Summary of Scientific Sessions and Workshops at PICES-2020

Science Board Symposium (S1)
How does 30 years of research on changing North Pacific ecosystems inform the UN Decade of Ocean Science for Sustainable Development Goals (SDGs)?

Convenors: *Vera L. Trainer (SB), Akash Sastri (BIO), Xianshi Jin (FIS), Mitsutaku Makino (HD), Guangshui Na (MEQ), Sung Yong Kim (MONITOR), Emanuele Di Lorenzo (POC), Jeanette C. Gann (TCODE), Steven Bograd (FUTURE), Sukyung Kang (FUTURE), Igor Shevchenko (Russia)*

Invited Speakers:
Steven Bograd (NOAA, NMFS, SWFSC, USA)
Pengbin Wang (Second Institute of Oceanography, MNR, China)

Background

For 29 years, PICES has conducted investigations of North Pacific ecosystems. There has been a significant focus on multidecadal ecological processes and a more recent emphasis on the impacts of changes in the ocean on the human societies that rely on the North Pacific. The FUTURE Science Plan has identified several important science questions about the status and future of North Pacific marine ecosystems. As a result, PICES scientists are well-positioned to contribute to the United Nations Decade of Ocean Science for Sustainable Development. It is now urgent for PICES scientists to identify the most important science questions which must be answered to achieve the objectives of the Sustainable Development Goals and to suggest effective ways to answer these questions, mobilizing the coordination within PICES and collaborations with other partners.

Summary of presentations

Dr. Steven Bograd gave the talk "PICES Engagement with the UN Decade of Ocean Science for Sustainable Development (UNDOS)", an international program that will begin in 2021. The overarching PICES Scientific Program, FUTURE, would like to lead the way in UNDOS activities. FUTURE is moving into a new phase where a greater emphasis will be placed on a unique course to bridge the natural and social sciences. This Social-Environmental-Ecological-Systems (SEES) approach will specifically address climate change impacts in the North Pacific. A publication (Bograd *et al*. 2019) gave several examples of integrated science implementing the SEES approach, for example, the study of jellyfish blooms in the western Pacific. The new phase of FUTURE will also be transdisciplinary and solution oriented, will engage with UNDOS and feature enhanced communication and early career ocean professional (ECOP) development. The UNDOS objectives focus on a strategic movement from the ocean we have to the ocean we want. This transformative science will feature multiple stakeholders, be solution focused, and integrative while including indigenous knowledge, less developed as well as developed country partnerships, and will promote diversity and inclusion. There are several unique aspects of the North Pacific that make it a perfect candidate for UNDOS involvement, including increasing demands on seafood, a rapidly growing economy, a changing ecosystem and climate change. Drs. Fangli Qiao and Erin Satterthwaite are members of the UNDOS executive planning group.

Ideas for PICES involvement in UNDOS will be developed and advanced by a new Study Group on UNDOS, co-chaired by Steven Bograd (USA) and Sanae Chiba (Japan). One idea is to build upon the knowledge gained from Working Groups 36 (*Common Ecosystem Reference Points across PICES Member Countries*), 40 (*Climate and Ecosystem Predictability*), and 41 (*Marine Ecosystem* Services) to propose a new WG on climate extremes. This will further develop the SEES approach and potentially bring in ECOP as fellows to coordinate and synthesize the collaboration among physical, biological and social scientists.

Dr. Pengbin Wang gave the presentation, "The contributions of Early Career Ocean Professionals to PICES within the context of the UN Decade of Ocean Science for Sustainable Development (2021–2030)". He described how climate change is a huge challenge to scientists, especially topics such as coral bleaching, marine pollution, marine debris and harmful algal blooms. Many expert groups within PICES have dealt with these issues. We need a different way of thinking to solve these issues, including ECOP as formal members of the PICES infrastructure. These ECOP are self-identified and are completing or have recently completed their professional training relevant to ocean knowledge. They represent a diverse range of sectors and are distinct from youth (school-age children to undergraduates). PICES should include ECOP for a variety of reasons, including: 1) Continuing the legacy of PICES, 2) Equipping a new generation of ocean leaders with skills, 3) Retaining institutional knowledge, 4) Gaining new perspectives, and 5) Creating a focal point of UNDOS activities within PICES by working with ECOP.

During the ECOP virtual workshop (W9) hosted by PICES, the initial 3 organizers were expanded to a total of 8 leaders. Many countries were represented from a wide range of expertise with many professional interests. Currently, 83% are not part of an ECOP network. There is great enthusiasm for the ECOP community to become more involved in PICES science. A proposal for a Study Group on ECOP has been submitted for consideration to Science Board at PICES-2020.

Dr. Stephanie Taylor gave a presentation titled, "The International Year of the Salmon Pan Pacific High Seas Expedition 2021: A collaborative international approach to understanding how a rapidly changing ocean affects Pacific salmon". The idea for this expedition was initially proposed by Dr. Richard Beamish. Recent years have been the worst on record for some North American populations of salmon, and there has been recent variability in the Northern Hemisphere ocean basins. The survey objective is to demonstrate how extreme conditions impact salmon populations. Two past winter surveys in the eastern Pacific, in 2019 and 2020, served as proof of concept. These earlier surveys showed that sockeye salmon are found in cooler waters with higher euphausiid concentrations, while chum and coho salmon were more abundant in warmer waters where higher pteropod concentrations were found. The next International Year of the Salmon surveys, originally scheduled for 2021, are postponed until 2022. This Pan Pacific winter survey will involve 4 ships and have 9 science themes. Emerging technologies will be tested, including environmental DNA (eDNA), genomic assessment and autonomous samplers. The project outcomes will include interdisciplinary collaboration, open data, fisheries management and enforcement, implementation of new technologies and methods. Another focus will be on training early career scientists and outreach and education with comprehensive communication plan, including live-streaming from sea, and journalists on ships. The International Year of the Salmon project sees strong possibilities for collaboration with FUTURE Phase III, the SEES approach, and UNDOS.

Dr. Misty Peacock, Salish Sea Research Center Director, gave the presentation "Collaborative Research with Indigenous partners: Meeting them on their waters". She stated that UN Decade for Sustainable Development Goals are consistent with diversity and inclusion, international engagement, policy and management, diverse forms of knowledge, outreach and communication. When partnering with tribal partners, dedicated time is needed in order to effectively communicate, listen, respect and understand. This will build trust and lead to

both giving and gaining knowledge. The ethical framework for indigenous partnership remembers that all indigenous partners are sovereign entities. Community engagement is key and helps build trust. Indigenous peoples have not always had equity in science, but have had science "done to them" rather than been involved in doing it as a partner. If science cannot be communicated with end users as initial partners, then science will not be effectively disseminated to them. The Lummi Nation, located on the Salish Sea, manages nearly 13,000 acres of tideland on the Lummi Reservation near U.S.–Canadian border and has members on both sides of the border. The Northwest Indian College is 4-year degree university with about 60 science major students which allows allows them to do science that speaks to their specific needs. Much of the collective community knowledge is shared between the many communities they are from. They will also often return to their respective communities to engage their degrees to help their communities.

The Salish Sea Research Center is working to help to prepare the next generation of Native environmental scientists and leaders by fostering respect for indigenous knowledge. The Research Center provides students with solid foundations in scientific methods of research. What can be done to collaborate with indigenous communities? Ask them what they would like to get out of the science. Understand the needs and desires of the stakeholders with collaboration in mind. For example, emergent harmful algae, decreasing fish stocks, and monitoring for climate change are key issues for the Lummi Nation. This allows them to manage their own waters the way that works best for them and make decisions rather than having outside entities tell them how to manage their own lands. In one current project is forage fish. Students collect fish at night using a net with hollow pole and listen for fish moving in the net (traditional method). They will study genomics and look for how far upstream the fish go, and how many different stocks are present. The college also works closely with the K-12 schools. The typical food web drawings do not look like their drawings, which creates a disconnect. Their way of looking at the food web is different in that they use tribal designs in their diagrams. These revised diagrams will more likely engage their students with something familiar. It is important to know your audience and who you are partnering with. Going out into the community with Lummi nation scientists helps to engage others in the community. Having people with similar backgrounds and that look like them, helps to foster engaging relationships and allows them to envision themselves in the role of 'scientist' more easily, should that be a path they want to follow. They do their own monitoring of harmful algal blooms through the SoundToxins partnership and determine when safe harvesting is possible. At first, seeing toxic shellfish signs come and go was fatiguing for much of the community without further in-depth understanding. They worked with the Lummi Nation and the cultural department to develop more signs that are indigenously designed. Originally, the signs had many languages but no cultural languages, so they added indigenous language as well which helped engage the community in paying attention to the signs and feeling like the info was coming from a more trusted source. Many of the local groups are monitoring for climate change as it is a concern for many tribal communities.

