



PICES External Review

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July 2024

PICES AT 32

An External Review Looking Forward in a Time of Change

Executive Summary

The North Pacific Marine Science Organization (Pacific ICES, PICES) has been an effective voice and proponent for North Pacific marine science for more than 30 years. During this time, PICES has provided a safe and active venue for the open exchange of science, developed an international science network that includes participants from academic and government institutions, and non- and inter-governmental organizations, and has taken on leadership roles in studying North Pacific ecosystems.

Accelerated climate change, increased uses of ocean resources, and other pressing issues are more and more affecting PICES member nations. These issues require actionable advice and are changing the role that PICES can and should have in North Pacific marine science. It is now appropriate and urgent to consider a revision and evolution of PICES's objectives and mission so that PICES can continue its key leadership role by *leading transformative science and providing actionable information* in addition to knowledge and understanding of North Pacific ecosystems relevant to the policy, science, and data needs of its Contracting Parties in the coming decades. To initiate the process of a changing role for PICES, the Governing Council commissioned an External Review Committee (ERC) to review and evaluate the PICES 1) organizational structure, 2) Secretariat, 3) provisioning of knowledge and informal advice to member states, 4) cooperation with other international organizations and 5) capacity development.

The ERC developed recommendations for the requested focal areas based on information provided by interviews with individuals who represented a diversity of PICES science and engagement, participation by the ERC in the 2023 PICES Annual Meeting, a visit by the ERC to the PICES Secretariat, and recommendations from representatives of the Contracting Parties. The findings and conclusions that support the recommendations are based on synthesis of interview responses and observations and inputs from Secretariat personnel, past and present.

Input to the ERC revealed consistent themes and areas of concern for PICES. From a synthesis of these responses, the ERC identified five high-priority areas that are essential to the future of PICES so that it continues to be the trusted, valuable, and leading marine science organization of the North Pacific. The priority areas are:

- **Role** of PICES be enhanced and expanded to provide transformative and actionable science-based information relevant to the Contracting Parties
- **Organizational Structure** that reflects current and emerging science
- **Integrative Scientific Program** that orchestrates scientific activities to provide relevant and desired products
- **Administration** functionality that supports a revised **Role**, PICES work and community
- **Capacity Development** across all career stages with increased disciplinary, scientific, and cultural diversity

The primary recommendations for each priority area point to a need for a changing role for PICES to provide actionable information and solution-based science that is relevant and needed by the Contracting Parties (Table 1). Recommendations for related areas focus on actions that are needed to advance the priority areas. Acceptance and implementation of these recommendations should be done through discussion with the Governing Council, Science Board and the PICES community.

Table 1. Summary of recommendations from the External Review for each priority area.

| Priority Area | Primary Recommendation | Related Areas | Recommendations |
|---------------------------------|---|--|---|
| Role | 1. PICES revise its role to provide actionable science information that is relevant to the Contracting Parties and facilitate actions towards science-based solutions | Strategic Plan | 1.1. PICES revise its strategic plan to identify and incorporate themes and products that reflect the transition to providing actionable scientific information needed by the Contracting Parties and communicate these to members, governments and stakeholders |
| | | Actionable Information and Solution-Based Science | 1.2. PICES revise its mission to focus on predictions and projections in support of solution-based science such that PICES becomes a unique and essential source of actionable information on the North Pacific Ocean that is policy-relevant for its Contracting Parties |
| | | | 1.3. PICES redesign the NPESR to support actionable information, including revisions for how ecosystem status and trends are acquired and provided, so that information is available at an appropriate time interval and format |
| Organizational Structure | 2. PICES evaluate and revise its current structure to optimally accomplish its updated mission and goals and represent current and emerging science themes | Data Provider | 1.4. PICES establish itself as a primary portal for data on the North Pacific Ocean with the goal of providing information that supports the needs of the Contracting Parties |
| | | Committee and Expert Group Structure | 2.1. PICES revise the structure of the Scientific Committees and expert groups to better reflect current and emerging science themes and facilitate actionable information and science-based solutions |
| | | Communication | 2.2. PICES develop and implement simple and efficient means to facilitate communication, cooperation |

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| | | | and integration within the organization |
| | | Intersessional Work | 2.3. PICES develop and implement procedures, such as a web platform, to facilitate intersessional cooperative work |
| Integrative Scientific Program | 3. PICES use the revised committee structure to develop an Integrative Scientific Program that will facilitate and produce products relevant to the interests and needs of the Contracting Parties | FUTURE and New Integrative Scientific Program | 3.1. PICES phase out FUTURE and initiate a process to gather and assess needs and outcomes that will support development of a science plan to guide a new Integrative Scientific Program |
| | | Science Plan | 3.2. PICES develop a science plan for a new Integrative Scientific Program with clear scientific questions, products for transformative actions, and metrics for measuring success |
| | | Integrative Scientific Program Governance | 3.3. PICES develop an implementation plan for the new ISP that includes governance and coordination that facilitates participation from all committees and expert groups and strengthens linkages and communication across all PICES activities |
| Administration | 4. PICES assess and implement changes to its administration, including innovative approaches to increase support, including through dedicated personnel and resources provided by Contracting Parties | Secretariat | 4.1. PICES Governing Council and Finance and Administration Committee explore, evaluate and, if appropriate, implement novel means of support of the Secretariat, including allocation of personnel, financial support, and facilities of Contracting Parties |
| | | Annual Meeting | 4.2. PICES revise the Annual Meeting format to support a shorter meeting and revise submission and decision dates for Annual Meeting session and workshop proposals |
| | | Timeliness of Decision Making | 4.3. PICES Governing Council members delegate nominations to their representatives on the |

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|-----------------------------|---|---|--|
| | | | Science Board to expedite nominations and remove unwanted delays |
| Capacity Development | 5. PICES initiate an expert group to develop innovative approaches and identify appropriate resources that will facilitate capacity development and enhance strategic partnerships across all career stages and increase disciplinary, scientific, and cultural diversity | Strategic Partnerships | 5.1. PICES enhance existing and develop new strategic partnerships to exchange knowledge and experience needed to facilitate transition to providing Contracting Parties with science-based actionable information |
| | | Recruitment and Retention | 5.2. PICES ensure participation across career stages by providing a forum for innovative and engaging science, making the Contracting Parties aware of the benefits to PICES from a diverse community, and making the benefits known to the Contracting Party and the ECOPs of their active participation in PICES |
| | | Engagement with Policy and Decision Makers | 5.3. PICES initiate multi-disciplinary workshops and training courses to engage policy and decision makers and PICES members in co-design and co-production of products that support science-based information that is relevant to the needs of the Contracting Parties, including use of projects |

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I. INTRODUCTION

In the late 1970s-early 1980s the North Pacific marine science community recognized the need for a forum that would allow the open exchange of information and data sharing, development of collaborative research projects, facilitate the understanding of the state and change of the North Pacific Ocean, and provide scientific advice about fisheries, similar to the role of the International Council for Exploration of the Sea (ICES) in the North Atlantic. To meet this need, the international intergovernmental organization, the North Pacific Marine Science Organization (Pacific ICES, PICES), was established under a Convention that entered into force in 1992 with the mandate “*to promote and to coordinate marine scientific research in the North Pacific Ocean and to provide a mechanism for information and data exchange among scientists in its member countries*”. The initial three PICES Contracting Parties, Canada, Japan, and the United States of America, expanded to six with the inclusion of China, Korea, and Russia. In the next 3 decades, PICES established itself as a leader for coordination, promotion, and development of initiatives to further North Pacific marine science, with particular focus on fisheries, ocean environment, and climate. It is the leading marine science organization of the North Pacific.

