Intersessional Science Board Meeting 2023 — Note from the new SB Chair
Sukyung Kang

Since the COVID-19 pandemic outbreak, PICES Science Board (SB) has held its inter-sessional Science Board (ISB) meeting virtually via Zoom. Although the global pandemic is no longer an obstacle to our in-person meetings, the 21st ISB meeting, like other PICES inter-sessional business meetings, was held virtually May 8-10, 2023 to reduce our carbon footprint. The 3-day meeting, led by new SB Chair Sukyung Kang, was attended by 11 SB members in addition to 3 Governing Council members, 7 invited guests, and 4 representatives from the PICES Secretariat. The SB welcomed one new committee chair, Lei Zhou (POC) and appreciated Andrew Ross for his participation as acting Chair of the MEQ committee.

The ISB meeting began with a report by the FUTURE Program Scientific Steering Committee (FUTURE SSC; Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems). The SSC reported the plans for the next FUTURE Open Science Meeting, which aims to highlight and synthesize accomplishments of the FUTURE Phase II (2014–2020) Science Program, and introduced the outlines of the

FUTURE Phase II Final Report and next FUTURE paper on climate variability and ecosystem resilience in the North Pacific. Recruitment of Early Career Ocean Professionals (ECOPs) into PICES expert groups is essential for the progress and growth of the Organization. Science Board reviewed a proposal to recruit more ECOPs to the FUTURE SSC to engage ECOPs in the planning and implementing of the FUTURE Science Program, and to provide them with valuable leadership experience for subsequent PICES Programs.

Many countries and international organizations are putting significant energy into the UN Decade of Ocean Science. Two of PICES's activities that have been endorsed by the UN Ocean decade, are Sustainability of Marine Ecosystems through Global Knowledge Networks (SmartNet) and Basin Events to Coastal Impacts (BECI). SmartNet is the flagship ocean decade program of ICES and PICES has been very active in 2022 and early 2023, building partnerships, both within and outside of ICES and PICES, and co-designing activities by forming subgroups on priority actions. Another important SmartNet activity to highlight is our growing relationship with other the UN Decade of Ocean Science Actions. The Basin Events to Coastal Impacts (BECI) project, an endorsed project of the UN Decade of Ocean Science, was co-proposed by North Pacific Anadromous Fish Commission (NPAFC) and PICES, and, if funding can be secured, is intended to become a PICES Special Project.

At ISB-2023, the chairs of the five Science (BIO, FIS, HD, MEQ, POC) and two Technical (MONITOR, TCODE) Committees reported on the progress and planned activities of their respective expert groups since the PICES-2022 annual meeting. Most Expert Groups, including Working Groups, Sections, Study Groups, and Advisory Panels, now engage in virtual inter-sessional meetings to connect with one another throughout the year and to make steady progress toward their goals, as requested earlier by Science Board and Governing Council. Some Advisory Panels (such as AP-SciCom and ECOP) have been meeting on a monthly or bimonthly basis to address their Terms of Reference. Nevertheless, because of the influence of COVID-19, the activity of a few expert groups was reduced to more limited TORs. The SB recommended at ISB-2023 the 1-year extension of term of those Expert Groups (SG-GREEN: Generating Recommendations to Encourage Environmentally-Responsible Networking; WG-45: Joint PICES/ICES working group on Impacts of Warming on Growth Rates and Fisheries Yield (GRAFY); and WG-47: Ecology of Sea Mounts).

Updates also were provided by the two current PICES Special Projects, SEAturtle, and Ciguatera. The SEAturtle project has been very productive despite the increased difficulty of undertaking scientific work during the pandemic, and SB congratulated the team on their achievement. The Ciguatera project has recently completed, and despite the fact that this team also suffered during the global pandemic, they conducted five field surveys. As a next step, they proposed a new project titled *"Creating a phytoplankton-fishery observing program for sustaining local communities in Indonesian coastal waters."* SB has recommended this new special project to Governing Council.

The SB reviewed the TCODE proposal to introduce the use of Digital Object Identifiers (DOI) for PICES publications. DOIs provide a unique, persistent string of characters to identify a specific publication and its location in perpetuity, so there would be value in PICES issuing DOIs for its publications to ensure the persistence of publication links. SB assessed the benefit of introducing DOI to official PICES publications.

Several recent publications listed below have been approved and are posted on the PICES website or in the peer-reviewed literature.

Boivin-Rioux A et al. Harmful algae and climate change on the Canadian East Coast: Exploring occurrence predictions of *Dinophysis acuminata, D. norvegica,* and *Pseudo-nitzschia seriata*. Harmful Algae. 2022 Feb 1;112:102183. DOI: 10.1016/j.hal.2022.102183

Emam M et al. Gill and Liver Transcript Expression Changes Associated With Gill Damage in Atlantic Salmon (*Salmo salar*). Frontiers in Immunology. 2022;13. doi.org/10.3389/fimmu.2022.806484

Esenkulova S et al. Indications that algal blooms may affect wild salmon in a similar way as farmed salmon. Harmful Algae. 2022 Oct 1;118:102310. DOI: 10.1016/j.hal.2022.102310

Esenkulova S et al. Harmful Algae and Oceanographic Conditions in the Strait of Georgia, Canada Based on Citizen Science Monitoring. Frontiers in Marine Science. 2021:1193. doi.org/10.3389/fmars.2021.725092
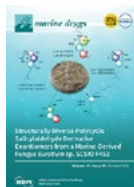
McIntyre L, Miller A, Kosatsky T. Changing trends in paralytic shellfish poisonings reflect increasing sea surface temperatures and practices of Indigenous and recreational harvesters in British Columbia, Canada. Marine Drugs. 2021 Oct 14;19(10):568. 10.3390/md19100568

McKenzie CH et al. Three decades of Canadian marine harmful algal events: Phytoplankton and phycotoxins of concern to human and ecosystem health. Harmful Algae. 2021 Feb 1;102:101852. DOI: 10.1016/j.hal.2020.101852

Rashidi H et al. Monitoring, managing, and communicating risk of harmful algal blooms (HABs) in recreational resources across Canada. 2021 May;15. DOI: 10.1177/11786302211014401

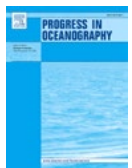Ueno et al. (2023) Review of oceanic mesoscale processes in the North Pacific: Physical and biogeochemical impacts. Progress in Oceanography 212. doi.org/10.1016/j.pocean.2022.102955

Planas et al. (2023) Integrating biological research, fisheries science and management of Pacific halibut (*Hippoglossus stenolepis*) across the North Pacific Ocean. Fisheries Research, Vol. 259 https://doi.org/10.1016/j.fishres.2022.106559

During the meeting, we heard the sad news that Vera Alexander, a PICES founder, and colleague was not doing well and now she is not with us anymore. However, her passion and love for the organization will always stay. Rest in peace.

As SB chair, I sincerely acknowledge the tremendous efforts and contribution of the Science Board members in steering PICES science activities, and thanks to the Secretariat for helping me to prepare the meeting.

PICES-2023 will be held at The Westin Seattle in Seattle, US from 20–27 October, 2023. The opening ceremony will be followed by the Science Board Session (S1), *"Connecting Science and Communities for Sustainable Seas."* S1 will focus on developing and strengthening PICES diverse partnerships, building on existing joint activities, and promoting cross-fertilization. In addition, 13 interesting topic sessions, 5 paper sessions, and 11 workshops are waiting for you. See www.pices.int/pices-2023 for more information. I look forward to seeing you in Seattle.

Sukyung Kang
Science Board Chair

FUTURE SSC's 9th Intersessional Meeting ~ Highlights
Hanna Na and Steven Bograd

The FUTURE Scientific Steering Committee (SSC) held its 9th inter-sessional meeting since 2014. FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems) is PICES' second integrative science program, which was launched at PICES-2009 and is currently in Phase III. This year's virtual meeting on April 27th was led and hosted by FUTURE SSC Co-Chairs Steven Bograd and Hanna Na. It was attended by ten SSC members and PICES secretariat representative, Sanae Chiba.

Review: 2022-23 and upcoming FUTURE activities

The SSC reviewed FUTURE activities since its last meeting at PICES-2022 and discussed upcoming FUTURE activities, as described below:

- FUTURE has been preparing the FUTURE Phase II final report and brochure. The target completion is December 2023.

- The SSC continued discussion on the next FUTURE Open Science Meeting, which is now planned as a one-day symposium at PICES-2024. There were a few format options suggested, including a plenary session, an 'ideation' workshop to create solution roadmaps, and Early Career Ocean Professionals (ECOP) activities and events. Details of the FUTURE Open Science Meeting will be finalized during the FUTURE SSC meeting before PICES-2023.

- The outline of the FUTURE Product Matrix paper has been updated. The journal manuscript will include the results from two approaches, i.e., the Product Matrix and quantitative analysis, to highlight key achievements of the FUTURE program, identify knowledge gaps and the reasons they remain, and determine the next steps for addressing FUTURE's goals. The quantitative analysis of the keywords, mainly based on the books of abstracts from previous PICES annual meetings, will explore progress and shifts in emphasis facilitated by the FUTURE program. FUTURE SSC will hold a manuscript-writing meeting during PICES-2023 in Seattle, USA with an aim to submit the manuscript by the end of 2023.

- FUTURE Phase III Priorities include bringing ECOPs into SSC membership for new ideas and enthusiasm. FUTURE SSC discussed suggesting potential candidates from each country and proposing them to be formally recommended by national delegates.

FUTURE ECOP Award for PICES-2023

The SSC discussed ways to promote and implement the FUTURE ECOP Award this year. The FUTURE ECOP Award is FULL travel support granted to an ECOP to attend the PICES Annual Meeting. It has been established to encourage recognition and application of the Socio-Ecological Environmental System (SEES) approach and engage ECOPs in PICES activities. Selections will be made from the abstracts submitted to the PICES Annual Meeting. The abstracts should describe the SEES approach taken for the study.

Details on who is eligible and how to apply can be found at: https://meetings.pices.int/awards/FUTURE-ECS-Award.
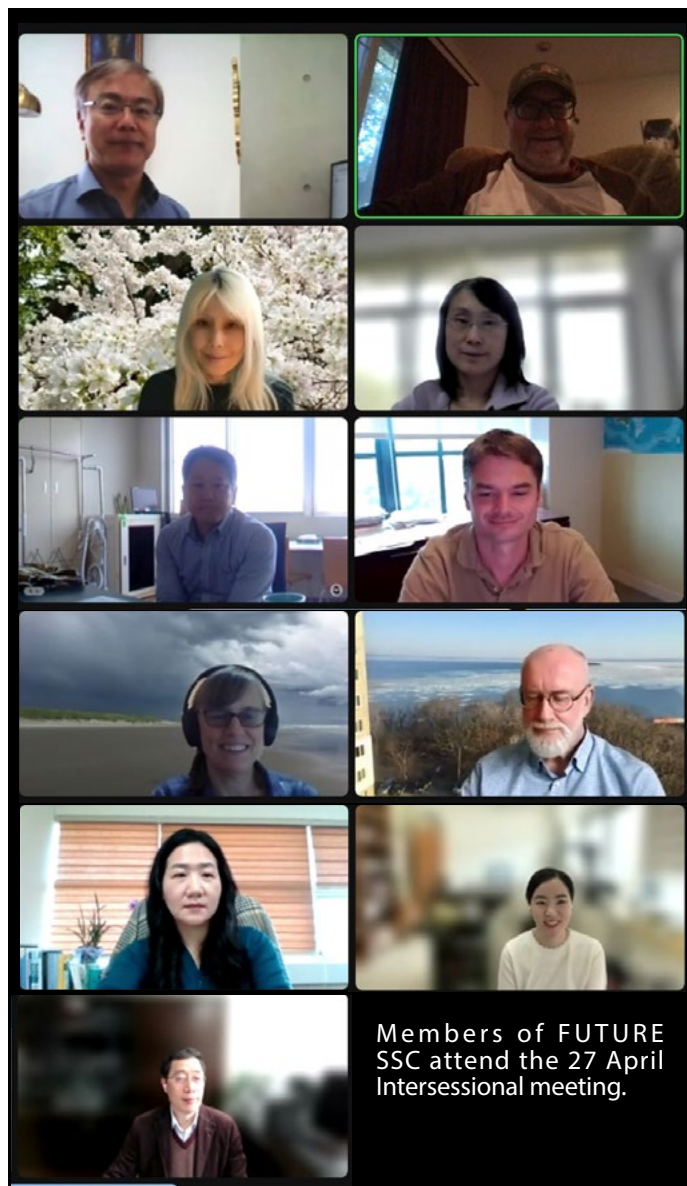
Members of FUTURE SSC attend the 27 April Intersessional meeting.

PICES-2023 ~ See you in Seattle!
Lori Waters

The PICES community sincerely hopes that you will join us for PICES-2023 at the Westin Hotel in Seattle, Washington, USA. Eleven pre-meeting workshops will be held from October 20-22, ahead of the main meeting which runs from October 23-27. The PICES-2023 Scientific Program will include fourteen topic paper sessions and five committee paper sessions, a special session with the International Pacific Halibut Commission, and an evening poster session. These rigorous activities will be lightened by many opportunities for the PICES community to gather and exchange ideas in a less formal atmosphere, including the evening events such as the welcome reception on October 23, the sports event on October 24, the poster session on October 26, and the Closing session

and presentation awards on October 27. Any ECOP who presents during PICES-2023 may wish to plan on attending the Closing session, as poster and oral presenters who self-identify as ECOP during the registration process are eligible for the presentation awards.

For anyone new to PICES meetings, these meetings are an excellent opportunity to discuss your work with like-minded colleagues, to develop collaborations, and to receive feedback on your work. The meetings have been described as inspiring and collegial, and PICES as more of a family than an academic community.

We look forward to welcoming you to Seattle in October!

**The 5ᵗʰ International Conference on the
Effect of Climate Change on the World's Ocean:
Together, we will work.**
Sanae Chiba

Hei venner! We met again under Bergen's April sky

The 5ᵗʰ International Conference on the Effects of Climate Change on the World's Ocean (ECCWO5) was held from 17-21 April, in Bergen, Norway. Some seven hundred ocean experts from around the world gathered online and under the sunny blue sky in Bryggen - an historic waterfront place. The stunning 3-masted tall ship *"Statsraad Lehmkuhl"* welcomed us, as it had just returned to the port after it's One Ocean Expedition, a 600 day around-the-world research and ocean literacy programme.

Norway is one of the keenest countries to engage in tackling the social-environmental-ecological issues induced by changing oceans. #ECCWO5 was scheduled to coincide with the *One Ocean Week* (April 15-21) of Bergen, also known as the Ocean City. A series of international and local meetings, workshops and activities were held to appreciate the ocean's contribution to human wellbeing and pioneer more sustainable uses of the ocean. The Ocean Week events brought diverse experts from private and industry sectors, decision-makers and high-profile international ocean policy organizations, and provided a great opportunity for ECCWO participants to further expand their professional and personal networks.

The ECCWO conference series was initiated in 2008, aiming to better understand the impacts on ocean ecosystems, the ecosystem services they provide, and the people, businesses and communities that depend on them. PICES, together with other partner organizations, ICES, IOC and FAO, have been major sponsors and organizers of this event. From the PICES community, Drs. Emanuel Di Lorenzo (POC), Mitsutaku Makino (HD), and Tsuneo Ono (S-CC) joined the ECCWO Science Steering Committee (SSC). As a biological oceanographer who has studied ecosystem responses to the changing world ocean, I have been regularly involved in the ECCWO meetings since their inception, as a speaker, session convenor, and Steering Committee member. Here I would like to report on the highlights of ECCWO5 and reflect on how the conference has evolved in the past decades, from my perspective.

Symposium structure and meeting gadget

The ECCWO5 symposium began with opening remarks by H.R.H. Crown Prince Haakon of Norway. He emphasized the connection between humanity and the ocean, the challenges the global ocean faces, and the need for humanity to take action to address the those challenges now and in the future. Keynote speaker, Dr. Randi Ingvaldsen from the The Institute of Marine Research (IMR) - the local host of the symposium, then spoke about *"Atlantification and borealization in the Barents Sea and adjacent Arctic Ocean."* She shared scientific evidence on the rapidly changing marine environment and its impacts on regional ecosystem structures.

A conference day consisted of several plenary talks representing respective Theme Sessions in a ballroom every morning then followed by four parallel sessions held in separate rooms. This helped the audience including myself to grasp the concept and focus of each session and to decide which session and talks to attend. Like other recent international conferences, ECCWO used a hybrid format for the first time in its history, to allow participants to attend the meeting either in-person or remotely. All plenary and Topic Session talks were live-streamed for online participants, and speakers who could not travel to Bergen gave their live talks remotely. Though it was often a tough decision when many interesting talks were inevitably scheduled in different rooms at the same time, participants could check the session timeline and

efficiently hop around the rooms, thanks to the use (on mobiles or laptops) of the meeting organizing application, Whova. Whova was also useful for session convenors to facilitate Q&A and discussion among hybrid audiences and it provided a forum for all participants with common interests to chat, expand their network and plan social events.

Sessions and Workshops
(See descriptions at: www.pices.int/eccwo-5*)*

Topic Sessions included:

- **Session 1:** Marine spatial management supporting climate change adaptation and mitigation

- **Session 2:** Smart fishing for climate change mitigation and adaptation

- **Session 3:** Assessing climate change vulnerability of marine and coastal areas and associated communities

- **Session 4:** Improving decision-making in response to change in marine-dependent coastal communities using transdisciplinary approaches

- **Session 5:** Measuring and predicting responses of marine social-ecological systems to climate extremes

- **Session 6:** Deep-Sea responses to, and solutions for, Climate Change

- **Session 7:** Nature-based Solutions for Climate Adaptation and Mitigation - From Planning to Practice

- **Session 8:** Advances in coupling regional climate and social-ecological models to improve climate-ready ecosystem management

- **Session 9:** Transitioning from Vulnerable to Resilient and Viable Fisheries Social-Ecological Systems

- **Session 10:** Beyond species on the move: emerging climate change impacts on the spatial dynamics of marine species, from detecting to forecasting and projecting

- **Session 11:** Ocean Deoxygenation: Physical, Biogeochemical and Ecological Research Advances and Future Needs

- **Session 12:** Improving pathways for delivery of multi-disciplinary ocean observations into marine assessments across multiple scales

- **Session 13:** Detectability of non-linearities, abrupt shifts and tipping points in marine ecosystems

- **Session 14:** Cumulative anthropogenic impacts on key Arctic species

- **Session 15:** Using Management Strategy Evaluation to establish robust fishery management in a changing ocean

- **Session 16:** Emerging challenges in socio-ecological systems brought about by climate-related ecosystem changes and how to equitably manage them

- **Session 17:** Coupling social science and economics in integrated marine climate modelling efforts

- **Session 18:** Beyond blue carbon: Ocean-based carbon dioxide removal (CDR) approaches

- **Session 19:** Ocean Acidification Research for Sustainability

Preceding the Opening Session, four parallel workshops *(listed below, and see descriptions at:* www.pices.int/eccwo-5*)* were held. W1 focused on the cultural and natural heritage and the development of tools to assess climate impacts on them; W2, co-convened by SmartNet, discussed co-designing actions and solutions for sustaining a productive, healthy and resilient ocean through the collaboration of various programmes and activities endorsed by the United Nations Decade on Ocean Science for Sustainable Development (UNDOS); W4 exercised inter-model comparison of marine ecosystem projection and ecological parametrization against climate change; and W5, co-convened by S-CCME, reviewed studies for historical and future tipping points and thresholds in marine ecosystems to better support climate-informed management advice. Workshop 3: "Reconstructing past marine ecosystem and their interactions with climate" was cancelled. Some of these sessions and workshops are described in more detail later in this issue.

- **Workshop 1:** A systematic and rapid assessment of climate vulnerability and adaptation in marine and coastal areas

- **Workshop 2:** The Climate-Fisheries Nexus Within the United Nations Decade on Ocean Science for Sustainable Development: Co-Designing Actions and Solutions for a Productive, Healthy and Resilient Ocean

- **Workshop 4:** A global ensemble of comparable marine ecosystem models to project climate risk to species and human communities.

- **Workshop 5:** S-CCME/SICCME Workshop on integrated modelling to identify climate change tipping points in marine ecosystems

There were also five 2-hour Special Sessions (listed below) in the afternoon on Wednesday, April 19 including a networking event of the UNDOS-endorsed programme SUPREME, which is very relevant to the PICES community. PICES ECOP members also showed their enthusiastic presence at an ECOP event, and lastly there was a Special Session on aquaculture.

- Aquaculture Special Session was held on Building Collaborations to Identify and Address Knowledge and Technology Gaps with the Goal of Promoting Resilient Aquaculture in the Face of Climate Change.

- SUstainability, Predictability, and REsilience of Marine Ecosystems (SUPREME) Session- A UN Decade of Ocean Science Programme to advance climate-informed marine ecosystem management.

- Science-policy-action Panel - How is ocean science used in policy and action?

- Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP) Information Session

- ECOP event: Conducting Science at the Intersection of Climate Change and Marine Ecosystems: A Networking Session & Discussion
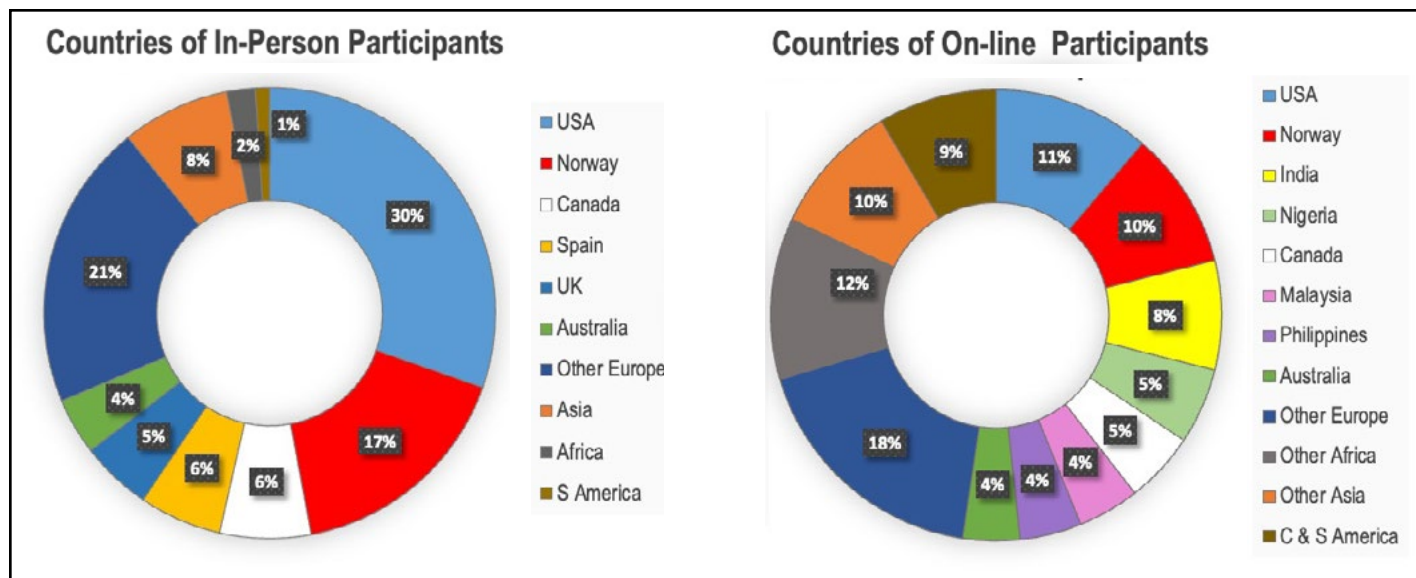
Figure 1. Countries represented by the participants of ECCWO5.

ECCWO5 by the numbers: the hybrid format helped wider participation, however...

Organizers initially received 52 topic session proposals, which is an indication of how seriously ocean experts are concerned about climate change and its impact on the world's ocean, ecosystems and human well-being. The symposium schedule was fully packed with the 19 Topic Sessions with 9 plenary talks, 4 Workshops and 5 Special Sessions described above. Together, the symposium provided 284 oral talks including 26 from invited speakers, and 186 posters were shared during the poster presentation. 716 experts registered to participate, including 254 who attended remotely. The female ratio was beyond 50% for in-person and online participants, and in total, 71 countries were represented, including more than one third of United Nations member states. ECCWO5 was truly an international conference with real geographical diversity and gender equality.

However, when looking at the breakdown of participants' countries of in-person and online participants, you see a clear difference between them (Figure 1). Nearly half of the in-person participants were from the USA (30%) and the host country, Norway (17%), followed by Canada, Spain, UK and Australia. The majority of the rest of the participants represented European countries. On the other hand, the country's composition of online participants is more diverse with a high component of Asian countries such as India, Malaysia and the Philippines, and African countries such as Nigeria. This figure indicates that the hybrid option certainly helped the participation of the experts in countries where funding support might be less available for long-distance travel. The online participants representing African countries might also be encouraged by the time zone of the conference, which was convenient for them.

While we observed benefits of the hybrid option in increasing the geographical diversity of participants, the organizers also experienced its challenges, i.e., its technical operation. Despite being prepared and tested well beforehand, many issues with the streaming service were reported by online participants from Day 1. IT technicians and conference organizers had to deal with troubleshooting and responding to the participants who could not secure a connection to the service, which was stressful and exhausting on both sides. The pros and cons of hybrid meetings have been repeatedly discussed everywhere, and I don't mean to repeat the argument here. Without doubt, a hybrid format will be the mainstream format of international conferences like ECCWO in the post-pandemic era. At present, however, the system is not fully matured and requires a large additional cost both for the technology and human resources to ensure the best service. This is unaffordable for many conference organizers. The user side also needs to be accustomed to the system and possess a proper, up-to-date platform.

How the Scope of ECCWO evolved from 2008-2023: from understanding to solutions

ECCWO symposia have evolved alongside the progress of global initiatives investigating and assessing climate change mechanisms and impacts, and United Nations Intergovernmental Panel on Climate Change (IPCC) Assessment Reports.

The first ECCWO symposium in Gijon, Spain, in 2008 was held just after the publication of the IPCC Forth Assessment Report (AR4) which warned the world about the evidence of global warming and confirmed its anthropogenic causation, greenhouse gases. The major focus of the ECCWO sessions was to detect changes and trends in the oceanic systems relevant to climate change for a better understanding of

the mechanism linking climate, ocean environment and ecosystems. I was shocked to know how few scientific studies were referred in AR4 to ecosystem changes in the North Pacific Ocean especially in the western North Pacific, despite the many monitoring programmes which had accumulated data. I realized how international collaboration and sharing data/information was important for ocean scientists to tackle globally common issues such as climate change.

4 years later, the second ECCWO was held in Yeosu, Korea, alongside the Ocean-themed Expo 2012. The symposium foci included innovative technology, tools and frameworks for better monitoring and prediction of the variations. *"Best practice"* became the key term then for ocean observing and modelling in all disciplines. Understanding uncertainty, coastal management strategies and ecosystem evolution responding to climate change were among the hot topics.

IPCC AR5, published one year after ECCWO2, paved the way for the late 2015 Paris Agreement on reducing carbon emissions (2015 The United Nations Climate Change Conference). The societal expectation for scientists to provide meaningful ocean information to influence policy then increased. At ECCWO3, held in Santos City, Brazil in 2016, though the main focus was set in a similar direction as ECCWO2, more studies on the adaptation of human community practices emerged, with the term *"climate-ready"* fisheries being popularized. Ocean acidification became a major topic as another global threat derived from anthropogenic GHG emissions.

At ECCWO4 held in Washington DC in 2018, the emphasis on adaptation and solution-based science became even clearer. Among the new keywords were *marine socio-ecological systems*, ocean-based solutions, and big-data science. Climate extreme studies emerged as an urgent topic as extremes seriously impact marine ecosystems and livelihoods in coastal communities. With the 2015 adoption of the United Nations Sustainable Development Goals (including Goal 14: Life below water), the timing of ECCWO4 coincided the dawn of the UNDOS. Cross-cutting topics within the UNDOS challenges were were raised during the symposium, including science communication, capacity development and equitable information service.

In 2021/2022 IPCC6 announced the target global temperature increase limit as 1.5°C to avoid catastrophic negative impacts on the global ecosystem and human society. Countries were urged to take measures to massively cut GHG emissions to meet the 1.5°C target. The demand for solution-based science to show practical methods and tangible targets rather than theory, is becoming mainstream. This trend was clearly seen in the ECCWO5 Session line-up, with about half of the 19 Sessions including the term *adaptive management* and *mitigation* against climate change, including case studies of small-scale fisheries and ocean-based CO_2 removal. The other half focused on impact assessment and projection of

ocean environments and ecosystem structure which will be useful for better management options. Some studies showed climate-socio-ecological models to assess the robustness of management strategies. One of the newer keywords used in describing adaptive management is "*smart*", for example, "*climate-smart*" and *"smart-fishing."* This describes optimal practices for sustainable development and resource use, but would only be possible only through multi-sectorial engagement: again, one of the UNDOS challenges.

Together, we will work

When I was an early career scientist in the 2000s, there were a couple of challenges in studying marine ecosystem responses to climate change. One was the geographical information gap, and we reached out to international colleagues and formed working groups to share data to fill the data gap to gain a global picture. Another challenge was the interdisciplinary collaboration of ocean scientists. As the marine ecosystem is a part of the ocean system, scientists must work together to understand the mechanisms of the

changes across disciplines: physical and biogeochemical and biological oceanography, and across approaches: data science, model and ocean observing. That is (still) not easy as each community uses different terms and concepts on common issues, but we have worked well to break the wall between us, brick-by-brick, and have developed a great network of oceanographers. Now, the united oceanographers are facing a similar challenge but this time, it is collaboration with people from the outer world: policymakers, economists, philanthropists, entrepreneurs, economists, lawyers, artists and more.

But I am positive about the future. At ECCWO5 I talked with colleagues from multiple sectors and observed them enjoy discussions with scientists. At the welcome reception, I was pleasantly surprised to run into two young experts – an oceanographer and a lawyer - who are both working on the same project at a university. The next meeting, ECCWO6, will be held around 2027~2028. It will be exciting to see many PICES scientists join and how the tide will be changing for ocean science in the coming several years.

Illustration by Sanae Chiba

#ECCWO5 Organizing team gathers at the Opening Reception. L-R: Peter Haugan (IMR), Kirsten Isensee (IOC), Sanae Chiba (PICES), Enrique Curchitser (PICES), Sonia Batten (PICES), Jörn Schmidt (ICES), Lori Waters (PICES), Tarub Bahri (FAO), Julia Yazvenko (PICES), Geir Huse (IMR), Camilla Scharff-Olsen (ICES), Terhi Minkkinen (ICES), Martin Rasmussen (ICES).

#ECCWO5 Attendees gather aboard the Statsraad Lehmkuhl tall ship, against the beautiful backdrop of historic Bryggen, for the Opening Reception.

#ECCWO5 venue shown above left, with people enjoying the ever-present Bergen sunshine alongside the harbour and Bryggen.
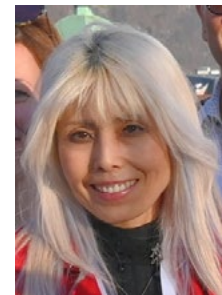
Sanae Chiba, who authored this article and has attended many #ECCWO Symposia, is PICES Deputy Executive Secretary.

#ECCWO5 VIP's and invited speakers gather at Håkonshallen (Haakon's Hall) at Bergenhus Fortress, for the symposium dinner on April 20th, the anniversary of its near destruction in 1944. L-R: Sonia Batten (PICES), Allan Haynie (ICES), Nils Gunnar Kvamstø (IMR), Enrique Curchitser (PICES), Deputy County Mayor of Vestland, Natalia Golis (Green Party), Geir Huse (IMR), Jörn Schmidt (ICES).

ECCWO5 - W1 Workshop Report

A Systematic and rapid assessment of climate vulnerability and adaptation in marine and coastal areas
Jon Day and Scott Heron, with photos by Mercy Mbogelah

The ECCWO5 W1 workshop comprised both plenary presentations (above left) and breakout group discussions (above right).

Given the urgency presented by climate change, climate vulnerability assessments (CVAs) are increasingly recognized as a fundamental tool to improve the understanding of the impacts of climate change. Marine and coastal protected areas are at the forefront of impacts from climate change, and hence there is an urgent need to assess their vulnerability systematically and rapidly. The ECCWO5 conference in Bergen provided opportunities for several CVA-related events, with a focus on systematically assessing impacts upon natural and cultural heritage values.