Dr. Jack Barth gave a presentation titled "Where are we now and where can we go with ocean technology for addressing climate change impacts on the North Pacific?" He stated that we make observations to understand our ever-changing planet. We can use PICES examples of Working Groups that focus on new technologies to address specific questions. The Global Ocean Observing System (GOOS) in 2009 came out with a framework for local observing and how that flows up to a global network for observing. GOOS has taken on the idea of incorporating essential ocean variables (EOVs), starting with physics (temperature, salinity), biogeochemistry (dissolved organic carbon, nutrients, particulates), followed by biodiversity and biomass. Zooplankton and phytoplankton biomass were next, moving up to marine mammals. The GOOS/Bio/Eco EOVs *vs* the international Group on Earth Observation (GEO) looking at essential biodiversity variables (EBVs). GOOS EOVs has formed a framework for thinking about EBVs. Technologies include Argo floats, with almost 4000 floats currently deployed around the world having good coverage in the deep ocean. Biogeochemical Argo floats can measure more EOVs, including dissolved, nitrate, pH, Chl-*a*, suspended particles, downwelling

irradiance. The goal is for data to be FAIR: Findable, Accessible, Interoperable, Reusable (Tanhua *et al*., 2019, *Front. Mar. Sci*.). Ocean Best Practices are also needed – these are agreed upon and broadly adopted for every activity in ocean observing from research to operations to applications (Pearlman *et al*., 2019 *Front. Mar. Sci.*). Even more advanced observations are achieved with cabled ocean observatories, a growing network. These use fiberoptic networks to get real time, interactive data on a local scale https://oceanobservatories.org. An ocean observing system report card can be found at: https://www.ocean-ops.org/reportcard2019/. Autonomous drifters and surface vehicles include Saildrones, CODE and WOCE surface drifters, Wave glider- liquid robotics, sea hunter-Vigo (large, could launch a saildrone or others), Submaran S10 made by OceanAero. Autonomous floats and vehicles include biogeochemical Argo, Long range AUV Tethys MBARI (w/eDNA now!), Underwater gliders (w/lots of sensors, listen for tagged fish *e.g*., also active acoustics for prey items-zooplankton and smaller fish). The Saildrone 2020 pollock acoustic survey, led by the Alaska Fisheries Science Center (NOAA), made up for loss of surveys in 2020 due to COVID-19. Getting instruments on fishing vessels could help fill gaps in knowledge. Scientists can use small, simple, inexpensive sensors to help fill data gaps. For example, temperature sensors in the hands of fisherman could expand coverage.

Finally[1], Carlo Cattano gave a taped presentation "*Changes in fish communities due to benthic habitat shifts under ocean acidification conditions"*. He spoke about benthic habitat shifts due to ocean acidification (OA) with his research study conducted in Japan. Fish are considered more tolerant to OA, but there are still many detrimental effects, especially for larval and juvenile stages. Few studies have looked at species interactions and OA exposure. Dr. Cattano used natural gradients in pCO_2 as a natural laboratory (using natural CO_2 "seeps" in the coastal ocean of Japan). Past studies found elevated OA reduced the complexity and richness of biogenic reefs, and a loss of diversity and complexity in temporal and tropical systems. His study hypothesis was that fish communities will change with decreasing habitat complexity with increasing OA. His study used two sites: control and elevated CO_2. He observed benthic habitat shifts at the elevated CO_2 site. The structure and composition of fish communities changed with increasing pCO_2; decreases in habitat complexity were also observed. Increased abundance of herbivores was observed with elevated CO_2, while planktivores and carnivores decreased. In summary, OA will change biogenic habitat and complexity as well as fish community structure. This will impact ecosystem health, by degrading biogenic reef health. There is a need to study interactions between OA and other stressors in the future.

List of papers

Oral presentations

PICES engagement with the UN Decade of Ocean Science for Sustainable Development
Steven J. Bograd

The contributions of Early Career Ocean Professionals to PICES within the context of the UN Decade of Ocean Science for Sustainable Development (2021-2030)
Erin Vera Satterthwaite, Aoi Sugimoto and Pengbin Wang

The International Year of the Salmon Pan Pacific High Seas Expedition 2021: A collaborative international approach to understanding how a rapidly changing ocean affects Pacific salmon
Stephanie Taylor, Mark Saunders, Vladimir Radchenko, Ed Farley, Laurie Weitkamp, Jackie King, Chrys Neville, Richard Beamish, Brian Riddell, Evgeny Pakhomov, Shunpei Sato, Shigehiko Urawa, Aleksey Somov and Sang-Seon Yun

Collaborative research with Indigenous partners: Meeting them on their waters
Misty Peacock, Rachel Arnold, Rosa Hunter and Thayne Yazzie

[1] For talks not summarized above, please refer to https://meetings.pices.int/publications/presentations/PICES-2020#session1 for recorded presentations.

Where are we now and where can we go with ocean technology for addressing climate change impacts on the North Pacific?
John A. Barth

Changes in fish communities due to benthic habitat shifts under ocean acidification conditions
Carlo Cattano, Sylvain Agostini, Ben P. Harvey, Shigeki Wada, Federico Quattrocchi, Gabriele Turco, Kazuo Inaba, Jason M. Hall-Spencer and Marco Milazzo

Population trends of the Kuril harbor seal Phoca vitulina from 1974 to 2020 in southeastern Hokkaido, Japan
Yumi Kobayashi, Jun Chishima, Tamura Kyohei, Toyota Masaki, Matsuda Nao, Nori Sasaki, Sekitani Yuta and Ayumi Yamada

Yearly changes in mesozooplankton biomass in the southeastern Bering Sea shelf during the summer of 1955-2013: Insights from T/S Oshoro-Maru data
Atsushi Yamaguchi, Hikaru Hikichi, Kohei Matsuno and Hiromichi Ueno

Vulnerable Marine Ecosystems of the Emperor Chain Seamounts: Indicator taxa, landscapes, and new data regarding the status and health of the North Pacific Ocean
Tatiana Dautova

E-Poster presentations

Long-term variations in fish community structure under multiple stressors in a semi-closed marine ecosystem in the South China Sea
Kui Zhang, Jianzhong Guo, Youwei Xu, Yane Jiang, Jiangtao Fan, Shannan Xu and Zuozhi Chen

Phytoplankton community structure and environmental factors in the East China Sea
Minbo Luo and Tingting Jian

PICES TCODE Catalog Service
Igor I. Shevchenko

MEQ Topic Session (S13) [VS3]
Using eDNA to assess and manage non-indigenous species in the North Pacific

Co-Sponsor: *NOWPAP*

Convenors: *Jeanette Davis (USA), Keun-Hyung Choi (Korea), Thomas Therriault (Canada)*

Invited Speakers:
Hitoshi Araki (Hokkaido University, Sapporo, Japan)
Satoshi Nagai (Japan Fisheries Research and Educational Agency, Yokohama, Japan)
Kwang Young Kim (Chonnam National University, Gwangju, Korea)

Background

Non-indigenous species (NIS) cause ecological and/or economic harm and are a threat to biodiversity. The spread of aquatic NIS has increased in the last decade due to globalization and other related human activities. Preventing all introductions is not possible, thus early detection is the most valuable cost-effective control and eradication option, yet many species are difficult to detect using traditional survey techniques, especially over large spatial areas. The use of environmental DNA (eDNA) as a new and rapidly growing tool to detect, monitor, and quantify species for biodiversity and conservation management is of considerable interest. In comparison to traditional methods, eDNA sampling is more sensitive, less harmful to the environment, cost-effective, safer for both species and field staff, and more targeted for identifying species of interest. Therefore,

eDNA is a promising tool for early detection of NIS. However, the effectiveness for this technique across many NIS taxonomic groups and habitat types is unexplored and could have important management implications. The goal of this session was to evaluate the landscape of how eDNA monitoring is being applied in the NIS community globally and to share information relevant to management and policy.

Summary

This virtual topic session on eDNA was held on Wednesday, October 28, 2020 starting at 18:00 Pacific Daylight Time (Thursday, October 29, 2020 in Asia). The session was composed of three invited presentations and four contributed oral presentations and three virtual posters. Convenors decided to pursue this virtual opportunity given the immense interest in eDNA but hope to be able to convene a face-to-face version that will allow more time for discussions at PICES-2021.

The session got underway following a brief overview by the convenors. The first invited presentation set the stage as Hitoshi Araki (Hokkaido University, Japan) gave an overview of eDNA and its applications to endangered and non-indigenous species (NIS). His presentation included information on what eDNA is and how it can be sampled for and then led into applications for biodiversity monitoring where environmental and logistical challenges can be large and species one is trying to find are rare. As a monitoring tool it is non-invasive, relatively easy and cheap to use, and does not require taxonomic skills to identifying individuals encountered. There are two major approaches for eDNA studies: i) species-specific approaches using techniques like qPCR and Hitoshi gave an example in Japan of work on the critically endangered Sakhalin taimon; and ii) taxa-wide approaches using metabarcoding or next generation sequencing to search for many species in a sample simultaneously. Hitoshi provided some additional examples of eDNA applications in Japan including uncovering the cryptic invasion of common carp, looking at sediment core samples to look at species assemblage changes over time, and identifying "Red Zones" where the population of rare or invasive species is used to inform management decisions. This presentation highlighted the many potential applications of eDNA that informed the discussion at the end of the session.

Satoshi Nagai (Japan Fisheries Research and Education Agency, Japan) was the second invited speaker in this session and he presented on an interesting monitoring time series from the northernmost area of Japan. This project that involved weekly sampling since about 2012 was designed to use eDNA metabarcoding to look at changes in biodiversity relative to environmental monitoring in the context of climate change. Species richness (measured as OTUs) increased with temperature and there were significantly fewer species detected during the cold, winter sampling events. Copepod blooms were easily detected using this eDNA sampling strategy and overall this study identified 1,799 species (509, 342, 199, 173, 127, 83, 210, and 156 species in Fungi, Metazoa, Bacillariophyceae, Dinophyceae, Ciliophora, Chlorophyceae, other microalgae, and other eukaryotes, respectively). Interestingly 43 OTUs were related to harmful algal species (HABs) suggesting greater diversity was revealed by metabarcoding compared to traditional methods and that this may represent cryptic diversity within HABs where the taxonomy is complex. The study was also successful in detecting *Marcalefidinium* sp., a NIS in northern Japan that was likely spread on ocean currents providing additional evidence that eDNA holds great promise for early detection of newly invading species.

Kwang Young Kim (Chonnam National University, Korea) provided an excellent example of how NIS protists (HABs) can be detected early using eDNA methods. Continuing the theme of challenges using traditional taxonomic approaches Kwang Young introduced a new digital-droplet PCR (ddPCR) assay that was designed to avoid the challenges of quantification of such species based on their external morphology under a light microscope or by using conventional molecular approaches that have limited sensitivity, specificity, and reproducibility. This new approach was based on small organelles enriched metagenomics (SoEM) and

provided increased resolution over traditional metabarcoding techniques. It was able to precisely quantify the target species (*e.g.*, *Alexandrium* sp.) in complex marine environmental samples and has promise for monitoring applications that require high sample throughput and low detection limit, even when species are rare or at a very low abundance in the environment.

