Chapter 2
Constructing PICES

> Many ideas grow better when transplanted into another mind than the one where they sprang up.—Holmes (1872)

PICES is structured to support scientists and their scientific work, and so understanding its construction, and the interactions among its components, reveals how it promotes and coordinates marine research in the North Pacific.[1] Because PICES is an intergovernmental organization, it must incorporate the interests of its member countries into its activities, as reflected in its early (Fig. 2.1) and recent structure (Fig. 2.2). The governing council, composed of national representatives, oversees two executive committees, one providing advice on finance and administration, and one on scientific issues. The science board establishes the scientific and technical standing committees that produce the scientific work and the integrating science program for the organization.[2]

Each country appoints two delegates to represent them on the governing council that sets the general direction and priorities of the organization. Although each country follows its own logic in choosing its delegates, in consultation with its national marine agencies and institutions, they are usually science managers, science administrators, or foreign affairs specialists with substantial training and experience in marine science. It is up to each government to choose who will best convey their interests. The resulting governing council elects a chair from within itself to represent the organization as a whole, and so that person no longer acts a national delegate. The chair is expected to put the interests of the organization ahead of any national interests to guide major decisions, policy and priorities. That can be a challenge at times, given their careers external to PICES as senior managers makes them well aware of national interests and priorities.[3] The council elects a chair and vice chair from different countries. By convention and tradition, most

[1] Its website, http://pices.int/, is a portal to its convention, members, news, projects, publications, meetings and capacity building efforts.
[2] In 2003, the governing council and the science board held their first joint meeting; among other business they created the position of vice chair for science board. *PICES Annual Report* (2003).
[3] Because the chair is no longer a delegate, the chair's country provides a replacement delegate.

S. Tjossem, *Fostering Internationalism through Marine Science*
DOI 10.1007/978-3-319-41435-5_2

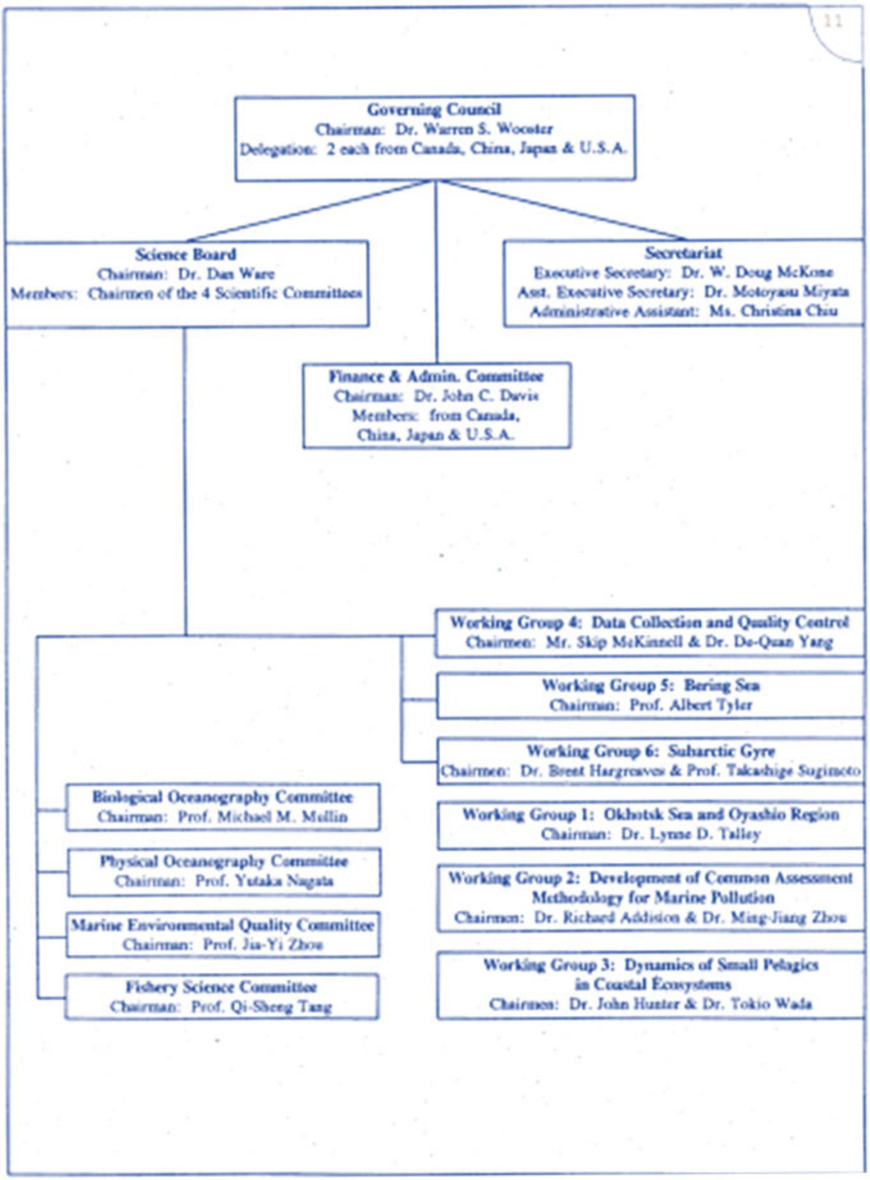

Fig. 2.1 Initial simple structure of the organization showing its four science committees and their working groups

matters before the governing council are decided by consensus; only rarely does anything go to a vote. If it does, the chair cannot vote on decisions, but tries to set a collegial tone for discussions.

Fig. 2.2 PICES organizational chart showing the growth of expert groups and their relationship to each other. The *top three rows* are the executive and permanent committees

For most countries, designation as a delegate is part of the duties of a position in a national marine agency. For instance, Canadian delegates have all been drawn from Fisheries and Ocean Canada, while delegates from Japan have come from the Fisheries Agency of Japan as well as the Tokyo University of Agriculture (Table 2.1).[4] Until 2014, China drew one delegate from the Ministry of Agriculture and one from the State Oceanic Administration (SOA). Now both delegates come from SOA after it became its lead agency. The US Department of State has traditionally appointed one delegate from the National Oceanic and Atmospheric Administration (NOAA) and a second from an academic institution. Some delegates have served for many years, while others have served, stepped away, and served again, depending on their other professional responsibilities. Delegates can have advisors help them with unfamiliar topics or with competing demands on their time.[5] For instance, academic delegates occasionally need advice on how to handle delicate political or financial issues, and fisheries agency officials may require support from their foreign affairs departments on aspects of international diplomacy and processes.

---

[4]Makoto Kashiwai was awarded the 6th annual Wooster Award (2006) for his dedication to the organization. He was a member of one of the first working groups, served as co-chair of the first PICES scientific program, as science board chair, and as a national delegate on the governing council.

[5]At the first meeting in 1992, each country had two delegates and two or three advisors.

Table 2.1 Characterization of selection of delegates by contracting parties

Canada
The delegates are the Regional Director of Science in the Pacific Region and the Director-General of Ecosystem Science (both Department of Fisheries and Oceans). The Institute of Ocean Studies on Patricia Bay near Victoria, BC, is host to the PICES Secretariat. Fisheries and Ocean Canada took a leading role in creating PICES, and its current Executive Secretary, Robin Brown, was previously Ocean Sciences Division Manager for Fisheries and Oceans Canada
China
Both delegates, one a scientist and one head of international cooperation, come from the State Oceanic Administration (SOA). SOA has a broad focus on general marine processes, in line with the ecosystem perspective that the organization promotes. Until 2014, Ministry of Agriculture (MOA) and SOA shared responsibility for engagement. The National Natural Science Foundation of China (NSFC) hosted the China GLOBEC study
Japan
One of the two delegates is from the Fisheries Agency and the other is from the Ministry of Foreign Affairs. The consular positions at the Fisheries Agency are rotated every 3 years, and learn from the previous holder of the position. Japan had the world's largest fisheries from 1972 to 1988 and is currently the world's largest importer of fish products.[a] The country and fisheries were severely impacted by the Great East Japan Earthquake (Great Tōhoku Earthquake) on 11 March 2011
Republic of Korea
Currently one delegate is an academic, and one is from a national agency. In the past, one delegate came from the Ministry of Fisheries and Oceans, and one from the Korean Ocean Research and Development Institute (KORDI), which was reorganized as the Korea Institute of Ocean Science and Technology (KIOST) in 2012. In the early years the delegates frequently rotated through the position, so they eventually appointed an academic delegate to provide continuity
Russia
Soviet scientists were an early and important part of the formal discussions to create PICES, but its accession was delayed by the dissolution of the Soviet Union in 1991. The Russian Federation became a full member in 1994, and Russia hosted the PICES annual meeting for the first time in 1999 in Vladivostok. Russia has five institutes in the East, each with its own staff, but TINRO-Centre (Pacific Scientific Research Fisheries Center) in Vladivostok is the largest research and fisheries management organization. Its Director, Lev Bocharov, is the current national delegate to the organization. In 2015 TINRO-Centre was awarded the 8th annual PICES Ocean Monitoring Service Award for their macrofauna inventory publication series. The second delegate position is Head of Division responsible for scientific affairs from the State Committee on Fisheries in Moscow
United States of America
The US is represented by two delegates appointed by the Secretary of State in consultation with relevant agencies and institutions. One delegate comes from a research university or other academic institution, and the other is Director of one of the four fishery centers on the Pacific Coast overseen by the National Oceanic and Atmospheric Administration (NOAA). The US nominates academics to serve on both PICES and ICES expert groups and funds their participation through a special National Science Foundation (NSF) grant administered by the US academic delegate

[a]Draft country note on fisheries management systems—Japan. FAO FISHSTAT data. http://www.oecd.org/tad/fisheries/34429748.pdf

These governing council delegates appoint their nation's member scientists at the core of the scientific mission of PICES. Those scientists serve on standing committees and expert groups such as working groups and study groups.[6] The council can also authorize sections and advisory panels to bring additional expertise to bear when advised by the science board. The governing council, science board, and secretariat all support the work of these appointed scientists.[7] Although the secretariat is in service to the mission, it must balance the ever-expanding wish list of activities by the science community against its capacity. The four permanent science committees encompass biological oceanography (BIO), fishery science (FIS), marine environmental quality (MEQ), and physical oceanography and climate (POC). Two current technical committees are for data exchange (TCODE), and monitoring (MONITOR).

The science board advises the governing council about scientific priorities, but the countries do not directly choose its membership. Instead, its membership comprises the chairs of the science and technical committees, along with the leadership of the integrative science program.[8] Ideally, the science board has all countries represented, however, so if a country does not have representation through a chair, they can elect a member to the board. Although broad research priorities come from the governing council, reflecting national priorities, it is the science board that advises the council how to implement them through coordinated research programs and data exchange. The science board governs the scientific activities approved by the council, like special scientific meetings. They also make recommendations to the council if any member country or other international organization asks for scientific advice. The board, with the agreement of the council, then creates any necessary expert groups, whether study groups, sections, working groups, or advisory panels. This nested organizational structure helps fill out the scope and assessment of the science issue and ensures that scientists are at the heart of the organization.

The vital core to PICES is its network of scientists with diverse interests and expertise in disciplines reflected in these expert groups. Organizations are necessarily dependent on the individuals who participate in their activities. The appointed members who commit their time and effort are critical for the organization's

---

[6]The expert groups are normally co-chaired by a scientist from each side of the Pacific. Working groups usually last at least three years, but can be extended to complete their work. Study groups normally operate for one year.

[7]Each contracting party can appoint up to two members to the finance and administration executive committee, with a two-year term for the chair, for a maximum two terms. They are responsible to keep the organization in sound financial health, and to make sure that the secretariat operates effectively.

[8]The science board was initially composed of the science board chair (not chair of any subsidiary group in PICES) and the four chairs of the scientific committees of BIO, FIS, MEQ, and POC; later joined by the chairs of the technical committees TCODE (1995) and MONITOR (2004). The first scientific program CCCC had two co-chairs, while the second scientific program FUTURE was initially implemented with the science board acting as its scientific steering committee.

mission, and the organization depends on volunteer commitments to move projects along. Almost all scientists who serve on expert groups have full-time jobs in academia or government agencies, and so must carve out time for added projects and meetings. Some scientists are motivated by the chance to interact with people outside of their usual professional circles on projects they help create, and the chance to push the frontiers of science. Others find projects that fit into their existing research interests. They come together to discuss issues in marine science in meetings that are designed to build a sense of community. Co-chairs strive to balance a sense of camaraderie with openness to newcomers so they can build scientific networks. The position of Executive Secretary is critical to shape the character of the organization, peoples' efforts, expectations, and outlooks.[9]

Although anyone can propose a new expert group, he or she must gather support for it from the proposed parent committee and science board. The organizers often have a core group of scientists in mind, but it must eventually include representatives from all member countries. Once terms of reference garner enough interest, they are passed to a parent committee, which in turn forwards the proposal to the science board and governing council. If they agree on its formation, then the executive secretary emails the contracting parties that the group is approved with a provisional list of participants. The countries, by way of their delegates, then ensure that their national needs are reflected. Sometimes, for instance, the organizer might have only thought of potential members because of familiarity with their published work or presentations. The national delegates may support all or some of the proposed participants from their country, or may recommend alternatives to balance agency interests, or foster the career of a junior person in a pivotal national agency. A contracting country can appoint as many members to an expert group as it wishes, depending on its interest in the subject. The target size for a working group is generally one to two dozen people, to make sure that each country has some presence, and there is enough attendance to make productive meetings. The member country governments are responsible for the costs of sending members to meetings, though groups occasionally find their own funding for extra expenses like inter-sessional workshops. These newly formed working groups address topics that need more attention, such as assessing different projections of climate change, or emerging topics in marine pollution.

The public face of the organization is its secretariat, hosted by the government of Canada at the Fisheries and Oceans Canada Institute of Ocean Sciences in Sidney, BC.[10] It coordinates and supports the component parts of the organization with four permanent staff of an executive and deputy executive secretary, a deputy of administration, and a database/web administrator. The secretariat supports the work of the

[9]See *PICES Press* 23 (2015) for tributes paid to Alexander (Alex) Bychkov on his transition from Executive Secretary (1999–2014) into the position of Special Projects Coordinator. He has served the secretariat in various capacities for more than twenty years.

[10]The Government of Canada also hosts the Pacific Salmon Commission, the North Pacific Anadromous Fish Commission and the Northwest Atlantic Fisheries Organization in separate facilities.

governing council, runs the daily operations, prepares budgets, coordinates, arranges international meetings and publications, and serves as its institutional memory. It also develops and maintains relations with other international marine organizations and fundraises for special activities. Its executive secretary, as the most senior administrative officer, provides information, options and advice to the governing council and sets the necessary tone of impartiality in the secretariat's functions. All countries, by way of their delegates, must feel respected and treated fairly.

The secretariat has a lean administrative structure, given the breadth of its year-round responsibilities. Country annual contributions initially set at CDN $88,000 in 1992 have grown only by the rate of inflation since then, meaning no real increase, while the activities of the organization have grown by all measures.[11] Currency fluctuations among member nations complicate the budget and planning for both those countries and the operations of the organization. It operates with combined national contributions of about CDN $766,200 for 2016, its 25th anniversary.[12] At times countries provide extra support for special projects or products that are of particular interest or concern to them. The ability to contribute to special projects is dictated by internal national policy and funding arrangements. Other projects have included scientific surveys translated from Russian to English, data management and the transition from early proprietary software to open-source and user-maintained software.[13] When the secretariat received special funds for a project on the effects of tsunami-generated marine debris on ecosystems, the funds were substantial enough to allow support for a visiting scientist dedicated to the project.[14] As the number of special projects has grown, and given the limited size of the secretariat, they have required a new coordinator position to handle them, filled by Alexander (Alex) Bychkov, former PICES Executive Secretary for fifteen years.

The organization needed to offer scientists more than just another forum for presenting scientific findings. Each nation already has its own national professional oceanography society, with regular meetings where scientists present their work to colleagues. Other regional, bilateral and international meetings also attract an international turnout. PICES meetings offer multinational and multidisciplinary gatherings on a more manageable scale than the many thousands who attend the big meetings like

---

[11]*PICES Annual Report* (1992). The study group on restructuring of the PICES annual meeting (SG-RAM-2010) found that the base financial support had not kept up with the rate of inflation over the previous decade. Despite fees increasing only slowly, some money from various sources has accumulated in a Working Capital Fund for special projects. The number of appointees to expert groups, its publications, and its tasks and projects had all grown.

[12]Levy et al. argue, "Indeed, keeping the size of secretariats small forces them to build bridges to other groups and develop networks rather than hierarchies. A reputation for competent professionalism may induce others to cooperate as well." (Levy et al. 1992, p. 32).

[13]On Korean metadata, see *PICES Press* 14 (2006): 8–11. 94/S/6 "The Secretariat will arrange with TINRO to translate into English detailed inventories of scientific surveys undertaken since 1984."

[14]The first PICES visiting scientist is Cathryn Clarke Murray, also Adjunct Professor in the Institute for Resources, Environment and Sustainability at the University of British Columbia.

the **A**merican **G**eophysical **U**nion (AGU).[15] Though the AGU holds a specialized Ocean Sciences Meeting that attracts worldwide attendance, North American scientists predominantly attend it. Its biennial meetings are too infrequent to capture breaking advances in science or bring people together regularly to work on projects, and so large that people can readily stay solely with their usual field of interest. PICES holds regular international, interdisciplinary gatherings that promote integrated approaches to tackling pressing questions about the marine environment. Its meetings are large enough to provide a breadth of subjects, while small enough to prompt attendees to participate in sessions outside their usual areas of expertise. The sessions themselves are often explicitly interdisciplinary as a mechanism to encourage the mixing that lays the conditions for interdisciplinary research. The animating idea is to build collaboration bound by common aspirations to better understand the ocean environment and threats facing it. Participants join together to investigate scientific questions across disciplines, agencies, institutions and countries.[16]

The organization's centerpiece activity is their annual meeting.[17] About half of the attendees are appointed by their governments to serve on the various expert groups, or are observers from other organizations. The member nations have committed to support their appointed scientists to travel to annual meetings and inter-sessional meetings, though budgets usually constrain how often scientists can travel. The rest of the attendees are interested scientists without such appointments. Most of the business meetings are open to all participants, regardless of their status. If scientists are not part of an expert group or an invited speaker, then they must pay their own way. The annual meeting serves several essential functions. It is a public forum for scientists to present and assess new research results in marine science in the North Pacific. Attendance is always highest by the host country scientists, which lets them see what the organization offers. Everyone can hear the plenary science session and other talks of interest to them, as well as view the poster session. Everyone can also build professional and social linkages across research groups and national boundaries, as well as between newcomers and longstanding participants. It is also the time for the major gathering of the "business meeting" part of the organization, where those scientists appointed to various types of expert groups review the progress in their terms of reference and develop new plans. In addition, the science board, finance and administration, and the governing council discuss and decide the organization's future activities.

