FUTURE Phase II Implementation Plan
Term 2016-2020

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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1. Introduction

Forecasting, and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems (acronym FUTURE) is a nominally 10-year interdisciplinary science program of PICES started in 2009. PICES promotes 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 North Pacific marine ecosystems 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 more reliable 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, Canada, People's Republic of China, Japan, Republic of Korea, Russian Federation, and the United States of America.

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, management and governmental communities 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.

The Vision of FUTURE is:
To understand and forecast responses of North Pacific marine ecosystems to climate change and human activities at basin and regional scales, and to broadly communicate this scientific information to members, governments, resource managers, stakeholders

and the public.

The overarching questions in the FUTURE Science Plan are in the Appendix I.

2. Goals of FUTURE Science Plan

The ultimate goal of FUTURE is to understand and communicate the present conditions and projected future states 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)

There is growing awareness that variability in marine ecosystems is neither simple nor linear either within or across scales, with consequences ranging from ecological disasters to unexpected benefits. Impacts can have a mixture of local, regional, basin and global-scale causes. In order to accomplish the goals of FUTURE, two objectives were set;

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?

Objective 2. Status Reports, Outlooks and Forecasts

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. Ideally, this could lead to better ocean stewardship, greater sustainability, and more resilient industries and communities. 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 improving future outlooks.

Objective 2 transforms FUTURE from a science program directed solely toward research and enhanced scientific understanding into the realm of knowledge and product delivery. Production of Status Reports, Outlooks and Forecasts entail associated issues of quality assurance, dissemination, and evaluation strategies. Formal prediction/forecast 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, and if value is demonstrated, hopefully the process will be continued by PICES beyond the FUTURE program. The products may also help to establish a process for engaging interested users of PICES' science from both within and outside the Organization.

3. Revised FUTURE Implementation Strategy

Developing FUTURE Scientific Steering Committee (FUTURE SSC)

Responding to the recommendations of the FEP (FUTURE Evaluation Panel), the FUTURE SSC was established in October 2014 to govern the FUTURE program. The FUTURE SSC is under the direction of Science Board and led by two Co-Chairs. The Third North Pacific Ecosystem Status Report (NPESR-3) and outreach were retained as high priority activities of PICES. FUTURE expert groups (EGs) are no longer directly tasked with outreach, but are anticipated to provide some guidance on the most significant products. Outreach will be the joint responsibility of the FUTURE SSC, Science Board and the PICES Secretariat. The FUTURE SSC may identify specific products/activities/publications worthy of more extensive outreach and recommend these to SB and Governing Council (GC) for support and dissemination. The

FUTURE-related products will be reviewed and integrated to ensure some common messaging by the FUTURE SSC.

The organizational structure of FUTURE and connections within PICES are shown at https://meetings.pices.int/Members/Scientific-Programs/FUTURE#FUTURE-elements-image-EG.

FUTURE SSC Terms of Reference (revised and approved October 2015)

1. Provide leadership and scientific direction to implement the PICES FUTURE program.
2. Report semi-annually to Science Board on progress achieved by the FUTURE science program, and to identify impediments that hinder progress, and to recommend solutions/actions to enable progress.
3. Work with PICES Standing Committees and Expert Groups to ensure collective and integrated delivery of FUTURE.
4. Develop new Expert Groups as required.
5. Integrate, promote and stimulate national activities around the vision statement and core science questions of FUTURE.
6. Identify and facilitate interactions with national/international research programs from which FUTURE could benefit.
7. Communicate FUTURE research and products with the aim of translating them into high level impacts for PICES and its member countries.

Expert Groups

The main activities of FUTURE are carried out by EGs recommended by the Scientific and Technical Committees and initiated by the Science Board. FUTURE SSC reviews scientific achievements and identifies issues requiring further activities to reach the goals of FUTURE. To facilitate broad input into this process, the FUTURE SSC holds a plenary Mini-Symposium and a FUTURE topic session during the PICES Annual Meetings (see below). As is necessary to make progress, FUTURE may organize intersessional workshops on specific focused topics. North Pacific ecosystems are changing rapidly under increasing anthropogenic pressures, thus it is imperative that the FUTURE program continue to expand research on North Pacific ecosystems. This will require the FUTURE SSC to recommend and facilitate the development of new Expert Groups, based on the needs articulated by the SSC, the Science Board, and the broader PICES scientific community.