Sergei Turanov (AV Zhirmunsky National Scientific Center of Marine Biology, Russia) introduced a new eDNA fish biodiversity monitoring program in Russia. Focal species for this pilot project included endangered and threatened species such as Sakhalin sturgeon and taimon. They are currently building a sequence reference database by developing species-specific primers. The goal is to be able to conduct rapid monitoring for fish in the Far East of Russia using metabarcoding. Unfortunately some of the preliminary results suggested contamination of the eDNA samples (or maybe salmon are just everywhere!) but it does serve as a template around which monitoring programs for rare species can be designed echoing back to Hitoshi's suggestion of great application for endangered and invasive species.

The next two presentations, Thomas Therriault and Kristen Westfall (DFO, Canada) presented Parts 1 and 2 of a larger research program within DFO developing different eDNA tools for NIS Early Detection and monitoring. One of the major goals of this project is to develop more cost-effective and sensitive methods for NIS detection that can be transferred to citizen science groups throughout British Columbia's complex coastal environment. The first study compared eDNA metabarcoding detections to traditional settlement plate surveys for biofouling species in British Columbia. New primers designed for important NIS groups (Arthropoda, Mollusca, Bryozoa, and Ascideacea) using multiple gene loci increased sensitivity and it was suggested eDNA sampling could complement existing surveys. The second was comparing the effectiveness of qPCR vs tNGS (targeted next generation sequencing – a newly developed method) using European green crab as the target organism. This new technique was much more effective at distinguishing between high and low density sites. Overall the results showed eDNA was always more variable among sites than over short time scales suggesting a high level of specificity and broad potential applications for NIS monitoring for a variety of NIS taxa.

The final oral presentation in this session was by Jeanette Davis (NOAA, USA) who highlighted how eDNA can best support management decisions. In order for eDNA to be fully utilized in this context it is important for managers to have very clear objectives since eDNA, like any other tool, has strengths and weaknesses that must be carefully considered. Often managers don't know exactly what questions to ask so a dialogue between managers and practitioners is essential. Jeanette provided an example of an intergovernmental working group that is working to resolve some of these challenges and may be a model for others. Despite a large number of agencies using eDNA it was not always clear it was being used in the same way or to answer the same questions. For example, some groups were using eDNA for the initial detection of NIS, some were using it to track the spread of NIS, and others were using it to evaluate the effectiveness of control measures. Clearly eDNA can be a powerful tool but management needs to understand what the tool can and cannot do and the uncertainties related to field collections, laboratory analyses, and data interpretation. Thus, it was suggested that minimum requirements for eDNA should be established to avoid a moving target among studies and applications.

Following the invited and contributed oral presentations, there was time allocated to discussing potential eDNA applications within PICES member countries and some of the key challenges and opportunities, especially as it pertains to NIS monitoring. Overall, session participants were overwhelming in favour of continued advancement of eDNA methodologies for NIS monitoring and felt PICES was well positioned to serve as a means to exchange information and experiences around the North Pacific, including collaborations with NOWPAP. Although this rapidly evolving technology has tremendous applications, there were some cautions and caveats expressed. For example, it was noted that any eDNA tool/approach would need to be fit for purpose

which may require additional research. Further, it was noted that existing sequence databases are incomplete and in the context of NIS monitoring, populating these with verified (*i.e.*, taxonomy done by a trained taxonomist) multi-gene sequences would be a priority. AP-NIS could contribute verified specimens to genetics labs working on this issue as a first step. Finally it was noted that eDNA results need to be interpreted with caution in many situations and that it is imperative that associated uncertainty be clearly communicated to NIS managers and policy makers. The co-convenors concluded the meeting by noting this discussion would continue at the next PICES Annual Meeting when it is hoped that discussions can happen face-to-face.

List of papers

Oral presentations

Environmental DNA for identifying "red zone" of endangered/invasive species (Invited)
Hitoshi Araki, Hiroki Yamanaka, Kimiko Uchii, Michinobu Kuwae and Hideyuki Doi

Recent progress of eukaryotic metabarcoding in Japanese coastal waters (Invited)
Satoshi Nagai, Sirje Sildever, Noriko Nishi, Satoshi Tazawa, Hiromi Kasai, Akihiro Shiomoto and Seiji Katakura

Early detection and quantification of non-indigenous protists using environmental DNA (eDNA) (Invited)
Kwang Young Kim

A preliminary report on the implementation of eDNA-based techniques to biodiversity monitoring of fish from the Far East of Russia
Sergei V. Turanov and Olesya A. Rutenko

Applied molecular biosurveillance in the Northeast Pacific part I: integrating a new eDNA tool for broad detection capacity
Kristen Marie Westfall, Thomas W. Therriault and Cathryn L. Abbott

Applied molecular biosurveillance in the Northeast Pacific part II: improving targeted detection and quantification
Kristen Marie Westfall, Thomas W. Therriault and Cathryn L. Abbott

The use of eDNA as an intergovernmental approach to tracking and managing nonindigenous species in the USA
Jeanette Davis

E-Poster presentations

Influencing factors and quantitative evaluation of environmental DNA metabarcoding
Shufang Liu, Ming Mu and Zhimeng Zhuang

First record of non-indigenous colonial ascidian in the Korean coasts, confirmed by DNA Barcoding
Taekjun Lee, Michael Dadole Ubagan, Seung Bin Park, Bal Dev Bhattrai and Sook Shin

Monitoring of drifting seaweed (*Sargassum horneri*) in Liaodong Bay in 2020
Chunjiang Guan,Yanlong Chen,Yongjian Liu,Yujuan Ma, Lu Yang, Jialu Shi and Jingfang Zhang

FIS Topic Session (S14) [VS4]
Implementing a collaborative, integrated ecosystem high seas survey program to determine climate/ocean mechanisms affecting the productivity and distribution of salmon and associated pelagic fishes across the North Pacific Ocea

Convenors: *Mark Saunders (NPAFC), Hal Batchelder (PICES), Suam Kim (Pukyong National University, Korea), Alex Zavolokin (NPFC), Brian Wells (NMFS), Motomitsu Takahashi (Japan Fisheries Research and Education Agency, Japan)*

Background

Pacific salmon, including Chinook, chum, coho, pink, and sockeye, are a commercially, ecologically and culturally important species for countries in the North Pacific rim. However, it is uncertain how changing ocean conditions will affect North Pacific salmon and their ecosystems. Because salmon have an anadromous life cycle, they are more vulnerable to environmental and human-caused changes and there are significant gaps in our knowledge and understanding of salmon, specifically during their long marine migrations. To understand and forecast the impacts of climate change on salmon and North Pacific ecosystems, more research is needed to study their ocean life history phase, where they spend at least half of their lives. Since salmon migrate across exclusive economic zones (EEZ) and intermingle in the high seas, an international effort is required to research North Pacific salmon during their marine phase. Also, the participation of various stakeholders including NGOs, government, academia, and private partners is needed. In 2019 and 2020, international expeditions were conducted in the Gulf of Alaska (GoA). The intent of these expeditions has been to demonstrate that international cooperation can be effective and provide baseline measurements of the Gulf of Alaska ecosystem during winter. Additionally, the expeditions demonstrate the utility of an international pan-Pacific survey to fill knowledge gaps regarding how increasingly extreme climate change in the North Pacific Ocean affects salmon abundance, distribution, migration, growth, and fitness. Scientists from NGOs, government, academia, and private partners from different North Pacific countries convened to review and present research results from the 2019 and 2020 International Gulf of Alaska Expeditions to guide the cruise plans for the 2022 International Year of the Salmon Pan-Pacific Winter High Seas Expedition.

Summary

Live talks: October 20, 2020

Mr. Mark Saunders (IYS Director, Pacific Region) opened the session on behalf of all convenors and welcomed participants. He briefly introduced the 2019 and 2020 Gulf of Alaska Expeditions and the plan for the International Year of the Salmon 2022 Pan-Pacific Winter High Seas Expedition.

Dr. Brian Riddell and Dr. Dick Beamish led the first session by presenting an overview of the “Gulf of Alaska expeditions in 2019 and 2020”. Preliminary results indicated that the surveys might provide an early warning of salmon returns, however, additional research and analyses are required. In particular, the patchiness of catches in 2022 and the low numbers of pink salmon point to the importance of multi-vessel surveys to cover the full distribution and investigate the patchiness.

Dr. Evgeny Pakhomov presented “Comparative oceanographic conditions during the International Gulf of Alaska Expedition 2019 and 2020”. The surveys effectively captured known features of water masses and their circulation in the NE Pacific Ocean and salmon were found to be associated with some of the observed conditions. In both years, the Gulf of Alaska waters were warmer than the long-term (1993-2015) means. The

waters in 2020, particularly in the northern region, were cooler than that of 2019. Overall, distributions of sea surface properties were similar in both years. There were strong southeast to northwest gradients in surface and subsurface ocean properties off the continental shelf. Temperature decreases and salinity and oxygen increases were also observed moving away from the shelf. A high concentration of chlorophyll was observed in 2019 in the northern waters, but the concentration of chlorophyll in the southern waters was higher in 2020 and this could be due to the later timing of the survey in 2020. There were differences observed in the zooplankton community composition between 2019 and 2020 samples. Specifically, the contribution of southern species in 2020 was more substantial than in 2019. Biomass in both the northern and southern parts of the Gulf of Alaska was dominated by large zooplankton in 2019. A concern for planning future expedition(s) was the failure of the zooplankton sampling gear to capture the full field of prey items required to understand salmon forage conditions. Therefore, sampling methods may need to be modified.

