PICES Press

2018 Inter-sessional Science Board Meeting: Notes from the Science Board Chair

May is a beautiful time of the year in British Columbia, Canada, where the PICES Secretariat has its headquarters. You may enjoy tender green and full blooms of dogwood, azalea and rhododendron. On May 8–10 Science Board members gathered for the 16th Inter-sessional Science Board meeting, at the Institute of Ocean Sciences (IOS), Sidney, where the PICES Secretariat has its headquarters. The venue and local logistics were organized by the PICES Secretariat and Fisheries and Oceans Canada (DFO). Dr. Hiroaki Saito, Science Board Chair, welcomed members and guests and declared the opening of the ISB-2018. Dr. Carmel Lowe, Director of the Fisheries and Oceans Canada, Pacific Region, also welcomed attendees and remarked that Canada is about to include marine ecosystems into DFO's research and the work being done by PICES in this regard is of great relevance.

One of the primary purposes of ISB-2018 is to review the activities and progress of PICES' Committees and Program FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems). Inter-sessional meetings of Science Board are an integral part of PICES, and provide an opportunity for Science Board to have a mid-term look at scientific activities and have in-depth discussions that cannot be accommodated at Annual Meetings. One of the first items on the meeting agenda was to look at FUTURE business.

The FUTURE program is guided by a Scientific Steering Committee which held its inter-sessional meeting April 10-12 in Honolulu, Hawaii. As FUTURE is nearing the end of its life span as PICES' integrative science program, one of the primary items discussed by the FUTURE SSC was the outline for a FUTURE synthesis paper based on its FUTURE SEES (Socio-Ecological-Environmental Systems) concept.

Front entrance to the Institute of Ocean Sciences, Sidney, British Columbia.

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The FUTURE SSC identified four examples of changing ecosystems in the North Pacific (fish species alternation, extreme high SST events, jellyfish blooms, shifts of migratory species responding to ocean warming) that were overlain on the FUTURE schematic in order to understand the mechanisms of ecosystem change and to evaluate the contribution of FUTURE to science and societal issues. For more details on SEES and the workshop, see page 17 in this issue.

Each Committee Chair described the activities of his/her expert groups since the last Annual Meeting and also brought up any issues impeding progress, and sought advice on solutions. A new PICES capacity building project, funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, was launched at PICES-2017.

The project, entitled "*Building capacity for coastal monitoring by local small-scale fishers*", or FishGIS for short, will run until 2020. It is a citizen-based approach, using smart phones, that is designed to improve the efficiency and effectiveness in monitoring fisheries and environmental conditions in coastal waters when technical or financial resources are limited. Dr. Joon-Soo Lee, Chair of the Technical Committee of Data Exchange (TCODE), is a member of the Project Science Team. He and other team members completed a successful meeting with local fishers at two sites in Indonesia to demonstrate a smart phone application to monitor water quality changes so that the information can be used to detect fish. The team also gave out a questionnaire for the fishers to fill out so that the team could assess what kind of difficulties they faced in the fisheries. For more on FishGIS, see page 20.

Science Board meeting participants, standing, from left: Igor Shevchenko (representing Russia), Jennifer Boldt (MONITOR), Joon-Soo Lee (TCODE), Steven Bograd (FUTURE SSC), Keith Criddle (HD), Harold (Hal) Batchelder (Deputy Executive Secretary), Tetsuo Fujii (Governing Council, Japan), Sukyung Kang (FUTURE SSC), Motomitsu Takahashi (representing Japan), Junichiro Otaka (Governing Council, Japan), Ken Fujimoto (Advisor, Governing Council, Japan), Chieko Kondo (Advisor, Governing Council, Japan), Nobuaki Suzuki (F&A); sitting, from left: Se-Jong Ju (BIO), Thomas Therriault (Acting Chair, MEQ), Hiroaki Saito (Science Board Chair), Chul Park (PICES Chair), Xianshi Jin (FIS), Robin Brown (Executive Secretary). Missing: Emanuele di Lorenzo (POC), but who participated at the meeting via WebEx. In the background, the Canadian Coast Guard Ship Sir Wilfrid Laurier is tied to the dock.

Some Expert Groups report to Science Board directly. One of them is the joint PICES/ICES/PAME Working Group on an *Integrated Ecosystem Assessment for the Central Arctic Ocean* (PICES WG 39) WG members held a workshop on "PICES contributions to Central Arctic Ocean (CAO) ecosystem assessment" March 22–23 in Sapporo, Japan. They summarized observations and research in the CAO and adjacent seas by PICES member countries and discussed how PICES can contribute to the monitoring and mapping of the CAO in the future. It was also reported that the T/S *Oshoro-Maru V*, Hokkaido University, will visit to Pacific Arctic in summer 2018. In April, WG members met in St. John's, Newfoundland, Canada, to review an outline for a report on Integrated Ecosystem Assessment of the Central Arctic Ocean. More details on the CAO can be found in Sei-Ichi Saitoh's article in this issue.

The Study Group on *Scientific Cooperation in the North Pacific Ocean* (SG-PICES-NPFC) was established at the last Annual Meeting in Vladivostok. The intent of this Study Group is to develop a framework for scientific collaboration between PICES and the North Pacific Fisheries Commission (NPFC) that will foster a greater understanding of pelagic ecosystem structure and variability and its effect on the dynamics and production of fisheries target species. On March 12–15, an NPFC/FAO workshop, sponsored by PICES, was held in Yokohama to discuss the interaction between deep-sea fishing and vulnerable marine ecosystems (VMEs) in the North Pacific. Potential collaboration with PICES can play a strong role by providing expertise, scientific advice and assistance with some of the scientific analyses related to assessing the impacts of fishing in VMEs, and developing tools for spatial management measures to assist in decision-making. The scientific cooperation outside of VMEs will likely be discussed at PICES-2018. For more details on the workshop, see the article by Chris Rooper and Masashi Kiyota in this issue.

The other new group established at PICES-2017 was the Study Group on *Marine Microplastics* (SG-MMP). Dr. Wonjoon Shim was recently appointed Chair of the Study Group. Some members of SG-MMP and the ICES Group on Marine Litter met informally at the International Marine Debris Conference, March 12–16, in San Diego. Discussions focused on the potential for collaboration, including the formation of a joint PICES/ICES working group. SG-MMP will meet at PICES-2018 to discuss a proposal for a working group, and collaboration with scientists outside of PICES.

Taking advantage of the fact that two chairs of expert groups work at IOS, Science Board invited them to report on activities of their expert groups. Dr. James Christian, Co-Chair of the Section on *Carbon and Climate*, presented a draft of an outreach publication on the current state of knowledge regarding ocean acidification and de-oxygenation in the North Pacific being developed by the Section. The report, similar in format as PICES' North Pacific Ecosystem Status Report Special Publications, will be aimed at scientifically literate readers such as teachers and policy makers. Science Board looks forward to seeing a completion of the draft at PICES-2018.

The third North Pacific Ecosystem Status Report (NPESR3) is a key activity of PICES to assess the status and trends in North Pacific marine ecosystems, and the vulnerability and resilience of ecosystems to changes in the climate and to human activities. Mr. Peter Chandler, Co-Chair of the Working Group on NPESR3 reported that a total of 119 environmental time series observations (ETSOs) from 6 PICES member countries have been submitted to the NPESR3 website so far but the distribution of ETSOs are very uneven among the PICES biogeographical regions, *e.g*., limited submissions for the regions in the high seas. This reflects the monitoring activities in the North Pacific but indicates that PICES and NPESR3 need to pay more attention to the ecosystems in the high seas which influence the changes observed in coastal environmental time series observations (ETSOs).

Symposium on "*Understanding changes in transitional areas of the Pacific*" took place April 24-26, in La Paz, Mexico. More than 140 scientists from 12 countries participated to exchange new findings of physical, chemical and biological processes taking place in complex transitional areas of the Pacific Ocean. Because of their nature, transitional areas are expected to reflect the impacts

ISB-2018 in session.

of climate variability and change more dramatically and sooner than other more homogeneous areas, making them regions of particular interest. Prior to the symposium, a ½-day PICES–Mexico Special Session was held to introduce PICES to the Mexican scientific community and Mexican scientific achievements and activities in marine science to PICES. This was followed by a round-table broad-ranging discussion on mutual interests of Mexico and PICES in North Pacific marine sciences and identifying any problems or gaps in engaging in closer collaboration. More information on PICES–Mexican collaboration and the Pacific transitional symposium and can be found later in this issue.

PICES also was the lead organizer/coordinator of the 4th Symposium on "*The effects of climate change on the world's oceans*" June 4–8 in Washington DC. Other primary cosponsors were ICES, IOC and FAO, and many other organizations contributed funding to support this important conference. Approximately 600 attendees took part from all over the world. You can read more on this symposium in the following articles.

Tom Therriault, Hal Batchelder and Steven Bograd reaching shirt consensus at the ISB-2018 meeting.

In order to tackle the emerging issues of the North Pacific caused by climate change and increasing human demands on marine ecosystem services, and to respond to requests from society, it is essential to collaborate with international organizations and projects. The United Nations is preparing the second World Ocean Assessment (WOAII) which will be basic information for the UN's Decade of Ocean Sciences for Sustainable Development (2021–2030). PICES nominated scientists to the pool of experts. It is expected that NPESR3, when completed, will contribute to the assessment report. PICES has collaborated closely with the International Council for the Exploration of the Seas (ICES) on several jointly investigated expert groups. The organizations have begun to discuss developing a potential joint expert group on aquaculture, a subject which is becoming critical for food supplies and economies in the North Pacific and North Atlantic. Science Board agreed to support an ICES-PICES Symposium on "*Shellfish – Resources and invaders of the North*" which will be held in Trømso, Norway, in 2019 (dates to be announced soon).

Also, Dr. Lidia Yebra (Spain) was approved and welcomed as an *ex-officio* member on the PICES WG on Zooplankton Production Methodologies, Applications and Measurements in PICES Regions (WG 37).

Part of the Science Board team enjoying beverages and good conversation after a full day of science business. Clockwise from bottom: Jennifer Boldt, Se-Jong Ju, Xianshi Jin, Igor Shevchenko, Joon-Soo Lee and Tom Therriault.

Science Board agreed it was essential to maintain a Science Board Chair-elect position to allow an incoming new chair time to understand duties and prepare for them before the completion of Dr. Saito's term at PICES-2019. This position enables a smooth transition into the duties of Science Board chairmanship and provides for continuity of Science Board business. The Chair-elect term is for one year, starting from PICES-2018. Individuals within or outside of PICES can be nominated or can apply, although they must be citizens of one of the 6 PICES member countries. The procedure for nominations or applications will be posted on the PICES website soon.

Science Board reviewed the theme of the PICES Annual Meeting in 2019, which will be held in Victoria, hosted by Canada. The theme is "*Connecting science across communities in a changing North Pacific*". We welcome submission of topic sessions and workshops addressing integrative and complex issues of the North Pacific and methods for communicating science to the public. Visit the PICES website to submit Topic Sessions or Workshops for PICES-2019.

PICES-2018 Annual Meeting will be held in Yokohama from October 25 to November 4, hosted by Japan. The theme is "*Toward integrated understanding of ecosystem variability in the North Pacific*". Port of Yokohama was one of the first ports to be opened in 1859 to international trade after Japan's 230-year seclusion from the rest of the world. After that, Yokohama quickly became the base of foreign trade in Japan, creating the exotic atmosphere of the city. I invite all of you to PICES-2018 in Yokohama!

Hiroaki Saito
Science Board Chair

2018 Pacific Ecology and Evolution Conference

by Travis Tai

PEEC 2018 attendees waving like kelp, Bamfield, Canada.

Another successful Pacific Ecology and Evolution Conference (PEEC) has come and gone. February 23–25, 2018 marked the 39th annual occasion, taking place in Bamfield, BC—the gateway to Barkley Sound on the west coast of Vancouver Island. Bamfield Marine Science Centre once again kindly hosted the conference, and has provided PEEC with outstanding service and 2018 was no exception. We had an excellent turnout this year from 8 different institutions, some as far as Laval, Quebec. There were 96 in attendance for PEEC 2018, including our workshop leaders and the keynote speaker and his family—one of the highest attendances in recent years.

PEEC 2018 began with an unexpected weather obstacle in the lower mainland on the morning of Friday, February 23. Anyone from Vancouver and the lower mainland knows far too well the chaos that ensues with any amount of snow, so an unusual late February snowstorm that dumped up to 15 cm of snow threw many parts of the city into a driving nightmare. As a result, we delayed the chartered ferry to take PEEC attendees to Bamfield. We thank the ferry operator (Lady Rose Marine Services) for kindly agreeing to delay the sailing by 1 hour and catering to those delayed by the snowstorm. While this was a major complication, we are glad it all worked out and everyone made the ferry. Bamfield bound!

Onboard the *Frances Barkley* for the ~3.5 hour sailing, we broke out into teams for an icebreaker scavenger hunt and trivia. Team names were based on various organisms and they were set to compete in science communication activities all weekend and gain points towards prizes. These teams were randomly assigned and facilitated in getting to meet new people. The idea was very positively received and added a new dimension of engagement and involvement by all!

Day 2 (February 24) of the conference was full of riveting scientific presentations and discussions. This year there were 59 oral presentations and 17 poster presentations. Oral presentations covered a number of very interesting topics which can be found in our conference abstracts here. This made it extremely difficult to choose between concurrent sessions! We also introduced an alternative to clapping for presentations. Presentation rooms are divided by thin partitions that allow sound to carry through very well. So instead, we got everyone to snap fingers. This took a few talks to get used to the change, but by the last talk everyone was doing it! The turnout to the evening session of posters was also a huge success. Posters were very well designed and kept people engaged for the entire session. We had to remind people to wrap up in order to start the evening party reception! We would like to congratulate all

attendees for a remarkable display of presentations, engagement, and respect as presenters and audience members. Every presentation was outstanding in quality, making the selection for the awards competition very difficult for judges. PEEC had three presentation formats up for competition this year: 12-minute oral presentations, 3-minute oral presentations, and poster presentations. Congratulations to the winners of the presentation awards (listed in order from 1st to 3rd):

12-min oral
Lily Haines (SFU); Mae Frank (TRU); Jen Magel (UVic)

3-min oral
Samantha James (UBC); Ellika Crichton (UBC); Kat Nicolich (UVic)

Poster
Melissa Orobko (SFU); Alex McDonald (VIU); Daniel Zayonc (SFU)

We would like to extend our appreciation to the 25 judges who made this possible and willingly agreed to take on extra judging.

This year's conference activities, workshops, and keynote speaker were organized around a central theme: science communication. Search #PEEC2018 on Instagram, Twitter, and Facebook to see photos and updates of the conference over the weekend.

Before dinner on day 2, we had two science communication workshops. The first workshop was on "How to use social media to communicate your science to non-experts, and why you should", and led by shark specialist Dr. David Shiffman. Dr. Shiffman provided an excellent overview of using Twitter (and other social media) as a platform to communicate science. Workshop participants left with a working Twitter account and knowledge on how to effectively use it for communication.

The second workshop was titled, "Science communication: the crash course". This was led by Mr. Michael Unger, from the Science Communication And Training (SciCATs) group. In this workshop, Michael stressed the use of the "so what?" question when communicating science to difference audience groups. Participants were then provided with a variety of techniques to communicate their science in ways that facilitate interest to different audience groups. Thank you to our workshop leaders; participant feedback was excellent and everyone was very impressed.

Clockwise from top left: Tim Cashion's time lapse GIF of fishing catch intensity; Anna Bishop capturing her audience's attention; stunning pollution facts by Mae Frank; winner Melissa Orobko beside her beautifully designed poster.

After all oral and poster presentations were completed, the evening PEEC dance party commenced. This year's costume theme was Science Superheroes and Villains. To my surprise, there were remarkably creative costumes this year! We were graced with the presence of superheroes such as Jane Goodall, the Pow-R Rangers, and The Magic Schoolbus' Miss Frizzle. Super villains were out and about, and we caught a glimpse of Public Anemone #1, Reviewer #2, and even The Great Pacific Garbage Patch was floating around. We even had a superhero-villain battle between The Averagers and Standard Deviation. Costume winners were Elon Muskox and the duo of Mermaid Girl and Barnacle Boy. We also had a projector showing video clips of Planet Earth II and Blue Planet II playing in front of the dance floor!

Science superheroes and villains.

On the final day, we continued along the theme of science communication for the keynote speaker, Dr. Chris Harley. Dr. Harley presented a clever integration of his research and science communication. He intertwined the two topics to show intertidal differences along a geographical gradient as a proxy of potential climate change impacts, whilst presenting the results in various ways that would interest kids, non-scientists, other scientists, and government. His talk was engaging and interactive, and provided the audience with an excellent summary of science and communication. We could not have asked for a better way to wrap up the overall theme of PEEC 2018. Thank you, Dr. Harley.

Keynote speaker, Dr. Chris Harley, on how to communicate to different audiences.

In our closing remarks, we announced prizes for team social media contests over the weekend. Teams competed in an Instagram contest, and #TeamPhage was the winner with the best team photo. The team with the most conference tweets in our twitter contest was #TeamAgaric. One of the social media highlights was #PEEC2018 making the trending list as identified by Trendsmap Vancouver. Even more, one of Dr. Shiffman's tweets caught the attention of one of BBC's Blue Planet II director/producers!

Year after year, Bamfield Marine Science Centre has continued to impress the organizing committee and attendees in helping PEEC operate flawlessly, providing accommodation, venue, food, and logistic support. Thank you, Bamfield Marine Science Centre, for your dedication to PEEC. Thanks to all members of housekeeping, kitchen, maintenance, administration, and foreshore staff that worked tirelessly to facilitate day-to-day operations during the conference. A special thanks to Tao Eastham (Events Coordinator) who was there almost every minute of the conference to ensure a successful PEEC 2018.

PEEC is a graduate student organized conference, and individuals of the organizing committee volunteer their time to make this successful every year to motivate individuals to return and inspire the next group of conference organizers. We would like to thank the organizers from the University of British Columbia (UBC) this year: Anna Smith (chair), Amelia Hesketh (finance & admin), Liam Coleman (scientific program), Pierre Rogy (communications), Stephanie Blain (marketing), Ellika Crichton (awards), Sam Straus (sponsorship), Samantha James (sponsorship), and Travis Tai (sponsorship). We wish the best for the next organizing committee from UVic (University of Victoria).

Lastly, PEEC would not be possible without the help of sponsors. PICES was a big contributor as a Gold Sponsor this year. We would like to extend our thanks to our Platinum Sponsors – University of Alberta (U of A) Department of Biological Sciences; Gold Sponsors – PICES, Pacific Salmon Foundation, UBC Faculty of Forestry; and Silver Sponsors – Tula Foundation, UBC Faculty of Science, U of A Faculty of Science, and Ocean Networks Canada. Thank you to all of our Bronze and Supporter Sponsors, and all businesses that donated gifts and prizes.

Travis Tai (t.tai@oceans.ubc.ca) is a PhD candidate at the Institute for the Oceans and Fisheries, UBC. His research is interdisciplinary and focuses on integrative approaches to determine ocean acidification effects on biophysical and socioeconomic components of marine capture fisheries at a global scale and in Canada.
Twitter: @trav_es_t; Website: http://oceans.ubc.ca/person/travis-tai/

Applying global experiences to regional assessments: A workshop on the Protection of Vulnerable Marine Ecosystems in the North Pacific Fisheries Commission Area

by Chris Rooper and Masashi Kiyota

Vulnerable marine ecosystems (VMEs) are benthic habitats comprised of taxa that are typically long-lived and slow growing, and that become reproductively mature at advanced ages. These life history characteristics make them very susceptible to impacts from disturbances, such as deep-sea fishing and seafloor mining activities. VMEs are may also be impacted by the effects of climate change and ocean acidification, since these ecosystems occur in generally stable deep-water environments and can require calcium carbonate or other minerals for their skeletons. In the North Pacific Ocean VMEs are generally comprised of taxonomic groups such as Gorgonians and Scleractinians (for corals) and Hexactinellids and Demosponges (for sponges). In the North Pacific Ocean, the existing VMEs are vulnerable to damage from both the ongoing bottom contacting fishing gear (bottom trawls, longlines, pots, gillnets) and the effects of climate change (warming and acidification). These ecosystems are of particular concern in the North Pacific Ocean because of their role as habitat for fishes, their trophic role in the ecosystem and their life history characteristics which make them slow to recover.

The North Pacific Fisheries Commission (NPFC) is the Regional Fisheries Management Organization (RFMO) for international waters (exclusive of nations' EEZs) of the northern Pacific Ocean. This includes the PICES region of interest (north of 30 degrees latitude), where it occurs in international waters. The objective of the NPFC is to "ensure long-term and sustainable use of the fisheries resources in the Convention Area while protecting the marine ecosystems of the North Pacific Ocean in which these resources occur".

Bottom fishing in the North Pacific Fisheries Commission Convention Area is limited to a subset of seamounts south of 45 degrees and north of the northern Hawaiian Islands (USA EEZ) in the Emperor Seamount chain in the western North Pacific Ocean and about 8 seamounts in four aggregations in the eastern North Pacific Ocean. Canada, Korea, Japan and Russia are convention members that currently participate in these fisheries, with Canadian fishing vessels operating exclusively on the eastern seamounts and Korea, Japan and Russia operating in the Emperor Seamount Chain. The Korean, Japanese and Russian fisheries utilize bottom trawls, gillnets and longlines and in recent times only a small number of vessels from each country have participated in the fishery (1, 4 and 1, respectively). The trawl and gillnet fisheries target the North Pacific armorhead (*Pentaceros wheeleri*) and the splendid alfonsino (*Beryx splendens*), and bottom longlines target skillfish (*Elirepis zonifer*). Historically, there has been a more extensive footprint of the fishery which included seamounts that are now part of the United States EEZ. The Canadian fishery is limited to a maximum of about 6 vessels fishing in a given year, with only a single vessel fishing at a time, and the vessels use longlined pots to capture sablefish (*Anoplopoma fimbria*).

Participants of the NPFC/FAO VME Workshop in Yokohama, Japan.

The goals of the four day workshop were to increase understanding of the interactions between fishing and VME's in the NPFC convention area and to draw on the experiences of other Regional Fisheries Management Organizations (RFMOs) and experts to make recommendations on how the NPFC can put in place appropriate measures to protect and assess impacts on VME's. The meeting was chaired by Drs. Masashi Kiyota (Japan) and Loh-Lee Low (USA). The workshop was held at the National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency in Yokohama, Japan, from March 12–15, 2018, and was sponsored by the NPFC, FAO and PICES. Representatives from Japan, Canada, China, the Republic of Korea, Russia and the United States attended the meeting. In addition, invited experts from two other RFMO's (the Convention for the Conservation on Antarctic Marine Living Resources and the South Pacific Regional Fisheries Management Organization) and representatives of PICES, FAO and the Deep Sea Conservation Coalition were also in attendance.

The workshop began with presentations by representatives of FAO and RFMOs on the role of these organizations in management of impacts on VMEs and deep-sea fisheries. These presentations provided a good introduction to the issues around VMEs, particularly with regards to United Nations General Assembly Resolution 61/105 that seeks document and mitigate significant adverse impacts of fishing activities on VMEs and implement a precautionary approach to VME management. Dr. Hassan Moustahfid highlighted a recently published [document](#) from FAO that reports on the global efforts to manage and protect VMEs and Dr. Tony Thompson presented the legal framework for international obligations for VME management. Dr. Odd Aksel Bergstad provided historical background on seamount bottom fisheries across multiple Atlantic Ocean RMFOs (presented by Dr. Ellen Kenchington) and the nations currently participating in NPFC fisheries each presented information on their current fishing activities in the region.

Invited experts examined VMEs from a number of perspectives, with many interesting presentations on current and historical research. These presentations fell into a number of sub-themes and each provided background and a summary of lessons learned. The workshop organizers drew from a wide variety of experts in order to provide examples of successful research and management of VMEs in other RFMOs and individual countries. Drawing on the presentations and discussions from both invited experts and representatives from NPFC member states, the interesting points and highlights of the workshop are given organized by sub-topic below.

Species characteristics and VME identification

One of the more informative topics brought out by presentations and general discussions was the definition and identification of VME taxa. Dr. Tatiana Dautova (Russia) provided an overview of her research on the taxonomy and connectivity of coral populations in the North Pacific. This presentation highlighted the connectivity of coral populations, not only in the North Pacific, but potentially on a broader scale (globally) for some taxonomic groups including *Paragorgia* corals. Potential mechanisms for connectivity among populations was discussed broadly by the group as well as the potential "source" in an evolutionary sense of the corals that occur in the North Pacific. Clearly more research is required on this research topic.

One of the key points of the discussions of species characteristics and identification was the relatively high level of taxonomic uncertainty for a number of VME groups in the North Pacific Ocean. Drs. Eunjung Kim (Korea), Bob Stone (USA) and Cherisse Du Preez (Canada) all spoke about their respective efforts to produce reference materials for VME identification. In particular, Dr. Kim's presentation provided an example of a taxonomic guide that was being developed by collaborators from Korea and the USA that could be easily used by fisheries observers to identify VME indicator species. It was clear from these discussions that a uniform approach to taxonomic identification and training observers was needed for the NPFC region.

Finally, a wide ranging discussion of VME characteristics brought out the important point that there are unique differences between VMEs in the eastern and western NPFC area. Although sponges and corals occur on both sides of the North Pacific Ocean, the discussion indicated that sponges tend to make up a larger portion of the VME taxa in the east than in the west. Gorgonian and Scleractinian corals appear to be more prevalent in the Emperor Seamounts than the seamounts in the eastern North Pacific.

Fisheries characteristics and potential impacts

Presentations describing the existing bottom contact fisheries in the North Pacific Ocean indicated that they appear to be fairly limited in terms of number of vessels participating (although concerns with unreported fishing activity that may be occurring was also referenced during discussions). However, there is limited life history information for the two species fished in the Emperor Seamounts (North Pacific armorhead and splendid alfonsino) and the occurrence of fishable abundance is determined by entry of new recruits to the adult population. The sablefish population that is fished on eastern North Pacific seamounts appears to be connected to populations within the EEZ of Canada and the USA and because of this, more is known about the population dynamics and status. The gear types used by the countries participating in the seamount fisheries; longlined pots (Canada), bottom gillnets (Japan) and bottom trawls (Japan and Korea) are all known to have impacts on VMEs.

Dr. Ellen Kenchington (Canada) presented an assessment of actions that have been implemented in other RFMOs in the Atlantic Ocean and the eastern Canadian EEZ to address significant adverse impacts on VME taxa. One of the highlights of this presentation was the discussion of the role of VMEs in ecosystems and benthic ecosystem functions. Studies examining sponges in the Atlantic revealed that they can filter 95% of the particulate matter from about 25,000 litres of water per day. The role of VME taxa in communities can thus be very important to the functioning of the ecosystem and Dr. Kenchington's presentation demonstrated the need and current methods used for identifying and surveying VMEs and assessing impacts on these communities.

Assessment of impacts of fishing on VME taxa is often difficult to document. Dr. Chris Rooper (USA/PICES) presented information on the rates of damaged VME taxa from the eastern Bering Sea in Alaska, where sea whips, corals and sponges have all been impacted by bottom fishing gear, with sea whips being the most commonly impacted due to their occurrence in an area with intensive fishing. Dr. Rooper also presented a summary of efforts in the Alaska region to account for bycatch of VME indicator species using fisheries observers and bottom trawl survey collections as well as changes in fishing gear implemented in Alaska that have led to reduced VME impacts.

An invited expert, Dr. Amy Baco-Taylor (USA), presented an overview of a recent research cruise to the Emperor Seamounts and northern Hawaiian Ridge. This presentation was broadly discussed throughout the workshop, as Dr. Baco-Taylor found evidence of the impacts of fishing on VME taxa at actively fished seamounts. Dr. Baco-Taylor also found evidence for recovery and potentially new recruitment of Scleractinian and Gorgonian corals in areas where fishing had stopped when the USA extended its EEZ. This is a relatively unique finding and prompted much discussion on the implications of recovery on management strategies (e.g. should management focus on "freezing the footprint" of existing fisheries or recovering previously impacted areas where VME taxa were likely to occur).

Another important conversation centered around the rules for what fishing vessels should do when they encounter VME taxa as bycatch. Dr. Masashi Kiyota (Japan) led a wide ranging discussion of these VME encounter protocols and their implications. Much of the focus of these discussions was guided by the experiences of other RFMOs in implementing encounter protocols (especially in the CCAMLR region). It was generally concluded that the existing encounter protocols were too generic and broadly applied across taxonomic groups and regions. For example, the absence of Scleractinian corals from bycatch in areas where they were known to exist creates some concern about whether encounter protocols are effective in

addressing concerns for these taxa. Additionally, there was a large amount of discussion on whether move-on rules, temporary closures and communication of temporary closures as currently implemented were effective at reducing encounters with VME taxa.

Exploratory fishing was a somewhat related topic addressed by Dr. Dirk Welsford (Australia/CCAMLAR). Exploratory fishing protocols can rely on the same encounter protocols as for non-exploratory fishing activity, so the participants raised some similar concerns for this topic with regards to move-on rules, temporary closures and regional and taxa-specific encounters. Another consideration for exploratory fishing is the importance of data sharing from these activities among member nations and fisheries and making distinctions (and potentially different rules) for research activity versus fishing activity. The experiences of Dr. Welsford and the different RFMOs were very helpful in guiding this discussion, as exploratory fishing is a topic that has been approached differently in the different regions.

Spatial management techniques

One of the approaches that can be used to evaluate and mitigate impacts of fishing activity on VMEs is by using spatial management techniques. Highlights of talks describing spatial management methods included the descriptions of experiences and approaches from other regions (SPRFMO, CCAMLR, and NAFO) and presentations on North Pacific seamount VMEs. The basis for many of the approaches from RFMOs outside the North Pacific and within member nations' EEZs is formulating maps or species distribution models that identify potential areas of VMEs.

