Summary of Scientific Sessions and Workshops at PICES-2019

Science Board Symposium (S1)
Connecting science and communities in a changing North Pacific

Convenors: *Hiroaki Saito (SB), Vera L. Trainer (SB), Se-Jong Ju (BIO), Xianshi Jin (FIS), Keith Criddle (HD), Guangshui Na (MEQ), Jennifer Boldt (MONITOR), Emanuele Di Lorenzo (POC), Joon-Soo Lee (TCODE), Steven Bograd (FUTURE), Sukyung Kang (FUTURE), Igor Shevchenko (Russia), and Motomitsu Takahashi (Japan)*

Invited Speakers:
Sean Anderson (Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, Canada)
Dohoon Kim (Pukyong National University, Korea)
Takeyoshi Nagai (Tokyo University of Marine Science and Technology, Japan)
Anna Zivian (Ocean Conservancy, WA, USA)

Background

The North Pacific Ocean is rapidly changing due to an increasing number of stressors. This presents challenges for understanding, collaboration, and communication. More specifically: 1) What are the effects of human activities and climate change on ecosystems and the services they provide?, 2) Are there ways to improve collaboration among organizations and integrate a variety of knowledge sources to answer this question?, and 3) How can we communicate this knowledge effectively to the public? Climate change is an over-arching stressor that delivers a non-stationary background upon which other stressors act. Further, there are a wide variety of human stressors, such as fishing, aquaculture, microplastics/marine litter, invasive species, and shipping that can alter ecosystem structure, function, productivity, and biodiversity. Anticipating and detecting ecosystem responses to these stressors is a challenge, especially when responses may be non-linear and synergistic or antagonistic. Additional challenges include integrating the complexity of multiple spatial and temporal scales and incorporating climate change into sustainable ecosystem management. PICES provides a unique forum for collaboration among North Pacific member nations and other science organizations to address these challenges. There are, however, opportunities for further collaborations to better improve our understanding of the North Pacific, such as engagement with Indigenous people, citizen science programs, collaborative surveys, and coupled coastal - deep water oceanographic monitoring programs. Communicating the results of ecosystem science to the public and coastal societies is another area for advancement, as many scientists receive little or no training in communicating their results to a layperson audience or in two-way communication, where feedback can inform science. Especially welcome were papers that dealt with issues related to PICES' FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems) Integrative Science program such as: 1) the effects of human activities on coastal ecosystems, ecosystem services, and human societies; forecasting the effects of climate change on the distribution and productivity of species and communities; incorporating climate change, multiple stressors, and different temporal and spatial scales into sustainable resource and ecosystem management; tools to evaluate ecosystem response thresholds and common ecosystem reference points; and forecasting impacts of coastal stressors (*e.g.*, microplastics, pollution, invasive species, shipping, aquaculture); 2) collaborative work with Indigenous people, with citizen science programs, with other science organizations, and across the western and eastern North Pacific; and3) methods for more effectively communicating science to the public.

Summary of presentations

Dr. Jackie King (DFO, Canada) provided the keynote talk titled "Connecting science to management, policy and people". Her presentation was focused on the cumulative impacts of human stressors on coastal ecosystems that are increasingly exacerbated by climate change. She highlighted DFO research programs on coastal human stressors that have actively made connections to coastal communities, resource managers and policy makers, and to the general public when designing, implementing or communicating scientific research. These programs build trust, relevance and accessibility for their science. Finally, she challenged PICES scientists to connect beyond their traditional science roles and relationships.

Invited speaker, Dr. Takeyoshi Nagai's (Tokyo University of Marine Science and Technology, Japan) presentation was on "How the Kuroshio enriches the southern coast of Japan and its downstream regions". Dr. Nagai's research addressed three questions regarding nutrient enrichment of the Kuroshio Current. He found that 1) induction accounted for approximately 30% of nitrate flux, 2) interannual modulation of subsurface nutrients were strongly correlated with ENSO variability, and 3) subsurface nutrients supplied to Kuroshio by turbulence in Kuroshio following the Tokara Strait.

Dr. Dohoon Kim (Pukyong National University, Korea), gave an invited talk titled "Better understanding of socioeconomic impacts of climate change in fisheries". Dr. Kim's presentation focused on connecting science and communities in a changing North Pacific. He noted that in order to understand interactions among climate change, ecosystems, human activities, we need effective communication among scientists, policy makers, fishers, and the public. The language difference among these groups, however, presents a challenge to communication and integration. He described case studies, using the language of these different groups, to show socio-economic and ecological impacts of climate change on fisheries in the Republic of Korea and he discussed how to connect science to the public. Dr. Kim considered analytical methods for estimating socio-economic impacts of climate change in fisheries for more effective strategies of management and governance.

Dr. Aoi Sugimoto's (Japan Fisheries Research and Education Agency) paper was on "Participatory ecosystem governance scenario building with coastal communities: The possibilities and challenges from a case study in Japan". She noted the challenge of incorporating cultural dimensions in the assessment and governance of Ecosystem Services (ES) and Nature's Contribution to People (NCP). Using a case study, she demonstrated a novel approach to integrate cultural dimensions at national-scale future scenarios for ES/NCP governance under rapid natural/social environmental changes. The case study includes surveys to identify resources, values, and changes that are important to or noted by the public. Her novel method externalized and assessed context-specific values both qualitatively and quantitatively.

Dr. Sean Anderson (DFO, Canada), gave an invited presentation titled "An automated synopsis of the state of Pacific Canadian groundfish and climate impacts" with a subtitle, "Black-swan events in fisheries". He gave examples of black swan events, including the Newfoundland black cod collapse in 1992, pyrosome blooms in the eastern Pacific in 2017, the Pacific heatwave in 2015 and the one developing in 2019. He discussed why black swan events should be expected in fisheries, including the fact that humans magnify the consequences of environmental change, and that too much confidence placed in models can leave us open to ecological surprises. There are more published fish mass mortality events than for any other taxa, caused by a multitude of factors – thus he suggested that we should be robust to these surprises by embedding surprises into models and making systems robust to surprise.

Dr. Laurie Weitkamp's talk, titled "The Winter 2019 Gulf of Alaska expedition: studying salmon ecosystemjs on the high seas", described the expedition aboard the R/V *Professor Kaganovsky*. The cruise stemmed from

Dr. Richard Beamish's idea that there was a need to study salmon in the North Pacific in winter. The goals were to determine whether adult salmon abundance is determined by the end of the first ocean winter and to see whether an international team could work together to make discoveries. This study, using biological, physical, and chemical oceanographic measurements, is a showcase for the Year of the Salmon. Five species of Pacific salmon were caught, including chum, coho, sockeye, pink and Chinook, with chum the dominant species. Genetic data showed, for example, that the chum salmon caught in the central North Pacific Ocean during the cruise originated from Japan, Russia, Alaska, Canada and Washington State, demonstrating the international interest in the data generated from this collaboration.

Dr. Anne Hollowed presented on "An assessment of climate change impacts on polar ecosystems". The second of two special IPCC Special Reports, this report focused on the ocean cryosphere covering all aspects of water and ice on our planet, from the highest mountains to the deepest oceans, from the equator to the poles. The polar region chapter focused on resource extraction, local and indigenous people, freshwater and marine systems, ocean circulation, sea ice, commercial activity, international cooperation, marine ecosystems, and more. Dr. Hollowed spoke about sea ice loss which has been astounding over the last several years. The loss has been likely unprecedented for at least 1,000 years. Surface oceans warmed at ~0.5°C per decade from 1982–2017. There is strong evidence of range extensions and retractions, including fish species with genetic evidence for cod moving north. Actionable science includes scenario planning that provides a strategy for the future and linking ecosystem services with human livelihood.

Dr. Elliott Hazen's paper described "Top predators as climate and ecosystem sentinels". He discussed new conditions that open the possibility of new risks, necessitating the use of high-level predators as sentinels of ocean change. For example, whale entanglements resulted from the marine heatwave, due to a harmful algal bloom, and shifting prey availability. This resulted in foraging humpback whales on the shelf coincident with the delayed placement of crab traps, resulting in entanglements. These sentinels provide information about ecosystem change in a timely and quantitative manner and offer a unique perspective into ocean processes.

Invited speaker, Dr. Anna Milena Zivian (Ocean Conservancy, USA), gave a talk titled "Connecting science and communities under a changing climate: the role of boundary organization". She wrote several sonnets to illustrate poetically the collaboration of nongovernmental organizations (NGOs) and 'boundary' organizations (such as PICES) as knowledge brokers, data producers, and connectors of communities. She asked, "How do we communicate across disciplines, communities, and sectors to enact positive change?" She has worked with the Ocean Conservancy and other organizations to bring knowledge to action. Her examples of success include Ocean Conservancy's action in California to promote climate action. Ocean Solutions is part of California's ocean science strategy to address climate change. They are one of the leaders in finding solutions for the world and have helped pass important legislation to mitigate the effects of climate change. She emphasized the importance of focusing at the boundary of science, knowledge, policy and action — Convert information to deeds!

Mr. Peter Chandler reported on PICES' "The North Pacific Ecosystem Status Report 2009–2015", a product of Working Group on the *Third North Pacific Ecosystem Status Report* (WG 35; WG-NPESR3). This work brings together a diverse group of marine scientists to produce a report that can be useful for policymakers and other decision makers. It features a web-accessible database of national and international environmental time series observations (ETSOs) and is reviewed by PICES committees. The chapters varied in focus from the atmosphere to phytoplankton, fish to mammals and human dimensions to emerging issues and climate change. Highlights of the NPESR 3 report include the influence of the marine heatwave in 2014–2016, lower concentrations of Chl-*a*, smaller phytoplankton, record toxic algae blooms, and shifts in distribution and community composition of fish populations.

Dr. Chengjun Sun, on behalf of Dr. Fangli Qiao, spoke about "The UN Decade of Ocean Science for Sustainable Development and PICES: for the perspective of a predicted ocean". She talked about how the UN Decade of Ocean science (2021–2030) will build upon 60 years of ocean science to achieve 6 major goals. Her talk was focused on 1 goal: A predicted ocean, highlighting the importance of coupled models especially considering surface waves will greatly improve our forecasting capabilities. The decade should create an "Ocean Generation" of informed citizens and promote data sharing.

Patricia T. Angkiriwang gave the talk "Participatory system modelling to increase climate resilience of seafood availability in Tia'amin Nation," focused on fish and food security using participatory systems mapping. She spoke about how the availability of catch are expected to decline with climate-driven change. Interviews and a participatory workshop were conducted with community members, natural resource and health managers, legislators and Elders to determine the interconnectedness of factors that will change. These included factors and dynamics at the individual and household level, barriers of change at the Nation level, and distal drivers and historical shocks. The participatory systems mapping has benefits (holistic, trans-disciplinary, promotes dialogue) and challenges (requires flexibility, requires trust, respect and time).

Dr. Thomas A. Okey's presentation was on "The local environmental observer network for inclusive documentation and understanding of unusual environmental/ecological changes that matter to communities". LEO is a network of people that allows anyone to report any observation potentially associated with unusual environmental change. LEO has over 3300 members with 1000 affiliations and is a collaborative "talking circle." Consultants can be contacted to provide advice on a reported event. The network connects 3 dimensions of knowledge: local, scientific and indigenous. These reports can help promote political will for change.

Dr. Mitsutaki Makino's presentation described "Capacity building in Indonesian fishing communities using smartphone technology to monitor the environment and fisheries". Environmental changes related to fisheries and seafood security need to be understood in order to anticipate changes. Therefore, monitoring over time is important. The project goal was to build capacity to monitor coastal ecosystems and fisheries management by local small-scale fishers using a transdisciplinary approach. Workshops were conducted to better understand the community needs for this project to allow it to be co-designed. In these workshops, 5 monitoring parameters were identified by the local communities that they wished to monitor: coastal water quality, phytoplankton, fish landing/catch, illegal fishing, floating garbage. All of these parameters are now monitored by mobile phone and stored on the Indonesian National Ocean Data Center. Capacity building is an overall goal that allows the fishers to teach other fishers and will bring a better understanding to the local people and researchers about environmental change.

List of papers

Oral presentations

Connecting science to management, policy and people (Keynote)
Jackie King

How the Kuroshio enriches the southern coast of Japan and its downstream regions (Invited)
Takeyoshi Nagai, Gloria Silvana Duran Gomez, Diego Andre Otero Huaman, Yoshie Naoki, Kazuki Ohgi, Daisuke Hasegawa, Sophie Clayton, Yusuke Uchiyama

Better understanding of socioeconomic impacts of climate change in fisheries (Invited)
Dohoon Kim

Participatory scenario building to conserve Cultural Ecosystem Services: The possibilities and challenges from a case study in Japan
Aoi Sugimoto

An automated synopsis of the state of Pacific Canadian groundfish and climate impacts (Invited)
Sean C. Anderson, Elise A. Keppel, Andrew M. Edwards, Philina A. English, Eric J. Ward

The Winter 2019 Gulf of Alaska Expedition: Studying salmon ecosystems on the high seas
Laurie A. Weitkamp

An assessment of climate change impacts on polar ecosystems
Anne B. Hollowed

Top Predators as Climate and Ecosystem Sentinels
Elliott L. Hazen, Briana Abrahms, Stephanie Brodie, Gemma Carroll, Michael Jacox, Matthew S. Savoca, Kylie L. Scales, William J. Sydeman, Steven J. Bograd

Connecting science and communities under a changing climate: the role of boundary organizations (Invited)
Anna Milena Zivian

The North Pacific Ecosystem Status Report 2009-2015
Peter Chandler

The UN Decade of Ocean Science for Sustainable Development and PICES: For the perspective of a predicted ocean
Fangli Qiao (presented by Chenjun Sun)

Participatory system modelling to increase climate resilience of seafood availability in Tla'amin Nation
Patricia T. Angkiriwang, Sachiko Ouchi, Tiff-Annie Kenny, Anne Salomon, Laurie Chan, and William Cheung

The Local Environmental Observer Network for inclusive documentation and understanding of unusual environmental / ecological changes that matter to communities
Thomas A. Okey, Michael Y. Brubaker and Michael J. Brook

Capacity building in Indonesian fishing communities using smartphone technology to monitor the environment and fisheries: The FishGIS project
Mitsutaku Makino, Mark L. Wells, Suhendar I Sachoemar, Naoki Tojo, Shion Takemura, Shigeharu Kogushi, Vladimir Kulik, Joon-Soo Lee, Charles Trick, Chang-an Xu and Alexander Bychkov

Poster presentations

Increasing input of anthropogenic nitrogen drives the East China and Yellow seas to phosphorus limitation
Kitack Lee, Ji-Young Moon, Eunil Lee and In-Seong Han

Spatio-temporal models provide new insights on the biotic and abiotic drivers shaping Pacific Herring (Clupea pallasi) distribution
Martin Godefroid, Jennifer L. Boldt, James Thorson, Robyn Forrest, Stéphane Gauthier, Linnea Flostrand, R. Ian Perry, Andrew R.S. Ross, and Moira Galbraith

POC Topic Session (S2)
Marine heatwaves in the North Pacific: Predictions and impacts in coastal regions

Convenors: *Jennifer Jackson (Canada), Tetjana Ross (Canada), Toshio Yamagata (Japan), Yun-Wei Dong (China), Emanuele di Lorenzo (USA)*

Invited Speakers:
Simone Alin (Pacific Marine Environmental Laboratory, NOAA, USA)
Sonia Batten (CPR Survey, Marine Biological Association)
Eric C.J. Oliver (Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada)

Background

Marine heatwaves have been occurring more frequently in recent decades and the biological impacts linked to these abnormally warm ocean temperatures have been making headlines, from sea cucumber die-offs in China to harmful algal blooms along the entire coast of North America. The occurrence of marine heatwaves can largely be explained by anomalous atmospheric conditions, however very little is known about the processes that cause marine heatwaves to persist or dissipate in the ocean. Thus, despite the damage marine heatwaves cause to the health of ocean ecosystems, their arrival, duration, and long-term impact has been difficult to predict without mechanistic knowledge of how they evolve. The focus of this session is to connect researchers studying the physics behind the evolution of marine heatwaves with those studying their impacts on coastal ocean properties and ecosystems, with the goal of improving predictions of future events. This session invites presentations on physical mechanisms that control the formation, spread, and dissipation of marine heatwaves, and on predictions of the future physical, chemical, and biological impacts of marine heatwaves in coastal regions. Presentations relevant to fisheries and aquaculture in the North Pacific are particularly encouraged.

Summary of presentations

This full-day session consisted of 16 oral presentations and 6 poster presentations that examined the physical, chemical, and biological impacts of marine heatwaves. In general, most presentations focused on the 2014 to 2016 Northeast Pacific marine heatwave. In addition, there was some work done on the potential to predict marine heatwaves. In total, 5 of the presentations (2 oral and 3 poster) were given by early career scientists.

We welcomed three invited speakers who separately covered physical, biological and chemical impacts. Eric Oliver (Canada) discussed the drivers of marine heatwaves and then future marine heatwave projections through 2100, which suggest that the global ocean will be in a permanent marine heatwave station by 2100. Sonja Batten (Canada) presented 2004 to 2018 zooplankton timeseries from the Northeast Pacific Ocean and showed large changes in ecosystem structure that differed between the coast and offshore. Simone Alin (USA) showed how the 2014 to 2016 marine heatwave impacted the biogeochemistry of the Salish Sea.

Of the other seven physical presentations, three (Michael Jacox (USA), Jing-Jia Luo (China) and Antonietta Capotondi (USA)) focused on prediction and four (Charles Hannah (Canada), Jennifer Jackson (Canada), Tetjana Ross (Canada), and Sofia Darmaraki (Canada)) focused on observations.

Of the other eleven biological presentations, one (Hakase Hayashida (Australia)) focused on primary production, three (Jennifer Fisher (USA), Meredith Elliott (USA), and Brian Hoover (USA)) focused on zooplankton, one (Mayumi Arimitsu (USA)) focused on fish, two (John Piatt (USA) and William Sydemann (USA)) focused on seabirds, two (Timothy Green (Canada) and Malcolm Cowan (Canada)) focused on oysters, and two (Matthew Baker (USA) and Julie Keister (USA)) focused on marine ecology linkages.

The one other chemical presentation (Hayley Dosser (Canada)) also was awarded the best poster by the Physical Oceanography and Climate (POC) Committee.

In general the session went well and led to much discussion, including an accepted proposal for a 2 day workshop at PICES 2020 (postponed to PICES 2021) titled '*The social-ecological environmental dynamics of climate extremes in Pacific coastal systems.'*

List of papers

Oral presentations

Historical and future projected changes in global marine heatwaves (Invited)
Eric Oliver, Markus Donat, M.T. Burrows, P. Moore, D. Smale, L. Alexander, J. Benthuysen, M. Feng, A. Sen Gupta, A. Hobday, N. Holbrook, S. Perkins-Kirkpatrick, H. Scannell, S. Straub, M. Thomsen and T. Wernberg

Predicting the evolution of the 2014-16 California Current System marine heatwave from an ensemble of coupled global climate forecasts
Michael G. Jacox, Desiree Tommasi, Michael Alexander, Gaelle Hervieux, Charles Stock

California Niño/Niña
Chaoxia Yuan, Jing-Jia Luo, Jiaqing Xue, Doi Takeshi and Toshio Yamagata

Effects of a prolonged marine heatwave on middle and upper-trophic level biota in the California Current
Jennifer Fisher and Richard D. Brodeur

The 2014-16 North Pacific marine heatwave's impacts on the marine ecosystem in central California, USA
Meredith L. Elliott, Jaime Jahncke, Danielle Lipski, and Jan Roletto

Marine heat wave impacts on lower trophic levels in the northern Gulf of Alaska (Invited)
Sonia Batten, Pierre Helaouet and Anthony Walne

Influence of temperature and the 2014-2016 heat wave on regional zooplankton community structure in the eastern North Pacific
Brian Hoover, Marisol García-Reyes, Sonia Batten, Chelle Gentemann, Kathleen Dohan, William Sydeman

Reduced energy transfer through forage fish disrupted marine food webs during the North Pacific marine heatwave
Mayumi Arimitsu, John Piatt, Rob Suryan, Dan Cushing, Scott Hatch, Kathy Kuletz, Caitlin Marsteller, John Moran, Scott Pegau, Matt Rogers, Sarah Schoen, Jan Straley, and Vanessa von Biela

Predicting physical drivers of marine ecosystems in the Northeast Pacific using a Linear Inverse Modeling approach
Antonietta Capotondi and Prashant D. Sardeshmukh

Was an "ectothermic vise" responsible for the mass mortality and breeding failure of seabirds in Alaska following the NE Pacific marine heat wave of 2014-2016?
John Piatt, Mayumi Arimitsu, Sarah Schoen, Vanessa Von Biela, Julia Parrish, Heather Renner, Kathy Kuletz and William Sydeman

Are marine heatwaves causing an increase in seabird breeding failure globally?
William J. Sydeman, Sarah Ann Thompson, David S. Schoeman, Marisol Garcia-Reyes, and the Seabird-Climate Working Group

Effects of the North Pacific marine heatwave and El Niño events of 2013–2016 on the biogeochemistry of the southern Salish Sea (Invited)
Simone Alin, Jan Newton, Richard Feely, Dana Greeley, and Beth Curry

Marine heatwave alters abundance, structure and virulence of Vibrio populations associated with the Pacific oyster resulting in a mass mortality event
Timothy Green, Malcolm Cowan, Gurdit Khatkar, Natalie Khtikian, Allister Clisham, Andrew Robinson, Chris Pearce and Gary Meyer

How unusual were ocean temperatures in the Northeast Pacific during 2014-2018?
Tetjana Ross and Howard Freeland

Characterizing marine heatwaves in British Columbia waters
Charles Hannah, Peter Chandler, and Stephen Page

A tale of three fjords: A comparison of marine heatwave impacts on three British Columbia mainland coastal systems
Jennifer M. Jackson, Eddy Carmack, and Jessy Barrette

Poster presentations

The Blob and its impacts on marine ecology in the Salish Sea
Matthew Baker, Jan Newton, Rebecca Guenther, Tara Wilson, Ryan McLaughlin, Emily Hamacher, Erin Horkan, Kali Williams, Jessica Thompson, Bryson Albrecht, Rayn Allen, Rachel Hale, Krista Nunnally, Ian Smith, Ye Tian, Gabriela Zayas del Rio

Sharp reduction in nutrient concentrations in deep British Columbian strait linked to marine heatwave
Hayley V. Dosser, Stephanie Waterman, Jennifer Jackson, Brian Hunt

Regional case studies on marine heatwaves and their impacts on primary production
Hakase Hayashida, Richard J. Matear, and Peter G. Strutton

Unexpected changes in zooplankton biomass and juvenile salmon growth during the 2015-2016 warm anomalies, Puget Sound, WA, USA
Julie Keister, Amanda Winans, Bethellee Herrmann, Julia Bos and Iris Kemp

Influence of *Vibrio* spp., temperature, reproductive development, and stocking density on Pacific oyster (*Crassostrea gigas*) summer mortality in Baynes Sound, British Columbia
Malcom Cowan, T. Green, P. de la Bastide, T. Finston, G. Meyer, B. McAmmond, J. Van Hamme, E. Bottos, W. Hintz, R. Marshall, C.M. Pearce

Mediterranean marine heatwaves: Physical drivers and future evolution
Sofia Darmaraki

POC/MEQ/BIO Topic Session (S3)
Coastal ocean modelling in the North Pacific

Convenors: *Laura Bianucci (Canada), Tarang Khangaonkar (USA), Chan Joo Jang (Korea), Susan Allen (Canada), Fei Chai (China), YouYu Lu (Canada)*

Invited Speaker:
Mike Foreman (Scientist Emeritus at the Institute of Ocean Sciences, Canada)

Background

The coastal ocean is a dynamic, complex region where multi-scale processes interact and create conditions suitable for rich ecosystems. For instance, the combination of processes such as land and river runoff, local and remotely forced upwelling, and wind and tidal mixing can bring nutrients to the surface waters, triggering high primary productivity rates. Coastal waters are subjected to the direct impact of human activities like fishing, aquaculture farming, wastewater runoff, *etc*. These anthropogenic perturbations along with other pressures exerted by climate change can lead to negative effects in the coastal ocean, such as pollution, hypoxia, ocean acidification, sea level rise, and loss of ecosystem biodiversity. Numerical models of the coastal ocean can be used to understand the physical and biogeochemical drivers in different regions, how these processes can change in the future, and what the implications of these changes are. The complexity of coastal regions, both in terms of geography and physical and biogeochemical dynamics, makes these modelling exercises challenging and region-specific. Nevertheless, commonalities can be drawn among different regions and models, such that the modelling community can benefit immensely by sharing experiences and results. The session's aim was to bring together researchers interested in learning and discussing about the challenges and advances in coastal ocean models.

Summary of presentations

This full-day session took place on October 24 in Victoria, BC, Canada. The session had one invited speaker who was then offered to provide a plenary talk (Mike Foreman, Canada), 14 oral presentations and two posters. The 18 presenters represented five PICES member countries (all but Russia) and four of them were early career scientists.

The session was well attended (up to ~40 people at times) and successfully brought together scientists working on and interested in the modelling of the coastal ocean. The presentations highlighted advances and issues on different coastal/shelf regions of the North Pacific and were based on different model architectures. Mike Foreman opened the day with his plenary talk, where he used his current modelling work on the west coast of Vancouver Island to highlight the challenges of modelling complex coastal environments (*e.g.*, intricate coastlines and bathymetry, multiple and highly variable forcing, *etc*.). After the plenary, the three-part oral session was organized such that the first part was devoted to physics-only models and the later two parts focused on models which included some kind of ecosystem, biological or biogeochemical module.

In the first part of the oral session, three of the four presentations focused on the Northeast Pacific (Yuehua Lin, Charles Hannah on behalf of Youyu Lu, Pramod Thupaki) and one on the Northwest Pacific (Toru Miyama). Furthermore, thee used the FVCOM[1] architecture (Lin, Thupaki, Miyama), while one was based on NEMO[2] (Hannah). The common topic was the importance of forcing in the different coastal domains. The Northeast Pacific regional model showed that remote wind forcing is a key driver of sea level variations for the shelf waters of British Columbia (Hannah). The role of freshwater forcing in regions closer to the coast was highlighted for the Central Coast of British Columbia (Thupaki) as well as in the Okhotsk Sea (Miyama). Lin described the effect of forcing the open boundary of his Queen Charlotte Strait model (also in British Columbia coastal waters) through nesting with a regional operational model.

Most of the presentations in the rest of the session focused on coupled physical–biological/biogeochemical/ ecosystem models and were also based on several different model architectures: FVCOM (Laura Bianucci), NEMO (Amber Holdsworth, Susan Allen, Elise Olson), and ROMS[3] (Angelica Peña, Guimei Liu, Mercedes Pozo Buil, Darren Pilcher, Dan Wang). Three talks focused on the Salish Sea region (Bianucci, Allen, Olson); two of them broadcasted the SalishSeaCast model for the Salish Sea. Allen presented an evaluation of model performance against observations for a 13-year hindcast and evaluated interannual variability in the Strait of Georgia, while Olson focused on the tidally-driven nitrate supply to the surface waters of the northwestern Strait of Georgia. Bianucci showed the initial stages of a model for the Discovery Islands and highlighted a new approach to deal with river discharges of ungauged rivers.

Two studies focused on the shelf waters of British Columbia. Peña investigated the interannual variability of primary production and biogeochemical conditions in the region and their correlation with the North Pacific Gyre Oscillation (NPGO) and El Niño events. Holdsworth presented climate projections, finding that under the emission scenario RCP4.5, the region is expected to become warmer, fresher, and more stratified by 2050s. Furthermore, more acidic and deoxygenated conditions are expected right outside the shelf break, such that episodic acidic and hypoxic conditions may become more likely. Besides Holdsworth, two other studies used regional models to downscale climate projections. With focus on the California Current System (mostly on the California and Oregon shelves), Pozo Buil investigated different downscaling methods, highlighting the advantages of the "time-varying delta" method (*i.e.*, it captures projected changes in interannual variability and resolves intermediate time frames, rather than just finding the changes between two given time periods, *e.g.*, 1980–2010 *vs* 2070–2100). Further north, Pilcher used a downscaling approach to produce projections of ocean acidification for the Bering Sea. All of these presentations emphasized the importance dynamical

downscaling in order to achieve a correct representation of shelf waters, which are usually under-resolved in Earth System Models.

Another presentation focused on short-term forecasting capabilities on shelf waters. Dan Wang described a comprehensive assimilation system of carbon observations from four monitoring stations in the China Sea as well as satellite (GOSAT, OCO-2, Tansat); these observations are then used within a forecasting system based on ROMS to predict alkalinity of seawater, total inorganic carbon and pCO_2 on the air–sea interface in the upcoming 120 hours in the China Sea. Lastly, a few presentations showed different approaches to coupled physical–biological models. For instance, Guimei Liu showed a different type of physical–biological coupling to investigate green macroalgae blooms in the Yellow Sea. It used the physical output of a ROMS model (as well as wind and radiation data from NCEP[4] Climate Forecast System Reanalysis) to force a Lagragian particle-tracking module, where the growth and extinction behaviour of the particles represented green algae. Yuanchao Wang used the Ecopath/EcoTroph model to represent the energy flow within 23 taxa that comprise the estuarine ecosystem of the Yangtze estuary and its adjacent waters.

To sum up, the session was successful at highlighting the importance of the coastal ocean and its complexity, which cannot be properly represented by larger scale, coarser resolution models. The issues of modelling the coastal environment are not necessarily shared with larger scale modelling exercises, but are common throughout different coastal regions. Some of these commonly shared issues are the need for high-quality and usually scarce river data, the requirement of atmospheric forcing with appropriate resolution for a given region, the predominance of both local and remote forcing (*i.e.*, some processes have to be properly represented in the model, while others depend strongly on the open boundary conditions that introduce remote forcing), the challenges of resolving complex bathymetry and coastlines while maintaining numerical stability, and many others.

[1] FVCOM: Finite Volume Community Ocean Model
[2] NEMO: Nucleus for European Modelling of the Ocean
[3] ROMS: Regional Ocean Modeling System
[4] NCEP: National Centers for Environmental Prediction

List of papers

Oral presentations

Challenges and progress in the development of a circulation model for the central west coast of Vancouver Island (Plenary)
Michael Foreman, Peter Chandler, Di Wan, Pramod Thupaki, Maxim Krassovski, and Laura Bianucci

Queen Charlotte Strait FVCOM modeling development
Yuehua Lin, Laura Bianucci, Maxim Krassovski, and Mike Foreman

Sea level and meso-scale eddy variations in the Northeast Pacific during 2007-2016 simulated with a high-resolution regional ocean model
Youyu Lu, Li Zhai, Xianmin Hu, Rachel Horwitz, Jean-Philippe Paquin, Charles Hannah and William Crawford (presented by Charles Hannah)

Modelling the riverine coastal domain along the Central Coast of British Columbia, Canada
Pramod Thupaki, Di Wan, Mike Foreman, and Maxim Krassovski

Role of river inflows from the Kamchatka Peninsula in the Okhotsk Sea
Toru Miyama and Humio Mitsudera

Modelling the energy flow structures and interannual dynamics of Yangtze estuary and its adjacent waters in China
Yuanchao Wang, Cui Liang, and Weiwei Xian

A coupled physical-biogeochemical FVCOM model for the Discovery Islands (BC, Canada)
Laura Bianucci, Mike Foreman, Hayley Dosser, Maxim Krassovski, Pramod Thupaki, Peter Chandler,and Jen Jackson

Modelling the interannual variability of biogeochemical conditions along the British Columbia coast
Angelica Peña, Isaac Fine, and Wendy Callendar

Projecting climate change for Canadian Northeast Pacific waters
Amber M. Holdsworth, James R. Christian, and Youyu Lu

Green macroalgae blooms and particle trajectories in the Yellow sea: A numerical experiment of lagrangian-particle-tracking coupled with biological processes
Guimei Liu, Shan Gao, Xuanliang Ji, Enye He, and JingYang

Using SalishSeaCast, a coupled bio-chem-physical model of the Salish Sea, to evaluate interannual variability in the Strait of Georgia
Susan E. Allen, Elise Olson, Nancy Soontiens, Michael Dunphy, Doug Latornell, Ben Moore-Maley, Tereza Jarnikova, and Jie Liu

Salish Sea Model Ecosystem - Lower Trophic: Tidally driven nutrient supply to surface waters in the northern Strait of Georgia
Elise Olson, Susan Allen, Ben Moore-Maley, and Doug Latornell

Future changes of the coastal waters in the California Current System
Mercedes Pozo Buil, Michael G. Jacox, Jerome Fiechter, and Michael A. Alexander

Importance of simulating coastal biogeochemical processes for projections of ocean acidification on the Bering Sea shelf
Darren J. Pilcher, Jessica N. Cross, Albert J. Hermann, Samuel Mogen, Kelly Kearney, and Wei Cheng

The value of the greenhouse gas monitoring system for climate change in the China Sea
Dan Wang, Honggang Lv, Yifei Jiang, and Shan Gao

Poster presentations

Methods for predicting short-term surface sea temperature and the forecasting service in Republic of Korea
Kwangnam Han, Byungmoon Park, Yong Huh and Donghyeon Yu

Effects of ocean warming on potential habitat distribution of Japanese anchovy (*Engraulis japonica*) in the seas around Korea: A maximum entropy approach
Minkyoung Bang, Chan Joo Jang, Sukyung Kang and Chang-Sin Kim

HD Topic Session (S4)
The impacts of marine transportation and their cumulative effects on coastal communities and ecosystems

Co-sponsor: *ICES*

Convenors: *Cathryn Murray (Canada), Sarah Bailey (Canada), Hideaki Maki (Japan), Paula Doucette (Canada)*

Invited Speaker:
Hideo Okamura (Research Center for Inland Seas, Kobe University, Japan)

Background

The marine ecosystems of the North Pacific Ocean are connected by an international shipping and transportation network. Commercial shipping provides significant economic benefits and opportunities and the distribution and intensity of commercial shipping is increasing. There is a growing need to assess and mitigate the impacts of vessel activities on the marine environment to balance the benefits of this industry. Commercial and recreational vessel activities can produce stressors such as underwater noise, strikes, debris, aquatic invasive species, and chronic and episodic pollution. These impacts can act individually and together in space and time, resulting in cumulative effects – the collective effects caused by the combined results of past, current and future activities. Cumulative effects assessment is needed to address the sheer volume and frequency of vessel movements, the interaction and summation of multiple impact pathways, and cumulative effects through

time. Vessel activities can have transboundary impacts and successful mitigation efforts require coordination and collaboration between trade partners. This session has links to the PICES Working Group on *Emerging Topics in Marine Pollution* (WG 31), the Advisory Panel on *Marine Non-Indigenous Species* (AP-NIS), and the Working Group on *Marine Ecosystem Services* (WG 41). The objective of the session is to convene expertise on the impacts of vessels and review the current state of knowledge and priority research needs for the future.

Summary of presentations

The impacts of marine transportation on the environment are diverse, as exemplified by the breadth of presentations within the session. Presentations focused on a wide variety of shipping-associated stressors, including contaminants, invasive species, ship strikes, grey water discharge, and oil spills. The invited speaker, Hideo Okamura, reviewed the knowledge on the toxicity of antifouling paints used to prevent biofouling on ship hulls. This important research area has contributed to regulatory change and continues to investigate emerging chemicals of concern. Biofouling has the potential to transport invasive species into marine protected areas because of the ships' connectivity to nodes of invasion hot spots. The threat of invasive species transport increases the need for antifouling options that do not exhibit concurrent toxicity impacts. The overlap between preferred habitat of large whales and shipping lanes means that there is high risk of fatal ship strikes in areas of the whales' habitat. Grey water discharge is an emerging stressor of concern, especially in areas considered pristine or relatively unaffected by human activities, such as the Arctic. The dispersion of oil spilled has been shown to be strongly affected by the type of oil and the wind and ocean conditions at the time of the spill.

All presenters highlighted mitigation and management measures that could be used to reduce or eliminate the impacts of shipping-related stressors. International bans on chemicals such as Cybutryne are being considered, and more research is needed on the control measures associated with implementing the ban. Increasing knowledge about the risks of ship strikes for large whales has led to mitigation trials, such as voluntary slowdowns. These slowdowns can be effective in reducing the risk, but their success is affected by the level of outreach and engagement with the shipping industry. Community concerns about discharge of grey water by the cruise ship industry have led to advanced mitigation systems for large vessels. Monitoring, sampling, and standards for grey water discharge have been implemented in Alaska that could be applied in other parts of the world. The effectiveness of response and containment options after an oil spill is affected by knowledge of oil type and the environmental conditions, increasing the ability to reduce impacts to the marine environment after a spill.

The new ICES working group (WGSHIP) on the impacts of marine shipping was introduced to the group and the Chair invited participation from members of PICES countries.

List of papers

Oral presentations

Ship antifouling biocides used in Japan and their environmental risk (Invited)
Hideo Okamura

Unwanted networks: vessel traffic heightens the risk of invasions in marine protected areas
Josephine C. Iacarella, Lily Burke, Ian C. Davidson, Claudio DiBacco, Thomas W. Therriault and Anya Dunham

Ship strike management in priority regions of the U.S. West Coast: Effectiveness of past efforts and potential for new strategies
R. Cotton Rockwood, Jeff Adams, John Calambokidis, Greg Silber and Jaime Jahncke

Environmental impacts and mitigation of grey water discharges from ships
Sarah Bobbe and Andrew Dumbrille

Influences of wind, sea state, and oil type on oil dispersion in the Salish Sea
Rachael D. Mueller, Shihan Li, Ashutosh Bhudia, Krista Cawley, Doug Latornell, Ben Moore-Maley, Susan E. Allen, Haibo Niu and Stephanie Chang

Marine eco-damage assessment methods based on the eco-restoration cost in China
Keliang Chen, Fenggui Chen, Jiwei Zhang, Jinkeng Wang and Bingkun Wang

Research on the application level of marine ecosystem services economic valuation in decision-making in China
Jingmei Li, Na Wang and Jin Hua

The variability of Japanese eel body larval length concerning the environmental factors of the migration route
Kuan-Mei Hsiung, Chi Ma, Yu-San Han, and Chia-Ying Ko

Poster presentations

Effects of TBT on sinking rate and physiological parameters of marine planktonic diatom, *Thalassiosira pseudonana*
Mst. Ruhina Margia Khanam, Yohei Shimasaki, Koki Mukai, Yuji Oshima

POC/BIO/FIS/FUTURE Topic Session (S5)
Trends in ocean and coastal ecosystems and their services and its future

Convenors: *Shin-ichi Ito (Japan), Angelica Peña (Canada), Kirstin Holsman (USA), Xiujuan Shan (China) Igor Yashayaev (Canada)*

Invited Speaker:
Naoki H. Kumagai (National Institute for Environmental Sciences, Tsukuba, Japan)

Background

Oceans and coastal ecosystems provide various ecosystem services to humans. However, ocean and coastal ecosystems are changing and showing trends in regional and synoptic scales responding to global climate change. It is urgent that we elucidate the mechanisms responsible for trends in ocean and coastal ecosystems and enable its future projections. We proposed a topic session that involved participation from multiple PICES committees and which focused on trends in ocean and coastal ecosystems responding to global climate change, specifically, presentations on topics such as (a) observational approaches to detect trends in ocean and coastal ecosystems, (b) elucidation of mechanisms of the ocean and coastal ecosystem responses, and (c) future projections of ocean and coastal ecosystems.

Summary of presentations

A 1.5-day session provided a forum for discussion of changes and trends in ocean and coastal ecosystems responding to global climate change. There was one plenary invited talk as well as 19 contributed oral presentation and 6 poster presentations. The session was attended by about 100 people.

Naoki Kumagai was an invited speaker. He presented community shifts from macroalgae to corals in the Japanese coastal region under climate warming. His research suggested not only that ocean warming but also the direction of current advection relative to climate velocity (geological isotherm shift velocity) is important to the marine life responses. Community shifts from macroalgae to corals in the Japanese coastal region were shown. He concluded that rises in temperature and a poleward-flowing current system are promoting macroalgal-to-coral shifts both directly by increased competition from the expansion of tropical corals into the contracting temperate macroalgae, and indirectly *via* deforestation by the expansion of tropical herbivorous

fish. As more proactive future conservation strategies of the macroalgae, abundance control of herbivorous fishes, artificial assistance for thermal adaptation through selection of thermal tolerant lineages, and relocation and translocation into cooler areas were proposed.

The session covered (a) observational approaches to detect trends in ocean and coastal ecosystems, (b) elucidation of mechanisms of the ocean and coastal ecosystem responses, and (c) future projections of ocean and coastal ecosystems.

Regarding (a) observational approaches to detect trends in ocean and coastal ecosystems, Carol Ladd showed an interannual trend toward weaker stratification in the Chukchi Sea. The weaker stratification was likely due to earlier ice retreat, but nitrate concentration was influenced by transport through the Bering Strait, which suggests that interplay between advective and local processes is complicated and important drivers (transport, ice, winds) are not independent.

Matthew Baker reported recent reduced duration and extent of sea ice in the Pacific Arctic and loss of thermal barriers previously evident in the Bering and Chukchi which potentially affect Pacific–Arctic connectivity, transport, primary production and phenology, and hence many aspects on marine ecosystems. He also showed a good example of international collaboration on monitoring the Pacific Arctic and Bering Sea.

