

## PICES science in 2019: Notes from the Science Board Chair

What can PICES do in an era of global change? The impacts of global warming and other anthropogenic perturbations became more visible and significant than ever in 2019, and they are a serious threat for the sustainability of our society. Not only warming or heat waves, but unexpected fluctuations in climate, overfishing, habitat destruction, *etc.*, also damage ecosystem components and degrade ecosystem services on which our society is dependent. In December 2017, the General Assembly of the United Nation proclaimed a UN Decade of Ocean Science for Sustainable Development, 2021–2030 (hereafter, Ocean Decade). This is a clear request from society to marine scientific organizations and institutions across the globe to prepare the best scientific knowledge with appropriate timing to enable science-based decision making that will prevent further degradation of marine ecosystems and to sustain our civilization. Because global change issues are quite complex in mechanisms and components, it is essential to include stakeholders and international collaboration of both natural and social scientists in tackling these issues. PICES has a long history and experience of transdisciplinary sciences under the scheme of international collaboration. I believe that PICES will be a leading organization of global change marine science in the coming decade. We should not miss

the last chance to prevent catastrophic degradation of marine ecosystem services. Under the critical situation of the Earth and society, PICES carried out various scientific activities in 2019 and established a foundation for future progress of North Pacific marine sciences.



*Empress Hotel, Victoria.*

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Governing Council participants, top row, from left: Seung Young Jung (Korea), Adam Bloomquist (USA), Robin Brown (PICES Executive Secretary), Wonjoon Shim (Korea), Toshiaki Kobayashi (Japan), Tetsuo Fujii (Japan), Nobuaki Suzuki (Japan). Front row, from left: William Karp (ICES), Jun Hyung Kim (Korea), Igor Shevchenko (Russia), Sun Ha Kim (Korea), Enrique Curchitser (USA), Ellen Johannesen (ICES), Anna Christine Brusendorff (ICES), Lesley MacDougall (Canada), Carmel Lowe (Canada), Laura Richards (PICES Past Chair), Chul Park (PICES Chair), Eun Won Yu (Korea), Yafeng Yang (China), Hyun-Joo Kang (Korea), Kazuki Ueda (Japan), Miyeon Kwon (Korea), Cisco Werner (USA), Kaori Imai (Japan), Michael Seki (USA).

The 28<sup>th</sup> Annual Meeting (PICES-2019) was held in Victoria, Canada, from October 16–27, 2019. The 1<sup>st</sup> PICES Annual Meeting was held in 1992 in the city of Victoria, and PICES-2019 was the 4<sup>th</sup> meeting in the Garden City. At the Opening Session we took a moment to recognize individuals who have made significant contributions to our organization. The PICES Chair Award was given to Ms. Patricia Livingston (USA) for her sustained dedication to scientific activity and administration of PICES. The Wooster Award was presented to Dr. Ian Perry (Canada) for his long-term and ongoing excellence in research and teaching of North Pacific marine science. The participants at the Opening Session were in a celebratory mood, praising the achievements of these two individuals with long-lasting applause. More details of the award recipients are presented in the following article.

The theme of PICES-2019 was “*Connecting science and communities in a changing North Pacific*”. In her keynote talk, Dr. Jackie King (Canada) discussed the various and cumulative impacts of anthropogenic forcing on coastal ecosystems, and presented best practices and challenges of how scientists collaborate with broad sectors of stakeholders for science-based decision making.

PICES-2019 was the biggest Annual Meeting ever. The number of attendees was 630 from 25 countries, including 148 early career scientists (ECS). There were 20 topic/paper sessions, 19 workshops and 30(!) business meetings. Although such a large meeting indicates high activity of PICES, it is also controversial for the many parallel sessions/meetings which generated scheduling conflicts for some of the attendees. Science Board and the Secretariat are jointly considering an appropriate size for future meetings, especially the number of sessions and workshops.

Many of the topic sessions were fully or partly related to Social-Environmental-Ecological Systems (SEES). It is not

unusual to have heated discussion on the social issues in the sessions that focus on cutting-edge natural science. PICES scientists understand and appreciate the “different language” expertise of natural and social scientific disciplines, and are familiar with transdisciplinary sessions and programs as a result of long conversations involving both natural and social scientists in PICES expert group activities and programs such as FUTURE. One of the unique activities at PICES-2019 was Workshop 3: Let’s Play the GAME! This workshop did not follow the presentation-discussion-writing style; instead it was a card-playing game involving different stakeholders to achieve ecologically, economically, and socially balanced fisheries development. The relaxed and playful atmosphere helped to induce discussion and exchange of ideas for educational and outreach activities for fisheries management.

FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems), the integrative science program of PICES, was quite active in 2019. In April, FUTURE Scientific Steering Committee (SSC) members held their 5<sup>th</sup> inter-sessional meeting in Yokohama, Japan. They produced a stylish [FUTURE outreach video](#) explaining what FUTURE is doing, why FUTURE sciences are essential in a changing North Pacific, and encouraged PICES members to link with FUTURE to achieve sustainable development. The FUTURE SSC also published a [review article](#) of FUTURE sciences in the journal *Frontiers of Marine Science*. It explains how the FUTURE Socio-Ecological-Environmental System (SEES) approach is applied to understanding and maintaining resilient marine ecosystems. Several “crisis” case studies in the North Pacific are described and show how our society is influenced by North Pacific marine ecological and environmental systems and the feed-back process to society. FUTURE is planning a FUTURE Open Science Conference to be held in 2021. Please wait for a while for details on the goal of the conference, as well as the schedule and venue.





Science Board participants, top row, from left: Motomitsu Takahashi (representing Japan), Harold (Hal) Batchelder (PICES Secretariat), Sukyung Kang (FUTURE SSC), Rosalie Rutka (PICES Secretariat), Xianshi Jin (FIS), Keith Criddle (HD), Emanuele Di Lorenzo (POC). Front row, from left: Joon-Soo Lee (TCODE), Hiroaki Saito (Science Board Chair), Jennifer Boldt (MONITOR), Se-Jong Ju (BIO), Steven Bograd (FUTURE SSC), Vera Trainer (Science Board Chair-elect), Guangshui Na (MEQ), Oleg Katugin (representing Russia).

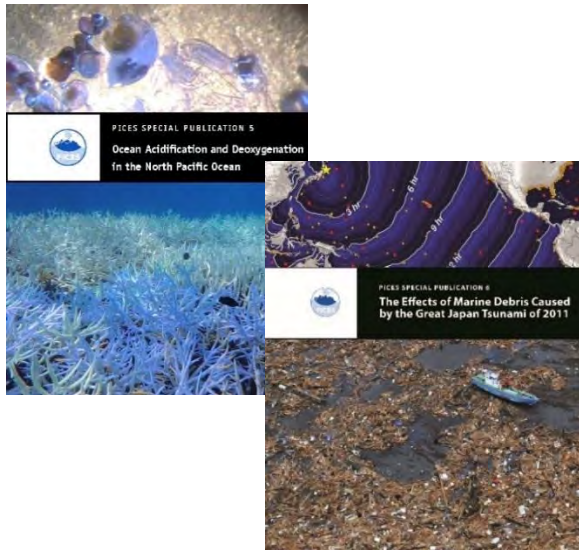
As mentioned earlier, PICES supports the concept of the Ocean Decade as the objectives are closely aligned with the goals of PICES. Last spring, PICES was represented at the 1<sup>st</sup> Global Planning Meeting in Copenhagen by the Executive Secretary, Mr. Robin Brown, and several PICES scientists led the discussion as Executive Planning Group members of the Ocean Decade. After the meeting, PICES co-sponsored with IOC/WESTPAC and MEXT/Japan a “Regional Planning Workshop for the North Pacific and Western Pacific Marginal Seas” in Tokyo. PICES scientists presented the uniqueness of the marine ecosystems and society of the North Pacific and its marginal seas relative to other regions, and led the discussion in six themes of the Ocean Decade (I. A clean ocean, II. A healthy and resilient ocean, III. A predicted ocean, IV. A safe ocean, V. A sustainably harvested and productive ocean, VI. A transparent and accessible ocean) as session convenors or presenters. We are happy to note that each PICES member country was also represented, as were many of our partner organizations.

Monitoring the present status of North Pacific marine ecosystems is essential for the process of science and decision making for conservation and sustainable use of marine ecosystems. Working Group 35 on the *Third North Pacific Ecosystem Status Report* (WG-NPESR3) has conducted the synthesis of the foundational Environmental Time Series Observations (ETSOs) of 15 biogeographical regions (see <https://meetings.pices.int/members/working-groups/wg35>). WG 35 met inter-sessionally and at PICES-2019 to draft the synthesis paper. The WG members were quite enthusiastic to synthesize the status of North Pacific

marine ecosystems, and it is expected that their synthesis paper will be published in 2020. The NPESR3 will contribute not only to PICES science but also to other international initiatives of marine ecosystems such as the Ocean Decade and UN Sustainable Developmental Goal 14 “Life below water”.

As a science organization, PICES communicates the results of its activities and achievements through a diversity of publications, from peer-reviewed journals, through to PICES Scientific Reports to outreach brochures. This year, the outcomes of PICES-organized symposia from 2017 (Small Pelagic Fish Symposium) and 2018 (PICES Transitional Areas Symposium) and (4<sup>th</sup> International Symposium on “*The effects of climate change on the world’s oceans*” (ECCWO-4)) and were published as special issues in the top quality journals *Marine Ecology Progress Series*, *Deep-Sea Research, Part II* and *ICES Journal of Marine Science* (see PICES [primary publications](#)). PICES also published two Special Publications on “Ocean Acidification and Deoxygenation in the North Pacific” and “The Effects of Marine Debris Caused by the Great Japan Tsunami of 2011”. The former was edited by the Co-Chairs of the Section on *Carbon and Climate* and explains how these two stressors are affecting ecosystems in different regions of the North Pacific. The “ADRIFT” project was the culmination of a 3-year study of the transport of marine debris, including marine life, by the 2011 tsunami of Japan. This provided the first opportunity in the history of marine science to track a multi-year, large-scale transoceanic rafting event of marine life from an exactly known source and sea-entry time. As PICES Science Board Chair, I am very happy to see such

beautiful and wonderful outreach products not only for scientists but also teachers, students and the general public, describing what is ocean acidification and deoxygenation, or how marine debris was transported, what are the impacts, and inspiring what we can do for a sustainable marine ecosystem. If you have not yet looked at these publications, please do so by downloading a PDF version through the [PICES website](#).



Many of the issues that we are facing due to global change are too big to tackle with one organization or one country. Also, these are not unique to the North Pacific. Therefore, it is important for PICES to collaborate with other organizations and programs. At PICES-2019, some 22 external organizations and programs attended. Several strategic partners (ICES, IPHC, NPFC, NPAFC, NPRB, CRP, Future Earth) were invited to the Science Board meeting to discuss ongoing and future collaboration with PICES. As an example, collaboration with ICES continues to get tighter and stronger. PICES and ICES have sponsored joint expert groups since 2008 and co-sponsor symposia, sessions/workshops and capacity development activities such as the PICES/ICES Early Career Scientist Conference series. PICES and ICES agreed to jointly contribute to the Ocean Decade and foster an international and diverse science network to expand the capacity for co-producing the science that enables sustainable development of marine systems at the interface of climate, fish, and society.

At PICES-2019, Governing Council approved the recommendation from Science Board to establish a PICES/ICES Working Group on *Small Pelagic Fish* (SPF; WG 43) to investigate the causes and consequences of fluctuations in SPF populations and to provide recommendations for strategies on marine ecosystem monitoring and small pelagic fisheries management. The planning of the WG started at PICES/ICES Small Pelagic Fish Symposium in March 2017. Now, WG members are going to be nominated to start the activity. Capacity

building, especially for supporting ECS, has been a high priority of PICES since its establishment. In 2019, PICES sponsored two capacity building workshops: the Zooplankton Production Practical Workshop, Phase 2 organized by Working Group (37) on *Zooplankton Production Methodologies, Applications and Measurements*, and held on Quadra Island, Canada, and the Pacific Ecology and Evolution Conference at Bamfield, Canada. PICES also supported 46 ECSs and students to attend PICES-2019 and symposia, conferences, and workshops co-sponsored or organized by PICES. Encouraging young scientists and finding resources to enable them to participate in PICES activities is essential for the Organization. To highlight the excellent science of ECS, PICES established a new PICES award, the Zhu-Peterson Early Career Scientist Award. The award is named in honor of Professor Mingyuan Zhu and Dr. William Peterson, two marine scientists who, during their careers, strongly encouraged early career scientists to become engaged in PICES. The Award will go to applicants who have performed innovative research at the frontiers of science relevant to the PICES mission. The first Award will be presented at PICES-2020. More details of the application will be announced on the PICES website.

PICES is often requested to provide science and technical expertise in special projects dealing with marine issues in countries outside of the PICES region. One such project is the “Building capacity for coastal monitoring by local small-scale fishers” project, or “FishGIS” for short, funded by Ministry of Agriculture, Forestry and Fisheries, Japan. In this effort, the PICES Project Science Team is working with local coastal communities in Indonesia to monitor environmental conditions and fisheries using smartphone technology, with the aim of assisting the Indonesian government to enhance its capacity for collecting data to improve management practices. Another project in which PICES’s objective is to share knowledge, data, and information within the PICES research community and beyond is the “SEAturtle” (Sea turtle ecology in relation to environmental stressors in the North Pacific region) special project funded by the Ministry of Oceans and Fisheries of Korea. The aim of this project is to research the endangered sea turtle populations found in the southern waters off Korea, Japan, and China in order to understand the threats to their habitat and ecology in relation to anthropogenic activities. SEAturtle Project Science Team members held their first meeting in August and have started to investigate the migration route using Iridium satellite-tracked tags. See more on the SEAturtle project on page 43 of this issue.

At the conclusion of PICES-2019, Drs. Se-Jong Ju (BIO, Korea), Keith Criddle (HD, USA), Dr. Jennifer Boldt (MONITOR, Canada) and Joon-Soo Lee (TCODE, Korea) completed their term as Committee Chairs. I sincerely acknowledge their contribution to their Committee and to Science Board activities. From the conclusion of the 2019 Annual Meeting, Dr. Vera Trainer (USA) assumed the role of Science Board Chair. New Committee Chairs, Drs. Akash



Sastri (BIO, Canada), Mitsutaku Makino (HD, Japan), Sung Yong Kim (MONITOR, Korea) and Jeanette Gann (TCODE, USA) also started their term. I am looking forward to the leadership of Dr. Trainer and the new Science Board for PICES scientific activities, with support from the PICES family.



Opening Session addresses at PICES-2019. From left: Dr. Chul Park (PICES Chair), Dr. Carmel Lowe (National Delegate for Canada), Dr. Kate Moran (President and CEO of Ocean Networks Canada).



FUTURE SSC business meeting.



W17 Integrated Ecosystem Assessment Scoping breakout groups.



Dr. Yuuki Terada instructing W4 Let's play the GAME! players.



Dr. Andrew Trites communicating science at the W1 Learn to effectively communicate your science workshop.



Participants at the PICES FishGIS project meeting.



Attentive audience at the W15 Machine Learning workshop.



Dr. Lisa Eisner speaking at the W7 PICES Contribution to the Central Arctic Ocean workshop.



Peter Chandler leading WG 35 (NPESR3) business meeting.



Dr. Mark Saunders presenting at the W16 Salmon and associated fishes across the North Pacific Ocean workshop.



***Some highlights from PICES-2019***



*Dr. Jackie King,  
Keynote Speaker*



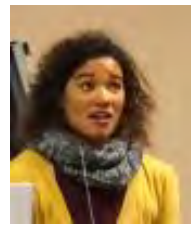
*Dr. Aoi Sugimoto,  
Early Career  
Scientist, S1*



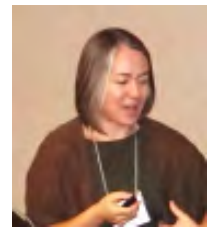
*Kuan-Mai Hsiung,  
Early Career  
Scientist, S4*



*Naoki Kumagai,  
S5 Plenary*



*Alexandra Davis,  
Early Career  
Scientist, W9*



*Cheryl Barnes,  
Early Career Scientist,  
S13*



*Lively discussions during coffee break.*



*Timothy Parsons (background) and  
Charles Hannah.*

***Sharing some light moments during the Meeting***



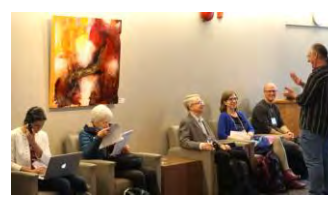
*Akash Sastri and Lidia Yebra*



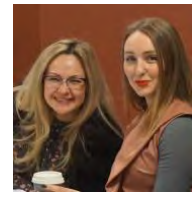
*Evgeny Pakhomov, Igor  
Shevchenko and Olga  
Trusenkova sharing  
information*



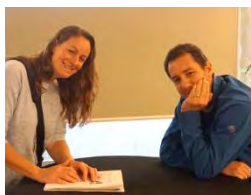
*Elliott Hazen at W13  
Common ecosystem  
reference points.*



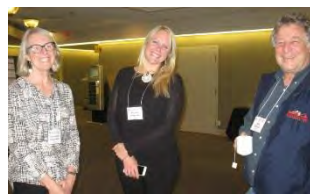
*Jim Christian telling a good story to  
his audience.*



*Anna Skvortsova  
and Ekaterina  
Kurilova*



*Jennifer Fisher and Jerome  
Feichter*



*Libby Logerwell, Kirsten Holsman  
and Lee Cooper*



*Brian Hunt and the (n)ever  
shy Tom Therriault*

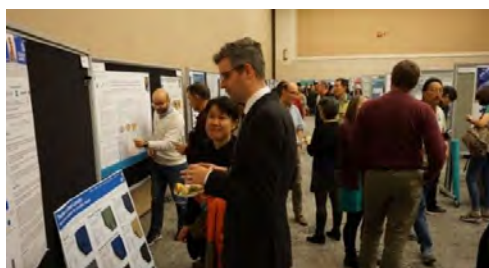


*Newly elected MONITOR  
Chair Sun Yong Kim*



*Chih-hao Hsieh and  
Hui Liu*

***Poster Session***



*The popular Poster Session where participants could view and discuss new and exciting research.*

**Sporting Event at PICES-2019**



Top left: Host country Canada’s axe throwing sporting event under way; bottom left: participants giving encouragement to each other; right: James Smith (USA) documenting his bull’s eye!

**Chairman’s Reception**



From left: PICES Chairman Chul Park and Executive Secretary Robin Brown; ICES representatives Ellen Johannesen and Anne Christine Brusendorff guarding Emanuele (Manu) Di Lorenzo; Wonjoon Shim, Vera Trainer, Sunha Kim, and Se-Jong Ju; Wendy Seki, Cisco Werner, Ian Perry and Michael Seki.



Incoming Science Board Chair, Vera Trainer, and Science Board Chair, Hiroaki Saito.

I finished my three-year term as Science Board Chair, from 2016 to the end of the PICES-2019. It was a really exciting experience to receive excellent outputs from expert groups and programs, and to know how international scientific activities were implemented. During my term, I came to realize that PICES science is based on strong enthusiasm and dedication of PICES scientists. It should be noted that my chairmanship was possible because of the hard work and support provided by the Science Board members and the staff of the PICES Secretariat. I am so happy to have worked with such wonderful colleagues. The role of PICES is becoming ever more important for marine science and society in a changing North Pacific. I know that the new

Science Board Chair, Dr. Vera Trainer, can lead the scientific activities of PICES with support from the PICES family over the next three years.

As mentioned at the beginning of this article, PICES is expected to play a leading role in the Ocean Decade. The title of the 29<sup>th</sup> PICES Annual Meeting (PICES-2020) is “How does 30 years of research on changing North Pacific ecosystem inform the UN Decade of Ocean Science for Sustainable Developmental Goals (SDGs)?”, which will be held in Qingdao, China. See you in Qingdao and other venues of PICES-hosted events in 2020!



Hiroaki Saito  
Science Board Chair



## 2019 PICES awards

On October 21, 2019, a presentation ceremony for PICES awards took place during the Opening Session at PICES-2019 in Victoria, Canada.

### ***PICES Chair Award***

The establishment of the PICES Chair Award was approved at the 2016 inter-sessional Governing Council (GC) meeting. It is given for sustained contributions to the development of the Organization that have allowed it to meet the purpose as set out in the Convention. The 2019 award presentation ceremony began with Dr. Chul Park (Chair of PICES) introducing the award and announcing the first recipient.

*PICES has grown and matured dramatically and is now established as a major contributor in marine science and a valued partner with other organizations. This does not just “happen”, particularly in an environment where the basic funding for the organization (the annual fees) has grown slowly. This requires sustained contributions from inspired people, often working “behind the scenes”.*

*For this reason, PICES established the PICES Chair Award in 2016 to recognize these inspired persons for their “sustained contributions to the development of the Organization that have allowed it to meet the purpose as set out in the Convention”.*

*I am pleased to announce that Ms. Patricia (Pat) Livingston is presented with the PICES Chair Award for 2019.*

*Ms. Patricia Livingston, usually called Pat, has been involved with PICES since the beginning—she was Co-Chair of the first integrative long-term program of PICES, Climate Change and Carrying Capacity, CCCC, from 1996–1998. During that time she built upon the strong linkages between PICES and GLOBEC program. This broadened the research networks of both organizations facilitating the innovative comparative studies that are a lasting legacy of that program. Pat also served as Science Board Chair from 1998–2001. In addition to her scientific contributions, Pat also made a very large commitment to the administration and proper functioning of our Organization through a period of expansion in the scientific activities of PICES.*

Accepting the Award, Ms. Livingston responded:

*Thank you very much for this honor. It was certainly an honor for me to serve PICES in many capacities over the years and I have really missed being a part of this organization. Although I have been keeping track of PICES activities from afar, it is never the same as being at the annual meeting in person. It is fantastic to be here in Victoria and I am looking forward to meeting up with many*

*old friends and making many new ones while I get a chance to see all the exciting progress and contributions being made by the PICES scientific community.*



*Ms. Pat Livingston, 2019 PICES Chair Award recipient, accepting the award from Dr. Chul Park (PICES Chair).*



### PICES Chair Award recipients

- 2016 Richard Marasco (USA); Alexander Bychkov (PICES Secretariat)
- 2018 Tokio Wada (Japan); John Stein (USA)
- 2019 Patricia Livingston (USA)



### **Wooster Award**

In 2000, PICES established an annual award for scientists who have made significant contributions to North Pacific marine science and have achieved sustained excellence in research, teaching, administration, or a combination of these in the area of the North Pacific. The award was named in honour of Professor Warren Wooster, a principal founder and the first Chairman of PICES.

The Wooster Award presentation ceremony was conducted by Dr. Hiroaki Saito (Chair of Science Board). Dr. Saito announced that the 2019 Wooster Award was being given to Dr. R. Ian Perry (Fisheries and Oceans Canada), and read the following Science Board citation which was accompanied by a slide show dedicated to Dr. Perry:

*In 2000, PICES Governing Council approved an award named in honour of [Professor Warren S. Wooster](#), a principal founder and the first Chairman of PICES, and a world-renowned researcher and statesman in the area of climate variability and fisheries production. The criteria for selection are sustained excellence in research, teaching, administration or a combination of the three in the area of North Pacific marine science. Special consideration is given to individuals who have worked in integrating the disciplines of marine science, and preference is given to individuals who were or are currently actively involved in PICES activities. Please join me in congratulating the recipient of the 2019 Wooster Award, Dr. Ian Perry.*

*Dr. Ian Perry is the Head of the Plankton and Fisheries Oceanography Program of the Pacific Region of the Department of Fisheries and Oceans. Ian is a world-renowned scientist who has spent a productive career advancing our understanding of North Pacific oceanography, and the impact of climate on fish distributions and recruitment. He has long been a leader in PICES, serving as Chair of Science Board and as Chair of the first PICES NPESR working group. He also served as an executive committee member of the PICES-GLOBEC Implementation panel and contributed to the science plan of the PICES-GLOBEC Program on Climate Change and Carrying Capacity. In the International GLOBEC Program, he served as the first Vice-Chairman from 1996-2002 and Chairman of the Scientific Steering Committee from 2008-2010. He also co-chaired GLOBEC Focus 4 Working Group on socio-ecological systems from 2002-2007. After the conclusion of GLOBEC, he became a founding member of the Human Dimensions Working Group (HDWG) of the IGBP/SCOR IMBER program to clarify what human institutions can do to adapt to global changes. His expertise in integrating natural science and social science in the IMBER HDWG resulted in him contributing to the development of PICES's human dimension activities.*

*He has been a contributing or lead author to multiple PICES Scientific Reports, including a recent one coedited with Dr.*

*Mitsutaku Makino on Marine Ecosystems and Human Well-being: The PICES-Japan MAFF MarWeb Project.*

*Throughout his career, Ian has exemplified high standards of scholarship, mentorship of younger scientists, and promotion of international collaboration in the marine sciences. PICES is very pleased to honor Dr. Perry with the Wooster Award.*

*Ian Perry was born in Vancouver, Canada, and is the oldest of brothers Keith and Greg brothers (whom I believe are in this room). It is rumoured that Ian thoroughly explored his crib in the left photo [slide 4], and may have been speeding a few times with his first set of wheels. In his teens and early adulthood was an adventurer. He was an avid backpacker and loved sailing. In high school, Ian was a member of flying sharks swim club and demonstrated swim safety for the Canadian life saving society. As an undergraduate at the University of British Columbia, Ian backpacked Europe, and a few years later, he enjoyed cycling (this time on two wheels) the beautiful coastline of southern British Columbia.*

*Ian met his wife, Ingrid, in Vancouver and married her in 1986. Later they produced a daughter, Jennifer. A true family man, Ian enjoyed activities with them, especially outdoor activities, as shown here in the photos of the family canoeing in Canada and enjoying a Venice canal excursion not requiring that they provide the propulsion. Here is a photo of Ian with Jennifer [slide 8] looking for the right pumpkin. We don't know if the desired pumpkin was found. Ian has traveled extensively – sometimes with family, who particularly like Europe, Japan and Hawaii and many times as an invited participant or contributor to working groups in really nice places. In this slide [slide 9] are shown various photos of Ian while traveling in Japan, probably without family, or perhaps with a family member taking the photo. Ian has visited Hawaii many times for PICES meetings/conferences, and seems to enjoy, in particular, opportunities to get in the warm water, and snorkeling. Yes, Ian occasionally went on research cruises like this one shown.....Oops, not this kind of research cruise... [slide 11] this kind of research cruise...sampling plankton off Vancouver Island [slide 12].*

*Growing up in Vancouver, Ian did his schooling there. After graduating from Lord Byng High School he attended the University of British Columbia, where he obtained a Bachelor of Science, with honours, in 1977, and a PhD in Zoology in 1984.*

*Prior to obtaining his current position as Head of the Plankton and Fisheries Oceanography Program at Fisheries and Oceans Canada, he spent time as a research scientist working on shellfish fisheries, at Saint Andrews Biological Station in New Brunswick, on the Atlantic coast. After returning to the West Coast of Canada, Ian also took an adjunct professor position at the Fisheries Center of the*

*University of British Columbia, and has since taught courses on fisheries oceanography in several countries world-wide.*

*For his service to Fisheries and Oceans Canada, Ian has received multiple awards, including the highly prestigious Fisheries and Oceans Canada Prix d'Excellence.*

*Ian's contributions to PICES are many and diverse—so much so that to illustrate his productivity requires three slides. This and the next slide illustrate some of his accomplishments for PICES. These span being a member of Working Groups...to being a co-chair of specific working groups and author or co-editor of at least 11 reports in the PICES Scientific Report Series, including the PICES-Marine Ecosystem Health and Human Well-Being project funded by the Ministry of Agriculture, Forestry and Fisheries of Japan.*

*Ian was an Executive Committee member of the PICES Climate Change and Carrying Capacity (or 4 Cs) program from its inception in 1995 until 2001. He stepped down from 4 Cs to become the 4<sup>th</sup> Chairman of Science Board of PICES. During his time on the 4 Cs project, he was a member of the 4Cs' MODEL Task Team, which he co-chaired for three years in the late 1990s. Ian contributed to more than just PICES. He was a leading scientist of the IGBP/SCOR/IOC sponsored GLOBEC project, which was the first interdisciplinary project that connected physical oceanographers, climate scientists, fisheries scientists and numerical models to understand fish and ecosystem dynamics. Ian served as the first Vice-Chair of GLOBEC (1996-2002) and as its last Chairman (from 2008-2010). Ian subsequently served as the co-chair of the IMBER Human Dimensions Working Group. This resulted in his making important contributions to PICES Human Dimension activities, including the current FUTURE program. Ian has an extensive publication record with more than 150 peer reviewed publications. Included in this are 19 books, book chapters or edited volumes since 1986. He has published three books for other organizations (GLOBEC and IMBER) which are equally important for the current activities of PICES.*

*Ian has been a regular participant at almost every PICES Annual Meeting since 1995. The next series of slides shows images of him at PICES Meetings between 1995 and 2008. [slides 20-22]. PICES-2001—Ian's first year as Science Board Chair and guest to Governing Council (Victoria).*

*2002 was a remarkably productive and busy year, as PICES cosponsored 5 symposia/conferences during the year. Ian must have loved the end of that year. For all of his scientific accomplishments, Ian has remained a humble and down-to-earth guy, and a friend and colleague to many. Please join me once again in congratulating Dr. Ian Perry as the recipient of the PICES-2019 Warren S. Wooster Award.*

*Please join me in congratulating Dr. Ian Perry as the recipient of the 2019 Wooster Award.*

Dr. Perry accepted the award with the following remarks:

*Wow! This morning, I stand before you speechless – which for those who know me is not my usual state-of-affairs. This comes as a complete surprise, and I am deeply honoured – although somehow my family has managed to be here this morning!*

*As Dr. Lowe mentioned in her opening remarks, I was at the first PICES Meeting, which was held in this very Conference Centre. Through that early involvement, I had the great privilege of getting to know Dr. Wooster personally, and to work with him in the planning and development of PICES' first major integrating program on Climate Change and Carrying Capacity in the North Pacific – the "4Cs" program. Warren had an amazing knack for thinking up a catchy acronym and then building an entire program around it. And I would like to recognise that another of my mentors, and my graduate advisor, Dr. Tim Parsons, for some reason also happens to be here in the audience this morning – which is very special for me.*

*PICES has been very good to me, and any successes I may have had have largely been because of the support of my friends and colleagues in this audience. And so I would like to conclude by issuing you a challenge: while the organisational structure of PICES may seem very complex, as you get more involved the structure becomes clearer, and you will make lots of new friends and discover exciting new science opportunities. I am sure that future Wooster Award recipients are already with us this morning.*

*Thank you!*

A slide show of Dr. Perry's Wooster Award nomination can be viewed [here](#).





*Dr. Ian Perry, 2019 Wooster Award recipient, with Science Board Chair, Dr. Hiroaki Saito (left) and PICES Chair, Dr. Chul Park..*



*Ian with his former PhD supervisor, Dr. Tim Parsons,*

#### Wooster Award recipients

2001	Michael Mullin (USA)
2002	Yutaka Nagata (Japan)
2003	William Percy (USA)
2004	Paul LeBlond (Canada)
2005	Daniel Ware (Canada)
2006	Makoto Kashiwai (Japan)
2007	Kenneth Denman (Canada)
2008	Charles Miller (USA)
2009	Kuh Kim (Korea)
2010	Jeffrey Polovina (USA)
2011	Bernard Megrey (USA)
2012	Richard Beamish (Canada)
2013	Vera Alexander (USA)
2014	Fangli Qiao (China)
2015	Anne B. Hollowed (USA)
2016	Sei-Ichi Saitoh (Japan)
2017	Suam Kim (Korea)
2018	Vyacheslav B. Lobanov (Russia)
2019	R. Ian Perry (Canada)

PICES congratulates the 2019 Award recipients, Patricia Livingston and Ian Perry.

### Call for Wooster Award, POMA, and PICES Chair Award nominations for PICES-2020

We are now soliciting nominations for the [Wooster Award](#) and the [PICES Ocean Monitoring Service Award](#). The closing date for Wooster Award and POMA nominations is **March 31, 2020**. Closing date for the [PICES Chair Award](#) is **July 30, 2020**. The awards will be presented during the Opening Session of PICES-2020 in Qingdao, China.

Please send your nominations to PICES [Executive Secretary](#) and include the following information: nominee's name, title, institutional affiliation and address, CV, and statement of justification for the nomination.

## Working Group 37 organizes Phase 2 of a Practical Workshop on “Production methodologies and measurements for in situ zooplankton”

*Akash Sastri, Jennifer Jackson, Karyn Suchy, Lidia Yebra and Toru Kobari*

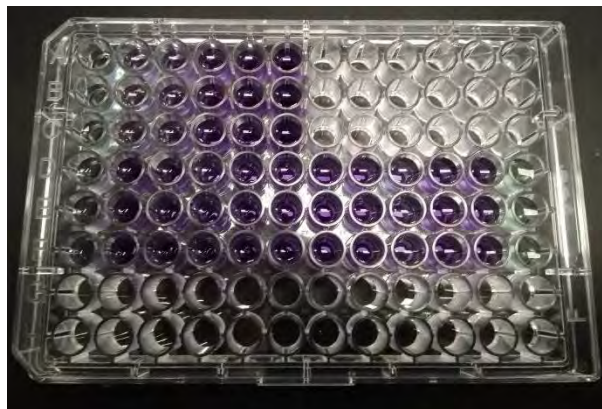
Zooplankton production represents a quantitative proxy for the functional response of marine ecosystems to regional and global climate change. Two practical workshops were organized by the Working Group on *Zooplankton Production Methodologies, Applications and Measurements in PICES Regions* (WG 37) with the objective of providing participants with the theoretical background and hands-on experience needed to estimate zooplankton production rates using traditional (Phase 1, 2018, Japan; PICES Press, [Vol. 27, No. 1](#), pp. 29–30) and contemporary (Phase 2, 2019, Canada; this article) biochemical methodologies. These workshops were also intended as a forum for encouraging international collaboration on zooplankton production measurements in the PICES region among early career scientists and students.

In October 2019, the Hakai Institute at Quadra Island, British Columbia, Canada, hosted eight early career scientists from 5 countries which included Canada, Chile, China, Japan and Korea, for the Practical Workshop Phase 2: “Production methodologies and measurements for in situ zooplankton”.

During this long-weekend workshop, hands-on activities, lectures, and field trips provided the participants with opportunities to learn about the physical and biological oceanographic properties of coastal British Columbia, to run enzymatic assays such as chitobiase and aminoacyl-tRNA synthetases (AARS) activity, to measure zooplankton protein content, and to learn how to analyze and interpret these metabolic measurements in the context of growth and production rates.



*Chris Mackenzie and Brett Johnson (Hakai Institute) showing participants how to deploy Niskin bottles for water sampling.*



*Microplate showing color-based zooplankton protein content assay results during laboratory work.*



*Participants Lady Liliana Espinosa Leal (Chile, standing) and Megu Iwazono (Japan) loading a microplate for AARS enzyme activity assays.*

On arrival at the Institute, participants and lecturers received a warm welcome from Hakai personnel, followed by a description of the facilities and the workshop agenda by the organizers, and an ice breaking reception and dinner during which participants introduced themselves.

During the following two days, local and invited experts lectured on oceanographic time-series and coastal oceanography (Dr. Jennifer Jackson, Hakai Institute), chitobiase activity (Drs. Akash Sastri, Fisheries and Oceans Canada, and Karyn Suchy, University of Victoria) and AARS activity (Dr. Lidia Yebra, Instituto Español de Oceanografía, Spain).





*Workshop participants enjoyed the scenery from Quadra Center and the good weather during the workshop.*

Several field trips onboard the Hakai Institute research vessel were organized to provide participants with hands-on experience in sampling coastal waters in the northern Strait of Georgia using standard sampling gear/techniques for characterization of physico-chemical water column properties as well as for collection and handling of sea water and zooplankton samples to conduct biochemical methods.

The busy weekend ended by celebrating Canadian Thanksgiving with dinner offered by the Hakai Institute at

the local pub. Prior to returning to Victoria to attend the PICES Annual Meeting, the workshop participants had the opportunity to go kayaking around Quadra Island on a sunny morning. All participants enjoyed the laboratory works, lectures and discussions regarding zooplankton production measurements and methodologies.

WG 37 would like to thank the hosting partners: the Hakai Institute and PICES for helping to make the PICES Phase 2 workshop an outstanding success.



