for sustainable use?

Appendix 3: Definitions

Basin-scale	studies in the open ocean, generally requiring international cooperation for their conduct
Regional-scale	studies in coastal waters, generally conducted by scientists of a single country comparing how ocean climate affects marine ecosystems along coastal margins
Local-scale	Studies near harbors, limited fishing grounds or ecological hot spots
Climate change and climate variation	used interchangeably to signify low frequency (seasons to centuries) fluctuations in atmospheric and oceanic conditions, both natural and anthropogenic in origin
Temporal scales of interest	interannual or longer
Ecosystems	species assemblages with distinctive trophic structure extending from autotrophs to top heterotrophs
Key species	identified by their contribution to the overall biomass and/or their role in energy transfer and trophic structure
Productivity	the rate of a biological production process
Production	the net accumulation of biomass over some specified time
Carrying capacity for a given population	the limiting size of that population that can be supported by an ecosystem over an arbitrary period of time and under a given set of environmental conditions