Dr. Chris Rooper (PICES/USA) presented research on how fishing closures have been implemented and evaluated in Alaska. The research began with building spatially explicit models of the distribution of coral and sponge ecosystems in Alaska and validation of these models using independent surveys. This work allowed evaluation of the proportion of VME habitat that was closed to fishing in each of Alaska's large marine ecosystems, as well as the proportion of high value, high density and high diversity areas that were currently in closed areas. This evaluation showed some interesting results for VMEs in Alaska, in that even though ~50% of the coral and sponge habitat was open to fishing in the Aleutian Islands, only ~15.4% of the open area was observed to be fished (estimated from vessel monitoring data). It also showed that for some regions, significant portions of closed areas were devoid of VME taxa. The major lesson learned from these studies was that careful evaluation of fishing patterns relative to the distribution of VMEs can provide important data for ecosystem management.
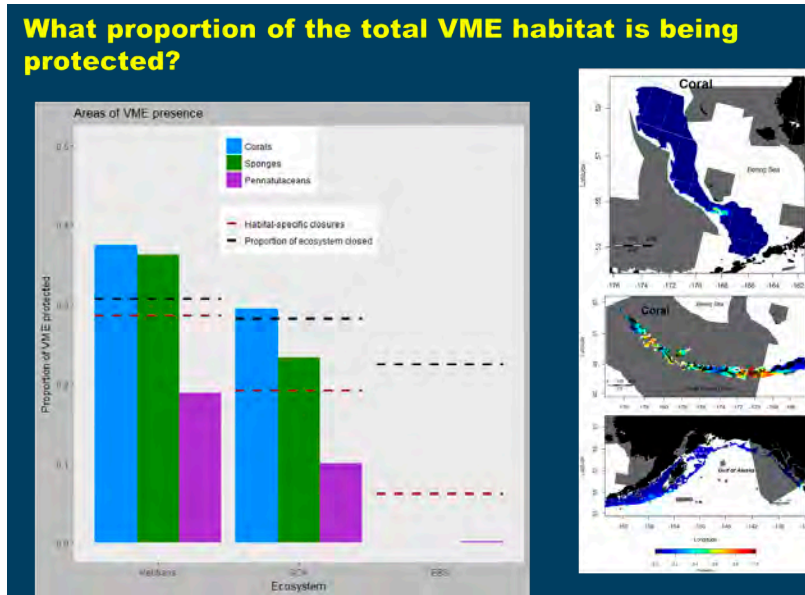
Estimated proportions of total area of coral and sponge (VME) presence protected from mobile bottom fishing gear in Alaska ecosystems using species distribution models and existing area closures (data courtesy of Chris Rooper Alaska Fisheries Science Center, USA, PICES WG 32 member and John V. Olson, NMFS - Alaska Regional Office, USA).
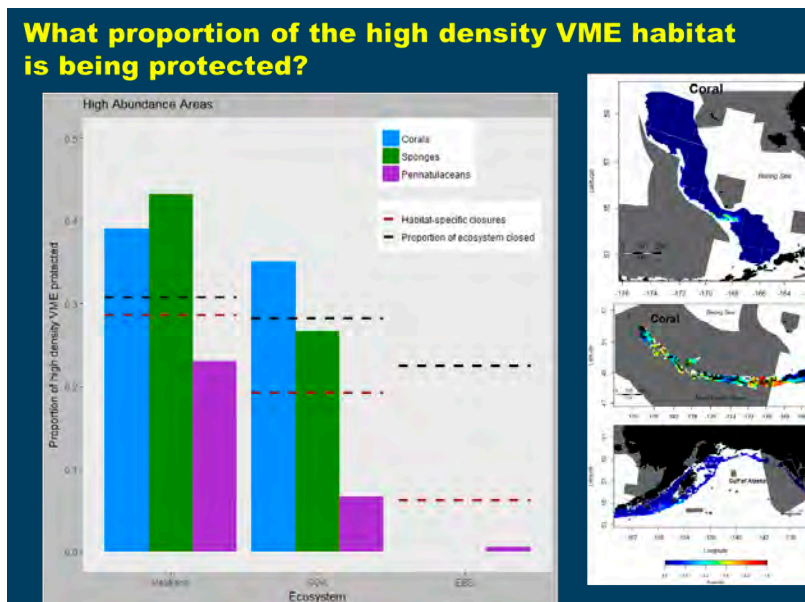

Estimated proportions of high density coral and sponge (VME) habitat protected from mobile bottom fishing gear in Alaska ecosystems using species distribution models and existing area closures (data courtesy of Chris Rooper Alaska Fisheries Science Center, USA, PICES WG 32 member and John V. Olson, NMFS - Alaska Regional Office, USA).

Dr. Ashley Rowden (New Zealand/SPRFMO) and Dr. Martin Cryer (New Zealand/SPRFMO) presented a summary of the SPRFMO experience in managing VMEs and fishing. This summary, in particular stood out as a very well developed example of the use of spatial management measures to protect and conserve VMEs. In this example, member nations developed distribution models for VMEs, tested and validated these models using field observations, brought in fisheries participants to map where fishing was occurring and was most profitable and then combined these in a spatial decision making software program (Zonation) to provide a tool with which management decisions could be made in a spatially explicit framework. The tool allowed stakeholders to consider trade-offs among objectives (such as maximizing fish production vs. maximizing VME protections) when evaluating management decisions. The example from SPRFMO would serve as an excellent guide for development of VME management for other RFMOs including the NPFC.

Within the NPFC, there have also been some initial steps to begin mapping and modeling VME distributions. Dr. Masashi Kiyota (Japan) presented the results of an impact assessment study for the Emperor Seamounts. The presentation included information from research that examined the overlap of fishing activity and benthic taxa on a small scale (using underwater cameras). As part of these analyses, Dr. Kiyota presented the results of association analysis developed by Dr. Mai Miyamoto to evaluate the representativeness of VME indicator taxa. These analyses were useful in identifying two actual VMEs occurring on the outer margins of main fishing grounds on the Emperor Seamounts.
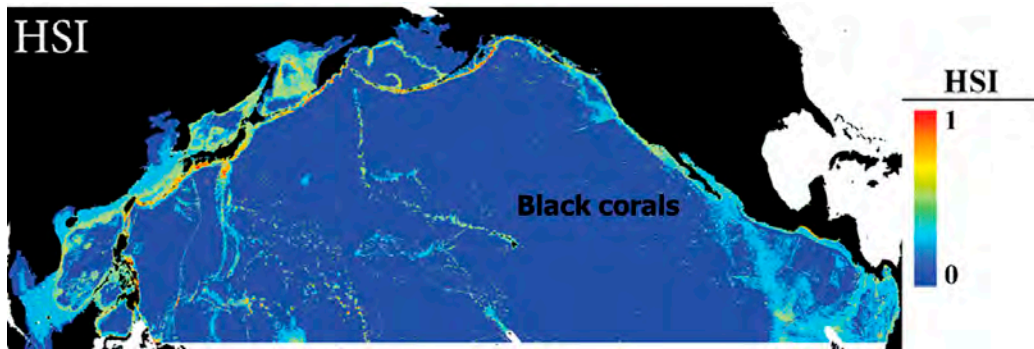
Predicted probability of habitat suitability (HSI) for black corals (Antipatharians) for the North Pacific Ocean based on maximum entropy modeling of presence records. Map courtesy of Samuel Georgian (Marine Conservation Institute, USA, PICES WG 32 member).

Also in the North Pacific Ocean PICES Working Group 32 (Biodiversity of Biogenic Habitats) has been working on VME distribution models for the North Pacific Ocean. In 2016 this working group sponsored a workshop (W3, Distributions of habitat-forming coral and sponge assemblages in the North Pacific Ocean and factors influencing their distributions). A number of workshop participants (predominantly from Canada and the USA) have been developing a suite of environmental indicators and species distribution models for VME taxa in the broader North Pacific Ocean. These efforts were summarized by Dr. Rooper, with reference to the upcoming PICES Topic Session titled "Indicators for assessing and monitoring biodiversity of biogenic habitats to be held at PICES-2018 Annual Meeting.

Recommendations

Each of the presentations were followed by wide ranging and interesting discussions. Breakout groups were also used to address specific topics. Many of these discussions and breakout groups resulted in recommendations that were assembled on the final day of the workshop. There were a number of recommendations for managing VME's (~30 in total) in the final report, covering topics such as data collection and management, encounter protocols, significant adverse impact assessments, fishing footprints, exploratory fishing protocols, and spatial management measures. The recommendations of particular interest to the PICES community were:

- The need to put in place a data sharing agreement among member nations;
- Standardization of data collection protocols (including taxonomic guides) among member nations;
- Development of area specific indicators and taxon encounter thresholds instead of generic indicators and thresholds;
- Development of measurable objectives for assessing impacts of fishing on VME's;
- Consideration of fisheries closures for both "pristine" and "recovering" VME sites;
- Development of tools for spatial management measures (SDM and maps, Zonation tools) that can assist in decision-making;
- Periodic reviews and updates of VME management with new information as it becomes available.

These and the other recommendations generally reflected the desire to put into place a framework that will allow for the input of additional relevant scientific data that can contribute to the decision-making processes within the NPFC. Finally, there was quite a bit of discussion of potential collaboration with other organizations (such as PICES) to provide expertise, scientific advice and assistance with some of the scientific analyses. This recommendation will likely be a topic of discussion for the Joint PICES-NPFC Study Group for *Scientific Cooperation in the North Pacific Ocean*.

Dr. Chris Rooper (chris.rooper@noaa.gov) is a research fisheries biologist with the National Marine Fisheries Service, Alaska Fisheries Science Center in Seattle, Washington. 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. Masashi Kiyota (m.kiyota@nagasaki-u.ac.jp) is a professor at the Graduate School of Fishery and Environmental Sciences, Nagasaki University, Japan. His Ph.D. study was on breeding systems and foraging ecology of northern fur seals and their relation to population dynamics and management. He worked at the Japan Fisheries Research and Education Agency for many years and conducted scientific research on large marine animals such as marine mammals, seabirds, and sea turtles to understand their ecology and mitigate their interactions with commercial fisheries. His recent studies focus on the assessment of fishery impacts on marine ecosystems, including bottom fisheries and VMEs. In PICES, he is Co-Chair of the Working Group (WG 32) on Biodiversity of Biogenic Habitats.

Activities of the joint PICES/ICES/PAME Working Group on an *Integrated Ecosystem Assessment for the Central Arctic Ocean*

by Sei-Ichi Saitoh

At PICES-2016 (San Diego, USA), ICES President, Dr. Cornelius Hammer, made a direct request to Governing Council that PICES join a newly formed Working Group for Integrated Ecosystem Assessment of the Central Arctic Ocean – WGICA established jointly by ICES and PAME (Protection of the Arctic Marine Environment). Approved by Governing Council, PICES joined as the third co-sponsor of this strategic group, making the WGICA a PICES/ICES/PAME Working Group for I*ntegrated Ecosystem Assessment of the Central Arctic Ocean* (PICES' WG 39, under the guidance of Science Board). Preparing an Integrated Ecosystem Assessment (IEA) for the Central Arctic Ocean (CAO) is a needed to provide scientific advice on issues such as the prospect for future fisheries in the Arctic Ocean and sensitivity and vulnerability in relation to shipping activities. The Working Group also aims to improve the understanding of climate and ecosystem variability of the North Atlantic as well as the Bering Sea and Gulf of Alaska in the North Pacific.

As defined in the Terms of reference below, WG 39 will consider approaches and methodologies for an IEA of the Central Arctic Ocean. For this purpose, it will collect relevant data and carry out analyses. Moreover, core research areas will be identified and an outline of the CAO ecosystem will be developed. At present, PICES is represented on WG 39 by six members: three from China, two from Japan and one from Korea. Canada and Russia and USA were represented already by members from ICES and PAME.

The WG 39/WGICA Terms of Reference are to:
1. Consider approach and methodology (-ies) for doing an IEA for the CAO
2. Assemble data and information and carry out appropriate statistical and other types of analyses including mathematical modelling
3. Prepare an IEA outline for the current status of the CAO ecosystem (CAO LME and adjacent slope waters including Atlantic and Pacific inflows and relevant shelf-basin exchanges) and effects, potential effects and vulnerability in relation to climate variability and change and human activities such as Arctic shipping and potential future fisheries
4. Consider requirements and design of monitoring of the CAO to meet the need for repeated IEA in the near future as well as other types of assessments (which can be modular components of IEAs)
5. Identify priority research issues which, when addressed, can improve the knowledge base for the future iterations of the IEA.

WG 39 held its first meeting at PICES-2017 in Vladivostok, Russiato review its terms of reference and to formulate plans for activities, including two inter-sessional workshops in 2018, discussed below.

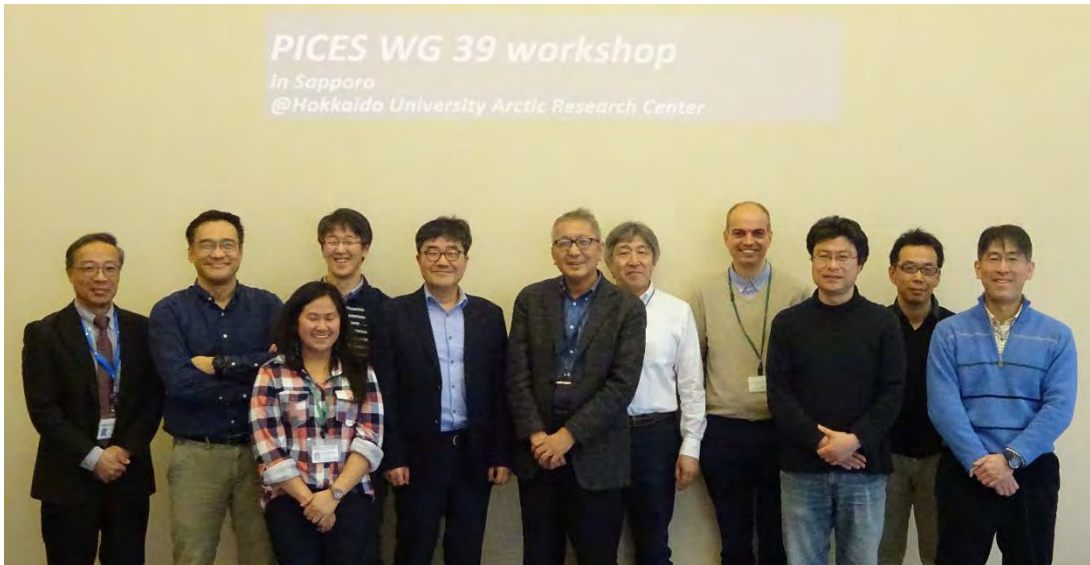### *WG 39's 1st inter-sessional workshop, Sapporo, Japan*

The first workshop of WG 39 on "PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment " was held on March 22–23, 2018, at Hokkaido University, Sapporo, Japan. Co-chaired by Sei-Ichi Saitoh (Arctic Research Center, Hokkaido University), Hyoung-Chul Shin (KOPRI: Korean Polar Research Institute), and Fujio Ohnishi (Arctic Research Center, Hokkaido University), this workshop was mainly technical in nature, and was mostly in preparation for the third meeting of WGICA, which would take place the following month in Canada. The major objectives of the workshop were to:
- Synthesize past activities on observations and scientific research in CAO and adjacent ocean by PICES members, including China, Korea and Japan;
- Assess the contributions of PICES WG 39 to the third WGICA meeting and its report;
- Discuss PICES' potential contribution to monitoring and mapping efforts of CAO in the future.

As a follow-up to this workshop, WG 39 will hold a ½-day workshop of the same name at PICES-2018 in Yokohama, Japan to consolidate the WG's findings and advice, connect it to those from ICES and to report to the wider PICES community.

Sei-Ichi Saitoh chairing the first workshop of WG 39.

Participants of the workshop on "PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment " was held on March 22–23, 2018 at Hokkaido University, Sapporo, Japan..

The 3rd WGICA meeting , St. John's, Newfoundland

WGICA met the first time at ICES headquarters in Copenhagen in June 2016 and for its second meeting in Seattle, USA in April 2017. The third meeting was held April 24–26, 2018 in the historical city of St. John's, located near the southern tip of Newfoundland, Canada. Nadine Templeman from the Department of Fisheries and Oceans Canada acted as local host, and provided the nice weather.

At the third meeting, compiled material to be used in the IEA was presented and reviewed, and a plan for the further work to complete the IEA during 2018 was drawn up.

The meeting was attended by 14 participants from 5 member countries (Canada, Japan, Norway, Russia, and the USA). Three members of the working group could not attend, but gave remote presentations.

In presentations and discussion, information on the various parts of the ecosystem of the central Arctic Ocean (CAO), from physics through lower trophic levels to birds and mammals, was considered with emphasis on spatial aspects and trophic linkages. The issues of vulnerability and linkages between ecosystem components (species and groups of organisms) and human sectors, activities and pressures in the context of Integrated Ecosystem Assessment (IEA) were also on the agenda. The three co-chairs will oversee the process of finalizing the draft IEA report and its publication as a joint ICES/PICES/PAME report. The target date for publication is before the end of 2018, with a complete draft expected to be finished by 1 October.
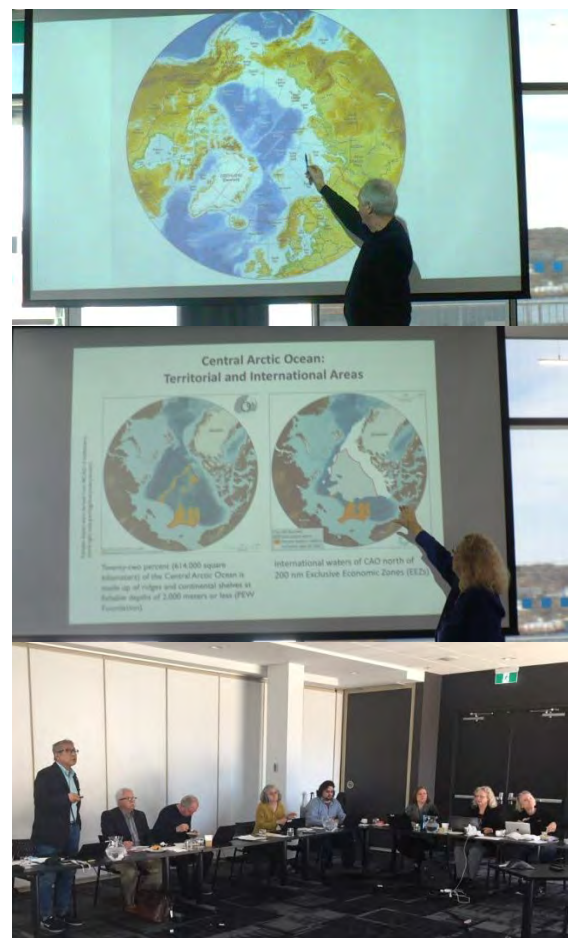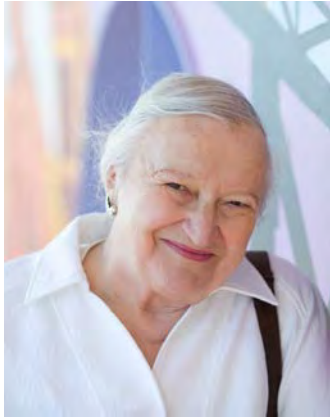

Top, Hein Rune Skjoldal (Co-Chair of WGICA, representing PAME), middle, Jacqueline Grebmeier (WGICA member, representing ICES), and bottom, Sei-Ichi Saitoh (Co-Chair of WGICA, representing PICES) making a presentation at the 3rd meeting of WGICA in St. John's.

In memoriam: Dr. Mary N. Arai

by Jennifer E. Purcell and David G. Welch

Mary N. Arai (deceased September 6, 2017) was a true scholar. Raised in a family of matter-of-fact Canadian feminists and marine biologists, including both her grandmother and mother, Mary promoted women's participation in marine science through her own research and also her review of the contributions of nearly a century of women scientists to Canadian marine science (Arai, 2016). Throughout her career Mary was a role model for women in science due to her exceptional scholarship, kindness, and integrity, as well as her intelligence and class.

Mary obtained a B.Sc. (Hons.) in Biology from the University of New Brunswick in 1952, an M.A. in Zoology from the University of Toronto in 1956 (working partly in Toronto and partly in England at University College London and the Plymouth Marine Biological Laboratory), and a Ph.D. at the University of California, Los Angeles in 1962.

Mary and Hisao Arai, at the 1996 PICES Annual Meeting in Nanaimo, Canada.

At the University of California, Los Angeles, Mary Needler married fellow graduate student, Hisao Arai, a parasitologist. Their long partnership connected their scientific interests across the North Pacific. Mary became one of the first of the few experts on the life cycles of parasites that include both jellyfish and fish (Arai, 1988; Purcell and Arai, 2001). Mary was employed for most of her professional career from Assistant to Full Professor (1969–1996) in the Department of Biology at the University of Calgary where Hisao was a tenured Professor. She spent every summer doing research at the family property adjacent to the Pacific Biological Station in Nanaimo, Vancouver Island, where they retired in 1996. Their retirement home, which they designed, included a laboratory and scientific library. Mary believed in knowing

all scientific contributions on a subject, which led to her numerous review papers (*e.g*., Arai, 1988, 2001, 2005, 2012, 2016).

The jellyfish community benefited greatly from Mary's scientific work. Some of the papers she published on jellyfish focused on topics that the wider research community would only realize the importance of decades later; other studies remain unique to this day, such as her work on prey chemically stimulating jellyfish to feed (Arai, 1991) and on the digestion of jellyfish by fish (Arai *et al*., 2000, 2003). In 1997, Mary published an exceptionally important book on the functional biology of Scyphozoa that continues to be a unique and valuable resource (Arai, 1997). In 2013, at the International Jellyfish Bloom Symposium in Hiroshima, Japan, her contributions to knowledge about jellyfish were honored with a Lifetime Achievement Award.

Mary added to the knowledge on jellyfish and their connections to fish through much of her academic career (*e.g*., Arai, 1988). She attended her first PICES Annual Meeting with Hisao in 1996 in Nanaimo, British Columbia, and gave an invited talk at the 2000 PICES Annual Meeting in Hakodate, Japan (Arai *et al*., 2000). She was a member and important contributor to PICES Working Group 26 (*Jellyfish Blooms around the North Pacific Rim: Causes and Consequences*; Uye and Brodeur (Eds.) 2017) beginning in 2011, and attended two meetings of the WG in Hiroshima, Japan in 2012 and 2013 as part of the Fourth International Jellyfish Bloom Symposium (Arai and Brodeur, 2013).

Mary, with David Welch at the 2004 PICES Annual Meeting, Honolulu, Hawaii.

The scientific community was lucky to have Mary and her contributions. Mary was blessed to be passionate about and contribute to those interests throughout her long life.

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Dr. Jennifer Purcell (purcelj3@wwu.edu) is a research associate in the Biology Department of Western Washington University and a recent Fulbright Senior Scholar. In PICES, she was a contributor to the Working Group (WG 26) and presented talks at Annual Meetings in 2004, 2006, 2007, 2009, 2011, and 2012.

Dr. David Welch (david.welch@kintama.com), President of Kintama Research Services, is the recipient of the Prix de Distinction (2007) and Prix d'Excellence (2008) from Fisheries and Oceans Canada, the J.P. Tully Medal in Oceanography (2011), and the Award of Excellence from the Fisheries Management Section of the American Fisheries Society (2012). David has participated regularly at PICES Annual Meetings since 1993.

Participants of the workshop 3rd WGICA at St. John's, Newfoundland, Canada, from left: John L. Bengtson (Co-Chair of WGICA, representing ICES), Hein Rune Skjoldal (Co-Chair of WGICA, representing PAME), 3rd from right: Sei-Ichi Saitoh (Co-Chair of WGICA, representing PICES).

Dr. Sei-Ichi Saitoh (ssaitoh@arc.hokudai.ac.jp) is the Director of Arctic Research Center and Professor at the Graduate School of Fisheries Sciences, Hokkaido University, where he conducts research, advises graduate students, and teaches courses in satellite oceanography, marine-GIS and fisheries oceanography. He has over 30 years of experience working as a satellite and fisheries oceanographer, GIS specialist, and consultant on fisheries issues in the North Pacific Ocean and its adjacent seas. He also studied the impact of climate change and global warming on marine ecosystems. Within PICES he is a member of the Technical Committee on Monitoring (MONITOR) and Co-Chair of WG 39. He is also one of sub project directors of the national flagship project, the Arctic Challenge for Sustainability (ArCS) supported by MEXT, Japan since 2015.

Highlights from the FUTURE SSC's 4th inter-sessional meeting

by Steven Bograd and Sukyung Kang

The FUTURE Scientific Steering Committee held its 4th inter-sessional meeting since becoming an SSC in 2014. FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems) is PICES' second integrative science program, which was launched at PICES-2009. This year's meeting took place April 10–12, 2018 in Honolulu, Hawaii, USA. The 3-day affair was led by Steven Bograd and Sukyung Kang who are the Co-Chairs of the FUTURE SSC. The meeting was attended by 8 SSC members, SB chair, one representative from the PICES Secretariat, and one guest from the NOAA Pacific Islands Fisheries Science Center, where the meeting was held.
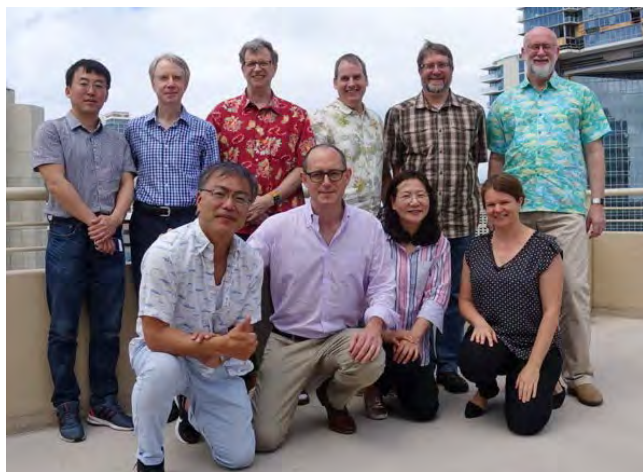
Members of the FUTURE Scientific Steering Committee at their fourth Inter-sessional Meeting in April 2018 in Honolulu, USA. Back row, from left: Guangshui Na (China), Ian Perry (Canada), Harold (Hal) Batchelder (PICES Deputy Executive Secretary), Thomas Therriault (Canada), Steven Bograd (FUTURE SSC Co-Chair/USA), Vyacheslav Lobanov (Russia). Front row, from left: Mitsutaku Makino (Japan), Emanuele Di Lorenzo (USA), Sukyung Kang (FUTURE SSC Co-Chair/Korea), Siri Hakala (PIFSC, NOAA). Missing from photo: Hiroaki Saito(SB chair)

Review of 2017–2018 activities

One of the first things we did was to review FUTURE SSC activities since our last meeting at PICES-2017 in Vladivostok, Russia. An important task identified last year was to populate the [PICES website](#) with easily accessible information about the FUTURE program, including its history, structure and activities. The SSC outlined a new format within the [Projects and Programs page](#) and identified material that still needed to be posted . We also discussed other means to provide improved outreach and communication about the FUTURE program and decided on a short video of the Co-Chairs discussing the FUTURE framework, to be posted online, as well as information on

the program to be included in the next Annual Meeting program (check the PICES website for updates).

The SSC reviewed recent and planned activities of the expert groups that FUTURE parents or co-parents: Working Groups 35 (Third North Pacific Ecosystem Status Report), 36 (Common Ecosystem Reference Points across PICES Member Countries), 40 (Climate and Ecosystem Predictability), and 41 (Marine Ecosystem Services). We noted that a number of WG 36 members are attending the International PICES/ICES/IOC/FAO Symposium on "*The effects of climate change on the world's oceans*" (ECCWO) in Washington, D.C. in June and will take advantage of the venue to hold a WG inter-sessional meeting.

One of the tasks of the SSC is to act as a channel to make sure there is active communication between PICES Standing Committees and their Expert Groups, and between the Expert Groups themselves, and to enhance two-way communications related to FUTURE activities. To do this, we confirmed the current SSC liaison assignments where each SSC member was responsible to look after the needs of his/her expert group(s).

We reviewed our Terms of Reference. While the existing ToR are still appropriate and are being actively addressed, the members decided that it was timely to add a new term to charge the SSC with leading the development of plans for the next, post-FUTURE, PICES integrative science program.

Other FUTURE business included agreeing to contribute funds to help the Section on Carbon and Climate complete its a report on ocean acidification and deoxygenation. The report, aimed at managers, school teachers and nonspecialist scientists will be published as a PICES Special Publication later this year. We also discussed other potential budgeting items, including support for Working Group inter-sessional workshops and support for a postdoctoral scholar or visiting scientist to work on FUTURE priority activities.

Synthesis of the FUTURE Framework

A significant portion of our inter-sessional meeting was used to discuss the existing FUTURE framework, as represented by the FUTURE schematic (below), and to outline a synthesis paper to describe the development and implementation of the FUTURE framework. In general, FUTURE is structured to facilitate communication and interaction amongst the components of our Social-Ecological-Environmental System (SEES). The SSC

revised the FUTURE schematic to give it a cleaner, more general look, and constructed a detailed outline for the synthesis paper with individual writing assignments. We also developed customized schematics and narrative outlines for four case studies that demonstrate the utility of the FUTURE framework to address SEES issues: (a) species alternation in the western Pacific, (b) ecosystem impacts of an extreme event in the northeast Pacific, (c) jellyfish blooms in the western Pacific, and (d) warming and distributional shifts of migratory species in the North Pacific. The synthesis paper will be prepared over summer 2018 by all SSC members, with a target submission to the journal *Frontiers of Marine Science* in October 2018.
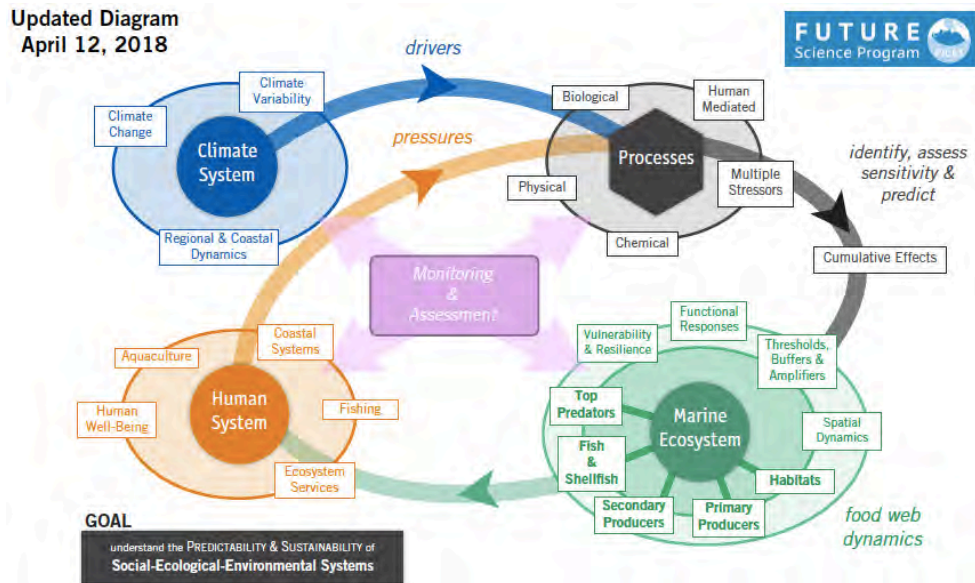
General version of FUTURE SEES.

