Science Board Meeting 2022 — Note from the Science Board Chair

Vera Trainer

What a joyous occasion it was for us to meet again at beautiful Haeundae Beach in Busan, Korea, for our 31st PICES Annual meeting (PICES-2022), 19-22 October 2022. Soon after I became the PICES Science Board Chair at the end of PICES-2019, it became clear that I might be a completely "virtual" Science Board Chair, destined to hold on-screen meetings for my entire 3-year term because of the Covid-19 pandemic. However, the Korean organizing committee, the PICES Secretariat, and the complex travel arrangements that many of you had to make before coming to Korea, ensured that our in-person conference was successful. It was wonderful to see people in 3 dimensions – to share a cup of coffee, catch up on science, and make new friends. For the first time ever, the conference organizers had to bring in more chairs for the Closing Ceremony – a testament to the fact that we were reluctant to say goodbye to one another. There were many highlights at PICES-2022, several of which I will share with you as my last assignment as PICES Science Board Chair.

In total, PICES-2022 welcomed 271 in-person attendees from 13 countries, with a total of 443 total participants, including those who connected virtually. These attendees included 111 Early Career Ocean Professionals (ECOP), 21 organizations or programs, 17 expert groups, and 7 committee meetings. At PICES-2022, we enjoyed the Science Board Symposium, 8 topic sessions, 4 paper sessions and 9 Workshops. There were a total of 170 oral presentations (8 invited) and 68 poster presentations.

Secretariat colleagues Julia Yazvenko and Lori Waters enjoy the PICES-2022 opening

The dedication of all the members of the local organizing committee and the PICES Secretariat: Sonia Batten, Sanae Chiba, Alex Bychkov, Christina Chui, Julia Yazvenko, Susan Hannah, Saeseul Kim, Rosalie Rutka, Lori Waters and Robin Brown (retired), are greatly appreciated.

PICES Annual Science Awards
The accomplishments of several PICES members were acknowledged at PICES-2022 through our annual science awards. The Chair award was presented to Professor Chul Park for guiding PICES with enthusiasm through all the challenges until the end of his term in 2020. Professor Park is currently serving as the past-chair of the PICES Governing Council and has had many leadership roles on PICES committees. The Wooster Award was presented to Dr. Hal Batchelder for his sustained excellence in research and teaching of marine science in the North Pacific Ocean. Although Hal could not participate in person at PICES-2022, a video highlighting Hal's extensive contributions was presented to thank Hal for his dedication to PICES over many decades. The Zhu-Peterson early career scientist award was presented to Dr. Matthew Savoca (USA), a member of the Advisory Panel on Early Career Ocean Professionals (AP-ECOP) and WG42, who makes valuable contributions to PICES science through his work on marine ecosystem responses to climate variability and change, cetacean movement and behavior, and marine debris and pollution. Finally, the PICES Ocean Monitoring Service Award (POMA), was given to the Japanese monitoring research activities on mesozooplankton for its long time series of mesozooplankton monitoring that began in 1949 with more than 17,000 zooplankton tows. This work has contributed to our knowledge of mechanisms of the long-term variability of fisheries productivity. More details about these awardees can be found in the companion article in this issue of PICES Press. I extend my heartfelt congratulations to all the winners!

PICES in the UN Decade of Ocean Science for Sustainable Development (UNDOS)
The collaborative UN Decade program with ICES, Sustainability of Marine Ecosystems Through Global Knowledge Networks (SmartNet) was officially endorsed as a Decade "Network Program" in early 2021, and leverages the expertise and infrastructure of ICES and PICES to reach far beyond our established networks, with the aim of advancing and sharing scientific understanding of marine ecosystems. SmartNet facilitates cross-cutting inclusivity themes relating to gender equality, early career ocean professional (ECOP) engagement, and involvement of indigenous communities and developing nations via PICES collaborations with ICES. In addition, the Advisory Panel on the UN Decade (AP-UNDOS), focuses more specifically on PICES contributions to the decade by looking beyond our PICES region to share our knowledge and skills with scientists around the world. SmartNet wishes to encourage and support new and existing PICES expert groups to participate in all aspects of the UN Decade. Examples of this participation are seen in the initiatives endorsed by UNDOS which PICES members are co-leading, such as: the ICES/PICES/FAO International Symposium on Small Pelagic Fish (SPF 2022) held from 7-11 November 2022 in Lisbon, Portugal; the ICES/PICES Early Career Scientist symposium, held from 9-12 May 2022 in St. John's, Newfoundland, Canada; and the Marine Socio-Ecological Systems Symposium (MSEAS), re-scheduled for 2024.

Environmental sustainability
We continue to discuss PICES contribution toward environmental sustainability. This can be achieved, in part, by holding some of PICES business meetings virtually. Virtual meetings reduce our carbon footprint and play a small part in mitigating climate change. Our cumulative carbon savings from holding virtual meetings was equivalent to: taking 230 cars off the road for 1 year; not burning 450,229L of gasoline; or the equivalent of CO_2 taken up by 17,478 tree seedlings over 10 years. This illustrates the importance of PICES scientists leading by example in adopting a combination of virtual and in-person meetings as a part of the organization's reduced-carbon vision. PICES will continue its tradition of holding some in-person meetings, with the realization that seeing one another in person is an irreplaceable way to connect. The Study Group on Generating Recommendations to Encourage Environmentally-friendly Networking (SG-GREEN), will meet over the next year to provide recommendations for PICES approach to increased environmental sustainability at future meetings.

PICES-2022 Meeting Highlights
PICES-2022 theme was *"Sustainability of Marine Ecosystems through Global Knowledge Networks during the United Nations Decade of Ocean Science for Sustainable Development"*.

Dr. Sukyung Kang delivers her Keynote Address during PICES-2022 Science Board Symposium

PICES is well-positioned as a northern hemisphere leader of multi-national collaborations to further our understanding of the ocean's natural systems, especially during the UN Decade. During the PICES-2022 opening Science Board Symposium, inspirational talks focused on various aspects of our work during the UN Decade, including a keynote presentation by Dr. Sukyung Kang, entitled, *"Better engagement of PICES science for the UN Decade of Ocean Science: A Korean Perspective"*. Other presentations highlighted our joint work on UN Decade issues including: *Intersection of the UN Decade and the PICES FUTURE science program* (Fangli Qiao); *Increasing capacity and incentives for data exchange* (Jeanette Gann); *How to engage with small island developing states* (Naya Sena); *Co-designing climate solutions* (Emanuele Di Lorenzo); *Plastics research* (Gennady Kantakov); *SmartNet goals and plans* (Steven Bograd); *A catastrophic ecosystem event on the Kamchatka Peninsula* (Vyacheslav Lobanov); *Hypoxia in the Pacific Northwest* (John Barth); and, *Lifting Indigenous voices to empower the next generation of ocean leaders* (Misty Peacock).

Other topic sessions held this year focused on human dimensions of ocean science, artificial intelligence, predicting climate variability and change, small pelagic fish, ocean acidification and other stressors, connecting science to decision making, eDNA, zooplankton, plankton imaging and more. The many speakers, followed by questions and conversations, showed the great versatility and commitment of PICES and partner scientists to connect with their colleagues by sharing their science. I extend my sincere thanks to all the presenters and organizers.

Many PICES expert groups, including Working Groups (WG), Sections, and Advisory Panels (AP), met virtually prior to PICES-2021. I am impressed by the dedication shown by the many PICES groups who held their meetings virtually prior to PICES-2022, then often met again during PICES-2022. Their reports can be found on the PICES website under the "Members" tab, with accomplishments that are too numerous to summarize here. However, I want to highlight the overarching accomplishments of two of the new PICES Advisory Panels whose future plans will have impacts on all of PICES science during the UN Decade and beyond: AP-ECOP and AP-SciCom.

Advisory Panels on Early Career Ocean Professionals and Science Communication

AP-ECOP view themselves as the "cross pollinators" of PICES. They held their first in-person workshop where the chairs of PICES Committees (POC, FIS, BIO, MEQ, HD, TCODE, MONITOR) gave presentations to ECOP to introduce them to their objectives, scientific focus, and ways for ECOP to become more involved. All PICES scientists, young and old, experienced and more novice, were inspired at this workshop and showed their commitment to engage with one another. The future of PICES through the engagement with ECOP is bright! The AP-ECOP is strengthening its collaborations with other early career networks, such as with the Deep Ocean Early Career Researchers (DOERs), ICES "Strategic Initiative on the Integration of Early Career Scientists" (SIIECS) and the UN Decade ECOP Programme. More information about ECOP accomplishments and activities can be found in a companion article in this issue of PICES Press. Please continue to include ECOP in new PICES Expert Groups and support their involvement in PICES by becoming a mentor.

Communication of our key and important scientific findings to the global community, including scientists from a wide range of disciplines, policymakers, and the general public was the focus of the workshop held over two days by the Advisory Panel on Science Communication (AP-SciCom)

(see related story in this issue). Effective communications strategies were discussed, especially those that build upon the And-But-Therefore (ABT) method, established by Dr. Randy Olson. This structure provides an analytical, objective way to work with the narrative fundamentals that reside inside everything from argumentation, to logic, to comedy, to the scientific method, and, of course, the telling of stories. Over the next year, the AP-SciCom will also be helping the PICES Secretariat to establish a new aesthetically-pleasing and informative public-facing page of the PICES website.

Moving into the FUTURE

Several new PICES expert groups approved in 2022 by PICES Governing Council (GC) include: the Working Group on Exploring Human Networks to Power Sustainability (WG51); the Study Group on the Arctic Ocean and the Pacific Gateways (SG-ARC); and the Study Group on Encouraging Data Awareness and Increased Transmission and Accessibility (SG-DATA). You can find out more about these groups by visiting their webpages on PICES website, and by reading the GC decisions here.

The overarching science program of PICES is *Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems* (FUTURE). The FUTURE steering committee has decided that during Phase III, this flagship program will be retained to continue integrating PICES varied science, and by including human dimensions into our work. FUTURE would like to facilitate cross-pollination by collaborating strongly with the PICES Advisory Panels, including AP-UNDOS, AP-ECOP and AP-SciCom. Around 2025-2027, the emergent themes identified in the UN Decade of Ocean Science for Sustainable Development will help mold a new Science Program for PICES.

As Science Board Chair, I'd like to remind PICES members - especially early career scientists, that FUTURE has a SEES (Social-Ecological-Environmental Systems) Award which supports travel costs of an early career scientist to a PICES Annual Meeting. No SEES Award was given this year, so I hope that PICES members will please consider nominating an early career scientist in future for this award. Please see PICES website for award criteria and application process.

Publications

Several interesting recent publications listed below have been approved and are posted on the PICES website or in the peer-review literature. Please take a look at these scientific communications if you have not already done so. All PICES-sponsored publications require review by Science Board (SB) and approval by GC before being posted on the website. Selected recent publications include a MONITOR-supported product of the North Pacific Continuous Plankton Recorder (CPR) project; the recent IPCC AR6 Report, supported by the Section on Climate Change Effects on Marine Ecosystems and authored by

many PICES members, including Dr. Shin-Ichi ito and Kirsten Holsman; Three papers resulting from the work of WG42, the Working Group on Indicators of Marine Plastic Pollution; and three papers resulting from the work of WG46, the Joint PICES/ICES Working Group on Ocean Negative Carbon Emissions (ONCE). Lastly, the work of WG36, the Working Group on Common Ecosystem Reference Points across PICES Member Countries, has submitted a manuscript which has been endorsed by FUTURE-SSC, and which will be published as PICES Scientific Report #64, to be entitled: Common Ecosystem Reference Points Across PICES member Countries. To review the available publications, please visit the links in the citations below.

- Batten, S.D., Ostle, C., Hélaouët, P. and Walne, A.W, (2021) Responses of Gulf of Alaska plankton communities to a marine heat wave. Deep Sea Research Part II: Topical Studies in Oceanography,105002,ISSN 0967-0645, https://doi.org/10.1016/j.dsr2.2021.105002.

- IPCC AR6 WKII : Climate Change 2022: Impacts, Adaptation and Vulnerability, https://www.ipcc.ch/report/ar6/wg2/

- Uhrin, A.V., Hong, S., Burgess, H.K., Lim, S. and Dettloff, K., 2022. Towards a North Pacific long-term monitoring program for ocean plastic pollution: A systematic review and recommendations for shorelines. https://doi.org/10.1016/j.envpol.2022.119862

- Shim, W.J., Kim, S.K., Lee, J., Eo, S., Kim, J.S. and Sun, C., 2022.Toward a long-term monitoring program for seawater plastic pollution in the north Pacific Ocean: Review and global comparison. Environmental Pollution. https://doi.org/10.1016/j.envpol.2022.119911

- Savoca, M.S.,et al.., 2022. Towards a North Pacific Ocean long-term monitoring program for plastic pollution: A review and recommendations for plastic ingestion bioindicators. Environmental Pollution. https://doi.org/10.1016/j.envpol.2022.119861

- Cai, W. J., & Jiao, N. (2022). Wastewater alkalinity addition as a novel approach for ocean negative carbon emissions. The Innovation, 3(4), 100272, https://doi.org/10.1016/j.xinn.2022.100272

- Wang, Y., Lu, Y., Liu, J., and Zhang, C. (2022). Advocating eco-engineering approach for ocean carbon negative emission. Bulletin of Chinese Academy of Sciences (Chinese Version), 36(3), 279-287. https://doi.org/10.16418/j.issn.1000-3045.20210308001

- Liu, J., Robinson, C., Wallace, D., Legendre, L., & Jiao, N. (2022). Ocean negative carbon emissions: A new UN Decade program. The Innovation, 3(5), 100302. https://doi.org/10.1016/j.xinn.2022.100302

Collaborations

Many of the issues facing our oceans are too big to be tackled alone by one organization or one country. At PICES-2022, several external organizations and programs attended. Several strategic partners including the International Council for the Exploration of the Seas (ICES), the Asia Pacific Network (APN), the North Pacific Fisheries Commission (NPFC), the Scientific Committee on Oceanic Research (SCOR), the Basin Scale Events to Coastal Impacts project (BECI), the International Pacific Halibut Commission (IPHC), the Integrated Marine Biosphere Research Project (IMBeR), the North Pacific Research Board (NPRB), PICES SEAturtle Project, and the Future Earth Global Network participated in PICES-2022 to discuss ongoing and future collaborations. These and other partners will be vital to PICES expanding its influence and geographical scope during UNDOS.

PICES is sometimes requested to provide science and technical expertise in special projects dealing with marine issues in countries outside the PICES region. One such special project, the Ciguatera Project, began in 2020, and is supported by the Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan. The project will build local warning networks to assess, detect, and avoid human ingestion of ciguatera fish poisoning in Indonesia, by training local communities to use PICES-developed smartphone technology to monitor environmental conditions and fisheries. This project aims to assist the Indonesian government to enhance its capacity for collecting data to improve management practices. Similarly, the PICES Special Project, SEAturtle, is funded by the Ministry of Oceans and Fisheries of Korea, and examines sea turtle ecology in relation to environmental stressors in the North Pacific region. Focused primarily on endangered sea turtle populations found in the southern waters off Korea, Japan, and China, the Project Science Team (PST) aims to understand the threats to sea turtle habitat and ecology in relation to anthropogenic activities. SEAturtle team members have demonstrated the migration route of sea turtles using Iridium satellite-tracked tags, and recently published a paper on the impact of derelict fishing gear on sea turtles. Both of these PICES Special Projects will end in 2022, and illustrate how PICES can extend its expertise to nations outside the PICES geographical area, especially during the UN Decade.

At the conclusion of PICES-2022, several PICES leaders completed their terms as Committee Chairs, including Dr. Sukung Kang who is stepping down as FUTURE Co-Chair and Professor Emanuele Di Lorenzo, who is stepping down as POC Co-Chair. I give my sincere thanks for their contribution to their Committees and their Science Board activities. Dr. Sukyung Kang, Korea, became the new PICES Science Board Chair at the closing of PICES-2022. Sukyung has been an active leader in PICES for many years, through her role as Co-Chair of FUTURE and more! Other

Outgoing and incoming Science Board Chairs Vera Trainer and Sukyung Kang together at PICES-2022

new Committee Chairs are: Jeanette Gann (USA) who was elected Vice-Chair of Science Board; David Kimmel (USA), BIO Committee Vice-Chair; Lei Zhou (China), POC Committee Chair; and Kym Corporon Jacobson (USA), MONITOR Committee Vice-Chair. Thank you to these new Committee members and those who have been re-elected to their Committee for a second term. I look forward to Dr. Kang's leadership, and to see these new Science Board members shape PICES activities with the support of the PICES family.

In closing, I finished my three-year term as Science Board Chair at the closing ceremony of PICES-2022. It was my dream to be able to attend, as SB Chair, at least one in-person meeting with the PICES community. This dream came true in Busan, Korea, where the enthusiasm and commitment of PICES scientists was rewarded with inspiring scientific talks, social events and plans for research collaborations for the future. The collegial atmosphere of PICES annual meetings is made possible through the hard work of the PICES Secretariat, to whom I am extremely grateful for their assistance. The role of PICES is even more important in this changing world where scientists hold hands to accomplish the difficult task of preserving our shared oceans, especially through collaborative science during the UN Decade of Ocean Science for Sustainable Development. As we look back at our numerous accomplishments this year, let us also remember the shoulders of those giants who have gone before us. We remember especially Timothy Parsons, who passed away on 11 April 2022. He was an active and influential member of the PICES community and a valued mentor of young scientists. As we look to our scientific and personal goals for the coming year, let us strive to be like Tim by building bridges in our communities close to home and across the seas.

I look forward to welcoming you all in person to my hometown, Seattle, Washington USA, for the PICES-2023 meeting, where we will continue our important work together. And finally, I wish you all a fulfilling end to 2022 and a very happy and healthy 2023.

FUTURE SSC's 8ᵗʰ Annual Meeting ~ Highlights
Steven Bograd, Sukyung Kang and Hanna Na

The FUTURE Scientific Steering Committee (herein after referred to as "FUTURE") held its 8th annual meeting since 2014. FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems) is PICES' second integrative science program, which was launched at PICES-2009. This year's annual meeting was held in-person (with hybrid option) on September 28th/29th at the PICES-2022 Annual Meeting in Busan, Korea. The meeting was led by FUTURE SSC Co-Chairs Steven Bograd and Sukyung Kang, and was attended by 10 SSC members in addition to three guests.

We reviewed recent activities of four working groups (WG36, WG40, WG41 and WG49), AP-ECOP and SG-UNDOS that are parented or co-parented by the SSC: 36 (Common Ecosystem Reference Points); 40 (Climate and Ecosystem Predictability); 41 (Marine Ecosystem Services); 49 (Climate Extremes and Coastal Impacts in the Pacific); AP-ECOP (Early Career Ocean Professionals) and SG-UNDOS (United Nations Decade of Ocean Science).

Review of 2022 activities

There has been a change in FUTURE SSC membership since the last PICES annual meeting. Dr. Tetsuo Fujii has stepped down as a FUTURE SSC member from Japan, to take on the role of PICES Vice-Chair. Dr. Daisuke Hasegawa has become a new SSC member from Japan to replace Dr. Fujii. We thank Dr. Fujii for his service to FUTURE, and welcome Dr. Hasegawa to the SSC! In addition, long-time SSC Co-Chair Dr. Sukyung Kang (Korea) has stepped down from her Chair role and is now the Science Board Chair. The SSC elected Dr. Hanna Na (Korea) as the new FUTURE SSC Co-Chair. We are very grateful for Dr. Kang's leadership for the FUTURE Science Program, and look forward to Dr. Na's leadership as FUTURE continues its Phase III. The SSC updated the FUTURE liaison table to reflect these changes.

The SSC reviewed FUTURE activities since its last (virtual) inter-sessional meeting in April 2022. A key accomplishment this past year was the completion of the FUTURE Product Matrix to include the latest expert groups, with tremendous assistance from Saeseul Kim from PICES Secretariat. The Product Matrix links products developed by PICES expert groups to specific objectives and questions of the FUTURE Science Program, allowing for an easily accessed catalogue of FUTURE-relevant products as well as a synthesis of products and a gap analysis of unmet objectives. At our annual meeting, the SSC prepared an outline for a journal manuscript that will use the Product Matrix to highlight key achievements of the FUTURE program, identify knowledge gaps and the reasons they remain, and determine next steps for addressing FUTURE's goals.

Some highlights:

• WG36 and WG40 have prepared final reports and completed their terms, which were very productive. WG36 produced two peer-reviewed manuscripts, on a case study of ecosystem responses to environmental and human pressures for the west coast of Vancouver Island, and on methodologies to quantify thresholds in ecological time series. WG40 organized a special issue of Frontiers in Marine Science on 'North Pacific Climate and Ecosystem Predictability on Seasonal to Decadal Timescales'.

• WG49 held a first virtual meeting in August 2022 and a first in-person meeting in Busan at PICES-2022, where they established a membership that is balanced by country, disciplinary expertise and career stage, and reviewed its terms of reference. New Co-Chairs were selected for WG49 and approved by SB and GC: Karen Hunter (Canada), Helen Killeen (USA), Chan Joo Jang (Korea), Hiroki Wakamatsu (Japan), and Antonietta Capotondi as ex officio from CLIVAR.

• SG-UNDOS continued to lead PICES engagement in the UN Decade of Ocean Science through April 2022, when they submitted a proposal for a longer-term Advisory Panel to guide PICES UNDOS activities. The new AP-UNDOS was approved by SB and GC and conducted its first meeting in Busan at PICES-2022.

The SSC continued planning for the next, long-delayed FUTURE Open Science Meeting, which would aim to highlight and synthesize accomplishments of the FUTURE Phase II (2014-2020) Science Program, with an emphasis on the application of the SEES approach in the context

Working Group 49: Climate Extremes and Coastal Impacts in the Pacific, at PICES-2022

of the UN Decade of Ocean Science for Sustainable Development. Due to travel constraints and delays related to the Covid-19 pandemic, and with many other meetings now being scheduled for 2022-23, we decided to target spring 2024 for the meeting and link a one-day FUTURE Symposium to an existing planned Meeting (e.g. the Marine Social-Ecological Systems Symposium in Yokohama) or an UNDOS Symposium in China. The SSC will continue to work with the Secretariat on meeting planning and logistics, including exploring alternate meeting structures such as 'ideation' workshops to develop ocean solution roadmaps and events aimed at early career ocean professional participation.

Additionally, the SSC heard a presentation from Robin Brown on the UNDOS-endorsed Project 'Basin-Scale Events to Coastal Impacts' (BECI). BECI, led by the North Pacific Anadromous Fish Commission, aims to be an ocean intelligence system for fish and people. The SSC expressed support for BECI and had a lively discussion on how to coordinate BECI activities with those of FUTURE and SmartNet.

Future of FUTURE program

Following our inter-sessional meeting in April 2022, the FUTURE SSC decided to continue strategic discussions about the plans and priorities for the FUTURE Science Program in the coming years. This discussion was motivated in part by the accelerating efforts PICES is committing to the UN Decade of Ocean Science (UNDOS), and especially the joint ICES-PICES UNDOS Program SmartNet (see SmartNet Workshop review in this issue of PP). A virtual joint meeting between FUTURE SSC and SB was held in August 2022, and the discussion continued at the PICES-2022 Annual Meeting. While there are a number of ideas about how to advance Phase III of the FUTURE Program, the SSC and SB agreed on several priority recommendations:

1. Retain a Flagship Science Program to integrate PICES science;
2. Maintain the momentum of FUTURE and proceed with Phase III tasks;
3. Bring ECOPs and others into SSC membership for new ideas and enthusiasm;
4. Facilitate cross-pollination across FUTURE, AP-UNDOS, AP-ECOP, AP-SciComm [FUTURE recommendation: Joint AP meeting at Annual Meeting];
5. Renewed focus on science-based solutions & operational products;
6. Around 2025-2027, rethink a new Science Program for PICES, informed by emergent themes identified in UNDOS.

Discussions about the future of FUTURE, and synergies with SmartNet and UNDOS activities, will continue within PICES.

Upcoming FUTURE activities

The FUTURE SSC prepared an Action Plan for the coming year, which includes:

- finalizing and disseminating FUTURE Phase II Product Matrix and Final Report;

- preparing a synthesis paper on the FUTURE Product Matrix;

- planning for the 2024 FUTURE Open Science Meeting;

- continuing strategizing on future of FUTURE; and

- preparing our next inter-sessional meeting in spring 2023 and FUTURE SSC annual business meeting in Seattle in October 2023.

PICES-2022 and the first hybrid annual meeting
Sonia Batten, PICES Executive Secretary

After two virtual annual meetings in 2020 and 2021, and much uncertainty this spring, it was truly fantastic to look around the venue at the opening ceremony for PICES-2022 and see so many familiar and new faces there in-person, even if partially hidden by masks! It was a smaller annual meeting than those in the years just before COVID, with 271 in-person participants instead of 500 or so. We had 342 registrants in total, so almost 80% were in-person, although this does not include the expert group members who attended the virtual business meetings for their group held ahead of time, but were not able to attend during the week of PICES-2022 as well. Of the registrants, 32% were Early Career Ocean Professionals (ECOP) with 91 present in-person. Providing an opportunity and a place for ECOP to present their science, for many of them for the first time in-person at an international event, was an important successful outcome of PICES-2022. We are also now collecting voluntary gender information from registrants and we can say that women made up 32% of registrants overall, and 44% of the ECOP. Our goal is to be closer to 50% and to maintain this ratio through all career stages and we look to our member countries for help and support in achieving this.

Several articles in this issue describe the workshops, sessions and other activities that took place so here I want to focus on the fact that because not everyone was able to travel we attempted to deliver a modestly-hybrid annual meeting to try to address that. The PICES Secretariat is small and we don't have the human resources to manage a completely hybrid event. Using a commercial company to deliver this component is costly and with the uncertainties regarding the pandemic still in place in spring 2022 we opted to keep it simple this year. We also have to work within our host country's capacity too which will be a consideration in future years.
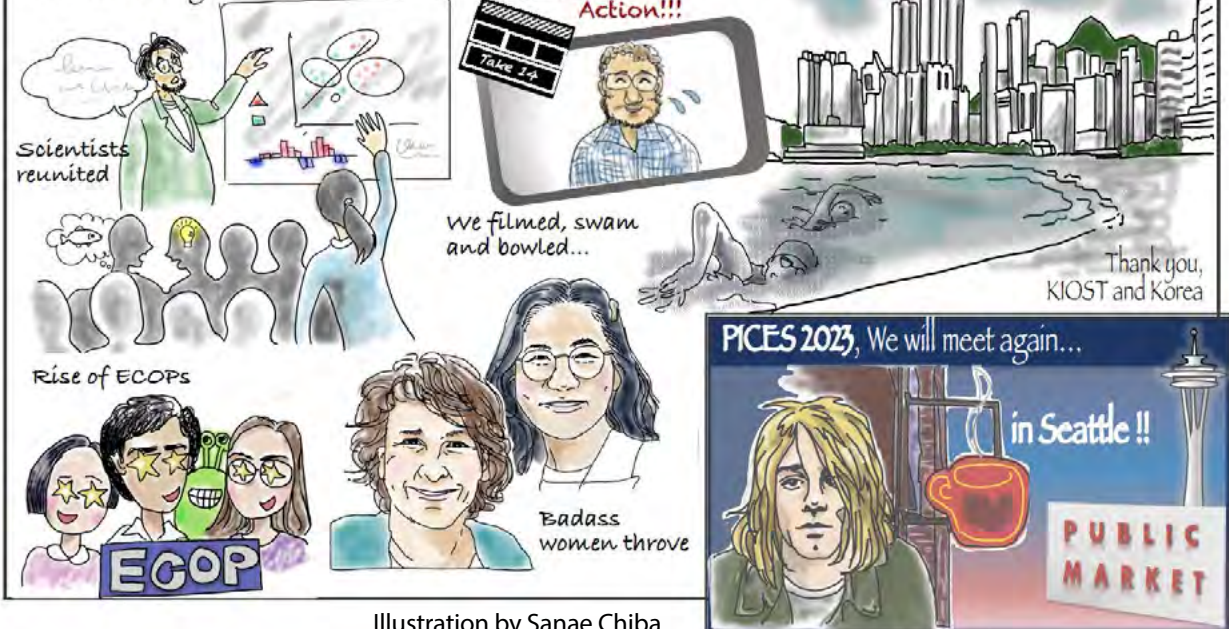

Illustration by Sanae Chiba

Sustainability of Marine Ecosystems
through Global Knowledge Networks during the
United Nations Decade of Ocean Science for Sustainability

PICES-2022

Sept 23 - Oct 2, 2022 | Busan, Korea

We had asked expert groups to hold virtual meetings in advance of PICES-2022 and this seemed to work well, allowing a timely flow of information to the Committees. During PICES-2022 itself Committee business meetings, and some workshops, made use of "Meeting Owls" and Zoom to enable remote and in-person attendees to get together. We also allowed recorded presentations in the topic sessions and most were a mixture of live in-person and pre-recorded talks. Our hosts from KIOST arranged live-streaming of the opening and closing ceremonies and the Science Board Symposium to remote participants too and provided extra Owls so that we were able to hold more simultaneous hybrid events.

We surveyed the convenors of these events that were held in hybrid mode afterwards, to get their feedback, and I'd like to share the main messages that came from that here:

• Hybrid events added additional challenges – technology wasn't always up to it (sound quality in particular) and more person-power was needed than normal to i) manage the technology and ii) make sure that remote and in-person participants were equally included and to take notes in workshops and business meetings. Many respondents felt that a dedicated person will be needed to manage the remote aspects, but it was also more demanding for the Chair/ convenors to run the session and the load needs to be shared in future so it is not on one person's shoulders.

• We can do a better job of sharing remote participation possibilities with our members ahead of time, to make sure that as many attend as possible, but everyone felt that hybrid business meetings are the way of the future and will maximise member participation.

• Having recorded presentations in topic sessions would be better if the author was available online afterwards to answer questions and make it more interactive for the audience, but it was noted that time zone differences may not always be helpful.

• Even post-covid, people will face challenges to travel to in-person meetings because of financial, time, mobility, or environmental constraints and all respondents felt that future annual meetings would be better as a hybrid than in-person only because it will likely increase participation. Most also felt that hybrid annual meetings would be better than virtual only, because of the value of in-person connections and discussion, but there are some types of smaller events that can be well done as virtual-only.

One of the unavoidable challenges we face with hybrid and virtual meetings is the issue of time-zones. From the east coast of North America to western Russia, PICES member countries span 13 time zones. We also frequently have invited speakers from other countries and our joint expert groups with ICES have members based in Europe too so in reality we may have people joining from every time zone. Many of us have now attended events on-line at unusual hours and this is manageable for a short meeting on one or two days, but it becomes much more challenging to remotely participate in an event that lasts 8 hours a day for multiple days in a row, especially if it occurs outside of office hours. Hybrid annual meetings will have to occur predominantly in the working day of the venue so for remote participants on the opposite side of the Pacific this won't be at an optimal time of day and it is likely that remote participants will have to be selective in the components they attend.

PICES-2022 Local Organizing Committee Members with PICES Executive Secretary, Sonia Batten.

The Secretariat would welcome any other feedback on aspects that may improve future hybrid events. Its still a fluid meeting landscape and we will try to evolve with it as best we can. Thank you to all of you who attended PICES-2022 events, and to our Korean hosts who went above and beyond, it all contributed to a highly memorable and successful meeting! For any of you who missed it, please enjoy the photo gallery from PICES-2022 on the following pages (and also on PICES Flickr account) where you'll see new and familiar faces. We hope to see you in Seattle!

PICES PRESS

Photo: Lori Waters
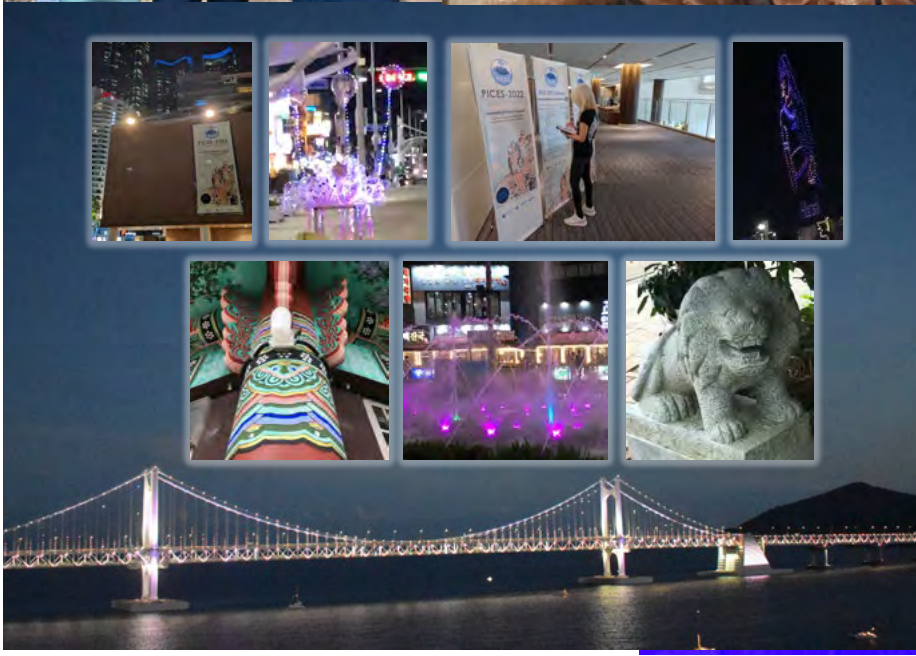
Congratulations to PICES-2022 Award Recipients

PICES-2022 Chair Award

The establishment of the PICES Chair Award was approved at the 2016 inter-sessional Governing Council (GC) meeting. It is given for sustained contributions to the development of the Organization that have allowed it to meet the purpose as set out in the PICES Convention: *to promote and coordinate marine scientific research in order to advance scientific knowledge of the area concerned and of its living resources, and promote the collection and exchange of information and data related to marine scientific research.* The 2022 award presentation ceremony began with Prof. Enrique Curchitser (Chair of PICES) introducing the award and announcing the recipient, Professor Chul Park.

PICES-2022 Chair Awardee: Professor Chul Park (Korea)

Professor Park is a very familiar face at PICES, as he has been involved in the organization for more than a decade, and has played a prominent role in governance, as well as contributing to PICES science programs and expert groups, meetings, and capacity development. His roles in PICES have included: several years as the National Delegate for Korea; Vice-Chair of PICES from 2012 - 2016; and Chair of PICES from 2016 - 2020. He is currently serving as the Past-Chair of PICES, providing ongoing consultation and support to the current chair, the Secretariat, and PICES members in Korea.

In addition to his governance roles, Professor Park was for many years a member of PICES F&A Committee, and a member of several Expert Groups, including: MONITOR; the SG to revise PICES Strategic Plan; and Working Group 14: Effective Sampling of Micronekton to Estimate Ecosystem Carrying Capacity. Additionally, he served on local organizing committees to organize PICES meetings, as the ECS advisor for the 3rd Early Career Scientist Conference held in Busan, Korea, in 2017, and earlier was a member of the MONITOR task team for PICES-GLOBEC Implementation for PICES CCCC Science Program. Information on his early involvement in PICES is available in an earlier issue of PICES Press.

In addition to his official roles within PICES, he has attended many PICES meetings, contributed and co-presented papers, and spoken at capacity-development events, such as the first CREAMS workshop on the East Asian Seas time-series, in 2005.

Professor Park has advocated for PICES to take larger roles on the global stage, suggesting to PICES Governing Council in 2011 that PICES seek to take a larger role in the United Nations Regular Process (UNRP) for Global Reporting and Assessment of the State of the Marine Environment. He, with PICES colleague Jake Rice, were editors of the UN World Ocean Assessment, Part VI, in 2019.

The unprecedented circumstances during the initial stages of COVID-19 placed Prof. Park under much pressure, but he gracefully and with good humour guided PICES with enthusiasm through all the challenges, until the end of his term as Chair, in 2020.

Professor Park continues to be a major advocate for PICES to the Korean ocean science community, and has encouraged many Korean scientists to participate in PICES.

Thank you for your contributions, Professor Park!

Dr. Chul Park's acceptance remarks

"*Thank you for this award. Frankly speaking, I'm not sure if I should be receiving this award as one of the committee members who established it. However, thank you! I am grateful and happy to contribute to the PICES community. Thank you.*"

PICES-2022 Wooster Award

In 2000, PICES Governing Council approved the Wooster Award – the highest award that can be granted to a PICES Scientist. It is named in honour of Professor Warren S. Wooster – founder and first Chair of PICES, and a world-renowned statesman and climate variability and fisheries production researcher. Given annually to an individual who has made significant scientific contributions to North Pacific Marine Science, such as understanding and predicting the role of human and climate interactions on marine ecosystem production, the award has many illustrious past recipients.


The Wooster Award selection criteria are: sustained excellence in research, teaching, administration or a combination of the three in the area of North Pacific marine science. Special consideration is given to individuals who have worked in integrating the disciplines of marine science, and preference is given to individuals who were or are currently actively involved in PICES activities.

PICES-2022 Wooster Awardee: Dr. Harold Batchelder

The 2022 Recipient of the Wooster Award selected by PICES Science Board and PICES Governing Council is Dr. Harold P. Batchelder, affectionately known in PICES as "Hal." Hal was born to his parents Mark (a structural engineer) and Janet (a homemaker) in Glen Cove, New York. Shortly after his birth, they moved to the Boston area, where Hal's brother Mark and sister Anne were born. He spent most of his early years in New England, completing elementary, junior and senior years in the Boston area. During the summers, Hal family and grandparents spent lots of time in Hampton Beach New Hampshire, and hiking on Mount Washington New Hampshire. It is during these trips that Hal's love of the ocean (and forests) was sparked. Hal moved to Maine for college in 1973, studying Biological Sciences, and in 1977, moved to the Pacific coast and Oregon State University (Newport and Corvallis), completing his Master's degree in Oceanography working on the population dynamics and structure of intertidal sea anemones under Charlie Miller. It was Charlie who then hired Hal and two others for oceanographic sampling and taxonomic analysis of zooplankton samples collected aboard Canadian Ocean Weatherships Quadra and Vancouver at Station P in the North Pacific.
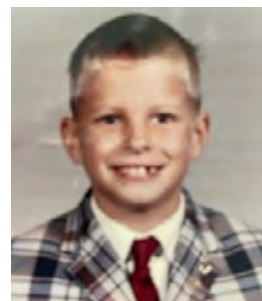
Hal received his pHD from Oregon State University in 1986 under Charlie Miller, using zooplankton samples from the subarctic Pacific. His parents were very proud, with his mother regularly joking about Hal being "her son the doctor, but not the kind that would do me any good." Following his PhD, Hal held postdoctoral and marine scientist positions at the University of Rhode Island, (with research programs and cruises in the Sargasso Sea and subarctic North Atlantic), before returning to the Pacific coast to become the first scientific director of the National U.S. GLOBEC Steering Committee Office in California. While there, Hal loved spending his spare time hiking in the Sierra Mountains, and sailing on San Francisco Bay. It

was during Hal's time at GLOBEC that PICES was founded. Following his GLOBEC adventures, Hal joined the faculty of Oregon State University. His distinguished career as a professor allowed him to champion and encourage many students and early career ocean professionals, including supervision of four Ph.D. students and three Masters students, in addition to serving on numerous graduate student committees. He also, during this time, served as Deputy Director for the NOAA-OSU Cooperative Institute for Oceanographic Satellite Studies from 2008 to 2014.

While also encouraging his OSU students, Hal worked tirelessly to facilitate early career scientist involvement in international meetings and symposia. He had active roles in planning the ICES/PICES early career scientist conference in Busan in 2017, from 2012-2021 as a member of the SCOR Capacity Building Committee, and in PICES, he set up marine science talks at middle schools in Qingdao in 2015, and was a keen supporter of early career scientists and the move to form an Expert Group dedicating to growing the role of ECOPs within PICES.

Hal's long involvement in PICES began with his attendance at PICES-1993 in Seattle, shortly after PICES' inception. He later became involved with many expert groups, including as Co-Chair of the Climate Change and Carrying Capacity program (4 C's) member of Science Board for eight years, and U.S. delegate to the Governing Council in 2012–2013. Hal joined PICES as Deputy Executive Secretary in 2014 – a role he filled until his retirement in 2021.

During Hal's time at PICES, he filled multiple functions, coordinating expert groups, planning meetings and symposia, and shepherding many PICES publications to completion, including the first North Pacific Ecosystem Status Report – one of PICES premier contributions to marine ecosystem science.

In addition to Hal's work at GLOBEC and PICES, he has contributed internationally through many workshops, symposia, and had great adventures in the process. Throughout his career, Hal has been a passionate and accomplished advocate for international cross-disciplinary marine sciences. And, with PICES colleagues, Hal was also a fashion trend-setter.

He has helped to encourage the next generation of marine scientists, also helping set the stage for the United Nations Decade of Ocean Science for Sustainable Development. His career as an internationally-recognized biological oceanographer and ocean ecologist has contributed to advancing our collective understanding of zooplankton ecology, biological-physical coupling, and marine ecosystem dynamics.

Hal has published over fifty frequently-cited journal articles in top-ranked international journals, and, on behalf of both GLOBEC and PICES, has significantly contributed to, and collaborated with, colleagues to produce several overview and synthesis articles that collectively contribute to our understanding of the world's oceans, and how best to facilitate our marine science initiatives to forward our understanding. And, all the while, Hal took time to enjoy life with colleagues, friends and family: kayaking, biking, and sharing time with PICES colleagues, including the PICES swim team.

In early September 2022, a group of PICES members and executives travelled to Oregon, to present Hal with his Wooster Award, to spend some time, and to celebrate Hal.

Hal is happy to have slowed down, and, in his retirement, he loves spending time with his grandchildren, his fur-babies (his cats), and his wife, Stephanie. Congratulations Hal, on your admirable and inspiring career, and thank you for your service to PICES and to marine ecosystems. PICES is proud to Award you it's highest award: The Wooster Award for 2022.

Dr. Hal Batchelder's acceptance remarks

Hal was very proud to receive PICES Wooster Award, and thanked all PICES members, saying: *"I really enjoyed all my time at PICES, all the interesting people that attended the PICES meetings. I want to thank you for this award"*

PICES-2021 Zhu-Peterson Award

The Zhu-Peterson Award was developed and recommended by Science Board, and established by PICES Governing Council in 2019, and is the most recent PICES award. The award is named in honor of the late Professor Minguan Zhu, formerly of the First Institute of Oceanography, State Oceanic Administration (now Ministry of Natural Resources), China, and the late Dr. William Peterson, formerly of the Northwest Fisheries Science Center of NOAA, USA. Professor Zhu and Dr. Peterson were strong advocates for encouraging early career marine scientists to become actively engaged in PICES. This ECS Award may be given annually to an individual who has performed innovative research at the frontier of science relevant to the PICES mission, as set out in the PICES Convention. Professor Zhu trained many graduate students and ECS, who carry on his legacy of honest enthusiasm for cooperative approaches to marine science research. Dr. Peterson was cherished by his students, technicians, and PICES ECS who regarded him as a "great teacher, and a fun, humble and inspiring mentor". Zhu and Peterson passed away far too early in their prime, while still actively engaged in their scientific interests. PICES honours the memories of their contributions with this Award.

PICES-2022 Zhu-Peterson Awardee: Dr. Matthew Savoca

The awardee chosen for this year's Zhu-Peterson award is Dr. Matthew (Matt) Savoca, a researcher at Stanford University. Matt received his B.S. from Cornell University;

and his PhD from University of California, Davis. He is an interdisciplinary marine ecologist with interests in marine ecosystem responses to climate variability & change, cetacean movement and behavior, biotic impacts of marine debris and pollution, and he was the winner of the 2018 'SciLifeLab Prize for Young Scientists' at a Nobel ceremony in Stockholm, Sweden. Matt is an enthusiastic science communicator, as you can see from his website: https://matthewsavocaecology.weebly.com/media--presentations.html

In PICES, Matt was a founding member of PICES WG42 on Indicators of Marine Plastic Pollution, and he is a member of the Advisory Panel on ECOPs (AP-ECOP).

Dr. Matthew Savoca's acceptance remarks

"This is great honor and quite a surprise. I have to thank Steven Bograd, who I am sure I need to give a pat on the back for it, because without him I wouldn't be here and be involved in this organization and it has really been like a fun scientific family and one I intend to be a part of for many years to come. So thank you everyone, thank you Steven and very happy to be here and accept this award. Really appreciate it."

PICES Ocean Monitoring Service Award (POMA)

The PICES Ocean Monitoring Service Award (POMA) aims to recognize organizations, groups and outstanding individuals that have contributed significantly to the advancement of marine science in the North Pacific through long-term ocean monitoring, data management, and innovative advances in ocean monitoring. The award also strives to enlighten the public on the importance of those activities as fundamental to marine science.