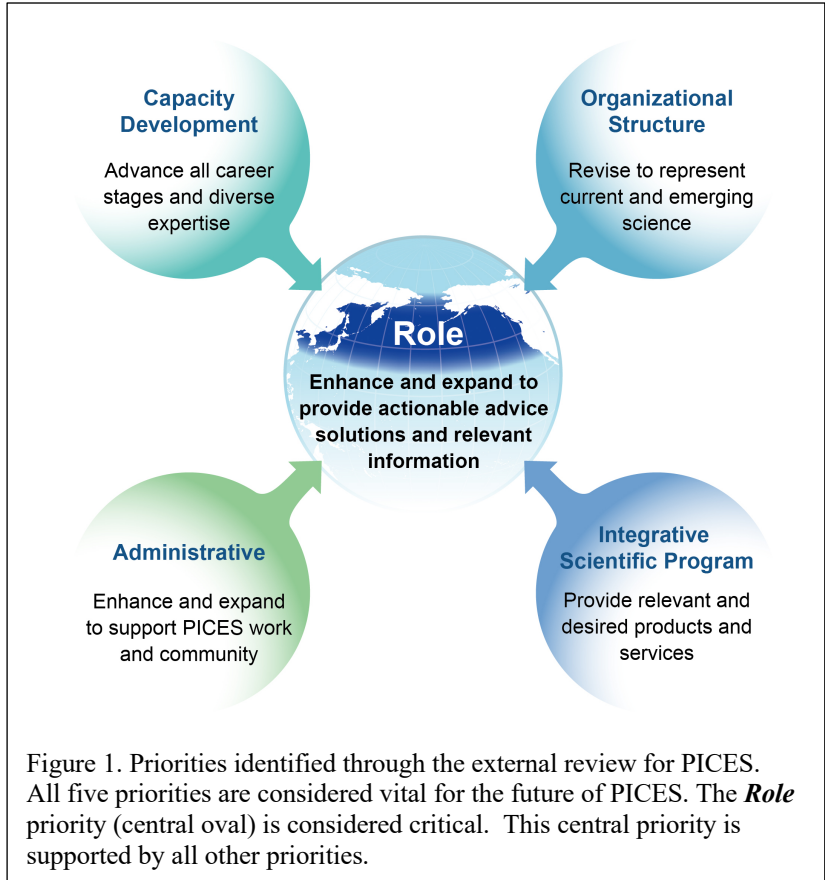
PICES has functioned as an effective voice and proponent for North Pacific marine science for more than 30 years. During this time, PICES has provided a safe and active venue for the open exchange of science, developed an international science network that includes participants from academic and government institutions, and non- and inter-governmental organizations, and has taken on leadership roles in studying North Pacific ecosystems. Importantly, PICES has facilitated research as evidenced by seminal studies of regime shifts (King 2005), carbon cycling in the North Pacific (Feely 2003, Dickson *et al.* 2007), fish population modeling (NEMURO, Kishi *et al.* 2007; CCS, Rose *et al.* 2015), salmon decline (Cohen 2012), tsunami debris tracking (ADRIFT, Carlton *et al.* 2017), ocean and climate prediction (Babanin 2023) and plankton observing (e.g., Batten *et al.* 2022). PICES was essential for each of these studies.

Accelerated climate change, increased uses of ocean resources, and other pressing issues affecting PICES member nations that require actionable advice are changing the role that PICES can and should have in North Pacific marine science. It is now appropriate and urgent to consider a revision and evolution of PICES’s objectives and mission so that PICES can continue its key leadership role by *leading transformative science and providing actionable information* (e.g., predictions and projections) in addition to knowledge and understanding of North Pacific ecosystems relevant to the policy, science and data needs of its Contracting Parties in the coming decades.

In anticipation of a changing role for PICES, the PICES Governing Council commissioned an External Review Committee (ERC, Appendix 1) with Terms of Reference (Appendix 2) to review and evaluate the PICES organizational structure, Secretariat, provision of knowledge and informal advice to member states, cooperation with other international organizations and capacity development.

The ERC identified five high-priority areas that are essential to the future of PICES so that it continues to be the trusted, valuable and leading marine science organization of the North Pacific. Enhancing and expanding the **Role** of PICES to provide transformative and actionable science information relevant to the Contracting Parties is considered critical for the future of PICES. An organizational structure that reflects current and emerging science, Integrative Scientific Programs (ISPs) that provide relevant and desired products and services and an

administration functionality that supports PICES work and community are vital for supporting a



revised PICES **Role** (Figure 1). The PICES community implements PICES science and thus Capacity Development across all career stages with increased disciplinary, scientific and cultural diversity is a priority.

The ERC developed recommendations for the five priority areas that are based on interviews with individuals who represented a diversity of PICES science and engagement, participation by the ERC in the 2023 PICES Annual Meeting and a visit by the ERC to the PICES Secretariat (Appendix 3). The findings and conclusions that support the recommendations are based on interview responses and observations and inputs from Secretariat personnel, past and

present. The recommendations thus represent a synthesis of opinions from the PICES community.

II. PICES ACHIEVEMENTS

It is important to recognize main achievements of PICES because these illustrate the benefit of the organization to its members, member states, the North Pacific marine science community and the global marine science community. The PICES achievements are many. The following notable examples illustrate the importance of PICES in understanding and guiding North Pacific marine science and providing a bridge that facilitates cooperation across a diverse community.

II.1. Regime Shifts

The work on regime shifts represents a major impact that PICES had on global marine science as a newly established organization. There was a long-standing debate about whether natural systems change incrementally or undergo abrupt transitions. In marine science, similar questions arose regarding climate, ecosystem properties and fish stocks. When PICES started its journey, a regime shift in marine ecosystems was a novel idea with little supporting evidence; even the word “regime” was infrequently used in the scientific literature. As the scientific activities of PICES gained momentum, the concept of regimes was forming as a result of

analysis and comparison of different regions in the North Pacific. This concept became one of the scientific questions addressed by the PICES ISP, Climate Change and Carrying Capacity (CCCC). As a regional program of the international Global Ocean Ecosystems Dynamics Program (GLOBEC), CCCC drew together different disciplines around the idea of systemic changes in marine systems. By the early 2000s, three PICES-sponsored special volumes of *Progress in Oceanography* and two PICES scientific reports focused on regime shifts were published. The PICES Scientific Report 28 (King 2005) provided a direct link between a request from the U.S. government to PICES on regime shifts and fisheries. The efforts by the PICES community to connect climate and ocean physics, lower trophic ecosystems and higher trophic ecosystems changed the view of how marine ecosystems respond to climate change.

II.2. Carbon in the North Pacific

In 1997 PICES established Working Group 13 to assess the role of the North Pacific in the uptake and fate of CO₂ as a contribution to the Joint Global Ocean Flux Study (JGOFS), an international program focused on understanding the global carbon cycle. Working Group 13 undertook a synthesis of North Pacific CO₂ data from underway *p*CO₂ measurements provided by a cooperative Japan-Canada vessel-of-opportunity program in the northern North Pacific (1995-1999) and measurements of dissolved inorganic carbon and alkalinity from the joint World Ocean Circulation Experiment and the JGOFS Global CO₂ survey of the Pacific Ocean (1991-1999). Important outcomes from Working Group 13 were CO₂ inter-comparison studies for carbon species, strategies for exchanging data at the international level and collaborative interactions towards the analysis and synthesis of the global CO₂ survey data (Feely 2003). The success of Working Group 13 led to PICES Working Group 17 on biogeochemical data integration and synthesis. Working Group 17 facilitated the establishment of the PACIFIC ocean Interior CARbon (PACIFICA) database (<https://www.ncei.noaa.gov/access/ocean-carbon-acidification-data-system/oceans/PACIFICA>) and the development of a manual on best practices for ocean CO₂ measurements (Dickson *et al.* 2007). These two working groups demonstrated PICES's leadership role in promoting and coordinating regional cooperation to advance understanding of the ocean carbon cycle, a globally important research problem.

II.3. NEMURO

Six years after PICES was formed, in 1998, the need for a standardized model and modeling approach for North Pacific ecosystems was identified at a PICES workshop convened in Fairbanks, Alaska. In 2000, 29 scientists from all the Contracting Parties met in Nemuro, Japan, to discuss how to create a numerical model of North Pacific ecosystems. The report of that foundational workshop (Megrey *et al.* 2000) provides a valuable perspective on what would become the internationally recognized model NEMURO, the North Pacific Ecosystem Model for Understanding Regional Oceanography (Kishi *et al.* 2007). Ecosystem modeling was a key research activity with the CCCC ISP of PICES. NEMURO resulted from an extensive dialog between modelers, plankton biologists and oceanographers. This lower-trophic level ecosystem model was developed with multiple phytoplankton and zooplankton components that allow simulation of structural and functional changes in the lower trophic levels. This capability was specifically directed at addressing the CCCC scientific questions and provided a basis for linking lower trophic levels to upper trophic levels. This model was subsequently expanded, as NEMURO.FISH, to include herring and saury (Kishi *et al.* 2011). It has been used widely, notably in end-to-end models of anchovy and sardine in the California Current (Rose *et al.* 2015,

Politikos *et al.* 2018). NEMURO epitomizes a founding principle of PICES of collaboration among scientists of all the Contracting Parties to achieve scientific understanding of North Pacific ecosystems and fisheries.

II.4. Cohen Commission

Low returns of sockeye salmon to the Fraser River, Canada, from the 1990s to 2009 led to a three-year closure of this valuable fishery. The Cohen Commission of Inquiry into the Decline of the Sockeye Salmon of the Fraser River (Cohen 2012) was created in 2009 to investigate the cause of this decline and recommend actions to improve sustainability of the fishery. PICES was awarded \$120,000 by the Commission to investigate the role of ocean conditions in sockeye salmon survival. Dr. Skip McKinnell, then PICES Deputy Director, led this investigation, provided testimony to the Commission and was first author of a resultant scientific paper (McKinnell *et al.* 2014). The Cohen Commission cited multiple possible contributing causes to the low survival and returns of Fraser River sockeye. PICES, led by Dr. McKinnell, showed that Fraser River sockeye salmon must survive numerous marine conditions as they emigrate to the sea as juveniles, a new paradigm termed the ‘marine gauntlet hypothesis’, with implications far beyond the Fraser River sockeye. These conditions are a result of North Pacific climate and ocean dynamics and provided significant insight into the cause of the recruitment failure of the Fraser River sockeye. This PICES project exemplified the ability of PICES to respond rapidly to a request by a Contracting Party, Canada, to study a primary focus of PICES, the effects of North Pacific climate and ocean conditions on a fishery.