The first CVA-related event was our W1 workshop entitle*d 'A systematic and rapid assessment of climate vulnerability and adaptation in marine and coastal areas,'* which involved a diverse group of participants, many of whom have been involved in various types of climate vulnerability assessments. Workshop participants drew upon their experience to examine key principles for undertaking CVAs within the context of cumulative threats. Through facilitated discussions, the topics addressed both in plenary and in two breakout groups, included:

- What is the purpose of a CVA and what are the key requirements to undertake a CVA? (e.g., rapid, comprehensive)
- What are the components within a CVA? (i.e., what should be assessed)
- What techniques have been demonstrated as successful and what are the barriers that need to be overcome?
- Political and fiscal realities of implementing CVAs
- Placing CVAs into a global context.

It was agreed that assessing vulnerability to climate change of cultural and natural heritage within marine and coastal areas (and beyond) needs to begin with a clear definition of the objectives and the desired characteristics and implementation components of the assessment process.

Key points agreed during the workshop included:

- there is a high importance in co-designing and co-producing CVAs with the relevant community;
- adaptability as part of a systematic assessment process leads to the best outcome for specific applications;
- effective communication is key and should be customised to the target audiences; and
- an imperfect analysis using the best available information, which can subsequently be improved upon, is better than postponing an assessment.

By sharing the lessons learned, and benefits and limitations of different approaches, the workshop aimed to provide guidance for future applications and practitioners on how to effectively assess climate vulnerability – and how to work out what to do in response to enable marine and coastal areas better cope with climate change. Implementing actions to reduce vulnerability can be affected by political and fiscal realities but can also benefit from broader perspectives across practitioner networks, which also require guidance and/or maintenance. Climate change, by the very term itself, is not stationary; nor should we expect that of CVA outcomes. Repeating systematic assessments at later times can provide insights as to how a system may have shifted from a previous baseline and how effective adaptation strategies have been.

(Also see related article in this issue on ECCWO5 Session 3).
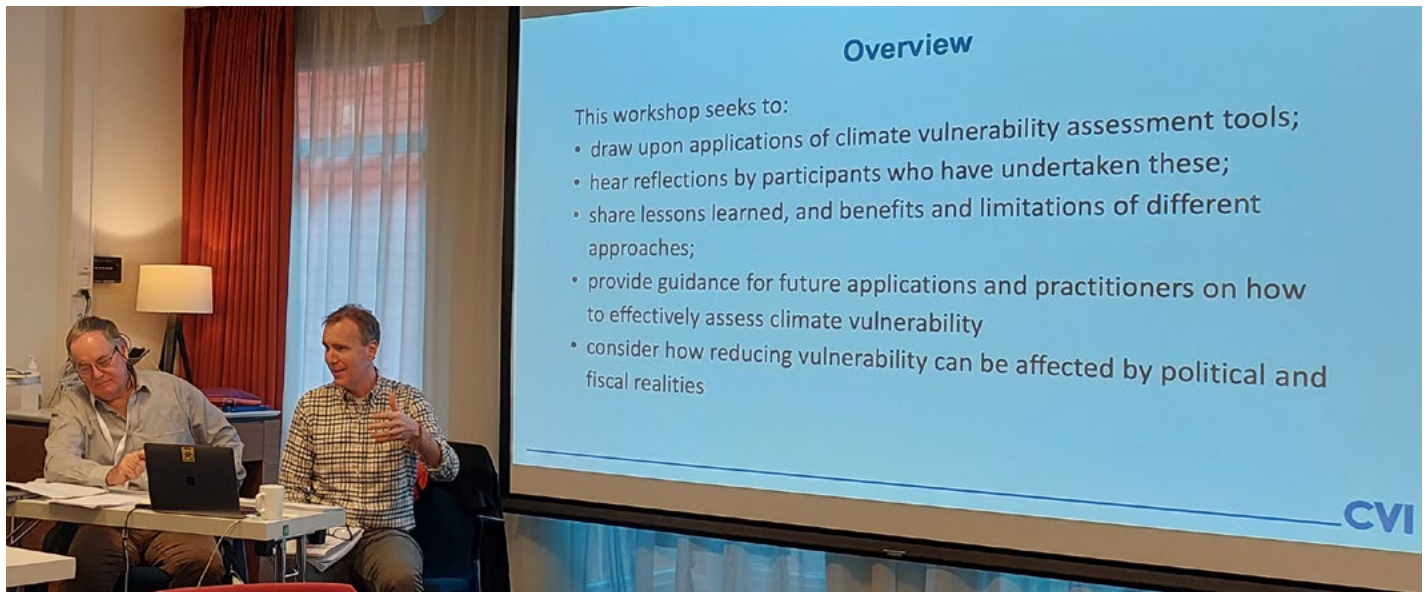
ECCWO5 W1 workshop was co-convened by Associate Professor Scott Heron (above right) with Dr. Jon Day (above left).

Dr Scott Heron is an Associate Professor in Physics at James Cook University (JCU) in Australia. He is a recognised world leading practitioner in the assessment of climate vulnerability for World Heritage (WH) and other areas of significance. Scott co-developed the Climate Vulnerability Index (CVI) with Jon Day – the CVI is a values-based, science-driven, community-focused tool that can rapidly and systematically assess climate vulnerability. The CVI responded to a need identified by UNESCO and partners to guide management responses to the anticipated impacts of climate change on heritage values. Scott is also internationally known for his research on coastal and near-shore environmental physics and links with ecological processes, specifically regarding impacts on coral reefs. He was the lead author of two UNESCO-published analyses of the impacts of climate change on WH coral reefs.

Dr Jon Day is an Adjunct Senior Research Fellow in the College of Science and Engineering at JCU. He was a protected area planner and manager in Australia for 39 years, including 16 years as a Director within the Great Barrier Reef Marine Park Authority (GBRMPA). Jon is recognised globally for his expertise in marine spatial planning, and in WH and other heritage matters. He attended eleven WH Committee meetings as an Australian government official (1998-2013) and was appointed as one of three experts comprising Australia's formal delegation during Australia's four-year term on the WH Committee (2008-11). Following his retirement from GBRMPA, Jon co-developed the CVI with Scott Heron, and together they have applied the CVI in areas of significance around the world, including a diverse range of natural and cultural WH properties.

ECCWO5 - W2 Workshop Report
The Climate-Fisheries Nexus within the UN Decade of Ocean Science for Sustainable Development: Co-Designing Actions and Solutions for a Productive, Healthy and Resilient Ocean
Steven Bograd, Hannah Lachance, and Jörn Schmidt

The UN Decade of Ocean Science for Sustainable Development (2021-2030; UNDOS) addresses challenges associated with ecosystem health, food security, and climate change through synergistic global activities. On April 16th, 2023, representatives from several UNDOS-endorsed Programmes hosted a workshop at the 5th 'Effects of Climate Change on the World's Oceans' (ECCWO5) Symposium in Bergen, Norway, with the aim of establishing collaborations and co-designing transformative actions within the climate-fisheries nexus. Approximately 25 workshop participants were in attendance and had the opportunity to learn about the UN Decade of Ocean Science for Sustainable Development, hear from excellent invited speakers and participate in breakout group discussions around the capacities and gaps in the climate change and fisheries/ecosystems nexus.

Following an overview by Hannah Lachance on the *UN Decade of Ocean Science for Sustainable Development,* each of the participating UNDOS Programmes gave brief overviews. Jörn Schmidt presented on *'Sustainability of MARine ecosystems Through knowledge NETworks'* (SmartNet), the network program led jointly by ICES and PICES that aims to advance and share scientific knowledge on the variability and sustainability of marine ecosystems. Steven Bograd presented on *'Sustainability, Predictability and Resilience of Marine Ecosystems'* (SUPREME), which aims to leverage efforts in the U.S. to advance and globally implement an infrastructure to support ocean forecasts and projections to guide climate-informed resource management (see article in this issue of *PICES Press*). Steven also presented (for Claudia Baron-Aguilar and Frank Muller-Karger) on '*Marine Life 2030'*, which seeks to generate and deliver actionable knowledge of ocean life, biodiversity, and marine ecosystem restoration. Kat Maltby presented on *'Fisheries Strategies for Changing Oceans and Resilient Ecosystems'* (FishSCORE), which is developing an international network to sustain fisheries as a source of food and jobs while protecting ecosystems in the face of a changing climate. Courtney McGeachy, the director of the *Ocean Visions-Decade Collaborative Center* (OV-DCC) housed at the Georgia Aquarium in Atlanta, described the OV-DCC's focus on advancing ocean-climate solutions and innovations within the Ocean Decade, and also gave an overview of the affiliated '*Global Ecosystem for Ocean Solutions*' (GEOS) Programme, which aims to develop and deploy a series of equitable, durable, and scalable ocean-based solutions for addressing climate change and Ocean Decade challenges. Finally, Jörn

Schmidt presented (for Ellen Johannesen) on '*Empowering Women for the UN Ocean Decade'*, which promotes equal opportunities for full participation and leadership by women in UNDOS activities.

Following these Programme introductions, we heard presentations from two invited speakers: Gretta Pecl from the University of Tasmania, Australia, and Ana Queirós from Plymouth Marine Laboratory, UK. Gretta presented '*Future Seas: What Could the Ocean Look Like by 2030 if We Shared it Equitably, and Used the Knowledge We Already Have Available?'*, which provided an overview of the Future Seas 2030 program (www.FutureSeas20230.org), a large, highly trans-disciplinary collaboration developing '*mobilizing narratives*' to secure a future equitable and sustainable ecosystem. Ana presented '*Bright Spots as Climate-Smart Marine Spatial Planning Tools for Conservation and Blue Growth'*. She described climate change 'bright spots', where oceanographic processes drive range expansion opportunities that may support sustainable growth, and noted that the identification and harnessing of these bright spots can provide nature-based solutions to mitigate climate impacts on ocean ecosystems.

Following these inspirational presentations and a lunch break, participants broke into three groups and engaged in lively discussions guided by the following questions:

1. What capacities (observations, models, technology, networks) does your Programme, country or organization have to sustain marine ecosystems under a changing climate?

2. What are your biggest gaps in sustaining marine ecosystems under a changing climate?

Workshop participants are in the process of synthesizing the breakout discussions and knowledge shared during the workshop, with the aim of producing (a) an infographic and (b) a white paper summarizing capacities and gaps within the climate-fisheries nexus and providing recommendations for achieving sustainable marine ecosystems under climate change. We hope these workshop products will provide the Ocean Decade with an inventory of current actions and capacities, as well as the gaps that need to be filled with new Decade actions.

Near the end of the day, the organizers and participants of each of the ECCWO workshops met in plenary to review their activities and discussions and identify areas of mutual interest and potential collaboration.

Photo of ECCWO5 W2 workshop participants (above), and photo of W2 breakout group session (below).

ECCWO5 - S2 Session Report
Smart fishing for climate change mitigation and adaptation
Jose A. Fernandes Salvador, Sara Hornborg, Manuel Hidalgo, Giovanni Codotto, Georg Engelhard, Kim Scherrer, Lancelot Blondeel, Igor Granado, Lohitzune Solabarrieta, Kayvan Pazouki, Karl-Johan Reite and Pingguo He.

The previous four ECCWO Symposia focused on the dramatically important topics of impacts from climate change on marine ecosystems, and on how fisheries and society can adapt. This fifth ECCWO symposium, for the first time, included a full session dedicated to climate change mitigation by the fishing industry, via reduced use of fossil fuels and consequent emissions. The sessions included a high diversity of complementary subjects, and consisted of 11 oral presentations and one invited plenary talk.

Antonello Sala's plenary talk (above) illustrated different approaches to estimate global greenhouse gas emissions by fishing vessels based on extrapolation of collected fuel use combined with fishing effort data. These approaches are associated with uncertainties and data gaps, highlighting the need for more detailed and robust data on fuel use in different fisheries in general. Examples of direct audit of fuel consumption from vessels were also provided (and also presented in one of the S2 session talks). This approach requires monitoring equipment to be installed on fishing vessels to collect data while at sea and in port for receiving, storing and processing. In many cases, this is done through technology companies which have already been providing data services to vessels (e.g., tuna vessels in the SusTunTech project and beam-trawl vessels in the VISTools project). Related to this, talks by Antonello Sala, Lancelot Blondeel and SusTunTech team (at right) informed the use of fishing vessels as cost-effective platforms for collecting environmental and fisheries data for scientific analysis and modelling. The collected data can also be offered as a decision support tool for vessel-owners and skippers, allowing them to gain insight in their own fuel consumption patterns.

Such novel approaches to data collection can feed global data portals, such as Copernicus and operational forecasting models aimed at redirecting and reducing

fishing effort to enable carbon efficient targeting patterns, as presented in the session's third talk by Lohitzune Solabarrieta framed in the SusTunTech project. Overall, some technological hurdles are still to be overcome (e.g., digitalization of the vessels, real time data quality control) for standardized quality data generation but also to follow FAIR (Findable, Accessible, Interoperable and Reusable) principles, to create final useful datasets. Beyond that, it is crucial to ensure that trust is maintained with the fishing industry while processing the potentially sensitive data, through data sharing agreements and appropiate anonymization of the data.

Several talks centred around efficiencies related to the level of fishing operation. The session's invited speaker from Marine Instruments (Carlos Groba), along with a researcher from AZTI (Igor Granado), presented their

SusTunTech Project members who participated in ECCWO5 S2 are shown above, L-R: Lohitzune Solabarrieta, Izaro Goienetxea, Carlos Groba, Igor Granado and Jose A. Fernandes.

work on optimizing the routes taken by tuna purse seiners. Their latest research demonstrated a potential reduction of up to 35% in time spent at sea and up to 50% in fuel consumption for full one-month trips. These decision support systems combine route optimization algorithms and machine-learning-based forecasting of fuel consumption and productive fishing grounds. Igor Granado also presented a literature review on how the shipping industry optimize their routes and how similar methodologies could be adapted for fishing fleets. Izaro Goienetxea presented forecasting likely fishing grounds for key tuna species while avoiding potential bycatch areas. Together with a digitalization and FAIR data talks, these talks are a result of the SusTunTech European project.

There are many ways to reduce emissions through strategies that improve energy efficiencies, spanning from fishing policy changes (e.g., ensuring healthy stocks, decreasing overcapacity and favouring fuel-efficient fishing techniques when allocating fishing opportunities) down to the individual fishers' actions and choices (e.g., changes in net design and materials, reducing or optimizing speed, minimizing biofouling, and good engine maintenance). However, there are also limitations and hindrances. For example, some species with high economic value offer limited opportunities for change in gear type, and their potentially high revenues might sustain the higher fuel use and associated cost. There may therefore also be a need to evaluate current incentives to reduce fuel consumption.

Three talks focused on the fishing policy perspective (by Kim Scherrer, Sara Hornborg and Georg Engelhard), underlined that management decisions could have profound effects on fuel use efficiency. For example, effects of Brexit on the fuel use efficiency in the Norwegian mackerel fishery, recently meant that developments towards improved energy efficiency were abruptly reversed and fuel use considerably increased. An overview on how to enable an energy transition of the fishing sector is currently high on the political agenda in the EU, with many different recent and emerging initiatives. Enabling and incentivising improved energy efficiency plays an important role in this process. Furthermore, it is important to have a systems perspective to achieve the greatest, long-term energy-efficiencies. Several possible policy actions could favour fuel use efficiency, including safeguarding sustainable exploitation levels and use of CFP Article 7 to allocate fishing opportunities. Opportunities also exist in redirecting fuel subsidies to energy-saving initiatives and introducing fees for use of high emission fuels. A lack of knowledge about the energy transition for fisheries beyond fuel use efficiency was also highlighted in several talks. Major uncertainties are related to which alternatives will be readily available, at what cost, and what is most suitable for different fishing operations and vessels.

We need technological changes (driven by researchers, engineers, and technological providers), operational changes (which can be suggested by researchers, but ultimately must be adopted by the fishers – and several are already being implemented), and policy changes (which need to be co-developed with fishing industry, and viable from a technological and scientific point of view). Careful navigation between short-term costs and long-term needs will be essential in providing incentives for change.

Offering an alternative viewpoint, a presentation by Giovanni Codotto (above) highlighted the role of consumers in mitigating carbon emissions from the fishing sector. The speaker emphasized that carbon emissions can be effectively reduced by decarbonizing not only production but also consumption. To enable this decarbonization at the consumption level, it is relevant to consider the wider implications of consumer choices through clear guidance towards low-emission fish products. It is argued that when the demand for specific fish products exceeds the sector's production capacity, emissions are influenced not only by the immediate sector but also by the consequences of shifting production towards alternative sources of seafood.

While several talks in the session already hinted at the importance of the human dimension (e.g. behaviour and incentives) in emission mitigation, this theme came especially to the foreground during the round table discussion that followed the session. There are limitations with technology due to, for example, sparse data sharing and a lack of multidisciplinary experts. However, for current technologies to be accepted by the end-user, appropriate incentives are essential – which is linked with policy. Therefore, dialogue and co-design with industry is needed, as well as appropriate funding and support. Better understanding of consumer demands and the potential provided by the use of eco-labels as incentive were also highlighted in several presentations.

Above, Manuel Hidalgo presents on *Integrative surface-to-bottom carbon footprint of fisheries: economic benefits and sustainable fishing of contrasting Mediterranean fisheries*

Overall, the establishment of policies around carbon emissions by fishing vessels need to consider countries that rely heavily on fish as food. This dependence might be reduced in the future: plenary speakers highlighted that global food production increased twice as fast as population has increased. Despite this, it is likely that many island nations will remain highly dependent on fish protein and export of fish for their national economies. High diversity in food and protein sources might benefit a society's resilience, but it also implies a substitution effect that the fishing industry will face due to other cheaper sources of food and protein. Climate change can also affect the sizes of fish stocks and species compositions, where small fish and undesirable species are generally less commercially valuable.

New evidence from around the world shows that, if we are to estimate the total carbon footprint of fisheries, estimates of emissions by fishing vessels will need to be complemented with estimated carbon release from the seafloor, at least for bottom trawling. A study in the Western Mediterranean on purse seiners and bottom trawlers shows that sea surface CO_2 footprint of purse seining and bottom trawling is among the lowest of animal protein production; however, when considering sweeping-released CO_2 from the seafloor the bottom trawling footprint becomes the animal protein production with the highest CO_2 footprint. Moreover, the lowest bottom-trawling released CO_2 estimation overrides 3-10 times the CO_2 buried in the seafloor through the biological pump in trawled areas, particularly in areas with strong river runoff. In the Western Mediterranean, the net profit per fuel-derived -CO_2 emission for all fleets is < 1€ $kgCO_2^{-1}$, being the lowest for large trawlers (0.025 € $kgCO_2^{-1}$). This exercise shows the value of integrative assessment of different sources of CO_2 emissions and spatial variation of fleets.

The session ended with a round table discussion between most of the session speakers. Topics discussed included the statement that increasing the efficiency of fishing is often associated with risks of overfishing. The latter is usually prevented by effective fishery management, where increased efficiency does not interfere with long-term sustainable fishing. In addition, given that management decisions can greatly influence fuel use, it will be key to include and pursue low emissions as an explicit objective in fisheries management. Still, choice of terminology may be important to reflect what is intended to be achieved: immediate mitigation through small changes in the vessels (accompanied with information and decision-support systems) or longer-term goals of net zero emission that might require more radical changes (other fuels, new engines and adapted port facilities). Regardless, the decarbonization process for fishing vessels has two components: fuel use reductions and achieving net zero. While fuel use reductions can be achieved in the shorter term (5 to 10 years) using existing technologies, fully achieving net zero is more challenging and will require major investments, although needed for long-term sustainability of the fishing sector. Net zero emissions will require a long-term strategy, informed by life cycle assessments, where vessels and energy providers are continuously replaced. Members of the fishery sector need to be included in this debate, to maximise uptake of new strategies and technologies. To the best of our knowledge such quantitative evaluation of best strategies has not yet been done. The round table ended with a discussion on what could be next steps such as identifying research funding, preparing an opinion paper to raise awareness, inviting known experts, or more involvement in existing expert groups and meetings (e.g. ICES or FAO).

Dr. Jose A. Fernandes Salvador is a data scientist in computing and artificial intelligence studies, translating data into valuable information for marine research, policy and industrial applications. He possesses curiosity, economic knowledge, data and information finding, understanding of statistics and machine learning, and multidisciplinary communicative skills which he has employed in >15 years in marine research institutions in Spain, Finland and the UK. His PhD thesis applied machine learning to automatically classify biological samples and to forecast fish recruitment. In the UK, he later developed species distribution models to consider impacts of climate change and socio-economic implications. For the past 6 years he has re-incorporated AZTI, leading the big data line of research to combine large and heterogenous datasets with artificial intelligence to aid fishing industry climate change adaptation and mitigation.

Dr. Sara Hornborg is a marine biologist and researcher at RISE – Research Institutes of Sweden. Her research focus is sustainable production and consumption of seafood, mainly from fisheries, and is centred around environmental system analysis (life cycle assessment and ecological risk assessment). Projects have included –among others– quantification of environmental effects from various fisheries management regimes from a product-perspective, decarbonisation of fisheries, evaluations of innovative production systems and feed concepts for aquaculture, method and indicator development for improved environmental assessments of seafood products.

Dr. Manuel Hidalgo is research scientist working for the Spanish Institute of Oceanography (IEO, CSIC). He a fisheries ecologist and oceanographer with experience in different components of impacted marine ecosystems, from species life history traits, through ecology and population dynamics, to the properties of communities and ecosystems. His main research framework focuses on understanding the complexity of the 'impact of fishing activity and climate variability on the ecological mechanisms that regulate exploited populations, communities and ecosystems' along with the design and assessment of adaptation and mitigation actions mainly for the fisheries sector.

Giovanni Codotto is a PhD student at the Danish Centre for Environmental Assessment, Aalborg University. He holds an MSc degree in Environmental Management and Sustainability Sciences from the same institution. His primary research focus is on Life Cycle Assessment applied to fisheries, specifically employing a consequential approach. Prior to his PhD studies, he gained experience as a research assistant at Aalborg University, where he actively contributed to different LCA projects.

Dr. Georg Engelhard is a principal scientist at the Centre for Environment, Fisheries & Aquaculture Science (Cefas), UK. He works on a range of subjects around marine climate change, including its impacts on marine life and dependent fisheries, on climate change risk and adaptation, and on mitigation. He is leading an ongoing study on the recent trends and current levels of emissions by the UK fishing fleet, which sets out potential pathways for reducing emissions towards net zero by 2050.

Dr. Kim Scherrer is a postdoctoral researcher in marine sustainability science at the University of Bergen, Norway. Her research focuses on the interactions between humans and ecosystems, especially on the sustainability and resilience of the world's fisheries under climatic, technological and societal change. She has published research on global fisheries modelling, climate change impacts on marine ecosystems, and on climate shock impacts on global food production. Currently, she is investigating how fisheries can contribute more to food security with a smaller climate footprint.

Lancelot Blondeel is a fishery technology researcher at the Flanders Research Institute for Agriculture, Fisheries and Food. His research focusses on improving the sustainability of the Belgian fishery (Visserij Verduurzaamt) and automatic real-time monitoring of beam-trawl vessels and reporting through decision support tools (VISTools project). The latter project is further being developed into a full Digital Twin of the Belgian fleet, with focus on constructing fuel-efficiency and catch-prediction models (ILIAD project).

Igor Granado is currently pursuing a PhD in Informatics Engineering at the University of the Basque Country, focusing on optimizing fishing routes to reduce environmental impact and enhance sustainability in the fishing industry. His work spans across several disciplines: fisheries, artificial intelligence, and operational research. His thesis topic involves developing a decision support system to help fishermen with planning and decision-making processes for fishing strategies. As a data scientist, Igor has actively implemented innovative solutions to tackle challenges faced by the fishing industry, with a strong focus on bridging the gap between academic research and industry.

Dr. Lohitzune Solabarrieta is a civil engineer with a PhD (2015) in Science and Technology for coastal management from the University of Cantabria, in collaboration with AZTI. Her research is focused on the characterization of surface ocean processes at different spatial-temporal scales, using data from remote sensing and in-situ instruments. She is also interested on the ocean data management and standardization.

Dr. Kayvan Pazouki is a Senior Lecturer in the Faculty of Engineering at NU specialising in marine engineering. He has extensive experience in engine monitoring tools through physical and inferential measurement systems and has participated in large UK and EU projects. His research interests are energy efficiency management, alternative fuels, ship performance and emission prediction.

Dr. Karl-Johan Reite has a PhD degree in Marine Cybernetics and a MSc degree in Nautical Sciences. With 10 years of experience as Research Manager, he has managed and conducted many research projects focusing on energy efficient fisheries, covering topics like onboard and onshore decision support for fishing vessels and fishing gear design and operation. This has involved gathering and analysing data from fishing vessels, simulations of marine systems and decision support web portals. He has held lead positions onboard ocean-going fishing vessels, and is the lead of the SINTEF Marine Data Centre, for which the acquisition and analysis of data from fishing vessels are important aspects and the development of FhSim, a marine systems simulation tool.

Dr. Pinguo He is Professor and Chair of the Dept. of Fisheries Oceanography in the School for Marine Science and Tech. at U. Massachusetts Dartmouth, in New Bedford, MA, USA. He holds a B.Engineering in fishing technology from China's Zhejiang Ocean University, and a PhD in fish physiology and behaviour, specializing in fish behaviour near fishing gear, from U.Aberdeen in Scotland, UK. He has worked in Asia, Europe, and N.America on fishing technology, fish behaviour, and conservation engineering related to marine capture fisheries, and has published extensively on fish physiology and behaviour, fishing (gear technology, impacts, and sustainability). He is the editor of the book "Behaviour of Marine Fishes: Capture Processes and Conservation Challenges".

ECCWO5 - S3 Session Report
Assessing Climate Change Vulnerability of Marine and Coastal Areas and Associated Communities
Scott Heron and Jon Day
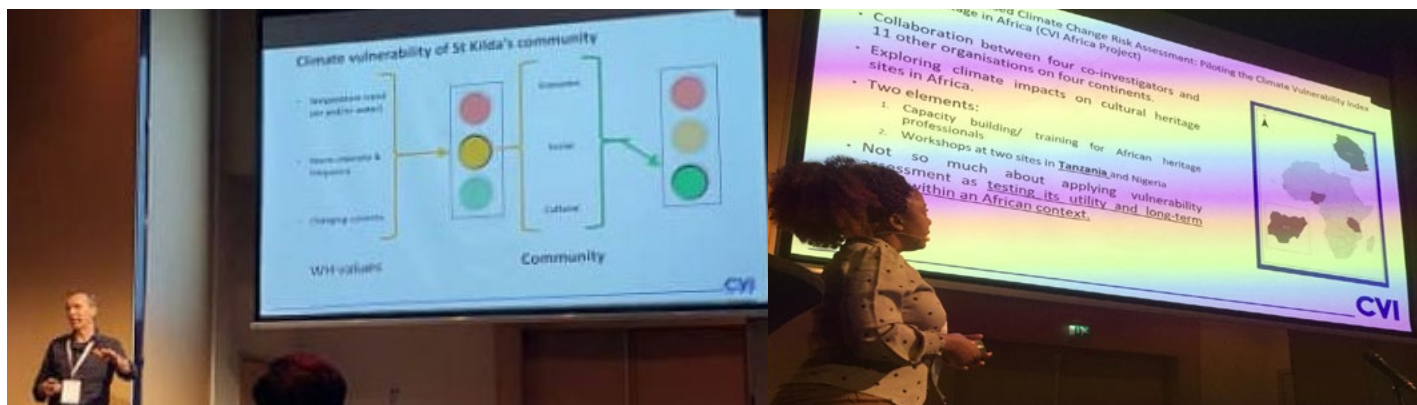
Associate Professor Scott Heron (left) and Ms. Mercy Mbogelah (right) give their keynote presenations during ECCWO5 S3.

Following the success of the CVA workshop, ECCWO5 Session S3 on *Assessing climate change vulnerability of marine and coastal areas and associated communities* involved a series of presentations, primarily about CVAs. The session considered existing tools used to evaluate the vulnerability of what were regarded as significant values but also addressed assessments of the vulnerability to economic, social and cultural aspects of the community associated with the area under assessment.

Presentations covered a diverse range of topics and included both in-person and pre-recorded talks on CVAs (the initial intent of the session), augmented by several other presentations on climate impacts. There were also a range of related posters. Presentations therefore addressed a wide range of marine and coastal protected areas, including for locations recognised internationally (World Heritage, RAMSAR), nationally (national heritage/trust, MPAs) and locally (First Nations land/sea country, community-based). Whilst many of these focused on particular species or ecosystem sectors, the session included a broader consideration of "value" – both natural and cultural – that systems provide to their associated communities.

In addition to the presentations, an important feature of the session was four dedicated discussion times that provided opportunity for multi-directional knowledge exchange. These robust discussions led to deeper dives into the presented topics and the implications for, and of, CVAs.

Key observations included:

- effective engagement with rightsholders and stakeholders is essential, including through co-design, co-development, co-production and reporting

- transparency with participants about the process and parties involved can be an important strategy to mitigate participant fatigue

- there is no one-size-fits-all CVA given the diverse array of systems, indicators and analysis objectives; flexibility inherent within a process is a valuable characteristic

- broad uptake of outcomes (particularly adaptation strategies) should be a key objective of CVAs; simpler processes can be easier to communicate, which can lead to community buy-in, and can also help prioritise where more comprehensive studies would be useful.

The workshop and the session each had two high-level objectives, both of which were achieved. Firstly, to develop a network of CVA practitioners and other interested parties to facilitate the sharing of outcomes, processes and lessons learned to support the understanding of climate impacts more broadly. Secondly, to foreshadow a special issue of the journal Heritage, entitled "Assessing Impacts of Climate Change on Cultural and Natural Heritage," and to encourage the submission of relevant manuscripts for this special issue.

For author biographies, please see article on ECCWO5 W1.

ECCWO5 - S5 Session Report
Measuring and predicting responses of marine social-ecological systems to climate extremes
Stephanie Brodie, Lisa Colburn, Kathy Mills, Gabriel Reygondeau

ECCWO Session S5 Invited Speaker Regina R. Rodrigues presents a paper on Extreme Compound Events in the tropical and South Atlantic

Over the last few decades, extreme climate events are interacting with longer-term climate change, leading to unprecedented environmental conditions for marine ecosystems and interconnected social systems across the globe. These events include rapid or episodic physical events (marine heatwaves, hurricanes, storm s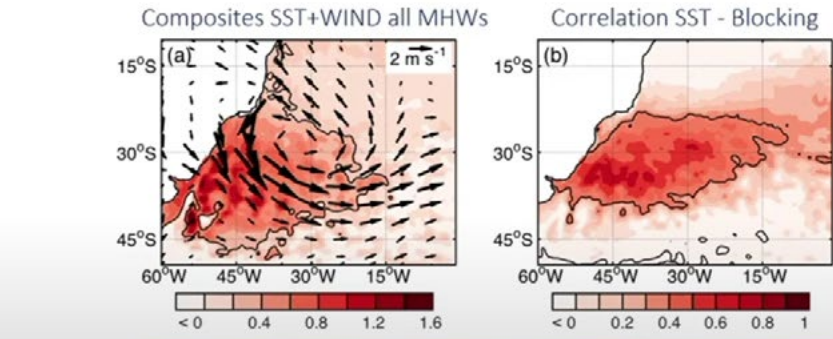urge) as well as disequilibrium triggered by biological responses to changing climate (ocean acidification, HABs, bleaching). These changes have caused widespread impacts on marine ecosystems and fisheries. ECCWO Session S5 focused on measuring and predicting responses of marine social-ecological systems to climate extremes, and highlighted several examples from the impacts of marine heatwaves on ecosystem function to storm events altering fishing activities and affecting human safety.

Marine heatwave studies were the dominant theme of the session, but no clear single or consistent response of biomass and biological community composition has been detected. The main emergent theme was that temperature alone is not enough to understand and quantify ecosystem impacts and recovery from marine heatwaves, and that we need to look beyond temperature (e.g., productivity) to consider multivariate effects and build a mechanistic understanding of the drivers of ecological responses to extremes. Importantly, evidence emerged highlighting the need to understand simultaneous occurrences of multiple climate extremes on both land and water, termed *compound events*, that have the capacity to exacerbate societal and environmental impacts beyond any extreme event in isolation. This challenges the resilience of ecosystems and coastal communities.

