



FUTURE Phase III Science Plan Addendum **Term 2021-2025**

**North Pacific Marine Science Organization
(PICES)**

PREAMBLE

**North Pacific Marine Science Organization
(PICES)**

September 2020



Preamble to FUTURE Science Plan

Following Phase I of the FUTURE Science Program and the 2014 report of the Future Evaluation Panel (<https://meetings.pices.int/members/scientific-programs/materials/FUTURE/2014-FUTURE-Evaluation-Team-Report.pdf>), a new Phase II Implementation Plan (<https://meetings.pices.int/Members/Scientific-Programs/Materials/FUTURE/FUTURE-PhaseII-Implementation-Plan.pdf>) was developed by a newly formed Scientific Steering Committee (<https://meetings.pices.int/members/Scientific-Programs/FUTURE-SSC#FUTURE-SSC-members>). Significant progress was made during FUTURE Phase II (2016-2020) in achieving FUTURE's two overriding objectives ([link to Product Matrix](#)):

- 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).

While progress has been made towards these objectives, it is clear that the primary goals, scientific priorities, research themes, and strategies outlined in the original FUTURE Science Plan (https://meetings.pices.int/members/scientific-programs/materials/FUTURE/FUTURE_final_2008.pdf#page=5) are still relevant and represent a useful guide for steering PICES integrative science. During the past year, the FUTURE SSC has conducted internal discussions, at Science Board request, to evaluate options for the next phase of PICES integrative science. Several recommendations were presented to and approved in principle by PICES Science Board at the 2019 PICES Annual Meeting:

- The momentum developed during FUTURE Phase II should be maintained;
- The overall objectives and key questions of the FUTURE program are still relevant and reflective of the needs of PICES integrative science;
- A new phase of the FUTURE program should be implemented to exploit recent accomplishments and developments in global marine science;
- FUTURE should evaluate Phase II progress towards objectives, determine which objectives cannot be resolved or are now of lower priority, and identify new activities needed to accomplish objectives;
- FUTURE should prepare a Phase II Final Report;
- FUTURE should continue to facilitate trans-disciplinary research and communication, although PICES should maintain traditional disciplinary activities;
- PICES integrative science should encourage and facilitate participation of early career scientists;
- PICES should address inherent geographical constraints through enhanced inter-sessional expert group activities.

Based on these recommendations, the FUTURE SSC has revised the FUTURE Implementation Plan for a new Phase III. In addition, the SSC has developed this Addendum to the FUTURE Science Plan to articulate an improved framework for conducting PICES integrative science and to leverage new developments in international marine science, particularly the United Nations Decade of Ocean Science for Sustainable Development (<https://oceandecade.org>).



A. Social-Ecological-Environmental Systems (SEES) Framework

One of the principal objectives of the FUTURE Science Program is to facilitate trans-disciplinary communication and research in order to understand and address changes in North Pacific marine ecosystems and their resulting impacts on coastal communities. During Phase II of FUTURE, the Scientific Steering Committee implemented a Social-Ecological-Environmental Systems (SEES) framework to address critical issues of relevance to nations that share North Pacific marine resources, specifically the member nations of PICES, with a focus on climate- and human-induced ecosystem changes that impact coastal communities (Bograd et al., 2019; Figure 1). This framework fosters a common trans-disciplinary language and knowledge base and provides the FUTURE Science Program, and PICES more broadly, with the capacity to better coordinate and integrate trans-disciplinary marine science. Bograd et al. (2019) demonstrated the application of this SEES framework to four ‘crisis’ case studies: (a) species alternation in the western North Pacific; (b) ecosystem impacts of an extreme heat wave in the eastern North Pacific; (c) jellyfish blooms in the western North Pacific; and (d) Pacific basin-scale warming and species distributional shifts.

During FUTURE Phase III, this SEES framework will be broadly applied within the PICES community to address the principal FUTURE objectives and research themes, and to accommodate the development of strategies to more effectively mitigate climate-driven and anthropogenic impacts on North Pacific ecosystems and communities.