II.5. Scientific Response to Fukushima Daiichi Nuclear Accident

The prevention and mitigation of marine disasters is a focus for the PICES Contracting Parties. This focus was tested when a M9.0 earthquake occurred on 11 March 2011 off northeast Japan generating a massive tsunami, which seriously damaged the Fukushima Daiichi Nuclear Power Plant and caused a nuclear crisis in the North Pacific that received intense global attention. With 20 years of continuous scientific exchange and cooperation, PICES and its related scientists were prepared to undertake studies that contributed to understanding the consequences of the nuclear disaster. PICES opened a forum for exchange of ideas and information and subsequently assembled a group of scientists ranging in expertise from radiation chemistry to circulation modeling to understand the consequences of the nuclear disaster and identify mitigation approaches. The three-dimensional transport and fate of the Fukushima Daiichi-derived radionuclides in the following decades were predicted and published within one month after the accident (Qiao *et al.* 2011), and the predictions were confirmed by observations in subsequent years (Maximenko *et al.* 2015, 2018). PICES established Working Group 30, “Assessment of Marine Environmental Quality of Radiation around the North Pacific”, in August 2013, which remained active until December 2017. The movement of the tsunami-generated debris in the open ocean was predicted and observed (Carlton *et al.* 2017). The effects of the nuclear disaster on the marine ecosystem, ocean organisms and marine products such as tuna were comprehensively identified by the Working Group (e.g., Buesseler *et al.* 2017, Yu *et al.* 2020). Collectively, these activities demonstrate that PICES has the ability to provide the Contracting Parties with science-based actionable knowledge and advice in a timely and efficient manner.

II.6. Networking and Trust

PICES has developed a strong convening power for scientists in the North Pacific and has gained trust as an independent and connecting organization that successfully bridges geographies, languages and cultures. This trust enabled PICES to also serve as a platform for special projects, such as FishGIS, intended to enhance capacity of small-scale fishers in Indonesia, and FishPhytO, designed to establish phytoplankton-fishery observing systems in Indonesia. PICES was also instrumental in establishing the Continuous Plankton Recorder Survey in the North Pacific in 1997, working with the Sir Alister Hardy Foundation for Ocean Science and facilitating funding from the North Pacific Marine Research program and the North Pacific Research Board.

In cooperation with other organizations, this convening power gained a global reach. Beginning with the Early Career Scientist Conference in Baltimore in 2007, PICES and ICES initiated a cooperative agreement to convene major events in areas of shared common interests, e.g., Climate Change in the World's Ocean, Zooplankton Production Symposium, and Small Pelagic Fish Symposium. Through cooperation with the Scientific Committee on Ocean Research (SCOR), PICES supports travel for early career scientists and enables science exchange with SCOR working groups, such Working Group 146 on 'Radioactivity in the Ocean, 5 Decades Later'.

PICES has always recognized research contributions of early-career scientists through awards for oral and poster presentations and travel grants to participate in PICES activities. Following the success of the 2007 Early Career Scientist Conference, PICES initiated efforts to include Early Career Ocean Professionals (ECOPs) as participants in all PICES activities as well as in leadership roles and encouraged involvement in international scientific research. PICES, with ICES, has continued to convene the Early Career Conferences; the fourth conference occurred in 2022. The robust ECOPs network that now exists within PICES is a clear indication of success.

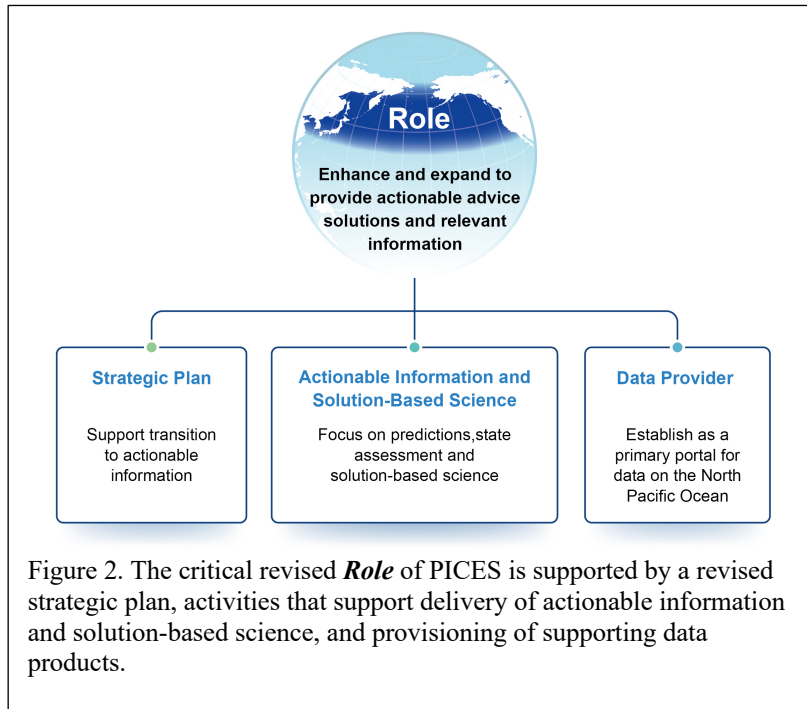
III. ROLE of PICES

PICES was founded in 1992 with the mission "*to improve the scientific understanding of the North Pacific Ocean and its processes, living resources, and oceanographic features*". Over the following 32 years, the North Pacific Ocean has changed in response to human activities, including resource use and climate change, and the combined populations of the PICES nations has increased by 19%. The demand for resources, including fish, has increased even more. Simultaneously, the North Pacific has been challenged by extreme events, including marine heat waves and harmful algal blooms, gradual change, including plastic pollution, ocean acidification and warming waters, and catastrophes, such as the Fukushima Daiichi nuclear accident (see Section II.5).

These short-term challenges and long-term changes affect PICES nations in specific and different ways. The expectation is that PICES will provide actionable scientific information that will inform approaches to prepare and react optimally to these challenges and changes. This shift in emphasis underlies a collective realization that emerged from interviews with PICES members, past and current chairs and members of the Governing Council, Science Board, Secretariat, Committees, Working Groups, Advisory Panels and Study Groups, which is that facilitating scientific understanding alone is no longer sufficient, nor is maintaining the status

quo. PICES must be more nimble, proactive, and responsive to the needs of its Contracting Parties. PICES should change its focus and approach so that it becomes essential to its members.

Another realization that emerged from the interview responses was that PICES should



focus on providing the Contracting Parties with science-based information supporting actions to prepare for and respond to the effects of human activities, including fishing, pollution and especially accelerating climate change. Such information ranges from knowledge and understanding to forecasts and predictions. There is opportunity for PICES to become essential to the Contracting Parties in this role. Taking on this role will require PICES to redirect its mission and goals from facilitating understanding to activities that will provide

actionable science information (Figure 2), a redirection in **Role** that is critical for PICES to remain relevant and a leader in North Pacific marine science.

Recommendation 1: PICES revise its role to provide actionable science information that is relevant to the Contracting Parties and facilitate actions towards science-based solutions.

III.1. Strategic Plan

Moving towards provisioning of actionable science information requires consensus on what constitutes relevant, needed and feasible products, but findings from interviews led to the conclusions: 1) the Contracting Parties are not fully aware of the potential of PICES and what it could offer, 2) PICES is not fully aware of the needs of the Contracting Parties, and 3) there are opportunities to match national needs with PICES products and ensure that results are effectively communicated to relevant stakeholders and user groups. The PICES strategic plan provides an opportunity to develop a framework that supports actionable information and builds community consensus on the areas of research and products that are relevant and needed (Figure 2).

Recommendation 1.1: PICES revise its strategic plan to identify and incorporate themes and products that reflect the transition to providing actionable scientific information needed by the Contracting Parties and communicate these to members, governments, and stakeholders.

III.2. Actionable Information and Solution-Based Science

The presentations, workshops and expert group meetings at the Annual Meeting and interview responses showed clearly that model-based forecasts, predictions, and long-term

projections are approaches for providing solution-based responses that underpin actionable information which is policy relevant. PICES can play an essential and leading role in facilitating global, regional- and smaller-scale models for forecasting and projecting states of coupled environmental-ecosystem-social systems. The needs and expectations of the Contracting Parties must be known and considered throughout all stages of model development and implementation. Also, model-based information needs to be grounded in data and the next generation of models must extend beyond physics and biochemistry and must include ecosystems, society and climate change. Revising the mission of PICES to support delivery of actionable information and advice that address the needs of the Contracting Parties is needed.