*Dr. Akash Sastri (Akash.Sastri@dfo-mpo.gc.ca) is an oceanographer with Fisheries and Oceans Canada at the Institute of Ocean Sciences in Sidney, British Columbia, Canada, where he leads the La Perouse/West Coast of Vancouver Island Plankton Monitoring field program. He has a background in biological oceanography with a focus on the roles of marine plankton communities in changing environments. His Ph.D. (2007) thesis at the University of Victoria focused on the development and application of novel ways to measure zooplankton productivity routinely at sea. In PICES he is the Chair of the Biological Oceanography Committee, co-chairs the Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG 37) with Toru Kobari, and is a member of the Advisory Panel on North Pacific Coastal Ocean Observing Systems.*



*Dr. Jennifer Jackson (jennifer.jackson@hakai.org) is a physical oceanographer at the Hakai Institute (funded by the Tula Foundation) in Victoria, British Columbia, Canada. She leads the Hakai Oceanography Program, which studies coastal waters along British Columbia's central coast. Her focus is on ocean climate including marine heatwaves, bio-physical interactions, and interactions between the open ocean and coastal waters. In PICES she is on the Physical Oceanography and Climate (POC) Committee.*



*Dr. Karyn Suchy (ksuchy@uvic.ca) is currently a Research Associate with the Pacific Salmon Foundation and the Department of Geography at the University of Victoria in British Columbia, Canada. Her broad research interests are in zooplankton ecology and biological oceanography. The main goal of her current work is to look at how seasonal patterns at the base of the food web (e.g. phytoplankton and zooplankton) are changing over time in the Salish Sea in response to different environmental drivers. In PICES, she is a member of the Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG 37).*

*(continued on page 17)*

## Communicating science

by Jackie King

At PICES-2019 (October 16–27, 2019) in Victoria, Canada, I was given the honour to provide the Keynote Talk on behalf of Canada. In line with the Annual Meeting's theme "Connecting science and communities in a changing North Pacific", I chose to highlight research undertaken by Fisheries and Oceans Canada that made significant connections to communities through collaboration, dialogue or outreach. I suggest that these three types of connections are fundamental in making our science trusted, relevant and accessible. To some degree, all of us may find some aspect of making these connections difficult, but connecting through outreach, or effectively communicating your science to a broader, non-scientific audience is often seen as the most difficult activity for many scientists. We just seem to find it hard to effectively communicate our science.

A key activity of the FUTURE Science Program is communication of our science, yet few scientists receive training on how to communicate to people outside of the scientific community. To address this gap, FUTURE sponsored a 1-day Workshop on "Learn to effectively communicate your science" on October 18 at PICES-2019. The Workshop also served as a follow-up from the PICES-2018 Topic Session on "Science communication for North Pacific marine science". The Workshop was convened by myself, along with Mitsutaku Makino (Japan), Matthew Baker (USA), and Emanuele Di Lorenzo (USA). Mitsutaku Makino opened the Workshop with his own personal experience in trying to communicate complex science to fishers, but without receiving scientific communication training. As he conveyed, the result was unsuccessful and it was only after working with a communications expert that he was able to successfully engage with the fishers.

This activity-based Workshop had two Invited Speakers: Alison Morrow (Morrow Media, USA) and Cherisse Du Preez (Fisheries and Oceans Canada, Canada) both with expertise on communicating science to the general public. Alison Morrow drew on her experience as an Environmental Science news reporter with a major TV station, and her current career in producing her own podcasts on environmental science. She introduced the concept of a revolution in news media, with the majority of the public now receiving their news from online sources, such as YouTube and podcasts. News media require rapid responses from scientists, and simple messages. Alison provided strategies when interacting with news media: Be able to describe your research in three words (*i.e.*, create your own headline), remove jargon from the story, stick to one issue only, and have a short one-page handout to give the reporter as a take-away for a broader background. Cherisse Du Preez provided an overview of social media and the various

platforms available for scientists to connect with the public. Cherisse often partners with communication experts to broadcast her deep-sea ecology expeditions to a broad audience. Her live video feeds of remotely operated vehicle (ROV) dives have generated 231 media stories, been viewed by 3.7 million people and watched in 130 countries. It is obvious that the impact can be large, and by communicating your science, you can draw society into a broader conversation on conservation and action.



Workshop participants created outreach videos: this one featuring Julie Keister, on the impacts of North Pacific marine heat waves.

The Workshop had four tutorials led by Convenors and Invited Speakers:

- 1) *The Message Box and Elevator Pitches* (Leads: J. King, A. Morrow, E. Di Lorenzo). The Message Box (<https://www.compassscicomm.org>) is a tool to help distill science issues and research into simple messages targeted to specific audiences. Each participant selected an audience of their choice, and built their own Message Box based on their research. They created simple messages that addressed the "So What?" of their research and identified solutions that the audience could contribute to, and the benefits of those solutions. Participants then used their Message Box to deliver an "Elevator Pitch" – a 30 second presentation.
- 2) *Video Blogs, Blogs and Podcasts* (Leads: M. Baker, A. Morrow). The technical equipment needed is simple: a cellphone with a camera and cellphone-tripod with microphone. By creating blogs and podcasts, scientists can take control of their own messages and use an extended time to convey more. Blog posts should only be about the equivalent of a single type written page. The tutorial was a discussion on what PICES scientists could produce as blogs, how to use "Story Maps" to convey fieldwork-based blogs, and how to connect with agencies or organizations that have blogs or podcasts to



serve as guest rather than commit to creating your own.

- 3) *Developing a social media strategy and Twitter-style presence* (Lead: C. Du Preez). Participants developed their own social media strategy by identifying why they might want to connect through social media: to promote their science, to network with scientists or to connect to the public. Using basic fundamentals, such as hashtags, handles, emojis, visuals and shortened websites, the participants wrote their own Twitter message for their science or a science message from #PICES2019.
- 4) *How to make your own science video* (Lead: E. Di Lorenzo). Participants reviewed three science videos, and discussed the successes and failures at each in engaging the audience and in conveying accessible messages. They then received instruction on how to use video editing software to produce their own videos based on elements such as: background visuals, background music, video interviews, text and graphics. Participants then worked in groups and produced 90-second videos on marine heat waves in the North Pacific.



*Invited Speaker Cherisse Du Preez (foreground) demonstrates the art of the selfie for posting to social media.*



*Invited Speaker Alison Morrow talks about the impact of podcasts for science outreach.*

The number of participants at this Workshop (32) indicates that there is strong desire within the PICES community to learn how to effectively communicate science, particularly to the general public. The participants provided two recommendations for PICES to consider:

- 1) PICES needs to develop an Outreach Strategy, one that connects the science to the public. It was noted that the lack of a social media presence by PICES is an anomaly among modern science organizations. PICES should consider a Twitter account and/or a Blog, both aimed at the general public. PICES scientists would also benefit from having a blog platform where they could provide guest blog posts.
- 2) PICES should hold annual science communication training workshops with each Annual Meeting. The topic of a Communication Workshop should reflect the host nation's interests or needs. The Communication Workshops should be organized and facilitated by science communication experts.

It is essential that results of ecosystem science are accessible to a wide audience in order for our science to have a meaningful impact on society. That accessibility requires each of us to learn how to effectively communicate our science.



*Dr. King is the Head of Basin and Coastal-Scale Interactions Program with Fisheries and Oceans Canada. Her research investigates linkages between coastal-scale ecosystems and basin-scale processes including climate forcing, large-scale oceanographic processes, and trophic energy exchange. She collaborates in integrative pelagic field studies along the continental shelf, with her primary focus on understanding the factors controlling the abundance, distribution, and production of salmon and associated species in marine ecosystems. Her research also focuses on Ecosystem-based Fisheries Management, specifically how to develop and deliver advice for fisheries management in an environment of changing climatic conditions. She has published research on a suite of disciplines including marine fish life history strategies, statistical methodology, climate impacts on ecosystems, ageing methodology, stock assessment, fish population dynamics and behavioural ecology. She is also the Head for the Canadian Pacific Shark Research Program, responsible for all Canadian Pacific elasmobranch research and conservation. In PICES, she is the Co-Chair of the PICES/ICES Section on Climate Change Effects on Marine Ecosystems, Vice-Chair of the FIS Committee and a member of the FUTURE Scientific Steering Committee.*

## ***Integrating biological research, fisheries science and management of Pacific halibut and other widely distributed fish species across the North Pacific in the face of climate change and environmental variability***

*by Josep V. Planas, Gordon H. Kruse and Chris Rooper*



*Participants of Workshop 2 at PICES-2019, Victoria, Canada.*

The North Pacific Ocean is a collection of productive large marine ecosystems that is characterized by strong interdecadal climate variability. One of the key fish species in the North Pacific Ocean ecosystem is the Pacific halibut (*Hippoglossus stenolepis*) due to its wide distribution along the continental shelf throughout the North Pacific and to its important trophic position. In addition to its key ecological role, the Pacific halibut is highly relevant from a socio-economic and cultural perspective in the North Pacific Ocean region because it supports important commercial, recreational and ceremonial or subsistence fisheries. The Pacific halibut stock in waters off North America is managed by the International Pacific Halibut Commission (IPHC) that also conducts research on the biology of the species. Due to its highly migratory nature, its key ecological role and its wide distribution in the North Pacific Ocean, increased efforts are needed to expand and integrate information on the biology and management of the Pacific halibut and interacting species across all countries involved in its fisheries, particularly in the face of a rapidly changing North Pacific Ocean. In recognition of this need, as well as acknowledging the mutual interests for cooperation, the IPHC and PICES finalized a Memorandum of Understanding (MoU) in 2019 with an objective “to facilitate cooperation between the IPHC and PICES with a view to supporting efforts to enhance North Pacific Ocean science of mutual interest.”

As a first step of this MoU and to cooperatively advance our understanding of the biology and management of Pacific halibut and interacting species throughout the PICES region, a FIS workshop (W2) entitled “*Integrating biological research, fisheries science and management of Pacific halibut and other widely distributed fish species across the North Pacific in the face of climate change and environmental variability*” was held on October 18, 2019 as part of the PICES 2019 Annual Meeting in Victoria, B.C. The one-day workshop was attended by up to 40 participants and manuscripts resulting from work presented at the workshop will be published in a special issue of the journal *Fisheries Research*.

The main objective of W2 was to provide state-of-the-art information on important current topics related to the biology and fishery of Pacific halibut and interacting species by bringing together researchers, scientists and managers from countries that are involved with this resource. W2 consisted of 3 invited and 14 contributed oral presentations, in addition to 9 posters, on specific topics related to the biology of the Pacific halibut and interacting species as well as management and policy issues. The presentations at W2 were organized around four major topics: Pacific halibut fishery management (introduced by invited speaker Dr. David T. Wilson, Executive Director of the International Pacific Halibut Commission), bycatch and discard survival



assessment (introduced by invited speaker Dr. Mark Lomeli of the Pacific States Marine Fisheries Commission), migration (introduced by invited speaker Dr. Janet Duffy-Anderson of the Alaska Fisheries Science Center-NOAA) and growth/size-at-age of Pacific halibut.



*Invited speaker, David Wilson, Executive Director of the IPHC, giving a presentation on the International Pacific Halibut Commission.*

The presentations were followed by a discussion session on national and international research and management efforts that are currently in place as well as opportunities for establishing novel cooperative efforts at an international level. Much of the discussion focused on topics related to east–west collaboration in the North Pacific Ocean and environmentally driven ecosystem changes. There was general consensus that these two topics were of sufficient interest to further pursue within the context of PICES. As a result, a proposal for a second workshop to be held at the 2020 PICES Annual Meeting in Qingdao, China was submitted and subsequently approved by Science Board and Governing Council. Based on the level of participation, quality and number of presentations, productive discussions, and the subsequent development of an accepted proposal for a second workshop in 2020, the Convenors agreed that this workshop was very successful.



*Dr. Josep V. Planas (josep.planas@iphc.int) is Manager of the Biological and Ecosystem Science Branch at the International Pacific Halibut Commission (IPHC) in Seattle, Washington, and leads the biological research efforts at the IPHC in the research areas of migration, reproduction, growth, discard mortality assessment and genetics and genomics. He received a MSc degree from the University of California at Berkeley and a PhD from the School of Aquatic and Fishery Science at the University of Washington. Prior to joining IPHC, he was Associate Professor in Physiology at the University of Barcelona, Spain, from 1998 until 2015.*

*Dr. Gordon H. Kruse (Gordon.Kruse@alaska.edu) is Professor of Fisheries Emeritus with the College of Fisheries and Ocean Sciences of the University of Alaska Fairbanks. He maintains broad interests in stock assessment, fishery oceanography, and fishery management, including ecosystem approaches to management. Gordon has been a member of the PICES Fishery Science Committee (FIS) since 1995.*

*Dr. Chris Rooper (Chris.Rooper@dfp-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada in the Stock Assessment and Research Division at the Pacific Biological Station in Nanaimo, British Columbia. His research interests are in the function of habitats for fishes, particularly rockfishes and deep-sea corals and sponges, using a combination of in situ studies with underwater cameras and regional scale modeling. In PICES, he is a member of the Working Group on Biodiversity of Biogenic Habitats (WG 32).*

*(continued from page 13)*



*Dr. Lidia Yebra (lidia.yebra@ieo.es) is a Research Scientist at the Spanish Institute of Oceanography in Málaga, Spain. Her interests include zooplankton physiology and ecology, and she developed methodologies to estimate production rates using biochemical approaches, such as the activity of the enzymes aminoacyl-tRNA synthetases (AARS). She is a member of the ICES Working Group on Zooplankton Ecology and contributes to the ICES Zooplankton Status Report. In PICES, she is an ex officio member, representing ICES, of Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG 37).*



*Dr. Toru Kobari (kobari@fish.kagoshima-u.ac.jp) is Associate Professor on the Faculty of Fisheries at Kagoshima University supporting “Biological Oceanography” and “Fisheries Oceanography”. He has a background in biological oceanography with a focus on the structural and functional roles of plankton communities on marine ecosystems. Toru completed his undergraduate studies in Faculty of Science at the Yamagata University, Yamagata, and a M.Sc. in Fisheries at the Hokkaido University, Hakodate. His Ph.D. (1999) thesis at Hokkaido University focused on the life cycles and interannual variability of Neocalanus copepods. His current research focuses on the trophodynamics and productivity of plankton food web in the Northwest Pacific. In PICES he co-chairs the Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG 37) with Akash Sastry.*

## Two decades of the North Pacific CPR program

by Sonia Batten, Sanae Chiba and William Sydeman



Participants of Workshop 5 at PICES-2019, Victoria, Canada.

### *Early days*

The North Pacific Continuous Plankton Recorder (CPR) Survey is essentially as old as PICES itself. At the very first PICES meeting, held in 1992, a proposal was made by Dr. Tim Parsons to the BIO Committee for a trans-Pacific CPR survey, to be initiated as soon as possible (PICES, 1992). Discussions between PICES scientists and the North Atlantic CPR survey team, run by (then) the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) in the UK, led to a trial tow from Long Beach, California to Alaska in the summer of 1997, behind an oil tanker. The samples were processed, and in 1998 Sonia Batten attended the MONITOR Task Team meeting to present results of this demonstration tow. An Advisory Panel (AP-CPR) was convened under MONITOR to implement a regular CPR survey that would contribute to the PICES 4Cs (Climate Change and Carrying Capacity) program.

### *Establishing the Survey*

In establishing the North Pacific CPR Survey, BIO and MONITOR wished to fill the major gap in high seas plankton sampling/monitoring and provide a link between existing sampling programs in the PICES marginal regions. Open ocean plankton sampling was needed to obtain a better understanding of fisheries dynamics, especially salmonids that spend their early lives in the subarctic gyre ecosystems. Two years of initial funding was obtained and in 2000 and 2001, six monthly CPR tows during spring through summer on the California to Alaska route were undertaken; additionally, a single trans-Pacific transect from the west coast of North America to Asia was conducted. Additional

funding led to three trans-Pacific transects in spring, summer and autumn from 2002 onwards. Increased port security concerns caused the oil tanker company to pull out of the program in 2003, so from 2004 onwards the transect into Alaska began in Juan de Fuca Strait, across the Gulf of Alaska to Cook Inlet, run six times per year from container vessels. Eventually, a funding consortium was set up, administered by PICES, so several agencies could contribute modest amounts in their area of interest (much less than the full costs of acquiring the data) and by the leveraging that this generated, ensured more financial security for the program. Contributors to the consortium over the years have included the North Pacific Research Board, the Exxon Valdez Oil Spill Trustee Council, Fisheries and Oceans Canada, SAHFOS, the Marine Biological Association (UK), PICES, JAMSTEC, Japan Society for the Promotion of Science, Japan Fisheries Research and Education Agency, and Hokkaido University. To all, we offer our sincere appreciation.

As of this year (2019), over 30,000 CPR samples (Fig. 1) have been collected and stored in the archive. One-third of the samples have been microscopically processed giving information on distribution and abundance for over 400 taxa (larger phytoplankton, some microzooplankton and mesozooplankton), and some additional components of the pelagic environment such as pollen and microplastics. Data for selected regions are available through the PICES website at <https://pices.int/projects/teprstnmp/main.aspx>, and all raw data are available on request. Sampling further north into the Arctic was also undertaken in 2018 and 2019 and it is a goal of the Global Alliance of CPR Surveys that this sampling is sustained.



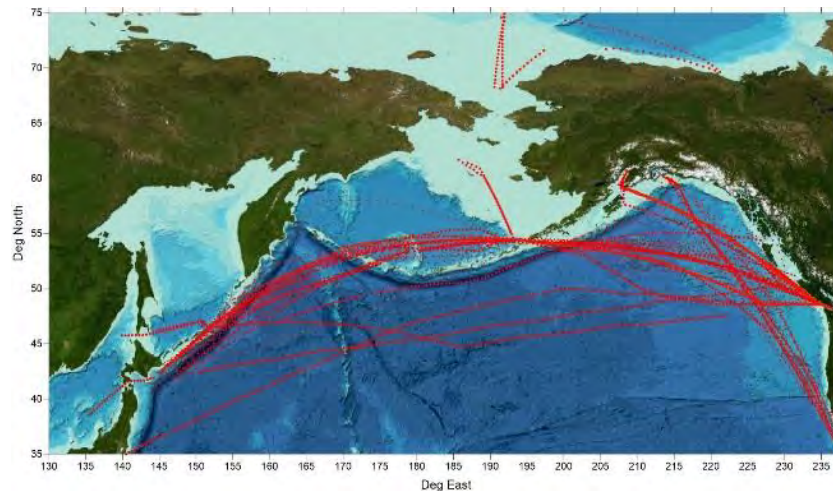


Fig 1. Location of CPR sampling from 2000 to 2019.

### Adding value

In addition to sampling the North Pacific plankton community, we have sought to expand the program and make the most of the sampling platform. Loggers mounted to the CPR (data are available from the [PICES website](#)) now measure ocean conditions including temperature, sometimes salinity and chlorophyll fluorescence. A separately-funded NPRB study added marine bird and mammal observations to the trans-Pacific transects for 5 years (2002–2007) to give simultaneous daytime observations of lower and upper trophic levels from North America to Asia (Sydeman *et al.*, 2010). Molecular techniques have been used to identify genetic variability within a species (Kirby *et al.*, 2007), and to identify organisms not distinguishable during routine sample analysis (such as *Pseudonitzschia* species, Stern *et al.*, 2018). More recently, stable isotopes have been measured in zooplankton specimens taken from samples across the Gulf of Alaska to model patterns of primary and secondary productivity (Espinasse *et al.*, 2019).



Volunteer commercial vessels that tow the CPR in the North Pacific (left and right columns).



### Outputs

Right from the beginning there was a need to include the results from the survey in regional ecosystem status assessments and reports. The Fisheries and Oceans Canada State of the Pacific Ocean annual report was one such venue (*e.g.*, Boldt *et al.*, 2019), as well as NOAA's [Ecosystem Considerations reports](#) for Alaskan waters, and of course the North Pacific Ecosystem Status Reports produced by PICES. Peer-reviewed publications which include Pacific CPR data are many. Some of the more notable ones are included in the reference list at the end of this article.

### Workshop at PICES-2019

As October 2019 marked the completion of the 20<sup>th</sup> year of North Pacific CPR sampling, we felt it was timely to hold a celebratory workshop at the PICES Annual Meeting to look forward as well as review past accomplishments. The workshop began with three introductory talks by the Conveners, covering CPR basics and the history of the North Pacific CPR Survey (Batten), studies that have linked the plankton data with higher trophic levels (Sydeman), and basin-scale studies on PDO-ecosystem variation using data from standard and special surveys conducted in the subarctic

North Pacific (Chiba). Our invited speaker, Pierre Heulouet from the North Atlantic CPR Program, described numerical methods for examining plankton communities with 60 years of data to stimulate ideas. There were then three contributed talks which described i) the use of CPR samples to examine spatial variation in ocean productivity patterns using stable isotopes (B. Hunt), ii) linking zooplankton community structure with large-scale SST and currents data from satellites (B. Hoover), and iii) the recent expansion of CPR transects into the Arctic Ocean including potential areas for future study (Ostle). The session also included one poster looking at western Pacific large copepod dynamics. Workshop presentations gave a thorough overview of many aspects of the Pacific CPR program from all regions, from detailed community data to using the sample archive. Presentations can be accessed via the PICES website at: <https://meetings.pices.int/publications/presentations/PICES-2019>.

Following the presentations there was a 45-minute period of audience discussion on issues reported and priorities for the future. The main points are summarized below:

- There was discussion about finer-scale resolution of the Pacific data since only about 1/3 of the samples are routinely processed. Satellite data can sometimes be used to identify mesoscale processes such as eddies but the sampling resolution of the CPR may miss this. It was pointed out that archived samples can be processed to fill in finer-scale as required for special projects, though there is a limit to how fine a scale CPR data can be used to inform as it is designed for large-scale sampling.
- The issue of microplastics contamination and sampling in CPR samples was discussed. The type of microplastics can be categorized quickly by new technology so that the likely contaminants (fibres) can be eliminated, and there can be a focus on particles whose presence will be due to ocean pollution. It was also mentioned that a time series is necessary to be able to determine when mitigation actions are being successful (as countries try to achieve their sustainability goals) and the CPR offers one of the only possibilities for such a time series.
- There was strong support for continuing to work in the Arctic, especially with the recent declines in sea ice in the northern Bering and Chukchi seas. It was also felt that a north to south transect extending into the transition zone proper would be very useful, for example, Alaska to Hawaii to fill the geographical data gap in lower latitudes.
- There was some discussion on emerging technologies, some of which are being considered alongside the Atlantic CPR program (for example, optical and DNA methods) and the additional sensors that can be attached to the CPR itself (Planktags to record temperature and salinity, CO<sub>2</sub> sensors). The group agreed that having simultaneous physical data was valuable since satellites only see the surface skin and salinity especially would be useful.
- The value of the funding consortium was seen as a major strength in that it gives the survey resiliency if one party withdrew. The importance of having early results, being timely with updates, and getting these updates into regular assessments was also seen as contributing to the success of the survey.

Overall, the survey has achieved the vision of those who sought to bring it to PICES at the very first meeting, recognizing the need for seasonal plankton data in the open ocean and coasts of the PICES region. It has had a successful first 20 years, and is in a good position to contribute to PICES science for years to come.

#### ***References cited and selected papers from the Pacific CPR Survey***

- Batten, S.D and Crawford, W.R. (2005). The influence of coastal origin eddies on oceanic plankton distributions in the eastern Gulf of Alaska. *Deep Sea Research II*, 52, 991–1009.
- Batten, S.D. and Walne, A.W. (2011). Variability in northwards extension of warm water copepods in the NE Pacific. *Journal of Plankton Research* 33, 1643–1653.
- Batten, S.D., Hyrenbach, K.D., Sydeman, W.J., Morgan, K.H., Henry, M.F., Yen, P.Y. and Welch, D.W. (2006). Characterising Meso-Marine Ecosystems of the North Pacific. *Deep Sea Research II*, 53, 270–290.
- Batten, S.D., Moffitt, S., Pegau, W.S. and Campbell, R. (2016). Plankton indices explain interannual variability in Prince William Sound herring first year growth. *Fisheries Oceanography*, 25, 420–432.
- Batten, S.D., Raitos, D.E., Danielson, S., Hopcroft, R.R., Coyle, K. and McQuatters-Gollop, A. (2018). Interannual variability in lower trophic levels on the Alaskan Shelf. *Deep Sea Research II*, 147, 58–68.
- Batten, S.D., Ruggerone, G.T. and Ortiz, I. (2018). Pink Salmon induce a trophic cascade in plankton populations in the southern Bering Sea and around the Aleutian Islands. *Fisheries Oceanography*. <https://doi.org/10.1111/fog.12276>.
- Boldt, J.L., Leonard, J. and Chandler, P.C. (Eds.). (2019). State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2018. *Can. Tech. Rep. Fish. Aquat. Sci.* 3314: vii + 248 p.
- Chiba, S., Batten, S., Sasaoka, K., Sasai, Y. and Sugisaki, H. (2012). Influence of the Pacific Decadal Oscillation on phytoplankton phenology and community structure in the western North Pacific. *Geophysical Research Letters* 39, L15603, doi:10.1029/2012GL052912.
- Chiba S., Batten, S., Yoshiki, T., Sasaki, Y., Sasaoka, K., Sugisaki, H. and Ichikawa, T. (2015). Temperature and zooplankton size structure: climate control and basin-scale comparison in the North Pacific. *Ecology and Evolution*, 5, 968–978
- Espinasse, B., Hunt, B.V., Pakhomov, E.A. and Batten, S.D. (2019). Defining isoscapes in the Northeast Pacific as an index of ocean productivity. *Global Ecology and Biogeography*. DOI: 10.1111/geb.13022
- Kirby, R.R., Lindley, J.A. and Batten, S.D. (2007). Spatial



heterogeneity and genetic variation in the copepod *Neocalanus cristatus* along two transects in the North Pacific sampled by the Continuous Plankton Recorder. *Journal of Plankton Research*, 29, 97–106.

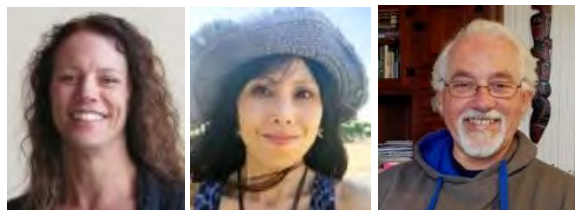
PICES. (1992). North Pacific Marine Science Organization (PICES) Annual Report.

Available at [https://meetings.pices.int/publications/annual-reports/1992/Ann\\_Rep\\_92.pdf](https://meetings.pices.int/publications/annual-reports/1992/Ann_Rep_92.pdf)

Stern, R., Trainer, V.L., Moore, S.K. and Batten, S.D. (2018). Spatial patterns of *Pseudo-nitzschia* genetic diversity in the North Pacific from Continuous Plankton Recorder surveys. *Marine Ecology Progress Series*.

<https://doi.org/10.3354/meps12711>.

Sydeman, W.J., Thompson, S.A., Santora, J.A., Henry, M.F., Morgan, K.H. and Batten, S.D. (2010). Macro-ecology of plankton-seabird associations in the North Pacific Ocean. *Journal of Plankton Research*. 32(12): 1697–1713.



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*Dr. Sanae Chiba (chibas@jamstec.go.jp) is a Senior Scientist at the Research Institute for Global Change at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in Yokohama, Japan. She works at JAMSTEC on marine ecosystem response to climate change. She has studied mechanisms of interannual to decadal ecosystem changes in regional to basin scales using historically collected plankton data set, such as the Odate Collection. In 2009, she started taking a part in the North Pacific Continuous Plankton Recorder (CPR) Survey, which has been operated by Sir Alister Hardy Foundation of Ocean Science (SAHFOS) since the early 2000s. She was on secondment at UNEP-World Conservation Monitoring Centre in the UK to learn marine science-policy interface for 2016–2019. Back in JAMSTEC, she is currently leading the new Marine Plastics Research Group at JAMSTEC with a keen interest in citizen science in global ocean observation systems. In PICES she was Vice-Chair of the Technical Committee on Monitoring from 2013 to 2019.*

*Dr. William (Bill) Sydeman (wsydeman@comcast.net) is a veteran ecosystem ecologist and participant in the PICES community. Dr. Sydeman served as the Co-Chair of the Advisory Panel for Marine Birds and Mammals from 2003 to 2010, and remains a member of the group, now classified as a Section. He has worked on the concept of seabirds as ecosystem indicators for decades, and currently conducts a variety of projects on forage nekton (krill and forage fish), seabirds, and marine mammals from the North Pacific to the South Atlantic (Benguela Current) focusing primarily on climate change, winds and upwelling, and ecosystem impacts.*

## PICES calendar of events for 2020

[National Academy of Sciences Workshop – Emerging Technologies to Advance Research and Decisions on the Environmental Health Effects of Microplastics](#) January 27–28, 2020, Washington, DC, USA

[PICES-2020 Spring School – Coastal ocean observatory science](#)  
March 4–8, 2020, Kagoshima, Japan

[International Symposium – Plastics in the Arctic and the Sub-Arctic region](#)  
April 21-23, 2020, Reykjavik, Iceland

[Ocean Past VIII Conference – Historical perspectives on marine ecosystems, fisheries, and futures](#)  
May 10–13, 2020

[MSEAS-2020 – Managing for sustainable use of the Earth’s marine and coastal systems](#)  
May 25–29, 2020, Yokohama, Japan

[ESSAS Annual Science Meeting – Linking past and present marine ecosystems to inform future fisheries and aquaculture](#)  
June 1–3, 2020, Sapporo, Japan

[ICES Annual Science Conference 2020](#)  
September 7–10, 2020, Copenhagen, Denmark

[PICES-2020 – How does 30 years of research on changing North Pacific ecosystems inform the UN Decade of Ocean Science for Sustainable Development Goals?](#) October 22–November 1, 2020, Qingdao, China

***PICES/ICES collaborative research initiative: Toward regional to global measurements and comparisons of zooplankton production using existing data sets***

*Lidia Yebra, Akash Sastri and Toru Kobari*



*Workshop 10 participants at PICES-2019, Victoria, Canada.*

About 20 zooplankton ecologists met October 16, 2019, to discuss zooplankton production methodologies and measurements at a 1-day workshop during PICES-2019 in Victoria, Canada. The workshop focused on: i) the application and synthesis of zooplankton production rate measurements in the field; ii) modeling and laboratory validation studies; and iii) regional assessments of the performance/utility of empirical models for estimating zooplankton production rates using biomass time series. Much of the group discussion centered on how to take best advantage of online resources which can be used to derive broad-scale secondary production rate measurements using empirical models of zooplankton growth rates. The workshop was intended to focus on a number of issues relevant to PICES Working Group ([WG 37](#)) on *Zooplankton Production Methodologies, Applications and Measurements in PICES Regions* and ICES Working Group on *Zooplankton Ecology* ([WGZE](#)). Workshop presentations included direct estimates of growth, empirical models and indirect biochemical indices of zooplankton production.

Prof. Shin-ichi Uye (invited speaker, Japan) talked about how to go from individual-based to population and community-based production estimations and stressed the need for more direct measurements of species-specific growth rates before we can advance toward a community-level assessment of zooplankton production in the field. He also presented new information on the importance of tertiary production, using a chaetognath as an example. Next, Dr. Pei-Chi Ho (Chinese Taipei) showed how copepod-specific growth rates estimated from relatively short artificial cohort incubations were used to test the importance of the predator/prey stoichiometry on zooplankton production in the field. Apart from direct measurements, indirect approaches were also presented, such as models and enzymatic methods to facilitate the assessment of growth at the individual and community level. Prof. Hui Liu (USA) showed a new Individual-Based Model (IBM) that allows the *in silico* development of natural and artificial cohorts to estimate field production rates of the jellyfish, *Aurelia aurita*. Dr. Kazuaki Tadokoro (Japan) presented examples



of a physiological model of zooplankton growth rates applied to existing zooplankton biomass time series data. Dr. Karyn Suchy (Canada) compared crustacean production rates estimated from a variety of empirical models and applied to the west coast of Vancouver Island and the Strait of Georgia, BC, Canada. Also, Dr. Akash Sastri (Canada) and Ms. Megu Iwazono (Japan) showed the importance of biomass in determining copepod production rates from chitobiase and aminoacyl-tRNA synthetases (AARS) activity in the laboratory. Prof. John Dower (Canada) described a major decline in crustacean zooplankton production rates (estimated with the chitobiase method) and increases in gelatinous plankton biomass along the west coast Vancouver Island, since 2015. Finally, Dr. Lidia Yebra (Spain) looked at the [COPEPOD website](#) as a potential online tool which may be used to move towards a global estimation and mapping of zooplankton production rates using existing time series data. Additional contributions, as poster presentations, by Ms. Megu Iwazono (Japan), Mr. Fukutaro Karu (Japan), and Mr. Takeru Kanayama (Japan) highlighted their studies on zooplankton growth and feeding rates in the laboratory and field.

The afternoon discussion focused on three areas relevant to WG 37's terms of reference. Our first discussion item centered around collaborative activities for zooplankton production measurements and methodologies with ICES WGZE. Dr. Yebra emphasized the importance of networking and regional to global collaboration as major achievements of the collaboration between ICES WGZE and PICES WG 37, and that there was a general agreement on pursuing further collaborations between PICES and ICES members. Dr. Yebra also noted that we should be aware of a large community of zooplankton production scientists from the Mediterranean and southern hemisphere. A representative example of similar efforts by the global community is the International Group for Marine Ecological Time Series (IGMETS) initiative.

The second discussion topic approached a WG 37 term of reference related to using existing biomass time series and empirical zooplankton growth rate relationships to compile and compare secondary production time series. Several existing collaborations were identified and a general concern about how to choose the best model for times series comparisons was raised. Drawing on the experience of participants, the most important issue is not to choose a single common empirical growth rate model, but rather to select a model which accurately describes growth/production in a particular region. This could take the form of choosing region-specific species models or providing a range of production estimates based on several global models. The ultimate goal is to develop comparable time series of zooplankton production rates.

Finally, we discussed novel approaches for advancing zooplankton production measurements in the field.

Participants noted that existing empirical models were developed 15 to 30 years ago. Thus, it was agreed that efforts to compile new data not included in those models would be an excellent option for updating existing models prior to their application for zooplankton production time series.

This workshop is the most recent in a series of international workshops organized to advance towards a global measurement and assessment of zooplankton production. Since the PICES-2012 workshop on “*Secondary production: Measurement methodology and its application on natural zooplankton community*” (Hiroshima, Japan, 2012) and the workshop on “*ICES/PICES cooperative research initiative: Towards a global measurement of zooplankton production*” at the ICES/PICES 6<sup>th</sup> International Zooplankton Production Symposium (Bergen, Norway, 2016), notable progress has been made by colleagues from PICES and ICES. Principal among these achievements is the establishment of PICES [WG 37](#) (2017–2020), and the publication of two review papers summarizing the recent advances in biochemical (Yebra *et al.*, 2017, *Advances in Marine Biology*, <https://doi.org/10.1016/bs.amb.2016.09.001>) and traditional (Kobari *et al.*, 2019, *Progress in Oceanography*, <https://doi.org/10.1016/j.pocean.2019.102137>) methodologies for zooplankton production estimation. To foster advances on these topics, additional workshops were organized by WG 37 during PICES Annual Meetings in 2017 (“*Advantages and limitations of traditional and biochemical methods of measuring zooplankton production*”, Vladivostok, Russia), and in 2018 (“*Regional evaluation of secondary production observations and application of methodology in the North Pacific*”, Yokohama, Japan), as well as a session at the 2018 Ocean Sciences Meeting (“*Zooplankton productivity as a function of trophodynamics in marine ecosystems*”, Portland, USA). Also, two practical workshops (Manazuru, Japan, 2018 and Quadra Island, Canada, 2019) were recently organized and convened by WG 37 members to provide early career scientists with training on state-of-the-art methodologies for *in situ* zooplankton production measurement within an international context.

A main outcome of W10 was the expanding of international collaboration among plankton ecologists from the North Pacific and Atlantic. The prospective activities proposed for development during the workshop include a regional comparison of zooplankton production rates estimated from zooplankton biomass coastal time series in the Northeast Pacific, fostering the use of online databases, updating of current production empirical models with recent zooplankton growth rates, and promoting further international collaboration by pursuing new venues for discussion and knowledge exchange in form of workshops and summer schools.

(continued on page 26)

**PICES/NPFC collaborative research:  
The influence of environmental changes on the potential for species distributional shifts and population dynamics of Pacific saury**

*by Chris Rooper, Vladimir Kulik, Kazuhiro Oshima, Yong Chen and Chih-hao Hsieh*

**Background**

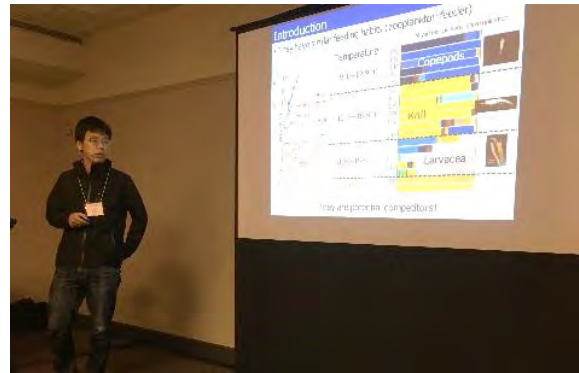
The North Pacific Fisheries Commission (NPFC) is a regional fisheries management organization with responsibility for managing high seas fisheries in the PICES region. In 2017 PICES and the NPFC formed a joint Study Group for [Scientific Cooperation in the North Pacific Ocean](#). The purpose of this Study Group was to promote collaboration between the two organizations towards a greater understanding of the pelagic ecosystem and its variability and the resulting impacts on fisheries production.

The joint PICES/NPFC workshop (W11) on the influence of the environment on Pacific saury, held at PICES-2019 on October 16, was the inaugural-sponsored activity of this collaboration between the two organizations. The objectives of the workshop were to examine environmental conditions and spatio-temporal changes in Pacific saury distribution, determine how these affected the habitat of Pacific saury, and explore what the implications of climate variability might be for Pacific saury populations dynamics.