FUTURE SSC Liaisons to EGs and Committees

An objective for the FUTURE-SSC is to enhance communication within PICES. As such, members of the FUTURE-SSC will serve as liaisons to specific EGs and Committees. The responsibilities of the liaisons will be to: (a) attend the EG and Committee meetings with which they liaise in order to monitor their progress and to report on FUTURE developments; (b) provide scientific direction towards implementation of FUTURE; and (c) report back to the FUTURE-SSC on the EG and Committee activities related to the FUTURE program. In addition, the Co-Chairs of the FUTURE SSC will solicit annual Activity Reports from each EG and Committee prior to the PICES Annual Meeting, and report semi-annually to Science Board on the progress and any impediments to the implementation of the FUTURE program.

FUTURE Mini-Symposium and FUTURE plenary session during Annual Meeting

During FUTURE Phase I, there were limited opportunities for EG chairs and members to learn of other EGs activities and the potential for collaboration between EGs. In order to report on the progression of the FUTURE science and identify any significant impediments to achieving progress, the FUTURE SSC will convene a FUTURE Mini-Symposium during each PICES Annual Meeting. Each EG chair will update all other EGs and the SSC of their achievements, identify any impediments to progress, and communicate specific requests for data, information and collaboration to other EGs.

In Phase II, FUTURE will organize dedicated topic sessions that focus on the key issues, tasks, results and products of the FUTURE program. In some years, the session will be held in plenary to attract as many PICES attendees as possible. FUTURE SSC may also convene intersessional symposia or workshops, as appropriate, on topics that require additional attention to achieve scientific progress leading to FUTURE products.

FUTURE diagram

During FUTURE Phase I, the Study Group on Socio-Ecological-Environmental Systems (SEES) produced a modeling framework to explore the dynamics underlying the complex interactions between the climate system, marine ecosystem and the human system. Developing the framework was a learning exercise that promoted a stronger transdisciplinary dialog within PICES and a better understanding of the integration among the ongoing interdisciplinary science efforts. Building on the results from the study group, the goal of the FUTURE science plan is summarized as "*understanding the*

predictability and sustainability of the North Pacific Social-Ecological-Environmental Systems (SEES)" (Figure 2). Mapping each EG's activity onto the FUTURE diagram, enables gaps to be identified that might be addressed by new EGs. Using the diagram as a roadmap, FUTURE is poised to achieve its objective of improving our understanding and communication of the future of North Pacific ecosystems and the potential impacts of human activities on the North Pacific and vice-versa.