Recommendation 1.2: PICES revise its mission to focus on predictions and projections in support of solution-based science such that PICES becomes a unique and essential source of actionable information on the North Pacific Ocean that is policy-relevant for its Contracting Parties.

To provide reliable actionable information, predictions need to be complemented by knowledge of the current status and trends. PICES has produced a series of publications that provide ecosystem status, the North Pacific Ecosystem Status Report (NPESR). Spanning more than two decades, the series presents an ongoing record of North Pacific ecosystems in a time of major global changes. As a flagship product of PICES, the series has provided basin-wide syntheses based on data from the ecosystems across the North Pacific on topics that range from climate to physics, chemistry, biology, including plants, invertebrates, fish, birds, and marine mammals, and human dimensions. Each status report focused on recent status and trends of many ocean and ecosystem variables. The NPESR needs to be revised and updated to serve the new role of PICES to provide actionable information. Major points to consider include formats, variables of interest, and update intervals.

The NPESR was originally planned to be updated at an interval of about five years. The last edition, published in 2021 and covering 2009-2016, was more than ten years after the prior status report, published in 2010 and covering 2003-2008. The delay in providing timely NPESRs arises from difficulties in recruiting authors, collecting and analyzing data and the time required for writing and publishing. Accelerated changes in global oceans call for less lead time so that response actions to the state of North Pacific ecosystems taken by stakeholders are informed by the best available science. To reduce lead time and to make the NPESR relevant and timely, new approaches are needed, such as adjusting update intervals to match the temporal scale of variables, using automated data collection and processing for some variables and, perhaps, artificial intelligence methods for data acquisition and processing.

Recommendation 1.3: PICES redesign the NPESR to support actionable information, including revisions for how ecosystem status and trends are acquired and provided, so that information is available at an appropriate time interval and format.

III.3. Data Provider

Products that support status assessments, predictions, forecasts and actionable information require data that are quality controlled and accessible. The interview responses showed that PICES 1) is a trusted broker of data, 2) can link data sources and users through its network and 3) could provide timely access to a range of data types and products. Enhancing its role in data discovery, access and management is an opportunity for PICES to provide actionable

information and products that serve specific needs of its Contracting Parties and be viewed as a primary data source for the North Pacific. It is recognized that providing a data portal will incur additional costs for PICES and this is addressed in the discussion of Administration needs (Section VI).

Recommendation 1.4: PICES establish itself as a primary portal for data on the North Pacific Ocean with the goal of providing information that supports the needs of the Contracting Parties.

IV. ORGANIZATIONAL STRUCTURE

From the start, PICES activities have been directed by the Governing Council, with its membership representing the Contracting Parties. The Governing Council works through the Finance and Administrative Committee that oversees financial and administrative matters for PICES, the Science Board that oversees PICES science activities and directions, and the Secretariat. These entities form a high-level structure that has worked well for overall decision making and operation. It is, however, the structure below the Science Board that plans, conducts and synthesizes the scientific activities of the organization. These scientific activities are operated in bottom-up processes that require efficient communication, adjustment, and coordination.

The Scientific Committees, established in the 1990s in the areas of biological oceanography (BIO), fishery science (FIS), physical oceanography and climate (POC) and marine environmental quality (MEQ), implement PICES science. A Scientific Committee focused on human dimensions (HD) was added in 2016 in recognition of emerging science areas with societal implications. The work of Scientific Committees is supported by Technical Committees on data exchange (TCODE) and monitoring (MONITOR). The Science and

Technical Committees are also supported by working groups, advisory panels, and study groups.

The current structure of Committees, Sections, Working Groups, Advisory Panels, Study Groups, and a Scientific Steering Committee for the ISP has fulfilled the needs and purpose of PICES and has grown organically over time. However, a finding that emerged from many interviews was that the current structure no longer reflects the needs of the organization and does not

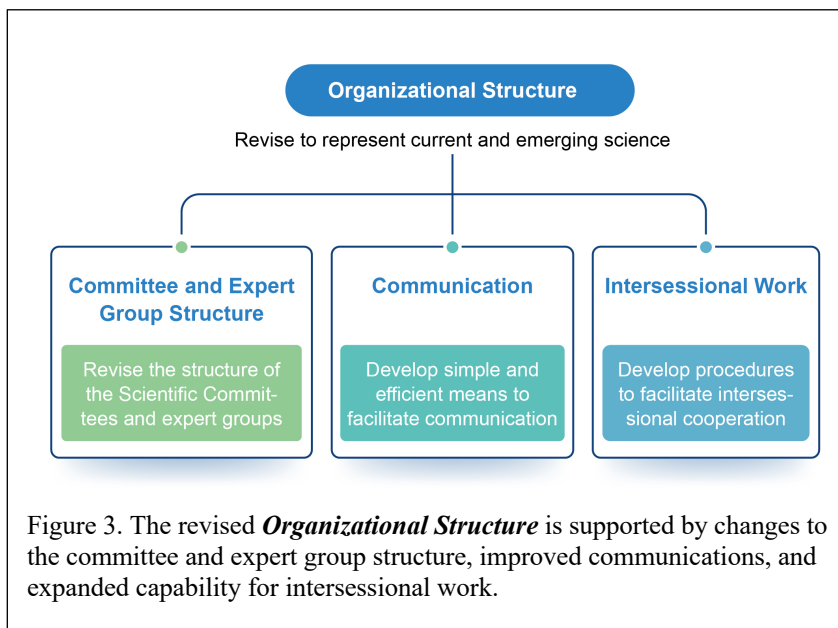


Figure 3. The revised **Organizational Structure** is supported by changes to the committee and expert group structure, improved communications, and expanded capability for intersessional work.

adequately represent emerging themes in science (e.g., climate, adaptation and mitigation, forecasting, artificial intelligence), mentoring and training. This finding supports the conclusion that the organizational structure of PICES requires changes to align with a revised mission and

goal to provide actionable information and facilitate the integration needed to provide science-based advice and solutions (Figure 3).

Recommendation 2: PICES evaluate and revise its current structure to optimally accomplish its updated mission and goals and represent current and emerging science themes.

IV.1. Committee and Expert Group Structure

The Scientific Committees coordinate and regulate the overall activities related to disciplinary areas and expert groups do the work of PICES. The current structure is based on disciplinary committees (Fisheries Science, Biological Oceanography, Human Dimension), functional committees (Technical Committee on Monitoring, Technical Committee on Data

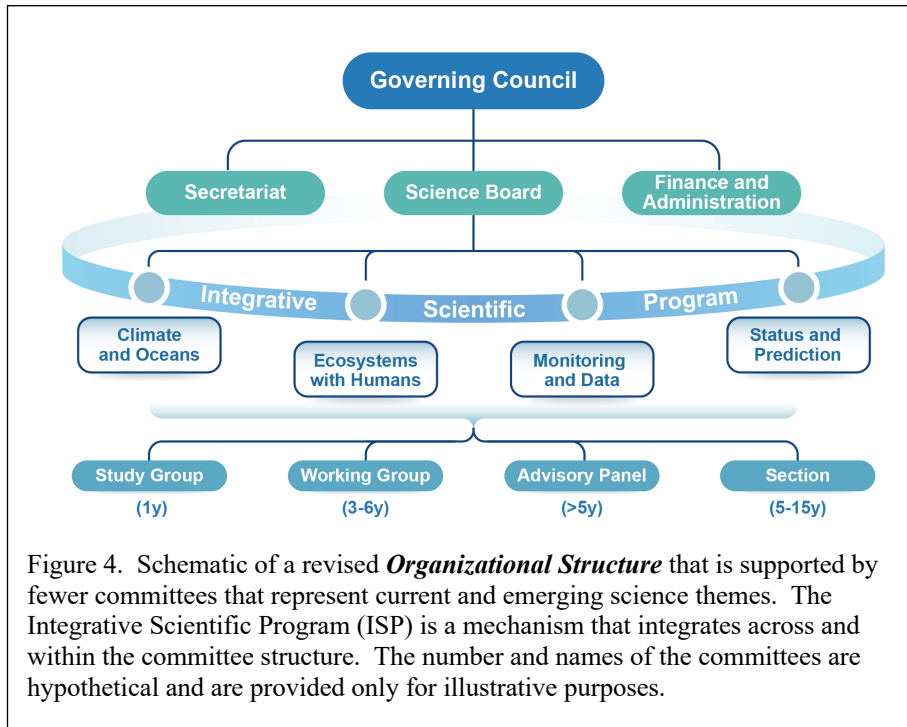


Figure 4. Schematic of a revised **Organizational Structure** that is supported by fewer committees that represent current and emerging science themes. The Integrative Scientific Program (ISP) is a mechanism that integrates across and within the committee structure. The number and names of the committees are hypothetical and are provided only for illustrative purposes.