Dr. Christoph Deeg presented: "Way out there: Pathogens and stressors of overwintering salmon in the Gulf of Alaska," and provided the first assessment of the health and condition of salmon in the Gulf of Alaska at the end of the winter. He collected 253 tissue samples from chum, coho, sockeye, and pink salmon. Pathogen diversity in the Gulf of Alaska was significantly lower compared to the British Columbia coast for all species except sockeye. The relative infection burden of chum was lower in the Gulf of Alaska but it was the opposite for coho. Overall, transcriptome profiling using Salmon Fit-Chips revealed that relative infection burden, and occasionally single pathogens were correlated with stress, size, condition factor, and imminent mortality of salmon. Furthermore, capture location influenced gene expression in all species, which was presumably caused by heterogeneous environmental conditions across the survey area. At this stage it is difficult to conclude how pathogen levels and virus loads affect the survival of Pacific salmon.

Dr. Laurie Weitkamp spoke on the "Potential effects of wounds and sea lice on the health of Pacific salmon on the high seas". They categorized 'marks' as wounds, scars, sea lice, and disease and analyzed the relationship of marks with salmon length, long-term health (condition factor), and short-term health (stomach fullness). Salmon with wounds, scars, and sea lice were usually larger than unmarked salmon. However, fish with diseases tended to be smaller than the unmarked ones. In addition, it was found that wounded salmon had statistically lower condition factors than fish that were not wounded. It was unclear why salmon with sea lice had higher stomach fullness overall, suggesting that more research is needed. It was recommended that subsequent surveys improve the descriptions and photographs of external marks that provide valuable clues with respect to predators and pathogens.

Dr. Brian Hunt covered "Salmon trophic ecology in late winter in the Gulf of Alaska". The objective of the study was to establish the importance of the high seas life phase for salmon. Tissue samples were collected from all components of the pelagic food web across the survey area. These samples were analyzed for their carbon and nitrogen stable isotope values to construct a food web for estimating trophic level, trophic niche width and overlap, and tracing organic matter sources. The research showed that chum salmon has the lowest trophic levels of co-occurring salmon. Overall, niche overlap was low between salmon species and the highest overlap observed was between pink and coho salmon at 19% overlap. Analyses of organic matter showed that shelf resources contributed more than 45% to coho diets and were important for 1st-year winter chum and sockeye. Shelf organic resources contributed more in 2020 than 2019, which may be caused by poor open ocean productivity or high shelf productivity.

Dr. Charles Waters discussed "Winter energetic status of Pacific salmon in the Gulf of Alaska". The aim of the study was to better understand the marine ecology of Pacific salmon in the critical winter period. Winter fitness of 412 chum, coho, pink, and sockeye salmon was investigated by estimating their lipid content, protein content, and energy density. Results showed that there were positive relationships for chum and sockeye

between energy density and fork length. For chum particularly, the positive relationship became stronger as the species increased in age from a negative relationship at age 1. None of the relationships between percent lipid and total mass of chum were statistically significant, whereas all the relationships between percent protein and total mass by different ages were significantly positive. However, none of these relationships were statistically significant in sockeye, coho, and pink salmon. Trends of lipid content and protein content by fish size did not show clear signs of fish starvation in winter. These results are expected to be used to develop indices of winter fitness for Pacific salmon.

Dr. Sarah Rosengard gave a talk on "Co-variability of Fraser River sockeye productivity and phytoplankton biomass in the Gulf of Alaska". The relationship between Moderate Resolution Imagine Spectroradiometer (MODIS), chlorophyll-a, and sockeye productivity was analyzed to add to an understanding of ocean processes that influence sockeye survival. Analytical results showed that there was a positive linear relationship between Fraser River sockeye productivity and MODIS chlorophyll-a concentrations. The correlation was strongest and statistically significant for the area adjacent to the continental shelf near Kodiak Island during late summer. Furthermore, elevated chlorophyll-a anomalies in the offshore waters near Kodiak Island were generally associated with eddy occurrence. Higher eddy activity is predicted to deliver prey to sockeye salmon foraging near Kodiak Island. These results may be used to improve the performance of Ricker Stock-recruit models.

Recorded talks

Ms. Halle Berger discussed "A regional vulnerability assessment for the Dungeness crab (*Metacarcinus magister*) to changing ocean conditions: insights from model projections and empirical experiments". The objective of the study was to inform fisheries management of the timing and areas where Dungeness crab populations are most vulnerable using a multi-faceted approach to assess the vulnerability of populations to changing oxygen, pH, and temperature conditions. The results revealed that crabs were vulnerable to low pH, low dissolved oxygen, and high temperatures, which will become more extreme in the future. Furthermore, it was shown that Dungeness crab respiration rates increased exponentially with temperature, which means they will be negatively impacted by changing ocean conditions. Therefore, modification of management practices or additional precautionary measures might be needed to sustain the Dungeness crab fishery. Vulnerability assessment methods may be considered in assessing vulnerability of salmon during ocean life history stages.

Mr. Siyu Meng presented a "Strengthened ocean-desert process in the North Pacific over the past two decades". Expansion of the North Pacific Ocean Desert (NPOD) was investigated by characterizing the intensity, area, and position of the NPOD. In most parts of the NPOD, oligotrophication and expansion processes were dominated by warming upper oceans, except in the southeast NPOD area where the chlorophyll-a variations dominantly correlated to the regional change in sea surface heights. The NPOD is adjacent to salmon winter habitat and connectivity between the two regions is clearly important to understanding the effect of changing climate on salmon distribution and productivity.

Dr. Ferdenant Mkrtchyan covered "GIMS (Geospatial Information Model System) technology in environmental monitoring of ocean ecosystem". A remote monitoring system for detecting anomalies on the sea surface was considered. Its block diagram was analyzed, which consists of a Holder, Resolver, and Searcher. The results showed that statistical characteristics for spottiness of brightness temperatures in the microwave radiometers could be used for detection and classification of the phenomena on the surface of the ocean caused by a degree of sea roughness.

Dr. Ferdenant Mkrtchyan also presented "Some aspects of the microwave radiometry and spectroellipsometric technologies for monitoring aquatic systems". The objective of the study was to create a compact information system for monitoring the quality of the aquatic environment, and to investigate its potential effectiveness. This system is based on the application of microwave and optical methods and algorithms for learning,

classification, and identification. The combined use of microwave radiometric and optical measurement technology and algorithms for detection and classification is expected to make it possible to create an original system for collecting and processing data on the aquatic environment, such as water quality data.

Ms. Megumi Enomoto spoke on "Vertical habitat changes of juvenile Japanese jack mackerel (*Trachurus japonicus*) estimated by otolith microchemistry". Otolith stable isotope ratios were analyzed to elucidate habitat layer change (HLC), which is important for species survival. HLC timing was divided by HLC moment and HLC duration to detect the signal when fish change their habitat in the short term and long term, respectively. Results showed that Japanese jack mackerel juveniles changed their habitat layer gradually for 28 days and started to change their habitat layer as they turned from larvae into juveniles. This method may be applied to Pacific salmon.

Dr. Brian Wells gave a talk on "An ecosystem-science approach to support salmon management." He emphasized that to improve the quality of salmon assessments, ecosystem-relevant information has to be more effectively incorporated. For this, he suggested 1) designing conceptual models representing the contemporary understanding of the ecosystem, 2) improving understanding of salmon behavior, growth, and mortality rate at sea, 3) improving salmon assessment models based on the research of ecosystem processes, and 4) developing life-cycle models to evaluate tradeoffs associated with management alternatives. This approach could enable the incorporation of high seas ecosystem research.

List of papers

Oral presentations

Gulf of Alaska expedition in 2019 and 2020
Dick Beamish and Brian Riddell

Comparative oceanographic conditions during the International Gulf of Alaska Expedition 2019 and 2020
Evgeny Pakhomov, Albina Kanzeparova, and International TEAM of the 2019 and 2020 Gulf of Alaska Expeditions.

Way out there: Pathogens and stressors of overwintering salmon in the Gulf of Alaska
Christoph Deeg, Albina Kanzeparova, Alexei Somov, Svetlana Esenkulova, Emiliano Cicco, Karia Kaukinen, Amy Tabata, Tobi Ming, Shaorong Li, Richard Beamish and Kristina Miller

Potential effects of wounds and sea lice on the health of Pacific salmon on the high seas
Laurie Weitkamp, Chrys Neville, Alexey Somov and Albina Kanzeparova

Salmon trophic ecology in late winter in the Gulf of Alaska
Brian Hunt, Evgeny Pakhomov, Nicole Link, Alexi Somov, Albina Kanzeparova, Mikhail Zuev and Vladimir Radchenko

Winter energetic status of Pacific salmon in the Gulf of Alaska
Charles Waters, Chrys Neville, Todd Miller, Emily Fergusson, Dion Oxman, Beverly Agler and Edward Farley Jr.