International collaboration requires building trust and, over time, relationships among participants, because progress depends on building goodwill and a shared

---

[15]The AGU is the largest single organization for earth, atmospheric, oceanic, hydrologic, space, and planetary scientists.

[16]*PICES Annual Report* (1994): p. 11. The governing council approved the adoption of a standing list of observers (Decision 94/A/3 and Endnote 4) to replace a more cumbersome method of seeking council approval before annual meetings.

[17]The fourth annual meeting (1995) in Qingdao, China, hosted the first full complement of country members, with the Russian Federation and Korea as the newest members, as well as a representative from FAO, and NPAFC.

sense of common purpose. It also depends upon considerable volunteerism, and a sense of the greater good in pushing the frontiers of scientific understanding. Chairs of expert groups do not exert any formal authority over participants from disparate institutions and countries, and so everyone must find internal motivation to contribute.

The Many Facets of Annual Meetings

> The best way to send information is to wrap it up in a person.—Physicist Robert Oppenheimer[18]

The PICES Annual Meeting is the largest and most important event of the year for both the science and business components of the organization. Since 2001, the meeting has had an overarching theme, such as boundary current ecosystems, or forecasting change in ecosystems (Fig. 2.3). Expert groups hold their workshops and business meetings, followed by the "regular" or formal scientific meeting. The format of the Opening Session has evolved over the years, but the basic pattern is that the PICES Chair welcomes the delegates, observers and researchers to the meeting, followed by remarks from a representative of the host country, and sometimes a local official as well. The presentation of awards and a recap of the past year's activities precede the keynote lecture chosen by the host country.[19] The plenary science board symposium on that year's theme follows, capped by the grand welcome reception held by the host country.

The plenary science board symposium on the first day of the main meeting brings in a diverse set of speakers from multiple disciplines and other regions to engage the broadest audience and bring fresh perspectives. Subsequent days are filled with various concurrent scientific sessions, as well as the business meetings of the governing council and permanent committees. The contributed papers address general topics in an area of marine science that are not covered by topic sessions sponsored by a committee.[20] The poster session increased its attendance after it was reconfigured to be an all-meeting social event and reception. The closing session is also held as a plenary, bringing everyone back together for final thoughts.[21]

---

[18]David Kaiser cites an anonymous *Time* magazine journalist in "The Eternal Apprentice." *Time* (1948): 52, p. 72 (Kaiser 2005).

[19]PICES has two major awards, the Wooster Award for individuals who have made significant scientific contributions to North Pacific marine science, and the PICES Ocean Monitoring Service Award (POMA) that recognizes scientific contributions from long-term ocean monitoring and data management.

[20]Scientists under the PICES umbrella propose topics sessions a year in advance of the target annual meeting. Each proposal describes the session, list of conveners, sponsoring committee, co-sponsor organizations (if any), length, and any planned publication. The committees rank proposals online, and then forward the ranked list to the science board for final selection.

[21]That evening the chair holds a special reception to recognize the officials of the host country, administration, invited speakers and representatives of international organizations.

The next day both the science board and the council meet concurrently to discuss their respective business, capped by the council discussion of the science board report.

Year	Meeting #	Location	Theme
2016	25	San Diego, CA, USA	25 years of PICES: Celebrating the past, imagining the future
2015	24	Qingdao, China	Change and sustainability of the North Pacific
2014	23	Yeosu, Korea	Toward a better understanding of the North Pacific: Reflecting on the past and steering for the future
2013	22	Nanaimo, BC, Canada	Communicating forecasts, uncertainty and consequences of ecosystem change
2012	21	Hiroshima, Japan	Effects of natural and anthropogenic stressors in North Pacific ecosystems: Scientific challenges and possible solutions
2011	20	Khabarovsk, Russia	Mechanisms of the marine ecosystem reorganization in the North Pacific Ocean
2010	19	Portland, OR, USA	North Pacific ecosystems today, and challenges in understanding and forecasting change
2009	18	Jeju, Korea	Understanding ecosystem dynamics and pursuing ecosystem approaches to management
2008	17	Dalian, China	Beyond observations to achieving understanding and forecasting in a changing North Pacific: Forward to the FUTURE
2007	16	Victoria, BC, Canada	The changing North Pacific: Previous patterns, future projections, and ecosystem impacts
2006	15	Yokohama, Japan	Boundary current ecosystems

Fig. 2.3 The first annual meeting with an overarching theme was in the 2001 meeting in Victoria, BC, Canada. Decision 99/S/7

2005	14	Vladivostok, Russia	Mechanisms of climate and human impacts on ecosystems in marginal seas and shelf regions
2004	13	Honolulu, HI, USA	Beyond the continental slope - complexity and variability in the open North Pacific Ocean
2003	12	Seoul, Korea	Human dimensions of ecosystem variability
2002	11	Qingdao, China	Technological advances in marine scientific research
2001	10	Victoria, BC, Canada	Ten years of PICES science: Decadal-scale scientific progress and prognosis for a regime shift in scientific approach
2000	9	Hakodate, Japan	(none)
1999	8	Vladivostok, Russia	
1998	7	Fairbanks, AK, USA	
1997	6	Pusan, Korea	
1996	5	Nanaimo, BC, Canada	
1995	4	Qingdao, China	
1994	3	Nemuro, Japan	
1993	2	Seattle, WA, USA	
1992	1	Victoria, BC, Canada	

Fig. 2.3 (continued)

This combination of "business" planning meetings and scientific program is why PICES calls the event an annual meeting, rather than a science conference like ICES.[22] The organization opted for a combined model in part because it is more economical for the member countries, and more efficient for scientists' schedules, given the large travel distances for scientists crossing the Pacific. Meetings on the opposite side of the Pacific from one's home country are particularly expensive for governments to send their scientists more than once a year to a particular organization's meeting. Scientists present their research findings, of course, but even more important are the additional delegated responsibilities that individuals take on in working groups and scientific committees. They review the past year's scientific work, and develop strategies for the coming year. The annual meeting is the time and place for scientists to commit efforts towards building the scientific activities and community of PICES, and may be the only time that they all gather in one place until the following year. The organization depends on participants taking on tasks that are for the good of the group, and recruiting new scientists, particularly junior ones, to take on such functions is a continual challenge.

Each member country hosts the annual meeting on a six-year rotation cycle.[23] Unlike organizations that always hold their annual meetings in a single place, such as IOC at its secretariat headquarters in Paris, the rotation of venues broadens each country's scientists' exposure to PICES. Once a country confirms that it is willing to host, it has about three years to organize and publicize it. The host country suggests a meeting theme that will generate wide interest and participation by their own scientists. For instance, the theme for PICES 2009 in Jeju, Korea, was "Understanding ecosystem dynamics and pursuing ecosystem approaches to management," a topic of broad interest and application to all countries. The theme is then explored in the meeting's science board symposium, and other sessions often work with it if they find it helpful. The secretariat is a conduit for all communication about planning the meeting, constructs its schedule and sessions, and attempts to avoid conflicts in concurrent sessions. It arranges invited speakers, builds the book of abstracts, and handles the registration, along with a myriad of other aspects.

Normally host countries choose a Pacific coastal city where a large number of marine scientists already work, or where they can reasonably travel to the meeting. In each city, an interested agency or university takes responsibility for the meeting's local organization, and showcases their institution and unique geography. Countries spread the opportunity to host across suitable cities to engage different science communities. For instance, Japan hosted its first meeting in the north in Nemuro, and then moved it gradually southward from Hakodate, to Yokohama and then Hiroshima. The host country and local organizers do a great deal of preliminary

[22]PICES "business" is any planning process. Committees review what happened in the previous year, and make plans for the future. ICES separates its science committee (SCICOM) meetings from its advisory committee (ACOM) meetings.

[23]Initially the annual meetings began on a four-year cycle, to reflect the first four country ratifications.

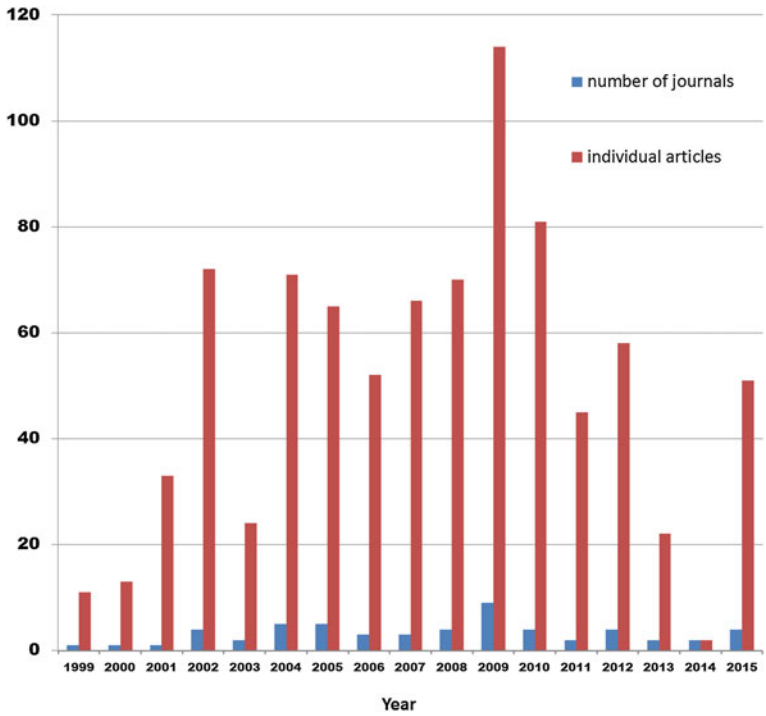

Fig. 2.4 Number of publications by year and type. The *blue bars* are the number of special volumes, and the *red bars* show the total number of individual journal articles

work to publicize the meeting, particularly to their own scientists. The secretariat and the local organizers strive to organize meetings with high attendance because they generate enthusiasm and the participants can broaden their networks. Attendance by the host country scientists is always highest because students and junior scientists can attend an international meeting at much lower cost than when it is held abroad. Many scientists recall their positive experience at a national meeting as the initial reason they became engaged in PICES work. The secretariat has found that advertising plans to produce special issues in high profile, peer-reviewed science journals also encourages participation (Fig. 2.4).

Given the great deal of planning involved, it is very difficult to change locations even when disaster strikes the host country, as happened for the 3rd annual meeting in Nemuro, Japan.[24] About a week before the October 1994 meeting, a massive 8.2 magnitude earthquake caused widespread damage to the city, including the conference space. Despite it, officials and the local organizing committee persevered and arranged for the over two hundred participants to meet in alternate space. Other circumstances can also change the order, as when China planned to host in 2014 but

[24] *PICES Annual Report* (1994).

needed to defer for a year when they switched their lead agency to the **S**tate **O**ceanographic **A**dministration (SOA) from the **M**inistry **o**f **A**griculture (MOA). Fortunately Korea, scheduled to host the following year, offered to swap with China, and despite the shortened preparation time, the meeting in Yeosu, Korea drew good attendance. The 2015 meeting was held in Qingdao, China, where the First Institute of Oceanography (FIO) of SOA, and Qingdao City made local arrangements.[25]

Annual meetings serve both a social and scientific role, and so every scientist seems to have a favorite meeting for different reasons. Sometimes it is because they have never been to a region before, such was the case for many scientists for the 2011 meeting in Khabarovsk, Russia. Others particularly enjoyed the Japanese meetings in Hiroshima and Hakodate that arranged for outreach with the general public and local elementary and college students. The 2014 meeting in Yeosu, Korea, also arranged school visits for scientists to see the marine-themed school and present their work. The host country showcases the quality of venue and nearby marine resources and institutes to the visiting international scientists. They get to hear from local experts and compare different marine systems. Local organizers take pride in arranging unique cultural attractions and activities for the visiting foreign scientists as well. In Qingdao, for instance, they arranged an exhibition and friendly game of the traditional Chinese folk sport of "jianzi," played with a weighted, feathered shuttlecock. That kind of social engagement is emblematic of the community building that PICES encourages among its members.

The annual meetings have changed somewhat as participation has increased and topics have evolved. In the early annual meetings when PICES was trying to introduce itself to the wider scientific community, it created paper sessions that took whatever scientists wanted to present, to attract as many scientists as possible. The science board expected that in time those general sessions would be replaced by more directed topic sessions. Instead, however, the paper sessions remain a permanent feature to attract early career scientists whose initial work might not fit into a specific topic session, and to allow flexibility for papers on late-breaking, exciting topics. The annual meetings must accommodate the annual science topic sessions, meetings of standing committees and expert groups, workshops and science board and governing council meetings. In 2002, the science board and governing council began to hold inter-sessional meetings in advance of the annual meeting to give more time to review scientific activities, cooperation with other organizations and programs, and plan the integrative scientific programs. They no longer had time at the annual meeting for all they needed to discuss.[26] The large difference in time

[25]The port city of Qingdao is a powerhouse of marine science in China. It hosts the Ocean University of China, one of its largest marine science universities; the Yellow Sea Fisheries Research Institute, the largest fisheries research institute in China; and the Institute of Oceanology of the Chinese Academy of Science, the largest oceanographic institute under the State Oceanographic Administration.

[26]*PICES Annual Report* (2007), GC inter-sessional meeting (Agenda Item 4). Also see article by Tokio Wada in *PICES Press* 15 (2007).

zones across the Pacific, and technical challenges limit the utility of webcam discussions.

In the first two years, the annual meeting lasted about five days, but by 2003 it had almost doubled to nine or ten days. Within that window the preliminary meetings of workshops and working groups took about five days, and the scientific sessions took the remaining five days, ending with two days for the science board and the governing council. When meetings were in distant places, like Fairbanks, Alaska, or Vladivostok, Russia, participants needed more travel time given the distance, and the meetings were longer to allow for more work. By 2007, the governing council wanted to know whether the annual meetings should be restructured to make them shorter and yet also allow for more discussion within committees and the science board.[27] The consensus was that the committees and science board needed more time to discuss priorities, deliberate, and choose topics for scientific sessions and workshops for the next annual meeting. The science board needed time to synthesize and present a thorough report to the governing council on the final day.

Yet excessively long meetings risked losing participants pressed for time in their busy schedules, and whose governments had limited travel funds. As the expert groups built out their terms of reference, they drew on their connections with other organizations, and the increased number of inter-sessional symposia and co-sponsored workshops meant additional demands on scarce travel budgets and time. Topics such as forecasting climate impacts on fish and shellfish were exactly what the governments wanted to see; pressing, economically important issues addressed through best available data and science. No one wanted to see that substance decreased or compromised by excessively restricting the length of meetings. Over the years, every country has experienced additional budget constraints on foreign travel, whether because of economic downturns, or political disagreements over budgets. For instance, when in 2013 the US Congress failed to agree over a national budget, the temporary shutdown of the federal government prevented travel by any US government scientist to that year's annual meeting in Nanaimo, Canada.

One way to shorten the meetings was to increase the number of parallel sessions, but that creates serious scheduling challenges for the secretariat and host countries. People involved in several expert groups would not be able make them all, and that would lessen the information sharing and interdisciplinary synergies at the core of PICES. National delegates and chairs of committees faced the most severe overall time commitments, because they had to stay beyond the closing ceremony to wrap up discussions through the science board and governing council. PICES decided to streamline the opening session by moving the member country remarks to the beginning of the governing council meeting. Committees benefited from a little more time for their discussions, so the net result was that although the meetings

---

[27] Study Group on Restructuring of the Annual Meeting (SG-RAM; 2008–2009), parent GC, chair Tokio Wada (Japan).

stayed the same length, they were more efficient as well. The lack of adequate time has remained a challenge as the organization's reputation has grown and it has carried out more joint initiatives, so groups try to balance efficiency with sufficient discussion. Each expert group also must negotiate the dynamic among different leadership styles, group composition, approach, and terms of reference. As PICES has expanded its roster of inter-sessional events like special workshops, international symposia, and training schools, it has revisited the issue of how best to schedule them all in an efficient, effective way (see Chap. 3).

The annual meetings are the venue for much of the work carried out by the underlying structure of the organization. Its nested structure guides the production of scientific work and shapes the communication among its parts (Fig. 2.2). To understand the scientific work requires a synopsis of these components.

Standing Committees

The scientific and technical committees are ongoing groups organized by either their scientific or technical subjects. They plan and oversee major research questions within the organization's general scientific aims. The national delegates must agree to their country's participants, who then contribute their skills and acumen.[28] The scientists drive the directions of inquiry, and what topics they focus on can impact their success. At times, the committees have struggled with incomplete national representation at committee meetings, sometimes due to budget issues or competing national priorities.[29] Committees need cohesion, while remaining open to new members who bring different perspectives and expertise as well as personalities.

The Four Scientific Committees of BIO, POC, FIS and MEQ

The four standing scientific committees of biological oceanography (BIO), physical oceanography and climate (POC), fishery science (FIS), and marine environmental quality (MEQ), reflect the organization of traditional marine scientific disciplines, to provide a sense of intellectual community. Participants share a body of knowledge and training that helps give them a sense of common purpose for their key tasks and topics. A defining aspiration and opportunity of the organization, however, is to bring these disciplines into conversation with each other, so although the

[28]The country delegate or delegates must agree to all scientists serving on any expert group, whether a committee, working group, advisory panel, or section.

[29]See for example, *PICES Annual Report* (2000); SB report, p. 40.

committees are organized along disciplinary lines, they are meant to work together on topics of common interest, producing joint sessions and symposia. The committees develop strategic plans, and create various kinds of subsidiary expert groups (like working groups, study groups and sections) to carry out components of their plans. Some expert groups have more than one parent committee when the scientific questions need more inclusive oversight. For example, the BIO, FIS and POC committees all share a section to address the large research area of climate change effects on marine ecosystems. BIO and POC share oversight of the long running section on carbon and climate.[30] Each committee also brings in invited speakers for outside perspectives, often from other regions of the world, for the science board symposium and topic sessions.