In addition, as new monitoring programs, Wiley Evans introduced a biogeochemical monitoring of surface seawater by the Alaska Marine Highway System M/V *Columbia*, which covers about 1300-km transits between Bellingham, Washington and Skagway, Alaska, with twice weekly temporal resolution. Colleen Kellogg introduced a monitoring of microbial variability with weekly temporal resolution in the northern Strait of Georgia since 2014. Carol Stepien introduced a community monitoring of invertebrates and fishes in the Salish Sea using eDNA water samples. Elizabeth Lee presented an example of a genotyping-by-sequencing approach to examine fine-scale genetic connectivity among Dungeness crab larval recruits in the California Current Ecosystem.

Cecilia O'Leary compared fishery-independent bottom trawl surveys using different gears and covering different regions in the Bering Sea, and found that the vessels used in the western Bering Sea had a lower fishing power, and local variance estimators provided a reduced abundance index uncertainty. This example indicates the difficulties of using multiple biological data sets.

Regarding (b) elucidation of mechanisms of the ocean and coastal ecosystem responses, Karyn Suchy investigated links between phytoplankton and zooplankton phenology in the Strait of Georgia based on satellite Chl-*a* data and monitoring zooplankton data from 2003 to 2016. She found that positive anomalies in spring Chl-*a* corresponded with earlier peak timing of juvenile calanoid copepods and euphausiids.

Ian Perry investigated decadal patterns of zooplankton, small demersal invertebrates and finfish using mesh bottom trawl multi-species surveys during 1973–2017 and zooplankton surveys in the southern Vancouver Island shelf during 1980–2017. The result suggest that the main drivers of decadal fluctuations are sea temperature (largely related to El Niño processes), atmospheric circulation patterns (represented by NPGO), and coastal upwelling.

Eric Bjorkstedt investigated assemblage and size-structure of euphausiids in coastal waters off northern California based on monitoring data collected from 2008–2018. The result revealed that concurrent shifts in assemblage and size structure were driven by changes in characteristics and origin of shelf waters, and major warming events disrupted or suppressed typical seasonal and spatial patterns.

Sheng-Yuan Teng investigated relationships between grey mullet catch fluctuation and environmental factors and found that sea temperature is a key factor. The results suggested that a see-saw fluctuation of the catch between South Korea and Taiwan–Japan depends on optimal temperature shifts between 1971 and 2010. David McGowan investigated variability in the location and timing of Pacific herring (*Clupea pallasii*) spawning within Prince William Sound (PWS) using aerial survey data collected between 1980–2017. Spawn timing trended earlier 15 and 25 days in the Western and Eastern PWS, respectively. Spawn timing shifts since 2006 coincided with changes in temperature regimes. Jessica Garzke measured RNA–DNA ratio and fatty acid composition as a parameter of fitness and nutritional condition of juvenile sockeye salmon near the coast of British Columbia during an extreme hot event (2015–2016). The results suggested that temperature did not directly affect juvenile fitness and nutritional condition, but rather these were affected by indirect effects of differences in prey species composition, food quantity and quality.

Caitlin Magel applied a Bayesian hierarchical integrated population model to quantifying the role of estuaries in Oregon Coast coho salmon production based on 21 independent population data during 1994–2016. The result indicated that local-scale factors, such as estuarine habitat size and quality, can contribute to coho salmon production.

In addition, Po-Yuan Hsiao reported about the influences of climatic variability on summertime environmental variations and ecosystem structures around the waters of Taiwan Bank required using primary production.

In regard to (c) future projections of ocean and coastal ecosystems, Haruka Nishikawa reported about the future ocean structure in the Kuroshio Extension projected by high resolution downscaling models. She focused on the Kuroshio–Oyashio layered structure which controlled spring primary production in the Kuroshio Extension. The distribution of layered structure contracted in MRI-CGCM3 and MIROC5 projections, which indicates decrease of primary production under future climate.

Phoebe Woodworth-Jefcoats investigated climate change impacts on fish species using a size-structured food web model with species-level resolution that includes the physiological effects of ocean temperature. The result suggested that climate change reduces yield across all species, with severity varying based in part on thermal habitat. In addition, the results support an idea that reducing fishing mortality may enable ecosystem resilience in the face of climate change.

Irene Alabia projected marine biodiversity in the Pacific Arctic under future climate using 10 algorithm species distribution models. The results revealed northward expansion of warm-adapted taxa, increase in species richness in the depauperate Arctic community and functional biogeographic shift in the Arctic – from smaller, shorter-lived taxa to larger, longer-lived species. The results indicate more vulnerable Arctic ecosystem to climatic disturbances, as trophic components become more connected and less compartmentalised.

Szymon Surma applied a mass-balanced food web model (Ecopath with Ecosim) to reconstruct and project trends in the marine ecosystem surrounding Haida Gwaii (an archipelago in the southeastern Gulf of Alaska). Simulated effects of future whale recovery were substantial, though somewhat sensitive to the primary productivity scenarios.

The session was well balanced in age structure (12 early career and 17 senior scientists), gender (12 female and 17 male scientists), and regions (11 US, 7 Canada, 4 Japan, 3 China, 2 Taipei, 1 Russia, and 1 South Korea). During the discussion, the co-convenors mentioned the S-CCME contribution to IPCC special report on “The Ocean and Cryosphere in a Changing Climate” and encouraged the participants to submit their findings to peer-review journals until the 1st of July 2020 (cut off date) to contribute to the IPCC Sixth Assessment Report of Working Group II. The co-convenors also encouraged the early career scientists to contribute to S-CCME activities, and adjourned the session.

List of papers

Oral presentations

Community shifts from macroalgae to corals under climate warming: Underlying processes and adaptation strategies (Plenary)
Naoki H. Kumagai, Jorge García Molinos, Hiroya Yamano, Shitaro Takao, Masahiko Fujii and Yasuhiro Yamanaka

Interannual variability in stratification, nutrients, and water mass structure in the Chukchi Sea
Carol Ladd, Calvin Mordy and Phyllis Stabeno

Shifts in the physical environment in the Pacific Arctic and implications for ecological timing and structure
Matthew Baker, Kirill Kivva, Jordan Watson, Maria Pisareva, Julia Selivanova

Resolving drivers of microbial community variability in the Strait of Georgia over multiple time scales
Colleen Kellogg, Rebecca Piercey, Caterina Giner, Justin Del Bel Belluz, Brian Hunt, Jennifer Jackson

Constraining along-coast surface seawater CO2 system variability and changeability from an Alaskan ferry
Wiley Evans, Geoffrey T. Lebon, Christen D. Harrington, and Allison Bidlack

The role of temperature in determining how marine fish will be differentially affected by climate change
Phoebe A. Woodworth-Jefcoats, Julia L. Blanchard, and Jeffrey C. Drazen

Synchrony between phytoplankton and zooplankton phenology in the Strait of Georgia, Canada
Karyn Suchy, Maycira Costa, Moira Galbraith, Kelly Young, and Ian Perry

Community species identities, diversity, and patterns across the Salish Sea: Metagenomic analyses of zooplankton and eDNA
Carol A. Stepien, Julie Keister, Elizabeth Slikas, Christopher Paight, Emily Norton, and Ellen Lee

Drivers of interannual and decadal-scale variability in the lower trophic levels of the marine ecosystem off Vancouver Island, Canada
R. Ian Perry, Moira Galbraith, Kelly Young, Roy Hourston, Richard Thomson, Ken Fong, and Brenda Waddell

Climate-related variability in assemblage and size- structure of euphausiids in coastal waters off northern California
Eric P. Bjorkstedt, Roxanne R. Robertson

Development of an ecosystem-based assessment approach for the northwestern Pacific mullet (*Mugil cephalus*) fishery
Sheng-Yuan Teng, Shin-ichi Ito, Nan-Jay Su and Ming-An Lee

Large multi-decadal space and time shifts in Pacific herring spawning in the Gulf of Alaska
David W. McGowan and Trevor A. Branch

Depressed condition and growth of juvenile sockeye salmon (*Oncorhynchus nerka*) during early migration
Jessica Garzke and B.P.V. Hunt

Quantifying the role of estuaries in Oregon coast coho salmon production
Caitlin L. Magel, Mark D. Scheuerell, Eric R. Buhle and Sally D. Hacker

Spatiotemporal dynamics of groundfish availability to Eastern Bering Sea bottom trawl surveys and abundance estimate uncertainties

Cecillia A. O'Leary, J.T. Thorson, J. Hoff, S. Kotwicki and A. Punt

Big fishery, big data, and little crabs: Examining fine-scale genetic connectivity among Dungeness crab (*Cancer magister*) larval recruits in the California Current Ecosystem
Elizabeth M.J. Lee and Kathleen G. O'Malley

Multiple facets of marine biodiversity in the Pacific Arctic under future climate
Irene D. Alabia, Jorge Garcia Molinos, Sei-Ichi Saitoh, Takafumi Hirata, Toru Hirawake and Franz J. Mueter

Simulated primary production in the Kuroshio Extension under the influence of the global warming

Haruka Nishikawa, Shiro Nishikawa, Tsuyoshi Wakamatsu Yoichi Ishikawa

Reconstructing and projecting trends in a Northeast Pacific ecosystem
Szymon Surma

Developing a community-based resilience assessment model to extreme ocean-climate events
Samuel O. Akande, Adekunle Osinowo, Olajumoke Jejelola, Olabanji Olajire and Oluwaseun Apenuwa

The influences of climatic variability on the summertime environmental variations and ecosystem structures around the waters of Taiwan Bank
Po-Yuan Hsiao and Kuo-Wei Lan

Poster presentations

Valuation of mangrove ecosystem along the coastal of Beihai in China which receives heavy anthropogenic disturbances
Changan Xu, Qinghua Wang, Peng Wu, Jingliang Wan, Shixin Huang and Xu Tang

Declining catch of Japanese sandeels
Shin-ichi Ito and Qinyao Li

The relationship between lake and marine forms of Pacific herring *Clupea pallasii* based on the polymorphism of the mtDNA control region and microsatellite loci
Denis S. Kurnosov, Svetlana Yu.Orlova, Elena A. Chikurova, Dmitriy M. Schepetov.

What has Canada caught, and how much is left? Combining catch reconstructions in three oceans with current biomass estimates
Rebecca Schijns and Daniel Pauly

Multi-decadal projections of biophysical conditions in the Bering Sea
Albert J. Hermann, Wei Cheng, Kelly Kearney, Georgina A. Gibson, Ivonne Ortiz, Kerim Aydin, Kirstin Holsman, and Anne Hollowed

Long-term variations on temperate phytoplankton communities in the Bohai and Yellow Seas, China
Qingshan Luan

FUTURE Topic Session (S6)

Identifying thresholds and potential leading indicators of ecosystem change: The role of ecosystem indicators in ecosystem-based management

Convenors: *Elliott Hazen (USA), Xiujuan Shan (China), Mary Hunsicker (USA), Jennifer Boldt (Canada)*

Invited Speakers:
Saskia A. Otto (Institute of Marine Ecosystem and Fishery Science (IMF) Center for Earth System Research and Sustainability (CEN) University of Hamburg)

Background

Abrupt nonlinear change in ecosystem structure and function can dramatically alter human-derived benefits from the ecosystem and can have negative impacts on people's livelihoods and well-being. A growing number of driver-response relationships in marine ecosystems are being identified as strongly nonlinear, indicating that they are potentially prone to inflection points and threshold dynamics. Better knowledge of where such thresholds occur might advance our ability to anticipate future conditions and critically inform what management actions can maximize ecological, social or economic benefits. Moreover, thresholds common across analogous systems can be used to develop robust reference points to prevent ecosystem components from tipping into undesirable states. This session invited presentations on ecosystem indicators and thresholds, leading indicators of loss of resilience and ecosystem change, and the future of indicators, such as novel indicators from socioecological systems and examples of how indicators have been used in management.

Summary of presentations

This topic session was well attended, with active participation from attendees.

Dr. Saskia Otto gave an invited talk titled "How can we develop suitable indicators to inform management of ecosystems under multiple pressures". She noted that despite advancement in the science of ecosystem indicators, relationships to pressures are frequently unclear as links can be obscured by environmental change, data limitations, food web dynamics, or non-linear and cumulative effects of multiple pressures. She explained

that developing a set of meaningful indicators calls for iterative indicator validations, accounting for natural processes and for trade-offs between management objectives, to enable learning and setting target levels and action thresholds in an adaptive manner. She highlighted the R package INDperform to assist with screening and validating the performance of indicators, which could improve the indicator's usefulness in a management context.

Dr. Philina English's presentation assessed the degree to which changes in distributions of groundfish populations can be explained by locality-specific climate velocities—the distance and direction of movement required to maintain similar climatic conditions through time. She constructed geostatistical spatiotemporal fish density models and compared them to local climate velocity predictions. These models will help anticipate changes in species interactions and fishing pressures.

Dr. Dan Liu examined changing patterns in piscivorous fishes in relation to biotic and abiotic drivers such as sea surface temperature (SST), and particularly the dynamics of their prey assemblage. She found step-changes in small pelagic and prey species. Significant correlations were found both in piscivorous fishes and prey assemblage with SST. She found that impacts of changes in fishing effort were greater than climate variability on catches.

Dr. David Kimmel's talk titled described shifting phenology impacts on the match–mismatch between zooplankton and their predators. He examined trends in zooplankton abundance and environmental conditions in the Gulf of Alaska over time. A novel finding of his research was that the change in abundance of several species appears to reflect a shift in phenology related to temperature effects on development rate.

Dr. Jason Link gave a talk titled "Evidence for ecosystem overfishing in North Pacific marine ecosystems". He presented novel indices of ecosystem overfishing (EOF), providing a brief summary and theoretical background of each, with thresholds. Index values were estimated for all the major large marine ecosystems in the North Pacific. From these he showed that there has indeed been EOF at points in time in many of these marine ecosystems. He also demonstrated that had we been monitoring EOF indicators, we would have detected major changes to fish and fisheries earlier than what we actually did by monitoring on a stock-by-stock basis. He concluded by posing recommendations of these EOF thresholds moving forward to detect and avoid any drastic changes to North Pacific fisheries systems.

Dr. Kelly Andrews investigated forecast performances for key California/Oregon ocean fishery stocks and high priority stocks of prey for endangered southern resident killer whales. He explored how well environmental indices explained variation in forecast performance, and tested for nonlinearities and thresholds. His results suggest environmental influences on preseason forecasts may create biases that unwittingly render salmon fisheries management more or less conservative, and therefore warrant further study and consideration.

Dr. Michael Litzow described how the physical and ecological conditions mapping onto the Pacific Decadal Oscillation index (PDO) and North Pacific Gyre Oscillation index (NPGO) have changed over multi-decadal time scales. These changes apparently began around a 1988/89 North Pacific climate shift that was marked by abrupt Northeast Pacific warming and declining temporal variance in the Aleutian Low, a leading atmospheric driver of the PDO. Dr. Litzow concluded that we cannot assume that relationships with the PDO and NPGO are stationary, and he recommended that primary environmental indicators are used when relating ecological to environmental conditions.

Dr. Stephanie Green gave a talk titled "Traits-based tools to account for the effect of shifting predator-prey interactions on the distributions of tunas under climate change". She outlined an initiative that seeks to address

this gap by using insights into species' foraging and anti-predation traits to incorporate the effect of climate-mediated range shifts on predator-prey interactions. She described the framework for this approach, and illustrated the process by which it has been applied to model the distribution of tunas and their prey in the California Current system.

Dr. Natasha Hardy looked at Albacore tuna as ecosystem samplers/indicators of ecosystem change. She tested whether key behavioural and morphological traits of prey have shaped the prey selection process for albacore tuna in NE Pacific food webs under past climatic conditions, using trait-based analytical tools. Traits of prey included body shape, habitat position and diel migration, refuge/avoidance behaviour, and physical defenses. She highlighted how this approach could be used to forecast the strength of predator-prey interactions as species' ranges shift under climate change in the NE Pacific.

Dr. David Costalago described the pathways and connections between plankton food web components, the seasonal development of these pathways and their spatial variation in the Strait of Georgia. He examined the bottom-up hypothesis that the quality of food is driving Chinook Salmon survival. He used fatty acid (FA) biomarkers, stable isotope analyses, and the ratio of essential FAs to examine Chinook Salmon prey quality. Dr. Costalago found that zooplankton nutritional quality varies seasonally and spatially, providing different quality of food for outmigrating salmon.

Kym Jacobson examined copepod metrics as indicators of regional ocean conditions. In a case study, she used cold-water and warm-water copepod biomass at one station to see how well it represented broader regional patterns. She quantified the spatial coherence of copepod biomass and identified regional and basin-scale environmental drivers of copepod distributions. Her results showed evidence of similarities in copepod biomass at one station (NH05) compared to other sampling stations of similar depths. The main drivers of copepod distribution included deep temperature, station depth, and the PDO.

At the end of the Session, attendees discussed scale issues. For example, the data requirements for trait-based analyses (taxonomic detail, life history stages, data types) were discussed. It was noted that life history stages of both predators and prey have different traits and there is work underway to address this. Another discussion point regarding scale was the comparison of ICES and PICES communities. Participants discussed how ICES was able to acquire and develop indicators from member nations. It was noted that it was a process that developed over time with various initiatives. For example, regional conventions (*e.g.*, HELCOM) with frameworks required indicators and the Marine Strategy Framework Directive (MSFD) brought more people together with varying expertise, leading to the adoption of novel approaches. Participants agreed that the exchange of ideas between organizations such as PICES and ICES should be supported, since it leads to innovative approaches to assessing marine ecosystems.

List of papers

Oral presentations

How can we develop suitable indicators to inform management of ecosystems under multiple pressure? (Plenary)
Saskia A. Otto

Are Canadian Pacific groundfishes shifting their distribution in response to local climate velocities?
Philina A. English, Sean C. Anderson, Eric J. Ward, Brendan M. Connors, Andrew M. Edwards, Robyn E. Forrest, Karen L. Hunter, Christopher N. Rooper

Identifying drivers and their thresholds for piscivorous fishes in the exploited China Seas under climate change
Dan Liu, Yongjun Tian, Caihong Fu, Shuyang Ma, Jianchao Li, Peng Sun, Zhenjiang Ye and Shijie Zhou

Zooplankton abundance trends and patterns in the Shelikof Strait, western Gulf of Alaska 1990-2017
David Kimmel

Evidence for ecosystem overfishing in North Pacific marine ecosystems
Jason S. Link

Ecological thresholds in forecast performance for key United States West Coast Chinook salmon stocks
William H. Satterthwaite, Kelly S. Andrews, Brian J. Burke, Jennifer L. Gosselin, Correigh M. Greene, Chris J. Harvey, Stuart H. Munsch, Michael R. O'Farrell, Jameal F. Samhouri and Kathryn L. Sobocinski

The changing physical and ecological meanings of North Pacific Ocean climate indices
Michael Litzow, Mary Hunsicker, Nicholas Bond, Brian Burke, Curry Cunningham, Jennifer Gosselin, Emily Norton, Eric Ward and Stephani Zador

Traits-based tools to account for the effect of shifting predator-prey interactions on the distributions of ocean species under climate change
Stephanie J. Green, Natasha A. Hardy, Michael Jacox, Elliott L. Hazen, Steven J. Bograd, Larry B. Crowder

Trait-based modeling for albacore tuna predator-prey interactions under climate change in the NE Pacific
Natasha Hardy, Elliott Hazen, Michael Jacox, Steven Bograd, Larry B. Crowder, Stephanie J. Green

Dynamics of the planktonic food-web of the Strait of Georgia (northeast Pacific) and implications for zooplanktivorous fish
David Costalago, Brian P. V. Hunt, Chrys Neville, Ian Perry, Kelly Young and Ian Forster

Characterizing spatial coherence of copepods as regional indicators in the Northern California Current
Michael J. Dumelle, Jesse F. Lamb, Kym C. Jacobson, Mary E. Hunsicker, Cheryl A. Morgan, Brian J. Burke, and William T. Peterson

Poster presentation

Using phytoplankton community index to assess water quality improvement in Hong Kong
Kedong Yin and Jianzhang He

MEQ Topic Session (S7)
Environmental indicators of plastic pollution in the North Pacific

Co-sponsor: *NOWPAP*

Convenors: *Matthew Savoca (USA), Chengjsun Sun (China), Lev Neretin (NOWPAP)*

Invited Speakers:
Stephanie Avery-Gomm (University of Queensland, Australia)
Daoji Li (Plastics Marine Debris Research Center, East China Normal University, China)

Background

Small fragments of plastic debris – known as meso- and microplastics – are pervasive in marine systems. These synthetic particles may transfer contaminants and pathogens to organisms that consume them; as such, meso and microplastics are now considered hazardous, persistent marine pollutants. Sampling an entire system for debris is challenging; therefore, having environmental indicators of plastic debris is critical to assess the status and trends of plastic pollution in addition to predicting ecosystem risk and quantifying potential impacts. The intent of this session was to identify and discuss potential organismal and non-organismal (*e.g.*, sediments) indicators of small synthetic material in the marine environment, including the potential sources and input pathways of small plastic debris (e.g., wastewater effluent) to the North Pacific and its marginal seas with a focus on indirect indicators of plastic pollution, such as plastic additives leading to chemical contamination in organismal tissues. A deeper understanding of these marine debris sentinels will help us elucidate the status

and trends of small plastic pollution and their environmental impacts in the North Pacific and globally, thus allowing us to make informed decisions for plastic usage and litter management policies.

Summary of presentations

Session S7 was introduced by a well-received and attended plenary by Dr. Stephanie Avery-Gomm titled "Past progress and future opportunities: Seabirds as biological monitors of microplastic pollution in the Pacific". Dr. Avery-Gomm's talk was a fantastic introduction to our session in that she discussed the work that had been done establishing Northern Fulmar (*Fulmarus glacialis*) as a bioindicator of plastic in the marine environment in the North Atlantic. These birds are often found stranded on beaches and bycaught as an unintended side effect of fisheries operations. As such, there is a steady stream of fulmars available to be sampled for plastic ingestion. In the ICES region they have determined a target of < 10% of samples fulmars with 0.1g of ingested plastic. Dr. Avery-Gomm provided a compelling argument that we should use the Northern Fulmar to monitor plastic pollution in the North Pacific as well. While the plastic ingestion targets may have to be adjusted for the PICES region, there is value in using the same species as a bioindicator of plastic pollution in both the North Atlantic and North Pacific.

Our main topic session began with an invited talk from Professor Daoji Li from East China Normal University with his talk titled "Main Advances in Marine Microplastics Research in China". This ptesentation was an excellent overview of microplastic research coming out of Professor Li's group, and out of the Western North Pacific region more broadly. Several of the projects that he spoke about included the abiotic fate of microplastics, a reassessment of the role of major Chinese rivers (*e.g*., the Yangtze) to ocean plastic pollution, as well as microplastic in marine food webs. It was interesting to learn that a paper came out of their group (Liu *et al*., 2019, *Marine Pollution Bulletin*) that described a method for sampling plastic *in situ* throughout the water column, similar to the study presented by Kyle Van Houtan later in the session.

Professor Wonjoon Shim (Korea Institute of Ocean Science and Technology) then presented a talk titled "Fast fragmentation rate of secondary nano- and microplastics from foamed polystyrene by sunlight exposure". In their study the researchers experimentally exposed expanded polystyrene (EPS) to seawater and sunlight over the course of 2–8 months and quantified the release of micro- and nanoplastics. They found more micro- and nanoplastics released over time with higher release rates with higher levels of irradiance. In some cases, they report the release of billions of micro- and nanoplastics from their experimental EPS. Next steps would be to try a similar experiment in a more natural (*i.e*., non-laboratory) setting.

Nicholas Vanderzyl (University of Hawai'i) presented his undergraduate research on "Microplastic accumulation patterns in sand at three Hawaiian beaches". He collected surface sand samples from three different beaches on the big island of Hawaii, from the high berm down to the low tide line. More plastic was found higher up on the beach, likely to plastic getting washed away and recirculated in the intertidal lower on the beach near the water. One of his beaches was newly created by the recent volcanic event at Kilauea, where he found the fewest microplastics. He is still waiting on FTIR to confirm the identity of putative microplastics.

For the last talk before lunch, we had Dr. Peter Ross from Ocean Wise give a talk titled "Microplastic pathways into the ocean: Lessons learned from Vancouver, Canada". This was an overview of a large body of research being spearheaded by Dr. Ross in the Vancouver area, in an effort to create a microplastic budget from land to sea. He discussed the rigorous determination of microplastic saying that every particle and fiber that has not been confirmed to be synthetic in nature by spectroscopy should be called a "suspected microplastic". In addition to talking about standardization and QA/QC methods his research group was advocating, he also provided information on the public-facing campaign that Ocean Wise and the Vancouver

Aquarium are coordinating to raise awareness about this issue locally.

After lunch we heard from Dorothy Horn on her doctoral research on "Impacts of environmentally-relevant concentrations of polypropylene rope on Pacific mole crab (*Emerita analoga*) development and lifespan" at Portland State University. Her thorough talk correlated the concentration of microplastics found in beach sand to microplastics found in mole crabs. She then reported results of a lab experiment demonstrating that the ingestion of microplastics by mole crabs had negative effects on crab behavior and physiology.

Chief Scientist at the Monterey Bay Aquarium, Dr. Kyle Van Houtan presented on "The vertical distribution and biological transport of marine microplastics across the epipelagic and mesopelagic water column," based on a study published earlier this year in *Scientific Reports*, and led by Dr. Anela Choy (now an assistant professor at UC San Diego) who reported the vertical distribution of microplastic from 5–1000 m depth in Monterey Bay, California. Surprisingly, plastic concentrations were highest in the midwater column, from 200–600 m depth. In addition, they found more plastics at their offshore, as compared to their nearshore, site. Using Raman Spectroscopy, they determined that PET, likely originating from single-use items such as disposable water bottles, was the most common plastic type found in their samples.

Graduate student Rhiannon Moore (Simon Fraser University) presented on her research "Microplastics in pelagic food webs: initial insights from a study on microplastic contamination in the Beaufort Sea beluga whales and its prey". Working with Ocean Wise, she collected samples of fish and beluga whale gastrointestinal material from the Canadian Arctic to examine for microplastics. Microplastics were found in every beluga whale sampled (n = 7) with an average of 102 plastic particles per whale. Fiber was the dominant microplastic type in fish, but particles were more common in whales.

Dr. Jennifer Lynch (Center for Marine Debris Research at Hawaii Pacific University) spoke about sea turtles as indicators of plastic marine debris quantities and types in the Central Pacific, giving an overview of plastic ingestion patterns in this taxon. Dr. Lynch mentioned the importance of standardizing methods to make studies comparable across regions and over time. In addition, zeros are valuable data points that we need to be recording and reporting. One overall trend in turtles she noted was that pelagic post-hatching turtles have more plastic ingested on average than older pelagic juvenile turtles and neritic adult turtles.

Dr. David Hyrenbach **(**Center for Marine Debris Research at Hawaii Pacific University) gave a talk titled "BIOPs: Towards seabird bioindicators of North Pacific plastic pollution". He gave us an overview on the plastic ingestion research his group has been conducting on the seabirds of the central North Pacific. Certain seabird species, like the Tristram's Storm-Petrel (*Oceanodroma tristrami*) and the Bonin Petrel (*Pterodroma hypoleuca*) are, despite being less charismatic than the North Pacific Albatrosses, still heavily affected by the ingestion of plastic debris. Certain species, like the Bonin Petrel, may be especially useful because they breed in the winter season, unlike other Hawaiian seabirds, and can help us track marine plastic during that time of the year when other commonly sampled shorebirds (*e.g.*, albatrosses) are not available to be sampled.

Professor Taewon Kim of Inha University reported on his research titled "The feeding preference for the color of plastic debris in the hawksbill turtle, *Eretmochelys imbricata*". He performed behavioral experiments on the turtles and found that they prefer yellow plastic over white or black plastic. Now he is working on a project to explicitly test the "jellyfish hypothesis," where he will present captive turtles with jellyfish and plastic bags to see which they prefer to feed on. This experiment will use olfactory, in addition to visual, cues.

Dr. Sang Hee Hong (Korea Institute of Ocean Science and Technology and University of Science and Technology) looked at quantities and characteristics of plastic debris ingested by sea turtles in the Korean

coastal waters. She reported results on 35 turtles of 4 species collected in Korean waters and reported that plastic ingestion trends differ by species, age of turtle, and region of Korea where the turtle was collected. These studies can be compared to turtles sampled in other regions of the North Pacific.

Dr. Miran Kim (Korea National Park Research Institute) reported on microplastic ingestion by seabirds in South Korea. She sampled 11 species of seabirds around the Korean Peninsula and found 5 of them to have ingested microplastic debris; however, only 5% of the 192 individuals sampled contained microplastic. Birds from the Yellow Sea region ingested microplastics most commonly.

Dr. Yutaka Watanuki from Hokkaido University discussed ingestion of plastics by seabirds and its potential effects. This ambitious study experimentally fed plastics to shearwaters in Japan and found higher concentrations of flame retardants and UV stabilizers in the bird's liver tissues if the individuals had been experimentally fed plastics. These causative studies are needed to provide direct evidence of harm from plastics to marine wildlife.

The talks in session S7 were concluded by NOAA's Peter Murphy who introduced "AMAP's Microplastics and Marine Litter Expert Group". The efforts being led by the nations bordering the Arctic Ocean were discussed as was the general structure of the Arctic Monitoring Action Plan. He concluded with a brief discussion of how PICES could be plugged into these efforts, as several of the PICES countries – Russia, Canada, United States – border the Arctic.

In summary, our session was well attended throughout, with no fewer than 30 people in attendance at all times. There was a lot of engagement with the speakers with questions ad discussions during lunch and coffee breaks. We had excellent representation of the PICES member countries in our session (though the only presentation from a Russian scientist was withdrawn in the days leading up to the meeting). We plan to continue the momentum from this session at the next PICES meeting in Qingdao, China, with a topic session titled "Using environmental indicators to assess baselines, targets, and risk of plastic pollution in the North Pacific".

List of papers

Oral presentations

Past progress and future opportunities: Seabirds as biological monitors of microplastic pollution in the Pacific (Plenary)
Stephanie Avery-Gomm

Main advances in marine microplastics research in China (Invited)
Daoji Li

Fast fragmentation rate of secondary nano- and microplastics from foamed polystyrene by sunlight exposure
Young Kyoung Song, Won Joon Shim, Sang Hee Hong, Soeun Eo

Microplastic accumulation patterns in sand at three Hawaiian beaches
Nicolas Vanderzyl, Steven Colbert and Tracy Wiegner

Microplastic pathways into the ocean: Lessons learned from Vancouver, Canada
Peter S. Ross, Katerina Vassilenko, Mathew Watkins, Stephanie Wang and Anna Posacka

Impacts of environmentally-relevant concentrations of polypropylene rope on Pacific mole crab (*Emerita analoga*) development and lifespan
Dorothy Horn, Elise Granek and Clare Steele

The vertical distribution and biological transport of marine microplastics across the epipelagic and mesopelagic water column
C. Anela Choy, Bruce H. Robison, Tyler O. Gagne, Benjamin Erwin, Evan Firl, Rolf U. Halden, J. Andrew Hamilton, Kakani Katija, Susan E. Lisin, Charles Rolsky, and Kyle S. Van Houtan

Microplastics in pelagic food webs: initial insights from a study on microplastic contamination in the Beaufort Sea beluga whales and its prey
Rhiannon Moore, Peter Ross, Leah Bendell, and Lisa Loseto

Sea turtles as indicators of plastic marine debris quantities and types in the Central Pacific
Jennifer M. Lynch, Melissa R. Jung, George H. Balazs, Thierry M. Work, Shandell Brunson, Alexander Gaos, and T. Todd Jones

BIOPs: Towards seabird bioindicators of North Pacific plastic pollution
K. David Hyrenbach, Lauren Chamberlain, Michelle Hester, Paula Hartzell, Meg Duhr, Jenn Lynch

The feeding preference for the color of plastic debris in the hawksbill turtle, *Eretmochelys imbricate*
Taewon Kim, Seonmyeong Choo, Jibin Im, Soojin Jang

Quantities and characteristics of plastic debris ingested by sea turtles in the Korean coastal waters
Yelim Moon, Sang Hee Hong, Gi Myung Han, Won Joon Shim, Youna Cho, Mi Jang, Il-Hun Kim and Min-Seop Kim

Microplastic ingestion by seabirds in South Korea
Miran Kim, Mijin Hong, Hee Young Kim, Sang-moon Cho, Ki-Baek Nam, Ha-na Yoo, A-hyeon Lim and Youngsoo Kwon

Ingestion of plastics by seabirds and its potential effects
Yutaka Watanuki, Naya Sena, Kosuke Tanaka, Rei Yamashita, Mami Kazama, Ken Yoda, Hideshige Takada

AMAP's Microplastics and Marine Litter Expert Group
Peter Murphy

Poster presentations

Introduction of convergence cluster for human and environmental safety research of (nano)microplastics in Korea
Yunwi Heo and June-Woo Park

Review of microplastic pollutions in captured and cultured seafood in China
Zuhao Zhu, Haibo Huang, Qiufeng Zhang and Jie Chen

Microplastic pollution in the Vancouver urban watershed: the role of Combined Sewer Overflows (CSOs)
Amir H. Parizi, Ryan Ziels, Stephanie Wang, Farida Bishay, Peter S. Ross, and Anna Posacka

Tackling microfiber pollution at source: an evaluation of washing-machine lint filters
Mathew J. Watkins, Katerina Vasilenko, José Gutiérrez-García, Farida Bishay, Peter Ross and Anna Posacka

FIS/BIO/POC Topic Session (S8)
Creating more effective Integrated Ecosystem Assessments (IEAs) in PICES countries

Co-sponsor: *ICES*

Convenors: *Alan Haynie (USA), Libby Logerwell (USA), Shigeto Nishino (Japan)*

Invited Speaker:
Phillip Levin (University of Washington, USA)

Background

Integrated Ecosystem Assessments (IEAs) are an adaptable approach to capture, understand, and communicate the diversity of interactions, ecosystem objectives, and resource trade-offs that occur within an ecosystem. While a core element of IEAs is the characterization of the natural ecosystem, humans are increasingly recognized as being central actors in most ecosystems, rather than an outside agent impacting the ecosystem. In this session, we are interested in elements of IEAs that capture how changes in the natural environment are being measured and the manner in which human activities are being incorporated into IEAs. IEAs have been implemented in a diversity of ecosystems in many PICES and ICES countries. In the United States, for

example, IEAs are an important tool through which NOAA describes ecosystem trends and communicates the trade-offs of using marine resources for fisheries versus other uses. ICES, PICES and PAME have also recently worked to develop an IEA of the Central Arctic Ocean (WG 39). In addition, PICES scientists working in PAME have drafted practical guidelines for implementing the Ecosystem Approach across LMEs in the Arctic. Members and chairs of several ICES and PICES working groups are also active in IEA implementation. The goals of this session were to 1) describe developments in IEAs across PICES countries and beyond, 2) identify opportunities to better integrate social and natural science in IEAs and communicate this with PICES scientists, and 3) discuss future directions for developing and comparing IEAs across PICES countries and LMEs, with the aim of building a foundation for further discussions at the MSEAS-2020 meeting in Yokohama. The goal of the session was to provide a roadmap for how social and natural scientists can more effectively work together in IEAs and in interdisciplinary projects in general. We concluded the session with a discussion of next steps for IEA research in PICES countries.

Summary of presentations

On behalf of the co-conveners, Alan Haynie offered comments about the goals and scope of the topic session; and introduced the invited speaker, Dr. Phillip Levin. There were ten oral presentations, two of which were given by early career scientists; there was one poster. Presenters were from the US, China and Japan. Approximately 25 people attended and there was active participation and lively discussion involving all.

Dr. Phillip Levin presented a summary of Integrated Ecosystem Assessment (IEA) from idea to implementation. He presented the challenge of answering the question “Is the ocean healthy?”. He stressed that ocean ecosystems provide a large number of goods and services; that these services interact, often in ways we don’t understand; and that people place different values on different services. A quote from E.O. Wilson provided a good perspective on IEAs: “The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely.” Dr. Levin suggested that IEAs can answer four key questions: What is our vision of a healthy ocean? Is the ocean healthy? What can we do? Where should we start? The strengths of IEAs are that they: emphasize interactions among ecosystem components; consider humans as an integral part of the ecosystem; integrate ecological, social, economic, and institutional perspectives; and recognize their strong interdependences. A review of scientific literature on IEAs shows that IEAs have been conducted mostly in the US, Canada, Central American, Europe and Asia. He then presented the results of semi-structured interviews to answer the question “How are IEAs doing?”. Some interviewees felt that IEAs were often too fisheries focused. Others pointed out the successes of IEAs, for example “The most recent reports are vital in having a starting point for management …it is probably the closest thing to facts we have out there. (State Fisheries Manager)”. Operational objectives were regarded as an ongoing challenge: “IEAs are a powerful tool but without a clear statement of goals and objectives, and a clear vision, it is just cool science (Stakeholder).” In fact, a global review of Ecosystem Based Management plans showed that 65% lack operational objectives with specific targets. Dr. Levin presented an interesting example of a project merging science and indigenous knowledge, concerning herring and the Haida Gwaii people. Chief Gidansta told scientists that “once herring lost the elders, they lost their way to their spawning grounds”. Scientific models comparing diffuse migration and learned migration arrived at the same conclusion. He concluded his excellent presentation by showing that where people, the planet and profit overlap is where sustainability resides.

Dr. Elliot Hazen presented a talk on behalf of Dr. Chris Harvey and Dr. Tobey Garfield on the California Current Integrated Ecosystem Assessment. He began his presentation with a thorough overview of the evolution of the NOAA IEA Program. He then described the recent Pacific Fisheries Management Council (PFMC) Climate and Communities Initiative which began in 2017. This initiative addresses an emerging

ecosystem goal: fishing communities that are resilient to species distribution shifts, climate variability and climate change. Dr. Hazen presented a partial list of what they have learned regarding the IEA process. For example, IEA is more a *process* than a *product*; we don't have to study *everything* in the ecosystem to do IEA (scale an IEA to a specific need); relationship building in good times is helpful during bad times; implementation of IEA science into management is slow. He also presented ideas about building a sustainable IEA program: support of leadership is essential for long-term sustainability; funds will always be limiting, so we must create opportunities; we need greater permanent investment in social sciences; we must develop diverse tools and products that can reach diverse audiences.

Dr. Takafumi Hirata presented the results of a project to develop a vulnerability index for Arctic marine ecosystems, considering Planetary Boundary processes as an essential environmental forcing. Exposure to environmental forcing was derived from Principal Component Analysis among Planetary Boundary Processes (PBP). Sensitivity/susceptibility of marine ecosystem to forcing was based on the strength of correlation between ecosystem variable(s) and environmental forcing. Resilience of marine ecosystems to forcing was based on Principal Component Analysis among ecosystem indicators (biodiversity and primary production). Finally, the potential vulnerability of the system was calculated as an index aggregating all of the effects above. Dr. Hirata's results showed that from a global perspective, the Arctic Ocean is likely one of the oceans most influenced by ocean-relevant Planetary Boundary processes. From a regional perspective, the ice edge and the Canadian Archipelago ecosystems are potentially most vulnerable.

Dr. Kirstin Holsman presented on behalf of Dr. Kerim Aydin and Diana Evans on the Bering Sea Fishery Ecosystem Plan (FEP). The Bering Sea FEP was developed by the North Pacific Fishery Management Council to: serve as a communication tool for ecosystem science and Council policy; create a transparent public process for the Council to identify ecosystem values and management responses; provide a framework for strategic planning that would guide and prioritize research, modeling, and survey needs; identify connected Bering Sea ecosystem components, and their importance for specific management questions; assess Council management with respect to ecosystem-based fishery management best practices, and identify areas of success and gaps indicating areas for improvement on a regular basis; provide a framework for considering policy options and associated opportunities, risks, and tradeoffs affecting FMP species and the broader Bering Sea ecosystem; and build resiliency of Council management strategies, and options for responding to changing circumstances. She stressed that the FEP facilitates co-production of knowledge. It aims to define Local Knowledge and Traditional Knowledge clearly in order to facilitate co-production of knowledge while protecting intellectual property as per the UN Declaration on the Rights of Indigenous Peoples (Articles 11.2, 31). The FEP has six ecosystem goals: maintain, rebuild, and restore fish stocks at levels sufficient to protect, maintain, and restore food web structure and function; protect, restore, and maintain the ecological processes, trophic levels, diversity, and overall productive capacity of the system; conserve habitats for fish and other wildlife; provide for subsistence, commercial, recreational, and non-consumptive uses of the marine environment; avoid irreversible or long-term adverse effects on fishery resources and the marine environment; provide a legacy of healthy ecosystems for future generations. Each of the ecosystem goals has a number of ecosystem objectives which serve as a bridge between ecosystem goals and ecosystem indicators for monitoring. She described two Action Module Work Plans: Evaluate effects of climate change and develop management considerations; and Develop protocols for Local Knowledge, Traditional Knowledge, and Subsistence. For outreach, NPFMC staff have developed story maps of FEP components, located on the BS FEP website https://www.npfmc.org/bsfep/.

Dr. Changun Xu gave a talk on implementation of Ecosystem-Based Management for net cage farming in Sandu bay Fujian China. This project took place in Sandu Bay, Ningde city, Fujian Province, China. Sandun Bay provides numerous ecosystem services, including: Large Yellow Croaker Habitat Reserve (MPA); algae

farming; sailing/navigation channel; tourism and sightseeing; sewage discharge; and recently, net cage farming. Net cage farming has caused conflict between stakeholders because of disorderly expansion of cage farming and the lack of management. However, as a result of stakeholder meetings, policy makers, resource managers and scientists reached a consensus to incorporate ecosystem-based language into management plans. Dr. Xu and colleagues developed a Human Impact Matrix (HIM) where each cell represents the effect of a specific human activity on a specific ecosystem service. They then developed a qualitative scoring system to evaluate how strongly one human activity impacts ecosystem services.