Plan for 2018-2019 activities

One of the PICES-sponsored events that the FUTURE SSC was involved in was the International Symposium on "*Understanding changes in transitional areas in the Pacific*" (PTA) in La Paz, Mexico, April 24-26 (see accompanying articles in this issue). At the PTA, this article co-author, Steven Bograd, presented an overview of the FUTURE program at the U.S.-Mexico PICES Summit, with the aim of alerting Mexican marine scientists to the program's activities and offering potential for collaboration. A poster of the FUTURE program was also featured at the Poster Session. Other meetings the FUTURE SSC members will be participating in will be the 4th climate change symposium (ECCWO) in June and PICES-2018 in Yokohama, Japan in October. At ECCWO, members of the FUTURE SSC will attend the WG 36 workshop on "*Quantifying thresholds in driver-response relationships to identify reference points*". At PICES-2018, FUTURE will sponsor a Plenary Session on "*The FUTURE of PICES: Next steps in understanding, forecasting and communicating climate impacts on North Pacific marine ecosystems*" which will serve to summarize FUTURE

activities and priorities for the PICES community and allow key Expert Groups to present their FUTURE-related activities and products. The FUTURE SSC will also propose to hold a workshop on "*A Guide to Communicating PICES Science to Scientists, Governments, Stakeholders and the Public*" at PICES-2019 in Victoria, Canada, which will address one of the key objectives of the FUTURE program, i.e., developing strategies for communicating PICES science to a variety of stakeholders. Another workshop on "*Implementation for SEES for Early Career Scientists*" may be proposed for a future Annual Meeting.

Finally, the SSC prepared an Action Plan for the remainder of 2018, which includes: (a) finalizing and distributing a FUTURE Product Matrix; (b) revising the Terms of Reference to include planning for the next PICES integrative science program; (c) developing FUTURE outreach products (video and conference booklet information); (d) preparing for PICES-2018; and, most importantly, (e) finalizing the FUTURE synthesis paper for submission.

PICES Interns

We are pleased to announce that Ms. Jinqiu Du is joining the Secretariat as a PICES intern in July 2018 and will be hard at work assisting with preparations for PICES-2018.

Jinqiu Du grew up in Tianjin, a northern coastal city in the People's Republic of China. Jinqiu is presently a Research Associate at National Marine Environmental Monitoring Center in Dalian, China. She graduated from Xiamen University with a M.Sc. in Marine Chemistry in 2011 and is currently pursuing her Ph.D. at the Ocean University of China. Her thesis is "Evolution Characteristics of the Sedimentary Environment in Coastal Sea Areas based on Isotope Tracers". She has participated and presented at several PICES Annual Meetings and special symposia. She is currently engaged in research projects studying sources and sinks for sedimentary organic carbon and contaminants in Liaohe estuary, Bohai Sea. Jinqiu has multiple publications in Chinese scientific journals, including an article titled "*Development and prospect of China's participation in PICES science activities*" (*Chinese J. Ocean Development and Management*, 2017, 34: 20–25.

Jinqiu enjoys travelling, hiking and making new friends. She will be accompanied by her husband and her 4 year old daughter. They hope to have the opportunity to enjoy the great Canadian outdoors during their stay.

We express our gratitude to Alexey Khoruzhiy for assistance provided to the Secretariat for the past year. Alexey will complete his PICES internship at the end of July 2018 and return to TINRO-Centre, Vladivostok, where he will resume his duties. Alexey took on many job assignments and tasks at the Secretariat in preparation for the Annual Meeting and two symposia, and many of you had a chance to meet him at PICES-2017 and ECCWO-4. We will miss his good humour, and listening to his experiences of weekend explorations by car of Vancouver Island with his wife, Olga. We wish him the best in his career and hope to see him involved in future PICES events.

Dr. Sukyung Kang (sukyungkang@korea.kr) is a Senior Scientist of the Fisheries Resources Management Division at the National Institute of Fisheries Science (NIFS) in Busan, Korea. After receiving her Ph.D. in fisheries oceanography from Pukyong National University in 2004, Sukyung began working in salmon research at NIFS. She currently works on the prediction of marine fisheries resources under climatic changes in Korean waters using ichthyoplankton and fishing data sets. Sukyung has been involved in several international organizations/projects besides PICES, such as NPAFC, Yellow Sea LME, and APEC. In PICES, she is a member of Science Board, Fishery Science Committee, and the Section Climate Change Effects on Marine Ecosystems. She co-chairs the FUTURE Scientific Steering Committee with Steven Bograd.

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.

A new PICES MAFF-sponsored project:
Building capacity for coastal monitoring by small-scale fishers

by Mitsutaku Makino and Mark Wells

Natural and anthropogenic pressures have been generating changes in the marine ecological system, and effects of these changes to the well-being of people living in coastal areas are difficult to predict because of the lack of understanding and many uncertainties in social and ecological systems (Guillotreau *et al.*, 2017). Therefore, one of the most important tasks for marine researchers is to scientifically assist local people in adapting to social and ecological changes for their sustainable livelihood and better well-being (Armitage *at al.*, 2017). This was the rationale for a new 3-year (2017–2020) PICES project on "*Building capacity for coastal monitoring by local small-scale fishers*" (FishGIS), funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), from the Official Development Assistance (ODA) Fund.

PICES member countries have resources for monitoring environmental conditions and fisheries in coastal waters, while developing nations are far more limited in their capacity for collecting data needed to advance their management practices. Citizen-based monitoring is an approach designed to improve the efficiency and effectiveness of monitoring efforts when technical and financial resources are not sufficient. There are successful examples of citizen-based monitoring in developed countries. However, this approach has not been widely applied yet to the collection of environmental and fisheries data in developing nations. The overall goal of the FishGIS project is to enhance the capacity of local small-scale fishers in Pacific Rim developing countries to monitor coastal ecosystems and coastal fisheries. The extensive use of smartphones in these countries offers a creative potential for implementing the project through a smartphone-based monitoring system used by local fishers and fish farmers.

The project key questions are: (a) How do global changes in climate and economy affect coastal ecosystems? and (b) How may enhanced capacity for monitoring activities by local fishers help to improve fisheries management in coastal areas? To investigate these questions, the project will focus on the following major initiatives to be supported by a series of capacity building workshops led by scientists from PICES member countries:
1. Coastal ecosystem monitoring activities by local small-scale fishers to detect ecosystems changes (*e.g.*, deviations in water quality and the changes in plankton community composition);
2. Coastal fisheries monitoring activities by local small-scale fishers to improve coastal fisheries management

(*e.g.*, information about fishing operations or species composition on the market);
3. Coastal and estuarine water monitoring activities by local small-scale aquaculture fishers to measure the effects of government clean water initiatives on water quality for aquaculture operations.

The project is expected to interact with, and support relevant activities of, PICES Scientific Committees on Human Dimensions (HD) and Fishery Science (FIS), PICES Technical Committees on Data Exchange (TCODE) and on Monitoring (MONITOR), and PICES FUTURE Science Program (Research Theme 3 on "*How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?*"). The project is being directed by the Project Science Team (PST) formed in November 2017 based on principles and procedures detailed in *the PICES Policy for approval and management of special projects* (http://meetings.pices.int/ publications/ annual-reports/2017/2017-GC-Decisions-Vladivostok.pdf; Decision 2017/A/7). All PICES member countries and all the above mentioned Committees are represented on the PST (Table 1 and Fig. 1). The PST Co-Chairs, Dr. Mitsutaku Makino and Dr. Mark Wells, are responsible for the scientific implementation of the project and annual reporting to MAFF and to PICES Science Board through the HD Committee. The Project Coordinator, Dr. Alexander Bychkov, is responsible for the management of the fund and annual reporting on its disposition to MAFF/JFA and to PICES Governing Council through the Finance and Administration Committee.

The first PST meeting was held January 17–19, 2018, at the Headquarters of the Japan Fisheries Research and Education Agency in Yokohama, Japan (Fig. 2). The participants reviewed the overall strategy and general directions for the project and developed timelines for project initiatives, activities and deliverables. A framework for a smartphone-based system for coastal ecosystem monitoring, including a prototype GIS fisheries data application to be used by local small-scale fishers, was introduced by Dr. Shigeharu Kogushi (GFL, Japan) and some additional considerations were suggested by PST members. Another discussion point was on possible approaches to selection of case study sites. The workplan for Year 1 was refined, and the workplan for Year 2 was drafted.

Indonesia was chosen as a developing Pacific Rim country to implement the project because of its role in the fisheries production of the world and large population of small-scale fishers. The importance of having more effective fisheries

Table 1   Membership of the Project Science Team

Name	Affiliation	Country/Group
Vladimir Kulik	TINRO-Center	Russia/MONITOR
Joon-Soo Lee	KODC, National Institute of Fisheries Science	Korea/TCODE
Mitsutaku Makino	Japan Fisheries Research and Education Agency	Japan/HD
Shion Takemura	Japan Fisheries Research and Education Agency	Japan/HD
Naoki Tojo	Hokkaido University	Japan/FIS
Charles Trick	Western University	Canada/S-HAB
Mark Wells	University of Maine	USA/S-HAB
Chang-an Xu	Third Institute of Oceanography, SOA	China
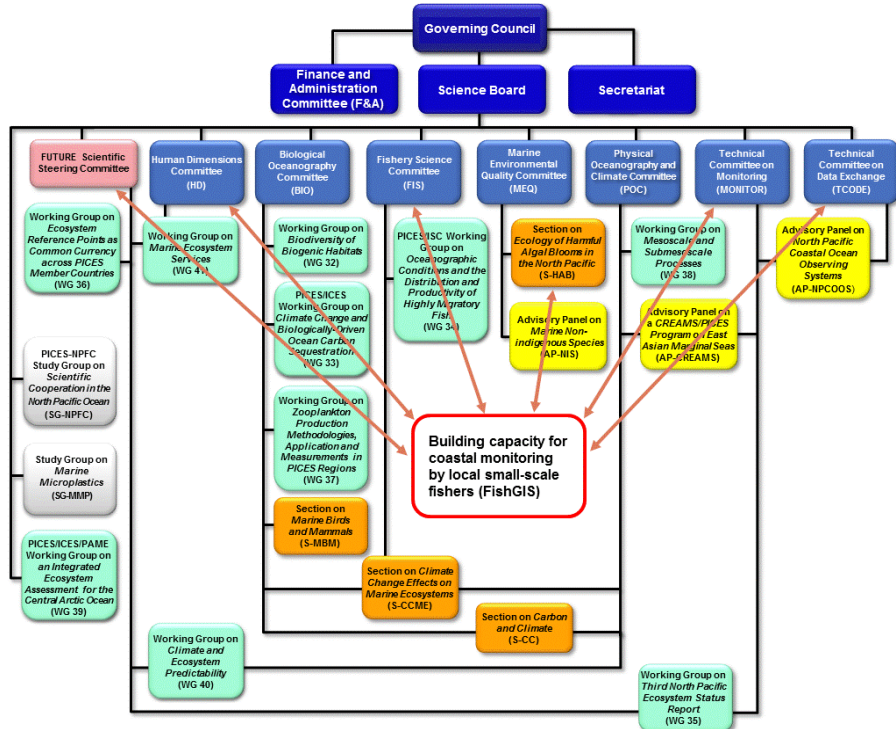
Fig. 1   PICES (North Pacific Marine Science Organization) structure for 2017–2018 showing links between the FishGIS Project and PICES Committees and expert groups.
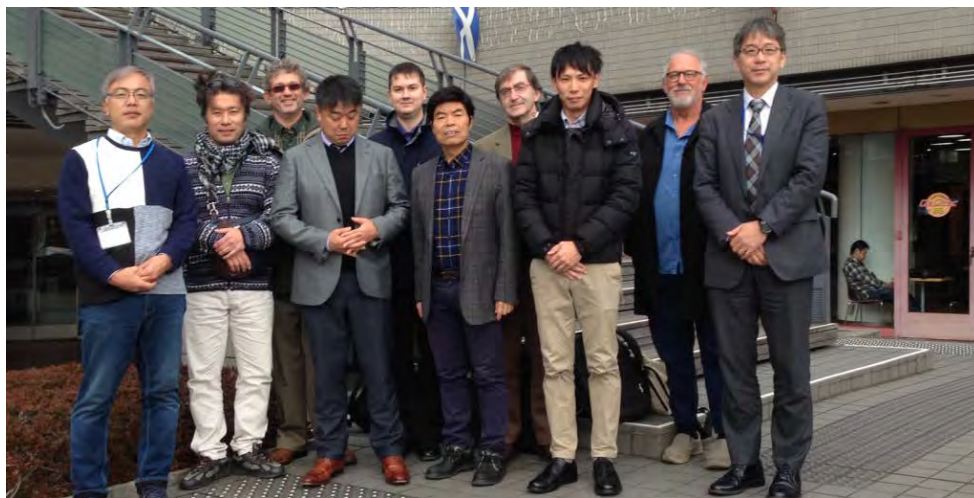
Fig. 2   Group photo taken during the first PST meeting in Yokohama, Japan (from left to right): Mitsutaku Makino, Naoki Tojo, Mark Wells, Shigeharu Kogushi (lead for the development of a GIS-based fisheries data smartphone application), Vladimir Kulik, Chang-an Xu, Alexander Bychkov, Shion Takemura, Charles Trick and Tomowo Watanabe (MAFF/JFA representative).

management practices is widely recognized in Indonesia, and this leads to support by the government and the willingness of local communities and stakeholders to consider new approaches such as the development and implementation of a fisher/citizen-based observation system linked with fisheries scientists and managers.

One of the first, and strongest, lessons learned from the previous PICES/MAFF projects is the importance of connecting with organizations in a developing country, which can facilitate and advance the project (Makino and Perry, 2017). The organization and the key people in it are crucial to understand the project and to translate it into the local context. The PST agreed that the Indonesian Agency for the Assessment and Application of Technology (BPPT) is the ideal partner for this project for two main reasons: (1) BPPT is responsible for leveraging advances in technology for the study of environmental systems to enhance Indonesian economic and societal development, and (2) a productive working relationship with BPPT was developed during the PICES/MAFF project on "*Marine ecosystem health and human well-being (MarWeB)*" (2012–2017), and the current project can build on this collaborative foundation.

The strategy was to introduce the project to BPPT colleagues to seek their advice on possible ways to implement it, including suggestions on potential locations for the demonstration case studies. On March 19–23, 2018, a group of PICES experts visited Indonesia to finalize the selection of case study sites, and to identify the key local individuals who will participate in the project, the type of training/capacity building needed, and the logistics for providing this training. This group included all PST members, Dr. Kogushi and two students, Takaaki Mori and Rinako Nakano, from Hokkaido University. On March 19, the Letter of Intent (LOI) between BPTT and PICES was signed as a basis for collaboration on the project, and a Focus Group discussion was held with researchers from BPPT, the Indonesian Ministry of Marine Affairs and Fisheries (MMAF), the Indonesian Institute of Sciences (LIPI), and local fishers and fish farmers on project implementation (Fig. 3).

On March 20–22, the PICES Team and BPPT staff visited three potential case study sites (Fig. 4): Muara Gembong (an aquaculture area with issues such as decreasing seaweed production due to the water quality degradation/pollution), Indramyu District (a capture fisheries-oriented area with

Fig. 3   Visit of the PICES Team to the Indonesian Agency for the Assessment and Application of Technology (BPTT) on March 19, 2018: Signing ceremony for the Letter of Intent between BPTT, represented by the BPPT Chairman, Mr. Unggul Priyanto, and PICES, represented by Dr. Mitsutaku Makino (top left); PICES Team members and BPTT leadership posing after the ceremony (top right); Focus Group discussion (bottom left), and Prof. Suhendar Sachoemar, local coordinator of the MarWeB and FishGIS projects (left), leading discussion (bottom right).
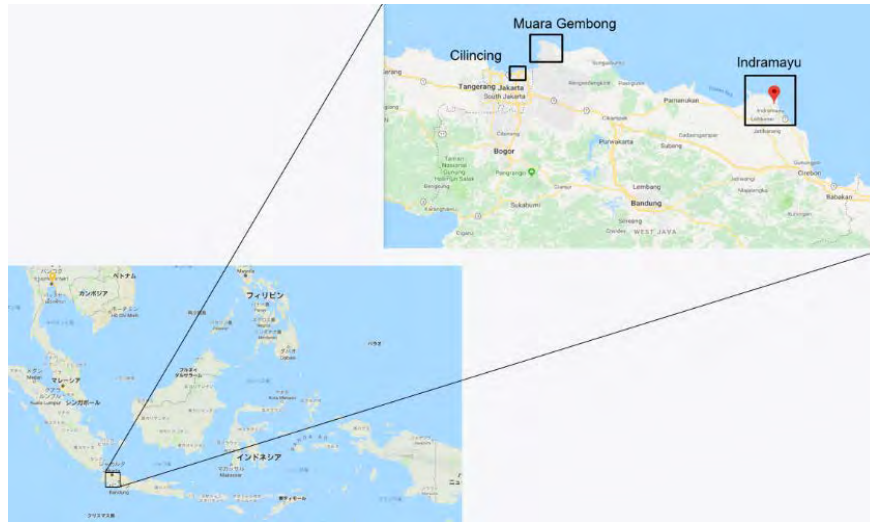
Fig. 4   Potential case study sites in Indonesia.

Fig. 5   Visits of the PICES Team and BPPT staff (March 20–22, 2018) to Indonesian communities considered as potential case study sites: Discussions with local fishers and fish/seaweed farmers at Muara Gembong (top row), Indramayu District (middle row) and Cilincing (bottom row).

issues such as overfishing, water quality degradation/ pollution, and loss of fish habitat), and Cilincing (a highly populated area of small-scale fishers near Jakarta, facing water quality degradation and biochemical pollution), to evaluate which sites have the overall best conditions for implementing the project.

Joint meetings and small group interviews were held in each community with local fishers and aquaculture farmers who were interested in hearing about the project, and willing to communicate their knowledge of the region (Fig. 5). The primary goal was to learn from these local citizen-experts on the state of their fisheries, their environment, and their primary concerns for local fisheries in the future. On completion of these community forums, the three sites were ranked in terms of the project goals using several criteria relevant to success of the project, including the presence of a strong local coordinator (considered vital to project success), ecosystem changes recognized by the people, evaluation of their recognition of the relationship between environment and fisheries (wild caught and aquaculture), and the overall interest in the community for education and training. Community members in all three case study sites were found to have mobile phones suited for the project, and each site had sufficient cellular signal strength to support the planned data transfer needs of the smartphone applications. The PICES Team was able to test out the prototype fisheries data application, both in terms of connectivity to data storage sites and in the ease of use for community members. A revision plan for the prototype application was designed based upon these efforts. The established

application for measuring water quality (HydroColor) was also tested and found to work well – no significant modification was considered necessary.

At a wrap-up discussion with Indonesian partners on March 23, Muara Gembong and Indramyu District were selected as the demonstration sites. Cilincing was reluctantly ruled out for several reasons, with the main ones being the high level of pollution from Jakarta, and that the community and its fishing operations are likely to be in transition over the next 5 years because of local commercial development. At this meeting, linkages with other components of BPPT (BPPT Center of Technology Development for Regional Resources Development) and other agencies (MMAF and LIPI) were identified as being beneficial to the project, and preparations were initiated for a series training/capacity building workshops to be held early in summer 2018.

In the next issue of the PICES Press, we are planning to introduce the technological aspects of the project.

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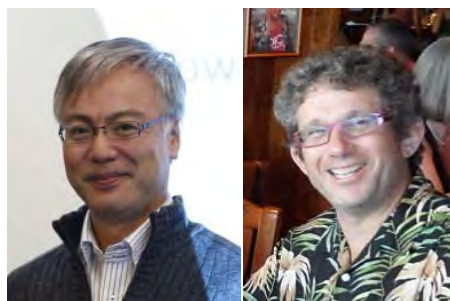
Dr. Mitsutaku Makino (mmakino@affrc.go.jp) is Head of the Fisheries Management Research Group at the National Research Institute of Fisheries Science, Fisheries Research and Education Agency of Japan. He specializes in fisheries and ecosystem-based management analysis. He teaches in several universities in Japan, and currently serves as an Editor of ICES Journal of Marine Science. His book entitled "Fisheries Management in Japan" was published by Springer in 2011. Within PICES, he is Vice-Chair of the Human Dimensions Committee and a member of the FUTURE Scientific Steering Committee and Working Group (WG 36) on Ecosystem Reference Points across PICES Member Countries. He co-led, with Dr. Ian Perry, the previous (2012–2017) PICES/MAFF project on "Marine ecosystem health and human well-being (MarWeB)" and now co-chairs the FishGIS project with Dr. Mark Wells.

Dr. Mark L. Wells (mlwells@maine.edu) is a Professor of Oceanography in the School of Marine Sciences, University of Maine, USA. His fields and topics of research are marine biogeochemistry, trace metal chemistry, and biological oceanography with emphasis on harmful algal blooms. Within PICES, he is a member of the Section on Ecology of Harmful Algal Blooms in the North Pacific. Mark was also involved in the PICES/MAFF project on "Marine ecosystem health and human well-being (MarWeB)" and now co-chairs the FishGIS project with Dr. Mitsutaku Makino.

Scientists from PICES and Mexico meet to discuss closer ties in North Pacific research

by Salvador Lluch-Cota

On April 23, 2018, a day prior to the International Scientific Symposium on "*Understanding changes in transitional areas of the Pacific*", an open-door PICES–Mexico "bridging" session was held at CICIMAR-IPN (Centro Interdisciplinario de Ciencias Marinas-Instituto Politécnico Nacional) in La Paz, Mexico. The main goals of this special session were to provide information on the common scientific interests and priorities between PICES and Mexico, to identify specific short-term actions to advance PICES–Mexico collaboration, and to facilitate direct scientist-to-scientist partnerships. During an entire afternoon, over 100 attendees that included scientists from PICES member countries and different Mexican institutions, and a large number of postgraduate students and early career scientists, listened to six scoping talks, interacted with panel experts in a round-table discussion, and socialized at an informal poster session that lasted until sunset.

Opening welcome addresses were delivered by Dr. Rubén Rodriguez-Sánchez on behalf of the hosting institution and by Dr. Chul Park, PICES Chairman. Scoping talks from PICES were: a presentation on past and future climate in the Pacific Ocean, based on historical observations and a critical review of modelling projections (Dr. Emanuele Di Lorenzo, Georgia Institute of Technology, USA); an overview of the PICES CCCC (Climate Change and Carrying Capacity) Program (1995–2009), focusing on its successes, shortcomings, lessons learned, and its legacy for future programs (Dr. Harold Batchelder, PICES Secretariat); and an introduction of the current PICES FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems) Program (Dr. Steven Bograd, NOAA Fisheries, USA). Mexican scoping talks described: the IMECOCAL (Investigaciones Mexicanas de la Corriente de California) Program, a monitoring effort carried during the last 20 years in the southern part of the California Current (Dr. Rubén Lara, CICESE – Centro de Investigación Científica y de Educación Superior de Ensenada); meso- to large-scale ocean ecology research being developed in the region, with special emphasis on

fisheries ecology (Dr. César Salinas-Zavala, CIBNOR – Centro de Investigaciones Biológicas del Noroeste); and ongoing studies of the Oxygen Minimum Zone trends in the Pacific off Mexico, its potential impacts, and the urgent need to integrate large-scale monitoring and modelling programs around this issue (Dr. Laura Sánchez-Velasco, CICIMAR).
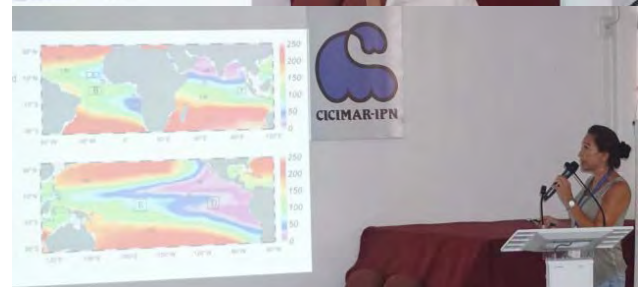
Plenary speakers, (top) Dr. Steven Bograd (PICES/NOAA Fisheries, USA), (middle) Dr. César Salinas Zavala (CIBNOR), (bottom) Dr. Laura Sánchez-Velasco (CICIMAR).

These presentations followed by a round-table, with panelists representing PICES and Mexican institutions. Thomas Therriault (PICES Marine Environmental Quality Committee) served as facilitator. Guided by a pre-set list of questions, each panelist presented his/her thoughts on how PICES and Mexico could work together on topics of mutual interest, how Mexican experience and capacity could be used in furthering PICES research, what topics of importance to Mexico could be better approached through more consistent and sustained interactions with PICES, and what the obstacles might be preventing such collaborations.

PICES–Mexico panelists, from left: Hiroaki Saito (PICES Science Board Chair), Keith Criddle (PICES Human Dimensions Committee Chair), Xianshi Jin (PICES Fishery Science Committee Chair), Angelica Peña (PICES Biological Oceanography Committee), David Rivas-Camargo (CICESE), Cisco Werner (PICES Governing Council), Sergio Hernández-Trujillo (Director, CICIMAR), Daniel Lluch-Cota (Director, CIBNOR).

Clockwise from top: Saul Alvarez-Borrego and Rubén Lara (CICESE), and Rubén Rodriguez-Sánchez (CICIMAR) exchanging views and ideas with Cisco Werner, Sergio Hernández-Trujillo and Daniel Lluch-Cota during round-table discussions.

Lively dialogue followed, with many questions and comments from the audience. Most of it considered the potential incorporation of Mexico into PICES. Some comments stated that in order to hold similar levels of responsibilities and rights with the existing member countries, Mexico should seek full and formal membership. On the other hand, it was also mentioned that, because of the foreign affairs legislations in Mexico, signing an international convention for solely scientific purposes is complex and would probably take a long time to achieve. Mexican scientists and representatives from various research institutions committed to continue pursuing the full formal membership by bringing other components into the quest for participation, such as Mexico's strong commitment to the UN's Decade of Ocean Science. Similarly, there was a common agreement that, independently from what happens in the future with the formal membership status, Mexican scientists will keep collaborating and interacting with the PICES community.

Specific proposed actions would be holding monitoring technology seminars and workshops (*e.g.*, related to the Argo floats program), promoting the involvement of early career Mexican scientists in PICES activities through postdocs and work visits and PICES summer schools, inviting and organizing more PICES events in Mexico, and participation of Mexican scientists in PICES Annual Meetings and symposia.
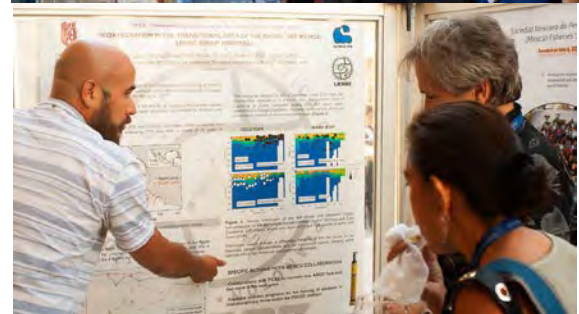
A chance to relax at the ice-breaker, and renew old and make new connections.

The session ended with an ice-breaker in the courtyard, where participants were able to continue conversations and view commissioned posters, introducing PICES activities and displaying PICES-like research being done in Mexico. From the interest garnered at this special session, it is anticipated that further positive developments will take place to include the Mexican presence in PICES.

See Salvador Lluch-Cota's bio in the next article.

An International Symposium on
"Understanding changes in transitional areas of the Pacific"

by Sachihiko Itoh, Salvador Lluch-Cota and Evan Howell

An international scientific symposium on "*Understanding Changes in Transitional Areas of the Pacific*" was held April 24–26, 2018, at CIBNOR (Centro de Investigaciones Biológicas del Noroeste) in La Paz, Mexico. This symposium was designed as a continuation to a PICES symposium on "*North Pacific Transitional Areas*", convened in April 2002 also in La Paz. The 2002 symposium brought together a wide-range of research ideas and provided the opportunity to contrast concepts, compare systems and methods, and bridge different views of what transitional area (TA) systems reveal, and the scientific challenge they represent. After the meeting, the study of these TA systems became part of the scientific agenda for many research groups. Therefore, a major focus of the 2018 symposium was to integrate research and knowledge on Pacific TAs over the last 15 years, as well as to further expand upon the idea of TAs beyond the pelagic realm. For both symposia, TAs were described as areas characterized by strong gradients in the physical environment that challenge biological communities, many of which are already exposed to their physiological limits. Because of their nature, TAs are expected to reflect the impacts of climate variability and change more dramatically and sooner than other more homogeneous areas, making them regions of particular concern. There is also great interest in the potential of TAs as regions of early detection of these changes.

The symposium was convened by Sachihiko Itoh (PICES/ Atmosphere and Ocean Research Institute (AORI), University of Tokyo, Japan), Salvador Lluch-Cota (CIBNOR, Mexico), Phoebe Woodworth-Jefcoats and Evan Howell (PICES/Pacific Islands Fisheries Science Center (PIFSC), NOAA-Fisheries, USA). The Scientific Steering Committee (SSC) was composed by a rich combination of scientists from the PICES region and Mexican institutions, and included François Colas (Institut de Recherche pour le Développement (IRD), France), Gerard DiNardo (Southwest Fisheries Science Center (SWFSC), NOAA-Fisheries, USA), Shingo Kimura (AORI, University of Tokyo, Japan), Minling Pan (PIFSC, NOAA-Fisheries, USA), Angelica Peña (Department of Fisheries and Oceans, Canada), Edward Weber (SWFSC, NOAA-Fisheries, USA), David Rivas-Camargo (Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Mexico), Rubén Rodriguez Sánchez (Centro Interdisciplinario de Ciencias Marinas (CICIMAR), Mexico), and César Salinas Zavala (CIBNOR, Mexico).