**Workshop contents**

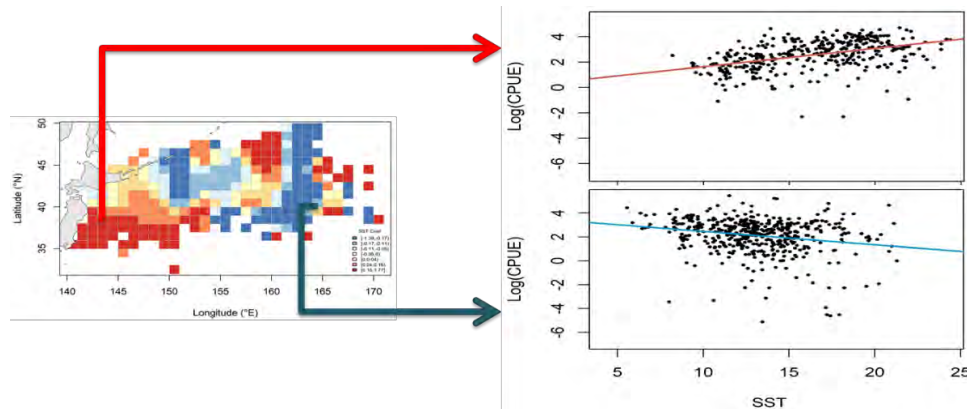
The workshop began with an introductory presentation by Dr. Kazuhiro Oshima that outlined the cyclical pattern in Pacific saury biomass estimated through the stock assessment by the NPFC. A key uncertainty is the level to which productivity, growth and survival might be influenced by changes in available habitat and ecosystem productivity. Next, Dr. Chuanxiang Hua presented analyses that examined relationships between Pacific saury fishery effort and sea surface temperature (SST) and its gradient (SSTG). A key finding was that SST appears to control the migration and

distribution of Pacific saury, whereas SSTG appears to be related to the aggregation of Pacific saury. Dr. Taiki Fuji talked about how the presence of competitors for prey species (particularly Japanese sardine) impacted the distribution of Pacific saury. The discussion that followed centered around uncertainties in the relationships between the oceanography and Pacific saury distribution, the types of variables (both oceanographic and biological) that are important for determining the abundance of Pacific saury, and in particular, the need for more study of the mechanisms underlying the environmental relationships.



*Dr. Taiki Fuji presents information on the feeding habits of Pacific saury and their competitors in the pelagic waters of the NW Pacific Ocean.*

The second topic for presentations at the workshop was an examination of modeling the distribution and environmental relationships of Pacific saury. Dr. Bai Li found evidence for non-stationarity in the relationships between environmental factors and catch-per-unit-of-effort (CPUE) of NPFC member fishing fleets, meaning the CPUE was responding differently to environmental covariates in different regions.



*Evidence for spatial non-stationarity in the relationship between sea surface temperature (SST) and catch-per-unit-of-effort (CPUE) for Pacific saury in the NW Pacific Ocean presented by Dr. Bai Li representing the North Pacific Fisheries Commission.*



Dr. Chih-hao Hsieh's presentation highlighted uncertainty in the relationships, as the variables found to be important in models were generally not consistent and no single modeling approach was the best. Dr. Midori Hashimoto next presented a vector-autoregressive-spatio-temporal model applied to Japanese trawl survey data and found that age 0 and age 1 Pacific saury had different high-density areas in the North Pacific. Her collaborator, Dr. Shin-Ichiro Nakayama, then showed data suggesting that the Pacific Decadal Oscillation (PDO) was linked to the distribution of age 0 fish, but was not strongly influencing the recruitment of age 0 fish. Dr. Andrey Krovnin and colleagues found significant correlations between Pacific saury CPUE and the North Pacific Gyre Oscillation (NPGO) at 0 and especially a 5-year time lag. The influence of the North Pacific Gyre has also been evident in other fish stocks with lag 0. Dr. Yong Chen presented an overview of global examples of incorporating the environment into stock assessment. Improving the data input, such as standardization of CPUE with environmental variables (e.g., tuna) can improve stock assessments. Improving the models themselves by using environmental variables that link ecological mechanisms to population parameters is also possible. There was an active discussion session following these talks that engaged on how future distribution modeling might be approached and how new information and relationships might be used in stock assessment.

### ***Recommendations and future directions for research on Pacific saury***

A number of recommendations for future research directions were developed during the workshop. The empirical relationships between Pacific saury distribution and oceanography that were identified during the workshop should be studied further to try to determine mechanistic processes. It was also noted that ecological studies would benefit from knowledge of competitor species and the spatial

overlap between Pacific saury and other small pelagic species.

Integrating the environmental and oceanographic mechanisms into future stock assessments for Pacific saury is also needed. Little is known of the impacts of large-scale environmental variability such as the PDO or NPGO on Pacific saury population dynamics and recruitment. Additionally, the habitat occupied by Pacific saury varies inter-annually and is dependent on water temperature and water properties. These estimates of habitat could potentially be used as measures of carrying capacity.

Research to link climate change projections and hindcasts of regional ocean models would also be useful for managing future projections of Pacific saury stock dynamics. One of the conclusions of the workshop was that commonly used biological reference points (such as maximum sustainable yield) for Pacific saury are likely to change in future climate scenarios. The integration of climate and oceanographic models into Pacific saury stock assessments would be useful in mitigating uncertainty around the future of the fisheries.

Many of the questions and recommendations considered during the workshop, such as large-scale oceanographic processes, are topics of ongoing research in the PICES community. One of the most important conclusions of the workshop was that collaboration with the PICES community of researchers should continue to be encouraged and further relationships between PICES and NPFC be developed. As a result, attendees at the workshop put forward a proposal for a Topic Session at the 2020 PICES Annual Meeting ("*Environmental variability and small pelagic fishes in the North Pacific: exploring mechanistic and pragmatic methods for integrating ecosystem considerations into assessment and management*"; subsequently accepted) that will serve as the next step in building a stronger scientific collaboration between PICES and the NPFC.



*Dr. Chris Rooper (Chris.Rooper@dfo-mpo.gc.ca) is a Research Scientist with Fisheries and Oceans Canada in the Stock Assessment and Research Division at the Pacific Biological Station in Nanaimo, British Columbia. His research interests are in the function of habitats for fishes, particularly rockfishes and deep-sea corals and sponges, using a combination of in situ studies with underwater cameras and regional scale modeling. In PICES, he is a member of the Working Group (WG 32) on Biodiversity of Biogenic Habitats.*



*Dr. Vladimir Kulik (vladimir.kulik@tinro-center.ru) is the Head of the Division for Fishing Statistics and Databases of the Pacific branch of VNIRO ("TINRO" – Research Institute of Fisheries and Oceanography) in Vladivostok, Russia. His responsibilities include calculating the total allowable catch for several stocks in the Far Eastern Seas, providing reports on fishing statistics, and overseeing the management of databases. In PICES, Vladimir is a member of the Technical Committee on Monitoring, Working Group (WG 35) on the Third North Pacific Ecosystem Status Report, Working Group (WG 36) on Common Ecosystem Reference Points across PICES Member Countries, and Working Group (WG 40) on Climate and Ecosystem Predictability, and a project science team member of FishGIS.*



Dr. Kazuhiro Oshima ([oshimaka@affrc.go.jp](mailto:oshimaka@affrc.go.jp)) is a Principal Researcher at the National Research Institute of Far Seas Fisheries (NRIFSF), Japan Fisheries Research and Education Agency. He received his PhD through a study on the stock assessment of brackish water clams in Lake Shinji based on field work. He started his career as a researcher to work on the stock assessment on Pacific saury at the Tohoku National Fisheries Research Institute. After moving to the NRIFSF, he was engaged in work related to the stock assessment of Pacific bluefin tuna (PBF). He also addressed a development of real-time monitoring scheme of the age-0 PBF recruitment. After approximately a 10-year career regarding PBF, he led studies on the ecological related species of tuna longline fisheries at the same institute for two years. In 2018, he returned to stock assessment work on Pacific saury, then joining NPFC-related meetings.



Dr. Yong Chen ([ychen@maine.edu](mailto:ychen@maine.edu)) is a Professor of Fisheries Science in the School of Marine Sciences at the University of Maine in Orono, Maine, U.S.A. Dr. Chen's research focuses primarily on fisheries stock assessment and management. Dr. Chen has authored and co-authored over 240 peer-reviewed papers in scientific journals, many technical and fish stock assessment reports, and has received over 8 million dollars in competitive research support for over 80 projects in marine capture fisheries stock assessment and management. Dr. Chen has an adjunct faculty appointment at the Shanghai Ocean University. He is currently a member of the United States New England Fisheries Management Council's Scientific and Statistical Committee. He is Editor-in-Chief of the Canadian Journal of Fisheries and Aquatic Sciences and the Aquaculture and Fisheries. His lab webpage is located at <https://www.umaine.edu/chenlab/>



Dr. Chih-hao (Zac) Hsieh ([chsieh@ntu.edu.tw](mailto:chsieh@ntu.edu.tw)) is a professor and the Deputy Director at the Institute of Oceanography, National Taiwan University. Zac received his Master degree from the Department of Zoology, National Taiwan University and Ph.D. degree from the Scripps Institution of Oceanography, University of California-San Diego. He is a theoretical ecologist as well as biological and fisheries oceanographer. His research targets range from microbes, plankton, to fish. His research integrates field observations, experiments, data analyses, and mathematical modeling. His research interests include forecasting dynamical systems, plankton food webs, and ecosystem-based approach to fisheries management.

(continued from page 23)



Dr. Lidia Yebra ([lidia.yebra@ieo.es](mailto:lidia.yebra@ieo.es)) is a Research Scientist at the Spanish Institute of Oceanography in Málaga, Spain. Her interests include zooplankton physiology and ecology, and she developed methodologies to estimate production rates using biochemical approaches, such as the activity of the enzymes aminoacyl-tRNA synthetases (AARS). She is a member of the ICES Working Group on Zooplankton Ecology and contributes to the ICES Zooplankton Status Report. In PICES, she is an ex officio member, representing ICES, of Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG 37).



Dr. Akash Sastri ([akash.sastri@dfo-mpo.gc.ca](mailto:akash.sastri@dfo-mpo.gc.ca)) is an oceanographer with Fisheries and Oceans Canada at the Institute of Ocean Sciences in Sidney, British Columbia, Canada, where he leads the La Perouse/West Coast of Vancouver Island Plankton Monitoring field program. He has a background in biological oceanography with a focus on the roles of marine plankton communities in changing environments. His Ph.D. (2007) thesis at the University of Victoria focused on the development and application of novel ways to measure zooplankton productivity routinely at sea. In PICES he is the Chair of the Biological Oceanography Committee, co-chairs the Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG 37) with Toru Kobari, and is a member of the Advisory Panel on North Pacific Coastal Ocean Observing Systems.



Dr. Toru Kobari ([kobari@fish.kagoshima-u.ac.jp](mailto:kobari@fish.kagoshima-u.ac.jp)) is Associate Professor on the Faculty of Fisheries at Kagoshima University supporting "Biological Oceanography" and "Fisheries Oceanography". He has a background in biological oceanography with a focus on the structural and functional roles of plankton communities on marine ecosystems. Toru completed his undergraduate studies in Faculty of Science at the Yamagata University, Yamagata, and a M.Sc. in Fisheries at the Hokkaido University, Hakodate. His Ph.D. (1999) thesis at Hokkaido University focused on the life cycles and interannual variability of *Neocalanus* copepods. His current research focuses on the trophodynamics and productivity of plankton food web in the Northwest Pacific. In PICES he co-chairs the Working Group on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG 37) with Akash Sastri.



## The 2019 International Gulf of Alaska Expedition: A pioneering exploration of the overwintering conditions of Pacific salmon

by Moronke K. Harris



Fig. 1 W16 organizers and some attendees, including members of the successful 2019 International GoA Expedition scientific research team, at PICES-2019, Victoria, BC, Canada (Photo Credit: Stuart McNish, Oh Boy Productions).

In the autumn of 2019, the North Pacific Anadromous Fish Commission (NPAFC; [npafc.org](http://npafc.org)) successfully completed two days of meetings (October 19–20) as part of the 2019 PICES Annual Meeting in Victoria, BC, Canada. As an integral part of the International Year of the Salmon (IYS; [yearofthesalmon.org](http://yearofthesalmon.org)) initiative led by NPAFC in the North Pacific and the North Atlantic Salmon Conservation Organization (NASCO; [nasco.int](http://nasco.int)) in the North Atlantic, the workshop (W16: *Developing a collaborative, integrated ecosystem survey program to determine climate/ocean mechanisms affecting the productivity and distribution of salmon and associated pelagic fishes across the North Pacific Ocean*) was co-sponsored by PICES, NPAFC and the North Pacific Fisheries Commission (NPFC; [npfc.int](http://npfc.int)). Significant funding was provided by the BC Salmon and Restoration Innovation Fund. It convened oceanographers, ichthyologists, climatologists and resource managers from around the Pacific Rim and abroad to explore findings from the ground-breaking 2019 winter expedition to the Gulf of Alaska (GoA). The voyage was the first comprehensive winter expedition examining Pacific salmon in the GoA and successfully established a baseline of environmental and ecosystem-level measurements for future comparisons.

Presentations were given by representatives from a wide variety of 2019 International GoA Expedition partner organizations including Fisheries and Oceans Canada, National Oceanic and Atmospheric Administration (NOAA) Fisheries, NPAFC, the Pacific Branch of the Russian Federal

Research Institute of Fisheries and Oceanography (TINRO), the Pacific Salmon Foundation, the University of British Columbia, the University of Victoria and Hokkaido National Fisheries Research Institute. They included members of the 2019 GoA scientific team. In total, W16 brought 24 researchers and multiple participants together from six countries to network, discuss and share their respective research (Fig. 1).

### 2019 International GoA Expedition

The high seas pelagic ecosystems of the North Pacific support six species of Pacific salmon and steelhead trout; chum (*Oncorhynchus keta*), coho (*Oncorhynchus kisutch*), sockeye (*Oncorhynchus nerka*), pink (*Oncorhynchus gorbuscha*), Chinook (*Oncorhynchus tshawytscha*) and masu (*Oncorhynchus masou*) salmon. During winter, approximately one third of all Pacific salmon, spanning all species but the Asian endemic masu, inhabit the GoA. Despite the importance of this region, the vast majority of previous salmon research has focused solely on freshwater and coastal habitats. The current lack of baseline data on salmonids in the GoA adds uncertainty to the already challenging task of forecasting returns and predicting salmon behavior and responses to the changing North Pacific ecosystem.

To bridge the knowledge gap concerning salmon overwintering conditions, the NPAFC as part the IYS, and

along with nongovernmental organizations (NGOs), government, academic and private partners, conducted a high seas expedition with scientists from around the Pacific Rim in winter 2019. The International GoA Expedition was completed with 21 scientific personnel from Canada, Japan, Korea, Russia and the United States aboard the chartered 62 m Russian R/V *Professor Kaganovskiy* (Fig. 2). Organized by Dr. Richard J. Beamish, the Pacific Salmon Foundation and NPAFC with funding from private individuals, government agencies and NGOs, it was the first in decades to study salmon in the winter high seas, and it set a precedent for addressing gaps in our knowledge through survey work concerning salmon, plankton, hydrochemical and physical conditions in the central GoA. The expedition covered an area of approximately 700,000 km<sup>2</sup> between February 16 and March 18, 2019 (Fig. 2). In total, 423 salmon (223 chum, 93 coho, 73 sockeye, 31 pink and 3 Chinook) were caught during the trawl surveys.

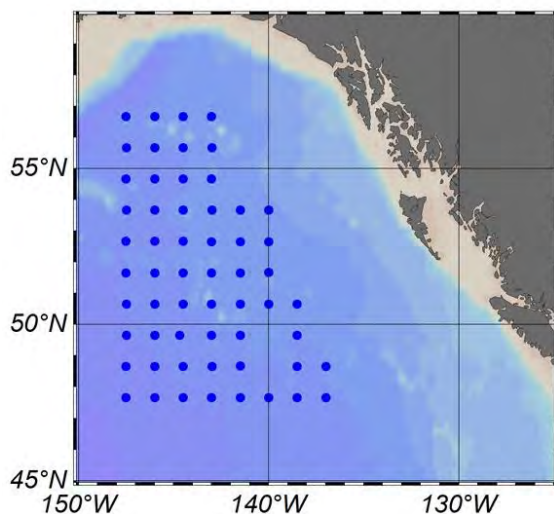


Fig. 2 Top: R/V *Professor Kaganovskiy* (Photo Credit: Pacific Salmon Foundation). Bottom: 58 expedition survey stations sampled between February and March 2019 in the GoA (Pakhomov et al., 2019).

The overarching objective was to demonstrate the effectiveness of using international science collaboration to test key hypotheses on factors regulating salmon survival in

the open ocean during the critical overwintering period of their life history. With these findings, scientists hope to create a strong research baseline for future expeditions leading to a program of coordinated integrated surveys across the entire North Pacific that will investigate the mechanisms affecting salmon distribution and productivity. The results of the 2019 survey will directly inform planning for tentative surveys in the GoA in March 2020 and across the full breadth of the North Pacific in 2021. In time, these efforts will provide communities and resource managers with the timely scientific advice needed to manage salmon and ecosystems in a rapidly changing world.

**GoA survey results: PICES-2019 W16**

The scientific results of the winter 2019 survey revealed that salmon distributions varied by species in the GoA and appeared to correlate with the environmental characteristics of water masses such as changes in ambient temperature, productivity and prey distributional patterns (Table 1, Fig. 3). Most surprising was the relatively high abundance of coho in the GoA catches, given they were previously thought to be mainly coastal in distribution, and the appearance of North American sockeye further west than expected in the small set of central North Pacific samples taken as the R/V *Professor Kaganovskiy* made the return journey from Canada to Russia upon completion of the 2019 expedition.

Novel genomic tools allowed researchers for the first time to conduct at-sea DNA analyses for stock identification, assess physiological conditions and test for the presence of pathogens. Interestingly, stock composition was largely independent of capture site, suggesting that distant stocks do not segregate according to origin but instead readily mix within the open ocean. For example, chum salmon of both Asian and North American origin co-mingled in the survey area.



Fig. 3 Ms. Chrys Neville (Canada) gave a presentation titled “Changes in our thinking of ocean life of sockeye salmon”. Overall, an unexpectedly low proportion of ocean age 2+ Fraser River sockeye and age 1 sockeye was observed in the 2019 International GoA catches. This could be a signal of poor returns to the Fraser River in 2020 (Photo Credit: Stephanie Taylor, IYS).



Table 1 Survey area dominance, frequency of occurrence in trawl catches, estimated numbers and biomass of Pacific salmon species in the upper epipelagic layer (0–30 m) throughout the investigated area in the GoA during winter 2019 at a catchability coefficient ( $q$ ) of 0.3 (Pakhomov et al., 2019).

Salmon Species	Survey Area Dominance	Frequency of Occurrence (%)	Numbers (million fish)	Biomass (thousand tons)
<b>Chum (<i>Oncorhynchus keta</i>)</b>	widely distributed	55.2	24.17	26.96
<b>Coho (<i>Oncorhynchus kisutch</i>)</b>	southern and westerly stations	37.9	13.59	10.37
<b>Sockeye (<i>Oncorhynchus nerka</i>)</b>	northern stations	31.0	8.94	10.28
<b>Pink (<i>Oncorhynchus gorbuscha</i>)</b>	southern and westerly stations	17.2	4.21	1.63
<b>Chinook (<i>Oncorhynchus tshawytscha</i>)</b>	rarely and sporadically occurred	5.17	0.37	1.32

Several discussions on new perspectives and ideas generated by the presentations were held between sessions. Participants suggested additional considerations and improvements for future expeditions, including sampling eDNA at greater depths to better understand vertical distribution of species, installing cameras in the trawl nets to determine if predators enter and exit the net during sets, having dedicated marine mammal and bird observers on board and determining the vertical migration of salmon during the day and night. However, the defining feature of both W16 and the 2019 survey was the enthusiasm that the international team of ocean and salmon scientific experts from around the Pacific Rim displayed:

*“This has been a really wonderful experience [because of] how well everyone is working together...the level of enthusiasm [displayed by] everybody has been fantastic” – Dr. Laurie Weitkamp, NOAA, USA*

*“We have a baseline that has never been available before, we have observations about species distributions that we cannot explain right now.” – Dr. Richard Beamish, Fisheries and Oceans Canada Emeritus*

*“I believe that [aside from] our scientific findings, this will bring our nations closer [diplomatically].” – Dr. Arkadii Ivanov, TINRO, Russia*

*“Being able to work in real time with [international] scientists, looking at similar questions [of interest] from around the North Pacific is fabulous...it’s very, very exciting.” – Ms. Chrys Neville, Fisheries and Oceans Canada*

### **IYS: Salmon and people in a changing world**

The 2019 expedition is a Signature Project of the IYS. The IYS is a five-year initiative (2018–2022) of the NPAFC and its North Atlantic partner, NASCO aiming to establish a new hemispheric-scale partnership of government, Indigenous Peoples, academia, NGOs and industry to effectively address the scientific and social challenges facing salmon and people in an increasingly uncertain environment. More on the preliminary results of the 2019 International GoA Expedition can be found at [yearofthesalmon.org/gulf-of-alaska-expedition](http://yearofthesalmon.org/gulf-of-alaska-expedition).

**Acknowledgements:** Many thanks to PICES, NPFC, Vladimir Radchenko (NPAFC Executive Director) and the extended North Pacific IYS team: Mark Saunders (IYS Director), Stephanie Taylor (High Seas Expedition Coordinator) and Laura Tessier (IYS Coordinator). The NPAFC sincerely acknowledges their dedication and contribution to facilitating and steering W16 activities. In addition, many thanks to the tremendous efforts of IYS partners, international scientists and media professionals without whom this meeting would not have taken place.

### **Reference**

Pakhomov, E.A., C. Deeg, S. Esenkulova, G. Foley, B.P.V. Hunt, A. Ivanov, H.K. Jung, G. Kantakov, A. Kanzevarova, A. Khleborodov, C. Neville, V. Radchenko, I. Shurpa, A. Slabinsky, A. Somov, S. Urawa, A. Vazhova, P.S. Vishnu, C. Waters, L. Weitkamp, M. Zuev, and R. Beamish. 2019. Summary of preliminary findings of the International Gulf of Alaska expedition onboard the R/V *Professor Kaganovskiy* during February 16–March 18, 2019. NPAFC Doc. 1858. 25 pp. Canada, Japan, South Korea, Russia, and USA (Available at <https://npafc.org>).

*Ms. Moronke Harris (moronkeharris@gmail.com) is an early-career biogeochemist and Assistant International Year of the Salmon Coordinator with the NPAFC. As a Supporting Member of the British Columbia High Seas Research Council, she facilitates hydrochemical characterization of the 2019 International Gulf of Alaska Expedition survey area, and preparation for the proposed 2021 International Pan-Pacific High Seas Expedition. Moronke has a background in microbiology and ocean biogeochemistry with a focus on aquatic disease diagnosis and the carbon and nitrogen cycles. Her research placements have taken her from using image analysis to quantify Canadian barnacle microtopography (University of Guelph, Canada), to studying climate engineering tactics in the Bermudian ocean (Bermuda Institute of Ocean Sciences), to facilitating large-scale water quality monitoring programs and examining the hydrochemical effects of Floridian seagrass beds on ocean acidification mitigation (Mote Marine Laboratory, USA). Moronke holds a HBS in Biological Science from the University of Guelph and aims to pursue MSc and PhD degrees in Oceanography.*



## ***GlobalHAB: Evaluating, reducing and mitigating the cost of Harmful Algal Blooms: A Compendium of case studies***

by Vera L. Trainer, Keith Davidson, Kazumi Wakita, Elisa Berdalet, Marc Suddleson, Geir Myre and Dean Trethewey

Over the last two decades, several reports have been compiled on what is known about the economic impacts of harmful algal blooms (HABs; *e.g.*, Anderson *et al.*, 2000; Hoagland and Scatasta, 2006; Trainer and Yoshida, 2014, and Sanseverino *et al.*, 2016). Although these reports attempted to gather comprehensive economic impact data, both the type and amount of data available were limited. One past study estimated the cost of HABs in the European Union at \$800 million USD per year (Hoagland and Scatasta, 2006) but most of that cost was extrapolated for very few HAB organisms. Furthermore, most countries have neither conducted economic analyses of HABs nor collected data that can be used to generate reliable quantitative estimates of net economic losses and economic impacts. The lack of data, appropriate and standardized protocols, and the dearth of peer-reviewed studies hampers efforts to quantify the societal costs of increasingly frequent, intense and long-lasting HAB events and to help evaluate the cost of various strategies being developed for HAB prevention, control, and mitigation.

To strategize how specific economic studies can be used to assess the economic impacts of HAB and mitigate their risks, a workshop (W18) was held on October 17–19 at PICES-2019. During this 2½-day workshop, over 48 international experts on economics and the science of HABs

from Australia, Canada, Chile, China, France, Japan, Korea, Norway, the United Arab Emirates, Scotland, Spain, UK and USA, discussed a compendium of case studies that highlight the economic impacts of HABs on farmed salmon and shellfish and on wild-caught, reef-based fisheries.

Workshop discussion topics included the net impacts of HABs, their costs, and coastal resilience to HABs worldwide. Plenary lectures included worldwide examples of wild fisheries, recreational fisheries and aquaculture losses. Five case studies included: 1. US west coast *Pseudo-nitzschia* and impacts on shellfish and marine mammals; 2. Korea *Cochlodinium polykridoides* including impacts on wild and aquacultured fish kills; 3. Ciguatera fish poisoning; 4. Fish aquaculture including examples from the European Union, Canada and Chile; and 5. Shellfish aquaculture losses.

The economic impact of HABs is recognized to be large, although currently poorly quantified in many of the world's coastal areas. The losses faced by insurers are huge. At the workshop, a representative from a reinsurance company specified that 45% of insurance claims are now from HABs. In fact, it was stated that the loss due to HABs is larger than any storm that insurers have ever faced. In Korea, one insurer has already collapsed due to the frequent and enormous losses of aquacultured fish due to HABs.



Participants from the GlobalHAB Workshop (W18): Evaluating, reducing and mitigating the cost of Harmful Algal Blooms, at PICES-2019, Victoria, British Columbia, Canada.





*Co-Convenor, Dr. Vera Trainer, speaking to workshop participants.*

Several examples of HAB-related losses and loss mitigation were discussed in detail at the workshop. A HAB incident in northern Norway alone resulted in the loss of 14 thousand tons of Atlantic salmon in May 2019, resulting in a total loss of at least 330 million USD, including insured losses of \$45 million USD, underinsured values and deductibles of \$40 million USD, losses of future salmon sales at \$160 million USD, cleanup costs at \$30–40 million USD, and loss of taxes and unemployment benefits at \$50 million USD. In Brittany, France, the Laboratoire d'Economie et de Management de Nantes-Atlantique (LEMNA), University of Nantes, is conducting a detailed estimation of the impacts of shellfish trade bans caused by HABs. Researchers at LEMNA are creating a database documenting these trade bans from 2004 through 2018 at shellfish harvesting areas in four French departments (Finistère, Morbihan, Loire-Atlantique and Vendée). These four areas encompass about 700 shellfish farms representing 37,600 tonnes of products with an estimated value €141 million (>\$156 million USD), *i.e.*, 20% of the national shellfish harvest.

Finally, breakout groups discussed strategies for mitigation including the value of information from better or more refined forecasts. Questions addressed included: Can contingency planning reduce loss? How do we open areas more quickly? How do we make closures shorter? What is the value of information from better forecasts? What is the cost benefit analysis of monitoring programs? How much should be spent on monitoring? For insurance purposes, how do we reduce the cost of HABs?

The huge HAB-related losses to industry, consumers and governments illustrate the need for insurers, aquaculturists, public health professionals, economists, and HAB scientists to work together to estimate the cost of HAB events relative to the costs of mitigation and management. Studies of

economic and social losses and their impacts need to be planned and teams need to be formed prior to HAB events to ensure that they are comprehensively studied. Toward this goal, the workshop further helped to establish greater connections between economists, industry scientists, and HAB researchers. Participants plan to refine and publish case studies to help guide future research and management priorities. A series of white papers are being prepared to document the workshop goals, the five case study examples, and summary recommendations for the future. These white papers will be published on the GlobalHAB and PICES websites. A summary of this work will be published in a peer-reviewed paper, providing several examples that can be used to steer future studies on the economic impact of HABs.



*Discussing mitigation strategies in one of the breakout groups.*

The workshop was sponsored by [GlobalHAB](#), [PICES](#), the Scientific Committee on Ocean Research ([SCOR](#)), the International Society for the Study of Harmful Algae ([ISSHA](#)), Northwest Pacific Action Plan Coastal Environmental Assessment Regional Activity Centre ([NOWPAP CEARAC](#)), [Greig Seafood Ltd.](#), the Intergovernmental Oceanographic Commission of [UNESCO](#), [GlobalHAB](#), and [AXA XL Reinsurance](#).

## References

Anderson, D.M., Hoagland, P., Kaoru, Y., White, A.W. 2000. Estimated economic impacts from harmful algal blooms (HABs) in the United States. WHOI-2000-11 Technical Report. 96 pp.

Hoagland P., Scatasta S. 2006. The economic effects of Harmful Algal Blooms. *In* Granéli E., Turner J.T. (eds.) *Ecology of Harmful Algae*. Ecological Studies (Analysis and Synthesis), vol. 189. Springer, Berlin.

Huppert, D.D., Trainer, V.L. 2014. Economics of razor clam fishery closures due to harmful algal blooms in Washington State. pp. 59–71 *In* Trainer, V.L., Yoshida, T. *Proceedings of the workshop on economic impacts of harmful algal blooms on fisheries and aquaculture*. PICES Sci. Report No. 47, PICES, Sidney, B.C. Canada.

Sanseverino, I., Conduto, D., Pozzoli, L., Dobricic, S., Lettieri, T. 2016. Algal bloom and its economic impact. JRC Technical Report. EUR 27905 EN.



*Dr. Vera Trainer (vera.l.trainer@noaa.gov) is a Supervisory Oceanographer at the Northwest Fisheries Science Center, Seattle, USA. Her current research activities include the study of extreme harmful algal bloom events worldwide and climate impacts on ocean ecosystem health, including phytoplankton diversity. She is the President of the International Society for the Study of Harmful Algae (ISSHA), and is a member, representing PICES, of the GlobalHAB Steering Committee. Vera was Co-Chair of the Section on Ecology of Harmful Algal Blooms in the North Pacific from 2003 to 2017 and is now the Science Board Chair of PICES.*



*Dr. Keith Davidson (Keith.Davidson@sams.ac.uk) is a full Professor and Associate Director at the Scottish Association for Marine Science (SAMS). His background is in physics but he has become increasingly interested in phytoplankton since he first started to attempt to model their growth as an undergraduate. Much of the focus of his research has been related to harmful algal blooms (HABs) and how the physical/chemical/biological environment of marine waters governs these events. He is a member of the GlobalHAB Steering Committee and the council of the International Society for the Study of Harmful Algae.*



*Dr. Kazumi Wakita (kazumiw@tokai-u.jp) is a Professor of ocean policy and coastal management in the School of Marine Science and Technology, Tokai University, Japan. Her research interests encompass the socio-psychological aspect and policy framework in managing the marine and coastal environment. She currently works on analyzing historical changes of harmful algal bloom issues in newspaper articles. She is a member of the Task Team on Harmful Algae and Fish Kill of International Program on Harmful Algal Blooms (IPHAB) of IOC/UNESCO, a member of the Steering Group of Harmful Algal Blooms Projects of IOC/WESTPAC, and a member in PICES of Working Group on Common Ecosystem Reference Points across PICES Member Countries (WG 36).*



*Dr. Elisa Berdalet (berdalet@icm.csic.es) is Research Scientist at the Institute of Marine Sciences (ICM-CSIC), in Barcelona, Spain. Her studies have focused on plankton ecology, in particular on physical–biological interactions and on harmful algal blooms (HABs). Her current research is centered on the benthic dinoflagellate *Ostreopsis* blooms. Since 2008, she has been involved in the IOC/UNESCO and SCOR programs GEOHAB and GlobalHAB, aimed at the coordination of the international research on HABs. At present she is Chair of the GlobalHAB SSC.*



*Mr. Marc Suddleson (marc.suddleson@noaa.gov) is a program manager with the National Centers for Coastal Ocean Science, NOAA in Silver Spring Maryland, USA. Marc has overseen the creation and management of national competitive research programs for over 20 years building effective partnerships between federal labs, universities, state and tribal agencies and industry to develop and implement harmful algae monitoring, alert, prediction and response systems. Marc is a member of the U.S. National HAB Committee and a member of International Society for the Study of Harmful Algae.*



*Mr. Geir Myre (Geir.Myre@axaxl.com) is Global Manager for Aquaculture Insurance with AXA XL Aquaculture Department, based in Bergen Norway. He is educated as Marine Engineer and Production Engineer. Geir has been working with underwriting insurance for the Aquaculture Industry for the last 32 years. His insurance experience includes most of the major HAB insured losses for the last two decades.*



*Dean Trethewey (Dean.Trethewey@griegseafood.com) is the Director of Saltwater Production and the Director of Regulatory and Certifications for Grieg Seafood BC. Dean has worked in the Aquaculture sector for 25 years with background in Professional Project management. He has led several initiatives towards changing practices and designing equipment for the Salmon Farming industry including ongoing plankton mitigation equipment, ocean data monitoring and machine learning applications. His current work is engaging with all stakeholders involved with ocean science and improving collaborative methods on sharing data to gain a better understanding of climate change and the effects on fin fish species.*



## PICES on the cloud

by Chelle Gentemann, Marisol García-Reyes, Trond Kristiansen and William Sydeman

At the 2019 PICES Annual Meeting, Marisol García-Reyes presented a talk on “Cloud computing of key NASA oceanographic data: Implications for automating aspects of ecosystem status reports” at the Topic Session (TS 8) on “Creating more effective Integrated Ecosystem Assessments (IEAs) in PICES countries”, which introduced a simple tool that provides time series of satellite-based environmental data for all 14 PICES regions, as defined for PICES’ third North Pacific Ecosystem Status Report (NPESR). The PICES Regional Ecosystem Tool was created by Earth and Space Research and Farallon Institute with support and funding from NASA’s Inter-agency Implementation and Advanced Concepts Team (IMPACT) to facilitate the reporting and comparison of oceanographic conditions across PICES regions while increasing accessibility to satellite data on the cloud.

Connecting environmental and ecological data allows us to better understand the effects of climate change and extreme events on marine ecosystems. About every 5 years PICES publishes a NPESR to provide a review and summary of the marine ecosystems in each of the 14 PICES regions (Fig. 1). The individual chapter leads are responsible for compiling relevant ecosystem and environmental information to create their assessment.

Currently, the relevant and comparable environmental satellite data exist but are at different archive centers, temporal samplings, and spatial resolutions. Creating time series, trends, and maps requires finding, downloading, and storing large amounts of data. Processing these differently-sampled data requires a high-level understanding of software development to extract and analyze them, limiting their usage and hindering comparative ecosystem analyses. Advances in open source software and cloud computing environments can provide access to environmental data without needing to download and store the data. Taking the analysis to the data, rather than the data to the user, makes analysis of the regional environmental conditions easier and reproducible.

As part of NASA’s plan to migrate copies of their data onto the cloud and make processing of data reproducible and shareable, we developed an online tool that allows one to easily generate spatially-explicit (customizable) time series of satellite-based data for all of the PICES regions. This tool is interactive and runs fully on the cloud. Moreover, the notebooks can be modified to customize data and regions and to do further analysis or different plots. This approach could be used not only to enhance the timeliness and utility of the PICES NPESR documents, but also to promote biophysical analysis by providing easy access to the data required to do so.

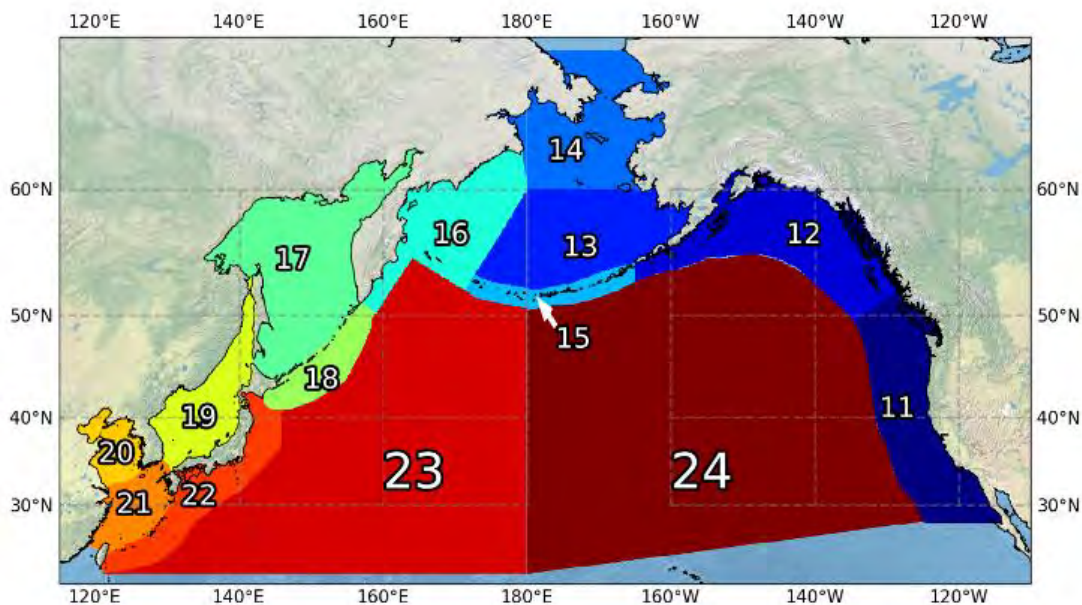
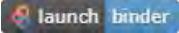


Fig. 1 PICES regions as defined in the 3<sup>rd</sup> NPESR.