Country delegates designate up to three scientists to represent them on each committee, for a maximum of eighteen people per committee. Though committees are restricted to a manageable size to encourage full engagement, anyone outside of that membership or not an official participant of the organization can also attend their meetings. Because committees cannot encompass all areas and topics, they assess how their individual expertise can contribute to a focused set of research questions. For instance, the scope of the BIO committee theoretically extends from microbes to marine birds and mammals (excluding fish, which are the purview of the FIS committee). At its outset, however, the BIO committee had no experts in marine birds and mammals (MBM), and so started a working group on them in 1995.[31] They are important components of the marine system, and may serve as indicators of ecosystem change due to their visibility and rapid, substantial responses to changing environmental conditions.[32] The science board decided to compose a study group to see how best to address the gap in expertise. Should it become a committee in its own right, or become another type of expert group? The board has to balance the benefits of a small number of scientific committees for simplicity and cost containment, against a broader coverage of marine science research activities. In the case of birds and mammals, it is now a section with a five-year lifespan. If a committee finds they need some different or additional expertise, they can propose creating a different kind of expert group with a defined remit and lifespan that reports to the parent committee. At times, the committees must negotiate with each other on what topics fall best within their range of expertise. The BIO committee, for example, opted against taking lead on toxic algal

[30]Section on Carbon and Climate (S-CC; 2005–2016), co-chairs James (Jim) Christian (Canada), Tsuneo Ono (Japan).

[31]Consumption of Marine Resources by Marine Birds and Mammals (WG 11; 1995–1999), cochairs Hidehiro Kato (Japan), George Hunt, Jr. (USA). Findings reported in *PICES Scientific Report* (2000): 14.

[32]The marine birds and mammals group expressed frustration at being a small group with limited opportunity for interdisciplinary collaborations within PICES, despite the broad relevance of the topic. They called for "a functional presence of marine mammal and seabird science in PICES." *PICES Annual Report* (1998); Endnote 3; Summary of WG 11 accomplishments.

blooms because, although biological, its link with coastal eutrophication makes the topic better suited for the marine environmental quality (MEQ) committee.

Each science committee discusses their general remit and creates key tasks and action plans that outline their purpose and structure, to give members a clear idea of what they need to get done, how to do so, and by whom. They need to construct questions that have enough shape to direct scientists' efforts, yet allow leeway for unexpected new opportunities. They plan activities, such as scientific sessions or workshops, as individual scientists with curiosity about trends and discoveries, while being representatives of their member states. Once these plans are approved by the science board, the participants create a structure and timeline of the overall work plan. Ideally their terms of reference simultaneously define scope, yet also allow for creativity within the overall goal.[33]

The biological oceanography committee focuses on organisms, from species to communities to ecosystems. It has done considerable work on particular classes of organisms, like micronekton and krill, and compared different life history strategies and alternative food web structures that may develop under climate change. It has contributed to regional and basin-scale comparisons of lower and upper trophic levels, and has acted as parent committee for cross-cutting issues such as the ecological roles of lower and higher trophic level organisms in relation to fisheries and ocean models. It also supports biogeochemistry work linking nutrients, organisms and climate change, such as iron fertilization studies and carbon cycling and ecosystem dynamics. As with all committees, it has helped contribute to the ecosystem status report series, as well as to long-term observational studies and modeling efforts within the PICES integrative programs. It is also interested in non-harvested components of the marine system. As the organization entered the second integrative science program FUTURE, it has contributed to harmful algal bloom studies and development of the concept of ecosystem-based management, linking anthropogenic factors, climate, and ecosystems.

The fishery science committee coordinates fisheries science work and its links with other disciplines. It has been particularly active in the recent joint projects with ICES, on effects of climate change on ecosystems, and forecasting its impacts on the productivity of fish and shellfish. It studied the potential for ecosystem-based management in conjunction with the MEQ committee, which is particularly interested in the ecology of harmful algal blooms, sources and fates of contaminants, marine environmental quality aspects of mariculture, and non-indigenous species and stocks. An understanding of the physics of the ocean and of its interaction with the atmosphere is an essential and basic component of all marine disciplines. The physical oceanography and climate committee (POC) has assessed both large and regional-scale ocean circulation and the impact of climate variability on water masses. It has helped characterize the properties of the Okhotsk Sea and the Oyashio region. Its work is impacted by new technologies and strategies to make observations. It carried out comparative work and worked with BIO to link carbon

[33]Sometimes terms of reference include risks and constraints.

with ecosystems. From the outset it built networks with other international programs, like the regional program CREAMS. Its members interested in ocean modeling were critical to the modeling work that came out of the first integrative science program CCCC.

Two Technical Committees of MONITOR and TCODE

The coordinated development, use, and sharing of data is critical in marine science, as is its consistent quality. The two current committees dealing with data (TCODE), and monitoring (MONITOR), have a natural affinity with each other because of the centrality of data management to both. The technical committees develop standards of practice for the science committees to meet their goals. Each technical committee's terms of reference lay out its remit, such as what other committees it should interact with, and what products it should help produce.

Measuring instruments, types of observations, research programs and more recently, software and analysis methods change over time, and vary across researchers and countries. Researchers may observe and collect data themselves or rely on others' data, but regardless are dependent on the quality and flow of data and lack of standard measurement techniques can produce different interpretations. Researchers studying marine ecosystems need access to information on ecosystem processes, from the seabed to the water column, and on to the atmosphere, as well as across vast horizontal stretches of ocean and international boundaries.

Although ships will always be needed in oceanography and fisheries studies, many measurements of open-ocean studies are being supplemented by newer technologies such as satellites, long-term buoys, drifting platforms, and gliders. The results of satellite oceanography in the late 1970s and 1980s laid the foundation for subsequent satellites with ocean-measuring instruments from several space agencies. Satellites and sensors allow investigation of the spatial structure of phenomena over time. These newer technologies create so much data that they are part of the transformation to "big data," and it is critical for researchers to know how to select the right measurements to address their research questions, as well as where to find those data. In addition, each source of data has associated and unavoidable sources of error, so users must know what they are. This technical area is a great opportunity for training early career scientists.[34]

Forecasts of climate or ecosystem conditions depend upon integration of large amounts of data across vast areas. Nations and research groups may hesitate to share data for all sorts of reasons, and data sharing practices are different between disciplines. For instance, physical oceanographers built the reputation of being quite practiced at sharing, while biogeochemists have lagged, in part because of the

[34]For example, the 3rd (2009) PICES summer school for students and early career scientists in Seoul, Korea was on the application of remote sensing to biological and physical oceanography.

complexity of their data and lack of rigorous standardization.[35] Interest and support for sharing data across national boundaries and disciplines quickened in the 1980s, when coherent patterns emerged in changes in fish populations in both the western and eastern Pacific, suggesting they had a measure of interdependence. The USA, through its **N**ational **O**ceanographic and **A**tmospheric **A**dministration (NOAA), led several large-scale efforts to share data through international consortia. For instance, scientists needed basin scale and global databases to carry out the goals of the international **J**oint **G**lobal **O**cean **F**lux **S**tudy (JGOFS; see below) on ocean carbon cycles, as well as the work of the IPCC.

The Critical Importance of Long Term Monitoring

> Models come and go, but a good data set lasts forever.[36]

Scientific monitoring activities have been a focus from the early days of the organization, having been explicitly called for in its convention.[37] Such measurements include physical, biological and chemical measurements of the ocean. Each science and technical committee needed to know what information was accessible in each country, gather inventories of available datasets, assess them for robustness, and make them accessible to researchers. A working group focused on monitoring issues started under the supervision of the science board, to plan the monitoring activities for the PICES region. It identified important observational programs useful for work in the subarctic Pacific, and created a wish list for data that included time series measurements of primary production and zooplankton stocks, as well as analysis of salmon scales as a measure of productivity, the heat content and freshwater variability in the subarctic, electromagnetic measurements of transport through the Kamchatka Strait, iron in the subarctic Pacific gyre, voluntary observing ship basin-scale measurements, and surface-velocity measurements using satellite-tracked drifters.[38] The working group operated for four years until it was elevated to task team status, so it could work in service to the organization's first integrative science program on climate change and carrying capacity (CCCC, see Chap. 4).

The science board recommended that the council establish a permanent technical committee (MONITOR) in 2004 in recognition of its fundamental, ongoing

[35]Interview with Robin Brown 13 Oct. 2013, Nanaimo, Canada.

[36]Paul Quay (2002) *Science* 298, 2344, as quoted in Masao Ishii, Toru Suzuki and Robert Key, "Pacific Ocean Interior Carbon Data Synthesis, PACIFICA, in Progress." *PICES Press* 19 (2011).

[37]"… to promote the collection and exchange of information and data related to marine scientific research."

[38]*PICES Annual Report* (1995), p. 37.

importance for comparative work.[39] Thus it moved from being a working group to a task team, and then as the CCCC program wrapped up, it was made a permanent technical committee. It cooperates with global observing programs such as the **G**lobal **O**cean **O**bserving **S**ystem (GOOS) that has a panel for climate and a planning group on living marine resources. GOOS grew out of the realization in the late 1980s that understanding and forecasting climate change requires a long-term, physical, chemical, and biological ocean observing system, and that system is built upon regional programs.[40] MONITOR also shepherded a long running advisory panel on the continuous plankton recorder, and advises the collaboration of PICES with CREAMS in the East Asian marginal seas. It works closely with the **T**echnical **C**ommittee **o**n **D**ata **E**xchange (TCODE) to make sure that data are shared in a timely and open exchange both inside the organization, and to external users. That helps control the quality and relevance of the data. MONITOR is key to the production of the signature series of **N**orth **P**acific **E**cosystem **S**tatus **R**eports (NPESR), a permanent, recurring activity of the organization. The committee identifies the need for particular times series of data, and how they may be used by the integrative science plan FUTURE, and has also conducted courses on ocean observing systems and ecosystem monitoring to help build capacity of early career scientists (see Chap. 3).

The committee also strives to raise the profile and appreciation of monitoring activities both inside and outside the organization through the **P**ICES **O**cean **M**onitoring Service **A**ward (POMA). It recognizes those who have been exceptional in advancing marine science through long-term ocean monitoring and data management. The list of awardees reflects the collective efforts critical to long-term observational programs that operate over years. It has been awarded to groups and organizations, including research vessels like the Japanese *Oshoro-maru* (inaugural winner 2008) and cooperative programs like the Marine Metadata Federation (2009).[41]

---

[39]Subarctic Pacific Monitoring (WG 9; 1994–1997), co-chairs Kimio Hanawa (Japan), Bruce A. Taft (USA). MONITOR Task Team under CCCC (1997–2004), co-chairs Phillip R. Mundy (2003–2004, USA), David L. Mackas (2000–2004, Canada), Sei-Ichi Saitoh (2003–2004, Japan), Yasunori Sakurai (1997–2000, Japan), Bruce Taft (1997–2000, USA); MONITOR Committee (2004–), chair Jennifer Boldt (2013–, Canada), vice-chair Sanae Chiba (2013–, Japan), past chairs Jeffrey Napp (2005–2007, USA), Phil Mundy (2004–2005, USA), Hiroya Sugisaki (2007–2013, Japan), past vice-chairs Phil Mundy (2007–2013), Sei-Ichi Saitoh (2004–2007, Japan).

[40]IOC and WMO established GOOS, which is now part of the Global Earth Observing System of Systems (GEOSS). It has many regional programs, such as NEAR-GOOS in the western North Pacific.

[41]POMA recipients: *Oshoro-maru* (2008), Metadata Federation project teams (2009), Station Papa/Line-P (2010), NFRDI Serial Oceanographic Observation in Korean Waters (NSO) (2011), **Cal**ifornia **C**ooperative **O**ceanic **F**isheries **I**nvestigations (CalCOFI) (2012), A-line Monitoring Program (2013), Trans-Pacific **V**olunteer **O**bserving **S**hip (VOS) Survey Program (2014), TINRO-Centre Macrofauna Inventory Publication Series (2015).

Technical Committee on Data Exchange (TCODE)

Data access is so fundamental for all research that the initial working group on data quickly became a standing committee, TCODE.[42] The first order of business for it was to figure out data of interest to scientists, and its associated data management protocols. PICES scientists need access to data on a wide range of topics, from operations to databases. Early on, just collecting research cruise schedules in one place fostered collaborations on shipboard or in later analysis. Scientists needed to know who was operating the ship, on what track, when, and for what purpose. More modern instrumentation, such as satellite oceanography and buoys, make some cruises less critical, but produce huge amounts of data from very different sources.

Each standing science committee needs access to and management of data, whether for physical, chemical and biological oceanographic data, birds and mammal distributions, fisheries, or marine environmental quality. All scientists benefit from remote sensing and meteorological data as well. They need access to common environmental indices such as El Niño and the Pacific/North American teleconnection pattern (PNA), both influential climate patterns in the Northern Hemisphere that operate over months or years. TCODE advises on the best software to analyze and process the data sets, whether contemporary or historical. Each country had unique challenges for data retrieval from historic records. For instance, the Korean and the Japan Oceanographic Data Centers both had many million data points that needed to be digitized and translated into English before being converted to English-language XML (extensible markup language). Those datasets then gained maximum exposure and usefulness when they were added to a searchable meta database.[43]

TCODE is composed of two scientists per member country, ideally one from physical oceanography and one from fisheries/biology. The committee's charge is to identify data management needs and develop strategic plans to address challenges of management and integration of data, including data sharing.[44] Robin Brown, the current Executive Secretary of PICES, began his association with PICES in 1994 when his then supervisor, John Davis, asked him to serve as chair of TCODE starting at his first annual meeting in Qingdao, China in 1995.[45] Brown served as chair for five years, during which PICES developed a plan to participate in the **GLOB**al **O**cean **EC**osystem Dynamics (GLOBEC) data management

[42]Data Collection and Quality Control (WG 4; 1992–1994), parent SB, co-chairs Skip McKinnell (PICES), De-Quan Yang (China). WG 4 was replaced in 1994 in Nemuro, Japan by a standing committee, TCODE, past chairs Robin Brown (1995–2001, Canada), Bernard Megrey (2007–2010, USA), Igor Shevchenko (2001–2007, Russia). Past vice-chairs Kyu-Kui Jung (2007–2010, Korea), Bernard Megrey (2005–2007, USA).

[43]*PICES Press* 15 (2007) "Japan Joins PICES Marine Metadata Federation."

[44]*PICES Press* 3 (1995).

[45]Interview 13 Oct. 2013 with Robin Brown, Nanaimo, Canada.

program.[46] TCODE looked to the field of meteorology for best practices because meteorologists are used to working with huge amounts of data that are time sensitive. They had developed standards and data exchange protocols to produce quality weather forecasts for clients like airlines.[47] Physical oceanographers learned from their approaches and techniques, and thus were also adept at sharing data, while biological data are much more complicated, given complex life history stages and interactions with their environments, creating more challenges in sharing data. TCODE has constituted an advisory panel on North Pacific coastal observing systems that it shares with MONITOR to advise on how to link coastal systems with open water systems, as well as the FUTURE science program and the North Pacific Ecosystem Status Reports.[48]

Hosting data is a huge and expensive undertaking, despite constant improvements in hardware and software alike, so PICES chose not to set up its own data center. Each committee, task or project brought new requests for advice. A pivotal challenge for data centers is the problem of duplicating data, and having it diverge from its core as it gets used in different ways for different purposes. The management of those duplicates becomes increasingly challenging and destabilizing for the original data. The data exchange committee took a "soft" approach to data acquisition, meaning that it strove to improve access to those data but did not collect nor manipulate it to minimize the risk of introducing error. A second risk is inherent in "outsourcing" data/information management responsibilities to what may at first be appropriate hosts. If that common repository for data later closes down their program, then the depositors of the data have to repatriate the information and host it themselves.

One solution to unify many databases across countries and laboratories is to produce a meta database. Metadata are data about data, that makes it "discoverable" because it describes the "who, what, when, where and how" of the data resource.[49] A well-constructed database reveals the context of the original study such as the name of the lead investigator, the scientific motivation for the study, when data were acquired, where, and kinds of samples with their units and sampling devices. Additionally, computerized data have information on file size and format, storage mechanism and location. The idea behind a metadata federation is that a centralized repository of metadata from different sources or nations helps foster integrated research approaches. Researchers can then choose information relevant to their project without first acquiring the actual data, and they have much more data to work from. It is called a "federation" because it is a group of organizations connected to a central clearinghouse through the web, but with independence in their internal affairs because they maintain their data on their sites.

[46]PICES Fourth Annual Meeting (1995), Qingdao, China.

[47]Interview 13 Oct 2013 with Robin Brown, Nanaimo, Canada.

[48]Advisory Panel on North Pacific Coastal Ocean Observing Systems (AP-NPCOOS; 2015–), co-chairs Jack Barth (USA), Sung Yong Kim (Korea).

[49]It describes characteristics of data, like its content, quality, and condition.

Effective linkages across sites require a shared communications protocol and data standards. For a nation, being part of an intergovernmental organization does not erase national concerns over sovereignty of certain kinds of information, such as that which impacts national security. A marine metadata federation allows users of any single metadata inventory to cross-search all the inventories of other system participants, without foregoing national ownership and security, and while maintaining data integrity. It helps scientists find data while being a less intrusive approach to sensitive information like fish stocks, contaminant loads in coastal areas, or the presence of sunken submarines.

Bernard Megrey of NOAA-Alaska Fisheries Science Center, and S. Allen Macklin of NOAA-Pacific Marine Environmental Laboratory, brought their experience developing the Bering Sea meta database to TCODE. When the methodology proved its utility, it was used as a template and expanded to the whole of the PICES region. It required a sustained collective effort by scientists from most member countries, and the effort was critical to developing PICES' approach to data. Unlike ICES, with its budget derived from providing requested advice to 20 member nations and international regulatory commissions that pass it on to commercial enterprises, PICES could not afford to set up a data center of its own.[50] PICES awarded them the second annual ocean monitoring service award (POMA) in 2009 for their sustained leadership of the effort to build the integrated database. They made it clear in their acceptance speech that it was the collective effort of experts from all member countries, by way of the technical committee on data exchange. That database continues to be added to and is available to anyone to search.

The PACIFICA Data Synthesis Project

The ability to make robust generalizations about climate change depends on precise techniques, their standardization, and guides to best practices for measurements. The cumulative work of the carbon expert groups within PICES contributed to all three areas. PICES has been instrumental in contributing data to global data centers such as the **M**arine **I**nformation **R**esearch **C**enter (MIRC, Japan), and the **C**arbon **D**ioxide **I**nformation **A**nalysis **C**enter (CDIAC).[51] CDIAC has become the "go to" place for carbon-related data from around the world. Its carbon management project receives submissions of data that it reviews for quality and reliability, then organizes, distributes and archives. It holds the archives of the **J**oint **G**lobal **O**cean **F**lux **S**tudy (JGOFS), the **W**orld **O**cean **C**irculation **E**xperiment (WOCE), and other CO_2 hydrographic cruises of the 1990s. Those data were synthesized to produce

[50]The ICES annual budget is approximately CDN $7.86 million (5.5 million Euro) in 2016.