While PICES served as the primary international sponsor, a number of institutions and agencies supported the event, reflecting the regional-to-global interest in TAs research: locally – CIBNOR, CICIMAR, and CONACYT (Consejo Nacional de Ciencia y Tecnología, Mexico), and as co-sponsors – AORI, IATTC (Inter-American Tropical Tuna Commission), IFFO (Marine Ingredients Organization), IRD, ISC (International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean), JSFO (Japanese Society of Fisheries Oceanography), JSFS (Japanese Society of Fisheries Science), NOAA-Fisheries (National Marine Fisheries Service, USA), NPFC (North Pacific Fisheries Commission), NPRB (North Pacific Research Board, USA), and SCOR (Scientific Committee on Oceanic Research).

More than 140 scientists from 12 countries (Brazil, Canada, China, Columbia, France, Germany, Japan, Mexico, Peru, Russia, The Netherlands, and USA) and 6 international and regional fisheries management organizations (PICES, FAO, IATTC, ISC, NPFC and SPRFMO (South Pacific Regional Fisheries Management Organization)) attended the

symposium. A large presence of scientists and students from Latin America (71 people – about half of the registered participants) greatly enhanced the focus and definition of Pacific TAs to include the important coastal TAs off the coast of Mexico and Peru.

The 3-day event consisted of an opening session, morning plenary sessions to provide overarching keynote presentations and to introduce topics of the sessions to be convened on the same day, 6 concurrent (three daily) topic sessions, each chosen to represent different foci of Pacific TAs, two evening poster viewings, and a plenary summing-up session. There were in total 28 invited and 83 contributed talks, and 27 posters covering the broad geographic region of the western TAs off Japan, the central North Pacific Transition Zone (NPTZ), the eastern TAs off the coast of the United States, Mexico and Peru, and meso- and local-scale TAs of regional relevance in the eastern Pacific.

The symposium had two general plenary speakers. Jeffrey Polovina (PIFSC, NOAA-Fisheries, USA), the 2010 Wooster Award recipient and one of convenors for the 2002 La Paz symposium, set the scientific foundation by discussing some key elements and themes from three decades of research and management in the NPTZ in his talk at the opening plenary. At the last-day plenary, Emanuele Di Lorenzo (Georgia Institute of Technology, USA), the Chairman of the PICES Physical Oceanography and Climate Committee, reviewed multi-scale impacts of climate on Pacific TAs and presented a framework to examine potential changes in Pacific TAs variance associated with anthropogenic forces.

General Plenary speakers, (top) Jeffrey Polovina and (bottom) Emanuele Di Lorenzo.

Session 1 on "*Effects of climate variability and change on the physics, biology, and fisheries in Pacific transitional areas*", convened by Shinya Kouketsu (Japan), Evan Howell, Edward Weber and Phoebe Woodworth-Jefcoats (all USA), was the largest session of the symposium and contained 37 oral presentations (2 plenary, 1 invited and 34 contributed) and 11 posters. In his plenary talk, Satoshi Osafune described the low frequency temporal sea surface temperature variability in the subarctic–subtropical gyre boundary region in the North Pacific as related to local wind stress and internal ocean variability. Cisco Werner's plenary presentation provided several examples of both long-term, sustained (secular) and abrupt, short-term (paroxysmic) environmental changes, their impacts on Pacific TAs, and challenges managers have in incorporating these changes into real-time management decisions. The invited talk by Sayaka Yasunaka focused on the effect of large-scale wind forcing on the southward movement of nutrient-rich waters from the subarctic into the TA in the North Pacific. Overall, the session presentations covered a wide-range of physical and biological processes using various approaches in TAs across the Pacific. Many of the presentations identified how the understanding of climate modes and associated indices (*e.g.*, PDO, Victoria Mode/NPGO, ENSO) can greatly help to understand large-scale changes in the coastal areas and pelagic transitional TAs. For example, many studies focused on the impacts by the ocean heatwave events, which were shown to be associated with North Pacific Gyre Oscillations (NPGOs). Many presentations showed that local or regional processes associated with the spatial contrast were very important to capture the variability of the environmental and biological conditions. There were also several studies focusing on the changes in the California Current System and west coast off Peru and Mexico, and a comparison of the studies will be potentially another good example to clarify the relationships of changes along the TA in the future. These presentations worked to broaden the previous definition of "Transitional Area" developed at the 2002 symposium.

Session 2 on "*Challenges in managing highly migratory and transboundary resources in Pacific transitional areas*", convened by Nicolás Gutiérrez (FAO), Salvador Lluch-Cota (Mexico) and Minling Pan (USA), had 17 presentations (1 plenary, 5 invited and 10 contributed talks, and 1 poster) from 7 countries and 5 international and regional fisheries management organizations (RFMOs). In his plenary talk, Nicolás Gutiérrez focused on several challenges in assessing and managing highly migratory tuna resources, such as multiple spatial and temporal scales, large-scale uncertainty in migration patterns, stock structures across regions, and reproduction in stock assessment, and illustrated how the tuna RFMOs are addressing these challenges. The invited speakers for the session reviewed the status of science-based fisheries management of transboundary species in the SPRFMO area (James Ianelli); presented the recently completed provisional stock assessment for Pacific saury by NPFC that incorporated some marine environmental

factors (Toshihige Iwasaki); discussed the use of electronic tags in the Tracking of Marine Animals project to describe and improve the understanding of highly migratory species habitat in the Western Pacific (Hidetada Kiyofuji); evaluated the biological and economic tradeoffs of purse-seine fishing and longline fishing in the Eastern Pacific (Jenny Sun, presented by Minling Pan); and introduced the concept of market-based programs such as the Marine Stewardship Council, a third-party certification standard that provides economic incentives to achieve management measures, such as harvest control rules set by RFMOs (Simon Bush). Overall, some of the studies in this session addressed the challenges in managing highly migratory and transboundary resources in Pacific TAs from economic, social, and institutional prospects providing theoretical and practical examples of assessment, management, stock identification and other management tools, while others dealt with the challenges in fisheries data and monitoring, changes of oceanographic and climate conditions, and uncertainty in stock assessments.

Session 3 on "*Challenges in observing and modeling Pacific transitional areas*", convened by Enrique Curchitser (USA) and Sachihiko Itoh (Japan), was composed of 12 oral presentations, including 3 plenary (Jack Barth, Toshio Suga and Kenneth Johnson) and 3 invited (Charles Stock, Masao Kurogi and Daisuke Hasegawa) talks and 1 poster, from 5 countries. The presentations spanned a range of topics. Observations described data being gathered by Argo floats, gliders, vertical profiling moorings, and CTDs with bio capabilities all the way down microstructure profilers. Some common threads here were the need for multi-parameter observations when researching marine ecosystems and the need for a better observational coverage in the Pacific (*e.g.*, the North Pacific is a hole for Biogeochemical-Argo). The modeling papers focused on global Earth System Models, downscaled solution for regional implementations, sub-kilometer resolution local models, biogeochemical and food-chain models, and use of Lagrangian approaches for both physics and upper trophic level dynamics. Some of these papers indicated the importance of multi-scale models that can describe the transition from global- to basin- to local-scales. Both observations and models highlighted the challenges of representing a wide range of scales relevant to TAs. It was also pointed out that increasing model–

observation synergies is critical in order to improve both, and the knowledge that emerges from them. Finally, there was a discussion that transitions are meaningful in spatial and temporal contexts.

Session 4 on "*Advances in understanding Pacific shelf-offshore transitional areas*", convened by François Colas (France), Hiroshi Kuroda (Japan) and Angelica Peña (Canada), contained 23 presentations (1 plenary, 2 invited, and 15 contributed talks, and 5 posters) from 5 countries. In his plenary talk, Dimitri Gutiérrez presented a thorough overview of various aspects of the functioning of the very productive coastal upwelling off Peru, and discussed observed trends of the system over the last decades. The invited presentations for the session described a low-trophic ecosystem model, which showed that sources of nutrients in the East China Sea result from complex cross-shelf transports from different areas and that both lateral and vertical exchanges need to be evaluated to have a complete understanding (Xinyu Guo); and work in the California Current region that combined physical ocean model output and satellite observations of chlorophyll to show the importance of considering the complex interaction between wind and nutrients to understand the bottom-up controls on productivity, and that knowing this interaction provides a powerful framework to better describe the ecosystem responses to extreme events (Michael Jacox). Overall, the session included presentations from several offshore-coastal transitional regions, including eastern (California and Humboldt currents) and western (Kuroshio) boundary currents and from the North and South Pacific. It was obvious from these presentations, that in recent years, interdisciplinary studies (*e.g.*, physics-biogeochemistry or physics-fish) have become a common approach. Despite clear differences among the regions, several presentations revealed that low-frequency variability, like PDO and NPGO, is important in both eastern and western boundary currents. Similarly, these studies demonstrated that the coastal-offshore transition region plays a significant role in determining water properties on the inner shelf. Major improvements in modelling (*e.g.*, mesoscale eddy-resolving models) and observing techniques (*e.g.*, observations from gliders) in the last decade have contributed to a better understanding of the complex spatio-temporal variability and the mechanisms driving these changes.

Rubén Lara-Lara (CICESE) S1, Ana Gabriela Uribe-Prado (CICIMAR) S1, Laura Lilly (Scripps) S1, José Augusto Valencia-Gasti (Univ. Autónoma BC, Ensenada) S2, Toshio Suga (Tohoku Univ./JAMSTEC) S3, Criscely Luján-Paredes (IRD/IMARPE) S4, Cherisse Du Preez (DFO) S5, Dante Espinoza Morriberón (IMARPE) S4, Jingmei Li (Ocean Univ. China) S6.

Session 5 on "*Biodiversity changes in Pacific Transitional Areas*", convened by Thomas Therriault (Canada), Xianshi Jin (China) and Rubén Rodriguez-Sánchez (México), was very diverse and included 21 presentations (1 plenary, 3 invited and 13 contributed talks, and 4 posters) from 6 countries. The plenary talk, given by Thomas Therriault on behalf of Paul Snelgrove, provided a wide-ranging overview of a number of projects being conducted as part of the Second Canadian Healthy Oceans Network (CHONe2), with respect to biodiversity changes in different transitional areas. The important message was that biodiversity in many of these systems is under stress and, given the critical linkages between biodiversity and the maintenance of ecosystem goods and services, it should be anticipated that coastal communities will be negatively impacted by these changes. It is possible though that some of these risks could be mitigated, at least partially, by management or policy actions to conserve biodiversity. The invited speakers for the session focused on long-term changes of macro-benthos in Chinese marginal seas (Xinzheng Li); changes in zooplankton at the meso- and basin-scale using Continuous Plankton Recorder data (Sonia Batten); and long-term changes in euphausiid species composition in the California Current (Bertha Lavaniegos). The session included three blocks of contributed talks covering changes in benthic (1), plankton (2) and nekton (3) communities. Overall, many of the studies presented in this session demonstrated the decline or loss in biodiversity, independent of system or taxa, in a wide variety of TAs. This highlights the need to maintain and/or enhance monitoring efforts and develop indices to better understand biodiversity changes over space and time, especially in the face of increased stressors such as climate change and many other human-mediated activities. The session also emphasized that predictions of biological changes are becoming more difficult, and more "abnormal" patterns and cycles are emerging such that what may have worked in the past might not be as effective in the future. Clearly identifying changes in biodiversity across multiple spatial and temporal scales is a challenge given its complexity, so building collaborations will be essential to finding possible solutions.

Session 6 on "*Transitional zones in coastal habitats*", convened by Francisco Arreguín-Sánchez (Mexico) and Jingmei Li (China), included 12 presentations (2 plenary, 2 invited, and 5 contributed talks, and 3 posters) from 5 countries. The plenary speakers focused on challenges for fisheries management under climate change and ecosystem reference levels as a strategy for sustainable fisheries (Francisco Arreguín-Sánchez); and a generalized framework that can be used to access the relative contribution of various ecosystem stressors on different

ecological and socioeconomic endpoints and to identify potential indicators to track ecosystem and community responses at different spatial and temporal scales (Thomas Therriault). In his invited talk, Zengjie Jiang reviewed potential impacts of coastal mariculture on marine ecosystems and sustainable approaches to mitigate these impacts. Jingmei Li's invited presentation described an approach for evaluating the loss of ecological benefits, caused by wetland reclamation. Overall, the papers in this session addressed the effects of natural and anthropogenic stressors in coastal habitats, ecosystem characteristics such as community structure and genetic diversity, and socioeconomic issues.

The symposium concluded with a plenary that included summaries of the six topic sessions followed by an open discussion. During the plenary, scientists shared their thoughts on the knowledge and technological advances made in PTAs over the last 15 years, as well as their ideas on what we may expect to see covered in the next PTA symposium to be held, hopefully, less than 15 years from now. A large part of this discussion dealt with the expansion in the focus of transitional areas to include the more insular and important areas off the coasts of Central and South America. In addition to putting forth the idea of hosting another PTA symposium in La Paz at a future date, the symposium convenors suggested a number of possible initiatives, such as: (1) establishing a PICES expert group with an objective of providing a more formal definition of transitional areas and identifying gradient systems of interest for PICES; (2) planning for a strong body of scientific work (*e.g.*, a book) on oceanic gradients; and (3) setting a goal of having workshops or topic sessions with a focus on PTAs at every PICES Annual Meeting.

The closing ceremony included awards to early career scientists (ECS). The Best ECS Presentation Awards were given to Wencheng Lau-Medrano and Ricardo Oliveros-Ramos (IMARPE, Perú), and Juan Payan Alcacio (CICIMAR, Mexico). The recipients of the Best ECS Poster Awards were Carina Böck (Universidade Federal do Rio de Janeiro, Brazil) and Adriana Gomez-Leon (CICIMAR, Mexico). By providing travel support to about 20 students and early career scientists, this symposium should lead to much future research on TAs.

At the end of the closing ceremony, the convenors thanked all sponsors, acknowledged a very professional support from the local organizers (especially the CIBNOR team led by Sylvia Alzaga) and the always-efficient PICES team, and made a special recognition to Alex Bychkov for his leadership and commitment in preparing and coordinating the symposium.
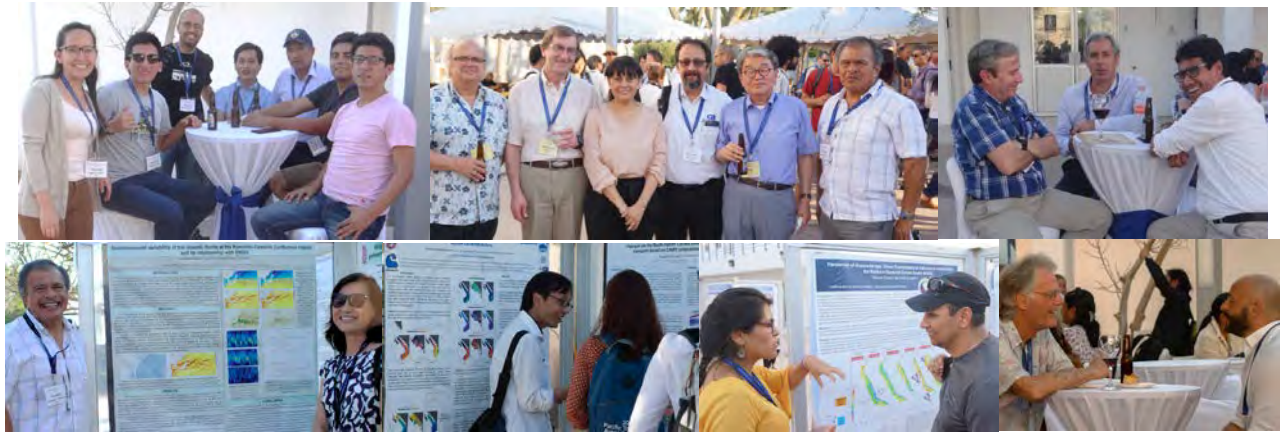
The Poster Session was held over two evenings at CIBNOR, where participants had a chance to look at the posters, enjoy refreshments, h'orderves and good conversation.

Last day of the Symposium. Convenors conducting a summary plenary session, followed by an open discussion.

From left: Best ECS Presentation Award – Wencheng Lau-Medrano (IMARPE, Perú), Ricardo Oliveros-Ramos (IMARPE, Perú); Best ECS Poster Award – Carina Böck (Universidade Federal do Rio de Janeiro, Brazil). Missing from presentation awards: Juan Payan Alcacio (Best Presentation) and Adriana Gomez-Leon (Best Poster) of CICIMAR.

Group photo taken at the "Dr. Felix Córdoba Alva" Auditorium (CIBNOR) after the summary plenary session and Closing Ceremony.

A great way to end the week's activities - an excellent dinner on the beach, outstanding display of Mexican folk dancing, and a chance for participants to match steps with the dancers.

Finally, publication plans were announced. Selected papers from the symposium and relevant manuscripts outside the symposium topic sessions will be published in a special issue of *Deep-Sea Research II*, with symposium convenors and several SSC members serving as Guest Editors. The expected publication date is September 2019. The Call for Papers for the volume was circulated on May 30, 2018.

After the formal conclusion of the symposium, CIBNOR organized a wonderful dinner on the beach, complete with a wide array of local beverages and entertainment. This was a memorable close to the event full of vibrant scientific discussions and sharing. Overall, the symposium was successful in bringing together scientists from many countries to discuss research advances and discoveries in the transitional areas of the Pacific Ocean. It was also a great opportunity to meet old friends and make new ones, and to enjoy the sights and hospitality of beautiful La Paz, Mexico.

PICES reaches new heights! A clever way to show PICES' 25th Anniversary video beamed against abandoned silos adjacent to the beach dinner venue for all to see.

Dr. Sachihiko Itoh (in the center; itohsach@aori.u-tokyo.ac.jp) is an Associate Professor at Atmosphere and Ocean Research Institute, The University of Tokyo, Japan. He participated in the 2002 symposium on "North Pacific Transitional Areas", which also took place in La Paz, as a Ph.D. student. His research interests span physical to biological and fisheries oceanography, including dynamics and biological roles of mesoscale eddies, surface mixed layer evolution and spring bloom, internal waves, turbulent mixing and nutrient transport, and frontal variability of ocean currents and larval transports. Within PICES, he serves as a member of WG 38 on Mesoscale and Submesoscale Processes.

Dr. Evan Howell (on the left; evan.howell@noaa.gov) is the Deputy Director of the Pacific Islands Fisheries Science Center, USA. Evan began work at NOAA-Fisheries in the Pacific Region in 1997, and through his career he has led and participated in scientific research on coupling physical and biological processes to better understand critical habitat and possible climate effects on highly migratory and protected species in the central North Pacific ecosystem. He now provides the oversight of all Science Center operations to support the NOAA-Fisheries scientific mission in the Pacific Islands Region.

Dr. Salvador E. Lluch-Cota (on the right; slluch@cibnor.mx) is Director of Sectorial Coordination (coordination of the 27 CONACYT Public Research Centers) and lead researcher on Fisheries Ecology at the Northwest Biological Research Center (CIBNOR). He served as President of the Mexican Chapter of the American Fisheries Society and the Mexican Fisheries Society (2007–2009), member of the Scientific Committee of the International Global Ocean Ecosystems Dynamics program (GLOBEC), and Lead Author for the IPCC AR5, WG2 Chapter 6 (Oceans). He holds the 2007 award in Natural Sciences from the Mexican Academy of Sciences, scientific career recognitions from the Universidad Autonoma de Baja California Sur (2007) and the Baja California Sur State Congress (2010), and level 3 recognition from the Sistema Nacional de Investigadores.

The 4ᵗʰ International Symposium on
"The effects of climate change on the world's oceans"

by Anne B. Hollowed, Jason Link, Roger Griffis, Margaret (Peg) Brady, Shin-ichi Ito, Véronique Garçon, Manuel Barange, Robin Brown and Wojciech Wawrzynski

The 4ᵗʰ Effects of Climate Change on the World's Oceans (ECCWO-4) symposium was held in Washington D.C., U.S.A. June 2-9, 2018. ECCWO-4 brought together more than 600 scientists from over 50 countries to share information, build understanding and advance responses to climate impacts on oceans and the many people, businesses and communities that depend on them. The symposium was jointly convened by the International Council for Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES), the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Food and Agriculture Organization (FAO) of the UN, and the National Oceanic and Atmospheric Administration (NOAA). Jason Link (ICES/NOAA), Shin-ichi Ito (PICES), Véronique Garçon (IOC-UNESCO), and Manuel Barange (FAO) served as co-conveners of the symposium. Several members from all five organizations served as members of the Scientific Steering Committee which set the meeting's agenda.

The ECCWO symposium series was launched in 2008 by the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES), and the Intergovernmental Oceanographic Commission of IOC-UNESCO to address the urgent need for information on changing oceans. The three prior symposia (Spain 2008, Korea 2012 and Brazil 2015) were important in advancing our understanding of the causes, consequences and responses to the effects of climate change on oceans.

ECCWO took place at a key juncture in understanding and responding to climate impacts on ocean systems. National and international assessments confirm that the Earth's climate and oceans are rapidly changing, the impacts are already evident in some regions and more impacts are expected with continued changes in the planet's climate system. There is much at stake. Changing oceans are expected to have significant impacts on a wide range of issues from food security, national security and international relations, to the resilience of peoples, communities and economies. Future efforts to inform the public of the risks associated with these changes will utilize the products, outcomes and lessons emerging from this symposium.

ECCWO-4 was organized around five overarching themes:
1. Oceans matter;
2. Oceans are changing;
3. There is much at stake;
4. Advance understanding of changes/risk;
5. Find solutions.

These themes attracted over 90 proposals for topic sessions which were pared down to 18 final topics. These included focused sessions on physical-biogeochemical responses and natural system responses, regionally focused sessions, and fully integrated sessions linking physics to the human dimension.

ECCWO-4 Theme Sessions	
S1	Ocean extremes and their impact on marine ecosystems
S2	From prediction to projection: the role of seasonal to decadal forecasts in a changing climate
S3	Carbon uptake, ocean acidification, and ecosystems and human impacts
S4	Deoxygenation in global ocean and coastal waters in relation to climate change
S5	Climate change impacts on high latitude systems on multiple scales in space and time
S6	The deep ocean under climate change
S7	Eastern Boundary upwelling systems: diversity, coupled dynamics and sensitivity to climate change
S8	Understanding the impact of abrupt ocean warming and continental scale connections on marine productivity and food security via western boundary currents
S9	Drifting into the Anthropocene: How will pelagic marine ecosystems be affected and what are the biogeochemical and lower trophic consequences?

S10	Management and conservation of species on the move
S11	Benthic and pelagic system responses in a changing ocean: From genes to ecosystem level functioning
S12	Scenarios and models to explore the future of marine coupled human-natural systems under climate change
S13	Multiple stressors at multiple scales: ecosystem based management in the face of changing ocean conditions
S14	Vulnerability and adaptation of marine socio-ecological systems to climate change
S15	Fisheries and aquaculture in the face of climate change: Current actions, identified solutions and opportunities in support of sustainable livelihoods and food security
S16	Climate, oceans and security
S17	Effects of climate change on ocean ecosystem health: Projecting occurrences of harmful algal blooms and disease outbreaks and assessment of the risk to ecosystem functioning, aquaculture, fisheries and human health
S18	Coastal ecosystem and their blue carbon science, conservation and policy progress (Poster Only)

ECCWO-4 Workshops

W1	Communicating and responding to climate change
W2	Advances in Earth System Models (ESMs) for marine applications
W3	Exploring potential ocean-based solutions to climate change impacts on marine biodiversity and ecosystem services
W4	Climate change adaptation of fisheries and aquaculture: Examples of field projects supporting countries and communities
W5	Climate change and fishing communities: Interactions with environmental conservation, sustainable livelihoods and food security
W6	Utilizing bioenergetics measurements and modeling to evaluate climate change effects on marine species and ecosystems
W7	What do seabirds reveal about the effects of climate change on the World's Oceans?
W8	Connecting climate, ocean and ecosystem observation – Ocean observation futures
W9	Vulnerability of Low Elevated Coastal Zones (LECZ) to SLR in changing oceans
W10	Intercomparison of fisheries and marine ecosystem models
W11	PICES Working Group 36 (CERP) on *Common Ecosystem Reference Points across PICES Member Countries* workshop: "Quantifying thresholds in driver-response relationships to identify reference points"

The topic sessions were augmented by 11 workshops which took place on the first weekend of the meeting. Fourteen sessions had plenary speakers. Four themes ran in parallel sessions for the remainder of each day. In total, ECCWO-4 included 350 oral presentations and 158 posters. The symposium was very successful in attracting early career scientists, with over 102 students attending the meeting. Several local schools participated in portions of the conference as well (more on this later).

The Opening Session offered several memorable moments. Dr. Jason Link opened the symposium and served as the emcee. Rear Admiral Timothy Gallaudet, the Assistant Secretary of Commerce for Oceans and Atmosphere and Acting NOAA Administrator, provided the official welcome address, followed by a keynote presentation from filmmaker, explorer and ocean advocate Phillippe Cousteau. Phillippe was joined by Olivia Blondheim, a member of the EarthEcho International Youth Leadership Council. A highlight of the Opening Session was a musical reflection – Confluence. The music was composed especially for this symposium by Zachary Friedland and performed by the Anacostia String Quartet. You can see the performance here.

Clockwise, top: Dr. Jason Link welcoming attendees to the Opening session; Rear Admiral Timothy Gallaudet (Acting NOAA Administrator) making a welcoming address, and Keynote Speaker, Phillippe Cousteau.

In the spirit of increasing the partnership between journalists and scientists, Nancy Baron (COMPASS) facilitated a science and media panel. Five esteemed members of the science community (Manuel Barange (FAO), Alistair Hobday (CSIRO), Lynne Shannon (MA-RE), Hon. Fran Ulmer (Chair US Arctic Research Commission, USARC) and Cisco Werner (NOAA-NMFS)) pitched a science story to a panel of well-known journalists (Cornelia Dean (New York Times), Christopher Joyce (National Public Radio), Alok Jha (UK Wellcome Fellow, Former Guardian and British Broadcasting Commission), Jessica Leber (Oceans Deeply) and David Malakoff (Science)).

Media and science panelist discussion with Nancy Baron (left) facilitating.

Each day of the symposium began with 3 or 4 plenary speakers highlighting the key session topics of the day. These were outstanding presentations from leaders in the field – all of the plenary talks can be viewed here on the ECCWO website along with photos and other information from the symposium. One of the exciting additional features was having an outstanding cartoonist, Bas Kohler, capture key ideas and topics from the plenary talks each day – the cartoons which can be viewed at the ECCWO website, was a highlight of each day. The symposium concluded on World Oceans Day and to mark the occasion, the following cartoon was created.

A new feature of the symposium was the inclusion of four lunchtime town hall meetings that provided an open discussion forum for engagement of the scientific

community. These town halls were sponsored by a variety of regional and global organizations and provided excellent opportunities for outreach to the broader ocean science community.

Women's Aquatic Network (WAN) Town Hall – Oh the places you'll go: Lessons for early career professionals

COMPASS Town Hall – Communicating science about the effects of climate change on the world's oceans

Lenfest Ocean Program Town Hall – Benchmarks for ecosystem assessments: Input on indicators for practical ecosystem-based fishery management

Intergovernmental Panel on Climate Change (IPCC) Town Hall – Ocean assessment in the Sixth Assessment Cycle of the Intergovernmental Panel on Climate Change

Three evening receptions provided exciting opportunities for discussion and debate. In addition to the traditional opening reception (Monday) and poster session (Wednesday), the Norwegian delegation and COMPASS held a joint reception on Tuesday night. The Tuesday night joint reception highlighted the Nansen Legacy Initiative and the importance of science communication. COMPASS hosted a "Pitch Pit" where scientists who were brave enough had three minutes to pitch their science story to a panel of journalists. It was fun and informative for everyone. Constructive feedback on each pitch was provided by the journal panelists.
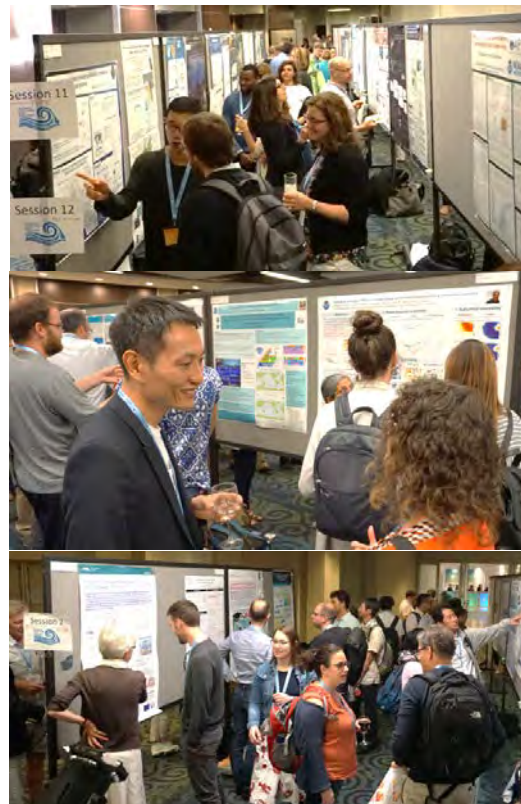
Monday's Welcome Reception.

Workshop 6 participants, inspired by their discussions, are looking upward and onward toward their next advancements in using bioenergetics measurements and modeling to evaluate climate change effects on marine species and ecosystems.

Future scientists at ECCWO-4.

Audience participation and engagement.

During session breaks, scientists had a chance to exchange ideas or, just take a break.

To kick off the Closing Session, Dr. Anne Hollowed, Scientific Steering Committee (SSC) Lead presented two questions to the audience on the findings, outcomes and expectations of the symposium:

Question 1 – What were your key scientific highlights from the week?
Question 2 – How has your thinking changed? What is different as you head home?

Participants were asked to answer the above questions on cards that had been distributed to them beforehand. These were collected at the end of the Closing Session and the information will be assessed by the symposium conveners to be used as guidance for the planning of the next ECCWO.

Dr. Anne Hollowed leads three cheers for the ocean!

As has been the practice in previous ECCWO sessions, symposium conveners, the SSC and topic session co-chairs worked together to identify key messages from the symposium. Ten key messages were discussed in Plenary during the Closing Session and are briefly examined here.