In short, the [PICES Regional Ecosystem Tool](#) runs completely on the cloud without need of a user background in cloud computing. To launch the tool, click on this  icon. Once the tool is running, simply click on the orange “PICES Regional Ecosystem Tool” icon on the left menu and a script window opens with instructions on how to run the script and customize time series output for particular regions and data types. Plots of the monthly data, the seasonal cycle, and the anomalies are created (Fig. 2). Further analysis can be completed within the tool, or the time series data can be downloaded.

We encourage you to try this tool and contact us with suggestions for features, plots, or other data you would like to see included. As part of this project we have also developed online and easy to follow workshops on Python for oceanographers, which are available [here](#). Our future work on the tool will include newly available cloud-optimized data and climate projections such as the Coupled Model Intercomparison Project Phase 6 (CMIP6) and Community Earth System Model (CESM) Large Ensemble Numerical Simulation (LENS) dataset.

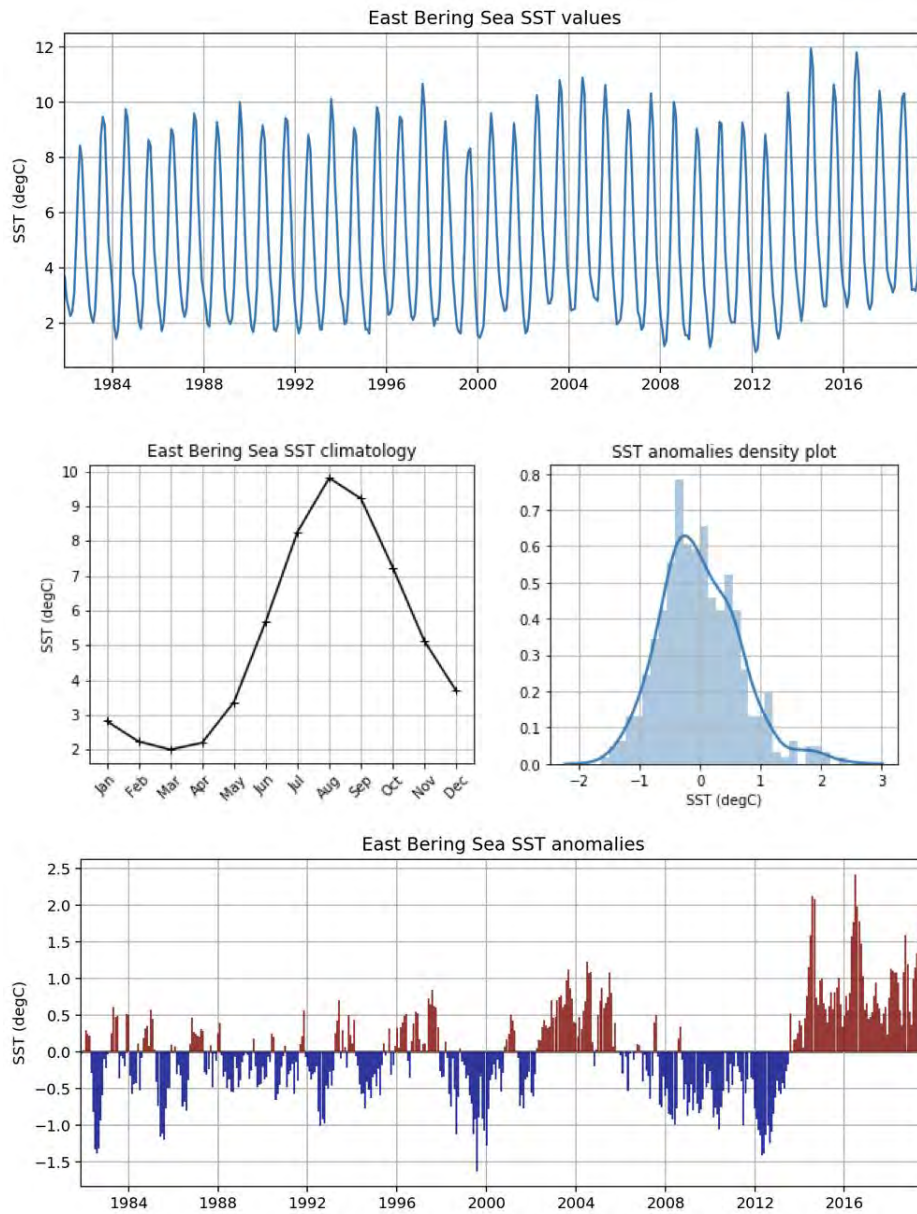


Fig. 2 Figures created by the PICES Regional Ecosystem Tool. PICES Region 13 - East Bering Sea monthly sea surface temperature (SST) data from 1981–present. From top to bottom: SST time series, climatology of the SST annual cycle and density plots of SST anomalies, and time series of monthly SST anomalies.

<sup>1</sup> <https://github.com/python4oceanography/PICES-tools>



**In A BOX*****The Technical Details*****Technology**

The PICES Regional Ecosystem Tool takes full advantage of new developments on open source software (OSS), which not only provides state-of-the-art data processing but more importantly facilitates and promotes the creation of reproducible research environments that can be publicly (or privately) shared. All of the OSS we developed for the PICES tool is hosted on [GitHub](#) an online software repository with version control. The tool runs from the GitHub repository, and accesses data included in the same repository. In future versions, as NASA data become available, the data accessed would be also on the cloud. We then utilize the free [Binder](#) service which creates a [Docker](#) image of the software repository, providing an interactive [JupyterHub](#) notebook environment that runs the PICES tool. This notebook is running on the Google cloud. Many of the OSS tools we used here make it almost invisible to a user that they are running their analysis on the cloud. We expect this type of OSS library development to continue, providing a gateway for research scientists who are not experienced software developers to access all the public data and computing power that is available on the cloud.

**Data**

GIS shapefiles for each region, provided by PICES, were processed using the open source [GeoPandas](#) and [Xarray](#) Python software libraries to generate each region's masks.

Currently, the tool includes SST ([NOAA Optimum Interpolation V2](#)), chlorophyll-*a* concentration ([GlobColour](#) SeaWiFs product version 2017.2), wind vectors (NOAA FNMOC 10-m surface winds), and surface ocean current vectors ([ESR OSCAR](#) surface currents). In a future version (currently in development) of the PICES Regional Ecosystem tool we will include output data from the recently released CMIP6 climate models that it has been made freely available by [Pangeo](#) and Google cloud.

[Dr. Chelle L. Gentemann](#) ([cgentemann@esr.org](mailto:cgentemann@esr.org)) is a Senior Scientist at both Earth & Space Research and the Farallon Institute. Her more recent research focuses on interdisciplinary science using cloud computing, open source software development, air-sea interactions, and upper ocean physical processes. She has worked on the calibration, radiative transfer modeling, algorithm development, validation, and operational near-real-time distribution of multiple satellite sensors.



[Dr. Marisol Garcia-Reyes](#) ([marisolgr@gmail.com](mailto:marisolgr@gmail.com)) is a Principal Scientist at Farallon Institute. Her research focus is on how variability of ocean climate impacts the marine ecosystem. One of the most time consuming, and at the same time, basic and important parts of this work is to acquire and process climate, atmospheric, and oceanographic data, and then synthesize them in a way that can be matched with biological and ecological data to look for biophysical relationships.



[Dr. Trond Kristiansen](#) ([trondkr@faralloninstitute.org](mailto:trondkr@faralloninstitute.org)) is a Principal Scientist at the Farallon Institute who is currently working on downscaling global climate models for the Arctic Ocean using ROMS, coupled particle-tracking and individual-based models for kelp, larval fish, and plastic, as well as trying to understand how habitats at higher latitudes may be affected by climate change.



[Dr. William J. Sydeman](#) ([wsydeman@comcast.net](mailto:wsydeman@comcast.net)) is President and Senior Scientist at Farallon Institute who studies how biological components of the marine ecosystem are affected by the variability of the physical environment. He leads collaborative projects that investigate climate impacts on multiple trophic levels. Bill's expertise is in the pelagic ecosystem, encompassing upwelling processes, spatial ecology, predator-prey interactions, and top predators such as seabirds. In PICES he is a member of the Section on Marine Birds and Mammals.



## New leadership in PICES

### Science Board

At PICES-2018, Dr. Vera L. Trainer (USA) was elected Chair-elect of Science Board. Following PICES-2019 in Victoria, Canada, she assumed the position of Science Board Chair for a 3-year term. PICES recognizes the dedicated service of Dr. Hiroaki Saito who has served Science Board since 2013, first as the Chair of the FUTURE Advisory Panel on Anthropogenic Influences on Coastal Ecosystems, followed by Co-Chair of the FUTURE SSC (2014–2016), then Vice-Chair (2013–2015), Chair-elect (2015–2016) and Chair (2016–2019) of Science Board.

Vera Trainer is a supervisory oceanographer at NOAA's Northwest Fisheries Science Center in Seattle, Washington, USA. She is an affiliate Associate Professor in the College of the Environment, School of Fisheries and Aquatic Science at the University of Washington and a Senior Fellow of the E.S. Morse Foundation for US/Japan scientific exchanges. She received her B.Sc. in Biology from Indiana University of Pennsylvania, her M.Sc. in Biological Oceanography and Ph.D. in Biochemistry and Molecular Biology from the University of Miami, with postgraduate work in the Pharmacology Department, University of Washington. Her current research on harmful algal blooms focuses on the assessment of climatic factors that influence toxic bloom development and understanding susceptibility of shellfish and marine mammals to toxins in their environment. Her recent publications demonstrate the influence of basin-wide increases in temperature on the intensity of harmful algal blooms caused by *Pseudo-nitzschia* in the Pacific Northwest. This work has led to a comprehensive "ecological forecast" to alert tribal, state and federal managers to toxic events that threaten the coastal shellfish harvest.

Vera has led international comparative approaches to study the intensity, geographical distribution and toxicity of harmful algal blooms which have increased our understanding of environmental stressors that promote these events across the North Pacific. Her collaborative work in the Arabian Sea has resulted in an understanding of the impact of environmental factors on the development of massive *Noctiluca* blooms that are changing the food web structure in this highly productive region. She has also led efforts aboard NOAA research vessels to map toxic blooms and has participated in numerous research cruises as principal investigator.

She is the President of the International Society on the Study of Harmful Algae and a member of the Steering Committee for the International Whaling Commission's Unusual Marine Mortality Events. She serves on the Global Harmful Algal Bloom (GlobalHAB) Steering Committee, the International Ocean Commission's Intergovernmental Panel on Harmful Algal Blooms and has served on the U.S. National Harmful Algal Bloom Committee. She enjoys national and international collaborations, particularly with early career scientists, as a means to enhance our cultural, scientific and personal understanding of one another.

Vera's first PICES Annual Meeting was in 1999 in Vladivostok, Russia, where she became a member of the Working Group (WG 15) on *Ecology of Harmful Algal Blooms (HABs) in the North Pacific* (1999–2003). In 2003 she helped to establish the Section on *Ecology of Harmful Algal Blooms in the North Pacific* (S-HAB), which she co-chaired through to 2017. One of



the achievements of S-HAB is the inclusion of data on HAB occurrences from each PICES member country into a joint ICES/PICES/IOC Harmful Algal Event Database (HAEDAT). This global database was developed only after several years of discussion to alleviate concerns voiced by PICES member countries about the differences in cultural norms and restrictions regarding data sharing. Such online data sharing and data access is an important legacy for PICES which will certainly form the basis for students and other researchers to understand the breadth and depth of HAB data worldwide.

Through her collaborations, she will continue to strengthen the connection of science to human health well-being. She led the PICES-MAFF project, "Development of the Prevention Systems for Harmful Organisms' Expansion in the Pacific Rim" which provided training classes to scientists in Indonesia, the Republic of the Philippines and Guatemala (2007–2012). She also participated in the PICES-MAFF project, "Marine Ecosystem Health and Human Well-being" as the lead investigator for Guatemala (2012–2017). This project has helped with the establishment of Marine Protected Areas in Guatemala in collaboration with the United Nations.

Vera believes that PICES should play a role in communicating consensus scientific findings to a wide audience on issues such as the impacts of climate change on ocean ecosystems. She is committed to promoting diversity and inclusion within PICES, specifically underrepresented people and early career scientists.



Vera lives in Seattle, Washington, with her husband, Len, and children, Roberto and Stephanny. In her free time, she drives Stephanny to soccer games and Roberto to baseball

practice to help with his aspiration of playing D1 ball in college. Together they enjoy skiing, hiking and hosting friends from around the world in their home.

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### Biological Oceanography Committee

*Dr. Akash Sastri (Canada) was elected Chair of BIO at PICES-2019, replacing Dr. Se-Jong Ju (Korea) who stepped down. Dr. Wongyu Park (Korea) was elected Vice-Chair, replacing Dr. Sastri. PICES thanks Dr. Ju for his active service as Chair of BIO.*

Akash Sastri is an oceanographer with Fisheries and Oceans Canada at the Institute of Ocean Sciences in Sidney, British Columbia, Canada, where he leads the La Perouse/West Coast of Vancouver Island Plankton Monitoring field program. Akash's background is in biological oceanography with an emphasis on bio-physical regulation of zooplankton productivity and plankton community response to short- and long-term environmental change. His plankton work in the field spans temperate, sub-tropical, and high latitude marine and freshwater systems. Akash completed his B.Sc. and M.Sc. in Marine Biology at the University of Guelph. During his doctoral studies at the University of Victoria, he studied the zooplankton response during the SERIES iron fertilization experiment and seasonal patterns of zooplankton productivity along the West Coast of Vancouver Island and in the Strait of Georgia. Before joining Fisheries and Oceans Canada, Akash was a postdoctoral fellow at National Taiwan University and Université du Québec à Montréal. Most recently, he held a senior staff scientist position at Ocean Networks Canada, leading the plankton dynamics and biogeochemistry research theme. In PICES, Akash currently serves as the Co-Chair of WG 37 (*Zooplankton Production Methodologies, Applications and Measurements in PICES Regions*) and as a member of the Advisory Panel on *North Pacific Coastal Ocean Observing Systems*. He grew up in Montreal, Quebec, and Toronto, Ontario, Canada, and now calls Victoria, British Columbia home. In his spare time Akash enjoys cycling and tending to a small vegetable garden with his wife and young family.



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### Human Dimensions Committee

*At PICES-2019, Professor Mitsutaku Makino (Japan) was elected Chair of the Human Dimensions Committee (HD), taking over from Professor Keith Criddle (USA). PICES extends its gratitude to Professor Criddle for his dedicated service as the very first Chair of the HD since its establishment in 2016.*

Mitsutaku Makino is a Professor at the Center for International Collaboration, Atmosphere and Ocean Research Institute (AORI), University of Tokyo, Japan. He has contributed to PICES activities as one of the founders of the human dimension sciences within PICES. He formed the Study Group on *Human Dimensions* with Dr. Ian Perry in 2009 to review the role of social sciences in marine science

([PICES Sci. Rep. 39](#), 2010). As recommends by the Study Group, a Section on *Human Dimensions of Marine Systems* (S-HD) was formed in 2011, which aimed to provide a forum for the integration of FUTURE-related studies using social science approaches and tools, and to facilitate the close discussions and communications among researchers from both the natural and social sciences. In 2016, the

Section was upgraded to a permanent Human Dimensions Committee, in which he served as the Vice-Chair for three years, since its establishment.

Mitsutaku received his B.Sc. in Fisheries Oceanography from Kyoto University. After spending one additional year as an undergraduate student to study social sciences, such as law and economics, he proceeded to a graduate course in environmental policy science as his first Master Degree (M.A.) in Kyoto University. He received a second Master Degree (M.Phil.) on institutional economics from the University of Cambridge. In 2003, he received his Ph.D. from Kyoto University by studying the institutional and bio-economic analysis of fisheries sustainability in Japan. His two-year post-doctoral research was at Yokohama National University, where he gained additional knowledge about ecology and environmental risk analysis, and wide human connections with the researchers in conservation ecology. He then moved to the Fisheries Research Agency of Japan (now, the Japan Fisheries Research and Education Agency) and engaged for 14 years in inter-disciplinary research activities on fisheries and marine environmental policy. In April 2019, he moved to the Atmosphere and Ocean Research Institute (AORI), University of Tokyo, and is now teaching marine conservation policy science.

Mitsutaku has been actively involved in the FUTURE SSC to promote the integration of human dimensions into conventional marine sciences. His 2015 S1 Best Presentation Awarded talk on the Marine Social-Ecological-Environmental Diagram became one of the theoretical bases of a FUTURE paper published in 2019 (Bograd SJ, Kang S, Di Lorenzo E, Horii T, Katugin ON, King JR, Lobanov VB, Makino M, Na G, Perry RI, Qiao F, Rykaczewski RR, Saito H, Therriault TW, Yoo S, Batchelder H; “*Developing a Social-Ecological-Environmental System framework to address climate change impacts in the North Pacific*” in *Frontiers in Marine Science*. He has also co-chaired PICES inter-disciplinary projects funded by the Ministry of Agriculture, Forestry and Fisheries, Japan. The first project, “[Marine Ecosystem Health and Human Well-being](#)” (2012–2017), co-chaired with Dr. Ian Perry (Canada), involved inter-disciplinary research on integrated multi-trophic aquaculture (IMTA), with special emphasis on Indonesia and Guatemala. The second PICES-MAFF project,

“[Building capacity for coastal monitoring by small-scale fishers](#) (2017–2020), co-chaired with Professor Mark Wells of the University of Maine, USA, involved the development of mobile-phone-based GIS technology for Indonesian local people to monitor the coastal ecosystem and fisheries. He will be involved in a third PICES-MAFF project from April 2020, which is an evolution of the previous project with additional monitoring items such as seafood safety (Ciguatera poisoning) for the local people of Indonesia. In May 2020, as a Co-Convener, he will host a PICES/ICES Symposium on Marine Social-Ecological Systems ([MSEAS-2020](#)) in Yokohama.

Mitsutaku now lives in Yokohama with his wife and two boys, and spends 6 hours commuting to and from his office located in Chiba Prefecture. Therefore, he struggles to find the time for cruising on his sailing boat, *Scent of Grace* (named after his lovely wife, Mikako), in Tokyo Bay. His personal webpage is <https://makino-marine.jimdo.com/>.



### Technical Committee on Monitoring

At PICES-2019, Dr. Sung Yong Kim (Korea) was elected Chair of MONITOR, replacing Dr. Jennifer Boldt, (Canada) who has held the position for two terms, since 2013. Dr. Lisa Eisner (USA) was elected Vice-Chair, replacing Dr. Sanae Chiba (Japan) who has also held the position for two terms. PICES thanks Dr. Boldt and Dr. Chiba for their devoted service to MONITOR. Dr. Boldt will continue to contribute to PICES as a member of MONITOR.

Sung Yong Kim is an Assistant Professor in the Department of Mechanical Engineering at the Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Republic of

Korea and the director of the Environmental Fluid Mechanics Laboratory at KAIST. He received B.Sc. degree in Naval Architecture and Ocean Engineering from Seoul



National University in 1999 and Ph.D. degree in Applied Ocean Science from Scripps Institution of Oceanography/University of California at San Diego, La Jolla, USA, in 2009.

His present research interests are in the areas of coastal circulation, sub-mesoscale processes, statistical and dynamical data analysis, environmental parameterization, and operational coastal ocean observing system.

He now serves as the Chair of the Technical Committee on Monitoring (MONITOR), and is the Co-Chair of the Advisory Panel on *North Pacific Coastal Ocean Observing Systems* (AP-NPCOOS) and a member of the Working Group on *Mesoscale and Submesoscale Processes* (WG 38) in the North Pacific Marine Science Organization (PICES), a member of the Boundary Currents and Shelf Sea Interactions (BC/SSI) Task Team under the Ocean Observations Physics and Climate (OOPC) Panel, Global Ocean Observing System (GOOS) and the Pool of Experts for United Nations Regular Process – World Ocean Assessment (1st and 2nd periods).

Sung Yong was elected as a member of the Young Korean Academy of Science and Technology in 2017 and as a member of the Ocean and Fisheries Science and Technology Committee under the Ministry of Oceans and Fisheries in

2019. He was the recipient of the Young Frontier Research Scientists Award in the Korean Academy of Science and Technology in 2013, the Young Scientist Award in the Korean Society of Oceanography in 2014, the Young Scientist Award to brighten Korea for the next 30 years (selected as one of 30 persons in Natural Sciences, particularly, Oceanography) in Pohang University of Science and Technology in 2016, and the Excellence Award of Marine and Fisheries Science and Technology Grand Award in 2019.



### Technical Committee on Data Exchange

*Ms. Jeanette Gann (USA) was elected Chair of the Technical Committee on Data Exchange (TCODE), replacing Dr. Joon-Soo Lee (Korea) who stepped down after completing his term. PICES expresses its appreciation to Dr. Lee for his service as Chair. Dr. Lee will continue to contribute to PICES as a member of TCODE.*

Jeanette Cosden Gann is an oceanographer working with the Ecosystem Monitoring and Assessment (EMA) program in the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) in Juneau, Alaska. She has been working with EMA for the past 10 years going, out to sea on fisheries–oceanographic surveys in the Bering Sea and Gulf of Alaska. She has primarily focused on phytoplankton projects in the Bering Sea and the Gulf of Alaska ranging from temporal and geographical changes in chlorophyll *a* biomass to primary production growth experiments. She is also responsible for the management of their oceanographic data and databases.

Jeanette is currently working on her Ph.D. at the University of Alaska Fairbanks, in the Department of Marine Biology. She is utilizing background data, including temperature and nutrients, to investigate variations in phytoplankton community structure in conjunction with filtered water samples analyzed for lipids. The expectation is that linking taxonomic shifts in phytoplankton to changes in lipid content will indicate how environmental variability may force bottom-up changes in trophic conditions and energetic transfer in marine food webs. She is also focusing on the

development of a genomics protocol to assess phytoplankton and microbial communities in the marine waters of Alaska.



Work with PICES began with Jeanette's involvement in Working Group 35 (*Third North Pacific Ecosystem Status Report*; WG-NPESR3), which quickly led to her additional involvement in the Technical Committee on Data Exchange.

Jeanette received her B.Sc. in Marine Science from Eckerd College in St. Petersburg, Florida, with a minor in Biology, and her M.Sc. in Oceanography at the University of South

Florida where she studied the geochemistry of platinum and palladium in seawater. She has held a variety of jobs in the past including as a vet technician, sailing instructor, and an environmental consultant. These days she spends much of her time with her husband who also works with NOAA and studies protected whales in Alaska, and their 4-year-old daughter, who loves to play outside, snuggle with their two dogs, and go skiing or swimming with her Mom and Dad.

### Section on Climate Change Effects on Marine Ecosystems

*At PICES-2019, Dr. Xiujuan Shan (China) was elected Co-Chair of the Section on Climate Change Effects on Marine Ecosystems (S-CCME), taking over from Co-Chair, Dr. Shin-ichi Ito (Japan). PICES extends its gratitude to Dr. Ito for his committed service as S-CCME Co-Chair since 2017. He will continue to contribute to PICES as a member of S-CCME.*



Dr. Xiujuan Shan is a senior fisheries biologist at the Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Science (CAFS), China. She comes from the city that is the center of marine science and technology—Qingdao, China—and where three PICES Annual Meetings have taken place. She received her Ph.D from the Chinese Academy of Sciences in 2008, and attended her first PICES Annual Meeting in 2010 in Portland, USA, as a postdoc. She later became more involved in PICES activities serving as a member of S-CCME, and as the Co-Chair of Working Group on *Common Ecosystem Reference Points across PICES Member Countries* (WG 36), as well as the co-convening a workshop and presenting talks during PICES Annual Meetings.

Xiujuan's research focuses mainly on fish stock assessment, fish biodiversity and the dynamics of marine ecosystems, particularly in the Bohai Sea and Yellow Sea ecosystem. Recently, she has started work on a project to project climate change on fisheries in China, through the support of the Ministry of Science and Technology, China, and as a leading author of the fish chapter in China National Report on Climate Change.

### Section on Carbon and Climate

*At PICES-2019, Dr. Alexander Kozyr (USA) was elected Co-Chair of the Section on Carbon and Climate (S-CC), replacing Dr. James R. Christian (Canada) who has held the position of Co-Chair since the establishment of the Section in 2005. PICES thanks Dr. Christian for his dedicated and able service as S-CC Co-Chair. He will continue to contribute to S-CC as a member of the Section.*

Alex Kozyr was born in Vladivostok, in what was then known as the Far East of Russian Federation Soviet Republic, USSR, where his mother worked as a teacher and his father was an electrical engineer. Ever since he can remember, he was fascinated by the large Navy based in Vladivostok, and the commercial ships that visited the harbor, constantly asking his parents if he could visit these ships to see them inside. Unfortunately, it was not possible at the time.

Originally from Kiev, Ukraine Soviet Republic, Alex's family moved back there when Alex was 7, but his dream about ocean-going ships never disappeared despite Kiev being far away from the ocean. After graduating from high school, Alex entered the Admiral Makarov's State Maritime Academy (LVIMU) in Leningrad (St. Petersburg), studying oceanography, hydrology and meteorology at the Department of Oceanography, Arctic Faculty. During his studies at



LVIMU, Alex's dream finally came true: he participated in two oceanographic expeditions onboard the Arctic and Antarctic Research Institute's famous research ships *Akademik Zubov* and *Akademik Vise*. Each expedition lasted three months and it was an incredibly exciting time for Alex.

After graduation, Alex found employment as a Scientist-Oceanographer, in the Oceanography Department, Sakhalin Administration of Hydrometeorological Service in Sakhalin Island, rising through the ranks to become Senior Scientist-Oceanographer and Oceanographic Group Leader. During his 10 years with the Hydrometeorological Service, he participated in 17 oceanographic expeditions in the Sea of Okhotsk, and Pacific and Indian oceans measuring and analyzing hydrographic and chemical data, and took part in ice observing missions from the small aircraft, IL-14 and AN-26, measuring sea surface temperature (by IR system), sea water pollution and ice conditions in the Sea of Okhotsk and Japan Sea. Alex also participated in the development and publication of the Atlas of Ice Conditions in the Sea of Okhotsk and the Northern Japan Sea, based on long-term observations.

In 1991, Alex and his family emigrated to the United States to join his brother's family and mother in Knoxville, Tennessee. In 1993, he received an offer to work as an Oceanographic Data Analyst at the Carbon Dioxide Information Analysis Center (CDIAC), Environmental Sciences Division, Oak Ridge National Laboratory (ORNL), U.S. Department of Energy (DOE), Oak Ridge, Tennessee. During his tenure at CDIAC, his responsibilities were to identify and obtain oceanographic data sets that contain CO<sub>2</sub>-related measurements resulting from the World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Study (JGOFS), International Global Ocean Carbon and Repeat Hydrography Program, Global Volunteer Observing Ship (VOS) Program, CO<sub>2</sub> Moorings and Time-series Project, Global Coastal Program, and other national and international program cruises. Alex also participated in the WOCE Indian Ocean I09N\_1995 cruise, Antarctic Expedition CLIVAR SR03\_2001 cruise, CLIVAR Pacific Ocean P16N\_2006

cruise, CLIVAR Atlantic Ocean A13.5\_2010 cruise and USCGC *Healy* Arctic Expedition in August 2018. When the DOE closed CDIAC in 2017, Alex relocated to NOAA's National Centers for Environmental Information (NCEI), successfully transferring the CDIAC Ocean Carbon database data base (now called the Ocean Carbon Data System (OCADS, <https://www.nodc.noaa.gov/ocads/>) to NCEI.

In private life, Alex likes skiing, sailing, and playing volleyball and tennis. He also enjoys visiting his daughter and her family in Chicago, and playing with his three grandsons Ethan (6) and twins Mails and Oliver (3).



### PICES Executive Secretary

*The North Pacific Marine Science Organization (PICES) is pleased to announce the appointment of Dr. Sonia Batten as the next Executive Secretary of PICES. Dr. Batten will take up the position on April 14, 2020. Sonia will replace Mr. Robin Brown, who is retiring but will continue on a part-time basis to assist Sonia in the transition. PICES thanks Mr. Brown for his administration in the Secretariat for the past 6 years.*

Dr. Batten is well-known in PICES and the broader ocean observation community. She has served in leadership positions in the Marine Biological Association of the United Kingdom and the Sir Alister Hardy Foundation for Ocean Science (which merged with the MBA in 2018). Sonia is perhaps best known as the Director of the North Pacific Continuous Plankton Recorder Survey, which celebrated 20 years of sustained observations at the recent PICES Annual

Meeting. Sonia is also a member of the Global Ocean Observing System (GOOS) Biology and Ecosystems Panel. She has published more than 50 papers in peer-reviewed journals with a focus on observations of changing plankton abundance and distribution and impacts on marine ecosystems.

Sonia has lived in Nanaimo for 19 years and has a 14-year-old son and three grown-up step-kids with her partner. Since

their extended family is spread over several continents (the UK, the Middle East, Australia as well as western and eastern North America) they spend a fair amount of their vacations visiting family, or having family come to visit Vancouver Island, which in Sonia’s view is one of the most beautiful places on Earth. She likes to keep active to make up for the desk-time, walking with the dog and usually has her camera with her since taking photographs, mostly of the wildlife and landscapes around the region or when travelling, is a hobby. As well as a dog, they have a cat, four ducks, a beehive and a large garden, which also takes up a lot of time!



### PICES Interns



As well as working with PICES, she has supported the international branches of KIOST in China, U.K., USA, and Peru, organized and supported many internal and international events, and arranged and followed up meetings like UNESCO/IOC, IOC/WESTPAC, PEMSEA, POGO.

Saeseul enjoys watching movies, especially the ones by filmmakers Wes Anderson, Hayao Miyazaki, Hirokazu Koreeda, and Jacques Demy. She likes travelling to other countries and has a lot of hobbies, including drawing, playing the ukulele, making flower centerpieces, yoga and pilates, and scuba diving. She hopes to try some new hobbies in Canada, and looks forward to not only enjoying outdoor recreations like kayaking and bicycling but also indoor activities like cooking, and making a good cup of coffee.

We are pleased to announce that Ms. Saeseul Kim joined the Secretariat as a PICES intern in October 2019.

Saeseul Kim was born and grew up in Seoul, and studied Natural Resources and Environmental Engineering at Hanyang University. After graduating, she began her career in the International Cooperation Department at the Korea Institute of Ocean Science and Technology (KIOST) from 2015. She has supported several PICES events including the Inter-sessional Science Board Meeting that took place in Busan in 2015 and the 3<sup>rd</sup> PICES/ICES Early Career Scientist Conference at Busan in 2017. She has also attended every PICES Annual Meeting since 2016.

Ms. Jinqiu Du completed her term at the Secretariat in June 2019, and returned to the National Marine Environmental Monitoring Center in Dalian, China, as a Research Associate. We appreciate the support received at the Secretariat by Jinqiu. She is a member of the Working Group on *Climate and Ecosystem Predictability* and so we look forward to seeing her at the next Annual Meeting in Qingdao as well as at other future PICES events.





## PICES Special Project: Sea turtle ecology in relation to environmental stressors in North Pacific regions

by Taewon Kim, Soojin Jang, Mi Yeon Kim and Jibin Im

Three of the world's seven sea turtle species are designated globally endangered or critically endangered by the International Union for Conservation of Nature (IUCN), and many populations of the remaining four species are similarly endangered. Sea turtles are subjected to threats from multiple anthropogenic stressors including climate change, habitat degradation, fishing activities, and marine debris. There is increasing need and demand for sea turtle research in the North Pacific Ocean. The SEAturtle project, launched at the end of 2018, is investigating sea turtles in the Northwest Pacific, with a focus on Jeju Island, Republic of Korea. This 4-year project is managed by PICES with special research project funding provided by the Ministry of Oceans and Fisheries of Korea.

At Korea's southern tip, three sea turtle species, the green, loggerhead, and hawksbill can be observed on its largest island, Jeju (Moon *et al.*, 2009; Kim *et al.*, 2016). However, in recent years the number of sea turtles has anecdotally decreased, and previously known nesting sites on Jeju Island and around Busan are no longer being used, probably due to increased anthropogenic activities.

Previously, some members of our project team conducted tracking on juvenile green sea turtles that had been incidentally caught in pound nets around Jeju Island in 2015 and 2016 (Jang *et al.*, 2018). In this study, the movements of eight green sea turtles from Jeju Island were categorized into: (1) moving westward towards China; (2) moving eastward towards Japan; and (3) staying near Jeju Island. An individual tracked for the longest period overwintered in the eastern area of Jeju Island. This result suggests that Korean waters, which are between China and Japan, possibly form part of the habitat as foraging area and/or over-wintering site for juvenile and adult green sea turtles in the Asian region. The result highlights the necessity for long-term movement and habitat utilization studies over spatiotemporal scales of sea turtles observed around Jeju Island.

Based on the results of previous studies, we set the overall project goal to research the sea turtle population found in the North Pacific regions centering on Jeju Island to enhance the understanding of their habitat use and ecology related to anthropogenic environmental stressors such as climate change and plastic pollution. Among other important questions, our project seeks to: (a) understand how sea turtles found in Korea, Japan, and China are connected to the other identified populations in the North Pacific region, and (b) identify the major environmental stressors to sea turtles.

### Kickoff meeting and research

A SEAturtle project kickoff meeting was held at the Jeju Research Institute of the Korea Institute of Ocean Science and Technology (KIOST) on August 26–27, 2019. Project members including George Balazs (Co-Chair of the project) from Hawaii, Hideaki Nishizawa from Japan, and Connie Ka-yan Ng from Hong Kong were invited and other Korean members (Taewon Kim, Byung-Yeob Kim, Soojin Jang, and Mi-Yeon Kim) and students (Jibin Lim, Byeongyong Park, and Jeongjoo Ha) participated. Each member gave a presentation on related sea turtle research and prospective plans for the SEAturtle project (Fig. 1). We also discussed the roles of members, collaborators, and partners. On the final day of the meeting, we released a green sea turtle with the first Iridium transmitter supported by the SEAturtle project (Fig. 2).



Fig. 1 Member presentations at the SEAturtle kickoff meeting.



Fig. 2 Group photo before releasing a sea turtle with an Iridium satellite-tracked tag (Standing, from left: Connie Ka-yan Ng, Soojin Jang, George Balazs, Taewon Kim, Hideaki Nishizawa, Byeongyong Park, a captain, and Byung-yeob Kim; front, from left: Jibin Lim, Mi Yeon Kim, Jeongjoo Ha).

**Tracking study with an Iridium tag**

The goal of this study is to establish a long-term conservation plan for sea turtles on Jeju Island, and collectively the North Pacific region. As a first step, we conducted sea turtle tracking research with Iridium tags to make an assessment of the North Pacific population and geographical distribution, and to define an index habitat. We attached transmitters to two (presumed female) green sea turtles. The information on the tagged turtles is shown in Table 1.

The first turtle (#710313) was captured in June in the southern area of Jeju Island and released in August after deploying it with a transmitter. The turtle moved to the south coast of the Korean peninsula and stayed around an island called Bu-do (Fig. 3). This small island covers an area of 0.303 km<sup>2</sup>, and is known for seaweed farming. The turtle moved back south at the end of November, and at last transmission in December, was located in the southeast area of Jeju Island (Fig. 3).

Table 1 Information of released turtles in 2019.