B. Orientation to the UN Decade of Ocean Science (2021-2030)

In December 2017, the United Nations General Assembly proclaimed the Decade of Ocean Science for Sustainable Development (2021-2030; <https://oceandecade.org>) to “support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide behind a common framework that will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the Ocean”. The Decade is designed to “facilitate stronger international cooperation to bolster scientific research and innovative technologies to ensure science responds to the needs of society”:

- A **clean ocean** where sources of pollution are identified and removed
- A **healthy and resilient ocean** where marine ecosystems are mapped and protected
- A **predictable ocean** where society has the capacity to understand current and future ocean conditions
- A **safe ocean** where people are protected from ocean hazards
- A **sustainably harvested ocean** ensuring the provision of food supply
- A **transparent ocean** with open access to data, information and technologies

The FUTURE Science Program, and PICES more generally, shares many of the goals of the Ocean Decade. Furthermore, as the key inter-governmental marine science organization in the North Pacific, PICES has the aspiration and capacity to be the key regional partner of the Ocean Decade (link to PICES Press article on NP workshop). FUTURE Phase III will provide the scientific and organizational infrastructure to implement the activities of the Ocean Decade in the North Pacific.



C. Communicating Knowledge and Solutions to Stakeholders

An important goal of FUTURE is to “*communicate scientific information to members, governments, resource managers, stakeholders and the public*”. Given the rising concerns regarding climate change and other anthropogenic stressors on the marine environment, this communication is most effective when it delivers knowledge that enables solution actions. This concept is not only central to the Implementation Plan of the UN Decade of Ocean Science, but it captures a more modern approach to marine ecosystem science that is informed by the solution needs of end-users (e.g. decision-makers, stakeholders, governments). To this end, FUTURE Phase III will prioritize the development of targeted multi-sector Expert Groups that bring together researchers, stakeholders, and decision-makers, to identify the solutions needs of specific ocean concerns (e.g., coastal sea level rise and extremes, ocean carbon sequestration, conservation of biodiversity, ocean hypoxia and acidification) and to develop scientific knowledge aimed at enabling ocean solution actions. The knowledge generated by the Expert Groups will include both technological and societal research and innovations, as well as the development of novel governance models. FUTURE is uniquely positioned to make significant advances in connecting scientific knowledge to solution actions for stakeholders, and in achieving the UN Societal Development Goals (<https://sustainabledevelopment.un.org/?menu=1300>).

References

Bograd, S.J., S. Kang, E. Di Lorenzo, T. Horii, O.N. Katugin, J.R. King, V.B. Lobanov, M. Makino, G. Na, R.I. Perry, F. Qiao, R.R. Rykaczewski, H. Saito, T.W. Therriault, S. Yoo, H. Batchelder, 2019. Developing a social-ecological-environmental system framework to address climate change impacts in the North Pacific. *Frontiers in Marine Science*, 6:333, doi.org/10.3389/fmars.2019.00333.