1. **The oceans and the social-ecological systems that depend on them are changing.** Many of the sessions (especially Sessions S5 and S10) provided evidence that the oceans are changing and these changes are impacting humans. Some of the most dramatic changes were observed in high latitude systems, with evidence of shifts in species composition and ecosystem structure occurring at the trailing edges. These changes have far reaching implications for weather, national security, food security and commerce.

2. **Our understanding of social-ecological systems has improved sufficiently to enable us to contrast the ecological and human impacts of different future scenarios. Opportunities for adaptation are more limited if society remains on a high emission scenario.** An exciting development since ECCWO-3 was the development of fully coupled social-ecological models capable of projecting future scenarios based on global responses of humanity to the challenges of climate change and regional responses to natural resource management (see talks from Sessions S2, S12

and S13–15). These new models provide a much clearer picture of the trade-offs associated with different societal responses. Early results from these models show that adaptation options are more limited if society continues on a high emission scenario.

3. **Tactical and strategic opportunities for adaptation to climate change have been revealed through engagement.** Researchers around the world have launched efforts to engage coastal communities in efforts to find effective climate adaptation strategies (See talks from Sessions S14 and S15). Whether these efforts are focused on small coastal communities or large commercial fishing centers, outreach and engagement has proven to be the most effective strategy in finding viable solutions. Commitments to an on-going iterative process will be necessary to keep up with the changing ocean ecosystems.

4. **Extreme events provide an opportunity to assess human and ecological responses to climate change (a "stress test"). Our ability to predict anomalous ocean conditions on seasonal to decadal time scales is improving.** For decades scientists have been striving to identify leading indicators of anomalous climate events. Session S1 provided an opportunity for scientists to assess the short- and medium-term forecasting skill of these studies. In several regions of the world there is promising evidence that short-term (3–9 months) skill in forecasting future ocean conditions is possible. This finding represents a breakthrough for the advancement of ecosystem-linked stock assessments. Several talks focused on the early detection of, and the management response to, marine heat waves. Retrospective studies of marine heat waves allow researchers to rehearse their responses to persistent anomalous warming events.

5. **Research continues to reveal complex energetic and physiological trade-offs associated with adaptation to changing environmental conditions. There are energetic and physiological costs to adaptation.** Sessions S9 and S11 focused on the ecological effects of climate change. The research findings from these two sessions build on previous ECCWO symposia and now reveal complex responses at different life stages, with lagged effects. Important lessons can be learned by examining the variations in adaptive responses and consideration of the full suite of environmental stressors within the socio-ecological system.

6. **Coastal communities are turning to aquaculture, marine ranching and fish attraction technologies to fill critical needs for food security. Research is needed to identify appropriate adaptation actions and good governance.** Sessions S14, S15 and S17 identified several case studies that highlighted the challenges facing small coastal villages in a changing

climate. While technological advancements in fish capture and fish production are emerging, holistic studies that assess the long-term implications of these adaptation responses will be needed to guide future developments to sustain food resources and preserve human health.

7. **More targeted measurements are necessary to better understand the oceanic carbon cycle and minimize uncertainties for both short-term prediction and long-term projection of carbon uptake, ocean acidification, and deoxygenation. Global Observation networks with technological advancements for data collection will improve our understanding of key processes.** Sessions S3–8 all noted the importance of continued and enhanced ocean monitoring as the foundation for detecting and understanding the implications of climate change on ocean systems. Several international groups are developing initiatives to enhance the storage capacity of, and improve access to, global ocean observations.

8. **Blue carbon solutions are emerging.** Session S18 provided an opportunity to highlight the innovations in blue carbon science as part of the global carbon budget. Several posters and the plenary speaker for this session highlighted the importance of mangrove forests as carbon sequesters in this effort.

9. **International planning and assessment activities play a key role in guiding and informing our research.** Several critical milestones have been achieved since the last ECCWO. The publication of the IPCC 5th Assessment Report (AR5) laid the foundation for a landmark international agreement to curb carbon emissions (the Paris Agreement, Conference of the Parties 21). The UN publication of the sustainable development goals (SDGs) provided a roadmap for global efforts to incorporate climate change impacts within the global socio-ecological system. The oceans play a key role in not only SDG 14 (life below the water) but many SDGs. For example, Session S16 highlighted the importance of how changing oceans has affected, or will affect, security.

10. **Oceans matter.** The Closing Session was held the day before World Oceans Day. The findings of the symposium certainly underscore the importance of the world's oceans. Symposia such as ECCWO provide a critical opportunity to share and discuss our research findings leading to valuable collaborations and research partnerships that will help to guide future science and communication of results to the decision makers and the public.

There were several firsts at ECCWO-4, on communication and capacity building. This was the first ECCWO meeting to include real-time Twitter feed postings (https://twitter.com/eccwo OR #ECCWO18. Second, at previous ECCWO symposia there was judging of early career scientists (ECS; ≤5 years post PhD) for the awarding of a few (2–4) best paper and best poster awards. However, there was no written feedback provided to any of the ECS. This year, instead of judging and presenting a few awards, there was a concerted effort in written judging of most ECS oral and poster presentations by session conveners and other senior scientists, with feedback provided after the meeting directly to the individual ECS about what was good and what might have been improved in their presentation and delivery. Finally, NOAA requested a category of participants that were invited at no charge to day one of the meeting. This category had badges labelled "Future Scientist" and consisted of 8th grade students from the Tacoma Park Middle School, Tacoma Park, Maryland. Now this is real outreach to the next generation of potential ocean scientists. Great job to the committees that took the lead on communication and capacity building at ECCWO-4!

All of us would like to say "Thank You" to the local organizers and numerous volunteers who provided the logistics to support this symposium. Their hard work behind the scenes made everything run smoothly. The venue selected by the local organizers allowed participants to readily catch talks from different parallel sessions and the social events brought everyone together to keep the discussions flowing. In particular, we would like to acknowledge the PICES Secretariat for its assistance in the planning and coordination of all that is required to run an international symposium. In addition to PICES, ICES, IOC, FAO and NOAA sponsorship, the following organizations and agencies made financial or in-kind contributions:

- Department of Fisheries and Oceans, Canada,
- COMPASS Science Communication,
- International Atomic Energy Agency,
- Integrated Marine Biosphere Research,
- Lenfest Ocean Program,
- Maine Coast Sea Vegetables Inc.,
- Monterey Bay Aquarium,
- North Pacific Anadromous Fish Commission,
- North Pacific Research Board, USA,
- Ocean Networks Canada,
- Surface Ocean-Lower Atmosphere Study,
- University Corporation for Atmospheric Research,
- Women's Aquatic Network.

We look forward to seeing all of you at ECCWO-5.

Important Deadline for Manuscript submissions

ECCWO-4 organizers arranged with Dr. Howard Browman, Editor of the ICES Journal of Marine Science, to publish papers on presentations made at the symposium. Instructions for the preparation of manuscripts and online submission is available at https://academic.oup.com/icesjms/pages/submission_online.

Deadline for submission of manuscripts for the ECCWO-4 special issue is September 3, 2018.
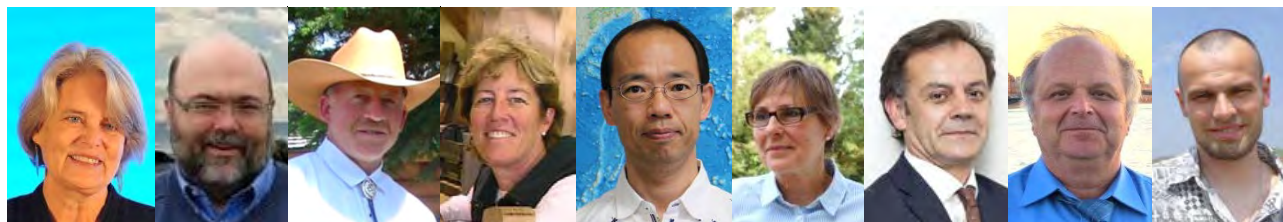
Dr. Anne B. Hollowed (Anne.Hollowed@noaa.gov) is a Senior Scientist with the U.S. National Marine Fisheries Service's Alaska Fisheries Science Center. She conducts research on the effects of climate and ecosystem change on fish and fisheries and leads the Status of Stocks and Multispecies Assessment (SSMA) program. Anne is an Affiliate Professor with the School of Aquatic and Fisheries Sciences at the University of Washington. She is a member of the NPFMC Scientific and Statistical Committee and the Weather, Climate and Fisheries Task Team of the Joint Committee for Agriculture and Meteorology (CAgM) and the Joint Technical Committee for Oceanography and Marine Meteorology (JCOMM) of the World Meteorological Organization. Anne served as Co-Chair of the joint PICES/ICES Section on Climate Change Effects on Marine Ecosystems from 2015 to 2017 and remains a member of the Section. She was the recipient of the Wooster Award presented at PICES-2015.

Dr. Jason Link (jason.link@noaa.gov) is a Senior Scientist at NOAA's National Marine Fisheries Service (NMFS). His research is in Ecosystem-based Management. His current scientific interests are applied ecological modeling and practical fisheries science for management, with a focus on management strategy evaluation, multi-species models, ecosystem models, essential fisheries habitat, and developing resource management tools and systems that have a stronger ecological basis.

Dr. Roger Griffis (roger.b.griffis@noaa.gov) is the Climate Change Coordinator for NOAA's National Marine Fisheries Service (NMFS). His current focus is on increasing the production, delivery and use of climate-related information in fisheries management, protected species recovery and habitat conservation. Efforts include implementation of the NMFS Climate Science Strategy, conducting marine species climate vulnerability assessments, and improving early warnings and responses to climate-related changes in marine ecosystems.

Ms. Margaret (Peg) Brady (Peg.Brady@noaa.gov) is Coordinator of NOAA Fisheries Ecosystem and Habitat Science Programs. Her focus is to ensure that science-based strategies are applied to sustain and enhance coastal and marine ecosystems for the communities that depend upon them now and into the future.

Dr. Shin-ichi Ito (goito@aori.u-tokyo.ac.jp) is a Professor at the University of Tokyo. His fields and topics of research range from physical to fisheries oceanography. He co-chairs the joint PICES/ICES Section on Climate Change Effects on Marine Ecosystems (S-CCME) and is a member of the Physical Oceanography and Climate Committee (POC) and Working Group on the Third North Pacific Ecosystem Status Report (WG 35).

Dr. Véronique Garçon (veronique.garcon@legos.obs-mip.fr) is CNRS Senior Scientist at Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Toulouse, France, where she is Head of the Physical Dynamics/Marine biogeochemistry (DYNBIO) team. Her research interests are marine biogeochemistry and ecosystem dynamics, large scale ocean circulation and tracers, global carbon and nitrogen cycles, and biogeochemical climatic monitoring. She is currently ex-officio in the Scientific Committee of the SOLAS (Surface Ocean Lower Atmosphere Study), and is a member of the Global Ocean Oxygen Network from IOC-UNESCO, of the IOCCP SSG and of the CLIVAR EBUS Research Focus group.

Dr. Manuel Barange (Manuel.barange@fao.org) is Director of the Fisheries and Aquaculture Policy and Resources Division at FAO. His expertise includes physical/biological interactions, climate and anthropogenic impacts on marine ecosystems, fish ecology, behaviour and trophodynamics, and fisheries assessment and management. In recent years, he has focused his research on predicting the impacts of climate change on marine ecosystems, and on the interactions between climate and other anthropogenic impacts on marine ecosystem services. In his role at FAO he emphasizes the importance conservation and sustainable development to secure food, livelihoods and trade of marine goods and services.

Mr. Robin Brown (Robin.Brown@pices.int) is the Executive Secretary of PICES and one of the ECCWO-4 Symposium Coordinators.

Dr. Wojciech Wawrzynski (wojciech.wawrzynski@ices.dk) is Head of the Science Support Department at ICES. With training in Economics, Wojciech has studied the effectiveness of financial mechanisms for research and innovation and has extensive experience in European science cooperation and science-policy projects. He is a member of the European Economic Association, European Association of Environmental and Resource Economists, European Association of Fisheries Economists and the International Arctic Social Sciences Association.

ECCWO-4 Workshop on "*Communicating and responding to climate change*"

by Bryony Townhill, Paul Buckley and John Pinnegar

This workshop (W1) was held on the first day (June 2, 2018) of the 4th International Symposium on "*The effects of climate change on the world's oceans*" (ECCWO-4) in Washington, DC, USA, to help develop better science communication on climate research. While much research is undertaken on marine climate change impacts, effective communication of the science to the target stakeholders is often lacking. Forty people attended the workshop, with one invited speaker and five other presentations. The workshop began with an introduction by co-convenor John Pinnegar from the Centre for Environment, Fisheries and Aquaculture Science (Cefas). He introduced the main objectives of the workshop, which were to share good examples of science communication, and to demonstrate ways in which science can be used by policy makers and communities to put in place adaptation responses to climate change.

Hazel Oxenford of the University of West Indies was invited to speak about research on *Sargassum* outbreaks in the Caribbean, and getting the correct messages to communities. Hazel highlighted the challenges of communicating advice to communities, and updating the advice as further research is undertaken. Following the workshop and the ECCWO-4 media event, *Science* ran a story on the problem of *Sargassum* in the Caribbean.

Co-convenors Bryony Townhill and Paul Buckley gave presentations about science communication in the UK, Caribbean and Pacific, where Marine Climate Change Report Cards have been produced to help policy makers and marine managers understand and interpret the complex research being conducted on various topics of marine climate change. The report cards are supported by detailed peer reviewed papers explaining each topic in more detail, with the card itself giving an overview relevant to each region.

A presentation on the Fish Manager's Guide to climate change and the Climate Adaptation Knowledge Exchange (CAKE) was given by Lara Hansen of EcoAdapt. The Guide provides information to fishers which they can use to better understand how climate change will impact them, and provides tailored guidance on how they can respond.

A talk on the UK's approach to adapting to climate change was given by John Pinnegar. He outlined the UK's combined Climate Change Risk Assessment (CCRA), National Adaptation Programme (NAP) and Adaptation Reporting Power (ARP) approach to identifying risks and adaptation methods in UK industry and environment. A second talk by Paul Buckley described a survey of European citizens and their understanding of marine climate change, and how this knowledge can be used to direct communication to stakeholders in the future.

Mona Behl was unable to attend the workshop, but her presentation on Sea Grant in Tybee Island and St. Marys (Georgia, USA) has been made available to all ECCWO attendees, and will soon be available on the PICES website.

The workshop highlighted examples of communicating climate change science to non-specialists that can then be applied by others looking to do the same. Also shown were examples of adaptation actions, particularly at the community scale, where stakeholders have been involved in all stages.

The afternoon session focused on receiving input from the workshop participants, of other examples of good science communication and of involvement of stakeholders in the research itself. The participants emphasized the importance of tailoring communication methods to the audience, and the need to include the public, educators, policy makers, marine managers, governments and international bodies in planning communication strategies. The intention is to write a short paper on the best practices of science communication to different audiences so that examples are available to illustrate and to improve science communication in the broader research community.

The workshop concluded that it is vital that the results of climate change research are effectively communicated to wider audiences outside of academia so that adaptation actions can be put in place. There are multiple ways to communicate scientific information for a broad audience, and to translate complex ideas and information into products that are useful for decision makers and practitioners. It is important to develop locally tailored practical and applied approaches to risk assessment, adaptation implementation and enhanced resilience of the marine environment and coastal communities.

ECCWO-4 Workshop on
"Advances in Earth System Models (ESMs) for marine applications"

by Takashi Mochizuki, Jasmin John and Michael Alexander

We convened Workshop (W2) focusing on *"Advances in Earth System Models (ESMs) for marine applications,"* on June 2, 2018, during the 4th International Symposium on *"The effects of climate change on the world's oceans"* in Washington, DC, USA. We had 6 contributions, including one invited talk in this 1-day workshop. More than 20 scientists discussed recent progress, remaining gaps and challenges in ESM research, and potential opportunities for collaborations between the ESM and impacts communities. We aimed at information exchange on new and innovative ocean physical, biogeochemical and ecological model developments and formulations incorporated into the 6th Coupled Model Intercomparison Project (CMIP6) models and simulations.
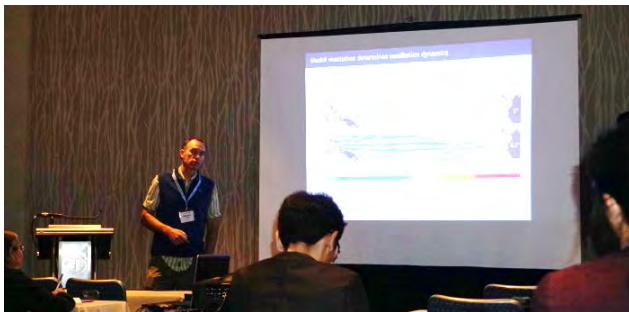
Matthew Long speaking on ESMs and marine ecosystems.

Matthew Long (NCAR, USA), the invited speaker, gave a comprehensive review of recent advances in ESM research in the context of climate variability and change. Matt pointed out that oxygen is a fundamental indicator of variability on annual, multi-annual and centennial timescales. The oxygen concentration reflects the dynamical changes of the global ocean and climatic responses to forced variations. However, at this stage we suffer from insufficient observations to know the actual changes, especially of subsurface oxygen in the tropics. Advanced ESMs can help us better understand complicated and integrated climate and biogeochemistry processes, even when available observations are quite limited. Nicole Lovenduski (University of Colorado, USA) introduced a prototype high-resolution ESM to explore the response of oxygen concentration and pH of the coastal waters to ENSO-related changes in the California Current System. She showed a consistent physical and biogeochemical response in the ENSO-related composite of the upper ocean together with remarkable diversity among the individual ENSO events.

Matthew Long also indicated that the bias of ESMs and uncertainty estimation were major issues when assessing the present and future environmental changes (*e.g.*, the ocean

biogeochemistry response to the volcanic eruption and long-term trend as a baseline). Toward reducing model bias and errors in the CMIP6 simulations, several modeling groups are developing and improving their ESMs by adding complexity (*e.g.*, calculations of nitrogen and iron cycles) and by increasing resolution. Michio Watanabe (JAMSTEC, Japan) introduced the latest version of ESMs developed by the Japanese MIROC modeling group, MIROC-ES2. Charles Stock (NOAA/GFDL, USA) introduced the GFDL's latest models, CM4 and ESM4, and highlighted the importance of model resolution to raise the level of performance in climate and biogeochemical simulations. When specifically focusing on modeled oxygen concentration, the bias in the CMIP5 simulation is usually derived from a combination of insufficient quality of modeling of both physical and biogeochemical processes. In particular, crucially important factors in the tropics are eddy mixing and diffusivity. Alexis Bahl (The Johns Hopkins University, USA) examined the sensitivity of ocean biogeochemical cycling to an eddy mixing parameter in an ESM under doubled CO_2 condition. She demonstrated that changes in the ocean circulation and stratification due to the eddy mixing parameter nonlinearly modified the oxygen and salinity distributions.

The comprehensive review by Matthew Long included earth system prediction. He introduced decadal prediction using the Community Earth System Model (CESM) with initialized climate and biogeochemical variables. Predicting the earth system has multiple challenges, including the difficulty of initializing biogeochemical variables, the influence of nonlinear processes on oxygen and nutrient fluctuations, and resonance of high-frequency variations on seasonal or longer timescales. In addition, the source of predictability is not always clear and it will be difficult to achieve a similar level of performance for earth system prediction compared to conventional climate prediction. For example, the lack of biogeochemical observations and the inconsistency between them can give rise to serious problems in initialization of actual predictions. Takashi Mochizuki (JAMSTEC, Japan) demonstrated the effectiveness of 4D-Var data assimilation for initialization of decadal climate predictions. While limited to climate prediction rather than earth system prediction, he also mentioned some implications for earth system predictions in the future. Data assimilation approaches that maintain consistency between the climate and biogeochemical fields are important for skillful predictions.

In addition to the above issues, we discussed how CMIP researchers could best collaborate with the impacts

community and policy makers. From the viewpoint of advancing ESMs, a hot topic was model bias, which could be a major source of errors and uncertainty for climate prediction and projection. Since model bias is inevitable due to imperfection of a model, we should focus on understanding underlying climate and biogeochemical processes and seek out and develop post-processing approaches suitable for extracting valuable information. CMIP data submitted in a uniform format are easy to use to make intercomparisons, and multi-model ensembles could be an effective approach to explore the detailed physical and biogeochemical processes relevant to model bias. In fact, sensitivity of model state to specific calculation and/or parameterization is quite different in each climate model and ESM. Even when focusing on atmosphere and ocean processes rather than biogeochemistry, a fully-coupled climate model has complicated mechanisms that can affect ocean biogeochemistry (*e.g.*, low-level clouds). Modeled states in oxygen, nutrients and pH are largely controlled by dynamically fluctuating climate at the sea surface as a boundary condition for ocean biogeochemistry.

We wrapped up the workshop by sharing the following key points relevant to advancing ESMs. Increasing model resolution and complexity of ESMs has helped reduce systematic model biases and helped decrease the multi-model spread in future scenario projections. More ocean observations are needed, especially in the subsurface, to help constrain model biases and understand relevant processes. Seasonal and multi-annual prediction for both physical and ocean biogeochemical variables is an exciting frontier, while model predictive skill (*e.g.*, decadal predictability and predictive skill of extremes) remains a challenge. This prediction arena will offer opportunities for collaboration between the modeling and impacts communities, by informing tactical decisions in the near-term and feeding into long-term strategic planning to build resilience. Additional approaches such as earth system downscaling and communication on how to handle climate predictions and projections should be explored.

Dr. Takashi Mochizuki (motizuki@jamstec.go.jp) is a senior scientist at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in Yokohama, Japan. His main research interests are in understanding global climate variability and predictability. His current research activity covers comprehensive climate prediction on annual, multi-annual to decadal timescales, contributing to Decadal Climate Prediction Project (DCPP) in CMIP6. Takashi has contributed to PICES activities as a member of Working Group on North Pacific Climate Variability (WG 27).

Dr. Jasmin John (Jasmin.John@noaa.gov) is a physical scientist at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, NJ, USA. Her research interests lie in understanding processes driving transitions and thresholds in the Earth System. A recent focus has been to understand and assess the legacy effects of climate change – in particular how the ocean and marine ecosystems respond under mitigation of greenhouse gases. Jasmin is also the technical lead for the management and development of NOAA/GFDL's Earth System Models on various high performance computing platforms for participation in CMIP/IPCC and other science initiatives, and is currently serving as GFDL's CMIP6 liaison and coordinator.
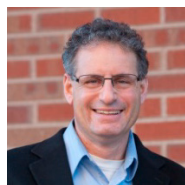
Dr. Michael Alexander (michael.alexander@noaa.gov) is a research meteorologist at the Physical Sciences Division of the NOAA Earth System Research Laboratory in Boulder, Colorado. Mike currently has three main research foci: air-sea-ice interactions, processes that influence moisture transport and heavy precipitation in the western United States, and climate change, including its impact on marine ecosystems. His studies of air-sea interaction include the influence of El Niño on global climate, precursors to El Niño events, and the effects of midlatitude sea surface temperatures and sea ice conditions on the atmospheric circulation. Mike has also worked closely with marine biologists to study how climate change may impact fish, such as the Atlantic croaker and river herring.

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Dr. Bryony Townhill (bryony.townhill@cefas.co.uk) is a Marine Climate Change Scientist, working on a range of climate-related projects determining the climate impacts on different species and sectors. Her research looks at the different aspects of marine climate change, their impacts on industry, species and ecosystems, adaptation options and resilience building. She specialises in the use of models in assessing the impacts of climate change on marine ecosystems, particularly on species distributions, and also on working with small island states to understand their vulnerabilities to climate change.

Dr. Paul Buckley (paul.buckley@cefas.co.uk) works at the science-to-policy interface, communicating the impacts of marine climate change to end users. As programme manager for the Marine Climate Change Impacts Partnership (MCCIP) in the UK, he helps draw together impacts evidence from across the scientific community and translates it for use by non-specialist audiences. He also works with industry and conservation agencies to support adaptation and has led work packages as part of EU projects on wider ocean literacy and public perception studies.

Dr. John Pinnegar (john.pinnegar@cefas.co.uk) has overall responsibility to provide leadership across the Cefas's climate-related portfolio. John provides strategic planning of research goals and initiatives at Cefas, as well as providing advice and evidence on marine climate change to governments. He carries out a range of fisheries, ecological and social studies on marine climate change in the UK and overseas.

ECCWO-4 Workshop on *"Exploring potential ocean-based solutions to climate change impacts on marine biodiversity and ecosystem services"*

by William Cheung, Elizabeth McLeod, Fiorenza Micheli and Colette Wabnitz

Marine biodiversity and ecosystems are now at a crossroads and the world is demanding effective solutions to mitigate and adapt to climate change and to maintain the natural services provided by the ocean. On June 3, 2018, as part of the 4th International Symposium on *"The effects of climate change on the world's oceans"* held in Washington DC, USA, we organized a 1-day workshop (W3) to explore and discuss potential ocean-based solutions to "avoid the unmanageable" and to "manage the unavoidable" risks from climate change on marine biodiversity and ecosystem services. The workshop was attended by 40–45 participants from multi-disciplinary (natural and social sciences) and sectoral (academics, government, non-governmental organization and private sector) backgrounds.

Through a series of presentations and breakout group discussions, the workshop explored the potential effectiveness of proposed or implemented strategies to moderate climate impacts, challenges and opportunities for their implementation, their implications for sustainable development, as well as research and policy needs to make progress toward meeting these challenges. The potential solutions discussed during the workshop included both mitigation and adaptation measures, nature- or technology-based, as well as for local and global scales.

The workshop was opened by an invited presentation by Ling Cao (Stanford University/Shanghai Jiao Tong University) on the role of aquaculture in climate solutions and contributions to food security. Dr. Cao provided an overview of the rapidly growing importance of aquaculture in food and nutritional security, and focused on the status and trends of aquaculture development in China. She highlighted examples of potentially sustainable aquaculture developments such as shellfish–seaweed polyculture to help adapt to climate impacts on seafood production as well as their role in mitigating carbon emissions. However, she also discussed challenges and trade-offs in large-scale aquaculture development, such as the transformation of coastal ecosystems, which would need to be avoided in developing sustainable aquaculture.

Dr. Cao's talk was followed by presentations by Alexandre Magnan (IDDRI) who provided a summary of a recently completed synthesis of ocean-based climate solutions and experiences, and Alastair Hobday (CSIRO) who provided ideas generated from practical implementation of adaptation experiments and interventions. The key messages are that a combination of adaptation strategies and options at the global and local-scale with different levels of effectiveness and co-benefits are needed. Also, the

effective communication of scientific knowledge and data could help guide autonomous adaptation by ocean-based sectors. Based on the severity of climate impacts, implementing active adaptation interventions will be necessary to safeguard species, habitats, and human communities, despite opposition by "adaptation skeptics" (*e.g.*, spraying antibiotics on seabird chicks to reduce their disease risk and to build their capacity to adapt to climate change).

Through a series of "lightning talks", a number of invited participants shared different perspectives and experiences about ocean-based climate solutions. Examples include: (1) the challenges faced by developing countries in implementing local climate solutions; (2) the importance of and experience with local communities in identifying factors that facilitate and impede adaptation as well as the evaluation of relative socio-ecological and economic benefits of different adaptation options; (3) barriers to adaptation, such as divergent expectations and stakeholder burnout; (4) the importance and role of autonomous adaptation; (5) research on exploring how sensitive existing ocean plans are to climate change and designing "climate-smart" spatial fisheries management; (6) opportunities and challenges that were raised at a recently held workshop on ocean-based climate solutions; and (7) initiatives from a private sector on developing technology for climate mitigation and adaptation.

W3 break-out group discussions.

In the break-out groups, the participants discussed a number of challenges and possible solutions. Challenges included: (1) effective communication; (2) lack of integration between traditional scientific knowledge and Local Ecological Knowledge and indigenous knowledge; (3) a disconnect between the pace at which institutional change is required *versus* needed, and among regulatory frameworks across different spatial scales (*e.g.*, regional *vs*

national); and (4) engaging community knowledge holders in initiatives from the start. Activities that were suggested as contributing to solutions included: (1) integrating scenario implementation when developing solutions across scales and sectors (*e.g*., scientists provide the basis, communities suggest scenarios, scientists come back with outcomes), (2) undertaking research on the science of proposed solutions and their consequences as well as long-term monitoring, (3) posterior assessment and mechanisms that allow for constructive feedback, (4) research on species that are resistant or better adapted to disease (greater resilience), (5) developing fisheries and citizen science programs at appropriate scales (6) involvement of the private sector, and (7) identification of engagement models that are efficient and produce rapid results.

Overall, from the discussion, we identified two major themes that we will develop further as main outcomes of the workshop. First is the development of effective climate adaptation pathways, including the need to include both natural and human dimensions, effectively involve local communities and stakeholders, recognize the importance of solution scales and the roles that different sectors (academics, government, NGOs and private) can and should play in moving forward. The second theme is autonomous adaptation. It is apparent that ocean-dependent communities and sectors have been responding to climate and environmental changes and there are already a lot of experiences accumulated from these autonomous adaptations. It would be useful to synthesize these experiences and determine how different efforts across scale and regulatory levels may best be coordinated to generate some best practices principles that could help guide effective autonomous adaptation. We also identified a few future opportunities to continue and expand upon these discussions, such as (1) a workshop on ocean- based climate solutions in the Pacific (end 2018–2019); (2) attendance and presentation at OceanVisions2019 – Climate Successes in Resilience, Adaptation, Mitigation and Sustainability which will be held in collaboration with the IOC-UNESCO and the Ocean Conservancy at Georgia Institute of Technology in April 2019; (3) contributions towards a special issue in *Frontiers in Marine Science* on success stories in climate adaptation/mitigation, with abstracts due in the fall of 2018; and (4) potential participation at the Uncommon Dialogue with stakeholders, to be held at Stanford University in September 2019, which will include a subset of ocean climate success stories that have the potential to be developed into scalable solution strategies.

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Dr. Elizabeth (Lizzie) Mcleod (emcleod@tnc.org) is the Nature Conservancy's Climate Adaptation Scientist for the Asia Pacific region and the Science Lead for the Reef Resilience Network which provides the latest scientific guidance and resources to help coral reef managers globally to address the impacts of climate change and local threats. Lizzie received her Ph.D. in climate vulnerability and adaptation in tropical systems from the University of Hawaii. Her research focuses on building the resilience of coastal communities and ecosystems to climate change.