Indiv. #	SCL (cm)	SCW (cm)	Capture				Release			
			Date	Address	Latitude	Longitude	Date	Address	Latitude	Longitude
710313	67.7	55.6	22-Jun-19	Kangjeong-dong	33.2238	126.4738	27-Aug-19	Kangjeong-dong	33.22487	126.4772
710314	84.3	69.7	28-Sep-19	Jongdal-ri	33.5108	126.9074	1-Nov-19	Jongdal-ri	33.4986	126.9173

SCL = straight carapace length; SCW = straight carapace width

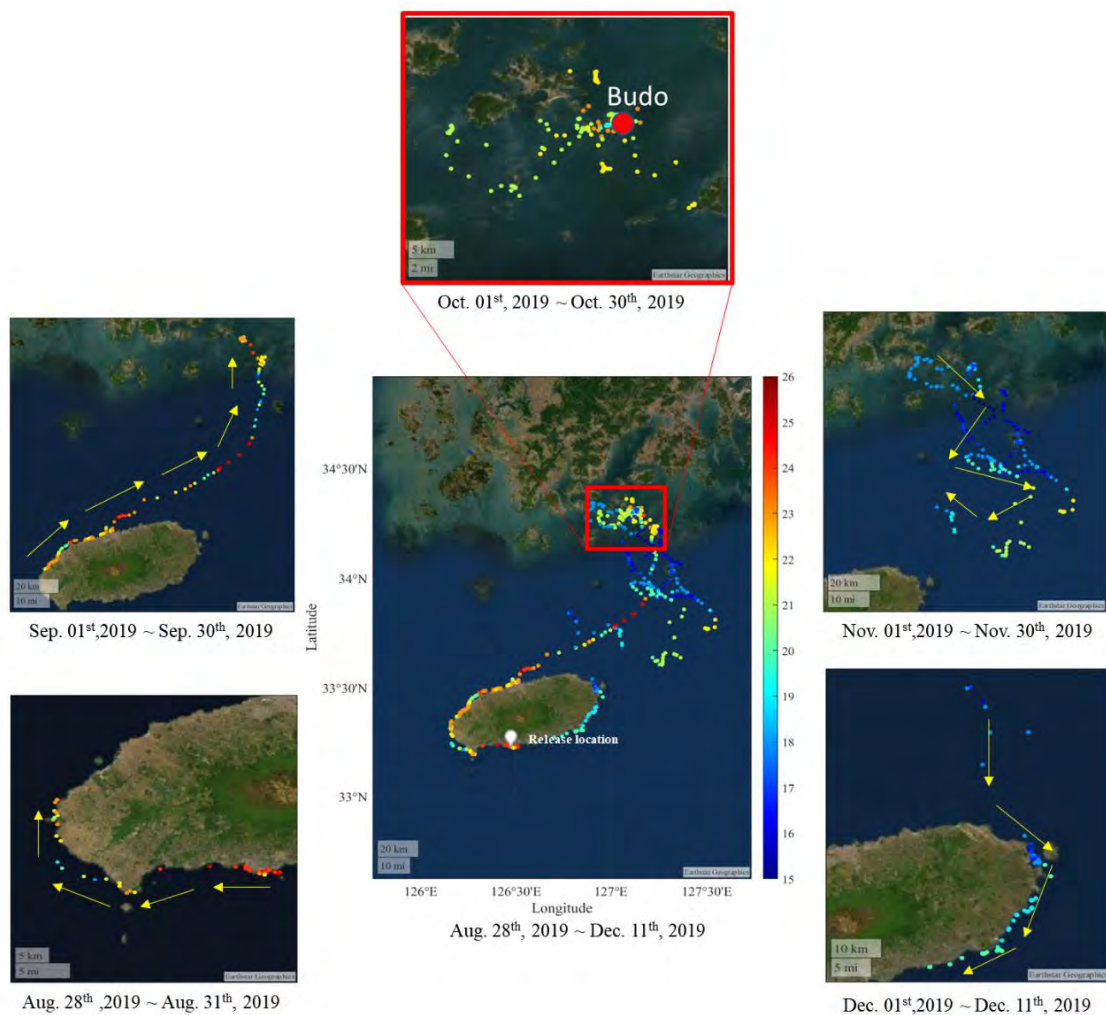


Fig. 3 Movement of the first sea turtle (710313) from August 27 to December 11. It moved to the southern part of the Korean peninsula and stayed there over a month. However, it moved back to southern Jeju Island when temperature dropped below 19°C.



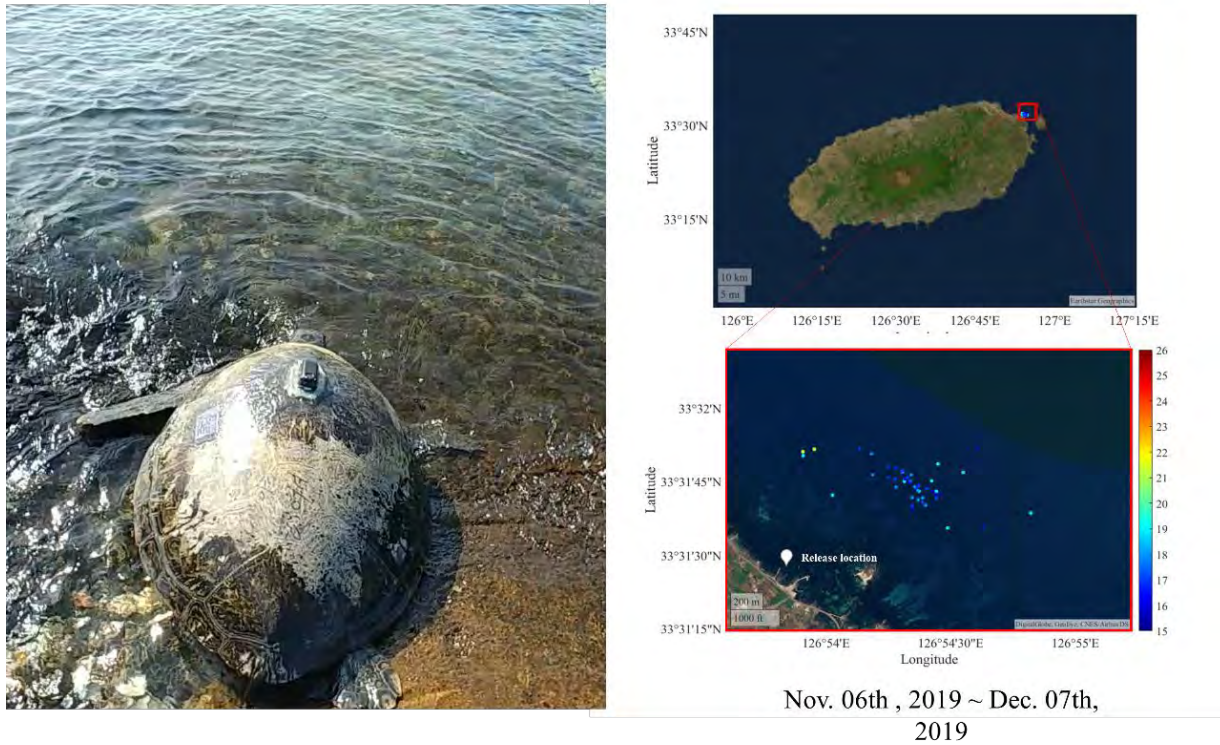


Fig. 4 Locations of the (presumed female) green sea turtle (710314, left) released from Jongdal-ri of Jeju in November 2019.

The second tagged turtle (#710314) was caught in a pound net on the northeast side of Jeju Island. This individual remained near the release site until the last transmission in December (Fig. 4). We will continue to follow these individuals and attach additional transmitters in the following years to take a deeper and more diverse look at sea turtles. In addition to immature green sea turtles, loggerhead turtles and adult turtles will be tracked. The continuation of this project in Korea is important due to its potential in: (a) further connectivity investigation of the North Pacific sea turtle population and (b) identification of habitat use and related environmental factors. The PICES SEAturtle project will be a step closer to sea turtle conservation in East Asia through tracking and further understanding of a species that travels beyond international borders.

### Trash monitoring

Marine debris is a known threat to sea turtles either due to entanglement or by accidental ingestion. The Jungmun Saekdal Beach of Jeju Island was a nesting site for sea turtles in the past and since 2017 there are sea turtle releasing events every summer organized by the Ministry of Oceans and Fisheries of Korea. The released sea turtles

are multiple species and are both wild bycatch and captive-bred. In 2018, there was a news report that “11 days after the loggerhead turtle was released, it was found dead in front of a Busan beach because of eating plastics.” This motivated us to monitor marine debris as a possible risk to sea turtles in the subtidal areas of Jungmun Beach from August 19 to September 8, 2019.

Using the underwater volunteers NSW protocol (<https://www.uvnsw.net.au/welcome-underwater-volunteers-nsw>), debris was monitored on the surface, in the middle and on the bottom column of the Jungmun inshore habitat. The most abundant debris type was plastic (Fig. 5a). Plastic debris generally is believed to float on the surface of the ocean because of its buoyancy. However, in this study the most of the plastic debris (> 25mm) was found in the bottom column (Fig. 5b). This could be dangerous to the green sea turtles because they feed on algae on the bottom (personal observation). Debris in the bottom column was accumulated differently according to the sediment types (*i.e.*, sand, sandy rock, rock, and boulder). The sandy rock bottom had more plastic debris than any other sediment type (Fig. 5c), suggesting that topography, substrate type, and currents are crucial factors that determine the distribution of debris in the bottom column.

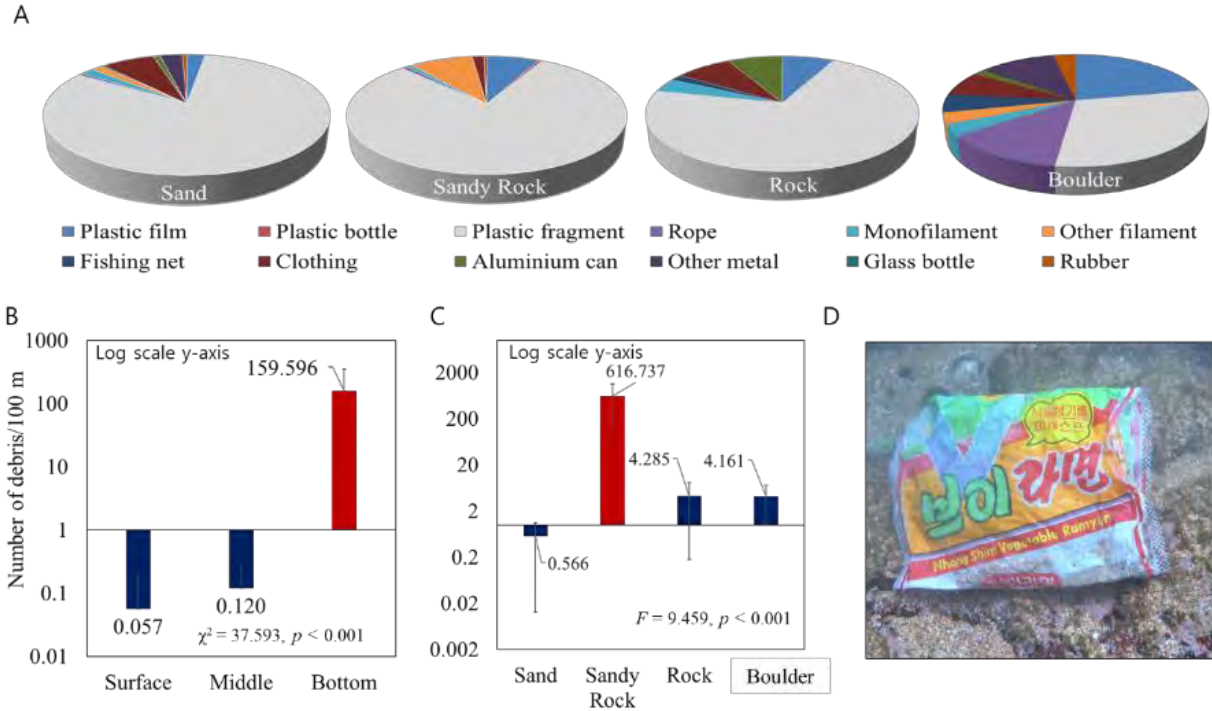


Fig. 5 (A) The composition of debris type on different sediment types. (B) The number of debris found in different parts of the water column and (C) on different bottom types. (D) A package of V-ramen which has not been in production since the 1990s was found on the bottom (from Lim et al. 2019).

**Stranding monitoring**

Coastal stranding studies provide important insights regarding the ecology and status of sea turtle species found in Korea. Here we reviewed stranding data from Jeju Island between May 2012 and August 2019. During this period a total of 43 bycaught and 61 stranded sea turtles were recorded. The stranded sea turtles around the shoreline of Jeju Island were primarily discovered dead (93.6%), but a few individuals were found injured or debilitated. At least three species were stranded: the green sea turtle *Chelonia mydas* (CM) (58.1%), the loggerhead sea turtle *Caretta*

*caretta* (CC) (24.2%), the hawksbill turtle *Eretmochelys imbricate* (EI) (6.4%), and unidentified (11.2%) with a temporal variation (Fig. 6). The temporal variation of sea turtle strandings could be explained by the incidental discovery of stranded sea turtles mainly by tourists, which also peaks in the summer months. Among stranded sea turtles, three individuals had impact-related (e.g., ship strikes) injuries, eight individuals were found entangled in ghost nets, and cause of death undetermined for the remaining turtles. Despite the high level of strandings, the lack of postmortem and standardized data collection at the stranding site limits our understanding.

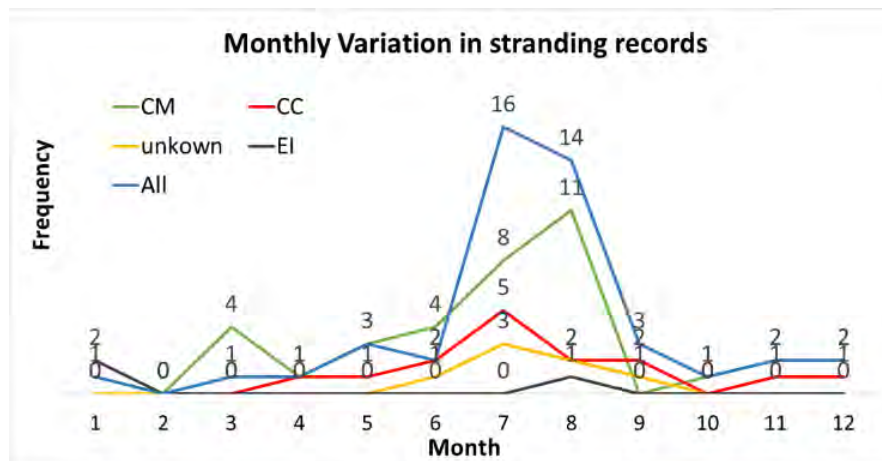


Fig. 6 Monthly variation of strandings recorded on Jeju Island.



As a part of the project, sea turtle strandings on Jeju Island will continue to be collected with improved and standardized data collection in collaboration with multiple institutions around the country to better understand the ecology of the sea turtle species found on Jeju Island.

### Cultural study

There is a sea turtle related to folk beliefs and stories of the indigenous people of Jeju Island who heavily depend on the ocean for their livelihood. Sea turtles are considered to be the third daughter of the Ocean God, whom islanders worship and wish for a fruitful and safe fishing season. As a sacred animal, the islanders will not harm sea turtles. The cultural practice of the belief is observed the most strongly in shellfish divers “Haenyeo,” who have a list of beliefs related to the animal (Box 1 and Fig. 7) (Min, 2011). The cultural identity and understanding what sea turtles mean to the Jeju people as a sacred animal could help scientists develop a stronger conservation plan and help conduct fundamental research for necessary background knowledge of the sea turtle population found in Jeju Island. Future

study will aim to understand the role of cultural identification of sea turtles and collect knowledge on sea turtles observed by the islanders through interviews through constructive question lists that can be applied and compared with collaborating PICES member countries.



Fig. 7 A stranded sea turtle being sent back to the ocean after a cultural ritual conducted by Haenyeo on Jeju Island.

Box 1. The practiced belief system related to sea turtles on Jeju Island (from Min, 2011)

1. Sea turtles should NOT be harmed.
2. If a diver witnesses a front face of the sea turtle, the turtle will make your wish come true.
3. When encountered with a sea turtle in the ocean, they should serve conch or other sea shells.
4. If a sea turtle is found dead, a traditional ritual should be performed and it should be sent back to the ocean.
5. If a gigantic sea turtle is witnessed, you will die.
6. Sea turtles die 9 times and come back to life 12 times.

### PICES-2019 meeting and our future

Two new members, Dr. George Shillinger (the Director of emerging sea turtle conservation NGO “Upwell” at Monterey, USA) and Dr. Nobuaki Suzuki (Fisheries Agency of Japan), and the project team leader Dr. Taewon Kim, held their first business meeting during PICES-2019 in Victoria, Canada on October 19. A workshop on “Sea turtles and environmental stressors in the North Pacific” proposed by the group has been accepted for PICES-2020 in Qingdao, China. We hope that this will open opportunities for researchers interested in sea turtle conservation and research to join the SEAturtle project. Anybody who is interested in sea turtles are welcome.

“Our Beginnings were Feeble, but Our End would be Grand.”

**Acknowledgements** This article was properly edited and improved by Hideaki Nishizawa, George Balazs, Connie Ka-yan Ng, and George Shillinger.

### References

- Jang, S., Balazs, G. H., Parker, D. M., Kim, B.-Y., Kim, M.Y., Ka Yan NG, C. and Kim, T. (2018) Movements of green turtles (*Chelonia mydas*) rescued from pound nets near Jeju Island, the Republic of Korea. *Chelonian Conservation and Biology*, 17: 236–244.
- Kim, I, Cho, I., Kim, M., Han, D., Lee, K., and Moon, D. (2016) Appearance trend analysis of Korean sea turtle and redescription of three sea turtle species. Annual Meeting of Korean Society of Herpetologists, pp. 11–12.
- Lim, J., Park, B., Park, S., and Kim, T. (2019) Spatio-temporal distribution of marine trash in the subtidal zone of the Saekdal beach in Jeju Island. Annual Meeting of Korean Society of Oceanography. BP25
- Min, Y. S. (2011). Folk beliefs of Jeju Women Diver as Principles for the coexistence. *The Study of Practice Folkloristics*, 18: 123–165.
- Moon, D. Y., Jung, M. M., An, Y. R., Choi, S. K., Oh, B. S., Kim, Z. G., Lee, C., Kim, M. J., and Kim, S. Y. (2009) Distribution and strandings of endangered sea turtles in Korea waters. *Korean Journal Fisheries and Aquatic Science*. 42: 657–663. (in Korean) (continued on page 50)

## Regional Consultative and Planning Workshop towards the UN Decade of Ocean Science for Sustainable Development (2021–2030), for the North Pacific and Western Pacific Marginal Seas

by Steven Bograd, Miriam O, Hiroaki Saito and Robin Brown



Fig. 1 Participants at the Regional Consultative and Planning Workshop towards the UN Decade of Ocean Science for Sustainable Development (2021–2030), for the North Pacific and Western Pacific Marginal Seas.

In December 2017, the United Nations General Assembly declared the UN Decade of Ocean Science for Sustainable Development (2021–2030), intended to develop a common framework for advancing ocean science and fully supporting countries in achieving the 2030 Sustainable Development Goals (SDGs), and particularly SDG 14 – Life Below Water (<https://www.un.org/sustainabledevelopment/sustainable-development-goals/>). The first Global Planning Meeting was held May 13–15 at the National Museum of Denmark, Copenhagen, in advance of regional planning workshops that will occur during 2019–2020 (see pp. 24–25 in [PICES Press, Vol. 27 No. 2](#)). The first of these Regional Consultative and Planning Workshops, for the North Pacific and Western Pacific Marginal Seas, was held from July 31 to August 2 in Tokyo, Japan, and was organized by the IOC Sub-Commission for the Western Pacific (WESTPAC), in close cooperation with the North Pacific Marine Science Organization (PICES), Japanese National Committee for IOC/UNESCO, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the University of Tokyo and other partners in the region.

This Regional Workshop brought together 150 participants, including scientists from academia and government agencies, policy makers and managers, civil society organizations, ocean businesses and industries, and donors and foundations (Fig. 1), with the majority of participants being scientists. Inclusion of the Western Pacific Marginal Seas (*i.e.*, WESTPAC countries) expanded the extent of this region beyond what is traditionally considered ‘North Pacific’. The workshop’s principal objective was to engage

these stakeholders from the North Pacific region and provide input to the development of the Implementation of the Ocean Decade. Specifically, the objectives were to:

- (i) Communicate **the purpose and expected results** of the Decade to all stakeholders, including marine scientific community, in the region;
- (ii) Identify the **knowledge gaps and regional scientific questions or priorities**, including additional R&D priorities, that need to be tackled in order to meet the six societal outcomes that the Decade aims to achieve by 2030;
- (iii) Elaborate **plans to address these science questions/priorities**, including existing and potential programmes, partnerships and resources;
- (iv) **Address cross-cutting priorities** that are crucial to the success of the Decade, such as capacity building and marine technology transfer, financing and partnerships, data and information sharing and knowledge exchange and communication;
- (v) **Connect with key stakeholders**, including marine scientific communities, in the region to build ambition and amplify engagement with the entire ocean community to prepare for the Decade.

Workshop participants met in breakout groups organized around the six desired societal outcomes: A Clean Ocean; A



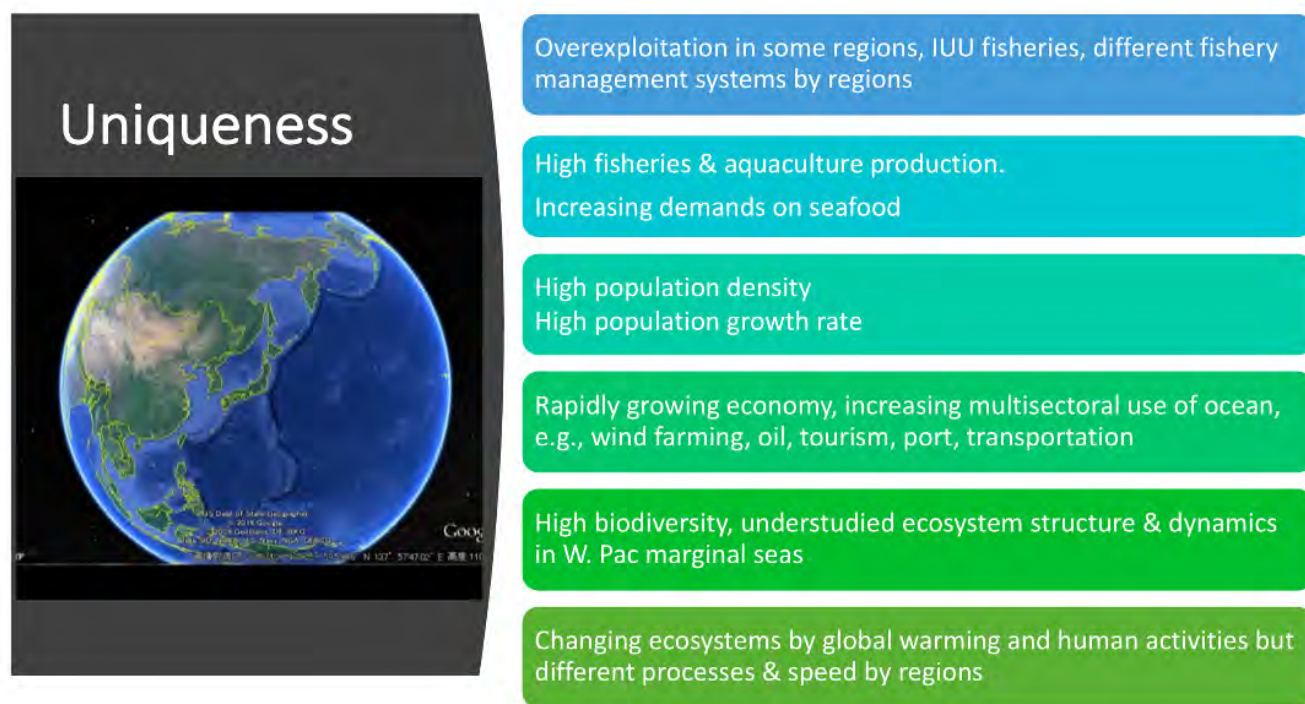


Fig. 2 A graphic indicating the uniqueness of the North Pacific region in its potential to contribute to the UN Decade of Ocean Science goals.

Healthy and Resilient Ocean; A Predicted Ocean; A Safe Ocean; A Sustainable and Productive Ocean; and A Transparent and Accessible Ocean. In each of these breakout groups, participants identified knowledge gaps, key science questions and R&D priorities related to that theme; catalogued existing and potential scientific initiatives, programs, partnerships and resources that can address the identified science questions; discussed the role of cross-cutting themes in addressing these science questions, including capacity building and marine technology transfer, financing and partnerships, data and information sharing and knowledge exchange, and communication and awareness raising; and identified any needed additions or modifications to the R&D priority areas in the Ocean Decade Implementation Plan. The inclusion of countries for both the North Pacific and Western Pacific Marginal Seas brought very different perspectives on knowledge gaps, key questions and priorities to these discussions. The final day of the workshop consisted of summaries from each of these breakout groups, including reflections from participants, institutions and countries on their preparations, willingness

and potential commitments to the Ocean Decade. A fundamental concept that emerged from the workshop was the uniqueness of the North Pacific with regard to the magnitude and potential solutions of the key issues identified for the Ocean Decade (Fig. 2). A final report from the workshop is forthcoming.

PICES remains committed to the UN Ocean Decade, and has received specific funding and encouragement from some contracting parties. Robin Brown, PICES Executive Secretary, Hiroaki Saito, Chair of Science Board, and Steven Bograd, Co-Chair of the FUTURE Scientific Steering Committee (SSC), were active participants in the Regional Workshop, and summarized some of the workshop's results at PICES-2019. The SSC is currently considering an evolution of the FUTURE Science Program to more closely integrate with the UN Decade of the Ocean. This will also be a key item of discussion at the upcoming Annual Meeting, as will PICES' evolving role amongst our network of partners including ICES, FAO, WESTPAC, NOWPAP, and Regional Fisheries Management Organizations.



*Dr. Steven Bograd (steven.bograd@noaa.gov) is a Physical Oceanographer at NOAA's Southwest Fisheries Science Center, Environmental Research Division, in Monterey, California. Steven is currently involved in a number of research projects studying climate variability and its impacts on the marine ecosystems of the North Pacific Ocean, and is Editor-in-Chief of Fisheries Oceanography. Steven has been active in PICES for many years, and is a member of Science Board, the Physical Oceanography Committee, and WG 35 on the Third North Pacific Ecosystem Status Report. He co-chairs the FUTURE Scientific Steering Committee with Sukyung Kang.*



*Miriam O (Miriam.o@dfo-mpo.gc.ca) is a Marine Biologist and has worked for the Science Branch of the Department of Fisheries and Oceans Canada since 2001. She has a broad background in conservation biology and currently leads the Marine Spatial Ecology and Analysis Section which provides science-based spatial solutions for sustainable oceans, an understanding of the marine environment and advanced applied ecological research to support effective management and marine policy development, science in support of protected areas, risk-based conservation solutions, and systematic conservation planning. Miriam participated as a Canadian delegate for the Regional Consultative and Planning Workshop towards the UN Decade of Ocean Science for Sustainable Development (2021–2030), for the North Pacific and Western Pacific Marginal Seas, held in Tokyo, Japan on July 31–August 2 2019.*



*Dr. Hiroaki Saito (hsaito@aori.u-tokyo.ac.jp) is an Associate Professor at the Atmosphere and Ocean Research Institute, the University of Tokyo. He has a broad range of interests but his focus lies in the role of marine organisms in food-web dynamics and biogeochemical cycles. He is one of the establishing members of the A-line monitoring programme for the western North Pacific. He was a core member of the SEEDS I, II and SERIES Fe fertilization experiments, led the DEEP (2002–2007), SUPRFISH (2007–2012) projects, and is leading the SKED project (2011–2021). He was also involved in IMBER, and was Chair of IMBER-Japan from 2004 to 2008. Hiroaki has been involved in PICES for many years, most recently as the Chair of Science Board (2017 to 2019).*



*Mr. Robin Brown (Robin.Brown@pices.int) is Executive Secretary of the North Pacific Marine Science Organization (PICES). When not traveling to far-off places to represent PICES, he can be found taking care of business at the PICES Secretariat in Sidney, Canada.*

(continued from page 47)



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*Soojin Jang (keshu00@gmail.com) is a Ph.D. candidate at Interdisciplinary Program of EcoCreative of Ewha Womans University studying on the behavioral ecology and conservation of marine mammals and sea turtles. She leads tracking sea turtles of Jeju Island. She is a founder of Marine Animal Research and Conservation (MARC), a research-oriented NGO which is committed to marine conservation through researches on marine animals and their habitat*

*Mi Yeon Kim (miyeonkim88@gmail.com) is a Ph.D. candidate at Wildlife Research Center of Kyoto University, Japan, focusing on the acoustic communication and behavioral ecology of marine mammals. She studies stranding and cultural aspects of sea turtles of Jeju Island. She is also a co-founder of MARC, Korea.*

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## Towards an integrated approach to understanding ecosystem predictability in the North Pacific

by Ryan Rykaczewski and Antonietta Capotondi



Group photo. (Photo credit: Y. Iwamoto)

Efforts to predict physical climate and ocean conditions that are relevant for ecosystem dynamics have developed independently across the PICES community, but the skill and utility of these predictions for ecosystem applications has been poorly quantified. By discussing and inter-comparing the various efforts, including the methods used to make predictions, their specific applications and user groups, as well as the dynamical mechanisms responsible for predictability, members of PICES Working Group (WG 40) on *Climate and Ecosystem Predictability* hope to improve the ability to translate scientific understanding into information that can facilitate improved resource management and societal action.

On June 20–22, the Working Group met at the First Institute of Oceanography (FIO) in Qingdao, China for a 2½-day inter-session workshop at the invitation of Professor Fangli Qiao, Deputy Director General of FIO. The main objective of WG 40 is “to identify, diagnose and quantify predictable responses in North Pacific marine ecosystems that arise from regional- and large-scale climate processes”. The goals of the inter-session workshop were to review some of the current ecosystem forecasting efforts, assess the mechanisms responsible for predictability in the different areas, and discuss the steps and action required to develop a common and integrated framework for forecasting activities. The International CLIVAR Program Office endorsed the objectives of the workshop, and several members from the Program Office attended the meeting. There is mutual agreement that continued collaboration between the two communities is desired, as it provides the basis for a very important, societally-relevant and inter-disciplinary endeavor. In that spirit, the CLIVAR Pacific Region Panel is planning to attend the PICES Annual Meeting in Victoria to meet jointly with WG 40. In addition to PICES representatives and members of the International CLIVAR Program Office, several early career scientists from local institutions (FIO, Xiamen University, the Institute of Oceanography of the Chinese Academy of Sciences, and the Yellow Sea Fisheries Research Institute) joined the discussion.

At this workshop, several of the participants provided brief introductions to the forecasting systems or mechanisms of predictability they were most familiar with. To create an overarching context for the discussion, Dr. Shoshiro Minobe outlined the different atmospheric and oceanographic processes that facilitate predictability in the western North Pacific, highlighting, in particular, the stratosphere-troposphere coupling and its influence on the Arctic Oscillation and the possible relevance of the 18.6-year tidal modulation. Workshop participants agreed that a list of the processes responsible for predictability of physical climate and marine ecosystems in the different PICES regions would be developed and shared.

Leading off the discussion of predictions and predictability in the eastern North Pacific, Dr. Ryan Rykaczewski described how coarsely resolved global models indicate that anomalous mixing in the western and central portions of the basin can produce anomalies in nitrate and oxygen that persist for years to decades and are slowly advected to the eastern side of the basin by the mean ocean circulation. This slow advection timescale, combined with *in situ* observations, could be exploited for predictions of eastern North Pacific biogeochemical anomalies years to a decade into the future. This mechanism and its potential for enhanced predictability will be further explored.

High-resolution regional models are key tools for physical and ecological predictions in coastal regions. Such regional models, however, require the prescription of lateral boundary conditions and surface forcing that are usually obtained from global coarser resolution climate models. “Downscaling” the coarse climate information to the much finer regional grid is in itself a research effort. Dr. Pozo Buil reported on a downscaling effort that focused on the California Current System. She showed that applying a combined statistical and dynamical downscaling method leads to improved representation of relevant ecosystem variables like sea surface temperature. She also showed that the predictability in higher-trophic-level properties (*i.e.*,

species distribution) is consistent with predictable temporal components (*i.e.*, climatology and low frequency) of the physical parameters.

While general circulation models are typically used for predicting future marine conditions, empirical dynamical models like Linear Inverse Models (LIMs) have shown a skill comparable to that of state-of-the-art operational prediction systems in the tropical Pacific. However, their performance in regions outside the tropical Pacific has been less investigated. Dr. Antonietta Capotondi presented an application of the LIM approach over the tropical and North Pacific regions to examine the predictability of the extreme and persistent warming (Marine Heat Wave) that occurred in the Northeast Pacific from the winter of 2013/14 to the winter of 2015/17. The LIM can also be run for a very long (O(100,000 years)) time to construct robust statistics of sea surface temperature and sea surface height (a quantity related to thermocline depth and upwelling) in the Northeast Pacific and establish the degree to which individual events, like those in 2014–2015, may be seen as “unusual” and extreme. Such application will be considered in the near future.

To finish the examples of prediction efforts in the eastern North Pacific, Dr. Caihong Fu presented a talk on marine ecosystem modeling to simulate species biological responses to environmental changes and management strategies. Such a modeling platform has the potential to address multiple stressors in marine ecosystems, including climate-induced environmental changes and over-exploitation of commercial fish species, and to project future states of marine ecosystems under future changes of climate and management strategies.

Participants with expertise in the western North Pacific shared their experience with prediction efforts, ranging from global models that explore predictability in basin properties (on timescales of several years) to models that focus on predicting the presence of harmful algae (on the scale of a few days). Dr. Fei Chai described his efforts to enhance the biogeochemical Argo network and the subsequent production of short-term forecasts of nutrients, oxygen and carbon cycle for the Northwest Pacific and the China Seas. Dr. Shoshiro Minobe reported on a large multivariate analysis effort using data of marine ecosystem indices from both sides of the North Pacific basin for the last half century. He noted that the first mode of variability in these indices is common between the western and eastern sides of the basin, but the second mode exhibits substantial differences between the two regions.

Dr. Masami Nonaka introduced JAMSTEC’s seasonal climate prediction activities that have been conducted for more than 10 years, focusing on the skill of this effort in the Northwest Pacific region. Also, potential predictability of eddy activities in the Kuroshio Extension region was

discussed based on an eddy-resolving ensemble simulation. Eddy activities in the downstream part of the region are suggested to have some deterministic and predictable component.

Prediction of the living components of marine ecosystems is just as critical as predicting anomalies in ocean and atmosphere physical properties. Dr. Yongjun Tian described the use of long-term time series of fisheries landings, climate, and oceanographic data to examine patterns of variability in small pelagic species and fish community structures in three current systems around Japan and the China Seas. Low-frequency variability in the fish communities of the northwestern North Pacific was evident and displayed good correspondence with climate change metrics. Applying such relationships to current climate observations may foster predictability for some small pelagic species.

Dr. Zengrui Rong provided a captivating example of the real-world application of marine predictions, describing how satellite observations combined with a hydrodynamic model is used to predict the advection of the “green tide”, a green algae that affects Qingdao and the Shandong Province in China. The capability of the forecasting system to predict the distribution and trajectory of the green tide has been evaluated, and it appears to perform well over a timescale of about 10 days.

The host of the workshop, Dr. Fangli Qiao, reported on the hindcast and seasonal prediction results derived from the FIO climate model (FIO-ESM V1.0). The seasonal prediction skill in the North Pacific has been much improved by including surface wave-induced vertical mixing in the ocean model component, allowing the possibility to provide operational seasonal prediction products for PICES member countries. In particular, the bias between the observed and modeled sea surface temperature decreases substantially in the transition zone between the subarctic and subtropical gyres in the North Pacific, and sea surface temperature variability can be successfully hindcasted in the climate model when the surface wave component is included.

Dr. Xuehai Liu introduced a systematic coastal ecology-sediment-environment coupled numerical model and its utilization for the South Yellow Sea and aquaculture bays. In particular, the model has been used to investigate the results of the spring bloom and the role of wave-induced mixing, the effect of sediment on biomass in shoal areas, physical-biochemical effects of aquaculture, the aquaculture carrying capacity, and the possibility of phytoremediation in eutrophic waters.

To conclude the examples of forecasting efforts, Dr. Liping Yin described the physical factors that influence the artificial stock enhancement for the edible jellyfish in Liaodong Bay, China. The resource of the wild edible jellyfish in China has



declined in the last decades and artificial releasing has started becoming an important approach to keep its yield.

Workshop participants were impressed by the diversity of prediction approaches, the need and utility of the predictions, and the existence of several mechanisms that facilitate these predictions. To better understand the range of efforts, Working Group members agreed to continue the development of an inventory of forecasting efforts in the North Pacific along with a list of the mechanisms that impart predictability. A journal special issue or section will be developed based on the workshop presentations and on the contributions to the Topic Session “*Advances in North Pacific marine ecosystem prediction*”, which has been organized by members of WG 40 for the 2019 PICES Annual Meeting.



WG 40 participants being given a guided tour of the First Institute of Oceanography's computing facility (top), the China Ocean Exploration Museum (right column, top), and with the R/V Xiang Yang Hong 18 (right column, bottom).



In addition to the group's scientific discussions, Dr. Fanqli Qiao arranged visits to many of the facilities of the FIO. Workshop participants were treated to tours of the China Ocean Exploration Museum, the FIO high-performance computing facility, and FIO's R/V *Xiang Yang Hong 18*. These visits were a great way to cap off a very productive and enjoyable inter-session workshop.