Exchange), a thematic committee (Marine Environmental Quality Committee), and a committee with a disciplinary and a thematic topic (Physical Oceanography and Climate Committee). In interviews it was mentioned that every structure has its strengths and shortcomings, but in relation to emerging themes (e.g., ecosystem assessment, climate impacts, conservation) and the transition to provide actionable

information and projections, these committees should represent current and emerging science themes and reflect the needs of the Contracting Parties. There was agreement that the current committee structure needs to change to meet the needs of a changing role for PICES. Synthesis of the interview inputs points towards a revised committee structure with fewer committees that combine expertise now distributed across several committees to make progress towards actionable solution-based science (Figure 4). Integration across committees is through the ISP (see Section V). Work of the committees is through study groups, working groups, advisory panels and sections, each appointed with specific tasks and term limits (Figure 4). Findings from the interviews strongly supported the conclusion that the current committee and expert group structure needs change for PICES to be relevant in the long term.

Recommendation 2.1: PICES revise the structure of the Scientific Committees and expert groups to better reflect current and emerging science themes and facilitate actionable information and science-based solutions.

IV.2. Communication

The current structural complexity requires strong communication and processes to ensure cooperation and exchange across the network. The interviews revealed a desire to better understand what other parts of the organization are doing and to identify synergies and means for collaboration.

Recommendation 2.2: PICES develop and implement simple and efficient means to facilitate communication, cooperation and integration within the organization.

IV.3. Intersessional Work

Currently PICES members, partners and observers come together and discuss developments primarily during the annual meeting. Intersessional work occurs but it is not formally and effectively supported. The challenge of working across many countries, languages and cultures means that any central communications platform needs to accommodate the different needs. Many interviewees expressed the wish to be able to work together intersessionally through a PICES platform rather than through individual ad hoc solutions.

Recommendation 2.3: PICES develop and implement procedures, such as a web platform, to facilitate intersessional cooperative work.

V. INTEGRATIVE SCIENTIFIC PROGRAM

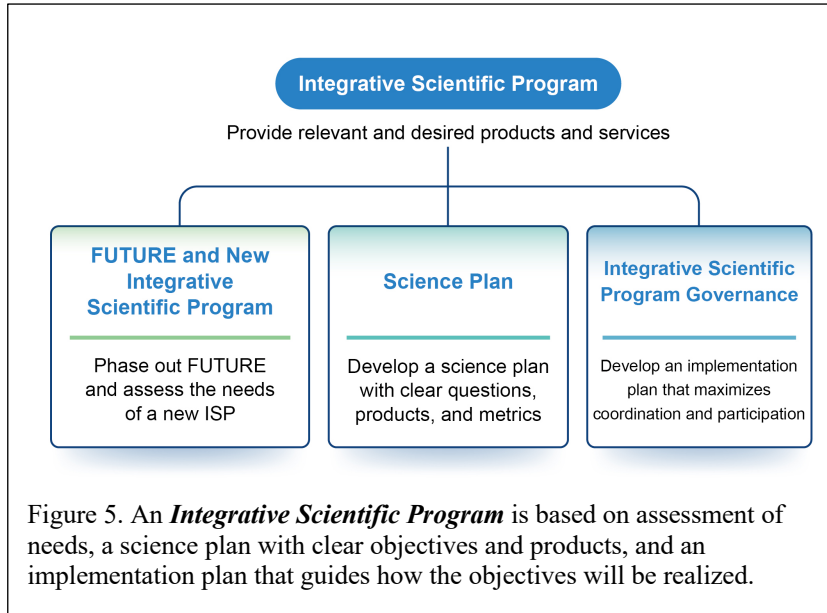
The PICES community is multidisciplinary by nature. As such, PICES occupies a unique niche in ocean science in the North Pacific, an aspect of PICES that was unanimously praised by those interviewed by the ERC. However, multidisciplinary science has the potential risks of selecting for disciplinary sector silos and of losing focus in the organization's efforts. An ISP is a device to minimize these risks because designing an ISP requires involvement of more than one discipline. Ideally, an ISP can be likened to a symphony that an orchestra produces. The majority, if not all, of the committees and expert groups participate in research based on a systematic overarching scientific theme and produce scientific products in a concerted way.

The first major interdisciplinary initiative undertaken by PICES, Climate Change and Carrying Capacity (CCCC, 1995 to 2009), focused on four central scientific issues: physical forcing, lower trophic level responses, higher trophic level responses, and ecosystem interactions. The CCCC program provided novel understanding of regime shifts and produced a community model, NEMURO (see Section II.3). However, progress towards the CCCC program overall goal "to forecast the consequences of climate variability on the ecosystems of the subarctic Pacific" was limited. Other aspects of CCCC that limited its impact were a domain that was largely open ocean, lack of consideration of anthropogenic impacts on climate, and lack of attention to human-ecosystem interactions other than fishing.

The second ISP, Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Ecosystems (FUTURE, 2009-present), was designed to address some of the limitations of the CCCC. FUTURE specifically emphasizes the connectivity of the climate system and the processes that support this connectivity across marine ecosystems and the human system. As such, the overarching theme of FUTURE addresses interdisciplinary issues, but with science objectives that are so broad, e.g., ecosystem resilience, as to be intractable, making progress difficult. FUTURE also aims to develop two types of predictions (outlooks and

forecasting). The FUTURE Product Matrix is an approach for classifying outputs from expert groups that are related to FUTURE questions, which are broad and vague. Therefore, the Product Matrix is an assortment of outputs from expert groups, rather than outputs that are designed in line with FUTURE’s specific scientific questions. Most of these products are not directly relevant to answers that the Contracting Parties desire or require.

The findings from the interviews and observations support the conclusions: 1) although the



main purpose of an ISP is to connect and integrate scientific activities of various groups and members across PICES, the past and ongoing ISPs operate with some degree of isolation from the PICES community; 2) the outputs/products from ISPs do not meet the current needs of the Contracting Parties; 3) FUTURE has not met expectations for promoting and facilitating interdisciplinary and transdisciplinary science across PICES and has become an activity mostly isolated

from the larger PICES community; and 4) FUTURE has produced few tangible products and little capability. These conclusions point to the importance of an ISP that provides relevant and desired products (Figure 5).

Recommendation 3: PICES use the revised committee structure to develop an Integrative Scientific Program that will facilitate and produce products relevant to the interests and needs of the Contracting Parties.

V.1. FUTURE and New Integrative Scientific Program

The findings related to FUTURE noted that the intellectual effort and resources expended on FUTURE by PICES members are significant, that the return on these investments is unclear, and that continued support for FUTURE is not a good use of limited resources. The conclusion from these findings is that FUTURE should be phased out. Although there was consensus about ending FUTURE, there was a clear recognition that a new ISP is needed to bring together PICES science (Figure 5).

The interview responses about a new ISP provided insights into how the PICES community envisions the process for its development. The findings were that the PICES community should provide input to define the new ISP, that the governance structure should be such that it allows the ISP to work effectively across the whole of PICES and that CCCC and FUTURE should be assessed to determine what did and did not work, including the planning process, science plan, organizational structure and outcomes. Additionally, there was consensus that a new ISP should

identify and be responsive to the needs of the Contracting Parties. The conclusion from these findings is that planning for a new ISP should be initiated (Figure 5).

Recommendation 3.1: PICES phase out FUTURE and initiate a process to gather and assess needs and outcomes that will support development of a science plan to guide a new Integrative Scientific Program.

V.2. Science Plan

The science plan for the new ISP should be based around scientific questions that address the needs of the Contracting Parties. The science questions should identify desired and relevant science products (e.g., forecasts, predictions) and a process for delivering maximum product value with the available resources (e.g., value chain), have clearly designed metrics for measuring success and support transformative science. The science plan could be viewed as a living document that will be periodically updated in response to changes in the North Pacific, changing needs of the Contracting Parties and scientific and technical advances.

Recommendation 3.2: PICES develop a science plan for a new Integrative Scientific Program with clear scientific questions, products for transformative actions and metrics for measuring success.

V.3. Integrative Scientific Program Governance

The new science plan should include an implementation plan that maximizes participation by expert groups, has efficient linkages, communication, and coordination across PICES and has a governance structure owned by the Science Board.

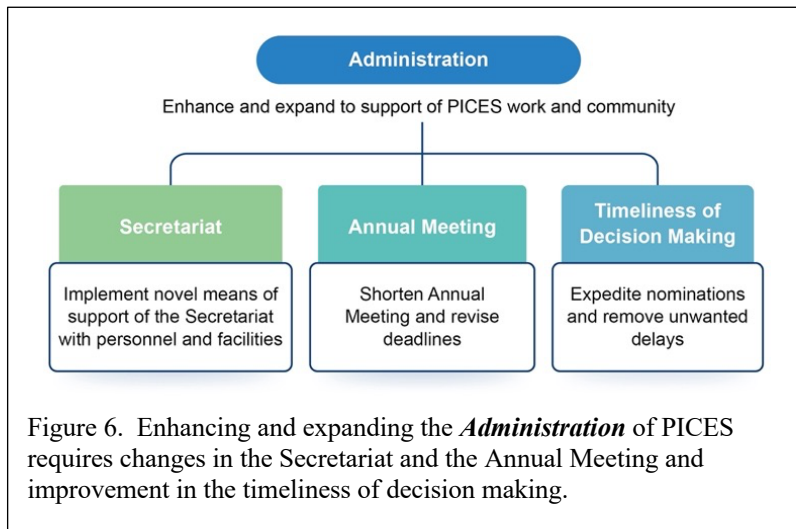
Recommendation 3.3: PICES develop an implementation plan for the new ISP that includes governance and coordination that facilitates participation from all committees and expert groups and strengthens linkages and communication across all PICES activities.