Dr. Fiorenza Micheli (micheli@stanford.edu) is Professor of Biological Sciences at Stanford University. She obtained her Ph.D. in marine sciences at the University of North Carloina at Chapel Hill. Her research focuses on the processes and interactions shaping coastal marine communities and incorporating this understanding in the management and conservation of marine ecosystems. Her reearch interests include community ecology, marine ecology, marine conservation, species interactions and habitat-organism relationships in aquatic ecosystems, structure and dynamics of marine food webs, marine protected areas, and marine ecosystem-based management.

Dr. Colette Wabnitz (c.wabnitz@oceans.ubc.ca) is a Research Associate with the University of British Columbia's Changing Ocean Research Unit. After receiving her Ph.D., Colette spent four years as a Fisheries Scientist for the Secretariat of the Pacific Community (SPC) in New Caledonia. Her research interests include understanding the functioning of ecosystems, how these may respond to human pressures and natural forcing, and the design, together with stakeholders, of appropriate measures for the sustainable use of their resources and the long-term conservation of their services.

ECCWO-4 Workshop on *"Climate change adaptation of fisheries and aquaculture: examples of field projects supporting countries and communities"*

by Tarub Bahri, Amber Himes-Cornell, Iris Monnereau and Adrien Comte

Workshop (W4) was organized with the purpose of presenting field projects supporting countries and fisheries-dependent communities adapt to climate change, and to address different angles from physical environment to social, economic and institutional aspects of climate change adaptation in different regions of the world (Caribbean, Africa, Asia, Latin America and Europe). The workshop was also intended to examine relevant tools and measures that can support adaptation and gather scientific, practical and methodological inputs from the participants of relevance to the field projects presented, in order to contribute to a major understanding of both the enabling conditions of adaptation and its main challenges.

W4 took place June 3, 2018, at the 4th International Symposium on *"The effects of climate change on the world's oceans"* (ECCWO-4) in Washington, DC, USA. The ½-day workshop was attended by 30 participants including 11 speakers. The opening remarks provided an overview of the state of scientific research on climate adaptation and presented conceptual frameworks which set the stage for the workshop. Marine Spatial Planning (MSP) was the focus of two presentations illustrating how it can support adaptation. One presentation provided an overview of climate-related risks and extreme events and suitable adaptation options to prevent or cope with their impacts. Nine presentations then provided adaptation examples from the field and analysed enabling conditions and challenges for climate change adaptation in the Caribbean, Chile, Benguela Current, Myanmar, India, Bangladesh, and Europe. Finally, an open discussion followed to share experiences among participants and to come up with cross-cutting issues regarding implementation of climate change adaptation projects.


Audience at W4.

To date, most of the climate adaptation research agenda on the ground has focussed on assessing impacts and vulnerability. While this is crucial, there is also a need to use the information gathered to build adaptive capacity and to foster adaptation. Presenting potential adaptation solutions and adaptation case studies, rather than solely the adverse effects and impacts of climate change, is likely to be more

engaging for practitioners and the public. The purpose of vulnerability assessment is to inform adaptation planning, with a key lever of action being building adaptive capacity. Key questions are:
- How to measure adaptive capacity?
- How to build it?
- What adaptation activities have already taken place?
- How do governance regimes affect adaptation (enable or constrain)?

An overview of adaptation related to risks and extreme events was presented, recalling definitions and describing the response tools available, *e.g.*, early warning systems, insurance, social protection, and safety at sea. Another increasingly used tool to plan for and manage marine activities, MSP will need to reflect the change in the distribution of ocean ecosystem services and the related uncertainty, as conflicts between uses, pressures, and legal issues and permits may arise from the relocation of activities as a consequence of climate change. MSP, if it is able to take into account multiple spatial and temporal dynamics, could also become a tool for adaptation to climate change across sectors.
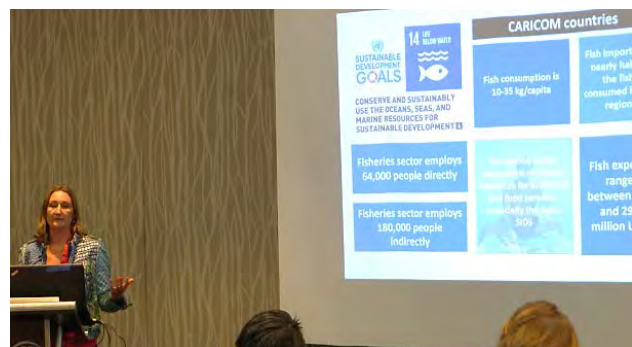
W4 convenor, Dr. Iris Monnereau.

The main conclusions of the discussions were:
- Adaptation is at an early stage; however, various adaptation actions (short term, medium term and long term) are taking place, at multiple scales, in response to current and future stressors, with various levels of progress and success.
- For appropriate adaptation action, we need good governance, and stakeholders' engagement and representation. These criteria are essential to ensure that adaptation plans are relevant and reflect local vulnerabilities that communities are facing. On the other hand, in some situations, there is no uptake by the stakeholders of the adaptation plans proposed because of a lack of awareness and a belief that the changes

observed are part of natural variability and not a long-term change that requires specific adaptation. There is a need for a two-way (top-down and bottom-up) adaptation process involving local, national and sometimes regional levels.

- Adaptation that involves social learning is an extensive and difficult process but is more robust and relevant. Social learning that includes stakeholders and ensures the scaling up of adaptation planning from local to national, and that address multi-sectoral issues are lengthy and difficult, but they are the most beneficial in terms of robustness of adaptation planning and relevance.

- Laws and regulations can be enablers or barriers to good adaptation. Suitable and flexible laws and regulations are enablers, in particular when multi-sectoral planning is carried out. To date fisheries policies, plans, and legislation rarely take climate change issues into consideration. At the same time, existing laws can be barriers for the implementation of adaptation measures (*e.g*., freshwater directives hindering aquaculture development).

- The monitoring and evaluation framework for successful adaptation needs further development. There is a gap in metrics measuring adaptive capacity and adaptation: suitable indicators to measure the success of adaptation need refining. While metrics to measure adaptation success and reduction in possible impacts are long-term efforts, metrics to measure improvements in adaptive capacity can be undertaken now. Sources of inspiration could be the disaster reduction methodology, with potential examples of metrics used for recovery from disasters. Another source of inspiration could be the Large Marine Ecosystem Projects that are addressing multi-sectoral issues (*e.g*., biodiversity, pollution, fisheries) and putting in place metrics to measure progress made.

- Positive messages are more effective to raise awareness and mobilize action, especially if they give a sense of hope and availability for potential solutions, rather than a focus on threatening images.

Dr. Tarub Bahri (Tarub.Bahri@fao.org), Fishery Resources Officer in the Marine and Inland fisheries Branch of the FAO, has a PhD in biological oceanography and a background in statistics. She is part of the FAO fisheries and aquaculture climate change working group and is involved in normative work and implementation of field projects. She has extensive experience in Ecosystem Approach to Fisheries, both in delivering training and supporting the development of fisheries management plans in Africa, Latin America and the Caribbean.

Dr. Amber Himes-Cornell (Amber.HimesCornell@fao.org) is a Fishery Officer in the Fisheries Policy, Economics and Institutions Branch of the Fisheries and Aquaculture Division of the FAO and is based in Rome, Italy. Dr. Himes-Cornell's work is focused on interactions between fisheries and marine protected areas (MPAs), assessing ecosystem services in MPAs, the role of tenure in fisheries management, coastal community vulnerability and resilience, social transformation, socio-economic impacts of climate change, climate change adaptation strategies, the socio-economic aspects of marine ecosystem services, and valuation of ecosystem services. Previously, she was a social science researcher jointly at the University of Brest (UBO), AMURE and LABEX where she was involved in two major research projects: The Global Environment Facility's Blue Forests Project, which focuses on defining and valuing ecosystem services in blue carbon habitats, and a European Union funded Horizon 2020 project called ECOpotential, which focuses on mapping coastal ecosystem services with remote sensing technology. Prior to coming to UBO, Dr. Himes-Cornell was a social scientist at NOAA's Alaska Fisheries Science Center where she focused on analyzing the importance of commercial, recreational and subsistence fishing to Alaskan communities

Dr. Iris Monnereau (Iris.Monnereau@fao.org) is the Regional Project Coordinator of the "Climate Change Adaptation in the Eastern Caribbean Fisheries Sector Project (CC4FISH)", based at the FAO Subregional Office for the Caribbean located in Barbados. Iris received her PhD in 2012 at the University of Amsterdam, The Netherlands, in the Department of Geography, Planning and International Development Studies for which she investigated the impacts of different lobster fisheries governance and value chains systems on the well-being of fishers in Belize, Jamaica and Nicaragua. She holds an MA in Non-Western Sociology with a Major in Environment and Development from the University of Leiden (The Netherlands). Prior to her post at the FAO she specialized for 4 years in climate change vulnerability and adaptation of the fisheries sector in the Wider Caribbean as a post-doctoral fellow and international researcher at the Centre for Resource Management and Environmental Studies (CERMES) at the University of the West Indies in Barbados.

Dr. Adrien Comte (adrien.comte@univ-brest.fr) is a post-doc at the Université de Bretagne Occidentale in France. His work focuses on marine and coastal social-ecological systems and climate change. At the interface between science and policy, Adrien's work aims at understanding vulnerability to climate change and informing climate policy, including nature-based solutions and ecosystem services provision. His current project investigates the vulnerability and adaptation to climate change of coral reefs and human populations who depend on them in French Polynesia.

ECCWO-4 Workshop on "*Climate change and fishing communities: Interactions with environmental conservation, sustainable livelihoods and food security*"

by Anthony Charles, Daniela Kalikoski and Lena Westlund

The 1-day workshop (W5) on "*Climate change and fishing communities: Interactions with environmental conservation, sustainable livelihoods and food security*" was held on June 3, 2018, as part of the 4th International Symposium on "*The effects of climate change on the world's oceans*" in Washington, DC, USA. The workshop examined how climate change both drives and exacerbates the multi-level imperatives of livelihood sustainability, food security and associated initiatives of community-based environmental conservation within coastal fishing communities globally. Within that context, the workshop also explored the types of governmental and international programs and policies needed to effectively engage with and support small-scale fishery and coastal community stewardship and security in the face of climate change. The workshop was jointly convened by the Community Conservation Research Network, Saint Mary's University (Canada), the Fisheries Expert Group of IUCN, and the Food and Agriculture Organization of the United Nations (Fisheries and Aquaculture Department and Strategic Programme on Rural Poverty Reduction).

The first phase of the workshop focused on "Insights and priorities for linking climate change with environmental conservation, sustainable livelihoods and food security: A fishing communities perspective". The theme was introduced with scene-setting presentations by the convenors. First, Anthony Charles (Saint Mary's University) spoke on how coastal communities globally are dealing with climate change and environmental threats to build sustainable livelihoods and food security. His presentation highlighted results of the Community

Conservation Research Network. Then Daniela Kalikoski and Lena Westlund presented on behalf of FAO about challenges, needs and opportunities for climate change adaptation in fisheries and aquaculture, with reference to the Small-Scale Fisheries Guidelines and FAO's poverty reduction efforts.

These were followed by two invited presentations that provided a series of strong insights into the social and ecological issues involved. Mohammad Mahmudul Islam provided lessons from Bangladesh on creating an enabling environment to support disaster risk reduction in the context of the Small-Scale Fisheries (SSF) Guidelines. Jake Rice talked about the importance of variability and viability in looking at communities, climate change and adaptation strategies. Thereafter, a set of contributed presentations covered experiences from around the world, looking at Indigenous fishers and climate adaptation in the Philippines (Maria Rebecca Alviar Campos), the vulnerability of a marine protected area to climate change in Sierra Leone (Sheku Sei), factors influencing climate change adaptation in India (Devendraraj Madhanagopal) and social vulnerability of fishing communities to climate change in Brazil (Maria Gasalla).

These presentations were followed by two discussion sessions in which participants were invited to share ideas and practical experiences focused on analysing broad issues and participants' experiences concerning interactions of climate change in coastal fishing communities with livelihood sustainability, food security and environmental conservation.

Workshop (W5) participants.

The second phase of the workshop focused on the interactions of poverty reduction and food security measures with climate change mitigation and adaptation in the context of coastal communities, coastal areas and Small Island Developing States (SIDS). A participatory process was followed, seeking to generate a variety of ideas, insights and priority directions relating to the interaction of climate change responses with poverty reduction. This provided input into a current initiative of the Food and Agriculture Organization of the UN to explore desired pathways to make progress on linking poverty reduction and climate change responses, including development, humanitarian, disaster risk reduction and climate adaptation perspectives.

An initial presentation, to set the scene, was made by Anthony Charles and Daniela Kalikoski, on the "nexus" of poverty and climate change in the context of coastal communities, coastal areas and SIDS. Each participant was then invited to share their perspectives, and small group discussions aimed to place the range of experiences, across the globe, within a suitable analytical framework. The results of the workshop analysis led to improvements in the analytical framework that will be tested in future forums, to generate insights for effective approaches linking climate responses and poverty reduction.

The workshop produced a number of conclusions, including:

- Fishing communities globally are on the front lines facing climate impacts, and are well placed to draw on important synergies between local environmental stewardship and climate responses.
- Climate responses interact with poverty and food security responses; a big challenge for the immediate future is to link the "climate agenda" and the "development agenda". The SSF Guidelines help in this direction by providing guidance on integrating fisheries with broader community, social, economic and governance systems.
- There is a gap in our understanding of whether, and how, climate change adaptation actions are increasing or decreasing poverty and inequality, and a corresponding need to find appropriate adaptation pathways that "leave no one behind".
- In particular, broad participation in climate adaptation initiatives is an important ingredient, to avoid harming coastal communities – which can occur if the design and implementation of adaptation measures does not fully consider possible negative impacts on poverty, sustainable livelihoods and food security.

Workshop participants expressed a desire to maintain and build connections, to further collective efforts to address the impacts of climate change on fishing communities, and interactions with environmental conservation, sustainable livelihoods and food security.

Dr. Anthony Charles (Tony.Charles@smu.ca) is a professor at Saint Mary's University (Canada) and a member of IUCN's Fisheries Expert Group. His research on fisheries, oceans and coasts focuses on climate change, sustainability and resilience, integrated management, ecosystem-based management, community-based management, and marine protected areas. He has authored and edited several books, including Sustainable Fishery Systems; Governance of Marine Fisheries and Biodiversity Conservation and Governing the Coastal Commons. He leads the Community Conservation Research Network (www.CommunityConservation.Net) which examines how local communities worldwide link environmental conservation and sustainable local economies.

Dr. Daniela Coswig Kalikoski (Daniela.Kalikoski@fao.org) works at the Food and Agriculture Organization of the United Nations (FAO). She is a Fishery Industry Officer and also serves as an Advisor of the FAO's Strategic Programme on Rural Poverty Reduction. She holds a PhD in Resource Management and Environmental Studies at the University of British Columbia (Canada). During her career to date she has been exposed to many different challenges in dealing with the relation between poverty reduction and natural resources management, with a specific focus on collective action, community-based and co-management interventions as well as fishing communities vulnerabilities to climate change.

Ms. Lena Westlund (Lena.Westlund@fao.org; MSc University of Gothenburg, Sweden) has extensive experience in fisheries and development cooperation. She has lived and worked both long and short term in-country and has been engaged in projects on poverty alleviation and food security in small-scale fishing and fish farming communities. At the global level, she has been involved with policy and has contributed to several FAO publications, e.g., on the ecosystem approach to fisheries (EAF) and on marine protected areas (MPAs) and fisheries. She was engaged in the Small-Scale Fisheries Guidelines development process and now supports their implementation. Ms. Westlund currently lives in Stockholm, Sweden, from where she continues to work as an FAO consultant.

ECCWO-4 Workshop on *"Utilizing bioenergetics measurements and modeling to evaluate climate change effects on marine species and ecosystems"*

by Myron A. Peck, Kirstin Holsman and Janet Nye

A workshop (W6) on *"Utilizing bioenergetics measurements and modeling to evaluate climate change effects on marine species and ecosystems"* was convened on Saturday, June 2, 2018 as part of the 4th International Symposium on *"The effects of climate change on marine ecosystems"* held in Washington, DC, USA. This 1-day workshop provided a forum for discussing recent advances in the study of bioenergetics and how physiological-based knowledge of organisms has been used (and/or can be used in the future) to inform and improve models examining climate impacts on fish, their predators and their prey. The workshop was attended by 35 scientists from 11 countries. A morning session included 10 talks while an afternoon session was dedicated to the discussion of key questions.

This workshop featured an invited presentation by Kenneth Rose that described recent advances on how behavourally mediated movements in fish are measured and a summary of how fish movement has been included in complex, 3-D, end-to-end models. Take-home messages from this presentation were that knowledge of animal movement including our current mechanistic understanding of where (and why!) fish move (at different time scales) is needed to make more robust projections of climate impacts that include both direct (*e.g*., temperature) and indirect (prey-driven) drivers. An additional message was a plea for stronger collaborations between research communities such as ecophysiologists, movement ecologists, and ecosystem modelers, who often work in isolation.

A series of talks provided illustrations of how bioenergetics has been incorporated into models of key species, including examples from the NE Pacific (Alaskan snow crab, *Chionoecetes opilio*), the NW Pacific (Pacific chub mackerel *Scomber japonicas*), the NW Atlantic (winter flounder *Pseudopleuronectes americanus*), and regions of the NE Atlantic including the Bay of Biscay (European anchovy, *Engraulis encrasicolus*) and the North, Barents and Norwegian seas (Atlantic herring, *Clupea harengus*). In some cases, the bioenergetics of multiple stages (*e.g*., embryos, larvae, juveniles and adults) was included in models depicting environmental impacts on the full life cycle. A number of talks discussed broader issues of relevance to the interface between bioenergetics and modelling. In one example, the availability of data from experiments examining the direct effects of changes in abiotic factors (temperature, pH, salinity and dissolved oxygen) on commercially important fish and shellfish inhabiting European marine habitats was discussed. That talk highlighted important gaps in knowledge stemming

from a lack of controlled laboratory work on specific life stages and from treatments of interacting factors. The two final talks of the workshop focused on more generic, size-based approaches to model fish communities and the ability to use these tools to make cross-system comparisons of climate impacts. These two presentations yielded lively discussions on the benefits and potential pitfalls of using trait-based approaches to represent multiple species and trophic levels within models.

Prior to the workshop, attendees received a questionnaire on how bioenergetics and/or movement has been incorporated into their recent / ongoing modelling approaches. In total, 15 models were summarized by respondents that depicted climate impacts on either single species, multiple species or food webs. Whereas all of the models incorporated the effect of temperature (in some fashion) only one model included the impacts of an additional abiotic factor. This was the case for dissolved oxygen and pH. Although only a miniscule subset of the marine science community's bioenergetics modelling efforts, this lack of emphasis on representing the impacts of additional factors (beyond merely temperature), appears to be a widespread, if not systemic, shortcoming, and is concerning. The lack of work (experimental and modelling) on hypoxia and its relation to animal movement, for example, was a theme echoed throughout the symposium sessions and in the summary of the symposium. Movement was included within about half of these models and was a major topic of discussion.

Dr. Shin-ichi Ito describing on going and future perspectives regarding climate variability impacts on living marine resources.

During the afternoon discussion, participants identified four key challenges and opportunities to advance bioenergetic models. These included:

1. **Integrating movement ecology and projection models.** In mobile animals, behaviourally mediated movement is a fundamental component of life history strategy and

ECCWO-4 Workshop on "*What do seabirds reveal about the effects of climate change on the world's oceans?*"

by Sarah Ann Thompson and William J. Sydeman

A 1-day workshop (W7), convened by William J. Sydeman (USA), John Piatt (USA), Yutaka Watanuki (Japan), Joel Durant (Norway), Lynne Shannon (South Africa) and Robert Crawford (South Africa), was held June 3, 2018 at the 4th International Symposium on "*The effects of climate change on the world's oceans*" in Washington, DC, USA. The workshop sought to:

1. Compare marine bird response to climate change across marine ecosystems and biomes, from the tropics to the Arctic and Antarctic,
2. Develop mechanistic understandings of these responses, including interactions between climate and forage fish fisheries, and
3. Educate informed laypeople (including managers and policy-makers from Washington, DC) on recent observations of apparent marine bird responses to climatic factors globally, including unprecedented seabird die-offs in many parts of the world.

Approximately 17 attended the workshop. The morning consisted of opening remarks by the conveners, introductions by the participants, overview of the workshop, and invited presentations.

Introduction and opening remarks

The group discussed producing a manuscript/report stemming from this workshop that could be targeted as a contribution for the forthcoming IPCC AR6 report. Additionally, there was discussion about potentially producing some sort of product that would be good for general public education.

Summary of presentations

Invited presentations were given by Richard Sherley (University of Exeter), Kate Searle (Centre for Ecology and Hydrology), Stephanie Jenouvrier (Woods Hole Oceanographic Institution), Claire Saraux (Ifremer, Marine Biodiversity, Exploitation, and Conservation), Jarrod Santora, (University of California Santa Cruz), John Piatt (U.S. Geological Survey), and Bill Sydeman (Farallon Institute).

There were many common themes throughout the presented material, including widespread difficulties of seabird populations to thrive. Even outside of the global meta-analysis by Sydeman *et al*., there was much evidence presented of declining seabird populations, punctuated by climate and weather events that periodically cause increased damage to local populations. Common

mechanisms of effects of climate change are bottom-up trophic changes and reduced food availability that are compounded by fisheries pressure (competition with humans for prey resources). The specific trends and effects on seabird populations are dependent on species and particular prey dynamics. Additionally, the researchers agreed there are aspects of seabird life history that are understudied, and there may be other effects on them that are also understudied.

Dr. John Piatt presenting evidence for the massive die-off of common murres in the Northeast Pacific during the marine heat wave of 2014–2016.

Open discussion

The participants agreed that the formation of a Seabird-Climate Working Group would be beneficial, given the similarities of change across seabird populations around the world, and that the effects of climate change are complex, further warranting a collaborative working group. A major topic of discussion centered on the idea of compiling a suite of papers for a proceedings or, alternatively, a larger single manuscript for publication on the subject of climate change effects on seabirds. The publication would be based on solid scientific research but then also be adapted to accommodate as well a more general audience.

One area that was identified as needing more work going forward was for population forecasts by models in relation to climate change. There seems to be a lack of confidence in understanding the complexity in climate models, but we have resources to undertake this challenge. In terms of understanding, we need to understand where we want to be (population forecasting for climate change), then reflect on where we are (correlations and meta-analyses). To begin with, we need a comprehensive literature review and meta-analysis of all current findings. Among the group, some efforts have been done in this direction, but a more focused project could still be done. One way to bring all of this together would be to have a special volume of papers

written by the regional experts. These papers would give the current state of knowledge (published literature) for each region, and follow a pre-determined template in order to make them cohesive as a collection (e.g., "apples to apples"). This special volume and the work compiled for it would set up the meta-analysis discussed earlier (see first paragraph for Open discussion).

Compiling this information for each study region means identifying gaps in important data. Areas of information to consider are the strength of direct and indirect effects in each system, population growth rates and their plasticity, and specific life history characteristics. The common framework to develop for each region includes climate and links to species in terms of their functional responses/traits and vital rates. In this framework, the regional experts can define the key links along the chain and determine which are the most important in that system. A subject of interest

across this broad compilation is which seabirds have been demonstrably impacted by climate effects. Related to this, we would want to show where we can parameterize population models for prediction efforts. This synthesis would serve as a feasibility analysis of where things can be done—how many species do we have enough data to do projections for? The papers would identify how much information we have on a global scale.

The formation of a Seabird-Climate Working Group would additionally be useful for policy. It's unclear how funding and sponsorship for a group like this would come together, however. The group would need travel support for collaborative meetings, perhaps several sponsoring agencies could contribute funding. Group members would also look to meet at forthcoming international conferences such as the 2019 10th International Penguin Conference and the 2020 3rd World Seabird Conference.

Sarah Ann Thompson (sathompson@faralloninstitute.org) is a Research Scientist at the Farallon Institute where she studies the climate effects on top predators. She manages the Farallon Institute's Integrated Marine Ecological Database (IMED) with physical and biological data sets for the California Current. She also holds an affiliate staff appointment in the University of Washington's Climate Impacts Group.

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.

(continued from page 49)

better representation of the triggers, cues and costs within models is required if we expect to realistically capture both direct and indirect (trophodynamic) impacts of climate change.
2. **Scaling from individual- to population-level responses.** Understanding density-dependent regulation of population-level growth and mortality as well as the adaptive capacity of individuals across populations is needed to move from measurements made on individuals to projecting effects within populations and species.
3. **Depicting realistic environments.** Organisms experience daily, seasonal and annual fluctuations in environmental conditions and face challenges in dealing with multiple, interacting abiotic and biotic factors. More realistic experimental designs and model simulations are needed (move beyond the "mean").

4. **Reducing uncertainty in model projections.** Utilizing scenarios and ensembles now help capture and estimate the uncertainty in physical and biogeochemical impacts of climate change. These techniques need to be applied within projections of climate impacts on higher trophic levels – moving beyond sensitivity analyses of individual parameters in single models.

Workshop participants are now drafting a paper based on these and additional discussions held during W6. This was an exciting start to a thought-provoking and productive week in Washington, DC. The conveners would like to thank the participants for their contributions and the symposium conveners for accommodating this workshop.

ECCWO-4 Workshop on "*Connecting climate, ocean and ecosystem observation – Ocean observation futures*"

by Jörn Schmidt, Sabrina Speich, Fred Whoriskey, Daniele Iudicone and John A. Barth

In the face of a changing ocean, we need to adjust our ocean observation systems to meet new needs. What do we need to know about the ocean-human system and what data do we need to collect to increase our knowledge and better manage its future development?

A 1-day workshop (W8) was held on June 3, 2018, at the 4th International Symposium on "*The effects of climate change on the world's oceans*" (ECCWO-4) in Washington, DC, USA. The workshop brought together 20 international experts with diverse disciplinary and institutional backgrounds to discuss the integration of fisheries, ecosystem and oceanographic observations.

The workshop started with two invited presentations:
- Multidisciplinary Ocean Time Series: for researcher aggregation and the generation of surprises and knowledge (Douglas Wallace, Dalhousie University/ Ocean Frontier Institute, Canada),
- Implementation of biological Essential Ocean Variables in the global observing system (Patricia Miloslavich, University of Tasmania, Australia/Universidad Simón Bolívar, Venezuela),

and three contributed presentations:
- Tara Oceans: Eco-Systems Biology at the Planetary Scale (Matthew B. Sullivan, Ohio State University, USA),
- The World Ocean Database – Conjoining research observations and observing systems across disciplines, across time (Tim Boyer, NOAA),
- Widespread microplastic distribution at a microtidal Amazon sandy beach (José Martinelli Filho, Federal University of Pará, Brazil).

The 5 presentations laid out the basis for further discussion on topics, including observing climate, ocean, eco- and human system related processes and variables. The participants discussed questions on why integration is necessary and what are the needs of different user groups and communities, including major societal needs that the observing systems are addressing, like ocean warming, changing dynamics, plastic litter, acidification, noise and overharvesting among others.

The workshop addressed different levels of connectivity across technology levels, different disciplines, different temporal and spatial scales, different needs of stakeholders and the connectivity between national funding agencies and institutions. It touched also on the related research data infrastructure needs to connect data across all these levels, including practical issues like standards and formats.

In particular, the link of fisheries and biodiversity observations to the Framework of Ocean Observing (FOO) and the Essential Ocean Variables and the use of current fisheries and biodiversity surveys to collect data for the wider oceanographic community were discussed.

Key issues identified in these discussions were the need for more collaboration and making data accessible, not only from large long-term observing platforms, but also short-term observations and experiments as well as project-based surveys. A specific need is the definition of end-user needs with respect to spatial and temporal coverage of observations, precision and accuracy of measurements, and the accessibility and minimum information needed in metadata. One example of end-user needs with respect to temperature measurements is, for example, the difference in resolution and precision necessary for 1) heat budget calculations and 2) input data for fish distribution models. Whereas measurements from 1 could be downscaled for the use in 2, it is not possible to upscale from 2 to inform 1.

Discussion period during W8.

Based on the discussions, an outline for a community whitepaper, submitted and accepted for the OceanObs'19 conference (www.oceanobs19.net), was produced. The paper looks at existing monitoring systems, ensuring currently the required database for fisheries and ecosystem management, which are already partially in place worldwide. They are coordinated, for example, through organizations like ICES in the North Atlantic and by PICES in the North Pacific. These organizations developed frameworks to identify observing targets, to coordinate data collection internationally, and to create observing products that inform users, while simultaneously identifying data gaps. However, existing systems are not sufficiently integrated to monitor core metrics at the appropriate spatio-temporal scales needed for management, and fail to deliver on societal needs due to a lack of consideration of all end-users. For example, FOO has been developed without considering fishery management needs and strategies.

The paper proposes an outline of fisheries and ecosystem observing systems and compares them with the FOO to assess potential integration of such requirements into the FOO. The analysis addresses technology levels, the logistical aspects of survey design, the integration of different disciplines, the relevant stakeholders and the scientific frameworks.

Recent advances in ocean observing technologies and modeling have the capacity to revolutionize the management of living marine resources. While traditional fisheries management approaches like single-species stock assessments are still common, a global effort is underway to adopt an ecosystem-based fisheries management (EBFM) approach that holistically considers changes in the physical environment and ecosystem interactions, including human uses. For example, integrated ecosystem assessments aim to synthesize a suite of observations (physical, biological, socioeconomic) and modeling platforms (ocean circulation models, ecological models, short-term forecasts, management strategy evaluations) to assess the current status and recent and future trends of an ecosystem, providing guidance on optimal management strategies. Similarly, species distribution models incorporate environmental data, often from remote-sensing platforms or output from data-assimilative ocean models, to guide fishing activity in near-real-time. These dynamic ocean management approaches are increasingly replacing static management approaches to reduce bycatch and improve fisheries sustainability. A common thread in EBFM approaches is the need for high-quality observations of ocean conditions, at scales that resolve critical physical-biological processes and are timely for management needs.