Dr. Ryan Rykaczewski ([ryan.rykaczewski@noaa.gov](mailto:ryan.rykaczewski@noaa.gov)) is a Research Ecologist at NOAA's Pacific Islands Fisheries Science Center Ecosystem Sciences Division in Honolulu, Hawaii, USA. His research focuses on the sensitivity of marine biogeochemical cycles, ecosystem structure, and fisheries production to changing ocean climate and physics. Ryan has been active in PICES and ICES for several years and strives to improve understanding of the mechanisms through which regional to basin-scale climate influences the dynamics of marine ecosystems. In PICES, he is a Co-Chair of the Working Group on Climate and Ecosystem Predictability and the Working Group on Small Pelagic Fish, and he serves as a member on the FUTURE Scientific Steering Committee and the Advisory Panel for the CREAMS/PICES Program in East Asian Marginal Seas.



Dr. Antonietta Capotondi ([Antonietta.Capotondi@noaa.gov](mailto:Antonietta.Capotondi@noaa.gov)) is a Physical Oceanographer at the University of Colorado and the NOAA Earth System Research Laboratory in Boulder, Colorado. Antonietta received a Bachelor degree (“Laurea”) in Physics from the University of Pisa, Italy, where her study focused on quantum mechanics. After receiving her degree, she worked for a few years in an Italian engineering company that designed marine structures for oil exploitation, where she discovered the field of Physical Oceanography and became very interested in deepening her knowledge and understanding of ocean circulation, an interest that motivated her to pursue a Ph.D. in Physical Oceanography in the MIT/Woods Hole Joint Program. She has been interested in understanding the role of the ocean in climate variations at interannual to decadal timescales, with a special focus on El Niño Southern Oscillation (ENSO) and its influence on the physical drivers of Northeast Pacific marine ecosystems. Antonietta is also a Co-Chair of the Working Group on Climate and Ecosystem Predictability.

## Shellfish – Resources and invaders of the North

by Gordon H. Kruse and Tomás Araya Schmidt

### Background

Shellfish are ecologically and commercially important components of marine ecosystems. Some are “ecosystem engineers.” Others serve as important prey resources for higher trophic levels. Still others provide a very high-quality food source and support major commercial fisheries in cold-temperate and polar areas. The mollusks and crustaceans that make up the shellfish group provide a high-valued, high-quality food source and support important commercial fisheries in boreal, subarctic and Arctic seas.

There is a strong interest in shellfish resources, their population dynamics and fishery management in both the North Pacific and North Atlantic Oceans. This interest is heightened under climate change, which is already stressing native cold-water species at the southern limits of their distribution and promoting their northward shift. Some are shifting into the High Arctic. For instance, the snow crab has expanded its distribution from the eastern Bering Sea into the Chukchi and Beaufort Seas, where their biomass has been increasing in the past decade. Although snow crab are more abundant in the Chukchi Sea than the Beaufort Sea, only snow crab in the Beaufort Sea currently achieve marketable sizes. Possibly, continued warming temperatures and further ice retreat may make exploitation of these species in the Arctic Ocean commercially feasible.

In addition to changes in distribution and abundance of native invertebrates under climate change, Arctic and subarctic marine ecosystems are subject to invasive species that may lead to ecosystem effects, as well as opportunities for new fisheries. For instance, an important case study is the red king crab, which was successfully introduced into the Barents Sea after multiple attempts over two to three decades. The growing red king crab stock created bycatch issues in other long-term fisheries, such as cod, and resulted in concerns about their ecological effects, as well as new fishing opportunities. More recently, snow crab have been discovered in the Barents Sea, though their appearance may be due to natural causes.

For these and other reasons, PICES co-sponsored a symposium, titled *Shellfish – Resources and Invaders of the North*, with the International Council for the Exploration of the Sea (ICES), and the Northwest Atlantic Fisheries Organization (NAFO). The symposium was hosted by Norway’s Institute of Marine Research (IMR). Additional funding was provided by The Research Council of Norway, Lyngenfjord, and Norges Råfisklag. PICES provided travel support for the PICES Convener and symposium Keynote Speaker, Dr. Gordon Kruse, who is a FIS committee member, and early career scientist, Tomás Araya Schmidt, who is a graduate student at the Fisheries and Marine Institute of Memorial University of Newfoundland.



Group photo of the Shellfish Symposium participants gathered in front of Tromsø Harbour. (Photo credit: Gunnar Sætra, IMR Norway)



## *The Symposium*

The symposium was held from November 5–7, 2019 in Tromsø, Norway. Conveners of the symposium were Professor Gordon Kruse of the University of Alaska Fairbanks, USA (PICES), Dr. Carsten Hvingel, Institute of Marine Research, Norway (ICES) and Dr. Bernard Sainte-Marie, DFO, Canada (NAFO). A Scientific Steering Committee included the three Conveners and 11 other scientists from Norway, Russia, and Denmark, and a local organizing committee comprised of six IMR and ICES colleagues.

The goal of this symposium was to discuss the role of cold-water shellfish both as a harvestable resource and as important ecosystem players in the northern hemisphere cold marine ecosystem. Specifically, the symposium sought to address the following questions:

- How do we exploit them sustainably?
- Can we explain the recent changes in distribution and population dynamics of example shrimp and snow crab, and what should be the management responses?
- What are the ecological effects of invasive species, and should they be controlled by excessive harvests or managed for sustainability?
- The ecosystem effects of the boom and bust of large shellfish populations are potentially massive; can these impacts be quantified?

To address these questions, the symposium was organized into four theme sessions:

1. Shellfish in new and changing environments
2. Assessment and population dynamics of shellfish
3. New ways of harvesting shellfish
4. Managing shellfish fisheries

Approximately 110 symposium participants were welcomed by opening addresses by Geir Huse (IMR), Wojciech Wawrzynski (ICES), Gordon Kruse (PICES), and Katherine Sosebee (NAFO). Subsequently each session was convened by two Chairs. All presentations were delivered as either oral talks in plenary session or as posters during poster sessions on November 5–6, 2019. There was a total of 60 oral and 25 posters presentations. Participants came from nine countries (Australia, Canada, Denmark, Greenland, Norway, Portugal, Russian Federation, United Kingdom, and United States), of which three are PICES member countries (Canada, Russian Federation, and United States). Twenty talks were given by scientists from PICES member countries, eight of which addressed shellfish from the North Pacific Ocean, including the symposium keynote address and two of four session keynote talks.

In the symposium keynote address, Gordon Kruse spoke about snow crab in the eastern Bering Sea and US Arctic as a case study owing to its global importance as a harvestable cold-water shellfish resource in both the North Pacific and

North Atlantic Oceans. It is also a well-studied species that was included in 18 oral presentations and seven posters at the symposium. He spoke about the northward shift in this Arctic species owing to warming of the eastern Bering Sea and commensurate increases in their abundance in the US portions of the Chukchi and Beaufort Seas. He noted that snow crab are challenged by the effects of temperature on their reproductive biology, ontogenetic migration patterns in a changing thermal landscape, dynamic predator–prey associations, and ocean acidification. He concluded that climate change poses mostly negative effects on snow crab population dynamics and that these changes pose major challenges to stock assessment and fishery management as former estimates of stock productivity and fishery management units no longer hold.



*The symposium attracted full attendance during each session.*

In the first session, “Shellfish in new and changing environments,” keynote speaker, Richard Wahle (University of Maine), talked about American lobster as a poster child for the impacts of environmental change on coastal ecosystems and economies. In southern New England mass mortality and disease induced by summer heat stress and hypoxia have led to a widespread collapse of the region’s fishery. However, they have expanded to the north into the Gulf of Maine, benefiting from the positive effects of the widespread depletion of predatory groundfish, such as Atlantic cod, to trigger an unprecedented boom in lobster production that has elevated the lobster to its current status as the most valuable single-species fishery in the US and Canada. Also in this session, Tom Therriault (AP-NIS, FUTURE SSC, MEQ) delivered a presentation on changing shellfish invasions under climate change in British Columbia. He contrasted differing patterns of habitat suitability for various bivalves throughout the province. He concluded that predicting suitable habitat for non-indigenous species not only holds promise for targeting limited resources towards early detection of new invaders in susceptible environments, but also provides insights into possible exploitation options for new invaders. This session

was the largest with 21 presentations on a wide range of species and topics including a number of talks on species invasions, changes in species distributions, declines in species abundance with changing climate, and other climate-related species dynamics.

The second session, “Managing shellfish fisheries,” composed of 16 talks, began with two keynote presentations. Elisabeth Sør Dahl on behalf of Vidar Landmark (Ministry of Trade, Industry and Fisheries, Norway) spoke about the four main elements of the Norwegian national fisheries management: research, regulatory measures, enforcement and sanctions. She pointed out that we regulate catch capacity to enhance efficiency and profitability for the fishing fleet, and use technical measures and quotas coupled with strict enforcement measures to ensure sustainability. She stressed that good knowledge and scientific advice is the key to good fisheries management. In the second keynote presentation, Jahn Petter Johnsen (Norwegian College of Fishery Science, UiT, The Arctic University of Norway) talked about how to govern ungovernable objects. Until the establishment of the Norwegian exclusive economic zone (200 nmi) in 1977, the resources in Norwegian waters were, in principle, ungovernable but with the new framework, people’s activities could be regulated in effective ways. Moreover, through this change industry became partners in governance. Over time both the ability to govern and willingness to be governed increased. Other presentations in this session addressed a number of fishery management issues, including bycatch, reconciling genetic stock structure, ghost fishing, social well-being, and effects of climate change and fishing.

The third session, “New ways of harvesting shellfish,” was comprised of 9 talks including one keynote by Brad Stevens (University of Maryland Eastern Shore, USA). He discussed the benefits and disadvantages of traps (pots) as a fishing gear. He pointed out that little research has been conducted on the response of target species to traps or the impacts of trap fishing. He further noted that trap impacts fall into three categories: direct impacts on target populations, impacts on non-target populations, and impacts on environment or habitat. After reviewing their effects, he concluded that the future of trap fisheries will depend on investment in research on new ways to reduce their negative impacts on benthic and pelagic resources. Other presentations in this session addressed issues such as alternative baits, effects of light and sound on crab catches, injury scoring of crabs after capture, live holding and transport of crabs and shrimp, and crab processing methods.

The final session, “Assessment and population dynamics of shellfish,” involved 16 talks. The keynote address was delivered by Cody Szuwalski (NMFS, Alaska Fisheries Science Center, USA). He spoke about his experiences in conducting stock assessments of crab resources in the eastern Bering Sea, USA. He pointed out that one of the key

challenges faced in assessing Bering Sea crab is estimating reference points because no clear stock–recruit relationships exist and population dynamics appear to have changed over time. He described several case studies and also provided an overview of an open-source assessment platform designed to streamline the stock assessment process called a General Model for Assessing Crustacean Stocks (GMACS). Many of the other talks in this session described surveys used to assess shellfish resources, including sea urchins, scallops, lobster, crab, shrimp and other species. In one novel approach, Carsten Hvingel (IMR, Norway) presented an approach to estimate the abundance of the invading snow crab in the Barents Sea using cod stomach analysis.



*Dr. Carsten Hvingel and Dr. Gordon Kruse moderating the symposium wrap-up session.*

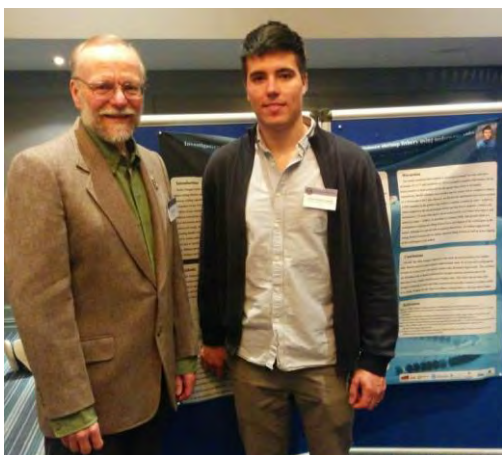
### **Perspectives of a Late Career Scientist –**

***Gordon Kruse***  
***FIS, University of Alaska Fairbanks, USA***

After a career that began in Alaska in 1985, I have been involved in many symposia, including numerous ones on shellfish. This symposium reinforced my impression that shellfish researchers are a relatively small but very collegial group of highly dedicated professionals. Given similar shellfish resource problems being faced around the world and given advancements in communication technology, this symposium provided evidence that there are growing opportunities for collaboration among shellfish scientists around the world. I also observed that many shellfish fisheries continue to remain data-limited worldwide, despite the high prices and large economic importance of many of them. In this regard, it is encouraging to see the cooperative research with the fishing industry in several regions of the world, including industry co-sponsorship of this symposium. Another area of progress evidenced by some of



the presentations includes recent technological advances. Impressive progress has been made in quantitative stock assessments, particularly in the Northeast Pacific region. However, much of that progress is tied to annual fishery-independent surveys, which are not as prevalent in some other regions. Other important advances include genetic stock identification that informs designation of management units, new tagging approaches to study movement, simulation modeling (e.g., larval drift), and other areas of research. Longer time series are also quite helpful as the accumulation of more observations of shellfish over time means that we can gain greater understanding of the dynamics of shellfish populations over a range of conditions. Yet, many presentations made it abundantly clear that this understanding is being significantly challenged by new environmental regimes that have never before been observed under climate change. Nevertheless, I left the symposium very encouraged by the overall progress being made. In my opinion, now should be an exciting time for early career scientists to begin a career of shellfish research, particularly for those who can bring to bear their knowledge on cutting edge technology, quantitative skills, and ability and motivation to tackle problems cooperatively.



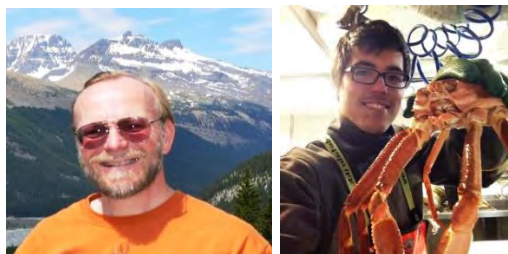
The authors of this article at the Poster Session standing in front of the poster prepared by Tomás, who also delivered an oral presentation.

## Perspectives of an Early Career Scientist –

**Tomás Araya Schmidt**

**Memorial University of Newfoundland, Canada**

As an early career scientist, I had never attended a symposium solely focused on shellfish resources. It was encouraging to see and hear a large number of researchers working towards a better understanding of ecologically and commercially important shellfish species. Similar challenges are faced by fisheries management, stock assessment, and fishing gear technology scientists around the world. On top of these challenges, shellfish scientists are working on the north face of rapidly changing environments, which adds uncertainty to the findings and creates an urge to deliver science promptly. Although there are uncertainties and data limitations in many shellfish fisheries, I observed a clear effort to provide the best evidence possible to continue the development and improve the management of shellfish fisheries. Exciting new concepts and technologies to harvest shellfish resources are being advanced as well. Coming from a fishing gear technology background, it was interesting to see how these new ways of harvesting shellfish can reduce ecological impacts, increase efficiency and, in turn, advance the development of sustainable shellfish fisheries. I believe that this symposium provided an excellent opportunity to disseminate research and, in the near future, collaborate with scientists from around the world, which I am sure will have a positive impact on shellfish research and fisheries. I am convinced that a considerable amount of effort is being made to sustainably use shellfish resources in the northern parts of the world, which is evidenced in the many presentations and posters of this symposium. However, several knowledge gaps persist, which provide exciting opportunities for research, collaboration and welcoming new scientists to shellfish research.



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## Highlights of the 2019 FAO International Symposium on Fisheries Sustainability: Strengthening the science-policy nexus

by Suzuette Soomai



Symposium banner. (Photo credit: FAO)

The Food and Agriculture Organization of the United Nations (FAO) hosted a three-day International Symposium on Fisheries Sustainability, November 19–21, 2019, at FAO headquarters in Rome, Italy. This conference adopted a forward-looking approach to achieving the principles of sustainability by identifying the challenges and opportunities at the science-policy interface. In keeping with the symposium’s title, “*Strengthening the science-policy nexus*,” discussions centered on identifying the pathways to strengthen the science and policy interplay in fisheries production, management, and trade. Within the context of the 2030 Agenda for Sustainable Development and the United Nations Decade of Ocean Science for Sustainable Development in the fisheries sector, the discourse sought to articulate society’s expectations for fisheries – What are we prepared to accept, what are the trade-offs, and what is the appropriate balance?



Plenary session during the FAO symposium. (Photo credit: FAO)

The opening of the symposium included a keynote presentation by Manuel Barange, FAO Symposium Convenor and Director of FAO Fisheries and Aquaculture Policy and Resources Division, on the global fishing

sustainability challenges and successes. He highlighted the challenges to achieving sustainability in a constantly changing ocean that is being increasingly influenced by climate change and anthropogenic factors such as



overfishing. Science continues to play an important role in informing the pathway to sustainability. According to the Director, we have been focusing traditionally on ecological sustainability but the global focus must now also include the use of social indicators of sustainability, for example, employment and gender imbalances. Filling gaps in social data in the fisheries sector and the need to address the human dimension were emphasized.

The Symposium was structured around a series of eight plenary discussions consisting of keynote lectures and panel discussions aimed at addressing some important topics, including:

- Measuring and monitoring fisheries sustainability,
- Identifying the challenges to the ecological, economic and social sustainability of fisheries,
- Aligning biodiversity conservation and fisheries objectives and trade-offs,
- Governance mechanisms that could help countries, regional bodies, and communities overcome sustainability challenges,
- What constitutes evidence and how to ensure an evidence basis for decision-making,
- Broadening traditional partnerships to support sustainable fisheries.

In the planning of each session, FAO highlighted how the discussions and themes link to the 17 Sustainable Development Goals, including SDG 14– Life Below Water and others. As well, linkages were made to the FAO Code of Conduct for Responsible Fisheries, and major policy directives, such as the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement. The discussions at the meeting focused primarily on marine capture fisheries, and inland fisheries was not given as much attention as intended. Issues related to aquaculture were not addressed at this symposium as this will be the focus of a similar conference in the future.

A wide range of stakeholders attended the symposium and included political decision makers from government and inter-governmental organizations, practitioners (such as resource managers), members of research and academic communities, business and private sector representatives; and global, regional national and local organizations, including indigenous groups; and other interested parties. The selection of keynote speakers and panelists reflected these diverse perspectives. On behalf of the FAO, PICES kindly supported the participation of a number of the

panelists in several sessions of the symposium.

A number of side events were scheduled between plenary sessions. Many of these events demonstrated recent innovations in the fisheries sector and the diverse opportunities for those working in the sector since the 2013 launch of FAO's Blue Growth Initiative. A main side event was the release of a [Blue Paper](#) by the High Level Panel for a Sustainable Ocean Economy. This Panel was established in 2018 and is a unique initiative of 14 serving heads of government. The Blue Paper addresses the challenge of feeding a growing global population by ensuring that adequate nutrition is available from seafood while maintaining sustainable fisheries and ensuring that the products are economically viable.

The main conclusions of each plenary discussion were summarised in the final session on Day 3 (<http://www.fao.org/3/ca7119en/ca7119en.pdf>). A common line of thought across the sessions was the importance of focusing on mechanisms to enhance and maintain communication among multiple stakeholders operating at the science-policy interface; to promote and strengthen partnerships as a means of achieving this; and recognising the important role of women in all facets of the fisheries sector, thereby warranting gender equity. The importance of multiple stakeholders working together for fisheries sustainability was reiterated throughout the symposium.

The conclusions of this symposium are expected to pave the way for developing a new vision for fisheries in which the sector is more responsive to the complex challenges facing society. A technical document will be prepared by the FAO Secretariat and tabled at its 34<sup>th</sup> Committee on Fisheries (COFI) meeting in July 2020. The document will include information on sustainability status, examples of best management and partnership practices, and recommendations on how to better connect evidence and policy to secure fisheries sustainability. This technical document will also form the basis of a high-level policy statement on the role, value, and sustainability status of global and regional fisheries in the 21<sup>st</sup> century. The statement may be open for endorsement during the 25<sup>th</sup> anniversary celebrations of the Code of Conduct for Responsible Fisheries, at the 2020 COFI meeting. The timing of these events is fitting as the 1995 FAO Code of Conduct for Responsible Fisheries is the first formal document that set international standards and practices to implementing the principles of fisheries sustainability.



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## The Bering Sea: Current status and recent trends

by Lisa Eisner

### *Climate and oceanography*

In what seems to be more the rule than the exception at the present time, the Bering Sea was considerably warmer than normal during the spring and summer of 2019, relative to historical norms. A map of the SST anomaly distribution for the months of April–September 2019 (Fig. 1 top) shows that it was particularly warm on the southeastern Bering Sea shelf, where the 6-month average temperatures were more than 3°C higher than their 1981–2010 averages. This constituted a virtual tie with 2016 for the warmest SST on record for the 6-month period and that portion of the Bering Sea. The warmth here was not confined to just near the surface; the vertically integrated heat content at Mooring 2 (M2) at 57°N, 164°W during the summer of 2019 was the greatest since it was first deployed in 1995 (Phyllis Stabeno, personal communication). The anomalous warmth extended along the west coast of the Alaska mainland into the Chukchi Sea north of Bering Strait, presumably at least in part due to the mean transport associated with the Alaska Coastal Current.

The period considered here started off warm for the Bering Sea because the previous winter of 2018–19 was so unusual. In particular, that winter featured wind anomalies from the southwest, which meant more mild maritime air than usual and hence reduced southward advection and development of sea ice. The warm anomalies in the Bering Sea continued to increase during the spring and summer of 2019 due to the overall regional weather patterns that prevailed during that period. As indicated by the sea level pressure anomaly map for April through September 2019 (Fig. 1, bottom), a ridge of higher than normal pressure extended from eastern Siberia across the North Pacific towards the west coast of North America, with its peak amplitude in the southern Gulf of Alaska. This pattern implies suppressed storminess for the Bering Sea, especially its eastern portion. It turns out that the climate model projections made in late spring 2019 for August and September 2019 (as briefly discussed in the summer edition of this piece, p. 34, [PICES Press, Vol. 27, No. 2](#)) indicated a regional atmospheric circulation that was quite similar to what actually occurred.

At the time of this writing, the climate models used for seasonal weather predictions are indicating another relatively warm winter for the Bering Sea. As a group, their forecasts are suggesting moderately warm air temperature anomalies in association with anomalous flow from the west, in comparison with the extremely warm temperatures that accompanied the strong flow anomalies from the southwest characteristic of the winters of 2017–18 and 2018–19. Given the delayed start to the formation of near

freezing temperatures in the northern Bering Sea, and the predicted atmospheric circulation, it is expected that it will be another light ice year, but not to the extreme extent of the previous two winters.

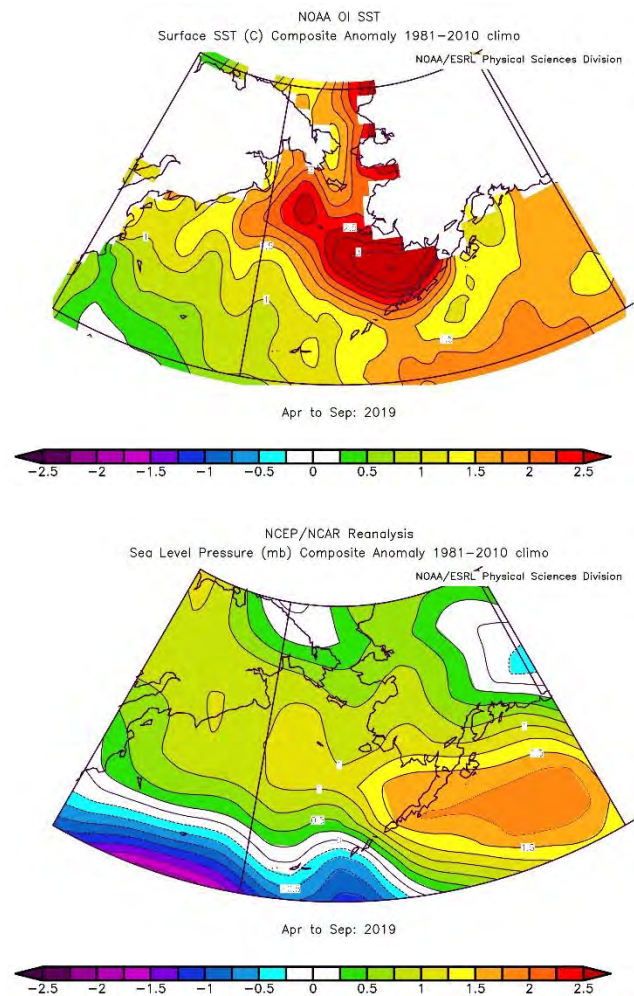


Fig. 1 Mean sea surface temperature (SST) anomalies (°C, top) and mean sea level pressure (SLP) anomalies (mb, bottom) for April–September, 2019. Figures courtesy of Nick Bond, NOAA, Pacific Marine Environmental Laboratories (PMEL).

### *Fisheries oceanography surveys and observations*

NOAA Fisheries’ Alaska Fisheries Science Center (AFSC) conducted several fisheries and oceanography surveys in the Bering and Chukchi seas in summer 2019. Information was contributed by scientists at NOAA, AFSC: Lyle Britt for Bering Sea bottom trawl surveys, Jim Murphy for the north Bering Sea surface trawl survey, Ed Farley for the Chukchi Sea ecosystem survey, and Elizabeth Siddon for key observations/ implications.



### Southeastern Bering Sea bottom trawl survey

The bottom trawl survey on the southeastern Bering Sea shelf was conducted from May 29 to August 2, 2019. Bottom temperatures were similar to those of 2018 (Fig. 2), whereby the limited seasonal sea ice from the previous winter resulted in the second smallest cold pool observed over the time series. In 2019, high water temperatures were observed in Bristol Bay and throughout the inner shelf (shallower than 50 m) north from Nunivak Island to Norton Sound, with bottom temperatures over 8°C, for the first time. In 2019, walleye pollock (*Gadus chalcogrammus*) biomass (total estimated weight of fish in the surveyed area) was 5.46 million metric tons (mt), a 75% increase from 2018 (3.11 million mt). The abundance (total estimated number of fish in the surveyed area) increased 53% to 9.13 billion fish compared to 2018 (6.0 billion). There was a substantial increase in young pollock in 2019 compared to 2018. Pacific cod (*Gadus macrocephalus*) biomass was similar to 2018 at 517 thousand mt and like pollock, Pacific cod abundance increased in the region (112%) due to a large increase in young fish. As observed in 2018, fishes that prefer colder water conditions, such as Arctic cod (*Boreogadus saida*), Bering flounder (*Hippoglossoides robustus*), and Alaska plaice (*Pleuronectes quadrituberculatus*) showed declines in abundance from previous years.

### Northern Bering Sea bottom trawl survey

The full standardized bottom trawl survey was conducted on the northern Bering Sea shelf from August 3–27, 2019. As

in 2017, another warm water year, large numbers of pollock and Pacific cod were observed in the northern Bering Sea in 2019 (Fig. 3). Prior to 2017, the last time the northern Bering Sea had been fully surveyed was in 2010. At that time, few pollock and Pacific cod were seen. In 2010 seasonal sea ice covered the northern Bering Sea in the winter and water temperatures were much colder in the summer (Fig. 3). In 2019, pollock biomass in the northern Bering Sea was 1.17 million mt, which was 11% less than 2017. The abundance increased 59% to 2.9 billion fish compared to 2017 (1.8 billion). As observed in the southeastern Bering Sea, much of this increase was due to more young fish in the area in 2019. As in 2017, the distribution of pollock was also most concentrated along the northernmost edge of the U.S.–Russia Maritime Boundary near the Bering Strait and southwest of St. Lawrence Island. Pacific cod biomass in the northern Bering Sea increased from 283 thousand mt in 2017 to 368 thousand mt (+30%) in 2019. Higher than expected abundances of juvenile pollock and Pacific cod (< 20 cm) were also observed in the northern Bering Sea. Findings from the 2019 survey show that large numbers of sub-arctic species of fish (e.g., pollock, Pacific cod, flathead sole (*Hippoglossoides elassodon*)) were distributed throughout the northern Bering Sea. The increased catch of very young pollock and cod strengthens the hypothesis that these species are overwintering in the region during periods of low or limited ice coverage and spawning. Distributional patterns were different in 2017, 2018, and 2019 (Fig. 3) suggesting that environmental conditions and prey resources are changing annually in the region, even with consistently warmer water conditions over the last three years.

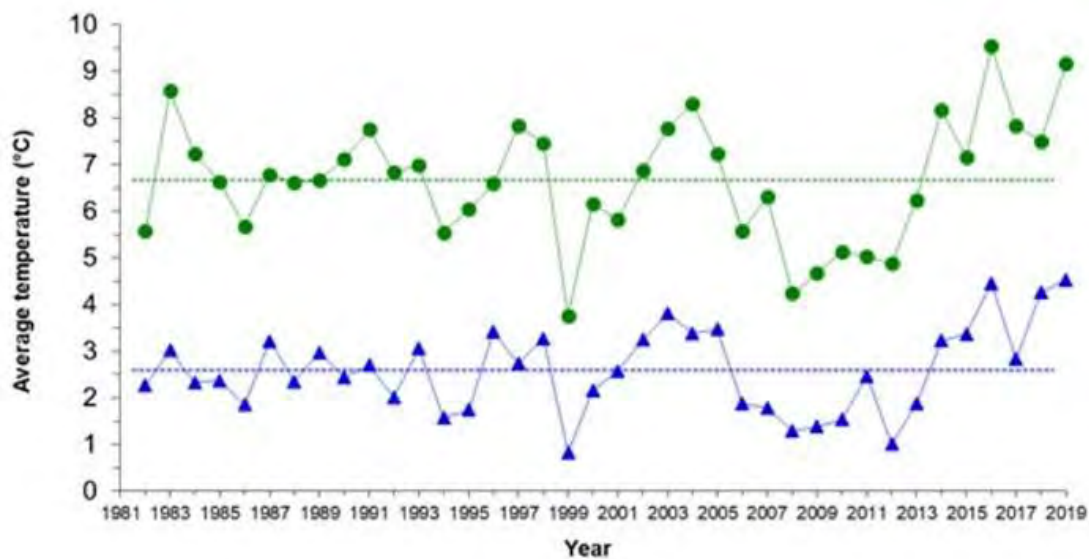


Fig. 2 Average water temperature measured on the summer bottom trawl survey at surface (green circle) and bottom (blue triangles) in the southeastern Bering Sea, 1981–2019. Figure courtesy of Lyle Britt, NOAA, AFSC.

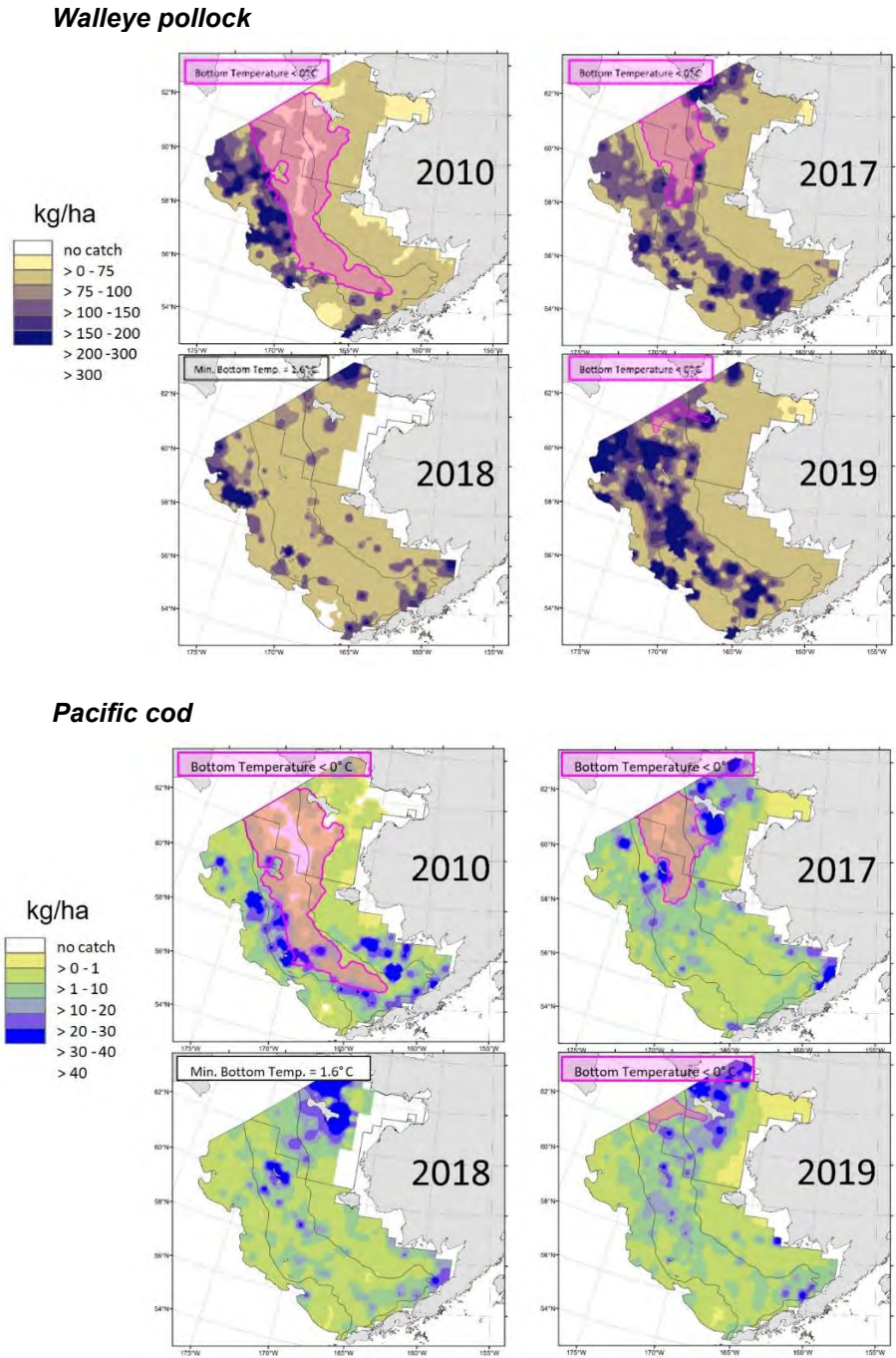


Fig. 3 Biomass of adult walleye pollock (top) and adult Pacific cod (bottom) from southeastern and northern Bering Sea bottom trawl surveys in a cold year (2010) and three warm years (2017–2019). The 0°C bottom temperature (pink overlay) was estimated from temperature sensors attached to the trawl net. Figures courtesy of Lyle Britt, NOAA, AFSC.

Northern Bering Sea surface trawl survey

The northern Bering Sea survey occurred from August 27 to September 20, 2019. This survey has been conducted on an annual basis since 2002. Its goal is to improve our understanding of the status of pelagic fish resources and the impact of loss of Arctic sea ice on the eastern Bering Sea ecosystem. Initial findings indicate that water temperatures were 2.5–3.0°C above average. Catches of Pacific herring

(*Clupea pallasii*) and juvenile salmon, except Chinook salmon (*Oncorhynchus tshawytscha*), were above average. Changes in the early life-history (freshwater and early marine) survival, as indicated by the number of juveniles-per-spawner (Fig. 4), is the primary factor impacting juvenile Chinook salmon abundance in the northern Bering Sea. The number of juveniles-per-spawner in 2019 is the lowest we have observed since 2003.



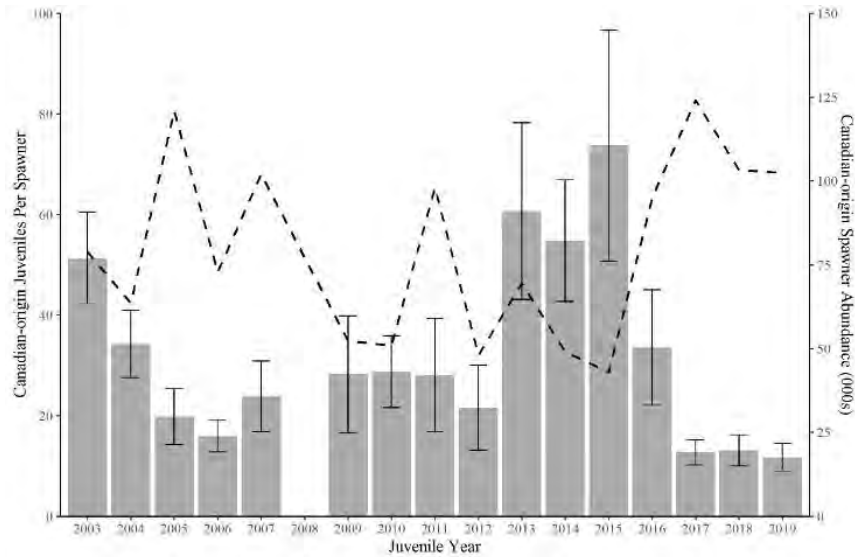


Fig. 4 Estimated number of juveniles-per-spawner (bars) and spawner abundance (dashed line) for the Canadian-origin stock group of Chinook salmon in the Yukon River, 2003–2019. Error bars are one standard deviation above and below of juvenile abundance estimates. The 2019 estimates are preliminary. Figure courtesy of Jim Murphy, NOAA, AFSC. See Siddon and Zador (2019) for details.