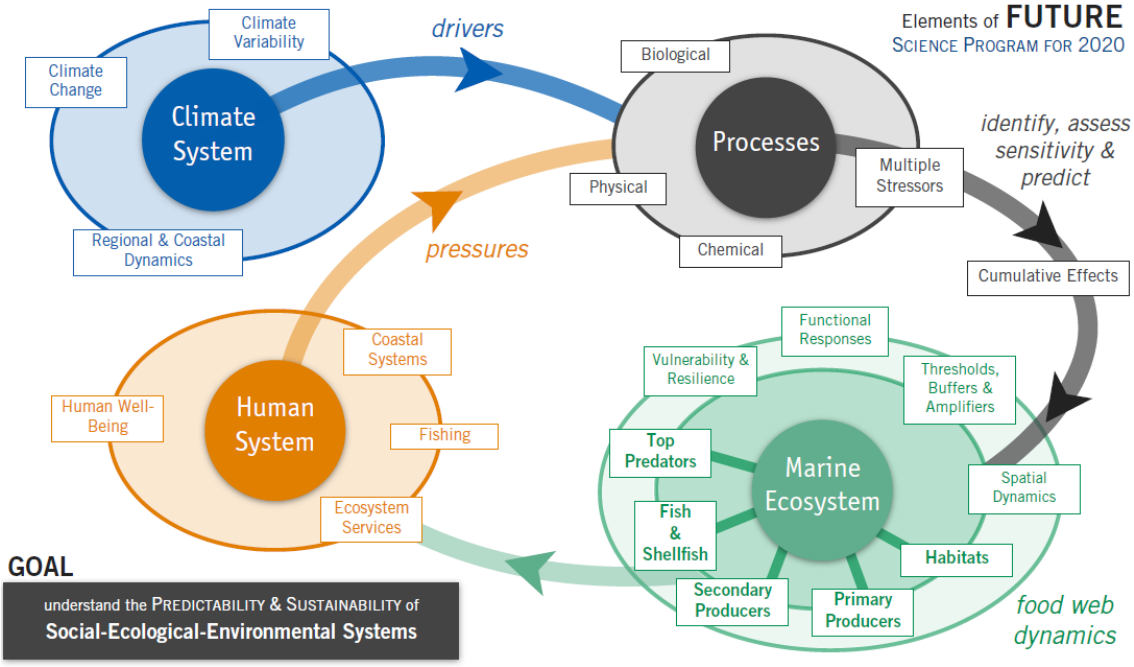

Figure 2. Schematic diagram of the PICES FUTURE Science Program elements.

Forecasts

Forecasting the future of the North Pacific is a core element of the FUTURE program. During the FUTURE Phase I, progress was made in developing ocean-climate forecasts. The next phase for ocean-climate forecasting work should be to integrate with the biological and social sciences, including forecasting climate change impacts on commercial fisheries, sustainable use of marine ecosystem services under global warming, etc. There also is a need in FUTURE science for 1-3 year and 5-10 year forecasts of climate and ocean conditions in addition to the current multidecadal projections. Such forecasts, although scientifically challenging, would assist FUTURE with exploring and eventually forecasting ecosystem responses to both natural and anthropogenically-driven climate variability and change. The forecasting of coastal

components may pose different challenges and need different tools (e.g. finer spatial resolution, more attention to anthropogenic and/or land-based inputs, etc.). To accomplish this ambitious challenge, it is essential to strengthen communication of the PICES forecasting community with PICES experts of coastal and oceanic issues, monitoring, data management, and social sciences.

Human dimension and SEES diagram

It is now widely accepted that the Earth has entered a new geological epoch of the Anthropocene with significant changes in geochemical cycles and ecosystem components with mass distinction. Global change in climate and degradation of ecosystem services are emerging issues for human society and well-being. To this end, PICES established the Section on Human Dimension (S-HD) in 2011 to tighten the link between natural scientists and social scientists. During FUTURE Phase II, FUTURE will work with S-HD to better understand and communicate the societal implications of future trends of North Pacific marine ecosystems and to facilitate collaboration among researchers from both the natural and social sciences. It is anticipated that each EG will respond to human dimension issues, and revise their ToR as necessary.

Early career scientists in FUTURE

FUTURE strongly encourages early career scientists to participate in FUTURE related science and activities. PICES (with ICES as a partner) has supported two early career scientist conferences previously (2007; 2012), and will support a third in May 2017. With logistical support from the PICES Secretariat, several of the PICES members have organized Summer Schools to engage younger scientists into PICES activities. It is important that PICES have multigenerational support of its activities in order to remain a robust, healthy and productive marine science organization that remains on the frontier of marine science research. FUTURE also encourages PICES member countries to support young scientists to be members of EGs with PICES, but especially within FUTURE.

National Contributions

For most regional scale components, national programs that are relevant to FUTURE and could contribute to the program are underway or have been proposed. FUTURE SSC will integrate the results of national activities around the FUTURE vision statement and core science questions in order to stimulate and promote their activity at national as well as multi-national levels. Scientists engaged in PICES FUTURE activities, including

the SSC members, need to actively seek out opportunities within their member countries that align well with FUTURE activities, and connect with national funding opportunities to push PICES science forward. PICES FUTURE will not be able to address all components of the science plan without targeted funding (for academic scientists) and support (for government scientists) from the PICES nations.