Progress in many aspects of marine science is based on ocean observations, monitoring, and the management and dissemination of the data provided by these activities. Long-term monitoring observations are particularly critical to detecting and understanding ecosystem changes. Monitoring activities are often taken for granted or even targeted for budget cuts when organizations experience financial constraints. With this in mind, PICES created the POMA, which aims to recognize organizations, groups and outstanding individuals that have contributed significantly to the advancement of marine science in the North Pacific through long term ocean monitoring, data management, and innovative advances in ocean monitoring. The award also strives to enlighten the public on the importance of those activities as fundamental to marine science. It draws attention to an important aspect of the PICES Convention that is not so much in the limelight: "*to promote the collection and exchange of information and data related to marine scientific research in the area concerned.*"

PICES Ocean Monitoring Service Awardee for 2022: Japanese monitoring research activities on mezozooplankton

This year's awardee, the Japanese monitoring research activities on mesozooplankton has been carrying on mezozooplankton monitoring activities since 1949, representing more than a half-century of research, and comprised of over 17,000 zooplankton tows.

The program has provided critical information regarding long-term variability of zooplankton biomass during a time of increasing climate change impacts. This work has helped to inform research on the impacts of climate change and has contributed to knowledge of mechanisms of the long-term variability of fisheries productivity.

Dr. Kazuaki Tadokoro's POMA acceptance remarks, on behalf of the Japanese Monitoring research activities on mezozooplankton

"Firstly, I would like to thank all related scientists and crews of the research vessels, students and staff who organized the sample collection, and for the help of the government of Japan. I would also like to thank Dr. Kazuko Odate who started the zooplankton sample collection. I am very happy to be related to this wonderful sample collection.

I would also like to thank PICES people, who understand sample collection. Thank you for choosing our program for the POMA Award. Our sample collection is now growing and being used for various study programs. I would like to collaborate with anyone in PICES who is interested in using our sample collection. If you are interested in working with our collection, please contact me. Thank you again."

2002 Early Career Scientist Best Presentation Awards

At PICES annual meetings, Early Career Ocean Professionals (ECOPs) / Early Career Scientists (ECS) are particularly encouraged to submit abstracts to present their work. These presentations offer an excellent opportunity for ECOPS/ECS to share their science, and presenters are also eligible for the Best Oral/Poster Presentation Awards. Awardees are chosen by PICES Scientific Committees.

Scientists are eligible for these awards if:

- they are less than 36 years old, or defended their PhD thesis within the last 5 years;

- the presented paper is primarily their research; and,

- they will present the paper.

Science Board

- **Best Oral: Naya Sena**: *Identifying the Ocean Decade challenges: A common framework for Small Island Developing States*

- **Best Poster: Hajime Tanaka**: *Japanese Consumers' Demand for Traceability Information - Tokyo Bay Fish Passport as a case study*

FUTURE Science Program

- **Best Oral: Hyung-Gyu Lim**: *Attribution and predictability of climate-driven variability in global ocean color*

- **Best Poster: Khushboo Jhugro**: *The role of stratification variability on biogeochemical properties across British Columbia's Queen Charlotte Sound shelf system*

Biological Oceanography Committee

- **Best Oral: Minju Kim**: *Fiddlers on the tidal flat: fiddler crabs change their tunes depending on the contexts*

- **Best Poster: Gakuto Murata**: *Copepod community determined with metabarcoding analysis represents advection of coastal waters to the Kuroshio*

Fishery Science Committee

- **Best Oral: Jen Hsu**: Evaluating the spatiotemporal dynamics of Pacific saury in the Northwestern Pacific Ocean by using a geostatistical modelling approach

- **Best Poster: Hyung-Gyu Lim**: *Oceanic and Atmospheric Drivers of Post-El-Niño Chlorophyll Rebound in the Equatorial Pacific*

Human Dimensions Committee

- **Best Oral: Hana Matsubara**: *Comparative and historical study of international guideline & policy documents of Japan relevant to gender equality in fisheries*

Marine Environmental Quality Committee

- **Best Oral: Nour Ayache**: *Acclimation of various US Dinophysis isolates to changing light intensity: effects on growth, photosynthetic efficiency and toxin production*

- **Best Poster: Jeongho Kim**: *Variation in genetics, morphology, and recruitment in the invasive barnacle Amphibalanus eburneus (Gould, 1841) in Korea*

Physical Oceanography and Climate Committee

- **Best Oral: Youngji Joh**: *Stronger decadal variability of the Kuroshio Extension under simulated future climate change*

- **Best Poster: Saat Mubarrok**: *Evaluation of Thermocline Depth Bias in the Seychelles-Chagos Thermocline Ridge (SCTR) simulated by the CMIP6 models*

Technical Committee on Data Exchange

- **Best Oral: Jeong-Yeob Chae**: *Artificial neural network for ocean surface current prediction around the Korean peninsula using transfer learning*

PICES-2022 W1: Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions.
Co-convenors: Janelle Curtis, Mai Miyamoto, Akash Sastri, Chris Rooper, and Samuel Georgian

W1 Convenors with their invited speaker. L-R: Akash Sastri, Janelle Curtis, Temlo Morato, Samuel Georgian, Mia Miamoto.

PICES' Working Group on Ecology of Seamounts (WG47) convened a 2-day workshop from 24-25 September 2022 to explore questions around biodiversity associated with seamounts in the North Pacific Ocean and factors influencing their distributions. There are tens of thousands of seamounts worldwide and their abundance is greatest in the North Pacific Ocean. Few seamounts have been extensively studied due to their occurrence at deep depths of remote regions of the oceans and the resulting difficulty in accessing these habitats. Thus, the ecology of most seamounts is poorly understood in terms of the pelagic, demersal, and benthic species that they support.

The primary aims of the workshop were to:

* Identify and understanding factors influencing the diversity and distributions of species associated with seamounts in the North Pacific Ocean.

* Build capacity to develop predictive habitat models for seamount species.

* Consider how seamount species distributions are likely to respond to natural and anthropogenic forcing, including climate change.

Over the course of two days, we had participants from Canada, Japan, Korea, Portugal, and the USA join us in person, and another six participants from Canada and the USA join us remotely to present and discuss their work on seamount ecology. It was fortunate that the PICES Secretariat and the Korean Institute of Ocean Science and Technology (KIOST) were able to assist us in conducting this hybrid workshop

as one of our co-conveners and three speakers were not able to join us in person. We were also grateful to Dr. Samuel Georgian for leading much of our discussion as an unofficial co-convenor.

The workshop was divided into three main topics: a series of oral and poster presentations on seamount ecology, case studies of particular topics on predictive modeling of seamount taxa and discussions of emerging issues that were inspired by the presentations and case studies.

Our workshop began with an informative presentation by our invited expert, **Telmo Morato**, from the Okeanos Research Institute of the University of the Azores in Portugal: *Improved deep-sea biodiversity assessments inform sustainable management of seamount and other geomorphologic features in a changing planet: Lessons learned from the North Atlantic.* A number of speakers and participants have an interest in the identification of vulnerable marine ecosystems (VMEs), which often comprise populations of corals, sponges, and other benthic taxa. Telmo contributed significantly to our discussions and has undoubtedly inspired colleagues to explore seamounts and the intersection between seamount research and policy.

Telmo's influential talk was followed by 9 oral presentations:
* **John Dower:** *Oceanographic influences on biological production and energy transfer in seamount ecosystems.*
* **Daniel Labbé:** *Investigating seamount effects on zooplankton in the Northeast Pacific.*
* **Réka Domokos:** *Seamount effects on micronekton at a subtropical central Pacific seamount.*
* **Georgina Gibson:** *Can Gulf of Alaska seamounts be a spawning ground for sablefish recruiting to inshore nursery habitats?*
* **Kota Sawada:** *Biology and fisheries of North Pacific armorhead and splendid alfonsino in the SE-NHR area.*
* **Samuel Georgian:** *Species Distribution Modeling to Identify and Protect Vulnerable Marine Ecosystems: Case Studies from the South Pacific Ocean.*
* **Chris Rooper:** *Using species distribution modeling to predict deep-sea coral and sponge communities, hotspots, diversity and indicators.*
* **Mai Miyamoto:** *Composition of cold-water corals and other deep-sea benthos in the Emperor Seamounts.*
* **Janelle Curtis:** *Using predictive habitat models and visual surveys to identify vulnerable marine ecosystems (VMEs) on seamounts in the North Pacific Fisheries Commission's Convention Area.*

3 posters were also presented as part of this workshop:

- **Alexey Somov, Albina Kanzeparova, Svetlana Orlova, Denis Kurnosov, Vladimir Belyaev, and Alexei Orlov:** *Features of spatial distribution of dominant groundfish species on the Koko Seamount (Emperor Seamounts) in 2019.*

- **Andrey Alferov:** *Distribution of giant grenadier (Albatrossia pectoralis) at different stages of ontogenesis in the Bering Sea.*

- **Yejon, Sung-jin Hwang, and Seonock Woo:** *Genetic resources of deep-sea corals from seamounts in West Pacific by de novo RNA sequencing.*

Three oral presentations examined zooplankton productivity around seamounts in offshore regions. The work by Dr. John Dower showed that much of the productivity in seamount benthic systems arises in the pelagic zone through overwintering zooplankton in deep waters. Dr. Réka Domokos showed that micronekton communities (an important food source for tuna) can be more abundant near seamounts using acoustic surveys. Interestingly, her work also documented both horizontal and vertical migrations of micronekton around the seamount flanks, potentially exposing them to predation by fishes at the tops of seamounts. Both of these studies documented the ways in which seamount zooplankton productivity can be aggregated at seamounts. Dr. Daniel Labbé added to the theme of seamounts as productive features of the ocean floor by showing that for three seamounts off the coast of Canada the assemblages of zooplankton can differ, both in species composition and in the relative abundance of each species. In part this may be influenced by how close the seamounts are to the continental shelf.

Photo: Fisheries and Oceans Canada

The fish fauna of seamounts was also explored through a series of presentations and posters. The potential for large scale oceanographic patterns to influence seamount fish fauna was shown by Dr. Kota Sawada who demonstrated that basin-scale oceanography had a weak but significant effect on recruitment patterns for North Pacific Armorhead. However, recruitment for this species is difficult to predict and measure given the strange life history of the species where it essentially stops growing upon settlement to benthic habitat on seamounts. Dr. Georgina Gibson used models of large scale circulation patterns to demonstrate the potential for connectivity between sablefish populations on the coastal shelf and those at seamounts. Her work also demonstrated that in years of high sablefish recruitment (e.g. 2016) the circulation patterns were much different than in years with average or low recruitment. Two poster presentations also examined the fish fauna of seamounts, with a description of the biology of giant grenadier in the Bering Sea (an important component of seamount fish fauna, Alferov et al.) and an examination of the fish fauna from Koko seamount using bottom trawl survey data (Somov et al.). The final topic addressed by presentations was the distribution and abundance of vulnerable marine ecosystems (VMEs) on seamounts in the North Pacific Ocean. Managing VMEs is an important topic in seamount ecology due to the risks to VMEs imposed by fishing and climate change, as well as the interaction of these two pressures. Two presentations (Georgian et al., and Rooper et al.) focused on methods for modeling the distribution and abundance of VMEs using environmental covariates. A presentation by Dr. Mai Miyamoto examined the species composition of deep sea corals and sponges in the Emperor Seamounts in the northwest Pacific Ocean, by examining fisheries bycatch and underwater images. Dr. Miyamoto found that the most important (measured by abundance) species in the Emperor seamounts tended to be Alcyonacean corals, while sponges were generally not as important in these areas. This was in contrast to the presentations on the northeast Pacific Ocean seamounts which tended to have fauna dominated by sponges. A poster presentation by Dr. Ye Jin Jo also demonstrated the potential for identifying and measuring biodiversity of corals using a combination of ROV collected specimens and DNA sequencing of function genes in deep-sea corals. Dr. Janelle Curtis finished up the oral presentations by demonstrating a method to identify VMEs using data on species presence or absence and its relationship to biodiversity. This is an important advance, as it allows for a quantitative definition of what a VME is, rather than using simply the presence of a VME indicator taxa.

Following the presentations, the workshop moved to discussing key topics related to predicting the distribution of taxa associated with seamounts. We began with a discussion of environmental factors that influence the ecology of seamounts. Dr. Samuel Georgian then presented a case study of predicting the distribution of corals in the northeast Pacific Ocean as a first step to identifying VMEs.

Key environmental factors that were highlighted as being important for both species distribution models (SDMs) and for spatial management based on those SDMs included bathymetry data and geomorphological structures. Participants also discussed the value of including surface variables, such as chlorophyll-a, as predictors in SDMs and considering how these variables may be important for different taxa. Many surface variables, including temperature, salinity, oxygen, phosphate, silicate, and nitrate, are available from the World Ocean Atlas and from PICES'Working Group on the Biodiversity of Biogenic Habitats (WG32).

Discussions of spatial scale of both modeling and species distributions were a highlight of the workshop. It was noted during the discussions that productivity variables, such as chlorophyll a do not vary on the small spatial scales at which many seamount taxa, including corals are distributed, so this raised questions about the importance of including these variables in SDMs of seamount taxa. Participants noted that we are not usually observing the environment or developing predictive models at a scale that is relevant to animals: what we can observe and what we predict are at different spatial scales. Over finer scales, multibeam bathymetry data could be coupled with interpolated World Ocean Atlas data to model the distributions of suitable habitat for species. Participants also noted that scale matters both horizontally and vertically (as evidenced by the presentation from Dr. Réka Domokos); some predictor variables do not vary considerably at the 100 km scale, but what might be very important for benthic species is what the environment is within 10 m of the seafloor. This disconnect may be more important when modeling climate change to identify refugia for benthic species, habitats and ecosystems.

Participants discussed the importance of flow patterns, including Taylor cones, around seamounts and their effects on deep scattering layers and the availability of food, including overwintering copepods. Food availability is an important variable for predicting the distribution of corals, so including variables related to turbulence, current stability and speed, and POC flux would improve SDMs of corals. Oceanography has an important role in driving species distributions on seamounts; even though water column variables may be similar over large spatial scales, turbulence at the seafloor is where most seamount species live. Participants discussed the potential value of sediment traps to measure POC and export flux on seamounts.

The implications of bentho-pelagic coupling and species interactions for SDMs were discussed at length. Plankton can be included in SDMs for benthic taxa. All of the presentations on zooplankton at seamounts demonstrated the linkages between pelagic productivity and the benthos. Participants noted that it is important to include

ecological interactions among species such as predation and competition when developing predictive models. The consequence of not including these interactions is that their omission may lead to models that predict species occurrence in sub-optimal habitat where they may be outcompeted by other species.

Participants discussed the importance of clearly communicating the uncertainty associated with model predictions, especially given the broader scale of explanatory variables that are often used to predict the distributions of species that are distributed over smaller scales. One of the challenges noted was that SDMs developed for seamount taxa are often modelled at high levels of taxonomic resolution (e.g. orders of corals). Species that are grouped at higher levels of taxonomic resolution vary in their niche space, which can potentially increase the uncertainty associated with corresponding model predictions and lead to overpredictions where the suitable habitat of a taxonomic group is likely to be found. Moreover, the remote location of most seamounts means that only a few have been sampled, and most have not been randomly sampled. Participants discussed the construction and use of relatively cheap drop camera systems that could be launched from small boats down to depths of 1000 m. Having such equipment on hand could improve our ability to collect visual data from remote seamounts and could improve our ability to use a design-based approach to surveying seamounts. Participants discussed the value of monitoring variability among seamounts by sampling across many seamounts and monitoring a few sites over time. Although surveys are costly, seamounts are remote and subject to seasonal, interannual, and climate change, moorings and a small fleet of autonomous underwater vehicles could help monitor changes in chlorophyll a, temperature, microscale turbulence and other variables during the course of one or more years.

The impacts of climate change on zooplankton and the seamount communities is generally unknown, however workshop participants were able to draw some broad conclusions regarding potential impacts in the future.

Long-lived species, such as many corals, may be affected by climate change over short time scales. The capacity of corals to adapt to change is slow and the most important variable is POC flux or availability of food. Some climate

models predict changes to the size structure and lipid content of zooplankton as well as to their production and ontogentic migration, which will in turn affect predators. There is also some evidence of increasing productivity on seamounts in the North Atlantic Ocean. Corals with more food may be able to cope with sub-optimal conditions, but if food availability is lower, they are less likely to adapt. The oxygen minimum zone is more anoxic and the upper layer is shoaling. As this zone continues to shoal, species that live on seamounts will begin to run out of space to interact with other species and persist. Uncertainty in climate projections is important to include and models differ in their degree of optimism. Species adaptation, acclimation, or dispersal of species is often ignored when projecting changes in response to climate change. Physiological studies can help build an archetype that can predict what is anticipated to happen to a group of species. It can also be helpful to publish a range of projected scenarios that can then be communicated to managers and the public.

Finally, we considered next steps for PICES' Working Group on Ecology of Seamounts (WG47). A key next step for WG47 was to compile more data on variables that are important for predicting the distribution of seamount taxa and existing data on areas where those taxa are present or absent. Indeed, participants acknowledged the importance of validating model predictions with visual observations collected with remotely operated vehicles (ROVs), drop cameras, or other camera systems. And ideally, we would be in a position to collect data that allowed us to understand mechanisms that influence species distributions instead of relying on predictive models.

Janelle Curtis is a research scientist in ecological modelling at Fisheries and Oceans Canada's Pacific Biological Station. Her research focuses on identifying vulnerable marine ecosystems (VMEs) on seamounts and assessing the relative risk of significant adverse impacts (SAIs) on VMEs in the northeast part of the North Pacific Fisheries Commission's (NPFC) Convention Area. She is currently chair the NPFC's Scientific Committee and Co-Chair PICES' Working Group on Ecology of Seamounts (WG47). When she's not undertaking research on seamounts, she edits two publications by the Alpine Club of Canada's Vancouver Island Section, which has a special interest in landmounts.


Dr. Akash Sastri is a Research Scientist with Fisheries and Oceans Canada at the Institute of Ocean Sciences in Sidney, BC, where he leads the Plankton Ecology program. He has a background in biological oceanography with a focus on the roles of marine plankton communities in changing environments. His Ph.D. thesis at the University of Victoria focused on the development and application of novel ways to measure zooplankton productivity routinely at sea. In PICES he is the Chair of the Biological Oceanography Committee (BIO), a member of Working Group on Towards best practices using Imaging Systems for Monitoring Plankton (WG48) and the Advisory Panel on North Pacific Coastal Ocean Observing Systems (AP-NPCOOS).

Mai Miyamoto is an environmental consultant working on marine environment and fisheries issues. Her research focuses on deep-sea coral species identification, analysis of the spatial distribution of VMEs, and SAI assessment of fishing grounds in the Emperor Seamounts of the northwest part of NPFC Convention Area. She received her PhD in Marine Science from Tokyo University of Marine Science and Technology in 2017. In PICES, she is currently the Co-Chair of the Working Group on the Ecology of Seamounts (WG47). She enjoys SCUBA diving on her days off.

Dr. Chris Rooper is a Research Scientist with Fisheries and Oceans Canada in the Stock Assessment and Research Division at the Pacific Biological Station in Nanaimo, British Columbia. His research interests are in the function of habitats for fishes, particularly rockfishes and deep-sea corals and sponges, using a combination of in situ studies with underwater cameras and regional scale modeling. In PICES, he is a member of the Working Group (WG47) on Ecology of Seamounts, the PICES-ICES Joint Working Group on Small Pelagic Fish (WG43) and the FIS Committee.
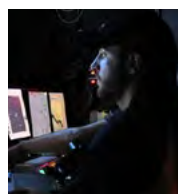
Samuel Georgian is a spatial ecologist working at Marine Conservation Institute, a non-profit organization dedicated to securing permanent, strong protection for the ocean's most important places. He received his Ph.D. in Biology in 2016 from Temple University studying the distribution and ecophysiology of deep-sea corals. His current research focuses on using ecological models to better understand and manage vulnerable marine ecosystems, with a special focus on deep-sea and seamount habitats. When he's not modeling, he enjoys climbing, mountaineering, and skiing.

PICES-2022 W2: Integrated Ecosystem Assessment (IEA) to understand the present and future of the Central Arctic Ocean (CAO) and Northern Bering and Chukchi Seas (NBS-CS)
Sei-Ichi Saitoh, Hyoung-Chul Shin, Libby Logerwell and Yury Zuenko

Group photo from Central Arctic Ocean, Northern Bering and Chukchi Seas Integrated Ecosystem Assessment Workshop (W2)

The target Large Marine Ecosystems (LMEs)of WG39 and WG44 are the Central Arctic Ocean (CAO) and the Northern Bering Sea-Chukchi Sea (NBS-CS), that are geographically and dynamically connected. The CAO is in rapid transition, driven by North Pacific environmental changes in significant part, and has become accessible to a range of activities. Rapid loss of sea ice cover has opened up the CAO for potential fishing opportunities. In this context, the agreement to Prevent Unregulated High Seas Fisheries in the CAO has been signed and entered into force, which will necessitate joint research and monitoring. The NBS-CS is also experiencing unprecedented warming and loss of sea ice as a result of climate change. Declines of seasonal sea ice and rising temperatures have been more prominent in the northern Bering and Chukchi seas as in most portions of the Arctic. Chronic and sudden changes in climate conditions in this Arctic gateway are clearly reshaping the system and its food-webs, and enlarging

opportunities for commercial activities (shipping, oil and gas development and fishing), with uncertain and potentially wide-spread cumulative impacts. An integrated ecosystem assessment (IEA) is a useful and pertinent approach in this circumstance, particularly with substantial science and policy challenges emerging in the Arctic, and this renders a coordinated IEA of the CAO and NBS-CS a priority task.

The main objectives for the workshop were to describe and discuss present ecosystem processes (sources, signals, significance) in the CAO and the NBS-CS based on achievements from existing and future research programs such as MOSAiC and SAS, numerous NBS-CS programs, and Indigenous Knowledge. In addition, it is pertinent and timely to develop future approaches for *The United Nations Decade of Ocean Science for Sustainable Development (UNDOS)* in these oceans, where science for resilience and sustainability is more important than anywhere else and

Central Arctic Ocean, Northern Bering and Chukchi Seas Integrated Ecosystem Assessment Workshop (W2) Participants

the relevant, regional UN program is yet to be properly initiated. There were about 30 attendees at this one-day in-person workshop held Sunday, September 25, 2022, from 09:00–18:00 in Busan, Korea. Two invited, 8 oral and one poster presentation were made at W2. PICES members from four countries and one ICES member from Norway contributed presentations. The workshop started with a brief introduction by **Prof. Sei-Ichi Saitoh**, outlining the background of CAO and NBS-CS issues and the workshop objectives.

In the morning session, **Dr. Lis Lindal Jørgensen**, (above) one of the Co-Chairs of WGICA, gave the first invited talk entitled *"Activities of the ICES-PICES-PAME working group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA)".* She noted that the main results from the ongoing reporting of the main human activities (global sources, shipping, military and tourism), pressures (contaminants, garbage, noise, non-indigenous species (NIS), disturbance, ship traffic, etc.) and the work completed to describe the vulnerability of the ecosystem. **Dr. Ferdenant Mkrtchyan** gave a recorded talk entitled *"About remote monitoring of water surface and ice cover of the Arctic".* He described the physical foundations of water and ice characteristics based on micro wave remote sensing data. **Dr. Dong-Gyun**

Han then gave a presentation entitled *"Passive acoustic monitoring in the Arctic Ocean for Integrated Ecosystem Assessment".* He collected underwater acoustic data using an autonomous passive acoustic recorder in the East Siberian Sea from August 2017 to August 2018. The correlations between temporal variability of sound pressure levels and marine environmental data such as sea ice concentration, extent, drifting speed, wind speed, and ocean current were determined. **Mr. Wuju Son** gave a talk entitled *"Vertical behavior of key copepod species subsequent to the midnight sun period in the East Siberian continental margin, Arctic Ocean".* He presented the vertical distribution of the key copepod species (*Calanus glacialis, Calanus hyperboreus,* and *Metridia longa*) subsequent to the midnight sun period in the Arctic Ocean. The findings could provide insight into monitoring and assessing the variation of the zooplankton distributions in the rapidly- changing Arctic marine environment. **Dr. Irene D. Alabia** gave a talk entitled *"Arctic marine biodiversity and species co-occurrence patterns under recent climate".* She pointed out that regional differences in the spatial patterns in species richness in the Arctic, despite the overall increasing trend in pan-Arctic during 2000-2019. Sea ice loss and rising temperatures have driven northward expansion of apex and mesopredators in major Arctic gateways. **Dr. Jee-Hoon Kim** gave a presentation entitled "Inter-annual changes of the mesozooplankton community structure in the Central Arctic Ocean (CAO) and Northern Bering and Chukchi Seas (NBS-CS) during summers of 2016-2020". He described mesozooplankton distribution in the Arctic (CAO, NBS, CS) and composition of zooplankton and total abundance related to the water mass distribution from multi-year observations in the NBS & CS and suggested that these variable patterns of mesozooplankton communities fluctuate latitudinally from south to north as warming progresses on a regional and bathymetric scale. This could be used to infer the future status of mesozooplankton communities in the study area.

In the afternoon session, **Dr. Lisa B. Eisner** gave the second invited talk entitled *"Recent ecosystem research in the Chukchi and north Bering seas".* She provided an overview of recent ecosystem research in the north Bering and eastern Chukchi seas. Ecosystem level projects include Arctic Integrated Ecosystem Studies (IES) phase 1 (2012 and 2013) and 2 (2017, 2019) in August-September, and Arctic Shelf Growth Advection Respiration and Deposition (ASGARD, 2017 and 2018) in June. She also introduced a recent NPRB-funded synthesis proposal to evaluate pelagic–benthic coupling that will use data from these projects and other surveys (e.g., Distributed Biological Observatory (DBO)) to model and predict the impact of a warming climate on pelagic and benthic ecosystems including trophic interactions and energy flow between these systems. **Dr. Kirill Kivva** gave a talk entitled *"Spatio-temporal variability of ice retreat in the Pacific Arctic".* He investigated the spatiotemporal variability of the date of ice retreat (DOR) in the Bering Sea, the Chukchi Sea and the adjacent Arctic regions. He noted that the differences in sea ice retreat between regions are mostly associated with the wind forcing in the Bering Sea and variability of heat transport through the Bering Strait in the Chukchi Sea. **Dr. Kivva** then gave another talk entitled *"Distribution of water masses in the Chukchi Sea in August 2019 and their chemical characteristics".* He used observation data from hydrographic surveys in the East Siberian Sea and found high temperature in Siberian coastal water (SCW) and differences in nutrient content and chemistry of different water masses. **Dr. Fujio Ohnishi**, a social scientist, gave a talk entitled *"The development of Japan's Arctic Policy and the citizens' awareness".* He analyzed the interest of Japan's general public in relation to Arctic policy and emphasized the need to better disseminate the results from Arctic research to the general public.

In general discussion, **Dr. Hyoung Chul Shin** summarized the overall presentations and discussion at the workshop and noted:

1. The workshop has presented updates on present studies/research in the CAO. Furthermore, how best to use the UNDOS-Arctic initiatives will need to be included in future works. Existing/emerging gaps in knowledge will need to be continually identified to guide future research.

2. WG44 (NBS & CS) will continue to work on the following activities another year: pooling of existing datasets and comparative studies between Arctic gateways using such datasets and inclusion of community-based research in northern Canada.

Finally, he led the discussion on the proposal of a new EG advisory panel (AP-ARC), to advance the work of WGs 39 and 44 in the Arctic Ocean context, and to bring more experts to this one-stop EG for Arctic issues. This was agreeable to both working groups and supported by the workshop participants. GC later agreed to establish a new study group, SG-ARC for one year until PICES-2023. SG-ARC will consist both WG39 and WG44 members. Group photos were taken at the closure of the workshop, although the feature picture at the beginning of this report unfortunately does not include all of the workshop participants. The full list of participants is available on PICES website for each relevant Expert Group, listed under products, for workshops held during PICES-2022.

Dr. Sei-Ichi Saitoh (ssaitoh@arc.hokudai.ac.jp) is Research Professor of Arctic Research Center, Hokkaido University. He has over 30 years of experience working as a satellite and fisheries oceanographer, GIS specialist, and consultant on fisheries issues in the North Pacific Ocean and its adjacent seas. He also studied the impact of climate change and global warming on marine ecosystems in sub-Arctic and Arctic seas. Within PICES he has been a member of MONITOR T/C and Co-Chair of WG39. He was also one of sub project directors of the national flagship project, the Arctic Challenge for Sustainability (ArCS) supported by MEXT, Japan 2015-2019.

Dr. Hyoung Chul Shin (hcshin@kopri.re.kr), a biological oceanographer by training, participated in and coordinated numerous expeditions to the Antarctic and the Arctic. On top of Antarctic krill biology, his activities and interests include the management of marine living resources in polar waters. He has been serving on the Korean delegation to the negotiation and implementation of the Central Arctic Ocean Fisheries Agreement. He is also part of the Central Ocean Ecosystem assessment efforts by WGICA and PICES WG 39, while serving as the vice President and chief scientist of the Korea Polar Research Institute.

Dr. Libby Logerwell (libby.logerwell@noaa.gov) is a Research Fishery Biologist at the Alaska Fisheries Science Center of NOAA-Fisheries in Seattle, Washington. Her research focuses on oceanographic processes that influence the distribution and abundance of seabirds, ichthyoplankton, juvenile and adult fish and epibenthic megafauna. She is a PI on the North Pacific Research Board Arctic Integrated Ecosystem Research Project. She is a member of the PICES Fishery Science Committee and Co-Chair of the PICES/ICES WG44 on Integrated Ecosystem Assessment of the Northern Bering-Chukchi Sea.

Dr. Yury Zuenko (zuenko_yury@hotmail.com) is a physical oceanographer, currently the head of Fisheries Oceanography Lab. in the Russian Research Institute of Fisheries and Oceanography, its Pacific branch (TINRO) located in Vladivostok, Russia. His activities and interests include a wide spectrum of physical and biogeochemical processes in the Far-Eastern Seas and North-West Pacific, from downscaling of the global climate change to bioproductivity of estuaries and environmental impact on physiology and reproduction of particular commercial species. He is a permanent member of the PICES Physical Oceanography and Climate Committee and its CREAMS Advisory Panel, previously worked in the MODEL Task Team of CCCC and several working groups, and now is a Co-Chair of the PICES/ICES WG44 on Integrated Ecosystem Assessment of the Northern Bering-Chukchi Sea.

Lori Waters
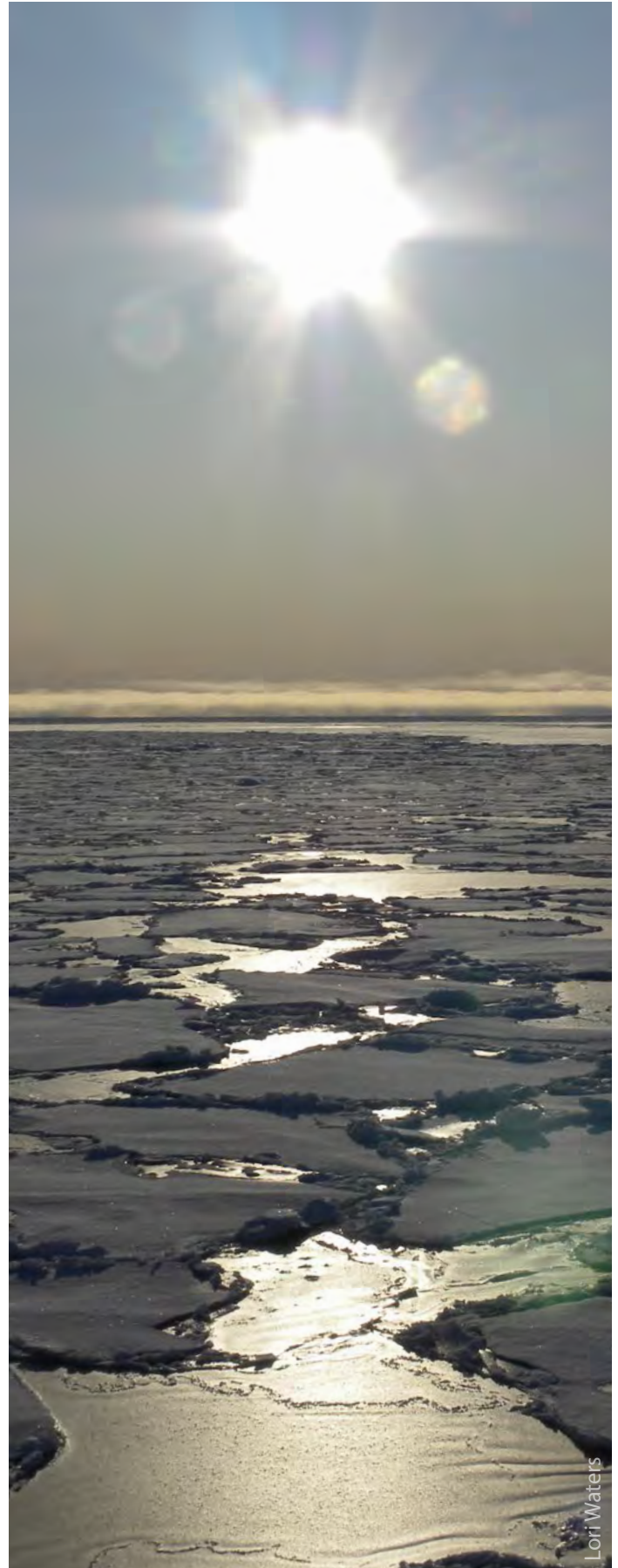
PICES-2022 W3: 'SmartNet: Promoting PICES and ICES Leadership in the UN Decade of Ocean Science for Sustainable Development'

Steven Bograd, Sanae Chiba, Khush Jhugroo

On World Oceans Day, June 8th, 2021, the Intergovernmental Oceanographic Commission announced the first set of activities endorsed as part of the UN Decade of Ocean Science for Sustainable Development (UNDOS; 2021-2030). The program submitted jointly by PICES and ICES, Sustainability of MARine ecosystems Through knowledge NETworks (SmartNet), was endorsed as an UNDOS Program, ensuring that ICES and PICES will play a leading role in the development of UNDOS from its inception. The aim of SmartNet is to support and leverage ICES, PICES, and member countries' priorities and initiatives related to the UNDOS. This is being done by emphasizing areas of mutual research interest and policy needs, including climate change, fisheries and ecosystem-based management, social, ecological and environmental dynamics of marine systems, coastal communities and human dimensions, and communication and capacity development. SmartNet will also incorporate strategies to facilitate UNDOS cross-cutting inclusivity themes relating to gender equality, early career ocean professional engagement, and involvement of indigenous communities and developing nations in the planning and implementation of joint activities. At PICES-2022 in Busan, Korea, SmartNet hosted a Workshop titled *'SmartNet: Promoting PICES and ICES Leadership in the UN Decade of Ocean Science for Sustainable Development',* to provide updates on SmartNet and other UNDOS activities and facilitate a broad discussion within the PICES community and amongst partners on methods and priorities for implementing SmartNet. Here we present a few highlights from the Workshop.

Following an overview of the UN Decade of Ocean Science for Sustainable Development and an introduction of SmartNet by Steven Bograd, we heard presentations from several UNDOS-endorsed Programs and Projects.

Hannah Lachance (above) presented on the 'Sustainability, Predictability and Resilience of Marine Ecosystems' (SUPREME) Program. SUPREME aims to leverage efforts in the U.S. to globally implement an infrastructure to support robust climate- and ocean-related forecasts, predictions, and projections to guide marine ecosystem management and adaptation strategies that reduce risks and increase resilience of marine/coastal resources and the people who depend on them.

Manu Di Lorenzo (above) presented on the 'Global Ecosystem for Ocean Solutions' (GEOS) Program. GEOS aims to develop and deploy a series of equitable, durable, and scalable ocean-based solutions for addressing climate change and Ocean Decade's challenges.
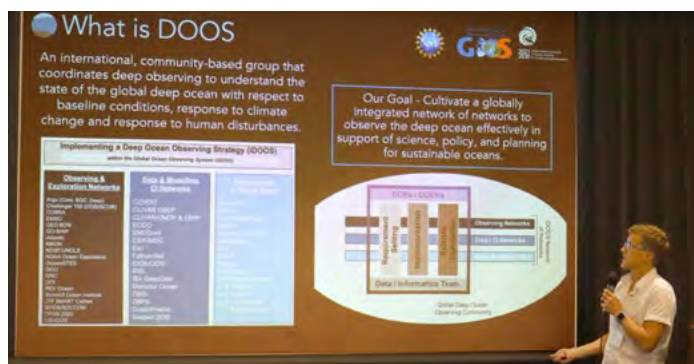

Robin Brown (above) presented on the 'Basin-scale Events and Coastal Impacts' (BECI) Project. BECI aims to develop an international ocean intelligence system capable of assessing changes and predicting impacts on local ecosystems and communities, using salmon as an exemplar species.

Leslie Smith (above) presented on the 'Deep Ocean Observing Strategy' (DOOS) Program. DOOS represents an interconnected network of deep-ocean observing, mapping, exploration, and modelling programs working together for the coming decade to 1) characterize the physics, biogeochemistry and biology of the deep ocean in space and time, 2) establish a baseline required to understand changes to its habitats and services, and 3) provide the information needed to have a healthy, predicted, resilient and sustainably-managed (deep) ocean. Leslie also described the 'DOERs', a cohort of early career ocean professionals providing leadership for the Program.

Following the UNDOS Program and Project presentations, Mitsutaku Makino (above) gave a presentation on a project being led by his group at the University of Tokyo and collaborators to implement a global survey on general public perceptions about the 7 outcomes of UNDOS. These survey results can contribute to a better formulation and prioritization of UNDOS challenges, as well as to guide PICES' international science collaborations and provide policy recommendations.

We then had an invited talk from Khush Jhugroo, (above) an early career ocean professional from the University of British Columbia and the Hakai Institute, entitled 'Early Career Ocean Professionals (ECOP) and Small Island Developing States (SIDS) engagement in the UN Decade of Ocean Science For Sustainable Development'. Khush reflected on the many challenges facing SIDS due to various anthropogenic and climate stressors, and as an example described the impacts of an oil spill in Mauritius, her home country. Khush also described some of the challenges faced by ECOPs. Importantly, Khush outlined some of the needs of both ECOPs and residents of SIDS, including inclusion and recognition; creation of a positive policy environment (with empowerment of women and ECOP engagement); improved technical development and science communication to local communities; and financial support from external sources.

The final presentation was given by Raphaël Roman, the UNDOS Regional ECOP Coordinator for Asia, on the engagement of ECOPs in PICES and UNDOS. Raphaël reviewed a number of opportunities for ECOP engagement, including through mentorship and training opportunities, regional engagement under the UNDOS umbrella, and communication networks through social media. Raphaël also gave a preview of the ECOP Workshop which was held immediately following the SmartNet Workshop (see ECOP Workshop report in this issue).

There were several outcomes from the Workshop, including:

- Introduced SmartNet and PICES-related UNDOS programs to the PICES community; (Steven Bograd and Sanae Chiba, below, left).
- Identified synergies for co-design of activities amongst UNDOS programs;
- Strategized ECOP engagement in SmartNet and other UNDOS programs;
- Developed list of activities and a SmartNet Action Plan for 2022-2023.

Throughout the PICES-2022 meeting, workshop participants continued discussions on potential collaborations amongst UNDOS Programs and Projects, and within PICES more broadly. An idea that gained traction in post-Workshop conversations was the potential to co-design UNDOS activities around a common theme for which each Program or Project could provide unique expertise. An example that will be pursued is to integrate our efforts around the theme of marine spatial planning to support ecosystem sustainability. Future reports will describe the outcome of these efforts.

The SmartNet Workshop was very well attended, with lively discussions and a remarkable level of interest and curiosity about potential for engagement and collaborations by the participants.

PICES-2022 W4: Exploring Engagement Opportunities for Early Career Ocean Professionals (ECOPs) within PICES and Internationally

Raphaël Roman, Hannah Lachance, Minkyoung Kim, Hana Matsubara and AP-ECOP Members

Together with several Advisory on Early Career Ocean Professionals (AP-ECOP) volunteers, Hannah Lachance (USA; AP-ECOP Co-Chair) and Raphaël Roman (Canada; AP-ECOP Co-Chair) co-moderated the afternoon ECOP workshop on Sunday, September 25th, which naturally and conveniently followed the SmartNet workshop in the first half of the day. As one of the more well-attended workshops, there were more than 30 people in attendance (see Figure1), with strong representation from the Republic of Korea. A master slide deck containing all of the presentations can be found here.

Hannah and Raphaël began with a warm welcome and walked participants through the session's agenda. Hannah provided a brief introduction of the PICES governance structure as well as the role, achievements and goals of the Advisory Panel on ECOPs (i.e. PICES and ECOP 101s), for attendees new to both. "Elevator pitches" were then presented by each PICES Scientific Committee.

A lightning round followed, where invited speakers (i.e. Co-Chair(s) of all PICES Scientific Committees and Special Programs – mainly senior professionals and mentors) had ~5 minutes to introduce their Committee or Program and reflect on cross-pollination opportunities with ECOPs (including specific needs for better ECOP engagement within their own Expert Groups and initiatives). Speakers included:

1. **Dr. Steven Bograd** (NOAA, USA) introduced PICES's endorsed UN Decade Programme "SmartNet"; its flagship science program, "FUTURE" ("**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems"), and a new working group (WG49) on climate extremes. Steven has been a strong supporter of involving ECOPs into leadership positions within the PICES structure (e.g. as Co-Chairs of Expert Groups and scientific programs such as FUTURE). Steven also highlighted FUTURE'S

early career scientist award, recently created to help cover travel costs (CAD$3,000) for one or more ECOPs to present their research during the plenary session of PICES Annual Meetings. Due to the Covid pandemic, this award has yet to be granted, however, FUTURE hopes to select awardee(s) to attend PICES-2023 in Seattle, USA.

2. Dr. Akash Sastri (DFO, Canada) introduced the Biological Oceanography Committee (BIO). He emphasized that WG47 on "*Ecology of Seamounts*" is Co-Chaired by an ECOP, while the now disbanded WG37 on "*Zooplankton Production Methodologies, Applications and Measurements in PICES Regions*" actively involved ECOPs in the writing of the final report and other key deliverables.

3. No representative from the Fishery Science Committee (FIS) was able to join the AP-ECOP event, however, Co-Chair Jackie King (DFO, Canada) kindly prepared slides to introduce the FIS Committee, which were presented by Raphaël on FIS's behalf (see slide deck).

4. Prof. Mitsutaku Makino (University of Tokyo, Japan) provided an overview of the Human Dimensions Committee (HD) – PICES most recent Scientific Committee. Working groups under the HD Committee cover a variety of disciplines and interdisciplinary topics, from economics, human wellbeing, fisheries management and science communications to indigenous knowledge systems and transdisciplinary ocean sciences, among many others.

5. Dr. Andrew Ross (DFO, Canada) introduced the Marine Environmental Quality Committee (MEQ), and encouraged interested ECOPs to contact the Co-Chairs of scientific committees directly, whether they have an idea for a new project or if they simply want to learn how they can participate and get further involved.

The MEQ Committee has a special project, PICES Ciguatera Project, in Indonesia, related to Ciguatera fish poisoning in Indonesian communities. This project allowed young scientists from PICES member countries to connect and collaborate with Indonesian ECOPs, some of whom attended and presented at PICES-2022. Andrew gave a special shoutout to ECOP presenters joining sessions (co-)convened by MEQ.

6. Prof. Emanuele Di Lorenzo (Brown University, USA) and Dr. Jennifer Jackson (Hakai Institute, Canada) are the two Co-Chairs of the Physical Oceanography and Climate Committee (POC). They highlighted opportunities for ECOPs to participate in hands-on activities and in new Expert Groups focusing on artificial intelligence (AI) and machine learning, among other innovative and cutting-edge ocean topics. Similarly, they encouraged ECOPs to not be shy and reach out any time. ECOPs can propose new Expert Groups on their own if they have an idea they want to pursue. The POC Committee will be more than happy to support them in the process.

7. Prof. Sung Yong Kim (Korea Advanced Institute of Science and Technology, South Korea) introduced the Technical Committee on Monitoring (MONITOR), which identifies the principal monitoring needs of the PICES region, and develops recommendations to meet these needs, including through training and capacity building initiatives, such as Summer Schools for ECOPs. The most recent example was the "Ocean Big Data" virtual summer school held in August 2022.

8. Ms. Jeanette Gann (NOAA, USA) was not able to participate in-person but instead kindly prepared slides on the role that the Technical Committee on Data Exchange (TCODE) plays within PICES. She also provided an informative and timely summary of the outputs and recommendations that derived from the TCODE workshop W10 two days earlier. She reiterated the importance of actively involving ECOPs in changing the data culture within PICES.