Co-variability of Fraser River sockeye productivity and phytoplankton biomass in the Gulf of Alaska
Sarah Rosengard, Cameron Freshwater, Yi Xu and Philippe Tortell

A regional vulnerability assessment for the Dungeness crab (*Metacarcinus magister*) to changing ocean conditions: insights from model projections and empirical experiment
Halle Berger, Samantha Siedlecki, Catherine Matassa, Simone Alin, Isaac Kaplan, Emma Hodgson, Darren Pilcher, Emily Norton and Jan Newton

Strengthened ocean-desert process in the North Pacific over the past two decades
Siyu Meng, Xun Gong, Yang Yu, Xiaohong Yao, Xiang Gong, Keyu Lu, Chao Zhang, Jie Shi, Xiaojie Yu and Huiwang Gao

GIMS (Geospatial Information Model System) technology in environmental monitoring of ocean ecosystem
Ferdenant Mkrtchyan and Vladimir Krapivin

Some aspects of the microwave radiometry and spectroellipsometric technologies for monitoring aquatic systems
Ferdenant Mkrtchyan, Vladimir Krapivin, Vladimir Klimov and Vladimir Soldatov

Vertical habitat changes of juvenile Japanese jack mackerel (*Trachurus japonicus*) estimated by otolith microchemistry
Megumi Enomoto, Shin-ichi Ito, Motomitsu Takahashi, Chiyuki Sassa, Tomihiko Higuchi and Kotaro Shirai

An ecosystem-science approach to support salmon management
Brian Wells, Nate Mantua, Brian Burke and Jerome Feichter

Poster presentations

Use of natural food attractants in the diet of Pacific salmon fish (*Oncorhynchus kisutch*) on Kamchatka
Nina Okrestina, Maxim Zharkov and Olga Isaeva

Oceanological conditions on the southeastern Sakhalin shelf according to surveys on standard sections and satellite SST observations
Georgy Shevchenko, Zhanna Tshay and Valery Chastikov

Amur River water and sea ice on northeastern Sakhalin shelf in June
Georgy Shevchenko and Valery Chastikov

SST lowering in the Sea of Okhotsk as the result of global warming
Dmitry Lozhkin and Georgy Shevchenko

Microevolutionary processes in Asian sockeye salmon *Oncorhynchus nerka* populations during Late Pleistocene climatic oscillations
Anastasia M. Khrustaleva, Ekaterina V. Ponomareva and Marya V. Ponomareva

BIO/POC Topic Session (S5) [VS5]
Atmospheric nutrient deposition and microbial community responses, and predictions for the future in the North Pacific Ocea

Convenors: *Jun Nishioka (Japan), Guiling Zhang (China), Huiwang Gao (China), Kitack Lee (Korea), Santiago Gassó (USA), Maurice Levasseur (Canada)*

Background

Atmospheric deposition is an important nutrient source for marine ecosystems, with consequences for local, regional, and global biogeochemical cycles, as well as the climate system. The focus of this session was on natural and anthropogenic atmospheric nutrient inputs to the North Pacific Ocean. Microbial communities respond to changing atmospheric inputs, which may result in significant effects on the marine carbon and nitrogen budgets, as well as on atmospheric carbon dioxide uptake. Key questions addressed within this theme were: How do biogeochemical and ecological processes interact in response to natural and anthropogenic material input from the atmosphere across costal and open ocean regions? How do global warming, ocean acidification, and other anthropogenic stressors synergistically alter the uptake of atmospheric nutrients and metals by marine biota in different oceanic regions? What is the prognosis for the future? New interdisciplinary presentations were invited as well as active discussions on physical, chemical, and biological sciences both from the ocean and atmospheric fields in this session.

Summary of presentations

On 29 October, 2020, a SOLAS-relevant BIO/POC topic session on “Atmospheric nutrient deposition and microbial community responses, and predictions for the future in the North Pacific Ocean” was held virtually at PICES-2020. The session had 7 live presentation, 5 recorded oral presentation and 15 electronical poster presentation. We had a number of exciting presentations and active discussions in the topic of understanding atmospheric iron and nutrient deposition to the ocean and its influence on ocean biogeochemistry in the Pacific Ocean. A wide range of results were reported such as atmosphere–ocean material cycles, atmospheric nutrient supply, atmospheric aerosol iron from coal combustion and its deposition to China adjacent seas, phytoplankton community response to trace metals deposition, controlling physical and chemical mechanism for biological production, dynamics of organic ligands in the Pacific water which is key to trace metals

dynamics, and air pollution and future forecasting for nitrate deposition to Pacific ocean. Among them, the subject of aeolian iron and nitrogen deposition, and the importance of anthropogenic aerosols and their solubility and impact on the ecosystem was thoroughly discussed. However, it is worth pointing out that these presentations were limited to discussing the impact on the waters of the near Asia adjacent sea, and a remaining issue on this session discussion was to quantitatively estimate the impact on the wider Pacific Ocean in the future.

The future directions of research are extracted from this session. The following issues should be further investigated in order to clarify the impact of the supply of nutrients derived from the atmosphere on biological production in the wider Pacific Ocean.

- To estimate the impact of atmospheric iron supply on oceanic phytoplankton growth, quantitatively, contribution of anthropogenic aerosol iron will be key issue. It is clear that more work is needed to reveal the anthropogenic aerosol iron transport scale, frequency, deposition area, residence time in surface water and dissolution rate, and fraction of bioavailable iron under natural conditions.
- There are still important gaps in the quantitative understanding along with a coherent explanation of the biological response in high nutrient low chlorophyll (HNLC) waters and subtropical low nutrient low chlorophyll (LNLC) waters in the North Pacific. It was frequently suggested that this must be made by incorporating both the knowledge of atmospheric iron supplies and the oceanic iron supplies. A modeling study which incorporates both atmospheric nutrients (nitrate and iron) deposition process with accurate oceanic nutrient dynamics, validated by observational data, should be constructed for understanding real biological production and forecasting future change in the North Pacific Ocean.

In order to discuss these remaining issues, it was agreed by many participants that we would continue to work with SOLAS to hold a session at next year's PICES Annual Meeting.

List of papers

Oral presentations

Atmospheric aerosol iron from coal combustion
Clarissa Baldo, Akinori Ito and Zongbo Shi

Atmospheric outflow of anthropogenic iron and its deposition to China adjacent seas
Chunqiang Chen, Lei Huang, Jinhui Shi, Yang Zhou, Jiao Wang, Xiaohong Yao, Huiwang Gao, Yayong Liu, Jia Xing and Xiaohuan Liu

Impact of atmospheric deposition on phytoplankton community structure in the Yellow Sea
Qin Wang

High-frequency observation of the spring bloom in the western North Pacific by Himawari-8
Asuto Sakai and Kosei Komatsu

Spatial and temporal variations in copper ligand concentration along Line P
Andrew R.S. Ross, Richard L. Nixon, Jasper George, Kyle G. Simpson and Marie Robert

Air pollutants promote the utilization of dissolved organic phosphorus (DOP) by phytoplankton in China coastal seas
Haoyu Jin, Chao Zhang and Huiwang Gao

Elucidating the role of climate and emission in modulating the atmospheric nitrogen deposition over the North Pacific Ocean
Yang Gao, Shuhui Guan, Xiaohong Yao and Huiwang Gao

Elevated nutrient supply caused by the Kuroshio approaching to the continental shelf in the south of Japan associated with submesoscale flows and near-inertial waves
Gloria S. Duran Gomez and Takeyoshi Nagai

Anthropogenic nitrogen-induced changes in seasonal carbonate dynamics in a productive coastal environment
Ja-Myung Kim, Kitack Lee, In-Seong Han, Joon-Soo Lee, Yang-Ho Choi, Ju Hyeon Lee and Ji-Young Moon

Herbaria macroalgae as a proxy for historical upwelling trends in Central California
Emily A. Miller, Susan E. Lisin, Celia M. Smith and Kyle S. Van Houtan

New ocean-atmosphere biogenic nitrogen recycling in the equatorial Pacific
Kazuki Kamezaki, Shohei Hattori, Yoko Iwamoto, Sakiko Ishino, Hiroshi Furutani, Mitsuo Uematsu, Kazuhiko Miura and Naohiro Yoshida

Diving classification of lactating northern fur seals based on three-dimensional movements
Yuta Sakuragi, Vladimir N. Burkanov, Russel D. Andrews and Yoko Mitani

E-Poster presentations

Fe redox status and its bioavailability in the East China Sea shelf break area
Koki Yamanaka, Yoshiko Kondo, Natsuho Fujita, Yudai Sunahara and Hajime Obata

Microbiome composition of azooxanthellate coral and seawater in the South Sea
Seonock Woo

Change of dominant phytoplankton groups in the eutrophic coastal sea due to atmospheric deposition
Haowen Li, Ying Chen, Shengqian Zhou, Fanghui Wang, Tianjiao Yang, Yucheng Zhu and Qingwei Ma

On the relationship between aerosol methanesulfonate and surface phytoplankton biomass in the mid-latitude oceans of the Northern Hemisphere
Shengqian Zhou, Ying Chen, Shan Huang, Guipeng Yang, Honghai Zhang, Adina Paytan, Hartmut Herrmann, Alfred Wiedensohler, Laurent Poulain, Haowen Li, Fanghui Wang, Yucheng Zhu and Tianjiao Yang

Extreme sea level rise off the northwest coast of the South China Sea in 2012
Lin Liu, Juan Li

Differentially expressed genes of octocoal, *Eleutherobia rubra* against heat stress and the local environment
Nayun Lee, Seungshic Yum and Seonock Woo

Dominant microalgae species in Paris Bay (Peter the Great Bay, Sea of Japan) near the net pens with marine mammals
Olga G. Shevchenko and Kirill O. Tevs

Spatial distributions of atmospheric water soluble nitrogen and phosphorus depositions to the Pacific Ocean
Rumi Naoe, Shigenobu Takeda, Kei Tamura and Masataka Doi

Dynamics of the bloom-forming genus *Skeletonema* from the Peter the Great Bay (Sea of Japan)
Anna A. Ponomareva, Olga G. Shevchenko and Kirill O. Tevs

Air emissions from shipping stimulate oceanic phytoplankton growth
Chao Zhang, Zongbo Shi, Yan Zhang and Huiwang Gao

Diel, seasonal, and vertical changes in abundance, biomass, and community structure of the pelagic polychaetes down to 1000 m depths in the western subarctic Pacific Ocean
Kanako Amei, Ryo Dobashi, Naoto Jimi, Minoru Kitamura and Atsushi Yamaguchi

Concentration distribution of atmospheric particulate nitrogen and phosphorus over the North Pacific Ocean
Gang Yuan and Jianhua Qi