Near-term forecasts of climate extremes are being delivered to ocean end-users to help them better prepare for and respond to extreme events. There was some discussion on how to communicate with end-users regarding forecasts but decisions to adapt are galvanized by a variety of influences, including traditional knowledge, personal experiences, and socio-economic conditions. A key research gap identified was that social science studies are not being conducted or not being paired with natural science efforts related to extreme events. These are important for understanding the societal impacts of extreme events, prediction timelines, and the alignment of predictive information with potential adaptation capacity and response timelines. There is thus more work needed on linking predictive models to societal timescales to prepare and plan for response.

ECCWO5 - S10 Session Report

Beyond species on the move: emerging climate change impacts on the spatialdynamics of marine species, from detecting to forecasting and projecting

Manuel Hidalgo, Shin-ichi Ito, Lorenzo Ciannelli, Lauren Rogers and Rebecca Asch

Barbara Muhling (above left) and Lisa Kerr (above right) during their ECCWO5 Session 10 plenary talks.

ECCWO5 Session 10, entitled *'Beyond species on the move: emerging climate change impacts on the spatial dynamics of marine species, from detecting to forecasting and projecting'* was held on April 17-18, 2023, and was very successful both in terms of content and submissions. With 34 oral presentations and 26 posters presented during the Symposium, it included a large number of contributions from early career researchers and from a large number of countries. The initial objectives of this session were two-fold:

1. to present advances in forecasting and projecting spatio-temporal dynamics of marine species;

2. to attract presentations on novel advances in understanding climate change impacts focused on less investigated spatial processes, including operational issues (model resolution, bias correction, model parameterization and validation) and conceptual frameworks (population structure, early life dispersal, spatially-dependent critical processes, collective behavior, and spatial co-occurrence and interactions of species).

The session's April 18 keynote talk was by Barbara Muhling (above left) on *'Species distribution modeling for pelagic fishes in the California Current System: Ecological insights, challenges, and future directions.'* There was also an invited talk by Lisa Kerr (above right) on *'Consequences of ignoring climate impacts on New England groundfish stock assessment and management.'* Both plenary talks provided complementary views related to the objectives of the session, with Barbara Muhling presenting on recent advances and emerging challenges in species distributions models, while Lisa Kerr illustrated, with several groundfish examples, the urgent – but feasible – need to incorporate climate change impacts – including the spatial dimension – into current stock assessment and management programs. The two plenary speakers also provided valuable insights on how to include more mechanistic processes in species distribution models, and how results on species range shifts can be an on-ramp to the inclusion of ecosystem and climate information in management models and decision making processes.

From a more technical perspective, several themes were echoed in the presentations, such as the importance of further considering scale-dependent processes. It is becoming increasingly important to merge datasets over larger spatial scales, even from different regions with different data sets and monitoring programs, to make sure that both the leading and trailing edges of species are captured. This implies that emergent relationships are more likely to incorporate species' fundamental niche vs. their realized niche. Also, response curves for individual regions may strongly differ from the joint multi-region response curve, which could lead to potential mismanagement if regional management measures are applied over areas with heterogeneous species responses. When thinking about spatial scale, it is important to note that local adaptation to climate might be important especially among sedentary or demersal species with

limited dispersal capacity or those that show high levels of philopatry. Several presentations also underscored the importance of model validation, particularly when models are used for projecting species distributions. The choice of the test data set to be used may determine the outcome of the validation. For instance, if the testing data are at the fringe of population distribution, or stratified over space, the cross validation may not be representative of the species full theoretical niche and may lead to potential errors in the projections. However, a solution presented was the use of stress-test approaches that consider extreme years (e.g., marine heat waves) and/or with extreme locations (e.g., leading and trailing edge) that are not included in the calibrating data set. Functional responses need to be robust to these stress conditions and thus suitable for projection performance.

Including novel elements in species distribution models was also discussed both from the perspective of environmental drivers and species biology and ecology. For instance, light levels and the lunar cycle may be important constraints on mesopelagic fish distribution. Several presentations highlighted the emerging use of climate velocity, both horizontally and vertically (i.e., as a function of depth), as an indicator of climate change exposure. Horizontal climate velocity is known to be on the order of tens of kilometers per year displaying high geographic variation, while a presentation in the session showed that species can move vertically at speeds of meters per year while still tracking climate velocity. The value of considering the physiological state of the species when analyzing its distribution was also highlighted through the examination of a metabolic index. At the level of ecological processes, the ability to integrate information on foraging often explained variations in species distribution or timing in cases where considering purely physical variables did not. Consideration of foraging behavior also increases the mechanistic basis of species distribution models. For instance, albacore foraging behavior measures explained east-west distribution shifts within this species' preferred temperatures, while Atlantic bluefin tuna larval occurrence timing was better explained by a combination of temperature, lunar phase and foraging conditions.

Several presentations extended beyond the species level, examining changes in large-scale biodiversity patterns and ecosystem structure. It is worth noting that global models in several talks projected a drastic reduction of ecosystem-structuring marine species (e.g., hard corals, seagrasses and kelp forests) within their historical ranges. These organisms are not very mobile and they have constraints in occupying new habitats. This will have implications for other organisms that use these habitats (e.g., nursery habitats). Some presentations also highlighted the need to further investigate the role of the spatial turnover

of species to perform species diversity projections that harmonize local and regional changes with larger global scales, and to avoid over- and underestimation of projected diversity changes.

There is a trend towards moving beyond species distribution models to finding "on ramps" to include information on shifting distributions in management decisions. In this context, there is a clear trend to using multimodal approaches to species distribution models - not relying on one method, but using an ensemble approach to counteract the known limitations of different methods and better quantify model uncertainty so that managers can understand potential best and worst case scenarios.

What did we miss in Session 10?

Species are surely on the move and will continue to be, which attracted most of the research we saw in this session. However, there are other spatial properties of marine populations impacted by climate change that transcend distribution shifts, such as individual aggregations, fragmentation and connectivity among habitats, that have still received little attention. For instance, it is still unknown how the alteration of population subunits in complex spatial structures by climate change impacts will alter the population dynamics of harvested stocks.

In addition, some of these spatial dynamics may be driven by ontogenetic changes in distribution, novel species interactions, and local adaptations, for which there are still critical knowledge gaps. In this line, non-stationary dynamics related to heterogeneous regional interactions between climate change and other local environmental processes are still under-investigated. Beyond warming, other environmental processes critical for species distributions, such as current patterns, vertical stratification, primary productivity, dissolved oxygen concentration, among others, will change due to climate change. However, the lack of predictions on how these processes will change still limit their use in terms of forecasting. As a particular example, extreme events have increased and are projected to increase in future. Extreme events trigger shocks in the marine ecosystems altering habitat characteristics of marine animals, while the temporal and spatial dimensions of their impacts are still difficult to project. Paleontological studies have observed discontinuous changes after mass extinctions caused by extreme events. A more mechanistic approach is needed to predict what habitat changes will occur over the time scale of future global climate change.

Finally, one of the main challenges over the last decade has been the downscaling earth system models to regional conditions and high-resolution spatial surveys (i.e., primary

Barbara Muhling presents at ECCWO5 Session 10 Plenary.

source of biological data) to allow projecting over different model frameworks and shared socio-economic pathway scenarios. This continues to be an increasingly common trend in the study of species range shifts, but only in regions where such products are available and have thus made rapid advances, whereas other regions lack such high-resolution datasets. In addition to being a modeling issue, this is also an issue of scales at which observations are made and underlying processes are inferred. For instance, recent developments of environmental DNA observation techniques and autonomous vehicles with acoustic or video monitoring enable high-resolution spatial surveys. These high resolution biological observations with satellite observations (e.g., SWOT) can be applied to study the habitat response of marine animals to sub-mesoscale phenomena. This should increase our understanding of marine animal responses to their environments, which allow us to investigate the mechanisms the marine animals are responding to. Therefore, a more mechanistic understanding of factors affecting species distribution or constraints to changes in distribution is also emerging. Among the new processes included in these models, we have seen inclusion of different life history stages, size explicit modeling approaches, fishery exploitation status, bottom morphology, light levels, lunar cycle, and metabolic theory.

To sum up, Session 10 succeeded in attracting to ECCWO5 highly novel research applied to species distribution models of marine species, including both conceptual and methodological advances. These presentations contributed to identifying current challenges and future directions in this field, including moving beyond species distribution model development to consider how to actually use information on shifting distributions in management decisions.
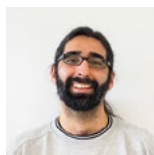
Manuel Hidalgo (jm.hidalgo@ieo.csic.es) serves as research scientist for the Spanish Institute of Oceanography (IEO, CSIC) in the Group of Ecosystems Oceanography. He performs research on synergistic effects of climate and fisheries, processes and indicators of resistance and resilience, ocean connectivity, and adaptation and mitigation to climate change. Manuel is involved in numerous ICES working groups and strategic initiatives, and serves as editor to the journal ICES Journal of Marine Science.

Dr. Shin-ichi Ito (goito@aori.u-tokyo.ac.jp) is a Professor at the University of Tokyo. His fields and topics of research range from physical to fisheries oceanography. He co-chairs the Joint PICES/ICES Working Group on Impacts of Warming on Growth Rates and Fisheries Yields (GRAFY) and member of the joint PICES/ICES Section on Climate Change Effects on Marine Ecosystems (S-CCME) and Advisory Panel on Early Career Ocean Professionals (AP-ECOP).

Lorenzo Ciannelli (lorenzo.ciannelli@oregonstate. edu): Professor, College of Earth, Ocean. and Atmospheric Sciences, Oregon State University, USA. He conducts research in fisheries oceanography, with emphasis on fish early life stages and interactions with physical and biological changes in the ocean. At OSU Dr. Ciannelli teaches courses in ecology of fish early life stages, fisheries oceanography, statistical analyses of fisheries and oceanographic data and transdisciplinary collaborations in marine science.

Lauren Rogers (lauren.rogers@noaa.gov) is a Research Fisheries Biologist at NOAA's Alaska Fisheries Science Center, USA, where she conducts research on early life stages of fishes in support of ecosystem-based fisheries management in Alaska. Her research focuses on understanding how fish and their ecosystems are affected by changes in climate, and developing new approaches to integrate ecosystem information into the fisheries management process.

Rebecca Asch (aschr16@ecu.edu) is an Assistant Professor at East Carolina University, USA. Her lab's research aims to advance understanding of how climate change and climate variability affect fish populations and provide knowledge for their effective management, with a more specific focus on changing seasonality in the ocean. Asch serves as a member of the PICES/ICES working group on small pelagic fishes, a contributing editor to the journal Marine Ecology Progress Series, and teaches classes on marine biology, fisheries biology, and ocean global change.

ECCWO5 - S18 Session Report
Beyond blue carbon: Ocean-based carbon dioxide removal (CDR) approaches
Darren Pilcher, Brendan Carter, Tiziana Luisetti, Prateep Nayak

ECCWO5 Session 18 Conveners, L-R: Darren Pilcher, Tiziana Luisetti and Prateep Nayak, before the session.

ECCWO-5 Session 18: *Beyond blue carbon: Ocean-based carbon dioxide removal (CDR) approaches* aimed to provoke discussion around potential natural and semi-natural mitigation options throughout the ocean. Options considered require human intervention and management like blue carbon ecosystem conservation restoration or enhancement, and other carbon dioxide removal techniques (e.g., alkalinity enhancement, ocean fertilization). To meet the ambitious target of maintaining global warming under 1.5°C in respect to pre-industrial levels as stated in the Paris Agreement, concerted action is necessary. Our keynote speaker, Dr. Sarah Cooley (Director of Climate Science at Ocean Conservancy - shown below), illustrated the mitigation options the ocean can offer, which may be indispensable if the 1.5°C limit is passed, illustrating challenges and opportunities of ongoing and emerging ocean-based solutions and related ethical concerns and/or enthusiasm.

The potential for mitigation actions in the vast ocean space, which offers the largest natural carbon sink, can be considerable.

Discussion following each talk and the session was lively within the crowded room, demonstrating keen interest in finding effective, quick and natural solutions to the climate change challenge. Eight speakers presented their natural science and related policy research in the area, as well as initial applications. The speakers illustrated CDR potential applications, discussed the actual potential of kelp forests and macroalgae to mitigate climate change, and discussed the limits of these actions if not coupled with a drastic reduction in greenhouse gas emissions. The session's eight talks included:

- Dr. Sarah Cooley: *"Transdisciplinary ocean carbon dioxide removal research and evidence-based decision making"*

- Dr. Jörg Schwinger: *"Ocean carbon cycle feedbacks and the seasonal cycle of the carbonate system under ocean alkalinization"*

- Prof. Emanuele Di Lorenzo: *"Solutions road maps for ocean CDR: advances on seaweed cultivation and sinking"*

- Dr. Peter de Menocal: *"An Ocean Vital Signs Network"*

- Dr. Nina Bednarsek: *"Predictable patterns within the kelp forest can indirectly create temporary refugia for ocean acidification"*

- Manon Berger: *"Biogeophysical constraints of macroalgae carbon dioxide removal identified with a high-resolution ocean biogeochemical model"*

- Dr. Lars Golmen: *"Storing captured and intentionally sequestered CO_2 in the deep ocean"*

- Dr. Sophia Johannessen: *"Why planting trees and seagrasses cannot offset fossil fuel emissions"*

A highlight of the session was invited speaker Dr. Sarah Cooley's overview presentation outlining reasons why optimism and enthusiasm, but also skepticism regarding ocean CDR, is warranted. Her talk served as an excellent foundation to start the session, as she provided key context for the necessity of CDR as a means to remove legacy carbon emissions, but showed CDR is not enough on its own – emissions reductions are paramount in order to *"turn off the tap."* Furthermore, a portfolio of various ocean CDR approaches will be required as any one technology alone is unlikely to produce the required scale of carbon removal. Some common themes emerged

among all groups interested in CDR, such as the need for more information and transparency, whilst limiting any detrimental side effects. Dr. Cooley highlighted the need for identifying *'the lines that we do not want to cross'* in order to address many people's concerns. A key takeaway was that a multi-disciplinary, diverse set of perspectives is essential as: trust is currently low; verification of carbon removal is presently impossible; equity is lagging; and liability is unresolved.

Dr. Jörg Schwinger presented work using an Earth System Model and a series of idealized ocean alkalinity enhancement scenarios. The results highlighted key sensitivities within the marine carbon chemistry system and noted how the magnitude of the effect of alkalinity enhancement varies depending on the atmospheric CO_2 concentrations when the approach is implemented. Lastly, he found that the seasonal cycle of CO_2 flux was enhanced following alkalinity enhancement, and that the seasonal cycle for surface pH and aragonite saturation state were returned to approximately preindustrial results. In the broader context of ocean CDR, this illustrated the potential for ocean acidification mitigation.

A consistent trend throughout the session was the enthusiasm and growing support for CDR research, particularly through coalitions and consortium building. This was highlighted by Prof. Emanuele Di Lorenzo's talk discussing the efforts of the research consortium, Ocean Visions. This consortium has started programs such as the U.N. Decade of the Ocean supported Global Ecosystem for Ocean Solutions, focusing on multi-sector community and research, innovation engines and development, and investment and deployment. The consortium aims to create road maps for the development of ocean CDR strategies. Di Lorenzo concluded by reinforcing Cooley's earlier point that we are currently flying blind with respect to monitoring, reporting, and verification (MRV) of ocean CDR, and that additional observational capacities, particularly for ocean biogeochemistry are likely required to define potential and identify risks. Like Dr. Cooley, Prof. Di Lorenzo emphasized the need for coordinated efforts and building trust around CDR.

Appropriately, Dr. Peter de Menocal then detailed the development by Woods Hole Oceanographic Institution of an Ocean Vital Signs Network to lead a new era of ocean exploration addressing the MRV challenge. Specifically, this entails a 4D ocean internet of sensors to *"turn on the lights for deep ocean processes."* This 5-year, $150M USD program is bringing together a consortium of funding partners, aptly demonstrating the importance of partnerships and community engagement to build trust (described by Prof. Emanuele Di Lorenzo in the previous talk).

One of the bigger surprises of the session was the relatively low effectiveness of kelp as a CDR approach. Dr. Nina

Bednarsek presented an experimental deployment of kelp in Puget Sound, Washington, which provided no measurable local ocean acidification mitigation. She attributed this lack of an observable signal to the high current speeds within the study location, with model results suggesting that an order of magnitude slower current speeds would be required. However, the project did find that marine calcifiers displayed fewer signs of dissolution within the kelp forest, compared to those on the boundaries. She attributed this to an increase in predictability (i.e. pH autocorrelation and the ability of the organism to predict its own environment) and increased food availability. She concluded that the kelp forest served more as a nature-based ecosystem solution rather than a climate mitigation strategy.

Moving from the local to global scale, Manon Berger then presented model results simulating the impact of an idealized kelp forest at a fixed carbon uptake rate, imposed within the coastal Exclusive Economic Zones (EEZs). The results illustrated that physicochemical processes reduce the CDR potential of this kelp forest, and that further including the impact on reduced nutrient availability for phytoplankton (due to nutrient uptake by the kelp) greatly reduced the net effect. In fact, the nutrient effect leads to some regions taking up less carbon than the control simulation without the kelp, yielding a negative CDR efficiency. Overall, the majority of the EEZs displayed CDR efficiencies between 0-10%, and removing 1 Gt of CO_2 would require harvesting 10 Gt of wet weight kelp, roughly equivalent to 120 times the annual fish catch.

Concluding remarks

- The CO_2 levels in the past have kept increasing despite a series of IPCC reports and climate summits.
- Has the easy and unfounded victory of those who stopped the experiment contributed to loss of confidence in science as well as confidence in science-informed ocean governance and management?
- It has for sure been demotivating to leading scientists as well as young recruits to this field of work.

Dr. Lars Golmen (above) then provided a retrospective summary of a CO_2 injection experiment in the early 2000s. The experiment tested the leakage and potential ecological impacts of injecting liquid CO_2 (which would be directly captured from fossil fuel power plants) into the ocean seafloor. The first experiment was planned for deployment off the coast of Hawaii (2001) and was then switched to Norway (2002) due to permitting issues. Further permitting issues with the new location and some discussion and public comments to the Norwegian Ministry of Environment ultimately resulted in the cancellation of the project. The talk highlighted how obtaining the proper permits for ocean CDR can be challenging, particularly when it's unclear which international and domestic laws and agreements apply.
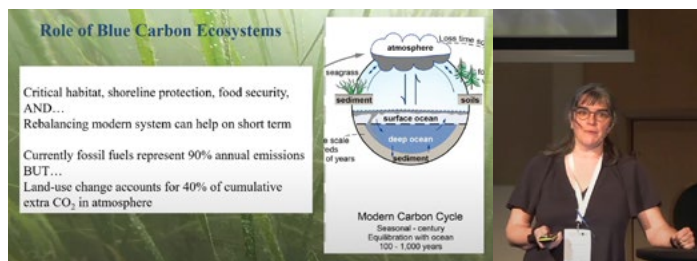
Dr. Sophia Johannessen (above) concluded the session by identifying communication of CDR (and blue carbon sinks in particular) as a critical challenge, not just between scientists and the media, but also between scientists themselves. Her work has found that most recent papers which quantified blue carbon calculated the standing stock rather than the fluxes. She argued that these blue carbon stocks should be viewed more as a liability rather than an asset, due to their vulnerability to climate change and the potential re-release of large quantities of CO_2 to the atmosphere when disturbed. They should therefore be protected as much as possible. However, she noted that blue carbon has many benefits outside the scope of CDR, including critical habitat, shoreline protection, and food security. Therefore, restoring these ecosystems is still critically important, in addition to quantifying these standing stocks since they may be at risk for loss due to climate change or anthropogenic disturbance, thereby adding substantially more natural carbon to the atmosphere. Dr. Johannessen finished by reiterating that emission reductions is still the most critical step, as the goal of CDR is to remove legacy carbon (already in the atmosphere) rather than to offset existing or future emissions. Dr. Johannessen also highlighted the importance of blue carbon as a nature-based solution and the potential for CDR to be a large scale solution, but one for which the actual potential effectiveness and risks, are yet unknown.

Some of the questions raised by the audience revolved around the themes presented by Dr. Sarah Cooley during the opening talk, including equity concerns for the global South, skepticism regarding our current capability for MRV given limited existing observational assets, and concern for local to regional scale negative environmental effects related to CDR in the present and future. Some speakers also highlighted that doing nothing is still a choice. It is clear that there is a lot of interest in, and questions, regarding ocean CDR, though there remain concerns and gaps in our current level of knowledge to fully address the feasibility, effectiveness, and impact. The main message of the session was the need for urgent research on ocean CDR approaches, including blue carbon, whilst ensuring that effective and actual risk-free climate solutions have been validated by experiments, so that inter- and intra-generational ethical concerns have been considered and addressed.

This is PMEL contribution #5526.

Dr. Darren Pilcher is a research scientist with the Cooperative Institute for Climate, Ocean, and Ecosystem Studies at the University of Washington and the NOAA Pacific Marine Environmental Laboratory. He's interested in marine and aquatic carbon cycling and the effects of climate change on marine ecosystems. In particular, he studies the effects of ocean acidification on polar ecosystems, including developing ocean acidification indices to help inform marine fisheries. Recently, he's also started working on marine carbon dioxide removal (CDR) approaches, particularly alkalinity enhancement. He primarily uses computational regional ocean models and Earth System Models for this work. Most of his work is in the Bering Sea, though he's also previously worked in the Gulf of Alaska, California Current System, and U.S. Great Lakes.

Dr. Tiziana Luisetti is an environmental economist leading the environmental economics and environmental social science areas at the Centre for Environment, Fisheries and Aquaculture Science (Cefas) in the UK. At IMBeR, Tiziana co-leads Innovation Challenge 6 (sustainable management of blue carbon ecosystems). Tiziana's research takes an interdisciplinary angle, exploring innovative ways to value and sustainably manage coastal and marine ecosystem services and to develop the Ocean (marine natural capital) accounts practice. Her research primarily focuses on the economics around nature-based solutions to climate mitigation and adaptation options such as blue carbon (through mangroves, seagrasses and saltmarshes ecosystems and marine sediments), but also cultural services (e.g. sustainable tourism), food security, invasive species and marine litter. This strand of research feels natural considering that her biggest passion is the sea, and her favourite hobbies include snorkelling and surfing.

Prof. Prateep Kumar Nayak is currently an Associate Professor & Associate Dean of Equity, Diversity, Inclusion and Justice in the School of Environment, Enterprise and Development, at the University of Waterloo. Prateep's academic background is in political science, environmental studies, and international development. He does transdisciplinary work with an active interest in combining social and ecological perspectives. Prateep's research focuses on the understanding of complex human-environment connections (or disconnections) with particular attention to change, its drivers, their influence, and possible ways to deal with them. His main areas of expertise and interest include commons, governance, social-ecological system resilience, wellbeing, environmental justice, and political ecology. Currently, he teaches international development and the environment. In the past, Prateep worked as a development professional in South Asia on issues around community-based governance of land, water, and forests, focusing specifically on the interface of research, implementation, and public policy.

ECCWO5 - S19 Session Report
Ocean Acidification Research for Sustainability
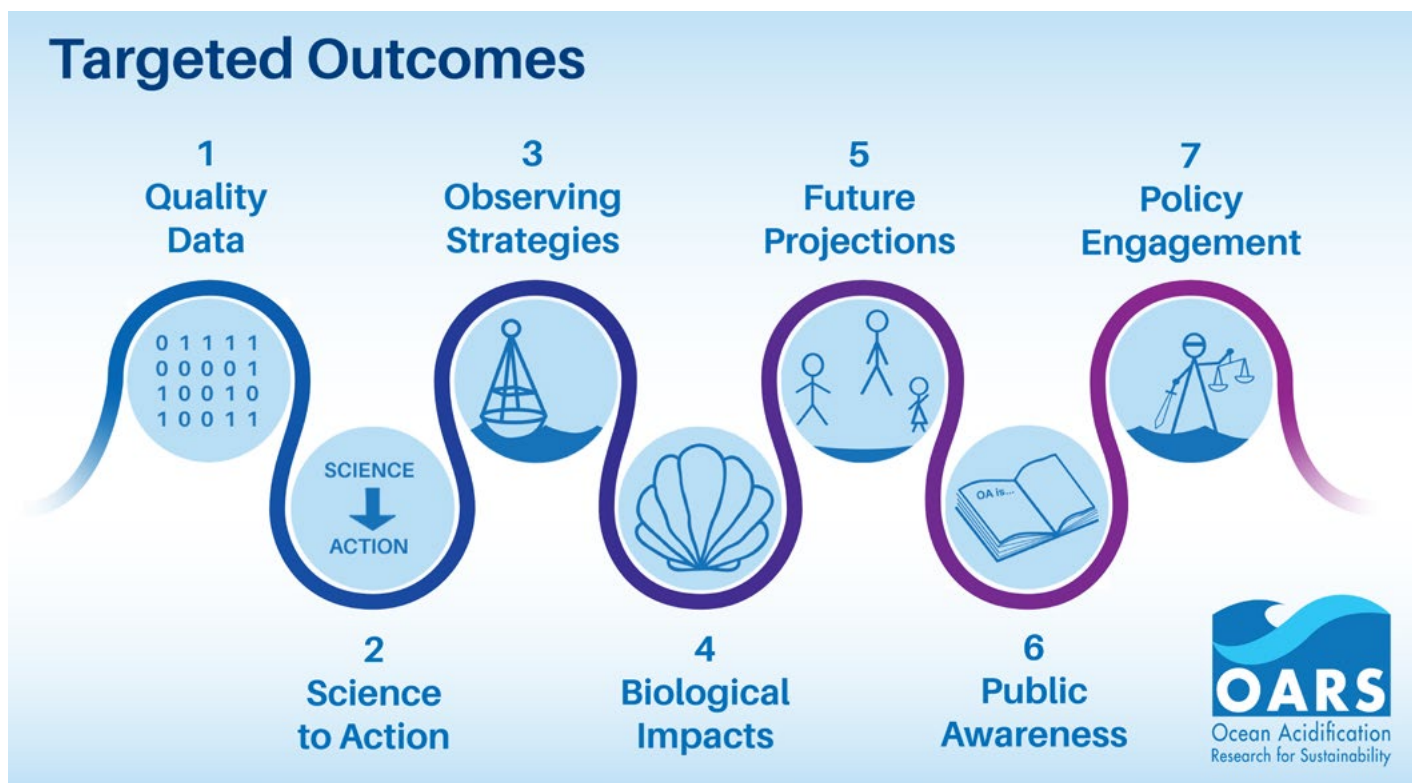*Jan Newton, Katherina Schoo and Kalina Grabb*

Figure 1. OARS outcomes; for further information see: www.oars-un.org.

ECCWO5 Session 19 focused on *Ocean Acidification Research for Sustainability*. The United Nations Decade of Ocean Science for Sustainable Development Programme "**O**cean **A**cidification **R**esearch for **S**ustainability (OARS)" supports the provision of ocean acidification (OA) data and evidence, identifies data and evidence needs for mitigation and adaptation, co-designs and implements observation strategies, and increases the understanding of OA impacts to protect marine life, by 2030. To ensure its success, OARS requires collaboration across the global OA community, spearheaded by OARS "co-champions" to coordinate these efforts, as defined by seven outcomes for the decade to achieve the success we need to better address ocean acidification. This session invited contributions that highlight activities addressing the seven outcomes of OARS (Figure 1, above, details at right).

The talks in session 19, chaired by Jan Newton (University of Washington and OARS co-lead) and Katherina Schoo (IOC-UNESCO and OARS Secretariat), touched on most aspects of what OARS aims to achieve, which we detail in this article, starting with some general observations.

The seven outcomes of OARS are:

1. **Quality Data:** The global science community will be equipped to provide ocean acidification data and evidence of known quality.

2. **Science to Action:** Specific data and evidence needs for mitigation and adaptation strategies, from local to global, will be clearly identified and provided.

3. **Observing Strategies:** Local, regional, and global ocean observing systems will be co-designed and implemented by scientists, funders, and end-user partnerships.

4. **Biological Impacts:** The risks and severity of ocean acidification impacts on marine organisms and ecosystems will be better understood and used to support the protection of marine life.

5. **Future Projections:** We will have accessible, societally relevant predictions of ocean acidification at all scales.

6. **Public Awareness:** The public will be aware of ocean acidification, its sources, and impacts, achieved via ocean literacy and public outreach.

7. **Policy Engagement:** There is wide adoption and implementation of effective OA policy with sustained resourcing in a diverse range of countries.

Co-design and the collaboration with stakeholders is a key feature of the Decade. An overarching highlight of the session was a large number of presenters who showcased their collaborations with local and regional stakeholders, Indigenous communities, as well as the interdisciplinarity of their research. This is particularly important for OA because while it is a global issue, we see local effects of OA across the globe that vary because of specific organisms or unique coastal characteristics; collaboration with diverse local stakeholders increases the value of a global community working together to assess OA and its effects. The Global Ocean Acidification Observing Network (GOA-ON), a collaborative international network of ocean acidification scientists and its regional hubs helps with this need. Many speakers within the session are actively engaged with their regional hubs and the global network. Several speakers stressed the need to involve multidisciplinary communities, across sciences and with local/indigenous communities, and decision makers. The value of 'boundary organizations' e.g., regional ocean observing systems and organizations with years of established and trusted stakeholder engagement, was highlighted as an effective way for scientists to foster this engagement.

Talks from diverse areas of the world showed evidence that the ocean is acidifying. Additionally, speakers stressed that ecosystem effects can be exacerbated by multiple stressors. Thus, the need for a holistic approach including modeling, analysis, and experiments under multiple stressors cannot be emphasized enough.

There were some significant scientific knowledge gaps identified by the speakers. For instance, Alban Planchat (LMD-IPSL, CNRS, Sorbonne Université, Paris, France) relayed that global simulations of $CaCO_3$ export were shown to be relatively unconstrained in terms of its future feedbacks and trajectories. This feedback is an important knowledge gap to constrain. Other speakers highlighted gaps in how our science is conducted. The need to coordinate across disciplines – in particular modeling and biology – was stressed by several speakers. Interdisciplinarity also serves the effectiveness of co-designed studies with decision makers, who require complete information to inform society and provide advice regarding adaptation strategies.

Plenary speaker Punyasloke Bhadury, (Centre for Excellence in Blue Economy and Department of Biological Sciences, Indian Institute of Science Education and Research Kolkata, India) spoke on *"Ocean acidification research for sustainable ocean - nexus between science, local knowledge, and policy framework"* (top right). His talk touched on many OARS outcomes but especially how we can arrive at outcome 7. Using compelling images and stories, he called for us to deepen science engagements
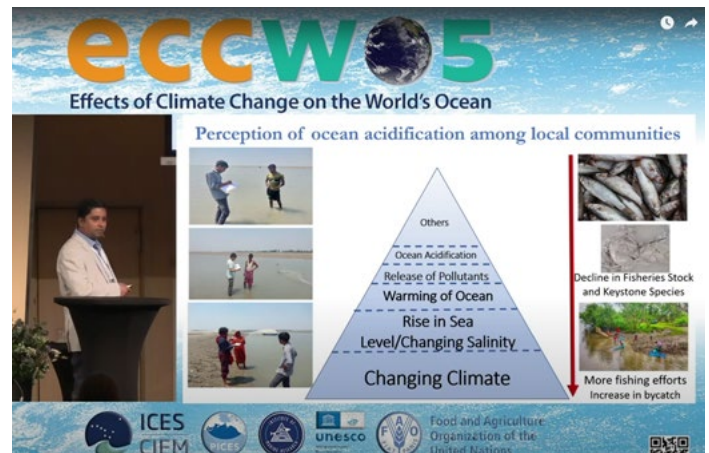
Plenary address by Punyasloke Bhadury, discussing the nexus between science, local knowledge, and policy framework.

to increase OA data and emphasized that Indigenous and local communities need to be consulted and can drive interactions. Raising awareness and understanding of the issue of OA in local communities has been shown to increase the willingness and ability of these communities to formulate and implement mitigation and adaptation strategies. When these strategies are being developed without local community knowledge, they are less likely to be adopted and implemented by the communities most affected. The financing of the research necessary for understanding climate change mechanisms at local scales, and especially with regard to marine ecosystems and their services, is still unresolved.