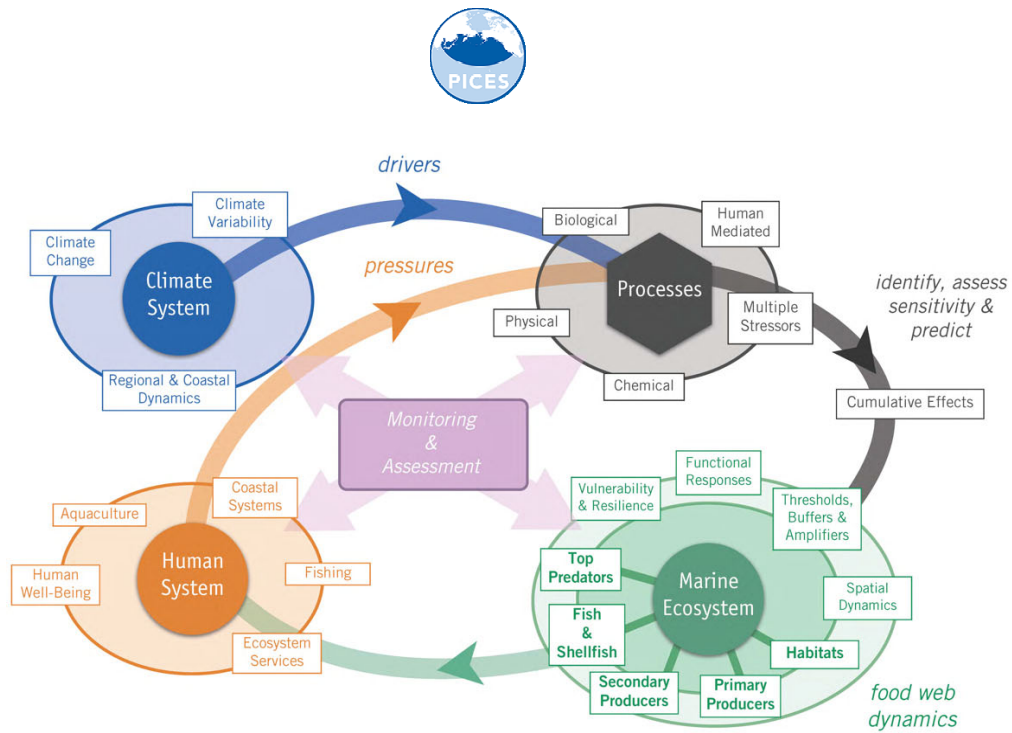


Figure 1: The PICES-FUTURE Social-Ecological-Environmental System framework. PICES Expert Groups map onto the framework to identify synergies and knowledge gaps.

FUTURE Phase III Science Plan Addendum Term 2021-2025

IMPLEMENTATION PLAN



North Pacific Marine Science Organization (PICES)

September 2020

Prepared by the FUTURE Scientific Steering Committee:

Steven J. Bograd (Co-chair), USA
Sukyung Kang (Co-chair), Korea
Jennifer L. Boldt, Canada
Emanuele Di Lorenzo, USA
Tetsuo Fujii, Japan
Oleg N. Katugin, Russia
Jacquelynn R. King, Canada
Vyacheslav B. Lobanov, Russia
Mitsutaku Makino, Japan
Guangshui Na, China
Hanna Na, Korea
Ryan R. Rykaczewski, USA
Fangli Qiao, China
Thomas W. Therriault, Canada
Sinjae Yoo, Korea

Citation

This report should be cited as follows:

PICES (2020): FUTURE Phase III Implementation Plan.
PICES Secretariat, Sidney 19 pp.



TABLE OF CONTENTS

1. Introduction	2
2. Goals of FUTURE Science Plan	3
Objective 1. Understanding Critical Processes in the North Pacific.....	3
Objective 2. Status Reports, Outlooks, Forecasts	4
3. Review of FUTURE Phases I and II	4
4. FUTURE Phase III Implementation	6
FUTURE SSC Terms of Reference	7
Role of Expert Groups	8
Social-Ecological-Environmental Systems (SEES) Framework.....	8
Orientation to the UN Decade of Ocean Science (2021-2030) and International Partnerships.....	10
Engagement of Early Career Scientists	12
National Contributions	12
Communication.....	12
Acronyms	14
Appendix I: FUTURE Research Themes from FUTURE Science Plan	15
Appendix 2: ICES-PICES Joint Statement on UN Decade of Ocean Science	17



1. Introduction

Forecasting, and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems (acronym FUTURE) was initiated in 2009 as the flagship interdisciplinary science program of PICES. 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 key 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.

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?

Several more specific research themes and questions related to these three key questions are presented in the FUTURE Science Plan and in *Appendix 1*.