[51]CDIAC has served since 1982 as the primary climate-change data and analysis center of the US Department of Energy. http://cdiac.ornl.gov/oceans/Handbook_2007.html.

a unified data set through the cooperative effort of the **GLo**bal Ocean **D**ata **A**nalysis **P**roject (GLODAP). GLODAP created a benchmark against which to compare future observational studies to understand increasing anthropogenic CO_2 emissions and climate change. The high quality database allows a global evaluation of anthropogenic CO_2 inventory.

CDIAC received carbon data for the Atlantic, Arctic and Southern oceans, but did not have equivalent data for the Pacific until PICES contributed data through its two carbon working groups (WG 13 and WG 17, see below), and its later section on carbon and climate. Starting in 2007, the carbon and climate section held data synthesis workshops for an activity they called **PACIF**ic ocean **I**nterior **CA**rbon (PACIFICA). They targeted unused historical datasets of physical and chemical data from 306 cruises as far back as the late 1980s, not stored elsewhere, to include (Suzuki et al. 2013).[52] Once PACIFICA was complete, they entered into a round of intercalibration and quality control and adjustment to contribute the North Pacific component to the **GL**obal **O**cean **D**ata **A**nalysis **P**roject **V**ersion **2** (GLODAPv2) for inorganic carbon and carbon-relevant variables. It also became part of Geonetwork, an open source portal for access to geo-referenced databases, maps, and metadata.

Working Groups as Building Blocks for Science

Working groups are central to activities carried out in the organization. They are composed of scientists suggested by the science board, and approved by the national delegates. Because PICES is not a source of funding for scientists, they must find the work intrinsically interesting, and sometimes they bring in support from external sources. Often working groups have co-chairs chosen from each side of the Pacific, to foster broad geographical perspectives and synthesis across regions. The groups have specific terms of reference and timelines, with oversight by a parent committee.[53] In early years, many of the working groups were constituted with a single parent committee, but by 2004, several of them shared dual committee oversight to foster more communication across the traditional fields.[54] The advent of the scientific program FUTURE also helped bridge the more

[52]"Pacific Ocean Interior Carbon Data Synthesis, PACIFICA, in Progress," by Masao Ishii, Toru Suzuki and Robert Key. *PICES Press* (2011): 19.

[53]In 2005, Michael (Mike) Foreman assessed what makes a successful working group, and found that the most productive ones have a clear mandate; resources (funding and time); collaboration with other organizations outside PICES; leadership; enthusiasm; active and dedicated members; and frequent communications.

[54]For example, FIS and MEQ shared oversight of the working groups on ecosystem-based management science and its application (WG 19; 2004–2009) and the environmental interactions of marine aquaculture (WG 24; 2008–2012), POC and BIO shared one on regional climate modeling (WG 29; 2011–2015).

traditional (BIO, FIS, POC and MEQ) and less traditional (social sciences) marine fields in expert groups.

At its founding, PICES began with six working groups, and as each finished its terms of reference, new ones took their place, totaling 34 so far. At a minimum, they need to accomplish their terms of reference, but ideally, they push frontiers and give advice to the science board as to where to go next with an issue. For instance, one of the current groups is on the causes and consequences of recent jellyfish blooms around the Pacific Rim, while another is on emerging topics in marine pollution. Their success can be measured in different ways; judged by the degree of participation by their members, and the quality and number of their scientific products.[55] Two new joint working groups between PICES and ICES are notable examples of increased cooperation between the two regional organizations.

All the groups require that individuals work independently between meetings, in the context of their national framework, and then bring the components into a cohesive synthesis of the issue. Some groups with the right combination of participants worked quickly and productively within well-defined terms of reference. Most working groups fulfill their terms of reference and disband at the end of their term, to be replaced by different areas of inquiry. A few working groups reveal enough new avenues that they give rise to additional working groups, or sometimes more substantial and longer-lived sections, in recognition of their significance. One of these areas has been on climate change modeling. For example, when the working group on evaluation of climate change projections (WG 20), completed its terms of reference and produced its report, the science board and council agreed that they needed two new working groups to follow up on its promising developments. One expert group was on climate variability and change (WG 27), and the second was on regional climate modeling (WG 29).

The early Bering Sea working group was an example of how PICES was the forum to bridge geography, national treatments, and disciplines to synthesize previously disparate treatments.[56] The region produces a huge amount of fish and shellfish, as well as sea birds and mammals, making it one of the most productive marine ecosystems. The Bering Sea group started at the first annual meeting to review the climatology, oceanography, and biology of the Bering Sea in response to environmental variability. They identified major gaps in that knowledge, and then developed a symposium on the Bering Sea ecosystem for the 1995 annual meeting that shed light on the new perspectives possible through a regional intergovernmental and interdisciplinary organization. The book, *Dynamics of the Bering Sea* (Loughlin 1999), synthesized the oceanography of the region across disciplines and countries and was the best compilation of the science of the Bering Sea at the time.

---

[55] Warren Wooster, as chair of PICES, spoke his mind at the second annual meeting in 1993 to warn that the success of working groups was "weakened by non-participation stemming from travel restrictions and shortages of travel funds at the national level… Let's bend our efforts to making it work." *PICES Annual Report* (1993), p. 8.

[56] Bering Sea working group (WG 5; 1992–1996), parent SB, chair Al Tyler (USA).

A very successful sustained effort began in 1997 with a working group on carbon dioxide.[57] The ocean plays a critical role in global climate regulation as a major carbon reservoir for CO_2 emitted into the atmosphere from many sources, including human activities like burning fossil fuel and biomass. The North Pacific helps mediate long-term climate changes through its capacity to absorb CO_2, but it also has some unique biogeochemical processes due to being at one end of the global transport of high nutrient water, and contrasting physical and chemical properties in its eastern and western regions. PICES became a coordinator for synthesis of ocean carbon research, and developed a network of ocean carbon observations in the North Pacific.

Global climate research requires the production of reliable and extensive carbon data, to study both the carbon cycle and the global carbon budget. The data help track CO_2 flux across the air-sea boundary, the amount of uptake in the ocean, as well as resulting ocean acidification. Such data are critical to the relatively new field of oceanic biogeochemistry. The CO_2 measurements need to be highly precise and accurate to be comparable across time and space, as well as across research efforts, and yet methods can vary between research groups and countries, as well as over time.

The working group on carbon dioxide identified gaps and problems in knowledge of the processes that control CO_2 in the North Pacific. Their parent scientific committee was POC, but they also worked with the technical and data committee (TCODE) to identify data sets to contribute to the PICES Marine Metadata Federation. They assessed different measurement methods, current knowledge of the processes controlling it, and found useable data sets to share. Group members reported on standards and quality control within their national contexts, to clarify potential for intercalibration. Their initial inventory of carbon data from all member nations was a start, but it needed a mechanism for continual additions of contemporary and historical data, as well as transformation into an accessible, searchable, and quality database. They co-sponsored two international symposia on CO_2, a topic session at the PICES Annual Meeting in 2000, and held inter-comparison studies to improve the existing methodologies of CO_2 measurements. Technicians from fifteen laboratories across member countries discussed best practices for inter-comparison studies.[58] The group encouraged Japan to restart their sampling of a long-term transect called WOCE P1, given the critical role of repeated ocean measurements in understanding long-term changes in anthropogenic CO_2. The carbon expert group work fed into the larger effort by WOCE and JGOFS to make a global survey of CO_2.

Given the continued challenge of intercalibration of techniques, and discovery of data of inconsistent measurements and variable quality, they advised that a new working group on biogeochemical data integration and synthesis take up their work on

---

[57]Carbon Dioxide in the North Pacific (WG 13; 1997–2001), parent POC, co-chairs Richard Feely (USA), Yukihiro Nojiri (Japan).

[58]The CO_2 data planning and data integration workshops were held in conjunction with TCODE. *PICES Annual Report* (2001), POC Endnote 3, Progress report of WG 13.

the carbon cycle and produce a best practices guide.[59] It is critical for scientists to have access to a guide of best practices and standard operating procedures for oceanic CO_2 measurements and data reporting. The working group agreed to help prepare such a guide, to maximize the likelihood of consistent data, and stimulate work by member countries that did not yet have robust shipboard sampling programs. They took as their starting point a 1994 US Department of Energy guide that covered issues of sampling, quality assurance, analysis, calibration, and computation, and also outlined solution chemistry for CO_2, and the additional physical and thermodynamic data required for calculations (Dickson et al. 2007). The **I**nternational **O**cean **C**arbon and **C**limate **P**roject (IOCCP) supported distribution of the original English version (IOCCP Report No. 8). IOCCP, co-sponsored by SCOR and IOC, is designed to interact with existing regional-scale research and observation groups working on ocean carbon. IOCCP wrote a letter of appreciation to PICES for their continued contribution of regional data for global observations. The guide was an example of productive interagency cooperation with IOC and SCOR. The authors used the CDIAC website to widen access to the report beyond PICES member countries.

Writing such manuals is not easy, and scientists are rarely awarded commensurate recognition in their promotion reviews, so it was a labor of service to the scientific community. Although many publishers charge for technical manuals, this one is free to download because its fundamental goal is to foster wide adoption of standardized approaches for measurements. It is meant as a living document to be revisited and revised as needed and volunteers have now translated it into Korean, Japanese, and Chinese. Its utility is not restricted to the Pacific region, however, and some of it has been translated into Spanish, with possible future translation into Persian (*PICES Press* 24 (2016).

One of the intents of the carbon work is long-term synthesis with other emerging international ocean programs.[60] The working group on biogeochemical data integration and synthesis in turn was approved for transformation into a section on carbon and climate (S-CC) in 2005, co-supervised by the parent committees of POC and BIO. From the 1990s onwards, scores of research cruises had collected samples to help determine the distribution of both natural and anthropogenic inorganic carbon in the world's oceans. The PICES section on carbon and climate wanted to support a similar carbon data synthesis project for the interior of the Pacific Ocean.[61] The longevity of the carbon effort, through two working groups and a

[59]*PICES Scientific Report* (2003): 24 on "CO_2 in the North Pacific Ocean." Carbon Dioxide in the North Pacific (WG 13; 1997–2001) was succeeded by Biogeochemical Data Integration and Synthesis (WG 17; 2001–2005), co-chairs Andrew Dickson (USA), Yukihiro Nojiri (Japan). WG 17 was replaced by the Section on Carbon and Climate (S-CC; 2005–2016), parents BIO, POC, co-chair James Christian (Canada), Tsuneo Ono (Japan); past co-chair Toshiro Saino (Japan, 2005–2014).

[60]Such programs included **Cli**mate and Ocean: **Var**iability, Predictability and Change (CLIVAR), **I**ntegrated **M**arine **B**iogeochemistry and **E**cosystem **R**esearch (IMBER) and **S**urface **O**cean—**L**ower **A**tmosphere **S**tudy (SOLAS).

[61]PICES collaborated with the IOCCP program of IOC.

section, signified that they had a committed group of scientists in all countries eager to work within the PICES environment on a topic fundamental to progress throughout marine science. The terms of reference for S-CC included the importance of ensuring effective two-way communication with other international scientific groups responsible for the coordination of ocean carbon research, such as with IOCCP and the SOLAS-IMBER working group on carbon. Having carbon and climate section members on each of the SOLAS and IMBER subgroups helps communication among these projects.[62]

The outcomes from the two carbon working groups and section were critical to the success of the first integrative science program on Climate Change and Carrying Capacity (CCCC). Some of those carbon scientists have also contributed to the more recent **I**ntergovernmental **P**anel on **C**limate **C**hange (IPCC) Assessments. Each generation of the models used in the IPCC reports have become more comprehensive. The **f**irst **A**ssessment **R**eport (FAR) in the early 1990s included a very simple representation of the ocean. Subsequent models increased the complexity by adding in ice cover and aerosols, but an integrated assessment of the impacts and risks of climate change and ocean acidification on the ocean as a region was still missing. Kenneth (Ken) Denman (Canada) became deeply involved in the assessment reports as an author, and was given the Wooster Award for 2007 in recognition of such fundamental contributions to marine science.[63] The IPCC reports can only draw upon peer-reviewed published research, so it takes foresight to plan and complete work in time for each new IPCC assessment report.

The working group on evaluating climate change projections (WG 20) assessed which IPCC projections could be downscaled to continental shelf and coastal ecosystem studies, part of the focus of the FUTURE science plan. Though WG 20 was originally given a 3-year term, it was extended a year to allow collaborations with the soon-to-be created joint ICES-PICES working group on Climate Change Impacts on Fish and Shellfish.[64] The IPCC 4th Assessment Report (2007) had concluded that global warming of the climate system was certain. PICES and ICES jointly nominated authors for the 5th Assessment Report (2014), and PICES scientists were among lead authors of its Working Group 1; chapters 3 (Observations: Oceans), and 6 (Carbon and Other Biogeochemical Cycles), and Working Group 2; chapter 28 (Polar regions).[65]

---

[62] http://www.scor-int.org/Annual%20Meetings/2012GM/Tab%206.pdf.

[63] Denman was a coordinating lead author of the 2nd (1996) and 4th (2007) Assessment Reports of the IPCC, and led many components of the international and Canadian JGOFS, GOOS, GLOBEC and SOLAS programs. He began his oceanographic work in physics, added plankton ecology, and then biogeochemistry of the subarctic Pacific.

[64] Joint PICES-ICES Working Group on Forecasting Climate Change Impacts on Fish and Shellfish (WG-FCCIFS, or WG 25; 2008–2011), co-chairs Manuel Barange (UK), Anne Hollowed (USA), Suam Kim (Korea), Harald Loeng (Norway) (Hollowed et al. 2011).

[65] Chapter 3: Howard Freeland and Richard Feely. In addition, the BIO committee reviewed an early draft of a section on high latitude spring bloom systems. *PICES Press* 20 (2012). Anne Hollowed was on WG 2, and a lead author on chapter 28: Polar Seas.

The Challenge of Mariculture

Some working groups faced long-running challenges, which arose in part from each country having significantly different situations. Mariculture was a topic that PICES scientists had discussed from its earliest days, but each nation's industry had different characteristics, policies, and national political considerations. In Korea, for example, mariculture production was tied to the state of the economy, and differed by region, with eastern regions focused on fish, and western regions focused on shellfish and seaweed. In Japan, the volume of aquaculture products remained stable while capture fisheries fell by 33 % between 1991 and 2001. The Japanese were particularly concerned about transmission of disease, rather than maximizing carrying capacity. China had the greatest amount of mariculture, with the large areas and densities of production leading to environmental concerns. For instance, from 1993 to 2004, benthic community biodiversity had reduced from over 200 to 30 species in some areas. Canada, the US, and Russia, in contrast, had relatively small marine mariculture operations, and the Russian ones were primarily government owned.[66] All governments expected that mariculture would expand in the future, and they wanted to understand its scientific aspects.

Several PICES committees discussed scientific issues associated with the development of mariculture, and there was considerable interest in the topic, particularly by China and Korea. The topic could be addressed through a novel joint effort from MEQ and FIS committees, or if it generated broad interest, the science board could sponsor it. It was hoped that more concerted attention to mariculture might increase participation across member countries. When the working group on mariculture was constituted in 2003, its terms of reference explicitly focused on the science, rather than the technology, of aquaculture. It was to review the status and trends in mariculture that significantly contributed to world aquaculture. As it did so, it hoped to characterize emerging issues in scientific terms rather than commercial terms, including environmental and ecosystem function, sustainability of production (that is, carrying capacity of ecosystems), and socioeconomics. Finally, it intended to produce recommendations for a PICES action plan on scientific issues of mariculture.

Although the working group held three scientific sessions, and produced national reports on status and trends in aquaculture, they failed to produce an overview of current and emerging issues.[67] In 2006, the science board constituted a study group on marine aquaculture and ranching to figure out why, despite governments agreeing on the importance of aquaculture, the working group struggled to fulfill its

[66] *PICES Annual Report* (2004) "Report of working group 18 on marine aquaculture."

[67] *PICES Annual Reports* (2004), (2005), (2006). Mariculture in the 21st Century: The Intersection Between Ecology, Socio-economics and Production (WG 18; 2003–2006), parents MEQ, FIS, co-chairs Ik-Kyo Chung (Korea), Carolyn Friedman (USA).

terms of reference and disbanded early.[68] Low participation at meetings and in email communication suggested that even when PICES leadership thought something was important, the members of the expert group needed to be equally invested. When the study group polled the member countries independently from the working group, it found that most wanted to explore aquaculture technology and management of operations as well as estimate the carrying capacity of commercial aquaculture activities. The study group speculated that it was problematic that people outside of aquaculture developed the original terms of reference. FAO and various national agencies already tracked status and trends by country and region, so efforts by the working group appeared redundant. They also pointed out that most scientists in the group were new to PICES, recommended by members who did not have a background in aquaculture, and without the social cohesion of more experienced members. Perhaps most problematic was that much of the rest of PICES seemed of low relevance to aquaculture scientists, and vice versa. Limited travel budgets meant that participants had to choose between their specialist meetings and PICES, making for low turn out. The study group concluded that another effort should be made, in part by examining how ICES successfully dealt with aquaculture. They hoped that allowing the members to develop their own terms of reference, focused around technology, would lead to better success. In 2008 a new working group on environmental interactions was constituted under MEQ and FIS, but still struggled to fulfill its goals.[69] Perhaps one issue was that mariculture is primarily a national commercial interest, and there might have been concern over collaborating with potential competitors. In addition, commercial enterprises generally have fewer or no scientists to participate in the activities of an interdisciplinary science organization. It may also have been an issue of timing, given that each country developed its engagement at different stages.

The Role of Study Groups, Sections and Advisory Panels

When the science board or governing council propose some action, but need assessment of its scientific or policy implications, they form a short-term study group on the matter. The recommendations often lead to the formation of new working groups. Among the two dozen past topics have been the creation and revision of strategic plans, mechanisms for increased cooperation, emerging scientific topics, and creation of an integrative science program. The study group on human dimensions reviewed the role of social sciences in ecosystem-based fisheries

[68]Study Group on Marine Aquaculture and Ranching in the PICES Region (SG-MAR; 2006–2007). Approved at PICES 15 (2006), (Decision 06/S/6), chair Michael Rust (USA).

[69]Environmental Interactions of Marine Aquaculture (WG 24; 2008–2012), parents MEQ, FIS, co-chairs Katsuyuki Abo (2008–2012, Japan), Kevin Amos (2008–2010, USA), Ingrid Burgetz (2008–2012, Canada), Brett Dumbauld (2010–2012, USA). They produced *PICES Scientific Report* (2013): 44.

management. Current study groups have a range of tasks that mostly focus on the challenge of incorporating the human dimension to the current integrative science plan FUTURE across member countries.