Invited speaker Samantha Siedlecki leads off the session discussing model projections applied to management needs.

Leading off Session 19, invited speaker Samantha Siedlecki (U Connecticut, USA) spoke on *"Can seasonal forecasts of ocean conditions including ocean acidification variables aid fishery managers? Experiences from 10 years of J-SCOPE"* (above). Her local example is most relevant to OARS outcome 5, showing how communities and scientists can work together with modeled projections to increase preparedness. She cited the need for localized information about OA conditions to support management decisions

– the goal of J-SCOPE (JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem), which is a seasonal time scale forecast used by state and tribal managers and also delivered to Pacific Fishery Management Council in March each year. Her keys to success were to: Work with end-users to determine interests; Focus model evaluation on observations that the community alreadu relies on; Communicate uncertainty; and Co-design decision points with end users and managers. These stakeholders are more likely to use the models and furthermore, they want to use them to make scientifically-informed decisions. A demonstrated and effective way to establish productive and trusting relationships between scientists and end users is through boundary organizations (e.g., ocean observing systems).

The following paragraphs summarize the remaining session 19 talks according to the OARS outcome that they most closely serve. There was at least one talk for each of the seven except for outcome 6, which aims to raise public awareness of ocean acidification, its sources, and impacts, achieved via ocean literacy and public outreach. The scientific community would be well-advised to work collectively to increase public engagement to serve this outcome.

Outcome 1: The global science community will be equipped to provide ocean acidification data and evidence of known quality.

- Friedrich Burger (University of Bern, Switzerland) *"Drivers of surface ocean acidity extremes under different climates"* relayed that ocean acidification extreme events in pH and saturation state are not necessarily linked, as in *"the Blob"* in NE Pacific heatwave.

- Dick Feely (NOAA, PMEL, USA) *"Interactions between acidification and deoxygenation along the west coast of North America"* assessed regional patterns in the Pacific, highlighting local variations within the California Current, driven by circulation and respiration.

- Simone Alin (NOAA PMEL, USA) *"Around the bend and back again: crossing buffering capacity minima in northwest US coastal and estuarine waters and implications for future regional ocean acidification trends and patterns"* spoke on the importance of how the buffering capacity has an inflection point that means the rate of change of CO_2 will vary.

- Agneta Fransson (Norwegian Polar Institute & University Centre in Svalbard) *"Observations in Svalbard fjords as climate change proxies for a changing Arctic: focus on Kongsfjorden, ocean acidification and drivers"* relayed that fjords are different in chemistry due to different water masses with varying interactions with sea ice and glaciers.

- Vineeta Ghosh (Asian Marine Conservation Association, India) *"Role of ocean acidification in changing characteristics of coastal ocean system in Bay of Bengal and Arabian Sea - evidence from pre-and post-Covid 19 lockdown"* found that seawater pH significantly increased from 2017/2019 to 2021.

Outcome 2: Specific data and evidence needs for mitigation and adaptation strategies, from local to global, will be clearly identified and provided.

- Jan Newton (University of Washington, USA) *"The Olympic coast as a sentinel: an integrated social ecological regional vulnerability assessment to ocean acidification"* addressed the place-based social-ecological system approach that is needed to work collectively with tribes, social scientists, and ocean scientists to identify adaptation and mitigation strategies for species that are culturally and economically important to tribes.

Outcome 3: Local, regional, and global ocean observing systems will be co-designed and implemented by scientists, funders, and end-user partnerships.

- Hronn Egilsdottir (Marine and Freshwater Research Institute, Iceland) *"A new laboratory to investigate the impact of multiple drivers on ocean life"* presented on a new laboratory space at the Marine and Freshwater Research Institute in Iceland designed for collaboration with resources to perform multi-stressor experiments and volcanic activity which provides naturally variable temperature and pH.

Outcome 4: The risks and severity of ocean acidification impacts on marine organisms and ecosystems will be better understood and used to support the protection of marine life.

- Laura Falkenberg (The Chinese University of Hong Kong) *"Consumer-resource interactions of calcifying marine organisms under ocean acidification and warming"* looked at the impacts of temperature and OA on gastropods and noted that under future CO_2 conditions, survival reduced as temperature increased.

- Anwesha Ghosh (Indian Institute of Science Education and Research Kolkata, India) *"Phytoplankton community dynamics under potential ocean acidification scenarios: a case study from the indian Sundarbans"* presented that low pH cause diatom population to increase and dinoflagellate population to decrease in the naturally variable environmental conditions within the Sundarbans mangroves and mesocosm experiments.

- Bill Cochlan (San Francisco State University, USA) *"Variable impacts of ocean acidification on the growth and toxigenicity of Pseudo-nitzschia diatoms from the California Current upwelling system"* discussed the variable production of particulate and dissolved domoic acid by harmful algae bloom species *Pseudo-nitzschia australis* and P. multiseries with decreasing pH in incubation experiments.

- Sierra Gray (University of Victoria, Canada) *"Climate change co-stressors and their effects on the biological, physiological, and genomic responses of juvenile pacific oysters"* observed the impact of high temperature and low pCO$_2$ on oysters and found significant differences in the oysters in high temperature after 6 and 12 weeks.

- Masahiko Fujii (Hokkaido University, Japan) *"Observed and projected impacts of coastal warming, acidification and deoxygenation on pacific oyster (crassostrea gigas) farming: a case study in the Hinase area, Okayama Prefecture and Shizugawa Bay, Miyagi Prefecture, Japan"* presented on data from the 20 OA monitoring sites in Japan, two of which also monitor shellfish and identified instances when saturation state and pH thresholds for Pacific oysters were crossed.

- Halle Berger (University of Connecticut, USA) *"Assessing vulnerability of the US Atlantic sea scallop to ocean acidification and warming: a dynamic energy budget modeling approach"* used models to project growth rate and recruitment changes in scallops and predicted that warming and OA could have scallops grow faster but reach smaller ultimate length with potential reproductive implications.

Outcome 5: We will have accessible, societally relevant predictions of ocean acidification at all scales.

- Alban Planchat (LMD-IPSL, CNRS, Sorbonne Université, Paris, France) *"Carbonate pump feedbacks on alkalinity and the carbon cycle in earth system and ocean biogeochemical model simulations"* showed predictions into the future to 2300, where salinity-normalized surface alkalinity could be used to estimate trends in the carbonate pump, which has limited influence on the global carbon cycle.

Outcome 7: There is wide adoption and implementation of effective OA policy with sustained resourcing in a diverse range of countries.

- Evan McGovern (Marine Institute, Ireland) *"The OSPAR assessment of ocean acidification in the North-East Atlantic"* presented a case study introducing scientific trends from observations, synthesis productions, and models into the policy arena to inform management, mitigation, and adaptation discussions.

Dr. Jan Newton is a Senior Principal Oceanographer and Affiliate Professor at the University of Washington and the Executive Director of NANOOS, the Northwest Association of Networked Ocean Observing Systems, part of U.S. IOOS. She is a biological oceanographer with research on coastal dynamics, including effects from climate and humans on water properties and plankton. She has focused on efforts to build ocean observing and connections to society. Her expertise is in linking observations and needs across scales from local to regional to global and engaging with diverse partners. She is a co-director of the Washington Ocean Acidification Center, working with Indigenous tribes and shellfish growers to assess ocean acidification. She is a co-chair of the Global Ocean Acidification Observing Network (GOA-ON) and co-leads its United Nations Ocean Decade endorsed programme Ocean Acidification Research for Sustainability, OARS, to build capacity and improve access to knowledge on OA status and effects worldwide.

Dr. Katherina Schoo is an Associate Project Officer at the Intergovernmental Oceanographic Commission of UNESCO where she works on Ocean Acidification projects and Programmes, with a special focus on the Sustainable Development Goal 14.3.1 Indicator and the global data collection efforts. Katherina is also part of the Global Ocean Acidification Observing Network (GOA-ON) Secretariat supporting capacity building to increase ocean acidification observation and data management. A biological oceanographer officer by training, Katherina has been part of several international and national research projects studying the effect of ocean acidification on marine food webs and trophic dynamics.

Dr. Kalina Grabb is a Knauss Fellow in International Policy in the NOAA Ocean Acidification Program. In this role, she is one of the Global Ocean Acidification Observing Network (GOA-ON) Secretariats where she represents the Pacific Islands (PI-TOA), Latin America (LAOCA), and North America Hubs as well as the early career scientist community (ICONEC). She also supports capacity development related to ocean acidification within the Caribbean and Canada. Prior to her Knauss Fellowship, Kalina earned her PhD in Chemical Oceanography from the MIT/WHOI Joint Program where she studied the dynamics of reactive oxygen species associated with coral. She is passionate about applying science across sectors to make it actionable and accessible to global communities. In her free time, Kalina can be found studying the ocean dynamics through diving, surfing, sailing, kite boarding, and/or long swims on the beach.

ECCWO5 - ECOP update
Conducting Science at the Intersection of Climate Change and Marine Ecosystems - An ECCWO5 interactive Workshop
Erin Satterthwaite, Natalya Gallo, Dawn Barlow, Yassir Eddebbar, Taraneh Westergerling, Emilie Vereide, Holly Perriman, Julie Keister, Sonia Batten, Steven Bograd, Hannah Lachance and M. Kelsey Lane

The ECCWO5 Symposium helped to facilitate the development of lasting relationships, which are an essential part of efforts to build a global community to address sustainability and resilience in a changing climate. ECCWO5 brought together experts from around the world to better understand the effects of climate change on ocean ecosystems and share potential solutions, such as the implementation of adaptation and mitigation measures.

During the symposium, Early Career Ocean Professionals (ECOPs) from around the globe organized in-person and virtual interactive workshop sessions focused on the theme of, *"Conducting Science at the Intersection of Climate Change and Marine Ecosystems."* The goals of the sessions were to bring together professionals across career stages, sectors, disciplines, and countries for networking and connection.

The virtual session brought together seven early career ocean professionals from seven different countries and four continents. Virtual participants shared their research and discussed opportunities and challenges in finding and fostering international collaborations. The in-person workshop brought together >75 ocean professionals in a lively set of interactive roundtable discussions that explored topics at the intersection of climate change and marine ecosystems. 7 tables were facilitated by 1-2 people from different career stages and there were two rounds of discussion with participants choosing two tables/topics. The discussions in the networking session covered a range of topics related to science and policy, career sustainability, international collaborations, communicating uncertainty, local impacts of climate change, and sustainable fisheries.

Ocean professionals from early to advanced career stages shared their experience and recommendations on conducting science at the intersection of climate change and marine ecosystems. A few themes from both sessions emerged. These include:

Connection & relationship building

- Engage policy makers in a two-way dialogue and early on to build trust, learn about what matters most to them

- Build and foster international collaborations through mentors, events, and networking opportunities, and sustain those relationships

- Utilize international collaborations as a way to provide opportunities for collaborators to expand skill sets, access different resources, learn different research cultures, share knowledge across similar systems (e.g., Eastern Boundary Upwelling Systems), and to bring new ideas and different diverse experience to challenging research problems

- Provide support (e.g., financial and regulatory) to promote international collaborations

Communication

- Hone your key message by simplifying, clarifying, and shortening your main points but understand that there is a tradeoff between being clear and straightforward in our message, and being complete and honest.

- Understand and communicate the uncertainties associated with your work and frame in more nuanced ways (e.g., focus on our level of confidence in the results)

- Use local stories and local impacts to connect with local communities

- Allow more emotion in pragmatic science to connect and communicate results and predictions

Sustainability of ocean professionals

- Ensure career paths are sustainable by providing support especially through opportunities to focus on research and career as well as time to recharge.

- Holistic, long-term approaches that, as much as possible, consider ecological, economical and social factors are important to ensure the sustainability of ocean professions (e.g., fisheries).

- Be understanding, open, and empathetic to different, non-traditional, career paths.

The in-person event was followed by a networking hiking event up Floyen (see photo at right) which brought nearly 100 people to climb up the mountain above Bergen. Overall, the event was well received, and some participants shared that the events provided a great opportunity to meet and connect with other people at the conference.

Erin Satterthwaite is a translational marine ecologist with California Sea Grant at Scripps Institution of Oceanography, UCSD. She works at the interface of applied marine research, diverse stakeholder engagement, and data communication to advance ocean knowledge for sustainability, on topics related to marine biodiversity, ocean observations, diverse engagement & knowledge co-production, fisheries & sustainable blue economy, social-ecological systems, participatory science, and biological oceanography. She is currently supporting coordination of the longest integrated marine ecosystem time series, CalCOFI; inclusion of under-represented voices – such as ECOPs – into knowledge co-production for sustainability; and integration of ecological and social observations into ecosystem-based management.

Yassir Eddebbar is an Assistant Research Scientist at Scripps Institution of Oceanography, at the University of California San Diego. His work combines observations and models to improve our process understanding and future projections of anthropogenic climate change impacts on marine ecosystems and the global carbon cycle.

Sonia Batten is the PICES Executive Secretary, based at the Secretariat in BC, Canada. In her former life she was a biological oceanographer studying plankton with a focus on large scale processes and using long term monitoring to study the impacts of climate variability on lower trophic level dynamics.

Julie Keister is a Program Manager in NOAA's Alaska Fisheries Science Center.. Prior to joining NOAA Fisheries in 2022, Keister was a Professor in the School of Oceanography and Adjunct Professor in the School of Aquatic and Fisheries Sciences at the University of Washington, in Seattle. Her research focuses on understanding the impacts of climate change on marine communities, principally zooplankton and the fisheries that depend on them.

Dawn Barlow is a Postdoctoral Scholar at Oregon State University's Marine Mammal Institute. Her research focuses on the ecology of marine mammals, combining tools such as species distribution modeling, bioacoustics, and oceanography to inform conservation management.

Holly Perryman is currently a Postdoctoral Scholar at the College of Marine Science at the University of South Florida. Her education centers around mathematical modeling, with much of her research pertaining to marine ecosystem modeling with the Atlantis framework. Her work includes model development and evaluation, management strategy evaluation, and climate change impacts.

Hannah Lachance is the International Fisheries Science Specialist for Leading Solutions in support of NOAA Fisheries but previously worked as a freshwater fisheries ecologist. In addition to a desire to enhance scientific engagements in the international realm, Hannah has a passion for supporting the integration of ECOPs into the Ocean Professional space and currently serves as one of the UN Decade US ECOP Node co-leads, a PICES ECOP Advisory Panel Co-Chair, and the SUstainability, Predictability and REsilience of Marine Ecosystems (SUPREME) ECOP lead.

M. Kelsey Lane is a PhD student in Ocean, Earth and Atmospheric Sciences at Oregon State University. Her research is focused on how marine heatwaves impact microzooplankton communities and using molecular tools to elucidate plankton community interactions.

ECCWO5 - Presentation Awards
Lori Waters

#ECCWO5 Attendees at the well-attended evening poster session.

Enormous gratitude is extended to the team of judges who had the unenviable job of choosing the winners for the #ECCWO5 Outstanding poster & presentation awards, from a large volume of worthy candidates. The purpose of these awards is to recognize, engage, and encourage excellence in Early Career Ocean Professionals (ECOP) presenters at #ECCWO5. Judging was coordinated by Mette Skern-Mauritzen from the Institute of Marine Research in Bergen, and judges included: Ana Queiros, David Schoeman, Noel Keenlyside, Tsuneo Ono, Alison Macdonald, Anne McDonald, Karin Limburg, Janet Nye, Ricaardo Oliverso Ramos, Arani Chandrapavan, Christian Pansch, Anders Frugård Opdal, Marco Reale, Gro van der Meeren, Samuel Rastrick, Renato Salvatteci, Geir Ottersen, Becca Selden, Agata Weydmann-Zwolicka, Frederic Cyr, Maureen Trnka, Meng Xia, Jack Barth, Manuela Krakau, Kelly Kearney, Lisa Crozier, Steve Latham, Michelle McClure, Charles Hannah, Frank Wesonga, Mike Litzow, Sung Yong Kim and Jörn Schmidt.

The awards were sponsored by EuroMarine Oyster Program (Orienting Young Scientists of EuroMarine) and the Journal of Marine Science and Engineering, who kindly provided an honoraria for the awardees.

Posters and presentations were judged on their merits according to the following criteria:

- **Scientific and societal value** – relevance, approaches, scope and generality, originality and conclusiveness

- **Structure and content** – structure, visual quality, logical storyline, easily understandable, effort involved

- **Verbal presentation** – clarity of verbal communication, enthusiasm, eye-to-eye contact, posture

- **Visual aids** - clarity, simplicity, relevance, easily understandable.

There were eight poster presentations selected for the shortlist, and the winners of the three Outstanding Poster Presentation Awards were:

- **Alaia Morell f**or *"Multispecies eco-evolutionary dynamics of North Sea exploited fish under climate change."*

- **Kalina C. Grabb** for *"Measuring Protons with Photons: A Hand-Held, Spectrophotometric pH Analyzer for Ocean Acidification Research, Community Science and Education."*

- **Jessica A. Bolin** for *"Forecasting and projecting swordfish quality for industrial climate adaptation."*

Ten presenters were shortlisted for the Outstanding Oral Presentation Awards, and the three winners were:

- **Dylan G.E. Gomes** for *"Integrating Information into end-to-end ecosystem models: data accessibility challenges and solutions."*

- **Alexa Fredston** for *"Marine heatwaves are not a dominant driver of change in North Atlantic and Pacific fish communities."*

- **Tom J. Langbehn** for *"Model evidence for photic barriers to poleward range shifts."*

We heartily congratulate the winners of these awards, and wish them continued success with their work and careers.

ECCWO5 Outstanding Poster Presentation Awardees

Alaia Morell

"Multispecies eco-evolutionary dynamics of North Sea exploited fish under climate change."

Kalina C. Grabb

"Measuring Protons with Photons: A Hand-Held, Spectrophotometric pH Analyzer for Ocean Acidification Research, Community Science and Education."

Jessica A. Bolin

"Forecasting and projecting swordfish quality for industrial climate adaptation."

ECCWO5 Outstanding Oral Presentation Awardees

Dylan G.E. Gomes

"Integrating Information into end-to-end ecosystem models: data accessibility challenges and solutions."

Alexa Fredston

"Marine heatwaves are not a dominant driver of change in North Atlantic and Pacific fish communities."

Tom J. Langbehn

"Model evidence for photic barriers to poleward range shifts."

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Interdisciplinary collaboration for effective adaptation
Francesca Barazzetta, Eurofish

The following article was first published in EuroFish magazine and is reprinted here with permission, for the interest of PICES colleagues, and to provide an alternative view of the ECCWO5 Symposium, specifically through the lens of fisheries. Other organizations also covered #ECCWO5 from other perspectives - including this one written by from Francesca Barazzetta from Eurofish. ECCWO5 received excellent feedback from many organizations, including this writeup from Plymouth Marine Laboratory, whose interdisciplinary scientists Dr Ana Queiros, Dr Océane Marcone, Dr Elizabeth (Liz) Talbot and Dr Stefanie Broszeit, all presented at ECCWO5.

Highlights from the fifth ECCWO symposium

Interdisciplinary collaboration for effective adaptation

The 5th Symposium on the Effects of Climate Change on the World's Ocean (ECCWO5), organised by the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES), the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), the Food and Agriculture Organization of the United Nations (FAO), and the Norwegian Institute of Marine Research (IMR), was held in Bergen from 17 to 21 April 2023.

This year's event was a hybrid version with both in-person and online attendance. The symposium brought together experts from around the world to discuss the latest knowledge on the effects of climate change on the world's oceans, the risks, challenges, and gaps, as well as potential solutions for adapting and mitigating these impacts. The very rich programme covered topics such as climate vulnerability assessments, which involve assessing the risks that climate change poses to various socio-ecological systems, marine spatial planning, reducing carbon dioxide emissions from fishing vessels, and improving ecosystem management and species dynamics, among many others.

The topic of vulnerability received particular attention—it was discussed on three days of the event at different sessions. In addition, a special workshop was held prior to the event to prepare attendees for the in-depth discussions that were to take place. The sessions consisted of 10-15 presentations each day and they showcased various studies providing valuable observations into the complexities of climate change's impacts on fisheries and related dependent communities. Some studies provided insights into the multidimensional nature of vulnerability, which includes social, political, ecological, and economic aspects. One of the speakers explained how vulnerability results from the lack of access to capital assets—human, physical, natural, social and financial—meaning the absence of well-being. Hence, building resilience, the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate, represents a way of dealing with vulnerability and responding to challenges. Existing tools to assess the vulnerability and risks to the impacts of climate change were also presented.

Artisanal fishers competing with industrial fleets are less able to adapt to climate change

Specifically, the risk assessment framework, developed by the Intergovernmental Panel on Climate Change, was applied in a case study on Ghanaian fisheries to evaluate the most climate-sensitive species, and the most vulnerable fisheries in the area. Among the 39 species assessed whose catches have been recorded in Ghana, using indicators such as biological traits, habitat preferences, and species' thermal tolerance, the study identified snappers, groupers and Congo dentex as the most climate-sensitive species of these fisheries. Among the nine fishery sectors present in Ghana, the artisanal demersal purse seine sector was shown to be the most sensitive fishery with a low adaptive capacity compared to other fisheries due to competition with industrial fisheries and the catching of highly sensitive species such as the bigeye grunt. Difficulties in adapting or transforming due to competition with industrial fisheries seem also to occur in artisanal fisheries targeting small pelagics in Galicia, Spain. These fishers appear to be more vulnerable than others due to the effort control management in place and to the total allowable catch (TAC) control measure in which artisanal fishers have to compete for the same resources with industrial

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The 5th Symposium on the Effects of Climate Change on the World's Ocean (ECCWO5) was held physically in Bergen, Norway, and virtually. The event was attended by over 700 people of which a third logged in remotely.

fisheries. The case study identified how artisanal small pelagic fishers are more likely to exit the sector from climate impacts due to their vulnerability.

This research will continue trying to understand fishers' historical perspective on TAC regulation and the related impacts on artisanal fisheries, since a higher number of fishers used to target small pelagics in the past compared with today. Other studies also revealed that adaptation strategies to be effective should consider different characteristics including individual factors such as personal knowledge, and experience, community dynamics—bonding relationships among fishers and institutions, management context, and co-production of knowledge with local communities. A study conducted in the Sundarbans, Bay of Bengal, sheds light on the impact of climate stressors on small-scale

inland fishing, specifically on forest fishers who catch prawns and crabs. The study shows that cyclones have a significant effect on local fisheries and that the co-production of knowledge with local communities can lead to better adaptation strategies. The research stresses the active role of fishers in coping with the risk generated by cyclones. In response to the challenges faced, the communities have improvised and started using ponds in their own households instead of continuing fishing in the inland forest. However, fishers were facing some challenges as they needed some scientific and technical knowledge. In response, academics and fishers have started a co-production of a training module for inland fishing. The co-learning experience also helped in re-understanding the way climate change is explained from an academic point of view. Overall, the study illustrates the importance of

co-producing knowledge with local communities to develop better adaptation strategies that are more relevant to their needs and realities.

Fishers' associations play an important role in their members' ability to adapt to climate change

Another study conducted with six small-scale fisheries communities in the Nayarit region of Mexico, a hotspot of climate change, sought to assess the potential response of fishers to a decrease in their catch due to climate impacts. The study found that fishers' perceptions of their catch volume between 2011 and 2021 decreased by 50%, with the majority of species caught decreasing except for Sphyraenidae. The study highlighted the role of community dynamics, fishing permits, and fisheries management in the

capacity of fishers to adapt to climate change. The interactions of fishers with their peers facilitated the process of continuing fishing, as did the availability of fishing permits provided by patrons. Fishers' associations were found to be crucial in creating safety nets within the communities, supporting each other in terms of knowledge and capacity. This study emphasised the importance of participatory approaches and co-production of knowledge, as fishers need to organize themselves to be resilient to the future. The findings suggest that supporting fishers' associations and providing relevant information can help small-scale fisheries communities adapt to climate change, and this is a critical aspect to consider for the long-term sustainability of small-scale fisheries in the region.

Overall, the symposium highlighted the urgent need for action to address the impacts of climate change on the world's oceans. Experts explained that the consolidation of effective adaptation strategies requires interdisciplinary collaboration and knowledge among the many actors involved to address the multidimensional nature of vulnerability and support resilience in fishery systems. However, they also emphasised the need for continued research to better understand the complex interactions between climate change and marine ecosystems and to develop more effective solutions to adapt and cope with these impacts.

Francesca Barazzetta, Eurofish International Organisation, francesca.barazzetta@eurofish.dk

PICES-MAFF Ciguatera Project – Summary of Activities

Mark Wells, Mitsutaku Makino, Alex Bychkov, Daisuke Ambe, Seung Ho Baek, Vladimir Kulik, Shion Takemura, Naoki Tojo, Vera Trainer, Charles Trick, Pengbin Wang, Suhendar Sachoemar and Arief Rachman

The request from the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan to undertake the project "Building local warning networks for the detection and human dimension of Ciguatera Fish Poisoning in Indonesian communities" (Ciguatera) was approved by PICES Governing Council in February 2020.

Project background

Benthic harmful algal bloom (HAB) species, such as the causative organism underlying Ciguatera Fish Poisoning (CFP), arguably have the greatest human health and economic impacts of any algal-based poisoning syndromes. CFP stems from the human consumption of fish containing toxins produced by benthic microalgae of the dinoflagellate genera *Gambierdiscus* and *Fukuyoa*, which are the initial sources of ciguatoxin. The effect of CFP on the human dimension extends far beyond the proximate health and economic outcome – chronically impacted communities become fearful of local and other fish sources and may alter their cultural heritage by transitioning from their traditional way of life to one where all protein is imported from foreign sources.

CFP is endemic in many tropical Pacific regions. Although ciguatera and other toxin-producing benthic HABs can occur in pristine environments, anthropogenic pressures and climate change are leading to its emergence in new regions, and intensification in others. There is evidence of range extension of these species into the waters of PICES member countries, which is raising significant concerns. The expansion of dead corals and eel-grass habitats that replace healthy coral reefs facilitates intrusion and establishment of exotic populations of toxin-producing benthic algae. Despite the widespread impacts of benthic HABs, the resultant health and socioeconomic effects remain poorly understood.

Indonesia was chosen as a developing Pacific Rim country to implement the project as the country is part of the Coral Triangle, the most biodiverse marine area on earth. Its extensive reefs are key to maintaining the ecological products that contribute to fisheries in this region. However, presently only about 7% of these coral reefs are in excellent condition, while anthropogenic stressors have left more than 35% in poor condition. Decreasing coral health in Indonesia is a relatively new phenomenon compared to other areas of the world, and human coastal populations living adjacent to the deteriorating corals are not yet fully aware of the consequences of this change. Communities must understand the risks of exposure to keep the impact of benthic HABs to a minimum. The highest risk is when the reefs, which communities depend on for fish, have large patches of dead coral or large seagrass mats, as these surfaces are ideal for the growth of benthic algal cells. Current reports of benthic HAB occurrences such as CFP are low in Indonesia, almost certainly because diagnosis is difficult without proper training and experience.

Project objective and initiatives

The objective of the 3-year (April 1, 2020 – March 31, 2023) Ciguatera project was to build the capacity of local small-scale fishers and community members to monitor their coastal ecosystems and coastal fisheries to benefit human health in Pacific Rim developing countries. The project's focus was to detect and monitor benthic HAB species in tropical reef fisheries to ensure seafood safety. The project was funded by MAFF, through the Fisheries Agency of Japan (JFA), from the Official Development Assistance (ODA) Fund. The total MAFF contribution was $292,653 CAD.

Consistent with the directives of the United Nations Decade of Ocean Sciences for Sustainable Development (UNDOS), the project included three major initiatives:

1. Coastal ecosystem monitoring activities by local small-scale fishers and other community members to detect ecosystem changes (e.g., changes in water quality and the presence and changes in the spatial distribution of dead coral and eel-grass benthic environments) using smartphone-based technology developed during the 2017–2020 PICES-MAFF project on *"Building capacity for coastal monitoring by local small-scale fishers"* (FishGIS) and modified/refined during the Ciguatera project;

2. Detection of CFP toxin-containing dinoflagellates in the reef environment using two approaches: (a) implementation of smartphone-based tools developed during the FishGIS project and modified during the Ciguatera project, and (b) employing internationally-standardized sampling protocols for toxic benthic algae;

3. Training of local fishers and community members to utilize these tools for generating citizen-science data available for local decision-making on coastal fisheries to avoid the transfer of contaminated fish to the tables of families until the presence of CFP toxin-containing dinoflagellates is minimized.

In addition to the primary initiatives, early steps have been taken to explore two secondary initiatives: modifying the FishGIS application to incorporate (1) artificial intelligence-based assessment of fish stocks from the collective catch data reported by the local fishers, and (2) a tsunami early warning notification for remote fishing communities, with the goal of laying the foundation for future full development of these capabilities.

Figure 1. Participants of the seventh PST meeting held March 16–18, 2023, in Yokohama, Japan (l to r):): first row – Suhendar Sachoemar (ITI, Indonesia), Pengbin Wang (S-HAB, China), Mitsutaku Makino (HD, Japan), Tatsuki Oshima (MAFF/JFA, Japan), Dong Wook Kim (NIFS, Korea), and Mihye Hwang (MOF, Korea); second row – Alexander Bychkov (PICES), Charles Trick (S-HAB, Canada), Mark Wells (S-HAB, USA), Naoki Tojo (FIS, Japan), Daisuke Ambe (TCODE, Japan), Seung Ho Baek (S-HAB, Korea), Shoto Sato (MAFF/JFA, Japan), Moonho Son (NIFS, Korea), and Arief Rachman (BRIN, Indonesia); missing from photo – Shion Takemura (HD, Japan).

Project organization in PICES

The project had strong connections with the PICES Scientific Committees on Human Dimensions (HD), Marine Environmental Quality (MEQ) (through the Section on Ecology of Harmful Algal Blooms in the North Pacific – S-HAB) and Fishery Science (FIS), PICES Technical Committees on Data Exchange (TCODE) and on Monitoring (MONITOR), and the PICES FUTURE science program. HD was the parent committee for the project.

To direct the project, a Project Science Team (PST) was formed by PICES Science Board based on principles and procedures detailed in the PICES Policy for approval and management of special projects (Decision 2017/A/7). All PICES member countries and all relevant committees were represented on the PST, led by Drs. Mitsutaku Makino (HD Chair, Japan) and Mark Wells (S-HAB Chair, USA). The PST Co-Chairs were responsible for the detailed planning and execution of the project, and annual reporting on its scientific progress to MAFF/JFA and to Science Board through the HD Committee. Dr. Alexander Bychkov was appointed to serve as the Project Coordinator and was responsible for fund management, and for the annual reporting to MAFF/JFA and to PICES Finance and Administration Committee.

During the lifetime of the project, the PST had seven formal meetings. Due to the COVID-19 pandemic, the first five meetings (all meetings in Year 1 and Year 2) were held online, and only the last two meetings in Year 3 (September 2022 in Busan, Korea and March 2023 in Yokohama, Japan) were in-person (Figure 1, above).

Project support in Indonesia

The importance of having more effective fisheries management practices is widely recognized in Indonesia, which has led to support by the federal government and stakeholder willingness to consider new approaches such as the development and implementation of a citizen/fisher-based observation system linked with fisheries scientists and managers. The Ciguatera project was the fourth PICES project in Indonesia funded by MAFF, with its foundation being the strong collaborations developed with the Indonesian government agencies and research institutions during PICES-MAFF projects conducted in the period from 2007 to 2020. One of the first, and strongest, lessons learned from these projects is the importance of connecting with organizations in a developing country which can facilitate and advance the project – these organizations and their key people are needed to understand the project and to translate it into the local context.

The Indonesian Agency for the Assessment and Application of Technology (BPPT) and the Indonesian Institute of Sciences (LIPI) were our major partners for the previous three PICES-MAFF projects (for more than a decade!) – "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" (2007–2012), "*Marine ecosystem health and human well-being*" (2012–2017; MarWeB), and "*Building capacity for coastal monitoring by local small-scale fishers*" (2017–2020; FishGIS). Recently, BPTT and LIPI have been incorporated into the National Research and Innovation Agency of Indonesia (BRIN), which better enables the collective collaboration in the Ciguatera project. Project activities also were supported through the Memorandum of Understanding between PICES and the Indonesian Institute of Technology (ITI) (signed in March 2022), and by the Provincial Government of West Nusa Tenggara, which provided invaluable assistance in organizing a training and knowledge dissemination workshop in Lombok, in January 2023.