Objective 2. Status Reports, Outlooks and Forecasts

The production of Status Reports, Outlooks and Forecasts serves 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. Second, 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 duration of FUTURE, and if value is demonstrated, 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. Review of FUTURE Phases I and II

The initial FUTURE implementation plan published in 2009 described the 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

(https://www.pices.int/members/scientific_programs/FUTURE/FUTURE_IP_final_2009.pdf). The initial FUTURE structure outlined in this implementation strategy was organized as three Advisory Panels (AP). AP-AICE (Anthropogenic Influences on Coastal Ecosystems) and AP-COVE (Climate, Oceanographic Variability and Ecosystems) were focused on Objective I, and AP-SOFE (Status, Outlooks, Forecasts, and Engagement) was focused on Objective 2. PICES Science Board, including the chairpersons of the three APs, served as the



Scientific Steering Committee for FUTURE. The Advisory Panels (AICE, COVE and SOFE) provided continuing direction, leadership, coordination, and synthesis within PICES toward attaining the FUTURE goals.

At the FUTURE Open Science Meeting in 2014, at the anticipated mid-point of the program, PICES established a FUTURE Evaluation Panel (FEP) to review progress towards achieving the goals of FUTURE as set out in the Science and Implementation Plans. The [2014 Report of the FUTURE Evaluation Panel](#) identified a number of organizational and implementation impediments to advancing FUTURE science, and made several recommendations to advance FUTURE and PICES in coming years. Foremost among the recommendations was the establishment of a FUTURE Scientific Steering Committee (SSC), separate from the PICES Science Board, that would provide leadership and scientific direction to the program. Following these recommendations, PICES Governing Council agreed to the formation and composition of a FUTURE Scientific Steering Committee (SSC) at the PICES 2014 Annual Meeting in Yeosu, Korea. Membership of the FUTURE SSC and its revised Terms of Reference can be found at the PICES website.

Responding to the recommendations of the FEP, the FUTURE SSC was established to govern the FUTURE program in October 2014, and developed a revised FUTURE Phase II Implementation Plan (<https://meetings.pices.int/Members/Scientific-Programs/Materials/FUTURE/FUTURE-PhaseII-Implementation-Plan.pdf>), including Terms of Reference, during 2015. The FUTURE SSC is under the direction of Science Board and led by two Co-Chairs. The FUTURE Advisory Panels (AICE, COVE, SOFE) were disbanded, but some elements of AP-SOFE (Status, Outlooks, Forecasts and Engagement), such as the North Pacific Ecosystem Stature 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. FUTURE SSC may identify specific expert groups, activities, and products worthy of more extensive outreach and recommend these to SB and GC for support. The FUTURE-related products are reviewed and integrated to ensure common messaging by the FUTURE SSC.

Several products were developed by the SSC during FUTURE Phase II, including a peer-reviewed article describing the implementation a Social-Ecological-Environmental Systems (SEES) framework to address critical issues of relevance to PICES member nations (Bograd et al., 2019); a video describing the FUTURE Science Program and ways for the marine science community to be involved (<https://www.youtube.com/watch?v=rbJjOgJObTY&feature=youtu.be>); a Product Matrix that summarizes a variety of science products developed within FUTURE, linked to the FUTURE core questions; and a Phase II Final Report.

4. FUTURE Phase III Implementation

The status and progress of the FUTURE Science Program was evaluated by the FUTURE SSC and Science Board in 2019, at the prescribed end of the Phase II implementation. It was recognized that the primary goals, scientific priorities, research themes, and strategies outlined in the original FUTURE Science Plan (https://meetings.pices.int/members/scientific-programs/materials/FUTURE/FUTURE_final_2008.pdf#page=5) are still relevant and represent a useful guide for steering PICES integrative science. The FUTURE SSC has conducted internal discussions, at Science Board request, to evaluate options for the next phase of PICES integrative science. Several recommendations were presented to and approved in principle by PICES Science Board at the 2019 PICES Annual Meeting:

- The momentum developed during FUTURE Phase II should be maintained;
- The overall objectives and key questions of the FUTURE program are still relevant and reflective of the needs of



- PICES integrative science;
- A new phase of the FUTURE program should be implemented to exploit recent accomplishments and developments in global marine science;
- FUTURE should evaluate Phase II progress towards objectives, determine which objectives cannot be resolved or are now of lower priority, and identify new activities needed to accomplish objectives;
- FUTURE should prepare a Phase II Final Report;
- FUTURE should continue to facilitate trans-disciplinary research and communication, although PICES should maintain traditional disciplinary activities;
- PICES integrative science should encourage and facilitate participation of early career scientists;
- PICES should address inherent geographical constraints through enhanced inter-sessional expert group activities.