Providing Additional Expertise Through Sections

Committees, limited to a maximum of 18 members, cannot possibly include all necessary expertise, so if they need additional input for an extended period, they can establish a section. Sections are the equivalent of a sub-committee, having a longer lifespan than a working group, and are useful for challenging issues. Four current sections on the effects of climate change, the human dimensions of marine systems, harmful algal blooms, and the interactions between carbon and climate, are instrumental in the integrative science program FUTURE.[70] The longest running section is on the ecology of **h**armful **a**lgal **b**looms (S-HAB).

A growing threat around the world is seafood tainted by harmful algal blooms (HABs), and some studies suggest links between climate change and the nature of blooms. Blooms can be of two broad types; high biomass but nontoxic blooms that deplete oxygen, and low biomass blooms that are toxic. Several genera of algae are shared among all PICES countries, and one idea was to study trends and commonalities among nations. They hoped to develop an early warning system to detect HABs, and develop and implement practical ways to safeguard humans and seafood products from harmful algae. In 2003, the committee on marine environmental quality started the section on the ecology of harmful algal blooms that grew out of a previous working group on HABS.[71] Its initial terms of reference included development and implementation of reporting procedures for blooms consistent with those of ICES, so that data could be combined into a **H**armful **A**lgal **E**vent **DAT**abase (HAE-DAT), as well as contribute to the ecosystem status report series.[72] An exchange of national reports is necessary for such a database, and allows assessment of the links between blooms and environmental factors, including possible anthropogenic stressors like eutrophication. The joint IOC-ICES-PICES HAE-DAT ideally allows global comparison of changes in harmful algal blooms.[73] One challenge is that

---

[70]Section on Ecology of Harmful Algal Blooms in the North Pacific (S-HAB; 2003–2017, renewed twice); Section on Carbon and Climate (S-CC; 2005–2016); Section on Human Dimensions of Marine Systems (S-HD; 2011–2017); Section on Climate Change Effects on Marine Ecosystems (S-CCME; 2011–2017); and Section on Marine Birds and Mammals (S-MBM; 2015–2020).

[71]S-HAB co-chairs Douding Lu (China), Vera Trainer (USA), past co-chairs Shigeru Itakura (Japan), Hak-Gyoon Kim (Korea). S-HAB grew out of a working group on the Ecology of Harmful Algal Blooms in the North Pacific (WG 15; 1999–2003), chairs Tatiana Orlova (Russia), Max Taylor (Canada).

[72]*PICES Annual Report* (2004). HAB-S Endnote 3.

[73]http://haedat.iode.org/.

along coastlines, administrative units can overlap, and monitoring programs differ in quality. As of 2016, the database contains records from the ICES area (North Atlantic) since 1985, and from the PICES area since 2000. IOC regional networks in South America, South Pacific and Asia, and North Africa are not yet in the system, but the intent is for global coverage.

The Role of Advisory Panels

If a committee or program needs specific technical expertise, they can ask to form an advisory panel, with co-chairs from the western and eastern North Pacific and two to four participants from each member country. Two recent advisory panels are on East Asian regional seas, and coastal observing systems.[74] Past advisory panels have been on marine birds and mammals, plankton surveys, data buoys, iron fertilization, and micronekton sampling.[75] The sixteen-year advisory panel on **M**arine **B**irds and **M**ammals (MBM) grew out of an early working group on the consumption of marine resources by birds and mammals. Though they are important components of the marine system, much is yet unknown about their population dynamics. The topic is a large one for a small number of experts to address, and so the advisory panel worked to improve the exchange between mammal and seabird experts and the broader PICES scientific community.[76]

The longest-lived advisory panel in PICES was on the **C**ontinuous **P**lankton **R**ecorder (CPR), a simple, yet effective sampling device for plankton.[77] Though satellite remote sensing beginning in the late 1970s launched the age of scanners to estimate the density of phytoplankton from chlorophyll pigment concentration, satellite sensing has not replaced the utility of the simple sampling device of the CPR. The North Pacific had very little data on plankton, and PICES helped bring the CPR program to the region, to improve the collection of open ocean plankton data. The advisory panel helped transition it from ad hoc funding to a more

[74]Advisory Panel on North Pacific Coastal Ocean Observing System (AP-NPCOOS; 2015–), under the direction of MONITOR and TCODE, and Advisory Panel for a CREAMS/PICES Program in East Asian Marginal Seas (AP-CREAMS; 2005–2019).

[75]The second PICES scientific program FUTURE also used the advisory panel structure, though in a different way.

[76]Consumption of Marine Resources by Marine Birds and Mammals (WG 11; 1995–1999), co-chairs George Hunt, Jr. (USA), Hidehiro Kato (Japan). Advisory Panel on Marine Birds and Mammals (AP-MBM; 1999–2015); co-chairs Douglas F. Bertram (1999–2003, Canada), Hidehiro Kato (1999–2010, Japan), Rolf Ream (2010–2015, USA), William J. Sydeman (2003–2010, USA), Yutaka Watanuki (2010–2015, Japan). Section on Marine Birds and Mammals (S-MBM; 2015–2020), co-chairs Kaoru Hattori (Japan), Rolf Ream (USA). It transitioned from an advisory panel to a section at the 2015 PICES meeting.

[77]Advisory Panel on the Continuous Plankton Recorder (AP-CPR; 1998–2014); past chairs Charles B. Miller (2000–2008, USA), Phillip Mundy (2008–2014, USA), Warren Wooster (1998–2000, USA).

permanent funding consortium to ensure its longevity. The CPR data are the only long-term biological indicator of global change that has broad coverage for the region, and are vital to assess ecosystem status.

Marine phytoplankton and microbes are fundamental to the ocean food web, with phytoplankton photosynthesis responsible for much of the transfer of CO_2 from the atmosphere to the ocean. Zooplankton have remarkable influence on the rest of the ecosystem. Their feeding can influence or even regulate primary production, so variations in their dynamics can affect the biomass of many fish and shellfish stocks. Sampling plankton is critical to the generation of hypotheses about ocean ecosystems. Dramatic multi-decadal decline in plankton biomass has been demonstrated in the North Sea and in the eastern North Atlantic by extensive sampling over a 44 year time period (Harris 1997). Competing hypotheses have been offered for this decline, so refining and testing these explanations is a major challenge for the field of ocean ecosystem dynamics.

British fishery biologist Alister Hardy tested his prototype of the CPR on the Antarctic voyage of the *Discovery* in 1925. A metal case is towed at a depth of about 7–10 m where it filters plankton from the water, and traps them on a moving band of silk mesh that is spooled into a storage tank of preservative. The simple yet effective sampling device is still used today to survey near-surface zoo- and phytoplankton, key trophic resources for fish and other marine organisms to assess their quantity, type and variability across the sampled area. Because it is virtually unmodified from its early design, it provides remarkable opportunity to compare samples over a long time and great distances to detect changes in the ocean. After over 80 years, the survey has become one of the longest running marine biological monitoring programs in the world, operated by the **S**ir **A**lister **H**ardy **F**oundation for **O**cean **S**cience (SAHFOS) operating out of Plymouth, England. It is now one component of the diverse monitoring array organized under the **G**lobal **O**cean **O**bserving **S**ystem (GOOS) platform.

Beyond the utility of the CPR sampling device itself, an innovative and critical part of the operation is its deployment by merchant ships. Frequent, routine sampling of plankton is impossibly costly for research vessels that serve tightly scheduled competing projects, so the surveys depend on the routine sailings of merchant ships, known as "ships of opportunity," to tow the recorders, producing a regular and long path of samples year-round. The resulting time and spatial series dataset is critical for a wide range of research questions ranging from basic taxonomy to questions on biodiversity, eutrophication, harmful algal blooms, fisheries and climate change. The foundation's marine monitoring program primarily collected data on the ecology and biogeography of plankton from the North Atlantic and the North Sea, though over time some sister surveys started in other regions.[78]

[78]See for instance, the Southern Ocean Continuous Plankton Recorder Survey, the Australian Continuous Plankton Recorder Project, and the Global Alliance of CPR Surveys.

T.S. Parsons (Canada), proposed a trans-Pacific program at the first annual meeting in 1992, under the development of the BIO committee.[79] By 1995 the BIO Committee reported on other potential CPR programs, such as a China-Korea program to start the next year and a Japanese ship-of-opportunity program they hoped to expand to a CPR program.[80] A growing focus on dynamics of climate change suggested that zooplankton populations are responsive to climate change and they are a critical link between atmospheric and upper food web dynamics, adding impetus to collect CPR data for the region. The 1997–1998 El Niño gave PICES scientists an additional motivation to advocate for such a sampling program.

In 1997 SAHFOS carried out a feasibility study in the northern Pacific region using an oil tanker traveling from Alaska to California.[81] By 1998 the CCCC program, through its new MONITOR task team, took over the CPR initiative and invited SAHFOS to present their work from the Atlantic region at the 1998 annual meeting to a receptive audience.[82] The task team called for two sampling routes, one going north-south from the Gulf of Alaska to California, and one east-west, starting from Vancouver. Though they initially wanted to collect samples six times a year on each route, they needed to scale back due to limited funding. The PICES governing council approved an advisory panel to suggest the most appropriate locations, timing and frequency of route, and recommended financial support for a CPR survey in the PICES region to collect plankton during 2000 and 2001, followed by support from the **N**orth **P**acific **R**esearch **B**oard (NPRB). They signed collaborative agreements with the Prince William Sound Science Centre in Valdez, and the DFO's Institute of Ocean Sciences in Sidney, BC to support local processing of samples, thus speeding access to data on local conditions, and ensuring its immediate utility. By 2007, the CPR sampling was its seventh year, and it was clear that continuity of funding was sorely needed to prevent any break in the data set and continue immediate processing and analyzing of samples. The advisory panel proposed that agencies in Canada and the USA that support marine science activities form a funding consortium.[83] Continuity of samples requires sustained funding over the long term, so in 2008 PICES created and coordinated a funding consortium for it that drew together the NPRB, the **E**xxon **V**aldez **O**il **S**pill **T**rustee **C**ouncil (EVOS TC), Canadian DFO and SAHFOS.[84] Scientists have used the survey data in over twenty scientific papers on topics ranging from comparative ecology, interannual and regional variation in

---

[79] T.R. Parsons was the winner of the Japan Prize in 2001 for his contribution to the development of fisheries oceanography and the conservation of fisheries resources.

[80] *PICES Annual Report* (1995, 1997).

[81] *PICES Annual Report* (1998). MONITOR Annex 2 Pilot Continuous Plankton Recorder Monitoring Program.

[82] MONITOR oversaw AP-CPR that was chaired by Warren Wooster (1998–2000, USA), Charles Miller (2000–2008, USA) and Phillip Mundy (2008–2014). *PICES Annual Report* (1998).

[83] *PICES Annual Report* (2007). Funding for the North Pacific CPR project (Agenda Item 1).

[84] *PICES Annual Report* (2009). CPR Funding Consortium. Sonia Batten (SAHFOS).

abundance, and impact of ocean-atmosphere climate variability.[85] CPR became a model tool for PICES to build cooperation and communication among nations in North Pacific marine science.

A regional program on **C**irculation **R**esearch of the **E**ast **A**sian **M**arginal **S**eas (CREAMS) has also had an advisory panel in PICES.[86] The CREAMS program was started in 1993 by Japan, Korea and Russia to study circulation in the semi-enclosed basin surrounded by those countries. The area has been undergoing several changes, including a long-term decrease in dissolved oxygen in its deep water and outbreaks of red tides.[87] The members carry out both bilateral and trilateral research cruises, and they use historical data, numerical modeling, and laboratory experiments to intensively study the area. Because the PICES region encompasses the focal area of CREAMS, they have a mutual interest in scientific studies, so in 2005, PICES authorized the advisory panel to develop a joint program for hydrography, circulation and biology in the East Asian marginal seas. They have held joint workshops and summer schools on such topics as ocean circulation and ecosystem modeling and satellite oceanography. They have also developed a capacity building program to provide training for the next generations of marine scientists. The advisory panel supports CREAMS in the development of permanent monitoring and data exchange for the region. It contributes to the integrative science plan FUTURE through its coordination of international activities on a regional level.

Providing Different Kinds of Scientific Advice

The PICES convention has a dual mission to advance scientific knowledge and apply it to societal needs through scientific advice.[88] Though PICES does not have any specific short-term fishery advisory role, as provided by fishery commissions, it works to strengthen the scientific foundations on which good management depends. Advice can be characterized broadly by its recipients—whether it is directed towards a scientific audience, or to the broader public, including policy makers.[89] Internal to the organization, PICES produces advice on methods and tools to guide scientific

[85] https://www.pices.int/projects/tcprsotnp/default.aspx/.

[86] Japan, Korea and Russia established CREAMS in 1993 to study the circulation in the semi-enclosed basin those countries surround, using historical data, field observations, numerical modeling, and laboratory experiments. Advisory Panel for a CREAMS-PICES Program in East Asian Marginal Seas (AP-CREAMS 2005–2019), parents POC, MONITOR, co-chairs Joji Ishizaka (Japan), Kyung-Ryul Kim (Korea), Vyacheslav Lobanov (Russia), Yasunori Sakurai (2005–2009, Japan); Fei Yu (China).

[87] The 2002 CREAMS-PICES symposium contributed to the first NPESR and some of the work also appeared in a special issue of *Progress in Oceanography* (2004): 61.

[88] Article V, 1(d) "to consider requests to develop scientific advice pertaining to the area concerned."

[89] *PICES Annual Report* (1992). Endnote 2: Resolution under Agenda Item 2, p. 15.

activities. For example, PICES hosts international capacity-building workshops on inter-calibration of sampling and measurement methods (see Chap. 3).

Requests for scientific advice can be unsolicited, or requested by a member country or an organization. Unsolicited advice is anything that the governing council deems useful, such as assessments of the trends in ecosystems. Solicited advice, in contrast, is usually a set of explicit questions that must be answered in full by an expert group. In 1993, at the second annual meeting, the governing council asked the science board to clarify the mechanism for dealing with requests for advice from member countries as well as from other organizations.[90] It was decided that once PICES received a written request for scientific advice from a member country or organization, the chair would refer it to the science board, which would pass it on to an existing or ad hoc expert group. The governing council has the ultimate authority to approve any proposed action. PICES must respond to the collective scientific requirements of its member countries, while remaining as independent as possible from any external political disagreements within or between countries. All scientific advice is reviewed first by the science board, and then by the governing council, before being sent on to the requesting government or organization.

Unsolicited Advice: The North Pacific Ecosystem Status Report (NPESR) Series

The first advice was generated from within the organization, as a showcase of what the organization was uniquely positioned to provide; to assess trends and predict changes in marine ecosystems of the North Pacific.[91] For instance, it has been hypothesized that with global warming, as sea temperatures rise, northern ecosystems may begin to look more like their more southern counterparts in their biological and physical characteristics. Latitudinal comparisons along coastlines might give insight into what could happen under different warming scenarios. As marine ecosystems undergo novel and dramatic change, understanding and forecasting conditions requires baseline data on the state of the environment. Then a set of indicators of ecosystem change might be used to predict future changes. An ecosystem status report could promote the collection and exchange of scientific data across the region, one of the main objectives of PICES. It could also identify knowledge gaps to help guide further study and build international collaborations.

In 2000, UN Secretary-General Kofi Annan called for a Millennium Ecosystem Assessment (MA) program to assess the consequences of ecosystem change for human well-being. It included a section on marine and coastal ecosystems, and characterized the threats to their ability to provide ecosystem services, including

[90] 93/A/5 established procedures on requests for advice.

[91] Ian Perry, chair of the PICES science board (2004), credits past science board chair Patricia (Pat) Livingston with the idea (Perry and McKinnell 2004).

habitat and biodiversity loss.[92] It made an argument for using **e**cosystem-**b**ased approaches to **m**anagement (EBM), and reviewed the gaps in knowledge that delay the application of the concept of ecosystem services. A fundamental requirement for EBM is assessment of status and trends in ecosystems.

The **N**orth **P**acific **E**cosystem **S**tatus **R**eport (NPESR) series is the first extensive unsolicited advice that PICES has produced.[93] Each report reviews and assesses the status and trends of marine ecosystems in the North Pacific to contribute to sustainable use of resources in the region. It provides baseline data against which to measure trends in ecosystem indicators, to reflect the dynamics of ecosystems. The first report was a pilot project to integrate the collective scientific knowledge of the North Pacific and its change over time to inform both the scientific community and policy- and decision-makers. They, in turn, could develop ecosystem-based management to be responsive to human needs for reliable ecosystem services.

The idea of producing periodic ecosystem status reports was well received throughout the organization. A better understanding of marine systems would benefit both science and the general public and their governments, especially in the face of climate change. The effort was ideally suited to an intergovernmental organization that had spent the previous decade building scientific and institutional relationships to access such data across the vast region. It would take a great deal of work and dedication to pull together in a short time, as well as openness to continual debates on best approaches. Despite considerable challenges, it has proved to be a significant contribution to understanding the state of ecosystems.

How Best to Produce Ecosystem Status Reports?

The PICES region is composed of distinct patterns in oceanographic characteristics, primary and secondary production, and commercial fisheries interests, from the seasonally ice-covered Bering and Okhotsk Seas, upwelling California Current, and sub-tropical Yellow and East China Seas. One must first be able to characterize systems before understanding how changes in variables may affect the state of an ecosystem. Marine ecosystems can be defined in many ways, such as by their map locations, their geographic names, or by their major species composition. How can these ecosystems be described and compared to build a dynamic understanding of their changes over time?

Consistent, long-term monitoring is fundamental to assessments of environmental change. In 1999, the living marine resources panel of the Global Ocean Observing System (GOOS) proposed a network of **R**egional **A**nalysis **C**enters (RACs) to

[92]The Millennium Ecosystem Assessment (MA) was carried out 2002–2005 to assess the linkages between ecosystems and human well-being, and the consequences of ecosystem change for human well-being (UNEP 2006).