Activities and outputs

Project Design Matrix

A Project Design Matrix (PDM) was developed by the PST to effectively manage the project. The PDM describes the logical structure of the project (the links between activities and objectives) as well as the data to be obtained. This framework assists in the planning process, facilitates communication of the "why" and "how" of the project, and provides a basis for assessing the project progression. It is structured to list the Project Goals (to codify the overriding objectives), the Project Purpose (the intended impacts and anticipated benefits), the Results/Outputs (the objectives the project management must achieve and sustain), and the Activities (steps taken to achieve the desired results/outputs). However, due to COVID-19, we were unable to take full benefits from this approach as the pandemic seriously affected the flow and progress of this project, especially by limiting the opportunity for PST members to visit field sites and organize meetings and training workshops with local people.

Observation tools

The 2017–2020 FishGIS project led to the development and implementation of smartphone tools (FishGIS application) for fisheries and environmental observations, such as water quality aspects, phytoplankton, fish catch, floating garbage (plastics) and Illegal Unregulated and Unreported (IUU) fishing, by local small-scale fishers and community members in Indonesia. The Ciguatera project was expected to adapt and refine these smartphone capabilities for measurement and automated reporting and to combine them with new automated technologies for plankton species identification.

The updated version of the FishGIS application is now available on Apple Store and Google Play and can be installed on iOS 10 and Android 7 or later smartphone devices. The major modifications include: (a) an improved user interface, (b) a reporting scheme that is consistent with ABS (Access to genetic resource and Benefit Sharing) rules of the UN Convention of Biological Diversity, (c) a function allowing

to directly launch the HydroColor water quality application, (d) a function allowing to directly launch the Info BMKG application (provided by the Indonesian government agency for Meteorology, Climatology, and Geophysics) to better incorporate a tsunami early warning notification for remote fishing communities, e) a function to map Ciguatera field survey data and to accumulate fisheries-related data (from photos of fish species in local fish markets), and (f) a dashboard for data management.

Planktoscope is a low-cost microscope platform that allows automated image collection of phytopolankton cells in a simple flow-through system. These images are uploaded to a dedicated server where artificial intelligence software can be trained to identify and quantify the composition of the phytoplankton assemblage. This tool will revolutionize plankton monitoring and is particularly suited to this project. A successful pilot deployment of several Planktoscopes took place during the January 2023 training workshop.

Field sampling program

Based on recommendations from our Indonesian colleagues, the Gili Islands (Gili Matra) region (West Nusa Tenggara Province) was selected as a case study site. The two criteria for selecting this site were the existence of a well-established local fishing community and an active BRIN research station in the area.

Initially, the field observations were planned to be carried out by local small-scale fishers and community members. However, the pandemic-related delays to the planned on-site training workshops led to augmenting and expanding BRIN-planned surveys of waters surrounding Gili Matra (consisting of three islands: Gili Trawangan, Gili Meno, and Gili Air) to facilitate data collection. A portion of Ciguatera project funds was re-directed to support a total of five extended surveys conducted in different seasons (Dry, Wet, Transition) during the period from May 2022 to February 2023. The smartphone-based FishGIS and HydroColor tools were actively used in these observations. In addition to water column and benthic samples, fish caught around Gili Matra were purchased for ciguatoxin analysis. Researchers from BRIN and the Mataram University also collected basic socioeconomic information in the area using the same methodology as in the previous PICES-MAFF projects (on-site surveys, questionnaires, and focus group discussions). Analysis of samples is still ongoing, but preliminary results indicate that the threat of CFP in this area is low. These activities in Lombok area were widely reported by the Indonesian mass media. Two talks on the Cituatera project by Indonesian researchers were presented at the 2022 PICES Annual Meeting in Busan.

Considering that one of the main goals of the project is capacity building, the PST has supported six undergraduate students from the University of Indonesia, Mataram University and ITI (two from each) to participate in the field sampling program by providing them partial tuition.

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Figure 2. Training workshop held January 25–27, 2023, in Lombok, Indonesia; Participants learn a and b) the FishGIS smartphone applications; c and d) Planktoscope, and e) HydroColor smartphone application; f) PICES experts at the Closing Ceremony.

Community training workshop

It was expected that the project's primary initiatives would be supported by a series of capacity building workshops led by PICES scientists, aiming to work with local communities to increase the sustainability of their fishing resources by providing them with CFP information. Due to COVID-19 though, only one training and knowledge dissemination workshop was held close to end of the project, on January 25–27, 2023, in Lombok. The main objectives of the workshop were to: (1) inform the community and policy makers in the Gilli Matra region on the goals of the project and technology for monitoring environmental conditions to increase their knowledge and understanding of CFP and ensure food safety and health of the aquatic environment and fishery resources, and (2) provide hands-on training in the water and plankton sampling, use of the FishGIS and HydroColor smartphone applications, and phytoplankton observations with Planktoscope (Fig. 2). This workshop was attended by more than 90 coastal community members and researchers and students from BRIN, ITI, University of Indonesia, Mataram University and provincial institutions.

Risk assessment model

A bow-tie risk assessment model (a modified version of the ISO 30100 risk assessment model) was constructed. This model summarizes the connections among coastal environment, ciguatoxins, human exposure to these toxins and the CFP risk, and demonstrates the principles of how the project's activities can prevent, adapt, and mitigate the risks. The model still needs to be linked to empirical data.

Next steps

Due to the COVID pandemic, not all of the originally planned activities for the Ciguatera project have been implemented. Fortunately, a new 3-year (2023–2026) PICES-MAFF project, entitled *"Creating a phytoplankton-fishery observing program for sustaining local communities in Indonesian coastal waters"* (FishPhytO), has been approved, with expectation that a major case study site will be in the Gili islands region, where a field sampling protocol has been already developed, preliminary network of local people and researchers has been set, and basic knowledge and technologies have been disseminated among the key people. Project activities will be supported by the existing PICES-ITI MOU and by the Provincial Government of West Nusa Tenggara which has already expressed strong interest and political will to assist in implementation of future PICES-MAFF projects.

Exploring National ECOP hubs in PICES member countries
*Raphael Roman, Minkyoung Kim, Jae-Hyoung Park, Kotaro Tanaka, Yushi Morioka,
Hana Matsubara, Ashley Bowes, Neha Acharay-Patel, Chunhua Jiang, Celina Harris,
Hannah Lachance, Erin Satterthwaite and Evgeniia Kostianaia*
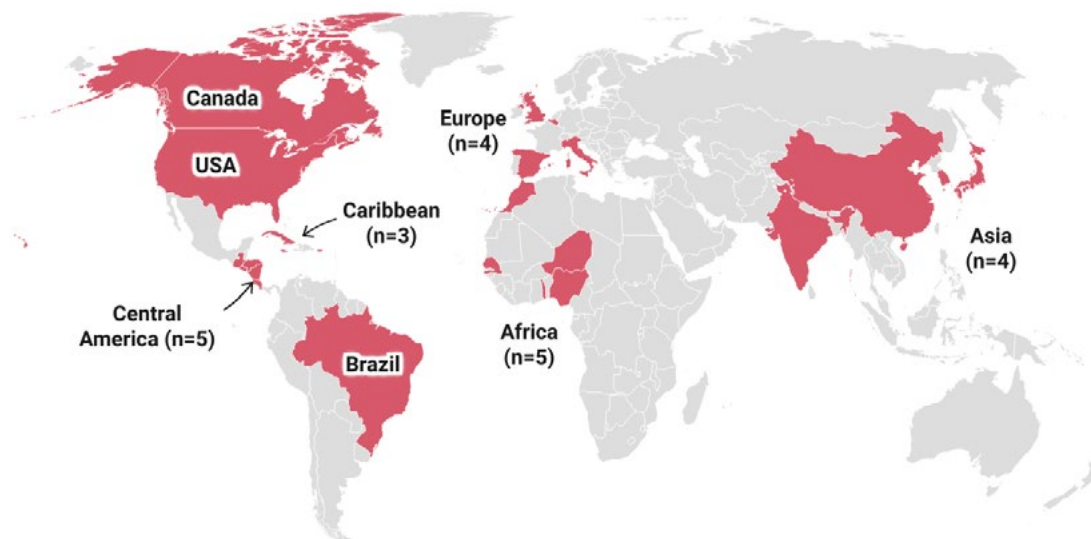
Global distribution of National ECOP nodes, as of May 2023.

The Early Career Ocean Professional Programme (ECOP Programme) is a Global Network Programme that was endorsed in June 2021 by the United Nations Decade of Ocean Science for Sustainable Development (2021–2030). As the ECOP Programme turns 2-years old on June 8, 2023, its geographical reach has increased remarkably, with no less than 5 regional nodes (in Africa, Asia, Caribbean, Central America and Europe) and 24 different national hubs. While not all ECOP nodes are at the same development stage, a little more than half have already been formalized with a presence on the ECOP website. More information about their mission, goals, activities and governance structure is available here.

Across the North Pacific, as of June 2023, all but one PICES member countries have an established ECOP node, with their own initiatives, collaborative ecosystem, engagement pathways and communication platforms. ECOP Canada was one of the very first nodes to become public in late 2021 (alongside Africa and Asia), before ECOP Japan and ECOP South Korea emerged in the summer of 2022, while the US ECOP node became official in the winter of 2023. ECOP China has been active since late 2022 (more information below) but is currently finalizing their governance structure and strategic vision, to ensure long-term sustainability beyond the end of the UN Ocean Decade in 2030. Russia is the only PICES member country who is missing a national ECOP team and engagement framework. Some ideas to get started with ECOP Russia are shared at the end of this article. In the following sections.

This article details the structure of each national ECOP node, what they have accomplished and are working on, and how people can get involved.

ECOP South Korea

ECOP South Korea is a network, currently of 94 emerging Early Career Ocean Professionals (ECOPs), from different backgrounds in South Korea, composed mainly of young early career experts who are passionate about understanding the ocean. With membership from across the country and abroad, the expertise of ECOP South Korea's members spans a broad range of topics, including ocean circulation, biogeochemistry, marine biology, and climate change. With access to state-of-the-art research institutions and facilities, and a supportive scientific community, ECOP South Korea strives to facilitate entry and engagement with the UN Decade of Ocean Science, promote both domestic and international research networks for oceanographic research, and to foster an Ocean Sustainability Nexus for researchers and other ocean stakeholders, including local communities. Our goal is to keep in touch and communicate for collaboration opportunities, job information, etc.

The national ECOP node was launched with its first virtual meeting in August 2022, followed by an in-person coordination meeting in April 2023 (composed of 5 males and 1 female), which was attended by: Prof. Jae-Hyoung Park: Physical Oceanographer; Dr. Bumsoo Kim:

Paleoceanographer; Prof. ChanHyung Jeon: Physical Oceanographer; Dr. Hyung-Gyu Lim: Climatologist; Prof. Minkyoung Kim: Chemical Oceanographer; and Prof. Seung-Tae Yoon: Physical Oceanographer.

During the spring meeting of the Korean Society of Oceanography that took place on 2-3 May, 2023 in Busan, the South Korean ECOP node organized several activities, including:

1. An "ECOP table" for communications among K-ECOP members;

2. A voluntary session or "Dissertation symposium" for ECOPs, which included 10 presentations (oral: 6, poster: 4);

3. An offline meeting between members of the coordination unit, during which we discussed plans for short video interviews of K-ECOP members, mentoring opportunities during conferences, and collaboration with the JOISS Ocean Big Data Project.

ECOP South Korea is working to resolve some issues and further clarify questions such as the role of ECOP, the range of ECOP members, and research into funding opportunities for sustainable activities. Anyone wishing to register with ECOP South Korea, to join the group and/ or receive updates on activities and ocean opportunities happening in South Korea, can contact the group at: ko.ecop.staff@gmail.com. Additional information and resources are also available on the ECOP South Korea website: https://www.ecopdecade.org/south-korea/.

K-ECOP special session during the spring meeting of the Korean Society of Oceanography in Busan (2-3 May 2023)
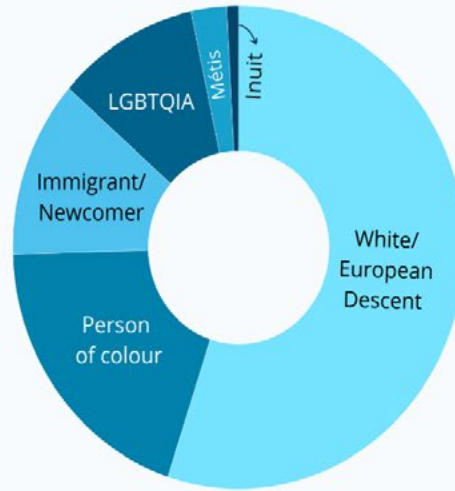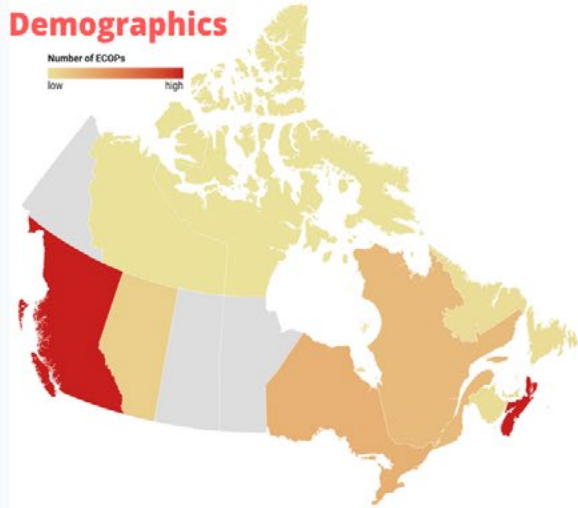

K-ECOP banner and a table during the spring meeting of the Korean Society of Oceanography in Busan (2-3 May 2023).

INSIGHTS FROM ECOPs IN CANADA

110 ECOPs shared their voice in a survey to help us better understand and meet the international and national needs of early career ocean professionals (ECOPs) during the UN Ocean Decade.
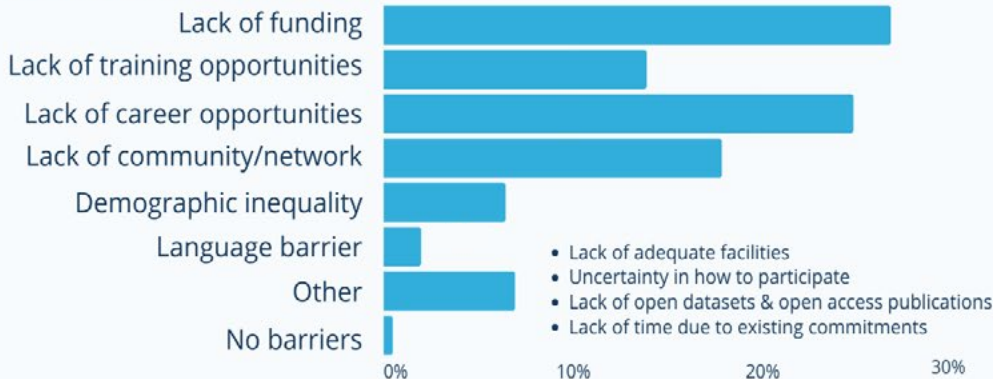
Demographics

Number of ECOPs
low — high

70% Female | 28% Male | 2% Non binary

Pie chart segments: White/European Descent, Inuit, Métis, LGBTQIA, Immigrant/Newcomer, Person of colour

The role of ECOPs

Wheel segments: Biology, Conservation, Academia, Fisheries, Industry, Science Communication, Oceanography, Policy, NGO, Government, Technology, Polar, Arts

Top words to describe an ECOP

Word cloud: sustainability, collaboration, protection, science, creative, support, future, community, limited entry, intergenerational learning, constant need, new knowledge, idea, underpaid, youth, marine biology, interdisciplinary science, transformation, ocean steward, resilient, diverse, opportunity, development, protect engage research, learn skill, digital technology, passionate, ocean science, competitive salary, keen, passion, lack of jobs, training, communication, health, innovative, willing to work, most impact, social media, coastal community, climate change, dedication, innovation, ocean climate action, opportunity creation, open access, policy interface, networking, environmental ngo, job, young, action, incoherent network, problem solver, conservation, engagement, learning, engaged, career development, scientist

Barriers to ECOP participation in the Ocean Decade

Bar chart categories:
- Lack of funding
- Lack of training opportunities
- Lack of career opportunities
- Lack of community/network
- Demographic inequality
- Language barrier
- Other
- No barriers

- Lack of adequate facilities
- Uncertainty in how to participate
- Lack of open datasets & open access publications
- Lack of time due to existing commitments

0%   10%   20%   30%

ECOP Canada

ECOP Canada aims to achieve intergenerational equity by strengthening the diverse voices of early career ocean professionals in all ocean fields across Canada.

The Canadian Node for the Global Early Career Ocean Professionals Programme was started in 2021 by three ECOPs, Neha Acharya-Patel, Samantha McBeth, and Ronnie Noonan-Birch who currently form ECOP Canada's steering committee. This committee and ECOP Canada's National Coordinator, Ashley Bowes, is advised by a board of seven ECOPs from various geographical locations, cultures, and professional roles in the ocean space.

ECOP Canada has now grown to engage over 220 members from across Canada and has partnered with over 20 international and national organizations, such as Fisheries and Oceans Canada (DFO), The Tula Foundation's Decade Collaborative Centre for the Pacific Northeast, and the Canadian Ocean Literacy Coalition (COLC). Through the Canadian DFO Decade office and COLC, ECOP Canada has now received over $300,000 in funding to grow the network and launch programs aimed at ECOP inclusion. These initiatives include sending ECOP delegations to international conferences, holding ECOP workshops and webinars, and curating resources and training opportunities for ECOPs across sectors.

One relevant example we can highlight for PICES members is a monthly ocean science webinar series entitled "*Decade Dialogues*", hosted in collaboration with the Tula Foundation's Decade Collaborative Centre for the Pacific Northeast. Each webinar focuses on a particular research topic and includes a 30-minute dialogue that invites ECOPs to engage with the expert speakers.

Currently, our node primarily exists through an active and engaging Slack channel, a monthly newsletter, and on social media (find us on Instagram, LinkedIn and Twitter). It serves to connect members with jobs, training, funding, leadership, and collaboration opportunities that are prioritized for ECOP Canada. This channel is FREE to join and allows you to be a part of an inspiring community that is making change for the health of our Oceans. Please Contact us at: canada@ecopdecade.org

ECOP China

The ECOP China node includes 123 registered ECOPs and is also managing a WeChat group with >160 members. ECOP China aims to develop a broad ECOP network in the ocean field across China, promote cross-sectoral exchanges among the Chinese ECOP community, and bridge the knowledge transmission gap between regions, industries and institutions. ECOP China is currently at the primary stage of team building and connection with ocean stakeholders.

The current ECOP China core team includes:

Coordination team: Chunhua Jiang: National coordinator, responsible for organizing and coordinating work; Mengyu Li: Partnerships coordinator, which involves connecting with academic stakeholders and other interested parties; Yangyang Zhao: Training coordinator.

Publicity team: Led by Dr. Baolan Wu, who will promote the ECOP China network during national and international events, as ECOP China ambassador.

Steering Committee: Composed of senior representatives from institutions in partnership with the ECOP China node. They will provide essential guidance and support to the ECOP China node.

The triangle structure of the ECOP China core team has a stable and natural energy transfer. The steering committee will provide financial and in-kind support to the coordination team, who will in turn allocate human resources to solve technical problems related to daily affairs while closely assisting the publicity team in their promotional and outreach efforts. The publicity team will work towards promoting the ECOP China network domestically and internationally, and report back to the committee members. The overall aim of this initiative is to empower Chinese ECOPs and establish a sustainable and long-lasting ECOP China network.

Apart from the core team, the ECOP China node will strive to expand its ECOP membership and regularly recruit new volunteers. Different task teams will be developed based on needs to support future activities. Online and offline activities will mainly include training series, academic salons and webinars, to meet the needs of researchers, NGO workers, industry personnel and other ocean enthusiasts. One recent successful example of how the ECOP China framework can be leveraged is their recent cooperation with the Institute of Plastic Cycling and Innovation from East China Normal University, who kindly covered promotional material fees and sponsored three ECOPs to participate in the Fourth National Environmental Microplastics Pollution and Prevention Conference.

ECOP Japan

Surrounded by the ocean from all sides and home to a diverse marine environment from the North to South, Japan has built its history alongside the ocean, with various stakeholders living in harmony with it over the generations.

ECOP Japan aims to develop a multidisciplinary network and sustainable partnership among ECOPs in various ocean sectors (research, education, government, industry, NPO/NGO, etc.). We introduce a wide range of ECOP activities across disciplines, provide useful information and opportunities (events, employment, grants, etc.) to address issues that face ECOPs, and identify ECOPs who will support the future of ocean sectors. Through these activities, ECOP Japan will contribute to the seven outcomes of the UN Decade of Ocean Science for Sustainable Development.

Coordinators

*   Yushi Morioka (Japan Agency for Marine-Earth Science and Technology (JAMSTEC))
*   Kotaro Tanaka (Ocean Policy Research Institute (OPRI) of the Sasakawa Peace Foundation)

Activities and projects

*   ECOP Japan Symposium: "Toward creating ECOP network in UN Decade of Ocean Science" (January 18, 2022, with recordings available in Japanese and English),
*   Video letters from ECOPs in Japan, which consist of interviews with ECOPs from a variety of ocean sectors and walks of life (available on the ECOP Japan website and on the ECOP Programme's YouTube Channel)
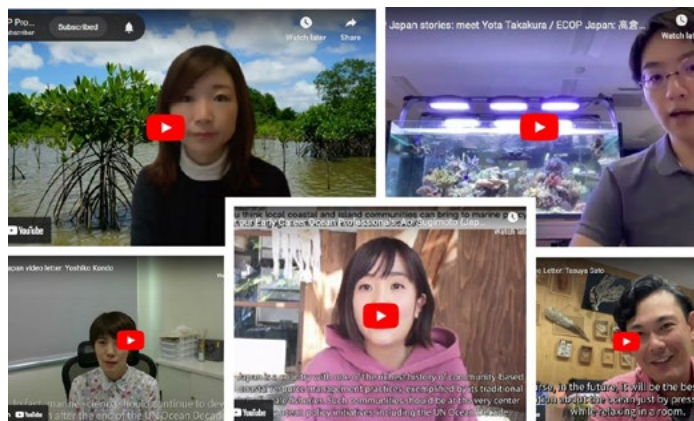
Articles

December 2022 issue of the OPRI Ocean Newsletter, available in Japanese and English,
Report summary of the 2022 ECOP Japan Symposium, available in Japanese and English
Presentation during events:
 "2023 Symposium on the UN Decade of Ocean Science—How can the Japanese atmospheric and oceanographic science community contribute?", recording available in Japanese,

Online Surveys

ECOP Asia survey in May 2021. Results were presented during the Virtual Early Career Ocean Professionals Day (or V.ECOP Day) on June 1st, 2021. An in-depth analysis can also be consulted in the 2022 ECOP Asia intermediary Report. ECOP Japan survey released in May 2023. Currently accepting responses until June 30th (though the deadline might be extended), see link here.

Communication and engagement pathways

ECOP Japan issues a newsletter to disseminate ECOP-related information from time to time. Communication materials (e.g., video letters and newsletter) are delivered in both Japanese and English. Those who are interested in our activities can engage using this registration form, and/or contact us at: japan@ecopdecade.org.

Relationships with PICES

Many ECOPs in Japan work on marine ecosystem research in the North Pacific, which is relevant to PICES activities. As we prioritize diversity in disciplines, sectors and geographical areas, we expect ECOP Japan to be a cradle of innovative collaborations for North Pacific marine research, building bridges with other professional groups such as PICES ECOPs. Leveraging the PICES platform to develop future collaborations between national nodes would inspire ECOPs in Japan.

website: https://www.ecopdecade.org/japan/

ECOP USA

The United States ECOP (US ECOP) Node was developed throughout 2022, and formally launched in March 2023. Organized through an initial steering committee chaired by Hannah Lachance and Erin Satterthwaite, it now has >320 individuals who have expressed interest in getting involved, based on an initial survey. The US ECOP node also has more than 150 members in its Slack group. The distribution of members spans the US, including the territories of Puerto Rico and the U.S. Virgin Islands (see map above) as well as some ECOPs currently located outside the US. Demographically, the US ECOP node is currently 75% female, 23% male, and 2% nonbinary and skews heavily towards those involved in academic organizations at various career stages (professor, post-doc, student, 58%), followed by government (25%) and then civil societies (8%), private industry (7%), and donor/foundation organizations (2%).

Currently, through the its Slack channel, US ECOPs share and learn about job opportunities, professional development opportunities, and webinars. The hope is the community will continue to build this channel with increasing numbers of ECOP members sharing opportunities, engaging in career development conversations, and helping to build and foster an impactful network of peers. In the coming months, the US ECOP node hopes to develop engagement plans based on feedback from the initial group of members. A virtual all hands meeting is being organized for mid-June to serve as a listening session to identify the needs of the members. Given the expansive geographic distribution of node members, there is also a desire to find ways to coordinate regional meet-ups to foster community building.

Other events the US ECOP node is currently working on include a webinar series with the Ocean Visions Decade Collaborative Center for Ocean-Climate Solutions (OV-UN-DCC) hosted at the Georgia Aquarium to engage with their community to collectively support goals of ECOP USA and OV-UN-DCC, and supporting the Ocean Decade Collaborative Center for the Northeast Pacific with their post-webinar ECOP hosted discussions. There are also some members of the steering committee who will be involved with a panel discussion this summer at the 2023 Ecological Society of Americas meeting in Portland, OR discussing opportunities for engagement with the UN Ocean Decade.

If you or someone you know is interested in joining the US ECOP node, please check out the webpage and our flier for more information!

ECOP Russia

Russia is the only PICES member country who is missing a national ECOP framework. There is currently no group that is developing the Russian ECOP node, although there are many well-established early career committees or young scientists' councils across research institutions in Russia. Considering the size and geographical span of the country, which straddles both Europe and Asia, having 2 coordinators or focal points representing the Western and Eastern parts would be a great start for the development of the national ECOP node in Russia.

If you are a Russian ECOP eager to help develop and coordinate a future national ECOP hub in Russia, we highly encourage you to get in touch with Evgeniia Kostianaia, the global coordinator of the ECOP Programme, who can be contacted at: e.kostianaia@unesco.org. She will provide additional information about the responsibilities and duties involved in the role of a national ECOP coordinator.

Regardless of someone's background, identity, geographic location, sector and career stage, they are all welcome to join and engage with the global ECOP network, and participate in their own capacity. Everyone is encouraged to stay connected by subscribing to the monthly ECOP newsletter and visiting the ECOP website. PICES ECOPs who are not yet connected with their respective national node(s) can explore ways to get involved by contacting the coordination teams. Senior PICES scientists and mentors can also help by disseminating this information among their early career colleagues and students. All national ECOP nodes are open to ideas for new collaborations and joint activities. They are also keen on discussing resources, whether in-kind and/or financial, that can contribute to their development and facilitate synergies and integration with the PICES community and their global partners.

The 44th Pacific Ecology and Evolution Conference (PEEC)
Kelly Scott

The 44th Pacific Ecology and Evolution Conference (PEEC) was hosted by Simon Fraser University (SFU) in Vancouver, BC and PICES was once again one of the Gold Level sponsors. The generous support of all the sponsors allowed PEEC 2023 to be one of the most successful so far. This year's conference took place at the SFU Harbour Centre in downtown Vancouver on 1-2 April, 2023. There were 115 people in attendance (see group photo above), with 90 students presenting their research to their peers. PEEC provides a unique opportunity for students to network and learn from their peers while gaining valuable experience. For many students this was their first time presenting at a conference, and PEEC provides a supportive environment to hone this skill. This was the first year since the COVID-19 pandemic that the conference was hosted entirely in person (with one exception being an online keynote presentation from Dr. Brett Howard). There were 80 student presentations in addition to 2 keynote speakers and 10 poster talks throughout the 2-day conference. In addition to the presentations, there were 3 workshops and a discussion on Eco-Grief in which students could participate. Students could also spend time with vendors during snack breaks to purchase locally-made art or ethically-sourced coffee and spices.

#PEEC2023 Logo by Elizabeth Oishi

Unfortunately, two last-minute changes to the conference program created challenges for the conference organizers, who worked together to make the event a great success despite the challenges. Elder Marie Hooper of Kwikwetlem First Nation was unable to attend to give her opening address. Instead, the conference welcome and land acknowledgement was provided by conference organizers Em Lim and Alyssa Allchurch. This was followed by the first keynote speaker, Dr Brett Howard, *(filling in for Dr. Zoe Todd who was unable to attend)*. Dr. Howard, an adjunct professor at SFU who is working on her research with the Department of Fisheries and Oceans, presented a riveting talk on the Law of the Seas, focused on the invasive European green crab along the BC coast. Her research will provide valuable tools for coastal managers attempting to monitor and control the spread of this invasive species. Students took away valuable information on the interconnectedness of policy and science in relation to invasive species management.

After the keynote presentation students could participate in one of three workshops. The College of Applied Biology hosted a workshop on the history of the profession and guided students through the application process for the Registered Professional Biologist certification, answering questions for many students who had questions about eligibility and registration requirements. They also provided career tips and other valuable information to young biologists beginning their careers. SFU's Community Engaged Research Initiative (CERi) held a workshop hosted by Tara Mahoney (CERi), Chantelle Spicer (SFU), Fiona Beaty (UBC), and Svetlana Esenkulova and Nicole Frederickson (Pacific Salmon Foundation), to introduce students to the concept of Community Engaged Research (CER) and allow them to ask questions of panelists. The final workshop was hosted by Wesley Greenwood from the University of Victoria to inform students about spatial data analysis using R. This extremely popular workshop was packed with both new and experienced R users, who gained the tools necessary to produce visually appealing maps and manipulate and analyze spatial data in R.

The afternoon consisted of 3- and 12-minute student-led presentations, with 24 12-minute presentations and 18 3-minute talks on Saturday on the following topics: Climate Change; Evolution; Forestry; Plankton

& Plants; Salmon Conservation; Physiology; Animal Behavior; Human Impact; Community Involvement; Modern Methods; Culturally Significant Relations and Management; Traditional Ecological Knowledge; Aquatic Policy and Management.

PEEC attendees celebrated the end of a successful first day of the conference by having a social at North Point Brewing and Café. Students were able to relax, socialize and participate in a game of biology-themed trivia. The evening was filled with smiles and laughter as students tried to recall the answers to questions like *"How many times has nature made a crab-like body form?"* There were some tough questions involving pop culture like *"At what address does Marlin find his son Nemo?"* Overall, everyone enjoyed themselves and were able to unwind before another big day of talks at the conference on Sunday.

PEEC's second day began with a networking opportunity over coffee and pastries, followed by the poster session (shown above) where students discussed their research on topics such as trapping strategies for the European green crab and otolith composition in hatchery-raised coho salmon. The poster session offered students an opportunity to discuss their research without the pressure of a formal oral presentation.

22 12-minute and 13 3-minute talks followed the poster session. Volunteers evaluated the talks and submitted judging forms to determine the best presentation in the 12-minute, 3-minute, and poster presentation categories, plus one presentation that was selected as the people's choice. This year's winner for the 3-minute talk was Emma Lunzman-Cooke, for her presentation on *investigating post-release mortality of coho salmon in a marine recreational fishery*. First place for the 12-minute presentation was awarded to Jamie Ojeda for their presentation on *unveiling reciprocal contributions between fishers and seabirds in the Patagonian hake fishery*. Emma Polard's poster presentation won first place, and was on *the effect of hatchery rearing conditions on otolith composition in juvenile coho Salmon*. The people's choice award for a presentation went to Saif Nayani for their talk on *microbe-mediated attraction of stable flies to host cattle* and the people's choice for poster was awarded to Milène Wiebe for their poster on *optimizing trapping strategies of European green crab*. All winners were awarded a variety of prizes, including gift certificates for Deep Cove Kayak, Van Duessen Garden tickets, and Bamfield Marine Science Centre hoodies.