VI. ADMINISTRATION

There was considerable agreement that the Contracting Parties should take a larger and stronger role in providing additional expertise and resources to enable new functions. The suggested change in focus to provide actionable information and potential expansion of services, such as a data portal, will necessitate innovative ways to provide an increase in support. In addition to conventional means, including increased dues, as specified in the Financial Regulations, novel means, such as dedicated support of personnel who engage in activities and services for PICES that are located at host institutions of the Contracting Parties should be considered. The Contracting Parties need to consider these and other innovative ways to provide extended support, resources, and expertise (Figure 6).

Recommendation 4: PICES assess and implement changes to its administration, including innovative approaches to increase support, including through dedicated personnel and resources provided by Contracting Parties.

VI.1. Secretariat



Much of the work of PICES is facilitated and coordinated by an effective and dedicated Secretariat that serves many functions in organizing and coordinating a diversity of activities undertaken by the Governing Council, Science Board and the many groups that implement PICES science. As such, the Secretariat is vital to the operation of PICES. The administrative needs anticipated to support the changing role of

PICES to provide actionable information and data access and expanding activities, such as a new ISP, will be delegated to the Secretariat for implementation and coordination. However, a clear finding from the interviews was that the capacity of the Secretariat to take on new tasks and responsibilities is limited in terms of personnel, expertise, and resources.

Expansion of the Secretariat was considered critical for PICES to maintain existing activities and undertake new activities. The current model of a centralized Secretariat limits the ability to hire personnel to serve existing activities (e.g., NPESR), take on new activities and potentially compromises current functions. Dedicated personnel that are located at the different institutions of the Contracting Parties provide an approach for obtaining expertise to implement specific tasks and/or activities that exceed the current capacity of the Secretariat. For example, revision and expansion of the PICES website to provide better functionality, accessibility and a central permanent repository for critical datasets is one specific task that requires new resources and expertise. Enhancement of in-kind or direct funding contributions by the Contracting Parties is an approach for supporting the anticipated expanded and some current activities of the Secretariat.

The existing PICES Intern Program could potentially address some of the need for additional Secretariat capacity. However, for this to be a viable approach, the scope of an intern position will need to be such that it benefits the scientific career of the intern. Providing only administrative experience is not sufficient nor is it conducive to attracting interns who want to engage in international science. Also, the salary associated with an intern position needs to be competitive and not present a financial challenge for an intern located at the Secretariat.

Recommendation 4.1: PICES Governing Council and Finance and Administration Committee explore, evaluate and, if appropriate, implement conventional and novel means of increasing support of the Secretariat, including allocation of personnel, financial support, and facilities of Contracting Parties.

VI.2. Annual Meeting

An important function of the Secretariat is to oversee and organize a diversity of meetings, workshops, and expert groups that involve participants from across the PICES community. Foremost among these is the PICES Annual Meeting, which is regarded as a critical

activity by the PICES members. The Annual Meeting is an expensive activity for the Secretariat in terms of time and resources required to organize and implement it. The Annual Meeting is also expensive in time, resources, and carbon footprint for participants because of its duration, which limits or prohibits attendance by some and results in questioning the utility of the meeting by governments and sponsors.

The interviews showed a consensus of opinions about the Annual Meeting: 1) the meeting should be shorter, 2) virtual meetings should be used better to do business prior to the Annual Meeting, 3) time at the Annual Meeting should focus on science and activities that are not conducive to a virtual meeting format and 4) the Rules of Procedures should be revised to support more use of virtual planning/business meetings. An additional finding was that the deadline now used for submitting session and workshop proposals for the next annual meeting is not flexible enough to accommodate urgent and/or emerging scientific issues or new session and workshop ideas arising from discussions during the Annual Meeting. The current proposal deadline is regarded as too early to reflect the outcomes of these discussions and newly emerging issues. There was considerable support for moving the proposal and decision deadline to follow the Annual Meeting.

Recommendation 4.2: PICES revise the Annual Meeting format to support a shorter meeting and revise submission and decision dates for Annual Meeting session and workshop proposals.

VI.3. Timeliness of Decision Making

Expert groups are integral to advancing PICES science and initiatives. Members of expert groups are nominated by Governing Council members who represent the Contracting Parties. These nominations are an important administrative function. Timeliness of action on these nominations affects the ability of expert groups to become engaged with PICES. A consistent finding from the interviews was that these nominations are frequently delayed and the reasons for the delay are not provided or are unknown. These unexplained delays have negative consequences for PICES because participation by new members of expert groups does not occur in a timely manner, thereby delaying progress of expert group activities, which in turn delays overall progress of PICES science.

Recommendation 4.3: PICES Governing Council members delegate nominations to their representatives on the Science Board to expedite nominations and remove unwanted delays.

VII. CAPACITY DEVELOPMENT

PICES was founded on the principles of inclusion, cooperation, and trust among representatives of the Contracting Parties and scientists. PICES has been active, in cooperation with other international organizations, in providing international forums on contemporary issues and has organized Conferences such as the Effects of Climate Change on the World's Oceans, the Zooplankton Production Symposium, and the Small Pelagic Fish Symposium. PICES facilitated interactions among scientists and representatives from government and non-governmental organizations. PICES has taken on the important role of facilitating the incorporation and engagement of Early Career Ocean Professionals (ECOPs) across the diversity of PICES science and organizational structure. PICES, together with ICES, organizes the PICES/ICES Early Career Scientist Conference every five years. PICES provides a forum for a diverse community to meet in an apolitical and safe environment to address common concerns.

This concept is more important now than ever due to changes in geopolitics, social networking and misinformation. A majority of interviewees cited these principles as emblematic of and

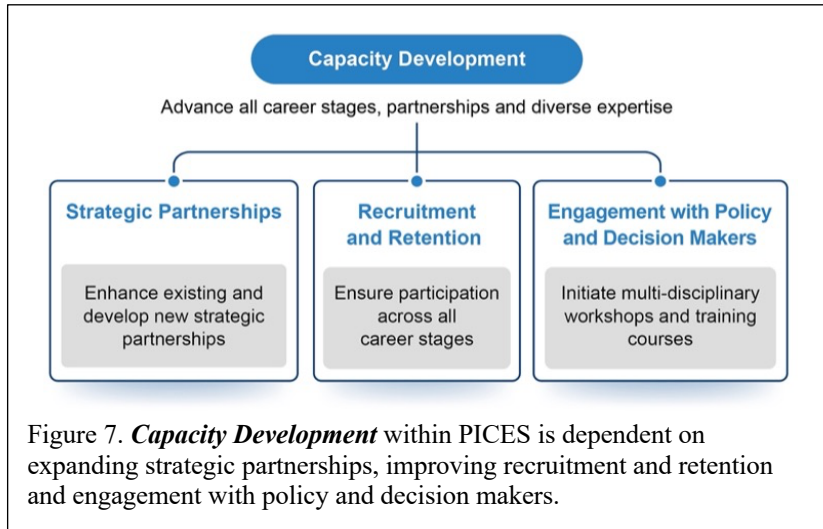


Figure 7. *Capacity Development* within PICES is dependent on expanding strategic partnerships, improving recruitment and retention and engagement with policy and decision makers.

essential to PICES. In addition, many interviewees said that social interactions at the Annual Meeting, workshops, courses and other gatherings facilitated communication, work and trust within and beyond PICES (see section II.6).

Continued success in facilitating communication and interactions is critical for the future of PICES. Ensuring that this continues requires constant attention, dedicated

resources and innovative approaches that will encourage positive interactions across disciplinary, scientific, and cultural diversity. A new ISP and a focus on providing science-based actionable information are opportunities to engage across the spectrum of disciplines, form strategic partnerships and include new communities. However, success depends on maintaining current efforts and developing innovative approaches that engage new disciplines and communities and ensuring that resources are available to implement the approaches (Figure 7).

Recommendation 5: PICES initiate an expert group to develop innovative approaches and identify appropriate resources that will facilitate capacity development and enhance strategic partnerships across all career stages and increase disciplinary, scientific, and cultural diversity.