Based on these recommendations, the FUTURE SSC has developed an addendum to the FUTURE Science Plan and this revised FUTURE Phase III Implementation Plan.

4a. FUTURE SSC Terms of Reference

The structure and function of the FUTURE Science Program within PICES remain largely unchanged from Phase II. The Terms of Reference for the SSC (listed below) are largely the same as those for the original Phase II, with the addition of terms allowing for the (a) development and parenting of PICES Expert Groups (ToR 4) and (b) provision of guidance for implementing PICES integrative science (ToR 8). Details of the FUTURE SSC are available here: <https://meetings.pices.int/members/Scientific-Programs/FUTURE-SSC>.

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 in order to translate them into high level impacts for PICES and its member countries.
8. Provide recommendations to Science Board on options for implementing PICES integrative science.

4b. Role of Expert Groups

The main activities of FUTURE are carried out by Expert Groups recommended by the Scientific and Technical Committees and the FUTURE SSC and initiated by the Science Board. FUTURE SSC reviews scientific achievements and identifies issues requiring further activities to achieve the goals of FUTURE and has the authority to serve as parent or co-parent of Expert Groups. During Phase II, FUTURE SSC organized plenary symposia at the PICES Annual Meetings to facilitate broad input into this process, to communicate progress on achieving objectives, and to identify any significant impediments to achieving progress. In addition, FUTURE SSC organized dedicated topic sessions at the Annual Meetings that focused on the key issues, tasks, results and products of the FUTURE program, as well as inter-sessional workshops on focused topics. During Phase III, FUTURE SSC will continue to organize symposia, topic sessions and workshops to maintain progress in achieving FUTURE's goals. The new capacity to parent (or co-parent) Expert Groups has facilitated the



prioritization of PICES activities towards unmet objectives, and the FUTURE SSC will continue to identify, propose and support new Expert Groups to address these gaps.

A principal objective of the FUTURE SSC is to enhance communication within PICES. As such, SSC members will serve as liaisons to all PICES Expert Groups and Committees ([https://meetings.pices.int/Members/Scientific-Programs/Materials/FUTURE/FUTURE-SSC Liaisons hpb edited 1page.pdf](https://meetings.pices.int/Members/Scientific-Programs/Materials/FUTURE/FUTURE-SSC_Liaisons_hpb_edited_1page.pdf)). The responsibilities of the liaisons are to: (a) attend the Expert Group and Committee meetings to which they are assigned in order to monitor their progress and report on FUTURE developments; (b) provide scientific direction towards implementation of FUTURE; and (c) report back to FUTURE SSC on their activities related to the FUTURE program. The FUTURE SSC Co-Chairs will report semi-annually to Science Board on the progress and any impediments to the implementation of the FUTURE program.

4c. Social-Ecological-Environmental Systems (SEES) Framework

One of the principal objectives of the FUTURE Science Program is to facilitate trans-disciplinary communication and research in order to understand and address changes in North Pacific marine ecosystems and their resulting impacts on coastal communities. During Phase II of FUTURE, the Scientific Steering Committee implemented a Social-Ecological-Environmental Systems (SEES) framework to address critical issues of relevance to nations that share North Pacific marine resources, specifically the member nations of PICES, with a focus on climate- and human-induced ecosystem changes that impact coastal communities (Bograd et al., 2019; Figure 1). By mapping each Expert Group's activity onto this diagram (<https://meetings.pices.int/Members/Scientific-Programs/FUTURE>), FUTURE SSC can identify gaps to be addressed through development of new Expert Groups. This framework fosters a common trans-disciplinary language and knowledge base and provides the FUTURE Science Program, and PICES more broadly, with the capacity to better coordinate and integrate trans-disciplinary marine science. Bograd et al. (2019) demonstrated the application of this SEES framework to four 'crisis' case studies: (a) species alternation in the western North Pacific; (b) ecosystem impacts of an extreme heat wave in the eastern North Pacific; (c) jellyfish blooms in the western North Pacific; and (d) Pacific basin-scale warming and species distributional shifts. A key feature of these case studies is their integration of scientific questions with their societal implications.