Dr. Mariska Weijerman gave a talk on "Evaluating Management Strategies for Ecosystem Services in a Hawaiian Islands Coral Reef IEA". Coral reefs are vulnerable to local population growth, wastewater management, fishing and coral bleaching. Ecosystem services provided by coral reefs include a resilient, productive reef, recreational uses (such as diving and snorkeling) and fishing (recreational and subsistence). She used the Ecopath with Ecosim (EwE) modeling framework to evaluate the performance of six management scenarios over the next 15 years. Based on the modeling results she created a decision support matrix for assessing the efficacy of each management scenario. Her results show that ecosystem models in IEAs make it possible to integrate natural and social science, take climate change impacts to the ecosystem into consideration, and evaluate socio-ecological tradeoffs of alternative management scenarios.

Dr. Robert Wildermuth presented his work on a Bayesian decision network model for ecosystem-based management of the Georges Bank social-ecological system. He explained how social-ecological models can assess multiple management objectives, account for multiple interactions and components, and integrate various sources of knowledge and information. He noted that they rely on data availability and an understanding of relationships. He developed a conceptual model of the Georges Bank social-ecological system which provided a framework. He then employed a Bayesian network to build on the framework. Bayesian networks are useful for this application because they reflect uncertainty in interaction strengths and functional form. They also allow prediction of the effects of management actions. Dr. Wildermuth presented the results of the Georges Bank *Wellamo* model (named after a Finnish legend). Take-home messages from initial model results are: there was additional correlation between Recreational Fishing and Profits; overall, ~70% of observed data predicted accurately; these may be driven by autocorrelation in the time series; and there were unexpected outcomes for Seafloor and Demersal Habitat in tested scenarios.

Dr. Marisol García-Reyes described a interesting new tool for cloud computing of key NASA oceanographic data: the PICES Regional Ecosystem Tool. This can be accessed from a web browser https://github.com/python4oceanography/PICES-tools (Click on the button to load the 'binder' with the PICES RET). Dr. García-Reyes gave a real-time demo of the tool, showing how the user can download satellite data (SST) for a PICES region over a specified period of time. The tool gives the user a time series graph of anomalies and a text file containing the data. The tool can be used to compare among regions, or compare among data (such as current, temperature and chlorophyll). All in attendance thought it was a really cool tool!

Dr. Gordon Kruse presented on behalf of lead author Dr. Judith Rosellon-Druker. Their presentation was on developing a placed-based participatory IEA framework for coastal communities in the Gulf of Alaska. Dr. Kruse reported on their place-based IEA case study in Sitka, Alaska, which is located in the eastern Gulf of Alaska. Conceptual models are an essential part of the IEA process, and so conceptual models were developed for the main species in the ecosystem. The conceptual models were developed with stakeholders in Sitka in focus group workshops. One workshop explored ecological connections, discussing environmental variables, prey, predators and competitors and knowledge gaps. A second workshop covered human dimensions, in particular residents' capacity to derive well-being from fisheries. The research team then developed Qualitative Network Models (QNM) to operationalize the conceptual models. The QNMs can be used to simulate the

effect of press perturbations and show which linkages are most important for the species and life stage of concern, such as small adult herring. In summary, Dr. Kruse and colleagues found that Sitka stakeholders have a deep understanding of their local ecosystem, and their participation in the IEA process resulted in an informed and empowered community in relation to their local ecosystem and resources. Their long-term goal is to incorporate socio-ecological distinctive regions of the Gulf of Alaska into one unifying IEA framework.

Dr. Kelly Andrews spoke about "Human activity indicators - management levers that translate between ecological and human dimension components". He first described the conceptual model for the California Current IEA and asked how the various human activities affected all the components of the ecosystem. He described the different human activities and showed time trends, from the State of the California Ecosystem report. Despite the conceptual linkages, initial analyses showed no relationships or thresholds between human activities and ecosystem indicators. This is probably the result of the large, coast-wide scale at which the analyses were conducted. Smaller scale, spatially-matched analyses may be more informative. Dr. Andrews closed with an interesting example of potential positive effects of human activity on the ecosystem. For example, fishing club members do remove fish, but they also invite speakers to their club meetings who may inform them about ecological ideas such as the impact of fishing on long-lived rockfish. The result can be that those individuals promote the use of conservation measures to reduce mortality of fish, such as fish descending devices. Dr. Andrews' take home points were: indicators of human activities could provide "early warnings" of activities to monitor; most useful if human activity data is at comparable spatial and temporal scales to ecological and human dimension data; human activity and human dimension indicators should continue to be developed for missing links among nodes of the conceptual model; and "positive" indicators of human activities may provide information on the importance of these activities to conservation and management.

Session participants returned after coffee for open discussion. Dr. Libby Logerwell told the group about the new Working Group proposed to conduct an IEA of the Northern Bering-Chukchi Sea and welcomed input, feedback and participation. The group discussed the challenge of incorporating local, traditional and indigenous knowledge in a large area such as Alaska where communities are numerous and remotely located. The group then discussed whether there were web-based abilities for stakeholders to explore conceptual models, which would help develop objectives. It was mentioned that NOAA NEFSC is developing such tools for their Ecosystem Assessments.

A participant asked the question "Is the management system ready to deal with climate change?" The work of AFSC's ACLIM project was put forth as an example. One step is to define the management questions.

Another topic of discussion was the size and complexity of IEA reports. They can be overwhelming for stakeholders. One solution could be a shiny app, such as one that is being developed to explore data in AFSC Ecosystem Considerations reports. The Center in Hawaii is considering doing the same.

List of papers

Oral presentations

Connecting science and communities through Integrated Ecosystem Assessments (Invited)
Phillip S. Levin

A brief history of the California Current Integrated Ecosystem Assessment: How we got here, what we've learned, and where we're headed
Chris J. Harvey (presented by Elliott Hazen) andToby Garfield

Potential vulnerability of the Arctic marine ecosystem due to environmental changes
Takafumi Hirata, Yoshio Masuda, Jorge García Molinos, Irene Alabia, Toru Hirawake, Sei-Ichi Saitoh

The Bering Sea Fishery Ecosystem Plan as a guidance tool for ecosystem-based fishery management in Alaska
Kerim Aydin (presented by Kirstin Holsman) and Diana Evans

Implementation of "ecosystem-based management" for net cage farming in Sandu bay Fujian China. an approach towards ecologically sustainable form of development
Changan Xu, Peng Wu, Shixin Huang and Xu Tang

Evaluating management strategies for ecosystem services in a Hawaiian Islands coral reef IEA
Mariska Weijerman, Jeffrey Polovina, Jamison Gove, Ivor Williams, William Walsh and Dwayne Minton

A Bayesian decision network model for ecosystem-based management of the Georges Bank social-ecological system
Robert P. Wildermuth, Gavin Fay, Sarah Gaichas and Geret DePiper

Cloud computing of key NASA oceanographic data: Implications for automating aspects of ecosystem status reports
Marisol García-Reyes, Chelle Gentemann and William Sydeman

Developing a placed-based participatory IEA framework for coastal communities in the Gulf of Alaska
Judith Rosellon-Druker, Kerim Y. Aydin, Curry J. Cunningham, Stephen Kasperski, Gordon H. Kruse, Jamal H. Moss, Melissa Rhodes-Reese, Ellen Spooner, Marysia Szymkowiak and Ellen M. Yasumiishi

Human activities - developing indicators that can translate costs and benefits across the human dimension and ecological domains of the socio-ecological system
Kelly S. Andrews, Karma C. Norman and Chris J. Harvey

Poster presentations

Sea ice reduction in the Arctic Ocean: its impact on biogeochemical cycles
Naomi Harada, Jonaotaro Onodera, Eiji Watanabe and Katsunori Kimoto

MONITOR Topic Session (S9)
Coastal Ocean Observing Systems, Essential Biological Variables and community-based monitoring

Convenors: *Charles Hannah (Canada), Sung Yong Kim (Korea), Kim Juniper (Canada)*

Invited Speakers:
Sanae Chiba (Japan Agency for Marine-Earth Science and Technology (JAMSTEC))
Eric Peterson (Hakai Institute, BC, Canada)

Background

The goals of FUTURE require systematic and sustained observations of marine ecosystems, especially in the coastal regions where the interactions between humans and the marine environment are most intense. The goals also require the integration of physical, chemical and biological state of the ocean. The Advisory Panel on North Pacific Coastal Ocean Observing Systems is responsible for advising PICES on the linkages between coastal ocean observing systems and the PICES FUTURE Science Program, and the North Pacific Ecosystem Status Report. A Science Session was convened to assess the current state of coastal ocean observing systems in the North Pacific Ocean with respect to the biological and ecosystem Essential Ocean Variables (eEOVs) recently developed by the Global Ocean Observing System (Miloslavich *et al*. 2018 DOI: 10.1111/gcb.14108), and to evaluate the potential for expanding the inclusion of eEOVs in coastal ocean observing in the North Pacific. The session provided a basis for identifying gaps in observing systems relative to FUTURE's goals of providing a synthesis of knowledge on: a) ecosystem resilience and vulnerability; b) ecosystems response to natural and anthropogenic forcing; and c) future ecosystem change. Contributions were invited from researchers, community based monitoring programs, and data managers that would address the questions: 1) which eEOVs should be measured; 2) does the technology exist to make the required measurements in a systematic fashion; 3) how do we integrate eEOVs into current and future coastal ocean observing programs?

Summary of presentations

The subject of this session is central to the theme of PICES 2019, 'Connecting Science and Communities in a Changing North Pacific'. Coastal Ocean Observing Systems (COOS) are the mechanism by which data and information will be delivered to the scientists and the broader community. To achieve the goal of connecting science to communities the systems must operate under the FAIR Principle of data management (Findability, Accessibility, Interoperability, and Reusability). Canada is in the process of developing an integrated coastal ocean observing system and this session should inform that development process.

A crucial issue is which data and observations should be collected and distributed through these systems. The Global Ocean Observing System (GOOS) has convened 3 expert panels to define the Essential Ocean Variables (EOVs):

- Physics and Climate
- Biogeochemistry
- Biology and Ecosystems

The expert group reports provide a framework for discussion about which variables should be collected and then distributed. One extremely valuable part of the panel reports is the discussion of what technology is available to observe each variable and how mature that technology is. This information is an essential part of any discussion of which variables to observe. The Biology and Ecosystems panel reported a year ago (Miloslavich *et al*. 2018 DOI: 10.1111/gcb.14108) and one of the goals of this theme session was to expose the PICES community to the material.

An important component of the process to decide what needs to be observed is captured by the phrase 'Observations to address societal needs' in Fig. 1 of Miloslavich *et al*. (2018). These needs inform the prioritization process that determines what gets observed. As such a key issue is, 'Who is in the room when decisions get made?' One talk made the point that government agencies tend to remove the human component from consideration and often limit discussion and options due to limits on agency mandates. On the other hand, BC First Nations tend to take a more holistic view and consider that discussions about marine ecosystems should include the coastal lands and people as part of the system.

Many of the variables that are important to communities will fall into the category of Biology and Ecosystems and will vary between communities. The diversity of the required observation and their intensely local scale will mean that community monitoring will play an essential role in observing many of the EOVs. Community monitoring may actually be essential to monitoring to support cumulative effects assessment. Overall, the collection, management, dissemination, and analysis of the suite of essential ocean variables will require the participation of all the players – governments, academia, NGOs and communities.

There were some common themes from the presentations on community monitoring. Successful programs have:

- Strong and consistent program management to keep the program on track, ensure quality control, build partnerships, and identify opportunities to do cool things;
- Community engagement in the planning of what to measure and the development of the implementation plan;
- The results of the community monitoring are regularly communicated back to the community;
- Strong connections to experts to help with data management, quality control, and training;
- Appropriate use of modern technology (cell phones, tablets, apps) to simplify processes.

It was also clear that well managed and well-resourced community monitoring programs can achieve surprisingly complete spatial and temporal coverage.

There is constant progress in technology that continues to expand the range of what Essential Ocean Variables can be measured on a routine basis. As such an observing system must be constantly surveying the field to see what should be added to the suite of observed system components. For example:

- Measurements of the components of the ocean carbon system used to required constant attention from experts. Now one can see the day coming when reliable measurements could be made by a community monitoring group (with suitable training and commitment).
- The use of passive acoustics combined with 'acoustic cameras' is being explored to observe and identify fish. This may eventually lead to systems for monitoring fish species abundance in the near-shore zones.
- It is now possible to detect acoustically tagged fish (in this case sturgeon and salmon) on the continental shelf with a hydrophone mounted on a glider and collect the relevant environmental data to define habitat at the same time.
- It is now possible to measure profiles of nitrate and turbulence simultaneously and thus provide direct estimates of the vertical flux of nutrients.
- Cell phones and tablets apps are being used to simplifying the process of data collection and data management in community monitoring programs.
- The ability to detect and quantify macro algae, in particular kelp, from satellites is improving and these observations will likely be available for operational application in a few years.
- The combination of physical forecast models and artificial intelligence methods can expand the range of what is possible. One presentation showed a system that provides daily forecast of the likelihood of success that day for a several coastal fisheries.

The session was very well attended with 60 people in the morning session and 25–40 during the afternoon.

List of papers

Oral presentations

The Hakai Institute: Supporting community-based science in British Columbia with global frameworks for biological Essential Ocean Variables (EOVs) (Invited)
Eric Peterson, Ray Brunsting, Luba Reshitnyk, Rebecca Martone, Markus Thompson and Margot Hessing-Lewis

Essential Ocean Variables for Biology and Ecosystem to inform policy in the Decade of Ocean Science for Sustainable Development (Invited)
Sanae Chiba, Patricia Miloslavich, Nic Bax, Daniel Dunn and members of the GOOS Biology and Ecosystems Panel

Developing a biological Global Ocean Observing System: Qualities, attributes, and readiness of existing biological Essential Ocean Variable networks
Erin V. Satterthwaite, Patricia Miloslavich, Nic Bax, Daniel Dunn and members of the GOOS Biology and Ecosystems Panel and PEGASuS project

Incorporating multiple community perspectives in development of essential ocean variables for monitoring port ecosystems
Paul A. Covert, James P. Mortimor, Spencer Taft, John Konovsky, Natasha Salter and Janet Mossman

Compilation of essential ocean variables for British Columbia based on nine decades of observations from disparate databases: Biogeochemical regionalization, variability and trends
Andrew R. Margolin, Brian P.V. Hunt, Stephanie Waterman and Jennifer M. Jackson

Development of information service for set net fisheries using satellite and numerical data
Sei-Ichi Saitoh, Takashi Hosokawa and Fumihiro Takahashi

Experience in developing and operating a marine Citizen Science Program in the Strait of Georgia, Canada
Isobel Pearsall, Terry Curran, Svetlana Esenkulova, Rich Pawlowicz, Ryan Flagg and Colin Novak

Establishing a long-term marine monitoring program for Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site
Lynn Lee and Chantal Vis

Community-based monitoring to support cumulative effects assessment in coastal BC
Rebecca G. Martone, Quinton Ball, Kyle Clifton, Maria Faria, James Herbert, Heather Johnston, Melissa Lucchetta, Kim Lutz, Maya Paul, Janine Pittman, James Prsala, Carmen Tattersfield and Nicole Wallace

Identifying forage fish beach spawning habitat in British Columbia – "To conserve and protect"
Jacklyn Barrs and Haley Tomlin

Using an underwater glider to detect acoustically-tagged green sturgeon
John A. Barth, Mary Moser, Steve Corbett, Daniel Erickson, Stephen D. Pierce and Anatoli Erofeev

Identifying fish sounds of British Columbia with an autonomous audio and video array
Xavier Mouy, Morgan Black, Kieran Cox, Jessica Qualley, Francis Juanes and Stan Dosso

Estimation of the biodiversity of fish and invertebrates using video and acoustics
Xavier Muoy, Fabio Fabio Cabrera De Leo, Stan Dosso and Francis Juanes

Development and observational examples of measuring vertical turbulent nitrate flux using sensors
Daisuke Hasegawa, Takahiro Tanaka, Takeshi Matsuno, Tomoharu Senjyu, Eisuke Tsutsumi, Hirohiko Nakamura, Ayako Nishina, Toru Kobari, Naoki Yoshie, Xinyu Guo, Takeyoshi Nagai, Takeshi Okunishi and Ichiro Yasuda

High-resolution carbonate dynamics of Netarts Bay, OR from 2014-2019
William M. Fairchild and Burke Hales

Tracer relationships in surface waters of coastal waters from the Gulf of Alaska, Bering and Chukchi Seas
Burke Hales, Laurie Juranek, William Fairchild, Selina Lambert, Carrie Weekes, and Katie Pocock

Poster presentations

Statistical analysis of seasonal water pollutants affecting phytoplankton proliferation on the South Korean coasts
Young-Sug Kim, Tae-Young Heo, Jung-No Kwon

Estimation of temperature of seaweed bed vegetation boundary in the Bungo Channel of the Western Seto Inland Sea using satellite SST
Anri Kabe, Naoki Yoshie, Hiromori Shimabukuro and Goro Yoshida

Sensitivity analysis on zooplankton bioregionalization of British Columbia
Patrick Pata, Ian Perry, Brian P. V. Hunt, Moira Galbraith, and Kelly Young

Coastal monitoring using Ocean Observation Camera (OOC) on Micro Satellite RISESAT
Sei-Ichi Saitoh, Takafumi Hirata, Irene Alabia, Toru Hirawake, Jun-Ichi Kurihara, Yukihiro Takahashi, Yuju Sakamoto, Toshinori Kuwahara, Shinya Fujita, Hanyu Kosuke, Yu Murata, Moroskot Sakal, Hannah Tomio, Yuji Sato, Ming-An Lee, Kan-ichiro Mochizuki, Fumihiro Takahashi, and Hiroshi Murakami

Developing a community-based coastal environmental monitoring system in Indonesia using smartphone app
Shion Takemura, MItsutaku Makino, Shigeharu Kogushi, Naoki Tojo and Mark Wells

Larval fish habitats and deoxygenation in the northern limit of the oxygen minimum zone off Mexico
Laura Sánchez-Velasco, Víctor M. Godínez, Erick D. Ruvalcaba-Aroche, Amaru Márquez-Artavia, Emilio Beier, Eric D. Barton and S. Patricia A. Jiménez-Rosenberg

MEQ Topic Session (S10)
Linking changes in climate, nutrient distribution, phytoplankton ecology, and production of algal exudates in the North Pacific

Convenors: *Andrew Ross (Canada), Sayaka Yasunaka (Japan)*

Invited Speakers:
Jun Nishioka (Hokkaido University, Japan)

Background

The unusual warming of NE Pacific surface waters in 2014 produced intense stratification that inhibited vertical mixing, reducing the availability of major nutrients and essential trace metals to phytoplankton. Significant changes in phytoplankton ecology were also observed during this event. Large and persistent phytoplankton blooms, some of which may be associated with the production of algal biotoxins, are also becoming more frequent in the coastal waters of the eastern North Pacific, raising concerns as to the potential impacts of harmful algal blooms (HABs) and associated biotoxins on marine ecosystems. Some biotoxins (*e.g.*, domoic acid) and other algal exudates (organic ligands) are known to bind trace metals like iron and copper, affecting their availability to phytoplankton. The goal of the session was to bring together scientists from across the North Pacific who are working on related aspects of plankton ecology, marine biogeochemistry and climate research to investigate potential linkages between changes in the distribution of nutrients, phytoplankton, and algal exudates; how these may affect, and be influenced by, primary productivity and climate change; and possible implications for the long-term health of fisheries and ecosystems in coastal waters and the open ocean.

Summary of presentations

Talks submitted for this half-day session were divided into two groups, with those relating primarily to harmful algae scheduled after the morning coffee break. In addition to these 11 talks, 5 posters describing relationships between nutrients and/or phytoplankton and other variables were also submitted to S10 for presentation at PICES-2019.

Talks during the first half of the session provided examples from across the North Pacific of linkages between environmental conditions and the diversity and abundance of marine phytoplankton. Environmental correlates of plankton ecology and productivity include water quality indices (particularly nutrients) in Chinese coastal waters, hydrography in the Bering and Chukchi seas, stratification in the Salish Sea, and the presence of metal-binding organic matter in the subarctic NE Pacific. Nutrients appeared to be an important factor, the (relative) abundance of macronutrients nitrate and phosphate and organic complexation of micronutrient trace metals being linked to phytoplankton biomass and composition. Stratification, driven by sea-ice melt and/or warming sea surface temperatures, was also important in the waters and marginal seas of the sub-arctic and eastern North Pacific, with implications for nutrient availability and marine productivity.

Talks during the second half of the session showed nutrients and temperature to be important factors in the growth and toxicity of harmful algae, which featured in some of the earlier talks as well. For example, *Azadinium* species isolated from Puget Sound tended to be more toxic at higher temperatures whereas the abundance of *Dictyocha* in the Strait of Georgia correlated, to some extent, with stratification and nutrient levels although such relationships were not straightforward. The latter study also illustrated the value of citizen science in making ocean observations. Other discoveries included marine bacterial toxins that kill algae and

the dependence of *Heterosigma* growth and hemolytic activity on exposure to particular wavelengths of light. Both have implications for the potential impacts of harmful algae, and bacteria, on aquaculture and marine ecosystems.

To summarize, factors that can affect the growth, composition and toxicity of phytoplankton include ocean temperature and stratification, the distribution and organic complexation of macro and micronutrients, the wavelength of incident light and, potentially, the presence of algicidal bacteria. The session thus achieved its aim of identifying possible linkages between climate change, nutrients, and associated changes in phytoplankton growth and toxicity in the North Pacific. The number of talks featuring harmful algae also indicates a growing interest in this field, lending support to a proposal from S-HAB for a session focusing on links between harmful algae and climate change at PICES-2020.

List of papers

Oral presentations

Micro- and macro-nutrient supply from the marginal seas to the North Pacific Ocean and its changing (Plenary)
Jun Nishioka, Hajime Obata and Ichiro Yasuda

Long-term monitoring and assessing of the eco-environment health of sea area around Laoshan Mountainin in Qingdao, China
Qiufen Li, Jun Zhao, Jufa Chen, Yan Zhang, Qian Yang, Yong Xu and Keming Qu

Variations in spring and summer phytoplankton communities across water mass gradients in the Chukchi Sea
Lisa B. Eisner, Michael W. Lomas and Jens M. Nielsen

High temporal resolution phytoplankton compositions and environmental drivers in the northern Salish Sea, British Columbia, Canada
Justin A. Del Bel Belluz, Angelica Peña, Jennifer M. Jackson and Nina Nemcek

Evidence for the production of copper-complexing ligands by marine phytoplankton in the Canadian Arctic and subarctic NE Pacific
Andrew R.S. Ross, Richard L. Nixon, Jasper George, David J. Janssen, Sarah L. Jackson, Jay T. Cullen, Kyle G. Simpson and Marie Robert

Long-term changes of nutrient regimes and their ecological effects in Bohai Sea, China
Ming Xin, Baodong Wang and Linping Xie

An algicidal bacteria secreted natural compound induces mortality in the marine phytoplankton
Ruoyu Guo, Ruize Xie and Yongyu Zhang

Linking harmful algal blooms and oceanographic conditions in the Strait of Georgia, Canada
Svetlana Esenkulova, Karyn Suchy, Rich Pawlowicz and Isobel Pearsall

The effect of temperature and salinity on growth rate and azaspiracid cell quotas in two strains of *Azadinium poporum* (Dinophyceae) from Puget Sound, Washington State
Xinfeng Dai, Brian D. Bill, Nicolaus G. Adams, Urban Tillmann, Catherine Sloan, Douding Lu and Vera L. Trainer

Studies on *Prorocentrum* (Dinophyceae) in the coastal water of China
Pengbin Wang, Ruoyu Guo, Xinfeng Dai and Douding Lu

Light triggered the hemolytic toxin production of fish-killing Raphidophyte: *Heterosigma akashiwo*
Robert Jay Nerit Ramos, Channimol Ky, Jingyao Zhang and Mengmeng Tong

Poster presentations

Barrier effect of the Pearl River estuarine plume on wind-induced coastal upwelling of nutrients
Kuo Wang and Kedong Yin

Spatio-temporal variability of surface water pCO_2 and nutrients in the tropical Pacific from 1981 to 2015
Sayaka Yasunaka, Shinya Kouketsu, Peter G. Strutton, Adrienne J. Sutton, Akihiko Murata, Shin-ichiro Nakaoka and Yukihiro Nojiri

Long-term trend of the diatom *Thalassiosira nordenskioeldii* population dynamics from the northwestern Sea of Japan
Mariia A. Shulgina and Olga G. Shevchenko

Optimizing the PCR clean-up method for 18S amplicons generated from phytoplankton samples collected in Bellingham Bay
Tamisha Yazzie, Rachael Mallon and Rachel Arnold

Relationships between the cell size and the primary production for diatoms, haptophytes and cyanobacteria in Japanese waters
Takafumi Hirata and Koji Suzuki

FIS/POC/BIO/HD Topic Session (S11)
Incorporating ecosystem variability and climate change into fisheries management: Progress and challenges for EBFM in the 21st century

Convenors: *Barb Muhling (USA), Carrie Holt (Canada), Kirstin Holsman (USA), Sukyung Kang (Korea), Gerard DiNardo (USA)*

Invited Speaker:
Stephani Zador (NOAA Fisheries, USA)

Background

Physical, biological and social components of marine ecosystems interact in complex ways through space and time, resulting in challenges for natural resource managers. Environmental variability and climate change can drive shifts in the spatial distribution and productivity of target and bycatch species. This can impact the effectiveness of stock assessment and management. Ecosystem-Based Fisheries Management (EBFM) aims to address these issues by including environmental effects, species interactions, and other ecosystem-level processes in the management process for exploited species, in addition to fishing pressure. Ecosystem variables can be considered qualitatively in management advice by providing context about the state of the ecosystem or quantitatively in models that derive management-relevant quantities (*e.g.*, allowable catch). However, despite the theoretical benefits of EBFM, most stock assessments and management measures still use single-species models with no ecosystem information incorporated. In this session, we sought presentations describing how ecosystem variability and climate change have been considered in management advice qualitatively and/or quantitatively, or on how management advice could consider those variables.

Summary of Presentations

The invited speaker was Stephani Zador (NOAA Fisheries, USA), who gave a presentation on "Merging contextual ecosystem advice with single-species stock assessment to inform fisheries managers in times of extreme environmental changes". She described how ecosystem advice is incorporated into the assessment and management of several fish stocks in the Bering Sea and Gulf of Alaska, both through inclusion in assessment models and provision of contextual advice later in the process. Recent developments in the region included the development of species-specific risk tables, to alert managers and industry to unusual trends or events which could impact stock status or catch limits.

Anne Hollowed presented on the NOAA Climate Fisheries Initiative, which is working on determining the climate information needs of natural resource scientists and managers in United States Large Marine Ecosystems. She described the current implementation plan, and future developments, including the planned adoption of MOM6 for regional downscaling efforts.

Szymon Surma (Early Career Scientist) described a Management Strategy Evaluation (MSE) for Pacific herring in the Northeast Pacific, using an ecosystem modeling framework (Ecopath with Ecosim). His results suggested that protected species which feed on herring, such as marine mammals, could benefit most strongly from low allowable catch rates for herring. However, these management actions are predicted to cause frequent closures to the herring fishery, resulting in large economic impacts. The ideal balance between forage fish protection and sustainable herring fisheries was thus difficult to achieve.

Isaac Kaplan presented research testing the performance of different stock assessments from the California Current and Nordic/Barents Sea under climate change conditions, using Atlantis ecosystem models. Stock assessment performance was evaluated by quantifying the bias and precision of derived quantities related to population size, fishing intensity, and depletion, and by evaluating management performance when fishing rates were set based on reference points estimated in the assessments.

Gloria Duran (Early Career Scientist) showed how the catch per unit effort of swordfish on longline gear was influenced by oceanographic features in the Kuroshio Extension system. Her results highlighted the importance of mesoscale eddies, as well as Kuroshio Current instability, in driving spatial distributions of catch rates.

Phoebe Woodworth-Jefcoats presented a number of different ways by which EBFM could be better incorporated into the deep-set longline fishery targeting bigeye tuna in the central and eastern North Pacific. Current management measures can cause a "race to fish", leading to instability in prices and profits for fishers. Alternative management strategies could ameliorate these issues, as well as providing ways to address potential future yield decreases in the region under climate change.

James Smith presented the results of a simulation study, looking at the effects of different spatial closures in the west coast US drift gillnet fishery. Dynamic spatial closures can provide more economic opportunity for fishers than static closures, but can also lead to potentially higher rates of turtle interactions. The low number of turtle observations available for building species distribution models was identified as a key uncertainty in the study.

Yan-Lun Wu described how global yellowfin tuna catch rates are correlated with a suite of climate indices, across different ocean basins. Wavelet analysis showed that basin-specific indices (*e.g.*, Pacific Decadal Oscillation, Atlantic Multidecadal Oscillation) were generally most influential in the region over which they are calculated, but they could also be important in neighboring basins.

Johanna Wren (Early Career Scientist) presented a network analysis for the Hawaii-based deep set longline fishery. This work used co-occurrence measures to show associations between target species (bigeye tuna), and various bycatch species. These associations were often stable through time, but varied across the spatial extent of the fishery.

Desiree Tommasi showed results from a study predicting Pacific bluefin tuna recruitment based on surface temperatures around nursery areas in the western North Pacific. She showed that multiannual forecasts of SST had some potential to predict recruitment in advance, but that more work is required to capture the observed variability in interannual recruitment for this species.

Melissa Karp (Early Career Scientist) presented recommendations from a recent workshop on the impacts of shifting distributions and productivity changes in managed stocks for the United States. She highlighted the importance of continuing survey data collection, appropriate modeling techniques, and communication with management agencies in addressing these issues.

Fan Zhang (Early Career Scientist) examined the presence of hysteresis and alternative stable states in populations of cod and American plaice in the Northwest Atlantic. He showed that hysteresis did exist in time series of abundance for these two species, but that these regime shifts did not appear to be predictable in advance using time series characteristics such as temporal autocorrelation and variance through time.

Kristin Marshall described work from the western United States examining the robustness of Pacific hake management strategies to environmental variability. Her results suggested that status quo management may lead to reduced management performance if hake distributions shift in the future, due to climate change.

Elliott Hazen presented work on behalf of Heather Welch describing how surface temperature metrics in the Southern California Bight can reduce bycatch of loggerhead turtles on fishing gear. This study found that a 6-month mean of surface temperature was the best indicator of turtle presence on the fishing grounds, and that turtles were more likely to be encountered when temperatures were anomalously high.

Briana Abrahms (Early Career Scientist) showed how ship strike risk for blue whales off southern California was predictable based on suitable foraging habitat for whales, and locations of shipping lanes. A dynamic ocean management strategy was shown to have potential advantages over a current voluntary ship speed limit imposed from spring through fall.

Johanna Wren presented work on behalf of Donald Kobayashi describing a climate vulnerability assessment for marine species in the Pacific Islands region. Vulnerability to future climate change varied widely depending on the habitat of each species, with sharks showing potentially high vulnerability out of the more than 80 species considered.

Carrie Holt described the results of a review examining how environmental information is incorporated into stock assessments and management decisions for Canadian fisheries. She showed that the incorporation of environmental metrics is most common at the hypothesis development stage, and as qualitative information during the assessment process, but is less commonly included when giving management advice.

James Thorson described how the decomposition of environmental drivers into large-scale indices, and local effects, can best represent the impacts of environmental regimes on species distribution shifts. He also showed how spatiotemporal aucotcorrelation frameworks can be useful to address gaps in survey sampling designs through time.

Yumeng Pang (Early Career Scientist) presented work examining the effects of temperature on the reproductive characteristics of two commercially important squid species. These were shown to be potential drivers behind observed changes in stock biomass through time, which have impact fisheries landings in the region.

Xiutang Yuan described the results of laboratory studies on impacts of warming and acidification on a species of sea cucumber. His work showed that this species attained larger sizes at warmer water temperatures, but that acidification negatively impacted growth.

Brian Wells presented results from a life cycle model for eastern Pacific salmon. This work highlighted the importance of predation to juvenile salmon survival during the marine part of their life history, as well as the impacts of juvenile size upon emigration from freshwater environments.

Barbara Muhling described historical changes in the distribution of eastern North Pacific albacore fisheries in the past several decades. Her results suggested that future climate change may have complex effects on albacore distribution, and that drivers of inshore-offshore shifts in the fishery need to be better understood.

Desiree Tommasi presented work on behalf of Kisei Tanaka showing the skill of temperature forecasts for estimating species distribution shifts in the Northwest Atlantic. Forecasts at 1- to 5-year lead times showed particular promise for future predictions.

Tatiana Kozlova described the dynamics of pink salmon abundance in riverine environments in coastal Russia. Her work suggested that environmental drivers were strongly influential in determining salmon dynamics, and thus availability to fisheries.

List of papers

Oral presentations

Merging contextual ecosystem advice with single-species stock assessment to inform fisheries managers in times of extreme environmental changes (Invited)
Stephani Zador, Elizabeth Siddon and Martin Dorn

National Oceanic and Atmospheric Administration's Climate Fisheries Initiative: Long-term projections
Anne B. Hollowed, Charles Stock, Alan Haynie, Albert Hermann and Kirstin Holsman

Towards ecosystem-based management of Northeast Pacific herring fisheries
Szymon Surma

Fragile ecosystems, robust assessments? Performance testing stock assessments for the California Current and Nordic and Barents Seas under climate change
Isaac C. Kaplan, Sarah K. Gaichas, Patrick D. Lynch, Christine C. Stawitz and Cecilie Hansen

Spatiotemporal interannual variabilities of swordfish catch in relation to fronts and eddies in the northwestern Pacific
Gloria S. Duran, Takeyoshi Nagai and Kotaro Yokawa

Ideas on how to incorporate EBFM into a pelagic longline tuna fishery
Phoebe A. Woodworth-Jefcoats, Justin Hospital, Johanna L.K. Wren, and Sarah Medoff-Wong

An evaluation of dynamic and static spatial management in a swordfish fishery: Balancing economic and bycatch concerns
James A. Smith, Desiree Tommasi, Michael Jacox, Elliot Hazen, Heather Welch and Stephanie Brodie

Application of time series analysis to detect the effect of multi-scale climate indices on global yellowfin tuna population
Yan-Lun Wu, Kuo-Wei Lan and Yong-Jun Tian

Network analysis in the Hawai'i-based longline fishery reveal spatiotemporal changes in network complexity and species association from 1995-2019
Johanna L. K. Wren and Phoebe A. Woodworth-Jefcoats

Integration of multiannual climate predictions in the estimation of stock status and rebuilding time frames for highly migratory species
Desiree Tommasi and Barbara Muhling

Accounting for shifting distributions and changing productivity in U.S. marine fisheries management: challenges and recommendations
Melissa Karp, Jay Peterson, Patrick Lynch and Roger Griffis

Regime shift and early warning signals of Atlantic cod and American plaice on Grand Bank off Newfoundland
Fan Zhang, Paul Regular and Eric Pedersen

A multi-model approach to better understanding the robustness of management of Pacific hake to environmental variability
Kristin N. Marshall, Isaac C. Kaplan, Kirstin Holsman, Grant Adams and Nis Jacobsen

Environmental indicators to reduce loggerhead turtle bycatch offshore of Southern California
Heather Welch, Elliott L. Hazen (presenter), Dana K. Briscoe, Steven J. Bograd, Michael G. Jacox, Tomoharu Eguchi, Scott R. Benson, Christina C. Fahy, Toby Garfield, Dale Robinson, Jeffrey A. Seminoff and Helen Bailey

The only constant is change: Incorporating socioecological variability into protected species management
Briana Abrahms, Hannah Blondin, Steven J. Bograd, Blake Feist, Mary Fisher, Arjun Hausner, Elliott L. Hazen, Jameal Samhouri

Assessing the vulnerability of marine life to climate change in the Pacific Islands region
Donald R. Kobayashi, Jonatha Giddens, Mark Nelson and Johanna Wren (presenter)

Incorporating climate, oceanographic and ecological change considerations into population assessments in Canada: A review and recommendations
Pierre Pepin, Jacquie King, Carrie Holt, Helen Gurney-Smith, Nancy Shackell, Kevin Hedges and Alida Bundy

Measuring the impact of oceanographic indices on species distribution shifts: The spatially varying effect of cold-pool extent in the eastern Bering Sea
James T. Thorson

Environmental effects on reproductive traits in cold/warm-water squids: implications on catch fluctuation
Yumeng Pang, Chin-Shin Chen, Tomohiko Kawamura and Yoko Iwata

Impact of seawater acidification and warming on the early development of the sea cucumber *Apostichopus japonicus* (Selenka) (Echinodermata: Holothuroidea)
Xiutang Yuan, Mingshan Song, Xiaolong Yang, Anguo Zhang and Lili Wang

Environmental determinants of spatiotemporal variability in salmon forage and its direct and indirect effects on salmon recruitment
Brian K. Wells, Whitney R. Friedman and Megan Sabal

Shifting distributions of fisheries for juvenile albacore in the eastern North Pacific
Barbara Muhling and Desiree Tommasi

Prospects for environmental prediction of annual fishery range expansion and contraction: a case study in the Northwest Atlantic
Kisei R. Tanaka, Fernando G. Taboada, Charles A. Stock, Desiree Tommasi (presenter), Malin L. Pinsky, Vincent S. Saba and Jorge L. Sarmiento

Dynamics of pink salmon (*Oncorhynchus gorbuscha*) abundance in the Tatar Strait rivers (Sea of Japan)
A.A. Dulenin and Tatiana V. Kozlova

Poster presentations

Is there a disruption in the food-web pathways in the Strait of Georgia that might be related to the declines in the Pacific salmon and Pacific herring in Canada?
David Costalago, Brian P.V. Hunt, Chrys Neville, Ian Perry, Kelly Young and Ian Forster

Traditional intertidal species regression study
Mikale Milne and Amy Cline

POC/BIO Topic Session (S12)
Impacts of meso-/submeso- scale processes on heat/material transport and on marine ecosystems

Convenors: *Hiromichi Ueno (Japan), Tetjana Ross (Canada), Olga O. Trusenkova (Russia)*

Invited Speaker:
Jody Klymak (School of Earth and Ocean Sciences, University of Victoria, BC, Canada)

Background

Mesoscale and submesoscale processes (with scales of 0.1–100 km) are widely distributed in the world's oceans; from coastal regions to the open ocean. These phenomena can be examined using *in-situ* and satellite observations as well as high-resolution numerical models. However, there is still a lot to be learned about the detailed structure and dynamics of these fine-scale features. Studies indicate that mesoscale and submesoscale processes have a significant impact on horizontal heat and material transport, *e.g.*, from coastal regions to the open ocean, as well as vertical transport, *e.g.*, from subsurface to surface layers. The heat and material transport by mesoscale and submesoscale processes is important not only in the context of physics and chemistry, but also

to marine ecosystems including plankton, nekton, birds and mammals. The aims of tthis opic session to discuss how the physics, chemistry, biology and sheries of mesoscale and submesoscale processes interact and also how these processes mediate interaction between regions (lateral) and layers (vertical). We invite presentations based on both observations and modeling.

Summary of presentations

The session included presentations focusing on the impact of meso-/submeso-scale processes on the heat/material transport and on marine ecosystems. Ten oral presentations including an invited presentation were given in the Tuesday afternoon session, and 3 oral presentations were given in the Wednesday morning session. This session also includes 2 poster presentations.

The invited speaker, Jody Klymak outlined efforts that his group has participated in to observe both the processes that drive lateral mixing, and to quantify lateral turbulence using statistical approaches. Their approach is to use *in-situ* ship observations using a fast-profiled CTD and the ship's ADCP, couple those observations with float and drifter data, and compare to numerical simulations to better understand the processes that drive lateral mixing, with an eye to parameterizing them in high-resolution models. He also briefly discussed plans to augment these ship-based studies with glider observations on the west coast. Tara Howatt talked about Glider observations of downwelling processes and zooplankton distributions in Clayoquot Canyon. Their results indicate that the physical processes in the region influence the distribution of zooplankton. Vadim Navrotsky presented theoretical and observational results of internal waves (IW) generation over the continental slope, and their breaking and specific IW-turbulence interactions, revealed with the help of detailed spectral analysis of heat, momentum and energy fluxes. Hui Liu discussed the impacts of the physical environment on on zooplankton communities in the northern Gulf of Mexico and highlighted the importance of the Mississippi River plume, and Loop Current front on the distribution and abundance of zooplankton in the northern Gulf of Mexico. Annalisa Bracco discussed how vertical transport within/across the mixed-layer is affected by submesoscale circulations in coastal areas as a function of mixed-layer depth and season. Their study contributes to a better understanding on how nutrients and plankton are distributed across the euphotic layer in various seasons in regions of elevated submesoscale and mesoscale activity.

After coffee/tea break, Hiromichi Ueno talked about the relative contribution of each eddy formation area from the perspective of "eddy yield". Their results indicate that frequent eddy formation in an area does not always correspond to important eddy formation in an area. Hanna Na discussed the heat and material transports by Kuroshio from south to north using current velocity data observed in the southern East China Sea from June 2015 to June 2017. Xiaopei Lin talked about the ocean's role in global climate change. They found that it largely depends on the meridional heat transport carried by the ocean circulation. Andrey Andreev discussed water dynamics in the western Bering Sea, which is characterized by a significant seasonal and interannual variability. Elena Ustinova focused on the impact of mesoscale processes on the saury, sardine, and mackerel fisheries in national and open waters against the backdrop of large-scale water circulation. The characteristics of the subsurface layer and the state of the seasonal thermocline are important to the fisheries.