Following the student presentations, we gathered for a discussion on Eco-Grief. It can be incredibly challenging as environmental stewards to work in the face of climate change and the other issues plaguing our planet. It can be overwhelming, resulting in high levels of stress and anxiety, and eventually apathy and burnout. This discussion explored how grief works and what we can do to help manage it. Having these conversations and relying on our community to help support us is important as we continue our careers in environmental fields.

Our second keynote speaker was Dr. Chelsea Little, who spoke on community assemblages and how communities of different trophic levels interact in their ecosystems. Dr. Little is an assistant professor at SFU in the Environmental Science and Resource and Environmental Management programs, and her work focuses on community assemblages in watersheds and the connection between landscape structure on aquatic ecosystems. She provided meaningful insight into how nutrients move throughout the landscape and the importance of meta-analysis in determining nutrient pathways. She ended the conference on a high note, inspiring early career biologists by showing them the possibilities of where their research might lead.

Kelly Scott (kascott321@gmail.com) graduated with her MSc in Ecological Restoration from SFU and BCIT in April of 2023. Her research focused on using fungi to filter stormwater before it enters urban streams. She is passionate about finding nature-based solutions to anthropogenic impacts on the environment. Currently, she is working as a Biologist for Tsawwassen First Nation, and is grateful to have the opportunity to continue working to protect and restore ecosystems.

PEEC 2023 highlighted the vast amount of impressive research being conducted throughout western Canada. This 44th annual conference had the most presentations of any PEEC to date and we expect it to grow even further next year. This platform helps inspire innovative ideas in the minds of those who will soon be the ones leading research initiatives. It also provides an opportunity for students to learn from each other and foster connections that will persist throughout their careers. Each year the University of Victoria, the University of British Columbia, and Simon Fraser University take turns hosting the conference. It is organized by a group of volunteers usually consisting of graduate students. This year's organizing committee was Em Lim, Alyssa Allchurch, Beth Oishi, Julian Gan, Katie Philip, Kelly Scott, Kiara Kattler, Miranda Dennis, Phoebe Gross, Raven Barbera, Sherry Young, Claire Attridge, Sarah Gutzmann, Rachel Fairfield-Checko, and Celeste Kieran who are all graduate students at SFU.

PEEC would not be possible without our wonderful sponsors who help support this conference each year. We are so grateful for their continued support and the PEEC 2023 organizing committee would like to extend their earnest thank you to our Gold Sponsors: PICES, SFU Faculty of the Environment, and the University of Alberta Faculty of Science. We would also like to thank our Silver Sponsors: SFU Faculty of Science, SFU Department of Biological Sciences, UBC Zoology, and UBC Faculty of Science. Lastly, we would like to thank our Bronze Sponsors: Ocean Networks Canada, UBC Biodiversity Research Centre, Canadian Institute of Ecology & Evolution, UBC Institute for Resources, Environment and Sustainability, UBC Department of Forest and Conservation Sciences, UBC Department of Botany, as well as all the other organizations and departments who supported this conference. A full list of all our sponsors can be found at www.peec.ca.

The Bering Sea: Current Status and Recent Trends
Editors: Emily Lamagie and Elizabeth Siddon

Climate and sea surface temperature

The regional atmospheric circulation in the vicinity of the Bering Sea during the period of October 2022 through March 2023 featured negative sea level pressure (SLP) anomalies to the northwest with peak magnitudes exceeding 3 millibars (mb) north of eastern Siberia, and positive SLP anomalies to the south, particularly over the western Gulf of Alaska (Figure 1). The latter anomaly is associated with a weaker than normal Aleutian low, which has occurred during each of the last four years at the same time of year. Relatively weak Aleutian lows tend to accompany La Niña; the winter of 2022-23 represents the third in a row with La Niña conditions in the tropical Pacific. The SLP pattern shown in Figure 1 was accompanied by wind anomalies of 1.5 to 2 m s^{-1} from the southwest across much of the Bering Sea.
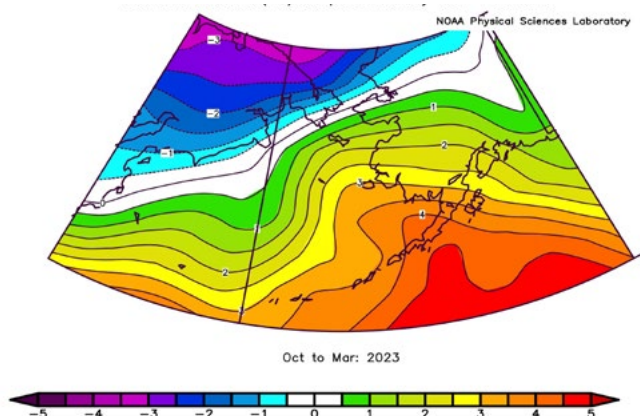
Figure 1. Mean sea level pressure (SLP) anomalies (mb) from the NCEP/NCAR Reanalysis for October 2022 – March 2023. Figure courtesy of Nick Bond, University of Washington (UW)/ Cooperative Institute for Climate, Ocean, and Ecosystem Studies (CICOES).

These wind anomalies might be expected to result in relatively warm air temperatures for the same period of October 2022 through March 2023, but as shown in Figure 2, this was only modestly the case, with departures from normal generally less than 1˚C. An exception was the far southeastern corner of the Bering Sea in the immediate vicinity of Bristol Bay where temperatures were a bit warmer. It is important to realize that the aforementioned wind anomalies from the southwest were expressed upon a mean flow that includes a component from the north, with the consequence that the primary source of air for the bulk of the Bering Sea was the Sea of Okhotsk, rather than the more mild region south of the Aleutian Islands. The northern Bering Sea was subject to a mean flow from the northeast off mainland Alaska, and while weaker than normal it was sufficient to bring near-normal air temperatures as far south as about 60˚ N.

The distributions shown in Figures 1 and 2 are relative to norms over the period of 1991-2020; notably regional air temperatures during this period included warm multi-year intervals during the early 2000s and the middle to late 2010s.
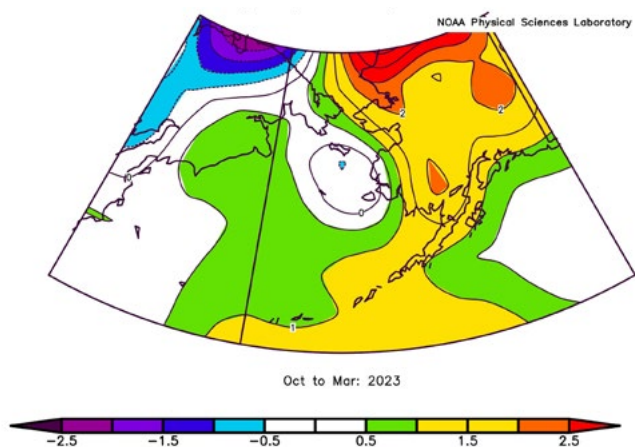

Figure 2. Mean sea surface temperature (SST) anomalies (°C) from the NCEP/NCAR Reanalysis for October 2022 – March 2023. Figure courtesy of Nick Bond, UW/CICOES.
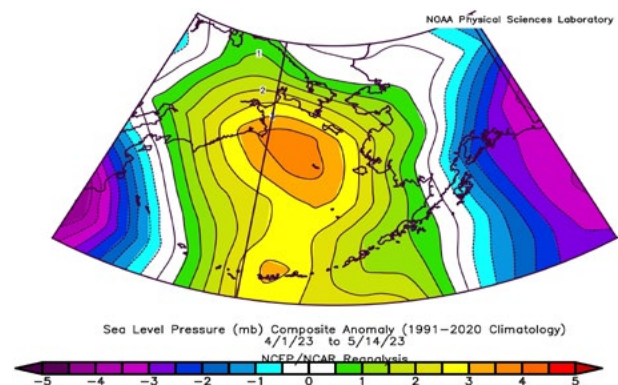

Figure 3. As in Figure 1, but for the period of 1 April – 14 May 2023. Figure courtesy of Nick Bond, UW/CICOES.

The positive temperature anomalies of 2-3˚C in northern Alaska reflect a resumption of regional warming that has become prevalent over high-latitude continental areas in general. The period of April through mid-May 2023 included a shift in the SLP pattern to a high pressure anomaly over the northern Bering Sea (Figure 3). This distribution was associated with wind anomalies of about 2 m s^{-1} from the north over the eastern Bering Sea shelf, resulting in a rather late series of southward advances of sea ice over the shelf. The ice near its southernmost extent was relatively thin and short-lived, and hence marginal for the development of a bottom cold pool as far south as M2 on the southeastern Bering Sea shelf.

Estimates of bottom temperature from the Bering 10K Regional Ocean Modeling System (ROMS)

In the winter of 2022/2023, the advance of sea ice in the Bering Sea occurred later than typical due to residual warmth in the system. Once sea ice formation started, it advanced quickly over the shelf. Sea ice retreat began at the end of April 2023, which is also later than typical. The Bering 10K Regional Ocean Modeling System (ROMS; Kearney et al., 2020, Kearney et al., 2021) captured the sea ice advance and maximum ice extent patterns well for 2022/2023.

Despite the delayed timing in sea ice formation and retreat, the ROMS is forecasting an average year for summer bottom temperatures in 2023 (Figure 4, top panel). The ROMS forecast shows the southeastern Bering Sea mean bottom temperatures to be slightly below average with a slightly larger-than-average cold pool based on bottom waters <2°C (Figure 4, middle panel) and a slightly smaller-than-average cold pool based on bottom temperatures <0°C (Figure 4, bottom panel).

Figure 5 shows the progression of forecasted bottom temperatures over the eastern Bering Sea shelf for June - August 2023. While the bottom temperatures over the middle shelf are forecast to remain fairly consistently <2°C, the bottom waters of the shallow inner domain are forecast to warm considerably throughout the summer.
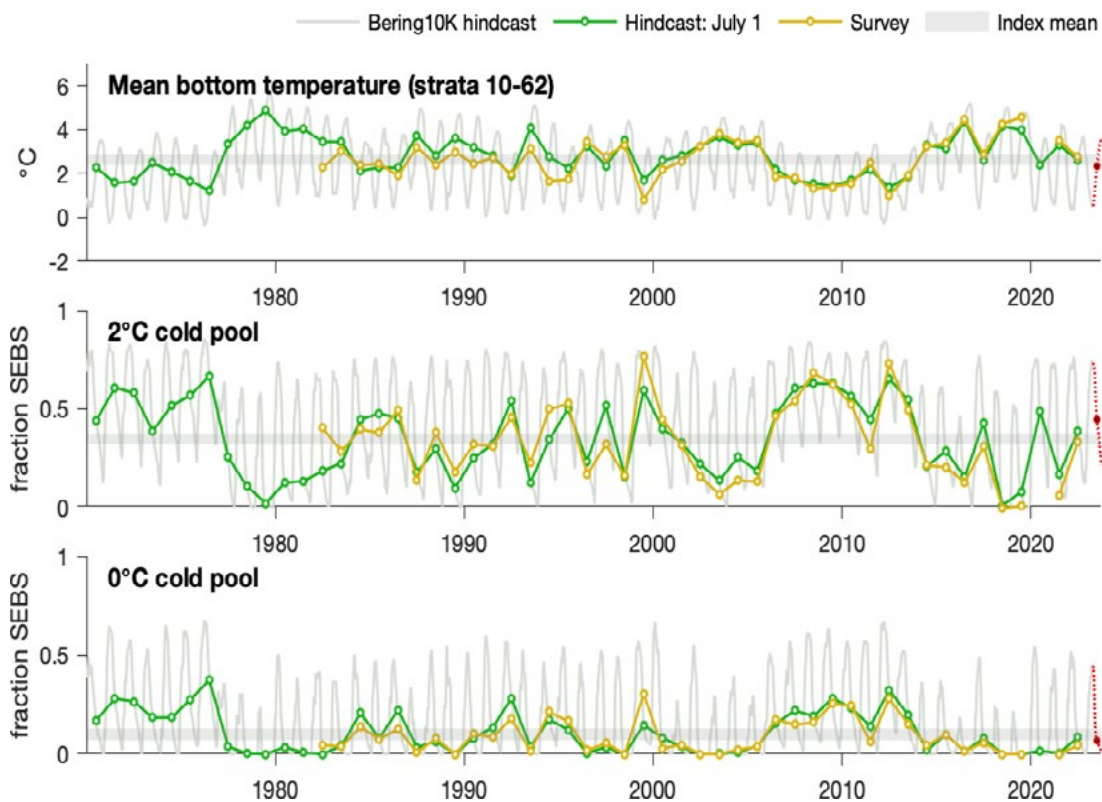
Figure 4. Regional Ocean Modeling System (ROMS) forecast of mean bottom temperatures over the eastern Bering Sea shelf (top panel), the fraction of the southeastern Bering Sea shelf with bottom water temperatures <2°C (middle panel), and the fraction of the shelf with bottom water temperatures <0°C for July 1, 2023. Figure courtesy of Kelly Kearney, UW/CICOES and NOAA-Alaska Fisheries Science Center.
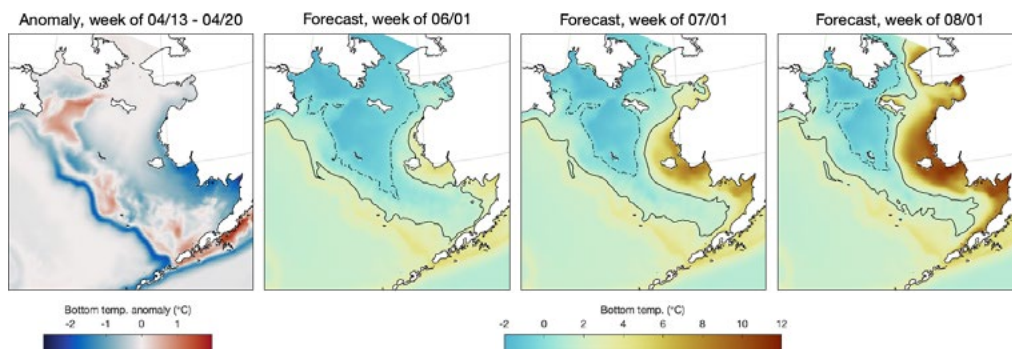

Figure 5. Regional Ocean Modeling System (ROMS) forecast of bottom temperatures in the eastern Bering Sea for summer 2023. Figure courtesy of Kelly Kearney, UW/CICOES and NOAA-Alaska Fisheries Science Center.

Western Alaska salmon trends and drivers

Major populations of Chinook (*Oncorhynchus tshawytscha*) and chum (*O. keta*) salmon occur broadly across Western Alaska and into Interior Alaska and the Yukon Territory in Canada. In addition to supporting vibrant local commercial fisheries, Chinook and chum salmon traditionally constitute the majority of subsistence salmon harvest in the Arctic-Yukon-Kuskokwim region and have supported Alaska's most northerly commercial salmon fishery in Kotzebue Sound. However, Western Alaska Chinook salmon runs have been in a state of decline for over a decade (Figure 6), and chum salmon runs declined dramatically in 2020 through 2022 (Figure 7), with both species seeing record low abundance throughout the region in recent years. These particularly poor run sizes had tremendous impacts on the people of this region as it led to closures to most fisheries, including subsistence fisheries, failures to meet escapement goals, and failures to meet US/Canada Pacific Salmon Treaty objectives for Canadian-origin stocks.

While Western Alaska Chinook and chum salmon are simultaneously experiencing record poor abundance, the timing and nature of the respective declines and available
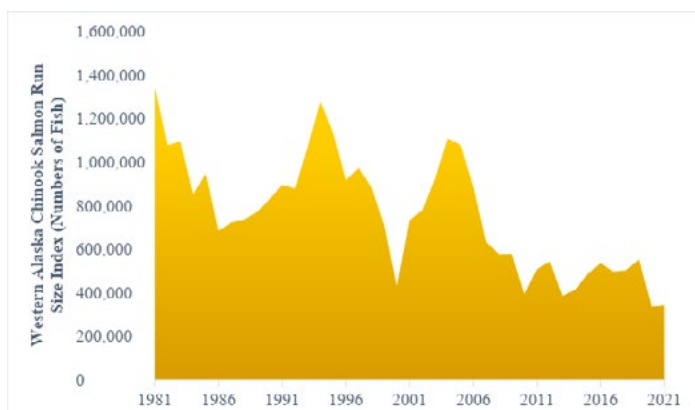

Figure 6. Western Alaska Chinook salmon run size index, 1981-2022. This run size index is comprised of Yukon River, Kuskokwim River, and Nushagak River run estimates to represent the regional patterns. Courtesy of Katie Howard, Alaska Dept. of Fish & Game.
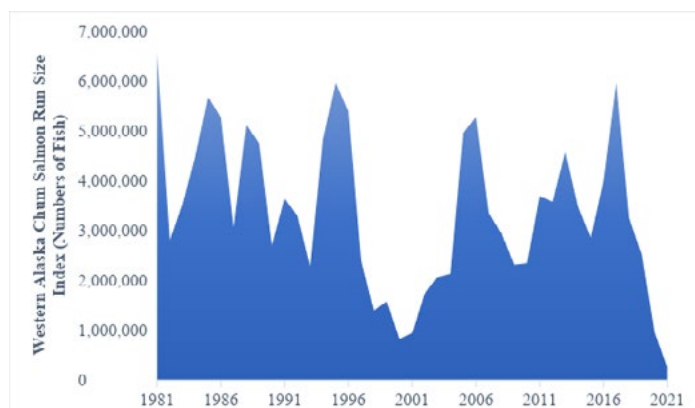

Figure 7. Western Alaska chum salmon run size index, 1981-2022. This run size index is comprised of Yukon River summer and fall runs and Kwiniuk River run estimates to represent the regional patterns. Courtesy of Katie Howard, Alaska Dept. of Fish & Game.

data regarding population dynamics indicate that the primary drivers of decline are species-specific and influenced by each species' life history and ecology. For Yukon River Chinook salmon, evidence clearly indicates that adult run abundance is determined very early in the life of these fish, by the end of their first summer at sea or the juvenile life stage (Murphy et al., 2017, Murphy et al., 2022, Howard et al., 2020). The number of juvenile Yukon River Chinook salmon that survive through their first summer at sea and are produced per spawning adult appears to be influenced by multiple environmental factors that affect metabolic processes (Howard and von Biela 2023). Current leading hypotheses for these Chinook salmon declines incorporate multiple metabolic stressors acting on the parents of the juveniles, including: disease prevalence (predominantly *Ichthyophonus hoferi*; JTC 2023); poorer parental marine nutrition and egg thiamine deficiencies (Honeyfield et al., 2016, Larson & Howard 2019); heat stress during the adult spawning migration (von Biela et al., 2020); and these environmental stressors are likely exacerbated by particularly long spawning migration in these very large river systems.

Recent dramatic declines in Western Alaska chum salmon returns occurred during the same time when Bristol Bay Sockeye salmon returns were at record highs. The question is, what is driving these differential production dynamics in these two species of salmon that occupy the eastern Bering Sea as juveniles? The U.S. conducts integrated ecosystem surveys in the northern and southern Bering Sea to better understand early marine ecology of juvenile Western Alaska salmon. This period in the life history of salmon is a critical period where they must grow large and attain sufficient fat reserves prior to winter. Results from these surveys illustrate that recent anomalously warm sea temperatures in the eastern Bering Sea had a differential impact on salmon fitness. For example, juvenile chum salmon captured in the northern Bering Sea were large in size but had significantly lower energy density (a measure of fat) during the most recent warm period when compared to the previous warm and cool periods (Figure 8). Juvenile sockeye salmon captured in the southern Bering Sea were also large in size, but had higher levels of energy density during the recent warm period when compared to past survey data. We note that juvenile chum salmon in the northern Bering Sea were feeding almost exclusively on low quality prey during the recent warm period, whereas juvenile sockeye salmon diet was similar to the previous warm period. In addition, relative abundance of juvenile chum and sockeye salmon on the eastern Bering Sea shelf was high during the recent warm period. These relatively high abundance indices for juvenile sockeye salmon have been related to increased adult returns two and three years later. However, the relatively high juvenile chum salmon abundance indices were followed by dramatic declines in adult returns two to four years later. We speculate that reduced fitness (fat levels) for juvenile chum salmon led to high overwinter mortality.
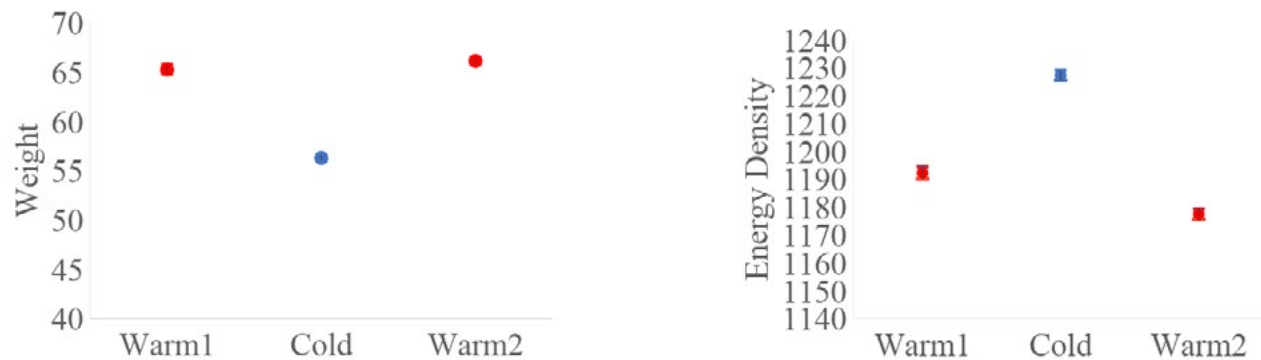
Figure 8. (L) Weight (g) and (R) Energy Density (cal g-1 wet weight) of juvenile chum salmon captured in late August – September in the northern Bering Sea during 2003 to 2005(Warm 1), 2006 to 2013 (Cold), and 2014 to 2019 (Warm 2) periods.

2023 surveys in the Bering Sea

- *NOAA Pacific Marine Environmental Lab (PMEL) and AFSC EcoFOCI spring oceanographic biophysical mooring and hydrographic surveys in the eastern Bering Sea on the R/V Oscar Dyson, 21 April - 7 May 2023.*
- *NOAA Marine Mammal Lab Harbor Porpoise Evaluation - Baseline Data Collection, small boat, 1 May - 30 August 2023.*
- *NOAA AFSC longline survey on the F/V Alaskan Leader, 30 May - 11 June 2023.*
- *NOAA Marine Mammal Lab Alaska W. Stock Steller Sea Lion (SSL) Abundance Trend Monitoring, NOAA aircraft, 20 June - 12 July 2023.*
- *NOAA Marine Mammal Lab W. Stock Steller Sea Lion (SSL) Vital Rates Monitoring (Vessel/Remote Cameras), R/V Tiglax, 22 June - 8 July 2023.*
- *NOAA AFSC Aleutian Island Coral Drop Camera Study, chartered vessel, 1 - 15 July 2023.*
- *NOAA Marine Mammal Lab Aleutian Islands Steller Sea Lion Vital Rates Studies, chartered aircraft, 12 - 18 July 2023.*
- *NOAA AFSC eastern Bering Sea (EBS) summer groundfish and crab bottom trawl survey on the F/V Vesteraaelen and F/V Alaska Knight, 25 May - 30 July. The northern Bering Sea survey will occur immediately after the EBS survey using the same vessels and gear, 1 - 30 August 2023.*
- *Harbor seal aerial survey in the eastern Bering Sea and western Gulf of Alaska using NOAA aircraft, 1 August - 15 September 2023.*
- *NOAA Marine Mammal Lab Northern fur seal vital rate survey on the Pribilof Islands, 1 August - 12 October 2023.*
- *NOAA Marine Mammal Lab Bogoslof Island Northern Fur Seal (NFS) Abundance Trend Monitoring, R/V Tiglax, 1 - 8 August 2023.*
- *NOAA AFSC northern Bering Sea surface trawl and ecosystem survey on the F/V Northwest Explorer, 27 August – 20 September 2023.*
- *NOAA Pacific Marine Environmental Lab (PMEL) and AFSC EcoFOCI fall oceanographic biophysical mooring and hydrographic surveys in the eastern Bering Sea on a chartered vessel, 15 September - 15 October 2023.*

Acknowledgements

References

Honeyfield, D., Murphy, J., Howard, K., Strasburger, W., and A. Matz (2016). An exploratory assessment of thiamine status in Western Alaska Chinook salmon (Oncorhynchus tshawytscha). North Pacific Anadromous Fish Commission Bulletin, 6(1), 21–31. https://doi.org/10.23849/npafcb6/21.31.

Howard, K.G., S. Garcia, J. Murphy, and T.H. Dann (2020). Northeastern Bering Sea juvenile Chinook salmon survey, 2017 and Yukon River adult run forecasts, 2018–2020. Alaska Department of Fish and Game, Fishery Data Series No. 20-08, Anchorage.

Howard, K.G., and V. von Biela (2023). Adult spawners: A critical period for subarctic Chinook salmon in a changing climate. Global Change Biology.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 2023. Yukon River Salmon 2022 Season Summary and 2023 Season Outlook. Page 189. Regional Information Report, Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage.

Kearney, K., Hermann, A., Cheng, W., Ortiz, I. and Aydin, K., 2020. A coupled pelagic–benthic–sympagic biogeochemical model for the Bering Sea: documentation and validation of the BESTNPZ model (v2019. 08.23) within a high-resolution regional ocean model. Geoscientific Model Development, 13(2), pp.597-650.

Kearney, K.A., Alexander, M., Aydin, K., Cheng, W., Hermann, A.J., Hervieux, G. and Ortiz, I., 2021. Seasonal predictability of sea ice and bottom temperature across the eastern Bering Sea shelf. Journal of Geophysical Research: Oceans, 126(11), p.e2021JC017545.

Larson, S., and Howard, K.G (2019). Exploration of AYK Chinook Salmon egg thiamine levels as a potential mechanism contributing to recent low productivity patterns, 2014 and 2015 (Fishery Data Series No. 19–22; p. 26). Alaska Department of Fish and Game.

Murphy, J., K.G. Howard, J.C. Gann, K.C. Cieciel, W.D. Templin, and C.M. Guthrie (2017). Juvenile Chinook salmon abundance in the northern Bering Sea: implications for future returns and fisheries in the Yukon River. Deep-Sea Research II. 135:156-167.

Murphy, J., S. Garcia, A. Piston, J. Moss, K. Howard, E. Fergusson, W. Strasburger, S. Heinl, S. Miller, E. Lee, R. Brenner, Z. Liller, A. Gray, and E. Farley (2022). Coastal Surveys in Alaska and Their Application to Salmon Run-Size and Harvest Forecasts. North Pacific Anadromous Fish Commission Technical Report No. 18.

von Biela, V. R., Bowen, L., McCormick, S.D., Carey, M.P., Donnelly, D.S., Waters, S., Regish, A. M., Laske, S.M., Brown, R.J., Larson, S., Zuray, S., and Zimmerman, C.E. (2020). Evidence of prevalent heat stress in Yukon River Chinook salmon. Canadian Journal of Fisheries and Aquatic Sciences, 77(12), 1878–1892. https://doi.org/10.1139/cjfas-2020-0209.

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Western North Pacific – Current Status and Updates:
Sea surface temperatures for the 2022/2023 cold season
Hideki Kaneko and Kei Sakamoto

The western North Pacific exhibited positive sea surface temperature (SST) anomalies over a wide area from 35 to 45°N throughout the 2022/2023 cold season as shown below in Figure 1. Values exceeding +3°C were observed east of Japan, where the Kuroshio extension shifted northward to around 40°N.

The notable +2°C anomalies also recorded in the Sea of Japan throughout the period are attributed the positioning of a polar front north of normal in the area during this period. Meanwhile, negative anomalies were observed over a wide area south of 35°N.
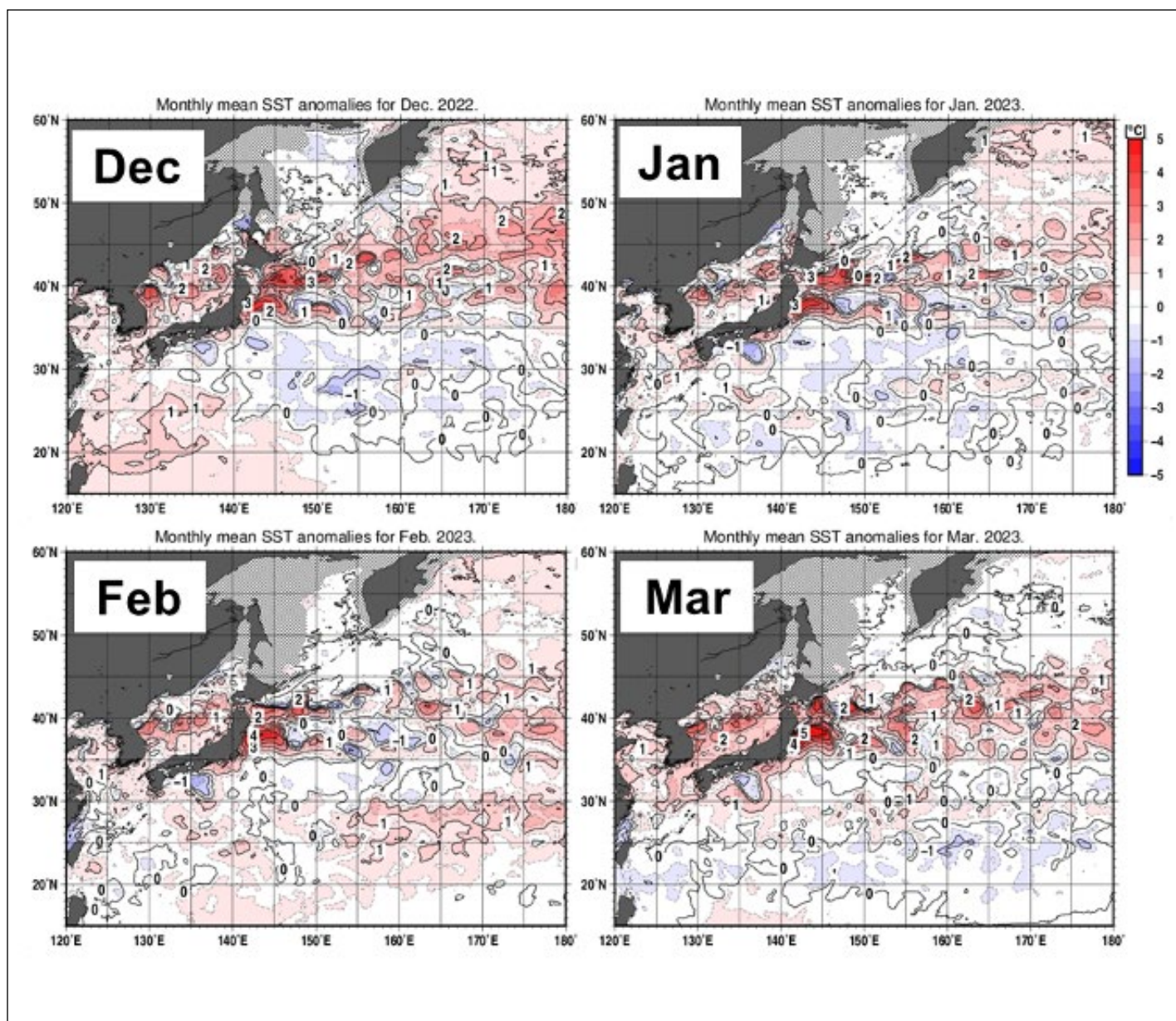

Figure 1. Monthly mean SST anomalies from December 2022 to March 2023 based on JMA HIMSST (High-resolution Merged Satellite and In-situ Data on Sea Surface Temperature) information. Anomalies are deviations from the 1991 – 2020 climatology.
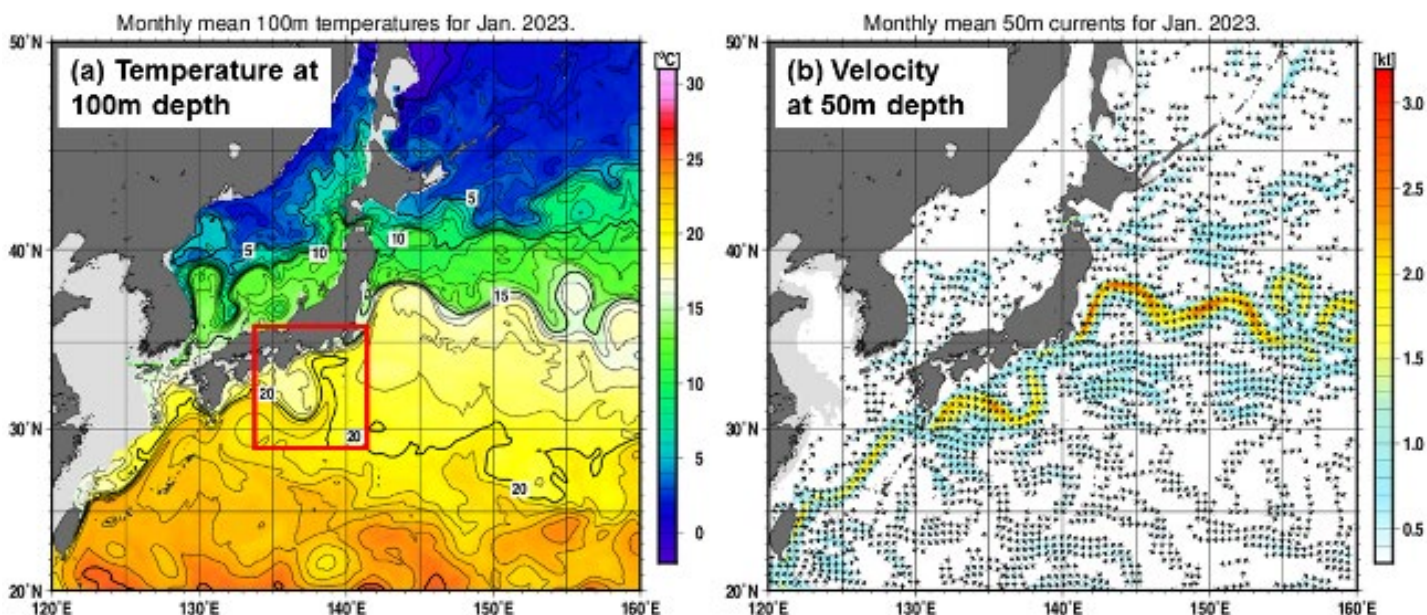
Figure 2. (a) Water temperature at 100 m depth and (b) current velocity at 50 m depth for January 2023 in the Northwest Pacific Ocean based on information from JMA's ocean data assimilation system (Hirose et al., 2019). In panel (b), color shading indicates flow velocity (unit: knots) and arrows indicate flow direction. Arrows are omitted in grids where current velocity is less than 0.2 knots. The red frame in (a) indicates the area of Figure 3.