During FUTURE Phase III, this SEES framework will be broadly applied within the PICES community to address the principal FUTURE objectives and research themes, and to accommodate the development of strategies to more effectively mitigate climate-driven and anthropogenic impacts on North Pacific ecosystems and communities. Using this SEES framework 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.

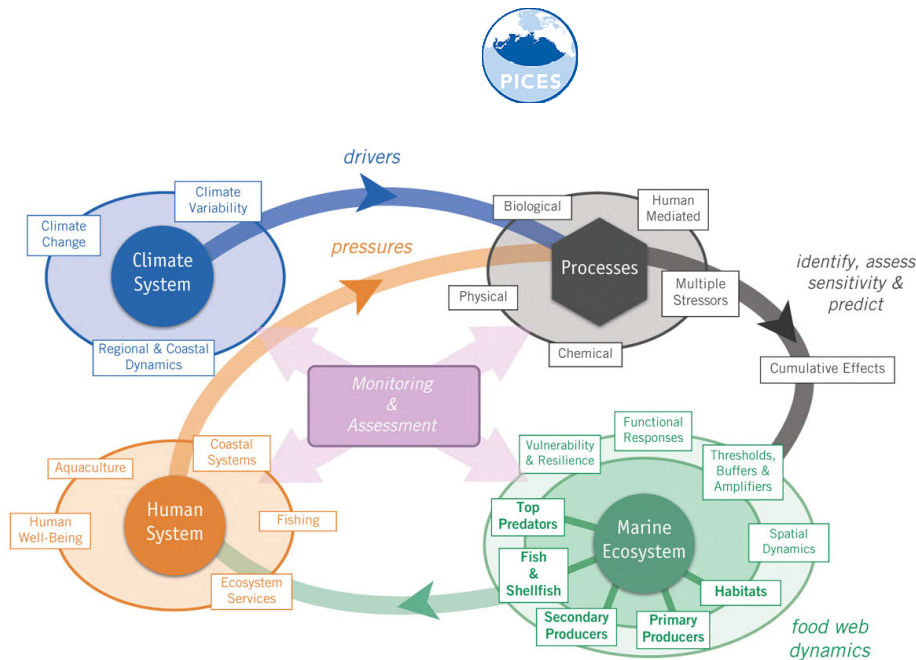


Figure 1: The PICES-FUTURE Social-Ecological-Environmental System framework. PICES Expert Groups map onto the framework to identify synergies and knowledge gaps.

4d. Orientation to the UN Decade of Ocean Science (2021-2030) and International Partnerships

In December 2017, the United Nations General Assembly proclaimed the Decade of Ocean Science for Sustainable Development (2021-2030; <https://oceandecade.org>) to “support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide behind a common framework that will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the Ocean”. The Decade is designed to “facilitate stronger international cooperation to bolster scientific research and innovative technologies to ensure science responds to the needs of society”:

- A **clean ocean** where sources of pollution are identified and removed
- A **healthy and resilient ocean** where marine ecosystems are mapped and protected
- A **predictable ocean** where society has the capacity to understand current and future ocean conditions
- A **safe ocean** where people are protected from ocean hazards
- A **sustainably harvested ocean** ensuring the provision of food supply
- A **transparent ocean** with open access to data, information and technologies

The FUTURE Science Program, and PICES more generally, shares many of the goals of the Ocean Decade. Furthermore, as the key inter-governmental marine science organization in the North Pacific, PICES has the aspiration and capacity to be the key regional partner of the Ocean Decade (<https://meetings.pices.int/publications/pices-press/volume28/PPJan2020.pdf#page=48>). FUTURE Phase III will provide the scientific and organizational infrastructure to implement the activities of the Ocean Decade in the North Pacific.