A short coffee break allowed for organic networking between the workshop participants before starting the next series of presentations by ECOP speakers. This second part of the workshop focused on international ECOP networks and engagement opportunities beyond the North Pacific. Invited representatives of these networks (i.e. ECOP Programme, ECOP Asia, ICES "Strategic Initiative on the Integration of Early Career Scientists" (SIIECS) and the Deep Ocean Early Career Researchers (DOERs), a program of the Deep Ocean Observing Strategy (DOOS)) were asked to introduce their ECOP community, their accomplishments to date, and to reflect on future synergies and areas of collaboration with the PICES

ECOPs. ICES and DOOS are key partners of PICES, which organically led to meaningful encounters between their respective ECOP communities. This workshop aimed to sustain the momentum and cement these nascent but promising relationships between early career groups that span many geographies, disciplines and ocean layers.

Figure 1. ECOP workshop attendees (top) and final brainstorming & networking session (bottom). Photos: Hannah Lachance and Raphaël Roman.

Invited ECOP speakers and their presentations were as follows:

1. **Ms. Evgeniia Kostianaia (Global Coordinator of the ECOP Programme, Russia)**. Despite not being able to join us in person in Busan, Evgeniia kindly recorded her presentation, entitled: "ECOP Programme: Connecting with international ECOP networks". She was an invited speaker at PICES-2022, where she talk provided a comprehensive overview of the progress achieved since the endorsement of the ECOP Programme in early 2021. Notable updates included the regional expansion of the ECOP coordination team (who grew from 3 to 6 regional and national nodes, welcoming new coordinators from Central America, the USA and Japan) and the resounding success of its capacity development initiatives. The latter included funded trainings in Africa and the Caribbean, online webinars and financial support to attend conferences, workshops and other capacity building events.

2. **Mr. Raphaël Roman (Regional coordinator of the ECOP Programme in Asia and PICES AP-ECOP Co-Chair, Canada).** Raphaël provided a regional perspective of the work and outreach the ECOP Programme has been pursuing in Asia, which was especially relevant to the South Korean audience. His presentation was entitled: "UN Ocean Decade Endorsed Programme for ECOPs: Regional Node in Asia", with a special focus on PICES member countries in Asia. Raphaël offered a brief overview of the current status of the ECOP network in Asia and their major activities since inception in the Spring of 2021. He happily shared the news about the recently launched National ECOP Node in Japan and his efforts to establish other ECOP hubs in the Republic of Korea and China. Raphaël also presented key findings from the 2021 and 2022 ECOP Asia surveys, with a focus on East Asian countries (i.e. China, Japan and the Republic of Korea). He mentioned other key strategic pillars of the ECOP Asia node and reflected on his time as a regional coordinator, reminiscing about his in-person experience at the UN Ocean Conference in Lisbon, Portugal and the ICES/PICES Early Career Scientist Conference in Newfoundland, Canada, in addition to many stimulating and creative early career meetings he's had the privilege to attend online. Finally, Raphaël invited members of the audience to join him in co-developing the ECOP Asia node and contributing to more inclusive ocean sciences in the North Pacific (e.g. enhancing understanding of national nuances and scientific cultures, joining forces in translating English materials into several languages, co-designing webinars, trainings, etc.).

3. **Ms. Hannah Lachance (PICES AP-ECOP Co-Chair and contractor at NOAA, USA)** introduced the ICES Strategic Initiative on the Integration of Early Career Scientists (SIIECS) on behalf of their Co-Chairs, who prepared slides, as they were unable to join the workshop due to the ICES Annual Meeting running in parallel to the PICES one in Dublin, Ireland. Hannah has been shadowing the ICES ECOP group since the beginning by attending a few of their online meetings, which made her the perfect fit for introducing them during the workshop. Specifically, ICES SIIECS aims to engage ECOPs in the activities of ICES in a mutually beneficial way. They mainly consist of a volunteer core team of ~20 ECOPs, coordinating and engaging a much wider ECOP community within ICES (> 150 ECOPs). Some recent accomplishments include the creation of the "Rising Tides" article series in the ICES Journal of Marine Science (no submissions from the North Pacific community yet!), the allocation of more keynote speaking roles for Early Career Scientists, interdisciplinary publications and important Diversity, Equity and Inclusion (DEI) work, among other important contributions detailed in their Terms of Reference.

4. **Dr. Leslie Smith (DOOS Project Director, USA).** The last presentation was given by the energetic and inspiring Leslie Smith, whose talk was entitled: "Fostering Future Leaders: The amazing things a program can achieve by simply showing young stars how bright they already are". Leslie's presentation followed up on her intervention during the SmartNet workshop in the morning of the same day. This time she dove deeper into the DOERs program of the Deep Ocean Observing Strategy (DOOS), which can be defined as a collaborative early career mentoring program designed to bring together ECRs from across the global deep sea community. She introduced their current cohort of six multidisciplinary ECOPs, who received 1.5 months of funding each, with the goal being to lead working group efforts and create project deliverables. The DOERs community spans the entire globe, with 160 participants, but has relatively low representation from Asia. They organize quarterly virtual professional development sessions (e.g. leading interdisciplinary cross-collaboration; FAIR data principles training; Communicating science to diverse audiences, etc.). Leslie then shared invaluable tips and insights on how to build an impactful Early Career Researchers (ECRs) Program, by trying to think differently, by focusing on:

- Assigning cool, high profile tasks to ECRs as a default,
- Spreading the workload across all team members for boring, menial tasks,
- Highlighting ECR successes to broad audiences, and
- Taking responsibility for program-wide failures and successes.

At DOOS, they strive to support their ECRs so they can lead. Leslie shared inspiring and heartfelt testimonials from the current members of their DOERs cohort. For instance, one of the testimonials reads: *"I feel very lucky to be an ECR in iDOOS. My previous experience as a named ECR was characterized principally by high pressure to complete major project deliverables. In contrast, within iDOOS ECRs are closely mentored in taking on meaningful leadership roles".* She also mentioned the need for someone to be their Champion, quoting Brene Brown in the process: *"A leader is anyone who takes responsibility for finding the potential in people and processes and who has the courage to develop that potential."*

With little remaining time before the end of the workshop, the conveners decided to blend the networking and brainstorming sessions together during the last hour. As a result, attendees would get sufficient time to interact and mingle with any of the ECOP and non-ECOP speakers they listened to during the workshop. Concurrently, the

AP-ECOP team set up four different white boards with several markers at the back of the room (see Figure 1 & Figure 2), with a different question on each board. Here are the 4 questions, alongside selected answers from participants:

1. **What would you like the ECOP mentorship platform to look like ?**
   - "Periodic events, e.g. every 3-4 months"
   - "Ongoing communications about activities throughout the year (between meetings) to help ECOP navigate the programs and processes and to stay informed even if they choose the 'low commitment' track".

2. **What kind of ECOP activities would you like to see in PICES ?**
   - "Networking events over beer"
   - "Communication with mid-career researchers"
   - "A regular newsletter about ongoing activities and opportunities"
   - "Recruitment opportunities that have a low 'cost of entry' such as an all-virtual pre-meeting to go over travel support or to explain the virtual business meeting coupled maybe with an online discussion forum"

3. **What support do you need from PICES ?**
   - "Airplane tickets"
   - "English text check" / "Please speak slowly and clear English"
   - "Training and workshops" / "Information sharing"
   - "Help develop Topic Session and workshop proposals"

4. **What has been your experience with PICES so far?**
   - "I met many lovely and respectable people from all over the Pacific, which stimulated me very much"
   - "Great to meet diverse people with lots of positive energy - quite inspiring"
   - "Lots of acronyms to remember"
   - "Amazing people" / "Many hard working people!" / "Good people, good talks, wonderful coffees"

Despite the undeniable fatigue that was felt at the end of such a long day of workshops, several attendees remained actively engaged by answering the brainstorming questions (see Figure 2) and by continuing to network with other fellow participants and guest speakers. Many fruitful discussions and exchanges of ideas were reported afterwards. The informative, inspiring and positive feedback we received will be truly instrumental in guiding future engagement initiatives and career development support for PICES ECOPs, including, inter alia, a mentorship platform, cross-cultural and inter-generational dialogues, networking and training opportunities, multilingual

knowledge sharing, project leadership, informative sessions dedicated to ECOPs, and further lobbying towards greater financial assistance of ECOPs to attend conferences, high-level symposia, summer schools and other events. Additionally, we received word that a few ECOPs engaged in the opportunities highlighted by the PICES Scientific Committees during their presentations, with some ECOPs attending various business meetings and sessions throughout PICES-2022 to learn more about the working groups and to network and engage more deeply with experienced PICES members. All in all this workshop was a success and AP-ECOP looks forward to planning future opportunities for PICES ECOPs at upcoming meetings such as Effects of Climate Change on the World's Ocean (ECCWO5) in Bergen, Norway and PICES-2023 in Seattle, USA.
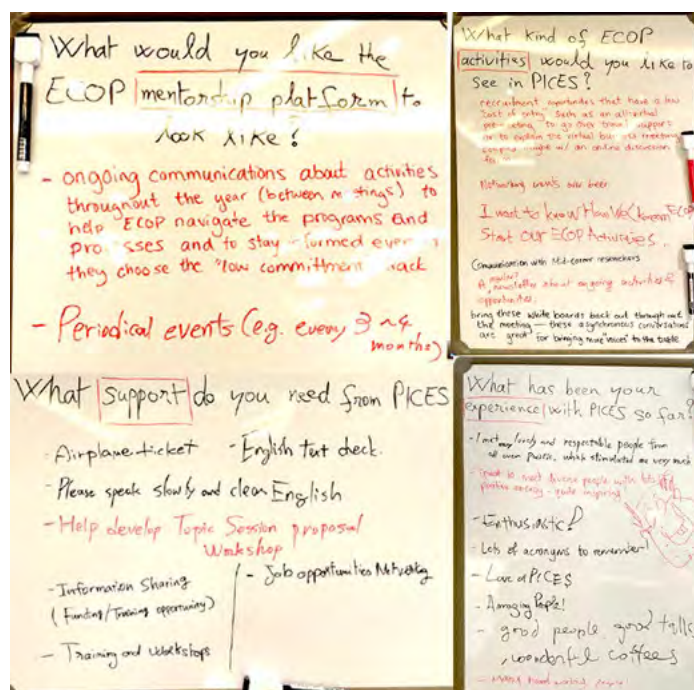

Figure 2. Pictures of the brainstorming white boards following the ECOP workshop (W4). Photo by Raphaël Roman.

PICES-2022 W5: Integrating biological research, fisheries science & management of broadly distributed flatfish species across the North Pacific Ocean in the face of climate and environmental variability

Josep Planas (corresponding; USA), Chris Rooper (Canada), Naoki Tojo (Japan), Roman Novikov (Russia)

Background

The North Pacific Ocean is a large and productive ecosystem characterized by strong interdecadal climate variability. This Ocean basin supports a number of fish species of great ecological and economic importance. A successful PICES FIS-Workshop (W2), co-sponsored by the International Pacific Halibut Commission (IPHC) at PICES-2019 focused on important current topics related to the biology and fishery of Pacific halibut and interacting species. The session brought together researchers, scientists and managers from countries invested in this resource. An important outcome of that workshop was the need to increase the application of integrative approaches to improve our understanding of the biology and management of widely-distributed species, such as Pacific halibut, in the North Pacific Ocean. This requires a high level of international cooperation. Therefore, to achieve these goals and as a step forward in addressing key areas of cooperation between PICES and IPHC as described in the current MoU between the two organizations, a Workshop was organized to address emerging issues in key flatfish species with broad distribution across the entire North Pacific Ocean. The Workshop consisted of several presentations on specific topics related to the biology of flatfish and interacting species and management and policy issues, followed by a discussion session. The main objectives of this Workshop were to:

1. improve the sharing of information on fishing efforts and management strategies across the North Pacific Ocean;
2. promote international collaborative studies to improve our knowledge on movement of flatfish populations and potential distribution changes of flatfish and other interacting species in the face of climate variability.

Summary of Presentations

This one-day Workshop held on September 25, 2022, was opened by Josep Planas who welcomed the participants and provided a brief introduction to the Workshop. The session featured 3 invited presentations and 4 regular oral presentations.

The first invited speaker, Dr. Melissa Haltuch of the Northwest Fisheries Science Center – NOAA, described the results of recent studies examining the oceanographic mechanisms that drive recruitment success of Petrale sole in the California current at different life stages. In addition, results on the modeled connectivity between deduced spawning areas and juvenile settlement areas in the context of particular oceanographic conditions (e.g. cyclonic eddies) were presented.

The second invited speaker, Dr. Patrick Thompson of Fisheries and Oceans Canada, gave a live online presentation on the effects of changes in temperature and oxygen concentrations in waters off the West coast of the USA and Canada on distribution and abundance of a wide variety of groundfish species. Results on future projections of temperatures and oxygen content by depth and the expected changes in fish biodiversity were presented.

The final invited speaker, Dr. Takeshi Tomiyama of Hiroshima University, Japan, provided an overview of the major Pleuronectidae species found in the Eastern (i.e. Hiroshima) and the Western (i.e. Fukushima) coasts of Japan and of key biological and ecological characteristics of these species at different life stages.

Contributed presentations included topics related to movement of Pacific halibut within the Bering Sea basin through the use of pop-up satellite tags (Mr. Austin Flanigan), stress profiles and survival estimates of Pacific halibut discarded by the recreational fishery in Alaska (Mr. Claude Dykstra), the seasonal reproductive development of Pacific halibut females during an annual reproductive cycle (Dr. Josep Planas), and, lastly, the generation of a chromosome-level assembly of the Pacific halibut genome and its application to studies on population structure of Pacific halibut in the northeast Pacific Ocean (Dr. Josep Planas).

After the presentations, a discussion session took place among participants. The need to share analytical tools for fishery management among researchers from the PICES regions was identified as important. In addition, it was suggested that the existence of international repositories of fishery and biological data would assist in efforts to foster international collaboration. Emphasis was made on the value of supporting Early Career Scientists and to promote mobility of researchers. Finally, the creation of a flatfish species list was suggested. The discussion session ended with support from participants for the submitted proposal of a third Workshop to be held at PICES -2023 in Seattle.

PICES-2022 W7: Anthropogenic stressors, mechanisms and potential impacts on Marine Birds, Mammals, and Sea Turtles
Patrick O'Hara, Miran Kim, Yutaka Watanuki

The anthropogenic stressors workshop was divided into Eastern and Western Pacific region-based sessions with presentations and discussions focusing on key threats to marine birds, mammals, and sea turtles. Two invited speakers, (one from each side of the Pacific Ocean), Dr. Jongmin Yoon from Korea (above, left) and Dr. Matthew Savoca from the USA, (above, right) began each session.

In total, there were 15 presentations (13 oral, 2 poster) with 8 presentations based in the Western and 7 presentations based in the Eastern Pacific PICES subregions. Presentations were varied in their focus, with either a taxa specific approach to understanding impacts from various stressors (for e.g., conservation challenges for sea turtles in Jeju Korea), or stressor specific approaches (for e.g., microplastics and their impact on marine organisms).

The workshop was held as a hybrid meeting and was fairly well attended with approximately 14 attendees participating online, and 12 attendees in person (Korea – 10, USA – 6, Canada – 5, Japan – 4, China – 1).

Our workshop began with a presentation by Dr Yoon, who described a very interesting indirect pathway of effect, with land reclamation near Incheon acting as an ecological trap, where colonizing breeding seabirds are exposed to elevated levels of predation from urban adapted predators. The real strength and potential outcome of this workshop lies in the comparison between the two PICES subregions (Western and Eastern Pacific), with the identification of important (and/or emerging) stressors, and how focal taxa interact with these stressors. We are currently drafting a more comprehensive report as a follow up discussion with workshop participants.

The abstracts for the workshop can be found in the Book of Abstracts for PICES-2022.

Alex Mustard Image from UNDOS Ocean Image Bank.

PICES PICES PRESS

N fertilization

storms

CO_2

UV & ozone

dust

nutrient/
pollution
run off

hypoxia

sediment warming

noise
pollution

acidification

shallower mixed layer

enhanced stratification

upwelling   habitat
destruction

litter

decreased
nutrient
supply

deoxygenation
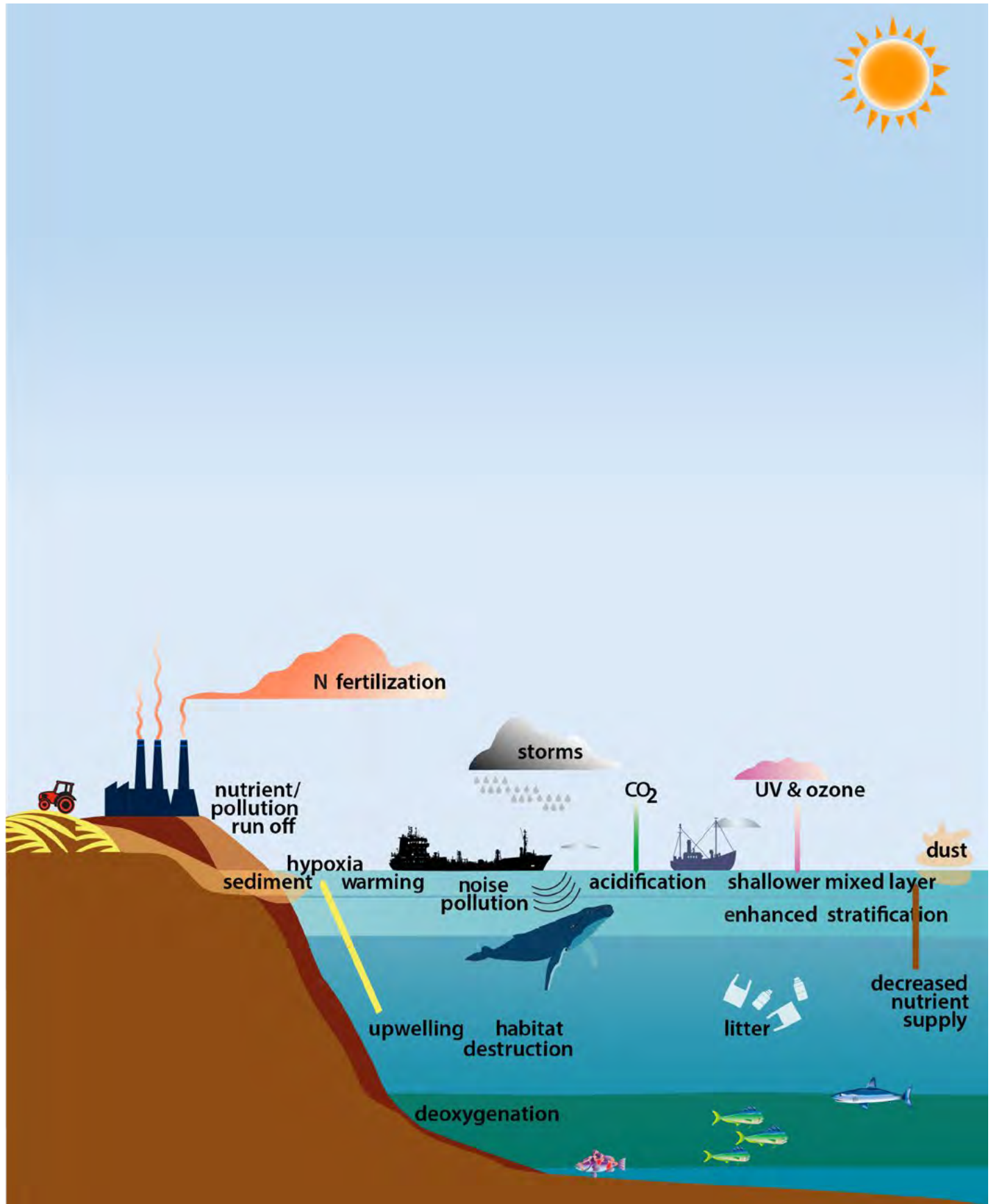
Adapted from Figure 2: IOC-UNESCO. 2022. Multiple Ocean Stressors: A Scientific Summary for Policy Makers. P.W. Boyd et al. (eds). Paris, UNESCO. 20 pp. (IOC Information Series, 1404) doi:10.25607/OBP-1724

PICES-2022 W8: Science Communication Training: How to Create Memorable PICES Science Stories.

Lori Waters, Vera Trainer, and Tammy Norgard.

Ocean scientists, including PICES members, usually do amazing science, and often feel that their results speak for themselves. But many scientists are eager to learn new ways to communicate their work more effectively, in order to facilitate improved ocean health. PICES has been working towards finding ways to support its members in better and more broadly communicating their science. This short workshop report describes the *"How to Create Memorable PICES Science Stories"* two-day workshop (participants shown above) held on September 23/24, during PICES-2022, by the Advisory Panel on Science communication (AP-SciCom). In keeping with the Terms of Reference for AP-SciCom, the panel will facilitate regular workshops to assist PICES members to learn more effective ways of communicating their science. This builds on previous PICES Science Communication workshops and Science Communication Expert Group work (described in previous issues of PICES Press).[1]

This year's Science Communications workshop focused on the 'ABT (And, But, Therefore) method' of communicating science, as this proven communication framework developed by Dr. Randy Olsen (and elucidated in his books such as "The Narrative Gym" and "Don't be such a Scientist") is designed to take advantage of a human neurological tendency to be compelled by narrative. Participants learned to craft their science into narrative stories in such a way that their audiences would not only connect with and believe our science stories, but also remember them.

The ABT workshop featured invited expert speakers Julie Claussen (Director of Operations, Fisheries Conservation Foundation, attending virtually) , Brian Palermo (comedian, improv coach, and science communicator, Palermo Improv Training) and John Pohl (Oceanographer, NOAA) with assistance from AP-SciCom members Vera Trainer, Elliot Hazen, and Lori Waters.

Palermo's compelling introductory presentation focused on audience connection, by teaching science communicators not to focus so much on *"did I say what*

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[1] *"Communicating Science"*
https://meetings.pices.int/publications/pices-press/volume28/PPJan2020.pdf#page=14
"PICES new Science Communication Study Group: Bringing our science to the world"
https://meetings.pices.int/publications/pices-press/volume29/PPJan2021.pdf#page=51

It's not what YOU present… it's what THEY perceive.
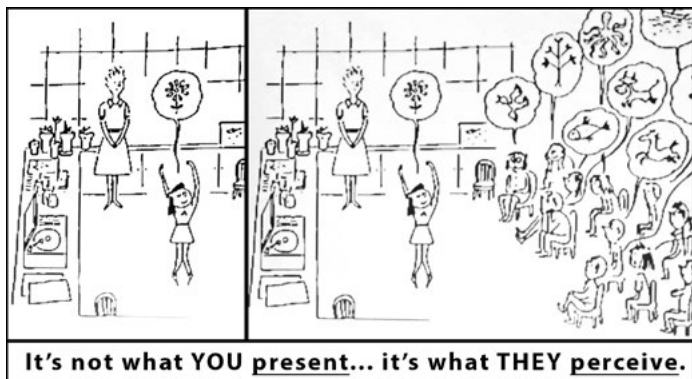
I wanted," but rather *"did the audience hear what I need them to hear,"* (see above). By first flipping the narrative from ourselves to our audience, science communicators are able to better engage with an audience, who will be better able to hear our compelling science story. And, Palermo points out that creating a narrative does not mean compiling a list of facts, as this traditional scientific "and, and, and" propensity serves not to compel audiences, but is more likely to send them to sleep. Instead, participants learned that the key to bringing their science stories to life is to set up agreement in the audiences mind, (this is the "And" portion of the story), introduce a problem, (the "But") and then to offer a solution (the "Therefore"). Agreement is key, as this engages the audience with your science. Introducing the problem then taps into the problem-solution dynamic so critical to storytelling, as it taps into human problem-solving propensities. Lastly, because our brains are activated by the tension between the agreement and the problem, offering a solution to relieve the tension, and this third piece – the "therefore" will help your audiences to remember (and ideally act upon) your key messages. The neurological impact of the ABT method has been tested, and shown to activate brain centers, as shown below.

This is your brain on…

Non-narrative   Narrative

Palermo describes the ABT method in simple terms as:

- **And:** this is the "heaven" – there are common threads. For example: "We all love the ocean" and "We all want to protect the ocean" are "and" statements that would build agreement and the beginning of a narrative.

- **But:** is the "hell" statement, and science communicators need to ensure that there is a great contrast between the heaven and hell. Using the ocean "and" statements above, the "hell" "but" statement could be something like: "But, plastic pollution is destroying our ocean ecosystems."

- **Therefore:** The final statement is the solution, and the consequence, and should reflect a changed world and a narrative of hope, in order for audiences to relate and remember the message. Using the example above, the therefore could be something like: "So scientists have developed a way of removing plastic pollution from ocean ecosystems."

Simplified ABT guide, courtesy of instructor Julie Claussen.

Further breaking down the methodology for creating and honing problem statements, Julie Claussen then gave an in-depth presentation on the ABT narrative framework. During her presentation she gave examples using the quick guide above, answered questions from workshop participants about the process and expected results, and shared several instructional videos (linked below in this report). Importantly, Claussen differentiated between narrative and non-narrative, providing the following example of what is NOT a story, but that many scientists would normally likely interpret as a story. *"There is this thing, and it was important to the ecosystem and people valued this thing and this thing did this and it did that and you want to be sure to know about this and…and…and…"*

Rather, it is the narrative structure set out in the ABT method that builds the story, by setting up tension in the mind of the reader between the agreement and the problem, before offering a solution. The reason that this narrative structure works, Claussen explained, is because humans, as natural problem-solvers, have brains which seek solutions as soon as a problem is presented: *"People are hard-wired to follow the 'Problem – Solution Dynamic.'"* Providing several examples from well-known and popular films, she summarized the narrative

Dorothy lives in Kansas
We're not in Kansas anymore
Clicks her heels to go home

arcs of these, and how they also fit into the ABT structure, with the creation of agreement ("heaven"), a problem ("hell"), and finally, provision of a solution, which satisfies our brains. Claussen emphasized the power of using this narrative method is that PICES scientists can use it to motivate their audiences by:

- A: Creating agreement by reminding the audience what they love;
- B: Creating tension by removing or destroying the thing that the audience loves;
- T: Give the audience hope, by creating a resolution, which also helps the audience to remember the narrative.

In summary, Claussen instructed that a statement using the method could be as simple as: *"In the past, life was like this, AND all was well. BUT we had this problem, THEREFORE, in the future, we're going to do this to solve the problem."*

However, while this *seems* simple, participants found that reducing the problem to *one* simple statement can be more difficult than it sounds. She stressed the importance of defining <u>one</u> singular problem, because if a scientist isn't able to decide their singular problem, it is likely to be difficult or impossible for an audience to do so. Using a fisheries example, participants were asked to consider whether the problem is climate change, policy, invasive species, staffing compliance, etc.) If there is more than one problem, then your audience is not able to focus, and, worse, Claussen explained that *if <u>everything</u> is important, then <u>nothing</u> is important*.

Our challenge as science communicators, she explained, is to better understand the narrative structure of stories so that we can better tap into a narrative dynamic, to better connect audiences with our science. Cautioning participants, she reminded the group that using the narrative framework, which seems deceptively simple, does not mean that undertaking the process of telling our science stories in this way is easy. Nor does the process mean that we need to dumb down our stories. Rather, in using the process well, we can create focused and concise stories that will be memorable for our audiences. Claussen further differentiated for the group that while the ABT form supplies the narrative structure for

our stories, the content is the information itself, which science communicators craft and hone. The information includes the "colour, depth, visuals, adjectives, humour, etc." Following on from Brian Palermo's introduction, the creation of this content also must balance what you – the scientist – wants to say, versus what the audience wants to hear. Messages need to be crafted for your chosen audiences, in order to connect with your audience so that they will understand your science.

Claussen's short videos detailed why scientists must tell their stories, the forces of narrative, defining audiences, and, a methodology video reminded participants that the less concise they are, the less compelling they are. Lastly, she introduced attendees to a storyboarding method as a means of honing their stories, and encouraged them to use a storyboarding template as a means of working through the ABT drafting process.

The group then focused, with Palermo's guidance, on ways – especially in verbal narration of audio and videos – of intentionally and holistically employing all of our communication skills and aspects of our selves to tell our science stories, which may run counter the traditions of science, which set out an implicit expectation of "objective" (emotionless) communication, which can hinder effective communication. He encouraged participants to use all of their abilities to convey their messages and be more engaging, explaining that messages are not solely about content but also about delivery. Connecting with other humans in order to have them hear, understand, and remember our messages means connecting with them on many levels, including delivering our messages via both verbal and non-verbal communication. Important to non-verbal communication is eye contact, expression of some emotion through facial expressions, and using "paralanguage" such as vocal volume, inflection, intonation and rhythm to emphasize your message, in conjunction with body language gestures.

Participants were led through a series of "improv" exercises designed to heighten awareness and skills in paralanguage, which participants found very helpful and that organizers hope to feature to the broader PICES audience at

PICES-2023.. The goal of these exercises was to enhance the ways in which PICES scientists can connect with their audiences. Through a series of "safe to fail" experiments participants will listen to understand, rather than respond, and can enhance their agility in being able to deliver messages in such a way that audiences can relate and better understand them.

Though these may seem counter-intuitive to the perception that a 'rational' scientist must demonstrate their impartiality by describing their work in restrained, passionless, reserved, or controlled terms, this tendency can in fact impair audience's ability to relate to, understand, or remember scientific messages, because the lack of emotional content in a scientific message may give the perception that the message is unimportant, that the scientist is condescending or boring, or that they are unconcerned with the impacts of the issue they're studying.

Participants were reminded that the most important thing is not that which you are presenting to an audience – it is what the audience is perceiving that is most important. A recent cultural example of the importance of emotional content that can help demonstrate this point is that emojis so commonly used in conventional daily communication were developed to enhance the emotional meaning of messages, by adding emotional content. Palermo emphasized that we are humans, and by adding the full spectrum of emotional content, we can better engage in full-spectrum communication, and that by enhancing our emotional expression when we communicate our science messages, we enhance the ability of our audience to understand our science and our messages. In short – Palermo reminds us – "if we don't reveal it, they don't feel it." And, if they don't feel it, your audience is unlikely to engage in, or seek to better understand (or remember) your science.

The final instructional portion of the workshop then focused primarily on visuals. Participants reviewed ABT videos made earlier by group members; John Pohl from NOAA provided an overview of composition basics; and Brian Palermo provided a primer for participants on technical aspects of creating and framing quality videos. Pohl's background reminded communicators to consider their audience, and in preparation for creating science communication deliverables, to determine what is known about the target audience, and what result is sought from the communication piece – i.e. what would you like the audience to think, feel, or do. Referencing the work of Edward R. Tufte, Pohl reminds us that stories must also be revised depending on delivery media, but that regardless of media, visual elements are key to effective storytelling. In addition to using words to tell our science stories,

creation of effective visuals can enhance understanding of ideas, and provoke emotions to better engage our audience. Pohl reminds us that an image with a few words is much more effective than words alone. Covering the basics of compositional space, line, contrast, shape, tone, colour, movement, Pohl also contrasted the impact of showing a series of graphs showing the impact of ghost nets and derelict fishing gear, versus the above photograph of a dead pinniped in a net, which conveys much more directly the impact, without the need of graphs or verbal description. To conclude his presentation, Pohl provided the links below to imagery that science communicators can freely use when producing their work.

- pexels.com
- thenounproject.com
- unsplash.com

Lori Waters in the PICES Secretariat can also provide access to PICES imagery for PICES members, and reminded participants that we also have access to the ocean image bank during the UN Decade of Ocean Science for Sustainable Development (UNDOS).

With this background, 3 groups of workshop participants created their own short (~1 minute) videos, using their new ABT skills:

- Advisory Panel on Science Communications (AP-SciCom) members provided an overview of the ABT method workshop, and its importance to PICES, inviting other PICES Expert Groups to use the ABT methods to share their work.

- SmartNet (Sustainability of Marine Ecosystems through global knowledge networks) steering committee members provided an overview of the goals and importance of the SmartNet UNDOS program.

- Section on Harmful Algal Blooms (S-HAB) members provided an overview of current HAB work being conducted in Indonesia, a special project funded by the Japanese Ministry of Forestry and Fisheries that is responsive to increasing incidence of HABs.

The purpose of these ABT videos is to provide audiences with a better understanding of PICES Expert Group work

and scientific highlights, in a user-friendly format. We also hope that they may spark collaboration, encourage further inquiry into PICES global work, and inspire PICES Expert Groups to make their own videos to share their work.

The PICES-2022 Science Communication workshop videos are featured on PICES' YouTube Channel, to help your Expert Group share your science:

- The Three Forces of Narrative, about the ABT method, by Brian Palermo.
- The One Thing, about honing your issue for the ABT method, by Rick Nelson.
- Audiences, about understanding your audience for the ABT method, by Nancy Knowlton.
- Tell your Story, using the ABT method, by Shirley Malcolm.
- Storyboarding your ABT video, as a way of honing your message using the ABT method, by Julie Claussen.

As part of the workshop, two additional videos created by PICES members using the ABT method were shown as examples to participants:

- Community Shellfish Monitoring of Harmful Algal Blooms (HABs), by Vera Trainer.
- Dynamic Ocean Monitoring as a tool for Sustainability and Conservation, by Elliot Hazen.

For PICES members wishing to use the ABT method, we hope that the resources contained in this report will be a good starting point. AP-SciCom members look forward to seeing your short videos and related work, which we hope you'll share. Please contact us if we can assist you. Completed videos can be sent to Lori.Waters@pices.int.

We look forward to seeing you at our PICES Science Communication workshop planned for PICES-2023 in Seattle, WA, which will focus on the development of compelling fact sheets to help PICES members better share their work.

Lori Waters is PICES Communications Officer. She holds masters degrees in both fine arts and science, with supplementary marine science courses at Bamfield Marine Science Centre. Her science communication work for many public and private organizations includes scientific illustrations, displays, animations, & outreach publications for Fisheries and Oceans Canada; scientific illustrations for the Canadian Wildlife Service and the Royal British Columbia Museum's Orca exhibit; cover and publication design and scientific illustrations for journals including Cell, Nature Biotechnology, Marine Pollution Bulletin, PICES publications, and others. Lori was a Ghanaian Commonwealth Scholar, Vesalian Scholar, Massey Jr. Fellow, and a Canadian Health Institute Science Communication Scholar. She combines her love of science and art as a naturalist who draws, paints, and teaches, and she collaborates on science field work teams whenever possible. She is the PICES Secretariat liaison to the Advisory Panel on Science Communications (AP-SciCom) and the Study Group on Generating Recommendations to Encourage Environmentally- Responsible Networking (SG-GREEN).

Vera Trainer is the research lead for University of Washington's Olympic Natural Resources Center marine science program, following a career with NOAA. Dr. Trainer is the past Science Board Chair, a member of AP-SciCom, AP-UNDOS, HAB-S, SG-GREEN, and WG-49, and a mentor for AP-ECOP. She has led international comparative approaches to study the geographical distribution of harmful algal blooms to increase our understanding of conditions that promote these events across the North Pacific and worldwide. She enjoys national and international collaborations and outreach to diverse audiences, spanning from schoolchildren to legislators, to enhance our cultural, scientific and personal understanding of one another.

Tammy Norgard is the Program Head within the Marine Spatial Ecology and Analysis Group at the Pacific Biological Station in Naniamo, Canada. Her main role is to work with existing science programs and develop new ones in the offshore region of Canada's Pacific - a unique area with many seamount and hydrothermal vents and this area was recently announced as an Area of Interest (AOI) for consideration as a Marine Protected Area (MPA) under Canada's Oceans Act. I She evaluates benthic impacts and species distribution with mapping/models of offshore seamounts and collaborates with academics and First Nations to gather baseline and monitoring data, conducts ecological monitoring and research to support evaluation of the large offshore area of interest. She and her team are currently conducting field work to support development of an ecological overview for the area.

PICES-2022 W10: A TCODE Workshop on "Openly Discoverable, Accessible, and Reusable Data and Information in the U.N. Decade"

Jeanette Gann, Jill Prewitt, Shelee Hamilton, Brett Johnson, Wan FangFang, Hernan Garcia

Ocean data in all forms contribute to understanding and informing management and sustainability of the world's oceans and its ecosystems. Open sharing of that data and information across international boundaries remains a formidable challenge. The overarching motto of the United Nations Decade of Ocean Science for Sustainable Development (UNDOS) is *'the science we need for the ocean we want'.* To obtain this, we need to share data openly across all regions, continents, and countries. There are many efforts at regional, national, and international levels working towards this goal. Keeping apprised of UNDOS data activities is paramount for PICES data and information management. Encouraging the facilitation of data mobilization and sharing across international boundaries and private institutions will help to bring UNDOS data goals to fruition.

PICES is in a unique position to engage scientists and data managers from countries around the North Pacific to help facilitate discussions about open data sharing. Inviting a wide range of participants, we discussed histories, successes, and challenges of open data. This workshop helped to guide TCODE to an actionable role in facilitating data sharing between PICES member nations for the UNDOS . Additionally, it helped to form a new study group devoted to investigating data and information management within PICES that will identify gaps, mishandling, or roadblocks for data flow, among other issues.

Workshop goals included the following:
- Assess barriers to open data sharing and/or exchange (i.e. FAIR-compliant)
- Draw a PICES data flow diagram
- Identify incentives to open data sharing
- Identify appropriate UNDOS-endorsed data platforms for PICES data and reports
- Assess the need for a study group to further increase PICES data management and sharing
- Update PICES data policy for submission to science board and general council
- Strategize ways in which TCODE can integrate with FUTURE and Smartnet, and include ECOPs into TCODE membership

Participation in the workshop included a hybrid format with invited speakers for our morning session (listed below), and an afternoon of discussion on a number of topics related to our goals for the workshop (above). Additionally, guest speakers (Drs Raphael Roman, and Steven Bograd) addressed the workshop regarding related PICES programs and ECOP initiatives where potential TCODE overlap/membership could occur.
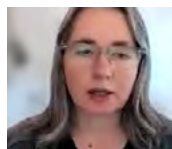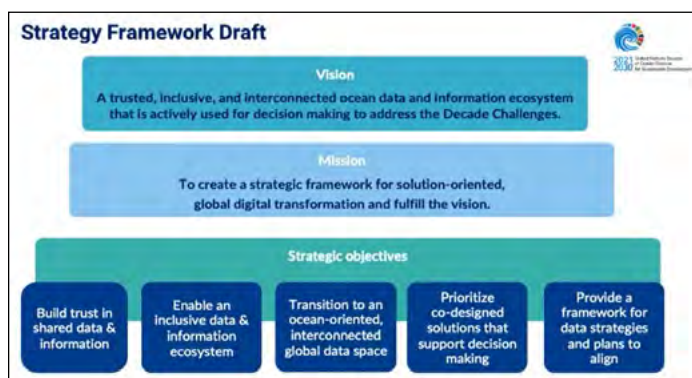
Ms. Kate Wing, founder of the Intertidal Agency, and Co-Chair of the IOC Ocean Decade Data Coordination Group (DGC), gave a presentation entitled *"Data coordination across government, private industry, and non-profit entities: increasing access through the U.N. decade."* Ms. Wing's presentation touched on a variety of topics regarding large scale data coordination efforts and included the introduction of the Ocean Data and Information System (ODIS) catalog that could improve communication of PICES data, information, and projects to a wider international audience.
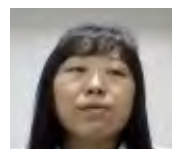
Ms. Han Chunhua from the National Marine Data and Information Service (NMDIS), presented a talk on *"China's practice on marine big data management and sharing."* Her talk centered on China's largest ocean data and information system and included information on understanding, management, sharing, and prospects of big data. Additionally, she discussed specifics of how data is collected, quality assured and quality-controlled (QA/QCd), and ultimately managed from the outset of each project. And finally, the NMDS marine observation data sharing and service platform plan to expand to greater international data sharing.

Digital ecosystem

- incorporate both already existing and newly constructed digital management platforms and tools
- contribute to understanding the ocean using historical, contemporary and modelled data to describe the past and current conditions and predict future ocean conditions
- data sources also include industry or citizen-science data, as well as indigenous and local knowledge
- a working group ensures the quality and fitness for purpose (not always scientific) of data and information assets (it needs to consider metadata catalogs as core elements of data management)

Dr. Igor Shevchenko (PICES and TINRO Center) talked about *"Lessons learned from TCODE metadata federation activities".* He discussed the many barriers to data sharing on an individual level, between various organizations and across international boundaries. His discussion points provided ideas on how PICES could benefit from better resources and focus on taking care of data and metadata, how PICES will need to add metadata into our data policy, and that UNDOS presents a good opportunity to increase data sharing and management in general.
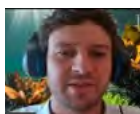
Mr. Tim Van der Stap and **Mr Brett Johnson**, both ECOPs from Hakai Institute in Canada, presented *"Mobilizing international salmon data from open ocean to open access".* Points made during this talk include how scientists often have limited funding and that using resources to manage and mobilize data for purposes of sharing tend to go to the bottom of the project list. The *Basin Scale Events to Coastal Impacts project* (BECI) was introduced, which plans to mobilize data to increase its value, and utilize a data science team helpful for mobilization, coordination, data exchange, and standardization.

Dr. Yutaka Michida, an ex-officio member of TCODE and a former Co-Chair of IODE, presented a talk on *"Oceanographic data and information sharing towards goals and outcomes of the UN Decade of Ocean Science".* His presentation highlighted past data sharing conferences, and encouraged PICES to participate in upcoming meetings: 2ⁿᵈ International Ocean Data conference, 20-21 March 2023, and the IODE XXVII ocean data meeting, 22-24 March 2023 in Paris, France.

Summary of workshop findings:

Barriers to data sharing:
- 3 categories: 1) social/cultural 2) technical 3) legal constraints organizations
- Language barriers add to data sharing blockages
- Scientists not generally awarded for sharing their data (opposite)
- Lack of Financial/Specialist/Admin support for proper management of data/metadata!

Incentives to data sharing:
- Possibly create PICES (or other) award on data management/sharing/interoperability
- Incentives for some are different than for others (industry vs gov vs academic, etc.)
- Have data management strategy ready at beginning of projects instead of an 'afterthought'

Other findings:
- PICES Data flow diagram has gaps (needs focused discussion)
- Culture of dealing with data is lacking. UN Decade >> fuel new culture, better management, sharing, mobilization.
- ECOPs could be very helpful in changing this culture!
- Study group would be very helpful to further improvements of data culture in PICES

As a direct result of this workshop, a new study group was formed on *encouraging Data Awareness and increased Transmission and Accessibility (*SG-DATA),(see TOR below). Anyone interested in joining is encouraged to contact the Chair, Dr. Hernan Garcia (Hernan.Garciea@noaa.gov).

SG-DATA Terms of Reference:
- To assess existing best practices, and complete a PICES data flow diagram
- To gather lessons learned from past, ongoing and planned projects, programs and initiatives;
- To identify solutions for known problems and bottlenecks regarding sharing of data within PICES and beyond;
- To facilitate harvesting of PICES metadata catalog records by UN Decade data platforms (like ODIS);
- To draft a checklist of questions to promote data sharing and the reproducibility of results for paper/report submissions;
- To consider what kind of infrastructure would be sufficient to enable those with "small" and "besides" science data who wished to contribute to a digital commons environment;
- To consider how to make FUTURE, IPOD organic parts of the future UNDOS digital ecosystem;
- To increase collaboration between TCODE and other PICES programs like Smartnet, in addition to external collaborations (ICES DIG).
- To identify a digital platform that is accessible by all PICES member nations/constituents for use in simultaneous document editing and updates that can be used by all committees and expert groups for more efficient and effective communications and work.
- Review the current PICES data management policy and forward any changes/edits to TCODE, SB, and GC for approval.

PICES 2022 AP-NPCOOS "Ocean Big Data" Summer School
Dave Riddell

2022 PICES Ocean Big Data Virtual Summer School, 8-19 August, 2022 - participants and instructors.

Recent years have seen rapid expansion in both the scale and scope of ocean observations enabled by distributed data-collection technologies such as cabled observatories, autonomous systems, and mobile sensors. This expansion is welcome and necessary not just for continued exploration but also to better understand and inform management of the impacts to marine environments over different spatio-temporal scales. Huge volumes of data from multiple sources and of different types are now generated with relative ease, with high-resolution and extended time series data sets becoming increasingly common in marine science.

These advances offer new opportunities for interdisciplinary research and analyses while also presenting new challenges associated with data processing, storage, management, and access, as well the need for education and training for marine scientists entering the world of big data.