[93]For example, since at least 2000, Canada and the US produced eastern Pacific region status reports for oceans and fisheries managers and scientists, but there was nothing comparable for the whole region.

analyze and make accessible the data coming out of its monitoring networks, as well as to build regional capacity to continue vital monitoring work (IOC-WMO-UNEP-ICSU-FAO Living Marine Resources Panel of the Global Ocean Observing System (GOOS) 1999). Researchers had explored the impacts of individual changes in water temperature and chemistry on species distribution, but the cumulative impact of these changes were rarely studied because of the complexity of ecosystems. GOOS hoped for rapid analysis and integration of living marine resources data with its physical oceanographic data. That could improve understanding of ecosystem functions, such as production of fish stocks. Regional analysis centers could synthesize climate, oceanographic and fisheries data from both national and international sources, to produce periodic reports on the status of ecosystems. Assessments of whole ecosystem conditions could then be used to forecast their probable future conditions. The centers could make these products available to the participating countries and disseminate them more broadly through the web.[94]

Around the same time, in 2000, the Sloan Foundation's **C**ensus **o**f **M**arine **L**ife (CoML) program began a decade-long effort to assess and explore marine biodiversity and its changing abundance around the world. The program was started in recognition that climate change and other stressors were changing the world's marine environments before it was known what organisms were in them. CoML had its own secretariat to form partnerships with organizations with complementary goals that could provide regional expertise, and PICES was a natural partner to provide information and analysis for the northern North Pacific (Ausubel et al. 2010). CoML and PICES held several joint workshops during the lifespan of the CCCC scientific program. Eventually, over 2000 scientists contributed towards CoML's goal to establish a baseline of marine life diversity, distribution, and abundance against which future change could be measured (Vermeulen 2013). The global effort gathered data on the taxonomic and functional diversity of key groups of organisms: bacterioplankton, phytoplankton, zooplankton, fishes and invertebrates, seabirds and marine mammals. The program documented taxonomy, distribution, and abundance of organisms, and linked that to their functional diversity in life histories, productivity, and spatial and temporal variability.

PICES established a study group to create an outline for a pilot ecosystem status report, and consider whether establishing regional analysis centers to produce such reports would be advisable or possible.[95] The study group needed to assess the

[94] *PICES Annual Report* (2000), p. 45.

[95] The study group included representatives of all committees (MONITOR became a committee in 2004), the scientific program CCCC, the secretariat, and Warren Wooster, on behalf of GOOS. Study Group on North Pacific Ecosystem Status Report and Regional Analysis Centers (SG-NPESR-RAC, 2000–2001). *PICES Annual Report* (2001). SB report, p. 15 stated, "Some Science Board members felt that the schedule for preparing the pilot North Pacific Ecosystem Status Report was too ambitious, and that the target for preparing the first draft should be delayed until fall 2002. Even with the revised schedule, the production of the pilot report will require that member nations provide the support and data necessary to its completion." A 2002 workshop in Seoul, Korea was on "Examine and critique a North Pacific Ecosystem Status Report."

current state of the field—what data and models existed, and what key organizations and groups could contribute to a status report. That information could become a North Pacific ecosystem meta database, to help future efforts to compile assessments of conditions. The effort drew upon the 1999 science board symposium on North Pacific climate regime shifts, and a year later, the PICES-led international conference on "Beyond El Niño," that highlighted pressures on ecosystems from both short and long-term changes in the climate (McKinnell et al. 2001). That conference was a first cooperative effort with four international fisheries commissions in the North Pacific, along with SCOR.[96]

A workshop in Hawaii in 2001, co-sponsored by CoML and the **I**nternational **P**acific **R**esearch **C**enter (IPRC), considered the feasibility of setting up regional centers.[97] Three possible options were a center with its own dedicated staff, one where outside researchers could visit to work with technical experts, or a virtual site to collect information. Whatever the approach, they could maintain a website with updated ocean information for different categories of users, with a ranked increase of detail and complexity depending on their need. At the most basic level it could offer an electronic "dashboard" that would show changing ecosystem conditions, fish stock reports, and maps of ocean conditions. A more specialized level for resource managers could have, for example, data on fish population community structure. The most technical level could allow access to raw formatted data provided by the institutions that made the observations.[98] The idea of an electronic status dashboard was exciting, but proved ahead of its time.[99] Some delegates thought that RACs were potentially controversial, given that FAO had primary responsibility for fishery statistics and their status, and the regional centers appeared too ambitious without commitments of national funding.[100] The study group recommended implementation of a virtual network of scientists, initially with one to two people within the secretariat to implement it.[101]

The 2001 workshop identified data sources and key components to create an ecosystem status report. A major impediment to the development of a PICES "state of the ocean" report was lack of a rapid method for identifying and updating annual

---

[96]The four fisheries organizations were the **I**nter-**A**merican **T**ropical **T**una **C**ommission, (IATTC); **I**nternational **P**acific **H**alibut **C**ommission (IPHC); Interim (now **I**nternational) **S**cientific **C**ommittee for Tuna and Tuna-like Species (ISC); and the **N**orth **P**acific **A**nadromous **F**ish **C**ommission (NPAFC).

[97]The workshop had over 60 participants. *PICES Annual Report* (2001), SB "Study Group Report: North Pacific Ecosystem Status Report and Regional Analysis Center," p. 15. "Proceedings of the PICES-CoML-IPRC Workshop on Impact of Climate Variability on Observation and Prediction of Ecosystem and Biodiversity Changes in the North Pacific," *PICES Scientific Report* (2001): 18.

[98]*PICES Annual Report* (2000), p. 46.

[99]See, for example, 'stop-light charts' for ecosystem conditions for salmon (Northwest Fisheries Science Center 2015).

[100]*PICES Annual Report* (2000), Agenda Item 7c, p. 38; SB Endnote 4 "North Pacific Ecosystem Status Report and Regional Analysis Center," pp. 44–46.

[101]In essence, the NPESR series is the virtual RAC. *PICES Annual Report* (2001), SB Endnote 7.

information from each member nation. Participants suggested sources and types of time series data, and existing diagnostic and predictive models for inclusion in a meta database.[102] The physical oceanography and atmospheric data were more available than information on the biological components, including annual fish stock assessments. An unresolved issue was how to provide expert opinions on the trends to decision-makers, as done by ICES. The science board suggested that other international organizations should be engaged in the assessments, possibly through the integrative science program CCCC (Chap. 4) as a lead group for producing the report.[103] A NPESR working group was established in 2002 to shepherd the production of the report.[104]

In 2002, the NPESR group and CoML combined efforts for a related, yet separate project called "Marine life in the North Pacific Ocean: The known, unknown and unknowable" (Perry and McKinnell 2005). Both partners wanted to develop methodologies for reporting on the state of ecosystems, and synthesize the available information on abundance, diversity, and distribution of marine life.[105] At the same time, they needed to know what was unknown for taxonomic groups and regions, and why it was unknown. A synthesis could determine whether the taxa were truly unknown, or information existed but was not yet accessible. Building a meta database would help address this challenge.[106] The ambitious project also hoped to forecast trends by identifying drivers of change. Workshop participants reviewed what was known about biodiversity at the basin and regional scales, and information on climate-linked changes in diversity. They also recommended time-series of physical and chemical oceanography data and measures of marine life that could be included in a NPESR. PICES produced a report for CoML that had synergies with the separate PICES initiative of the ecosystem status report (Perry and McKinnell 2005).

In 2003, the third PICES Workshop on Okhotsk Sea and Adjacent Areas, cosponsored by TINRO-Center and CoML, attempted to synthesize its major findings to contribute to the NPESR. The **K**orea **O**cean **R**esearch & **D**evelopment **I**nstitute (KORDI), PICES and CoML cosponsored a second workshop, on the

---

[102]Bernard Megrey and Allen Macklin (US NOAA) started the North Pacific Ecosystem Meta-database in 1997 as the Bering Sea Ecosystem Biophysical Meta-database. See *PICES Scientific Report* (2001): 18.

[103]In 2001, the Exxon Valdez Oil Spill Trustee Council (EVOS) offered financial support for production of the NPESR. The letter detailed their views on the editorial process, and their desire to have human dimensions included in the report. The PICES science board agreed to include additional external review, but decided that human dimensions were outside the scope of the pilot report, given its rapid production schedule and the underdeveloped research field. *PICES Annual Report* (2001) "High priority scientific projects," Agenda item 8e.

[104]CoML co-sponsored the first workshop in Honolulu, USA, with subsequent ones hosted by Seoul National University, TINRO-Center, and Korea Oceanographic Research and Development Institute. NOAA/Fisheries and EVOS supported the preparation of the report.

[105]PICES science board chair Ian Perry was instrumental in both efforts.

[106]*PICES Press* 12 (2004). Bernard Megrey (USA) spoke on the North Pacific Ecosystem Meta-database promoted by NOAA.

variability and status of the Yellow Sea and East China Sea ecosystems. Both seas had experienced increased water temperature over the past decades, as well as rapid changes in the species composition and abundance of major fisheries. The countries closest to the target regions invited local experts to regional workshops to contribute their expertise. That outreach required additional translation support to make the experts and their data available. They faced the same challenge as any other ecosystem assessment—how to provide greater analysis and synthesis of data within and between areas. The availability of up-to-date information proved to be quite variable across regions, and that influenced chapter balance, content and scope. The authors of some regional assessments drew upon data from well-established programs, while others needed to find out what was available. Participants discussed and refined their chapter contributions to the NPESR.[107] The pilot report was a chance to learn lessons on both procedures and content for subsequent iterations.

In 2004, the first ecosystem status report entitled "Marine Ecosystems of the North Pacific" was published in the new "special report" series aimed at marine scientists, governments concerned with marine resources, and the general public (Perry and McKinnell 2004). The report was the first attempt by scientists of the North Pacific to compare and contrast entire marine ecosystems throughout the region, to assess present conditions against those of the recent (five-year) past, and to identify key stresses likely to affect future conditions. Each regional chapter included information on the status and trends in climate, chemistry, plankton, fish and commercial invertebrates, and marine birds and mammals, and assessed critical factors causing change in ecosystems. Three international fisheries commissions, the IPHC (halibut), the IATTC (tuna), and the NPAFC (Pacific salmon) also contributed chapters on their expertise.

Key findings on climate were that after 1998 a new atmospheric pattern altered storm tracks across the North Pacific, which warmed the central Pacific and cooled the eastern Pacific coast. A moderate El Niño in 2002 warmed coastal waters of North America, but its effects disappeared by the following year. In the biological realm, the synchronous decline of small pelagic fish like sardine suggested an important role of climate patterns on their abundance. Stock management appeared to have helped some salmon and halibut stocks, while other species like walleye pollock in the Okhotsk Sea and hairtail in the Yellow Sea were likely overexploited. Blooms of phytoplankton and jellyfish had increased in the previous five years, and

[107] Third PICES Workshop on Okhotsk Sea and adjacent areas (2003, Russia); co-sponsors PICES, TINRO-Center and CoML. Hyung-Tack Huh and Sinjae Yoo (KORDI), and Skip McKinnell and Ian Perry (PICES) convened the KORDI/PICES/CoML Workshop on "Variability and status of the Yellow Sea and East China Sea ecosystems," in Seoul, South Korea. It had been delayed twice due to the outbreak of SARS that year. *PICES Press* 12 (2004). The same year, PICES held a three-day inter-sessional workshop on Regional marine life expert (2003, Canada); co-sponsors PICES and CoML, to help produce the CoML report. When CoML reached its 10-year lifespan in 2010 and closed, BIO held a half-day topic session to share its global results, including new techniques like DNA barcoding, advances in microbial ecology, and activities in the Arctic.

proved detrimental to fish and shellfish mariculture, as well as to marine mammals like Steller sea lions. In the eastern North Pacific, zooplankton species and assemblages showed dramatic changes. Not surprisingly, coverage varied among regions, dependent on available time series data, authorship, and the rapid production schedule. The pilot report identified areas where comparable data were needed for climate, ocean productivity and living marine resources. It also suggested potential future directions for the series, such as potential comparisons between near shore and intertidal areas, and new topics, like marine contaminants.

The pilot report accomplished two things. First, it signaled government consensus on the importance of the NPESR effort, and a willingness by individual scientists to collaborate on it. Robust assessment of ecosystem trends requires institutional and governmental commitments to support the underlying science. Second, by systematically cataloging each year's anomalies, NPESR developed a baseline for an information archive and portal on the role of variability in ecosystems.[108] Subsequent iterations would benefit from critical review and new approaches. For instance, it was hoped that in the future it could include an electronic dashboard of ecosystem conditions to help inform ecosystem-based management.

In 2007, following recommendations from the study group on ecosystem status reports, the governing council and science board endorsed the development of a second NPESR. The second report covered the five-year period from 2003 to 2008, and addressed some of the gaps in the pilot report, with the help of a synthesis workshop. It drew broadly from the products from working groups and advisory panels to build a suite of variables for each PICES region. The second NPESR, published in 2010, included a more detailed analysis with larger data sets (McKinnell and Dagg 2010).

The first two status reports highlighted climatic, oceanographic, and biological changes, and though some chapters sketched human impacts, the volumes did not yet include human use of ecosystems in any systemic way. One suggestion was that future reports include a uniform set of tables and graphs across regions to help cross-comparison of biological, chemical and physical characteristics as well as trophic information. It was also hoped that they would link to a dynamic meta-database to assess trends. Phil Mundy, representing the FUTURE advisory panel SOFE, suggested that NPESR should be incrementally updated annually-to-biennially through a web-based system, with more detailed analysis at five- or six-year intervals and be expanded to include human dimensions through socio-economic indicators.

The initial NPESR relied heavily on the work of individual scientists who showed that it was feasible. That engaged more individuals to contribute to the second one, but it was a great deal of work to carry out in a short time frame. Just as the IPCC assessment reports went through successive refinements, the NPESR

[108]Response by Jim Christian (Canada) to Alex Bychkov questionnaire (2015) on PICES achievements.

series was envisioned as open to a similar process. A NPESR series needs serious commitment from organizations to sustain it, however. The intent for it to be timely continues to be a challenge, in part because of the additional expectations for subsequent reports. The NPESR series began to incorporate an explicitly human component of social and economic indicators with the formation of the **s**ection on **H**uman **D**imensions of Marine Systems (S-HD) in 2011.[109]

Scientists need common metrics to detect ecosystem-level changes in a consistent and standardized way. Ecosystem indicators can measure impacts of stressors, and identify systems that are resilient or vulnerable to them. When stressors produce changes to ecosystem structure and function, they can affect their overall productivity, and negatively impact the societies that depend on them. In 2011, PICES held an inter-sessional workshop to choose common indicators of status and change within North Pacific marine ecosystems.[110] Given marine ecosystems have a certain amount of inherent variability, the metrics also needed to incorporate measures of uncertainty surrounding future scenarios that could be conveyed to managers and policy makers. The workshop built on progress since the 2004 IOC-SCOR-GLOBEC-ICES-PICES-sponsored symposium in Paris, France on quantitative ecosystem indicators for fisheries management (Drinkwater et al. 2005). A working group on ecosystem indicators and multiple stressors (WG 28) built on emerging issues from the impact of iron supply on biogeochemistry and ecosystems (WG 22), the comparative ecology of krill (WG 23), and on non-indigenous marine species (WG 21).[111]

The objective of a 2013 workshop in Hawaii, USA, was to develop human development indicators for the third NPESR.[112] The participants were asked to bring as much data as they could on such topics as their country's fisheries sector, consumption rates and patterns, governance structure, and cultural aspects of their fisheries. Around the same time, the United Nations had started their **W**orld **O**cean **A**ssessment (WOA) project (see below) and the NPESR work proved foundational to the subsequent North Pacific components to WOA. The third NPESR required a new study group to develop an implementation plan to incorporate comments by independent peer reviewers. This group recommended an inter-sessional workshop

---

[109]Section on Human Dimensions of Marine Systems (S-HD; 2011–2020), co-chairs Keith Criddle (USA), Mitsutaku Makino (Japan).

[110]Inter-sessional FUTURE workshop on Indicators of Status and Change within North Pacific Marine Ecosystems, 26–28 April, 2011. Conveners Sachihiko Itoh (Japan), Jacquelynne (Jackie) King (COVE-AP; Canada), Tom Therriault (AICE-AP; Canada).

[111]Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors (WG 28; 2011–2015), parents: BIO and MEQ, co-chairs Ian Perry (Canada), Motomitsu Takahashi (Japan).

[112]PICES Meeting to Develop Human Dimension Indicators and Information in Support of the PICES Ecosystem Status Report and the First World Ocean Assessment, Honolulu, Hawaii, USA, 13–15 June, 2013, co-conveners Keith Criddle (USA), Mitsutaku Makino (Japan), Ian Perry (Canada), Tom Therriault (Canada).

in 2016 to review time series and ways to produce a robust report. For instance, it recommended adoption of a uniform biogeographical classification of data.[113]

Contributing to Ecosystem-Based Management (EBM)

The idea of assessing status and trends in ecosystems was incorporated into the new integrative program of FUTURE. Habitat loss, overexploitation, pollution and climate change have put great pressure on marine systems and threaten their future and the livelihoods of humans who depend on them. The concept of ecosystem-based management (EBM) for marine systems has developed over the past fifteen years in the face of ever-increasing use and degradation of marine resources (Garcia 2003).[114] The scientific community debated whether EBM is about “natural” ecosystems, or humans as an integral component of them. Although definitions vary, the overall goal is to manage human activities through collaborative stewardship to ensure the sustainability of marine ecosystems. It is a more inclusive and holistic management approach than that of single species or sectors. It strives to balance the resource requirements of local communities with protection of the marine ecosystems on which they rely. The 2003 study group on EBM science and its application to the North Pacific was established under the direction of the FIS and MEQ committees to review and assess the utility of the concept for the PICES member nations. Representatives from each country submitted a summary of their country’s approach to EBM. They found that ecosystem-based management challenges differ between China, Japan and Korea compared to Russia, Canada and the USA. Some of that difference is due to the former countries having greater coastal populations, and higher exploitation of resources, than the latter ones. Their goal for EBM was to rebuild depleted stocks and minimize detrimental run-off in coastal areas. In Russia, Canada, and the USA, in contrast, human density and development were lower, and despite fishing, energy development and transportation, the management focus was on maintaining relatively intact biological communities and habitats. The study group identified emerging scientific issues related to the implementation of ecosystem-based management, and suggested a 3-year expert group on ecosystem-based management, under the direction of the FIS and MEQ committees.[115] One of their major recommendations was that PICES needed a standardized reporting framework to describe impacts of human activity on ecosystems beyond fisheries, but which would allow each country to have different objectives for ecosystem-based management. Their report on EBM

---

[113]Study Group on North Pacific Ecosystem Status Report (SG-NPESR3; 2015–2016).

[114]The variation applied to fisheries is called ecosystem-based fisheries management (EBFM).

[115]Ecosystem-based Management Science and its Application to the North Pacific (SG-EBM; 2003–2004), parents MEQ, FIS, co-chairs Glen Jamieson (Canada), Chang-Ik Zhang (Korea).

application to the North Pacific foreshadowed the current interest in the topic (Jamieson and Zhang 2005; Paul 2004).