VII.1. Strategic Partnerships

Since its formation, PICES has developed and maintained relationships and partnerships with a variety of external entities, both within and outside the Contracting Parties. Examples are indigenous communities in Canada and the United States, fishing communities in Indonesia, and the communities invested in salmon fishing (see section II.4). PICES gains and transfers knowledge, recognition, and capacity through external partnerships, which will become more important as PICES moves towards providing science-based actionable information. The expertise needed for this transition will necessitate engaging with external communities that have not traditionally been part of the PICES community (e.g., World Meteorological Organization, World Climate Research Program) and strengthening connections with the United Nations Educational Scientific and Cultural Organization Intergovernmental Oceanographic Commission (UNESCO/IOC) and United Nations Decade of Ocean Science for Sustainable Development.

Climate is recognized as a primary driver of change in the North Pacific Ocean and this large-scale variability extends beyond the domain that is included in PICES. There is acknowledgment of the importance of the Arctic for the North Pacific. Similarly, connectivity to the western Pacific and lower latitudes is recognized to affect the environment and ecosystems of the North Pacific. As a result, the revised **Role** of PICES to provide actionable information will

require expanding the geographic footprint of PICES to represent large-scale climate variability and its effects on the North Pacific Ocean and ecosystems. Some efforts are underway within PICES to form partnerships with groups and organizations working in the Arctic and these efforts should be strengthened and expanded. Partnerships with groups and organizations working in the western Pacific (e.g., Southeast Asia) and other regions outside the PICES domain should be pursued and encouraged. Similarly, a large fraction of the ocean in the PICES domain consists of international waters. In addition to partnering with climate, ocean and coastal ecosystem and human dimension groups, PICES should engage with Regional Fisheries Management Councils and other organizations concerned with fisheries and ecosystems of international waters in the PICES domain. Such expansions of partnerships would potentially set a foundation for further cooperation and collaboration that may naturally lead to expanding PICES membership.

Recommendation 5.1: PICES enhance existing and develop new strategic partnerships to exchange knowledge and experience needed to facilitate transition to providing Contracting Parties with science-based actionable information.

VII.2. Recruitment and Retention

Approximately 28% of the attendees of the 2023 PICES Annual Meeting were ECOPs; the remaining 72%, were mid- to late career, with many having long-term associations with PICES. The almost one-third representation by ECOPs indicates that the deliberate efforts by PICES to engage this career stage have been successful. However, comments made by ECOPs during interviews indicated that many were unsure of their ability to continue with PICES once they have a full-time position, especially if their employment is not focused on the North Pacific. All indicated concern about access to sufficient resources to engage in PICES workshops, expert groups, and the Annual Meeting. Similar concerns were expressed by some mid-career participants at the Annual Meeting. These concerns highlight the importance of engagement and retention of ECOPs and all other career stages. PICES must be accessible to all career stages. A failure to maintain a balance across career stages represents a significant threat to the organization's long-term viability.

Recommendation 5.2: PICES ensure participation across career stages by providing a forum for innovative and engaging science, making the Contracting Parties aware of the benefits to PICES from a diverse community, and making the benefits known to the Contracting Parties and the ECOPs of their active participation in PICES.

VII.3. Engagement with Policy and Decision Makers

The long-term viability of PICES depends on providing information that is relevant to the needs of the governments of Contracting Parties. Providing relevant and useful information necessitates establishing a dialogue with the end users and engaging them in development of the information. PICES has some engagement with policy makers through its members, but this is mostly on an ad hoc basis. A focused approach that engages the end users in co-design and co-production of information from the start would ensure provision of products that advance the needs of the Contracting Parties. Workshops and training courses that bring together end users and members of the PICES community, of all career stages, provide an approach for initiating discussions about products that are desired and relevant and the capability within the PICES

community to provide these products. Projects have been a valuable means for PICES to serve the marine community rapidly with direct funding. The use of this mechanism to address timely and targeted studies should be encouraged in the future.

Recommendation 5.3: PICES initiate multi-disciplinary workshops and training courses to engage policy and decision makers and PICES members in co-design and co-production of products that support science-based information that is relevant to the needs of the Contracting Parties, including continued use of projects.

VIII. WAY FORWARD

The ERC recommendations center on a new **Role** for PICES as an international marine science organization in a time of accelerated global change. The primary recommendation that supports this new **Role** is derived from interviews and interactions with many members of PICES community.

To pursue the new **Role**, PICES will need to undergo organismic changes in structure and function. The PICES Governing Council as defined by the Convention decides on the structure and function of the organization, within the constraints of the Convention. Thus, the Governing Council will undertake implementation of required changes once the PICES community has reached consensus about the new **Role** for the organization. Recommendations two to five support the structure and function changes needed for PICES to achieve the new **Role**.

The ERC acknowledges that views will vary about the recommendations and how these will be acted upon. With this acknowledgment, the ERC suggests that discussions regarding the recommendations should start from recognizing the new **Role** and reaching consensus across the whole PICES community. The ERC encourages the PICES community to review the External Review Report and discuss the findings and recommendations in a systematic manner. These important discussions will lead to decisions about which or which parts of the recommendations to accept in the short term with others designated for longer term consideration or not accepted. The outcomes of this community discussion then provide the basis for developing one or more implementation plans for the recommendations.

The ERC has been careful to not appear to be too prescriptive and has avoided suggesting detailed implementation steps for the recommendations. The most effective implementation plan will arise from the PICES community following extensive discussion and deliberation of the recommendations. The ERC recognizes that PICES is an intergovernmental organization and, as such, must serve the Contracting Parties. This service is by the PICES community, in conjunction with external partners. Thus, the ERC believes that an approach for moving forward should be as inclusive as possible

IX. ACKNOWLEDGMENTS

The External Review Committee thanks the PICES Governing Council for the opportunity to participate in the important process of providing inputs to facilitate the future role of PICES. We thank the PICES Secretariat personnel, Sonia Batten, Sanae Chiba, Alexander Bychkov, Saeseul Kim and Julia Yazvenko for outstanding logistics support and for their willingness to spend considerable time answering questions and engaging in discussions with the External Review Committee. We thank prior Secretariat personnel, Robin Brown and Skip McKinnell, for their insights and guidance about past PICES as well as current and future PICES. We also thank all the interviewees who generously gave their time for discussions and provided inputs and ideas about the current and future status of PICES.

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XI. APPENDICES

Appendix 1. Review Committee

Chair: *Eileen Hofmann* is Professor and Eminent Scholar in the Department of Ocean and Earth Sciences and a member of the Center for Coastal Physical Oceanography at Old Dominion University. She received a B.S. in biology from Chestnut Hill College and M.S. and Ph.D. in marine sciences and engineering from North Carolina State University.

Eileen's research interests are in the areas of physical-biological interactions in marine ecosystems, environmental control and transmission of marine diseases, and descriptive physical oceanography. She uses coupled physical-biological models as an approach for investigating marine ecosystems. Her research on understanding physical-biological interactions in marine ecosystems was recognized by her election as Fellow of the American Geophysical Union.

Eileen has held various roles in international science organizations, most recently as Co-Chair of the Southern Ocean Observing System (SOOS). She served as Chair of the Integrated Marine Biosphere Research Project and as Chair of the Southern Ocean Global Ocean Ecosystem Dynamics program. She served as Chair and member of several of the U.S. National Academies of Sciences, Engineering and Medicine's (NASEM) committees. She is Co-Editor-in-Chief for *Deep-Sea Research Part I*. She is currently a guest editor for an Antarctic-themed special Issue of *Frontiers of Young Minds* that is directed at children, and a special issue of *Fisheries Oceanography* on interactions of fisheries, offshore wind development and climate.

Member: *David M. Checkley, Jr.* is a biological and fisheries oceanographer. He obtained B.S. degrees in Oceanography and Zoology from the University of Washington and a Ph.D. in Biological Oceanography from the Scripps Institution of Oceanography. He has held academic positions at the University of Texas, University of Alaska, North Carolina State University and the University of California San Diego, currently Professor Emeritus, Scripps Institution of Oceanography, University of California San Diego.

Dave's research focuses on how oceanography and climate affect plankton and fish. He has led the development of several oceanographic instruments, including the Continuous Underway Fish Egg Sampler (CUFES) and the SOLOPC. He led USA state and international programs on fisheries oceanography and climate, including CalCOFI, the Cooperative Institute for Marine Ecosystems and Climate (CIMEC) and Small Pelagic Fish and Climate Change (SPACC). He was Editor-in-Chief of *Fisheries Oceanography* for twelve years. He retired in 2016 and currently splits his time between California and Washington states while continuing to complete research.

Member: *Fangli Qiao* is a member of Academia Europaea (MAE), Academician of International Eurasian Academy of Sciences and Co-editor-in-chief of *Ocean Modelling*, is the Chair Professor of physical oceanography, and the Deputy Director General of the First Institute of Oceanography (FIO) of the Ministry of Natural Resources of China.