Responding to this need, in August 2022, Ocean Networks Canada (ONC) hosted 27 early-career scientists from 10 countries—including all six PICES-member countries as well as Brazil, France, India, and Nigeria—for a PICES Summer School on "*Ocean Big Data.*"

With the unpredictability of the global pandemic limiting travel and in-person attendance, the 2022 summer school was held entirely online: a first for PICES. During this two-week-long workshop participants learned skills and gained valuable hands-on experience in the analysis of large oceanographic time-series data sets: data sets increasingly recognized for their value in establishing oceanographic baselines and for detecting ocean change. Data sets were provided by instructors from Japan, Korea, Canada, and the USA, together with appropriate statistical tools for identifying trends and events in the data.

An important feature of the summer school was that the structure and learning experiences were mapped to Universal Design for Learning (UDL) guidelines (https://udlguidelines.cast.org/), an educational framework based on neuroscience research which has identified primary neurological networks that impact learning—the "why" (affective network), the "what" (recognition network), and the "how" (strategic network)—and which seeks to increase learning access and reduce barriers for students to engage equitably in the educational process. Please contact the author (riddelld@uvic.ca) if you are interested in specific mapping notes for the 2022 PICES *Ocean Big Data* Virtual Summer School.

Gliders, HF radars (CODAR ,WERA), P station, hydrographic lines (137E, A lines)

Study domain of datasets featured in the 2022 PICES Virtual Summer School. Image courtesy of Prof. Dr. Sung Yong Kim, Korea Advanced Institute of Science and Technology (KAIST).

Lectures and introductions to the data sets took place over the first three days of the summer school. Time-zone differences of up to 17 hours between participants required that teaching and learning in these initial days occurred asynchronously. In addition to recorded lectures on deep ocean deoxygenation and acidification (Dr. Tetjana Ross, Fisheries and Oceans Canada), coastal upwelling and hypoxia (Dr. Jack Barth, Marine Studies Initiative), time series analysis (Dr. Richard Dewey, ONC and Dr. Sung Yong Kim, Korea Advanced Institute of Science and Technology), and an introduction to data science, machine learning, and cloud computing (Dr. Richard Dewey), participants also learned about data QA/QC practices (Megan Kot, ONC), research data management and data citation (Chantel Ridsdale, ONC), and the Jupyter Notebook interactive environment (Fahim Alam, ONC).

Following this introductory content, participants selected a project on ocean big data on which they worked with other group members for the remainder of the school schedule. Data sets and associated project options included: extracting climate-change-relevant trends in physical and biogeochemical time series data (Dr. Tetjana Ross); using glider data to explore upper-ocean productivity, hypoxia, and shelf-deep ocean connections (Dr. Jack Barth); using CODAR or WERA data to investigate the complexity of submesoscale coastal surface circulation and variability (Dr. Richard Dewey,

Dr. Sung Yong Kim); and identifying interannual to decadal trends and variations of physical and biogeochemical properties in the western north Pacific (Dr. Takahiro Tanaka, Japan Fisheries Research and Education Agency).

With learning support from instructors and ONC staff, participants completed their data analysis projects in different computer environments (locally, virtual machines, and Jupyter Notebook) and in different programming languages (Python, MATLAB, and R). Synchronous and asynchronous online tools such as virtual meetings (Zoom), forums (Brightspace), repositories (GitHub), and cloud computing environments (sygyzy.ca) facilitated regular discussion, collaboration, and sharing of ideas, challenges and solutions, and example code.

Group project presentations took place virtually on the final day of the school. Each session provided additional opportunities for school participants to learn from and critique the work of other project groups. Instructors were also present throughout the sessions and contributed to project discussions. Sessions were recorded and archived along with shared code and all school materials made accessible to participants for download for an additional two weeks following the final day of the school—a resource that will remain valuable as school participants advance in their careers.

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In addition to the summer school, three University of Victoria graduate students in oceanography and biology also participated in a 1.5-credit course organized by ONC and facilitated by Dr. Jack Barth to complement and extend their project work undertaken in the virtual summer school.

Summer school and graduate course participants were invited to complete a school/course evaluation at the end of our time together. The feedback received was very positive and included comments such as: "It was such a great time to learn how to manage team projects from colleagues living in different time zones and cultures. The materials from the school […] were super beneficial for me."; "This summer school was truly enjoyable and intellectually stimulating. It's my great honor to be part of the summer school this year."; "I learned a lot from the lectures and team projects. It was a meaningful time for me to step up into a new world of physical oceanography. Thank you once again for giving me this opportunity."; "Thanks for a great course, I learnt a lot and enjoyed working with so many new people."; "I am glad to achieve this opportunity for attending this virtual school and hope for more studying opportunities from PICES in the future."

In his role with Ocean Networks Canada's Learning & Community Engagement department, Dr. Dave Riddell (riddelld@uvic.ca) supports the teaching and learning of marine and environmental science in universities, colleges, and communities through the design and delivery of courses and field programs centred around data from ONC's underwater observatories and mobile sensors. Originally from Northern Ireland, Dave emigrated to Canada in 2000 to complete his Ph.D. and post-doctoral research with the National Hydrology Research Centre and Environment Canada at the University of Saskatchewan, before moving east as the Education Director of the Environment and Sustainable Development Research Centre at the University of New Brunswick, and finally west to the Bamfield Marine Sciences Centre and ONC at the University of Victoria. Dave's research background is in ecotoxicology, with a particular focus on the roles of community science and community-based research in addressing local environmental problems. As an educator, Dave's work is trauma-informed and embraces critical pedagogy, open education, and transformative praxis.

Acknowledgements

PICES AP-CREAMS Virtual Summer School on *Ocean Turbulence: From Observing to Research*
Jianfeng Wang and Fei Yu
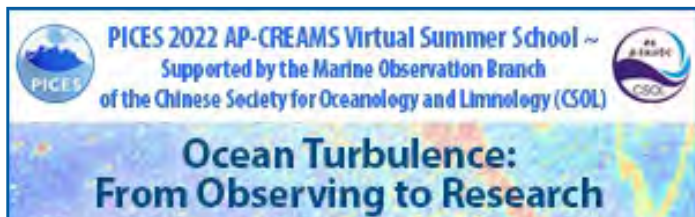
Turbulence occurs on small spatial and temporal scales which influences a wide range of oceanic motions, including the local ecosystem, global thermohaline circulation, and has broader implications for the Earth's climate. Locally, turbulent mixing controls mixed layer nutrient budgets, heat content, and sea surface temperature. Globally, turbulent fluxes affect the sequestration of carbon. Knowledge of ocean turbulence and its effects is crucial in understanding how the ocean works and in the construction of models to predict how the ocean will change, or how its interactions with the atmosphere will be altered in the future. The study of ocean turbulence and mixing has largely increased in the past decades, especially in field direct measurements. Modern development of fast response, high-resolution shear and temperature sensors allow a direct estimate of diffusivities and associated irreversible mixing.

From August 22 to 26, 2022, the Advisory Panel for a CREAMS/PICES Program in East Asian Marginal Seas (AP-CREAMS) held a PICES Summer School on *"Ocean Turbulence: From Observing to Research"* at the Institute of Oceanology, Chinese Academy of Sciences (IOCAS) in Qingdao, Shandong, China. Twenty-five early career scientists and students from 10 countries, including PICES' six member countries, as well as from Mozambique, Thailand, India and Peru participated .

Because international travel was restricted due to COVID-19, the week-long summer school was conducted online through Zoom, and consisted of lectures and interactive discussion. The summer school provided participants with opportunities to learn about basic theory and the significance of ocean turbulence. Observational methods, instrument deployment, and data processing techniques were also introduced to help participants learn how to observe, analyze and interpret field data.

Seven global experts provided lectures on the basic theory, field measuring, and data processing of turbulence, and recent progress made in research. Introduction and understanding turbulence in the ocean was reported by Prof. Hao Wei from Tianjin University (China). Prof. Wei introduced the basic theories and features of turbulence, which gave participants their first insight into turbulence basics. Turbulence characteristics in different areas and topographic features were also discussed.
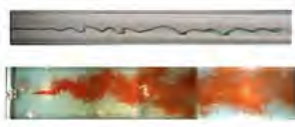

Prof. Hao Wei provided an introduction and lecture on understanding turbulence in the ocean.

Prof. Fei Yu lectured on shear probes and the spectrum of turbulent shear.
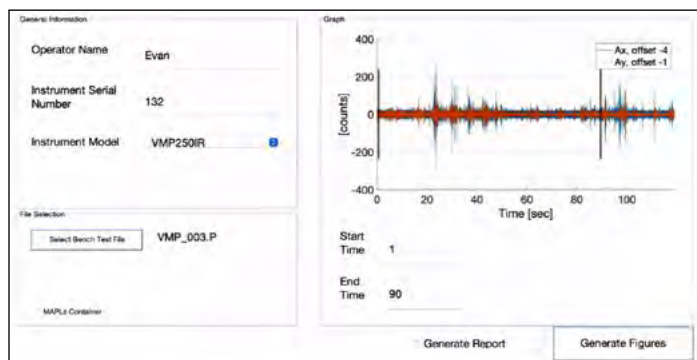

Dr. Jianfeng Wang lectured on the introduction of ocean turbulence measuring instruments and techniques.
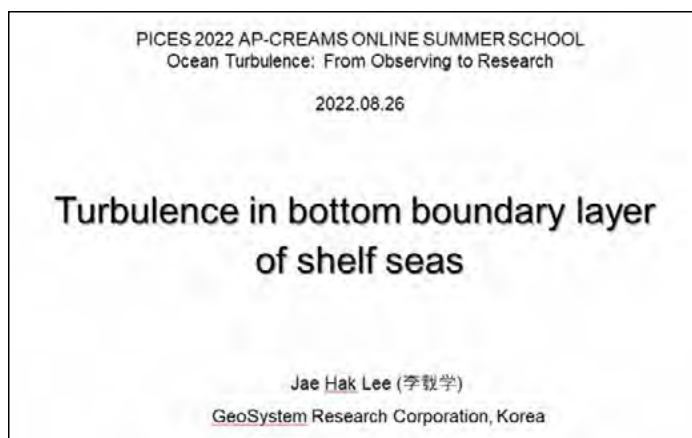
Dr. Jianfeng Wang (IOCAS, China) introduced various ocean turbulence measuring instruments and techniques, and participants learned the basics of the instruments and their application from Prof. Fei Yu's group. VMP probes, sensors, deployment checks and maintenance were introduced by Evan Cervelli (Rockland Scientific International, Canada). The shear probe and the spectrum of turbulent shear knowledge were presented by Prof. Yu (IOCAS). The participants learned about skills needed to deal with turbulent data from Dr. Zifei Chen (IOCAS) who discussed data processing techniques. MATLAB codes were also shared within the summer school. Besides the basic knowledge, talks on recent progress in turbulence studies were given by Prof. Chuanyu Liu (IOCAS) who discussed *"Physical interpretation of the observed turbulence mixing in the eastern Equatorial Pacific Ocean"* and Prof. Jae-Hak Lee (KIOST, Korea) who reported on *"Turbulence in bottom boundary layer of shelf seas".* The online summer school ended with exchanges about experience with turbulence measurements organized by Prof. Yu. Experts and participants presented their involvement in field observations and discussed future turbulence studies.

Prof. Jae-Hak Lee lectured on turbulence in the bottom boundary layer of shelf seas.

AP-CREAMS would like to thank hosting partners: Institute of Oceanology, Chinese Academy of Sciences (IOCAS), Marine Observation Branch (MOB) of the Chinese Society for Oceanology and Limnology (CSOL), and Northwestern Pacific Ocean Circulation and Climate Experiment (NPOCE) program.

Evan Cervelli lectures on the introduction to VMP probes, sensors, deployment checks and maintenance.

Because of COVID-19 restrictions, the summer school could not provide field experiment and instrument operation opportunities, so online training on instrument deployment and maintenance was instead provided. Dataset processing skills and related MATLAB codes were also shared. Graduate students and early career scientists all considered their understanding of ocean turbulence and ability to analyze the data of ocean turbulence to be greatly enhanced by the summer school experience. Evaluations received from the participants were very positive, including comments such as *"It was a fantastic and helpful summer school"; "We can get pretty comprehensive knowledge from the summer school"; "The summer school provided useful knowledge for starters like us!"* Based on the feedback, IOCAS would like to host another summer school in the future.

Dr. Jianfeng Wang (jfwang2013@qdio.ac.cn) has been an assistant professor in the Key Laboratory of Ocean Circulation and Waves, Institute of Oceanology, Chinese Academy of Sciences since 2013. He received his B.Sc. and Ph.D. from the Ocean University of China in 2007 and 2013, respectively. He was a visiting scholar at the University of Massachusetts, Dartmouth, from 2010 to 2012. The primary focus of his research is turbulent mixing and the variation mechanisms. He is a sea-going scientist who has done extensive field work and has rich experience in instrumentation and data processing.

Prof. Fei Yu (yuf@qdio.ac.cn) is Chief Scientist at the Institute of Oceanology, Chinese Academy of Sciences (IOCAS). He has been a Professor in the Key Laboratory of Ocean Circulation and Waves, IOCAS since 2008. He received his B.Sc. from the Ocean University of China (1991) and a Ph.D. from the Institute of Atmospheric Physics, Chinese Academy of Sciences (2001). The primary focus of his research is marine in-situ observation and regional oceanography. His recent work involves the 3D structure of the Yellow Sea Warm Current, mechanism of the Yellow Sea Cold Water Mass, daily variability of the North YSCWM Front, water exchange between the Kuroshio and East China Sea, circulation in the Pacific and climate change, mesoscale processes and turbulent mixing, and has shed new light on the 3D structure of the YSWC, mechanism of the YSCMW and subsurface eddy in the western Pacific. He has been involved in over 30 projects, including National Nature Science Funds, Strategic Priority Research Program of the Chinese Academy of Sciences, National Key Technologies R&D Program, Global Change and Air-Sea Interaction. Within PICES he co-chairs the Advisory Panel for a CREAMS/PICES Program in East Asian Marginal Seas (AP-CREAMS).

List of Lecturers

Name	Institute	Title
Fei Yu	Institute of Oceanology, Chinese Academy of Sciences, CN	Professor
Hao Wei	Tianjin University, CN	Professor
Chuanyu Liu	Institute of Oceanology, Chinese Academy of Sciences, CN	Professor
Jae-Hak Lee	Korean Institute of Ocean Science and Technology, Korea	Professor
Jianfeng Wang	Institute of Oceanology, Chinese Academy of Sciences, CN	Assistant Professor
Zifei Chen	Institute of Oceanology, Chinese Academy of Sciences, CN	Assistant Professor
Evan Cervelli	Rockland Scientific International, Canada	Technician

Science and Innovation to Scale Up Ocean Action: UN Ocean Conference 2022
Erin Satterthwaite

Convened by the United Nations General Assembly and co-hosted by the Governments of Kenya and Portugal, the United Nations Conference to Support the Implementation of Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development, was held from June 27 to July 1, 2022 in Lisbon, Portugal. The overarching theme of the conference was *"Scaling up ocean action based on science and innovation for the implementation of Goal 14: stocktaking, partnerships and solutions."*

More than 6,000 participants, including 24 Heads of State and Government, and over 2,000 representatives of civil society attended the conference. The call for urgent and concrete actions to tackle the ocean crisis, from rising sea levels and marine pollution to ocean acidification and habitat loss, was addressed.

PICES, a strong supporter of early career ocean professionals (ECOPs), provided funding for me to travel to the conference. During the conference, I had the opportunity to facilitate a Sustainable Ocean Netwalk (above) and a mixer

as well as present in two side events. The Sustainable Ocean Netwalk brought together over 35 people to discuss timely topics related to ocean sustainability. Many ECOPs mentioned that this event was the best opportunity that they had for networking and connecting with people throughout the entire conference. I participated in a presentation and panel discussion (below) during the side event *"Future Earth's marine networks: a trans- and interdisciplinary scientific community working toward the achievement of the SDGs"* in the French Institute. This occasion brought together around 50 people, including representatives of national governments. I also talked about "The Early Career Ocean Professionals (ECOP) Network Programme: Engaging the next generation of ocean leaders", specifically, I discussed what the ECOP Programme is and its recent accomplishments and activities.

I participated in a panel discussion during the side event, "Ocean observing for ocean sustainability" (shown on next page) hosted by Scripps Institution of Oceanography and GEOMAR Hemholtz Centre for Ocean Research Kiel. The panel was facilitated by Director of Scripps Institution of Oceanography, Dr. Margaret Leinen, and was focused around the Status and Challenges for Ocean Observation. I shared on the status and challenges related to biological ocean observations in my talk entitled, *"Marine ecosystem observations to support sustainability and resilience"*. Specifically, I discussed research that had been conducted as part of the Global Ocean Observing System (GOOS) Biology and Ecosystems Panel detailing the coverage of marine biological observations in the global surface ocean to be only 7%. Thus, they need to be sustained, coordinated, integrated, and expanded. Other notable speakers during this event included Toste Tanhua (GOOS co-chair) and Ambassador Ronald Jumeau (Permanent Representative to the United Nations and Ambassador for Climate Change, Republic of Seychelles). Finally, I participated in an educational live stream interview with children in China.

I also engaged in other conference events, including the high level interactive dialogues, Ocean Decade Forum, and an educational video on a fishing family in Cabo Verde. I attended invited networking and reception events as well, including the Ocean Decade Reception (see images at right), American Geophysical Union (AGU) dinner, and a Scripps Institution of Oceanography dinner. Throughout the conference I met with representatives from such organizations as the AGU, World Economic Forum, the Aspen Institute, Future Earth, the Ocean Conservancy, ICES, World Maritime University, Stockholm Resilience Center, and U.S. National Academy of Sciences, among many others.

Key takeaways from the event included:

- Build capacity for co-design of ocean solutions through iterative and collaborative processes that bring together different types of expertise, knowledge, and actors;

- Provide accessible & equitable information so that we can gain 'existential insights' from ocean observations and other long-term data. (Nicole LeBeouf, NOAA);

- Engage youth and early career professionals in meaningful ways and to be inclusive of how we define the 'we' in 'the science we need for the ocean we want'

- *"Great periods of oceanography are defined by new concepts of what oceanography is and who does it"* (Margaret Leinen, SIO Director).

Acknowledgements

Diversity Equity and Inclusivity (DEI) ECOP Task Team members gather at the UN Ocean Decade Reception event.

Alfredo Giron (World Economic Forum), Erin Satterthwaite (Scripps Institution of Oceanography, UCSD), and Alison Clausen (IOC-UNESCO) gather at the UN Ocean Decade Reception event.

Earth Negotiations Bulletin

A Reporting Service for Environment and Development Negotiations

Summary of the Second UN Ocean Conference: 27 June – 1 July 2022

Having amassed billions of dollars in voluntary commitments and pledges to save the Earth's most vital resource, the curtains came down on the second UN Ocean Conference. This renewed commitment could not have come a moment too soon. The science is clear: anthropogenic threats including deoxygenation, ocean acidification, marine pollution, and overfishing, have translated to a steep decline in ocean health.

To galvanize action to address these threats, the UN General Assembly adopted resolution 73/292 in 2019 to convene a high-level Conference to Support the Implementation of Sustainable Development Goal (SDG) 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development in 2020. After two years of postponements due to the COVID-19 pandemic, the Conference finally convened under the theme, "Scaling up ocean action based on science and innovation for the implementation of SDG 14: Stocktaking, partnerships and solutions."

The Conference featured both a general debate and interactive dialogues on:
- marine pollution;
- strengthening ocean-based economies;
- managing, protecting, conserving and restoring marine and coastal ecosystems;
- minimizing and addressing ocean acidification, deoxygenation, and ocean warming;
- making fisheries sustainable and providing access for small-scale artisanal fishers to marine resources and markets;
- increasing scientific knowledge and developing research capacity and transfer of marine technology;
- enhancing the conservation and sustainable use of oceans and their resources by implementing international law, as reflected in the UN Convention on the Law of the Sea (UNCLOS); and
- leveraging interlinkages between SDG 14 and other Goals towards the implementation of the 2030 Agenda for Sustainable Development.

Delegates announced over 300 voluntary commitments, with approximately 50 high-level commitments and pledges, including an investment of at least USD 1 billion to support the creation, expansion and management of marine protected areas (MPAs) and Indigenous and locally governed marine and coastal areas by 2030,

made by the Protecting Our Planet Challenge. Other voluntary commitments of note included:
- The Alliance of Small Island Developing States (AOSIS) launch of the Declaration for the Enhancement of Marine Scientific Knowledge, Research Capacity and Transfer of Marine Technology to Small Island Developing States (SIDS);
- The Development Bank of Latin America's commitment of USD 1.2 billion to support ocean projects in the region;
- Panama's commitment to increase its protection of at least 40% of the marine surface area by 2030;
- China's pledge to launch 31 marine ecological preservation and restoration projects in the next five years and provide assistance to developing countries, especially SIDS, through the One Belt One Road initiative;
- Kenya's plans for a blue economy bank fund;
- Portugal's plan to invest in producing ocean renewable energies with a view to reaching 10 gigawatts of capacity by 2030;
- The European Investment Bank's commitment to extend an additional EUR 150 million across the Caribbean Region as part of the Clean Oceans Initiative;

Additional information on the UN Ocean Conference 2022 is available in the IISD Earth Negotiations Bulletin at:
https://enb.iisd.org/sites/default/files/2022-07/enb3238e.pdf

ECOP Perspective on the 4th Early Career Scientist Conference (ECS4)
Raphaël Roman and Hannah Lachance

The ICES/PICES Early Career Scientist Conferences (ECSC) happen every 5 years, with host countries rotating between the Atlantic and Pacific Ocean basins. As the third ECSC was held in Busan, South Korea, in 2017), the ECSC this year was held on the Atlantic shore, with St. John's, Newfoundland, Canada selected as the host for 2022. Inspired by the momentum behind the United Nations Decade of Ocean Science for Sustainable Development (2021-2030), the theme for ECSC4 was "Ocean sciences for the future we want", and in 2020, it was officially endorsed as an Ocean Decade Activity. Co-organized by the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES) and Fisheries and Oceans Canada (DFO), the conference is geared towards providing a unique opportunity for early career scientists (ECS) or early career ocean professionals (ECOPs) to share their work and network exclusively with each other. This conference is also, in part, designed by and for ECOPs, and had a Scientific Steering Committee (SSC) made up of nine ECOPs (3 each from ICES, PICES, and DFO Canada) from a variety of disciplines, backgrounds and geographies. The job of the SSC was to lead and develop the conference program, main themes, and associated sessions. The PICES SSC members were Raphael Roman (Canada), Hannah Lachance (USA), and Heejoong Kang (Korea).

Over the span of 1.5 years, the SSC held regular online meetings with conference organizers and other members of the ECSC4 coordination and communication team. One of the most important tasks of the early career SSC was to first create the guiding themes of the conference and then to find consensus on the underlying sessions to which future participants would submit their abstracts. The SSC leveraged the diverse expertise of its members to ensure an inclusive, stimulating, contemporary and interdisciplinary scientific program.

The program centered around three broad themes and nine different sessions, with 2-3 SSC conveners per session:

1. **Ecosystem and ocean processes**
   • Biodiversity and ecosystem functions,
   • Understanding food webs and biogeochemical cycles,
   • Developments in taxonomy and systematics (later canceled as there were too few submissions),
   • Connecting biological, oceanic, and atmospheric processes of different scales.
2. **Inclusive, interdisciplinary and transparent ocean sciences**
   • Human-ocean interactions,
   • Science, management, and policy for a sustainable and productive Blue Economy,
   • Science communication, inspiration, and engagement.
3. **Emerging technologies and techniques for ocean science**
   • Using remote and in-situ technologies to inform marine science,
   • Advances in techniques and technologies: from 'omics to gear modifications to data analysis.

The SSC then assessed the quality of the more than 230 submitted abstracts (presentations and posters) and selected the best ones for each session, with the option to have some waitlisted abstracts in the process. This was a difficult task, because there were many high-quality submissions from ECOPs all around the world. In the end, ~117 ECOPs from 20 different countries (see Table 1) participated in the conference, which was a bit lower and less geographically distributed (50% from North America, 45% from Europe, 3% from Asia and 2% from other continents) than initially anticipated. This situation was largely caused by the COVID pandemic and the many uncertainties that remained around travel and regulatory restrictions, including delays with visa processing and logistical chaos at international airports. The ECSC4

was one of the first marine science conferences to return to in-person attendance, and the organizers had already been compelled to postpone it from May to July 2022 to minimize disruptions. However, hosting the 4-day conference in late July 2022 allowed a greater number (such as those shown below during the opening ceremony) of participants to relish the conference while basking in the the exceptional weather that St. John's was blessed with that particular week.

Despite all the logistical roadblocks the organizing team had to overcome in the lead-up to the conference, all nine SSC members made it to St. John's in person, and had the chance to finally meet face-to-face after 1.5 years of virtual preparations and brainstorming. The chemistry and synergy between members of the organizing team helped them resolve last minute changes and hurdles effectively, walking through the final hotel, conference, presentation, welcome session and convening logistics before the start of the opening ceremony. Each of the following days began with a plenary session and keynote presentation, before breaking into parallel sessions that alternated between the three broad themes of the conference.

Distinguished keynote speakers included:

• **Day 1: Shelly Denny** from Unama'ki Institute of Natural Resources, spoke on indigenous and western knowledge systems in ocean governance (*"Preparing for the Future WITH Indigenous Peoples"*), and Liisa Peramaki from DFO, who introduced the UN Ocean Decade, its governance structure in Canada and the role ECOPs play in it ("*Ensuring success under the Ocean Decade: the Important role of ECOPs*")

• **Day 2: Sonia Batten,** PICES Executive Secretary, replaced Enrique Curchitser, PICES Chair, and offered her perspective on a career path in international science (*"Serendipity: Reflections on a meandering career in Oceanography"*)

- **Day 3: Paul Snelgrove** from Memorial University, who talked about opportunities for collaboration and networking available to early career scientists in marine science today (*"Sustaining Marine Biodiversity on a Complex Ocea n Planet: A Decade of Opportunity"*). Bárbara de Moura Neves, from DFO and also one member of the SSC, gave a science talk titled: *"Towards the development of confidence scores for taxa identification from seafloor imagery in Canada: A case study on cold-water corals in Newfoundland,"* in order to emphasize the importance of developments in taxonomy and systematics, a research area that was initially proposed as its own session, but which was removed due to low volume of abstract submissions.

As members of the SSC, we were responsible for ensuring the theme sessions we were co-convening ran smoothly, including providing technical support, introducing speakers, keeping time in check, as well as facilitating Q&A and open discussions. Regarding the latter, each theme session was structured to end with 15 to 30 minutes dedicated to open, inclusive and respectful reflections and discussions on topics and issues related to the theme session. Assisting with social media communications, side events, workshops and excursions were also key tasks we were thrilled to take part in, as some of us had been planning and coordinating such events in the lead-up to the conference.

Specifically, conference participants benefited from two successful workshops led by Canada's Marine Environmental Observation, Prediction and Response Network (MEOPAR)

and the National node of the ECOP Programme in Canada (ECOP Canada). While MEOPAR hosted an engaging networking event on the first evening of the conference focusing on storytelling and social networking, ECOP Canada moderated a UN Decade-themed workshop with special guests from the ECOP Programme, rotating roundtables (shown above) to provide attendees with a better understanding of the seven Ocean Decade outcomes and an increased awareness of the role they can play to contribute to the Decade's success.

Another highlight was the afternoon excursion to the Cape Spear National Park, which was scheduled between the last two days of the conference, followed by a much anticipated shoreline clean-up at Topsail beach, (shown at right above), hosted by both ECOP Canada and the Surfrider Foundation Canada.

The rich and varied conference programming helped build new friendships and connect like-minded ECOPs who for the first time in two long years had an opportunity to network, share ideas and exchange knowledge in person. With more than 80% of participants being ECOPs (117 out of 140), the energy, enthusiasm and inquisitiveness we witnessed at our respective theme sessions and during breaks and social networking events were truly uplifting and something we will never forget. We also need to mention the resounding success of the Whova app, which was provided by ICES and downloaded by every participant on their mobile phone. While one of the main goals of the Whova app was to offer an easily navigable, live and paper-free program of the

conference, with room numbers, time slots for each speaker and titles of presentations and posters, it ended up being the perfect platform to arrange all sorts of meet-ups throughout the 4-days event, e.g. finding hiking partners, visiting a museum, scheduling a vegan dinner, getting together with ECOPs from a particular country, region, network, etc.

The best way to capture a glimpse of what the conference was all about is to watch this short and nostalgic summary video produced by the ICES communication team. The bids are now open for countries in the Pacific to submit a proposal to host the 5th ICES/PICES Early Career Scientist Conference in 2027. Rumour has it that a country in East or Southeast Asia would be an ideal candidate. While some of us will have aged out from the early career arena by 2027, we cannot overstate enough the value and benefits of joining those Early Career Scientist Conferences. They happen too rarely to miss it!

Table 1. Number of ECOP participants by country of residence.

Country	Number of Participants
Australia	1
Canada	33
Denmark	5
France	1
Germany	3
Iceland	1
Ireland	1
Italy	3
Latvia	2
Lithuania	5
Mexico	1
Netherlands	1
Norway	7
Poland	4
Portugal	4
Korea	4
Spain	3
Sweden	3
United Kingdom	10
United States	25

Symposium in Lisbon Re-unites the Global Community Investigating Small Pelagic Fish in Marine and Inland systems
Myron Peck, Akinori Takasuka, Ignacio Catalan, Ryan Rykaczewski and Susana Garrido

The 334-seat auditorium had a nearly full house for the Small Pelagic Fish symposium's opening plenary session on 8 November, 2022.

The international symposium "Small Pelagic Fish: New Frontiers in Science and Sustainable Management" was held November 7–11, 2022, in Lisbon, Portugal, re-uniting a community of scientists and managers who aim to improve the ecological understanding, management, and future status of these critical populations, and who last gathered in 2017, in Victoria, Canada. Research concerning small pelagic fish (SPF) populations has flourished, in part, due to the history of comparisons among ecosystems from around the world. The symposium in Lisbon was a cherished opportunity to advance that theme of international collaboration, particularly given the challenges to travel and social interactions that we have faced in the last several years. Lisbon could not have been a better setting for a meeting of forage fish fanatics, as the interests of the symposium's participants were matched by the prominence of sardine in the culture of Portugal. The artwork, cuisine, and history of the region served as persistent reminders of the significant role that SPF can play in ecological and socioeconomic communities.

The symposium attracted 288 participants hailing from 39 countries and 4 international organizations (PICES, ICES, FAO and NPFC). Scientists came from six continents: Australia – 5, Africa – 18, Europe – 168, Asia – 36, North America – 47, and South America – 15, with 47 participants being from developing countries. Participation of experts in climate, physical oceanography, zooplankton, fisheries biology and socioeconomics clearly indicated the interdisciplinary nature of research on SPF. The group was nearly gender-balanced (47% female, 53% male), with a substantial portion of the attendees identifying as early career scientists (44%). The generous support of more than 20 co-sponsors (with the primary international organizers being PICES, ICES, and FAO) facilitated the participation of many of these young scientists from around the world. In addition, the Calouste Gulbenkian Foundation donated the use of their fabulous conference center in the heart of Lisbon and the support of their Public Relations and Audiovisual teams. With the help of volunteers from the Portuguese Institute for Sea and Atmosphere (IPMA), the

meeting venue was staged with photographs of the Horácio Novais Collection from the Art Library of the Calouste Gulbenkian Foundation, exhibiting historical scenes from traditional Portuguese SPF markets and fisheries. Also on display throughout the symposium was the documentary "Portuguese Sardine – A Natural Wealth" that was produced for the National TV (RTP) in 2022.

The symposium scientific program was composed of six half-day workshops (selected from the proposals submitted by the scientific community) held on the first day of the event (outlined in this issue of PICES Press) and seven theme sessions on a wide range of topics addressing the science and management of SPF. Morning plenary sessions on November 8–10 provided overarching keynote presentations and introduced topics for the concurrent sessions that were convened that day:

- S1 – Trophodynamic Processes
- S2 – Life Cycle Closure: Advances in Process Understanding
- S3 – Understanding Population- and Ecosystem-level Shifts: From Seasonal Timing to Tipping Points
- S4 – Responses to Climate Variability and Change at Decadal to Centennial Scales
- S5 – Progress in Pelagic Surveys: From Biomass Estimates to Monitoring Ecosystems
- S6 – Reconciling Ecological Rules and Harvest Goals: Development and Testing Management Strategies to Enhance Marine Ecosystem Services
- S7 – Advancing Social-ecological Analyses and Sustainable Policies for Human Communities Dependent on SPF

Evening networking events included a welcome reception in an 18th century manor house in Monsanto Forest Park (Quinta da Pimenteira); a poster session/reception; a symposium dinner, and a mentoring event for early career scientists that was structured around techniques, topics and regions of interest vital to SPF science and management. During the closing ceremony nine awards were given to early career scientists for best oral presentations – Florian Berg (Norway), Miram Gleiber (Canada), Naseera Moosa (South Africa), Antonio Palermino (Italy) and James Robinson (UK), and best posters – Pedro Fonseca (Portugal), Kim Nuñes (Philippines), Jazel Ouled-Cheikh (Spain) and Francisco Plaza (Chile).

In total, there were 278 presentations at the symposium: 14 plenary talks, 7 invited and 173 contributed talks, and 84 posters, which were discussed thoroughly during an evening poster-viewing session. Below, we offer a summary of the key research themes discussed, including recommendations for future work.

The use of state-of-the-art and emerging techniques to study SPF was highlighted in all topic sessions of the symposium. For example, genetics and genomics techniques are now being applied to SPF. These techniques are rapidly advancing (e.g., eDNA), and it was recognized that the communication between population geneticists and fisheries managers is challenging. It is clear that a common technical language is needed, not only for application to SPF, but for applications to other fishes and stocks more generally. DNA metabarcoding is helping to identify prey items consumed by SPF, including gelatinous species and other rapidly digested organisms, and these results challenge traditional paradigms of the foraging habits of SPF. Future advancements in genetic identification of prey items will contain more quantitative estimates of contributions to diet in addition to presence/absence studies. A second technology that has developed considerably since the 2017 SPF symposium is numerical modeling, including coupled physical–biological and ecosystem models, end-to-end models, and machine learning techniques. These are now important tools for generating hypotheses, informing field surveys and for conducting management strategy evaluation. Emerging solutions for coupling Species Distribution Models (SDMs) to more complex (e.g., multispecies or ecosystem) models were discussed, focusing on ongoing efforts to further develop end-to-end models for the California and Humboldt Eastern Boundary Upwelling Systems. By incorporating new process knowledge, ecosystem models may be able to capture the "boom-and-bust" characteristics of SPF. Once these rapid fluctuations can be simulated, the models may provide a tool for short-term forecasting of SPF and aid in developing harvest control rules.

The symposium discussions helped to identify key gaps in our understanding of SPF dynamics that must be addressed if we seek to adapt management approaches to changing conditions. Notably, better mechanistic understanding of how individuals and stocks respond to environmental change is required. The concept of non-stationarity in ecological systems was raised, recognizing that the critical processes that influence population variability may shift over time as climate conditions and population status change. Adaptive capacity is understudied, as is the ability of individuals to acclimate to better cope with changes in the mean and variance of environmental factors such as temperature, pH and dissolved oxygen. Several presentations addressed the plasticity of responses of species and populations (providing evidence for acclimation) or genetic adaptation based on either molecular, laboratory rearing or modeling experiments. At a more basic level, there remains a need to understand the fundamental (as opposed to the realized) niche of SPF, their prey and their predators. Knowledge on these niches would improve the mechanistic depiction of movements and habitat residency in SDMs and how food webs respond to climate variability and change.

Fleet flexibility and adaptation (e.g., vessels shifting portfolios, which fleets already mix target species seasonally or have shifted in recent years) and how prices, markets, and fish size or quality drive fleet dynamics and decisions were discussed. In total, examples from 11 regions were presented (Portugal, Bay of Biscay, Oman, Mauritania, Spain, Mexico, USA, Denmark, Peru, Italy and broad ranging freeze trawlers). Spatial closures and shifting transboundary stocks are key challenges for the industry. The potential expansion of fleets to exploit mesopelagic fishes such as myctophids (particularly during periods of SPF population collapse or fishing moratoria) was considered suggesting the need to expand our science and research on SPF to include these groups.

Diet studies on SPF and their predators remain particularly relevant and timely. Many techniques, such as stomach content, stable isotopes and fatty acid analyses as well as DNA metabarcoding, are now being combined to understand the trophodynamics of SPF. Compound-specific stable isotope analysis was highlighted as a powerful and practical tool, because coincident data on the isotopic content of baseline primary producers are not needed. During the symposium, trophodynamic studies from 12 regions were discussed, including areas in the North Atlantic (NE Atlantic, Baltic Sea, North Sea, Iberian Atlantic waters, Canary Current, and Mediterranean), North Pacific (California Current, Alaska, Bering Sea, Kuroshio Current) and South Pacific (Humboldt Current). There were also six presentations making global-scale comparisons and reviewing topics such as the accumulation and distribution of pollutants and parasites in SPF. The majority of these diet and pollutant studies was on adults with relatively few studies on larvae. There is much potential to utilize laboratory and mesocosm experiments to advance our understanding of larval stages of SPF as both predators and prey.

Life cycle closure is critical to the persistence of populations, and large gaps in knowledge were recognized in understanding of the mechanisms responsible for the life cycle dynamics of SPF and how these change through time and space. Large differences in knowledge exist across species and Large Marine Ecosystems, particularly for key processes (e.g., migrations, nursery areas, stock mixing). The number and length of time-series has increased, allowing analyses of trait variability and cross-regional analyses and collaborations. Considerable knowledge can be derived from testing hypotheses at the individual to population levels using mechanistic (e.g., bioenergetics and individual base) models. Moreover, there appears to be a substantial amount of underutilized data for model validation and corroboration. When data streams are combined with new technologies (e.g., genetics, isotopes, passive acoustics), key life stages and processes can be effectively monitored with higher precision and lower cost. Integrating these approaches and increased multidisciplinary collaboration will allow a full view of habitats required by various developmental stages to promote a more integrated knowledge of SPF life cycle closure.

A session also focused on tipping points and non-linear dynamics, ubiquitous features of marine systems that can lead to multiple alternative stable states where near-term recovery of SPF stocks or populations may not be possible. The early detection of tipping points remains challenging. It is unclear how often phenological mismatches lead to tipping points or whether rapid natural selection can "solve" these mismatches. Moreover, it is important to document multi-trophic level mismatches (e.g., phytoplankton to zooplankton to SPF to their predators) to understand the ecosystem-level impacts of climate change. Bayesian Dynamic Factor Analysis was presented as a new tool that can be used for the rapid detection and one-year forecasting of ecosystem-level tipping points. Better understanding population- and ecosystem-level changes will lead to improved advice to promote resilient fisheries.

Paleo studies examining changes in SPF populations and proxies of their habitat at the scale of centuries are providing insight on how future, climate-driven environmental conditions (climate-driven warming, expansion of oxygen minimum zones) may influence food webs supporting SPF. The number of sites with historical reconstructions from sediment cores is increasing (Peru, Japan, coastal areas in the Baltic Sea), and innovative measurements are being applied (e.g., DNA). Mechanism-oriented approaches combining knowledge on physiological traits constraining habitat suitability are now being used to explain historical spatial and temporal changes in SPF. The field has, therefore, advanced beyond purely correlative analyses, and various types of models (e.g., Individual-based Models, Dynamic Energy Budget Models, Earth System Models) are making projections of potential climate change impacts on habitat suitability in relation to other factors and processes (e.g., density-dependence and fishing pressure) for different species. Previous debates and disagreements evident a decade ago between scientists working at paleo and contemporary time scales are being reconciled. Some recent events (e.g., the unexpected anchovy boom in the California Current System) are challenging previous paradigms and fostering interdisciplinary discussions. Recent evidence of tipping points in some systems (predominance of jellyfish and gobies in northern Benguela) could be a harbinger of undesirable, climate-driven changes in the Humboldt Current system with potential world-wide impacts via decreased availability of traditional (anchoveta-based) fishmeal for aquaculture.

Advances in monitoring of SPF resources and the need to continue, enhance and expand surveys despite ongoing budget constraints were discussed. Collaboration across regions and adaptively adjusting surveys to account for spatial or temporal changes in fish distribution (particularly in relation to climate change) were recommended. Creative approaches that mix different types of technological advances with "traditional" monitoring data are important as is taking advantage of measurements made at different scales (e.g., transect versus fixed-point surveys) and by different groups such as fishing fleets. Using uncrewed vehicles, coordinating and integrating across monitoring methods, and taking advantage of non-directed data streams to assess SPF and fisheries are key opportunities. Fisheries may utilize technologies better than those applied in existing fishery-independent surveys, and opportunities for industry funding of assessment surveys should be explored. There is a need to apply tools that can test the suitability of acoustic surveys based on simulated abundance and distribution of stocks from spatial distribution or mechanistic ecosystem models (in a manner similar to observation system simulation experiments used in physical oceanography).

An important topic of the symposium was social-ecological analyses highlighting how human communities rely on SPF in marine and inland waters for nutrition, food security, and employment and the management and governance arrangements necessary for the equitable access to SPF resources. One session provided a venue for reconciling ecological versus different harvest goals of SPF. Assessments are increasingly incorporating multispecies and ecosystem considerations to develop sustainable Harvest Control Rules based on "simple" biological rules. This was another example of the potential benefits of incorporating the increased spatial coverage of data from fisheries to help develop more robust indicators of stock shifts, with the ultimate goal of producing early warning signals for managers, industrial and artisanal fisheries, and other dependent human communities both in marine and inland waters. The symposium provided examples of contrasting perspectives of fishers and fisheries managers on the effectiveness of regulations and the factors making the sector vulnerable to climate change. Presentations highlighted adaptations taken by fishing communities and downstream sectors to changes in access to SPF resources (e.g., response to fishery closures and COVID). Critical information can be gained from dialog with diverse stakeholder groups to understand changes in the profitability of fishing fleets and alternative governance strategies increasing sustainability and resilience (of stocks and livelihoods).

A final plenary session on November 11 included talks outlining the history of international collaboration on SPF and emerging topics. A panel discussion and symposium summary presentation identified key research themes to be addressed in the future. One of the take-home messages from nearly every session was the need for more interaction among scientists from different disciplines. The combination of various techniques (e.g., spatially explicit ecosystem modeling, stock assessment, population dynamics, paleo measurements, genetics and genomics, economic analyses) and people across disciplines and sectors will improve our understanding of the causes and consequences of SPF fluctuations and the trade-offs in the sustainable and equitable management of these resources. Expanding our work to include more social-ecological analyses will increase the societal relevance and impact of our science. It is expected that two special issues resulting from the symposium will be published in Marine Ecology Progress Series (sessions 1-4 and workshops 1, 2 and 4) and Canadian Journal of Fisheries and Aquatic Science (sessions 5-7 and workshops 3, 5 and 6).

A visit to Lisbon would not be complete without enjoyment of fado, a soulful musical genre with Portuguese origins which was recently acknowledged by UNESCO as part of the World's Intangible Cultural Heritage. Before symposium participants returned to their home institutions with reinvigorated focus on SPF, we were all treated to an evening of fine dining and fado music (above) during the symposium dinner at Pátio da Galé located in the historical center of Lisbon on Praça do Comércio. The architectural detail and historical significance of the venue (located where the Royal Palace stood when the 1755 earthquake struck) left us in awe. The concert featuring the Portuguese guitar was performed by a trio led by Marta Pereira da Costa, the first and only woman to professionally play Portuguese guitar in fado. The trio played traditional Portuguese music and other sonorities such as blues, Brazilian chorinho, and Cape Verdean morna. The artists returned to stage to perform an encore after the audience demanded it, by applause.

Above left: Symposium participants were welcomed to Lisbon during the Opening Plenary by Dr. Julie Kellner (Professional Officer, ICES), Dr. Miguel Miranda (President of the IPMA Directive Council, Portugal), Dr. Teresa Coelho (Secretary of State for Fisheries, Ministry of Agriculture and Food, Portugal), Dr. Enrique Curchitser (Chair, PICES) and Dr. Ryan Rykaczewski (symposium convenor). Above right: Dr. Manuel Barange (Director of the Fisheries and Aquaculture Division, FAO) provided words of encouragement and inspiration during the opening plenary session.

Organizing the joint symposium was a Term-of-Reference of the ICES-PICES Working Group on Small Pelagic Fish (PICES WG 43, ICES WGSPF) and was directly followed by a two-day (November 12–13) in-person meeting of this working group where about 60 participants discussed products closely aligned to symposium topics such as the compilation of world-wide data sets, integrative analyses, and peer-reviewed manuscripts. The meeting also provided an opportunity to broaden the working group network by welcoming new members, including many early career scientists. Given the success of the event, we hope to schedule future international symposia on SPF every four to five years.