Characterization and source apportionment of size-segregated atmospheric particulate matter collected at ground level and from the urban canopy in Tianjin, a coastal city
Jiao Wang, Ming Zhou, Bao-shuang Liu, Jian-hui Wu, Xing Peng, Yu-fen Zhang, Su-qin Han, Yin-chang Feng and Tan Zhu

Horizontal scale of chlorophyll a variability affected by eddy activities in the midlatitudes of global oceans
Hitoshi Kaneko and Shin-ichi Ito

Zinc and lead accumulation by *Fucus distichus* (Fucales) in coastal waters of southeastern Kamchatka and Commander Islands during 2000-2020
Liliya A. Pozolotina, Anna V. Klimova and Nina G. Klochkova

General E-poster presentations

The role of environmental indicators in ecosystem-enhanced Bering Sea pollock fishery management
Mikhail A. Stepanenko and Elena V. Gritsay

Oceanographic and biological conditions ensuring the presence of a high productive bottom community in the marine feeding area of gray whales near north-eastern Sakhalin Island
V.S. Labay, G.V. Shevchenko, I.V. Motylkova, N.V. Konovalova, I.A. Atamanova, V.N. Chastikov, R.V. Turchin and B.A. Dotzenko

Rapid detection of aquatic microplastics on filter substrates based on hyperspectral imaging
Chunmao Zhu, Yugo Kanaya, Ryota Nakajima, Masashi Tsuchiya, Hidetaka Nomaki, Tomo Kitahashi and Katsunori Fujikura

Spatio-temporal variations in the potential habitat of neon flying squid in the Northwest Pacific Ocean
Wei Yu, Jian Wen, Zhong Zhang, Xinjun Chen and Yang Zhang

Identification of functional genes in deep-sea corals from seamounts in West Pacific by de novo RNA sequencing
Ye Jin Jo, Seungshic Yum and Seonock Woo

Spatial and temporal dynamics of Pacific capelin (*Mallotus catervarius*) in the Gulf of Alaska: using data synthesis to improve monitoring of small pelagic fishes in the Northeast Pacific
David W. McGowan

Seasonal dynamics of dominant fish populations in Zhoushan Archipelago Seas: role of oceanic front and fishing
Yongjiu Xu, Hongliang Zhang, Joji Ishizaka, Cungen Yu, Huijun Wang and Yali Hu

Enhance ecosystem-based approach principles in Marine Policy of Pacific Russia to contribute to fulfilling the Ocean Decade Challenges
Amrtatjuti V. Sereda

Detection of fine-scale internal disturbances generated at the Kuroshio front
Kosei Komatsu, Akira Kuwano-Yoshida and Keisuke Ariyoshi

An income pooling system in a Japanese trawl fishery: The case of Muroran, Japan
Yutaro Sakai

Harbor seals (*Phoca vitulina*) discriminate 3D objects: Effects of brightness and shape
Monica Ogawa, Ayako Momoi, Toshihiko Kushihiki and Yoko Mitani

SB Workshop (W4) [VW4]
How does the Pacific Arctic gateway affect the marine system in the Central Arctic Ocean (CAO)?

Convenors: *Sei-Ichi Saitoh (Japan), Hyoung-Chul Shin (Korea), Guangshui Na (China), Lisa Eisner (USA), Libby Logerwell (USA)*

Invited Speaker:
Jacqueline M. Grebmeier (University of Maryland, USA)

Background

The Central Arctic Ocean (CAO) is in rapid transition, largely driven by North Pacific environmental change, allowing it to become accessible to a range of activities. Rapid loss of sea ice cover has opened up the CAO for potential fishing opportunities. The agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (CAO) has been signed by Canada, United States, Iceland, Kingdom of Denmark, Norway, Russia, the European Union as well as China, Japan, and Korea, and is expected to enter into force soon. Scientific research in the CAO to inform and support policy decisions, however, remains scarce in contrast to an abundance of research in the neighboring North Pacific Ocean. With substantial science and policy challenges occurring in the Arctic, an integrated ecosystem assessment of the CAO is a priority task. PICES joined forces with ICES and PAME (Protection of the Arctic Marine Environment) for such an assessment by joining the Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA)/PICES WG 39 in 2016, with its mission period ending 2021. The goals of the Pacific Arctic Gateway (a key gateway influencing the CAO) activity in the WGICA are to describe the status and trends of ecosystem components in the region and the connection of these parameters to the CAO. The Pacific Arctic Gateway has experienced rapid environmental change in recent years due to reduced sea ice extent and seawater warming that can impact shelf-basin exchange of water mass components and biological taxa into the offshore Arctic basin. Therefore, the main objective for the workshop was to describe and discuss ecosystem processes in the Pacific Arctic Gateway and how physical and biological components extend into the CAO, with spatial focus on the outer shelf/slope regions to the basin.

Summary of presentations

About 30 people attended this 3-hour virtual Science Board-sponsored workshop on October 13, 18:00-21:00 Pacific Standard Time, in Sidney, British Columbia, Canada) at PICES-2020. One invited, 6 oral and 2 poster presentations were made. PICES members from three countries and ICES member from Norway contributed the presentations. The workshop started with a brief introduction by Prof. Sei-Ichi Saitoh, outlining the background of CAO issues and the objective of this workshop.

Dr. Jackie Grebmeier gave an invited talk titled "The Pacific Arctic Gateway: connecting the marine ecosystems of shelf/slope regions to the Central Arctic Ocean" using recorded video. She noted that key environmental drivers that influence ecosystem dynamics and response of the CAO and shelf-basin interactions include: decreases in sea ice extent and duration, seasonally warming seawater temperatures, changes in prey concentrations, and northward movement of some species, including commercial fish. She explained that the planned international Synoptic Arctic Survey (SAS) in the Pacific Arctic Gateway region and Canadian Basin seeks to quantify the present state of the physical, biological, and biogeochemical components during the 2020–2022 period coincident with other pan-Arctic SAS programs.

Dr. Hein Rune Skjoldal gave a talk titled "The influence of Pacific water on the central Arctic Ocean ecosystem: some productivity considerations". He pointed out a paradox that the low productive Beaufort Sea is the summer feeding ground for 20,000 bowhead whales and 40,000+ beluga whales. The copepod *Calanus hyperboreus* is thought to be the dominant zooplankton species in the AO and is assumed to be a main prey for bowheads.

Due to internet connectivity problems, Dr. Xiaofan Luo could not present her paper on "Mechanisms of persistent high primary production during the growing season in the Chukchi Sea". Instead, PICES showed her slide presentation, but without audio commentary.

In Dr. Takafumi Hirata's talk, titled "Sensitivity study on Planetary Boundary forcing to the Arctic marine ecosystems", he showed a sensitivity study on the quantification of environmental forcing by using different indicators for the Planetary Boundary processes as well as using different datasets for the three indicators, environmental forcing on the Arctic marine ecosystem, sensitivity of the Arctic marine ecosystem to the forcing and the resilience of the ecosystem itself.

Dr. Atsushi Yamaguchi analyzed life cycles of two sympatric mesopelagic carnivorous copepods (*Paraeuchaeta glacialis* and *Heterorhabdus norvegicus*) based on a year-long time-series of vertical stratified net plankton samples collected at an ice-station drifting through the Canada Basin to the Mendeleev Plain (SHEBA project). He pointed out that food availability is considered to be an important factor in determining the seasonality in life cycles of the mesopelagic carnivorous copepods.

Dr. Kohei Matsuno used general dissimilarity modeling (GDM) based on field data (including biological and hydrographical) and satellite data (*e.g.*, sea-ice concentration, surface chlorophyll a) during autumn from 2008 to 2017, and predicted the effect of sea-ice extent, temperature and chlorophyll a on the zooplankton community. He suggested a combination of ship observations and modeling with satellite observations could resolve the dilemma of spatial–temporal limitation of the ship-observation, and could be used to evaluate the impact of climate change on the zooplankton community in the Pacific sector of the Arctic Ocean.

Dr. Irene Alabia examined the impacts of climate change projections in the 21st century (2026–2100) on marine biodiversity in the Eastern Bering and Chukchi seas within the Pacific Arctic, a climate-sensitive

boreal-to-Arctic transition zone. She showed that future poleward shifts of boreal species in response to warming and sea ice changes are projected to alter the taxonomic and functional biogeography of present-day Arctic communities as larger, longer-lived and predatory taxa expand their leading distribution margins.

In general discussion, Prof. Sei-Ichi Saitoh introduced a plan for WG 39 to continue the momentum from this workshop with a workshop on "Integrated Ecosystem Assessment (IEA) to understand the present and future of the Central Arctic Ocean (CAO) and Northern Bering and Chukchi Seas (NBS-CS)", jointly with WG 44 (PICES/ICES WG on Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea), at the next PICES Annual Meeting in 2021.