### Eastern Chukchi Sea ecosystem survey

The Chukchi Sea survey was conducted from August 1 to October 4, 2019. This is the fourth integrated ecosystem survey conducted along the Chukchi Shelf (other years include 2012, 2013, and 2017), with the goal to understand how loss of seasonal sea ice in the Chukchi Sea impacts the food web from physics to higher trophic levels. Overall sea temperatures on the Chukchi Sea shelf were warm, 5.3 to 10.9°C. Large copepod abundance was very low compared to previous years. Age-0 Arctic cod dominated the midwater catch, however, the acoustic backscatter for these fish indicated fewer fish in the region when compared with 2017. Of note were the large numbers of age-0 pollock caught along the 70.25°N transect as well as in the southern Chukchi Sea. Invertebrates including notched brittlestars (*Ophiura sarsi*), snow crab (*Chionoecetes opilio*), northern nutclam (*Nuculana pernula*), basket stars and common mud stars (*Ctenodiscus crispatus*) dominated the catches on the ocean floor. An unusual high number of dead birds were collected on the survey.

For additional information on these and other surveys, see: <https://www.fisheries.noaa.gov/alaska/science-data/alaska-fisheries-science-center-surveys-arctic-2019-preliminary-findings>

### **Key ecosystem observations and implications**

- A second winter of low sea ice in the northern Bering Sea; unprecedented warm inner domain. Impacts to fish distribution (juveniles and adults).
- Zooplankton prey base dominated by small, lipid-poor copepods; low abundances of large copepods and euphausiids. Impacts to carrying capacity throughout the Bering and Chukchi seas.
- Pollock increase in southeastern Bering Sea represents movement of adult fish into this area; 2018 year classes appear strong, Pacific cod biomass continues to increase in the northern Bering Sea. Groundfish conditions increased from 2018 indicating positive groundfish responses to ecosystem conditions.
- Seabird die-off, mainly short-tailed shearwaters (*Ardenna tenuirostris*), in the Bering and Chukchi seas attributed to starvation (Fig. 5). Concerns about food security in northern Bering Sea. Fish-eating seabirds at colonies did better than expected. Indicates mixed responses by seabirds.
- Gray whale (*Eschrichtius robustus*) and ice seal Unusual Mortality Events. Indicates impacts of changes in food web structure and carrying capacity of the northern Bering Sea. For information on gray whales, see <https://www.fisheries.noaa.gov/national/marine-life-distress/2019-gray-whale-unusual-mortality-event-along-west-coast>.

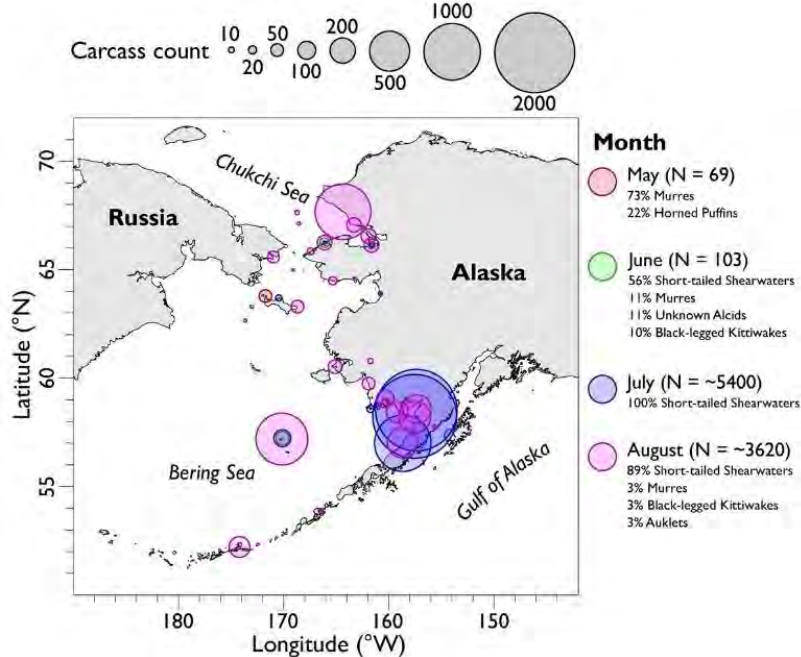


Fig. 5 Seabird carcass counts in the Bering and Chukchi seas, May–August, 2019. Figure from T. Jones, Coastal Observation and Seabird Survey Team (COASST), obtained on-line (December 6, 2019): <https://www.nps.gov/subjects/aknatureandscience/commonmurrewreck.htm>. Many scientists and volunteers participated in data collection. Please see web link for partnerships and additional details.

**Upcoming Bering Sea surveys in 2020**

- PMEL and AFSC, NOAA will conduct mooring work, and oceanography and plankton sampling aboard the NOAA Ship *Oscar Dyson*, April 29–May 11 and September 18–30.
- AFSC, NOAA will conduct surveys in the southeastern Bering Sea aboard the NOAA Ship *Oscar Dyson* for larval fish, May 14–29, and for forage/juvenile fish and oceanography (BASIS survey), August 16–September 13.
- AFSC, NOAA will conduct bottom trawl surveys in the southeastern Bering Sea (June, July) and northern Bering Sea (August).
- AFSC, NOAA will conduct a surface trawl survey in the northern Bering Sea aboard the F/V *Northwest Explorer*, late August–September.

**Upcoming meetings on Bering Sea**

- [Alaska Marine Science Symposium](#), January 27–31, 2020, Anchorage, Alaska, USA.
- [Ocean Sciences Meeting](#), February 16–21, 2020, San Diego, California, USA.

**Relevant information**

Please see the NOAA Arctic report card update for 2019 for information on the climate and ecosystem, and comments from indigenous communities in the Bering Sea: <https://arctic.noaa.gov/Report-Card/Report-Card-2019>.

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**Reference**

Siddon, E. and Zador, S., 2019. Ecosystem Status Report 2019: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.



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## Copepod responses to, and recovery from, the recent marine heatwave in the Northeast Pacific

by Jennifer Fisher, David Kimmel, Tetjana Ross, Sonia Batten, Eric Bjorkstedt, Moira Galbraith, Kym Jacobson, Julie Keister, Akash Sastri, Karyn Suchy, Samantha Zeman and R. Ian Perry

### Introduction

The anomalously warm water that formed in the North Pacific during the winter of 2013/2014, nicknamed “the Blob” (Bond *et al.*, 2015), persisted for several years and was a major and unprecedented event in the Northeast (NE) Pacific. This marine heatwave was associated with significant impacts on many marine species, disrupted typical food webs, and caused closures of several commercially important fisheries throughout the region (*e.g.*, McCabe *et al.*, 2016). Copepods are ubiquitous members of marine zooplankton assemblages worldwide, and are key components of marine food webs, transferring energy from phytoplankton to fish and marine mammals. Given this ecological role and importance to fisheries, there are multiple zooplankton monitoring programs in the NE Pacific that span a large geographic region (Fig. 1).

Shifts in copepod species composition in response to the recent marine heatwave have been documented from some locations, yet the response to this extreme event at the scale of the NE Pacific has not been addressed. For example, off Newport, Oregon, the copepod community shifted to a

community comprised of smaller lipid-poor taxa, greatly altering the bioenergetics of the food chain (Peterson *et al.*, 2017). In the Gulf of Alaska, Batten *et al.* (2018) found that the positive relationship between temperature and zooplankton biomass from 2000 to 2013 broke down during the warm years of 2014 and 2015. They concluded such extreme warm events could alter trophic patterns and interactions. Understanding the effects of warm events is critical as they could become more prevalent and widespread (Oliver *et al.*, 2018).

In this article, we examine the responses (and possible recovery) of copepods to this extreme event at the scale of the NE Pacific. We focus on two species: *Calanus pacificus*, representing a warm water copepod typically found in high abundances off California and southern Oregon but occurring throughout the region; and *Acartia longiremis*, representing a cool water species typically found in high abundances in British Columbia and Alaskan waters. We selected these two species to contrast the responses of typical warm water, and typical cold water, copepods in the NE Pacific.

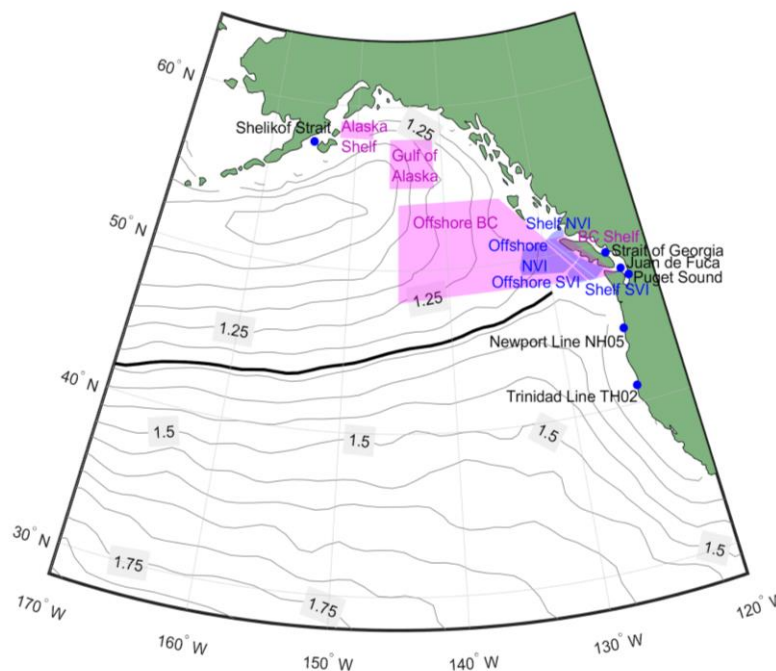


Fig. 1 Map of zooplankton monitoring locations in the NE Pacific. Contour lines show the mean dynamic height across the region based on a mapping of Argo data (2004–2019). The thick black line indicates the mean bifurcation latitude; on average the water north of the line flows north after hitting the coast of North America and the water south flows south.

## Approach

We assembled data from a range of sampling programs in the NE Pacific (Table 1). Since these programs use a variety of different gears and sampling protocols, we reduced the data to Spring–Summer (May–September) anomalies for each year. Anomalies were calculated by subtracting the May–September mean abundance in each year from the long-term (May–September) mean abundance across years, and then dividing by the standard deviation of the means. The coherence in the response of the two copepod species (*C. pacificus* and *A. longiremis*) across the regions was visualized using cluster analysis. Years that are linked in the cluster dendrogram represent periods when the pattern of species abundance was more similar across regions compared to years that are not linked.

To provide the physical background within which to compare these copepod anomalies, we used Argo float data to look at the circulation of the NE Pacific. We used the Roemmich-Gilson gridded Argo temperature and salinity climatology (Roemmich and Gilson, 2009) to calculate and

map the monthly mean dynamic heights of sea level (Fig. 1). We used the contours of dynamic height (the streamlines) to locate the bifurcation streamline (*i.e.*, the streamline which divides the water that will move north along the coast from that which will move south; the mean bifurcation streamline is shown as a thick black line in Fig. 1). Using the dynamic height of the bifurcation, we then calculated the differences in dynamic height between the bifurcation and a point in the middle of the Alaskan gyre (53°N, 155°W;  $\Delta D_{\text{Gak}}$ ) and a point off the coast of California (35°N, 150°W;  $\Delta D_{\text{CCurr}}$ ). These differences in dynamic height then scale with the flow going north ( $\Delta D_{\text{Gak}}$ ) and south ( $\Delta D_{\text{CCurr}}$ ) along the coast of North America (Fig. 2). Additionally, we calculated the difference between the locations off the coast of California and the Gulf of Alaska ( $\Delta D_{\text{NPC}}$ ), which scales with the overall magnitude of the North Pacific Current (NPC) in the NE Pacific (Fig. 2). Thus, this analysis provides information on the mean latitude of the center of the NPC (shown to be important in Sydeman *et al.*, 2011), *i.e.*, the mean latitude of flow across the NE Pacific, and the fraction of that flow that moves south along the Oregon and California coasts ( $f_{\text{CC}}$  in Fig. 2) or north into the Gulf of Alaska ( $1-f_{\text{CC}}$ ).

Table 1 Zooplankton sampling programs in the NE Pacific used in this analysis. See Figure 1 for locations.

Program	Location	Provider	Year range
Trinidad Head Line	Northern California	Eric Bjorkstedt	2008–2016
Newport Hydrographic Line	Central Oregon	Jennifer Fisher, Kym Jacobson, Samantha Zeman	1996–present
Puget Sound	Puget Sound	Julie Keister	2014–present
Strait of Juan de Fuca	Strait of Juan de Fuca	Julie Keister	2003–2017
Strait of Georgia	Strait of Georgia, BC	Moira Galbraith, Ian Perry, Kelly Young, Karyn Suchy	1996–2018
La Perouse/West Coast of Vancouver Island	Southern continental shelf off Vancouver Island; Southern off-shelf waters of Vancouver Island; Northern continental shelf off Vancouver Island; Northern off-shelf waters of Vancouver Island	Moira Galbraith, Ian Perry, Akash Sastri	1990–2019
Shelikof Strait	Shelikof Strait, Alaska	David Kimmel	1990–present
Continuous Plankton Recorder program – Pacific (CPR-Pacific)	Four regions were delineated, two offshore (northern Gulf of Alaska and west of BC) and two shelf regions (Central Alaska and BC)	Sonia Batten	2000–present (offshore) 2004–present (shelf)



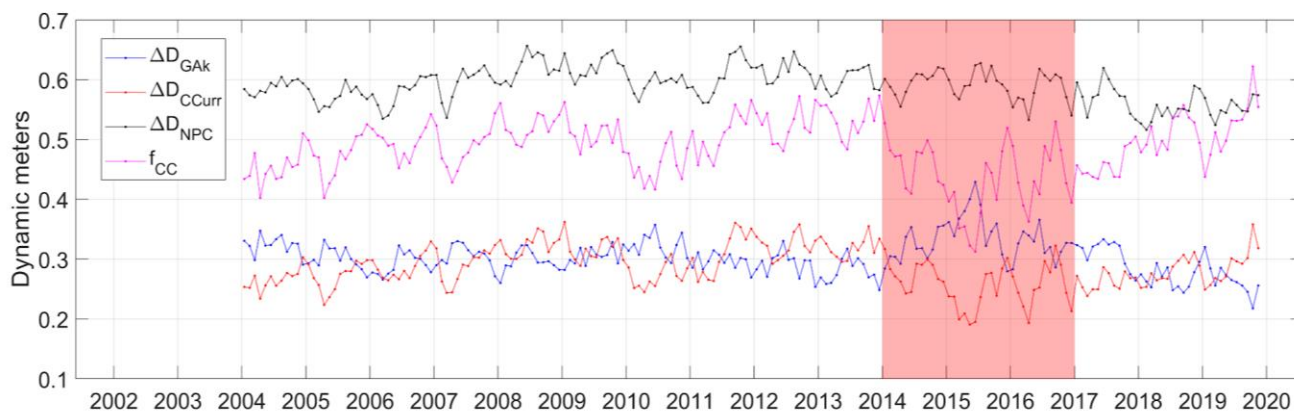


Fig. 2 Time series of differences in dynamic heights (in m) between the bifurcation streamline for the North Pacific Current (NPC) and the Gulf of Alaska ( $\Delta D_{GAK}$  in blue), the bifurcation streamline and a point off the California coast ( $\Delta D_{CCurr}$  in red) and across the NPC ( $\Delta D_{NPC}$  in black). The pink line ( $f_{CC}$ ) shows the ratio  $\Delta D_{CCurr}/\Delta D_{NPC}$ , which is the fraction of the NPC that flows south along the coast of North America. The shading highlights the recent marine heatwave years in the open NE Pacific (2014–2017).

### What we found

Strong changes in the fraction of water transported from the NPC into the California Current began in 2014 and persisted through 2017 (Fig. 2). Note the lack of a large change in the overall strength of the NPC during this time, so the flow into the Gulf of Alaska became stronger and the flow into the California Current became weaker.

At the onset of the unusually high fraction of the NPC turning north in 2014, positive anomalies of *C. pacificus* started occurring at many of the northern locations in the NE Pacific (Fig. 3; Alaska shelf, Gulf of Alaska offshore, South Vancouver Island offshore and on the shelf, Strait of Georgia and Puget Sound). However, they remained negative in open coast locations to the south (Fig. 3; Newport and Trinidad lines). These patterns follow the temporal evolution of the marine heatwave that started in the Gulf of Alaska and offshore in the NE Pacific, but did not inundate continental shelf waters at lower latitudes until coastal upwelling winds subsided in the fall of 2014. From 2015–2017, positive anomalies of *C. pacificus* occurred across almost all of the regions while negative (or neutral) anomalies of *A. longiremis* occurred across all regions (Fig. 4).

The coherence of abundance changes of these two species across the regions was stronger for *C. pacificus* compared to *A. longiremis*. Years associated with the marine heatwave (2015–2017) clustered together with 2005, another warm ocean year (Mackas *et al.*, 2006), indicating that the shifts in abundance of *C. pacificus* across regions were similar during these years (Fig. 5A). The grouping of the warm years for *A. longiremis* is less consistent, with 2016 and 2005 clustering together, and 2015 and 2017 clustering with 2004 (Fig. 5B).

Weak, but negative anomalies of *C. pacificus* abundance occurred in many regions in 2018 and the coherence of the signal across the regions meant that this year clustered with other years in the study, indicating that the copepod community might have been stabilizing in 2018. However, strongly positive anomalies of *C. pacificus* occurred on the shelf off North and South Vancouver Island in 2019 and *A. longiremis* abundance remains below average across many of the regions. It appears the effects of the marine heatwave remain apparent in the copepod community despite a decline in anomalously high ocean temperatures.

### Implications

Despite variability in the abundance of *C. pacificus* and *A. longiremis* across these monitoring regions throughout each time series, patterns in response to the recent marine heatwave emerged. Positive anomalies of *C. pacificus* and negative anomalies of *A. longiremis* generally occurred across all of the regions, as would be expected given the spatial extent and magnitude of the positive temperature anomalies and the water mass affinities of these two copepod species. The coherence of abundance changes of these two species across regions was also similar in 2005, however, the changes in abundance of the two species was not. During 2005, positive anomalies of both species occurred in the northern regions while mostly negative anomalies of both species occurred across the central to southern regions. Positive temperature anomalies also occurred during 2005, however, the mechanism, magnitude, and geographic extent of this warm anomaly was different compared to the marine heatwave. Therefore, when assessing the possible impact a physical perturbation might have on lower trophic level communities, it is important to understand the magnitude and geographic extent of the event in question.

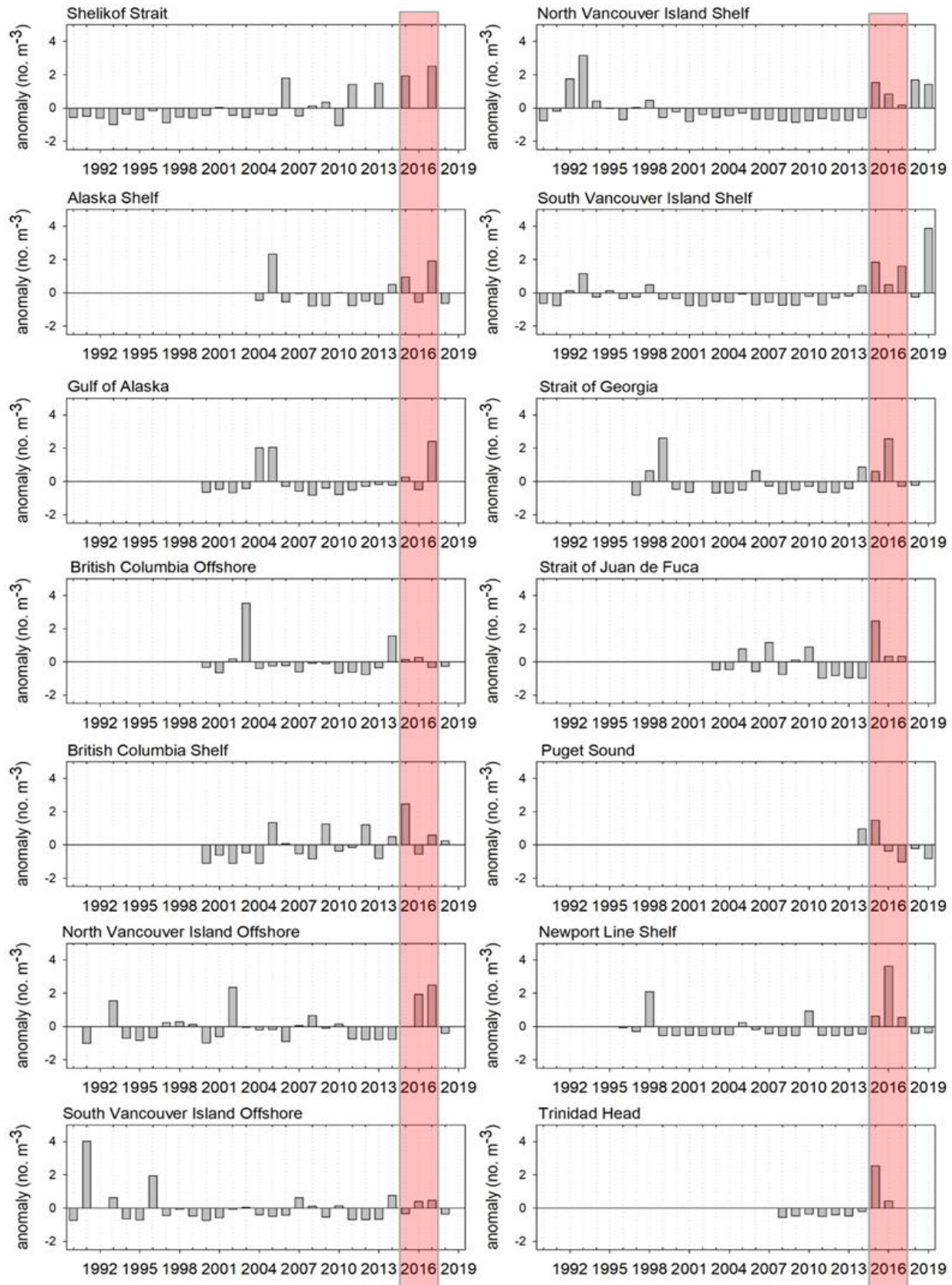


Fig. 3 Annual anomalies of *Calanus pacificus* density ( $\text{no. m}^{-3}$ ) from May–September across the study regions. Shaded regions represent the recent marine heatwaves years along continental and adjacent waters of the NE Pacific (2015–2017).

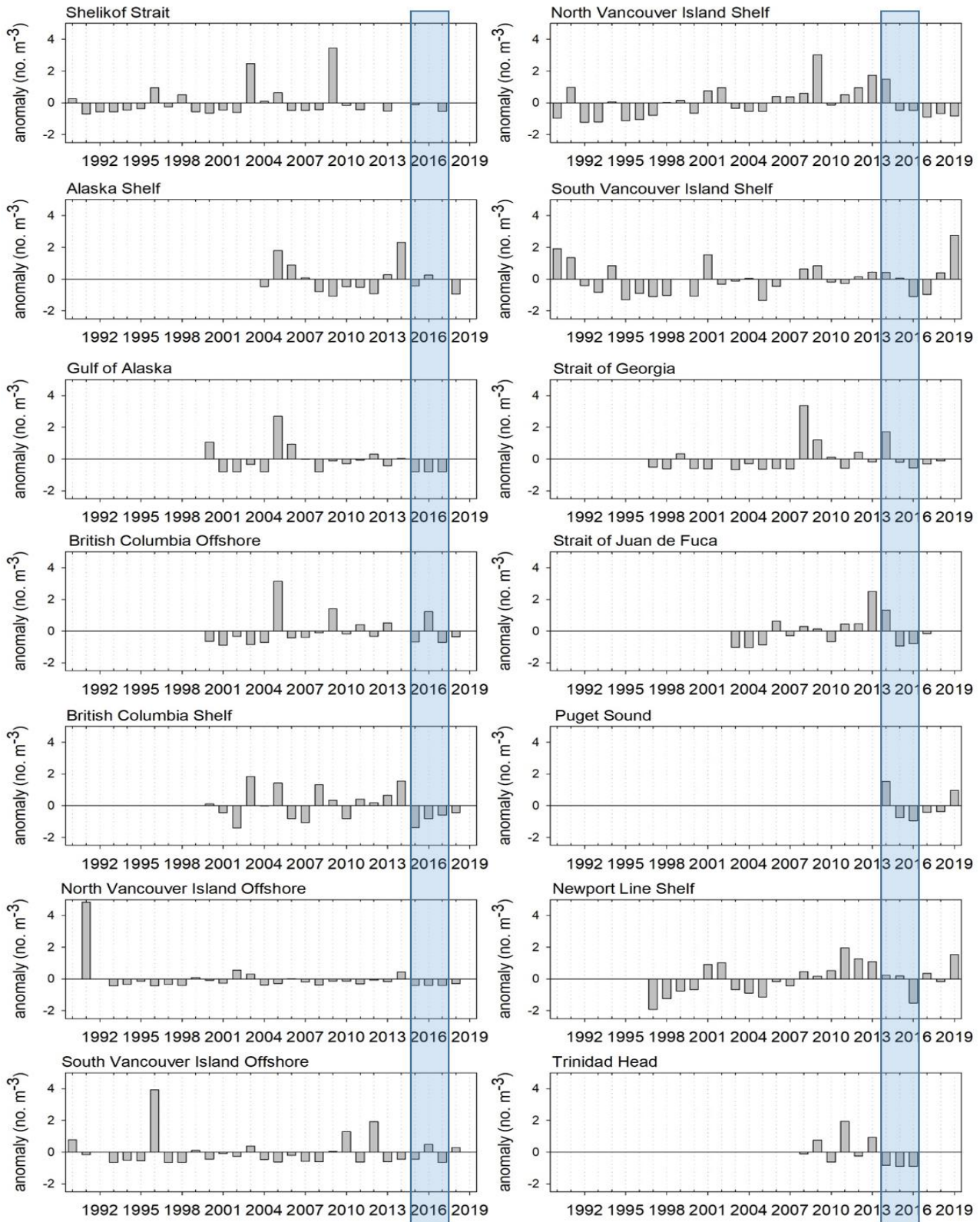


Fig. 4 Annual anomalies of *Acartia longiremis* density (no. m<sup>-3</sup>) from May–September across the study regions. Shaded regions represent the recent marine heatwaves years along continental and adjacent waters of the NE Pacific (2015–2017).



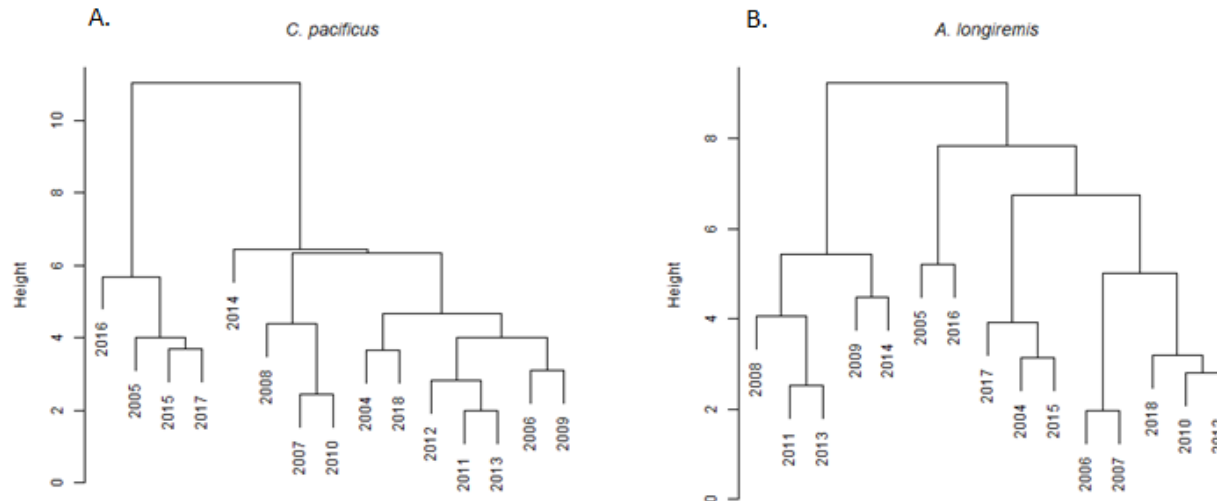


Fig. 5 Cluster dendrogram showing the similarity in abundance shifts for A. *Calanus pacificus* and B. *Acartia longiremis* across the regions from 2004–2018. Dissimilarity across regions was calculated using Euclidean distance on square root transformed densities for each species.

The marine heat wave has resulted in a variety of biological impacts from reduced chlorophyll biomass to species range shifts and bird die-offs. From the copepod perspective, the positive anomalies of *C. pacificus* throughout the region may have consequences for trophic transfer in NE Pacific food webs. This species is smaller and has lower lipid storage reserves compared to its congener, *C. marshallae*. A prey base with a greater proportion of *C. pacificus* relative to *C. marshallae* would be most impactful in northern latitudes where the latter is an important resource supporting juvenile fish, adult forage fish, and bird populations.

## References

- Batten S.D., Raitos D.E., Danielson S., Hopcroft R., Coyle K., McQuatters-Gollop A. 2018. Interannual variability in lower trophic levels on the Alaskan Shelf. *Deep Sea Research Part II: Topical Studies in Oceanography*. 147: 58–68.
- Bond N.A., Cronin M.F., Freeland H., Mantua N. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophysical Research Letters*. 42(9): 3414–3420.
- Mackas D.L., Peterson W.T., Ohman M.D., Lavaniegos B.E. 2006. Zooplankton anomalies in the California Current system before and during the warm ocean conditions of 2005. *Geophysical Research Letters*. 33(22): doi 10.1029/2006GL027930.
- McCabe R.M., Hickey B.M., Kudela R.M., Lefebvre K.A., Adams N.G., Bill B.D., Gulland F.M., Thomson R.E., Cochlan W.P., Trainer V.L. 2016. An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions. *Geophysical Research Letters*. 43(19): 10,366–10,367.
- Oliver E.C., Donat M.G., Burrows M.T., Moore P.J., Smale D.A., Alexander L.V., Benthuisen J.A., Feng M., Gupta A.S., Hobday A.J., Holbrook N.J. 2018. Longer and more frequent marine heatwaves over the past century. *Nature communications*. 9(1): 1324.
- Peterson W.T., Fisher J.L., Strub P.T., Du X., Risien C., Peterson J., Shaw C.T. 2017. The pelagic ecosystem in the Northern California Current off Oregon during the 2014–2016 warm anomalies within the context of the past 20 years. *Journal of Geophysical Research: Oceans*. 122(9): 7267–7290.
- Roemmich D. and Gilson, J. 2009. The 2004–2008 mean and annual cycle of temperature, salinity, and steric height in the global ocean from the Argo Program. *Progress in Oceanography*, 82: 81–100.
- Sydeman W.J., Thompson S.A., Field J.C., Peterson W.T., Tanasichuk R.W., Freeland H.J., Bograd S.J., Ryzakzewski R.R. 2011. Does positioning of the North Pacific Current affect downstream ecosystem productivity? *Geophysical Research Letters*. 38(12): L12606.



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*(continued on page 74)*

## The western North Pacific during the 2019 warm season

by Takafumi Umeda and Hidetada Kiyofuji

The western North Pacific was characterized by positive anomalies of sea surface temperature (SST) in 2019 over large areas outside around 30°N, 150°E in June and around 40°N,

170°E from July to September. In particular, such anomalies persisted throughout the season in the Sea of Japan and to the east of Hokkaido (Fig. 1).

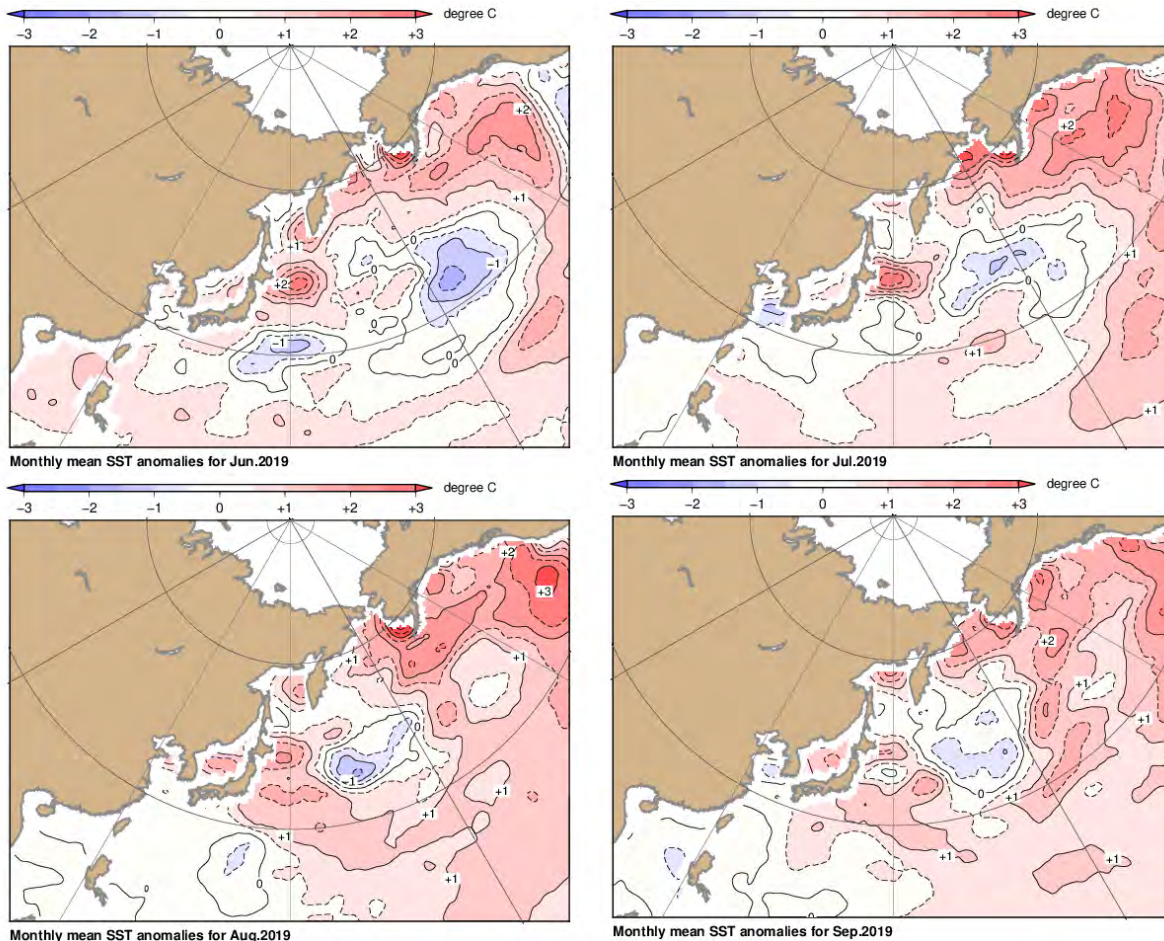


Fig. 1 Monthly mean sea surface temperature (SST) anomalies from June to September 2019. Monthly mean SSTs are based on JMA's COBE-SST (centennial in-situ observation-based estimates of variability for SST and marine meteorological variables). Anomalies are deviations from the 1981–2010 climatology.

### Potential effects of the Kuroshio large meander on coastal skipjack fishery activities

Coastal trolling and pole-and-line fishery activities in the area from Japan's Kochi Prefecture to Chiba Prefecture in spring and early summer target skipjack tuna (*Katsuwonus pelamis*), which migrate from subtropical and/or tropical areas. However, a lack of quantitative analysis means that the related effects of the Kuroshio large meander (Fig. 2 (3)), which emerged for the sixth time since 1965 in August 2017 (Table 1, Fig. 3), remain unclear.

The data here show very preliminary results from consideration of these effects for several ports in Wakayama Prefecture based on coastal trolling fishery activities (Fig. 4). The overall average catch during Kuroshio large meander periods is lower than usual (Welch's t-test:  $p < 0.05$ ), possibly because the meander shifts fishing grounds with temperatures of 18°C (the lower thermal limit for skipjack tuna) and above farther from port areas. Further analysis is necessary to clarify local skipjack fishing ground presence in relation to the Kuroshio meander.



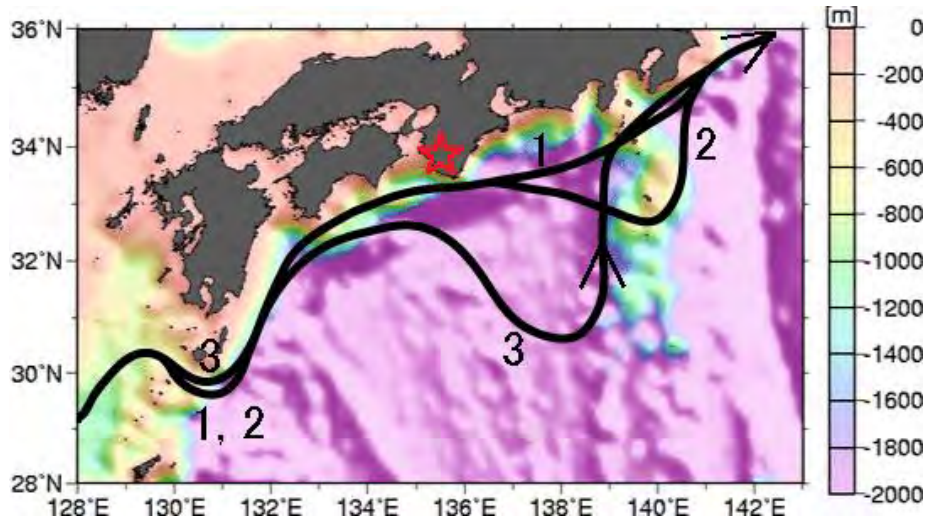


Fig. 2 Typical current paths of the Kuroshio south of Japan. Nearshore non-large-meander (1), offshore non-large-meander (2), and large-meander (3). Red star represents Wakayama Prefecture.