The subsequent working group on ecosystem-based management science was charged with describing national marine ecosystem monitoring approaches to identify information gaps and challenges to research and implementation.[116] They reviewed the quantitative ecosystem indicators suggested for fisheries management during the 2004 symposium co-sponsored by IOC, SCOR, GLOBEC, ICES and PICES on ecosystem-based management science. When they began to work through their terms of reference, however, they found that no PICES country had enough application of ecosystem-based management to be able to measure its effects. The group instead tracked progress towards developing the framework, and focused on fisheries as being the most well known application. The experience in ICES was that they had a great deal of data on indicators, but that did not mean that countries necessarily followed the advice (Perry et al. 2010; Dahl 2000). Each country had its own approach to developing such ecosystem-based management dependent on different human pressures on the marine environment. Under the first integrative science program of CCCC, the modeling task team suggested tools to understand the impact of climate variability on marine systems, while the second integrative project FUTURE is expected to explore how to construct and include socio-economic indicators.[117] The 2010 international symposium in Sendai, Japan, was a synthesis for this considerable work on ecosystem indicators.[118]

Solicited Advice: Formal Requests by Governments, and Special Projects

Fisheries and Ecosystem Responses to Recent Regime Shifts (FERRRS)

Unusually warm temperatures in the equatorial Pacific characterize the phenomenon of El Niño, which has significant impacts on weather around the world. The strong El Niño of 1997–1998, for example, produced the wettest and warmest

[116] Ecosystem-based management science and its application to the North Pacific (WG 19; 2004–2009), parents MEQ, FIS, co-chairs Glen Jamieson (Canada), Patricia Livingston (USA), Chang-Ik Zhang (Korea).

[117] WG 19 also gave advice on the structure and content of future NPESR (see next section on providing scientific advice).

[118] PICES, ICES and FAO were the primary international sponsors, along with local sponsors, of the 2010 International symposium on Climate Change Effects on Fish and Fisheries: Forecasting Impacts, Assessing Ecosystem Responses, and Evaluating Management Strategies, in Sendai, Japan.

months in over a hundred years in the US.[119] The North Pacific climate experienced a dramatic and rapid transition in its characteristics, suggesting that a regime shift had occurred. Previous regime shifts had strong impacts on plankton, fish, and ultimately the fishing industry and consumers. Highly productive stocks can lose their productivity, while formerly minor species can become dominant (Committee on the Bering Sea Ecosystem 1996). The West Coast fishing industry was concerned about the effects of a regime shift, as had occurred in 1925, 1947, and 1976, and wanted to know the implications for management of marine resources.

In 2003 the chair of PICES, Vera Alexander, received the first formal request for advice from a member government. The US government, by way of the National Marine Fisheries Service, wanted to know the implications of the 1998 regime shift for fisheries management. The unique character of solicited advice is that the requesting entity has specific questions that must all be answered to the best of its ability. The questions were, (1) has the North Pacific shifted to a different state or regime since the late 1980s, (2) what is the nature of the new state, (3) what are the ecosystem responses, (4) how long can the shift be expected to last, (5) is it possible to predict when the regime will shift back, and what indicators should be used to determine when it happens, and (6) what are the implications for the management of marine resources?

This request precipitated formation of a study group on strategic issues, with members from both the science board and governing council.[120] Its charge was to develop a draft strategic plan for PICES to codify its vision, its purpose to both understand the Pacific system and identify emerging issues, and its goal to advance scientific knowledge and capacity.[121] Providing certain kinds of advice had always been an expectation for the organization, so the strategic plan reiterated that PICES should give advice on issues such as productivity regimes. Though PICES did not have a mandate to provide formal fisheries management advice, it could provide conceptual and general guidelines that could be applied to management issues. Additionally it laid out the central themes for the organization to advance, apply, and spread scientific knowledge, in part by building partnerships. It was to help guide the selection of future activities by requiring periodic action plans from each PICES committee. They would map out what topics they wanted to address in the following few years, with an eye to how they would fit together with the topics of other committees.

In response to the US request for advice, PICES formed a multinational working group of 21 scientists on fisheries and ecosystem responses to recent

[119]USA National Oceanic and Atmospheric Administration (NOAA). 1998 was also the UN Year of the Ocean.

[120]Richard (Rich) Marasco, Director, Resource Ecology & Fisheries Management Division, Alaska Fisheries Science Center and US delegate to PICES, to Vera Alexander, chair, PICES 2 October 2003. The acceptance arrived soon after, on 27 November 2003. Study Group on PICES Strategic Issues (SG-SI; 2003–2004), parent GC, chair Vera Alexander (USA).

[121]The PICES Strategic Plan (2003). http://pices.int/about/PICES_strategy.pdf.

regime shifts.[122] The group held two workshops to organize and decide how to proceed. The first order of business was to determine whether a regime shift had happened, characterize the new state, and detail the ecosystem responses. The group compiled, reviewed and synthesized information on ocean conditions and ecosystems for five regions of the North Pacific, and concluded that a regime shift had happened. The second workshop reviewed material developed by individual scientists and discussed what indicators best determined when a shift happened. More problematic was answering when the system might return to its previous state, or whether it would instead enter into some new state. Other unknowns were how long the shift might last. Such a workshop was one avenue to produce an international consensus on broad- scale phenomena critical to resource management. In the long term, it would be helpful to figure out whether it was possible to predict when another shift would happen, and thus anticipate the impact on the fishing industry of a potential climate-ocean regime shift.[123] They answered all six questions asked by the US government, and the report was presented in 2005. In addition, they published a brochure for a broader audience that gave concise recommendations for future fisheries management (King 2005).

They found that southern regional ecosystems showed a greater response to the 1998 regime shift than northern ones. In the eastern North Pacific, surface waters continued to warm at their northern bounds despite being cooler in the southern regions. So for instance, the Bering Sea and Aleutian Islands had no apparent regional response, but the temperature of their surface waters increased while their sea ice declined. The pattern of responses was opposite to the eastern North Pacific, with more sea ice in the Sea of Okhotsk, while southern surface waters continued to warm. The winds along the coasts also caused significant differences in water circulation patterns. They also looked at productivity of plankton, invertebrates, and fish to characterize patterns, and found they differed across regions, with the central north Pacific showing decreased productivity, while the California Current showed increased productivity. They could not answer how long the regime shift would last, because that required understanding the underlying mechanisms for regime shifts, a field that is only now being developed. One confounding factor they faced was that another El Niño event in 2002 complicated describing the 1998 regime shift. A particularly interesting observation was that the request for advice included a question of when the regime might "shift back," implying a two-state world. Instead, the report pointed out that regime shifts could also produce novel states. All of their conclusions were based on climate and ocean indices of the sort fostered by long-term monitoring networks that are critical in measuring changes in climate and ocean conditions. Satellite remote sensing promised newer indices that might someday be able to show fish productivity more directly.

[122] Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts (SG-FERRRS 2003–2004), chair Jackie King (Canada).

[123] The National Marine Fisheries Service is part of NOAA.

Their overall recommendations included the utility of the regime concept for marine ecosystems and resource management. Studies of historical data suggested that regime shifts are recurring in marine ecosystems, so understanding future conditions needed a comprehensive program to monitor changes in climate, ocean systems and their ecosystems. Sets of climate indices could help monitor ecosystems and link them to the variability of the climate system. The fishing industry could benefit if fishery managers used integrated stock assessments and decision rules that took into account different scenarios under climate change. They could then adopt management schemes best suited for the most vulnerable fisheries.

The Cohen Commission on Fraser River Salmon (2009)

In 2010, PICES received its second formal request for scientific advice, this time from the Government of Canada. In 2009, the Government of Canada began a judicial inquiry into the causes of a dramatic decline of sockeye salmon in the Fraser River in British Columbia that led to the closure of the sockeye salmon fishery (McKinnell et al. 2012). Skip McKinnell, at the time the PICES Deputy Executive Secretary, made a presentation in Vancouver, Canada, on the status of sockeye salmon on the high seas, and suggested PICES could provide its expertise to the commission. A fundamental precept of PICES is that fisheries and oceanography work together to build a comprehensive picture of complex marine ecosystems, and PICES had just completed work on the second ecosystem status report (NPESR), in which the NPAFC had led the Pacific salmon sections of the oceanic and synthesis chapters. In spring of 2010, the commission invited PICES to participate in the inquiry as a source of comprehensive, independent research expertise in the region (McKinnell et al. 2012). Two key questions were whether the 2009 decline in Fraser River sockeye salmon could be explained by the conditions the fish experienced in the marine environment, and whether declines in marine productivity or changes in Fraser River sockeye distribution were associated with the 15-year gradual decline in Fraser River sockeye productivity.

The commission proceedings were widely followed in the Canadian press, and stirred strong emotions over the fate of the iconic fish. Justice Bruce Cohen was assigned Commissioner of the inquiry, and thus the inquiry took the working name of the "Cohen Commission." Over three years the federal inquiry gathered testimony from scores of witnesses and collected a record number of documents. Many experts who testified came from the Department of Fisheries and Oceans Canada, and among those were over a dozen scientists and science managers active within PICES. The report team had only two months to analyze and assemble a thorough assessment of the marine component of the life history of Fraser River sockeye salmon. One of the big challenges was making sense of seemingly conflicting observations of other sockeye salmon returns that were higher than expected.

One of the Cohen Commission's questions was whether the collapse of the salmon run in 2009 could be explained by the conditions that they had experienced in the marine phase of their life history. The PICES report team made the compelling argument that it was anomalous high surface temperatures, extreme salinity and wind anomalies in Queen Charlotte Strait/Sound in 2007 that led to extreme mortality of the Fraser River juvenile salmon so that they did not produce a fishery in 2009 when they reentered freshwater. The PICES advisory panel on **S**tatus, **O**utlooks, **F**orecasts and **E**ngagement (SOFE) reviewed the report, and it became Technical Report No. 4 of the Cohen Commission. In 2012, the Cohen Commission published its final report, *The Uncertain Future of the Fraser River Sockeye*, with one conclusion being that climate change is one of the most significant stressors for the fish.

An ironic coda to the Commission was that 2010 produced a bonanza return to the Fraser River, allaying some peoples' concerns over the ultimate fate of the salmon runs. The inquiry had considered the impact of aquaculture, predators, diseases, and environmental changes along the Fraser River through to the ocean. It underscored the complexity and uncertainty of their ecosystem and their ties to human wellbeing. Interesting issues of interagency cooperation and responsibility were aired over the role of environmental contaminants and other conditions that may have also decreased the ability of sockeye salmon to reach their spawning grounds or the ocean. A large policy issue was how, or whether it was possible to work towards a balance of economic pressures and sustainable ecosystems. The Commission examined the Fraser River populations within the framework of the existing Canadian "Wild Salmon Policy" that governs conservation of wild salmon and their habitats.

Country Requests for Special Projects

Projects Supported by the Ministry of Agriculture, Forestry and Fisheries, Japan

In 2007, the Government of Japan requested PICES undertake a 5-year project entitled "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*", to be funded by the **M**inistry of **A**griculture, **F**orestry and **F**isheries (MAFF). The goal of the project, with two distinct components—one on **n**on-**i**ndigenous **s**pecies (NIS), and the second on harmful algal blooms (HABs), was to enhance seafood security in developing Pacific Rim countries. The science board and the governing council accepted the proposal, and directed the project to two PICES expert groups under the Marine Environmental Quality Committee (MEQ), working group on Non-indigenous Aquatic Species (WG 21) and Section on Ecology of Harmful Algal Blooms in the North Pacific (HAB-S), with each group overseeing a specific component.

Two initiatives were carried out under the NIS component. The database initiative, led by Henry Lee II (USA), focused on the development of a database and an atlas of marine/estuarine species to be used to capture information on non-native species and allow sharing of this information among PICES member countries, and more broadly with any community studying non-indigenous species. The taxonomy initiative, led by Tom Therriault (Canada), used a series of **r**apid **a**ssessment **s**urveys (RAS) to develop and disseminate techniques for the quick detection and identification of non-indigenous species currently in an area.

NIS, being established in new locations outside their native range, can have a disastrous impact on ecosystem structure and function that can ultimately threaten productivity and seafood security. Prevention is the first line of defense against NIS, and knowledge about the distribution of potential NIS, dispersal vectors, and their ecological characteristics, allows characterization of their invasion risk. With this information in hand, managers can determine the likely extent and type of risk associated with a new invader, and the best course of action for mitigating the impacts on local species. The atlas and database are a valuable resource for agencies and scientists who must manage and research non-indigenous species in the North Pacific.

Given the continued exchange of species globally by various vectors, it is important to establish collaborations among taxonomists and invasion biologists on both sides of the Pacific Ocean, in order to truly understand species distribution patterns, and hence invasion patterns. To foster these collaborations a series of four PICES RASs were conducted with the help of local hosts in Dalian, China (2008), Jeju, Korea (2009), Newport, USA (2010) and Vladivostok, Russia (2011).

Building capacity, especially in developing countries, is critical to better understand invasion dynamics and maintain safe and productive marine ecosystems. Three demonstration workshops on “Rapid Assessment Survey Methodologies for NIS” were hosted in Awaji Island, Japan (2010), Phuket, Thailand (2011) and Nagasaki, Japan (2012) to increase awareness about marine and estuarine NIS, and to provide “hands-on” experience for participants from PICES member countries and developing countries. Over 50 participants from China, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Thailand, and Vietnam have received training. The 2011 workshop was organized jointly with WESTPAC, and the 2012 workshop was co-sponsored by WESTPAC and NOWPAP. Increased collaboration on NIS, especially taxonomic exchanges between PICES member countries and with the international organizations NOWPAP and WESTPAC, is a long-lasting benefit from this project.

Increased harmful algal bloom (HAB) events are causing damage to fisheries and ecosystems around the Pacific Rim. This is a particularly serious problem for developing countries where fisheries and marine tourism are a significant part of their national economies. The main objective of the HAB component of the project, led by Vera Trainer (USA), was to build the capacity of scientists working on the prevention of impacts of harmful aquatic organisms on fisheries and ecosystems, by holding country-specific training courses most needed to ensure seafood safety in the Pacific Rim developing countries outside the PICES region. The Philippines, Guatemala, and Indonesia were selected for training activity. The selection was based on the nature and magnitude of the HAB problem, the need for training, and the likelihood of program sustainability. The first PICES training course was taught in 2009, in Manila, Philippines, followed by courses in Guatemala City and San Jose in Guatemala in 2010, and Jakarta, Indonesia in 2012. A "community research partnership" approach was used in all three countries to ensure sustainable success in monitoring seafood safety for the domestic and export markets.

In 2012, the Government of Japan, satisfied with the outcomes from the project on "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*," requested PICES to undertake another 5-year project (2012–2017), also to be funded through MAFF. The goal of this project on "**Mar**ine ecosystem health and human **we**ll-**b**eing" (MarWeB), was to identify the relationships between sustainable human communities and productive marine ecosystems in the North Pacific, using the concept of fishery **s**ocial-**e**cological **s**ystems (SES). This concept, known in Japan as the "Sato-umi" fisheries management system, recognizes that global changes are affecting both climate and human social and economic conditions. The project was expected to explore how marine ecosystems support human well-being as well as how human communities support sustainable and productive marine ecosystems. It was also intended to foster partnerships with developing Pacific Rim countries.

The science board and the governing council accepted the proposal in recognition that the proposed project is linked to one of goals for the PICES integrative scientific program, FUTURE, "to assess how human activities affect and are affected by coastal ecosystems." This time, the project science team, co-chaired by Mitsutaku Makino (Japan) and Ian Perry (Canada), drew upon several PICES expert groups, including the sections on human dimensions; climate change effects on marine ecosystems; ecology of harmful algal blooms in the North Pacific; and the working group on development of ecosystem indicators to characterize ecosystem responses to multiple stressors.[124]

The project has been using a case studies approach to explore the application and benefits of the SES concept to nations in the North Pacific basin to build the capacity of communities through field experiments and capacity building workshops for ecosystem approaches to marine management. The two case studies are integrated multi-trophic aquaculture for shrimp in Indonesia, and oyster aquaculture in Guatemala.

[124]Sections on (1) Human Dimensions of Marine Systems (S-HD), co-chairs Keith Criddle (USA), Mitsutaku Makino (Japan). (2) Climate Change Effects on Marine Ecosystems (S-CCME), co-chairs Anne Hollowed (USA), Shin-ichi Ito (Japan), Brian R. MacKenzie (ICES), John Pinnegar (ICES). (3) Ecology of Harmful Algal Blooms (S-HAB), co-chairs Douding Lu, Vera Trainer (USA); past co-chairs Shigeru Itakura (Japan), Hak-Gyoon Kim (Korea). Working group on Development of Ecosystem Indicators to Characterize Ecosystem Responders to Multiple Stressors (WG 28; 2010–2013), co-chairs Ian Perry (Canada), Motomitsu Takahashi (Japan).

Project Supported by the Ministry of Environment, Japan

The catastrophic Great East Japan Earthquake of 2011 produced a tsunami that led to a large loss of life, and environmental and fishing industry damage. Although most debris sank along the coastline, it is estimated about one and a half million tons was carried into the Pacific, including collapsed houses, driftwood, fishing vessels and cargo containers.[125] Some of that was swept up by winds and currents that move eastward across the Pacific, and floating pieces have been making landfall along the western coast of North America as well as the Hawaiian Islands since the winter of 2011–2012. This scattered "acute" debris mixed with a considerable amount of chronic marine debris, and little is known about what impact that debris might have on North American ecosystems.

In 2014, the Government of Japan, through the **M**inistry **o**f the **E**nvironment (MoE) of Japan, requested PICES' help in evaluating the impact of tons of tsunami debris swept into the Pacific Ocean, and proposed to fund a three-year project with a goal to assess and forecast the effects of debris generated by the tsunami, especially those related to non-indigenous species (NIS) on ecosystem structure and function, the coastlines and communities of the west coast of North America and Hawaii, and to suggest research and management actions to mitigate any impacts.

PICES was well positioned to respond to the request because of its aggregate expertise, and the science board and the governing council accepted the charge and formed a project science team, comprised of researchers from the three countries most directly affected by the tsunami debris; Canada, Japan, and the USA, and co-chaired by Tom Therriault (Canada), Hideaki Maki (Japan), and Nancy Wallace (USA) to implement the project. The ADRIFT (**A**ssessing the **D**ebris-**R**elated **I**mpact of **T**sunami) project is focused on three main areas of research; modeling movement of **J**apanese **T**sunami **M**arine **D**ebris (JTMD) to forecast the amount, pathways and timelines of its arrival on the west coast of North America and in Hawaii; surveying and monitoring JTMD landfall and accumulation, and assessing risk and potential impacts from JMTD-associated invasive species to coastal ecosystems in North America and Hawaii.