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 Sea, Equatorial and South Pacific Ocean. In addition to leadership within the UN Ocean Decade, 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 and advice to emerging requests from our societies. This cooperation is organized around:

- Research in climate change and marine ecosystem responses
 - a. International Council for Exploration of the Sea (ICES), through joint Expert Groups (e.g. SCCME), strategically-determined joint scientific activities, co-sponsorship of conferences and sessions, and contributions to Assessment Report 6 of the International Panel of Climate Change (IPCC) (see *Appendix 2*)
 - b. Future Earth, through relationships with IMBER and SOLAS
 - c. CLIVAR, through joint participation in Expert Groups (e.g. WG-40)
- Biodiversity, fishery and marine environmental quality agencies, through relationships with international programs such as NOWPAP, WESTPAC, NPAFC, NPFC, RFMOs and regional fisheries management agencies.

For FUTURE to better relate to stakeholders, it must have effective partnerships with national and regional regulatory agencies that set policy for management of marine resources, protection of water quality, and conservation of protected species and marine biodiversity. This will require a new focus on development and dissemination of scientific products such as ecosystem assessments, ecosystem forecasts, etc.

4e. Engagement of Early Career Scientists

FUTURE strongly encourages early career scientists to participate in FUTURE-related science and activities. It is important that PICES have multi-generational 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 Expert Groups. During FUTURE Phase I and II, PICES supported early career scientist conferences (2012, 2017) and organized Summer Schools to engage younger scientists into PICES activities. FUTURE will continue to support these activities during Phase III.

4f. National Contributions

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. PICES scientists engaged in FUTURE activities, including the SSC members, will 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. 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.

4g. Communicating Knowledge and Solutions to Stakeholders

An important goal of FUTURE is to “*communicate scientific information to members, governments, resource managers, stakeholders and the public*”. Given the rising concerns regarding climate change and other anthropogenic stressors on the marine environment, this communication is most effective when it delivers knowledge that enables solution actions. This concept is not only central to the Implementation Plan of the UN Decade of Ocean Science, but it captures a more modern approach to marine ecosystem science that is informed by the solution needs of end-users (e.g. decision-makers, stakeholders, governments). To this end, FUTURE Phase III will prioritize the development of targeted multi-sector Expert Groups that bring together researchers, stakeholders, and decision-makers, to identify the solutions needs of specific ocean concerns (e.g., coastal sea level rise and extremes, ocean carbon sequestration, conservation of biodiversity, ocean hypoxia and



acidification) and to develop scientific knowledge aimed at enabling ocean solution actions. The knowledge generated by the Expert Groups will include both technological and societal research and innovations, as well as the development of novel governance models. FUTURE is uniquely positioned to make significant advances in connecting scientific knowledge to solution actions for stakeholders, and in achieving the UN Societal Development Goals (<https://sustainabledevelopment.un.org/?menu=1300>).

References

Bograd, S.J., S. Kang, E. Di Lorenzo, T. Horii, O.N. Katugin, J.R. King, V.B. Lobanov, M. Makino, G. Na, R.I. Perry, F. Qiao, R.R. Rykaczewski, H. Saito, T.W. Therriault, S. Yoo, H. Batchelder, 2019. Developing a social-ecological-environmental system framework to address climate change impacts in the North Pacific. *Frontiers in Marine Science*, 6:333, doi.org/10.3389/fmars.2019.00333.