Longest-ever Kuroshio Large-Meander Duration
Kei Sakamoto (Japan Meteorological Agency)

Introduction
The Kuroshio current along the western boundary of the North Pacific subtropical gyre is the most dominant flow in the area. It follows either a large-meander path to the south of Japan or a non-large-meander path along the coast of the country, and is closely monitored because its path affects maritime operations, fishing grounds and coastal water levels. This report summarizes recent characteristics.

Recent conditions

Figure 2 shows the recent path of the Kuroshio current, water temperature distribution and velocity for January 2023 based on information from the ocean data assimilation system of the Japan Meteorological Agency (JMA). A high-temperature zone around 100 km is seen in association with the current's extension from the coast of the island of Taiwan to the East China Sea and the southern coast of Japan. To the south of Japan, this zone meandered southward to 30°N in the range of 135 – 138°E. The velocity distribution of 2 knots or more (Figure 2 b) is typical of a large-meander path.

Vessel-based surface-velocity monitoring and satellite SST observations also indicated meandering. Along the 137°E survey line in Figure 3 (period: as per Figure 2), strong flow reaching 2 knots was observed in the 29.5 – 30.5°N range. From 137°E, 32°N to the northeast, a north-northwestward 2 – 3 knot flow was seen at 33 – 34°N, and an eastward 2 knot flow was seen north of 34°N. Combined with satellite SST distribution data, this suggests a complex meandering path (blue line).

To evaluate the Kuroshio large-meander path, JMA determines whether offshore stability is observed at Shionomisaki (Figure 3) and whether the southernmost point of the current in the 136 –140°E range is south of 32°N. The path (Figs. 2 and 3) currently satisfies these conditions, and is therefore judged as a large meander.

Large-meander duration

Figure 4 shows a time-series representation of large-meander periods at the southernmost latitude of the Kuroshio current in the range of 136 – 140°E. Non-large-meander paths are seen from 1992 onward (except for 2004 – 2005), and transition to a large-meander path is seen in August 2017. This was still observed as of May 2023, making its duration 5 years and 10 months. This far exceeds the previous maximum of 4 years and 8 months (1975 – 1980), and is the longest since 1965 (the period for which sufficient analysis data are available).
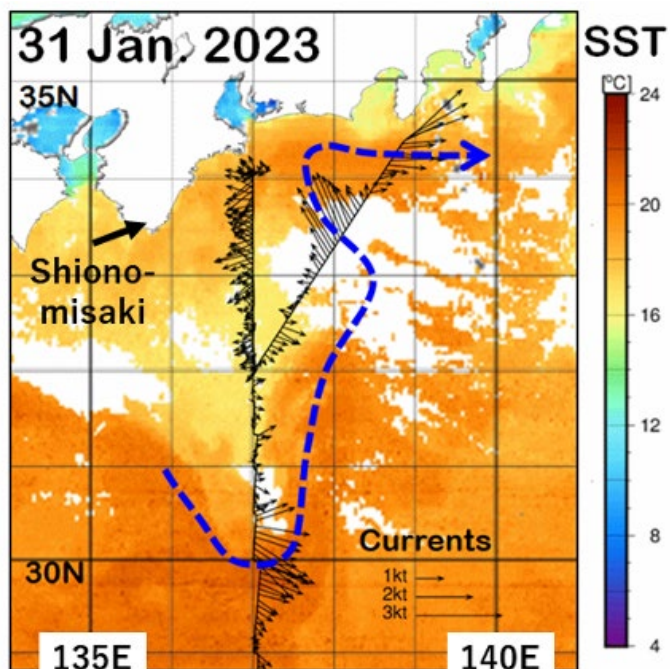
Figure 3. Vessel-based surface-current observations (arrows) and satellite SST observations (colors) south of Japan on January 31 2023. The blue line indicates the estimated path of the Kuroshio current. The region corresponds to the red frame in Figure 2a.
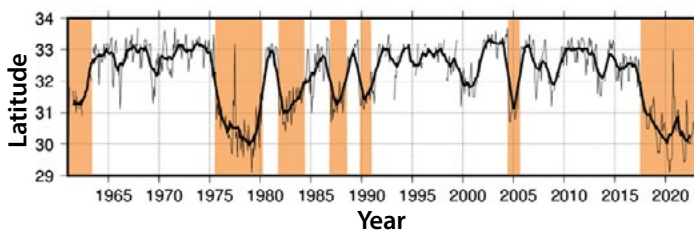

Figure 4. Time-series representation of the Kuroshio current's southernmost latitude in the range of 136-140°E (1961 – 2022). The thin line indicates monthly values, and the thick line indicates 13-month moving averages. The orange sections indicate large-meander periods as judged by JMA.

Reference

Hirose N, Usui N, Sakamoto K, Tsujino H, Yamanaka G, Nakano H, Urakawa S, Toyoda T, Fujii Y, and Kohno N (2019) Development of a new operational system for monitoring and forecasting coastal and open ocean states around Japan. Ocean Dynamics, DOI 10.1007/s10236-019-01306-x

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The Northeast Pacific: Update on marine heatwave status and trends
Andrea Hillborn, Charles Hannah and Tetjana Ross

Since our last PICES update, marine heatwave (MHW) conditions in the Northeast Pacific (NEP) surface ocean have calmed down somewhat. To recap, in the Winter of 2022 summary (Ross et al., 2023) we illustrated an extensive MHW during autumn, and those of us that live in the Pacific Northwest will recall our unseasonably warm October (and perhaps picking some very late tomatoes). That MHW encompassed most of the continental shelf off of British Columbia and southern Alaska from mid-September through to late October, then weakened and receded to further offshore (see Figure 1). The MHW was notable given its intensity, both along the northern coast of North America and across the broader NEP, with some areas exceeding the 99th percentile of previous observations in the climatological period (1991-2020). While we remember the 2014-2016 "Blob" for its intensity and negative impacts throughout NEP marine ecosystems (Bond et al., 2015; Cavole et al., 2016; Di Lorenzo and Mantua, 2016), it is perhaps jarring to remind ourselves that those years are now included in the SST climatology.

Since winter of 2023, offshore conditions have remained slightly warmer than usual, with a MHW event west of 145°W in April. On the other hand, the continental shelf conditions have been cooler than usual by a few degrees until recently, beginning in November 2022. This cool pattern fluctuated over the winter, where mid-January to mid-February had neutral or slightly positive SST anomalies. By mid-February the continental shelf returned to cool conditions until the recent May 2023 heatwave (NASA, 2023) event that began approximately May 14th. This coincided with elevated SST anomalies and a small-extent MHW in the nearshore (see Figure 2A, Figure 3, and visit our Github SST page to see buoy and satellite temperature plots from this period). This MHW area has

shrunk in the weeks since, though anomalously warm areas offshore have expanded (Figure 2B). In the NEP as a whole, for the past four years at least, some areas have shown MHW conditions on any given day. This year is no exception.

At the time of writing, NOAA Climate Prediction Centre has declared (NOAA, 2023) that El Niño conditions are present, with the expectation that they will strengthen through the year. However, regardless of El Niño, the surface ocean has warmed this spring during the transition from La Niña to neutral ENSO conditions, and the warming is now expected to continue. Since mid-March of this year, global mean SSTs (60°S to 60°N) have been the highest on record (https://climatereanalyzer.org/clim/sst_daily/), with no sign of cooling down to normal. Currently the global mean SST is 0.2°C higher than the previous maximum in the satellite SST record (which occurred last year, during La Niña!) Further, every day of 2023 has exceeded two standard deviations from the 1971-2000 base climatology used by some meteorological organizations (also true in 2019, 2016 and 2015).

Finally, a warmer atmosphere and ocean both provide more energy for extreme events including marine heatwaves (Holbrook et al., 2020), harmful algae blooms (Zhu et al., 2017), atmospheric "heat domes" (Zhang et al., 2023), heavy rainfall, early snow melt and atmospheric rivers (Baek et al., 2021). Similarly, marine heatwaves are predicted to occur more frequently, and be longer in duration (Oliver et al., 2018). As said in a recent statement from the World Meteorological Organization (WMO, 2023a), *"We need to be prepared".*
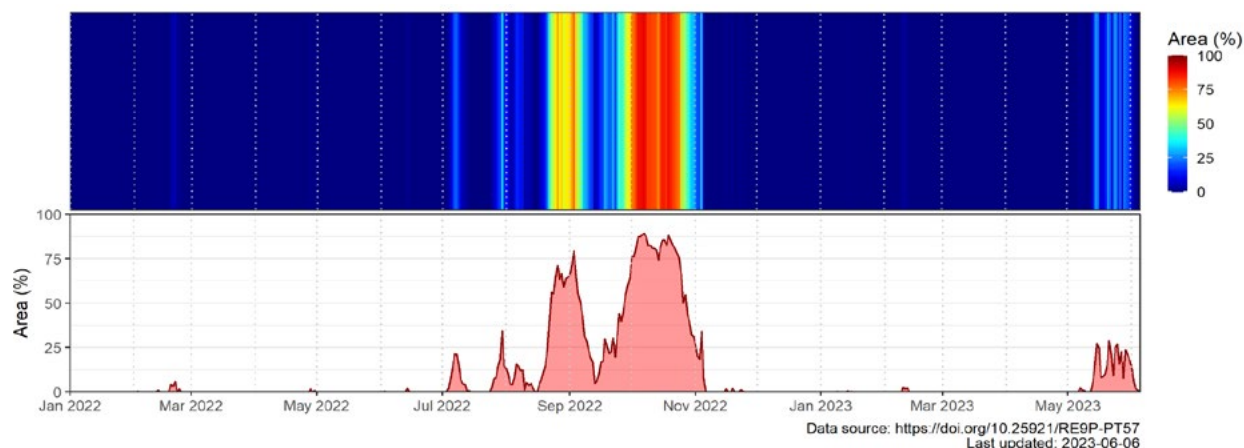
References

Figure 1. Time series of marine heatwave conditions within 200 nautical miles of the British Columbia, Canada coastline since the beginning of 2022. While La Niña conditions persisted, the NEP consistently had regions under marine heatwave status, though it was more rare for MHWs to extend closer to the coast as shown here.
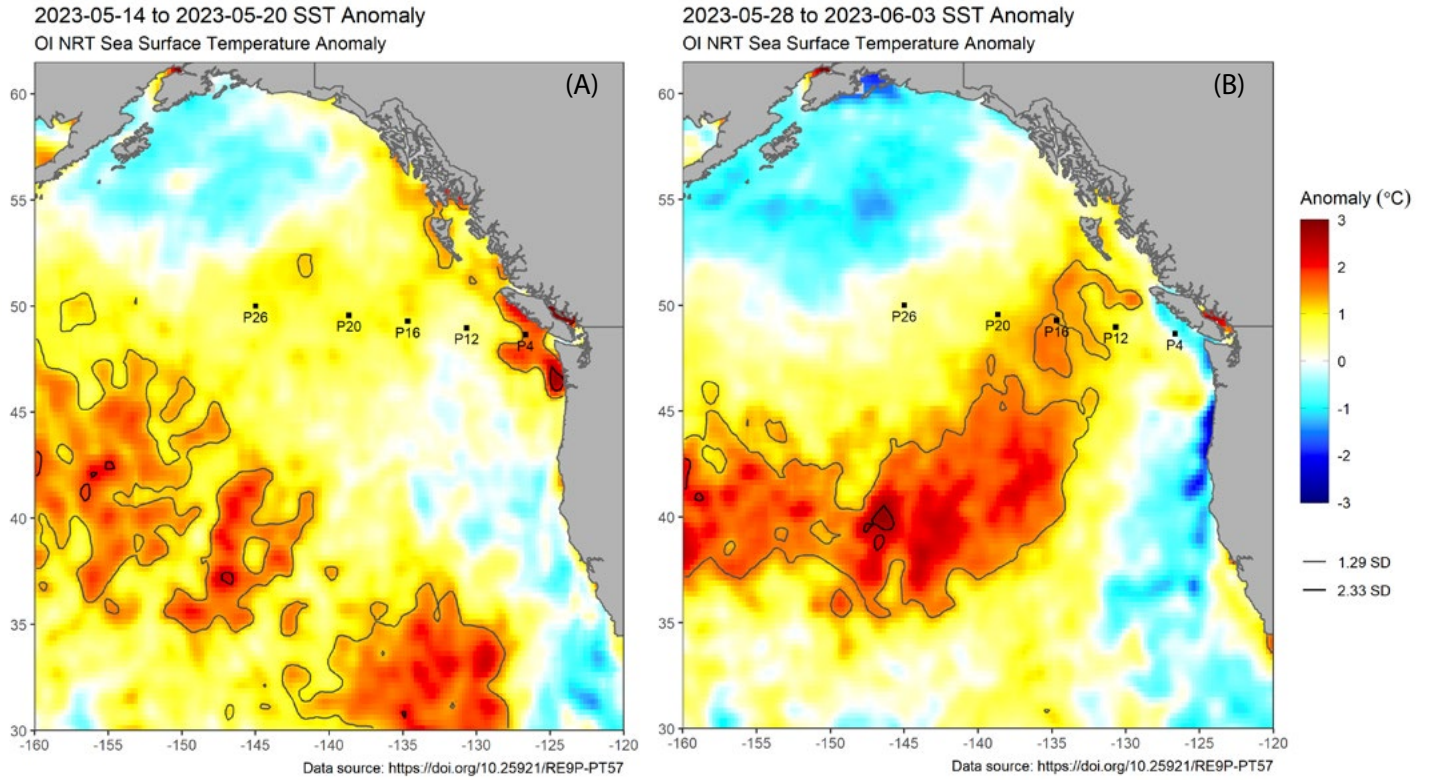
Figure 2. SST satellite imagery from (A) the week of May 14th to May 20th, 2023, and (B) the final week of the month.
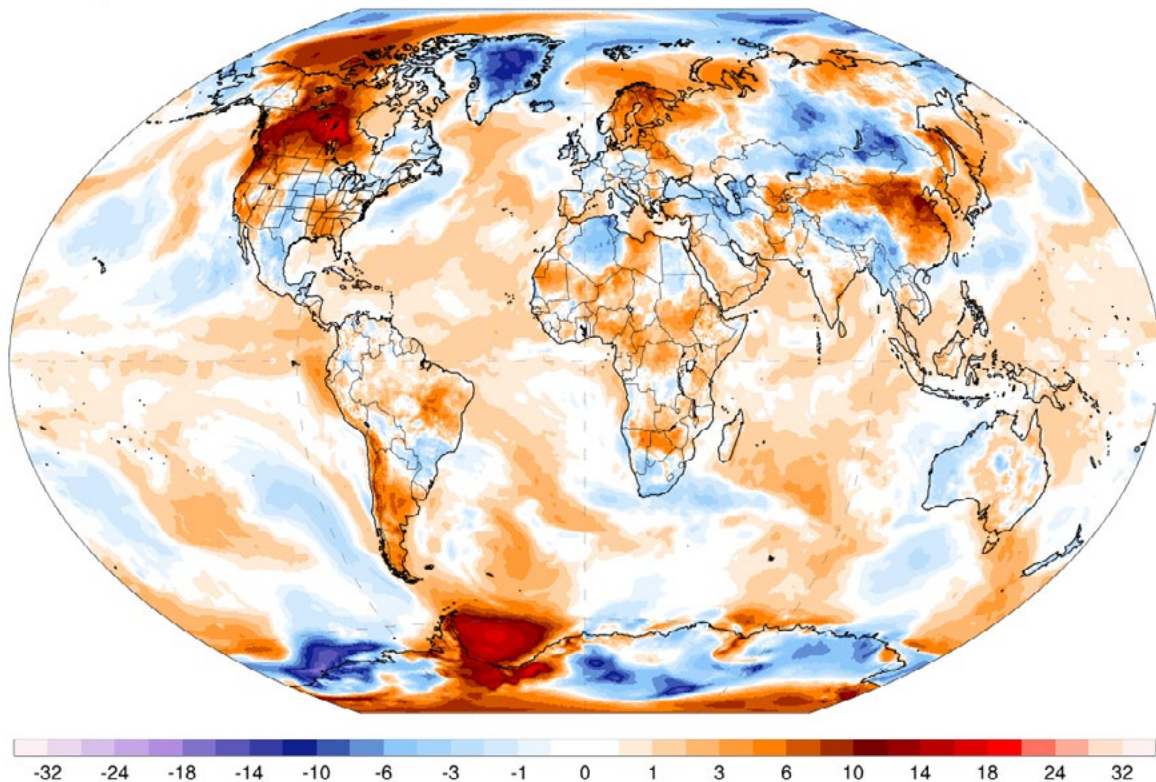

Figure 3. Map of global 2-metre temperature anomalies during the May 2023 heatwave. Image from ClimateReanalyzer.org (Birkel, 2023). North America had regions during this time with anomalies of greater than 10°C.

Baek, S.H., Lora, J.M., 2021. Counterbalancing influences of aerosols and greenhouse gases on atmospheric rivers. Nat. Clim. Chang. 11, 958–965. Doi: 10.1038/s41558-021-01166-8

Birkel, S.D. 'Today's Weather Maps', Climate Reanalyzer (https://ClimateReanalyzer.org), Climate Change Institute, University of Maine, USA. Accessed on 2023-06-09.

Bond, N.A., Cronin, M.F., Freeland, H. and Mantua, N., 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophysical Research Letters, 42(9), pp.3414-3420. doi: 10.1002/2015GL063306

Cavole, L.M., A.M. Demko, R.E. Diner, A. Giddings, I. Koester, C.M.L.S. Pagniello, M.-L. Paulsen, A. Ramirez-Valdez, S.M. Schwenck, N.K. Yen, M.E. Zill, and P.J.S. Franks. 2016. Biological impacts of the 2013–2015 warm-water anomaly in the Northeast Pacific: Winners, losers, and the future. Oceanography 29(2):273–285. doi: 10.5670/oceanog.2016.32

Hoegh-Guldberg, O., D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K.L. Ebi, F. Engelbrecht, J. Guiot, Y. Hijioka, S. Mehrotra, A. Payne, S.I. Seneviratne, A. Thomas, R. Warren, and G. Zhou, 2022. Impacts of 1.5°C Global Warming on Natural and Human Systems. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 175-312, doi:10.1017/9781009157940.005

Holbrook, N.J., Sen Gupta, A., Oliver, E.C.J. et al., 2020. Keeping pace with marine heatwaves. Nat Rev Earth Environ 1, 482–493. doi: 10.1038/s43017-020-0068-4.

NASA, 2023. "Summer Temperatures Arrive Early." Webpage published May 15, 2023. https://earthobservatory.nasa.gov/images/151349/summer-temperatures-arrive-early

NOAA, 2023. El Niño/Southern Oscillation (Enso) Diagnostic Discussion. Webpage published June 8, 2023. https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.shtml

Oliver, E.C., Donat, M.G., Burrows, M.T., Moore, P.J., Smale, D.A., Alexander, L.V., Benthuysen, J.A., Feng, M., Gupta, A.S., Hobday, A.J. and Holbrook, N.J., 2018. Longer and more frequent marine heatwaves over the past century. Nature communications, 9(1), p.1324. doi: 10.1038/s41467-018-03732-9

Ross, T., Hannah, C., Hilborn, A., Freeland, H. and Leising, A., 2023. PICES press (The Northeast Pacific: Update on marine heatwave status and trends, PICES Press Vol. 31, No. 1, Winter 2023). North Pacific Marine Science Organization. Link: https://meetings.pices.int/publications/pices-press/PICES-Press-2023-Vol31No1.pdf#page=105

WMO, 2023a. Global temperatures set to reach new records in next five years. Press release published May 17, 2023. https://public.wmo.int/en/media/press-release/global-temperatures-set-reach-new-records-next-five-years

WMO, 2023b. World Meteorological Organization Global Annual to Decadal Climate Update (Target years: 2023-2027). Link: https://library.wmo.int/index.php?lvl=notice_display&id=22272 (PDF). Accessed 2023-06-07.

Zhang, X., Zhou, T., Zhang, W. et al., 2023. Increased impact of heat domes on 2021-like heat extremes in North America under global warming. Nat Commun 14, 1690. doi: 10.1038/s41467-023-37309-y

Zhu, Z., Qu, P., Fu, F., Tennenbaum, N., Tatters, A.O. and Hutchins, D.A., 2017. Understanding the blob bloom: Warming increases toxicity and abundance of the harmful bloom diatom Pseudonitzschia in California coastal waters. Harmful Algae, 67, pp.36-43. Doi: 10.1016/j.hal.2017.06.004
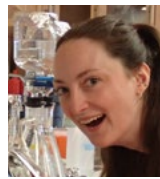
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The Continuous Plankton Recorder as a platform for sensor development
Clare Ostle, and Pierre Hélaouët

The Continuous Plankton Recorder Survey uses volunteer ships of opportunity to collect plankton samples from across the North Atlantic (>60 years of data and >280,000 samples collected) and the North Pacific (>20 years of data and >33,000 samples collected in the Pacific CPR Survey). Thanks to support from shipping companies, the CPR Survey has excellent coverage (both spatially and temporally) across the North Atlantic and North Pacific Oceans and a high taxonomic resolution, routinely identifying over 650 taxa (Figure 1).
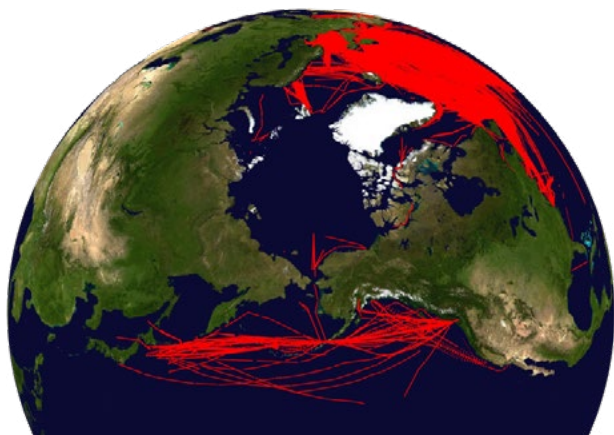

Figure 1. CPR sample locations within the N.Pacific and N.Atlantic.

The CPR survey has strived to add oceanographic sensors to the CPR body to provide more simultaneous environmental information alongside the plankton taxa counts from the samples, however there are numerous complications to overcome when deploying sensors attached to the CPR body. When using the CPR as a sensor platform, the main challenges to overcome are that the sensors should:

- be robust enough to withstand being deployed while the ships are travelling at speeds of ~ 20 knots

- not interfere with the traditional CPR sample collection, so should not impede water flowing into the instrument

- need minimal/no action from the ship's crew to deploy, retrieve or activate

- be able to have enough power to run throughout the tow (which could be up to two weeks for the longest deployments)

In the Pacific, the CPR survey has regularly deployed small temperature loggers or CTDs attached to the body of the CPR. However, a new sensor (PlankTag) that measures sea surface temperature, salinity, conductivity, and fluorescence was recently trialled. PlankTag data can be collected at a much higher temporal resolution than CPR samples,

providing a more detailed picture of the water that the CPR has passed through. The longest route that the CPR survey transects regularly is from Canada to Japan - a crossing that takes ~10 days. Figure 2 shows the first successful trans-Pacific PlankTag tow across the North Pacific in October 2022. These data can provide useful information on the water masses, and potential fronts can be picked up in the fluorescence signal. The Pacific CPR Survey plans to deploy PlankTags on all available routes in the future.

One of the latest additions to the CPR has been the new capability to generate power for sensors using impellers when the CPR is being towed, using the integrated CPR (iCPR, see Figure 3). This is revolutionary as battery power no longer becomes an issue, and the system is designed to become a flexible (plug and play) sensor platform.

Using the new iCPR capability the CPR team have been working with Plymouth University to include *in situ* imaging capabilities alongside the traditional CPR sampling method. This has been achieved using a holographic camera within the payload bay of the CPR (Figure 3). This CPR imaging capability has been trialled off the coast of Norway and tested on a regular CPR route with great success. The holograms are being processed to obtain individual images for each particle of interest. A suite of bespoke algorithms are able to quickly generate measurements (e.g., length, width, area, etc.) for each particle as well as different kind of classifications. We are currently training artificial intelligence models (i.e., convolutional neural network (CNN)) to automatically identify key plankton taxa and groups. The outputs so far have been promising and are able to provide information that compliments the traditional CPR dataset. For example, chain forming diatoms at high spatio-temporal resolution (i.e., meters / minutes) were easily isolated using the images, which can provide information on the morphological characteristics of the plankton community. Once the work and data-flow protocols have been refined for the use of iCPR imaging, the plan is to enhance more of the fleet of CPRs with imaging capabilities. Imaging outputs can provide many different advantages alongside traditional CPR sampling, such as providing early classification of the plankton community at different spatio-temporal scales, leading to early-warning detection of potentially harmful plankton.

By combining the vast coverage of the CPR Survey with the latest advances in technology and power generation, alongside consistent historic sampling of the plankton needed for monitoring long-term changes, the CPR is an ideal platform for monitoring the world's oceans.
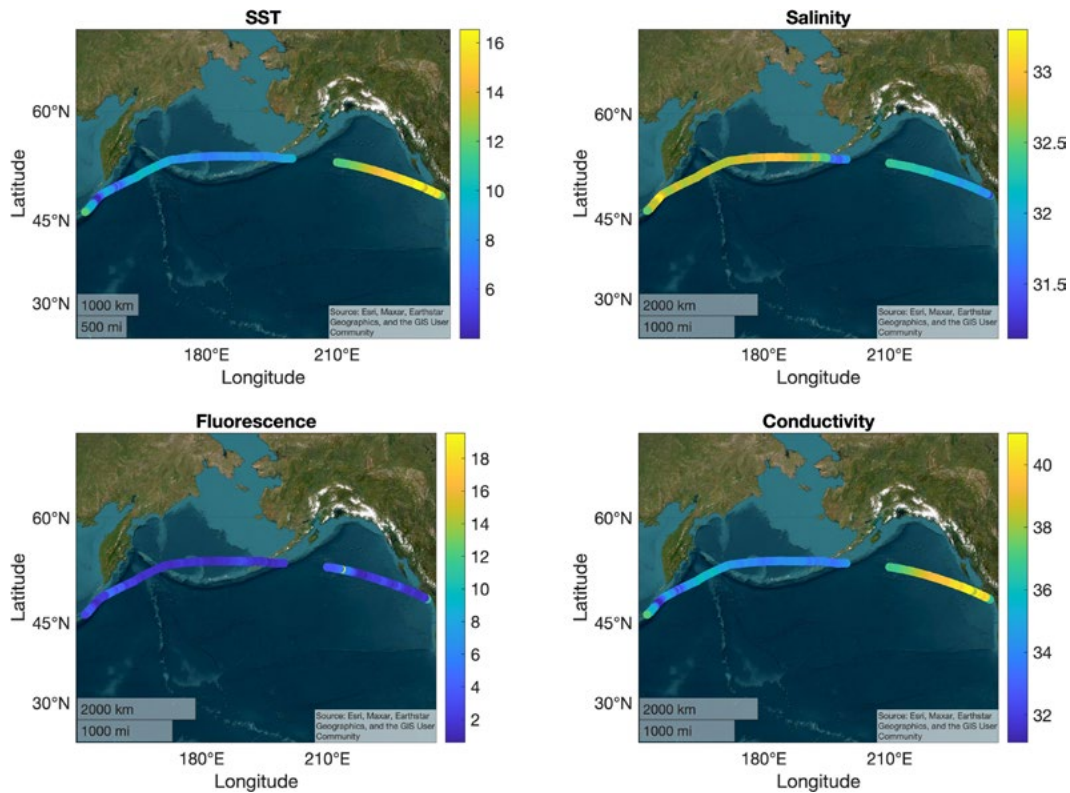
PICES PRESS

Figure 2: Maps showing the data collected by the PlankTag sensor deployed on a CPR in October 2022. Note: The data gap shows the CPR removal from the water, and redeployment the following day. The PlankTag records only when in contact with seawater.
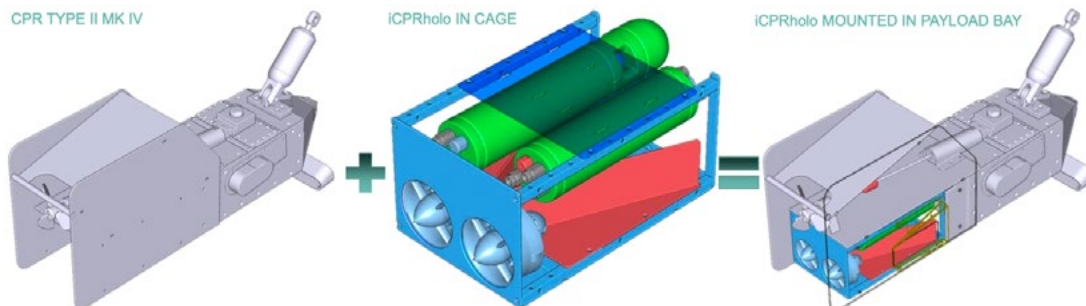

Figure 3. Schematic of the iCPR sampler with holographic camera mounted in the payload bay.

Dr. Clare Ostle is the co-ordinator of the Pacific Continuous Plankton Recorder (CPR) Survey, at the Marine Biological Association in Plymouth, UK. Her research focuses on the use of CPR data for investigating plankton as indicators of the marine environment, linkages with the marine carbon cycle, and oceanic plastics. She enjoys football (soccer) and being on/in the sea.

Dr. Pierre Hélaouët is a senior numerical ecologist at the Continuous Plankton Recorder (CPR) Survey as well a data scientist at the Marine Biological Association (MBA). His research is focused on developing and using ecological concepts, statistical analysis and associated data processing pipelines to explain spatio-temporal variability in planktonic communities. He is also leading the iCPR project, which aims at enhancing the existing CPR platform by integrating new technologies within the most geographically extensive marine biological survey in the world. The project contributes to the development of AI enabled biological observing systems through the creation of an autonomous platform gathering in situ images alongside biological material.