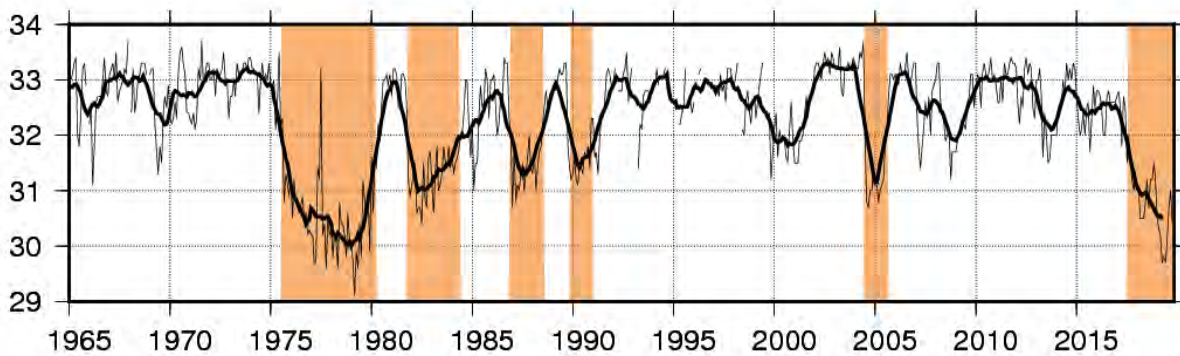


Fig. 3 Time-series representation of the southernmost latitude of the Kuroshio path south of Japan (136°–140°E). Shading indicates periods of Kuroshio large-meander events, the thin line indicates monthly values, and the thick line indicates 13-month running means. Kuroshio large-meanders are defined as being south of 32°N.

Table 1 Historical Kuroshio large-meander periods since 1965.

Period	Duration
August 1975 – March 1980	4 years, 8 months
November 1981 – May 1984	2 years, 7 months
December 1986 – July 1988	1 year, 8 months
December 1989 – December 1990	1 year, 1 month
July 2004 – August 2005	1 year, 2 months
August 2017 – Ongoing	2 year, 4 months (as of November 2019)

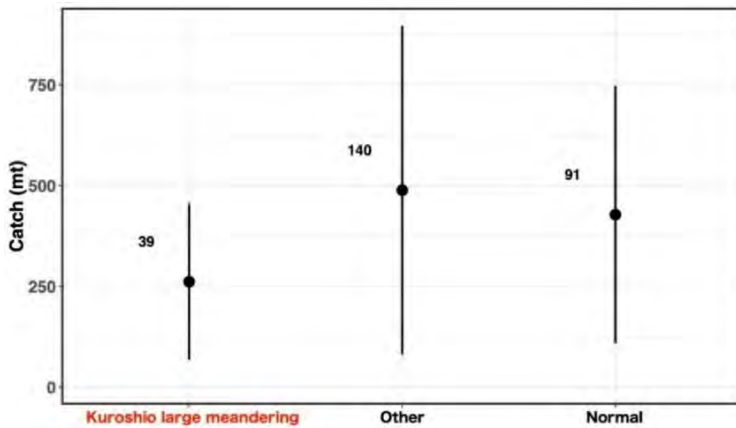


Fig. 4 Skipjack catches (mt) in Wakayama Prefecture from coastal trolling activities based on Kuroshio current trajectories. Large Kuroshio meanders are defined as those with a latitude of 32°N between 136°E and 140°E, while the normal situation is defined as straight flow along Japan’s southern coast and other instances are defined as neither of the above. Numbers next to bar plots represent monthly data counts.



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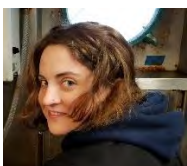
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## Northeast Pacific juvenile salmon summer surveys in 2019

by Jackie King, Jennifer Boldt, Brian Burke, Correigh Greene, Jamal Moss and Chrys Neville

Pacific salmon (*Oncorhynchus* spp.) in the eastern Pacific enter the ocean from several main watersheds, most notably the Columbia River between Oregon and Washington, the Puget Sound and Fraser River basins of the Salish Sea, the Nass and Skeena Rivers in northern British Columbia, and the Kenai and Yukon Rivers in Alaska. Juvenile salmon migrate northwards along the coast towards overwintering grounds in the central Gulf of Alaska. Summer coastal surveys for juvenile Pacific salmon are conducted by federal agencies from Canada (Fisheries and Oceans Canada) and the United States (National Marine Fisheries Service) along the Pacific coast from Oregon and Washington to the Northern Bering Sea (Fig. 1). Juvenile salmon caught in these coastal surveys are of mixed stocks originating from several of the main watersheds. Last year, we reported for the first time on the results of the summer juvenile Pacific salmon surveys conducted throughout the northeast Pacific with the intent of providing an indication of broad-scale patterns in salmon marine survival throughout their migratory corridor (King *et al.*, 2019a). This year we update trends by reporting results from summer surveys in 2019.

### Survey time series

Time series on the relative abundance of juvenile salmon are available from eight long-term surveys conducted in the coastal waters of Oregon-Washington (OR-WA), the west coast of Vancouver Island (WCVI), Skagit Bay in Puget Sound (PS), the inland waters of the Strait of Georgia (SOG), coastal waters in Southeast Alaska (SEAK), in the Gulf of Alaska (GOA), the southeastern Bering Sea (BS) and the Northern Bering Sea (NBS) (Fig. 1). Catch per unit effort (CPUE) was calculated for five Pacific Salmon species: Chinook Salmon (*Oncorhynchus tshawytscha*), Chum Salmon (*O. keta*), Coho Salmon (*O. kisutch*), Pink Salmon (*O. gorbuscha*) and Sockeye Salmon (*O. nerka*). Each CPUE series was expressed as a standardized anomaly and natural log transformed for comparison between surveys. Below, we briefly describe each survey.

**OR-WA:** The Northwest Fisheries Science Center, in conjunction with scientists from Oregon State University's Cooperative Institute of Marine Resources Studies, conducted a surface-water trawl survey from June 20–27, 2019 using a Nordic 264 Rope Trawl (Net Systems, Bainbridge Island, Washington). This survey has been conducted annually since 1998. Forty-four sampling stations were located along 8 transects ranging from the northwest coast of Washington (48° 13.7' N) to Newport, Oregon (44° 40' N), including a transect directly south of the mouth of the Columbia River. CPUE was calculated as number of fish per distance trawled (km). CPUE for

Chinook Salmon are for yearling-type only; very few Pink Salmon are encountered off OR-WA, and therefore, no CPUE was estimated for this species.

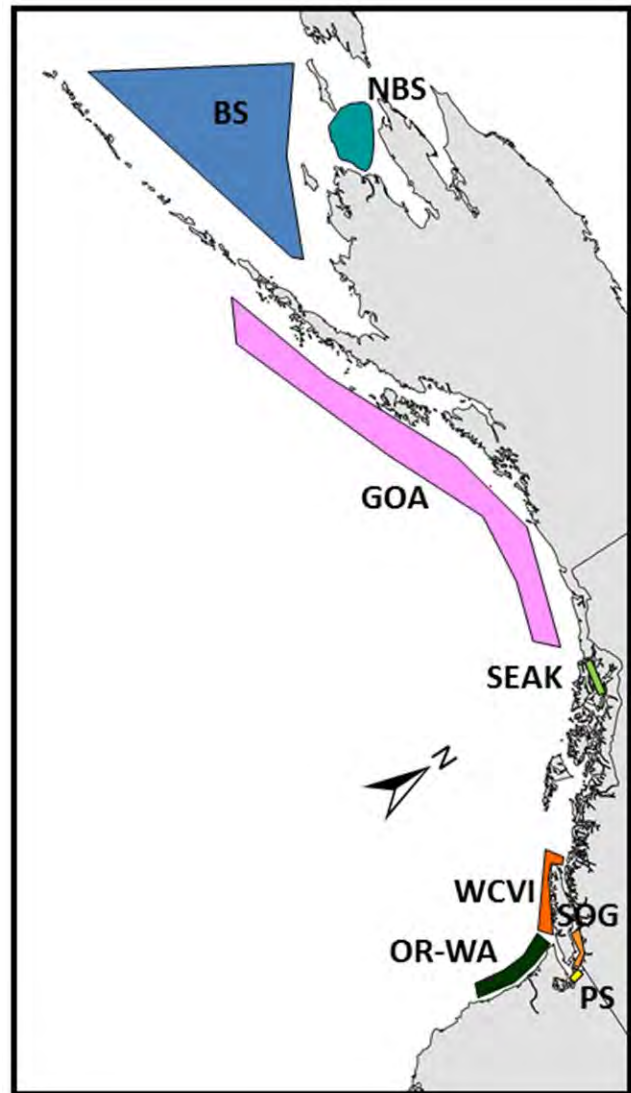


Fig. 1 Summer juvenile salmon surveys are conducted by Canada (Fisheries and Oceans Canada) and the USA (National Marine Fisheries Service) throughout the Northeast Pacific and into the Bering Sea (general survey areas denoted by polygons). Here we report on the most recent observations off Oregon-Washington (June 20–27, 2019; OR-WA dark green); off the west coast of Vancouver Island (June 15–July 15, 2019; WCVI dark orange), from Puget Sound (monthly from April–October 2019; PS yellow); from the Strait of Georgia (June 18–July 6, 2019; SOG light orange); coastal waters in Southeast Alaska (June 18–23, July 21–31, and August 20–26, 2019; SEAK light green); the Gulf of Alaska (last survey: July 7–August 16, 2017; GOA pink); southeastern Bering Sea (last survey: September 20–October 4, 2018; BS blue); and northern Bering Sea (August 27–20 September 20, 2019; NBS teal).



**WCVI:** Summer juvenile salmon surveys have been conducted by Fisheries and Oceans Canada on the continental shelf off the west coast of Vancouver Island since 1999. From June 15–July 15, 2019, surface trawling was conducted with a mid-water trawl net (LFS Ltd, Bellingham, Washington); prior to 2018 a CanTrawl 250 mid-water trawl net was used. From 1999–2015, surface trawls (0 and 15 m) were conducted along cross-shelf transects; beginning in 2017 surface trawls (0 and 15 m) were conducted with a random stratified survey design (King *et al.*, 2019b). CPUE was calculated as number of fish per distance trawled (km) based on daytime trawling only

**PS:** Since 2001, The Northwest Fisheries Science Center has conducted a monthly surface trawl survey in Skagit Bay of Puget Sound from April through October using a paired Kodiak trawl (Rice *et al.*, 2012; Greene *et al.*, 2015). From 2001–2005, sampling occurred at index sites, but thereafter the survey design employed stratified random site selection off a 0.5 km grid. CPUE is calculated as number of fish per area trawled (ha) and annual averages are calculated using a space-time model that integrates temporal and spatial autocorrelation (Lindgren and Rue, 2015).

**SOG:** Fisheries and Oceans Canada conducted an upper-water (0–60 m) trawl survey from June 18–July 6, 2019 in the Strait of Georgia using a CanTrawl250 mid-water net (CanTrawl Ltd., Richmond, BC). These surveys have been conducted since 1998. Fishing occurs along a standard track line with random selection for headrope depths ranging from surface to 45 m, in increments of 15 m with targeted proportional representation (Beamish *et al.*, 2000; Sweeting *et al.*, 2003). CPUE is calculated as number of fish per trawl duration (hr), based on surface and 15 m trawl depths for Chum, Pink and Sockeye Salmon, 30 m trawl depths for Coho Salmon and on 45 m trawl depths for Chinook Salmon (Beamish *et al.*, 2000; Sweeting *et al.*, 2003).

**SEAK:** The Alaska Fisheries Science Center has conducted the annual Southeast Coastal Monitoring Survey designed to study the early marine ecology of Pacific Salmon, other epipelagic fishes, plankton, and physical properties in Icy Strait of northern Southeast Alaska since 1997. In 2019, the survey was conducted monthly from June 18–23, July 26–

31, and August 20–26 with a Nordic 264 rope trawl (Net Systems, Bainbridge Island, Washington). CPUE was calculated as number of fish per 20 min tow and averaged as per Wertheimer *et al.* (2009).

**GOA:** The Gulf of Alaska assessment survey is a fisheries and oceanographic survey conducted in the eastern GOA during the summer season since 2010. The survey is designed to characterize ecosystem status and function and is a coordinated research effort among scientists within the Recruitment Processes Alliance at the Alaska Fisheries Science Center. No survey was conducted in 2018 or 2019, but we present the last survey results observed from July 7–August 16, 2017. Trawling was conducted with a Nordic 264 rope trawl (Net Systems, Bainbridge Island, Washington). CPUE was calculated as number of fish per 20 min tow and averaged as per Wertheimer *et al.* (2009).

**BS:** The Bering Sea Subarctic Integrated Surveys conducted by the Alaska Fisheries Science Center are focused on improving and reducing uncertainty in stock assessment models of important commercial fish species through the collection of acoustics information, fish and zooplankton samples, and fisheries oceanographic indices in the southeastern Bering Sea. These surveys were initiated in 1996 and have occurred annually from 2002 to 2012, and biennially since 2014. No survey was conducted in 2019, but we present the last survey results observed from September 20–October 4, 2018 with a CanTrawl 400 rope trawl (CanTrawl Ltd., Richmond, BC). CPUE was calculated as number of fish per 20 min tow and averaged as per Wertheimer *et al.* (2009).

**NBS:** The Northern Bering Sea Survey provides an integrated ecosystem assessment of the northeastern Bering Sea to support the Alaska Fisheries Science Center's Loss of Sea Ice Program, the Alaska Department of Fish and Game Chinook Initiative research program, and the Distributed Biological Observatory. The Northern Bering Sea Survey has occurred annually from 2002 and in 2019 was conducted from August 27–September 20 with a CanTrawl 400 rope trawl (CanTrawl Ltd., Richmond, BC). CPUE was calculated as number of fish per 20 min tow and averaged as per Wertheimer *et al.* (2009).

**Observations for 2019**

**Chinook:** Juvenile Chinook Salmon relative abundance in coastal waters off OR-WA, WCVI, and in SOG improved in 2019 relative to 2018; however, relative abundance in WCVI remains below average (Fig. 2). Conversely, in PS, SEAK and NBS waters the relative abundance of juvenile Chinook Salmon declined in 2019 from 2018.

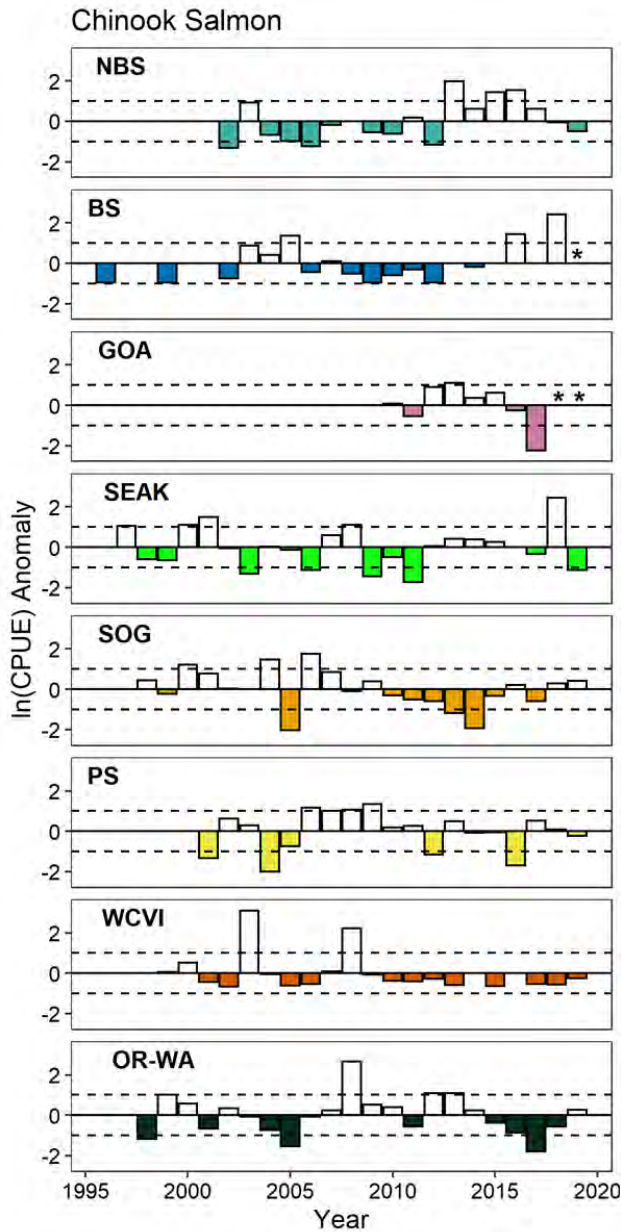


Fig. 2 Standardized CPUE anomalies (mean of zero: solid line;  $\pm 1$  standard deviation: dashed lines) for juvenile Chinook Salmon from summer surveys throughout the Northeast Pacific: Oregon-Washington (OR-WA); west coast of Vancouver Island (WCVI), Puget Sound (PS); Strait of Georgia (SOG); coastal waters in Southeast Alaska (SEAK); the Gulf of Alaska (GOA); southeastern Bering Sea (BS); and Northern Bering Sea (NBS). Asterisk denotes no survey completed in 2018 or 2019 in GOA, and no survey completed in 2019 in BS.

**Chum:** For most regions in the Northeast Pacific the recent juvenile Chum Salmon CPUE has been near average in the last several years, albeit with regional differences on whether the anomaly value is positive or negative (Fig. 3). Exceptions include OR-WA, PS and NBS with notable positive anomalies in 2019. In all regions, except the SOG, the relative abundance of juvenile Chum Salmon increased in 2019 compared to 2018.

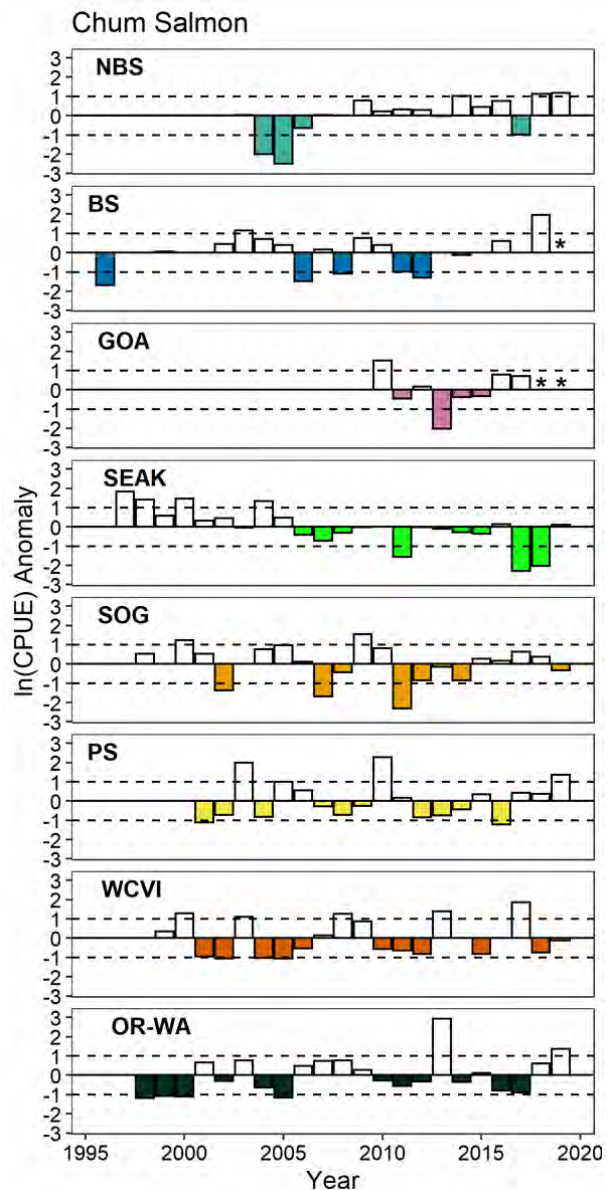


Fig. 3 Standardized CPUE anomalies (mean of zero: solid line;  $\pm 1$  standard deviation: dashed lines) for juvenile Chum Salmon from summer surveys throughout the Northeast Pacific: Oregon-Washington (OR-WA); west coast of Vancouver Island (WCVI), Puget Sound (PS); Strait of Georgia (SOG); coastal waters in Southeast Alaska (SEAK); the Gulf of Alaska (GOA); southeastern Bering Sea (BS); and Northern Bering Sea (NBS). Asterisk denotes no survey completed in 2018 or 2019 in GOA, and no survey completed in 2019 in BS.

**Coho:** Anomalies for juvenile Coho Salmon varied greatly across the regions of the Northeast Pacific (Fig. 4). Relative abundance in 2019 remained above average in SOG and NBS, below average for WCVI and SEAK, and close to average for OR-WA and PS.

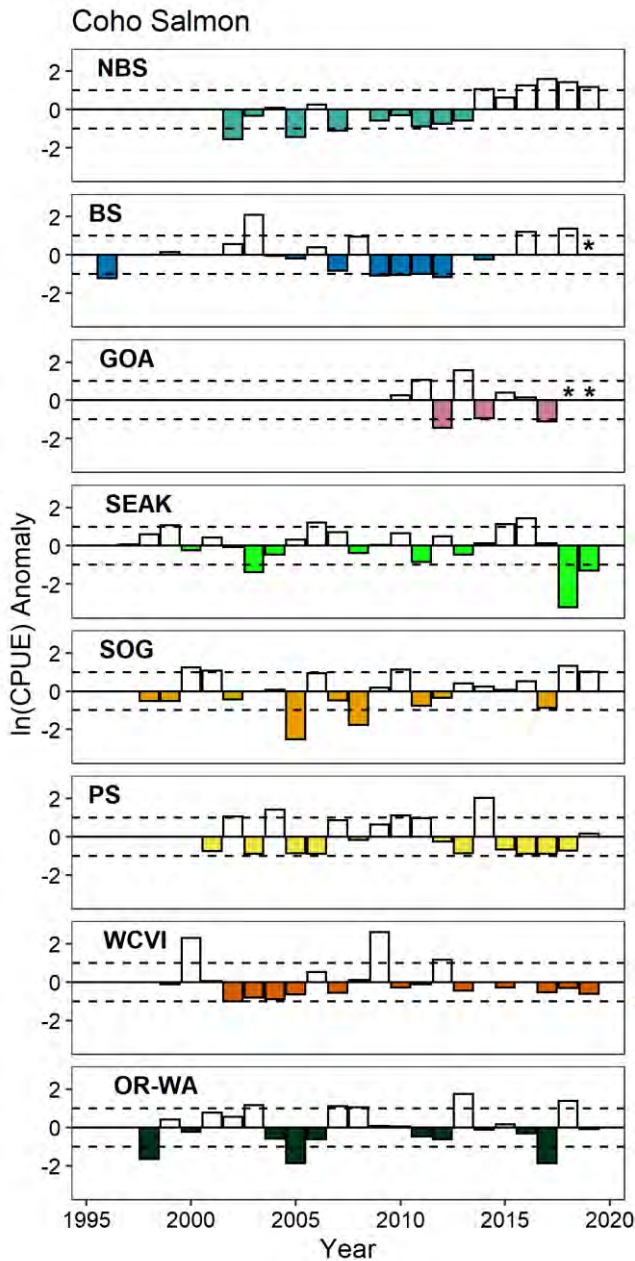


Fig. 4 Standardized CPUE anomalies (mean of zero: solid line;  $\pm 1$  standard deviation: dashed lines) for juvenile Coho Salmon from summer surveys throughout the Northeast Pacific: Oregon-Washington (OR-WA); west coast of Vancouver Island (WCVI), Puget Sound (PS); Strait of Georgia (SOG); coastal waters in Southeast Alaska (SEAK); the Gulf of Alaska (GOA); southeastern Bering Sea (BS); and Northern Bering Sea (NBS). Asterisk denotes no survey completed in 2018 or 2019 in GOA, and no survey completed in 2019 in BS.

**Pink:** Juvenile Pink Salmon catches follow the cyclical dominance with high catches in even numbered years. Pink Salmon are rarely encountered in surveys off OR-WA, and are mainly encountered in even numbered years off WCVI (Fig. 5). When compared to other odd year catches, the 2019 relative abundance of juvenile Pink Salmon was about average in SOG, PS and SEAK, but anomalously high in NBS.

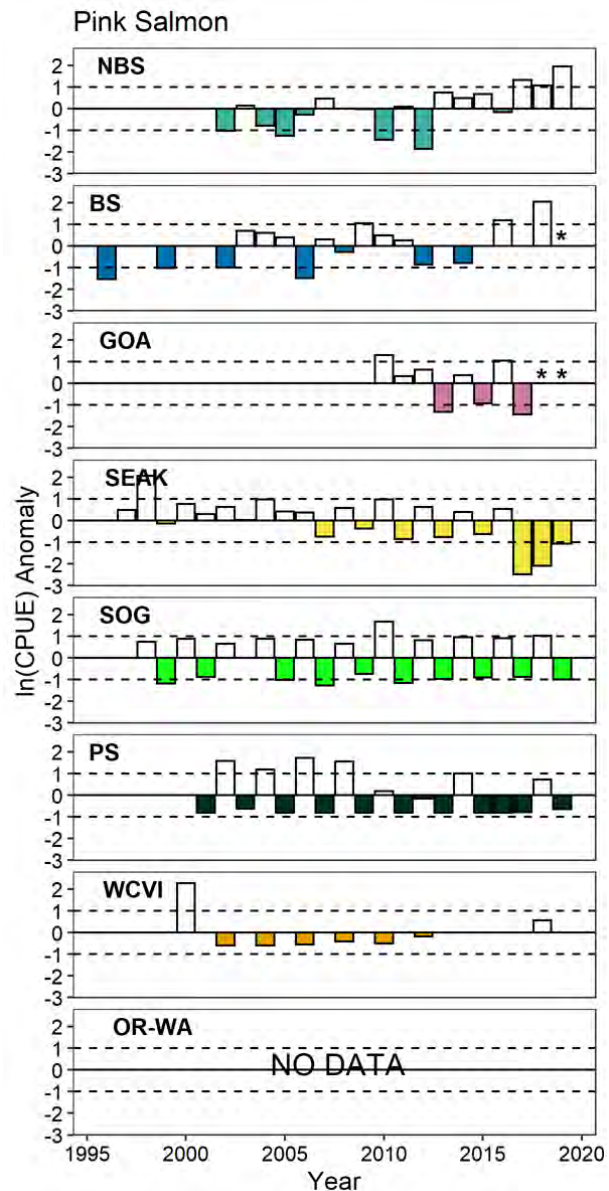


Fig. 5 Standardized CPUE anomalies (mean of zero: solid line;  $\pm 1$  standard deviation: dashed lines) for juvenile Pink Salmon from summer surveys throughout the Northeast Pacific: Oregon-Washington (OR-WA) catches are too low to provide CPUE data; west coast of Vancouver Island (WCVI; even year catches only), Puget Sound (PS); Strait of Georgia (SOG); coastal waters in Southeast Alaska (SEAK); the Gulf of Alaska (GOA); southeastern Bering Sea (BS); and Northern Bering Sea (NBS). Asterisk denotes no survey completed in 2018 or 2019 in GOA, and no survey completed in 2019 in BS.



**Sockeye:** The 2019 relative abundance of juvenile Sockeye Salmon was below average in OR-WA, WCVI and SOG waters (Fig. 6). In PS, the 2019 juvenile Sockeye Salmon CPUE was near the long-term mean and the relative abundance for juvenile Sockeye Salmon was above average in SEAK and NBS.

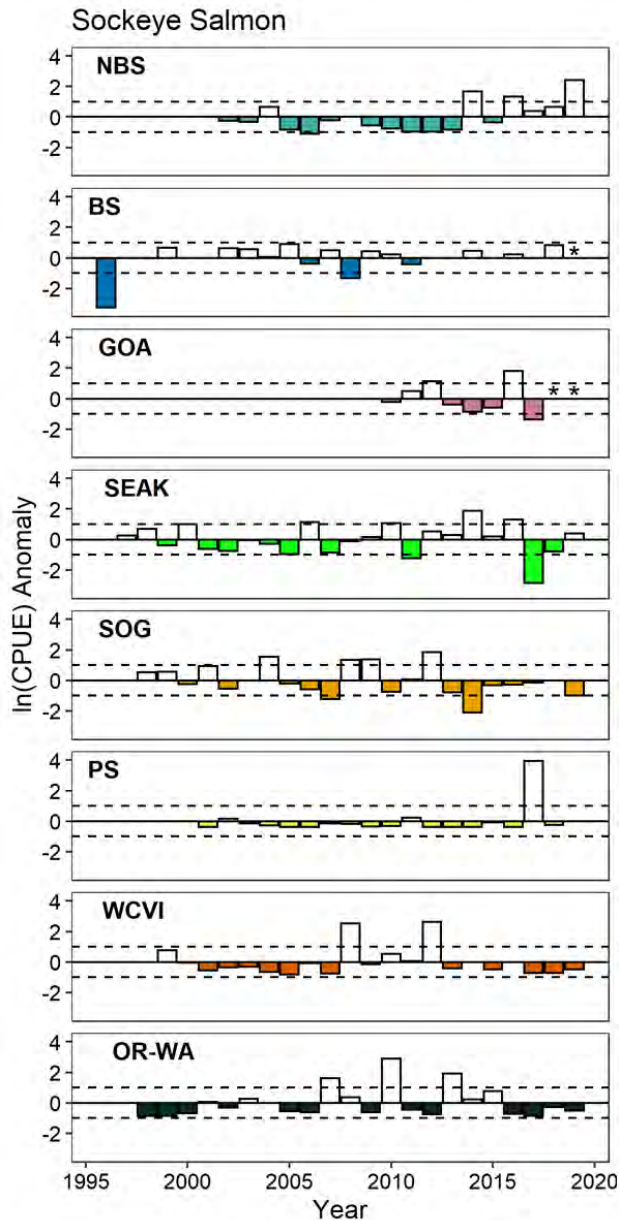


Fig. 6 Standardized CPUE anomalies (mean of zero: solid line;  $\pm 1$  standard deviation: dashed lines) for juvenile Sockeye Salmon from summer surveys throughout the Northeast Pacific: Oregon-Washington (OR-WA); west coast of Vancouver Island (WCVI), Puget Sound (PS); Strait of Georgia (SOG); coastal waters in Southeast Alaska (SEAK); the Gulf of Alaska (GOA); southeastern Bering Sea (BS); and Northern Bering Sea (NBS). Asterisk denotes no survey completed in 2018 or 2019 in GOA, and no survey completed in 2019 in BS.

ICES has a long history of sponsoring integrated North Pacific marine research linking climate and ocean conditions to fish population dynamics (Beamish, 1995; Hollowed *et al.*, 2011; Alheit *et al.* 2019). Pacific salmon are a culturally and economically important species in the North Pacific, and their status upon returning to freshwater serves as a useful integrator of ocean conditions over the past few years. Several basin-scale and regional indices, including ecological indices, have been linked to the marine survival of Pacific salmon at the juvenile stage (Mantua *et al.*, 1997; Wells *et al.*, 2008; Burke *et al.*, 2013). Pacific Decadal Oscillation and North Pacific Gyre Oscillation patterns correspond to coastal temperature spatial variability, with cascading impacts on lower trophic level community structure, such as zooplankton composition and abundance (Peterson *et al.*, 2014), and coherency to broad-scale patterns in Pacific salmon marine survival (Malick *et al.*, 2017). Ecosystem dynamics impact the first marine summer growth, migration, and overall survival juvenile salmon (Moss *et al.*, 2005; Burke *et al.*, 2013; Burke *et al.*, 2016; Freshwater *et al.*, 2018;). To better understand these ecological dynamics, these summer coastal surveys for juvenile salmon provide relevant data on ocean conditions and an early indication of Pacific salmon marine survival, and ultimately inform ecosystem models that support management decisions.

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#### References

- Alheit, J. Di Lorenzo, E. Rykaczewski, R. and Sundby, S. (eds.). 2019. Drivers of Dynamics of Small Pelagic Fish Resources. *Deep Sea Research II* 159: 1–3.
- Beamish, R.J. (ed.). 1995. Climate Change and Northern Fish Populations. Canadian Special Publication of Fisheries and Aquatic Sciences No. 121. 739 pp.
- Beamish, R.J., McCaughan, D., King, J.R., Sweeting, R.M. and McFarlane, G.A. 2000. Estimating the abundance of juvenile coho salmon in the Strait of Georgia by means of surface trawls. *North American Journal of Fisheries Management* 20: 369–375.
- Burke, B.J., Peterson, W.T., Beckman, B.R., Morgan, C., Daly, E.A. and Litz, M. 2013. Multivariate models of adult Pacific salmon returns. *PLoS One* 8(1): doi.org/10.1371/journal.pone.0054134.
- Burke, B.J., Anderson, J.J., Miller, J.A., Tomaro, L., Teel, D.J., Banas, N.S. and Baptista, A.M. 2016. Estimating behavior in a black box: how coastal oceanographic dynamics influence yearling Chinook salmon marine growth and migration behaviors. *Environmental Biology of Fishes* 99: 671–686.

- Freshwater, C., Trudel, M., Beacham, T.D., Gauthier, S., Johnson, S.C., Neville, C.E. and Juanes, F. 2018. Individual variation, population-specific behaviours and stochastic processes shape marine migration phenologies. *Journal of Animal Ecology* 88(1): 67–87.
- Greene, C.M., Kuehne, L., Rice, C., Fresh, K. and Penttila, D. 2015. Forty years of change in forage fish and jellyfish abundance across greater Puget Sound, Washington (USA): Anthropogenic and climate associations. *Marine Ecology Progress Series* 525: 153–170.
- Hollowed, A., Ito, S.-I., Kim, S. Loeng, H. and Peck, M. 2011. Climate change effects on fish and fisheries: Forecasting impacts, assessing ecosystem responses, and evaluating management strategies. *ICES Journal of Marine Science* 68(6): 984–985.
- King, J.R., Boldt, J., Burke, B., Greene, C., Moss, J. and Neville, C. 2019a. Northeast Pacific juvenile salmon summer surveys in 2018. PICES Press, Vol. 27 No. 1, pp. 19–26.
- King, J.R., Boldt, J., Dennis-Bohm, H., Zubkowski, T., Tucker, S. and Flostrand, L. 2019b. Integrative Pelagic Ecosystem Surveys on the Vancouver Island Continental Shelf, July 7–August 2, 2017 and July 5–July 29, 2018. Canadian Technical Report of Fisheries and Aquatic Sciences 3318: xi + 115 pp.
- Lindgren, F. and Rue, H. 2015. Bayesian spatial modelling with R-INLA. *Journal of Statistical Software* 63(19): doi:10.18637/jss.v063.i19.
- Malick, M.J., Cox, S.P., Mueter, F.J., Dorner, B. and Peterman, R.M. 2017. Effects of the North Pacific Current on productivity of 163 Pacific salmon stocks. *Fisheries Oceanography* 26: 268–281.
- Mantua, N.J., Hare, S.R., Zhang, Y., Wallace, J.M. and Francis, R.C. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society* 78(6): 1069–1080.
- Moss, J.H., Beauchamp, D.A., Cross, A.D., Myers, K.W., Farley Jr., E.V., Murphy, J.M. and Helle, J.H. 2005. Evidence for size-selective mortality after the first summer of ocean growth by pink salmon. *Transactions of the American Fisheries Society* 134(5): 1313–1322.
- Peterson, W., Fisher, J., Peterson, J., Morgan, C., Burke, B. and Fresh, K. 2014. Applied fisheries oceanography: Ecosystem indicators of ocean conditions inform fisheries management in the California Current. *Oceanography* 27: 80–89.
- Rice, C.A., Duda, J.J., Greene, C.M. and Karr, J.R. 2012. Geographic patterns of fishes and jellyfish in Puget Sound surface waters. *Marine and Coastal Fisheries* 4: 117–128.
- Sweeting, R.M., Beamish, R.J., Noakes, D.J. and Neville, C.M. 2003. Replacement of wild coho salmon by hatchery-reared coho salmon in the Strait of Georgia over the past three decades. *North American Journal of Fisheries Management* 23: 492–502.
- Wells, B.K., Grimes, C.B., Sneva, J.G., McPherson, S. and Waldvogel, J.B. 2008. Relationships between oceanic distribution and growth of Chinook salmon (*Oncorhynchus tshawytscha*) from California, Washington, and Alaska, USA. *Fisheries Oceanography* 17(2): 101–125.
- Wertheimer, A.C., Orsi, J.A., Fergusson, E.A. and Sturdevant, M.V. 2009. Calibration of Juvenile Salmon Catches using Paired Comparisons between Two Research Vessels Fishing Nordic 264 Surface Trawls in Southeastern Alaska, July 2008. NPAFC Doc. 1180. 18 pp. (Available at <http://www.npafc.org>)



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