We want to take this opportunity to emphasize our gratitude to the symposium sponsors. In particular, the symposium would not have been possible without the dedication of IPMA staff, the support of the Gulbenkian Foundation, and the efforts of the PICES secretariat. Finally, the team of Dr. Susana Garrido (at the helm of the local organizing committee) and Dr. Alex Bychkov (PICES Special Projects Coordinator) was the driving force behind the organization of the meeting. Without the leadership and tireless efforts of Susana and Alex, it is doubtful that the symposium would have proceeded with such success.

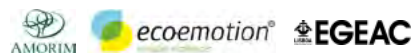## Thank you to our 2022 Small Pelagic Fish Symposium Sponsors

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Above left: The closing plenary session included a panel discussion of prominent SPF researchers composed of Dr. Carl van der Lingen (South Africa), Dr. Desiree Tommasi (USA), Dr. Jennifer Boldt (Canada), Dr. Martin Pastoors (Netherlands), Dr. Shin-ichi Ito (Japan) and Dr. Salvador Lluch-Cota (Mexico). Above right: Symposium convenor Dr. Myron Peck (ICES) offered a summary and synthesis of the scientific sessions during the closing plenary session.
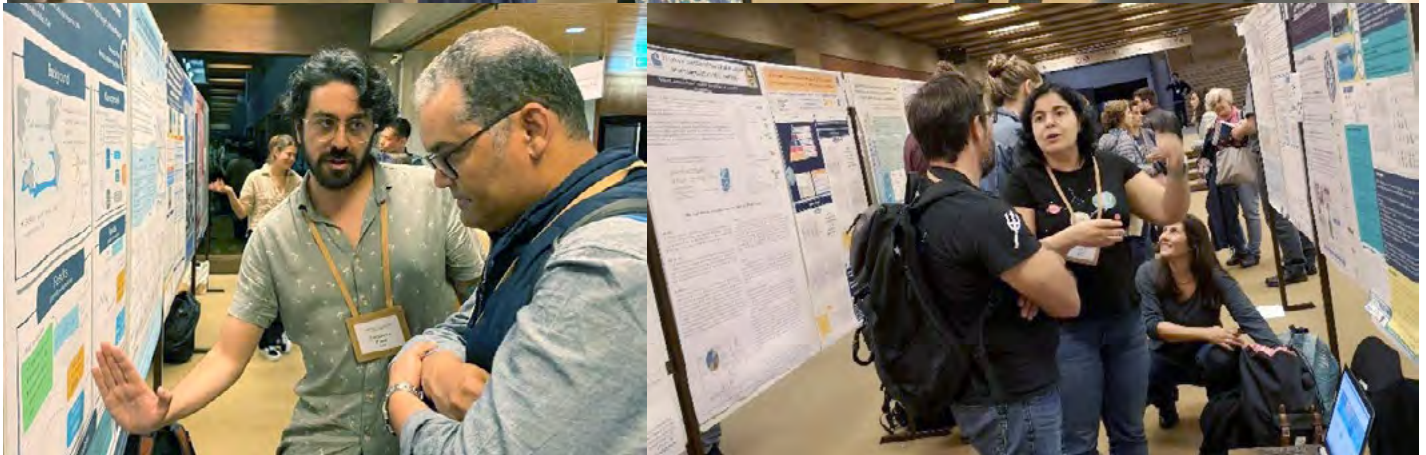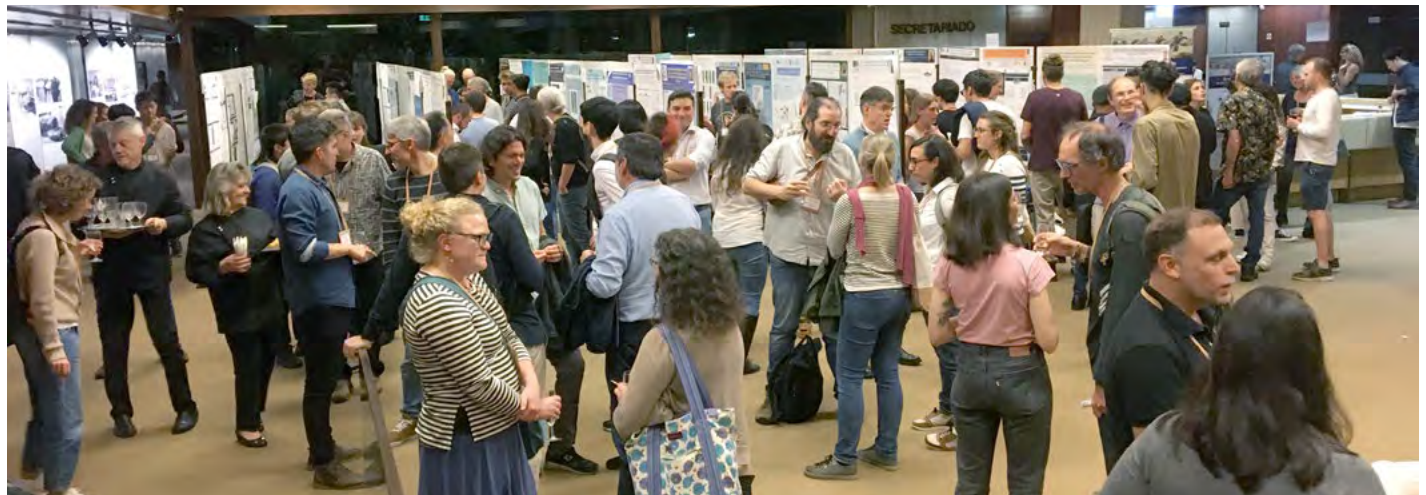

Above: Symposium participants gathered during the poster session to socialize and discuss the latest advancements in SPF science and management, activities that many have yearned for after a long period of limited in-person interactions.

Above: A symposium dinner at the Pátio da Galé in the historical center of Lisbon.

Above: Enthusiastic discussions during coffee breaks were often accompanied by refreshments selected by convenor Dr. Susana Garrido to highlight aspects of Portuguese culture.
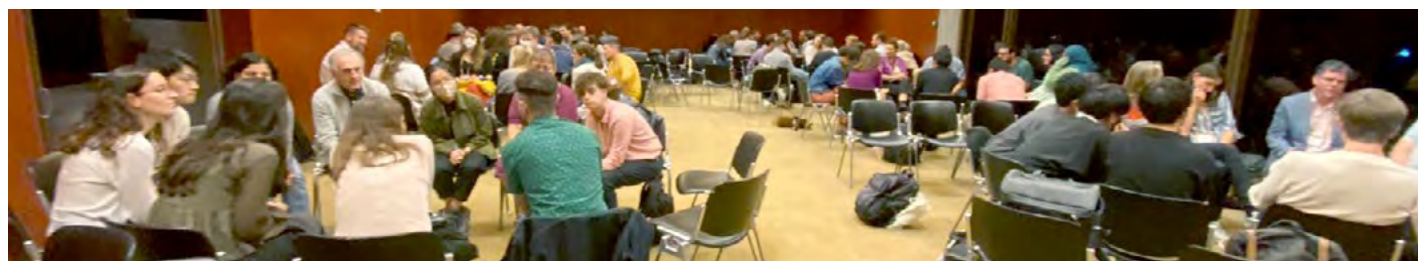
Above: A mentoring event for early career scientists included discussion groups structured around techniques, topics and regions of interest vital to SPF science and management.

Above left: MSc students Rikuto Utsugi, Naoya Iwamoto, Tomohiro Hirasawa and Shota Tanaka with their Professor Akinori Takasuka (Fisheries Biology Laboratory, the University of Tokyo, Japan) and his former mentor Dr. Yoshioki Oozeki. Above right: PhD students Sk. Istiaque Ahmed and Lin Zhen and MSc student Ziqin Wang with their Professor Shin-ichi Ito (AORI, the University of Tokyo, Japan).

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Artwork by Lori Waters (PICES)

Above: Symposium attendees received a reusable bag made of Portuguese cork (for which the area is famous) emblazoned with the symposium logo, as well as an original porcelain piece of art created by Portuguese artists from an annual contest held in Portugal, celebrating sardines.

Above left: Symposium coordinator Dr. Alex Bychkov (PICES) and convenor and local organizer Dr. Susana Garrido (IPMA, Portugal) were a superb team that led the symposium planning, logistics, and coordination with a combination of patience, persistence, vigor, and grace. Above right: Staff of the PICES Secretariat (Saeseul Kim, Christina Chiu and Julia Yazvenko) enjoy a precious, relaxing moment prior to the symposium dinner.

The symposium convenors, Drs. Akinori Takasuka (PICES, Japan), Ryan Rykaczewski (PICES, USA), Susana Garrido (Portugal), Ignacio Catalán (ICES, Spain) and Myron Peck (ICES, Netherlands), posing with sardines.

Dr. Myron A. Peck (myron.peck@nioz.nl) is Head of the Department of Coastal Systems (COS) at the Royal Netherlands Institute for Sea Research (NIOZ) and Special Professor of Life Cycle Ecophysiology of Marine Animals at Wageningen University. His group's research integrates laboratory experiments on ecophysiology, field surveys and process studies of species and communities, and bio-physical and food web modeling to help gain a cause-and-effect understanding of how environmental drivers such as climate change influence estuarine and marine systems. The main goal is to provide robust, science-based advice for policy and management of living marine resources. Myron coordinated the EU Blue Growth project 'CERES' (2016-2020) examining risks and opportunities of climate change to European fisheries and aquaculture, and now serves as the coordinator of two EU H2020 projects: 'FutureMARES' (2020-2024) implementing nature-based solutions to sustain marine biodiversity and ecosystem services in a future climate, and 'ACTNOW' (2023-2027) examining the impact of multiple stressors and developing robust indicators of ecosystem health. He co-chaired the ICES/PICES Strategic Initiative on Climate Change Impacts on Marine Ecosystems (SICCME) and is a co-chair of the ICES/PICES Working Group on Small Pelagic Fish (WGSPF). Myron is the Coordinating Editor-in-Chief of Marine Ecology Progress Series.

Dr. Akinori Takasuka (atakasuka@mail.ecc.u-tokyo.ac.jp) is a Professor of the Fisheries Biology Laboratory in the Department of Aquatic Bioscience at the Graduate School of Agricultural and Life Sciences, the University of Tokyo (Japan). After working for Japan Fisheries Research and Education Agency, he returned to the laboratory for education of his junior fellows. His interests are in the fields of Fisheries Biology and Oceanography. His current major research themes include biological mechanisms behind climate impacts on population dynamics, growth and survival dynamics during the early life stages, and density-dependent and density-independent processes in the life history of fish. Akinori is a co-chair of the joint ICES/PICES Working Group on Small Pelagic Fish (WG 43).

Dr. Ignacio A. Catalán (ignacio@imedea.uib-csic.es) is a Research Scientist at a joint research center (IMEDEA) between the Spanish National Research Council (CSIC) and the University of the Balearic Islands (UIB), Spain. His research interest is in fisheries oceanography. In the last years, he has focused on understanding individual-level responses of fish to intrinsic and extrinsic drivers, including climate change, and the analysis of coastal recruitment processes. He has also worked on applying new technologies to the study of fish ecology. Ignacio is a co-chair of the ICES/PICES Working Group on Small Pelagic Fish (WGSPF).

Dr. Ryan Rykaczewski (ryan.rykaczewski@noaa.gov) is a fisheries oceanographer with the Ecosystem Sciences Division at NOAA's Pacific Islands Fisheries Science Center in Honolulu, USA. His research focuses on the sensitivity of marine biogeochemical cycles, ecosystem structure, and fisheries production to changes in ocean climate and physics. Ryan has been active in PICES and ICES for several years and strives to find ways to incorporate knowledge of regional to basin-scale climate processes into the management of living marine resources. He is a member of the PICES FUTURE Scientific Steering Committee and is a co-chair of the ICES/PICES Working Group on Small Pelagic Fish (WG 43).

Dr. Susana Garrido (susana.garrido@ipma.pt) is the Head of the Coastal Pelagic Fish Research Group at the Portuguese Institute for Sea and Atmosphere (IPMA) in Lisbon, Portugal. Her research mainly focuses on marine trophic webs, larval physiology and survival, and understanding the impact of environmental variability on SPF population dynamics, aiming at developing indicators to improve management advice. In her work, Susana uses complementary techniques, including field surveys and laboratory experimentation, gut content analysis, fatty acid biomarkers and stable isotopes. Additional research interests include zooplankton ecology and parental effects. She is also responsible for the stock assessment of the European anchovy in Portugal. Susana is a member of several ICES Working Groups such as WGHANSA and WGSPF.

SPF2022- Workshop 1: Application of Genetics to Small Pelagic Fish
Ana Veríssimo, Malika Chlaida, Jan McDowell and Rita Castilho

Workshop theme and structure

A half-day workshop, focusing on the application of molecular tools to address different questions relevant to small pelagic fish (SPF) biology, ecology and management, was held on November 7, 2022, as part of the of the international symposium on "Small Pelagic Fish (SPF): New Frontiers in Science and Sustainable Management" in Lisbon, Portugal. The scope of the symposium recognized the importance of reviewing historical and modern molecular methods used to clarify questions of stock/population structure, which are pivotal for integration into fisheries management advice and for their sustainable use. The workshop aimed to introduce participants to a range of genetic and genomic tools, including methodological overviews of recently developed environmental DNA (eDNA) and genome-wide analysis-based techniques, that support the management of fishery resources, and to provide a critical assessment of costs and benefits. The workshop targeted a broad community of researchers, including those with some experience in genetics/genomics and those who are less familiar with the topic.

The main topics of focus were:

*   What are the different genetic methods that have been used over time?
*   What have we learned - especially from the newer methods?
*   How have these methods been used to answer questions about SPF?
*   What are the questions that are still outstanding?

This half-day workshop, convened by four women researchers co-authoring this article, was structured in two parts. Part 1 consisted of four introductory talks by the workshop convenors. These presentations, in addition to a state-of-art review of SPF genetics, overviewed the available molecular genetic tools with examples and case-studies of their application (Figure 1). Part 2 included four selected talks by workshop participants presenting recent and/or ongoing molecular genetic studies on SPF. Below, we offer a brief summary of the talks presented during the workshop.

Part 1 presentations

The first talk *"From allozymes to eDNA: an overview of molecular methods"* by Jan McDowell provided a brief non-technical overview of different marker types and methods, including costs, sample size requirements, sample quality, bioinformatic burden, and limitations. The markers
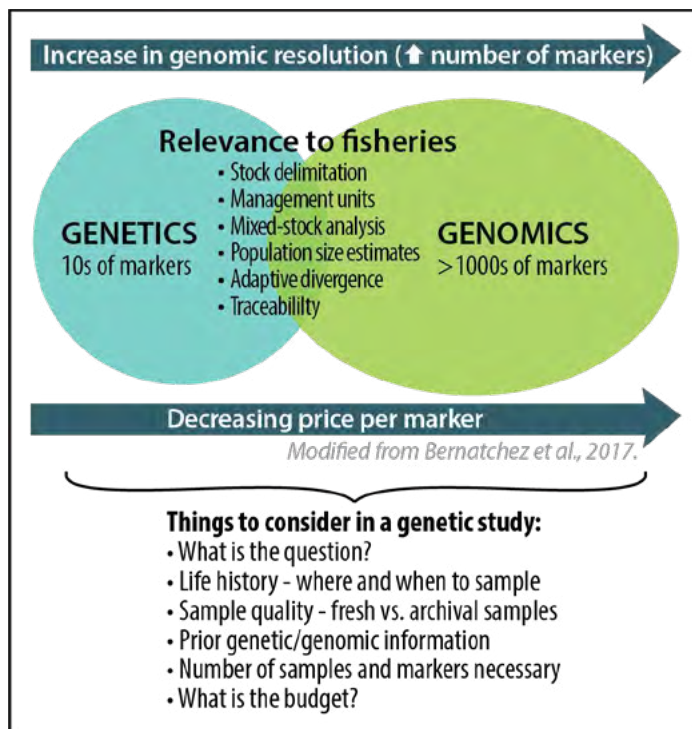

Figure 1. General overview of the main molecular genetic approaches currently available in terms of the number and price per marker, as well as some of the applications relevant to fisheries management and aspects to consider when planning a molecular genetic study.

used in genetic studies of fishes range from allozymes to polymerase chain reaction (PCR) based methods of assaying variation, including mitochondrial DNA, nuclear microsatellites, and single nucleotide polymorphisms (SNPs). It was highlighted that traditional marker discovery was technically burdensome and restricted the number of markers for a given target taxon, limiting the power to discriminate among populations. The advent of next-generation sequencing (NGS) has enabled a variety of genotyping-by-sequencing (GBS) methods that have streamlined the marker discovery process and vastly increased the number of markers available for quantifying differences among populations. NGS has also facilitated advances in the analysis of gene expression, including RNASeq and in environmental DNA approaches (eDNA and eRNA).

In her presentation *"The potential of Next-Generation-Sequencing: from genes to genomes, and from single to multiple markers"*, Ana Veríssimo introduced the basics of NGS and reviewed several case-studies, highlighting its potential application to relevant questions in fisheries science and management, fish biology, ecology and evolution. NGS is a major technological improvement in sequencing that allows easy and cost-efficient access to whole genome and

transcriptome data from virtually all living species. As a result, the focus of genetic studies has shifted from single/a few genes to whole genomes. Currently, hundreds of individuals can be genotyped at 1000s-100000s of genetic markers simultaneously in species for which no genetic resources are available. Of particular relevance to SPF, access to whole genome sequences allows greater power to detect genetic differences among populations with large effective sizes and high gene flow. The development of large panels of genome-wide markers for stock delineation can also be used to monitor the genetic diversity of populations in time and space to aid the traceability of individuals to their populations of origin, or to improve mixed-stock analysis even among closely related populations.

The talk *"From allozymes to neutral molecular markers: Population genetics of sardines and anchovies"* by Malika Chlaida provided a general overview of how the field of population genetics in sardines and anchovies has advanced through time, and what has been gained over the years in terms of information in the Northwest Africa coasts and adjacent seas. Knowledge of genetic structure is key to understanding species connectivity patterns and to defining the biological units and spatiotemporal scales over which conservation management plans should be designed and implemented. SPF, namely European sardine (Sardine pilchardus) and European anchovy (Engraulis encrasicolus), are important fisheries resources and are subjected to intense fishing activity throughout their distribution range. In addition, as small pelagic fishes, they play a major ecological role in their ecosystem. Given their importance, sardine and anchovy population structure has been addressed using several genetic markers to delineate the number of stocks, which is important information to integrate into the stock assessment process.

"Small pelagic fish genomics: how far have we gone?" was the last talk of Part I, presented by Dr Rita Castilho. Small pelagic fishes play central ecological roles in marine ecosystems. The species' short generation times and dependence on lower trophic levels lead to massive decadal to centennial patterns of boom-and-bust dynamics. These patterns are closely linked to climate variability, severely impacting some of the world's most economically valuable fisheries resources. The consequences of these pendular dynamics, combined with large dispersal potential during several planktonic life-stages and the apparent absence of physical barriers to movement between ocean basins or adjacent continental margins, conduct to shallow population histories. For those reasons, the management units of small pelagic fish are difficult to delimit. Traditional techniques such as genetic analyses based on a small number of markers, body shape, otolith morphometrics or microchemistry and parasites have shown equivocal power to distinguish unique reproductive units in small pelagic fishes. The recent developments of genomic-based methods, which rely on thousands to millions of markers, can contribute to clarifying questions of stock delineation and population structure, which are pivotal for sound fisheries stock management advice. The presentation introduced emblematic case studies illustrating how genetics have positively contributed to addressing fisheries' existing management and policy needs.

Part 2 presentations

In her talk *"Range-wide genetic stock delineation of the European sardine (Sardina pilchardus) using whole genome sequencing (Pool-Seq)"*, Pilar Cabezas presented the first results of an ongoing research project focusing on clarifying the genetic population structure of this important SPF at a large spatial scale, including samples from multiple locations in the Mediterranean Sea (east and west basins) and eastern North Atlantic (from the British Isles to Morocco). Using a Pool-Seq approach, the genomic DNA from sample collections of 25 individuals per location were pooled together and sequenced simultaneously, generating whole-genome sequencing data used in SNP discovery and genotyping at 100000s of markers. The results confirmed the marked separation between samples from Mediterranean and Atlantic locations, and further delineated the structure within each region. Notably, a high level of genetic divergence was found between southern Morocco and all remaining collections. A genetic break also found at the northwest tip of the Iberian coast, separating Atlantic collections in Cantabria and northwards from those in the western Iberia southward to central Morocco.

Florian Berg's presentation *"From genome assembly to fisheries assessment: a case study of Atlantic herring"* was an overview of the complex population structure of Atlantic herring and showed results of a recent project generating whole genome sequence data for populations across the Atlantic Ocean and the Baltic Sea, and the identification of genetic markers discriminating populations differing in spawning time, temperature or salinity at spawning. As several discrete herring populations may mix during different times of the year and are subjected to mixed-stock fisheries, it is essential to allocate catches to the correct populations. Results of newly developed diagnostic SNP panels applied to catches revealed the presence of populations that were assumed not to occur in given areas and mixed-stock fisheries. Thus, the development of new genetic methods has helped the understanding of herring population structure and mixing and has the potential to improve future fisheries assessments substantially.

In the talk *"Combining ecologic and genomic modelling to inform sustainable management of fisheries stocks in a tropical sardine"* by Jessica Coelho, the target taxa were the scaled-sardines Harengula sp., which are economically important fisheries resources in Brazil but still lack a clear taxonomic designation. The authors used ecological niche models and genomic methods to estimate this species' population

structure and habitat connectivity, and their change over time. The results showed two highly differentiated populations of scaled-sardines: (1) a larger coastal population showing signs of expansion and with a latitudinal gradient of diversity reflecting isolation by distance at the Brazilian coast and (2) a smaller island population, exclusive to the oceanic archipelago of Fernando de Noronha, showing less diversity and a potential bottleneck. The low level of connectivity between coastal and archipelago populations is consistent with habitat discontinuity, possibly driven by depth. It also raises concerns about the recent deregulation of sardine fisheries in the archipelago, as the low level of genetic diversity may compromise future population resilience to exploitation. On the other hand, the coastal population is shared among Brazilian state waters and requires coordination to set size and catch quotas among littoral states to attain sustainable management.

The presentation *"A genetic toolkit to better understand small pelagics and their interactions with the ecosystem"* by Naiara Rodríguez-Ezpeleta touched upon multiple research questions relevant to SPF and fisheries management, and how different genetic approaches can be used to address them. Briefly, the abundance and distribution of SPF in the Bay of Biscay was assessed using environmental DNA analyses and revealed patterns of diel vertical migrations of small mesopelagic fish. Also, the trophic interactions between several species, including anchovy, sardine, mackerel and horse mackerel were reconstructed using metabarcoding of stomach contents. Finally, the connectivity of Atlantic mackerel throughout the Atlantic Ocean was estimated using population genomics. The potential impact of these findings on species conservation and the lessons learned from communicating and integrating genomic data into fisheries assessment were discussed.

Outcomes

Throughout the workshop, participants were encouraged to follow-up with discussions, bring forth their own research questions, and brainstorm about the technical options available as well as the pros and cons of different molecular methods. In fact, one of the major goals of this workshop was to provide the audience with a better understanding of the different molecular approaches available and confidence in matching questions with methods. It was made clear that all methods have strengths and weaknesses, and that great care should be taken when considering the sampling needs and the number and types of markers required to address the specific question. It was also emphasized that costs are an important aspect to consider and that traditional methods can provide useful/relevant answers despite the recent (but more expensive) technological improvements in the field. With this workshop, it is hoped that genetic methods become more commonly applied in SPF research, where they can greatly contribute to improving our current knowledge on many

different aspects of their biology, ecology and evolution. Given the low number of talks and posters presented in this symposium where genetic tools were used, the convenors would like to motivate and encourage researchers and students to apply molecular genetic methods in their studies and to present their findings in upcoming ICES/PICES venues. Communication between population geneticists and fisheries managers is often difficult, and further interactions between the two groups is needed to achieve more efficient knowledge transfer.

The main outcomes of the workshop on *"Application of Genetics to Small Pelagic Fish"* were presented at the closing plenary session:

1. Provide a better understanding of different genetic/genomic approaches and their potential applications in a fisheries science context.
2. Foster discussion with workshop attendees on how to apply genetic methods to their research questions and to SPF fisheries management.
3. Recognition of the communication difficulties between population geneticists and fisheries managers and the need for a common technical language.

Dr. Ana Veríssimo (verissimoac@gmail.com) is an Auxiliary Researcher at the Research Center for Biodiversity and Genetic Resources, Portugal. She is a population geneticist with a background in Marine and Fisheries Science, and her research has focused on commercially exploited fisheries resources. Ana works in close collaboration with fisheries scientists at the Portuguese Institute for Sea and Atmosphere, who provide fisheries management advice.

Dr. Malika Chlaida (ma_chlaida@hotmail.com) is a Senior Researcher and Head of the Research and Development Unit on Marine Biology and Biodiversity at the National Institute of Fisheries Research (INRH), Morocco. Her expertise is on marine population genetics, marine ecology and marine biodiversity with a focus on ecology, genetics and biodiversity of small pelagic fish (SPF). She supervises and directs research for PhD candidates, Master's degree students and undergraduates in population genetics and biodiversity of SPF. Malika is a research project coordinator at INRH and a partner in several international research projects focusing on population dynamics, migration, genetic stock identity and connectivity of SPF.

Dr. Jan McDowell (mcdowell@vims.edu) is an Associate Professor at the Virginia Institute of Marine Science, William & Mary, USA. Her research focuses on the population genetics and conservation of commercially and recreationally important marine species, including small pelagic fish.

Dr. Rita Castilho (rcastil@ualg.pt) is an Assistant Professor at the University of Algarve and a Senior Researcher at the Centre for Marine Sciences, Portugal. She is a population geneticist interested in marine connectivity and patterns of genetic structuring and speciation in the North-Eastern Atlantic. Rita is a member of the ICES Working Groups on "Application of Genetics to Fisheries and Aquaculture" and "Stock Identification Methods".

SPF - Workshop 2: The Devil's in the Details of Using Species Distribution Models to Inform Multispecies and Ecosystem Models
Isaac Kaplan, Elliott Hazen, Robert Wildermuth, Stefan Koenigstein,
Mariana Hill-Cruz, Pierre-Yves Hernvann and Barbara Muhling

Workshop theme

The half-day SPF Symposium workshop entitled *"The Devil's in the Details of Using Species Distribution Models to Inform Multispecies and Ecosystem Models"* brought together 30 global experts in Lisbon, Portugal, on November 7, 2022 to discuss the detailed decisions required to couple the burgeoning field of species distribution models (SDMs) to more complex multispecies and end-to-end models such as Ecospace, Ecosim, Atlantis, OSMOSE, EcoOcean, and MICE models. The workshop was led by the co-authors of this article (Elliott and Barbara were unable to attend and worked behind the scenes from California). Three co-convenors (Mariana, Pierre-Yves and Robert) were early career scientists.

During the workshop, co-convenors directed small group discussions focused on decisions related to how, when, and why to couple species distribution models to complex multispecies or ecosystem models. The topic is particularly relevant for SPF, which have shifted spatial distributions over past decades in response to oceanography and stock size, and which are expected to shift rapidly under long-term climate change. Incorporating species distribution shifts into complex ecosystem models allows quantification of how shifts affect or interact with predator-prey dynamics and fishing, but experience from those working deep in the guts of the models brought up a series of key considerations and questions, including the following:

- Does the SDM predict a broad fundamental niche, or a narrower realized niche more precisely identifying where the animals are truly observed?
- If that SDM is coupled to an ecosystem model, does that ecosystem model expect information on realized versus fundamental niche?
- The type of foraging behavior in the complex model should be considered when deciding whether to use SDM forcings that represent realized versus fundamental niches.
- Is the complex ecosystem model trying to forecast dynamics in the recent past or present, as opposed to decadal-scale climate change projections? Spatial covariates may be more appropriate for the recent past and present while long-term climate change should only include environmental covariates.
- What age classes, seasons, and regions are well surveyed and well modeled by the SDM – and when and how must SDMs be extrapolated to inform complex ecosystem models?
- When SDMs are based on ocean model output, has that output been bias corrected?

Throughout the small group conversations, the global perspective provided parallels and learning opportunities as we compared across models and regions, especially for the OSMOSE examples from the Humboldt Current and the Atlantis model in the California Current and Nordic and Barents Seas. These regions and models were introduced in a series of four talks.

The first talk *"Integration of species distribution models into Atlantis end-to-end models: Should fish stay or should fish go? …and other distribution parameters"* by Pierre-Yves Hernvann included case studies from the California Current and Nordic and Barents Seas, utilizing the Atlantis ecosystem model framework. The presentation clearly illustrated the options for modeling species distributions within Atlantis, including habitat preferences, foraging movement, spawning habitat, and oxygen vs temperature effects. Examples from Pierre-Yves Hernvann highlighted how ecosystem models informed by SDM outputs can track the impacts of long-term and seasonal changes in prey-predator spatial overlap through the food web. Examples from Ina Nilsen (Institute of Marine Research (IMR) and University of Bergen, Norway) and Berengere Husson (IMR) illustrated the importance of defining thermal niches for different life-stages, forced seasonal distributions, and optimal foraging behavior.

A series of three talks from the Humboldt Current *"Habitat impact on the interannual variability of fish in the northern Humboldt Current System"* by Mariana Hill-Cruz, *"Realized vs. Fundamental Niche SDMs for the coupling with complex multispecies and ecosystem models: The OSMOSE model as case example"* by Ricardo Oliveros-Ramos, and *"Understanding the impact of the spatial distribution of fish in the ROMS-PISCES OSMOSE model for the Peru Current Upwelling Ecosystem: Insights from a sensitivity analysis of model forcings"* by Criscely Luján - applied the OSMOSE modeling framework, which has undergone recent improvements in the incorporation of species maps and foraging behavior. The OSMOSE work investigated the relative impact of interannual variability in fish distribution maps vs only in plankton food for the fish, the utility of food (plankton) maps as a proxy for habitat availability to mesopelagic fish, the importance of considering realized vs fundamental niches, how fish movement and distribution has been incorporated in different versions of OSMOSE, and the relative utility of habitat maps vs simulating foraging behavior. OSMOSE model behavior was also evaluated in the face of climate events (El Niño), with examples of challenges and solutions regarding ontogenetic shifts in distribution and incorporating uncertainty in the complex models.

Anticipated outcomes/products

We will produce a peer-reviewed manuscript summarizing the state of the art and emerging solutions for coupling SDMs to more complex multispecies and ecosystem models. This will include an overview of the challenges and decisions, and case studies from the California Current, Humboldt Current, Barents Sea, and other regions relevant to small pelagic fish and fisheries.

Acknowledgements

Dr. Isaac Kaplan (Isaac.Kaplan@noaa.gov) is a Research Fishery Biologist at NOAA's Northwest Fisheries Science Center in Seattle, USA. His recent focus has been on small pelagic fish (Future Seas project) and groundfish (Groundfish, Communities, and Climate Change in the California Current project) – applying a suite of oceanographic models, species distribution models, and Atlantis ecosystem models to understand species and fisher vulnerability to climate change. Isaac is also a member of the joint PICES/ICES Working Group on Small Pelagic Fish (WG 43).

Dr. Elliott Hazen (elliott.hazen@noaa.gov) received his Ph.D. from Duke University in 2008. Currently, he is working at the NOAA's Southwest Fisheries Science Center in Monterey, California. His general research interests fall in the realm of ecology and ecological modeling with an added interest in predator-prey relationships, scale, and oceanographic forcing.

Dr. Robert Wildermuth (rwilderm@ucsc.edu) is a postdoctoral scholar at the University of California Santa Cruz, working with the NOAA's Southwest Fisheries Science Center in La Jolla, USA, testing harvest strategies for coastal pelagic species in a changing climate as part of the Future Seas project. He earned his PhD from the University of Massachusetts Dartmouth and MS from Arizona State University. His research interests involve marine ecosystem-based management, quantitative ecology, and conservation behavior.

Dr. Stefan Koenigstein (stefan.koenigstein@noaa. gov) is a marine ecologist studying climate impacts on marine ecosystems and fisheries, striving to better understand system responses, feedbacks and possible future trajectories. As a Project Scientist at University of California Santa Cruz and NOAA's Southwest Fisheries Science Center, he has been working on integrative population dynamic models for small pelagic fish species in the California Current.

Dr. Mariana Hill (mhill-cruz@geomar.de) is a postdoc at the Biogeochemical Modelling group at GEOMAR, Germany where she did her doctorate. Her project focused on understanding the top-down, such as fishing, and bottom-up, or environmental, impacts on the Northern Humboldt Current Ecosystem. To do so, she used an end-to-end model which simulates the physical, biogeochemical and higher trophic levels components of the ecosystem. Currently, Mariana is also interested in exploring the mesopelagic region of the ocean and how it is linked to other parts of the ecosystem such as deep diving animals.

Dr. Pierre-Yves Hernvann (pierre.yves.hernvann@gmail. com) is a postdoc at the University of California Santa Cruz and NOAA's Northwest Fisheries Science Center in Seattle, USA. His research project focuses on quantifying the impacts of climate change on the abundance, productivity and distribution of small coastal pelagic species and their propagation to the predators and fisheries supported by these key species (Future Seas project). To do so, he uses an end-to-end ecosystem model and other ecological modeling approaches fed by a diversity of biological data, oceanographic projections and fisheries dynamics analyses. This work will support the implementation of a climate-informed ecosystem management strategy evaluation in the California Current.

Dr. Barbara Muhling (barbara.muhling@noaa.gov) is a Project Scientist at the University of California Santa Cruz, based at the NOAA's Southwest Fisheries Science Center in La Jolla, USA. She completed her PhD in Perth, Australia, and did her postdoc on the spawning dynamics of tunas in the Gulf of Mexico and Caribbean Sea, through the NOAA's Southeast Fisheries Science Center in Miami, Florida. Her current research focuses on the distribution and ecology of pelagic fishes in the California Current System, and the broader North Pacific. She is a member of the CLIOTOP Scientific Steering Committee and has co-chaired working groups on climate change and species distributions through PICES and NOAA.

SPF - Workshop 3: Small Pelagics for Whom?
Challenges and Opportunities for the Equitable Distribution of Nutritional Benefits
*Molly Ahern, Maarten Bavinck, Marian Kjellevold and Jeppe Kolding*

Small freshwater and marine fish, often consumed whole, are particularly rich in micronutrients and aid in the absorption of nutrients from plant-based foods with which they are commonly eaten. Small fish are still a relatively low-cost food in most countries of the world when compared to other animal-sourced foods, and can be purchased in small quantities, making them more accessible to the poor.

A half-day workshop on *"Small Pelagics for Whom? Challenges and Opportunities for the Equitable Distribution of Nutritional Benefits"* was held on November 7, 2022, as part of the international symposium on "Small Pelagic Fish (SPF): New Frontiers in Science and Sustainable Management" in Lisbon, Portugal. This workshop, led by co-authors of this article, focused on the post-harvest aspects of small pelagic fish and explored their contribution to the food security and nutrition of poor and undernourished populations in the developing world through the sustainable food system framework (Figure 1; HLPE, 2020). The role that small-scale fisherfolk play in access to small fish for food and nutrition security, and environmental, social and economic sustainability of food systems was highlighted throughout the workshop. The sustainable food system framework was used to set the discussion, as it expands upon the traditional supply chain approach by looking at the availability, access, utilization, stability, agency and sustainability of small fish in food systems, addressing drivers, scales and levels, stakeholders, interactions, feedback and the multiple outcomes from food systems, including trade-offs such as the use of small fish for fish-based animal feeds.

Figure 1. Sustainable Food System Framework (HLPE, 2020).

Aiming to address food security, nutrition and socioeconomic aspects of the small pelagic post-harvest sector, the workshop focus was on questions such as:

• How are SPF embedded in local food cultures and what are the related socio-economic benefits?

• What is the impact of change in demand for SPF, in particular for fish meal production, on the equitable distribution of livelihood and nutritional benefits from these species?

• What is needed to ensure that SPF continue to contribute to equitable livelihoods and nutrition for the most vulnerable?

The short presentations, followed by interactive group discussions and a wrap-up by a group of experts provided insights on the nutritional value of SPF, especially for more vulnerable consumer groups, and on the distributional segment of small pelagic supply chains, with a focus on Africa. The session was timely, given that it was held during the International Year for Artisanal Fisheries and Aquaculture (IYAFA, 2022), the UN Decade of Action on Nutrition (2016-2025), the UN Decade of Action on Ocean Science (2021-2030), and following the UN Food Systems Summit (2021).
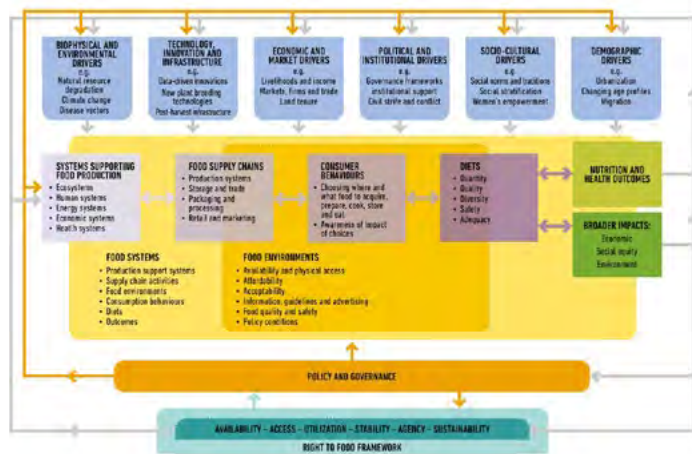
Marian Kjellevold (IMR/University of Bergen, Norway) presenting on the role of small fish in diets.

30 people participated in the workshop, mostly from academic institutions and universities, including many people from developing countries. It was kicked off with an introductory talk to present the background of the upcoming FAO technical paper on small fish food systems (Bavinck et al., 2023). This was followed by presentations

Workshop organizers - Molly Ahern (front row, first left), Jeppe Kolding (back row, first right), and Marian Kjellevold (back row, first left) - and some participants at post-workshop networking event.

from the FAO technical paper editors on the role of SPF in each of the food systems "components": 1) consumer behaviour, 2) diets, 3) trade and marketing, 4) processing, 5) production systems and 6) governance. Short abstract presentations, submitted by researchers from various institutions, were interspersed throughout the workshop, in order to bring in further examples for consideration and discussion.

It was clear from the workshop that there are concerns over governance of SPF for nutrition, particularly in relation to these fish being used for animal feed in some areas of the world. Additionally, there was discussion on the role of gender and indigenous people in small fish food systems, the potential for meeting demand through greater harvesting of small fish in some regions, reducing food loss in small fish supply chains, and stimulating demand in other regions. Issues discussed covered barriers to consumption, including availability, accessibility, affordability, consumer perception, culture or tradition relating to consumption, and desirability and convenience of fish products, in order to improve targeting of consumers to increase fish consumption.

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HLPE. 2020. Food security and nutrition: Building a global narrative towards 2030. A report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

Molly Ahern (Molly.Ahern@fao.org) joined the FAO Fisheries Division based in Rome, Italy, in 2019 as a food security and nutrition specialist, where she works to support the promotion of aquatic foods for sustainable healthy diets and their inclusion in national food security and nutrition policies. She also leads capacity building for data collection and analysis on aquatic food consumption and food composition. Molly coordinates a global project to support small-scale fisheries, particularly through upgrading fish supply chains and developing fish products for nutrition programs in the first 1000 days and school feeding, and also the development and implementation of nutrition education programs and dietary assessments focused on aquatic foods.

Dr. Maarten Bavinck (J.M.Bavinck@uva.nl) was a professor of coastal resource governance at the University of Amsterdam and the Arctic University of Norway. His long-standing engagement with small-scale fishworkers has focused, for several years now, on South Asia, particularly India and Sri Lanka, and to a lesser extent western and southern Africa. He takes a livelihood perspective, working on issues of law, tenure and governance. Maarten is the founding director of the Centre for Maritime Research (MARE) in the Netherlands, which provides a platform for social scientists interested in coastal and marine matters. His research projects have included a social action component. Since joining the International Collective in Support of Fishworkers (ICSF) in 2017, Maarten has chaired its board.

Dr. Marian Kjellevold (marian.kjellevold@hi.no) is the Head of Research at the Institute of Marine Research (IMR) in Norway. She has extensive experience in seafood intake and nutritional epidemiology, with a particular focus on food composition, dietary intake of micronutrients and micronutrient status in children and pregnant women. In recent years, Marian has worked with longitudinal cohort studies on pregnant women and infants, and randomized intervention trials with fish. Outcome variables are status (iodine, vitamin D, marine fatty acids and mercury), mental health and cognitive performance. The IMR is a reference laboratory for the Norwegian Food Safety Authorities, and her research group is responsible for the projects providing analytical data for the Norwegian food composition table. Her research work has resulted in over 60 peer-reviewed publications.

Dr. Jeppe Kolding (Jeppe.kolding@uib.no) is a Professor in Fisheries at University of Bergen, Norway, specializing in small-scale fisheries in developing countries and their importance in terms of food security. Previously Jeppe was employed by the Institute of Marine Research, Centre for Development Cooperation in Fisheries, where he worked with the R/V Dr. Fridtjof Nansen programme under FAO. Jeppe has lived and worked several years in various African countries and have experience from shorter-term engagements in more than 25 developing countries. His primary research interest is fish stock assessment, ecology, harvest strategies and management of small-scale tropical fisheries.

SPF - Workshop 4: Evaluating Inter-Sectoral Tradeoffs and Community-Level Response to Spatio-Temporal Changes in Forage Distribution and Abundance

Desiree Tommasi, Felipe Quezada Escalona, Isaac Kaplan, Dorleta Garcia and Robert Wildermuth

This half-day workshop on *"Evaluating Inter-Sectoral Tradeoffs and Community-Level Response to Spatio-Temporal Changes in Forage Distribution and Abundance"* was held on November 7, 2022, in Lisbon, Portugal during the Small Pelagic Fish (SPF) Symposium. 29 participants attended the workshop, which was co-chaired in-person by the co-authors of this article. Three additional conveners, Dr. Tim Frawley, Dr. Juan Carlos Seijo and Dr. Stephen Stohs, were unable to attend the symposium, but contributed to the scoping and preparation of the workshop.

SPF exhibit large fluctuations in abundance and distribution in response to environmental variability, harvest, and predation pressure. Given their critical ecological role in transferring energy from the planktonic food web to higher trophic levels, such changes in SPF dynamics impact both directed fisheries on SPF, and other dependent predators, including commercially important finfish and protected species. Therefore, it is of interest to SPF fishery managers to evaluate tradeoffs between large-scale directed catch of SPF and their role in (1) supporting regional marine ecosystems as a forage base and (2) providing direct benefits to coastal communities as a source of livelihoods and nutrition. However, to maintain resilience of fishing communities and develop adaptation strategies to climate change, improved understanding of how fishers respond to spatio-temporal shifts in forage availability is also paramount. Fishers might have heterogeneous responses depending on local regulation, fleet sizes, industry structure, market institutions, and social norms. This workshop was designed to highlight innovations and challenges in modeling responses of fishers and fishing communities to variability of SPF availability through a comparison of case studies of SPF fisheries around the world. The anticipated outcome of the workshop will be a synthesis manuscript highlighting best practices and challenges in modeling responses of fishers and fishing communities to SPF variability through a comparison of case studies of SPF fisheries around the world.

An introduction by the conveners outlined the goals of the workshop:

- To bring together community of practice to learn from each other and improve exchange of ideas for future collaborative papers;

- To review and edit a draft paper outline and discuss potential case studies, section topics, and format.

The introduction was followed by five presentations on methodological advances in integrated biological-economic models, ecologically informed economic models of fisher behavior, models of fishing community response and adaptation to climate, as well as approaches that focused on the heterogeneity in fishers' realities and their response to historical changes in SPF abundance and distribution.

Felipe Quezada Escalona presented a potential case study from the California Current region. Using a Bayesian hierarchical approach, he analyzed how historical changes in forage species distribution and the closure of the Pacific sardine fishery affected landings of three coastal pelagic species: Pacific sardine (*Sardinops sagax*), market squid (*Doryteuthis opalescens*), and Northern anchovy (*Engraulis mordax*) that are targeted by the US West Coast Coastal Pelagic (CPS) fleet. To account for heterogeneity in fishers' responses, CPS vessels were grouped into eight different fleet segments using cluster analysis to enable estimation of cluster specific coefficients in the landings models. He also outlined application of a discrete choice modeling approach to study how target species spatial distribution and closures affected participation decisions in the US CPS fleet.