Dr. Jörn Schmidt (jschmidt@economics.uni-kiel.de) is a Research Scientist at the IFM-GEO MAR in Kiel, Germany. Jörn's main focus is in fisheries and he is currently also expanding to general sustainability questions in the oceans. Since 2009 he has been working in the Department of Economics at Kiel University and is work package leader within several BMBF and EU funded projects. He is also German representative in the Science Committee (SCICOM) of the International Council for the Exploration of the Sea (ICES) and Second Vice Chair of the Deutsche Gesellschaft für Meeresforschung (DGM). He is the Co-Chair of the ICES Benchmark Steering Group, which should ensure the effective transfer of science into assessment and advice.

Dr. Sabrina Speich (speich@lmd.ens.fr) is Professor of Geosciences at the Ecole Normale Supérieure, Paris, France. She studied Physics in Italy at the University of Trieste (Italy), at CERN in Geneva (Switzerland), and at the University of Pierre et Marie Curie in Paris (UPMC Paris VI, France). Prof. Speich's research interests concern the uncovering and understanding of ocean dynamics and its role on climate variability and change. She is a world-recognized expert in ocean modelling as well as in organizing wide programs of in situ observations. She pioneered the use of Argo floats to observe the ocean. She is recently focusing her research on scale-interactions in ocean dynamics, and how they affect the global ocean circulation, air-sea exchanges and ecosystems.

Dr. Fred Whoriskey (FWhoriskey@Dal.Ca) is Executive Director of the Ocean Tracking Network of Dalhousie University. Fred's research interests are in fish biology and ecology, and the impacts of exotic species on native ecosystems. He has been heavily involved in public policy issues, especially with regard to environmental impact assessments, and has worked extensively in public education. He has served on the Board of AquaNet (Canada's National Centre of Excellence in Aquaculture), and Chaired the Board of the Huntsman Marine Science Centre.

Dr. Daniele Iudicone (daniele.iudicone@szn.it) is a Research Scientist in the Department of Integrated Marine Ecology, Anton Dohrn Zoological Station, Naples, Italy. His fields of study have ranged from variability of Mediterranean Sea circulation to physical/biogeochemical oceanography of the Southern Sea and climate. He is presently with the Physical-Biological Coupling Group, Laboratory of Ecology and Evolution of Plankton.

Dr. Jack Barth (barth@coas.oregonstate.edu) is a Professor of Oceanography and Associate Dean for Research in the College of Earth, Ocean, and Atmospheric Sciences (CEOAS) at Oregon State University. His research seeks to understand the spatially and temporally variable ocean circulation, water mass structure and ecosystem response in coastal waters including a focus on low-oxygen zones off Oregon. Within PICES, Dr. Barth is a member of the Technical Committee on Monitoring (MONITOR) and Co-Chair of the Advisory Panel on North Pacific Coastal Ocean Observing Systems.

ECCWO-4 Workshop on *"Vulnerability of Low Elevated Coastal Zones (LECZ) to SLR in changing oceans"*

by Sathaporn Monprapussorn

A 1-day workshop (W9) was convened by Dr. Sathaporn Monprapussorn (Thailand) on June 2, 2018 at the 4th International Symposium on *"The effects of climate change on the world's oceans"* in Washington, DC, USA. The focus of the workshop was on sea level rise (SLR) impacts on LECZ, the vulnerability of these areas to the projected SLR rates, the related socioeconomic issues, in addition to the coastal risk factor and design. The workshop was comprised of two oral presentations and one poster presentation, and the issues raised by the presentations and group discussion are the following.

Inundation from flooding is one of the major problems in low elevated coastal zones and island countries. Analysis of frequency and magnitude of coastal flooding, total water level and the relationship between waves and climate in different locations is very important for vulnerability assessment. The coupled impact of sea level rise and the increasing trend in urban settlement and infrastructure expansion in low elevated coastal zones are the main contributors responsible for coastal flooding and its impact on socioeconomics and livelihoods. Infrastructure-based adaptation (building levees and pumping stations, cyclone shelters, flood warning systems) is of great importance to coastal communities in terms of protecting socioeconomic and ecosystem resources. Ecosystem-based adaptation in coastal areas, such as mangrove restoration, has been proposed as an increasingly popular strategy to alleviate coastal vulnerability to climate change. It should be encouraged by governments and coastal communities to sustain co-benefit in terms of protecting against natural disaster and improving community well-being.

In regard to future research, focusing on the impact of sea level rise on coastal (mangrove communities) and marine ecosystems (invasive species) is a challenge. Communication gaps between scientist/policy makers and coastal communities should be filled by providing effective communication channels such as training schools for children, examples of good practices, disclosing vulnerability data to the public, and better disaster communication and planning. However, such different perspectives and divergent interests in each coastal region are very important for the assessment of coastal vulnerability to climate change.

Top: Dr. Furqon Alfahmi projecting increasing coastal inundation over Semarang, Java. Middle: Dr. John Marra presenting on coastal flooding in Hawai'i. Bottom: Dr. Marufa Ishaque discussing sea level rise along the Bangladesh coast.

The tremendous potential of GIS and remote sensing to benefit coastal research is widely realized by research communities. When using satellite data to analyze the coastal impact from climate change, suitable time scales and resolution should be taken into account. Global sea level projection is a key to understand climate change impacts on ocean and coastal regions and to conduct vulnerability assessment and adaptation effectively.

Dr. Sathaporn Monprapussorn (satha13@hotmail.com) is a lecturer of Geography at the Faculty of Social Sciences, Srinakharinwirot University (SWU), Bangkok, Thailand. He obtained his Ph.D. in Environmental Management. His research interests include climate change impact assessment and adaptation, coastal ecosystem services, and land use change. His current research project focuses on climate change impact on coastal ecosystem in term of resilience and adaptability of community.

ECCWO-4 Workshop on *"Quantifying thresholds in driver-response relationships to identify reference points"*

by Robert Blasiak, Jennifer Boldt, Elliott Hazen, Mary Hunsicker and Xiujuan Shan

Participants of Workshop 11 at the 4ᵗʰ International Symposium on "The effects of climate change on the world's oceans" in Washington, DC. Workshop convenors (and authors of this article) are Robert Blasiak (fifth from left), Xiujuan Shan (sixth from left), Elliott Hazen (kneeling), Mary Hunsicker and Jennifer Boldt (right hand side of photo, front).

How are conditions in marine ecosystems shaped by diverse sets of dynamic atmospheric and oceanographic drivers? Which responses within these systems are linear in nature, and which are nonlinear? Is it possible to identify thresholds beyond which small changes in one variable can have large impacts on others? Where do human dimensions and all the associated drivers fit into this? And how can PICES member countries identify relevant ecosystem reference points and utilize these to avoid undesirable management outcomes?

These and many other questions were the basis for the 2-day PICES WG 36 workshop (W11) on *"Quantifying thresholds in driver-response relationships to identify reference points"* at the 4ᵗʰ International Symposium on *"The effects of climate change on the world's oceans"*, June 2–3, 2018 in Washington, DC. The workshop aimed to:

1. Specifically identify focal ecosystems and indicators for the Working Group, collect available data sets from PICES member countries, select methods for identifying thresholds in the ecosystem indicators, and apply analyses to focal ecosystems and indicators;
2. Review and learn from similar efforts from other organizations such as ICES working groups and IndiSeas;
3. Identify potential partnerships between PICES and other organizations to advance the science of thresholds and leading indicators of ecosystem change.

With these broad aims, the first day of the workshop was designated as a closed session aimed at making progress towards achieving WG 36's terms of reference. The morning session began with presentations by representatives from PICES member countries focused on each country's mission, goals and governmental science plans related to the establishment of reference points. In

addition, Lynne Shannon (University of Cape Town, South Africa) provided an overview of the IndiSeas project's approach to identifying common ecosystem indicators across various marine ecosystems, along with Dr. Kelly Ortega Cisneros (Rhodes University, South Africa) and Scott Large (NOAA Fisheries, USA). In the afternoon, WG 36 participants provided datasets, time series data, and programming scripts that enabled some initial analyses aimed at identifying thresholds in driver-response relationships, with assistance from Scott Large.

The open workshop on the second day was well attended, and filled with excellent presentations and lively discussions. It provided an excellent opportunity for the PICES Working Group to engage with members of other research communities, including ICES and IndiSeas. An introductory presentation about WG 36 was provided by WG Co-Chair. Mary Hunsicker (NOAA Fisheries, USA).

Scott Large delivered an invited presentation on *"Quantifying critical points in ecological indicator responses to fishing and the environment"*. He gave an overview of how we can move from driver-response relationships to identifying ecosystem thresholds to inform management. Among other things, he emphasized the complexities involved with assessing the multiple indicators interacting within an n-space, and subsequently communicating the outcomes of such assessments.

Additional presentations were delivered by Caihong Fu, Gro van der Meeren, Saskia Otto, and Kirstin Holsman. Common threads among all the presentations included the challenges and value of identifying the most relevant and applicable ecosystem reference points in different regions. Speakers emphasized the need for effective ways of communicating

the science and uncertainty inherent to such analyses and feeding this into decision-making processes.

Caihong Fu (Department of Fisheries and Oceans, Canada) talked about ecosystem-level biological reference points under varying climate and ecosystem states. She and her collaborators, including Yunne-Jai Shin (UMR MARBEC, France), are planning to use the individual-based model OSMOSE (Object-oriented Simulator of Marine biOdiverSity Exploitation) to identify more effective indicators of ecosystem change and thresholds, and to develop optimal ecosystem-level fishing strategies that are adaptive to changing environment and ecosystem conditions.

Gro van der Meeren (Institute of Marine Research, Norway) presented an overview of common ecosystems from the perspective of the Barents, Norwegian and North seas ecosystems. Indicators and thresholds have been identified for all of these systems and are mostly linked to climate change. Two take-home messages from her presentation are: 1) ecosystem state and trends are reported by natural scientists but the advice often lacks inclusion of legal, social or economic research and 2) global assessments of indicators and thresholds need to include local expertise involved in regional ecosystem assessments.

Saskia Otto (University of Hamburg, Germany) presented the status of indicators and thresholds in the Baltic Sea. Saskia first presented a summary of the latest HOLAS (Holistic Assessment) report by HELCOM (Helsinki Commission) and gave an overview of how the Ecological

Quality Ratio is used within a holistic assessment to determine environmental status. She also gave an overview of an R package that she has developed (INDperform), which can be used to: 1) validate ecological state indicators, 2) select a suite of complimentary and well performing indicators and 3) assess the current state of the system in comparison to a reference period (Otto *et al.*, 2018). This R package is a potential resource for WG 36 and may provide a foundation for future analyses.

Kirstin Holsman (NOAA Fisheries, USA) was the final presenter in our workshop and she gave a comprehensive overview of indicators and thresholds from the perspective of Alaska ecosystems. She described how ecological and human dimension indicators are incorporated within the Alaska Ecosystem Considerations Report and Integrated Ecosystem Reports and gave examples of how the Alaska Fisheries Science Center (AFSC) is trying to make ecosystem thresholds more operational. She also explained the North Pacific Fishery Management Council Process where the ecosystem status report is presented prior to AFSC stock assessments. She emphasized the value in having a presentation on ecosystem information timed together with the stock assessment for management uptake.

The workshop concluded with strong interest and discussions among the participants about future collaborations. The coming months will see stronger links between researchers engaged in studying ecosystem reference points and thresholds in the North Atlantic and North Pacific.

Dr. Robert Blasiak (robert.blasiak@su.se) is a Research Scientist at the Stockholm Resilience Centre (Stockholm University) and a visiting Research Scientist at the Graduate School of Agriculture and Life Sciences (The University of Tokyo). His research interests include biodiversity in areas beyond national jurisdiction, vulnerability of communities to climate change impacts on fisheries, and the emergence of conflict and cooperation in management of ocean resources. In PICES, he is a member of Working Group 36 on Common Ecosystem Reference Points across PICES Member Countries.

Dr. Jennifer Boldt (Jennifer.Boldt@dfo-mpo.gc.ca) is Research Scientist at the Pacific Biological Station, Fisheries and Oceans Canada. Her research interests are pelagic forage fish ecology, including responses to biological and environmental drivers, and ecosystem indicators and assessments. In PICES, she chairs the MONITOR Committee and is a member of Working Group 36 on Common Ecosystem Reference Points across PICES Member Countries.

Dr. Elliott Hazen (Elliott.hazen@noaa.gov) is a Research Ecologist at NOAA Fisheries Southwest Fisheries Science Center. His research interests include 1) Species Ecology, Movement, and Distribution: How do ocean species use both ocean features and prey landscapes to migrate and forage? 2) Foraging Theory and Behavior: How does prey mediate fine scale foraging ecology and behavioral plasticity of rorqual whales? 3) Climate Variability and Climate Change: How is climate change expected to change pelagic ecosystems and the people that depend on them? Elliott is a member of the PICES WG 36 on Common Ecosystem Reference Points and the Section on Marine Birds and Mammals.

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The Bering Sea: Current status and recent trends

by Lisa Eisner

Climate and oceanography

The Bering Sea experienced generally warmer than normal weather during the period of October 2017 through March 2018. This represented the fifth year in a row of above normal air temperatures during this time of year. It was especially warm in the northern Bering Sea during the 6-month period, with a peak air temperature anomaly exceeding 8°C near the eastern tip of Siberia (Fig. 1). This pattern resembles its counterpart for the previous year (October 2016 through March 2017), with the more recent fall/winter being even more extreme. Notably, 2017–2018 included a considerably greater southward extent of positive temperature anomalies exceeding 2°C. An obvious consequence of the much above normal air temperatures was considerably less sea ice than usual. This was particularly the case for the northern Bering Sea which featured very late onset of sea ice (Bering Strait did not freeze over until about the first of the year) and a very early retreat of the ice in spring 2018. There were some intervals of relatively cold weather observed in the Pribilof Islands during fall 2017 and early 2018, but they were of minor amplitude and short duration.

The warm air temperatures for the Bering Sea during October 2017 through March 2018 can be attributed to the mean sea level pressure (SLP) anomaly pattern (Fig. 2). The much higher than normal SLP that was present south of the Alaska Peninsula in combination with lower than normal SLP over eastern Siberia resulted in strong wind anomalies from the southwest, and hence enhanced transport of mild maritime air masses originating from south of the Aleutian Islands. The wind anomalies across the southeastern Bering Sea shelf were as large as 4 m s^{-1} and represent the greatest southwesterly wind anomalies for the 6-month period in the historical record extending back to 1948. Higher than normal SLP to the south of the Being Sea, *i.e.*, a weak Aleutian Low, often occurs in association with La Nina in the tropical Pacific, and indeed a moderate event of that type was present during the fall and winter of 2017–2018. From a large-scale climate perspective, the warmth in the Bering Sea can be attributed to a combination of the unusual weather pattern, the long-term warming and loss of sea ice of the Arctic, and aftereffects of the record-setting North Pacific marine heat wave of 2014–2016, but the relative importance of these factors is unknown.
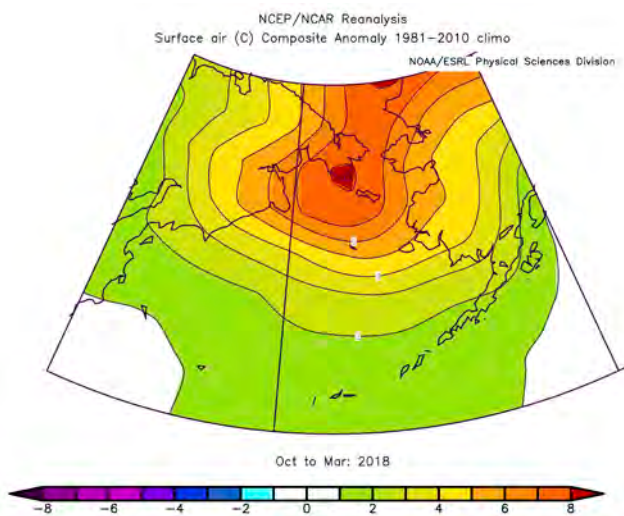

Fig. 1 Mean surface air temperature anomalies (°C) from the NCEP/NCAR Reanalysis for October 2017 through March 2018. Figure courtesy of Nick Bond, PMEL, NOAA.
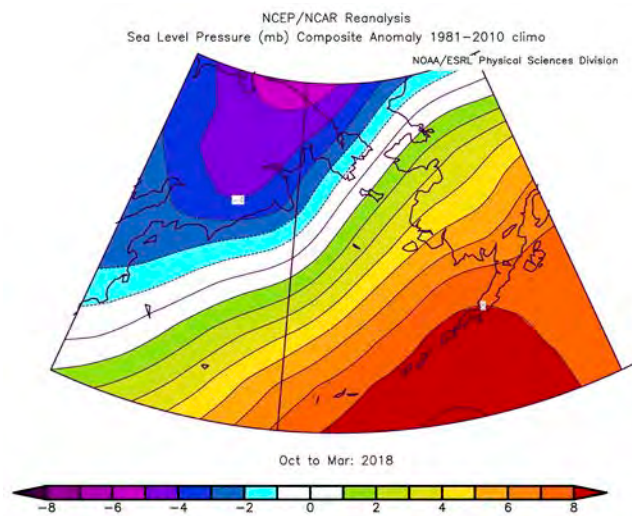

Fig. 2 Mean sea level pressure (SLP, mb) anomalies from the NCEP/NCAR Reanalysis for October 2017 to March 2018. Figure courtesy of Nick Bond, PMEL, NOAA.
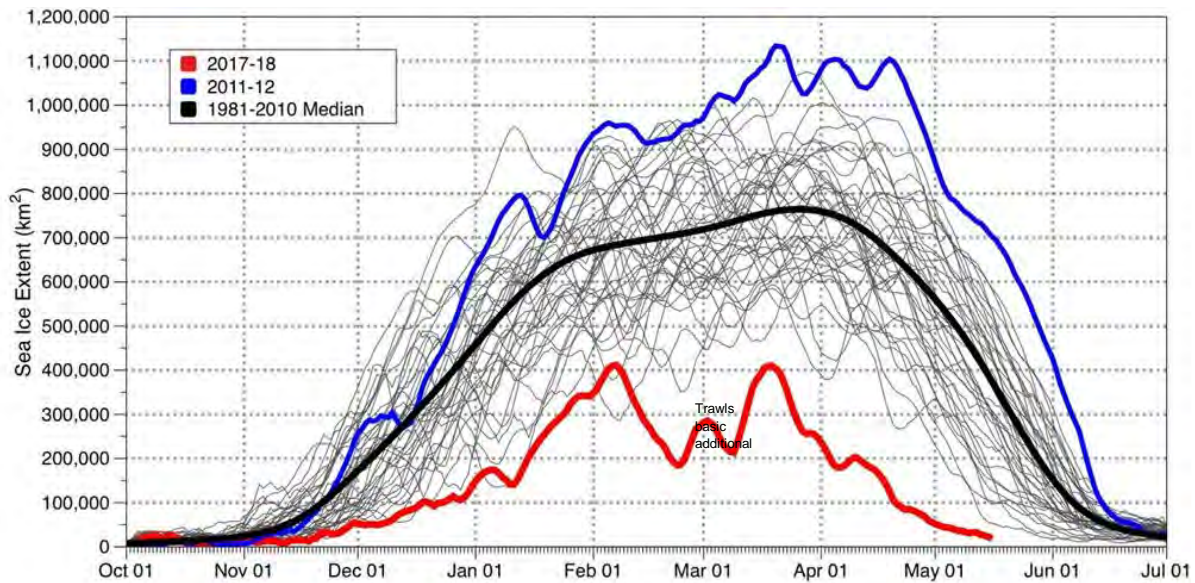
Fig. 3   Bering Sea daily sea ice extent 1978–2018. Figure courtesy of Rick Thoman, National Weather Service Alaska Region and James Overland, PMEL, NOAA.
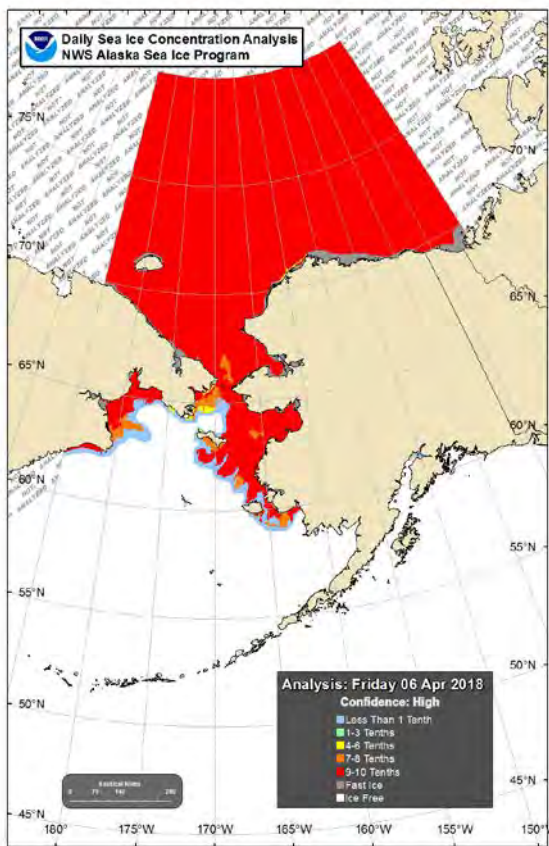

Fig. 4   Sea ice extent (indicated by red) for April 6, 2018. Figure courtesy of Rick Thoman, National Weather Service Alaska Region and James Overland, PMEL, NOAA.

As mentioned above, sea ice extent in the eastern Bering Sea was anomalously low (not nearly as far south as in previous years) during winter/spring 2017–2018 (Figs. 3, 4). (https://earthobservatory.nasa.gov/IOTD/view.php?id=9208 4). The low amount of sea ice in April had large implications

for ecosystems and local communities. For example, thin or non-existent ice may have hindered subsistence harvest of marine mammals near St. Lawrence Island. Several recent and upcoming fisheries and oceanography surveys will evaluate the impact of the reduced sea ice and warm temperatures on abundance and distribution of zooplankton, fish, marine mammals, and sea birds, and the overall health of the Bering Sea ecosystem.

Fig. 5 Larval pollock distributions in the southeastern Bering Sea during spring 2018. Figure courtesy of Steve Porter, AFSC, NOAA.
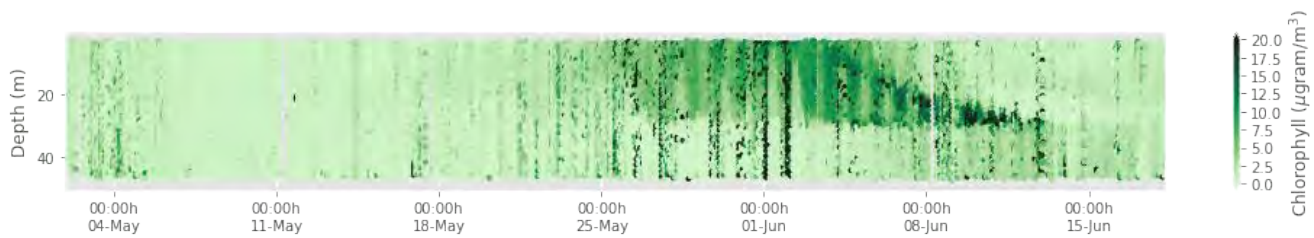
Fig. 6   Chlorophyll-a Prawler data from ITAE (Innovative Technology for Arctic Exploration program) mooring in the southeastern Bering Sea, May 4–June 18, 2018. Data and figure courtesy of Phyllis Stabeno and Shaun Bell, PMEL, NOAA.

Walleye pollock in the western and northeastern Bering Sea in 2017

In the western Bering Sea during 2017, TINRO-Center scientists observed that conditions were extremely warm, with low ice, high temperature anomalies in all layers, and a strong Slope Current. In response, the Russian pollock fishery was very successful. The fishery was distinguished by an early start (late May, with the first high catches in early June), wide distribution of pollock aggregations (up to the northern Anadyr Bay), and high Catch Per Unit Effort (CPUE) in summer and fall until late December (70 t/day on average for large vessels, the highest level since 2007) (Gritsay, 2018). The total catch of pollock by the Russian fleet in the western Bering Sea in 2017 was 436,350 t, a bit lower than in 2016 due to fewer fishing vessels (Gritsay, 2018). The very warm winter of 2017–2018 (as was the case in 2016–2017) suggests that conditions may be similar this summer.

As reported in the winter 2017–2018 PICES Press, Vol. 26, No. 1, pp. 29–33), the eastern Bering Sea shelf bottom trawl survey conducted by the NOAA Alaska Fisheries Science Center (AFSC) was extended northward in the northeastern Bering Sea (NBS) in August 2017. This was the second time this survey occurred–the first time was in 2010. A key finding was the high survey biomass of pollock in the NBS which increased over 6,000 percent from 0.02 million mt in 2010 to 1.3 million mt in 2017. Therefore, pollock appeared to be in relatively high numbers in the northeastern as well as the western Bering Sea in summer 2017. For more information on the NBS survey, see Hot Topics in the eastern Bering Sea Alaska Marine Ecosystems Considerations report.

Bering Sea surveys in 2018

Spring surveys in the eastern Bering Sea

▪ In addition to the larval pollock survey described above, PMEL (Pacific Marine Environmental Laboratory) and AFSC, NOAA conducted mooring work and oceanography and plankton sampling on board the NOAA Ship *Oscar Dyson*, April 29–May 10. The reduced ice conditions allowed sampling at Mooring 8 (M8, 62.19°N, 174.69°W) for the first spring since this time series began in 1997.

▪ The University of Alaska Fairbanks and the University of Washington, with guest collaborators from the U.S. Fish and Wildlife Service and NOAA conducted an oceanography and fisheries survey on the R/V *Sikuliaq*, from about June 5–24 in the northern Bering and Chukchi seas. A similar survey was conducted June 2017.

Summer surveys in the eastern Bering and Chukchi seas

See summaries and maps of 2018 NOAA AFSC fisheries oceanography surveys this summer. Briefly,

▪ Bottom trawl surveys to monitor trends in groundfish, crabs and other bottom-dwelling species on the shelf are being conducted onboard the F/V *Alaska Knight* and F/V *Vesteraalen* from May 30–August 8. Please see the survey blog.

▪ Bottom trawl surveys in the Aleutian Islands are being conducted onboard the F/V *Sea Storm* and F/V *Ocean Explorer* from June 5–August 14.

▪ Acoustic trawl pollock surveys in the eastern Bering Sea are being conducted onboard the NOAA Ship *Oscar Dyson* from June 6–August 15.

▪ The eastern Bering Sea BASIS oceanography and juvenile/forage fish survey will be conducted onboard the NOAA Ship *Oscar Dyson* from August 20–September 18.

▪ AFSC and the Alaska Department of Fish and Game will conduct a salmon and juvenile/forage fish survey on the northeastern shelf from August 28–September 20.

▪ PMEL, along with AFSC, will retrieve and deploy moorings and conduct oceanography and plankton surveys on board the NOAA Ship *Oscar Dyson* on the eastern shelf from September 21–October 6.

▪ Marine mammal field work in the eastern Bering and Chukchi seas will be conducted from June–October. See maps and details.

▪ A multi-institutional research team, including AFSC and PMEL, will conduct oceanography and benthic sampling at Distributed Biological Observatory (DBO) sites in the Chukchi and Beaufort seas onboard the US Coast Guard Cutter *Healy* from August 6–23.

Summer and fall surveys in western Bering and Chukchi seas

▪ The R/V *TINRO* departs from Vladivostok on August 1 to survey the northwestern Bering during August (trawl-acoustic and oceanographic survey targeted on pollock), survey the Chukchi Sea in September, followed by a bottom trawl survey on the southwestern Bering Sea shelf, with a return to port on November 11, 2018. Additionally, the R/V *Professor Levanidov* will work in the deep-water part of the western Bering Sea in October, conducting a trawl and oceanographic survey targeted on salmon. See North Pacific Anadromous Fish Commission (NPAFC) documents 1747 and 1748 for maps and details.

Summer survey in central Bering Sea

▪ The Japan Fisheries Research and Education Agency will conduct salmon research (including oceanography) in the central Bering Sea (basin), onboard the R/V *Hokko Maru*, from July 23–August 3, 2018. This is similar to field work conducted in 2017 (NPAFC document 1765).

Upcoming Bering Sea meeting

▪ Alaska Marine Science Symposium, late January 2019, Anchorage Alaska.

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The Northeast Pacific: Current status and recent trends

by Tetjana Ross, Jennifer Fisher and Moira Galbraith

Over the last few years, reports on the Northeast Pacific (NEP) in PICES Press have focused on the status of the large sea surface temperature (SST) anomaly (the "Blob") that first appeared in late 2013. In July of 2016, it disappeared from SST observations (Peterson *et al*., 2016) and, indeed, recent SST observations (averaged over November 2017–May 2018; Fig. 1a) are near-normal in the NEP. The SST map shows that there was a relatively strong La Niña present throughout the last 6–8 months. La Niña was strong in November 2017 (Fig. 1b), peaked in December 2017, and had largely disappeared by May 2018 (Fig. 1c). La Niña generally leads to a cooler than average winter in the NEP and western North America, but it was coupled with an overall land and ocean warming trend (*e.g*., https://www.ncdc.noaa.gov/sotc/) such that air and surface water temperatures were near normal.