List of papers

Oral presentations

The Pacific Arctic Gateway: connecting the marine ecosystems of shelf/slope regions to the Central Arctic Ocean (Invited)
Jacqueline M. Grebmeier

The influence of Pacific water on the central Arctic Ocean ecosystem: some productivity considerations
Hein Rune Skjoldal

Mechanisms of persistent high primary production during the growing season in the Chukchi Sea
Zijia Zhen, Xiaofan Luo, Hao Wei and Wei Zhao

Sensitivity study on planetary boundary forcing to the Arctic marine ecosystems
Taka Hirata, Yoshio Masuda, Jorge García Molinos, Irene Alabia, Keiko Sato, Toru Hirawake, Eiji Watanabe, Maki Aita-Noguchi and Sei-Ichi Saitoh

Life cycles of the two dominant mesopelagic carnivorous copepods (*Paraeuchaeta glacialis* and *Heterorhabdus norvegicus*) in the Arctic Basin: Insights from SHEBA samples
Atsushi Yamaguchi, Carin J. Ashjian, Robert G. Campbell

Predicting changes on zooplankton community in the pacific sector of Arctic Ocean analyzed by generalized dissimilarity modeling
Kohei Matsuno and Amane Fujiwara

Marine biodiversity patterns under warming and sea ice-free Pacific Arctic
Irene D. Alabia, Jorge Garcia Molinos, Sei-Ichi Saitoh, Takafumi Hirata, Toru Hirawake and Franz J. Mueter

E-Poster presentations

Occurrence and transport of persistent toxic substances in the North Pacific - Arctic region under climate change
Ruijing Li, Guangshui Na, Hui Gao, Shuaichen Jin

Dynamical Importance Triangle: a new model to explain the multi-scale variation of groundfish in Eastern Bering Sea
Peng Lian, Zelin Chen, Jiayue Gu, Suwen Ye, Xinyu Li, Xiaoyue Cui, Jiaqian Gao, Meiqi Zhang

FIS Workshop (W6) [VW6]
Research priorities for understanding the population dynamics of small pelagic fish in the North Pacific

Convenors: *Ryan Rykaczewski (USA), Akinori Takasuka (Japan)*

Background

Small pelagic fish (SPF) are critical components of marine ecosystems in the North Pacific and in various systems worldwide. These fish are the target of major commercial fisheries that provide necessary diets for the world's rapidly expanding aquaculture operations. SPF are also vital to the diets of higher predators, playing a role in the transfer of energy and organic matter from zooplankton to higher predators. However, another common characteristic of SPF populations is their high degree of temporal variability, with biomasses that can fluctuate by several orders of magnitude at decadal or multidecadal timescales. These fluctuations have been attributed to changes in climate and ocean properties, shifts in distribution or migration behavior, various ways of interspecific interactions, and variable sensitivity to commercial harvesting. The need for a forum to synthesize new findings and coordinate multidisciplinary research efforts is the motivation for a new joint ICES/PICES working group on SPF. The intent of this workshop was to discuss and prioritize research questions concerning the dynamics of SPF populations in the North Pacific.

Summary of presentations

PICES WG 43 on *Small Pelagic Fish* is a joint endeavor with ICES to apply a comparative approach to examine ecological, management, and socioeconomic questions concerning the massive populations of planktivorous fishes that sustain both commercial and subsistence fisheries. Populations of these fishes have exhibited sensitivity to climate variability and change, and the response of their ecosystems to anthropogenic forcing (both climate and fishing) can have consequences for populations of marine predators, aquaculture and marine natural products industries, and human communities that rely on these fishes as an important source of animal protein and income.

A major goal of WG 43 is to organize an international symposium on the science, management, and socioeconomics of small pelagic fishes. The PICES co-chairs viewed a workshop at the 2020 PICES Annual Meeting as an opportunity to engage with the broader PICES community (particularly with early career scientists) while highlighting plans and stimulating some enthusiasm for the symposium that is scheduled for February 2022.

We had broad participation from the PICES member countries that included both WG 43 members and guests. A total of seven talks – six of which were presented by early career scientists – and three posters were presented during the workshop. The talks focused on a variety of small pelagics from around the North Pacific basin (and included presentations on nektonic invertebrates as well as on bony fishes), and addressed a spectrum of life stages (*e.g.*, spawning, larval transport and distribution, recruitment, and adult landings). Brief periods of questions followed each talk, and a lengthier discussion followed the last of the presentations. In this discussion, it was noted that regardless of the location or taxon of focus, there are some persistent issues that emerge in our study of small pelagics. Apparent sensitivity to interannual variability in the physical conditions of the ocean (*e.g.*, temperature and the direction and intensity of advective currents) was evident in the ichthyoplankton distributions, spawning locations and timing, or in landings as highlighted during the session's talks. These shared characteristics, though not unusual in marine fishes, are probably emphasized in populations of small pelagics given their swimming abilities and rather short life spans. Another issue that was noted is the persistent challenge of forming conclusions regarding interannual-to-decadal variability given observational data that are short in duration. Another widespread need is an ability to resolve environmental-fisheries relationships in a manner robust enough so that environmental information can be incorporated into stock assessments and harvest guidelines.

A last-minute cancelation of a talk allowed the co-convenors to highlight the topics being discussed within the joint Working Group and announce the dates and location of the scheduled international symposium that is being planned. The co-convenors and the other members of WG 43 feel that the session and subsequent discussions were fruitful and helped to stimulate interest in the Working Group's activities. We are grateful for the opportunity to lead a workshop despite the restrictions of travel and social engagement that were currently faced.

List of papers

Oral presentations

Trans-Pacific "synchrony" in multidecadal change of habitat patterns for *Ommastrephes bartramii* and *Dosidicus gigas*
Wei Yu, Jian Wen, Xinjun Chen, Yi Gong and Bilin Liu

Some data on biology and distribution of larval capelin (*Mallotus villosus catervarius*) on the west Kamchatka shelf
Tatiana Naumova

Diel vertical migrant species in structure of epipelagic nekton of Pacific waters off the Kuril Islands in autumn of 2019
Pavel Emelin

Influence of environmental and population factors on herring spawn timing in Prince William Sound
Beatriz S. Dias, David W. McGowan and Trevor A. Branch

Evidence of time-varying processes in Pacific sardine stock assessments
Peter Kuriyama, Paul Crone, Kevin Hill and Juan Zwolinski

Particle tracking reveals pelagic red crabs as indicators of anomalous conditions in the California Current
Elizabeth Saraf, Stephanie Brodie, Megan Cimino, Isaac Schroeder, Michael Jacox, Steven Bograd and Elliott Hazen

Towards a plankton-based predictor of tuna recruitment
Phoebe A. Woodworth-Jefcoats and Johanna L.K. Wren

E-poster presentations

Accounting for price responses in economic evaluation of climate impacts for a fishery
Chang K. Seung, Juhyun Yi, and Dohoon Kim

Polar cod (*Boreogadus saida*) stock in the Bering Sea
Olga Maznikova, Aleksey Somov and Aleksey Baitaliuk

Variability and change of the oceanographic conditions in the feeding migrations and reproduction areas of sardine, mackerels and saury in the Northwest Pacific
Elena Ustinova, Viktor Filatov and Yury Sorokin

FUTURE Workshop (W9) [VW9]
Building a PICES early career professional network

Convenors: *Erin Satterthwaite (USA), Aoi Sugimoto (Japan), Pengbin Wang (China)*

Background

For several years, PICES has provided support for the participation of early career scientists in workshops and symposia and has recognized excellence of presentations by early career scientists at its annual meetings. It has been suggested that early career scientists should help PICES play a leading role in the UN Decade of Ocean Science for Sustainable Development (2021–2030) by bringing fresh ideas to the next chapter of scientific discovery. The purpose of this workshop was to explore formalizing the role of early career scientists in PICES, including strategies for revitalizing communications, outreach, and engagement with other international organizations.

Summary of presentations

This PICES Early Career Ocean Professional Workshop met under the co-chairmanship of Erin Satterthwaite (USA), Aoi Sugimoto (Japan), and Pengbin Wang (China) and with the support of the ECOP Workshop Leadership Team: Raphael Roman (Japan), Hiroaki Sugino (Japan), Yanhui Zhu (Japan), Alexandra Davis (Canada), and Taylor Goelz (USA), on October 15, 1800 (PDT) and October 16, 0900 (Beijing time) and 1000 (Tokyo time).

The meeting was attended by about 58 PICES participants who identified as early career ocean professionals (ECOPs) and PICES ECOP mentors.

Participants were interested in attending the workshop for:
1. Networking and collaboration: connecting with PICES ECOPs and mentors and interdisciplinary collaboration;
2. Learning how to contribute to PICES;
3. Cultivating leadership in PICES, such as PICES science;
4. Ensuring that ECOPs are engaged in PICES and their voices integrated into PICES.

Training and Mentorship: Panelist discussion

The Panelist discussion was centered around the theme of Training & Mentorship and the goal of the session was to: 1) hear from PICES mentors about their experiences, roles in PICES, and thoughts for the future, 2) provide an overview of PICES for new PICES members, and 3) to explore how training and mentorship can be an integral part of PICES ECOP engagement. The panelists, Vera Trainer (Science Board Chair), Cisco Werner (S-CCME), and Sonia Batten, presented on their involvement in PICES, the history and philosophy of PICES, the governing structure of PICES, and advice on shaping the PICES ECOP efforts. The common themes from each presentation included:
1. ECOPs should be part of PICES sections and working groups;
2. Mentorship integration is a key component for ECOP development;
3. PICES is part of a bigger picture – it has ties to many other groups and meetings;
4. PICES members have become lifelong friends;
5. PICES is a great way to meet collaborators and get large grants and funding;
6. ECOPs are way better at communication than the older generation, and they want ECOPs' help expanding the communications of PICES;
7. Maybe the PICES Annual Meeting is not enough, and we should think about multiple virtual meetings during the year;
8. Role of ECOPs in the FUTURE framework is vital.

Cisco Werner
The motto Cisco Werner used was: "PICES: it's business and it's personal". PICES is a regional and intergovernmental organization, but has generally shunned advisory roles due to fishery politics. Despite that there are many international collaborations and working groups that flourish. The vision of FUTURE needs ECOPs to sustain the work.

Sonia Batten
Sonia Batten has been a part of PICES for over 20 years! She believes that mentorship is a vital part of PICES but can be more defined than when she first joined. The PICES community has provided her with a win/win situation where she not only gets to communicate her science and participate in groups, but she has also made

connections and friends. PICES needs ECOPs to help facilitate interactions with diverse organizations, to improve on the science communication, and to integrate new skills and ideas into the community.

Vera Trainer
Vera Trainer presented on her history as a PICES member and how she became the Elected PICES Science Board Chair. She also discussed the many collaborations and successes that she has been a part of and how these types of interactions lead to more opportunities for international collaborations, mentoring, and friendships.