In the Wednesday morning session, Réka Domokos discussed spatiotemporal variability of two North Pacific fronts and their effects on micronekton and the need to further their understanding of the role of micronekton in the region's ecosystem to improve management of our living marine resources in a changing climate. Dongfeng Xu discussed the diel vertical migration of zooplankton and micronekton on the northern slope of the South China Sea observed by a moored ADCP. Olga Trusenkova described the mesoscale and submesoscale dynamic structures off the Primorye coast and their impact on chlorophyll-a concentration using satellite imagery and moored profiler measurements.

List of papers

Oral presentations

Submesoscale observations in the Northeast Pacific (Invited)
Jody M. Klymak

Glider observations of downwelling processes and zooplankton distributions in Clayoquot Canyon
Tara Howatt, Tetjana Ross and Stephanie Waterman

Interaction of multi-scale dynamic processes in the coastal ocean and their biological impacts
Vadim Navrotsky

Impacts of the Loop Current associated mesoscale processes on zooplankton communities in the northern Gulf of Mexico
Jillian Gilmartin and Hui Liu

Role of submesoscale circulations in vertical transport within and across the mixed-layer
Annalisa Bracco and Guanpeng Liu

Eddy yield in the North Pacific
Hiromichi Ueno, Isao Fujita, Tetjana Ross and Carol Ladd

Kuroshio variability and its relationship with mesoscale eddies in the southern East China Sea
Hanna Na, Hong Sik Min, Dong Guk Kim, Jae-Hun Park, Chanhyung Jeon, Hirohiko Nakamura, Ayako Nishina and Xiao-Hua Zhu

Meridional heat transport variability induced by mesoscale processes in the subpolar North Atlantic
Xiaopei Lin, Jian Zhao, Amy Bower and Jiayan Yang

Water dynamics in the western Bering Sea and its impact on chlorophyll concentration and chum salmon abundance
Andrey G. Andreev, Maxim V. Budyansky, Gennady V. Khen, Michael Yu. Uleysky and Sergey V. Prants

Impact of mesoscale variability in the Northwest Pacific on the saury, sardine and mackerels fishery in summer and autumn in recent years
Elena Ustinova, Eugeny Basyuk and Viktor Filatov

Spatiotemporal variability of two North Pacific fronts and their effects on micronekton
Réka Domokos

Diel vertical migration of zooplankton and micronekton on the northern slope of the South China Sea observed by a moored ADCP
Chenghao Yang, Dongfeng Xu and Zuozhi Chen

Mesoscale and submesoscale dynamic structures off the Russian coast in the northwestern Japan/East Sea and their impact on chlorophyll-a concentration: Satellite imagery and moored profiler measurements
Olga Trusenkova, Alexander Ostrovskii, Alexander Lazaryuk, Vyacheslav Dubina, Svetlana Ladychenko and Vyacheslav Lobanov

Poster presentations

Impact of ocean physics on marine ecosystems in the Kuroshio and Kuroshio Extension regions: A high-resolution coupled physical-biological model study
Yoshikazu Sasai, Makio C. Honda, Eko Siswanto, Sami Kato, Kazuyuki Uehara, Hideharu Sasaki and Masami Nonaka

Regional differences in the impact of mesoscale eddies on chlorophyll in the North Pacific
Isao Fujita, Ayumi Takeichi, Hiromu Ishiyama and Hiromichi Ueno

BIO Topic Session (S13)
Implications of prey consumption by marine birds, mammals, and fish in the North Pacific

Convenors: *Andrew Trites (Canada), Robert Suryan (USA), Tsutomu Tamura (Japan), Kirstin Holsman (USA)*

Invited Speaker:
David A Beauchamp (Western Fisheries Research Center, USA)

Background

Consumption by marine birds, mammals and fish has implications for ecosystem health and sustainability of fisheries. It has the potential to induce trophic cascades and influence the dynamics of species sought by fisheries—and has bearing on how fish, seabirds and marine mammals will adapt to climate change. However, there is uncertainty about how much they currently consume, how their consumption has changed over time, and whether or not they compete with fisheries and impede the recovery of threatened and endangered species. This topic session invites papers that address 1) decadal changes in prey consumption by marine birds, mammals and fish, 2) direct and indirect effects of consumption on food webs and species recovery, 3) impacts of climate change and inter-annual variability on food consumption, 4) the influence of prey quality on the health and dynamics of top predators, and 5) potential competitive interactions between fisheries and marine birds, mammals and fish. This session is the culmination of a 4-year project to document diets and estimate amounts of prey consumed by seabirds and marine mammals in the North Pacific. Presenters will be encouraged to submit manuscripts from this session to a special issue proposed in a leading scientific journal.

Summary of presentations

We had 17 papers submitted focused on fish (4 submissions), birds (1) and marine mammals (10). Of these 7 were led by researchers from Canada, 6 from the USA, 3 from Japan, and 1 from China (which was later withdrawn). Of the remaining 16 submissions, 2 were accepted for the poster session, and 14 for the oral session.

The species discussed and presented included walleye pollock, roqual whales, sei whales, Bryde's whales, minke whales, Steller sea lions, spotted seals, ribbon seals, Bluefin tuna, California sea lions, northern fur seals, harbour seals, and marine mammals in general.

Topics presented included consumption models, competition with fisheries, decadal changes in consumption, prey switching, environmental drivers of consumption, spatial variation in consumption, daily food requirements.

The session was attended by from 60 to 80 people and was very well received. The session covered a broad suite of species and topics, and presented findings that appeared to interest PICES participants from a broad range of backgrounds and areas of expertise.

List of papers

Oral presentations

Development of a predation index to assess spatiotemporal variation in consumption of Walleye Pollock in the Gulf of Alaska
Cheryl L. Barnes, Anne H. Beaudreau, Martin W. Dorn, Kirstin K. Holsman and Franz J. Mueter

Rorqual ingestion estimates for the Eastern North Pacific based on direct measures of feeding rates and prey quality
Matthew Savoca, Shirel Kahane-Rapport, Dave Cade, Max Czapanskiy, James Fahlbusch, Paolo Segre, John Calambokidis, Douglas Nowacek, Dave Johnston, K.C. Bierlich, Julian Dale, Elliott Hazen, Ari Friedlaender and Jeremy Goldbogen

Spatial estimation of prey consumption by sei, Bryde's and common minke whales in the western North Pacific during the summers of 2008 – 2009: Density surface model approach
Hiroko Sasaki, Tsutomu Tamura, Takashi Hakamada, Koji Matsuoka, Hiroto Murase and Toshihide Kitakado

Daily food requirements of Steller sea lion, spotted seal and ribbon seal distributed along the coast of the Nemuro Strait, Hokkaido, Japan
Yoko Goto and Andrew W. Trites

Daily prey consumption by marine mammals is a function of their cost of living
Andrew W Trites

Modeling the importance of prey quality to endothermic predators in the Northeast Pacific
Szymon Surma

Variability in the energy density of prey and its consequences for growth in juvenile Chinook Salmon
Jacob Weil, Will Duguid and Francis Juanes

Ontogenetic shifts in the trophic role and consumption demand by Chinook salmon and Pacific herring in Puget Sound (Invited)
David A. Beauchamp

Environmental drivers of variation in energy intake by Pacific bluefin tuna over 15 years
Gemma Carroll, Stephanie Brodie, Steven Bograd, Elliott Hazen, Rebecca Whitlock and Barbara A. Block

Shifts in prey consumption by seals and sea lions in the North Pacific
Andrew W. Trites

Prey switching and consumption by seabirds in the central California Current upwelling ecosystem: Implications for forage fish management
Pete Warzybok, Jarrod A. Santora, David G. Ainley, Russell W. Bradley, John C. Field, Phillip J. Capitolo, Ryan D. Carle, Meredith Elliott, Jessie N. Beck, Gerard J. McChesney, Michelle M. Hester and Jaime Jahncke

Estimation of prey consumption by marine mammals in the PICES regions -Update of Hunt et al. (2000)-
Tsutomu Tamura, Kenji Konishi, Koji Matsuoka and Takashi Hakamada and Andrew W. Trites

Assessing decadal changes in prey consumption by marine mammals and forecasting the impacts of marine mammals off western Canada
Caihong Fu, Thomas Doniol-Valcroze, Strahan Tucker, Jennifer Boldt, Norm Olsen, Yi Xu, Huizhu Liu, Philippe Verley and Yunne-Jai Shin

Marine mammal prey consumption and competition with fisheries in the Northeast Pacific
Szymon Surma

Poster presentations

A marine salmon diet database for the North Pacific
Caroline Graham, Evgeny A. Pakhomov and Brian P.V. Hunt

Effects of ocean climate on forage fish condition in the Gulf of Alaska
Sarah Ann Thompson, Marisol García-Reyes, William J. Sydeman, Mayumi L. Arimitsu, Scott A. Hatch and John F. Piatt

HD/FIS Topic Session (S14)
Integrating economic and social objectives in marine resource management

Convenors: *Keith Criddle (USA), Alan Haynie (USA), Mitsutaku Makino (Japan)*

Invited Speaker:
Sean Pascoe (Marine Resource Economics Team CSIRO Oceans and Atmosphere, Australia)

Background

While sustainable resource management is a commonly expressed goal, this means many different things to different people. From a narrow single-species biological perspective, sustainable management means adopting regulatory measures that ensure that stock and recruitment levels do not fall below acceptable levels. More holistic goals have been articulated in many contexts, such as in the National Research Council report on Sustaining marine fisheries (NRC 1999), which characterizes sustainable fishing as "fishing activities that do not cause or lead to undesirable changes in biological and economic productivity, biological diversity, or ecosystem structure and functioning from one human generation to the next; sustainable fishing does not lead to ecological changes that foreclose options for future generations". Our experience has shown that fisheries policy that neglects social and economic considerations and objectives is unlikely to sustain fish, fishermen, or fishery-dependent communities and does not transparently consider the many goals of managers when they make decisions. This transdisciplinary approach has been embraced by ICES and PICES and is a central motivation for the MSEAS-2020 meeting. The intent of the session was to also draw from the experiences of the ICES Strategic Initiative on the Human Dimension (SIHD). Papers were invited that addressed how we evaluate ecological, economic, and social goals in marine resource management. Possible specific topics include papers that 1) present examples of how social and economic goals have been integrated into fisheries management, 2) propose or discuss novel approaches to engage stakeholders in the specifying of management objectives, and 3) develop management tools to achieve those objectives.

Summary of presentations

On Tuesday, October 21, under HD Committee sponsorship, Keith Criddle (USA), Alan Haynie (USA), and Mitsutaku Makino (Japan) convened a topic session, "Integrating economic and social objectives in marine resource management" The 1-day session presented a diversity of topics by one invited speaker and eight selected speakers from many countries and varied disciplines. Six of the selected speakers were early career scientists.
Sean Pascoe (CSIRO, Australia), the invited speaker, gave a talk titled "Integrating economic and social objectives in marine resource management: Australian experiences." He described how the objective of fisheries management in Australia evolved from maximum sustainable yields (MSY) to maximum economic yields (MEY) and is now evolving to Multi-objective optimal yields (MOOY). By the 1950s, good surplus production and age-structured models were developed and MSY was seen as the target. Over the next 4 decades, MSY evolved from a target to a limit and MEY emerged as a target. In 2007, the Commonwealth formally adopted three objectives – ensure sustainable resources, maximize net economic returns (MEY), and minimize bycatch – but did not establish a hierarchy among these objectives or establish criteria for tradeoffs among these objectives. In 2017, the Commonwealth added the requirements that fisheries management plans must consider recreational and indigenous fisheries and consider social implications. Nearshore fisheries in Australia are managed by the states and territories and have also come to include social objectives as well as biological, ecological, and economic objectives, For example, Queensland has a requirement that fisheries management should consider policies that serve to maximize "equity".

Dr. Pascoe discussed two case studies, the Northern Prawn Fishery (NPF) and the Queensland Coral Reef Finfish Fishery (CRFFF). These fisheries are at opposite ends of the spectrum in terms of management complexity. The NPF is a simple commercial with well-established stock assessment processes and harvest control rules, and no local community considerations. Management of the NPF fishery is not very controversial. In contrast, the CRFFF includes multiple competing sectors, lots of local jobs, and operates in the Great Barrier Reef Marine Park (*i.e*., many objectives and different management system). The CRFFF case study contrasted the preferred outcomes under a bioeconomic framework and a multiple criterion decision analysis (MCDA) framework. The MCDA approach (an Analytic Hierarchy Process model) used expert judgements to derive estimates of impacts against objectives. The bioeconomic model assumed that social outcomes were linked to catch and effort. For the CRFFF, the outcomes of the two frameworks were correlated. The advantage of MCDA was that it was perceived as being more inclusive of stakeholder values and preferences. The advantage of the bioeconomic framework was that it did not entail time consuming and costly public engagement.

Kiva Oken gave a talk titled "A bioeconomic simulation for understanding the roles of synchrony and permit access in driving revenue stability on the U.S. West Coast." A simulation loosely based on U.S. west coast fisheries for Dungeness crab, Pacific salmon, and groundfish found that holding multiple permits stabilized revenue when stock variation was asynchronous but destabilized revenue when stock varied in synchrony.

Raphael K. Roman discussed "How fisheries portfolio diversification can enhance social-ecological resilience along the Sanriku Coast of Japan." The study focused on three prefectures in northern Honshu – Iwate, Migyi, and Fukushima – 15% of total catch production of Japan. There were big losses after the 2011 Great East Japan Disaster, including a 60% increase in unemployment. Two hundred and sixty villages and 14,000 vessels were destroyed. Fukushima had a large share of its catch in the 80s from sardines. Based on a Shannon Index and catch diversity, it was found that catch variability is inversely related to catch diversity.

Hiroaki Sugino reported on "Infrastructuring big data of multispecies fishery catch for agile-up fishery strategy." The author scraped market data sources from the internet for 1994-2016 and found interesting connections among species, including squid and amberjack. He has communicated with fishers about their needs from the data and is exploring other opportunities.

Timothy Frawley discussed "Recent changes to the structure and function of the North Pacific albacore fishery". He and his co-investigators found that due to the convergence of ecological (shift in target species distribution), economic (market differentiation and increased value) and regulatory factors (effort restrictions in other historically important fisheries), the albacore troll fishery represents an increasingly important part of the harvesting portfolio's of small boat fishermen in Oregon and Washington.

Iwao Fujii spoke on "Capacity building for the successful management of the high seas, with a focus on NGOs – in the context of the Pacific region".

Yu-San Han from National Taiwan University talked about dispersal routes of Japanese glass eel in the East Asian continental shelf and its sustainable use. There are different distributions by species from Indonesia to Japan with different spawning grounds. The presentation also showed eel dispersion from North America to Europe, which takes more than a year. Another key point from the perspective of this session is that there are transboundary larval transfer connections. There has been a big decline in three eel species catch over the last three decades. Japanese eel listed as endangered was on red list in 2014; American eel and European eel are also listed. The declines are attributed to habitat destruction, overfishing, and climate change.

Meng Su discussed marine fishery development and user rights management in Jimo (China). Jimo is a major fishing area in China. Meng Su described fisher perceptions of the changes in the region since 1988. There were some unmotorized vessels still being used until 2002. Fishing licenses are for 5 years and have limits for time and the quantities of target species.

Minje Choi presented a talk on a "Comparative analysis of stock assessment models for planning the effective fishery resource management: Analyzing potential yield of West sea, Republic of Korea".

List of papers

Oral presentations

Integrating economic and social objectives in marine resource management: Australian experiences (Invited)
Sean Pascoe, Toni Cannard, Natalie Dowling, Catherine M. Dichmont and Trevor Hutton

A bioeconomic simulation for understanding the roles of synchrony and permit access in driving revenue stability on the U.S. West Coast
Kiva L. Oken, Daniel S. Holland and Andre E. Punt

How fisheries portfolio diversification can enhance social-ecological resilience along the Sanriku Coast of Japan
Raphael K. Roman, Tomoaki Goto and Gakushi Ishimura

Infrastructuring big data of multi-species fishery catch for agile-up fishery strategy
Hiroaki Sugino and Nobuyuki Yagi

Recent changes to the structure and function of the North Pacific albacore fishery
Timothy Frawley, Barbara Muhling, Gwendal Le Fol, Megan Cimino, Steven Bograd, Elliott Hazen and Michael Jacox

Capacity building for the successful management of the high seas, with a focus on NGOs – in the context of the Pacific region
Iwao Fujii and Miko Maekawa

Dispersal routes of Japanese glass eel in the East Asian continental shelf and its sustainable use
Yu-San Han

Marine fishery development and user rights management in Jimo (China)
Meng Su

Comparative analysis of stock assessment models for planning the effective fishery resource management: Analyzing potential yield of West sea, Republic of Korea.
Minje Choi, Jaebeum Hong and Dohoon Kim

Poster presentations

Impact and adaptation of coastal fisheries under climate change - a case study of set-net fishery in Taiwan
Ching-Hsien Ho

Bioeconomic analysis of small yellow croaker in the Republic of Korea
Minje Choi, Jaebeum Hong and Dohoon Kim

POC/FUTURE Topic Session (S15)
Advances in North Pacific marine ecosystem prediction

Convenors: *Mike Jacox (USA), Fei Chai (China), Jinqiu Du (China), Shoshiro Minobe (Japan)*

Invited Speaker:
Takeshi Doi (JAMSTEC, Japan)
Nicole Lovenduski (University of Colorado, USA)
Stephanie Brodie (UC Santa Cruz, USA)

Background

Modern ocean and ecosystem models are rapidly developing the ability to make skillful forecasts of the physical, and more recently biogeochemical and higher trophic level, components of marine ecosystems at timescales from days to decades. Such forecasts often align with the tactical decision-making timescales of individuals, businesses, and governments, giving them significant potential to inform climate-ready management strategies. Much work has now been done to identify potentially predictable ecosystem components and to develop prototype forecast systems.

Summary of presentations

Session 15 was developed as a forum to learn and discuss how climate–ecosystem relationships are being exploited to understand predictability and implement marine ecosystem forecasts across the North Pacific. This session was proposed by WG 40 (Climate and Ecosystem Predictability) and was meant to advance the terms of reference of that working group. Submission that highlighted advances in predicting physical, biogeochemical, and ecological components of the earth system, as well as socioeconomic impacts, were encouraged.

Nikki Lovenduski was an invited plenary speaker for the session, and she presented the state of the art in decadal prediction of biogeochemistry in the North Pacific. Her presentation was remarkably clear and compelling, outlining both the utility of decadal predictions and the significant promise for skillful forecasts of carbon cycle variables (*e.g.*, pH) on multiannual timescales.

The remainder of the session consisted of 16 talks (7 by early career scientists) and one poster. The presentations were diverse in terms of their specific applications (physics to biogeochemistry to forage fish to top predators), modeling approaches (*e.g.*, machine learning, empirical dynamical modeling, mechanistic coupled models), and time scales (from seasonal to centennial). The session was well attended, with over 50 participants throughout the day.

The first set of talks dealt with short-term (seasonal) forecasts. Invited speaker Takeshi Doi presented skill assessment for SSH forecasts from the SINTEX-F model, showing that forecast skill for SSH is often higher than that for SST and extends in some cases to 12- to 18-month lead times. This skill is largely related to ENSO and the Indian Ocean Dipole. Next, Kelly Kearney discussed seasonal predictions of the Bering Sea Cold Pool, an ecological oceanographic feature, using a regional downscaled model (ROMS) forced by the Climate Forecast System. Forecast skill is dependent on the time of initialization, due to a winter predictability barrier. October and January initialized forecasts are skillful for just one to two months, while forecasts initialized in April have high skill through summer. A similar regional downscaling approach was employed in the Pacific Northwest, using the J-SCOPE model, by the next two speakers. Emily Norton presented models of Dungeness crab larvae presence and found that incorporating not only concurrent environmental conditions, but also

exposure history (obtained by tracking particles backward in time), improved model fit and performance. Michael Malick presented work on forecasting Pacific hake distributions; to date they have found that hake distributions are well described by static variables (longitude, latitude, distance from continental shelf), and temperature may provide additional information but this aspect requires more study as it so far has not improved out-of-sample skill.

The next set of talks focused more on predictability (*i.e.*, understanding physical and ecological dynamics that might lead to forecast skill) rather than forecasts themselves. Toru Miyama discussed 2010–2016 warming in the Oyashio region and its association with the ocean circulation, particularly a weaker first Oyashio intrusion of the summer season and accompanying enhancement of anticyclonic eddies. Baolan Wu argued that the Atlantic Multidecadal Oscillation has a large role in forcing Northwest Pacific variability, though there was considerable debate about the robustness of these conclusions due to the experimental setup. The next two studies explored statistical links between large-scale climate modes and ecological indicators of the North Pacific. Shuyang Ma discussed these relationships in the Northwest Pacific, where regional sea surface temperatures were found to be related more closely to the East Asian Monsoon and the Arctic Oscillation than the Pacific Decadal Oscillation. Shoshiro Minobe presented a correlation analysis in which tens of marine ecosystem indices were combined in an EOF analysis, and the first two modes of the EOF were found to be related to long-term warming and decadal variability (PDO, NPGO), respectively. This middle portion of the session ended with two talks describing modeling methods that may aid ecosystem prediction. Peter Kuriyama described the application of Empirical Dynamic Modeling to ichthyoplankton time series off southern California, showing the potential for a few "sentinel" locations to be used to predict variability at other sites. Al Hermann then described a hybrid dynamical–statistical downscaling method in which statistical relationships between coarse- and fine-scale model output can be used to construct large ensembles of model forecasts without the computational expense of a large number of dynamically downscaled runs.

The last set of talks dealt primarily with ecological responses to environmental change across timescales including long-term (climate change). Invited speaker Stephanie Brodie discussed considerations for incorporating environmental data in species distribution models, taking into account the spatiotemporal scales of physical and biological variability, and how predictable these different scales are. Yongjun Tian examined variability in an assemblage of thirteen fish species over the past century in the Northwest Pacific, finding shifts in these assemblages to be often associated with sign changes in large-scale climate oscillations. Caihong Fu (presenting for Chuanbo Guo) described an ecosystem model used to examine synergistic effects of fishing, warming, and acidification off British Columbia since 1940. Interactive effects of these stressors varied by trophic level, but most common were dampened responses, where the combined effect is less than the sum of individual effects. Megan Cimino presented a new statistical model for krill species based on a regional ocean model of the California Current System, showing how the two primary krill species are associated with winter preconditioning, static (*e.g.*, bathymetric) features, and environmental covariates. Jerome Fiechter described the results of a coupled physical–biogeochemical-individual based model for sardine and anchovy in the California Current System under long climate runs, with a key finding being that even without environmental variability the fish behavior can lead to strong population variability. Finally, Andrey Krovnin explored historical time series of North Pacific climate and fish stocks and identified a decadal (~15-year) and a multi-decadal (~60-year) mode of variability. Projecting these modes into the future suggests a new "sardine period" in the 2030s and a new "salmon period" in the 2040s–2070s.

Following the session, efforts have been made to capture this broad range of expertise and research in a journal special issue. The Co-Chairs of WG 40 have organized a Research Topic titled "North Pacific Climate and Ecosystem Predictability on Seasonal to Decadal Timescales" in *Frontiers in Marine Science*. Approximately 15 articles are expected, with the target of publication before the 2020 PICES Annual Meeting.

List of papers

Oral presentations

Decadal predictions of ocean biogeochemistry in the North Pacific (Plenary)
Nicole Lovenduski, Stephen Yeager, Kristen Krumhardt and Riley Brady

Seasonal-interannual prediction of sea surface height using an ocean-atmosphere dynamical model "SINTEX-F" (Invited)
Takeshi Doi, Masami Nonaka and Swadhin K. Behera

Seasonal forecast skill for the Bering Sea cold pool
Kelly Kearney, Al Hermann, Wei Cheng and Kerim Aydin

The importance of environmental exposure history in forecasting Dungeness crab megalopae occurrence using J-SCOPE, a high-resolution model for the US Pacific Northwest
Emily L. Norton, Samantha Siedlecki, Isaac Kaplan, Albert Hermann, Jennifer L. Fisher, Cheryl A. Morgan, Suzanna Officer, Casey Saenger, Simone A. Alin, Jan Newton, Nina Bednarsek and Richard A. Feely

Skill and uncertainty of environmentally driven forecasts of Pacific hake distribution
Michael J. Malick, Mary Hunsicker, Melissa Haltuch, Sandy Parker-Stetter, Isaac Kaplan, Aaron Berger, Samantha Siedlecki, Nicholas Bond, Albert Hermann and Emily L. Norton

Exploring the determinants of ecological predictability (Invited)
Stephanie Brodie

Marine heatwave of sea surface temperature of the Oyashio region in summer since 2010
Toru Miyama, Shoshiro Minobe and Hanako Goto

The impact of Atlantic Multi-Decadal Oscillation on the North Pacific Subtropical Mode Water
Baolan Wu, Xiaopei Lin and Lisan Yu

Climate variability patterns and their ecological effects on ecosystems in the northwestern North Pacific
Shuyang Ma, Yongjun Tian, Jianchao Li, Haiqing Yu, Jiahua Cheng, Caihong Fu and Yoshiro Watanabe

Basin-scale relations between marine ecosystem indices and physical environment in North Pacific
Shoshiro Minobe, Emiyati, Nathan Mantua, Shin-ichi Ito and Emanuele Di Lorenzo

Applying empirical dynamic modelling to identify intraspecific spatial scales of dynamics and improve in-sample predictability in the CalCOFI ichthyoplankton survey
Peter T. Kuriyama, Brice X. Semmens and George Sugihara

Expanding the biophysical ensemble: hybrid dynamical-statistical downscaling methods based on spatial/temporal scale
Albert J. Hermann

Regime shifts in the fish assemblages around Japan over the last century and their early warning signals
Yongjun Tian, Shuyang Ma, Kazuhisa Uchikawa, Jiahua Cheng, Yoshiro Watanabe, Akihiko Yatsu, Jürgen Alheit and Caihong Fu

Interactive effects of fishing, ocean acidification and ocean warming on a marine ecosystem off western Canada
Chuanbo Guo, Caihong Fu (presenter), Robyn E. Forrest, Norm Olsen, Huizhu Liu, Philippe Verley and Yunne-Jai Shin

Winter preconditioning, mesoscale variability and geomorphology influence the distribution and abundance of krill in the California Current System
Megan Cimino, Jarrod Santora, Isaac Schroeder, Michael Jacox, Elliott Hazen and Steven Bograd

A downscaling approach to predict climate change effects on forage fish abundance and distribution in the California Current
Jerome Fiechter, Michael G. Jacox, Mercedes Pozo Buil and Michael A. Alexander

Prospects of long-range prediction of changes in fish stocks based on the large-scale climatic factors in the Northern Hemisphere
Andrey S. Krovnin, Kirill K. Kivva and George P. Moury

Poster presentations

Potential predictability of interannual-to-decadal variability in eddy activity in the Kuroshio Extension
Masami Nonaka, Hideharu Sasaki, Bunmei Taguchi, and Niklas Schneider

BIO Contributed Paper Session

Convenors: *Se-Jong Ju (Korea), Akash Sastri (Canada)*

Background

The Biological Oceanography Committee (BIO) has a wide range of interests spanning from molecular to global scales. BIO targets all organisms living in the marine environment including bacteria, phytoplankton, zooplankton, micronekton, benthos and marine birds and mammals. In this session, papers on all biological aspects of marine science in the PICES region were welcomed. Contributions from early career scientists were especially encouraged.

Summary of presentations

The BIO Paper Session at PICES-2019 had among the paper sessions the most presentations, with a total of 9 oral (cancellation of 1 oral) and 13 poster presentations. Oral sessions were held in a half day and were well attended (over 30 participants). Oral and Poster presentations mainly focused on lower trophic levels (bacteria, phytoplankton and zooplankton) of biological issues with a few higher trophic talks (salmon). The convenors recognized that this regular session provides important opportunities for PICES scientists to present their results and for early career scientists to participate in PICES activities.

Pei-Chi Ho presented what factors (body size, light intensity, nutrient supply, trophic strategy, *etc*.) determine the stoichiometry of mixotrophic plankton. They found that the variation in C:N ratios is mainly explained by body size, followed by light intensity and nutrient concentration. Furthermore, the trophic strategy is also an important factor to determine the stoichiometry. The size-based plankton food web model simulation reproduced that the C:N ratio of organisms, smaller than 51 μm, increases with body size due to an increase of photosynthetic carbon, whereas C:N ratio of organisms, bigger than 51 μm, decrease with size due to decreasing photoautotrophic but increasing heterotrophic uptake. From these results, they suggest that the determination of the stoichiometry of mixotrophs should be considered size and trophic strategy dependent.

Siyu Jiang presented the results of the size-fractionated dilution experiments in the subtropical and equatorial Eastern Indian Ocean to understand the importance of picophytoplankton in the oligotrophic oceans, where nutrients are extremely limited. It was found that picophytoplankton (< 3 μm) dominated the community and their higher growth was not limited by nutrient scarcity. The daily consumption of phytoplankton production by microzooplankton was generally lower than 50%. However, the study stations influenced directly by the Wyrtki Jet showed distinct characteristics, including more than two-fold phytoplankton biomass and microzooplankton grazing pressure higher than 100%. The picophytoplankton still dominated the community as other oligotrophic regions. However, in contrast to the Pacific, they showed low growth limited by nutrients in the Eastern Indian Ocean. It may be caused from the complex physical processes which could lead to distinct geographical variations of picophytoplankton in the Indian Ocean.

M. James McLaughlin presented the photo-physiological response of algae to strong tidal mixing (reaching 11 m on spring tide) in coastal waters of north-western Australia. This results in some of the largest tropical tides measured in the world. Phytoplankton biomass inside King Sound, a large embayment which opens to the Indian Ocean, was dominated by large diatoms, shifting to a community largely comprised of picophytoplankton offshore. Rates of primary production on the shelf decreased from coastal areas to offshore waters. They examined phytoplankton photo-physiological response to natural light in closer detail at different phases of the spring-neap tide, and different vertical water-column positions, to explain why primary

productivity is reportedly so high in the estuary. Incubations of phytoplankton sampled within the estuary displayed reduced photosynthetic efficiency, elevated maximum photosynthetic rates, and no measurable photo-inhibition. This response is typical of high light adapted phytoplankton, and contrasts with phytoplankton on the adjacent shelf which display high photosynthetic efficiency, and strong light inhibition typical of low light adapted phytoplankton.

Samantha M. Zeman presented the long-term variation of copepod assemblage in the Northern California Current large marine ecosystem using hydrographic and zooplankton data collected monthly along the same transect (NH-line) off the coast of Newport, Oregon for the past 23 years. At a shelf station, copepod species composition exhibits a strong seasonal cycle, yet inter-annual low frequency variations in the copepod community are largely driven by basin-scale processes. However, along a cross-shelf gradient spanning out into oceanic habitats, the on and offshore copepod community during summer reflects dominant source water currents with assemblages separated into nearshore and offshore groups. Initial analyses of seasonal community data suggest that the community dynamics nearshore are in synch with those offshore during the winter months. During the spring and summer, community variation occurs at the shelf stations, with a different community occurring offshore. Understanding which processes control zooplankton species composition and community structure has implications for higher trophic levels and can explain future shifts in a changing ocean.

Tracy Shaw presented population dynamics of the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera*, with notes on *Thysanoessa inspinata,* off of Newport, Oregon, USA using the samples from 2001-2016 on the Newport hydrographic line. All three species occurred throughout the study period, with *E. pacifica* by far the most abundant, followed by *T. spinifera*. *T. inspinata* was present throughout the study period but was never abundant. The adults of both *E. pacifica* and *T. spinifera* were smaller during warm years and larger during cool years. *E. pacifica* were strongly associated with the offshore stations, with similar abundances during cool and warm phases of the PDO. At inshore stations *T. spinifera* were more abundant during cool years and rare during warm years but abundances at offshore stations were similar during cool and warm years. *T. inspinata* were also associated with the offshore stations but were not abundant enough to discern seasonal patterns or assess any response to environmental variability. Biomass and length results were also discussed for *E. pacifica* and *T. spinifera* in the context of environmental conditions.

Jennifer Fisher presented the differences in body condition, elemental composition and total lipids of *Euphausia pacifica* and *Thysanoessa spinifera* in the northern California Current, USA. *T. spinifera* had a higher length-weight, Fulton's K, hepato-somatic index, carbon to nitrogen ratio, and total lipid compared to *E. pacifica*, indicating that *T. spinifera* have a higher energetic value for predators. However, there were strong seasonal differences in the energetics of *T. spinifera*. Carbon and lipids were highest in non-reproductive life history stages of *T. spinifera* from August through October. Despite strong ontogenetic and inter-specific differences, the lipid and fatty acid compositions in both species followed a seasonal progression.

Iria Giménez showed the results of viability testing on marine organisms, including results from experiments decoupling pH and Ω aragonite on larval and post-larval stages of Pacific oyster (*Crassostrea gigas*) using own-house built carbonate control system, which is capable of decoupling pCO_2, pH or Ω and producing dynamic treatments by independently manipulating total alkalinity and total inorganic carbon. This experimental system provides a novel tool to evaluate organismal effects of exposure to decoupled carbonate system variables and to past, current and future dynamic carbonate chemistry scenarios. She also discussed further applications including the incorporation of multi-stressors.

Julie Keister presented what mechanisms seasonally and annually change zooplankton composition in the Strait of Juan de Fuca (SJF), USA. The largest temporal changes in the SJF zooplankton community are strong seasonal shifts from a summertime community dominated by warm-water species with Puget Sound affinities, to a winter community dominated by cold-water species that are rare in Puget Sound, but dominate on the coast during summer upwelling. The shifts in composition, and an opposite cycle of dominance in the SJF compared to the coast, suggest that changes in advection are important controls on species composition, and may also drive inter-annual variability. She used data from a zooplankton time series sampled monthly since 2003 in the eastern SJF, and particle-tracking experiments in a high-resolution ROMS model of the Salish Sea, to explore climate-related changes in species composition and advective pathways, with a focus on understanding the climate-mediated role of ocean-estuary exchange. The mechanisms that control the SJF species composition differ from those that control California Current zooplankton, illustrating the importance of regional ecosystem monitoring.

Minna Hiltunen talked about the quality of juvenile salmon prey during early marine residence in Puget Sound, WA, USA. Prey composition and quality (content of essential fatty acids; EFA) are critically important to the growth of juvenile salmon and their survival to adult. The results indicated that the prey taxa varied in their EFA content, and amphipods, in particular, were found to be high quality food resources. An integrated measure of food quantity and quality, created by combining data on juvenile salmon prey biomass distribution (measured by quantitative net tows) with EFA content of the taxa, revealed variation in both the timing and magnitude of peak availability of important EFAs among different regions. Notably, availability of EFAs was highest in the northern regions and lowest in South Sound, indicating better feeding conditions in the north. In the long-term, the results of this study could lead to more sensitive indicators of salmon survival, which incorporate both zooplankton species composition and the EFA content of important prey taxa.

List of papers

Oral presentations

Body size, light intensity and nutrient supply determine plankton stoichiometry in mixotrophic plankton food webs
Pei-Chi Ho, Chun-Wei Chang, Fuh-Kwo Shiah, Pei-Ling Wang, Chih-hao Hsieh and Ken H. Andersen

Comparison of phytoplankton growth and mortality in oligotrophic subtropical North Pacific and Eastern Indian Ocean
Siyu Jiang, Fuminori Hashihama and Hiroaki Saito

An investigation of the biophysical oceanography in coastal waters of north-western Australia and photo-physiological response of phytoplankton to tidal mixing
M. James McLaughlin, Jim Greenwood, Martin Lourey, Christine E. Hanson, Nagur Cherukuru, Peter Thompson, Paul Branson and Charitha Pattiaratchi

Copepod community dynamics across a shelf and oceanic gradient in the northeast Pacific from 1998-2016
Samantha M. Zeman, Jennifer L. Fisher, Cheryl A. Morgan and William T. Peterson

Population dynamics of the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera*, with notes on *Thysanoessa inspinata*, off of Newport, Oregon, USA
C. Tracy Shaw and Jennifer L. Fisher

Comparison of condition metrics and lipid content between *Euphausia pacifica* and *Thysanoessa spinifera* in the northern California Current, USA
Jennifer L. Fisher, Jennifer Menkel, Louise Copeman, C. Tracy Shaw, Leah R. Feinberg and William T. Peterson

Developing a mechanistic understanding of ocean acidification sensitivity in marine bivalves: Experimentally decoupling pH and saturation state and reproducing natural variability
Iria Giménez, Burke R. Hales, George G. Waldbusser, Wiley Evans and Helen Gurney-Smith

Climate controls on zooplankton composition and ocean-estuary exchange in the Strait of Juan de Fuca, USA
Julie E. Keister, Bethellee Herrmann, Andrew Mandovi and Parker MacCready

The quality of juvenile salmon prey during early marine residence in Puget Sound, WA, USA
Minna Hiltunen, Ursula Strandberg, Julie Keister, David Beauchamp, Miika Kotila and Michael T. Brett

Poster presentations

Seasonal dynamics of phytoplankton community using microscopic and Chemotax pigment analysis in Seomjin River Estuary, Korea
Minji Lee and Seung Ho Baek

Feeding ecology of chaetognaths in the Yellow Sea and the East Sea inferred from gut content and fatty acid analyses
Hyunjin Yoon and Se-Jong Ju

Zooming in microbiome dynamics for short and intensive observation (replace) during *Akashiwo sanguinea* (Dinophyta) blooms
JunSu Kang, Hyun-Jung Kim, Taek-Kyun Lee and Seung Won Jung

Analysis of planktonic bivalve larvae focusing on *Anadara kagoshimensis* and *Tegillarca granosa* and using metagenomics next-generation sequencing in the Boseong coastal waters, South Korea
Hyun-Jung Kim, JunSu Kang and Seung Won Jung

Description of new vessel hull fouling diatom *Olifantiella* (Naviculales, Bacillariophyceae) from the northwest temperate Pacific region
Joon Sang Park and Seung Won Jung

The utilization of cold-water zooplankton as prey for chum salmon fry (*Oncorhynchus keta*) in Yamada Bay, Iwate, Pacific coast of northern Japan
Yuichiro Yamada, Kei Sasaki, Kodai Yamane, Miwa Yatsuya, Yuichi Shimizu, Yoshitomo Nagakura, Tadahide Kurokawa and Hideki Nikaido

Population dynamics of marine cladocerans in the offshore area in Suruga Bay, Japan
Akiyuki Kenmochi, Hiroyuki Matsuura, Takashi Yoshikawa, Rumi Sohrin, Yumiko Obayashi and Jun Nishikawa

Basin-shelf connectivity of the zooplankton community in Bering Canyon, Alaska USA
Colleen Harpold, Carol Ladd, Wei Cheng, Janet Duffy-Anderson and Phyllis Stabeno

Plankton production in spring around the Izu Ridge, south of Honshu, Japan
Kiyotaka Hidaka, Shinji Shimode, Takashi Setou and Tadafumi Ichikawa

Life history and food-habit of a lophogastrid *Gnathophausia longispina* in Suruga Bay, Japan
Jun Nishikawa, Sohta Yonekubo, Takashi Yoshikawa, Hiroyuki Matsuura, Rumi Sohrin and Yumiko Obayashi

Responses of bacterial communities and extracellular enzyme activities to addition of protein or free amino acids in the subtropical and subarctic North Pacific
Yumiko Obayashi, Satoru Suzuki and Koji Hamasaki

Response of the ubiquitous pelagic diatom *Fragilaripsis doliolus* to manganese nodule exposure
Joon Sang Park and Kyun-Woo Lee

Oceanological, hydrochemical and micronecton investigations in the upper epipelagic zone of the northeastern Pacific Ocean in march 2019
Anna S. Vazhova, Albina N. Kanzeparova, Alexey A. Somov, Denis S. Kurnosov, Svetlana Yu. Orlova, Mikhail A. Zuev and Alexey M. Orlov

FIS Contributed Paper Session

Convenors: *Xianshi Jin (China), Jackie King (Canada)*

Background

This session invited papers addressing general topics in fishery science and fisheries oceanography in the North Pacific and its marginal seas, except those covered by Topic Sessions sponsored by the Fishery Science Committee (FIS).

Summary of presentations

The Fisheries Science Committee held a half day Contributed Papers Session with poster presentations onOctober 24, 2019 and paper presentations on October 25, 2019. The session was comprised of papers addressing general topics in fishery science and fisheries oceanography in the North Pacific and its marginal seas. There were 11 poster presentations and 6 paper presentations with 3 presentations from Early Career Scientists. The FIS Best Poster Presentation Award was presented to Kei Nakaya (Japan) for "Early life history of Japanese horse mackerel *Trachurus japonicus* in the north Satsunan area, southern Japan".