Scientific Collaboration

Most FUTURE questions, especially those related to global climate change and anthropogenic impacts on marine ecosystems, are important not only to the PICES region but also to other regions such as North Atlantic Ocean, Arctic Seas, Equatorial and South Pacific Ocean. FUTURE has the opportunity and responsibility to accelerate cooperation of PICES with other international organizations, programs, initiatives and research activities to solve shared questions related to global change and to provide evidence-based responses/advice to emerging requests from our society.

Climate Change and Marine Ecosystem Responses

PICES collaborates with the International Council for Exploration of the Sea (ICES) through the joint Section on Climate Change Effects on Marine Ecosystems (S-CCME). Publishing papers and developing synthesis of the trend and forecast of North Pacific Ecosystems to be contributed to Assessment Report 6 (AR6, scheduled for release in 2019) of the International Panel of Climate Change (IPCC) is a target activity. In 2015, a new transdisciplinary research initiative, Future Earth (FE), was launched under ICSU. FE is to provide knowledge and support to accelerate the transformation of our society towards a sustainable world. Several international projects of IGBP that were focused on the oceans, specifically IMBER and SOLAS, were transitioned into FE, with increased emphasis on societal needs and pressing problems related to changes in the ocean and atmosphere. The FUTURE science program of PICES seeks to establish strong collaborations with these FE programs, something that PICES did with JGOFS, GLOBEC (CCCC), and IMBER (including CLIOTOP and ESSAS) when they were programs within the IGBP portfolio. PICES and IGBP programs established joint exchanges of observers, held jointly sponsored symposia or sessions in each other's meetings, and contributed to each other's summer schools. These efforts will continue through linkages between PICES FUTURE and relevant FE projects. CLIVAR (Climate and Ocean: Variability, Predictability and Change) under WCRP has been a project focused on climate sciences and physical oceanography. In 2014, CLIVAR moved more closely to ecosystem and social issues related to global change. FUTURE seeks to

collaborate with CLIVAR on shared interests such as regional modeling, forecasting short and long term ecosystem change, etc.

Biodiversity, Fishery and Marine Environmental Quality Agencies

Under increasing human activities and demands on marine food resources, international collaboration for maintaining healthy marine environments, biodiversity and sustainable fisheries are becoming essential not only for coastal ecosystems but also oceanic ecosystems beyond national jurisdiction. FUTURE continues to collaborate with marine environmental quality agencies and international programs such as NOWPAP and WESTPAC, and with ICES, NPAFC, NPFC and regional fisheries council. 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. During FUTURE Phase I, there has been increased concern on declining marine biodiversity. FUTURE seeks collaboration with international projects, national agencies and NGOs on the conservation of marine biodiversity for sustainable use of marine resources and maintenance of ecosystem services as well as to share benefits from marine ecosystems internationally.

Acronyms

CCCC: The Climate Change and Carrying Capacity Program
CLIOTOP: Climate Impacts on Oceanic Top Predators
CLIVAR: Climate and Ocean: Variability, Predictability and Change
EG: Expert Group
ESSAS: The Ecosystem Studies of Sub-Arctic Seas
FE: Future Earth (ICSU)
FUTURE: Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems
GLOBEC: Global Ocean Ecosystem Dynamics
ICES: International Council for the Exploration of the Sea
ICSU: International Council for Science
IMBER: Originally, Integrated Marine Biogeochemistry and Ecosystem Research; recently renamed to Integrated Marine Biosphere Research
IGBP: International Geosphere-Biosphere Programme
IPCC: Intergovernmental Panel on Climate Change
JGOFS: Joint Global Ocean Flux Study
NOWPAP: Northwest Pacific Action Plan
NPAFC: North Pacific Anadromous Fish Commission
NPFC: North Pacific Fisheries Commission
PICES: North Pacific Marine Science Organization
SOLAS: Surface Ocean - Lower Atmosphere Study
WCRP: World Climate Research Programme

Appendix I: FUTURE Research Themes from FUTURE Science Plan (January 2008)

Overarching question:

What is the future of the North Pacific given current and expected pressures?

Questions for improved communication of the science from FUTURE:
How can forecasts, uncertainty and consequences of ecosystem change be communicated effectively to society?"

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 structure[1] affect the relationships between ecosystem components[2]?
   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?

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?