Science, Policy, Communication, and Diverse Engagement: Presentations by workshop organizers

Based on the feedback on top PICES ECOP priorities received from a pre-workshop survey, the workshop organizers (Erin Satterthwaite , Aoi Sugimoto, Pengbin Wang, Raphael Roman, Hiroaki Sugino, Yanhui Zhu, Alexandra Davis, and Taylor Goelz) structured the conversation around these emergent priorities. The organizers created presentations on, and facilitated discussions around, three main areas: Collaborative science, Policy and Science Communication, Coordination and Diversity Initiatives as related to ECOP engagement within PICES.

1. Collaborative science
Yanhui Zhu and Pengbin Wang

Background and introduction
Collaborative science needs to be both multidisciplinary and interdisciplinary. We should start collaborating between PICES members, but also with people from social sciences such as economics and cultural studies.
Key questions
1. Should we combine social and natural sciences?: Yes (100%).
2. Which aspect is the most important to carry on regional collaboration?: 88% said collaborative projects, 38% study groups, 13% senior professional lectures (note you could vote for more than one option).

2. Policy and science communication
Aoi Sugimoto, Hiroaki Sugino, Raphael Roman and Taylor Goelz

Background and introduction
Directly relating this topic to the United Nations Decade of Ocean Science for Sustainable Development (2021–2030). We need to engage in training and workshops to develop the communication capacity of ocean scientists in collaboration with communication specialists.

Key questions
1. What is the most important to improve science communication capacity?
2. What does ECOP engagement look like in the ocean decade?

2a. Policy engagement
Raphael Roman and Taylor Goelz

The sub-theme of policy engagement aimed at sparking conversations around ways to involve ECOPs in the science–policy interface and to reflect on how they can contribute to the UN Ocean Decade (2021–2030). Specifically, key topic areas included:
- How to communicate and build lasting relationships with mid and later career ocean professionals? (*e.g.*, opportunities for career development);

- Advocating for a greater voice in decision-making bodies;
- Policy engagement integration into a future PICES ECOP Study Group;
- What does ECOP engagement in the UN Ocean Decade look like?

Throughout the session, it appeared clear that PICES was an ideal platform to connect different stakeholders and to develop a shared understanding of contemporary issues related to the health of our blue planet. One communication roadblock to overcome is the adoption of lay and comprehensible language, especially during interactions between scientists, policy-makers and local/frontline stakeholders.

More work needs to be done to create a stakeholder base for PICES and to help ECOPs communicate and engage outside of academic and scientific circles (which is rendered difficult by PICES' membership system, which mainly targets government scientists and academics). Senior PICES members have acknowledged how challenging it has been to engage with and target different audiences around the North Pacific, making it critical to think about clear mechanisms to draw in these other communities within PICES.

It is also crucial to start developing our vision (*e.g.*, "the ocean we need for the future we want") to form a clearer and more targeted messaging aimed at informing the science we need and at reaching the right decision makers to encourage behavioral change. In addition, ECOPs can play an important role in disseminating valuable research outputs from PICES (*e.g.*, peer-review articles, reports, *etc*.) to a broader audience, and to do so in a more accessible and attractive way. This is especially true when considering dramatic ocean-related issues that require greater coverage in the near-future, and for which PICES needs support.

An example of public engagement commented on by Thomas Therriault during the workshop were organized school tours in China (during PICES-2015) and Russia (during PICES-2017), which allowed PICES scientists to interact with young audiences.

- Emmanuele Di Lorenzo proposed having a PICES delegation (which would include ECOPs) sitting down and engaging with local decision makers and marine ecosystem managers.
- Vera Trainer showed enthusiasm and optimism in the involvement of external stakeholders within PICES. She recalled the 2019 PICES-2019 workshop that engaged with fish farmers. It is another reminder of the benefits of two-way learning between the scientific community and frontline stakeholders, which further builds the case for not only increasing public engagement but also for making sure that these other communities constitute an integral part of the PICES process.
- Erin Satterthwaite mentioned the potential benefit of a connection to the US Sea Grant program and/or other Sea Grant-like organizations, especially considering their experience working with stakeholders on the ground.

Finally, some participants encouraged our proposal to include ECOPs within advisory panels and committees to notably better engage with the upcoming Ocean Decade, as it would provide ECOPs with a much better understanding of the bigger picture and of how things work at higher decision-making levels. Beyond simply ticking boxes for ECOPs representation at conferences, panels, high-level meetings and other key international gatherings, one idea would be to create task teams to allow coordination and greater communication among ECOPs (both within and outside of PICES) while ensuring that we leverage their voices accordingly.

3. Diversity and coordination

Alex Davis and Erin Satterthwaite

Background and introduction

Broadly, ECOP engagement is about sustaining diverse engagement. By increasing engagement from unrepresented countries and disciplines into PICES and the ECOP group, we can ensure that we continue to enhance diversity within PICES. We also need to consider how to ensure that diverse voices are included within PICES structure and how to engage with practitioner and other diverse audiences outside of PICES researchers. Thus, the coordination and diversity discussion was centered around 3 key questions.

Key questions

1. What are key priorities and opportunities for ECOP engagement within PICES? How can we best align with existing PICES groups and partners?
2. What other organizations serve as good models for early career professional engagement?
3. How do we identify key areas for assessment of diversity/equity/inclusion?

The discussion predominantly focused on the priorities and opportunities for ECOP engagement in PICES, how to align with existing PICES groups, and other ECOP engagement. Some general themes that emerged from the discussion included:

- *Enhance diversity within PICES expert groups*. Specifically, asking working groups to ensure diverse representation, such as career stage, may be a way to integrate and enhance diversity within PICES moving forward. For example, one participant pointed out that as new working groups are created, an effort should be made to include ECOPs.
- *Provide training on interdisciplinary and international collaboration through multiple avenues of engagement in PICES.* Since PICES is an intergovernmental science organization, it utilizes its strengths and structure to train ECOPs on intergovernmental organizations, provide exposure to both research and non-research activities, and build leadership skills.
- *Include an ECOP voice within PICES structure to ensure diverse representation*. It may be important for ECOPs to have a more long-term structure within PICES that can advise on the engagement of ECOPs. This would likely be a more permanent entity than a study group. For example, an advisory panel would be a valuable and effective medium/platform, since it can adapt to the needs of the scientific and PICES communities. This would enable the ECOP community to speak with one coherent voice, rather than having a small voice within a separate larger expert group. In addition, an ECOP could sit on the Science Board or serve on various advisory panels.
- *ECOPs can participate in existing PICES expert groups to learn by doing (e.g., international science collaboration, PICES structure, leadership skills)*. ECOPs can participate in multiple PICES expert groups that fit their individual areas of expertise and these ECOPs can report back to the ECOP group.
- *Integrate and ensure connectivity with PICES structures and other ECOP groups*. It is important that the PICES ECOP group is integrated into PICES. For example, it may be useful for the ECOP group to meet with the FUTURE Scientific Steering Committee regularly to exchange ideas on FUTURE. This is one mechanism by which ECOPs can work toward interdisciplinary and international science collaborations. In addition, participants suggested that connectivity to other ECOP networks and groups, such as those like IMECaN, are important to share knowledge, experience, and resources and when possible synergize activities.

Summary and Closing Remarks

There was strong support from the group for continuing to explore opportunities for continued ECOP engagement. PICES ECOP engagement could be through: 1) training and mentorship, 2) interdisciplinary and international science collaboration, 3) policy engagement and science communication, and 4) diverse engagement and collaboration.

Some of the main action items that were discussed include:

- *Connect: Establish a PICES ECOP community and network*. In order to attract our future ECOPs, it is necessary to build up an inclusive community that aims at providing opportunities and enhancing broader communication between our members. The established community should consist of ECOPs, supporters, and mentors. This will start as a PICES ECOP study group.

- *Train: Use the structure of PICES to train the next generation of ocean leaders in international, interdisciplinary, and cross-sectoral scientific collaborations and communication*. Since PICES is an intergovernmental science organization, it can utilize its strengths and structure to train ECOPs in intergovernmental organizations, provide exposure to both research and non-research activities, and build leadership skills. Specifically, ECOPs could participate in existing PICES expert groups to learn by doing (*e.g*., international science collaboration, PICES structure, leadership skills). ECOPs could participate in multiple PICES groups that fit their individual areas of expertise, these ECOPs could report back to the ECOP group, and they could possibly be able to develop a more permanent entity, (*e.g*., an advisory panel) to adapt to the needs of the scientific and PICES communities. In addition, an ECOP could sit on the Science Board or serve on various advisory committees to cultivate governance and leadership skills.

- *Communicate*: *Convert science and knowledge into practice*. Our ECOP community should convert our knowledge into practice. Composed of interdisciplinary members, our community has an advantage of exchanging fresh, various, and creative ideas. Those ideas can contribute to the progress of sustainable development within the context of the marine environment. The future PICES ECOPs community will collaborate with other organizations such as universities, governments, NGOs, industries, and foundations. Collaboration and development of our science communication with those outside of PICES will help us discover problems and create cooperative solutions.

- *Sustain diverse engagement*: *Be an important component in the future of PICES*. Our future ECOPs will be integrated into PICES and look forward to growing into a vital part of PICES. Following PICES science and focal areas, our work will also focus on the regions in the North Pacific Ocean. Although we are a young community, we will lead with conviction and contribute to the PICES. Additionally, we envision that the proposed study group may recommend an advisory panel for the PICES governing body to ensure diverse and inclusive representation in PICES.

We greatly appreciated all of those who developed, supported, and attended the workshop.

List of papers

Oral presentations

Discussion on early career ocean professional engagement in PICES

Topics included: collaborative interdisciplinary science, policy engagement and science communication, and early career professional coordination and diverse engagement

E-Poster presentations

Economic feasibility of developing the low-fishmeal feed for Olive Flounder
Juhyun Yi and Dohoon Kim

Marine fishery policy adjustment in China since 2011
Meng Su, Lingling Wang, and Jiahao Xiang