List of papers

Oral presentations

Revisiting Lasker's stable ocean hypothesis: The influence of wind events on larval fish mortality in the southern California Current Ecosystem
Brendan D. Turley and Ryan R. Rykaczewski

Impacts of environmental changes on ichthyoplankton assemblages in the northern Bering Sea
Yuki Takemuro, Yukari Kurihara, Yui Kono, Atsushi Yamaguchi, Hisatomo Waga, Atsushi Ooki, Toru Hirawake and Orio Yamamura

Distributional changes of NE Pacific groundfish owe more to ontogeny than to temperature change
Lingbo Li, Anne Hollowed, Edward Cocket and Michelle McClure

Environmental variables effects on the early growth of largehead hairtail (*Trichiurus japonicus*) in China Seas
Peng Sun, Qi Chen, Jianchao Li, Haiqing Yu, Zhenjiang Ye, Yang Liu, Chi Zhang, Yongjun Tian

Estimation of the potential fisheries production in the Korean waters based on ecosystem approach
Hyunjoo Lee, Seonggil Go and Sukgeun Jung

State of chinook salmon Oncorhynchus tschawytscha (Walbaum) stock in Kamchatka territory
Olga Zikunova

High resolution Sockeye salmon (*Oncorynchus nerka*) early marine growth a response to environmental conditions
Yuliya Kuzmenko, Tymofiy Spesivy, Evgeny Pakhomov and Brian Hunt

Poster presentations

Interannual diversity Bering Sea pollock spatial distribution due to ocean warming in continental shelves of the Bering and southern Chukchi Seas
Mikhail A. Stepanenko and Elena V. Gritsay

Age and growth of *Ceratoscopelus warmingii* (Myctophidae) in the South China Sea
Yan Wang, Jun Zhang, Zuozhi Chen, Yane Jiang, Shannan Xu and Yutao Yang

Whole body energy density of juvenile Pacific Herring (Clupea pallasii) in the Strait of Georgia in the fall of 2012-2018
Hilari Dennis-Bohm, (presented by Jennifer L. Boldt), Matthew Thompson, Matthew H. Grinnell, and Jaclyn Cleary

Impact of a marine heat wave on Pacific salmon habitat
Steve Lindley and Nate Mantua

Early life history of Japanese horse mackerel *Trachurus japonicus* in the north Satsunan area, southern Japan
Kei Nakaya, Gen Kume, Toru Kobari, Tsutomu Takeda, Hiroumi Kuroda, Mutsuo Ichinomiya, Tomohiro Komorita, Junya Hirai, Maki Aita-Noguchi and Fujio Hyodo

Seasonal occurrence pattern of leptocephali in the north Satsunan area, southern Japan
Gen Kume, Satoru Jinno, Toru Kobari, Kazuhiro Shiozaki, Atsushi Narumi, Shuya Ito, Kei Nakaya, Mutsuo Ichinomiya and Tomohiro Komorita

Potential habitat of skipjack tuna in the western North Pacific using HIMAWARI satellite data
Hiromichi Igarashi, Hiroshi Ishizaki, Masafumi Kamachi, Yoichi Ishikawa, Fumihiro Takahashi, Yoriko Arai, Shinichi Sekioka and Sei-Ichi Saitoh

Interalnual features of Walleye pollock distribution off the southern Kuril Islands
S. Ovsyannikova, E. Ovsyannikov and A. Sheybak

Spatio-temporal modelling of size distributions with incomplete survey data in a flat fish
Jin Gao, Noel Cadigan, Laura Wheeland and Bob Rogers

Reconstructing salmon runs to support sustainable fisheries management
Lingbo Li, Brittany Jenewein and Pieter Van Will

Predicting spatially explicit growth potential and contribution to recruitment for Pacific Ocean perch in the Gulf of Alaska
Christopher N. Rooper, Jennifer L. Boldt, Sonia D. Batten and Peter J. Hulson

MEQ Contributed Paper Session

Convenors: *Guangshui Na (China), Andrew Ross (Canada)*

Background

Papers are invited on all aspects of marine environmental quality research in the North Pacific and its marginal seas, except those covered by Topic Sessions sponsored by the Marine Environmental Quality Committee (MEQ).

Summary of presentations

The goal of the MEQ-P session is to provide a forum for speakers, including early career scientists, who wish to make a presentation related to Marine Environmental Quality at a PICES Annual Meeting but who cannot be accommodated by other sessions due to the subject matter, the number of abstracts submitted to those sessions, and/or the scheduling of oral and poster sessions at the meeting. Scheduling of MEQ-P and poster sessions towards the end of the PICES-2019 meeting, together with the number of other MEQ-sponsored sessions (including S7 and S10), may have contributed to the small number of MEQ-P papers presented this year. Indeed, the talk originally scheduled to start the MEQ-P session was subsequently moved to S10, at the author's request.

During his opening remarks the Chair indicated that the remaining talks would take place on schedule in accordance with the instructions given to session conveners. This was particularly important given the last-minute change of venue for MEQ-P, which might otherwise have resulted in conference attendees missing talks given at a different time and/or location than originally scheduled. Nevertheless, the session was fairly well attended with the speakers being called upon to field a number of questions from the audience regarding marine debris and plastic pollution.

The first talk described the use of observer data gathered via a pelagic long-line fishery based in Hawai'i to estimate the abundance of marine debris in part of the central North Pacific that includes the subtropical convergence zone (STCZ). Such zones are highly productive but tend to accumulate debris, such as the eastern Pacific garbage patch (EPGP). Using data gathered since 2007 and an appropriate (generalized linear/zero-inflated negative binomial) modelling approach, it was possible to determine an annual standardized catch per unit effort (CPUE) for debris in deep and shallow waters. Key findings include the prevalence of derelict nets in the STCZ, moving towards the EPGP in accordance with model trajectories of surface drifters, and a steady decline in marine debris, which is consistent with a global moratorium on large pelagic driftnets.

The second and final talk described microplastic pollution in Nepal, a developing Asian country on China's southern border. Using methods previously applied to the collection and analysis (by microscopy and FTIR-ATR) of samples from rivers and roadsides in China, Japan and Vietnam the abundance and composition of microplastic (MP) particles in roadside dust from Kathmandu and the receiving waters of the Bisunumati and Bagmati Rivers were compared with those measured in other western Pacific countries. The numbers of MP particles found in Nepalese samples were at least 2 orders of magnitude greater than those found in China, Japan or Vietnam. The high relative abundance of polyacrylate in river and waste water suggests the latter as a significant source of microplastics, and a need for better waste water management, in Nepal.

To summarize, talks in this session demonstrated the value and importance of engaging industry and other stakeholders in monitoring marine environmental quality, and of turning attention to developing countries and other less well-studied regions to understand more fully the extent to which microplastics and other pollutants impact the North Pacific and its marginal seas. In addition, 2 posters on perfluorinated and radioactive contaminants were submitted to MEQ-P for presentation during PICES-2019.

List of papers

Oral presentations

Marine debris as bycatch: Using fishery observer data to estimate trends over time in the North Pacific Subtropical Convergence Zone
Amy V. Uhrin, William A. Walsh and Jon Brodziak

Occurrences of microplastics in surface water of Bisunumati and Bagmati Rivers, and on the roads in Kathmandu city, Nepal
Moemi Okamoto, Shuhei Tanaka, Satoru Yukioka, Shigeo Fujii, Sangeeta Singh and Hideshige Takada

Poster presentations

Perfluorinated environmental contaminant concentrations in sea turtle blood and eggs from Hawaii to Saipan
Cathryn Wood, George H. Balazs, Marc Rice, Thierry M. Work, T. Todd Jones, Eleanor Sterling, Tammy M. Summers, John Brooker, Lauren Kurpita, Cheryl King and Jennifer M. Lynch

Monitoring for radiocesium in sea-sediment around off Fukushima
Daisuke Ambe, Shigeho Kakehi, Yuya Shigenobu, Toru Udagawa, Daisuke Hasegawa and Takami Morita

POC Contributed Paper Session

Convenors: *Emanuele Di Lorenzo (USA), Yury I. Zuenko (Russia)*

Background

Papers were invited on all aspects of physical oceanography and climate in the North Pacific and its marginal seas, except those covered by Topic Sessions sponsored by the Physical Oceanography and Climate Committee (POC).

List of papers

Oral presentations

Pacific water in the northeastern Chukchi Sea
Miaki Muramatsu, Hiromichi Ueno, Motoyo Itoh, Eiji Watanabe and Jonaotaro Onodera

Non-seasonal variability of the Kuroshio shelf intrusion and its associated changes in the ocean environment over the East China Sea during 1993-2017
Jiwon Kang and Hanna Na

Global distribution and interannual variation of winter halocline
Masato Oda, Hiromichi Ueno, Katsura Yasui and Humio Mitsudera

Dynamic biogeography of the subarctic North Pacific
Kathleen Dohan, William Sydeman, Chelle Gentemann, Marisol Garcia Reyes (presenter), Brian Hoover and Sonia Batten

Impact of surface waves on wind stress under low to moderate wind conditions
Sheng Chen, Fangli Qiao, Wenzheng Jiang, Jingsong Guo and Dejun Dai

Effects of the non-breaking surface wave induced vertical mixing on winter mixed layer depth in subtropical regions
Siyu Chen, Fangli Qiao, Chuanjiang Huang and Zhenya Song

The 2019 Alaskan Heatwave and recent changes in North Pacific climate
Emanuele Di Lorenzo and Dillon Amaya

An evaluation of the short-term prediction skill of FIO-ESM in the North Pacific
Yajuan Song, Yiding Zhao and Xunqiang Yin

Poster presentations

Short-term forecasting for Korean coastal sea surface temperature and monitoring its levels based on Machine-Learning algorithms
Seunghwan Lee, Yoonsang Cho, Yong Huh, Gwangnam Han and Donghyeon Yu

Prediction of SST fronts using a recurrent neural network (RNN) in the South Sea of Korea
Eun-Joo Lee, Jeong-Yeob Chae, Jae-Hun Park, Yong Huh and Kwang-Nam Han

GP - General Poster Session

Poster presentations

Influence of El Niño events on wintertime North Pacific atmospheric river, water vapor transport and precipitation
Xuejuan Ren and Yating Xiong

Vulnerability of marine ecosystems to stressors
Jocelyn C. Nelson, Lucie C. Hannah and Cathryn Clarke Murray

Jellyfish blooms in coastal waters nearby thermal discharges of nuclear power plant
Chunjiang Guan, Yongjian Liu, Chuan Jia and Hao Guo

Population structure of *Ampithoe valida* (Amphipoda) in Cheongsapo, Busan of South Korea
Ye Ji Lee and Won Gyu Park

Development of a multi-target tissue approach for the prediction of non-uniform accumulation of radioactivity in fish
Kyeong Ok Kim, Roman Bezhenar, Vladimir Maderich, Hanna Kim, Mee Kyung Kim and Kyung Tae Jung

Submarine groundwater discharge (SGD) and coastal biogeochemistry in Jeju Island by Typhoon
Byung-Chan Song and Tae-Hoon Kim

Spatio-temporal variations of Dissolved Organic Matter (DOM) in coastal water of Jeju Island
Jin-Wook Song and Tae-Hoon Kim

Persistency in the DMSLs of sea level in the Coast of Korea
Ho-kyun Kim

Separation of Pacific skipjack and bigeye tuna fishing grounds using public domain catch data
Shirley Leung and LuAnne Thompson

Subtidal biodiversity on the central coast of British Columbia
Matthew Lemay, Gillian Sadlier-Brown, Kyle Hall and Matthew Whalen

Forecasting the demand of extruded pellet feed in Korea
Juhyun Yi and Dohoon Kim

Optimizing sea urchin gonad enhancement with newly-designed formulated feeds and assessing benthic impacts of commercial-scale sea urchin farming to ensure environmental sustainability.
Emily M. Warren, Mark Flaherty, Stephen F. Cross and Christopher M. Pearce

A traits-based approach to predict predator-prey uncoupling under climate change scenarios
Cole B. Brookson and Stephanie J. Green

A retrospective study on spatio-temporal dynamics of pacific herring (*Clupea pallasii*) spawning groups in East Bering Sea
Shohei Sasabe and Naoki Tojo

Transecting the Riverine Coastal Domain – observations of oceanographic properties on British Columbia's central coast from an estuary to the open ocean
Bryn Fedje, Emma Myers, Chris Mackenzie, Chris O'Sullivan, Eva Jordison, Jessy Barrette, Justin del bel Belluz, Eddy Carmack and Jennifer Jackson

FUTURE Workshop (W1)
Learn to effectively communicate your science

Convenors: *Jackie King (Canada), Manu Di Lorenzo (USA), Mitsutaku Makino (Japan), Matt Baker (USA)*

Invited Speakers:
Cherisse Du Preez (IOS-DFO, Canada)
Alison Morrow (K5News, King County, WA, USA)

Background

As the integrative Science Program of PICES, FUTURE ('Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems') facilitates research on how marine ecosystems in the North Pacific respond to climate change and human activities, and on forecasting ecosystem responses to those stressors. Another key objective of FUTURE is to effectively communicate new insights of PICES science to its members, governments, stakeholders and the public, a skill that is not broadly shared among PICES scientists. It is challenging to convey the complex and integrative research undertaken by PICES scientists, but it is essential that results of ecosystem science are accessible to diverse audiences in order for our science to have a meaningful impact on society. That accessibility requires us as scientists to develop our own ability to communicate science concepts and research with outreach products. In this workshop, professional science communicators provided training on how PICES scientists can effectively communicate their science to diverse audiences.

Summary of presentations

A key activity of the FUTURE Science Program is communication of PICES science, yet few scientists receive training on how to communicate to people outside of the scientific community. To address this gap, FUTURE sponsored a 1-day Workshop on "*Learn to effectively communicate your science*" on October 18 at PICES-2019. The Workshop also served as a follow-up from the PICES-2018 Topic Session on "*Science communication for North Pacific marine science*".

This activity-based Workshop had two Invited Speakers: Alison Morrow (Morrow Media, USA) and Cherisse Du Preez (Fisheries and Oceans Canada, Canada) both with expertise on communicating science to the general public. Alison Morrow drew on her experience as an Environmental Science news reporter with a major TV station, and her current career in producing her own podcasts on environmental science. She introduced the concept of a revolution in news media, with the majority of the public now receiving their news from online sources, such as YouTube and podcasts. News media require rapid responses from scientists, and simple messages. Alison provided strategies when interacting with news media: Be able to describe your research in three words (*i.e.*, create your own headline), remove jargon from the story, stick to one issue only, and have a short one-page handout to give the reporter as a take-away for a broader background. Cherisse Du Preez provided an overview of social media and the various platforms available for scientists to connect with the public. Cherisse often partners with communication experts to broadcast her deep-sea ecology expeditions to a broad audience. Her live video feeds of remotely operated vehicle (ROV) dives have generated 231 media stories, been viewed by 3.7 million people and watched in 130 countries.

The Workshop had four tutorials led by Convenors and Invited Speakers: *The Message Box and Elevator Pitches* (Leads: J. King, A. Morrow, E. Di Lorenzo), *Video Blogs, Blogs and Podcasts* (Leads: M. Baker, A. Morrow), *Developing a social media strategy and Twitter-style presence* (Lead: C. Du Preez), and *How to make your own science video* (Lead: E. Di Lorenzo).

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

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

List of papers

Oral presentations

Communicating science through social media 101: the art of speaking nerdy (Invited)
Cherisse Du Preez

Be your own newsroom: how to make your science engaging (Invited)
Alison Morrow

FIS Workshop (W2)
Integrating biological research, fisheries science and management of Pacific halibut and other widely distributed fish species across the North Pacific in the face of climate and environmental variability

Co-sponsor: *IPHC*

Convenors: *Josep Planas (International Pacific Halibut Commission - IPHC), Gordon Kruse (University of Alaska Fairbanks, USA), Chris Rooper (DFO, Canada), Roman Novikov (Kamchatka Research Institute of Fisheries and Oceanography, Russia), Naoki Tojo (Hokkaido University, Japan)*

Invited Speakers:
Janet Duffy-Anderson (NOAA, USA)
Mark Lomeli (PSMFC, USA)
David Wilson (IPHC)

Background

The North Pacific Ocean is a large and productive ecosystem that is characterized by strong interdecadal climate variability. One of the key species in the North Pacific Ocean ecosystem is the Pacific halibut due to its wide distribution along the continental shelf throughout the North Pacific and to its important trophic position. In addition to its key ecological role, the Pacific halibut is highly relevant from a socio-economic and cultural perspective in the North Pacific Ocean region because it supports important commercial, recreational and ceremonial or subsistence fisheries. In the Northeastern Pacific Ocean, the Pacific halibut stock in waters off north American is managed by the International Pacific Halibut Commission (IPHC) that also conducts research on the biology of the species. Due to its highly migratory nature, its key ecological role and its wide distribution in the North Pacific Ocean, increased efforts are needed to expand and integrate information on the

biology and the management of the Pacific halibut and interacting species across all countries involved in its fisheries, particularly in the face of a changing North Pacific. Therefore, the main objective of this Workshop was to provide state-of-the-art information on important current topics related to the biology and fishery of Pacific halibut and interacting species by bringing together researchers, scientists and managers from countries that are invested in this resource.

Summary of presentations

The 1-day workshop held on October 18, 2019 consisted of 3 invited and 13 contributed oral presentations, in addition to 9 posters, on specific topics related to the biology of the Pacific halibut and interacting species as well as management and policy issues. The presentations were organized around four major topics: Pacific halibut fishery management (introduced by invited speaker Dr. David T. Wilson, Executive Director of the International Pacific Halibut Commission), bycatch and discard survival assessment (introduced by invited speaker Dr. Mark Lomeli of the Pacific States Marine Fisheries Commission), migration (introduced by invited speaker Dr. Janet Duffy-Anderson of the Alaska Fisheries Science Center-NOAA) and growth/size-at-age of Pacific halibut.

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

List of papers

Oral presentations

The International Pacific Halibut Commission: approaching 100 years of science-based fishery management decision making (Invited)
David T. Wilson

Accounting for temporal variability in productivity and dynamic reference points in tactical and strategic decision-making
Allan Hicks, Piera Carpi and Ian Stewart

Features of the Pacific halibut fishery in the western part of the North Pacific Ocean
Roman Novikov and Igor Glebov

Fully subscribed: Evaluating yield trade-offs among sectors utilizing the Pacific halibut resource
Ian Stewart and Allan Hicks

Reducing Pacific halibut bycatch in groundfish bottom trawl fisheries: A review of trawl modifications (Invited)
Mark J.M. Lomeli, W. Waldo Wakefield and Bent Herrmann

Model-based discard mortality rates of Pacific halibut from covariates in the North Pacific trawl fishery
Geoffrey M. Mayhew and Jennifer A. Cahalan

Alaska's approach to estimating recreational discard mortality of Pacific halibut
Sarah Webster and Scott Meyer

Improving discard mortality rate estimates of Pacific halibut (*Hippoglossus stenolepis*) in the directed longline fishery
Claude L. Dykstra, Timothy Loher, Ian J. Stewart, Allan C. Hicks, Nathan Wolf, Bradley P. Harris and Josep V. Planas

Controlled experiments to explore the use of a multi-tissue approach to characterizing stress in wild-caught Pacific halibut (*Hippoglossus stenolepis*)
Anita C. Kroska, Nathan Wolf, Josep Planas, Matthew R. Baker, T. Scott Smeltz and Bradley P. Harris

The visual system of flatfish: how retinal studies can help assess and reduce fisheries bycatch mortality
Inigo Novales Flamarique

Process and mechanistic studies of Pacific halibut early life stages can inform management strategy and decision making in the North Pacific (Invited)
Janet Duffy-Anderson, Esther Goldstein, Josep Planas, Lauri Sadorus, Ian Stewart and Ray Webster

Early life connectivity of Pacific halibut (*Hippoglossus stenolepis*) within and between the Bering Sea and Gulf of Alaska
Lauri L. Sadorus, Esther Goldstein, Raymond Webster, Josep V. Planas and Janet Duffy-Anderson

Movements of Pacific halibut (*Hippoglossus stenolepis*) in the Bering Sea and Aleutian Islands: evidence of variance in relative connectivity and regional spawning dynamics
Timothy Loher

Assessing the potential for competition between Pacific halibut and arrowtooth flounder in the Gulf of Alaska
Cheryl L. Barnes, Anne H. Beaudreau, Mary E. Hunsicker and Lorenzo Ciannelli

Environmental, ecological, and fishery effects on size-at-age of Pacific halibut
Jane Y. Sullivan, Gordon H. Kruse, Steven J.D. Martell and Franz J. Mueter

Exploring the role of diet in driving declining size-at-age in Pacific halibut in the Gulf of Alaska
Brian Ritchie, Nathan Wolf, Ian Stewart, Josep V. Planas and Bradley P. Harris

Poster presentations

Genetic population structure of Pacific halibut: Progress to date
Lorenz Hauser, Daniel Drinan, Heather Galindo, and Tim Loher

Pacific halibut (*Hippoglossus stenolepis*) maturity status explored via histology and macroscopic maturity staging methods
Teresa Fish, Nathan Wolf, Bradley P. Harris and Josep V. Planas

Genetic sex identification of Pacific Halibut (*Hippoglossus stenolepis*) commercial landings
Anna Simeon, Dan Drinan, Lorenz Hauser, Timothy Loher, Lara Erikson, Ian J. Stewart and Josep V. Planas

Identification of molecular growth signatures in skeletal muscle of juvenile Pacific halibut (*Hippoglossus stenolepis*) for monitoring growth patterns in wild fish
Josep V. Planas, Dana Rudy, Anna Simeon and Thomas P. Hurst

A decade of coastwide environmental monitoring on the annual IPHC fishery-independent setline survey and practical applications of the data in a spatio-temporal assessment model
Lauri L. Sadorus and Raymond Webster

Can we reconstruct the growth history of the Pacific halibut (*Hippoglossus stenolepis*) population by otolith increment analysis?
Dana Rudy, Joan Forsberg, Tim Loher, Ian Stewart, Chris Johnston, Robert Tobin and Josep V. Planas

Re-ageing of archived otoliths from the 1920s to the 1990s at the International Pacific Halibut Commission
Joan E. Forsberg, Dana Rudy, Chris Johnston, Robert Tobin and Ian J. Stewart

First records of killer whales (*Orcinus orca*) depredation on Greenland turbot (*Reinhardtius hippoglossoides*) and Pacific halibut (*Hippoglossus stenolepis*) fisheries in Western Bering Sea
Olga A. Belonovich, Roman N. Novikov, Dmitry A. Terent'ev

FIS Workshop (W3)
Let's play the GAME! (to achieve sustainable fisheries development in the PICES regions)

Convenors: *Aoi Sugimoto (JFRA, Japan), Siri Hakala (NOAA, USA)*

Invited Speaker:
Yuuki Terada (the University of Tokyo, Japan)

Background

Sustainable fisheries development has been one of the most critical issues for marine sciences among PICES countries. Despite the obvious importance of this issue, it has been challenging to achieveecologically, economically, and socially balanced fisheries development in the PICES region. Given the complexity of the above three pillars for considering the issues related to sustainability of socio-ecological systems, serious games have increasingly proven their value in contributing to the analysis and design of such systems. One of the most significant examples among numerous projects is the series of MSP (Marine Spatial Planning) games which have been developed through EU transdisciplinary marine science platforms at an ICES Workshop, November 2011. Thus, serious games are now recognized as an influential tool to promote discussion on the sustainable use of marine resources among scientists, policy makers, business sectors, NGO/NPOs and local communities. Given this trend, a serious game workshop focused on sustainable fisheries development, where particpants would play a game among policy makers, citizens, business sectors and PICES scientists to enhance the discussion on sustainable fisheries development in the North Pacific region, was proposed. The intent of the workshop was to enhance the participant's understanding of potential similarities and differences of sustainable fisheries among PICES countries, which could lead to new research, education, and outreach projects among them.

Summary of presentations

Aoi Sugimoto (HD, WG 41) reported on *W3: Let's Play the GAME! (to achieve sustainable fisheries development in the PICES regions*). The goal of this workshop was to demonstrate the application of serious game methods in the context of marine resource management.

Workshop participants (9 people from 4 countries (including 4 students, 5 females, 4 males) learned about serious game applications in education and challenges in the development of games to highlight key choices, and participated in one round of the game with roles determined by goals suggested by the participants.

The key findings of the workshop were as follows:

- Players could not help expressing their real-world behaviors during the game regardless of socio/econ/ cultural position(scientists/fishers/managers) and the scale of the workshop setting (local – regional – international);
- PICES scientists showed "much less money-centered", and "much more environment-centered" behavior than other groups that have done this exercise in Japan;
- Serious game methodology has been attracting people in/outside of Japan, and in/outside of the marine science community, which could mean this method is useful for stakeholder engagement in the marine/fishery resource governance.

Workshop 3 participants playing the GAME.

List of papers

Oral presentations

Let's play the fishing village revitalization game to achieve sustainable fisheries development in the PICES regions (Invited)
Yuuki Terada, Hiroaki Sugino, Osamu Imai, Aoi Sugimoto, Takaaki Matsuki

POC/FIS/BIO Workshop (W4)
Circulation, biogeochemistry, ecosystem, and fisheries of the western North Pacific marginal seas: Past and future of CREAMS (Circulation Research of East Asian Marginal Seas)

Convenors: *SungHyun Nam (Korea), Fei Yu (China), Joji Ishizaka (Japan), Yuri I. Zuenko (Russia)*

Invited Speaker:
Kuh Kim (Formerly, Professor of Physical Oceanography at Seoul National University, Korea)

Background

The western North Pacific, one of the areas of the global ocean most affected by climate change and anthropogenic activities, consists of several marginal seas. Two time series programs have contributed to significant advances in understanding of these seas/regions, named East Asian Seas Time-series (EAST-I and EAST-II regions) since the CREAMS (Circulation Research of East Asian Marginal Seas) program was initiated beyond the national borders several decades ago (early 1990s). We proposed a workshop that involves participation from multiple PICES committees and focuses on circulation, biogeochemistry, ecosystems, fisheries, and human interactions of the East Asian Marginal Seas.

This workshop provided a forum for summarizing progress made during the decades of CREAMS and during the 15 years of the PICES Advisory Panel (AP-CREAMS; active since 2005) since its birth in early 1990s, and for envisioning the future of CREAMS over the coming decades. This workshop was an opportunity to share the knowledge/findings and experience/lessons learned in hydrodynamics, biogeochemistry, ecosystem, and fisheries variability at multiple scales in the regions. There were contributions from studies including, but not limited to, weakening of ventilation, mesoscale eddies, shelf circulation, Kuroshio intrusion, changes of biological community structures, and more. We also discussed cooperation of the CREAMS with other international organizations/programs such as WESTPAC WG06, NOWPAP, and more.

Summary of presentations

About 30 persons attended this 1-day workshop on October 18, 2019. One invited, 14 oral and 1 poster presentations were made at W4. PICES members from four countries contributed the presentations. The workshop started with a brief introduction by Prof. SungHyun Nam, outlining the need to summarize progress made during the decades of CREAMS and the 15 years of the AP-CREAMS, and to envision the future of this program.

An invited talk by former Prof. Kuh Kim introduced his personal lessons learned from 1973's MODE (Mid-Ocean Dynamics Experiment) where more than 100 scientists participated. The experiment provided conclusive evidence of mid-ocean eddies, bottom-intensified currents, and more, and his personal learnings (highly variable eddies in space and time, only beginning of new and full understanding, critical importance of instruments, calibration, and quality control of data, unselfish cooperation of scientists, open ocean *vs* marginal seas) as a graduate student at that time that motivated him to establish a marginal sea program, CREAMS after returning to Korea. He introduced a detailed history of Pacific Asian Marginal Seas (PAMS) as a follow up of the Japan and East China Seas study (JECSS) in the 1980s, and initiation of CREAMS in the 1990s as a collaborative effort between Korea, Japan, and Russia. Then, progress with the first full understanding of the water mass structure of the EAST-I region was shown with other findings on warming over the entire water column and structural changes in dissolved oxygen and ventilation pattern of the sea. He also introduced descriptions on this program in a series of PICES Press articles published in 1997 and 1998 (including US participation *via* ONR JES), IPCC fourth Assessment Report, and special issues of *Journal of Oceanography* (1999), *Marine Technology Society Journal* (1999), *Progress in Oceanography* (2004), *Deep-Sea Research* (2005), and *Oceanography* (2006).

A contributed talk by Dr. Vyacheslav Lobanov introduced a brief history of further development of a very informal (so successful) CREAMS program along with CREAMS-II (ONR JES DRI) supported by PICES, and leading to the establishment of AP-CREAMS in 2005. The main results in the time series program (EAST-I) achieved *via* POI-SNU joint-cruises since 2001 were introduced and needs for further development of this program, CREAMS 3.0, were suggested considering UN Decade of Ocean Science 2021–2030 and cooperation with other organizations/programs (NEAR-GOOS, WESTPAC WG06, CSK-II, UNEP/NOWPAP, GEOTRACES, PEACE, and PAMS). The WESTPAC WG06 was introduced by Prof. SungHyun Nam on behalf of Prof. Jing Zhang, with an emphasis on recent extension and needs for future cooperation with CREAMS. Dr. Takafumi Yoshida introduced NOWPAP of UNEP where the four member countries, China, Japan, Korea, and Russia have four centers. He showed the history of PICES–NOWPAP collaboration, and the establishment (2014-2015) of the joint PICES-NOWPAP SG which developed a set of prioritized topics (harmful algal blooms and marine pollution) of interest to each organization.

On behalf of Dr. Olga Novikova, Prof. SungHyun Nam showed fisheries results from one of the East Asian Marginal Seas, the Okhotsk Sea. He showed the influence of external environmental factors on the dynamics of the number of Pacific cod and saffron cod of the eastern part of the Okhotsk Sea. Then, long-term variations of microbenthic community in the southern Yellow Sea, influence of the Kuroshio Current on the East China Sea shelf were presented by Dr. Xinzheng Li. He showed global change and long-term variations of the species distribution pattern in the Yellow and East China seas, and long-term variations of the macrobenthic community distribution pattern in the Yellow and East China seas, emphasizing the importance of the region in 32°–33°N on the distribution of macrobenthos. A contributed talk by an early career scientist, Ms. Ji Hyun Kim, showed long-term variations in nutrient concentrations, particularly the N:P ratio, in the upper ocean of the East-I region from the analysis of CREAMS and other historical data collected from 1980 to 2017. A contributed talk by early career scientist, Mr. KyungJae Lee, showed statistical characteristics of the mesoscale

eddies detected, tracked, and grouped in the East-I region using satellite altimeter data from 1993 to 2017. His eddy detecting method from satellite altimetry was verified with hydrographic observations, and statistical characteristics of mesoscale eddies and group categorization were presented with discussions on speed and direction of eddy movement in the sea in comparison with those in the global ocean. Moreover, a contributed talk by early career scientist, Ms. Jiwon Kang, showed non-seasonal variability of the Kuroshio shelf intrusion and its associated change in the environment over the East China Sea during 1993–2017. She introduced Kuroshio shelf intrusion (KSI) index, and seasonal and non-seasonal (intra-seasonal, interannual, and decadal) variations of the KSI in close relationship with wind stress curl and wind stress, air–sea turbulent heat flux, sea surface temperature, and eddy kinetic energy.

During the afternoon, a contributed talk by early career scientist, Mr. Hojun Lee, showed observational results on the cyclonic circulation and retroflection of the Jeju Warm Current in the southern front of the warm-tongue in the northern East China Sea. He presented the Changjiang-Yangze Front (particularly the southern front), the only thermohaline front in the northern East China Sea, well developed in winter, and confirmed from recent hydrographic observations in February 2017 and April 2018 as well as historical hydrographic data, and relevant circulation. A contributed talk by early career scientist, Mr. Min-Young Lee, discussed monthly wet depositional fluxes of organic matter in precipitation of Jeju Island to determine dissolved organic carbon and particulate organic carbon concentrations in precipitation based on the data sampled from January to December 2018 and calculated backward trajectories (HYSPLIT model). A contributed talk by Dr. Yong Xu showed spatial pattern of benthic macroinvertebrate communities and their relationship with environmental variables on the East China Sea shelf. In particular, he described the influence of the bottom current (nearshore branch of intrusion of Kuroshio Current onto the shelf) on the benthic communities based on the sampling with an Agassiz trawl (R/V *Kexue III*). A contributed talk by Prof. G. Kim showed results of estimating the vertical fluxes of nutrients using Ra-228 as a tracer in the EAST-I region. Using the long-lived Ra isotopes (MnO_2 fiber attached to the moorings) he estimated vertical eddy diffusivity (Kz) to 9.6 cm^2/s (averaged over 20 years) at depths ranging from 100 to 500 m. A contributed talk by early career scientist, Mr. Kazuki Ogi, showed the effects of strong turbulent mixing on phytoplankton around the Tokara Strait (shallow, complex topography, many seamounts/islands, strong turbulent intensity) based on *in-situ* observations from 2015 to 2018. He tested his hypothesis that turbulent intensity increases from upstream to downstream Kuroshio, supplying nutrients to the euphotic layer and increasing phytoplankton and rapidly grazing zooplankton. A contributed talk by early career scientist, Ms. JiYun Shin, showed intraseasonal abyssal current variability of bottom-trapped topographic Rossby waves in the southwestern EAST-I region from the analysis of mooring observational data and reanalysis model data. She characterized the bottom-trapped topographic Rossby waves with several parameters and dispersion relations, accounting for the deep intraseasonal current variability in the eastern Ulleung Basin and Ulleung Interplain Gap. In addition, a contributed talk by Dr. Dongfeng Xu showed slope current and diel vertical migration of zooplankton and micronecton in the northern continental slope of the South China Sea where one cyclonic circulation in winter and two counter-rotating circulations in summer are dominant. He presented results from mooring observations in 2015–2017 and drifter observations in October 2014 *vs* June 2015. Diel vertical migration of zooplankton and micronecton derived from acoustic intensity was shown. Also, a poster was presented by early career scientist, Mr. Koki Mukai, on the effect of environmental factors on bloom formation of a toxic dinoflagellate in Kariya Bay of northern Kyushu, Japan.

From the above presentations, we found there was a wide need for international coordination and collaboration to study the variability and changes of hydrodynamics, biogeochemistry, ecosystems, and fisheries, and influence of human activities at multiple scales in the East Asian Marginal Seas, including the Okhotsk Sea and South China Sea. It was also suggested that there be more focus on the interactions among the marginal seas. PICES scientists are vigorously studying processes in this region, and supporting continuation of CREAMS (CREAMS 3.0) with broader impacts. We look forward to continue this program for next term.

List of papers

Oral presentations

History of PAMS, CREAMS-I and II (JES) with important findings in 1981-2005 (Invited)
Kuh Kim

Toward CREAMS 3.0: recent achievements of collaborative studies in the northern Asian marginal seas and future challenges for sustainable development of the region
Vyacheslav Lobanov

Material exchanges between land and the open ocean - A framework for cooperative studies in the western North Pacific Marginal Seas (WESTPAC WG06)
Jing Zhang (presented by SungHyun Nam)

NOWPAP activities and cooperation with PICES
Takafumi Yoshida

Influence of external environmental factors on the dynamics of the number of cod and saffron cod of the Eastern part of the Sea of Okhotsk
Olga Novikova (presented by SungHyun Nam)

Long-term variations of macrobenthic communities from the Yellow Sea and East China Sea, under the climate change
Xinzheng Li

Long-term variations in nutrient concentrations in the upper ocean of the East/Japan Sea
Ji Hyun Kim and Guebuem Kim

Statistical characteristics of East Sea (Japan Sea) mesoscale eddies detected, tracked, and grouped using satellite altimeter data from 1993 to 2017
KyungJae Lee and SungHyun Nam

Non-seasonal variability of the Kuroshio shelf intrusion and its associated changes in the ocean environment over the East China Sea during 1993-2017
Jiwon Kang and Hanna Na

Observations on the cyclonic circulation semi-persistently formed in the northern East China Sea
Hojun Lee, Kyungjae Lee, SungHyun Nam and Jae-Hak Lee

The monthly wet depositional fluxes of organic matter in precipitation of Jeju Island
Min-Young Lee, Tae-Hoon Kim and Na-Yeong Song

Spatial pattern of benthic macroinvertebrate communities and the relationship with environmental variables in the East China Sea shelf
Yong Xu and Xinzheng Li

Estimating the vertical fluxes of nutrients using Ra-228 as a tracer in the East/Japan Sea
Yongjin Han and Guebuem Kim

Effects of strong turbulent mixing on phytoplankton around the Tokara strait
Kazuki Ogi, Naoki Yoshie, Anri Kabe, Toru Kobari, Daisuke Hasegawa and Joji Ishizaka

Intraseasonal abyssal current variability of bottom-trapped topographic Rossby waves in southwestern East Sea (Japan Sea)
JiYun Shin and SungHyun Nam

Diel vertical migration of zooplankton and micronekton on the northern slope of the South China Sea observed by a moored ADCP
Chenghao Yang, Dongfeng Xu, Zuozhi Chen et al.

Poster presentations

Effect of environmental factors on bloom formation of the toxic dinoflagellate *Alexandrium catenella* in Kariya Bay of northern Kyushu in Japan
Koki Mukai, Yohei Shimasaki, Yukie Ohara, Abrianna Elke Chairil and Yuji Oshima

BIO Workshop (W5)
Celebrating two decades of North Pacific CPR sampling, and future directions

Co-sponsor: *CPR Survey at the MBA*

Convenors: *Sonia Batten (Canada), Sanae Chiba (Japan), Bill Sydeman (USA)*

Invited Speaker:
Pierre Hélaouët (Marine Biological Association (MBA), UK)

Background

The North Pacific Continuous Plankton Recorder (CPR) Survey marks its 20th year of collecting data in 2019. This workshop is a chance to celebrate the achievements of the first PICES project at the end of its first two decades and perhaps more importantly, to look forward to the next. Presentations that presented and reviewed the results and diversity of applications resulting from the project to date were encouraged. There have been 25 primary publications utilizing the North Pacific CPR data, spanning large scale oceanography based on satellite data, climate variability and trophic relationships with fish and birds as well as plankton-only foci. The workshop also invited presentations on what could be done with the CPR data and/or sample archive that are particularly relevant to the PICES community, *e.g.*, including further developments of past studies, developing indicators, or metrics for inclusion in ecosystem models, expansion to new parts of the PICES region, integration of plankton data with remote sensing, molecular analyses on specific taxa, or other novel analyses of the samples.

Summary of presentations

As October 2019 marked the completion of the 20th year of North Pacific CPR sampling, it was timely to hold a celebratory workshop at the PICES Annual Meeting to look forward as well as review past accomplishments. The ½-day workshop, held October 18, 2019, began with three introductory talks by the Convenors, covering CPR basics and the history of the North Pacific CPR Survey (Batten), studies that have linked the plankton data with higher trophic levels (Sydeman), and basin-scale studies on PDO-ecosystem variation using data from standard and special surveys conducted in the subarctic North Pacific (Chiba). Our invited speaker, Dr. Pierre Healouet from the North Atlantic CPR Program, described numerical methods for examining plankton communities with 60 years of data to stimulate ideas. There were then three contributed talks which described i) the use of CPR samples to examine spatial variation in ocean productivity patterns using stable isotopes (Brian Hunt), ii) linking zooplankton community structure with large-scale SST and currents data from satellites (Brian Hoover), and iii) the recent expansion of CPR transects into the Arctic Ocean including potential areas for future study (Clare Ostle). The session also included one poster looking at western Pacific large copepod dynamics (Yutaka Fukai). Workshop presentations gave a thorough overview of many aspects of the Pacific CPR program from all regions, from detailed community data to using the sample archive.

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

- There was discussion about finer-scale resolution of the Pacific data since only about 1/3 of the samples are routinely processed. Satellite data can sometimes be used to identify mesoscale processes such as eddies but the sampling resolution of the CPR may miss this. It was pointed out that archived samples can be processed to fill in finer-scale as required for special projects, though there is a limit to how fine a scale CPR data can be used to inform as it is designed for large-scale sampling.

- The issue of microplastics contamination and sampling in CPR samples was discussed. The type of microplastics can be categorized quickly by new technology so that the likely contaminants (fibres) can be eliminated, and there can be a focus on particles whose presence will be due to ocean pollution. It was also mentioned that a time series is necessary to be able to determine when mitigation actions are being successful (as countries try to achieve their sustainability goals) and the CPR offers one of the only possibilities for such a time series.
- There was strong support for continuing to work in the Arctic, especially with the recent declines in sea ice in the northern Bering and Chukchi seas. It was also felt that a north to south transect extending into the transition zone proper would be very useful, for example, Alaska to Hawaii to fill the geographical data gap in lower latitudes.
- There was some discussion on emerging technologies, some of which are being considered alongside the Atlantic CPR program (for example, optical and DNA methods) and the additional sensors that can be attached to the CPR itself (Planktags to record temperature and salinity, CO_2 sensors). The group agreed that having simultaneous physical data was valuable since satellites only see the surface skin and salinity especially would be useful.
- The value of the funding consortium was seen as a major strength in that it gives the survey resiliency if one party withdrew. The importance of having early results, being timely with updates, and getting these updates into regular assessments was also seen as contributing to the success of the survey.