Fangli's research interests cover ocean and climate model development, ocean dynamics, turbulence and air-sea interactions etc. He determined the key roles of small-scale surface waves in the large-scale ocean circulation and global climate system through modulating ocean turbulence (B_v) and air-sea fluxes, called Qiao Theory. The theory has been used by many research centers from different countries, and oceans, dramatically improving ocean and climate models. He developed the first-in-the-world new generation surface wave-tide-circulation fully

coupled ocean model (FIO-COM) which overcame long-term challenges of too shallow simulated mixed layer depths in the upper ocean and overestimates of sea surface temperature, especially in summer. The atmosphere-ocean-wave coupled Typhoon/Hurricane model (FIO-AOW) greatly enhances the Typhoon intensity forecasting ability, a bottleneck for several decades, and the earth system model including surface waves (FIO-ESM v1.0 and 2.0) removes more than half of the long-standing tropical biases.

Fangli was first a member of the Executive Planning Group, and then a Decade Advisory Board member for the UN Decade of Ocean Science for Sustainable Development. He is also a Governing Council member of PICES. He has received numerous academic awards including the PICES Wooster Award and the National Innovation Awards of China. He has more than 400 publications in peer-review scientific journals.

Member: *Jörn Schmidt* is WorldFish Director for Sustainable Aquatic Food Systems. He previously served as Chair of the Science Committee of the International Council for the Exploration of the Sea (ICES) in Copenhagen, Denmark. He is also an adjunct professor at the Marine Affairs Program at Dalhousie University, Canada, and a senior researcher at the Center for Ocean and Society at Kiel University, Germany.

Jörn works on social-ecological systems, marine and fisheries ecology, inter- and transdisciplinary concepts and knowledge co-production. He is also a member of the Group of Experts and German Focal Point for the UN World Ocean Assessment and a member of the high-level stakeholder advisory board of the *Empowering Women for the United Nations Decade of Ocean Science for Sustainable Development* project.

Member: *Sinjaee Yoo* is a research consultant with KIOST (Korea Institute of Ocean Science and Technology) and is based in Busan, Korea. He was a professor at Korea Maritime and Ocean University and University of Science and Technology, Korea. Sinjaee received his B.S. and M.S. in oceanography from the Seoul National University, and his Ph.D. in ecology and evolution from the State University of New York at Stony Brook.

Sinjaee's scientific interests include the dynamics of primary production and the phytoplankton community in various marine environments. He has written over seventy peer-reviewed papers on environmental control of phytoplankton dynamics and photosynthetic properties in the marginal seas of the northwest Pacific, North Pacific, and Southern Ocean. He has also co-authored several books. He served on the advisory committee for Korea Science and Engineering Foundation. He has advised the Korean government in various capacities. Sinjaee has been working for international research projects including the Yellow Sea Large Marine Ecosystem. He has been involved with international programs/organizations such as IMBER and PICES. For PICES, he served as Chair of the Science Board. He was also a panel member of IOCCG and Coastal-GOOS. He is currently President of the Scientific Committee on Oceanic Research (SCOR).

Appendix 2. External Review Panel Terms of Reference

Among the questions we suggest the Panel considers in its review, framed by the Terms of Reference below, include:

- What are PICES' main achievements? What has made PICES the leading marine science research organization in the North Pacific?
- Is PICES' mission – as presently written – still appropriate? If not, how should PICES evolve to continue to lead?
- Is there a growing role for PICES to play in provision of science, data, and advice to other bodies (e.g., data consolidation and serving, fishery management, observation and prediction of ocean/coastal conditions, etc.)?
- What are the main obstacles to PICES remaining as the leading marine science organization of the North Pacific?
- Should PICES consider an evolution of its working relationships with other organizations?
- Should PICES consider expanding its membership?

1. The External Review Panel shall review the documents of the organization (Convention, Rules of Procedure, Strategic Plan and other such policies, procedures and outputs that are deemed relevant) and assess whether they are comprehensive, adequate, or require revision and updating.

2. The Panel shall conduct interviews with key personnel from the Organization including members of the Secretariat, Executive Committees and national representatives. The Panel could also consider a survey of the wider PICES membership.

3. The Panel should also reach out to, or survey, Agencies and Departments of contracting parties beyond the national representatives, and to the other international organizations and RFMOs that PICES has significant relationships with, to determine whether PICES is responsive to their needs and how this could be improved.

4. The Panel should address the following criteria in their assessment, indicating where changes could be made:

a. Organizational Structure.

- i. Is the structure of the organization effective at achieving its Purpose according to the Convention, and to the Vision of the organization as laid out in the 2016 Strategic Plan? What changes could be made going forward that take into account evolving global science priorities and ways of working?
- ii. Is the Governance structure (comprising Governing Council, the Executive Committees for Finance and Administration and Science Board) an effective and efficient way meet the spirit of the Convention?
- iii. Does the structure of discipline-focused Standing Committees, thematic Expert Groups and a longer-lived Science Program still work to foster collaboration and advance scientific knowledge of the North Pacific?
- iv. A review of the financial structure should be done, including the Secretariat, capacity development, other work of the organization.

b. Secretariat

- i. Is the Secretariat adequately staffed (number of personnel and their skills) and funded? If the recommendations of the Panel are implemented would staffing changes in the Secretariat be required?

- ii. Is the Intern program a good vehicle for early career individuals from PICES member countries to gain experience in operations of an intergovernmental scientific organization? Is it of net benefit to the Secretariat?
- c. Provision of knowledge and informal advice to member states
 - i. Do Contracting Parties feel that PICES provides useful information and that it is generated in a timely and accessible manner?
 - ii. Are the products (NPESR, scientific reports, primary peer-reviewed publications, PICES website) of high quality and an effective way to provide this knowledge?
 - iii. Does the organization adequately promote data collection and exchange?
 - iv. Is communication by the organization with contracting parties, the membership, and the community at large effective? Is it timely? How can it be improved?
- d. Cooperation with other international organizations.
 - i. Does PICES interact sufficiently well with other organizations with which it shares its convention area and/or scientific objectives? Are the current methods the most effective?
 - ii. Some interactions are relatively formal, through MoUs or cooperative science frameworks, and these are mostly with RFMOs that have an overlapping area of jurisdiction. Does PICES provide adequate science to help RFMOs with their management needs?
 - iii. Informal, ad-hoc, relationships exist with other regional or international organizations which may involve invitations to attend and present at PICES Expert Group meetings, co-sponsorship of events or scientific sessions. Are there more effective ways of cooperating?
- e. Capacity Development.
 - i. The Capacity development strategy was developed in 2003 PICES Strategy on Capacity Development - PICES - North Pacific Marine Science Organization. Do the current practices successfully address this strategy?
 - ii. Does the strategy need revising? If so, where especially?
 - iii. Is capacity development adequately funded? (consider the various mechanisms; voluntary contributions, travel support from the Annual Budget and PICES work with other organizations) and if not what is a better model and what should be the goal?
 - iv. PICES recently established an Advisory Panel on ECOP to better integrate younger scientists into the PICES structure. It may be too early to assess its effectiveness but direction would be useful. Is the organizational structure conducive to participation by new-to-PICES ECOP?

Appendix 3. Review Process

The External Review Committee (ERC) was appointed and convened in August 2023. The first virtual meeting of the ERC was with the Governing Council Chair and PICES Executive Secretary to review the Terms of Reference and discuss attending the PICES Annual Meeting in Seattle, WA in October 2023. Following this meeting the ERC met virtually in early October 2023 to discuss approaches for obtaining information and inputs at the Annual Meeting. The ERC developed questions and strategy for interviewing participants at the Annual Meeting. Emphasis was placed on interviewing past PICES officers and early career scientists, as well as participants who represented a cross-section of career stages and expertise.

At the Annual Meeting the ERC observed PICES activities and interviewed participants. The ERC members attended workshops held prior to the Annual Meeting. During the Annual Meeting, ERC members attended Committee meetings, poster and oral sessions, the Governing Council meeting, and the Science Board meeting. The ERC met as a group with the Early Career Ocean Professionals Advisory Panel. Some participants at the Annual Meeting were interviewed by more than one ERC member to provide diversity in questions and responses. Following the Annual Meeting, the ERC received written inputs to questions from the PICES Contracting Parties. The ERC also interviewed individuals who did not attend the Annual Meeting, for example the incoming chair of the Finance and Administration Committee.

The ERC visited the PICES Secretariat in Sidney, British Columbia in late January 2024. During this visit the ERC interviewed the PICES Executive Secretary, Deputy Executive Secretary, Special Projects Coordinator, and Administrative Officer. The ERC also interviewed two previous Executive Secretaries, one previous Deputy Executive Secretary, and the Chair of the Governing Council. During this meeting the ERC synthesized information from the many interviews and developed a draft of its findings and recommendations. The ERC also met virtually at about monthly intervals to synthesize the interview responses, assess the need for additional inputs, and to develop conclusions and recommendations.

The recommendations that resulted from the external review are based on inputs, suggestions, and advice obtained from the many interviews, primarily at the PICES Annual Meeting and during the Secretariat visit. As such, the recommendations represent the ERC's interpretation and synthesis of the views of the PICES community.