Acronyms

CLIVAR: Climate and Ocean: Variability, Predictability and Change

EG: Expert Group

FE: Future Earth (ICSU)

FUTURE: Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems

ICES: International Council for Exploration of the Sea

IMBER: Integrated Marine Biogeochemistry and Ecosystem Research

IPCC: International Panel of Climate Change

NOWPAP: Northwest Pacific Action Plan

NPAFC: North Pacific Anadromous Fish Commission

NPFC: The North Pacific Fisheries Commission

PICES: The North Pacific Marine Science Organization

SOLAS: The International Surface Ocean - Lower Atmosphere Study

WCRP: World Climate Research Programme



APPENDIX 1: FUTURE Science Research Themes

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?
- 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 2: ICES-PICES Joint Statement on UN Decade of Ocean Science

The UN Decade of Ocean Science for Sustainable Development - An ICES/PICES contribution

6 April 2020

Dear Governing Council members, and Council Delegates,

As you are aware, PICES and ICES individually have indicated their strong support for the Ocean Decade and have participated in various global and regional planning workshops, including those with a specific focus on the North Atlantic, and the North Pacific hemisphere.

We have also been in active communications with our research partners, key Intergovernmental Oceanographic Commission (IOC) staff and members of the Executive Planning Group for the Ocean Decade. Perhaps more importantly, ICES and PICES have been in regular bilateral discussions on joint ICES and PICES activities for the Ocean Decade. The strategic plans and objectives of both organizations are well-aligned with the Ocean Decade objectives and we have experience in successfully conducting joint research across our organizations and associated networks. Frankly, we believe that ICES, PICES and our associated networks have a great deal of expertise and experience to "bring to the table" for the Ocean Decade priorities and societal outcomes.

We have identified multiple potential project areas, but the leading candidate is an expansion of the current joint ICES/PICES activity on Climate Change and Marine Ecosystems, with an enhanced focus on credible projections of the state of future marine ecosystems, including fish, fisheries, aquaculture and dependent communities. We think this is an activity that ICES and PICES are ideally positioned to lead and is central to the science objectives for our organizations and the Ocean Decade.

It is clear that a substantive contribution to the Ocean Decade will require activities and investments that go beyond the "business as usual" activities of our organizations. In particular, Ocean Decade activities will likely require:

1. An expansion of our activities to other geographic areas, beyond the North Pacific and the North Atlantic. We don't plan to change the constitutions of our organizations. Rather we plan to seek new partner organizations to achieve this for the Ocean Decade period;
2. A larger commitment to capacity building/ capacity development in non-member countries, particularly Small Island Developing States (SIDS) and Least Developed Countries (LDC). We have some limited experience with this;
3. A new commitment to engage/work with indigenous communities and other under-represented groups. We plan to seek new partner organizations to achieve this for the Ocean Decade period;
4. A larger investment in outreach/ocean literacy activities;
5. An increased emphasis on supporting Early Career Scientists/Early Career Ocean Professional and providing roles for them in joint Ocean Decade activities. This will include a gender equality focus. Our organizations have already taken some steps in this direction, including planning for the 5th ICES/PICES Early Career Scientist Conference in 2022 with an Ocean Decade theme. Canada has agreed to be the local host for this event.

IOC is also consulting directly with their member states and IOC representatives in your countries will have received documents for comment. We have attached the e-mail that was sent out by IOC asking for comments to the Zero Draft of the Ocean Decade Implementation Plan, for your further reference.

We encourage you to:

- connect with these representatives and discuss the potential role of joint ICES/PICES activities (not restricted to the project discussed above).
- Review the draft Implementation Plan for the Ocean Decade keeping in mind the possibility of joint ICES/PICES projects.
- Consider providing support for joint ICES/PICES activities as part of any national strategy to contribute



to the Ocean Decade. As you can see from the information above credible Ocean Decade projects imply a scaling-up of current science activities and investments in non-traditional areas for our organizations for the Ocean Decade period.

We would be happy to discuss these ideas with you or your representatives.

Sincerely from the informal ICES—PICES study group on the Decade of Ocean Science,

Anne Christine Brusendorff, Bill Karp, Ellen Johannesen, Emanuele Di Lorenzo, Erin Satterthwaite, Hal Batchelder, Hiroaki Saito, Robin Brown, Steven Bograd, Vera Trainer