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

List of papers

Oral presentations

Background and evolution of the North Pacific CPR Survey
Sonia Batten

A review of studies using the data to understand upper trophic level dynamics
William Sydeman

A review of studies using the western Pacific CPR survey data
Sanae Chiba

60 years of plankton community in the northern North Atlantic Ocean (Invited)
Pierre Helaouet

Defining isoscapes in the Northeast Pacific as an index of ocean productivity
Boris Espinasse, Brian P.V. Hunt, Sonia D. Batten and Evgeny A. Pakhomov

Interannual variation in regional zooplankton community structure in the eastern North Pacific
Brian Allan Hoover, Marisol García-Reyes, Sonia Batten, Chelle Gentemann, Kathleen Dohan and William Sydeman

Extending the North Pacific CPR Survey pole-ward into the Arctic and potential future investigations
Clare Ostle, Sonia Batten, Jon Fisher, David Johns, Humfrey Melling, Doug Moore, John Nelson and Rowena Stern

Poster presentation

Seasonal abundance, population structure, and diel changes in abundance of five large dominant copepods evaluated by CPR samples collected in the western subarctic Pacific
Yutaka Fukai, Sanae Chiba, Sonia Batten, Yuka Sasaki, Hiroya Sugisaki and Atsushi Yamaguchi

HD Workshop (W6)
Assessing marine ecosystem services: A comparative view across the North Pacific

Convenors: *Daniel K. Lew (USA), Shang Chen (China)*

Invited Speaker:
Chanda Littles (US Army Corps of Engineers, USA)

Background

The PICES Working Group on Marine Ecosystem Services (WG-MES/WG 41) was established to facilitate exchange of information and share the experiences and approaches used to identify, measure, value, and use marine ecosystem services (MES) information in North Pacific waters in order to promote ecosystem service science and improve the consideration of MES in decision making related to marine integrated management. To accomplish this, the working group is conducting two projects. One task is to review the range and types of MES found in the North Pacific region and compares the methods used to measure and value them using case studies for a subset of MES across countries. The second is a survey project that will collect information, opinions and experiences from resource managers, researchers, policy analysts and decision makers from multiple North Pacific countries. The information collected will provide country-specific insights into how MES information is valued and utilized in decision making, and provide guidance on prospects and potential for future use and integration in policy analyses and decision processes. The results of the survey should identify challenges and opportunities for improving the utility of MES information. This workshop has two primary goals: (1) to share and synthesize results of country-specific reviews of the MES literature in the North Pacific region and (2) to update progress on development of the survey to collect information on the knowledge, current and future utilization, challenges, and opportunities related to MES ecological, economic, and sociocultural information. To this end, the intent of the workshop presentations was to focus on the progress and results for the working group's projects. Although the focus of the workshop presentations and discussion are on the working group's activities, other interested scientists interested in MES were highly encouraged to attend and participate.

Summary of presentations

On Saturday, October 19, 2019, the Working Group on *Marine Ecosystem Services* (WG-MES/WG 41) convened the workshop, "Assessing marine ecosystem services: A comparative view across the North Pacific." The session was a full day in length and included presentations and discussion. The morning session consisted of presentations and an extended discussion period. The afternoon session involved focused discussions on MES, primarily by members of WG-MES and the invited speaker.

The workshop was co-convened by Dr. Dan Lew (USA) and Dr. Shang Chen (China) and was sponsored by the HD committee. At the last minute, Dr. Chen was unable to attend in person, so it was chaired by Dr. Lew, who provided an introduction that included a description of the session and its goals and introductory material on marine ecosystem services. The session was well-attended, with 17+ people in the morning session and a smaller group in the afternoon. Five speakers were originally scheduled to give presentations, but three cancelled. One WG-MES member (Dr. Gisele Magnusson) volunteered to fill the spot left vacant by the last-minute cancellation by Dr. Chen. Her presentation was a good fit for the workshop and complemented one of the other presentations, since it was on the same subject (environmental economic accounting in system of national accounts).

There were three presentations in the morning session. The first was by the invited speaker, Dr. Chanda Littles, who presented work she and her colleagues had done while at the U.S. Environmental Protection Agency (EPA). Her presentation focused on work to assess final ecosystem goods and services (FEGS) in coastal habitats in the temperate North Pacific. They took a weight of evidence (WOE) approach for assessing habitat-FEGS linkages that was applied to a systematic review of the ecosystem services literature, wherein each study found in the literature was evaluated on several scoring criteria to assess linkages between FEGS and coastal habitats. Their analysis demonstrated the varying degrees to which coastal habitats contribute to human well-being through the lens of existing knowledge, as represented by the published ecosystem services literature. Ten types of beneficiaries and twelve types of coastal habitats were examined. The most prevalent habitat-FEGS linkages were found between three types of coastal habitats (estuarine waters, saltmarsh, and mangroves) and three types of beneficiaries (industry, recreation, and indirect services). Most published evidence for FEGS beneficiaries was for the Cortezian and Yellow Sea ecoregions.

The second morning presentation was by Dr. Peng Zhao (Fourth Institute of Oceanography, China), who made a presentation about China's efforts to extend environmental-economic accounting to oceans. He provided background about the United Nations' System of Environmental-Economic Accounting (SEEA) and China's National Resources Asset Accounting frameworks. He then described some of the difficulties with extending these frameworks to the ocean, noting specifically the deficiencies in data availability and the multi-dimensionality of the ocean that make extending these frameworks challenging. His presentation summarized efforts to develop an inventory of the oceanic environmental assets and ecosystem services, as well as progress on efforts to engage stakeholders. He then illustrated the application of these concepts to a pilot study in the Behai Golden Bay Mangrove Reserve in Behai, Guangxi.

The third morning presentation was by Dr. Gisele Magnusson (Department of Fisheries and Oceans, Canada), who described Canada's efforts to develop ocean accounts for environmental-economic accounting purposes. This work was intended to update a 2006 report ("Economic Impact of Marine Related Activities in Canada") that had most recently been updated in 2015 and that had used existing input-output regional economic models to estimate economic impacts of marine-related activities on Canada's economy. Their "Ocean Accounts Pilot" was an effort to develop a satellite account based on the SEEA that would systematically group information for assessing the capacity of ocean ecosystems to deliver services to present and future generations and to monitor and value the flows of services. Dr. Magnusson discussed a number of challenges they faced in this task, including issues raised in Dr. Zhao's earlier talk, such as gaps in data related to access, timeliness, and confidentiality; spatial resolution; and geographic and temporal inconsistencies in time series. She also discussed other challenges related to the need to agree upon definitions (ocean *vs*. coastal *vs*. marine, ecosystem classifications, MES classifications) and valuation (concepts of value and treatment of "non-market" exchange values). In addition, she mentioned that her work was part of the Global Ocean Accounts Partnership (GOAP) and that there was an upcoming meeting to discuss the regional pilots in November 2019 and develop technical guidance documents for the various pilots.

Following the morning presentations, the presenters and audience engaged in a discussion about challenges related to ecosystem service values, including challenges in the measurement and application of these values (economic as well as cultural ones). The afternoon discussion expanded on topics brought up in the morning discussion and covered topics of interest to WG-MES projects. Of particular note is the focus on the concept of final ecosystem goods and services (FEGS) and the classification of ecosystem services that has evolved over the last decade.

List of papers

Oral presentations

Coastal ecosystem services in the Temperate Northern Pacific: An emphasis on beneficiaries (Invited)
Chanda J. Littles, Chloe Jackson, Theodore DeWitt and Matthew Harwell

Developing a system of environmental-economic accounting for oceans: A Chinese perspective
Peng Zhao, Feixue Li and Yunlan Zhang

Ocean accounts for Canada
Gisele Magnusson

SB Workshop (W7)
PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment (Third)

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

Invited Speaker:
Elena Eriksen (Institute of Marine Research, Norway)

Background

The Central Arctic Ocean (CAO) is experiencing a rapid transition, largely driven by a changing North Pacific, that has led to substantial recent loss of sea ice cover, which has opened up the Central Arctic Ocean (CAO) for potential fishing opportunities. Debate and policy initiatives have already been launched for regulating fisheries that have not yet been implemented in the CAO. Scientific research in the CAO remains too scarce to inform and support policy decisions, in stark contrast to the abundance of research occurring in the neighboring North Pacific which informs and influences policy decisions. With substantial science and policy challenges present in the CAO, an integrated ecosystem assessment is a priority task. PICES joined with ICES and PAME for such an assessment by forming PICES WG 39 with its mission period ending in 2018. WG 39's intent, despite its late start, was to provide significant Pacific input into the final joint report. We also had an intersessional workshop in 2019. As a follow-up to these activities, a half-day workshop was held at PICES-2019 to consolidate our findings and advice, connect it to those from ICES, and to report to the wider PICES community. The major emphasis of the third CAO workshop at PICES-2019 was on key locations in the Pacific Arctic and the critical processes to determine biological production, the characterization of major changes for recent decades, and the ramifications for ecosystem monitoring and management in the region. Ultimately needed is sustainable monitoring by ice breakers and research ships in the CAO with coordination among PICES and ICES countries, including both Arctic and non-Arctic nations. One of the tasks for WG 39 was to search for and make use of existing datasets and databases, aided by the general findings of previous reports and literature surveys encompassing the regions.

Summary of presentations

Co-Convenor, Sei-Ichi Saitoh, provided an introduction to the workshop. He began by providing an overview of WG 39 on *Integrated Ecosystem Assessment for the Central Arctic Ocean*, which operates through 2021. WG 39 is a joint working group with ICES, PICES, and PAME (Protection of the Arctic Marine Environment). Currently, seven IEA programs are underway within ICES. The CAO includes both a Pacific Gateway and Atlantic Gateway. In 2017 an agreement was reached to ban fishing in the CAO. An IEA report

was prepared that included a description of the ecosystem, including ecosystem components and connections, as well as vulnerability. Shipping is one of the important activities yet to be addressed.

Invited speaker, Elena Eriksen, spoke about experiences with the Barents Sea Integrated Ecosystem Assessment (IEA). For that region, the Working Group includes about 40 members. Members have a diversity of expertise on the ecosystem. The Barents Sea sits in a transition zone between the Atlantic and Arctic. The Barents Sea is a very productive system for fish, invertebrates, seabirds and marine mammals. The system is well monitored by a joint Norwegian-Russian survey since the 1960s. The region has experienced significant increases in air and sea surface temperature and declines in sea ice, particularly since the 1980s. A large and increasing fraction of the region is covered by warm Atlantic water. This has resulted in an increase in phytoplankton and zooplankton. In general, recruitment has increased to fish stocks, including cod, herring, haddock, capelin, polar cod, and redfish. Fish biomass has increased, particularly in the 2000s, in response to increased recruitment and good fishery management. This system response has led to improved feeding conditions for seabirds and marine mammals. During this time, as boreal species have increased in abundance and distribution, the biomass and distribution on Arctic species has declined. Declines were attributed to habitat loss (smaller area of suitable cold temperature), as well as increased predation pressure.

Individual fish species show diverse trends. The Barents Sea cod stock has increased with an age structure like the unfished stock observed in the late 1940s. Capelin experienced four stock collapses since the early 1970s due to high predation pressure and poor recruitment. Polar cod abundance was large in the early 2000s, but declined with few strong year classes since 2002. The stock was affected by reduced ice, increased temperature and increased exposure to predators. Snow crab was first observed in the Barents Sea in 1996. Since then, the snow crab population has increased in size and expanded its distribution. Cod is a major predator of snow crab; about 10% of the cod diet is comprised of snow crab.

Atlantic water flows through the Barents Sea and into the CAO. Variability in this flow, and associated transport of *Calanus* copepod species, are important considerations for the CAO.

Hiromichi Ueno talked about Pacific water in the northeastern Chukchi Sea. There has been a decline in sea ice in the Pacific sector of the Arctic. Most Pacific water enters the Arctic through the Bering Strait and enters the Canada Basin through Barrow Canyon. Mooring sites were deployed during 2003–2005 and 2015–2017 near Barrow Canyon (BC) and two sites to the northwest (NHC, HSN). The occurrence of Pacific summer water was monitored at the sites. Water from the Barrow Canyon is transported in a west-northwest direction. It appears to take 17 days (range of 1 week to 2 months) for water to be transported from BC to NHC and HSN to the northwest. Temperature and salinity declined between the two periods, suggesting an increase in vertical and horizontal mixing.

Lisa Eisner talked about variations in spring and summer phytoplankton across the northern Bering and Chukchi seas. A motivating question is, how will reductions in sea ice and associated changes will affect the marine ecosystem? Data were collected on surveys during spring 2017 and 2018 (ASGARD program) and summer 2017 and 2019 (Arctic Eis program) plus observations from year-round moorings. Data collections included currents, water properties, sedimentation, microbes, plankton, epifauna, infauna, marine mammals and seabirds. Lisa's talk focused on phytoplankton. Results showed the influence of Alaskan Coastal Water (ACW), Bering Summer Water, and Pacific Winter Water. A phytoplankton hotspot comprised mainly of large phytoplankton occurred off Point Hope, represented primarily by diatoms. In general, the highest chlorophyll-a concentrations were associated with large phytoplankton with some seasonal variation. Large fraction chlorophyll-a was associated with diatoms in spring and with diatoms and dinoflagellates in summer. High stratification in the northeast was associated with low biomass of the large size fraction of phytoplankton.

Results from different transects were presented. In August 2017, small phytoplankton occurred nearshore in ACW. Larger phytoplankton were also located closer to shore in association with ACW. *Alexandrium*, a toxic alga, was observed. Some north-south differences were observed. For instance, more dinoflagellates were found to the north and more diatoms were found to the south. Fatty acids associated with diatoms were higher in spring than summer. Fatty acid diatom markers were higher in 2018 than 2017. In general, fatty acid marker data were consistent with phytoplankton observations. Analysis of these data continue.

Yuri Fukai spoke about spatial changes of the phytoplankton community in the northern Bering Sea during summer 2017–2018. It is known that the magnitude and timing of the phytoplankton bloom is affected by changes in timing of spring sea ice retreat. Here, the effects of environmental changes on the phytoplankton community were studied. Data were collected during cruises of the R/V *Oshoro Maru*. This talk focused on diatoms, dinoflagellates and nutrients. Total cell density was higher in 2017 than 2018. Cluster analysis separated the phytoplankton into four groups: A, B, C, and D. Community structure differed between 2017 and 2018. Group B (largely *Chaetoceros* sp.) dominated in 2017. Group C (including *Chaetoceros* convolutes, common to temperate waters, and *Th. nitzschioides*) dominated in 2018. It was concluded that group B was comprised largely of cold-water species, whereas more cosmopolitan species comprised group C. Sea ice retreat was earlier in 2018 than 2017. Results were related to Hunt's et al. (2002) model of bloom formation – early in cold pycnocline waters during years of late ice retreat, and late in warmer waters from solar heating during years of early ice retreat. In the former case, cold-water species, such as *C. socialis* dominated, while in the latter case, the bloom was dominated by more cosmopolitan species. Despite these general patterns, differences in hydrographic variables could not fully explain the differences in phytoplankton communities; there were no statistically significant relationships between the phytoplankton community and temperature and nutrients.

Yoshiyuki Abe talked about spatial and interannual changes in zooplankton community structure in the western Arctic Ocean during summers 2008–2017. This study is unique for the Arctic in that it covers a broad area over an extended period of time. From previous studies, it is known that zooplankton abundance and biomass increased and geographic distribution shifted north from 1991/1991 to 2007/2008. Zooplankton were collected by vertical net hauls from a maximum depth of 150 m. Chlorophyll-a was measured for each water layer by fluorometer. Species diversity was calculated, and cluster analysis and nonmetric multidimensional scaling were performed. General linear models (GLMs) were conducted on dominant species in each group with five explanatory variables from CTD data and four variables from satellite data. A total of 69 species were identified. Zooplankton abundance and biomass was high in the shelf region and low in the basin. Using cluster analysis, the zooplankton community was divided into four groups corresponding to basin, slope, shelf and other (group D). Abundance varied greatly among these groups: slope and shelf > basin > group D. *Calanus glacialis* was the most abundant species with highest abundance in the basin group. *Pseudocalanus* sp. was particularly abundant in the shelf group. The four groups showed clear geographic separation. Group D was most abundant when sea ice melt day was significantly earlier. Small environmental changes were observed in the basin; large environmental variability occurred on the slope, where *C. glacialis* varied widely. For the basin there was a significant positive relationship between salinity and copepod abundance. *C. glacialis* was significantly related to satellite data. Overall, environmental variability has significant consequences to the zooplankton community.

In the final presentation, Sei-Ichi Saito talked about multiple facets of marine biodiversity in the Pacific Arctic under future climate. He examined the impacts of future warming and sea ice loss on biodiversity of the Arctic. The eastern Bering Sea, northern Bering Sea and Chukchi Sea were divided into three domains: Arctic (southern Chukchi Sea), transitional (northern Bering Sea), and boreal (southeastern Bering Sea). NMFS trawl survey data were analyzed over 1993–2017. Analyses focused on 20 species of which 5 were Arctic and 15

were boreal. Environmental data included sea surface temperature, sea ice concentration and ocean depth. The future period considered was 2076–2100. A variety of analytical methods were employed, including GLM, GAM, Boosted Regression Trees, and others. IPCC model predictions of future conditions were used to project changes in habitat conditions. The number of species in the Arctic domain were projected to increase owing to poleward expansion under warmer and ice-free conditions. Also, an increase in species trait redundancy was projected for the Arctic domain. Principle components analysis identified two components explaining 63% and 32% of the variation. Component 1 was associated with attributes of species morphology and life history, whereas component 2 was associated with attributes of species mobility. It was projected that species in the Arctic domain will shift from smaller, short-lived to larger, long-lived taxa, and from less mobile to highly mobile, predatory taxa. Overall, large changes are projected for species and functional composition in the Arctic. A polar range expansion of generalists will alter ecosystem functioning.

A useful discussion followed the conclusion of formal presentations. It was noted that the CAO remains a data-limited region; more data on the CAO are needed. From the presentations given, it was noted that the Bering Strait region is the global hotspot in terms of primary production owing to Anadyr water flowing through shallow areas fueling primary production. On the other hand, there is very low productivity and a carbon minimum in the Canada Basin. So, an emerging issue concerns the transition between these two global extremes. The CAO basin is a highly-stratified system fed by freshwater input. Many models for the CAO predict an increase in freshwater. Contributions of wind mixing are projected to remain modest, even with loss of sea ice. Thus, increased stratification for the Canada Basin is most likely, indicating a future decline in production.

It was suggested that a comparison of changes in the Atlantic gateway (Barents Sea) and Pacific gateway (northern Bering Sea and Chukchi) may be useful. As noted in Elena Eriksen's presentation, the Barents Sea is a data-rich region.

Potential changes in krill were discussed, as well as the need for more information about them. Short-tailed shearwaters feed on krill. So, changes in krill can have broader ecosystem effects. Moreover, it was pointed out that additional research on changes in the benthos are needed; some efforts are underway. Benthic invertebrates are consumed by some seabirds (*e.g.*, eiders) and ice seals, both of which may be affected by borealization of the Arctic with more predatory fishes.

Expected changes in fish stocks were recognized and the prospects for new fisheries was raised. Polar cod stocks reside on the continental shelves, but it is not well known how much these stocks extend their distributions into the CAO. More data on fish in the CAO are needed. Regardless, the likelihood of substantial fish populations to support future fisheries in this region appears to be very low. If fish stocks increase in the CAO, they would be managed by an international agreement. Specific agreements on fisheries management would commence under such circumstances.

It was suggested that there is a need for a well-coordinated, international effort in the Arctic. This would be more productive and efficient that the current piecemeal approach to allocate limited resources in this region that is undergoing rapid, large changes.

List of papers

Oral presentations

WGIBAR activities and development integrated ecosystem assessments for the Barents Sea with prospect for connecting WGICA activities (Invited)
Elena Eriksen

Pacific water in the northeastern Chukchi Sea
Miaki Muramatsu, Hiromichi Ueno, Motoyo Itoh, Eiji Watanabe and Jonaotaro Onodera

Variations in spring and summer phytoplankton communities across water mass gradients in the Chukchi Sea
Lisa B. Eisner, Michael W. Lomas and Jens M. Nielsen

Spatial changes of phytoplankton community in the northern Bering Sea during summers of 2017 and 2018
Yuri Fukai, Yutaka Fukai, Yoshiyuki Abe, Kohei Matsuno and Atsushi Yamaguchi

Spatial and inter-annual changes in zooplankton community structure in the western Arctic Ocean during summers of 2008−2017
Yoshiyuki Abe, Kohei Matsuno, Amane Fujiwara, Atsushi Yamaguchi and Toru Hirawake

Multiple facets of marine biodiversity in the Pacific Arctic under future climate
Irene D. Alabia, Jorge Garcia Molinos, Sei-Ichi Saitoh, Takafumi Hirata, Toru Hirawake and Franz J. Mueter

Poster presentations

What has Canada caught, and how much is left? Combining catch reconstructions in three oceans with current biomass estimates
Rebecca Schijns and Daniel Pauly

Temporal changes of zooplankton community and population structure in the northern Bering Sea from June to September in 2017
Fumihiko Kimura, Yutaka Fukai, Yoshiyuki Abe, Kohei Matsuno, Russell R. Hopcroft and Atsushi Yamaguchi

Yearly comparison on abundance, horizontal, and vertical distribution of epipelagic ctenophores and scyphomedusae in the northern Bering Sea in summer of 2017 and 2018: Quantification by underwater video imaging analysis
Marie Maekakuchi, Yutaka Fukai, Yoshiyuki Abe, Kohei Matsuno and Atsushi Yamaguchi

BIO Workshop (W8)
Synthesis of bio-acoustics programs for monitoring zooplankton and fisheries in the North Pacific

Co-Sponsor: *ONC (Ocean Networks Canada)*

Convenors: *Lu Guan (Canada), Mei Sato (Canada), Hidekatsu Yamazaki (Japan), Hyoung Sul La (Korea)*

Invited Speakers:
Stéphane Gauthier (Institute of Ocean Sciences, Sidney, BC, Canada)
Kouichi Sawada (Fisheries Research and Education Agency (FRA) National Research Institute of Fisheries Engineering Japan)

Background

Fixed and mobile echosounders offer greater temporal and vertical resolution for surveying and monitoring zooplankton and fish than traditional net sampling. Our ability to extract biological information from echosounder backscatter has improved over the last two decades with the continued development and more widespread use of these instruments. Technical advancements include (1) the use of continuously powered (fixed-cabled) instruments for high-resolution, long term time-series, and (2) improvements in multi-frequency

and broadband instruments for fixed and mobile platforms that increase discrimination of backscatter targets on the basis of size, shape and in some instances, species. Contributions describing (1) existing or proposed monitoring programs, (2) instrument-specific applications, (3) approaches for size-class or species identification, (4) assessment of broader-scale trophic interactions, (5) tools for processing large-volume acoustic data sets, and (6) theoretical/modelling studies which take advantage of active acoustics data-sets were encouraged.

Summary of presentations

During PICES-2019, ONC co-sponsored a BIO bio-acoustics workshop (W8: *Synthesis of bioacoustics programs for Monitoring Zooplankton and Fisheries in the North Pacific*) on October 17. This workshop was convened by Lu Guan (Ocean Networks Canada, University of Victoria), Mei Sato (Institute for the Oceans and Fisheries, University of British Columbia), Hyoung Sul La (Korea Polar Research Institute), and Hidekatsu Yamazaki (Tokyo University of Marine Science and Technology).

As the first bio-acoustics workshop within a PICES Annual Meeting, the goals of this workshop were: 1) to share information on active acoustic biological monitoring programs in the North Pacific, and 2) to form a community of practice to advance and promote use of bioacoustic tools for fisheries and ecosystem monitoring. This full-day workshop began with two invited talks, given by Dr. Stephane Gauthier (Research Scientist, Institute of Ocean Sciences, Fisheries Oceans Canada) and Dr. Kouichi Sawada (Chief Researcher, National Research Institute of Fisheries Engineering), and then continued with 12 oral presentations given by researchers from Canada, U.S., Korea and Japan, and finished with a 1½-hr discussion session.

The first invited speaker Dr. Stephane Gauthier, who is leading the DFO Fisheries Acoustics Research Program in the Pacific Region, introduced two studies from the west coast of Canada to illustrate applications of strategically positioned bottom-moored Acoustic Zooplankton and Fish Profiler (AZFP) in monitoring outmigration of juvenile Pacific salmon to the open Pacific Ocean through Discovery Passage and monitoring Pacific hake on the continental shelf off the west coast of Vancouver Island during their northward feeding migration (Talk was titled "*Bottom-moored echosounders to monitor the migration dynamics of fish population*"). For both studies, distinct migration patterns were observed at high temporal resolution for discrete periods of time, offering a unique view of fish migration dynamic processes. Using two similar mooring-based multi-frequency AZFPs, the second invited speaker Dr. Kouichi Sawada provided a case study of its application in zooplankton dynamics monitoring to estimate zooplankton densities by size categories, and to assist determining appropriate timing for salmon fry release and improving salmon return rate in Sanriku area, Japan (titled "*Development of monitoring techniques for zooplankton using multi-frequency profilers moored in Yamada bay, Tohoku, Japan*").

Korean scientists introduced their on-going research program in the Polar Oceans. Dr. Hyoung Sul La gave an overview of zooplankton acoustic projects in both Antarctic and Arctic regions, specific examples presented were: 1) spatial variability of ice krill density in the Amundsen Sea, 2) investigation of krill abundance and vertical distribution in the Ross Sea, and 3) monitoring seasonal variability of arctic zooplankton in the Pacific Arctic Ocean (as part of a Korea-Arctic Ocean Observing System). Mr. Wooseok Oh investigated the distribution and density of Antarctic silverfish in the Antarctic Ross Sea based on a field survey conducted in January 2019 using ship mounted multi-frequency EK60 echosounder. Acoustic data was analyzed using the dB-differences method. The horizontal distribution of Antarctic silverfish schools was estimated. Similarly, Dr. Kyounghoon Lee estimated the biomass and distribution of Antarctic krill around South Shetland Island based on the combination of acoustic surveys and ground-truth midwater trawls. Spatio-temporal and vertical distributions of Antarctic krill were mapped, and a biomass of 70,000,000 T in sub-area 48 was suggested. The

results of this study will be used for Antarctic krill management for sustainable fisheries around South Shetland Island. In addition, Dr. Kyounghoon Lee presented a case study on exploring the relationships between fish and zooplankton, two important components in the marine food web, by providing details in survey design, acoustic data processing, and analysis.

Ms. Yanhui Zhu's presentation provided a good example of applying acoustic methods for assessing fishery resources in terms of fish distribution and abundance. Based on field surveys covering fishing seasons during 2016–2018 in Suzu, Yanhui observed the changes in fish abundance, fish vertical and horizontal distributions, and the dominate fish species along with the change of the flow path of the Kuroshio current. She suggested combining acoustic data analysis with information and communication technology for more accurate and efficient fishery resource management in the future.

Dr. Lu Guan introduced long-term bio-acoustic monitoring of zooplankton dynamics, operated by Ocean Networks Canada, in Saanich Inlet (British Columbia, Canada). The major studies using this acoustic zooplankton time series are: 1) quantification of the seasonal variability in diel vertical migration timing of euphausiids, and 2) characterize zooplankton dynamic features on multiple temporal scales and explore the driving forces/processes using Empirical Dynamical Modeling. These two studies gave good examples of the application of mooring acoustic system in long-term monitoring on components of ecosystem.

Several scientists presented their research that applied acoustic techniques to whale studies. Dr. Mei Sato tried to address whether a shortage of prey is the major cause of the decline of southern resident killer whales (SRKW) in British Columbia by using ship-based multifrequency echosounders and direct sampling to identify the prey fields of killer whale populations. Ms. Rhonda Reidy investigated spatially-explicit humpback whale feeding patterns in accessible regions in Queen Charlotte Strait and Juan de Fuca Strait (off north and south Vancouver Island, respectively) by using acoustic prey mapping and whale tagging. Ms Abigail McCarthy of NOAA revealed the spatial distributions of fin and humpback whales and their competition for available preys off Kodiak Island, Alaska based on repeated fisheries surveys that included active sonar recording, ground truth trawling and whale observation, and suggested that simultaneous acoustic-trawl and cetacean surveys can help explain cetacean habitat selection and foraging.

Dr. Jeffrey Dorman reviewed his research program in Farallon Institute based on an acoustic krill time series (2000–2018) collected from California Current Ecosystem. The specific topics discussed were: 1) the physical drivers of krill aggregation, 2) model verification using acoustics, and 3) estimating regional krill biomass, distribution and availability. Last, Dr Wu-Jung Lee introduced a Python package – echopype, which was developed to interoperate ocean sonar data from heterogeneous sources with the long-term goal of making ocean sonar data an integrated component of standard oceanographic data sets.

Our workshop presentations introduced existing vessel-based and mooring-based active acoustic monitoring programs and research projects in North Pacific, and showed the common interest in application of active acoustic methods/approaches to characterize and monitoring the different components of the ecosystem (plankton, mesopelagic organisms) to support fisheries and ecosystem management. Specific topics discussed after the presentations were: 1) species and group classification using frequency difference approaches, 2) best practice of fish and zooplankton biomass estimates, 3) mooring based AZFP (Acoustic Zooplankton and Fish Profiler) frame work/applications, 4) questions/challenges related to transition from EK60s to EK 80s (*e.g.*, calibration issues, data comparison and analysis, application of broadband techniques, *etc*.), and 5) potential within region and across region collaborations. It was a very successful workshop and participants expressed strong interest in continuing to work on fisheries acoustics to address specific questions.

List of papers

Oral presentations

Bottom-moored echosounders to monitor the migration dynamics of fish populations
Stephane Gauthier

Development of monitoring techniques for zooplankton using multi-frequency profilers moored in Yamada Bay, Tohoku, Japan
Kouichi Sawada, Tohru Mukai, Tomohiko Matsuura and Yoshiaki Fukuda

Vertical distribution and density of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea, Antarctic using multi-frequency
Wooseok Oh, Huoungsul Na, Wuju Son, Inwoo Han, Geunchang Park and Kyounghoon Lee

Assessment of fishery resources around Set-net using acoustic methods for sustainable fishery
Yanhui Zhu, Kenji Minami, Yuka Iwahara, Kentaro Oda, Koichi Hidaka, Osamu Hoson, Kouji Morishita, Sentaro Tsuru, Masahito Hirota and Kazushi Miyashita

Estimating the species identification and abundance of Antarctic Krill (*Euphausia superba*) Using 2-frequency difference method
Inwoo Han, Seokgwan Choi, Sangdeok Chung, Wooseok Oh, Geunchang Park and Kyounghoon Lee

Zooplankton acoustic surveys of Korea Polar Research Institute in the Polar Oceans
Hyoung Sul La, Wuju Son, Eun Jin Yang, Kyoung-Ho Cho, Tae-Wan Kim, Jinyoung Jung, Youngju Lee and Sung-Ho Kang

Long-term bio-acoustics monitoring of zooplankton dynamics in Saanich Inlet (British Columbia, Canada)
Lu Guan, Mei Sato, Akash Sastri, Chih-hao Hsieh and Richard Dewey

Bio-acoustic monitoring with the Acoustic Zooplankton Fish Profiler
Steve Pearce, Jan Buermans, Stephane Gauthier, Alireza Rezvanifar, Tunai Porto Marques, Melissa Cote, Alexandra Branzan Albu and David Lemon

"Seeing" prey provides insights into the decline of southern resident killer whales
Mei Sato, Andrew W. Trites and Stephane Gauthier

Mapping prey fields of foraging humpback whales in British Columbia, Canada
Rhonda Reidy, Stephane Gauthier, Laura Cowen and Francis Juanes

Spatial distribution of fin (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales in relation to environment and acoustically measured prey distribution
Abigail McCarthy, Alex De Robertis, Stan Kotwicki, Kathy Hough, Paul Wade and Chris Wilson

Spatial organization and abundance indicators of euphausiids across the California Current ecosystem
Jeffrey G. Dorman, William J. Sydeman, Jarrod A. Santora, Brian Hoover, and Sarah Ann Thompson

Interoperating ocean sonar data of heterogeneous sources using echopype
Wu-Jung Lee, Valentina Staneva and Kavin Nguyen

Poster presentation

Acoustic reflection intensity of Sargassum horneri
Kenji Minami, Chihomi Kita, Makoto Tomiyasu, Hokuto Shirakawa, Takashi Kitagawa and Kazushi Miyashita

MONITOR/MEQ Workshop (W9)
Monitoring non-indigenous species in PICES member countries: Towards best practices

Convenors: *Thomas Therriault (Canada), Hiroshi Kawai (Japan), Jeanette Davis (USA)*

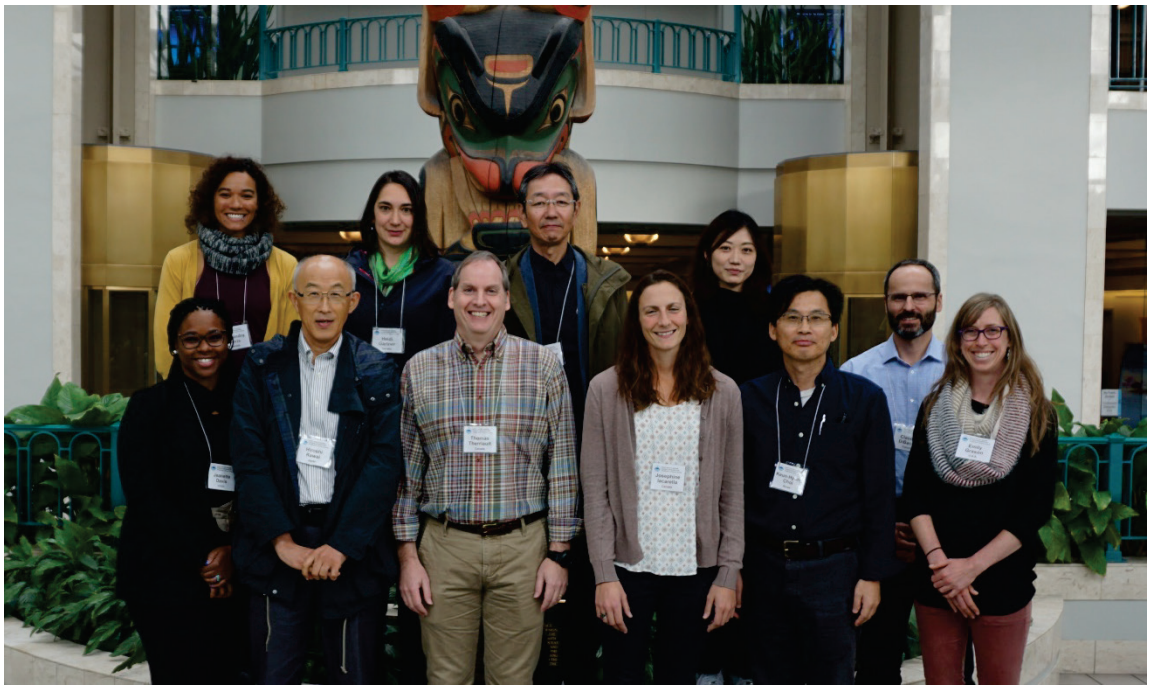
Invited Speaker:
Emily Grason (Washington Sea Grant, College of the Environment, University of Washington, USA)

Background

Globally, marine non-indigenous species (NIS) introductions continue due to an increasing number of humanmediated vectors (e.g., shipping, recreational boating, aquaculture-related movements) and pathways that are connecting previously discrete marine ecosystems. Once introduced outside their native range, NIS can significantly reduce native biodiversity and ecosystem goods and services thereby negatively affecting coastal communities and economies. Management of new incursions is often most effective when NIS are detected early when populations are small and spatially constrained. One approach to early detection of new invaders or tracking the spread of existing invaders relies on the establishment of effective monitoring programs that consider the type of species/taxa most likely to be introduced and the areas they are most likely to be introduced to (such as ports and marinas) or vulnerable/sensitive areas (such as Marine Protected Areas). There is a long history of marine invasions in the North Pacific and among PICES member countries early detection monitoring programs for NIS are likely to vary. In this workshop we will explore the types of NIS monitoring programs that are in place (or are being planned) with a focus on the North Pacific. This workshop will include both traditional monitoring techniques (*i.e.*, settlement plates, trapping or beach surveys) and more recent molecular approaches (*i.e.*, highthroughput sequencing, qPCR). By reviewing the strengths and weaknesses of these various NIS monitoring approaches/programs we aim to identify best practices for NIS monitoring in the North Pacific thereby informing one of AP-NIS's Terms of Reference.

Summary of presentations

This workshop was convened as an activity of the PICES Advisory Panel on *Marine Non-indigenous Species* (AP-NIS) in order to advance key components of its Terms of Reference (ToR), specifically those related to NIS monitoring around the North Pacific. The structure of this workshop was designed to ensure broad discussion by workshop participants informed by both a targeted invited presentation a limited number of contributed papers. Our invited speaker, Dr. Emily Grason, highlighted how a network of citizen scientists can be developed to conduct large-scale early detection/monitoring for a high risk invader (European Green Crab) in the Salish Sea. Using Lionfish in the Caribbean as a working example, Dr. Alexandra Davis highlighted some of the ecological and economic tradeoffs inherent in developing control and mitigation measures for a high impact marine invasive species. Dr. Claudio DiBacco discussed some of the challenges in developing a large-scale monitoring program and how objectives and deliverables change and need to be refined over time to ensure products are meaningful for management and policy development. Finally, Dr. Thomas Therriault highlighted the importance of community/stakeholder engagement in developing monitoring programs for NIS and showed how such a program was developed on British Columbia's North Coast in the port of Prince Rupert. Following these presentations the workshop turned to the discussion phase convened by Dr. Therriault. The key elements arising from the discussions are summarized here. Also, one poster by Dr. Kyoungsoon Shin was attached to this workshop.



Back row, from left: Alexandra Davis, Heidi Gartner, Toyomitsu Horii, Yumi Okochi, Claudio DiBacco. Front row, from left: Jeanette Davis, Hiroshi Kawai, Thomas Therriault, Josephine Iacarella, Keun-Hyun Choi, Emily Grason.

Initial Question/Area of Opportunity: What are thoughts or guidelines when the public expects experts to reduce the impact of an invasive species but eradication is not possible, such as Lionfish? Do we have guidelines for decision making to determine when to continue to monitor *versus* when to stop trying to eliminate a particular species?

Discussion:

- Identifying high risk NIS or areas *a priori* can gain important "buy-in" from stakeholders/community groups that will aid in monitoring and/or control efforts.
- It is important for managers/stakeholders to understand that it will take concerted and coordinated efforts to control or eliminate a marine NIS in shared waters. If efforts are different among different jurisdictions then the efforts almost certainly will fail. This was highlighted in both the Lionfish and European Green Crab presentations. Due to large-scale public interest there is a Lionfish program where 13 countries are working together to control and mitigate the impacts and potential spread of this high risk species. As part of this program the public is highly engaged and is willing to undertake removal efforts (*i.e.*, spear-fishing). Similarly, in the Salish Sea, community groups are undertaking trapping efforts to detect and remove European Green Crab. Both examples showcase the need and importance of public engagement.
- Research suggests that Lionfish may have reached their carry capacity in Caribbean waters. If we are looking to develop cross-country guidance, is there a particular quantity reduction we are trying to reach? There is a continuum between eradication and doing absolutely nothing. Perhaps Lionfish, like other marine invaders, cannot be eradicated over large spatial scales but this then makes control measures even more important to maintain "healthy ecosystems" by reducing and maintaining the abundance/density of the invader at a lower threshold. Admittedly, this threshold might not be known and further research would be required for each invader, possibly in each region it invades. NIS control can be a moving target and community groups, stakeholders, managers, and scientists need to work together for maximum flexibility

and adaptive management. Unfortunately there are limited tools available, and would be a valuable area of future research.
- As conservation/no-take areas, Marine Protected Areas can inadvertently facilitate the maintenance or spread of marine NIS.

Initial Question/Area of Opportunity: Lionfish and European Green Crab are potential good case studies for better understanding and setting a threshold for an ecological target. What are their impacts to an ecosystem and what is the threshold to maintain key functions?

Discussion:
- What is the process for determining such a threshold? Would the goal be to ensure control measures are used to reduce population abundance/density below this?
- Perhaps we can develop a white paper using Lionfish as an example and provide details about establishing ecological thresholds necessary to ensure the maintenance of ecosystem structure and function. The paper should also include tools and approaches that can be used for engagement and monitoring. Workshop participants self-identified if this activity was of interest to them.
- During the workshop there was general discussion about what some of the impacts to be identified/ measured could include and how success of control measures might be determined.
  - Response of native community and ecosystem *vs* number/density of invaders;
  - What is the functionality, what is the number of invaders to get back to functionality of an ecosystem…? (work backwards);
  - Consider other environment conditions, *i.e.*, climate change that may be impacting an ecosystem so removal of an invader may not show a linear response (in fact this would almost certainly be non-linear);
  - Consider non-native species that are providing ecosystem goods or services
- Messaging has to be clear, simple and non-contradictory when talking to various groups about NIS that coastal communities use to derive benefits (*i.e.*, Pacific Oyster or Manila Clam in Canada).
- Due to the very high number of invaders the Mediterranean, largely due to the opening of the Suez Canal, may be a good case study to look at ecosystem-based services derived from NIS.
- Establish functional relationships for invasive and native species.
- Look to get a quantitative measure or density for impacts. What density of removal is needed to get back to previous functional relationships? What ecosystem-based service does the NIS provide and how does this differ from the system pre-invasion?
- Use systems that are currently impacted. What level of control efforts would ensure ecological structure and function are either maintained or improved (assumption being the NIS has degraded these)?
- Ideally there would be baseline information prior to invasion. We could use lessons learned from other places the NIS has invaded. However, impacts may be different in different regions given the context-dependent nature of most invasions.
- What are the impacts on a system by undertaking removal efforts? Does this impact sustainable economic operations such as fisheries/aquaculture?

Initial Question/Area of Opportunity: We should consider and incorporate climate change into invasive species tracking. How do we adjust and account for extreme year events such as marine heat waves, not just climate change projections? Are these extreme events and variable years going to be consistent? Perhaps we should start incorporating extreme years to better predict future invasive species projections.

Discussion:

- Considerations regarding climate change:
  - Identify a handful of target organisms with environmental conditions.
    - Establish a process for establishing impact of global invaders,
    - Sites around the Pacific may be useful.
  - Look at a variety of species distribution models and identify change over time.
    - Near-term 10–20 years,
    - There are extreme events happening consistently around the world one needs to be cautious about when defining the "new" normal,
    - Look at areas with extreme events geographically (temperature, salinity). Do these extreme events impact establishment, reintroductions of species?
  - Are there pathways and/or vectors that we should be monitoring in North Pacific?
    - This is valuable for countries trying to predict the next invader,
    - Pathways can also change due to climate change.