The presentation by Gonçalo Araujo was an investigation of Portugal's mainland purse seine fishery spatio-temporal activities footprint based on georeferenced data. Satellite data and machine learning (ML) algorithms were combined to allow identification of the fleet's fishing grounds and economic value attribution. Trips were defined by using Automatic Identification System (AIS) data and high-resolution spatial polygons to extract vessel positions at specific locations. Using observer data, supervised ML algorithms were trained to classify vessel's trips operations. These trips were matched to corresponding landings, with volume and revenue estimated by species and commercial size. Preliminary results indicate similar spatial patterns for vessel groups with similar technical characteristics and targeted species. While some fishing grounds face consistent focused pressure over time, other areas show a broader range of activity, suggesting different strategies between the vessel groups.

Xiurou Wu introduced a novel spatial dynamic model of an individual fisher's trip level decision making on location choice, fishing effort, and travel route. The work showed how high-resolution mobility data improves the understanding of human behavior using fishing trip observations from the Gulf of Mexico's bottom longline

fishery. Global positioning data was used to empirically model fishers' decision-making. Previous research exploring these decisions had focused on one aspect (e.g., fishing location), treating other aspects as exogenous. These decisions, however, are interconnected and conditional on the underlying vessel capital stock (e.g., hold and fuel capacity). Xiurou Wu's results demonstrate that technology constraints endogenously determine the trip length and impose a shadow price affecting the fisher's choice of location and effort from the outset of a trip. The work also shows that the degree of route planning and technological constraints consideration depends on the level of forward-looking behaviour: the more forward-looking, the closer it approaches the dynamic optimal.
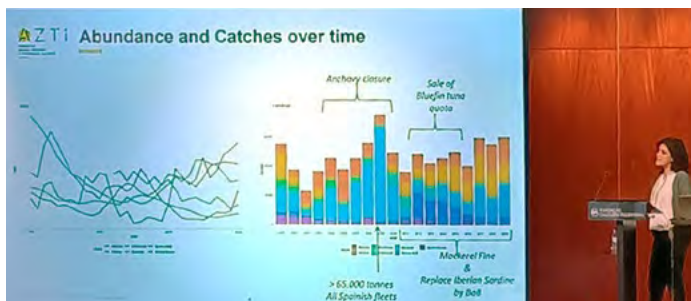
Dr. Dorleta Garcia describing historical trends in abundance and catch for the Spanish inshore fishery during the workshop.

Dorleta Garcia presented a case study from the Spanish inshore fishery. She showed how the fleet responded to shocks driven by changes in the abundance of SPF over the historical period. Shocks, such as an anchovy closure, impacted different fleet segments differently. The presentation ended with an overview of current threats to SPF fisheries, including a decrease in anchovy size, a mackerel expansion in the North Sea leading to transboundary issues, and how new requirements for reduced CO_2 emissions and decreased energy consumption might impact the fleet in the future.

The final talk by Jennifer Beckensteiner outlined a case study from the Bay of Biscay. She conducted an empirical resilience analysis to assess how fishing communities and fishery management institutions have responded and adapted to large-scale shocks in the last two decades, one being the closure of the anchovy fishery from 2005 to 2010. The resilience to shocks differed by fleet segment. French operators experienced negative repercussions due to displacement of fishing effort, increasing pressure on other species, and loss of market, while Spanish operators were more resilient to changes. She also highlighted that while the anchovy stock has recovered, the fishery socio-ecological system has not returned to its pre-collapse status.

In a brief discussion that followed, it was highlighted that in addition to specific case studies the presentations showed common insights to be expanded upon in the synthesis paper, namely (1) methods to best define fishing footprints, and how those may change over time, are important for ocean zoning and spatial management, particularly under further expansion of the blue economy and increased ocean industrialization; (2) how the response of fishers' to changes in SPF is heterogeneous, and that this diversity in responses needs to be recognized in analyses assessing resilience of the fishing industry to changes in SPF dynamics.

The workshop then split into three small groups and spent one hour discussing, for each of the regions represented by participants in the groups, dynamics and operations of the main SPF fisheries, shocks that have occurred over time and their impact on the fishing communities, and issues and challenges related to climate change facing both industry and managers in each region. The small group discussions outlined potential case studies for Portugal, Bay of Biscay, Oman, Mauritania, Spain, Mexico, the US West Coast, US East Coast, South Africa, Denmark, Peru, Italy, and freeze trawlers. The participants agreed that for the synthesis paper it would be important to first provide an overview of operations in the different systems and then, for each region, describe shocks overtime driven by changes in the abundance and distribution of SPF to assess the adaptive response of fishing communities and industries as well as fisheries management with the goal to examine potential opportunities or barriers to adaptation and to identify management mechanisms that can foster resilience.

In discussing the paper outline, it was decided that identified case studies will be assigned to different sections to showcase different drivers of the response of SPF fisheries to climate variability and change. These potential sections will be (1) challenges to industry from spatial closures and shifting transboundary stocks, (2) how price and markets mediate the response of the fleet to shocks driven by the boom-and-bust dynamics of SPF, (3) socio-economic impacts of changes in fish size and quality, (4) socio-economic impacts of changing predator distributions, and (5) the changing energy and CO_2 emission landscape and impacts on the SPF fishing operations. The workshop concluded with an overview of the next steps, which include the creation of a listserv of interested participants and development of the current paper outline into a manuscript.

Acknowledgments

Dr. Desiree Tommasi (desiree.tommasi@noaa.gov) is a Project Scientist at the University of California Santa Cruz, working at the NOAA's Southwest Fisheries Science in La Jolla, USA. Her research aims to understand the effects of climate change and variability on marine ecosystems, and to apply this understanding in support of fisheries management. Her recent work has focused on developing management strategies evaluations for highly migratory species in the North Pacific. She is also leading the Future Seas project assessing performance of management strategies for SPF in the California Current under climate change.

Dr. Felipe Quezada Escalona (felipe.quezada@noaa. gov) is a postdoctoral scholar at the University California Santa Cruz, working at the NOAA's Southwest Fisheries Science Center in La Jolla, USA, on the Future Seas Project. He holds a master's degree in Environmental and Natural Resources Economics from the University of Concepción in Chile, and a Ph.D. degree in Resource Economics at the University of Massachusetts Amherst. He is interested in conducting research on common pool resources and fisheries management, coalition formation, and price determination. For the Future Seas project, he is working on the effect of climate change on forage species landings, vessel participation, and fishing grounds.

Dr. Isaac Kaplan (isaac.kaplan@noaa.gov) is a Research Fishery Biologist at NOAA's Northwest Fisheries Science Center in Seattle, USA. His recent focus has been on small pelagic fish (Future Seas project) and groundfish (Groundfish, Communities, and Climate Change in the California Current project) – applying a suite of oceanographic models, species distribution models, and Atlantis ecosystem models to understand species and fisher vulnerability to climate change. Isaac is also a member of the joint PICES/ICES Working Group on Small Pelagic Fish (WG 43).

Dr. Dorleta Garcia (dgarcia@azti.es) is a Senior Researcher in AZTI (Spain) and ACOM vice-chair in ICES. She has long experience in the implementation and development of mathematical models to describe fishery systems, stock assessment and management strategy evaluation. Dorleta has led the development of the bio-economic simulation model FLBEIA that has been broadly used in the evaluation of management strategies for mixed-fisheries and is currently used in ICES to provide mixed-fisheries considerations. She is particularly interested in the uncertainty conditioning and global sensitivity analysis of simulations models.

Dr. Robert Wildermuth (rwilderm@ucsc.edu) is a postdoctoral scholar at the University of California Santa Cruz, working with the NOAA's Southwest Fisheries Science Center in La Jolla, USA, testing harvest strategies for coastal pelagic species in a changing climate as part of the Future Seas project. He earned his PhD from the University of Massachusetts Dartmouth and MS from Arizona State University. His research interests involve marine ecosystem-based management, quantitative ecology, and conservation behavior.

Bruno de Giusti

SPF - Workshop 5: Recent Advances in the Daily Egg Production Method (DEPM): Challenges and Opportunities
Andrés Uriarte, Tim Ward, Cristina Nunes, Luis Cubillos and Kostas Ganias

Participants in the SPF22 workshop on *"Recent Advances in the Daily Egg Production Method (DEPM): Challenges and Opportunities"*.

Introduction

Application of the Daily Egg Production Method (DEPM) to the assessment of pelagic fish populations has been expanding and being refined since its development for anchovy at the Southwest Fisheries Centre in California in the 1980s (Lasker, 1985). It is now applied to many fish species like sprats, sardines, mackerels, horse mackerels, snappers, etc., all over the world. Since the 1990s several workshops have been conducted to share the progress in the application of the method (e.g., San Sebastián, Spain, Motos 1997; Concepción, Chile, Castro et al., 2005; Athens, Greece, Bernal et al., 2012, Adelaide, Australia, Ward et al., 2015).

Over the last decade, several advances in estimation procedures for both egg production and adult parameters have occurred which warrant discussion and debate. The international symposium on "Small Pelagic Fish (SPF): New Frontiers in Science and Sustainable Management" offered a timely opportunity for scientists working on the DEPM on different species and in ecosystems from around the world to gather and discuss their new findings, ongoing challenges and future opportunities. The half-day workshop, convened by the co-authors of this article, was held on November 7, 2022, and had a total of 35 participants.

Workshop structure

In response to the contributions received, the workshop was structured around three topics, each followed by 20-30 min discussion:

1. Estimating daily egg production and mortality - ongoing challenges and potential solutions (8 presentations);

2. Issues on adult parameters and spawning biomass estimates (4 presentations);

3. Problems and challenges of applying the DEPM to scombrids (mackerel and horse mackerel) (3 presentations).

Presentations and discussions

Topic 1 was opened by Rick McGarvey's talk on *"Alternative methods for estimating total daily egg production"*. He showed that the method applied to the South Australian snapper based on mean egg abundance over all stages corrected for assumed mortality, local temperature and hatching time, permitted estimations of single daily egg production P0i per station. These P0i allowed for the application of geo-statistics to produce total daily egg production across the study region as the integral under the geostatistical egg density surface. Leire Citores presented a Bayesian estimation of daily egg production applied to the sardine in the Bay of Biscay. The method ensures egg mortality values (Z) have the correct sign by setting density function priors for the Z values based on information from the literature. The method resulted in tighter credible intervals of both P0 and Z than the usual Generalized Linear Model (GLM) approach. Leire Ibaibarriaga expanded the former approach to obtain spatially explicit estimates of daily egg production by applying a Bayesian GLM allowing for random effects by stations. Total daily egg production is estimated as the integral of the daily egg production rates per station raised to the areas represented by each station. Application of the method to sardine in the Bay of Biscay provided consistent results with the previous presentation except for a few years where the reasons behind these differences require further study. Luis Cubillos first analysed the spatial effects of daily egg cohort on the daily egg production rate of anchovy and common sardine off central-southern Chile, by using a Bayesian hierarchical model. Egg count followed a negative binomial distribution as a function of age, bottom depth, and daily cohorts distributed into a gaussian spatial field. He found significative spatial effects of bottom depth and distribution of daily cohorts on the egg density of the two species. The daily egg production was estimated through a weighted area procedure, improving the precision of the final estimates.

In the second talk, "The precision of daily egg production and mortality rates: the importance of weighting by egg aggregation indices of the daily cohort", he showed that using a Lloyd's Index of patchiness significantly reduced the CV of the egg production estimates (and of Z), without major effects on the final point estimates compared to the standard procedures. Alex Ivey presented "Precision of P0; insights from simulation modelling and field experiments". Simulation modelling suggested an oblique sampler may provide more precise P0 than vertical samplers, but these findings were not supported by field trials using Nackthai, CalVET and Bongo samplers. Field results suggested that using Bongo nets, which filter more water and capture more eggs than the CalVET nets may be warranted for species with low egg production, and that other ways for improving the precision of P0 need to be explored. Maria M. Angélico compared "Egg Production estimation for Atlantic Iberian sardine using CUFES sampling" with the traditional PairoVET net, by implementation of a biophysical model to assess the egg vertical density distribution. Results showed some underestimation of stages 1 and 3 by CUFES compared to PairoVET. This is, however, the first time these paired comparisons have been made, and this work is still in progress. Finally, Gretchen Grammar in her talk "How precise are estimates of spawning area and spawning biomass of sardine off southern Australia" showed that Bongo nets filter more water and can detect lower densities of eggs than CalVET nets and that spawning area can be estimated consistently using Calvet nets. Future studies will compare estimates of spawning area, P0 and total egg production obtained using the two samplers.

The discussion focussed on the way forward for estimating egg production. Most of the presentations permitted better estimates of the egg production by applying statistical methods which allow spatial variability to be considered. These procedures overcome the simplification of the traditional assumed single decay exponential model fitted with a GLM over the entire spawning area ignoring the spatial variability and structuring of egg production in space. However, it was acknowledged that the estimation of egg mortality is still a challenge and is a major source of uncertainty in the application of the DEPM. The importance of matching annual and spatial estimates of P0 and spawning fraction were also discussed.

In Topic 2, Tim Ward dealt with the benefits of replacing batch fecundity $\hat{F}$ and female weight Wf with the relative fecundity (F/Wf) when applying the DEPM, showing that the latter combined parameter has lower coefficients of variation (CVs) than both $\hat{F}$ and Wf, and was stable across years and over a wide range of Wf, for several species off south-eastern Australia. Andres Uriarte confirmed the greater stability F/Wf compared with the individual parameters for anchovy in the Bay of Biscay, but found that the benefit of reducing the variance estimates of the daily

fecundity was relatively small if the original application fully accounted for the covariation $\hat{F}$ and Wf. Katerina Charitonidou presented a novel method of estimating the spawning interval in the Mediterranean sardine (SI method), using the ratio of oocyte growth period (time lag between the onset of secondary oocyte growth and spawning), over the number of oocyte cohorts in spawning capable females. The results were comparable to previous estimates for this and other European sardine populations, suggesting that the method could be applied to various multiple spawning species. Andrei Makarchouk explained the calculations of spawning-stock biomass of sprat in the Gotland Basin of the Baltic Sea with the DEPM in the years 2019-2021, using quasi-synoptic ichthyoplankton surveys conducted from June 15 to June 21 each year. Future applications of the method require better adult estimates and international coordination with neighbouring countries as the spawning area exceeds the current coverage of the survey.

In Topic 3, Dolores Garabana, Paula Alvarez, and Cristina Nunes (with Maria M. Angelico) summarized their respective posters, explaining the difficulties in applying the DEPM to the mackerel and horse mackerel along western European coasts. For mackerel proper estimation of batch fecundity and spawning frequency are problematic due to weak synchronicity of spawning and short inter-spawning interval, difficulties in dating post-ovulatory follicles and potential spatial heterogeneity of adult parameters for an area expanding across thousands of nautical miles. In addition to the former difficulties, poor sampling (and/or insufficient coverage of the population demographic structure) hampers a reasonable estimation of adult parameters for horse mackerel. ICES WGMEGGS is chairing the transition from the annual egg production method to the DEPM, and a workshop is devised for next year. For horse-mackerel of the southern stock the DEPM has been applied, with several developments, since 2010. As for most DEPM applications, major challenges relate to reliability of yearly egg mortality estimates and the validation of POFs ageing for spawning fraction calculations.

Discussions on these two topics pivoted around the applicability of the 'SI method' to other species along with its sampling requirements, spatial heterogeneity of adult parameters when spawning expands over broad regions (for instance in Australia mackerel spawning frequency may change with latitude), or potential bias on adult parameters arising from the bias sampling of adults, either associated to the gear or area of sampling. For scombrids metanalysis and sharing or borrowing data fecundity parameters from other stocks might be valid to obtain preliminary spawning stock biomasses. In contrast, the problems in daily fecundity estimates are being solved for particular stocks.

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Follow up

The workshop was closed by recalling the potential for submitting contributions to the special volume of the CJFAS and by launching an initiative for a review paper on recent advances on the DEPM during 2023 within ICES-PICES WGSPF Activity 6 on Survey design and monitoring.

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Dr. Andrés Uriarte (auriarte@azti.es) is Senior Scientist at AZTI, Basque Research and Technology Alliance (BRTA), Spain, with >30 years of experience working on fish population dynamics, assessment and management of small pelagic fishes (SPF). He has been involved in the application of the DEPM to the Bay of Biscay anchovy since 1987 and has chaired and collaborated with some ICES working groups dealing with the DEPM (WGACEGGs) and integrated assessment (WGHANSA). He has participated in many international projects and has about 50 publications in SCI journals.

Dr. Tim Ward (timothy.ward@utas.edu.au) has led research on Australia's two largest fisheries, the South Australian Sardine Fishery and Commonwealth Small Pelagic Fishery, for more than two decades. The multi-institutional research teams that Tim has routinely led apply the DEPM to stocks of sardine, blue mackerel (Scomber), jack mackerel (Trachurus) and Redbait (Emmelichthys) off south-eastern Australia. He has published over 70 scientific papers in SCI journals, 12 book chapters and 170 peer-reviewed technical reports designed to inform fisheries managers and government policy makers. Tim has supervised 7 honours and 6 Ph.D. students.

Dr. Cristina Nunes (cnunes@ipma.pt) is Senior Scientist at the Portuguese Institute of Sea and Atmosphere (IPMA), developing research for the past 20 years in biology/ecology applied to fisheries of marine SPFs, with expertise in histological/microscopical analyses (areas of reproduction and bioenergetic). She is IPMA's co-coordinator of DEPM surveys applied to sardine and horse-mackerel in Iberian waters, member of several ICES WGs related to SPF surveys and provision of biological parameters. Cristina has participated in several projects on SPFs, contributed to academic responsibilities (students' supervision, dissertations' juries), and co-authored 16 peer-reviewed scientific papers, 2 book chapters and more than 40 technical-scientific documents.

Dr. Luis Cubillos (lucubillos@udec.cl) is an Associate Professor at the Department of Oceanography, Faculty of Natural Science and Oceanography, University of Concepción, Chile. In addition, he is an associated researcher at the Centre for Oceanographic Research in the eastern South Pacific COPAS-COASTAL. Luis has assessed the spawning biomass of SPF using the DEPM since 2000, particularly sardine and anchovy in central-southern Chile.

Dr. Kostas Ganias (kganias@bio.auth.gr) is an Associate Professor at the University of Thessaloniki, Greece, who studies the reproductive life-history and ecology of fishes. His research is mainly focused on applications of egg production methods and the amelioration of fish fecundity estimations, including the implementation of novel image analysis and statistical approaches. Kostas edited a book titled "Biology and Ecology of Sardines and Anchovies" (CRC Press) and led a methodological chapter on fish fecundity. He authored/co-authored more than 65 papers in SCI journals, coordinated 14 research projects, and supervised 4 PhD theses.

SPF - Workshop 6: Small Pelagic Fish Reproductive Resilience
Rosario Dominguez-Petit, Susan Lowerre-Barbieri, Leonardo Castro and Akinori Takasuka

Participants in the SPF22 workshop on *"Small Pelagic Fish Reproductive Resilience."*

The reproductive resilience paradigm takes an eco-evolutionary perspective to identify species-specific traits in spawner-recruit systems that drive reproductive success and consequently resilience to fishing pressure (Lowerre-Barbieri et al., 2017: Fish and Fisheries, 18(2), 285-312. Doi: 10.1111/faf.12180). To operationalize the use of the reproductive resilience paradigm to inform management requires increasing scientific dialogue across fields including fisheries ecologists, geneticists, early life biologists and stock assessment scientists. We need to move beyond the intrinsic population growth equation to understand drivers of transgenerational productivity.

The objectives of the workshop held on November 7, 2022, as part of the international symposium on "Small Pelagic Fish (SPF): New Frontiers in Science and Sustainable Management" were:

1. drawing on diverse scientific expertise to discuss advances in understanding drivers of reproductive success in SPF stocks and reproductive resilience as an indicator of population and marine ecosystem status for sustainable management of marine stocks and ecosystems,

2. using the reproductive resilience paradigm to identify core factors in SPF as well as knowledge gaps and research and modeling needs,

3. outlining a draft for a special issue or review paper in SCR journal focused on reproductive resilience of SPF.

Furthermore, the workshop aimed to create a networking environment for research on fish reproductive resilience, which would promote collaboration among scientists working on fish reproductive resilience and related fields.

The half-day workshop, convened by the co-authors of this article, had a total of 60 participants and included 6 oral presentations and 3 posters, as well as 2.5 hours of active discussion organized around four topics:

*   State of the art: What has been done so far, and what has been left to be done?

*   Identifying key topics of reproductive resilience: What do you think will be key issues to be solved?

*   Potential data sources: What surveys, analyses, etc., are available and will be required for a future breakthrough? and

*   Addressing the challenge: Any concrete study designs to clear the issues?

For promoting participation of all participants in the discussion, the interactive online tool Aha Slides was used (© 2022 AhaSlides; https://ahaslides.com).

In the first talk, Susan Lowerre-Barbieri reviewed the reproductive resilience paradigm to stimulate workshop discussions on current understanding of SPF reproductive success, knowledge gaps, and future research directions. She highlighted the complexity of the spawner-recruit system in marine species compared to terrestrial animals, and especially in the case of small pelagics that include species with a wide range of life histories, spatial ecology, and longevity. Alba Jurado-Ruzafa introduced the monitoring program of pelagic fishes in the Canary Islands (Spain) by the Spanish Institute of Oceanography (IEO-CSIC). This program collects data on a wide range of life-traits of adults, but not from larvae, which should be a priority for studying the reproductive resilience of these stocks. Mathieu Doray presented a method

Figure 1. Word cloud with the drivers of the boom/bust processes in SPF identified during discussion.

complementing CUFES and acoustics sampling to develop a relative daily fecundity index which could be mapped. Results indicate that relative daily fecundity is not homogenous over space or time as interplay between fecundity, environment and condition exists and egg production is not consistent over space and time. Antonio Cuba analyzed the influence of El Niño and La Niña events from years 1992 to 2020 on reproductive timing (based on the gonadosomatic index) and spawning fraction of anchoveta (Engraulis ringens), with implications for productivity over time. Katja Mäkinen examined egg quality in Baltic herring, reporting a reduced body size in the past decades and an apparent decrease in egg quality based on lipids and TH levels. Both salinity and temperature were found to be important abiotic factors affecting egg quality (oral presentation). Her additional experimental work (poster) assessed maternal phenotype, egg quality and larval survivorship at two temperatures. Reproductive success was highly variable and temperature affected embryonic development, egg survival, and hatching success. Aarne Lauerma in his poster examined the impact of maternal thyroid hormones on the egg size, hatching success and larval properties (length, yolk sac size and percentage of vertebral malformations) of the Baltic herring. Finally, Isabel Riveiro (poster) analyzed the influence of maternal attributes and environmental conditions on egg size in two pelagic species from the Cantabrian Sea (Spain): Atlantic mackerel, a very abundant species with high recruitments in the recent years, and Iberian sardine, a stock that has suffered a historic decline in abundance and biomass prior to 2019, after which it began to recover. The study highlights how some species may take rapid advantage of favorable environmental conditions.

During active discussion through real-time surveys, several drivers of the boom/bust processes in SPF were identified, as well as important gaps in knowledge on reproductive behavior (natal homing, site fidelity, optimal habitat, reproductive phenology etc.), larval ecology and connectivity, key aspects of reproductive resilience. The difficulty of studying the spatio–temporal variation of all these parameters with systematic oceanographic surveys carried out on fixed dates and areas was also highlighted (Figure 1).

The lack of sufficient long time-series of reproductive parameters was another handicap identified for analyzing reproductive resilience at the appropriate time scale. In this regard, a quick scan was made of what kind of data series and sample collections are available in the participants' institutions (Figure 2A), and what new methodologies could be used to obtain information for the study of reproductive resilience (e.g., microchemistry in otoliths and genetics in fresh and some preserved tissue samples, or egg and larval ecology studies in ichthyoplankton samples). Finally, participants contributed to a survey as to which form of collaboration they considered most appropriate to advance the study of SPF reproductive resilience. Research projects and working groups were identified as the most efficient ways to achieve this (Figure 2B).
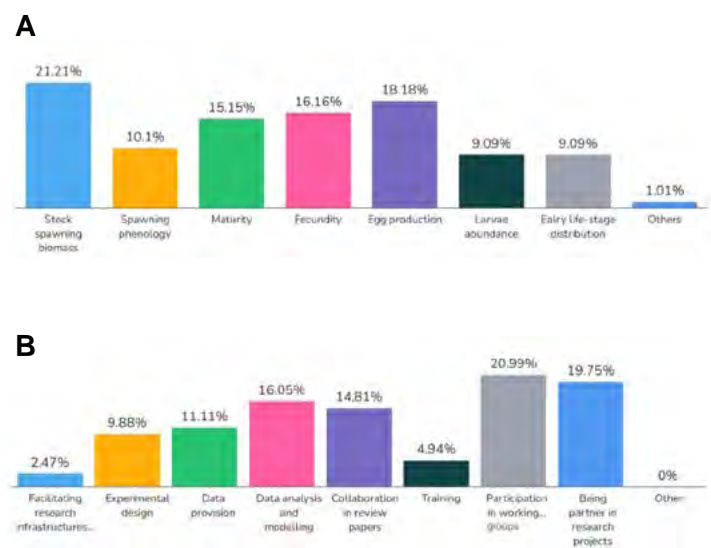
A

B

Figure 2. Barplot with A) SPF series available for studying reproductive resilience and B) potential collaboration of the participants.

Convenors of the SPF22 workshop on *"Small Pelagic Fish Reproductive Resilience"*
(L-R: Akinori Takasuka, Sue Lowerre-Barbieri, Rosario Dominguez-Petit, and Leonardo Castro).

Dr. Rosario Domínguez-Petit (rosario.dominguez@ieo.csic.es) is a Senior Researcher in the Oceanographic Center of Vigo of the Spanish Institute of Oceanography (Spain). Her main research focuses on the study of the life history of exploited marine species and its variations, including studies of reproductive ecology, bioenergetics of reproduction and maternal and environmental effects on the reproductive potential of fish, as well as studies on fish growth by using sclerochronology, analysis of environmental and fisheries impact on life history, population dynamics and resilience of exploited species.

Dr. Sue Lowerre-Barbieri (Susan.Lowerre-Barbieri@myfwc.com) is a Research Professor in Fisheries and Aquatic Sciences/School of Forest, Fisheries and Geomatic Sciences at the University of Florida (USA), who collaborates closely with colleagues at the Florida Fish and Wildlife Research Institute. Her research focuses on movement ecology and reproductive resilience of marine fishes and promoting integrative science by bringing together scientists from different fields and sectors. Current research includes studies on marine fish population structure, spatio-temporal reproductive behavior, spawning population abundance and effective population size, early life dispersal, sex change in sequential hermaphrodites, and the effect of habitat context on spatial ecology.

Dr. Leonardo Castro (lecastro@oceanografia.udec.cl) is a Research Professor at the Department of Oceanography of the Faculty of Natural and Oceanographic Sciences and researcher at the Copas Coastal Center of the University of Concepción (Chile). His main research interests are the ecology of the early life stages of fish and invertebrates, with emphasis on commercially important species, including oceanographic processes affecting their distribution, survival and aspects such as egg quality, developmental rates, larval growth, feeding, migrations and transport. Recent studies on biological oceanography also include carbon transfer, trophic webs, and biomarkers in zooplankton, ichthyoplankton and fish.

Dr. Akinori Takasuka (atakasuka@mail.ecc.u-tokyo.ac.jp) is a Professor of the Fisheries Biology Laboratory in the Department of Aquatic Bioscience at the Graduate School of Agricultural and Life Sciences, the University of Tokyo (Japan). After working for Japan Fisheries Research and Education Agency, he returned to the laboratory for education of his junior fellows. His interests are in the fields of Fisheries Biology and Oceanography. His current major research themes include biological mechanisms behind climate impacts on population dynamics, growth and survival dynamics during the early life stages, and density-dependent and density-independent processes in the life history of fish. Akinori is a co-chair of the joint PICES/ICES Working Group on Small Pelagic Fish (WG 43).

SOLAS Open Science Conference, 2022
Li Li, Jessica Gier, and Katye Altieri

Participants of the SOLAS Open Science Conference 2022. Photo credit: SOLAS IPO

The Surface Ocean-Lower Atmosphere Study (SOLAS) held its 8th Open Science Conference (OSC) from 25-29 September 2022, as a hybrid meeting in Cape Town, South Africa - a first SOLAS OSC in the Southern Hemisphere. Organised by a committee of 28 people from 15 countries, the conference welcomed nearly 200 ocean-atmosphere scientists from over 30 countries to share their research work and knowledge of SOLAS science and connect with colleagues from all over the world (see above).

SOLAS is an international community whose research explores the interactions between the ocean and atmosphere through quantitative understanding of biogeochemical and physical processes at the air-sea interface. SOLAS is a bottom-up organisation, in which the scientific community sets the agenda, its OSCs play a key role in that process since 2000. At the 8th instalment of the conference, the five Core Themes and three Cross-Cutting Themes outlined in the SOLAS 2015-2025 Science Plan and Organisation (Figure 1) were covered by 33 plenary talks and 124 poster presentations (Figure 2). Seven discussion sessions were convened to identify new frontiers to explore under the framework of the United Nations

Decade of Ocean Science for Sustainable Development 2021-2030 (the Decade) and other international platforms. The conference also featured an Early Career Scientists Day (ECSD), which brought together 30 early career scientists during dedicated early-career workshops on Grant and proposal writing and on Equality, Diversity, and Inclusion, as well as a networking event. Additionally, a 2-day side meeting was organised by the Working Group 163 of the Scientific Committee on Oceanic Research (SCOR) on Coupling of ocean-ice-atmosphere processes: from sea-Ice biogeochemistry to aerosols and Clouds (CIce2Clouds).

Credit: surface ocean **solas** lower atmosphere study
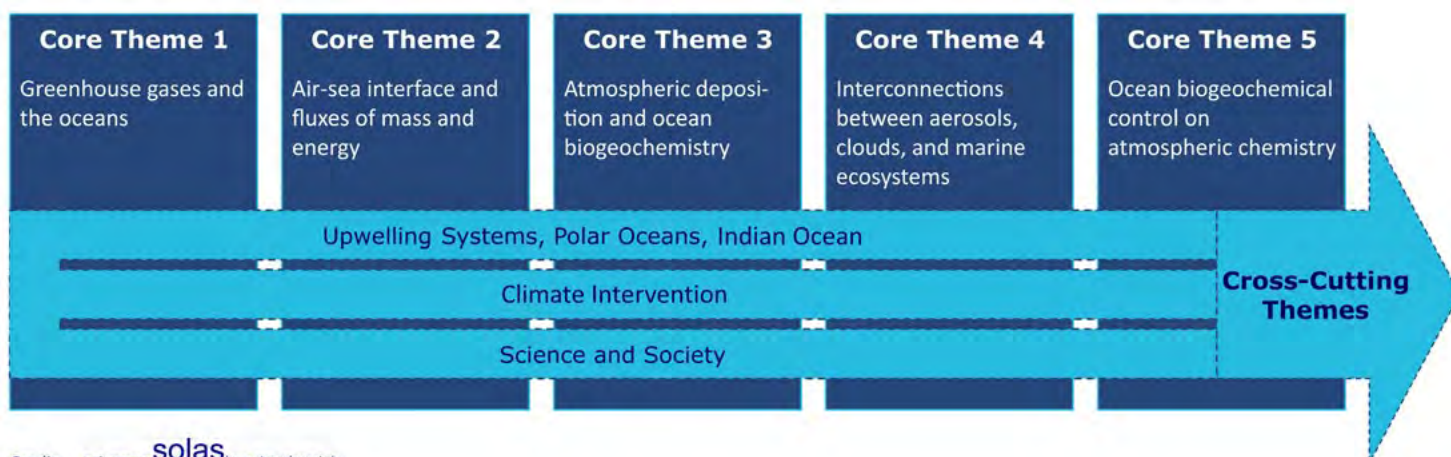
Figure 1. The five Core Themes and three Cross-Cutting Themes of the SOLAS 2015-2025 Science Plan and Organisation.

Core Theme 1, "Greenhouse gases and the oceans," focuses on the most significant long-lived greenhouse gases, such as CO_2, CH_4 and N_2O and their natural cycles in the ocean and atmosphere, which interact with anthropogenic inputs and lead to climatic feedback and environmental impacts. The session featured a keynote talk from Precious Mongwe from the Council for Scientific and Industrial Research, South Africa, on the impact of anthropogenic forcing on the Southern Ocean CO_2 sink.

Core Theme 2, "Air-sea interface and fluxes of mass and energy," is dedicated to oceanic and atmospheric processes, driven for instance by waves, bubbles or surfactants, which influence the transfer of mass and energy between the ocean and atmosphere. Meghan Cronin from the National Oceanic and Atmospheric Administration, USA, introduced her work on large-scale patterns of warm layer vs. cool skin corrections to bulk sea surface temperature and reflections on the Observing Air-Sea Interactions Strategy (OASIS).

Core Theme 3, "Atmospheric deposition and ocean biogeochemistry," explores the impact of particles of continental origin which enter the ocean from the atmosphere. These particles can be from natural processes, such as dust or volcanic eruptions, or human activities, such as the burning of fossil fuels and biomass or agriculture. The keynote talk of this session was given by Minako Kurisu from the Japan Agency for Marine-Earth Science and Technology, Japan, on application of Fe isotope ratios for a better understanding of the Fe cycle in the surface ocean and lower atmosphere.

Core Theme 4, "Interconnections between aerosols, clouds, and marine ecosystems," is dedicated to understand how aerosols, clouds, and marine ecosystems form a system as a whole, in which change in one component is manifested in another. Bingbing Wang from Xiamen University, China, gave a keynote talk on micro-

spectroscopic characterisation and ice formation potential of marine related aerosol particles.

Core Theme 5, "Ocean biogeochemical control on atmospheric chemistry," focuses on ocean emissions of aerosols and reactive gases and their impacts on atmospheric photochemistry, air quality and stratospheric ozone. Taking the upper-ocean dimethylsulfide cycling and its impact on aerosols in polar regions as an example, the keynote speaker of this session Martí Galí from the Institut de Ciències del Mar, Spain, talked about the gaps in ocean biogeochemistry-atmospheric chemistry studies from weather to climate scales.

Cross-Cutting Theme on Integrated Topics is dedicated to regional, high sensitivity, and high-priority oceanic systems where 5-Core Theme integrated studies are required and urgent, such as upwelling systems, polar oceans and sea ice and the Indian Ocean. The keynote talk given by Moagabo Ragoasha from the University of Cape Town, South Africa, addressed the inconsistencies of observations and climate models in the impacts of climate change on the Eastern Boundary Upwelling Systems. Odile Crabeck from the Université de Liège, Belgium, gave a broad overview of the role of sea ice biogeochemistry processes in the polar ocean and presented how the sea ice communities tackle the challenges. Zouhair Lachkar from New York University Abu Dhabi, United Arab Emirates, talked about examples of recent advances and gaps in understanding of the air-sea interaction and physical-biogeochemical coupling in the Indian Ocean. Cross-Cutting Theme on Science and Society focuses on SOLAS research with social relevance and on activities which have a direct impact on society, such as air quality, human health, ship emissions, marine resources, and climate regulation. The keynote talk given by Edem Mahu from the University of Ghana, Ghana, discussed ways by which science can effectively contribute to addressing immediate and unforeseen societal challenges.

Photo gallery of SOLAS OSC22 plenary sessions and poster sessions. Photo credit: SOLAS IPO

Cross-Cutting Theme on Climate Intervention explores climate intervention approaches and their environmental and societal impacts. The keynote talk given by Nadine Mengis from the Helmholtz Centre for Ocean Research Kiel, Germany, was about the feasibility, uncertainties, and contribution of carbon dioxide removal to net-zero.

The outcomes and reports of the discussion sessions and side events will be published in the upcoming issue of the SOLAS Event Report, the release of which will be announced in the SOLAS Newsletter. More information about the ECSD can also be found in the article that follows.

Cape Town is the ideal coastal city to host the SOLAS OSC. South Africa's "Mother City" is surrounded by the Atlantic and Indian Oceans, which strongly influence the local climate, and is also a gateway city to the Southern Ocean and Antarctica. The Benguela upwelling system on South Africa's west coast is one of the world's most productive ecosystems, supporting a diversity of socio-economically important fisheries, and is the focus of active cross cutting SOLAS research. To the east is the Agulhas Current, the strongest western boundary current on Earth, that transports heat and salt from the Indian to the Atlantic Ocean, thus playing a critical role in global ocean circulation. South Africa also has a strong geographic advantage for conducting research in the Southern Ocean, as many SOLAS scientists will know from time spent in Cape Town harbor before and after sampling expeditions. SOLAS scientists have explored the approximately 4000 km^2 of open and ice-covered ocean that separate Cape Town from Antarctica in the context of all the SOLAS science themes. Additionally, the Cape Point Global Atmosphere Watch station, located 60 km south of Cape Town, hosts a variety of research platforms developed to investigate the marine atmosphere. Attended by over 40 scientists from South Africa, the OSC will further boost SOLAS science in the country and the region.

After the conference, the 17 members of the International SOLAS Scientific Steering Committee met in a hybrid mode. This 2-day meeting focused on discussions of current research issues and their implementation, as well as the future of SOLAS science and organisation. For example, for the Core Theme 3, SOLAS intends to focus more intensively on fire emissions as a source of nutrients to different ocean basins and their societal impacts. Following a discussion session at OSC 2022 on "UN Decade of Ocean Science Proposal: Aerosol Exchange with Marine Ecosystems" and a COP27 side event on "Wildfire increase, a challenge for Earth system and societies", SOLAS will organise a workshop on Fire science Learning AcRoss the Earth system (FLARE) in 2023, and eventually target on a Decade programme around topic.

The next international SOLAS Open Science Conference is scheduled for 2024.

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Dr. Katye Altieri (katye.altieri@uct.ac.za) is a SOLAS SSC member and Chair of the OSC 2022 Local Organising Committee. She works at the University of Cape Town, in South Africa.

Early Career Scientist Participation in SOLAS Open Science Conference, 2022
Inge Deschepper, Royston Uning, Mohamed Ahmed and Mashiat Hossain

The authors were supported to attend the SOLAS Open Science Conference (OSC) 2022 , which brought experts in surface ocean and lower atmosphere studies to the UCT Graduate School of Business, Conference Centre in Cape Town, South Africa. 86 on-site and 97 online participants joined five days of topical presentations in the mornings, with discussion sessions in the afternoon. There was wide global representation at the conference, with representation from the Global North and South and an equal representation of late and early career researchers and scientists. The presentations and discussion sessions focused on the SOLAS's five main themes and three integrated topics:

- Theme 1: Greenhouse gases and the ocean
- Theme 2: Air-sea interface and fluxes of mass and energy
- Theme 3: Atmospheric deposition and ocean biogeochemistry
- Theme 4: Interconnections between marine ecosystems, aerosols, and clouds
- Theme 5: Ocean biogeochemical control on atmospheric chemistry
- Polar Oceans
- Indian Ocean & Upwelling systems
- Climate intervention & Science and society

Early Career Scientist Day

The SOLAS OSC 2022 started with the Early Career Scientist (ECS) day, held on September 25th, with 23 in-person and 10 online participants. The ECS day was designed to upskill the SOLAS ECS's in different areas of their professional career. The day kicked off with a workshop on Grant and Proposal Writing: Tips and Tricks, provided by Dr. Ramontsheng Rapolaki, a researcher at the Agricultural Research Council in South Africa. He provided guidance on where and how to start with a proposal, and tips on ensuring you are as successful as possible, but with the knowledge that you may not receive all the grants for which you apply. The workshop ended with the organizational committee providing the participants with a booklet collated with all the tips and tricks collected from experienced applicants, and ECS's that have written and assessed grant applications. Some of the main tips provided were:

- start early
- follow the rules and guidelines to the T
- be clear about your objectives
- a good proofreader is essential
- be realistic in your budget

The second workshop was on Diversity, Equity and Inclusion (DEI), provided by Kirsten Klopper, who is a Change Management Coach. The workshop was on awareness of one's privilege and bias within both our personal lives and professional careers. We participated in exercises to identify our privileges depending on our origin and institutional reputation at different levels of the scientific framework. We were also given tools to become more aware of our own bias and become allies to those who experience inequality and discrimination, whether outright or subtle, within the field of science.

At the end of the workshops, the in-person participants headed to the Cape Point National Park to visit the South African Weather Station, which is part of the NOAA Global Monitoring Laboratory program. The participants were given a tour of the facility and the instrumentation and measurements taken. Due to the station's position, it is ideal for measuring air masses that have passed over the South Atlantic and the Southern Ocean in winter and the air masses that come from the Southern African land mass in summer. Some of the measurements taken are carbon dioxide, methane, nitrous oxide, and ozone. Once the tour was over, the ECS's could hike to Cape Point and enjoy some of the nature the area has to offer.

Poster sessions

The poster session has always been a favourite and important part of the SOLAS OSC. As the 8th SOLAS OSC was a hybrid meeting, the two-day poster session (Sept 26/27, 2022) was held both onsite in Cape Town, and online via gather.town. 90 posters were presented with 42 onsite and 48 online posters. For the benefit of online participants, all of the onsite posters were also available online.

The posters included in the session represented all of SOLAS's 5 main core themes and additional integrated topics:

- **Theme 1:** "Greenhouse Gases and the Ocean": 15 posters
- **Theme 2:** "Air-Sea Interface and Fluxes of Mass and Energy": 17 posters
- **Theme 3:** "Atmospheric Deposition and Ocean Biogeochemistry": 12 posters
- **Theme 4 :** "Interconnections between Marine Ecosystems, Aerosols, and Clouds": 11 posters
- **Theme 5:** "Ocean Biogeochemical Control on Atmospheric Chemistry": 7 posters
- **Integrated topics:** 20 posters

Inge Deschepper presented and was awarded one of two best on-site poster awards for some of her Ph.D. findings that she presented at the in-person poster session (Integrated topics category). Her poster titled *"Impact of physical controls on nutrient availability on ecosystem productivity in the seasonally ice-covered Hudson Bay region"* presented results evaluating a 2 biogeochemical regional ocean models, BLING v0+DIC, simulations run with 2 different CMIP5 climate forcings. The simulations were evaluated with observed satellite data for 2018 for the sub-Arctic region, Hudson Bay. Her poster also illustrated the impact of different physical forcings such as mixed layer depth shoaling and sinking and river discharge into the bay can have on the percentage of chlorophyll-a production for the region through Empirical Orthogonal Function statistics (See Figure 1 below). This research has recently been submitted to JGR Biogeosciences.
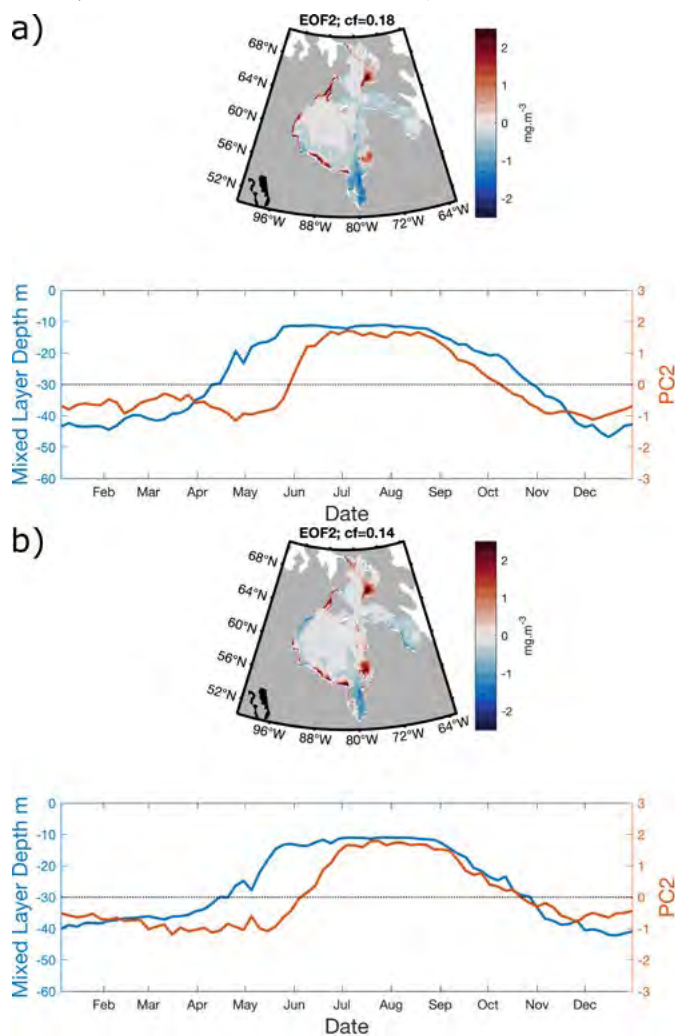
Figure 1. An example of the EOF results obtained by Inge Deschepper. EOF 2 for the a) MIROC5 and the b) MRI forced simulations. The mode (spatial plot) shows the surface chlorophyll-a associated with the EOF in mgm^{-3} and the principle component (PC) shows the average mixed layer depth (m) in blue and with the principle component in orange plotted for their respective simulations for the Hudson Bay Complex. cf indicates the percentage of the variability explained by the mode.