To be able to assess the risk to coastal ecosystems posed by species arriving on JTMD, one must first understand the trans-Pacific transport of different debris types, because the conditions encountered during transport can influence biological processes, such as survival, recruitment, and settlement, as well as species diversity. The modeling team has been using a suite of numerical models to simulate movement of marine debris arising from the Great Tsunami of 2011. These models have been refined and calibrated based on the best available observational reports in order to forecast distributions and timelines of JTMD arrival on the Pacific coast of North America and in Hawaii. The optimized models successfully reproduce the main peaks of JTMD arrivals in 2012–2015, and predict that much of the remaining

---

[125] Ministry of the Environment, Japan. March 2014. A report on forecasts of tsunami driftage location. 7 pp. (http://www.kantei.go.jp/jp/singi/kaiyou/hyouryuu/qanda_eng/gaiyou.pdf).

floating debris is entrained in the Pacific gyre and may continue to arrive in the future. The results also illustrate how different types of JTMD are transported—light-weight or floating debris like polystyrene were transported rapidly and were generally removed from the ocean within a few years of the tsunami, while heavier-weight, submerged or sunken debris such as fishing vessels, may remain in the ocean for a very long time. The latter have the potential to become entrained in the Pacific gyre "garbage patch".

These models are also being used to estimate JTMD trajectories of individual items and characterize the environmental parameters like temperature, salinity, productivity, encountered during their movement from Japan to North America and Hawaiian ecosystems. The output from the models will inform risk assessments of JTMD as vectors for invasive species, through relative estimates of landings, by debris type, and for each of the receiving eco-regions for which the risk assessment is being conducted. Collaboration between the NIS and modeling researchers is essential to better understand how conditions experienced during transit relate to invasion risk.

The surveillance and monitoring team identified and characterized tsunami debris landings. Aerial surveys of more remote areas in British Columbia and in Hawaii were carried out to provide critical information on debris accumulation, help validate modeling results, and inform the vector risk assessment. Novel approaches to image analyses enable description and quantification of JTMD on beaches. In addition, a pilot webcam system was placed at a site in Oregon to track debris landings and removals to better understand temporal dynamics of debris on beaches. These surveillance and monitoring techniques and findings have applications beyond the project (Murray et al. 2015).[126]

The invasive species team also conducted field surveys to detect established populations of JTMD species in North America and Hawaii. About 500 debris items were sampled, from which more than 350 living Japanese biofouling species (invertebrates, algae and fish) were identified using both traditional taxonomy and genetic methods. A large number of these species are not yet present on North American and Hawaiian coastlines, highlighting the need to continue research on the incoming debris items and their potential as vectors for invasion.

Risk assessments can inform policy and management decisions about NIS. The risk assessment team is using the results of the modeling, monitoring and biodiversity research. Through a series of workshops, they have developed a framework for a tsunami debris vector risk assessment that allows comparison of tsunami debris as a vector for NIS against other well-known vectors, such as ballast water and hull fouling. As most managers are concerned about potential impacts of specific NIS, screening-level risk assessments will be conducted using a database of life history traits, characteristics and invasion histories for all species associated

[126]Alex Bychkov is currently PICES Special Projects Coordinator, and the projects on marine debris and human well-being are one of his primary responsibilities. He was PICES deputy executive secretary (1996–1999), and executive secretary (1999–2014).

with tsunami debris. The group plans to produce a watch list and field identification guide for higher risk NIS for each eco-region in North America and Hawaii to inform monitoring, management, and policy development.

The project's results will be shared with the scientific community at a special topic session at the 2016 PICES Annual Meeting in San Diego, USA, and its results will be published in peer-reviewed journals. The project results also will be presented to the people of Canada, Japan, and the USA at public events.

The Many Roles of PICES Publications

Publications are critical to communicating both within and outside the organization. Scientists earn their reputations in part by the quality and frequency of their publications, so it is to everyone's benefit that manuscripts from workshops or sessions are published as quickly as possible. It is also advantageous for all scientists to publish their work in as high impact a journal as possible. The PICES secretariat and fellow reviewers offer editorial assistance in preparing manuscripts, and over the years, early career scientists have come with greater ease of operating in English. The founding decision to use English can sometimes shape the dynamics of interactions on joint manuscripts. Leading journals demand smooth language along with high quality science, so PICES created a manual of style to help everyone work within those standards. Experienced editors help manuscripts by being attuned to any language issues, so that reviewers can focus on the science, and the best reviewers have broad experience. In the early years of PICES, for example, the editors sent an internationally coauthored manuscript to two reviewers, one experienced in collaborating across languages, and one who was not. At first the latter reviewer rejected the paper due to its quirks of language. The second, more experienced reviewer, merely smoothed word usage without changing its science, and the manuscript was accepted. Of course, being a native English speaker is no guarantee of succinct, powerful writing.

The very first PICES publication was its newsletter, *PICES Press*, to announce working groups, any breaking news, contact information and schedules for meetings and research cruises. Though it began as a newsletter, it quickly grew into a substantial outlet online to keep the community updated on progress on projects, new research developments, notices of upcoming events, and listings of new publications. It became a de facto institutional memory, and early on gave recognition to and introduced authors to their audience with pictures and short biographical sketches. The biannual *PICES Press* highlights current research and associated activities of PICES, and provides timely updates on the state of the ocean and climate for the Bering Sea and the Eastern and Western Pacific. The newsletter was not set up to keep track of the many good ideas aired at the discussion phase of scientific meetings, however. In ICES, with a more rigid structure, the rapporteur detailed the purpose of scientific sessions, provided brief summaries of the papers, and critically, prepared a summary of the discussions on research gaps, recommendations for future sessions, groups, or work and any recommendations for further actions.

The *PICES Annual Report* summarizes the activities of PICES committees and expert groups and includes decisions by the science board and governing council since the previous annual meeting. After 2001, PICES included the discussions following meeting sessions in annual reports to help track scientific advice and advances that came from the meetings, beyond those compiled later into *PICES Scientific Reports* or other publications.[127] Recorded recommendations can be relayed more reliably to the parent sponsor committee of the session, and impact the next year's plans.

The *PICES Scientific Report* series publishes the various outputs from expert groups, workshops, programs, and data reports, to make the material more accessible. It is considered "grey literature" given the submissions undergo varying levels of editorial review, so is not recognized as a peer-reviewed journal in the broader literature. The authors are given time and editorial help from the secretariat to revise their work in light of discussions they receive in the workshops. The topics are meant to be of broad interest and reasonable quality, whether of manuscripts, data, or inventories. For instance, the science plan for the PICES-GLOBEC program was published in the series, and some of the brief reports first published in *Scientific Report* 10 were subsequently expanded and published in primary journals. The observation that the three most cited reports were all on the Okhotsk Sea, may suggest a unique role of PICES in covering a geographic area rarely covered by the English language scientific literature.[128]

For peer-reviewed scientific papers, PICES discussed whether to produce its own journal or rely on existing publications.[129] It is difficult and expensive to launch a new journal in a crowded field of existing journals. It can be cost-effective to publish in well-established outlets that have more resources and a ready audience. For external journals, the secretariat assessed the journal's speed of publication, its impact factor, and its audience, as well as production cost. Before 1999, authors submitted their papers individually to peer-reviewed journals because there were no coordinated special issues in peer-reviewed journals. Everyone wanted to produce issues of consistent quality, that were timely, were well publicized, and accessible to all researchers. As PICES scientists produced more collections of papers organized around themes, the secretariat coordinated submission of special issues in established journals, with good readership and high impact.

Because expert groups have produced on a breadth of issues over time, it made sense to submit collections of papers to an appropriate specialized journal.

---

[127] *PICES Annual Report* (2002). SB Endnote 3 Review of procedures to enhance documentation of PICES scientific sessions.

[128] *PICES Annual Report* (2007), Publication program review, Brian Voss and Janet Webster, pp. 269–296.

[129] *PICES Annual Report* (2001) mentioned that the publication committee had not conducted any business for the preceding two years, so the science board recommended disbanding it.

For instance, a collection of papers on invasive species might happen only once a decade, so submitting them to a specialized journal made more sense than to start one's own journal. Thus, marine environmental quality work goes to journals such as the *Archives of Environmental Contamination and Toxicology*, and work on carbon fluxes goes to *Deep Sea Research II*, a journal whose format is for special issues, and which does not charge extra for them.[130] The journal *Fisheries Oceanography*, though it is well regarded and a good outlet, has prohibitively high page charges for special issues, unfortunately. Many PICES scientific papers have appeared in *ICES Journal of Marine Science*, as well as *Progress in Oceanography*, which covers the entire spectrum of disciplines within oceanography, and publishes collections of papers and conference proceedings as well as longer, more comprehensive papers and historical analyses of long-term datasets (see Fig. 2.3). Although the special issue approach is good for readers to gain a broad appreciation of a topic, it can be more difficult for authors, because it requires that they accept an aggregate group responsibility to produce the issue. Scientists who work quickly may feel slowed down by the requirement that all papers must be accepted before the special issue can come out. Speedy scientists take the risk of a lagged publication, which is not good for any author. On the other hand, the slower authors can feel peer-pressure to keep up with their colleagues, and may receive help to ensure timely submissions.

After about a decade of operation, a 2003 external review of the PICES publication program counted 65 publications (14 peer-reviewed) in six different publication series over the 12-year history of PICES, a solid accomplishment, especially given such a small secretariat staff.[131] Symposia or topic sessions that are particularly robust and of wide interest are published in special issues of peer-reviewed, primary scientific journals such as *ICES Journal of Marine Science; Progress in Oceanography; Marine Ecology Progress Series; Aquaculture Economics & Management; Fisheries Research; Deep-Sea Research; Continental Shelf Research; Journal of Oceanography; Journal of Marine Systems; Journal of Northwest Atlantic Fishery Science; Ecological Modelling; Marine Environmental Research;* and the *Canadian Journal of Fisheries and Aquatic Sciences*. A 2007 external review of publications found that the special issues were being read and cited by researchers. One important issue for the organization was increasing the visibility of its institutional brand through its publications. Journals have different approaches to branding. *Progress in Oceanography* always allowed the PICES logo to share its cover, while in the early years, special issues in ICES journals only showed the ICES logo. That practice changed by 2010, when the ICES and PICES logos shared the cover of special issues of *ICES Journal of Marine Science* arising from joint symposia (Hammer et al. 2010).

[130] *Deep Sea Research II* is for special issues, while *Deep Sea Research 1* accepts individual papers.

[131] *PICES Press* 12 (2004). The review team was W.L. Hobart, NOAA NMFS Scientific Publications Program and G.J. Duker, Publications Program, NOAA NMFS Alaska Fisheries Science Center.

The International Association of Aquatic and Marine Science Libraries and Information Centers was requested to review the PICES publications program in light of escalating costs and emerging options for digital communications. The second external review of publications in 2007 found that citation patterns and website use both showed that all types of PICES publications were adding to scientific dialogue. One challenge was that the special issues in well-regarded journals were more accessible to researchers in Canada and the US than in other PICES countries. Researchers had good accessibility to other in-house publications through the revamped website. Searchable PDF formats and an open access digital repository improved access even further. Probably the greatest issue was that the organization had no capacity to expand its publications unless it added more editorial assistance.[132]

More recently, the organization has produced brochures for a general audience, including science managers and social scientists, on such topics as fisheries under climate change, and the economic impacts of harmful algal blooms. From time to time, PICES has also supported book-length publications such as on the Bering Sea, a historical atlas of the North Pacific, or ecosystem-based fisheries management (Loughlin 1999; Hayes 2001; Kruse et al. 2012). PICES also has a *Special Publication* series as a critical outlet for products meant for general or targeted audiences. These include the North Pacific Ecosystem Status Report (NPESR) synthesis series (2004, 2010), the collaboration with CoML on the North Pacific, and the guide to best practices for ocean CO_2 measurements to encourage standardized methods among countries (Dickson et al. 2007). In 2007, PICES introduced an electronic *Technical Report* series meant for "living documents" which require frequent updates, like the metadata federation of the PICES countries.

References

Ausubel, J.H., D.T. Crist, and P.E. Waggoner, eds. 2010. *First Census of Marine Life 2010: Highlights of a decade of discovery. Census of Marine Life International Secretariat.*

Committee on the Bering Sea Ecosystem. 1996. *The Bering Sea ecosystem*, edited by Polar Research Board. Washington, D.C.: National Academy Press. doi:10.17226/5039

Dahl, A.L. 2000. Using indicators to measure sustainability: Recent methodological and conceptual developments. *Marine Freshwater Research* 51: 427–433.

Dickson, A.G., C.L. Sabine, and J.R. Christian, eds. 2007. Guide to best practices for ocean CO_2 measurements. *PICES Special Publication* 3, 191 pp.

Drinkwater, K.F., H. Loeng, B.A. Megrey, N. Bailey, and R.M. Cook. 2005. Introduction. *ICES Journal of Marine Science* 62(7): 1203–1204.

Garcia, S.M. 2003. The ecosystem approach to fisheries: issues, terminology, principles, institutional foundations, implementation and outlook. *FAO Technical Paper* 443.

[132] *PICES Annual Report* (2007). Review of PICES publication program by Brian Voss, NOAA Libraries, Seattle, WA, and Janet Webster, Oregon State University Libraries, Newport, OR.

Hammer, C., O.S. Kjesbu, G.H. Kruse, and P.A. Shelton. 2010. Rebuilding depleted fish stocks: Biology, ecology, social science, and management strategies. *ICES Journal of Marine Science* 67(9): 1825–1829. doi:10.1093/icesjms/fsq039.

Harris, R. 1997. *Global ocean ecosystem dynamics (GLOBEC) science plan*. Sweden: Stockholm.

Hayes, D. 2001. *Historical atlas of the North Pacific Ocean: Maps of discovery and scientific exploration, 1500–2000*. Seattle: Sasquatch Books.

Hollowed, A., M. Barange, S. Ito, S. Kim, H. Loeng, and M. Peck. 2011. Climate change effects on fish and fisheries: Forecasting impacts, assessing ecosystem responses, and evaluating management strategies. *ICES Journal of Marine Science* 68(6): 983–1373.

Holmes, O.W. 1872. *The poet at the breakfast-table*. Boston: James R. Osgood and Company.

IOC-WMO-UNEP-ICSU-FAO Living Marine Resources Panel of the Global Ocean Observing System (GOOS). 1999. Intergovernmental Oceanographic Commission Reports of Meeting of Experts and Equivalent Bodies. Third Session, Talcahuano, Chile. *GOOS Report 83.*

Jamieson, G.S., and C.I. Zhang. eds. 2005. *Report of the study group on ecosystem-based management science and its application to the North Pacific*. *PICES Scientific Report* 29, 77 pp.

Kaiser, David. 2005. *Drawing theories apart: The dispersion of Feynman diagrams in postwar physics*. Chicago: The University of Chicago Press.

King, J.R. ed. 2005. Report of the study group on the fisheries and ecosystem responses to recent regime shifts. *PICES Scientific Report* 28, 162 pp.

Kruse, G.H., H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, P.A. Livingston, D. Woodby, and C.I. Zhang, eds. 2012. *Global progress in ecosystem-based fisheries management.* University of Alaska Fairbanks: Alaska Sea Grant.

Levy, M.A., P.M. Haas and R.O. Keohane. 1992. Institutions for the Earth—Promoting International Environmental Protection. *Environment* 34(4): 12–36.

Loughlin, T.R. 1999. *Dynamics of the Bering Sea: A summary of physical, chemical, and biological characteristics, and a synopsis of research on the Bering Sea*. University of Alaska Fairbanks: Alaska Sea Grant.

McKinnell, S.M., and M.J. Dagg, eds. 2010. Marine ecosystems of the North Pacific, 2003–2008. *PICES Special Publication* 4.

McKinnell, S.M., R.D. Brodeur, K. Hanawa, A.B. Hollowed, J.J. Polovina, and C-I. Zhang. 2001. *An introduction to the Beyond El Niño conference: climate variability and marine ecosystem impacts from the tropics to the Arctic*. *Progress in Oceanography* 49(1): 1–6.

McKinnell, S.M., E. Curchitser, C. Groot, M. Kaeriyama, and K.W. Myers. 2012. PICES advisory report on the decline of Fraser River sockeye salmon *Oncorhynchus nerka* (Steller, 1743) in relation to marine ecology. *PICES Scientific Report* 41, 149 pp.

Murray, Cathryn Clarke, Alexander Bychkov, Thomas Therriault, Hideaki Maki, and Nancy Wallace. 2015. The impact of Japanese tsunami debris on North America. *PICES Press* 23(1): 28–30.

Northwest Fisheries Science Center. 2015. Ecosystem indicator ‘stop-light charts’. https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/g-forecast.cfm%20-%20TableSF-02.

Paul, L. 2004. The 2003 Pew Oceans Commission Report: Law, policy, and governance. *Natural Resources & Environment* 19(1): 10–16.

Perry, R.I., and S.M. McKinnell, eds. 2004. Marine ecosystems of the North Pacific. *PICES Special Publication 1.*

Perry, R.I., and S.M. McKinnell, eds. 2005. *CoML report: Marine life in the North Pacific: The known, unknown, and unknowable*. *PICES Special Publication 2*.

Perry, R.I., P. Livingston, and E.A. Fulton. 2010. Ecosystem indicators. In *Report of Working Group 19 on Ecosystem-based Management Science and its Application to the North Pacific*. *PICES Scientific Report* 37: 83–89.

Suzuki, T., M. Ishii, M. Aoyama, J.R. Christian, K. Enyo, T. Kawano, R.M. Key, N. Kosugi, A. Kozyr, L.A. Miller, A. Murata, T. Nakano, T. Ono, T. Saino, K. Sasaki, D. Sasano, Y. Takatani, M. Wakita, and C. Sabine. 2013. PACIFICA data synthesis project. ORNL/CDIAC-159, NDP-092, edited by Oak Ridge National Laboratory Carbon Dioxide Information Analysis Center.

UNEP. 2006. Marine and coastal ecosystems and human wellbeing: A synthesis report based on the findings of the Millennium Ecosystem Assessment. UNEP.

Vermeulen, N. 2013. From Darwin to the Census of Marine Life: Marine biology as big science. *PLoS ONE* 8(1): e54284. doi:10.1371/journal.pone.0054284.

http://www.springer.com/978-3-319-41434-8

Fostering Internationalism through Marine Science
The Journey with PICES
Tjossem, S.
2017, XXV, 160 p. 3 illus., 2 illus. in color., Hardcover
ISBN: 978-3-319-41434-8