Initial Question/Area of Opportunity: eDNA and invasive species is a popular topic these days. What are countries doing with respect to eDNA and is it being used to monitor NIS?

Discussion:

- Japan is using this technique for endangered species and is interested in using it for invasive species. However, there are some logistical challenges such as developing primers specifically for NIS, especially when the species is not already in Japan.
- Perhaps this group can help establish universal or targeted genetic primers for top invaders of mutual interest among PICES member countries.
  - How universal are "universal" primers?
  - Share primer information. Can this information be housed for the international scientific community?
  - This technique can also be useful for establishing thresholds for ecosystem responses by looking at the change in DNA signatures over time/space or for specific species.

Suggestion:

Given the interest in eDNA at PICES-2019, W14 (see below in Session Summaries) and a growing interest among many PICES countries, it is recommended that AP-NIS develop a session/workshop proposal for PICES-2020 to look more closely at potential eDNA use in NIS monitoring and early detection.

List of papers

Oral presentations

Community science to capture the leading edge of an invasion: European green crab on Washington State's inland shorelines (Invited)
Emily W. Grason, Jeff Adams, P. Sean McDonald and Kate Litle

Developing spatially explicit tools to minimize costs and maximize benefits of marine invasive species control
Alexandra C.D. Davis and Stephanie Green

Development of an aquatic invasive species monitoring program: past, present and next steps
Claudio DiBacco and J. Benjamin Lowen

A collaborative science-based approach to non-indigenous species monitoring on British Columbia's North Coast
Thomas W. Therriault, Jason Scherr, Natasha Lebedick and Caitlin Smith

Poster presentation

Preliminary study on risk assessment of in-water cleaning method to remove the ship's hull fouling organisms.
Bonggil Hyun, Pung-Guk Jang, Jung-Hoon Kang, Min-Chul Jang and Kyoungsoon Shin

BIO Workshop (W10)
PICES/ICES collaborative research initiative: Toward regional to global measurements and comparisons of zooplankton production using existing data sets

Convenors: *Toru Kobari (Japan), Akash Sastri (Canada), Lidia Yebra (Spain)*

Invited Speaker:
Shin-ichi Uye (Hiroshima University, Japan)

Background

Material and energy transfer in the lower food web are integrated through zooplankton communities. The standing stock and productivity of this group represent a proxy for the functional response of marine ecosystems to regional and global climate change. A variety of methods and information on zooplankton production rates have been assembled over the past half century, however, we still struggle to evaluate zooplankton productivity and its driving forces. Presentations and discussion on novel applications of traditional and biochemical methodologies and/ or new approaches for evaluating zooplankton productivity in the field were encouraged.

Summary of presentations

The 1-day workshop was convened on October 16, 2019 to discuss aspects of the assessment of standing stock and productivity of zooplankton communities. In particular, talks focused on i) application and synthesis of zooplankton production rate measurements in the field; 2) modeling and laboratory validation studies; and iii) regional assessments of the performance/utility of empirical models for estimating zooplankton production rates using biomass time series. Much of the group discussion centered on how to take best advantage of online resources which can be used to derive broad-scale secondary production rate measurements using empirical models of zooplankton growth rates. The workshop was intended to focus on a number of issues relevant to the Working Group 37 (Zooplankton Production Methodologies, Applications and Measurements in PICES Regions). There were a total of 9 talks with 18 participants from 6 countries: Canada, Chile, Chinese Taipei, Japan, Spain, and USA. The 3 poster presenters also highlighted the major results of their studies as part of the afternoon session.

The afternoon discussion focused on three areas relevant to WG 37's terms of reference. Our first discussion item centered around collaborative activities for zooplankton production measurements and methodologies with the ICES Working Group on Zooplankton Ecology. Dr. Lidia Yebra emphasized the importance of networking and regional to global collaboration as major achievements of the collaboration between ICES WGZE and PICES WG 37, and that there was a general agreement on pursuing further collaborations between PICES and ICES members. Dr. Yebra also noted that we should be aware of a large community of zooplankton production scientists from the Mediterranean and southern hemisphere. A representative example of similar efforts by the global community is the International Group for Marine Ecological Time Series (IGMETS) initiative. The second discussion topic approached a WG 37 terms of reference related to comparing secondary production time series based on conversion of biomass time series using empirical growth rate models. Several existing collaborations were noted and a general concern about how to choose the best model for times series' comparisons was raised. Drawing on the experience of participants; the most important issue is not to choose a single common production empirical model but rather, to select a model that accurately describes production at a particular site. This could take the form of choosing region-specific species models or providing a range of production estimates based on several global models. The ultimate goal is to develop comparable time series of zooplankton production rates. Finally, we discussed novel approaches

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

In brief, our invited speaker, Prof. Shin-ichi Uye (Japan) presented how to go from individual-based to population- and community-based production estimations and stressed the need for more direct measurements of species-specific growth rates before we can advance towards a community-level assessment of zooplankton production in the field. He also presented new information on the importance of tertiary production, using a chaetognath as example. In this sense, Dr. Pei-Chi Ho (Chinese Taipei) showed how specific growth rates estimated from relatively short artificial cohort incubations were used to test the importance of the predator/prey stoichiometry on zooplankton production in the field. Apart from direct measurements, indirect approaches were also presented such as models and enzymatic methods to facilitate the assessment of growth at the individual and community level. Prof. Hui Liu (USA) showed a new IBM model that allows the *in silico* development of natural and artificial cohorts to estimate field production rates of jellyfish, *Aurelia aurita*. Dr. Kazuaki Tadokoro (Japan) presented examples of a physiological model of zooplankton growth rates applied to existing zooplankton biomass time series data. Dr. Karyn Suchy (Canada) presented and compared crustacean production rates estimated from a variety of empirical models and applied to the west coast of Vancouver Island and the Strait of Georgia, BC, Canada. Also, Dr. Akash Sastri (Canada) and Ms. Megu Iwazono (Japan) showed the importance of biomass in determining copepod production rates from chitobiase and AARS activity in the laboratory. Prof. John. Dower (Canada) presented a major decline in crustacean zooplankton production rates (estimated with the chitobiase method) and increases in gelatinous plankton biomass along the west coast Vancouver Island, since 2015. Finally, Dr. Lidia Yebra (Spain) presented online options through the COPEPOD website (https://www.st.nmfs.noaa.gov/copepod/) to move towards a global estimation and mapping of zooplankton field production using existing time series data. To close, the poster presentations by Ms. Megu Iwanzono (Japan), Mr. Fukutaro Karu (Japan), and Mr. Takeru Kanayama (Japan) highlighted their studies on zooplankton growth and feeding rates in the laboratory and field.

Workshop 10 participants in the entrance of the Victoria Conference Center, Victoria, Canada. Back row, from left: Sei-ichi Uye, Samantha Zeman, Julie Keister, Karyn Suchy, Akash Sastri, Lidia Yebra. Front row, from left: Hui Liu, Kazuaki Tadokoro, Kim Corporon Jacobson, David Kimmel, Pei-Chi Ho, Megu Iwazono, Takeru Kanayama.

List of papers

Oral presentations

Zooplankton production in temperate coastal waters: from individual to community level (Invited)
Shin-ichi Uye

Prey stoichiometry, primary production, and plankton composition influence production of marine zooplankton
Pei-Chi Ho, Esther Wong, Fan-Sian Lin, Akash R. Sastri, Carmen García-Comas, Noboru Okuda, Fuh-Kwo Shiah, Gwo-Ching Gong, Rita S.W. Yam and Chih-hao Hsieh

What have we learned from 13 years of chitobiase-based measurements of crustacean zooplankton productivity along Canada's west coast?
John F. Dower, Theresa A. Venello, Karyn D. Suchy and Akash R. Sastri

Seasonal population dynamics, biomass, production, and feeding of the chaetognath *Aidanosagitta crassa* in a temperate eutrophic inlet
Shin-ichi Uye and Liang Dong

A simulation model for estimating the growth and production of jellyfish (*Aurelia aurita*)
Hui Liu

Chitobiase-based estimates of developing biomass, growth rate, biomass production rate for a synchronous cohort of *Pseudodiaptomus inopinus* in culture
Akash Sastri, John Dower, Alex Clancy, Yuichiro Yamada, Tomonari Kotani, Toru Kobari and Yuka Matsuura

Application of the physiological model to the existing data sets for estimating zooplankton production rates
Toru Kobari, Kazuaki Tadokoro, Megu Iwazono and Debbie Steinberg

Biomass production rates of copepod communities along the West Coast of Vancouver Island and in the Strait of Georgia, BC, Canada: An application of multiple empirical growth rate models
Akash R. Sastri, Karyn D. Suchy, Lian E. Kwong, and Moira Galbraith

A global collaboration for the worldwide mapping of marine zooplankton biomass and production
Lidia Yebra and Todd D. O'Brien

Poster presentations

Trophic sources and feeding impacts of microzooplankton on phytoplankton community in the Kuroshio
Takeru Kanayama, Toru Kobari, Fukutaro Karu, Koji Suzuki, Naoki Yoshie, and Gen Kume

Energy sources and feeding impacts of mesozooplankton community in the Kuroshio
Fukutaro Karu, Toru Kobari, Koji Suzuki, Naoki Yoshie, Taiga Honma, Takeru Kanayama and Gen Kume

Evaluation of protein synthetases activity as a proxy for zooplankton biomass and production rate using cultured copepod population, *Pseudodiaptomus inopinus*
Toru Kobari, Yuka Matsuura, Akash Sastri, Yuichiro Yamada, Megu Iwazono and Tomonari Kotani

FIS Workshop (W11)
PICES/NPFC collaborative research: The influence of environmental changes on the potential for species distribution shifts and population dynamics of Pacific saury

Convenors: *Chris Rooper (Canada), Vladimir Kulik (Russia), Eddy Kennedy (Canada), Yong Chen (School of Marine Sciences, University of Maine, USA), Chih-hao Hsieh (National Taiwan University, Chinese Taipei), Kazuhiro Oshima (National Research Institute of Far Seas Fisheries, FRA, Japan)*

Invited Speakers:
Chuanxiang Hua (College of Marine Science and Technology, Shanghai Ocean University (SOU), China)
Bai Li (NPFC; School of Marine Sciences, University of Maine, USA)
Kazuhiro Oshima (National Research Institute of Far Seas Fisheries, FRA, Japan)

Background

This workshop is the inaugural joint activity to advance collaboration between PICES and NPFC. Under the proposed PICES-NPFC Framework for Enhanced Scientific Collaboration, the theme area of stock assessment support was identified as a priority area for future collaborative work. Pacific saury is a priority species for NPFC, and one that has experienced large fluctuations over the past several decades. Members of the NPFC have reported catches ranging from 124 to 629 kilotons between 1950 and 2017 with an average of 350 kilotons. In 2017, catch was reported to be 216 kilotons. The NPFC Technical Working Group on Pacific Saury Stock Assessment first met in 2017 to determine stock status by employing a Bayesian state-space biomass dynamic model; however consensus on stock status among members could not be reached in 2018. Collaboration of PICES and NPFC may enable recommendations for employing alternate models that incorporate environmental and ecosystem variables that might better explain stock fluctuations and predictions of stock abundance and distribution in space and/or time. The objectives of the workshop were to (1) provide an overview of environmental changes in areas that overlap Pacific saury distributions, (2) identify time periods with significantly different conditions (*e.g.*, regime shifts) that could influence the abundance of Pacific saury, (3) outline projections and associated uncertainties of changes in habitat suitability for saury, and (4) propose mechanisms for further research to understand the interaction of ecosystem changes on Pacific saury distribution and associated consequences on estimating abundance.

Summary of presentations

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

The workshop began with an introductory presentation by invited speaker, Dr. Kazuhiro Oshima, who outlined the cyclical pattern in Pacific saury biomass estimated through the stock assessment by the NPFC. A key uncertainty is the level to which productivity, growth and survival might be influenced by changes in available habitat and ecosystem productivity. Next, second invited speaker, Dr. Chuanxiang Hua, presented analyses that examined relationships between Pacific saury fishery effort and sea surface temperature (SST) and its gradient (SSTG). A key finding was that SST appears to control the migration and distribution of Pacific saury, whereas SSTG appears to be related to the aggregation of Pacific saury. Dr. Taiki Fuji talked about how the presence of competitors for prey species (particularly Japanese sardine) impacted the distribution of Pacific

saury. The discussion that followed centered around uncertainties in the relationships between the oceanography and Pacific saury distribution, the types of variables (both oceanographic and biological) that are important for determining the abundance of Pacific saury, and in particular, the need for more study of the mechanisms underlying the environmental relationships.

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

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

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

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

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

Many of the questions and recommendations considered during the workshop, such as large-scale oceanographic processes, are topics of ongoing research in the PICES community. One of the most important conclusions of the workshop was that collaboration with the PICES community of researchers should continue to be encouraged and further relationships between PICES and NPFC be developed. As a result, attendees at

the workshop put forward a proposal for a Topic Session at the 2020 PICES Annual Meeting ("*Environmental variability and small pelagic fishes in the North Pacific: exploring mechanistic and pragmatic methods for integrating ecosystem considerations into assessment and management*"; subsequently accepted) that will serve as the next step in building a stronger scientific collaboration between PICES and the NPFC.

List of papers

Oral presentations

Results of stock assessment on Pacific saury by the NPFC (Invited)
Technical Working Group on Pacific Saury Stock Assessment and Kazuhiro Oshima

Aggregation habitat variation of Pacific saury and its influence factors based on HSI model (Invited)
Chuanxiang Hua, Qingcheng Zhu, Siquan Tian, Fei Li and Yongchuang Shi

Habitat of Pacific saury *Cololabis saira* is affected by the distributional change of other small pelagic fishes in the North Pacific
Taiki Fuji, Yasuhiro Kamimura, Sho Furuichi, Hiroomi Miyamoto, Midori Hashimoto, Shin-ichiro Nakayama, Kazuhiro Oshima and Satoshi Suyama

The impact of water temperature on the Pacific saury catch distribution
Vladimir Kulik, Aleksei Baitaliuk, Oleg Katugin and Elena Ustinova

Estimating spatial non-stationary environmental effects on the distribution of Pacific saury in the Northwest Pacific Ocean (Invited)
Bai Li

Ensemble forecasting of spatial distribution of Pacific Saury (*Cololabis saira*) in the Northwestern Pacific Ocean
Jin-Ying Lee, Yi-Jay Chang, Wen-Bin Huang, and Chih-hao Hsieh

Pattern transition of age-specific distribution for Pacific saury *Cololabis saira* in the Northwestern Pacific Ocean
Midori Hashimoto, Taiki Fuji, Shin-Ichiro Nakayama, Satoshi Suyama and Kazuhiro Oshima

Property of Pacific saury recruitment in the North Pacific Ocean
Shin-Ichiro Nakayama, Satoshi Suyama, Taiki Fuji, Midori Hashimoto and Kazuhiro Oshima

The climate impact on Pacific saury (*Cololabis saira*) stock dynamics
Andrey Krovnin, Sergey Melnikov, Kirill Kivva (presenter) and George Moury

Incorporating changes in environmental conditions in fish stock assessment
Yong Chen

BIO Workshop (W12)
Potential food competition between top predators and fisheries in the North Pacific

Convenors: *Yutaka Watanuki (Japan), William Sydeman (USA), Elizabeth A. Logerwell (USA), Andrew Trites (Canada)*

Invited Speaker:
Susanne McDermott (Alaska Fisheries Science Center, NMFS, NOAA, USA)

Background

The potential for resource (food) competition between large predatory fish, marine mammals, seabirds, and fisheries is a long-standing concern in many marine ecosystems globally, but it is extremely difficult to study and document. These top predators and fisheries may target similar resources (*e.g.*, small pelagic fish and

euphausiid crustaceans), but simple overlap in prey species, consumptions and landings is insufficient to document competition. For example, changes in the forage fish and mesozooplankton populations targeted by both fisheries and upper trophic level predators may be primarily forced by climate more so than by consumption by top predators or harvest by fisheries. This workshop will contribute to the S-MBM project on Climate and the Trophic Ecology of Marine Birds and Mammals, production of comprehensive PICES North Pacific Ecosystem Status Reports, as well as interface with the fundamental goals of FUTURE to understand and predict the interaction of climate and anthropogenic factors on marine ecosystems.

Summary of presentations

In this workshop, we looked for evidence and the non-evidence of resource competition between large predatory fish/squids, marine mammals, seabirds, and fisheries within PICES regions. We recognized that competition with fisheries may affect body condition and population of marine mammals but could not find clear evidence. The Aleutian Island western Steller sea lion population declined in the western portion of their range (western Aleutian Islands) but is sustained in the eastern portion (eastern Aleutian Islands). Studies at three spatial scales did not give a clear pattern supporting fisheries' impact in the west. Also fur-seal population in this area is declining. Overlap of diet and spatial pattern between fur seals and fisheries indicate potential competition. There is also evidence of declining killer whale body condition, while effects of fisheries are not clear. Two species of whales are positively associated with krill but at different depths, indicating segregation. A case study indicated that more than 10 times biannual change of pink salmon stock size affected the body mass of non-breeding birds and their breeding performance, indicating competition between krill-eating fish and seabirds and further indicates trophic cascade. Modelling experiments indicate the removal of whales but not seals affect stocks of some species of fish but not all.

Several questions were pointed out in general discussion section:
1) Lack of evidence of competition (negative effects on energy acquisition, reproduction, survival and population) – Overlap of diet is not always the evidence. Climate change, that affects the prey community, and fish discards, that may benefit some species of seabirds, confound the effects of competition. A study modelling (predictive model and hindcasting) the competition of various whales and krill fishery found competition between whales but not the krill fishery. A change in the use of specific fish prey can be modelled in the context of the environment. Empirical evidence, where climate effects were statistically controlled for, shows competition between the sand eel fishery and birds in the UK.

2) Mismatch of the scale of research – Fisheries management/measurements often operate on a much larger spatial scale than what is important for central place foraging birds/mammals. So, linking fisheries management and seabird/mammal ecology is often a challenge. Different scales of the study of seabirds, marine mammals, large fish and fisheries make it difficult to detect interaction. Seabirds take so little of the prey but are severely impacted by other changes, can this be evidence of mismatch in scale of research?—localized depletion question for seabirds that is not always adequately included in the models. Seabirds have such a small biomass compared to the fish in the system and they have much more limited foraging area available to them (colony ranges and foraging depths). What is more relevant, finding a specific impact or finding a link that is relevant to management? Fisheries can change the population structure and make the population more susceptible to other types of predation. What are the natural behaviors and adaptations that fish have to minimize predation? We need to look at differences between species, even those that are otherwise similar.

Ecosystem models should be able to help with these types of questions. However, a lot of information is in the results but they are hard to interpret. It is not easy to pick among model results and blame the data. There is a

lot of variability in the data and how well the forcing functions fit. Spatial dynamics and distributions are hugely relevant. So we need more spatial analysis.

3) Are competition negative effects: directional or bilateral? Life history and behavior is important to consider for consumption rates and direction of competition. Seabirds are highly impacted because they are so dependent on that small percentage of the food—question of availability. One or two papers/analyses deal directly with fisheries and marine mammals (Daniel Hennen *et al*. 2006 *Ecol. Appl*., Andrew).

Additional questions to discuss will be:
4) Level of resources where competition is observed – This gives important implication for ecosystem-based management of fisheries. Different fisheries management strategies can be evaluated based on different levels of competition to obtain optimal management strategies.

5) Mechanism of competition – Exploitative or interference depends on what specific fish species and what specific fisheries you are looking at. The competition between cod fisheries and mammals can be exploitive as mammals feed on cod, while that between halibut fisheries and mammals can be interference, as much of halibut's prey can be consumed by mammals. For herring, both can happen; mammals are exploitative competitors of herring fisheries as they consume herring; mammals also interfere as they also feed on herring's predatory fish.

6) How does the behavioural positive interactions, especially between seabirds and whales/tuna works? Whales, because of their large body size, can also serve as marine ecosystem engineers by shaping patterns of spatial redistribution of nutrients and energy (Roman *et al*., 2014), increasing primary productivity and thus potentially enhancing the productivity of tuna.

List of attendees

Name	Affiliation	Country
C Fu	DFO	Canada
L Guan	Ocean Networks	Canada
M Sato	University of British Columbia	Canada
A Trites	University of British Columbia	Canada
Y Xu	DFO	Canada
Y Goto	Hokkaido Local Goverment, Research Organization	Japan
K Hattori	Fisheries Research and Educational Agency	Japan
H Sasaki	Fisheries Research and Educational Agency	Japan
T Tamura	Institute of Cetacean Research	Japan
Yutaka Watanuki	Hokkaido University	Japan
E Eriksen	Institute of Marine Research	Norway
HR Skijoldel	Institute of Marine Research	Norway
Betsy Baker	NRPB	USA
E Hazen	NOAA, SWFSC	USA
G Hunt	University of Washington	USA
K Kuletz	USFWS, Anchorage	USA
L Logerwell	NOAA, AFSC	USA
A McCarthy	NOAA, AFSC	USA
I Ortiz	University of Washington	
SA Thompson	Farallon Institute	USA

Summary of results of presentation, and questions and responses:

Libby Logerwell (for Susanne McDermott): Populations of sea-lions are still declining in the western Aleutians and Bering Sea. Fisheries mitigations are implemented because of concern for competition (minimize interactions between sea lions and fisheries). There are Atka mackerel fisheries closures around western Aleutians. There are three scales of assessment. 1. Fishery interaction – is there localized depletion near rookeries? Atka mackerel biomass is greater in the east and lower in the western Aleutians. Exploitation rate was lower than 10% (mark of localized depletion) both in the west and east, indicating that mitigation measures seem to be working. 2. Ecosystem – Atka mackerel decreases east to west, but northern rockfish increases east to west indicating that the relationships between environment and fish density differs between species. 3. Sea lion foraging – Atka mackerel size was larger in the east and smaller in the west. More Atka mackerel was observed in the area closer to rookeries in the east and farther from the rookeries in the west. Atka mackerel show different diurnal patterns between the east and west. Sea lions forage at night so the west timing for sea lion foraging and fish presence at the surface don't match up. More favorable foraging conditions for sea lions in the east. Fisheries impacts could be more intense in the west where conditions are tougher, but mitigations seem to be working

Questions and Responses:

Why different diurnal patterns in the fish?
> It could be due to different Atka mackerel prey preferences in the west.

What were the sea lions eating when the population was high?
> There was increased sea lion hunting for consumption during whaling period, early 1900s, and then they recovered.
> It's a question of nutrition, there is more to it than density or quality.
> The fish in the west do seem to be smaller.
> Many fish are like that in the Aleutians, smaller in the west. Also other pinnipeds are suffering out there and there seems to be a system problem in that area.

Related to eddy fields? Can this be related to a different quality of water? Nutrient availability? Needs an ecosystem assessment because the patterns are bigger. Has there been an oceanographic change?
> There could be a factor of nutrient availability. Even a little bit of fisheries pressure can have a large effect in this delicate system.
>Sea lions have natural fluctuations; the conditions for the species are poor; energy density can fluctuate greatly within Atka mackerel.

Ivonne Ortiz: Northern fur-seals are declining. There is a management plan but that does not affect pollock management. The most competition for pollock as prey is for juvenile pollock rather than the adults. There is a sizeable effect of fishery on adult pollock. Juvenile pollock mortality is widespread among fish and mammal predators, including pollock (cannibalism). The one rookery at Bogoslof is thriving while the others are not, and they are holding the population in the entire eastern Bering Sea. Modelling of the NFS foraging range and fish distribution is required to see areas of overlap/competition between the NFS and the other fish predators of pollock and fisheries data are incorporated.

Questions and Responses

George and Stephani Zador found negative relationships between arrowtooth flounder and northern fur seals; prior to 1978, there was not a lot of pollock—the birds were eating age 0-1 pollock and capelin. It is worthwhile to look at older, less accurate data.

Northern fur-seals also eat other things beside pollock, especially at Bogoslof.
> There are acoustics showing northern fur seals only dive in the absence of large pollock.

Andrew Trites: The southern resident orcas are endangered; they are fish eaters, specifically salmon, and specifically Chinook salmon. Chinook are present all year-round; they are calorie-rich. Fishery catches have been decreased and kept low since 1985. Survival of orcas has been low for several decades (since ~1982). Drones provide aerial photos of the whales that allow assessment of body condition and showed that southern resident whales are on average much thinner than the northern resident whales.

Questions and Responses

Why?
Canada closed their Chinook fishery in 2018 and 2019. Correlation between Chinook and orca numbers showed that there is a significant correlation using a Chinook abundance index and a weak indication of some impact on fecundity. There is no evidence that fishery reduction would adequately increase the number of Chinook. Historical numbers of orcas are low—only 60–70 in the 1960s; high of 98 animals since then. Average whale needs 10-12 Chinook/day; 7000-9000/summer, which is well below the estimated 600,000 Chinook abundance estimate. Perhaps those fish were not available even though the abundance was there. Steller sea lions are also eating Chinook, and their populations are increasing in BC. There does not appear to be a shortage of Chinook, but it cannot be proven that competition is not occurring

Abigail McCarthy: Whales spatially associate with krill but much less with fish (supported by model results). Fin whales associate with krill at depth (supported by model results). Humpbacks are negatively related to krill depth indicating niche partitioning between the fins and humpbacks.

Questions and Responses

In the krill data, was there accommodation for time of day and year?
> Analysis was by day as a unit; no other accommodation.

Are there different feeding behaviors?
> Whales also forage during the night.

Schooling could have an effect?
> Schooling is evident in the echograms.

Yutaka Watanuki: A review of work in the Bering Sea. Strong interannual variability in pink salmon abundance with biennial oscillation; low in even years and high in odd years. High pink salmon biomass negatively affected body condition of short-tailed shearwater feeding on krill spending non-breeding period but not on that of tufted puffin feed on mainly on fish and squids. Negative impact was also observed in the number of breeders of short-tailed shearwaters. Salmon abundance does affect some aspects of kittiwake and puffin breeding, though they may or may not share food. Pink salmon abundance also affects pink salmon driving a trophic cascade, including the size of other salmon species and the abundance of some zooplankton and phytoplankton. In the literature, seabirds are always outcompeted by fisheries and mammals.

Questions and Responses

Annual variability in shearwater bycatch?
> We did not find clear effects on the bird density.
> There are some data on more seabird bycatch in fisheries when there are years of lower prey availability.
> There is some even-odd year variability in mammal predators as well.

Caihong Fu: Assessed food competition between marine mammals and fisheries off the west coast of Canada by ecosystem model OSMOSE. Six scenarios (removal of predators) tested; response of six fish species were predicted. Herring still had high mortality in all scenario, *i.e.*. removing the mammal predators makes them available to other types of predators. Pinnipeds had a smaller effect than cetaceans due to their relatively small biomass. Increasing cetaceans affects fish species due to their high consumption.

Questions and Responses

Do distributions change under the scenarios?
> Assumed overlap, some use of proxy, but work needs to be done.

Was fishing included in the model, what about leaving out fishing?
> Not been done yet.

How is the model validated?
> An optimization package is used to minimize the differences by tuning the parameters; fitted to the data.

Why was there so little impact on the herring by cetaceans?
> It could perhaps be due to changing environmental conditions.

Other models have concluded that the presence of seals preying on hake is responsible for high biomass on herring
> Based on stock assessment, there was not an increase in recruitment.

Is there fish movement in the model?
> Yes, they randomly move in the mapped grids.

Are there any direct measures of zooplankton that might be coming and going? Observed interannual variability of seabird predation of herring in San Juans—are there data about zooplankton abundance? Suggest the use of the Newport Line.
> Yes, it could be a useful index for these models.

List of papers

Oral presentations

Steller sea lions and Atka mackerel in the Aleutian Islands; abundance and spatial patterns in fish distributions - A tale of scale (Invited)
Susanne F. McDermott, Kimberly Rand and Elizabeth Logerwell (presenter)

Northern fur seals and competing pollock fish predators in the eastern Bering Sea: variability in prey size availability and spatial overlap
Ivonne Ortiz, Elizabeth McHuron and Jeremy Sterling

Evaluating competition between marine mammals and fisheries: a case study of the southern resident killer whales
Andrew W. Trites

Spatial distribution of fin (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales in relation to environment and acoustically measured prey distribution
Abigail McCarthy, Alex De Robertis, Stan Kotwicki, Kathy Hough, Paul Wade and Chris Wilson

Potential competition between fish and seabirds: a case study in the Bering Sea
Yutaka Watanuki

Assessing food competition between marine mammals and fisheries off western Canada over the past six decades
Caihong Fu, Thomas Doniol-Valcroze, Strahan Tucker, Jennifer Boldt, Norm Olsen, Yi Xu, Huizhu Liu, Philippe Verley and Yunne-Jai Shin

FUTURE Workshop (W13)
Common ecosystem reference points

Convenors: *Jennifer Boldt (Canada), Vladimir Kulik (Russia), Elliott Hazen (USA), Xiujuan Shan (China), Mary Hunsicker (USA), Jongseong Ryu (Korea)*

Invited Speaker:
Kirstin Holsman (NOAA Alaska Fisheries Research Center, Seattle, USA)

Background

WG 36 on "Common Ecosystem Reference Points across PICES Member Countries" is addressing PICES FUTURE Science Program's research theme question: "How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?" Strong nonlinearities in marine ecosystems indicate the existence of thresholds beyond which small changes in pressure variables can cause large responses in other ecosystem components. Better knowledge of where thresholds occur can advance our ability to anticipate future conditions and critically inform what management actions can maximize ecological, social or economic benefits. Moreover, thresholds common across analogous systems can be used to develop robust sets of reference points to prevent ecosystems from shifting into undesirable states. The purpose of this workshop was to finalize WG 36 TOR-4: "Determine shapes or functional forms of driver - response relationships from available datasets, and to quantify thresholds to identify potential ecosystem reference points". WG 36 convened a workshop at PICES-2018 for which members built a GitHub repository. This GitHub repository includes R code for single pressure GAMs, dynamic factor analyses (DFA), and gradient forest approaches. Participants from each PICES member nation ran the R code on a California Current dataset, and then expanded analyses to country-specific indicators. The Working Group met intersessionally in 2019 to advance progress on TOR-4, and to be more prepared to complete the full set of objectives of the WG at the hands-on practical workshop at PICES-2019. The practical workshop was for WG 36 members and other interested participants to (1) compare results of the threshold quantification analyses, (2) refine the analyses based on group feedback, (3) examine model diagnostics , (4) complete additional analyses using gradient forest and DFA approaches, (5) identify next steps, and (6) document the analyses completed and the R code used.

Summary of presentations

PICES Workshop 13 on Common Ecosystem Reference Points was convened on October 17, 2019. The workshop was well attended with participants actively discussing thresholds and techniques for programming. Workshop conveners welcomed participants, participants introduced themselves, and the agenda was reviewed. Jennifer Boldt reviewed WG 36 Terms of Reference (TOR), the timeline for accomplishing TORs, how this work fits into the PICES Science Program (FUTURE), WG 36 membership, completed WG 36 activities and reports, and the goals of the workshop.

Invited talk

An invited talk was given by Kirstin Holsman titled "Beyond singular driver-response tipping points and thresholds, recent examples and emerging approaches". She began with the definition of tipping points as defined in the IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels (IPCC SR1.5): "Tipping points refer to critical thresholds in a system that, when exceeded, can lead to a significant change in the state of the system, often with an understanding that the change is irreversible." She then summarized current research and examples of multivariate threshold studies. For example, she

highlighted studies that 1) identified principles for managing ecosystems that are prone to tipping points and noted that management actions can change tipping points, 2) showed within year ecosystem sampling /monitoring increases the detectability of reaching thresholds, and 3) there is a need for adaptive thresholds. Leading indications that tell managers when an ecosystem is approaching a tipping point may include deterioration of autocorrelation, increased variance, increased synchrony (asynchrony among communities stabilizes ecosystem function of metacommunities), and declines in spatial heterogeneity. Finally, Dr. Holsman identified potential future approaches to advance our understanding of multivariate thresholds that would be relevant for the working group.

Discussion

Dr. Holsman then led a discussion on multivariate thresholds and potential next steps in WG 36's analyses and future analyses. Workshop participants first identified some science and management questions important to this topic.

Science and management questions:

1) Can we do simulation work based on an heuristic model and real data to help identify tipping points better? This could be *via* tools such as qualitative network models or mental models.
2) How long does a data set need to be to determine tipping points?
3) Can cryptic tipping points be revealed through multivariate approaches? The caveat being that long time series are likely needed for this approach.
4) How can we clearly communicate multivariate thresholds to management?
5) Can we make modeled tipping points contingent on management or state to get at dynamic tipping points?
6) What are the temporal and spatial resolution needs for surveys to identify tipping points? Lack of heterogeneity may be an indicator of an approaching tipping point; therefore, if surveys are not conducted at a fine enough spatial or temporal resolution, this may affect our ability to predict tipping points. When a tipping point is approached, that may be an indication that funds should be directed to monitoring (*e.g.*, Selkoe *et al*. 2015).

Workshop participants discussed these questions and then formulated questions to be addressed in WG 36 analyses (potentially a manuscript) and in future analyses:

1) **How do changes in sampling frequency and spatial scale influence the ability to detect tipping points? Can intensified sampling near a tipping point help identify it?**
2) **How do social and ecological tipping points differ?**
3) How can we identify dynamic (those that change depending on environmental state) and multivariate tipping points?
4) **What if social hysteresis is strong (*e.g.*, new state is desired state)? When an ecosystem gets to a new state how hard is it to get back? Or, in some cases, if it's too difficult or expensive to change the current state, do we settle for the current state?**
5) What are some early warning indicators and how do they perform? *e.g.*, changes in variance, synchrony/asynchrony, heterogeneity, change in trend.

Questions 1, 2, and 4 are the questions that WG 36 will work towards answering within the next year and Questions 3 and 5 can be addressed in future analyses.

ICES Working Group

Dr. Mary Hunsicker provided a summary of the ICES Working Group on Common Ecosystem Reference Points. Their TORs are similar to those of WG 36 and the timeline of the ICES WG is 2019–2021. Their first meeting was convened in September 2019, the next meeting will be convened in November 2020, and their final meeting will be convened in 2021. During the September meeting, participants were able to address some of their Terms of Reference. Dr. Hunsicker pointed out a valuable online tool, ICES SharePoint, that

enables ICES Working Group members to share electronic files. This sort of tool would be valuable for the PICES community.

WG 36 TOR discussion

WG 36 members then discussed how they will address TORs 5 and 6. It was decided that TOR 5 could include a case study and not necessarily all ecosystems. In addition, the potential manuscript that was discussed (noted below for TOR3, including the use of simulated data) could address this TOR.

A conceptual diagram/mental model could address TOR 6 and could include social indicators (not necessarily quantitatively).

For TOR3, WG 36 members are working on a methods review paper. It was suggested that this manuscript would be strengthened with simulations that Dr. Saskia Otto (ICES) can include. Dr. Hunsicker will share a link to Dr. Otto's work with WG 36 members.

WG 36 members discussed the need for a 1-year extension to finish the final report.

Regional analyses

WG 36 members then provided updates on their regional analyses. All member countries have made progress on analyses; some members needed to complete some steps of analyses, others requested input on results interpretation. There was discussion of additional analyses that could be done (*e.g.*, Bayes DFA).

Work session

Dr. Hunsicker asked members to update excel table of the list of indicators that each member nations have for analyses.
The attendees broke out into subgroups:
1. Individuals working on analyses with the help of other members,
2. Individuals outlining a potential manuscript that was discussed in the morning,
3. Individuals writing an outline for the final report.

Summary

Overall, the W13 workshop objectives were accomplished. Members made significant progress on modeling and result interpretation, developed an outline for a manuscript, and wrote an outline for the final report. Additional R training might be useful to improve PICES member countries' capabilities in future code-dependent efforts.

Workshop 13 participants. Back row, left to right: Sukyung Kang, Shion Takemura, Jackie King, Aleksandr Zavolokin, Kirstin Holsman, Elliott Hazen, Tom Okey, JongSeong Ryu, Vladimir Kulik; Front row, left to right: Kazumi Wakita, Mary Hunsicker, Jennifer Boldt.

List of attendees

Name	Affiliation	Country
Joanna Strzelecki	CSIRO	Australia
Jennifer Boldt*	DFO	Canada
Jackie King**	DFO	Canada
Tom Okey*	School of Environmental Studies/ Ocean Integrity Research	Canada
Zengjie Jiang	Yellow Sea Fisheries Research Institute, CAFS	China
Shion Takemura*	National Research Institute of Fisheries Science, FRA	Japan
Kazumi Wakita*	Tokai University	Japan
Sukyung Kang	NIFS	Korea
Jongseong Ryu*	Anyang University	Korea
Vladimir Kulik*	TINRO	Russia
Elliott Hazen*	NOAA/SFSC/NMFS	USA
Kirstin Holsman*	NOAA/AFSC/NMFS	USA
Mary Hunsicker*	NOAA/NFSC/NMFS	USA

**indicates interest in participating in drafting manuscript*
*** indicates interest in R code developed*

List of papers

Oral presentations

Beyond singular driver-response tipping points and thresholds, recent examples and emerging approaches. (Invited)
Kirstin Holsman

BIO Workshop (W14)
New frontiers: The application of molecular approaches in marine ecology and fisheries science

Convenors: *Brian Hunt (Canada), Kristi Miller (Canada), Junya Hirai (Japan)*

Invited Speakers:
Hitoshi Araki (Faculty of Agriculture, Hokkaido University, Japan)
Ryan Kelly (School of Marine and Environmental Affairs, University of Washington, USA)

Background

Molecular ecology has developed rapidly over the last decade, opening up possibilities for a wide range of applications in marine and fisheries science. This workshop focused on two aspects of molecular ecology that have the potential to significantly advance the current state of our knowledge: (1) Environmental (e)DNA – all organisms release genetic material into the environment as they move through it. The ability to detect this free DNA in water samples is revolutionizing our ability to determine species occurrence, with applications in biodiversity monitoring, invasive species tracking and community ecology; and (2) Food web ecology – traditional methods of diet analysis involving microscopy having been essential to characterizing the diets of all levels of the marine food web. They allow quantification of dietary contributions and digestion state, however, they are time consuming and are not suitable for identifying heavily digested or fragile prey, and challenging to apply to smaller organisms (*e.g.*, zooplankton) hindering our ability to resolve the diets and

trophic connection of lower trophic levels. Molecular approaches provide a means to assess entire dietary content for all organism types and size classes. Contributions were invited on diverse taxonomic groups and from diverse ecosystems, covering topics including invasive species, community ecology, organism diets, and biodiversity monitoring. As a developing field, contributions on method development, new applications, and calibration studies (*e.g.*, eDNA trawl catch comparisons) were also welcomed. The aim of this workshop was to connect researchers applying molecular approaches in the North Pacific, and to facilitate international collaborations and coordinated development in the North Pacific region.

Summary of presentations

This one-day workshop was held on October 17, 2019 in Victoria (BC, Canada) during PICES-2019. The workshop was co-convened by Dr. Brian Hunt (Canada), Dr. Kristi Miller (Canada), Dr. Junya Hirai (Japan), and attended by approximately 35 people.

W14 covered two major themes of molecular research:
1. Current status and applications of Environmental DNA (eDNA)
2. The application of molecular approaches in organism diets

The two invited speakers, Dr. Ryan Kelly and Dr. Hitoshi Araki, both delved into Theme 1. Dr. Kelly delivered the opening presentation, starting with providing a background on eDNA methods which set up the speakers to come. He then expanded on three case studies that covered the topics of using eDNA for quantitative fish estimates, tracking community change, and measuring community gradients. Dr. Araki introduced two key approaches in eDNA research. Firstly, he discussed the targeted species-specific approach (q-PCR), with examples of using qPCR for determine the spawn timing of chum salmon and detecting and monitoring the occurrence of rare / endangered species. Of particular interest to the group was his research on quantifying estimates of taxon numerical abundance, an application that is particularly relevant to fisheries managers. Secondly, Dr. Araki discussed the development of NGS metabarcoding for whole fish community analysis, starting with testing of fish universal primers (MiFish) before moving into case studies on the application of this tool in fish biodiversity assessments.

Following the invited speakers, the workshop continued with a series of presentations arranged according to the two themes, starting with eDNA. Dr. Joanna Strzelecki presented a case study on the application of eDNA in sedimentary macroinvertebrate community census. This was of interest to the pelagic-focused participants as it provided novel insights into the challenges associated with collecting and extracting sediment DNA. Dr. Matt Lemay presented on the Hakai Institute biodiversity mapping project, and the process in developing barcode libraries in novel environments. He also discussed the suitability of eDNA to community monitoring programs. Dr. Jennifer Sunday elaborated on this community monitoring program, and how it is being used to track species range shifts in British Columbia. Dr. Kristi Miller gave an overview of the Canadian Fisheries and Oceans eDNA program, including approaches to validating the eDNA method and researching pathogen dynamics in salmon migration pathways. Dr. Miller also discussed future directions, with a key component being validation of eDNA for quantitative stock assessment. Three presentations followed, from Dr. Caterina Giner, Dr. Colleen Kellogg, and Svetlana Esenkulova on metabarcoding of bacteria, heterotrophic protists and autotrophic protists, respectively. These presentations highlighted that the eDNA method has long been used by microbial ecologists, and that this area has deep knowledge of methods in sample collection and data analysis that can be more broadly applied in eDNA research. They also underscored the power of eDNA to resolve high temporal frequency and small spatial scale community dynamics.