Dr Royston Uning remotely presented a poster entitled *"The interplay between the marine atmospheric boundary layer VOCs and the surface ocean bacteria and bacterial-derived DOM cycles: A laboratory and field studies"* (See Figure 2 below), that fall under the SOLAS core theme 5. His poster's main aim was to deliver his group's most recent finding on the potential role of bacteria-derived dissolved organic matter (DOM) and its relation to oxygenated VOC (OVOC) in surface seawater based on a preliminary study. His group study showed that bacterial-derived DOM fluorescence was highly photo-degradable which may suggest the transformation of bacterial-derived DOM to labile compounds (e.g., OVOC). More information is expected to be available after the ongoing studies are completed.
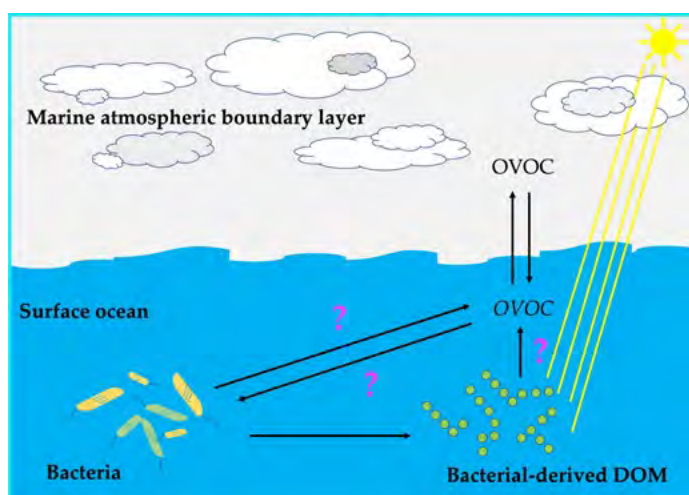
Figure 2. Marine bacteria and OVOC (bacterial-derived DOM and its potential role on the photo-production of OVOC in the surface seawater) - figure produced by Royston Uning.

Mashiat Hossain presented a poster on site, entitled *"Quantifying the impacts of marine aerosols on chemistry and climate over the Benguela upwelling region using a global chemical transport model,"* under SOLAS Integrated topic: Upwelling systems. Her work employs a 3-D global transport model, GEOS-Chem, to emphasize the effects of seasonality and latitudinal variability of marine aerosols on the tropospheric chemical composition. Her work aims to shift the focus from biomass burning aerosols to marine aerosols as coastal upwelling promotes high productivity which when paired with the extensive persistent low-level stratocumulus clouds strongly influences the global radiative budget. To this end, she has found sea-salt aerosols play a dominant role in the aerosol composition particularly during austral summer when peak marine biogenic activity is observed.

Presentations

The presentations were categorized into SOLAS's themes and integrated topics, with each session having around 4 oral presentations:

- **Theme 1:** Greenhouse gases and the oceans. This session was held on the first day of the conference (morning session) and focused on studying the carbon and oxygen cycles using in situ observations and biogeochemical models.

- **Theme 2:** Air-sea interface and fluxes of mass and energy. This session was held on the second day of the conference (morning session) and focused on the oceanic and atmospheric processes that impact the air-sea interface and regulate the fluxes of mass and energy between the ocean and atmosphere.

- **Theme 3:** Atmospheric deposition and ocean biogeochemistry. This session was held on the first day of the conference (afternoon session) and focused on the broad range of particles of continental origin that our ocean receives from the atmosphere.

- **Theme 4:** Interconnections between marine ecosystems, aerosols, and clouds. This session was held on the third day of the conference (morning session) and focused on the broad range of particles of continental origin that our ocean receives from the atmosphere.

- **Theme 5:** Ocean biogeochemical control on atmospheric chemistry. This session was held on the fourth and last day of the conference (morning session) and focused on the ocean emissions of aerosols and reactive gases and their impacts on atmospheric photochemistry, air quality and stratospheric ozone.

- I**ntegrated topics: Polar Oceans.** This session was held on the second day of the conference (afternoon session) and focused on studies using models and in situ observations to study the marine and sea ice biogeochemistry of the polar oceans.

- **Integrated topics: Indian Ocean / Upwelling.** This session was held on the third day of the conference (afternoon session) and focused on studies using models and in situ observations to study the marine biogeochemistry and upwelling in the Indian Ocean and the upwelling of the eastern boundary upwelling systems.

- **Integrated topics: Climate Intervention / Science and Society.** This session was held on the final day of the conference (afternoon session) and focused on opportunities and challenges associated with ocean carbon dioxide removal (CDR).

Dr. Mohamed Ahmed presented remotely from Canada during the first session of the conference (Theme 1). His presentation title was *"Undersaturation of oxygen in the subsurface waters of the Northwest Pacific during the wintertime convections from Argo-O2 data."* In this talk, he showed the significance of using Argo float observations to improve our estimates of the oxygen content and the extent of surface oxygen disequilibria during wintertime convection in the Northwest Pacific. Although the session was very early in the morning (2:00 AM MST) for him, his conference experience was great, and he appreciated that the sessions were recorded so the attendees could view them again at a later time.

Discussion sessions

SOLAS Open Science Conference hosted 7 impactful discussion sessions focused on a multitude of research concerns and interests. Each session was hosted by experts from an affiliated field which prompted spirited conversation and active participation of the audience. The sessions began with an engrossing session entitled *"UN Decade of Ocean Science Endorsement,"* focused on SOLAS Theme 3. The talk explored the feasibility of endorsing wildfire-related research to the UN in the coming year. Discussions delved into the impacts of wildfire on primary productivity, fish population, nutrient availability, and carbon cycling as a global concern. Emphasis has been placed on social science research on wildfires and translating the research endeavour into services such as real-time predictions of fire events. Overall, the wholesome session had significant insights from oceanographers, atmospheric scientists, and marine biologists.

Another session which garnered massive interest from the underrepresented groups in the scientific community was focused on strengthening partnerships between the Observing Air-Sea Interactions Strategy (OASIS) Programme and the Global South. This session offered an opportunity for the scientists from Global South (particularly Brazil and South Africa) to voice their concerns over the lack of training and resources, and barriers in scientific publications. Participants discussed ways of fostering investment strategies for technological advancement and business model development in the Global South, to provide increased access to modern equipment and calibration facilities. The session ended with a commitment towards the growth of the Global South community and their increased participation in OASIS Theme teams.

The presentation and discussion sessions were stimulating, and encouraged the community to think about many topics that we may not usually think about. Heartfelt thanks must go to the conference organizers for all the work put into the organization of the conference. Thanks also for the support from PICES to attend the conference online, and for Dr. Li Li and Dr. Jessica Gier from SOLAS for their help and communications before the conference.

SOLAS OSC 2022 in-person participants in front of Table Mountain, at the UCT Graduate School of Business Conference Centre in Cape Town, South Africa.
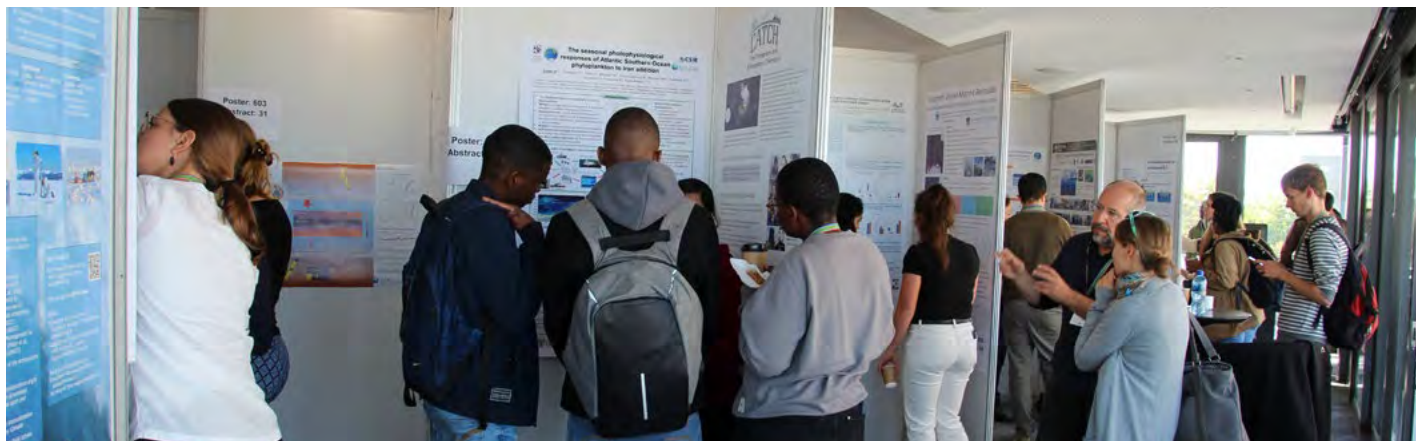
SOLAS OSC22 In-person poster session, Sept. 26, 2022.

Inge Deschepper is a Ph.D. candidate at Université Laval in Quebec City, Canada. She studies the interactions between Arctic marine biogeochemistry and the physical environment. She uses biogeochemical models coupled with regional physical oceanographic models to understand this interaction in the ocean and sea ice within the subarctic system, Hudson Bay. She is currently working remotely from South Africa.

Royston Uning is a research associate at Tanimoto Laboratory at the National Institute for Environmental Studies (NIES), Tsukuba, Japan. He studies the air-sea exchange of volatile organic compounds (VOC) and focuses on the photoproduction of VOC from marine dissolved organic matter (DOM). He originally hails from Sabah, Malaysia and currently lives in Ibaraki, Japan.

Dr. Mohamed Ahmed is a Higher Education Specialist at Esri Canada and formerly he was working as a Postdoctoral Associate at the School of Earth and Ocean Sciences at the University of Victoria in Canada. Dr. Ahmed's work focuses on air-sea gas interactions in the Arctic and Pacific waters and studying marine ecosystem changes due to natural and anthropogenic changes using ship observations, Argo floats, and geospatial technologies.

Mashiat Hossain is a Ph.D. student in the department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign, USA. Her current research work explores the role of marine aerosols in modulating the atmospheric chemistry and climate in the Benguela upwelling region. She uses a 3-D chemical transport model (GEOS-Chem) coupled with satellite data to improve the parameterization of precursor chemistry and the characterization of the chemical composition of aerosols. She comes from Bangladesh and has recently moved to the United States to pursue her graduate studies.

PICES SeaTurtle researchers find clues linking derelict fishing lines of "Urban Fishermen" to sea turtle stranding
Kyungsik Jo, Taewon Kim

PICES SEAturtle research team has just reported that there may be a link between derelict fishing gear and sea turtle strandings on Jeju Island. The research paper entitled "Possible link between derelict fishing gear and sea turtle strandings in coastal areas," was published in the December 2022 issue of Marine Pollution Bulletin. The SEAturtle project leader, Prof. Taewon Kim, from the Department of Ocean Sciences at Inha University was in charge of the research, and Kyungsik Jo, a master's degree student in the Program in Biomedical Science and Engineering, was the lead author. This is the first published scientific paper on the sea turtle research supported by PICES special project funding.

Sea turtles, most of which are on the Red List of the International Union for Conservation of Nature (IUCN) as endangered or vulnerable species, are associated with various habitats, migratory behaviors, and complex life histories. Thus, they are highly vulnerable to the impact of derelict fishing gear (DFG). DFG, which is abandoned, lost, or otherwise discarded fishing gear is a growing concern in the marine ecosystem. To figure out the effect of DFG on the strandings of sea turtles, submerged marine debris were investigated to assess the impact on the strandings and mortality of sea turtles on Jeju Island.

In the summer of 2020, the investigation was conducted on the northwestern coast of Jeju Island in South Korea. Jeju Island is thought to be the northern boundary of the sea turtle habitat with a presumed sporadic nesting place. Quadrats (5 m x 25 m) were placed and marine debris in the quadrats was filmed and collected. Collected debris was brought to the lab and categorized by use and material. The collected debris were compared between two coastal sites which differ in sea turtle stranding rate. Also, to determine which types of marine debris are most likely to negatively affect sea turtles, necropsies were conducted on two carcasses of sea turtles stranded on Jeju Island. Through necropsy, the health status and the cause of death were investigated.

A total of 403 items were found in the investigation area of 4,750 m². The collected debris included fishing-related DFGs (fishing lines, lures, ropes, net, buoy, weight, and hooks) and other miscellaneous plastic, metals, fiber, or glass. The DFGs accounted for 71.46 % of all items (Figure 1). Among the DFGs found, fishing lines and fishing lures were more common than ropes and nets.

Comparison between DFGs found in the area with a higher sea turtle stranding rate and those in the area with a lower rate showed that there were more, thicker, and longer derelict fishing lines found in the area with more sea turtle stranding numbers (Figure 2). Other features of DFGs did not show statistical differences between the areas. Sea turtles have a higher risk of interacting with longer and thicker derelict fishing lines, thus increasing the likelihood of serious health such as feeding restrictions, respiratory issues, or behavior failure. This result suggests the possible impact of derelict fishing lines on sea turtle strandings in the coastal area.

The impact of derelict fishing lines is supported by the necropsies (Figure 3). Besides the fishing line hooked in the oral cavity, the carcasses did not show physical injuries outside. The sea turtles had injuries caused by fishing lines and hooks in their mouth and esophagus. A carcass had sufficient body fat and muscle and did not have external injuries, drowning caused by fishing line entanglement was likely to be the cause of death. The other carcass, judging from its deficient body fat and muscle, appears to have died due to the inability to consume food following the ingestion of the fishing line which caused inflammation in the digestive tract. Although the number of sea turtle necropsies is limited to certify the magnitude of the effect in the present study, the result supports the negative effects of fishing lines on sea turtles.

The fishing lines collected in the underwater investigation were mostly less than 1 mm in thickness, and the lures found were shrimp shaped. Based on these, the DFGs collected in the study were presumed mostly from recreational fishing. Recreational fishing like rock fishing and breakwater fishing can introduce DFGs into the coastal marine ecosystem that could influence marine animals. To achieve sea turtle conservation, further research and governmental regulations are needed.
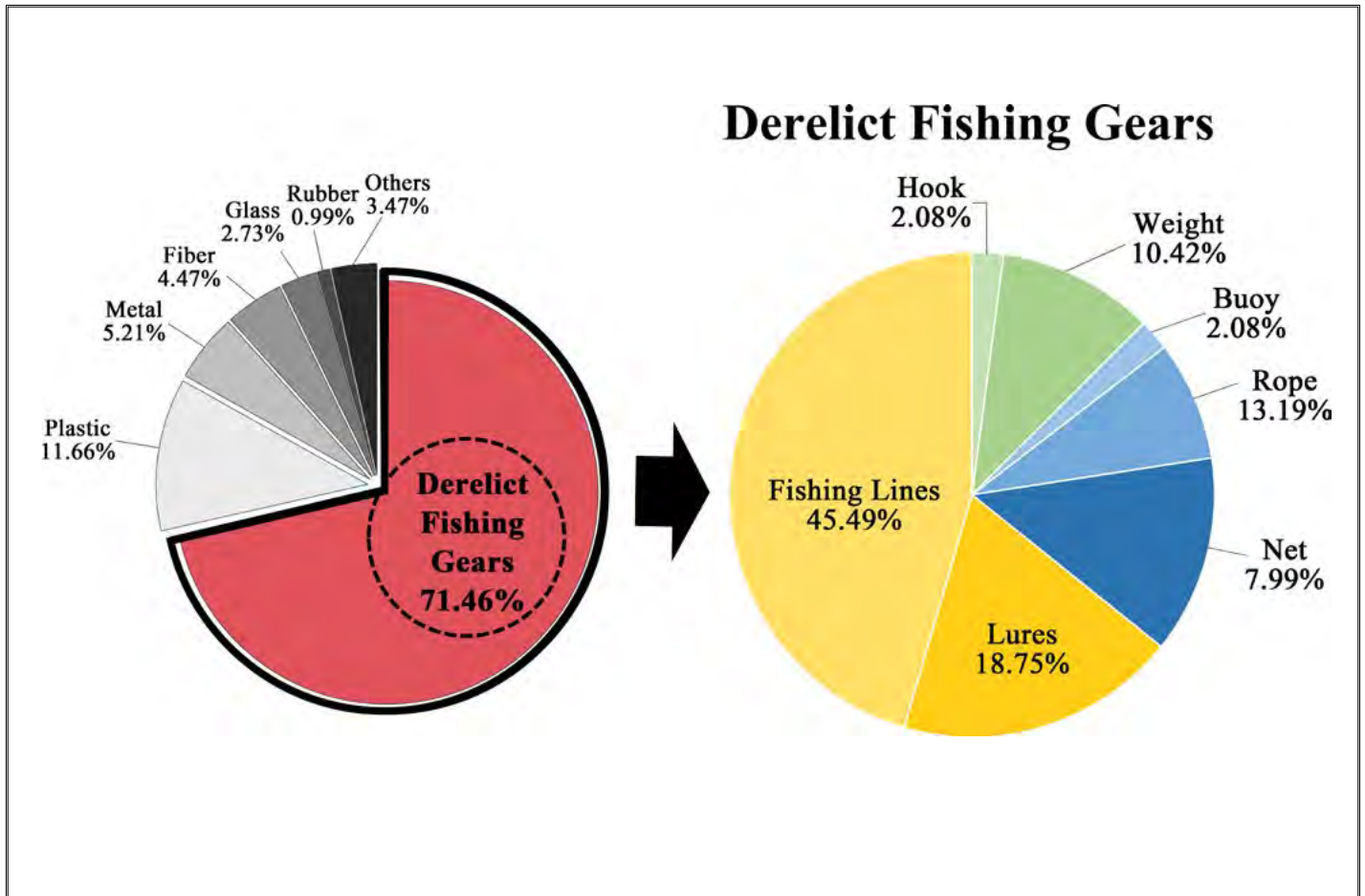
Figure 1. Marine debris found during the dive investigations. Each item was counted as a single item regardless of its size. Items shaded in blue are from commercial fishing and those shaded in yellow tones are from recreational fishing. Hooks and weights, shaded in green, are uncategorized due to uncertainty regarding their source (from Jo et al., 2022).

Figure 2. Fishing lines and fishing lures found at (a) Gwideok-ri and (b) Sinchang-ri. More fishing lines and lures were found at GD where more sea turtle strandings occurred. The average diameter of the derelict fishing line was 0.77 ± 0.12 mm at GD and 0.49 ± 0.09 mm at SC respectively, which was indicative of the thin fishing lines often used in recreational fishing. The fishing lures were shrimp-shaped, mostly targeting bigfin reef squids (*Sepioteuthis lessoniana*) (From Jo et al., 2022).

Figure 3. Necropsies of two stranded loggerhead sea turtles found on Jeju Island: (a) JJ200821–1 and (b) JJ200821–2. Traces of fishing lines were found in both carcasses. (c) JJ200821–1 had a trail of fishing line connected to the (d) oral cavity, and the fishing line trail was connected to (e) a fishing hook piercing the esophagus tissue. (f) JJ200821–2 had inflammation in the esophagus tissue caused by an embedded fishing hook which may have restricted ingestion. The red circles indicate areas affected by fishing hooks (From Jo et al., 2022).

The goal of this research was to raise awareness that there are various causes of marine pollution and alert that marine animals are under threat as the marine ecosystem is being polluted. The derelict fishing gear on the coastal area could threaten the lives of not only endangered sea turtles but also other large marine animals such as southern bottlenose dolphins and finless porpoises. Currently, the Korean TV show "The Fisherman and the City," in which celebrities enjoy recreational fishing, is very popular. Influenced by this, the population enjoying recreational fishing is increasing in Korea. However, there is no regulation or license for the recreational fishing activity. It is urgent to introduce regulation systems as derelict recreational fishing gear can be more threatening than that of the commercial fisherman.

Reference

Jo, K., Im, J., Park, B., Cho, B., Joo, S., Kim, B.-Y., & Kim, T. (2022) Possible link between derelict fishing gear and sea turtle strandings in coastal areas, Marine Pollution Bulletin. 185, Part A,114240. https://doi.org/10.1016/j.marpolbul.2022.114240

Kyungsik Jo is a master's degree student majoring in Biomedical Science and Engineering in Marine Zoology Lab at Inha University. He studies to understand sea turtles and other large marine animals to protect them from being endangered due to the negative influence of anthropogenic activities. Kyungsik also currently conduct stable isotope analysis of commensal barnacles on sea turtles of Jeju Island to presume their migration patterns and use the information for sea turtle conservation.

Dr. Taewon Kim is an associate professor at the Department of Ocean Sciences, Inha University and a leader of Marine Zoology Lab (MaZooL). He is a BIO committee member of PICES and leads PICES SEAturtle project as a co-chair with George Balazs. Taewon is interested in how environmental stressors influence behavior and physiology of marine animals. He also has a dream to contribute to conservation policy based on ecology and evolution of marine animals.

P.Lindgren

NPAFC IYS Synthesis Symposium - Key Takeaways
Camille Jasinski

From October 4th – October 6th, 2022, the North Pacific Anadromous Fish Commission (NPAFC) and North Atlantic Salmon Conservation Organization (NASCO) held a synthesis symposium in Vancouver, British Columbia, to synthesize the knowledge gained over the course of the International Year of the Salmon Initiative (IYS). This symposium welcomed over 200 participants from dozens of countries who came together to explore the conditions necessary for the resilience of salmon and people in a rapidly changing world. The IYS Synthesis Symposium *'Salmon in a Rapidly Changing World: Synthesis of the International Year of the Salmon and a Roadmap to 2030'* was the culmination of over 13 workshops and symposia, three historic High Seas Expeditions, and over 80 associated events across the North Atlantic and North Pacific Basins.

Salmon scientists, managers, and Indigenous knowledge holders from across the Northern Hemisphere presented live and recorded presentations which were organized under the five IYS research themes. Each IYS theme had an overarching objective and a range of sub-themes. The outcomes from these presentations and discussions which took place during the symposium will be synthesized into a comprehensive IYS Roadmap to 2030 which will provide advice that can be utilized by governments, academia, Indigenous communities, and private industry on salmon research and management in an increasingly uncertain future. The IYS Roadmap to 2030 will identify critical knowledge or method gaps and potential solutions based on the outcomes of the research themes, and will be published in the peer-reviewed NPAFC Bulletin.

As collaborators across the Northern Hemisphere work on the synthesis process, the IYS has gathered some preliminary key takeaways, highlights, and summaries from the rich presentations and discussions over this three-day period at the Westin Bayshore hotel in the heart of Downtown Vancouver. Participants were given the chance to review the five research themes and identify gaps and/or roadblocks to reaching the various theme objectives, as well as opportunities to overcome these gaps.

IYS *Status of Salmon* Research Theme Objective: to understand the present status of salmon and their environment .

Reaching this objective requires the support of broad collaborations that increase and build on our current understanding of salmon and their environments, as well as the changes occurring to them. As indicated by the IYS High Seas Expeditions, the early life history and beginning of the ocean life stage of salmon is still poorly understood, and scientists are still unsure of which salmon life history phase is experiencing the highest loss of fish. As urban development increasingly impacts saltwater environments, barriers to reliable predictions and forecasting are increasing. To have a complete understanding of salmon during each of their life history stages, it is important to try and link freshwater to ocean life stages and look at macro effects, including a multi-species point of view. It is also crucial to include multiple knowledge systems into this work.

Overcoming the gaps to understanding the complex status of salmon and their environment requires sustaining resourcing of long-term recovery, restoration, monitoring, and data repositories. Most importantly, we must determine what collaborations are needed, and which collaborations need support, and at what scope and scale.

IYS *Information Systems* Research Theme Objective: to ensure freely available information systems contain historic and current data about salmon and their environment.

Scientific surveys and research projects which are run locally or nationally are not always broadly available, and some researchers don't contribute large chunks of data. When information exists in silos it creates gaps in effective collaboration and communication, we therefore require hemispheric-wide access to information and data that has already been gathered and learned in salmon science and

related fields. This information needs to be shared with the right people and applied to different layers of knowledge, and, most importantly, needs to be shared with Indigenous knowledge holders and applied to advance Indigenous data sovereignty.

Although there is still far to go in advancing information systems, we have come a long way. Novel technologies are allowing for near real-time monitoring to help improve management decisions, help disseminate data and allow for more effective communication.

IYS *Salmon in a Changing Salmosphere* Research Theme Objective: to quantify and understand the effects of natural environmental variability and human factors affecting salmon distribution and abundance.

Ecosystem-based and whole life cycle approaches are required to achieve this objective. Similar to IYS's project the *Likely Suspects Framework*, which brought together partners from across the Northern Hemisphere to apply a holistic life cycle approach to inform annual forecasts, recovery planning, and management strategy evaluations to support resource management decisions and climate change risk assessments, there is a strong need for some kind of mechanism that puts research and information together. There is growing urgency to better understand the effects of anthropogenic impacts on fish, and this IYS research theme could benefit from being combined with the Status of Salmon for clarity and effectiveness.

IYS *New Frontiers* Research Theme Objective: to advance new technologies and analytic methods and ensure that they are applied to salmon research, carried out to fill gaps in poorly-studied regions of the salmosphere.

Stronger decentralization of specific fields of salmon science (such as DNA) is important, as few people have access to this kind of information. Better tools and methods are needed to both assess and address the limiting factors in these analytic methods, and effectiveness should be enhanced so that the process of filling these gaps can be sped up. It is crucial that we continue to fill in data gaps and illuminate the 'black boxes' in salmon research, such as the marine life history phase and ocean survival. Additionally, Indigenous communities and community stewards need better accessibility to new technologies and research and information.

IYS Human Dimensions Research Theme Objective: To ensure that communities, Indigenous peoples, youth, harvesters, scientists, and resource managers across the Northern Hemisphere share knowledge and collaborate in the development of new tools and approaches to restoring, managing, and sustaining salmon.

New tools and approaches to restoring, managing, and sustaining salmon. Having multiple knowledge systems working together is the only way to solve a problem as complex as that of understanding salmon in a rapidly changing world.

Indigenous peoples and local communities need to be present in discussions around salmon research and management at every level, from government to private industry. Outreach and communication should

be strengthened to broaden public awareness and support around salmon science and management outcomes. Effective communication encompasses both traditional outreach and strong communication between disciplines. This includes supporting various systems to collate relevant data and make this data accessible to managers, researchers, and communities – a running thread throughout the IYS theme outcomes. We need to determine at what scale and scope we should be targeting our communication strategies and creating the long-term platforms that will bring together the right people across the Northern Hemisphere

Conclusion

Over the course of the three-day IYS Synthesis Symposium, participants had a chance to network and engage with a wide range of topics related to the IYS research themes. During the final plenary discussion, there was a unanimous agreement that there is an urgency to this work which requires informed action. In order to achieve this, there is a strong need for collaboration of people, data, and effective communication, as well as full recognition of Indigenous rights and ways of knowing that must serve as the foundation of Indigenous Peoples' involvement in salmon research and management.

The Bering Sea: Current Status and Recent Trends
Edited by Lisa Eisner, Emilie Lamagie, and Elizabeth Siddon

Climate and sea surface temperature

The atmospheric forcing and sea surface temperature (SST) of the Bering Sea during the period April through September 2022, relative to seasonal mean norms, are summarized here. The six-month mean sea level pressure (SLP) anomaly pattern, based on climatological averages for the years of 1991 through 2020, is shown in Figure 1. This pattern features low pressure in the north, particularly over the Chukchi Sea, and higher pressure to the south, especially to the south of the western portion of the Aleutian Island chain. This distribution resulted in surface wind anomalies from the west ranging from about 2 m s^{-1} off the east coast of the Kamchatka Peninsula to about 1 m s^{-1} over the southeast Bering Sea shelf. This trend of the wind anomalies leads to equatorward Ekman transports in the upper ocean, which generally represents a cooling effect. But the enhanced westerly flow over the western Bering Sea also delivered more relatively warm continental air from east Asia. This factor helped produce the distribution of SST anomalies for April through September 2022 (Figure 2), namely relatively warm temperatures west of the dateline and slightly cooler than normal temperatures over the southeast Bering Sea shelf.
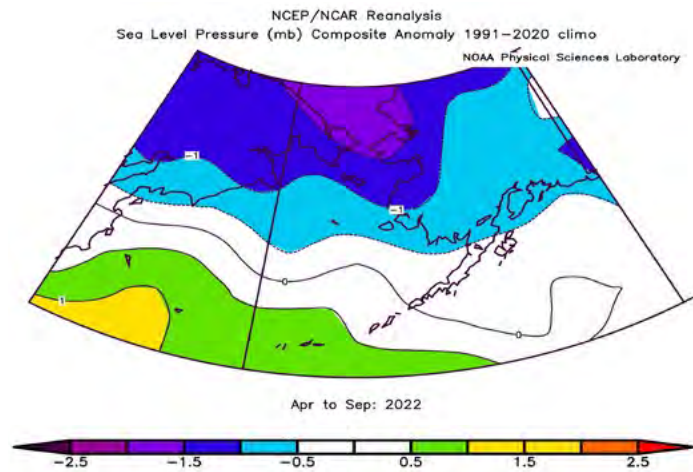
Figure 1. Mean sea level pressure (SLP) anomalies (mb) from the NCEP/NCAR Reanalysis for April – September 2022. Figure courtesy of Nick Bond, University of Washington (UW)/ Cooperative Institute for Climate, Ocean, and Ecosystem Studies (CICOES).

The year of 2022 represents the third year in a row of moderate temperatures in the Bering Sea following the abnormally warm period of 2014 – 2019. The difference between the two epochs is more pronounced for the eastern portion compared with the western portion of the Bering Sea, as illustrated in the time series of mean April through September SSTs for the two regions (Figure

3) for the years of 1948 – 2022. The eastern Bering region consists primarily of shelf waters, with an interannual variability in seasonal mean temperatures that is roughly 75% greater than that of the generally deeper western Bering region. In addition, the warming trend is greater for the eastern portion, with linear fits to the time series yielding overall SST increases since 1948 of about 0.7 °C for the eastern portion versus about 0.4 °C for the western portion. It remains to be seen whether the Bering Sea will resume warming in the near future. Ensembles of climate models used for seasonal weather predictions indicate that in late spring/early summer 2023 the western Bering Sea will be about 1 °C warmer than normal, and the eastern Bering Sea will have near normal temperatures.
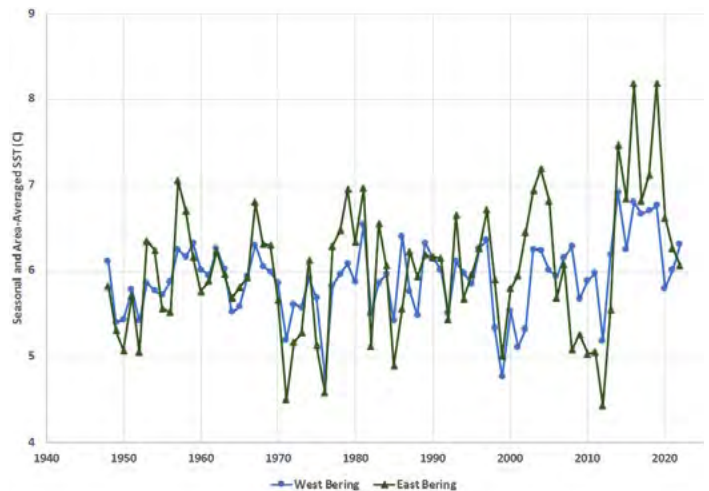
Figure 2. Time series of mean SST (˚C) for April – September for the western Bering Sea (52.5 – 60 N, 160 E – 175 W, blue trace with circles) and the eastern Bering Sea (52.5 – 62.5 N, 175 W – 160 W, green trace with triangles). Figure courtesy of Nick Bond, UW/ CICOES.courtesy of Nick Bond, UW/CICOES.
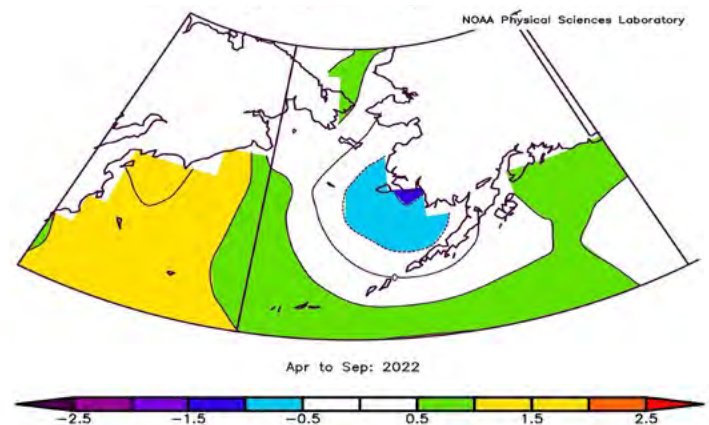

Figure 3. Mean sea surface temperature (SST) anomalies (°C) from the NCEP/NCAR Reanalysis for April – September 2022. Figure courtesy of Nick Bond, UW/CICOES.

This summary concludes with a short description of an unusually powerful storm that occurred in the Bering Sea during September 2022. This event began as tropical cyclone/typhoon *Merbok* in the lower latitudes of the western North Pacific. *Merbok* formed as a tropical depression on 9 September and reached its maximum intensity in the tropics on 14 September as a Category 1 typhoon with peak sustained winds of about 40 m s^{-1} (~144 km/h). Shortly afterwards it transitioned to an extratropical cyclone, and moved north-northeastward across the western Aleutian Islands near 175 °E into the Bering Sea and ultimately over Bering Strait into the Chukchi Sea. It was the strongest September storm to impact the region in 70 years. Its central pressure was as low as 937 hPa on 16 September, and it produced wind gusts of about 45 m s^{-1} at Cape Romanzof, measured significant wave heights exceeding 15 meters at NOAA Buoy 46035, and a storm surge of at least 3 meters at Nome, Alaska. It is unknown whether pre-existing ocean conditions played an important role in its evolution, but the storm did pass over waters that were about 3 °C warmer than normal between roughly 40 and 45 °N. Alaskan waters are occasionally subject to storms that began as tropical cyclones during the boreal fall, but Merbok will be long remembered for its intensity and the damage it caused along the west coast of Alaska.

Eastern Bering Sea crab biomass

Total mature male biomass of commercial crab stocks observed on the 2022 NOAA Alaska Fisheries Science Center (AFSC) bottom trawl survey was 64,894 t, an 11% increase over the record-low 2021 estimate (Figure 4). Abundance estimates for mature male snow crab (*Chionoecetes opilio*) were the lowest in the 47-year timeseries and prompted the first Bering Sea snow crab fishery closure in history. However, there was evidence of recruitment to the snow crab stock, with estimated immature abundance increasing from record-low 2021 estimates. Bristol Bay red king crab (*Paralithodes camtschaticus)* abundance estimates increased across all size and sex categories although continued low abundance of mature females prompted the closure of the Bristol Bay red king crab fishery for the second consecutive year.
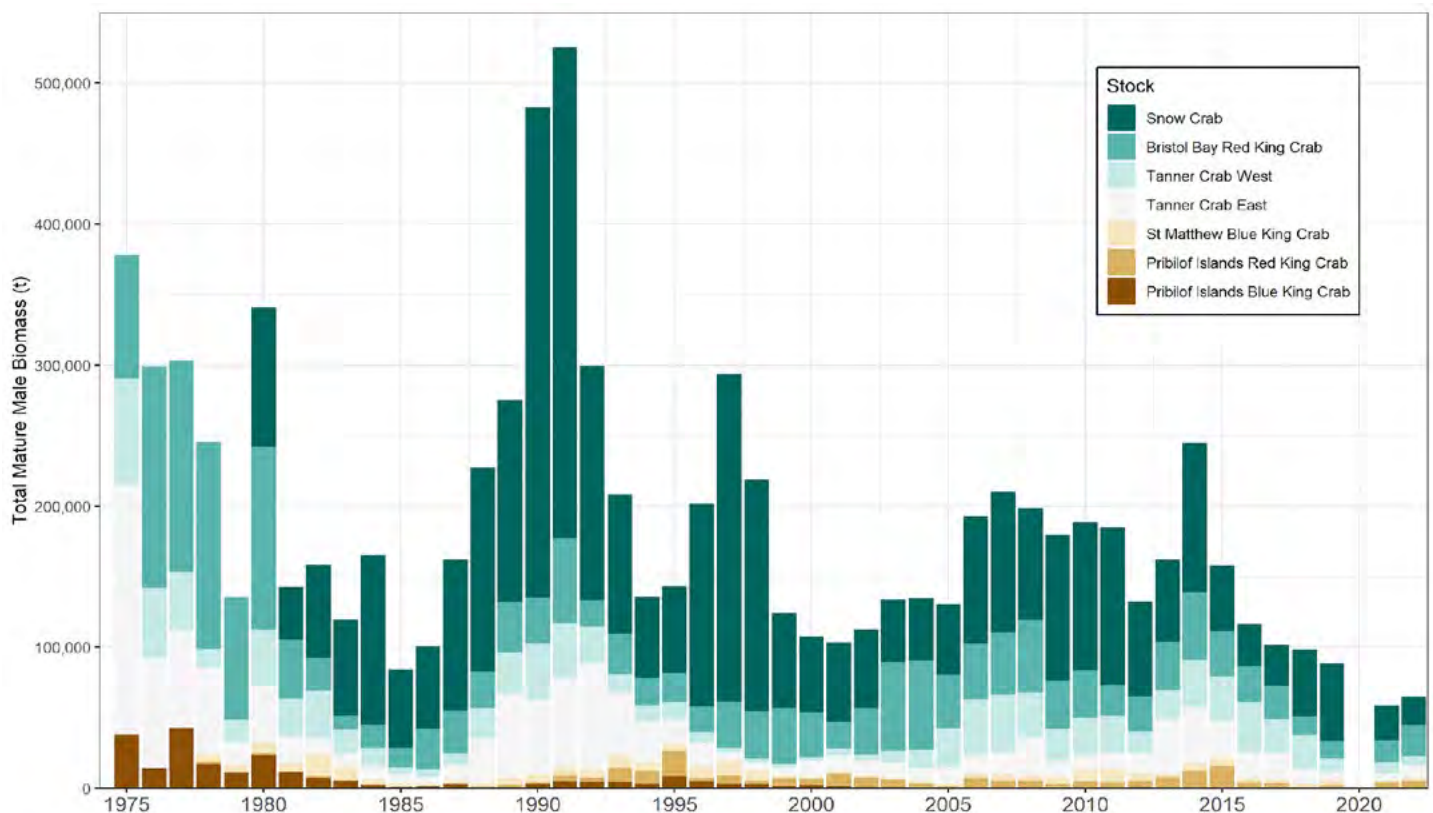
Figure 4. Mature male biomass (t) for commercial crab species caught on National Marine Fisheries Service eastern Bering Sea bottom trawl surveys from 1975 through 2022, by stock. Figure courtesy of Erin Fedewa and Mike Litzow, NOAA, AFSC.

Ocean acidification

There is a clear need to track and forecast the spatial extent of acidified waters in the eastern Bering Sea since this impacts marine calcifiers and subsequent predator and prey interactions throughout the ecosystem. Updated carbonate chemistry output from the Bering Sea ROMS model (Bering10K; Pilcher et al., 2019) and discrete samples collected on late summer AFSC fisheries oceanography surveys in the south eastern Bering Sea in 2022 were used to map pH over the shelf (Pilcher et al., 2022). Preliminary results indicate that pH values < 7.8, below which there can be negative effects on red king crab and tanner crab growth and survival (Long et al.,2013), were found in portions of the middle and outer shelf (Figure 5). However, other environmental factors (e.g., temperature) are important to the prediction of crab abundance and distribution, and there is no direct evidence that the low pH is linked to recent declines in crab populations.
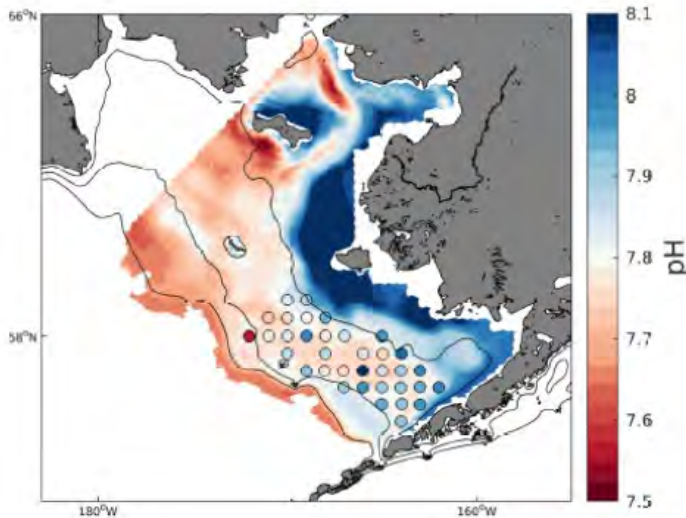
Figure 5. Model spatial maps of Jul-Sep averaged bottom water pH for 2022 hindcast. The circles in the left panel represent the preliminary data collected on-board the fall BASIS survey, plotted on the same colorbar as the model output. Contour lines denote the 50m, 100m, and 200m isobaths. This is Figure 106 from Pilcher et al., 2022.

Walleye pollock in the eastern Bering Sea

The 2018 year class of pollock in the EBS is well above-average (Figs. 6, 7; Ianelli et al., 2022), likely due to a combination of factors. For example, several indicators of bottom-up drivers of recruitment success support the hypothesis of increased overwinter survival to age-1 in 2019. Specifically, age-0 pollock experienced relatively cool summer SSTs in 2018 followed by warmer spring conditions for age-1 fish in 2019 (Yasumiishi, 2022). Diet composition of age-0 pollock in 2018 revealed a large proportion of euphausiids (Andrews, et al., 2019),

supporting the hypothesis that increased euphausiid abundances during warm years may compensate for lower large copepod abundances (Duffy-Anderson et al., 2017). Additionally, the CEATTLE model (Holsman et al., 2022) has shown continued declines in predation mortality on age-1 pollock due to declines in total predator biomass (i.e., reduced predation and mortality 2019-2021). A reduction in predator biomass is combined with a likely reduction in the spatial overlap between juvenile and adult pollock (Mueter and Litzow, 2008). The reduction in cold pool extent, and subsequent expansion of the adult pollock distribution into the northern Bering Sea, further released predation pressure on the 2018 year class.
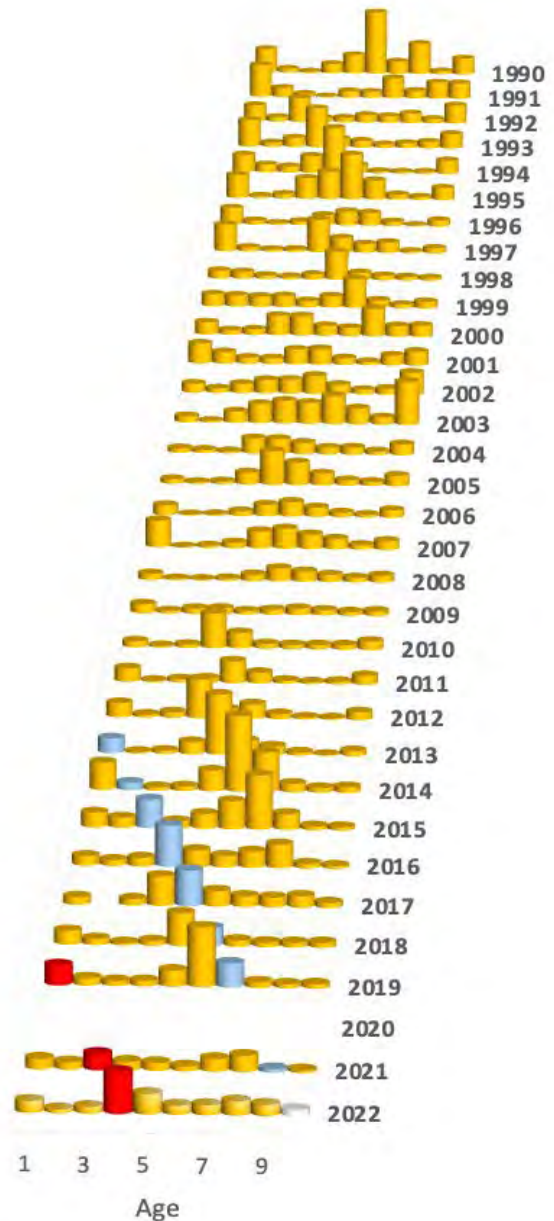
Figure 6. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1990–2019,2021-2022). The 2012 year-class is shaded in blue and the 2018 year class in red. This is Figure 1-18 from Ianelli et al.,(2022).
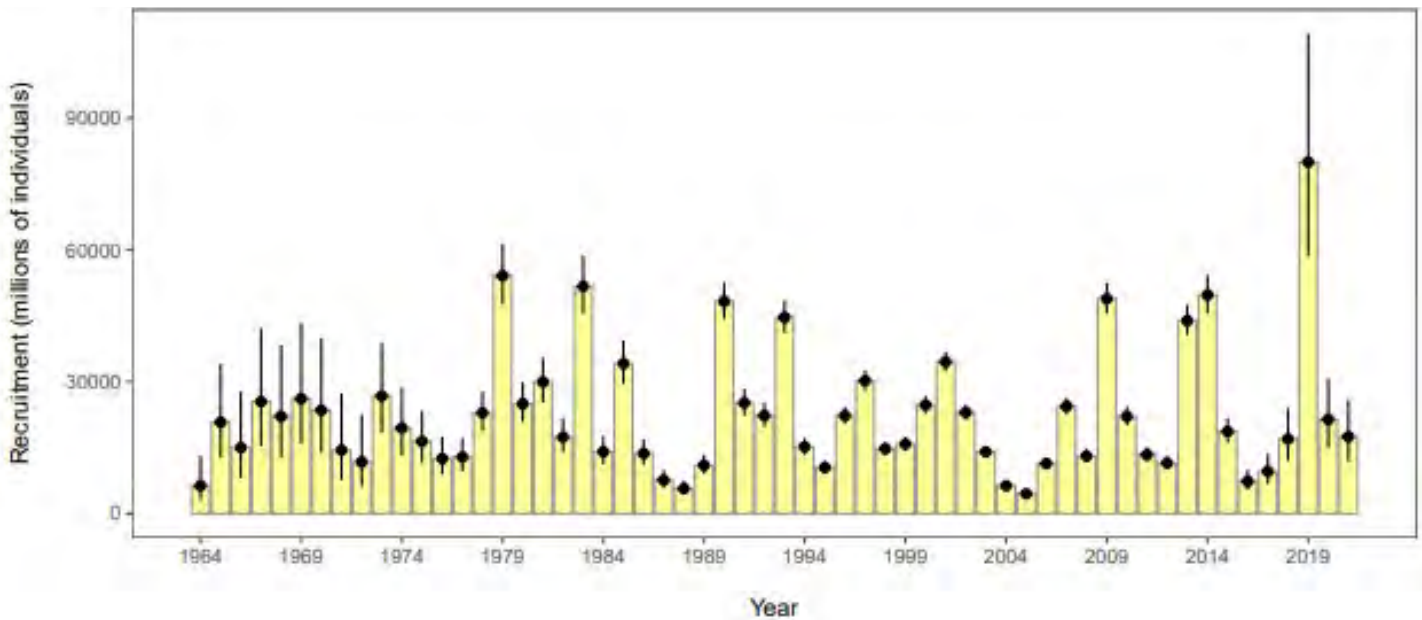
Figure 7. Recruitment estimates (age-1recruits) for EBS pollock for all years since 1964 (1963–2021 year classes) for Model 20. Error bars reflect 90% credible intervals based on model estimates of uncertainty This is Figure 1-59 from Ianelli et al.,(2022). Note 2019 age-1 are from the 2018 year class.