ICES Annual Science Conference, 2022: Theme Session J
Temperature impacts on fish growth and consequences for fisheries
Zhen Lin, John Morrongiello, Asta Audzijonyte, Paul Spencer, Alan Baudron, Shin-ichi Ito

ECOPs network during ICES 2022 Annual Science Conference was held in Dublin, Ireland, from 19–22 September, 2022. L-R: Juan Pardo, PhD student from the Norwegian Institute for Water Research; Rojzin Chand Manoj, PhD student in University of Agder; and Zhen Lin , PhD student and PICES-Sponsored ECOP.

Due to the effects of global warming, sea-water temperature is continuing to rise in many areas of the oceans. Direct effects of rising sea-water temperatures on marine organisms include distributional shifts to higher latitudes, changes in phenology, and changes in body size.

At the ICES 2022 Annual Science Conference held in Dublin, Ireland (right) from 19–22 September, 2022, Theme Session J provided an opportunity to: compare different modelling approaches suitable for isolating temperature effects on fish growth; review empirical evidence about changing individual growth rates of fish in multiple marine ecosystems; consider implications of body size changes for fisheries management; and, coordinate international scale research efforts in the field. The session had 29 contributed oral presentations and 4 posters from delegates spanning a wide range of career levels, from recent Masters graduates to prominent researchers like Professors Daniel Pauly and David Atkinson. PICES supported the attendance of Ms. Zhen Lin, a PhD student, to Session J as one of the Early Career

Ocean Professionals (ECOPs). This article reports on Session J, Lin's participation in the session, and her impressions. The session's panel discussion attracted over 100 attendees registered on the Whova application. Session J was grouped into four main themes, briefly presented below, which were used as the basis for panel discussions.

1. Assessing the temperature effects on growth and body size, as well as possible underlying mechanisms

With presentations from Max Lindmark, Daniel Pauly and Mimi Elizabeth Lam, Vytautas Rakauskas and Asta Audzijonyte, David Atkinson, Henry Wootton, Jennifer Bigman and Federico Cali, this theme addressed questions about the physiological mechanisms behind temperature impacts on fish growth, especially focusing on the temperature-size rule (TSR) proposed by David Atkinson in 1994, suggesting that ectotherms grown in warmer conditions grow faster as juveniles and mature at smaller body sizes.

During the session, the generality of TSR was explored using long-term empirical fish growth data from two artificially heated ecosystems (nuclear power plant cooling systems) in Sweden (Max Lindmark) and Lithuania (Rakauskas and Audzijonyte). Both studies showed that TSR is not universal: there were species-specific growth responses to temperature, although in nearly all cases even small changes in temperature (2°C in Lithuania) led to clear changes in growth. Despite the empirical evidence for species-level differences in TSR responses, David Atkinson's presentation suggested that TSR could be used as a general expectation of ectotherm responses to temperature, against which other environmental or ecological influences should be assessed. The mechanisms behind the TSR were debated by presentations from Daniel Pauly/Mimi Elizabeth Lam, Asta Audzijonyte and Henry Wootton. These presentations provided opposing theoretical and empirical perspectives on the role of maintenance costs versus life-history (growth-reproduction) trade-offs in defining fish growth trajectories across temperatures. During the live panel discussion, David Atkinson pointed out the discrepancies between the original definition of TSR (defined largely from observations of terrestrial ectotherms with determinate growth), which described temperature impacts on juvenile growth and maturation size only, and current use of the term in fisheries-related studies, which often focus on the maximum fish body size.

2. Presenting new analytical methods to assess temperature-dependency of growth and body size

The second theme included a series of talks from Christine Stawitz, Alan Baudron, Timo Rittweg, Deirdre Brophy and Leire Ibaibarriaga, that explored different analytical approaches to detect and quantify growth and body size responses in wild populations, and how complex these models really need to be. Christine Stawitz and Alan Baudron both analysed the same California Current fish age-size data set using different models (state space model vs. dynamic factor analysis). Interesting differences arose from each model, leading to a discussion of the value of mechanistic versus statistical modeling frameworks. For

example, can we use estimated parameters (e.g. the length infinity size in the von Bertalanffy equation) to infer TSR, or should we be using actual size-at-age? The different modelling approaches presented in this theme and also in theme 3, highlighted the importance of considering life-stage and age-dependent thermal sensitivities. Such an approach makes intuitive sense, given that the TSR theory makes different predictions for the effects of temperature on the growth of juveniles and recently matured fish. Lastly, the remaining talks explored new ways to derive age and growth information from otoliths, which could have important applications in detecting seasonal (as opposed to annual) growth patterns, and estimating an individual's growth history when otolith increments are not clear.

3. Analysing long-term growth patterns in large marine ecosystems

Theme 3 included presentations from Tuan Anh Bui, Lea Simonet, Shin-ichi Ito, Zhen Lin, Sarah Willington, Aidan Long and John Morrongiello, and demonstrated the value of analysing existing long-term fisheries length-age datasets to explore temperature impacts on fish growth. A key outcome of the talks (e.g. Sarah Willington, John Morrongiello, Aidan Long) and the subsequent panel discussion was that researchers need to consider the possibility for strong interactions between fishing and temperature on growth trajectories. Fishing can affect growth in multiple ways, including a reduction in stock density that could lead to density-dependent responses, as well as the potential for fishery selection of the fastest-growing fish at a given age. Further, large variation in growth due to internal and external processes affecting fish populations can make it difficult to disentangle the true TSR-like effects of temperature on fish body size. Another more practical issue is that outside of the major fisheries in the North Atlantic, there is often a lack of sufficient data across ages, sizes and time periods to perform necessary analyses. Nevertheless, given the strong evidence presented for temperature affecting fish growth (e.g. Shin-ichi Ito, Zhen Lin, Lea Simonet, Tuan Anh Bui), all speakers argued that it is important to account for warming impacts in fisheries assessment models. There was a consensus from speakers and members of the audience that we need to urgently improve our monitoring of fish growth in fisheries around the world.

4. Assessing the impacts of warming on commercial fisheries and forecast trends in future productivity

The fourth theme comprised a series of presentations by Noah Khalsa, Miguel Barajas, Laurel Smith and Alan Baudron that explored how we can incorporate temperature sensitives biological rates into stock assessment models. This is obviously a non-trivial task,

but nonetheless empirical (Laurel Smith) and simulation studies (Miguel Barajas, Noah Khalsa) showed that this is something we need to consider. The panel discussion then addressed more general questions of: how do we effectively communicate temperature driven fish growth changes and its implications to stakeholders?, and what information do we need in order to make good forecasts of temperature-dependent growth in the future?

Conclusions

Session J attracted a series of engaging and informative presentations that explored how temperature impacts fish growth, and the subsequent implications of fish body size changes for ecosystems and fisheries. The session was very popular with conference delegates, as evidenced by the high in-person and virtual attendance and keen engagement during the panel discussion. Despite the theoretical predictions of TSR on how temperature affects body size, many presentations showed observations indicating that responses in natural populations can be more complex, and that other factors such as fishing and food availability must be appropriately considered. Our session highlighted that there are still large disagreements in the underlying mechanisms of temperature impacts on fish size in natural ecosystems. It did, however, reinforce to all attendees that: temperature does have strong impacts on fish populations (directly or indirectly); careful experimentation and analysis of fisheries data offers exciting opportunities to test new theoretical models; and, concerted effort is urgently needed to appropriately consider temperature effects in fisheries models.

Impression of Session J by Zhen Lin, PICES ECOP

On September 19–22, 2022, I had the privilege of attending the ICES Annual Science Conference 2022 at Aviva Stadium in Dublin. This incredible event was made possible, in part, by the generous support of the PICES travel grant for early career scientists. As it was my first time in Dublin, I was immediately captivated by the city's majestic trees and the tall stature of its people. This experience reinforced my belief in Bergmann's rule or TSR (Temperature-Size Rule), which posit a correlation between body size and temperature.

During the conference, I had the opportunity to deliver an oral presentation titled *"Fish Body Weight Long-term Variability around Japan: Part 2 - Recent Variations Responding to Climate Change"* in Session J. I felt honored to share my findings on the declining trend of fish populations around the Japanese Archipelago, particularly during the past two decades, and especially in the 2010s.

The themes explored in Session J provided me with a wonderful opportunity to enhance my understanding of the potential underlying mechanisms behind the fish size responses to temperature. I was deeply impressed by the realization that these responses were highly specific to regions, species, and life stages. This realization

underscored the significance of collaborative efforts to unravel the complexities of the vast ocean ecosystem. I gained greater understanding of the risks of blindly adopting conclusions from others and recognized the importance of independent analysis and interpretation.

In addition to presenting my research, I actively participated in the panel discussions held during the session. This novel and engaging format allowed me to communicate and exchange ideas with other researchers. It served as a timely reminder of the crucial role that effective communication plays in advancing scientific research. Throughout the conference, I had the pleasure of meeting several members of WG GRAFY, whom I had previously met via Zoom. Their enthusiasm and kindness left a lasting impression on me. I am particularly grateful to Dr. Alan Baudron for his warm-hearted assistance in reviewing the results of my analysis. Furthermore, one of the highlights of the event was the opportunity to have a photograph taken with Prof. David Atkinson (see left), the scientist who originally termed the TSR. This encounter was akin to a fan meeting an idol, and it filled me with immense excitement and inspiration.

In recognition of the unique challenges faced by early career scientists, the ICES ASC also provided valuable assistance through career advice and guidance on proposal-writing skills. Among the many impactful messages I received during this conference was the idea that scientists must think boldly. It resonated deeply with me and will serve as a profound source of inspiration for my future studies.

Overall, my experience at the ICES Annual Science Conference 2022 was nothing short of exceptional. The exchange of knowledge, the camaraderie among researchers, and the invaluable lessons learned have invigorated my passion for scientific inquiry.

I am profoundly grateful for PICES offered me this opportunity to have been a part of this remarkable event.

Zhen Lin (lin-zhen695@g.ecc.u-tokyo.ac.jp) is a PhD course student in the Graduate School of Agriculture and Life Sciences The University of Tokyo. She is studying about climate change effects on fish growth.

John Morrongiello (john.morrongiello@unimelb.edu.au) John is a Senior Lecturer in Marine and Freshwater Biology at the University of Melbourne and is passionate about fish biology. He works in both marine and freshwater systems investigating how animals respond to environmental change on contemporary and evolutionary time scales. He co-chairs the Joint PICES/ICES Working Group on Impacts of Warming on Growth Rates and Fisheries Yields (GRAFY).

Asta Audzijonyte (asta.audzijonyte@utas.edu.au) Asta Audzijonyte is a research fellow in macroecological modelling at the Institute for Marine and Antarctic Studies. She has an inter-disciplinary research experience combining molecular ecology, evolutionary biology and ecological modelling. Her current research focuses on assessing human impacts on fish size diversity using a wide range of data, including non traditional sources (citizen science, apps).
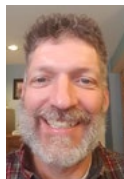
Paul Spencer (paul.spencer@noaa.gov) Paul Spencer is a fisheries research scientist at the Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration. His research focuses on fisheries stock assessment and management, and the effects of environmental variation and climate change on fishery population dynamics. He co-chairs the Joint PICES/ICES Working Group on Impacts of Warming on Growth Rates and Fisheries Yields (GRAFY).

Alan Baudron (Alan.Baudron@gov.scot) Alan Baudron is a fish population modeller at Marine Scotland, his research revolves around improving the knowledge and management of marine resources. He co-chairs the Joint PICES/ICES Working Group on Impacts of Warming on Growth Rates and Fisheries Yields (GRAFY)

Dr. Shin-ichi Ito (goito@aori.u-tokyo.ac.jp) is a Professor at the University of Tokyo. His fields and topics of research range from physical to fisheries oceanography. He co-chairs the Joint PICES/ICES Working Group on Impacts of Warming on Growth Rates and Fisheries Yields (GRAFY) and member of the joint PICES/ICES Section on Climate Change Effects on Marine Ecosystems (S-CCME) and Advisory Panel on Early Career Ocean Professionals (AP-ECOP).

The Development of the SUPREME Network
SUstainability, Predictability, and REsilience of Marine Ecosystems
Grace Roskar, Steven Bograd, Hannah Lachance, Ed Gorecki and Roger Griffis

SUstainability, Predictability and REsilience of Marine Ecosystems

Climate-driven changes in ocean conditions are impacting the distribution and abundance of many species, with significant implications for fisheries, protected resources, coastal communities and food security. The SUPREME (SUstainability, Predictability, and REsilience of Marine Ecosystems) Programme is convening global partners through an international knowledge network to share information and support the production of robust climate and ocean-related forecasts, predictions, and projections to guide effective marine ecosystem management and adaptation strategies in a changing climate. This interdisciplinary programme was endorsed by the Intergovernmental Oceanographic Commission (IOC) in October 2021 as a programme of the United Nations Decade of Ocean Science for Sustainable Development ("UN Ocean Decade").

The overall goal of SUPREME is to advance the modeling tools needed to reduce risks and increase resilience of marine/coastal resources and the people who depend on them. The Programme will draw from existing efforts such as NOAA's Climate, Ecosystems, and Fisheries Initiative (CEFI) designed to build a national ocean modeling and decision support system, and Australia's Future Seas project and Atlantis ecosystem model that are examples of the interdisciplinary efforts needed to reduce impacts, increase resilience and help marine resources and resource users adapt to changing ocean conditions. By sharing information on these and other efforts, the SUPREME Programme will help advance the end-to-end decision support systems needed to provide decision makers with actionable information and capacity to prepare for and respond to changing conditions today, next year and for decades to come.

Formed in early 2023, the SUPREME Network brings together international partners to:

1. provide easy access to information, examples, experts and peers and

2. help advance this important field through sharing successes, challenges, and lessons learned.

Based on an initial outreach effort to government agencies from around the world, inter-governmental organizations (e.g., PICES, ICES), academia, non-governmental organizations, specific research or modeling initiatives, and related UN Decade Programmes conducted in early 2023, over 85 individuals across 45 different entities have joined the Network. After this initial call for members, a survey was sent to confirmed partners to better understand how the SUPREME Programme could be most useful to its members and their interests, needs, and ideas. Results from the survey informed subsequent conversations in two Network meetings: an initial virtual Network meeting in March 2023 and an in-person /hybrid Network meeting in April 2023 at the Effects of Climate Change on the World's Ocean Symposium (ECCWO5).

The results of the survey revealed (see word cloud below) that Network members are most interested in topics such as the challenges and needs surrounding advancing climate-related ocean, ecosystem, and fisheries hindcasts, forecasts, predictions, projections; finding pathways to link climate science and management action; the effective use of the best available scientific data/knowledge to bring solutions to socio-economic issues; and the overall exchange of information and building new collaborations. Network members noted they are eager to explore what technical tools and products exist, what capacity-building services or trainings are available, different approaches to climate- and ocean-related modeling and forecasting, and how modeling information is used, such as how to create connections with stakeholders and policymakers to contribute to effective management and adaptation strategies.

The survey also helped narrow the scope of topics that the Network thinks SUPREME should focus on, such as:

- Data/observations availability and needs
- Advancing or improving modeling efforts
- Capacity-building
- Using climate information in decision-making
- Links to social questions
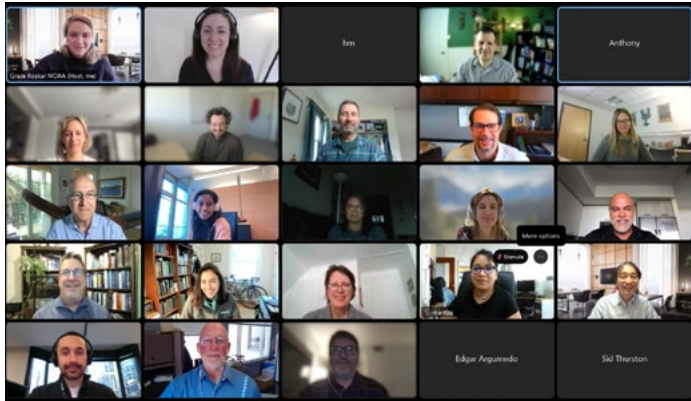
SUPREME held a virtual network meeting (above) over two sessions in March 2023 where the results of the survey were presented to Network members followed by a discussion. Network members raised points about ensuring that Decade programmes complement each other, thinking creatively about ways to engage those around the world involved in the topics SUPREME is focusing on, and engaging with management agencies to further engage these end users and decision makers.

In April of 2023, over 60 Network members and interested individuals gathered both in-person and virtually for a special session on SUPREME during the Effects of Climate Change on the World's Ocean Symposium (ECCWO5) in Bergen, Norway (see below, right). The focus of this meeting was to continue discussions on member needs and interests and how to move forward and continue addressing those needs. Key takeaways from this meeting included the need for an organizational chart of networks and programs to better understand how partners overlap and what their strengths and weaknesses are as well as the need for Network members and related UN Ocean Decade programmes to join efforts with SUPREME to develop an inventory of climate and ocean data, code, models, climate-ready decision support programs, tools, and best practices. To engage with underrepresented groups or regions, it was suggested that SUPREME develop a gap analysis of the SUPREME network organizational chart to identify the types of groups/regions that are not currently represented in the Network and would make the inventory more robust and equitable. Ideas for a future SUPREME workshop were also discussed at the meeting, with suggestions focused on connecting with international

partners in ocean management sectors and regional bodies to learn how they engage stakeholders and incorporate stakeholder feedback into their management regimes. Another key next step for SUPREME is to form and utilize regional and topical subgroups to fuel innovation and co-development of applications and management tools.

The next UN Decade workshop that SUPREME is co-leading is scheduled for Saturday, October 21, 2023 at the PICES Annual Meeting in Seattle, WA. This workshop, titled "Sharing Capacity and Promoting Solutions for Marine Ecosystem Sustainability within the UN Decade of Ocean Science" will be a follow up on the ECCWO UN Decade workshop as well as the ECCWO SUPREME side meeting including taking the Climate and Fisheries/ Ecosystem nexus inventory that is under development and beginning a gap analysis to identify what key gaps need to be addressed to help SUPREME and other UN Decade programmes and projects advance their goals. In the lead-up to this meeting, members will continue to develop the inventory and are seeking content contributions from the global community. To learn more about this inventory and to contribute please reach out to SUPREME coordinator.

In the coming year, SUPREME expects to form and utilize regional and topical subgroups as well as utilize other venues (i.e., side meetings at conferences) to help advance an improved understanding of marine ecosystem dynamics and a suite of decision support tools available to a broad range of stakeholders. Network members are the invaluable backbone of the SUPREME Programme by sharing information and participating in relevant discussions, meetings, and other SUPREME efforts related to advancing climate-informed marine ecosystem management, thereby also helping to advance international collaboration and coordination. The SUPREME Network is a dynamic group with diverse expertise and interests and welcomes new members at any time. For more information and to join the SUPREME network please email the SUPREME coordinator, Grace Roskar (grace.roskar@noaa.gov).

Remembering Vera Alexander
Gordon Kruse

Dr. Vera Alexander, a beloved founding member of PICES, passed away peacefully, surrounded by family members, on May 11, 2023, in Fairbanks, Alaska. She was 90 years old.

Vera was born in 1932 in Budapest, Hungary, where she became enamored with animals, especially horses. With the onset of World War II, her family fled Hungary to England in 1939. As a 7-year-old, Vera trained her dog Tigger to pull a cart, while she sold duck eggs to neighbors during the war. As a teenager she enjoyed riding through the countryside on her pony, *Cobweb*, the very first of many horses she owned during her lifetime. She dropped out of high school at age 16 to work on an English farm, but her interest in agriculture later led her to science. During these years, she also developed a life-long love of music. In fact, in England she earned firsts in music composition at the Berkhamsted School for Girls and passed the Royal Academy of Music (London) piano performance exam. After the war, her family moved to Princeton, New Jersey, U.S.A.

Vera's interests in farming led her to the University of Wisconsin. Why did she pick Wisconsin for school? In a 2015 interview she said *"I didn't want to be on the east coast, I wanted to be as far west and north as I could go, and where there were farms. I wanted to be a farmer, and muck around in the woods".* At Wisconsin an advisor told her that *"you really need to get your sciences in order to be good at agriculture."* She went on to earn a BS in Biology and a MS in Zoology. During college days, she enjoyed other activities – particularly mountain climbing – and she took several trips with the Wisconsin Hoofers Mountaineering Club to the mountain ranges of the Tetons and the Canadian Rockies. Vera married fellow graduate student and Hoofer, Richard (Dick) Dugdale, and had two children, Graham and Elizabeth Dugdale. After repeated research trips to Alaska, Vera and Dick moved to Fairbanks in 1962 while she was working on her Master's degree from Wisconsin. When they arrived in Alaska she said *"I am never leaving".*

In the 1960s, Vera started at the newly formed Institute of Marine Science (IMS) at the University of Alaska. She participated in research at IMS as she pursued her own research leading to a Ph.D. on the topic of *seasonal succession in nitrogen-limited algal blooms and their relationship to the nitrogen cycle in a lake*. Vera finished her doctoral studies in three years and was the first woman to be awarded a Ph.D. at the University of Alaska in 1965. At the time she earned her degree, women weren't allowed on research ships, though, fortunately, that soon changed. After joining the faculty of IMS, Vera established a vibrant research program and trained graduate students in marine and freshwater research. She was a scientific pioneer in many ways. For example, she was among the first to use the N-15 isotope to study nitrogen fixation in lakes. At the time, it was commonly thought that bacteria were the primary source of fixed nitrogen, but Vera found that most of it was fixed in lakes by blue green algae. Since then, this same process was found in other environments including tundra terrestrial ecosystems, where lichens fix nitrogen. After early interests in marine ecology and particularly the role of sea ice in biological processes in polar seas, she turned her attention to the Bering Sea, where she was intrigued by the production processes leading to large harvestable resources. She discovered that the ice was a critical factor determining spring productivity in the arctic region. Many of her research studies, such as heterotrophy of sea ice algae, or developing suitable techniques to measure ice algal activity, were firsts in marine science.

Vera (PICES Vice-Chair at the time) played Rachmaninoff during the Chair's reception at PICES 10th Anniversary Annual Meeting (October 2001, Craigdarroch Castle, Victoria, Canada).

Vera went on to become the Director of IMS and then became the first Dean of the School of Fisheries and Ocean Sciences at the University of Alaska Fairbanks, serving in this capacity for nearly 20 years until 2004.

Vera with Bob Elsner, long-term planners of the R/V Sikuliaq, at the launch of the vessel in 2012 in Marinette, Wisconsin. Inset: Vera and Bob's initials were welded into the hull of the ship.

Vera was instrumental in the conceptualization and development of the Research Vessel Sikuliaq, one of the most advanced university research vessels in the world, capable of breaking ice up to 2.5 feet thick. In 2012 she had the great honor to christen the ship on the occasion of its inaugural launch, a crowning achievement in her career.

Vera's distinguished scholarship in biological oceanography, leadership in marine science, and influence in marine policy, has been recognized nationally and internationally. She authored over 70 papers that were published in peer-reviewed literature and she received many honors, including elections as a Fellow of the American Association for the Advancement of Science, the Arctic Institute of North America, and the Explorers Club. Vera was honored to receive an honorary Doctorate of Laws degree from Hokkaido University in recognition of her work promoting international scientific cooperation.

Among her many achievements were 16 years of service on the Marine Mammal Commission, 12 years on the International Scientific Steering Committee of the Census of Marine Life, service on the National Research Council Committee as well as Treasurer of the Board of Directors of the Arctic Research Consortium of the U.S. (ARCUS). She also served as chairman of the National Science Foundation's Committee on Ocean Sciences and NOAA's Science Advisory Board and the Ocean Research Advisory panel.

Vera was a champion of PICES from the very beginning of the organization. She is considered one of the founding members of PICES having been extremely active and a staunch advocate for PICES during its formative early years. She served as United States delegate to PICES Governing Council starting with the formation of PICES in 1992 and continuing until 2002.

In addition to encouraging a number of young scientists to become engaged in PICES, she helped shepherd the first major science initiative of PICES; the 10-year investigation

of Climate Change and Carrying Capacity, a program that involved scientists from across the Pacific Rim and was supported through GLOBEC. Vera was PICES Vice Chair during 1998-2002 and Chair during 2002-2006. Vera was the recipient of the prestigious 2013 Wooster Award for a career of sustained excellence in marine science. Her dedication and contributions to PICES are well recognized.

In spring 2023, Vera Alexander received a commendation from the Alaska State Legislature affirming her many remarkable contributions to the history of the university and to the state of Alaska. During her time at UAF, she shattered many glass ceilings, and during March 2023 UAF celebrated Dr. Alexander, along with many other women who have been inspired by her example.

Throughout her life, Vera demonstrated her love for animals including many dogs, cats, and horses. Her close friends will recall her enjoyment of a "wee dram" of fine Scotch whiskey. However, few may know that she was elected as a Fellow in the Academy of Malt Scotch Whisky in 1980. Vera nurtured her love of the piano, demonstrating her talents on the concert stage and as the first accompanist for the Fairbanks (Alaska) Light Opera Theater.

Vera was predeceased by her sister, Catherine Alexander, and her brother, Robin Alexander. She is survived by her son, Graham Dugdale (Elizabeth Benson), and her daughter Zoe Dugdale (Neilan Pierce, Jr.); daughter Elizabeth Alexander and her children Celia Jackson (Rob Wolter, Jr.) and Everett Jackson (Kara Epple); horses Vinur and Vangeur; dog Lady Byrne; cat Arne.

Vera (US national delegate) at the first PICES Governing Council meeting (October 1992, Victoria, Canada). L-R: Dr. J.C. Davis (Canada), Dr. V. Alexander (USA), Dr. L.S. Parsons (Canada), Dr. W. Aron (USA), Dr. H. Hatanaka (Japan), Dr. W.S. Wooster (USA), Prof. Y.K. Xu (China).

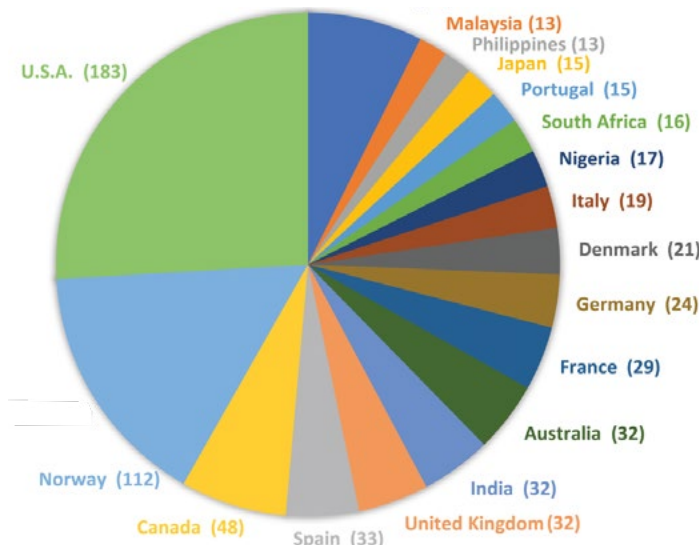## PICES by the Numbers ~ #ECCWO5 Calculated Carbon Emissions
Lori Waters

eccwo5

- **71** Countries participated

- **716** Registrants (Online: 254; In-person: 462)

- **4,179,316 Kilometres travelled**
  to/from #ECCWO5 by in-person attendees*

- **1284.01 Metric tonnes #ECCWO5 Total Carbon Emissions****

- **2.8 Metric tonnes #ECCWO5**
  Average Carbon Emissions / in-person attendee***

  *   Sum of Round-trip Flight Distances for all in-person attendees
  ** Calculated using round-trip flights of all in-person attendees (Using Methodology from Wynes et al., 2018, applying Short, Medium, and Long-haul flight emission factors, and uplift factors).
  *** Average of overall calculations divided by in-person attendees

eccwo5 Countries (# *Attendees from country*)

U.S.A. (183)
Malaysia (13)
Philippines (13)
Japan (15)
Portugal (15)
South Africa (16)
Nigeria (17)
Italy (19)
Denmark (21)
Germany (24)
France (29)
Australia (32)
India (32)
United Kingdom (32)
Spain (33)
Canada (48)
Norway (112)

Travel Distances by Country (# of Attendees)

COUNTRY (#attendees)	KMs**	COUNTRY (#attendees)	KMs**	COUNTRY (#attendees)	KMs**	COUNTRY (#attendees)	KMs**
U.S.A. (144)	1,950,600	KOREA, R (5)	81,400	CHILE (1)	25,000	TANZANIA (1)	16,600
AUSTRALIA (20)	573,076	FRANCE (20)	62,800	INDONESIA (1)	22,800	ANGOLA (1)	15,440
CANADA (27)	317,400	HONG KONG (3)	52,800	BRAZIL (1)	21,800	ISRAEL (2)	15,200
SOUTH AFRICA (8)	169,600	PORTUGAL (9)	49,200	PERU (1)	21,600	KUWAIT (1)	9,400
JAPAN (7)	120,400	UK (23)	48,400	DENMARK (13)	19,600	ICELAND (3)	9,000
SPAIN (27)	119,800	NORWAY (77)	45,800	THAILAND (1)	18,000	OTHER (25)*	27,400
CHINESE TAIPEI (5)	114,000	ITALY (10)	42,000	GUATEMALA (1)	17,800		
INDIA (6)	90,000	GERMANY (17)	27,400	COLUMBIA (1)	17,600		

* "Other" is defined as the following twelve countries, each with a total distance flown of <4000 kms, and each with less than or equal to 5 attendees: Poland (1), Faroe Islands (2), Switzerland (1), Slovenia (1), The Netherlands (2), Monaco (1), Ireland (2), Austria (2), Belgium (3), Sweden (5), Finland (3), Morocco (1).
**KM's: The total of round-trip Kilometres flown by #ECCWO5 Attendees from that country.

Percentage of #ECCWO5 flights by Haul Distance:

- **0% Short Haul**
  (<463 km One Way; 3,800 of 4,179,316 kms)

- **15.4% Medium Haul**
  (463—3700 km One Way; 644,600 of 4,179,316 kms)

- **84.4% Long Haul**
  (>3700 km One Way; 3,530,916 of 4,179,316 kms)

#ECCWO5 GHG Emissions are equivalent* to:

- 🚗 DRIVING 286 gasoline-powered passenger vehicles for 1 year

- ⛽ CONSUMING 546, 924 Litres of gasoline

- 🏠 BURNING 248, 080 Kg of Coal

- CONSUMING 2,970 Barrels of Oil

According to the US EPA GHG Calculator

Recommended Reading, References, and Tools:
Methodology: Wynes, S., & Donner, S. D. (2018). Addressing greenhouse gas emissions from business-related air travel at public institutions: a case study of the University of British Columbia. Pacific Institute for Climate Solutions. https://pics.uvic.ca/sites/default/files/AirTravelWP_FINAL.pdf
- Flight CO_2 Calculator: https://co2.myclimate.org/en/flight_calculators/new
- USA Environmental Protection Agency (EPA) Greenhouse Gas Equivalencies Calculator: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

PICES Events Calendar

- **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)**
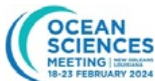 Yokohama, Japan , June 3–7, 2024

PICES' Partner Events

- **ICES Annual Science Conference**
  Bilbao, Spain, 11–14 September 2023

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

- **Ocean Sciences Meeting**
  New Orleans, Louisiana, USA, February 18 –23, 2024

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

Capacity Development Events

- **ITCP-CLIVAR Summer School 2023**
  Trieste, Italy, July 24-29, 2023

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

Your PICES Science Images
Lori Waters

Tall ship *Statsraad Lehmkuhl* returned to Bergen, Norway, on April 15 2023, (just before the ECCWO5 Symposium, detailed earlier in this issue, starting on page 6). She is more than just a pretty vessel, and was a fitting venue for the opening reception of this global climate change symposium. Returning from a largely wind-powered, (sustainable), 604-day, 60,000 nautical mile journey, the *Statsraad Lehmkuhl* was the platform for the *One Ocean* expedition, during which a comprehensive science plan was executed. Organized in part by one of ECCWO5's contributing organizers, the *Norwegian Institute of Marine Research* (IMR), the 105-year-old sailing vessel was equipped with advanced research equipment that enabled it collect data throughout its sustainable voyage, with inline water quality and pCO_2 sensors, echosounders, camera systems, hydrophones, and biological sampling gear. In addition, the vessel stopped regularly for water samples for eDNA and other analyses, with the help of scientific crew members, including students.

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!

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