While the recent surface temperatures were near neutral (Figs. 1 and 2), subsurface temperatures remain anomalously warm beneath 120 dbar throughout the NEP (Fig 2). The time series of temperature anomalies in the NEP (an area-average of Argo float data in the NEP box shown in Fig. 1a), shows that at present a strong warm anomaly is still apparent between 150–300 dbar. The anomaly is waning, but still quite strong with respect to the variability seen in the 2004–2018 Argo data record. Note that while the deeper anomalies are further away from the mean (over 2.5

standard deviations, rather than the earlier/shallower 2 standard deviations seen in surface waters during the winters of 2014 and 2015), this is because the variability is smaller in the 150–300 m depth range, not because the deep temperature anomaly is larger in absolute value. These deep temperature anomalies have a large spatial extent, but are strongest in the Gulf of Alaska, near the epicenter of the earlier SST anomaly (*i.e*., the Blob, which can also be seen in Figure 2 in the surface waters during 2013–2016). This sustained deep temperature anomaly is in waters at depths that are typically upwelled onto the shelf in the spring and summer and thus may have an impact on productivity. The warm anomalies observed along the Newport Line (44.6°N; Fig. 3) demonstrate that coastal waters as far south as Oregon have remained warm. Deep water temperature anomalies on the slope and shelf off Newport, Oregon have been persistently and strongly positive from the fall 2014 until summer 2017. These warm ocean conditions are associated with a lipid-deplete copepod community and a gelatinous-dominated zooplankton community, which have also persisted throughout the NEP since September of 2014. These warm ocean conditions remain off the North American coast in 2018; however, the strength of the anomalies has modulated and the pelagic ecosystem appears to be in a state of flux.
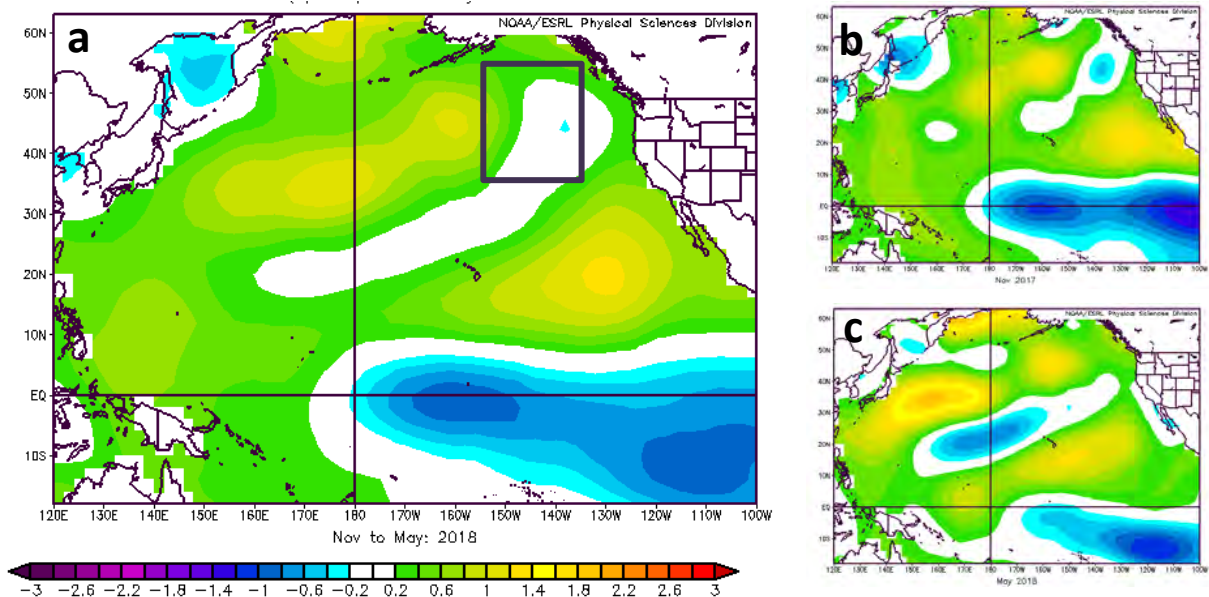

Fig. 1   Maps of sea surface temperature anomalies in the Pacific Ocean for (a) November 2017 to May 2018, (b) November 2017 and (c) May 2018. The colour bar, showing the temperature anomaly in °C, applies to all panels. The brown box in (a) indicates the area averaged over in Fig. 2. Source: NOAA Extended SST v4 http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl.
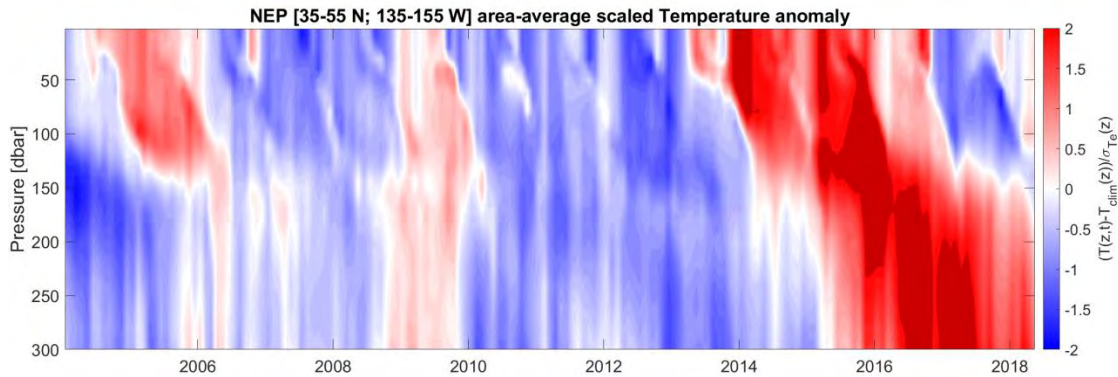
Fig. 2   False colour plot of scaled-temperature anomalies, as observed by Argo floats in the Northeast Pacific. To create the time series, the Roemmich and Gilson (2009) gridded Argo temperature dataset was spatially averaged over 35–55°N and 135–155°W (box shown in Fig. 1) and then scaled temperature anomalies were calculated at each monthly time step by subtracting the 2004–2018 seasonally corrected mean and then dividing by the 2004–2018 seasonally corrected standard deviation. The cool colours indicate cooler than average temperatures and warm colours indicate warmer that average temperatures in units of the standard deviation at that depth and in that month.
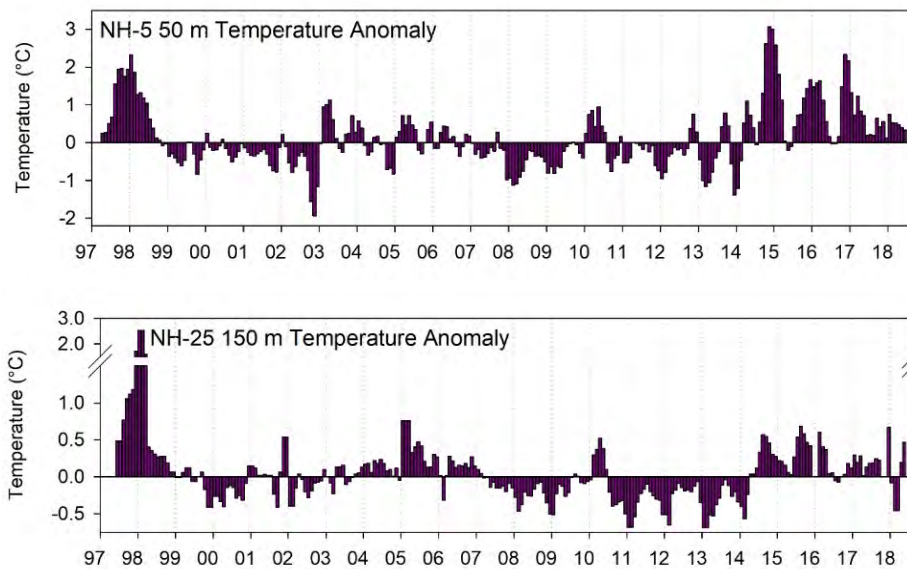
Fig. 3   Temperature anomalies at a depth of 50 m at a shelf station (NH-5, top panel) and at 150 m at a slope station (NH-25, bottom panel) located 5 miles (9 km) and 25 miles (46 km),respectively, offshore Newport, Oregon (44.6°N).

During the period of strong temperature anomalies (fall 2014 until summer 2017), strongly positive anomalies of southern copepods were observed on the shelf along the North America west coast (left panels of Fig. 4). The positive anomalies in southern copepod biomass (Mackas *et al*., 2004) were coupled with strongly negative anomalies of northern copepods off Oregon and moderately negative anomalies of northern copepods off Southern Vancouver Island (Fig. 4), signaling a food chain deplete of lipids for higher trophic levels. However, this was not true for Northern Vancouver Island which experienced positive anomalies in both southern and northern copepod biomass. The positive anomalies in the northern copepod biomass were indeed lower during the Blob years than in the years preceding 2013, indicating a response to the arrival of

warmer waters for that group. The bifurcation of the North Pacific Current mid-Vancouver Island leads to different zooplankton dynamics and might be contributing to the mixed response of the northern copepods on the northern and southern shelves.

Along the Newport Line, in 2015 and 2016, the seasonal shift from a warm winter copepod community to a cold summer community did not occur because of the extended period of warm ocean conditions. However, during a brief period in summer of 2017, deep water on the shelf and slope was more neutral, weakly positive biomass anomalies of northern copepods were observed and the copepod community transitioned to a cold water community.
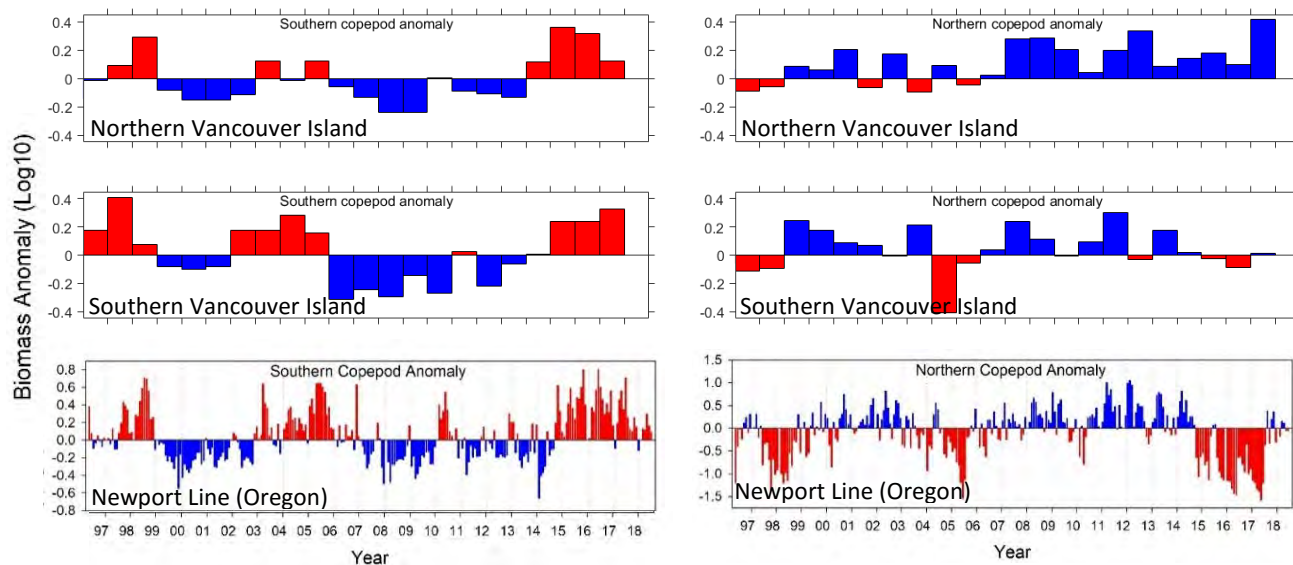
Fig. 4   Biomass anomalies of copepod species that have warm water affinities (southern copepods; left panels) and cold water affinities (northern copepods; right panels). The anomalies come from the La Perouse and Newport Line sampling program and are arranged north to south, with the top row showing annual averaged anomalies for the Northern shelf of Vancouver Island, the middle row for the Southern shelf of Vancouver Island and the bottom row the monthly anomalies from the Newport Line station (NH-5) located on the shelf 9 km offshore of Newport, Oregon (44.6°N). Positive biomass of southern copepods and negative biomass of northern copepods indicates a lipid-poor copepod community and the inverse indicates a lipid-rich copepod community.

Strong winter storms mixed the deep water on the slope off Oregon and negative temperature anomalies persisted for two months during the winter of 2018 (Fig. 3). During this time, the biomass anomalies of the northern copepods fluctuated while positive anomalies of the southern copepods persisted (bottom row of Fig. 4). During the spring and early summer of 2018, the shelf and slope water are still warmer than average off Oregon and the abundance of southern copepods are still higher than average on the shelf. However, the biomass of the northern copepods is still fluctuating, and trending to be more neutral, signaling that the pelagic ecosystem is in a state of instability between a warm copepod community and a cold upwelling community.

Another indication that the pelagic ecosystem has not returned to a cold water lipid-rich state is the presence of the colonial tunicate, *Pyrosoma atlanticum*, in high densities. These organisms are common in tropical open ocean environments and they bloomed in large numbers throughout the coastal waters from Oregon to the Gulf of Alaska during the winter of 2016 (Brodeur *et al*., 2018). These organisms were collected in large numbers throughout 2017 when they increased in density and size compared to 2016. After the onset of upwelling in 2017, they were rarely collected on the shelf off Newport, but following the fall transition, they started washing up on Oregon beaches in high densities. Pyrosomes were collected again in the spring of 2018, throughout the northern California Current and over the shelf and shelf break along Vancouver Island, and they have been observed both with higher relative densities further north and in higher absolute densities than in 2017, indicating

that the pelagic ecosystem has still not returned to its pre-2014 state.

The continued prevalence of pyrosomes, combined with the likelihood that warmer than usual water will be upwelled onto the shelf in summer 2018, suggests that the ecosystem may remain in a warm/lipid-poor and/or fluctuating state throughout 2018.

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The western North Pacific during the 2017/2018 cold season

by Toshiya Nakano

The western North Pacific was characterized by positive sea surface temperature (SST) anomalies at around 40°N throughout the 2017/2018 cold season (Fig. 1). Negative SST anomalies relating to the Kuroshio large meander were observed off the southern coast of Japan.

The winter maximum sea ice extent in the Sea of Okhotsk was 1.12 million km^2 in late March, which was around 96% of the 30-year average of 1.17 million km^2. The seasonal maximum exhibits a long-term decreasing trend of 0.066 million km^2 per decade, which corresponds to 4.2% of the Sea of Okhotsk's total area (Fig. 2).
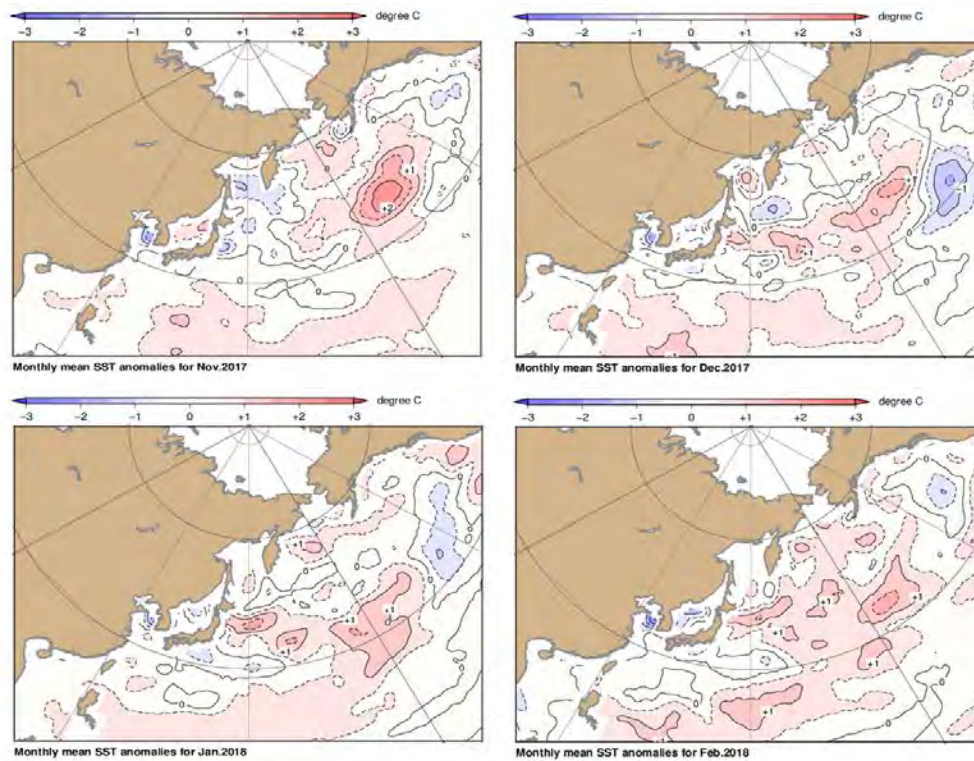

Fig. 1   Monthly mean sea surface temperature (SST) anomalies for November and December 2017, and January and February 2018. Monthly mean SSTs are based on JMA's COBE-SST (centennial in-situ observation-based estimates of variability for SST and marine meteorological variables). Anomalies are deviations from the 1981-2010 climatology.
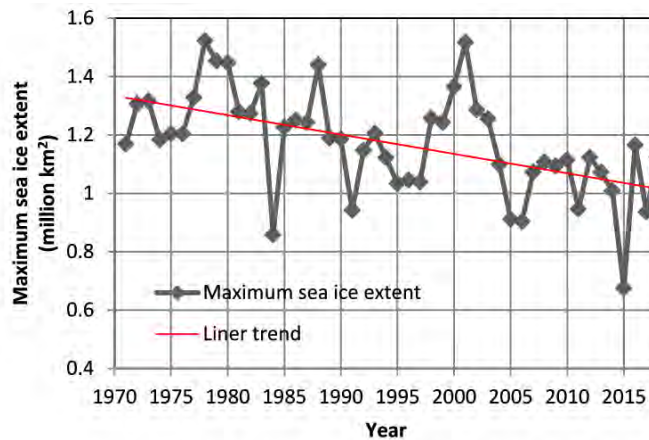

Fig. 2   Time series of winter maximum sea ice extents in the Sea of Okhotsk from 1971 to 2018. The red line denotes the long-term linear trend.

The first Kuroshio large meander current in 12 years

The Kuroshio is the western boundary current of the North Pacific subtropical gyre, and its maximum current speed along the southern coast of Japan is sometimes more than 2.5 m/sec (about 5 knots). The Kuroshio takes three typical paths south of Japan: the typical large meander path (LM), the offshore non-large meander path, and the nearshore non-large meander path (Kawabe, 1995). Fluctuations of its path have a large influence on fisheries and ship navigation. Furthermore, once the Kuroshio large meander (KLM) appears, coastal sea levels from the Tokai region to the Kanto region tend to rise. If sea level rises associated with typhoons or low-pressure systems occur simultaneously, damage caused by inundation in low-lying land areas is expected to be exacerbated by the influence of the meander.

In the summer of 2017, a large meander event occurred for the first time in 12 years, since 2005, and has continued (as of May 2018) (Fig. 3). The formation process of the KLM in 2017, at first, a small meander southeast of Kyushu generated in late March 2017. The small meander propagated eastward to the east of the Kii Peninsula, south central Honshu, in August and developed into a large meander in late September 2017 (Fig. 4).
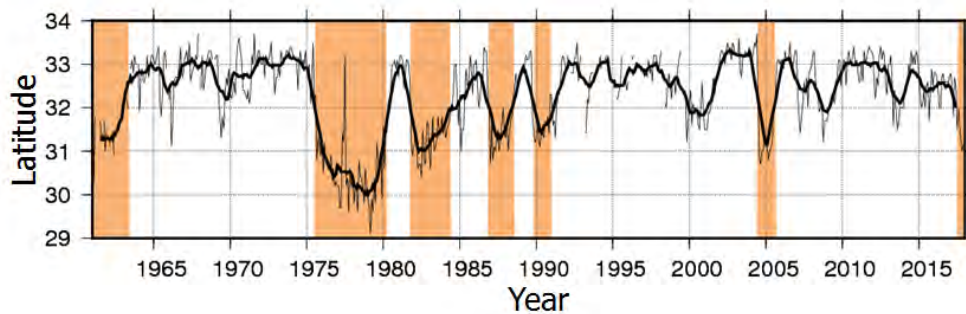

Fig. 3   Time series of the southernmost latitude of the Kuroshio path south of Japan (136°E–140°E). Shades indicate Kuroshio large meander periods, thin line denotes monthly data and the thick line denotes 13-month running mean values.
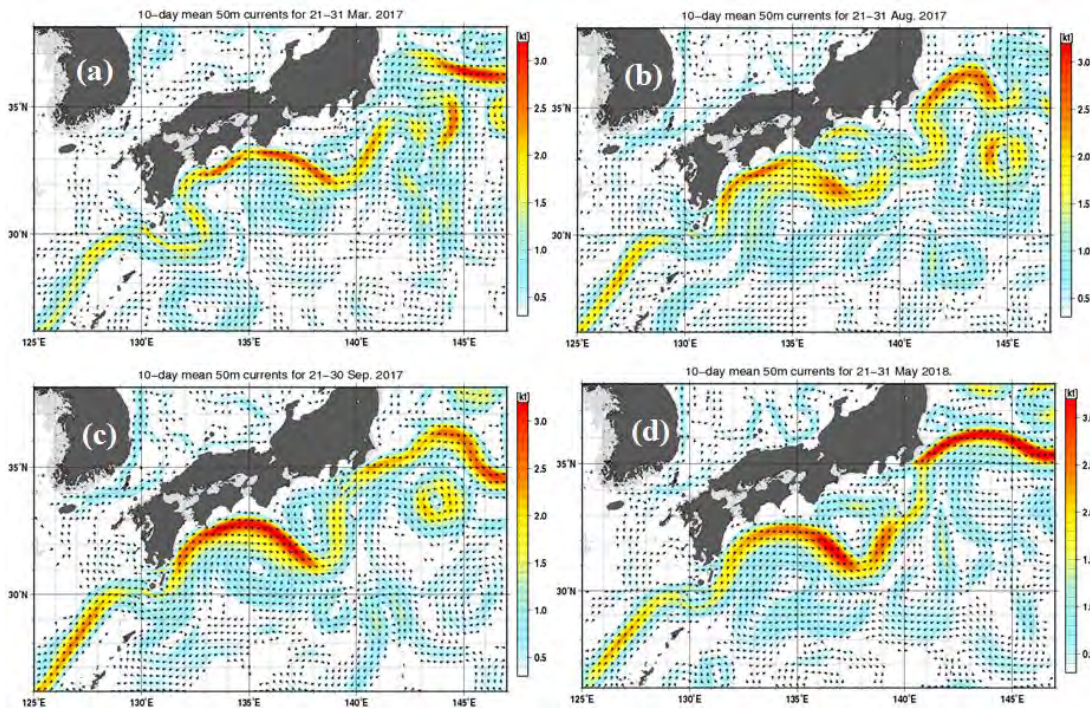

Fig. 4   Ten-day mean surface currents in the Kuroshio region. (a) March 21–31, 2017, (b) August 21–31, 2017, (c) September 21–30, 2017, and (d) May 21–31, 2018.
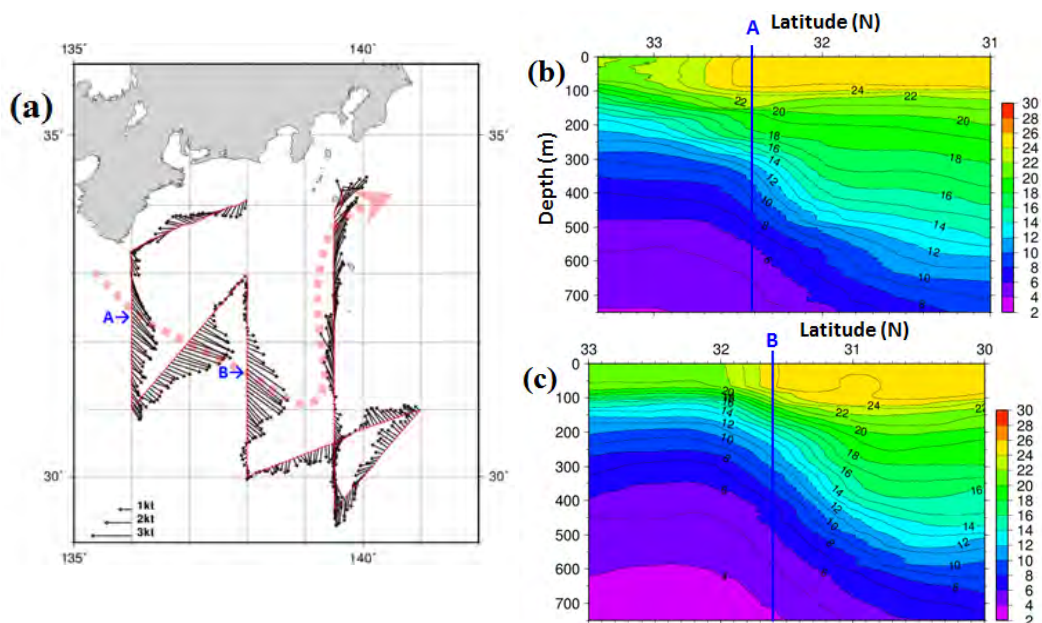
Fig. 5   Observation results from the R/V Ryofu Maru, November 14–17, 2017. (a) subsurface current (solid red line: shipping route; dashed red arrow: estimated Kuroshio path; black lollipops: observed current speed and direction). A and B indicate the positions of the Kuroshio axis. (b) and (c) are vertical sections of temperature along 136°E and 138°E.

Since September 2017, the Japan Meteorological Agency (JMA), using the R/Vs *Ryofu Maru* and *Keifu Maru*, has conducted subsurface temperature and current observations, and performed several examinations of temperature distribution corresponding to the Kuroshio path (Fig. 5).

The JMA provides ocean current analysis and monthly forecasts every 10 days based on observational data and ocean model results. The JMA operates a portal site (http://www.data.jma.go.jp/kaiyou/data/db/kaikyo/etc/kuroshio_portal_201710.html (in Japanese only)) to provide information on the KLM, including synopses of the latest situation, one-month forecasts, and the results of observations conducted by two research vessels.

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Topic sessions and workshops at PICES-2018

- **S1: Science Board Symposium**

Toward integrated understanding of ecosystem variability in the North Pacific

- **S2: FIS/BIO Topic Session**

Fish production through food web dynamics in the boundary current systems

- **S3: FUTURE Topic Session**

Science communication for North Pacific marine science

- **S4: BIO Topic Session**

Indicators for assessing and monitoring biodiversity of biogenic habitats

- **S5: POC Topic Session**

Seasonal to interannual variations of meso-/submeso-scale processes in the North Pacific

- **S6: FUTURE Topic Session**

The FUTURE of PICES: Next steps in understanding, forecasting and communicating climate impacts on North Pacific marine ecosystems

- **S7: POC/FUTURE Topic Session**

Ecological responses to variable climate changes and their applicability to ecosystem predictions
Co-sponsored by CLIVAR

- **S8: POC/FUTURE/MONITOR Topic Session**

Internal tides, nonlinear internal waves, and their impacts on biogeochemistry, climate and marine ecosystems via ocean turbulent mixing processes

- **S9: HD Topic Session**

Integration of science and policy for sustainable marine ecosystem services

- **S10: POC/BIO Topic Session**

Ocean acidification and deoxygenation and their impact on ocean ecosystems: Synthesis and next steps
Co-sponsored by the International Council for the Exploration of the Sea (ICES)

- **S11: MONITOR Topic Session**

Influence of climate and environmental variability on pelagic and forage species

- **S12: FIS Topic Session**

Applying ecosystem considerations in science advice for managing highly migratory species
Co-sponsored by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) and the Inter-American Tropical Tuna Commission (IATTC)

- **BIO, FIS, HD, MEQ, POC Contributed Paper Sessions and a General Poster Session**

- **W1: BIO Workshop**

Ecological roles of gelatinous zooplankton: Evaluation, integration and future prospects in a more gelatinous ocean

- **W2: MONITOR/FIS Workshop**

PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment (Second)

- **W3: TCODE Workshop**

Development of a systematic approach to data management in PICES

- **W4: POC/FIS/BIO Workshop**

Synthesizing projected climate change impacts in the North Pacific
Co-sponsored by the International Council for the Exploration of the Sea (ICES)

- **W5: FUTURE Workshop**

Identifying common reference points and leading indicators of ecosystem change

- **W6: BIO Workshop**

Regional evaluation of secondary production observations and application of methodology in the North Pacific

- **W7: BIO Workshop**

Diets, consumption, and abundance of marine birds and mammals in the North Pacific

- **W8: HD Workshop**

Taking stock of Marine Ecosystem Services in the North Pacific - Exploring examples and examining methods

Progress in Oceanography: Special Issue on Climate, Zooplankton and Salmon

A Commemorative Issue to Honor William (Bill) Peterson

Dr. Bill Peterson passed away on August 12, 2017 after having bravely faced cancer for the past three years. Bill was an oceanographer, marine biologist and climate scientist for NOAA, who most recently (since 1995) worked at the NOAA lab co-located in the Hatfield Marine Science Center complex (Newport, Oregon) as a senior scientist for more than 20 years. The marine and freshwater zooplankton community world-wide knew Bill through his participation at many of the International Zooplankton Production Symposia (ZPS)—Bill having attended all of the ZPS from #2 (Plymouth, UK, 1994) through #5 (Pucón, Chile, 2011). Bill served on the Scientific Steering Committee of the 3rd ZPS (Gijón, Spain, 2003) and was an editor of the published ICES Marine Science Symposia, Vol. 220 (The role of Zooplankton in Global Ecosystem Dynamics: Comparative Studies from the World Oceans). At the 4th ZPS (Hiroshima, Japan, 2007), Bill co-convened a 1 day workshop titled "Krill research: current status and its future" with So Kawaguchi (Australia) which resulted in publication of a special issue of Deep Sea Research Topical Studies in Oceanography on Krill Biology and Ecology. Bill especially loved to talk with students and early career scientists at their posters in poster sessions. This was a more relaxed setting for discussing the ecology and dynamics of zooplankton, and one Bill relished.

This issue will commemorate Dr. Peterson's love of zooplankton and the engaging of young scientists in this field. The editors of this special issue identified five themes to comprise this special issue:
1) zooplankton rate measurements (molting, growth, production, mortality) [RATE MEASUREMENTS],
2) the importance of zooplankton species composition and distribution in informing about ocean conditions and advective processes [ZP COMPOSITION AND DISTRIBUTIONS],
3) using ocean ecology, including lower trophic indices, and local to basin scale physical indices for forecasting future Pacific salmon and higher trophic level (birds/mammals) conditions [OCEAN ECOLOGICAL FORECASTING],
4) observing and documenting climate events and anomalous conditions and responses of the California Current ecosystem [CLIMATE EVENTS AND CC ECOSYSTEM RESPONSES], and
5) investigations of the ecology, abundance, and behavior of krill (euphausiids) [KRILL ECOLOGY].

We encourage submissions on these topics related to zooplankton dynamics and processes.

Manuscript submission: https://www.journals.elsevier.com/progress-in-oceanography

Enter Manuscript Information:

Issue: Use the drop down menu to select "VSI: Climate Zoopl & Salmon"

Article Type: Most will use the drop down menu to select "Full Length Article"

Complete the fields as necessary…and upload the manuscript.

Questions about the special issue can be directed to the Managing Guest Editor, Hal Batchelder (hbatch@pices.int).

Deadline for submissions to this Special Issue on Climate, Zooplankton and Salmon is December 15, 2019.