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Western North Pacific: Current status and recent topic:
Sea Surface Temperature during the 2022 warm season
Kazuhiro Nemoto (Japan Meteorological Agency) and Yugo Shimizu (Japan Fisheries Agency)
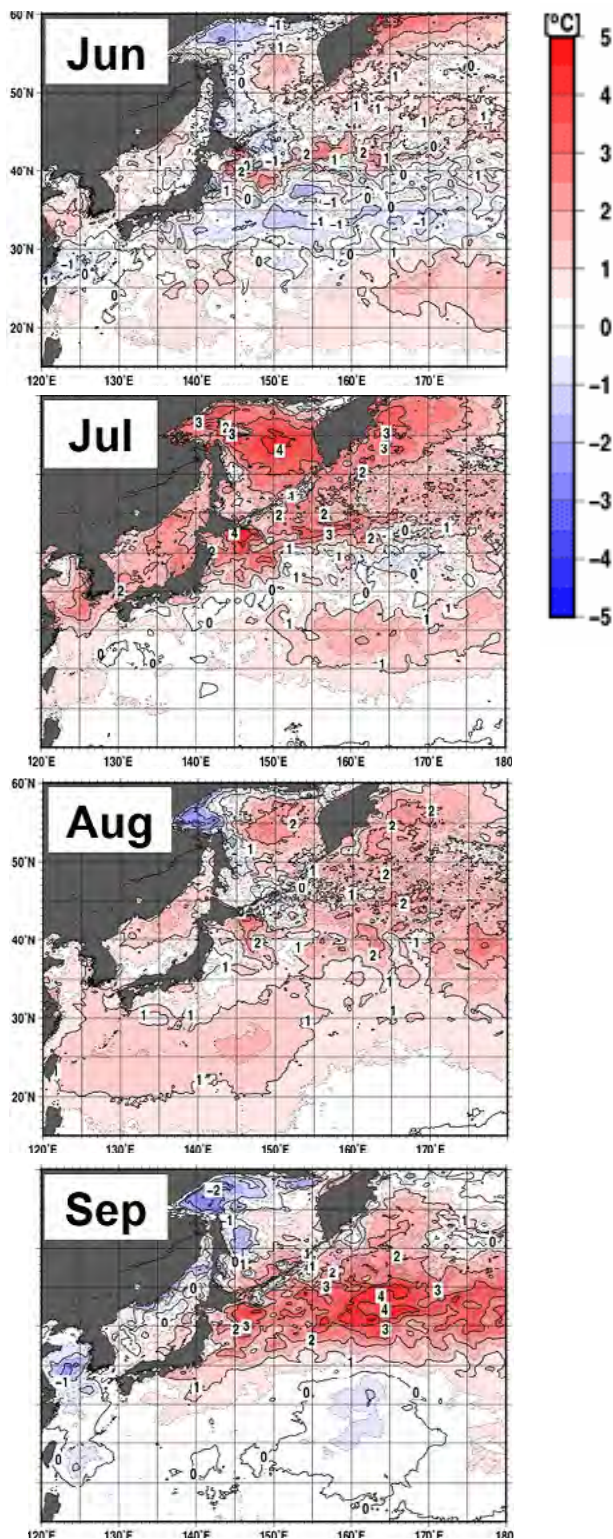
Figure 1. Monthly mean SST anomalies from June to September 2022. Monthly mean SSTs are based on JMA's HIMSST (HIgh-resolution Merged satellite and In-situ data Sea Surface Temperature). Anomalies are deviations from the 1991-2020 climatology.

The western North Pacific was characterized by positive anomalies of sea surface temperature (SST) in the area north of 40°N throughout the 2022 warm season (Figure 1). In particular, positive SST anomalies exceeding +2°C prevailed from east of Kamchatka Peninsula to east of Japan in July and in the area from 40°N to 50°N in September.

Positive SST anomalies exceeding +1°C were seen in the area around 25°N from 165°E to the dateline in June and around 30°N from 160°E to the dateline in July, and from south of Japan to around 30°N, 155°E in August 2022.

Impact of Global Warming on Fisheries around Japan
(Yugo Shimizu, Japan Fisheries Agency)

1. Ocean warming, marine heatwave, and their impact on fisheries around Japan

Long-term ocean warming due to global warming will affect the marine ecosystem, fishery resources, and the fishing and aquaculture industries in the oceans around Japan. The mean increase rate in sea surface temperature (SST) in Japan's coastal area for approximately the last 100 years to 2021, is about 1.2°C/century (Figure 2), which is greater than the global average of 0.56°C/century. A 2022 Japan Fisheries White Paper reported some remarkable phenomena in fisheries, possibly due to ocean warming. For example, in recent years, there has been a rapid increase in catch of warm-water yellowtail fish in Hokkaido (Figure 3), northward expansion of the Spanish mackerel migration, northward shift of mackerel spawning grounds off the south coast of Japan (Kanamori et al., 2019), and a rapid decrease in catch of salmon (Figure 4).
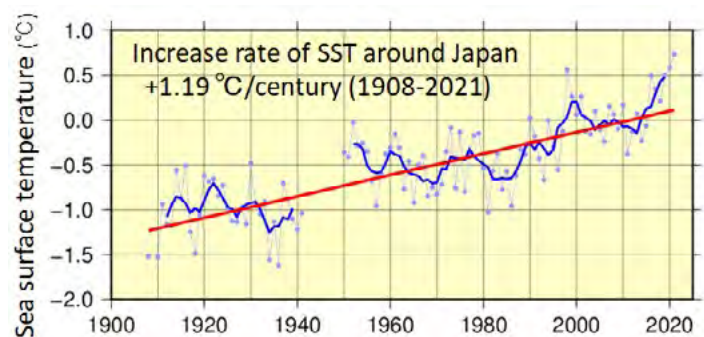
Figure 2. Long-term change in sea surface temperature averaged in the areas surrounding Japan coast (Japan Meteorological Agency). Blue circles indicate annual mean anomalies from long-term mean, solid blue lines indicate five-year moving averages, and solid red line indicates long-term change trends.
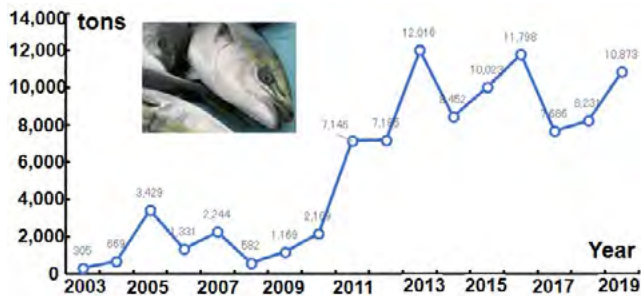
Figure 3. Changes in yellowtail catch in Hokkaido based on the fisheries statistics by Hokkaido local government.
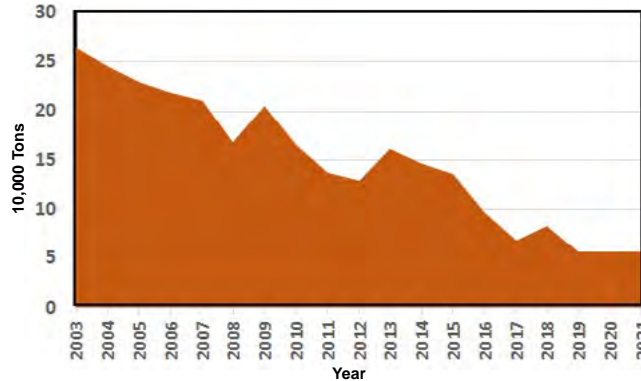

Figure 4. Changes in salmon catch in Japan based on Agricultural and Forestry Statistics.
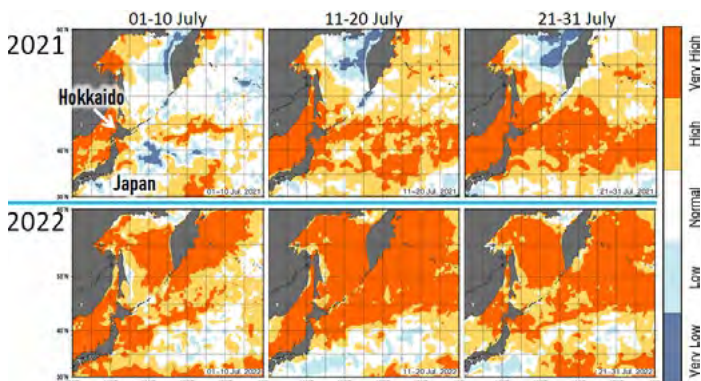

Figure 5. Distribution of SST rankings in the northwestern Pacific in each 10 or 11 days of July 2021 (upper) and 2022 (lower). The SST is ranked in order of occurrence frequency over 30 years from 1991 to 2020: SST is categorized as "Very High" (deep orange) or "Very Low" (deep blue) by the occurrence frequency 1/10 or less, and "High" (light orange) or "Low" (light blue) by 1/10-1/3 in each warm/cold side, and the other SST around the mode is "Normal" (white), respectively (Japan Meteorological Agency).
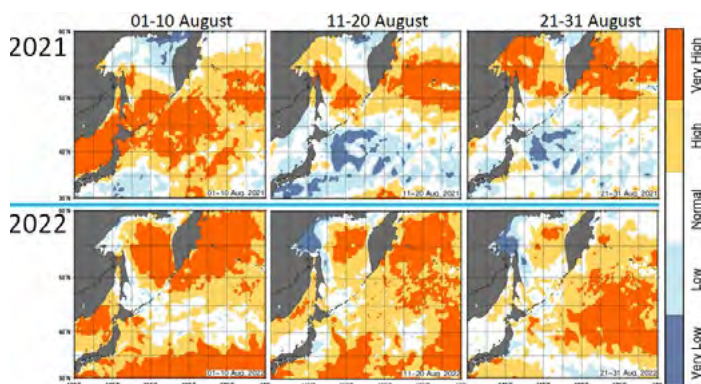
Figure 6. August, same as Figure 5 (Japan Meteorological Agency).

The frequency of occurence of extreme events is considered to be increasing due to global warming. Marine heatwaves (MHW) are a type of extreme event in which seawater temperature stays continuously much greater than normal in a specific sea area, which can cause significant damage to marine ecosystems and fisheries resources. MHW became widely recognized more recently following several reports on severe ecosystem damage caused by MHW off western Australia, or the "Blob" off the US/Canada West Coast and the Gulf of Alaska. Around Japan, Miyama et al., (2021) reported that MHW have occurred every year off the northeast coast of Japan from 2010 to 2016, and Kuroda and Setou (2021) reported that the largest record-breaking MHW occurred in the northwest Pacific including the area around Hokkaido in July to August 2021. However, direct damage by MHW such as the seabird mass death reported by Piatt et al., (2019) have note been reported in Japan, except for some speculation such as the change in yellowtail catch related to MHW (Miyama et al., 2021), or the occurrence of red tide following MHW (Kuroda et al., 2022). More research is necessary to determine the damage that may be caused by MHW around Japan.

2. Characteristic summer SST changes in 2022 and recent years

As mentioned above, MHW occur frequently in the northwestern Pacific, and off the southeast coast of Hokkaido. Here, we describe the characteristics in summer SST changes in these areas in recent years, including 2022.

SST in July 2022 was as high as SST in July 2021 across a wide subarctic area in the northwest Pacific. There, SST reached its hottest anomaly in mid-July, with wide deep orange areas "Very High" in Figure 5. In the area where the 2021 MHW occurred (approx. 40°N-50°N, 140°E-180°) and northwards, including in the Sea of Okhotsk, SST was higher in 2022 than 2021. In August (Figure 6), SST in the 2021 MHW area decreased rapidly to be closer to seasonal average in mid-August, whereas SST in 2022 largely stayed hotter until late August.

Off the southeast coast of Hokkaido, the SST anomaly changed to be negative in late August 2021, while it stayed positive until the end of August 2022 (Figure 7). In fact, the SST anomaly in 2021 was the highest from early to mid-August than it had been for the last 6 summers, but decreased rapidly to almost the lowest in late August in this region (Figure 8). Thus, the SST change off the southeast coast of Hokkaido in summer 2021 was unique, with a rapid cooling in mid-August in recent years. The rapid sea surface cooling there in August 2021 was considered to be due to the passing of Tropical Storm Lupit (T2109) and Typhoon Mirinae (T2110), and the following southward expansion of the Okhotsk high pressure system. SST however, stayed warm in summer 2022 because of the existence of a strong warm eddy at about 42°N and 147°E. Since rapid sea surface cooling can drastically alter the plankton distribution through vertical mixing and nutrient supply, we must investigate the subsequent marine ecology change not only as to overall SST increases, but also SST transitions.
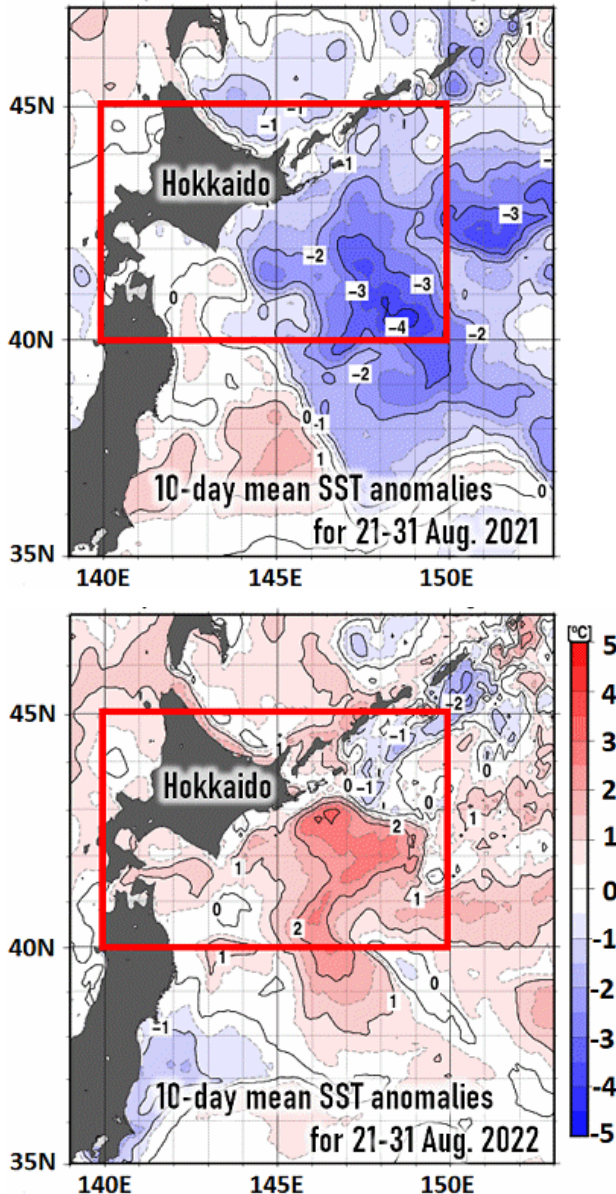
Figure 7. Maps of sea surface temperature anomalies in late August in 2021 (top) and 2022 (bottom) around northern Japan (Japan Meteorological Agency).
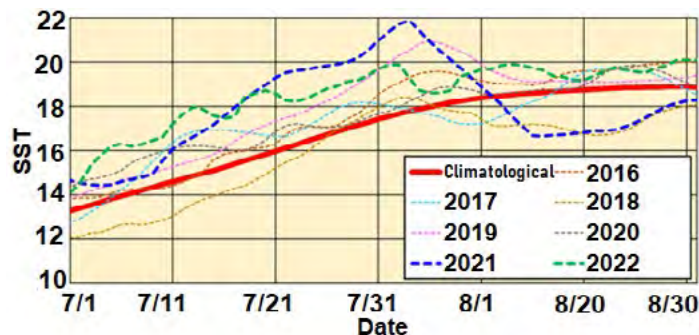

Figure 8. Changes in daily mean sea surface temperature in the area around Hokkaido (40°N-45°N, 140°E-150° E, as rectangular region by red line in Figure 6, based on the analysis by Japan Meteorological Agency). The thick red line indicates the climatological value averaged between 1991 and 2020.

3. Fisheries Policies to the climate change in Japan

As shown in the IPCC forecast scenario, global warming will continue at least for a few decades, regardless of global efforts to reduce greenhouse gas concentrations. Thus, the ocean temperature will continue to rise, and the frequency of occurrence of extreme events such as MHW will increase.

The Basic Plan for Fisheries provides medium-term guidelines for comprehensively and systematically promoting fisheries policy based on the Fisheries Basic Act. Since the formulation of the first Basic Plan for Fisheries in 2002, the Plan has been revised every five years, considering changes in situations surrounding fisheries, and evaluation of the effectiveness of the policy.

The new Basic Plan for Fisheries was formulated in March 2022, and considers changes in situations such as changes in marine environments and growing interest in a sustainable society. The policy will be developed focusing on three pillars:

1. steadily implementing fisheries resource management, considering changes in marine environment;

2. realizing the transformation of fisheries into a growth industry, considering increasing risks; and

3. promoting activation of fishing communities that support their respective regions. See the White Paper on Fisheries (https://www.jfa.maff.go.jp/e/annualreport/index.html) or the Basic Plan for Fisheries (https://www.jfa.maff.go.jp/j/policy/kihon_keikaku/index.html, in Japanese), for details.

Acknowledgment

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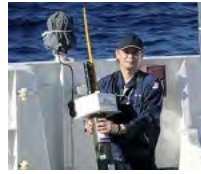
Mr. Kazuhiro Nemoto is the Head of the Atmospheric and Marine Environment Analysis Center, Atmospheric Environment and Ocean Division of the Atmosphere and Ocean Department of the Japan Meteorological Agency, in Tokyo, Japan.

Dr. Yugo Shimizu is the Principal Research Coordinator of the Fisheries Agency, in Tokyo, Japan.

The Northeast Pacific: Update on marine heatwave status and trends
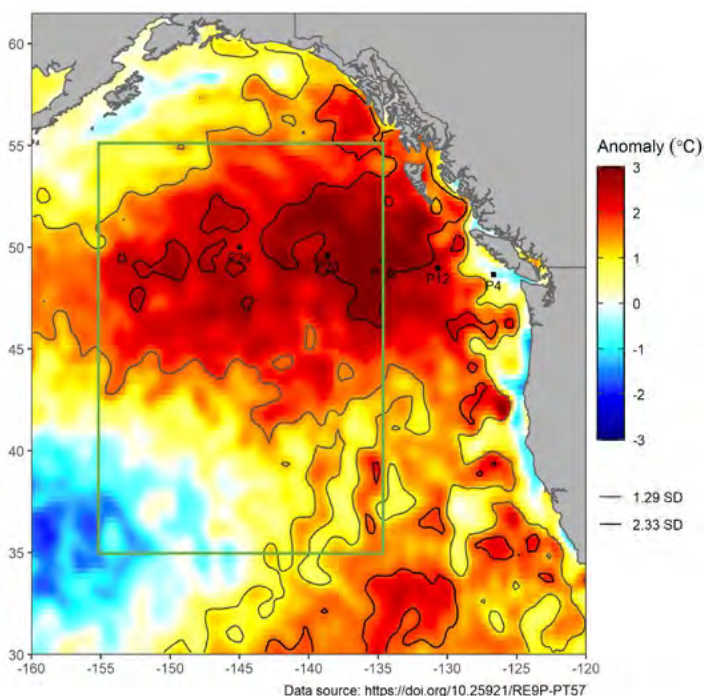*Tetjana Ross, Charles Hannah, Andrea Hillborn, Howard Freeland and Andrew Leising*

Figure 1. Map of sea surface temperature (SST) anomalies in the northeast Pacific Ocean for the week of Oct 11-17, 2022. SST data shown are NOAA Optimal Interpolation gap-filled SST (OISST; Huang et al.,2021). SST pixels exceeding 1.29 (2.33) standard deviations above the climatology are delineated with a thin (thick) black line. These indicate areas above approximately the 90th (99th) percentile, thresholds used for tracking marine heatwaves and determining their extent. Also indicated are the locations of the Line P oceanographic monitoring stations (black dots labelled with station name). Green box indicates area of analysis used for Figures 3 and 4).

At the time of writing the Northeast Pacific has a marine heatwave (MHW) ongoing. Figure 1 shows a map of the extent and intensity of the sea surface temperature (SST) anomalies for this MHW from closer to its maximal extent (Oct 11-17, 2022). However, at this moment, nearly a decade since the research community first took notice of the patch of sustained anomalously high SSTs that was nicknamed "the Blob" (e.g. Bond et al., 2015), this seems like an obvious statement.

In recent years, the Northeast Pacific nearly always has a marine heatwave ongoing. The 2022 event pictured in Figure 1 is (to date, as it's still ongoing) the fourth largest and fourth longest MHW observed in the Northeast Pacific. There are a number of ways of defining MHWs and even more ways of judging whether they are increasing; nevertheless, nearly all of these metrics, based on the SST data and analysis from a number of sources, including the summary provided on the California Current Marine Heatwave

Tracker website,[1] which is summarized in Figure 2, provide evidence of an increase in the Northeast Pacific. For instance, the number of MHWs initiated each year in the Northeast Pacific is increasing (Figure2a), they are more intense on average (Figure 2a), they tend to last longer (Figure 2b) and cover a larger area (Figure 2b). This is in line with global results suggesting that marine heatwaves are becoming more common (Oliver et al., 2018; Holbrook et al., 2020). However, looking beneath the sea surface helps to understand both why MHWs are increasing (e.g. through changes to stratification; Amaya et al., 2021) and their potential impacts on marine ecosystems.
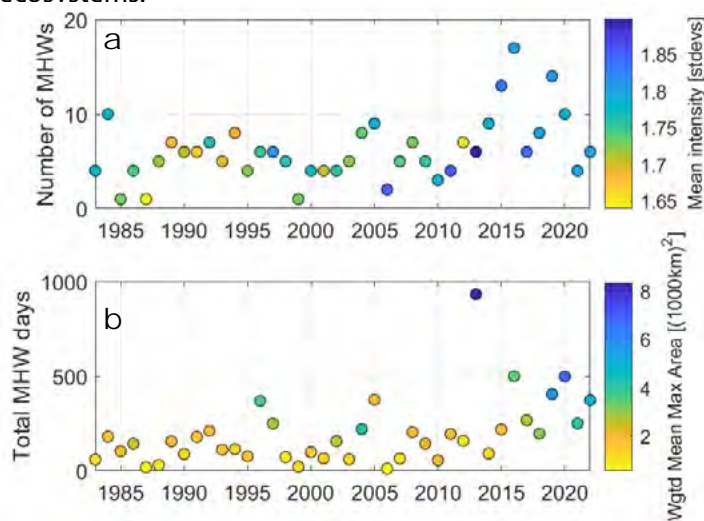

Figure 2. Panel a: Number of marine heatwaves (MHWs) initiated each year in the northeast Pacific (NEP). Markers are colored by the weighted mean intensity of the NEP MHWs initiated in that year (weighting by MHW duration). Panel b: Total number of MHW days initiated each year in the NEP colored by the weighted mean maximum areas (i.e. averaging the maximum area for each MHW in that year weighted by their duration). Data are from https://oceanview.pfeg.noaa.gov/erddap/tabledap/cciea_OC_MHW_EV.htmlTable (again based on OISST data, see Figure 1.)

For example, the 2014-16 MHW (i.e. 'the Blob') differed from subsequent Northeast Pacific marine heatwaves in a few key ways. First, the vertical extent of the 2014-16 MHW was larger (Figure 3; temperature anomalies derived from Argo data; see Ross et al., 2019 for methodological details). While there are largely only warm colors in the full upper 300 m in Figure 3 after 2014, the outline indicating 2.33 standard deviations from the monthly climatology is only observed below the permanent pycnocline (around 125 m) for the 2014-2016 MHW. Second, the MHWs occurring after 2018 have been accompanied by a significant salinity

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1 https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-marine-heatwave-tracker-blobtracker
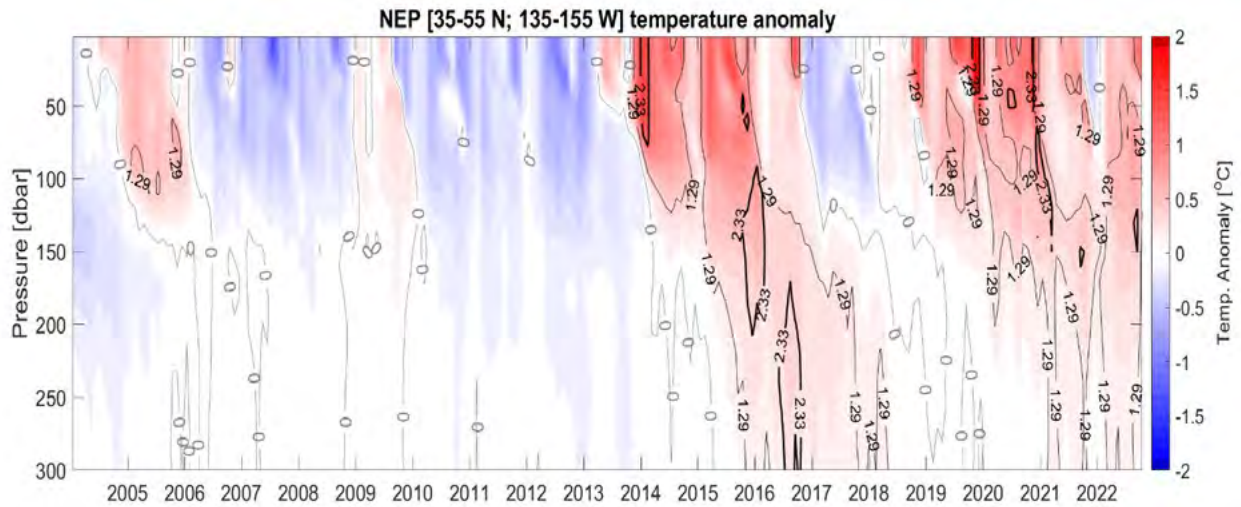
Figure 3: False colour plot of temperature anomalies as observed by Argo floats in the Northeast Pacific. To create the time series, the Roemmich and Gilson (2009) gridded Argo temperature dataset were spatially-averaged over 35-55 N and 135-155 W (green box shown in Fig. 1), anomalies calculated at each monthly time step by subtracting the 2004-2018 seasonally-corrected mean based on the gridded Argo record. As in Figure 1, temperatures exceeding 1.29 (2.33) standard deviations from the 2004-2018 mean for that month are enclosed in a thin (thick) black line. The grey line shows zero temperature anomaly.
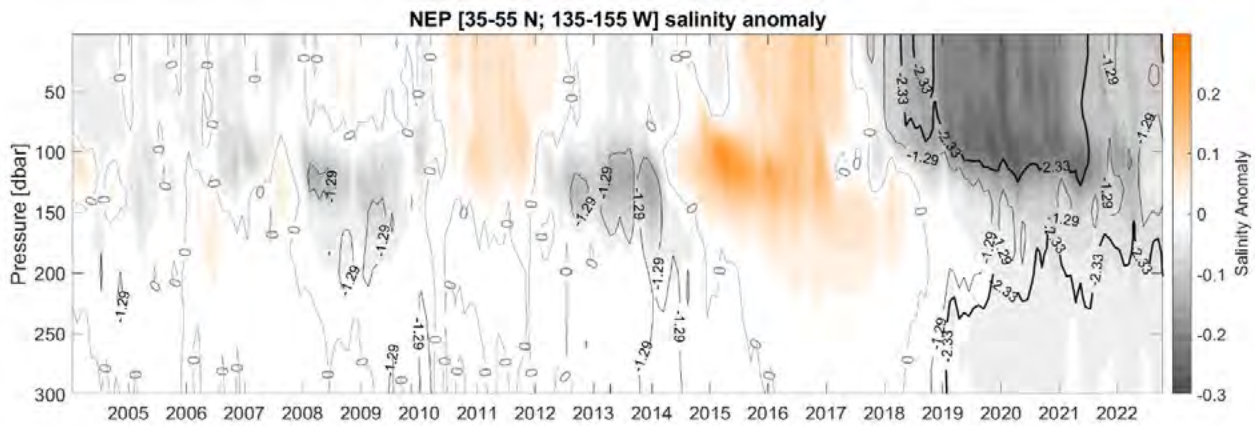

Figure 4: False colour plot of salinity anomalies as observed by Argo floats in the Northeast Pacific. Timeseries created using same method as for temperature (Figure 3) using Roemmich and Gilson (2009) gridded Argo data. Here negative salinities are highlighted, with anomalies lower than -1.29 (-2.33) standard deviations from the 2004-2018 mean for that month are enclosed in a thin (thick) black line. The grey line shows zero salinity anomaly.
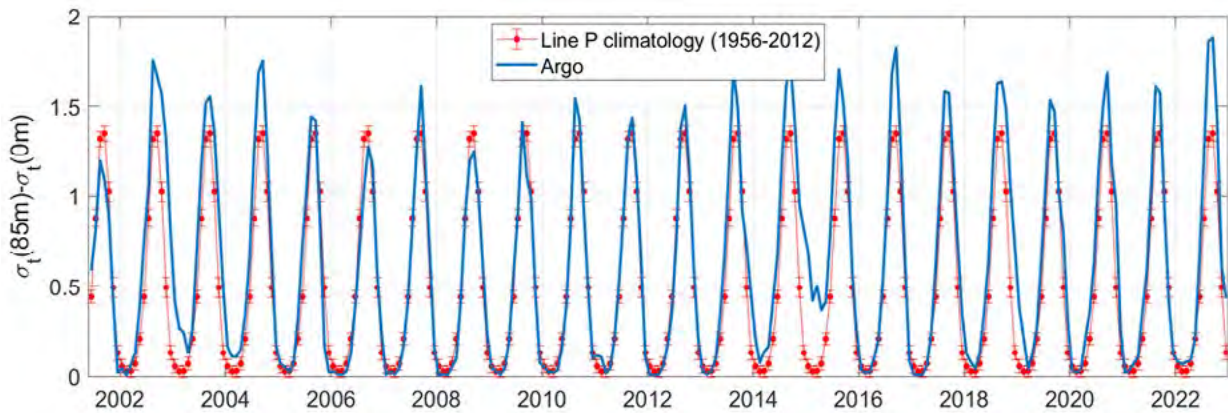

Figure 5: Time series of density difference between the surface and 85 m depth at the Line P oceanographic monitoring Station P26 (50N and 145W, location indicated on Figure 1). The blue line shows the density difference calculated from Argo profiles collected within 2 degrees of P26 in a given month, which are distance-weighted averaged with an e-folding scale of 300 kms to create a single monthly profile. The red line shows a climatology based on the shipboard sampling of the Line P monitoring line (the climatology is repeated for each year for comparison to the blue line).

anomaly in the near surface waters (Figure 4). It might be tempting to conclude that the fresh anomaly is causing the increase in marine heatwaves in recent years, by increasing stratification and thereby allowing the thinner surface layer to be more easily warmed. However, while summer-time stratification has been increasing (e.g. at Station P26 in the Northeast Pacific; Figure 5; Cummins and Ross, 2020) which is consistent with this idea, there has been no trend in winter-time stratification (Figure 5) and the salinity anomaly is consistent across seasons (Figure 4), which is inconsistent with this idea. Additionally, the salinity anomaly occupies the entire depth of the winter mixed layer, so does not increase near surface stratification. The only wintertime stratification anomaly occurred during the 2014-16 MHW, again indicating how distinct 'the Blob' was.

The impacts of marine heatwaves on ecosystems are beginning to be well documented (Smith et al., 2023), but to date much of the research in the Northeast Pacific has focused on the impacts of 'the Blob' (e.g. Brodeur et al., 2019; Barbeaux et al., 2020; Mogen et al., 2022; Nielsen et al., 2020; Zhu et al., 2017). However, impacts to biogeochemical variables, such as oxygen and carbonate saturation state, will evolve differently depending on whether a MHW manages to isolate the upper ocean waters from the atmosphere for more than a year. The impacts on zooplankton and fishes are sure to be more complicated, likely compounding biogeochemical and other effects. Another aspect of MHWs that influence their relative impact is whether they enter near shore waters, affecting coastal ecology. The 2022 event has had a lot more intrusions into the nearshore region than any MHWs since 2019, due to some major relaxation events in the typically upwelling winds along the coast of North America during summer 2022.

Acknowledgements

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Dr. Tetjana Ross is a Research Scientist at the Institute of Ocean Sciences, Fisheries and Oceans Canada, in Sidney, BC. She is an ocean physicist who develops new ways to observe the ocean – from observing ocean mixing using sound to taking photographs of zooplankton in turbulence. Nowadays, she rarely goes to sea, sending robots out to do the work for her: both gliders and Argo floats (i.e., she currently leads the Pacific component of DFO's Argo and glider programs). In PICES she is member of the Technical Committee on Monitoring and the Working Group on Submesoscale Processes and Marine Ecosystems. (WG 50). In PICES she is member of the Technical Committee on Monitoring and the Working Group on Sub-mesoscale Processes and Marine Ecosystems (WG-50).

Dr. Charles Hannah is a senior Research Scientist for Fisheries and Oceans Canada based at the Institute of Ocean Sciences in Sidney, BC. His research program is focused on the oceanography of the central and north coast of British Columbia and he is currently leading a program of moored observations along the British Columbia continental shelf. Within PICES he is member of the Advisory Panel on North Pacific Coastal Ocean Observing Systems (AP-NPCOOS).

Ms. Andrea Hilborn is a remote sensing biologist who has been working for Fisheries and Oceans Canada since 2019 with the operational remote sensing group at the Bedford Institute of Oceanography in Halifax, NS. She's currently collaborating with the Institute of Ocean Sciences in Sidney, BC and living in Victoria. Her current projects focus on evaluating and implementing ocean colour satellite algorithms in the Beaufort Sea, and satellite monitoring of temperature and productivity in the northeast Pacific. Outside of the office she is usually found cycling, snorkeling and exploring Vancouver Island.

Dr. Howard Freeland is a scientist emeritus at the Institute of Ocean Sciences in Sidney, BC. Despite his retirement, he maintains a keen interest in the Argo program and ocean climate change.

Andrew Leising received his bachelor's degree in Biology and Marine Science from the State University of New York at Stony Brook, and his doctorate in Biological Oceanography from the University of California, San Diego, Scripps Institution of Oceanography. His research there focused on the ecology of marine crustaceans and their response to environmental variation. After graduate school, Leising conducted experimental fieldwork on the behavior of microzooplankton under varying food and temperature regimes, and modeling experiments of planktonic ecosystem responses to oceanic variability and climate change, at the University of Washington, Seattle. Currently, Leising works for the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA-Fisheries), at the Southwest Fisheries Science Center. His current work focuses on the responses of fish and zooplankton to climate variability, and the characterization of oceanic variability (i.e. marine Heatwaves), through his work as part of NOAA's California Current Integrated Ecosystem Assessment (CCIEA) team.

PICES Events Calendar
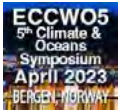
- Effects of Climate Change on the World's Ocean (ECCWO5)
  Bergen, Norway, April 17–21, 2023

- PICES-2023
  Seattle, USA, October 23 –27, 2023

- ICES/PICES Zooplankton Production Symposium (ZPS 2024)
  Hobart, Tasmania, Australia, March 17 –22, 2024

- Marine Socio-Ecological Systems Symposium (MSEAS)
  May - June, 2024, TBC

- PICES event associated with Expo2025
  Osaka, Japan, 2025 event date TBD.

PICES-sponsored Capacity Development Events

- SOLAS Summer School 2023
  Cape Verde, Senegal. June 5 – 16, 2023 Dates TBC.

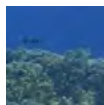- Open Science Training for ECOPs
  Virtual. Spring / Summer, 2023

Partner Events

- Ocean Visions Biennial Summit 2023
  Georgia Aquarium, Atlanta, USA, April 4–6, 2023

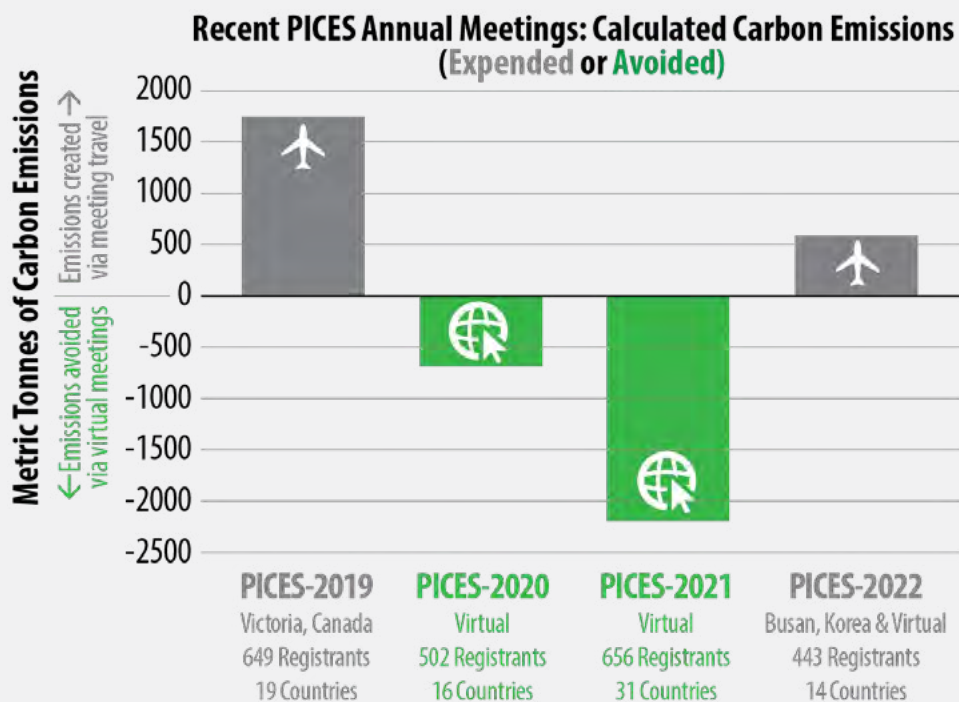- WCRP Open Science Conference
  Kigali, Rwanda, October 23–27, 2023

- GOOD-OARS-CLAP-COPAS Summer School 2023
  Universidad Católica del Norte, Chile, November 6–12, 2023

- 9th World Fisheries Congress
  Seattle, USA, March 3 – 9, 2024

PICES by the Numbers, and an Invitation to join SG-GREEN
Lori Waters

Recent PICES Annual Meetings: Calculated Carbon Emissions
(Expended or Avoided)

Metric Tonnes of Carbon Emissions

Emissions created via meeting travel →

← Emissions avoided via virtual meetings

	PICES-2019	PICES-2020	PICES-2021	PICES-2022
	Victoria, Canada	Virtual	Virtual	Busan, Korea & Virtual
	649 Registrants	502 Registrants	656 Registrants	443 Registrants
	19 Countries	16 Countries	31 Countries	14 Countries

PICES community is concerned about climate change and rising greenhouse gas (GHG) emissions, as many of our experts are focused on studying climate change, including working to ameliorate future impacts. This and our other important work often necessitates international travel to collaborate and contribute to PICES and its partner organization meetings. Unfortunately, a culture of international travel means that as an organization, we contribute significant amounts of GHG emissions to our atmosphere, and thus to negative climate impacts. However, PICES demonstrated that emission savings can be gained via virtual meetings. Therefore, PICES Governing Council recently approved the establishment of an Expert Group to study PICES carbon footprint, and to make recommendations for overall reduction of our GHG Emissions, and for more environmentally-friendly meetings. This Expert Group will provide the opportunity for PICES to play a greater leadership role in defining an appropriate balance of in-person and remote meetings, and to set an example for the international community in our collective move towards carbon neutrality. The Study Group on Generating Recommendations to Encourage Environmentally-Responsible Networking (SG-GREEN) seeks members to contribute to these efforts. Those interested please contact SG-GREEN Chair, Vera Trainer, at verat@uw.edu. For additional information, please visit the SG-GREEN webpage, and review the Terms of Reference at right. **SG-GREEN members look forward to your participation!**

SG-GREEN Terms of Reference

- Identify a mechanism agreeable to all PICES member countries for sustained green meetings within the PICES scientific structure. In particular, to establish a mechanism that is inclusive to under-represented people and communities, early career ocean professionals, etc.

- Create recommendations for PICES on best practices to reduce GHG emissions and waste relative to meetings

- Establish organization-wide green initiatives, such as: eliminating single use plastics, reduced printing, reduced purchases of single use or limited use items at meetings, including meeting gifts.

- Exploration of PICES investment in climate-responsible industries.

- Provide recommendations for best practices in purchasing carbon offsets for members for face-to-face meetings, including suggestions for including offsets as part of the conference registration fees

- Provide suggested actions to promote PICES green initiatives and climate change information.

Cristina Mittermeier image from UNDOS Ocean Image Bank.

Open call for PICES Press submissions

PICES Press welcomes your articles, especially during the UN Decade of Ocean Science for Sustainability, where we're seeking to increase partnerships, better our science communications, and improve our collective ability to create the "Ocean we Want." Please consider submitting articles on: research; conference or event highlights; program news; and announcements. Please see our Submission Guidelines. Previous issues are online at: https://pices.int/publications/pices-press/ Deadlines are June 1st and December 1st for Summer and Winter volumes, respectively.

PICES appreciates you sharing your work.
Thank you for your contributions!

About PICES Press: Published twice annually in July (Summer edition) and January (Winter edition), PICES Press is distributed globally to over 4500 PICES scientist members and institutions worldwide. Celebrating and highlighting the activities and achievements of PICES members - from participation in PICES-related programs and projects, to individual participation in PICES and PICES partner science symposia and other events - PICES Press is an important vehicle for sharing research and launching partnerships.   ISSN 1195-2512

Please visit www.PICES.int for additional information on PICES scientific research, publications, events and meetings.