Four presentations were given under theme two: The application of molecular approaches in organism diets. Dr. Junya Hirai detailed a case study using metabarcoding to resolve diets and species interactions across multiple trophic levels – copepods and forage fish. This study showcased the power of the molecular approach to diet analysis, particularly for small organisms whose diets are otherwise extremely difficult to examine. Dr. Jackie Maud discussed a new study using metabarcoding to resolve zooplankton diets. Dr. Maud underscored one of the major challenges associated with working with plankton – their high taxonomic diversity requiring the simultaneous use of multiple primers to obtain a complete picture of diets. Fanyu Zhou presented a case study of euphausiid diets in the North Pacific, including the interesting finding of a high percentage of fungal sequences. This novel finding raises the question of whether fungi are parasites or ingested as part of the euphausiid diet. Finally, Dr. Strahan Tucker presented a study on metabarcoding as tool in resolving marine mammal (pinniped) diets, focusing on the challenge of developing quantitative estimates of prey proportions.

Three poster presentations were allocated 5 minute speed talks. However, none of the poster presenters were able to attend the workshop. Hui Zhang sent his poster via email before the workshop and this was delivered to the group by Dr. Brian Hunt – it presented a study on using eDNA to resolve seasonal fish community structure in the Yangtze estuary.

The workshop ended with approximately 45 minutes of discussion on emerging themes and outcomes.

- A recommendation from the participants was the development of standardized protocols in sample collection, contamination management, and Primer sets used.
- Amphipods were a group that received discussion due to challenges in amplification of this taxon's genetic material. This was a common problem encountered by a number of participants and it was resolved for group members to continue to share their experience in method development.
- Alternative sampling strategies were discussed, including tapping into archival samples, using sediment traps which have long time series with good seasonal coverage, and ocean basin scale analysis from Continuous Plankton Recorder water sampling devices.

The workshop participants ended with a discussion on the value of connecting pan-Pacific molecular research. This workshop served to provide an important meeting point for sharing ideas, challenges, and connecting researchers. The participants have resolved to maintain connection and continue to build a research program network. A PICES Working Group for molecular methods was discussed and considered to be of value, but was not proposed for PICES-2020.

List of papers

Oral presentations

Using environmental DNA (eDNA) to track changes in species and ecosystems. (Invited)
Ryan P. Kelly, Ramón Gallego and Emily Jacobs-Palmer

Environmental DNA for fish monitoring in the wild (Invited)
Hitoshi Araki, Hiroki Mizumoto and Takashi Kanbe

Evaluation of infauna community structure through microscopy and eDNA
Joanna Strzelecki, Sarah Stephenson, Mick Haywood, John Keesing, Lydiane Mattio, Damian Thomson and Melanie Trapon

A census of coastal biodiversity through DNA Barcodes
Matthew Lemay, Gillian Sadlier-Brown and Kyle Hall

Multi-species quantitation with eDNA – is it possible?
Kristina M. Miller, Shaorong Li, Tobi Ming, Angela Schulze, Amy Tabata and Christoph Deeg

Tracking seawater eDNA in British Columbia coastal waters
Jennifer Sunday, Ben Millard-Martin and Matt Lemay

Marine food webs: what can metabarcoding tell us about the true trophic pathways of the dominant mesozooplankton of the Strait of Georgia
Jacqueline L. Maud, Brian P. V. Hunt, Colleen Kellogg and Vera Tai

Metabarcoding diet analysis for revealing predator-prey relationships during the spawning period of Japanese sardine and Pacific round herring in Tosa Bay
Junya Hirai, Yoko Hamamoto, Daiske Honda, Kiyotaka Hidaka, Satoshi Nagai and Tadafumi Ichikawa

Possible prey of three species of euphausiids in the North Pacific Ocean inferred from DNA metabarcoding
Fanyu Zhou, Junya Hirai, Koji Hamasaki and Atsushi Tsuda

Diet segregation of Northwest Pacific pinniped communities; Application of novel high-throughput DNA techniques to scat
Strahan Tucker, Sheena Majewski, Chad Nordstrom, Angela Shulze, Wendy Szaniszlo and Kristina Miller

Microbial diversity along a land-sea continuum in coastal British Columbia: Using microbial source tracking to resolve the terrestrial influence on coastal ecosystems
Colleen Kellogg, Ian Giesbrecht, Brian Hunt, Bill Mohn and Steven Hallam

Assessing the seasonality of the planktonic protists in the Northern Strait of Georgia, British Columbia (Canada)
Caterina R. Giner, Rebecca Piercey, Colleen Kellogg and Brian P. V. Hunt

Metabarcoding, qPCR, and microscopy identification of taxa associated with harmful algal blooms
Svetlana Esenkulova, Amy Tabata, Ben J.G. Sutherland, Nicola Haigh, Christopher M. Pearce and Kristina M. Miller

Poster presentations

Seasonal fish assemblage structure based on environmental DNA in the Yangtze Estuary as a primary study
Hui Zhang and Weiwei Xian

DNA barcoding: A potential tool for fishery biodiversity conservation
Shufang Liu and Zhimeng Zhuang

Workshop (W15)
Application of machine learning to ecosystem change issues in the North Pacific

Convenors: *Charles Hannah (Canada), Cisco Werner (USA), Hiroyasu Hasumi (Japan), Michael St. John (Denmark))*

Invited Speaker:
Debra P.C. Peters (USDA Agricultural Research Service, NM, USA)

Background

The two tools typically used for understanding and predicting ecosystem change are 1) dynamical models that simulate the important processes, and 2) statistical models that exploit straightforward relationships observed between parameters of interest. Outside of marine science, the newly dominant approach to finding important relationships between parameters in large data sets and predicting future behavior is a family of techniques that go by the names machine learning, artificial intelligence, and neural networks. While easy to use programming tools are available, machine learning techniques are not widely used in marine science. However, given their growing importance in finance, automotive industry, advertising, and now potentially earthquake prediction, it is time to investigate the potential for their application to the goals of PICES FUTURE Science Program. The goal of this workshop was to find researchers interested in pursuing the applications of machine learning to ecosystem change issues in the North Pacific and to develop a work plan.

Summary of presentations

The 1-day workshop, held on October 17, 2019, was a first attempt to gauge the interest in the application machine learning (ML) and artificial intelligence (AI) tools to marine science issues in the PICES area. The workshop was well attended, with attendance varying from 25–35 people.

Primary results from the workshop:

- The Workshop supports the creation of a PICES Study Group to investigate the application of machine learning to improve the predictive forecasting of shifting species ranges due to climate change. At this meeting, the importance of the proposed study group was reinforced by a number of presentations, including the focus of Workshop 11 entitled "The influence of environmental changes on the potential for species distribution shifts and population dynamics of Pacific saury." PICES provides an excellent international forum where interdisciplinary experts from physics to fish, modellers to observationalists, and pan Pacific can work collectively on this urgent challenge.
- This presents a unique and timely opportunity for PICES to work collaboratively with the ICES Working Groups on Machine Learning in Marine Science (WGMLEARN) to remain current as the applications and techniques of machine learning (ML) rapidly evolve.
- The Workshop also supports a proposal for a PICES-2020 Topic Session on "Applications of artificial intelligence to advance the understanding of North Pacific ecosystems." This would help identify more practitioners of these modern tools who are already working on PICES-related problems and would continue the process of building an AI community within PICES.
- ML offers a framework for enhanced processing and analyses of the enormous data stream provided by modern sensors and technology (*e.g.*, real time sensors, satellite systems, optical systems, acoustic systems). For example, manual analysis of images of plankton is not possible when a single cruise generates on the order of 1 billion images of plankters which need to be classified by species in order to generate spatially resolved maps of each species density. With the recent applications of machine learning, there are cases where automated image detection and classification has reduce the post-processing by 90–90% (from months to days) with improved accuracy..
- ML is not the technology of the future, but rather it is the technology of now.
  - The combination of modern instrumentation with real time delivery and satellite data means that ecosystems tend to be data rich and information poor. Properly used, ML can speed the process of turning data into information.
  - Data harmonization, the process of getting disparate data sets into common formats and projected into common grids is the crucial first hurdle in successful application of ML to ecosystem issues.
  - One of the early payoffs of the NOAA AI strategy has been very large reductions in processing time for many operational image processing applications. Similar improvements are expected in the area of data QA/QC.
  - The groups that get their data work flows streamlined, and the data organized and accessible will make major advances quickly.
- For the purposes of this Workshop the phrase 'machine learning' was intended to encompass a broad range of techniques that go by names such as neural networks, artificial intelligence, deep learning, machine learning, and many others.
- ML when used as a multivariate regression tool, essentially generates correlations, and since correlation does not imply causation, hypothesis testing plays an important role in ensuring robust results.
- It is import to keep the human in the loop. Data outliers and situations where the data analysis system generates strange results are opportunities. They represent states of the system that have not been explored previously and the opportunity to improve the understanding of the ecological system.

Invited speaker, Dr. Debra Peters, provided an overview of the data and analysis system of the Jornada Basin Long Term Ecological Research Program (Las Cruces, NM, USA). Machine learning serves several roles in an integrated system that is designed to provide a pathway for transforming observations of the entire ecosystem into advice for resource managers. Lessons relevant to the application of ML to the North Pacific include:

- The combination of modern instrumentation with real time delivery and satellite data means that ecosystems tend to be data rich and information poor. Properly used, machine learning can speed the process of turning data into information.
- The increasing magnitude of the data streams requires automated QA/QC systems. In many cases it is no longer possible for a person to look at every data value. Such systems need to start by learning from the experts doing the job now.
- Harmonization of data sources is an essential first step to application of machine learning to most ecosystem problems. For Jornada Basin this meant projecting most of the environmental data onto a common 1 km grid for the entire continental USA.
- The generation of derived datasets can be crucial. In the Jornado Basin (the high New Mexico desert), the crucial metric distance to water required combining high spatial resolution data on where the water courses were with temporal information on whether a stream actually has water in it.
- Machine learning, when used as a multivariate regression tool, essentially generates correlations, and since correlation does not imply causation, hypothesis testing plays an important role in ensuring robust results.
- It is import to keep the human in the loop. Data outliers and situations where the data analysis system generates strange results are opportunities. They represent states of the system that have not been explored previously and the opportunity to improve the understanding of the ecological system.

A discussion of NOAA's AI strategy revealed many topics of interest. Lessons relevant to the application of ML to the north Pacific include:

- The strategy to implement AI is interconnected with many of the discussion points among the workshop participants; (1) building proficiency and partnerships to advance AI research, (2) need to enhance data accessibility, training data, and work flow using open source tools, and (3) the ultimate priority is to ensure the integrity of the science by evaluating and documenting the predictive model performance and error rates.
- Given large data sets with enriched metadata and labeled training data to valid model performance, the benefits of applying ML to reduce data processing costs and improve data assimilation and predictive forecasting can be realized.
- One of the early payoffs of the strategy has been very large reductions in processing time for many operational image processing applications. This is a good example of transferring technology developed for commercial applications into marine science.
- Making data accessible is an issue for everyone. The groups that get their data work flows streamlined, and the data organized and accessible, will make major advances quickly.
- Partnerships between government, academia, and private sector is critical for scientific exchange, building collaborative efforts, and advancing the application of AI as it rapidly evolves in the upcoming years, and PICES can play a lead role in this regard..

The use of machine learning for image analysis represents an essential application for marine science. Modern visual and acoustic systems generate enormous amounts of data which cannot be analysed by more traditional methods. Lessons relevant to the application of machine learning to the North Pacific include:

- Training data sets for ML are labour intensive, but necessary to validate the model performance and error rates. Annotation software and user friendly end-to-end tools that integrate computer vision and ML can lessen the burden of building training data and ensuring good results.

- ML can enhance data assimilations and predictive forecasting using a range of biological and environmental observations.

Machine learning offers methodologies for incorporating environmental variability into traditional stock assessment models and for creating species distribution models. Lessons relevant to the application of ML to the North Pacific include:

- The use of ML methods to add environmental variability into traditional stock assessment models holds promise, especially where there are long records of fish stock size.
- There are open questions related to how one treats the models when new observations are outside the range of the training data sets. For example, what are the conditions under which one can use a ML model (or any statistical model) for predicting extreme values or the impacts of climate change? Can we at least figure out when we are extrapolating rather than interpolating?
- Comparing different methods on the same data set can provide insights into the robust features and the weakness of both the results and the methods. It also offers the opportunity for providing advice based on an ensemble of different model types.
- Importance of measuring zero during surveys in order to constrain range distribution models (fish surveys).

The ICES Working Group on Machine Learning in Marine Science (WGMLEARN) met for the first time during April 2019. One of their concerns is how to lower the barriers to entry the application of ML techniques to marine science. Items relevant to PICES include:

- WGLEARN has assembled a comprehensive literature database. Approximately 500 papers were compiled covering various data types (*e.g.*, acoustics, imaging), ML techniques (classic learning, deep learning, *etc*.), and topics (stock assessment, biogeochemistry, *etc*.). The database can be accessed at https://www.zotero.org/groups/2325748/wgmlearn.
- The WGLEARN has identified a need for training of marine scientists. Possible new directions include the creation and maintenance by members of the group of an online list of relevant conferences and training options (such as video lectures and MOOC courses) or the organisation of dedicated ICES training courses.
- There is clearly an opportunity for cooperation between ICES and PICES.

Other items of interest:

- For people new of the field, it would be useful to have a family tree of machine learning techniques. There are many different families of methods offered and a person needs a framework to understand the options.
- There was interest in cooperating with ICES MLEARN on a 'lessons learned' wiki page which would help new users get up to speed and avoid the well known pitfalls.
- There are new developing technologies where results from one technique or application are used to improve the results of a different application. One of these techniques go by the name 'transfer learning' and 'reinforcement learning.' This emphasizes that many machine learning techniques can be applied to multiple fields and knowing what is going on in other fields.
- The top priority of the artificial intelligence/machine learning community is to ensure the integrity, credibility, and reliability of results derived from ML. Therefore, the need to develop technical guidance, standards for testing model performance, and the need of scientific exchange must be made readily available to the wider community.

List of papers

Oral presentations

AI and machine learning to improve understanding and prediction of complex ecosystem dynamics (Invited)
Debra P.C. Peters, Heather Savoy and Geovany Ramirez

Using machine learning techniques to estimate pelagic species distributions under novel environmental conditions in the California Current system
Barbara Muhling, Elliott Hazen, Stephanie Brodie and Michael Jacox

Computer vision-based detection of schools of herring from acoustic backscatter time series
Alireza Rezvanifar, Tunai Porto Marques, Melissa Cote, Alexandra Branzan Albu, Alex Slonimer, Thomas Tolhurst, Kaan Ersahin, Todd Mudge and Stéphane Gauthier

What will influence Chilko Lake sockeye salmon as climate changes?
Yi Xu, Mike Hawkshaw, Caihong Fu, David Patterson, Roy Hourston and Peter Chandler

A machine learning approach to evaluating the impacts of multiple stressors on biotic indices at multiple trophic levels
Caihong Fu, Yi Xu, Jennifer Boldt, Cliff Robinson, Charles Hannah, Angelica Peña, Roy Hourston and Richard Thomson

Application of machine learning to automated image analysis
Robert K. Cowen, Moritz S. Schmid, Christian Briseño-Avena and Christopher Sullivan

Where is machine learning going in the marine world
William L. Michaels and Cisco Werner

Exploratory machine learning applications in oceanography
Di Wan, Pramod Thupaki and Gregor Reid

FIS Workshop (W16)
Developing a collaborative, integrated ecosystem survey program to determine climate/ocean mechanisms affecting the productivity and distribution of salmon and associated pelagic fishes across the North Pacific Ocean

Co-sponsors: *North Pacific Anadromous Fish Commission (NPAFC), North Pacific Fisheries Commission (NPFC)*

Convenors: *Mark Saunders (NPAFC), Hal Batchelder (PICES), Dick Beamish (DFO, Emeritus), Ed Farley (NMFS/NOAA), Suam Kim (Pukyong National University, Korea), Chrys Neville (DFO), Evgeny Pakhomov (UBC, Canada), Shigehiko Urawa (Japan), Laurie Weitkamp (NMFS/NOAA), Alex Zavolokin (NPFC)*

Invited Speakers:
Alexey Somov (VNIRO-TINRO, Vladivostok, Russia)
Kjell Rong Utne (Institute of Marine Research, Bergen, Norway)
Laurie Weitkamp (Conservation Biology Division, NWFSC, USA)

Background

The high-seas pelagic ecosystems of the North Pacific support five species of Pacific salmon and Steelhead trout as well as associated species including saury and North Pacific Armorhead. Communities and resource managers around the Pacific rim are challenged to understand and forecast the impacts of an increasingly uncertain climate on the distribution and productivity of these culturally and economically important fishes. New knowledge is required to determine how climate uncertainty is affecting distribution and productivity across scales from coastal to high seas and how human intervention with hatchery production impacts the

structure of North Pacific ecosystems in relation to carrying capacity. The NPAFC along with NGOs, government, academic and private partners as part the International Year of the Salmon, have initiated a high seas expedition with scientists from around the Pacific rim in winter 2019. This expedition will begin to address gaps in our knowledge through survey work of salmon, plankton, and physical conditions in the central Gulf of Alaska. The intention is that this effort will lead to a program of coordinated integrated surveys across the entire North Pacific that will allow us to test hypotheses related to mechanisms affecting salmon productivity and to provide timely forecasts and advice. A workshop of salmon/fish specialists, oceanographers, climatologists and resource managers was convened to review the progress made during the March 2019 survey and recommend the core elements of a pan-Pacific high seas ecosystem research survey program that would be implemented through 2022 to assess the ocean/ climate mechanisms affecting salmon distribution and productivity.

Summary of presentations

Day 1: October 19, 2019

Mr. Mark Saunders (IYS Director, Pacific Region) opened the workshop on behalf of all convenors and welcomed participants. More than 60 individuals participated in the workshop and there were 27 presentations that took place over two days.

Dr. Ed Farley opened the first session by discussing "The challenges to understand how rapid climate warming impacts marine ecology of Pacific salmon." As a changing climate and associated anomalous events in the large marine ecosystems of the subarctic North Pacific Ocean (NPO) progressively expose Pacific salmon to conditions that are outside "normal" climate cycles, society will encounter new resource management issues. One challenge is to understand how winter ocean conditions and potential competition impact the distribution, migration, and survival of Pacific salmon in the NPO.

Dr. Richard Beamish presented a general overview of the "2019 Gulf of Alaska Expedition" from inception to completion. Responsible stewardship of Pacific salmon in a future of changing ocean ecosystems requires a better understanding of the mechanisms that regulate production during their ocean residence. The Gulf of Alaska expedition on the Russian ship, R/V *Professor Kaganovskiy*, during the winter of 2019 brought together 21 researchers from Pacific salmon producing countries to gather data to test hypotheses concerning the mechanism(s) that control salmon production in the ocean. The principal hypothesis is that juvenile salmon that grow the fastest in their first few weeks in the ocean survive the best, with survival mostly determined by the end of the first ocean winter, with the understanding that rapid growth during the first months in the ocean increases survival rates.

Invited speaker Dr. Alexey Somov gave an "Overview of methodology and high-level results of Russian salmon research and comparison with results obtained in 2019 GoA salmon expedition". The IYS Gulf of Alaska survey in February–March 2019 partially filled the spatial gap of salmon winter ecology studies. Applying the identical methodology with previous Russian research in the western NPO allows a comparison with the Gulf of Alaska. Decades of Russian regular observing provides an understanding of long-term abundance dynamics, limiting factors and carrying capacity of salmon marine feeding habitat.

Dr. Evgeny Pakhomov presented an "Overview of preliminary findings during the February-March 2019 International Gulf of Alaska Expedition". The expedition encountered the development of a phytoplankton bloom and possibly copepod reproduction. While overall zooplankton abundance was low, analysis has also revealed that during the survey period, mesozooplankton assemblages in the Gulf of Alaska were uniform, but the microzooplankton assemblages were unique. There was also a strong mismatch between the Juday net

plankton distribution and prey species found in salmon stomachs, suggesting that future surveys consider alternate sampling gear.

Invited speaker Dr. Laurie Weitkamp covered "Pacific salmon ecosystems on the high seas: Initial findings from the Winter 2019 Gulf of Alaska Expedition". The study area spanned roughly 10° latitude (47–57°N) and longitude (138–148°W) and it encompassed the eastern extreme of the North Pacific Current and the beginning of the northbound Alaska current. There was clear spatial variation in water conditions and catches across the study area. However, the spatial distributions and abundances of salmon species had some unexpected surprises, including a relatively abundance of Coho salmon which is supposedly coastal species found far from shore. Wide variation in salmon condition—even for conspecifics caught together in the same haul—suggested that mechanisms regulating survival may be more complex than anticipated. Results from this expedition increased our understanding of the Gulf of Alaska in late winter which has received little attention, and provided an important baseline for future studies, including proposed research in 2021.

Ms. Anna Vazhova spoke on a "Hydrochemical study in the open part of the Gulf of Alaska in the winter 2019". Two domains were determined within the surveyed area: 1) The first domain was located in the northwestern part of the area, where the cyclonic circulation of the Subarctic gyre provides high concentrations of dissolved oxygen and nutrients, 2) The second domain was influenced by both Subarctic front and the coastal processes that forms its transformed waters of the Gulf of Alaska. In this area, oxygen content and pre-vegetative concentrations of nutrients were lower. Below the thermocline (~200 m), the maximum concentrations of silicon, dissolved phosphate and nitrogen were observed in the centre of Subarctic gyre. The nutrients concentrations decreased southward. These chemical observations made it possible to identify the areas of heightened productivity and to assess the state of the ecosystem.

Mr. Vishnu Perumthuruthil Suseelan spoke about "Winter dynamics of phytoplankton biomass in the Gulf of Alaska derived from Sentinal 3 imagery." The objective of this study was to use satellite-derived phytoplankton biomass to define the habitat condition of Pacific salmon in the Gulf of Alaska. An above-water hyperspectral radiometer (HyperSAS) was installed on the bow of the ship to measure the sea surface reflectance. The satellite images indicated that the surface Chl a concentration did not exceed values higher than 1.0 mg m^{-3} in GoA between February to March. In general, high biomass (0.7 mg m^{-3}) was observed in the central region of the GoA, however, a similar biomass also observed in the northern region (0.6 mg m^{-3}). Furthermore, there is a trend of elevated biomass during March, especially towards the shelf region (>1.0 mg m^{-3}). A detailed further analysis will be conducted to spectrally separate dominant phytoplankton groups from Sentinel 3 imagery.

Dr. Brian Hunt presented information on a "Mega-Swarm of northern sea nettles in the Gulf of Alaska (*Chrysaora melanaster*) in the winter of 2019." He reported on the occurrence of an unprecedented bloom of the northern sea nettle *Chrysaora melanaster*. This species occupied the northern part of the survey area (~ 300,000 km^2) with abundance averaging 1,800 individuals per km^2 and a standing stock biomass of 1.23 million tons wet weight. The center of distribution for *C. melanaster* is believed to be the Aleutian Islands, as the shelf supports their benthic polyp phase. The *C. melanaster* in the Gulf of Alaska likely originated from the Aleutian shelf. The dry weight of *C. melanaster* was 5 times the dry weight of salmon estimated to be in the Gulf of Alaska. Both species feed on zooplankton leading to concerns that the high abundance of *C. melanaster* in the Gulf of Alaska are competing with Pacific salmon during winter.

Following the first 8 presentations, participants discussed what had been revealed in these talks. Participants were asked three questions:

I. Has your understanding changed after what was heard today?

II. What was the most surprising thing you have learned today?
III. What are the emerging high priority hypotheses to be tested?

Participants noted that there were many prey species found in salmon stomachs that were not observed in the bongo, neuston, or Juday net results. New technologies such as gliders or alternate net types (micronekton) should be considered for future expeditions. Interestingly, the presentations revealed that the observed phytoplankton and zooplankton domains in the Gulf of Alaska matched up very well. Other suggestions were to study more detailed water chemistry parameters such as iron and pH, add multiple tows at each station where salmon are present to determine vertical distribution of salmon, expand the survey to the boundaries of salmon range, and to incorporate acoustics.

Dr. Vladimir Radchenko spoke about "Pacific salmon abundance and biomass as estimated by trawl survey in the Gulf of Alaska in winter 2019." The expedition results showed that no northern shift of distribution was revealed in Pacific salmon distribution throughout the survey area. Surprisingly, pink salmon were not prevalent in the catch as expected. Pink salmon were caught in the southern portion of the survey, indicating that they may spend the winter further south, which concurs with historical records. Chum salmon were the most abundant salmon species in the Gulf of Alaska in winter and their distribution was mainly in the periphery zones of cyclonic eddy and anticyclonic meander of the Subarctic Current (northern branch). Sockeye salmon mostly occurred in the northern part of survey area with a sea-surface temperature (SST) of less than 7ºC. The survey covered no more than 15% of the potential geographical range of North American sockeye stock distribution. Coho salmon distribution density is an order of magnitude higher in the Gulf of Alaska than found in Russian surveys in the northwestern North Pacific.

Ms. Chrys Neville presented information on "Changes in our thinking of ocean life of sockeye salmon." During the winter of 2019, in addition to the Gulf of Alaska survey, there was additional fishing conducted in February 2019 in the central Pacific. She presented preliminary results describing the stock and age specific distribution of sockeye salmon in these two regions and how the information may provide new information on distribution pattern specifically for Fraser River sockeye salmon. This work is part of ongoing research examining stock specific distribution and condition of sockeye within the Pacific.

Dr. Shigehiko Urawa gave a talk on "Origins and status of chum salmon caught in the Gulf of Alaska in the winter of 2019." A total of 223 chum salmon were caught using a surface trawl, which was the most abundant catch among all types of Pacific salmon. Although chum salmon were widely distributed within the survey area, they were relatively abundant in southern warm waters. The SST of chum salmon habitats averaged 6.7°C, ranging between 5.0°C and 7.5°C. Genetic stock identification (GSI) using a Pacific-wide single nucleotide polymorphism (SNP) baseline indicated a mixture of 20% Japanese, 20% Russian, and 60% North American chum salmon. The GSI also demonstrated that most of Japanese chum salmon were distributed in the southern area south of 52°N. Otolith analysis detected 32 marked chum salmon, including 3 from eastern Hokkaido, Japan, 22 from Southeast Alaska, 3 from Southcentral Alaska, and 4 unknown marks. Fifteen percent of chum salmon showed "skinny" condition (0.9 < Condition Factor), most of which were ocean age 2 or 3, originating from both continents. The present study suggested three hypotheses: 1) Not only first winter but also following winters may be critical for chum salmon, 2) Chum salmon may have a survival strategy that they feed less overwinter and mainly use energy stored in the previous summer/fall season, and 3) the energy content level prior to the winter season and the winter habitat temperatures may affect the survival of chum salmon. To test these hypotheses, we need follow-up research in the Okhotsk Sea, Bering Sea, and the Gulf of Alaska during summer and fall before and after the pan Pacific winter research proposed in 2021.

Dr. Kentaro Honda spoke about "Condition of salmon stocks in the summer Bering Sea." Aboard a Japanese research vessel and mainly using a surface trawl, a summer high-seas research cruise to monitor the condition of Pacific salmon stocks and their habitats has been conducted in the central Bering Sea annually since 2007. The most abundant species was chum salmon, which represented more than 80% of the catch every year, followed by sockeye salmon (12.9% on average) and Chinook salmon (2.9% on average). Chum salmon was more abundant at north-eastern stations, while sockeye salmon tended to be caught at eastern stations. Nonetheless, no clear relationship between salmon abundance and physical environment or prey biomass has been found to date. Among chum salmon, ocean age 1 fish accounted for more than 50% in any given year. Proportions of older fish were lower, possibly because of their homing migration or winter mortalities. Results of genetic stock identification showed Russian chum stocks occupied the largest proportion every year as 60–75%, followed by Japanese stocks at 15–35%.

At the end of Day 1, participants were asked the same questions that followed the morning session. Participants suggested additional considerations and improvements for future expeditions including sampling eDNA at greater depths to better understand vertical distribution of species, installing cameras in the trawl nets to determine if predators enter and exit the net during sets, having dedicated marine mammal and bird observers on board, and determining the vertical migration of salmon during the day and night.

Day 2: October 20, 2019

Mr. Mark Saunders started Day 2 of W16 by reviewing the main findings from Day 1. The presentations from Day 1 created compelling context for the work being done using scientific data from the 2019 International Gulf of Alaska Expedition. Dramatic shifts in salmon abundance in the catch and productivity were associated with warm and cold ocean conditions and differed depending on the area of the NPO. Generally, warmer oceanographic periods appear to be detrimental for salmon production in the Gulf of Alaska, but good for stocks in the Bering Sea. Bristol Bay sockeye where they are supported by the high abundance of Age 0+ pollock associated with the warm years. Russian experience in the western NPO indicated that winter surveys are well suited to study mechanisms but are not recommended to support forecasts given that the broad expanse of winter salmon distribution is difficult to cover in its entirety. Summer surveys have the capacity to cover a geographically smaller range that can be used as a basis for forecasting.

Ms. Albina Kanzeparova discussed "Non-salmonid species during the winter 2019 survey in the Northwestern Pacific and the Gulf of Alaska." Macrozooplankton dominated in all areas, with *Chrysaora melanaster* being dominant in the Gulf of Alaska and *Aequorea* sp. being dominant in the Northwestern Pacific Ocean and Aleutian waters. *Boreoteuthis borealis* was the most abundant squid (by biomass). The biomass of *B. borealis* adults did not vary significantly, but biomass of juveniles increased as the ship travelled from west to east within the survey area. *Tarletonbeania crenularis* was dominant among the mesopelagic fishes. The highest fish biodiversity was recorded in the Gulf of Alaska. This was likely due to a high number of sampling stations and variable water masses.

Dr. Oleg Katugin presented information on "Distribution patterns of squid in the upper epipelagic layer of Gulf of Alaska in winter 2019." A total of 9 species of squid and 1 species of pelagic octopus occurred in net hauls during the upper epipelagic trawl survey. Two squid species (*Boreoteuthis borealis* and *Onychoteuthis borealijaponica*) were the most abundant and accounted for almost 98% of all assessed cephalopod biomass in Gulf of Alaska trawl catches. *B. borealis* occurred across the entire survey area, whereas *O. borealijaponica* was captured mainly in the southern portion of the survey grid. *Okutania anonycha*, which has been known to be an abundant species in the northeast Pacific Ocean, were absent from trawl catches but did occur occasionally in the stomach contents of Pacific salmon. The observed distribution patterns for different

species of squid are associated with numerous factors, such as species-specific latitudinal and vertical occurrence, differences in ontogenetic and diel vertical migrations, and the ability of trawl net to catch squid.

Dr. Charles Waters gave a presentation on "Winter energetic status of Pacific salmon in the Gulf of Alaska." Winter has been hypothesized as a critical period for Pacific salmon, when inter- and intra-species competition is highest as prey resources are low. To better understand this critical period, the winter fitness of fish in the Gulf of Alaska was assessed using energy densities. Preliminary analyses suggest that energy densities between species were similar, despite different prey preferences and feeding intensities. Median energy values for chum, coho, pink, and sockeye salmon were comparable. Sockeye salmon was the only species for which energy densities were potentially correlated with environmental factors, but much more analyses are needed before any conclusions can be drawn.

Dr. Christoph Deeg presented a talk on behalf of Dr. Kristina Miller on "Genomic science tools being implemented on samples from the first Gulf of Alaska expedition in 2019." Recently, they have developed genomic tools to assess the health and condition of salmon. These include 1) a high throughput infectious agent monitoring tool to simultaneously identify the presence and abundance of dozens of pathogens and 2) a series of curated biomarker panels of salmon genes that when co-expressed can recognize the presence of specific stressor responses (*e.g*., hypoxia, thermal, osmotic and general stress), inflammation, state of immune activation, viral disease development, and the likelihood of imminent mortality, all run simultaneously on a salmon "Fit-Chip." When the Gulf of Alaska results were compared to coastal surveys run in 2018, although there was a drop in overall pathogen diversity and burden of most pathogenic species from coastal areas to the high seas, two parasites were observed at the highest burdens recorded: *Loma salmondae* and *Ichthyophonus hoferri*. It remains to be determined if the low pathogen diversity was due to the fish dying or recovering from most coastal infections. Follow up analyses will include histopathology to assess disease potential on fish with the two high burden parasites and application of the "Fit Chip".

Dr. Alexey Somov discussed "Food habits of Pacific salmon in the North Pacific Ocean in winter 2019." There was a spatial differentiation in the diet of all salmon observed in the North Pacific. Euphasiids were the most prevalent in the subarctic, while pteropods and jellyfish were the most common in the transformed waters of the Gulf of Alaska. A positive relationship between feeding intensity and body condition was observed. In the Central Pacific in 2019, feeding intensity across all species was very low, which is unusual for this region and time.

Dr. Christoph Deeg also gave a talk about "At sea genetic stock identification of overwintering coho salmon in the Gulf of Alaska: Evaluation of nanopore sequencing for remote real-time deployment." Genetic Stock Identification by SNP sequencing has become the gold standard for stock identification in Pacific salmon, which are found in mixed stocks during the oceanic phase of their lifecycle. However, recent advances in third-generation single-molecule sequencing platforms, like the Oxford Nanopore minion, provide base calling on portable pocket-sized sequencers and hold promise for the application of real-time in-field stock identification on variable batch sizes. Nanopore sequencing at sea yielded stock assignment for 52 of the 75 assessed individuals. Future development will focus on improving turnaround time, accuracy, throughput, and cost, as well as augmentation of the existing baseline. If successfully implemented, nanopore sequencing will deliver an attractive alternative to the current centralized large-scale assessment approach, providing a democratized management tool to diverse stakeholders.

Dr. Gennady Kantakov presented information on "Spatial distribution and abundance of floating macro- and microplastics based on visual observation and neuston net survey in the Gulf of Alaska in Winter 2019." Spatial distribution and abundance of floating macro-and microplastics were estimated during the 2019

International Gulf of Alaska expedition. Surface-floating macroplastics were spotted at 25% of observation stations, and density of distribution in these areas ranged from 1.1 to 2.3 pieces per km^2. Among floating objects, packing materials (57.1%), food/drink containers (28.6%) and fishing gear (14.3%) were most abundant. Microplastics, including hard fragments and fibers, were present in neuston net samples in small to moderate abundance. Pre-production plastic pellets were surprisingly absent from microplastic samples collected, and the abundance levels were similar to those measured in 1986. He suggested that ocean circulation in the Northeast Pacific does not appear to concentrate microplastics in the open ocean in the GOA.

Dr. Vladimir Radchenko discussed "Live fish trap for pelagic trawl and problems for its use for salmon revealed at the International Gulf of Alaska expedition in Winter 2019." The live fish trap is a pelagic trawl device that ideally allows holding and lifting on board a research vessel of live, undamaged fish from the trawl catch for further study and/or tagging. Several fish, squid, and microzooplankton species were taken on board alive, including 2 coho salmon which were tagged using disk tags. Unfortunately, both salmon lost too many scales to guarantee a successful return to natal rivers. Jellyfish specimens had clear net imprints on their exumbrellas, which was evidence that individuals captured in the live-tagging box were experiencing hard contact with the net. Adjustments will be made to improve the effectiveness of the live-tagging box.

Participants discussed potential hypotheses for future high seas expeditions. In particular they discussed whether or not the salmon were moving throughout the ocean. Indications from the work presented during this workshop suggest that they may be milling about, which many found surprising. To shed further light, elemental analyses of otoliths can be performed, and tagging will also help fill in the blanks. There is also emerging work which could allow scientists to reconstruct stress history of fish from their scales. This could help identify if tagging is causing increased stress. It can also shed more light on the apparent decrease of infectious agent load as fish head out to sea – is their health improving or are the infected fish not making it out to sea? By determining where salmon are in the high seas during the winter and combining it with the genomics work on infectious agent load, questions regarding disease transfer between populations can also be answered.

Dr. Kym Jacobson spoke about "Juvenile salmon and ocean ecosystem studies in the northern California Current System". Northern California Current (Washington and Oregon coasts) surveys have been conducted from 1979 to 1985 by Oregon State University and from 1998 to the present by researchers from the National Marine Fisheries Service Northwest Fisheries Science Center and Oregon State University. Based on these surveys, much information has been gathered on the stock-specific distribution and migration patterns of several species of salmon along with detailed information on the growth, feeding, and health condition of individuals relative to environmental variables. The surveys have revealed two underlying mechanisms that control salmon returns in coastal waters: 1) ocean conditions are bottom up drivers for juvenile salmon survival through prey abundance and availability and 2) predation is also an important factor but has been difficult to measure. The Northern California Current survey programs have also successfully developed tools such as indicator stoplight charts and life cycle and population models, to communicate findings and forecasts to management.

Ms. Chrys Neville presented information on "Annual surveys for juvenile Pacific salmon in the coastal waters of British Columbia." Juvenile Pacific salmon surveys have been conducted along the southern British Columbia coast since 1998. In 2017, along the west coast of Vancouver Island (WCVI), integrated pelagic ecosystem surveys were initiated. These surveys combined the offshore juvenile salmon surveys and pelagic ecosystem nighttime trawl surveys. Acoustic transects were also completed as part of this. In addition to the surveys on WCVI, summer and fall surveys in the Strait of Georgia have also been completed since 1998.

Integration of these surveys with the high seas work will allow for testing of key hypotheses on the mechanisms regulating ocean survival of Pacific salmon.

Dr. Kentaro Honda gave a presentation on "How does sea-entry condition of juvenile chum salmon affect their subsequent survival and growth? A case study on eastern Hokkaido, Japan." Chum salmon (*Oncorhynchus keta*) are thought to experience considerable size-selective mortality during their early marine life stages. They found favorable sea-entry conditions (*i.e*., timing and body size) of Japanese juvenile chum salmon improved survival during their coastal residency. Most juvenile chum salmon sampled at Konbumori were found to migrate to the sea after SST exceeded 5°. Juveniles smaller than 50 mm FL at the time of sea entry were likely to die before reaching Konbumori, while those larger than 65 mm FL were expected to grow quickly in this region. It is possible that these findings are not novel and may just be supporting our current ideal release strategy. However, if the period of favorable conditions was limited during this experiment like it has been in recent years in Japan, we may be able to state that intensive release of large-sized juveniles during a limited favorable period is an effective strategy to reduce mortality.

Dr. Suam Kim spoke about "Chum salmon monitoring using electronic tags in Yeongok river or mid-eastern coast, Korea." As chum salmon do not eat during the spawning period, they must migrate and spawn using finite resources. Therefore, the movement strategy used to reach river spawning locations is critical. Salmon behavior in the downstream portion of the Yeongok river was monitored from October 24, 2018 to November 8, 2018 using electronic tags. Most salmon indicated that they preferred to reside deep in the water column and riverbank during upstream migration in the daytime. Regardless of release time, salmon began their upstream movement just after sunset. There was no difference in swimming speed between male and female specimens in the study area. However, females showed a higher fluctuation in environmental temperature than the males did, indicating that the females moved vertically in the water column more actively compared to the males.

Dr. Kjell Utne presented information on "International ecosystem survey in the Northeast Atlantic." The international ecosystem survey in the Norwegian Sea and surrounding areas (IESSNS) is a collaboration between five countries where an area of more than 3 million km^2 is covered annually. The primary objective of the survey is to produce an annual swept-area index used in stock assessment of Northeast Atlantic mackerel, but the survey also targets herring and blue whiting acoustically and Atlantic salmon through surface trawling. Scrutinized acoustic data, oceanographic data, and all fish sampled data are kept in a common database accessible to all member nations. All the data are reviewed by multiple individuals to ensure quality. These surveys have also been an excellent opportunity for public outreach and communicating research being conducted to a wider audience.

Dr. Aleksandr Zavolokin discussed "Non-anadromous species in the subarctic North Pacific Ocean". The goal of this study was to review past NPO pelagic surveys with emphasis on the period between January and March. This was done to identify species of North Pacific Fish Commission (NPFC) interest that could be caught during the winter 2019 Gulf of Alaska IYS Expedition. A review of historic high seas catch data revealed that all NPFC priority species have been caught in the North Pacific. Potential by-catch from the IYS Expeditions is of great interest to the NPFC due to the potential information it can offer concerning these priority species, as well as over 950 other mandated NPFC species. Collaboration between the NPFC and NPAFC concerning IYS surveys could support future collaborative studies on marine ecosystems, modelling, and the development of integrated information systems between the two organizations and their member nations.

The last presentation of the workshop was by Dr. Brian Wells on "Integrating salmon ocean research results into a management framework." While accessible managerial levers affecting salmon recruitment are largely in freshwater, the efficacy of freshwater practices for recovery and rebuilding populations can only be evaluated by including the ocean habitat that comprises the majority of the salmon life cycle. To develop strategies to mitigate apparent changes in seascape processes, well-parameterized ocean models are required. Decades of studying salmon at sea have elucidated many of processes that affect salmon dynamics (e.g., growth, maturation, predation, distribution). However, this knowledge has been slow to be integrated into salmon management. With an eye on the future, strategic management of salmon to aid in their recovery, promote a stable fishery, and improve coastal community resilience must be proactive. Oceans surveys must define applicable objectives and, from those findings, ocean processes and habitats should be integrated into stock assessment, life-cycle, and ecosystem models to evaluate managerial strategies.

A facilitated discussion session was held to synthesize information presented over the past two days into actionable ideas. The focus of this discussion was on how in-season intense management can benefit from a greater understanding of life-cycle processes. The following ideas were presented:

1. Currently preseason forecasting is an important tool in the United States (US) for ensuring that systems are not overutilized. However, preseason forecasts are variable in their success and more often the past has not been a good predictor of the future. Additional information on abundance from ocean expeditions may help improve models
2. Salmon returns in 2019 deviated from forecasts (in both directions) along the west coast of North America. Utilizing the knowledge gained from surveys such as the 2019 cruise may increase the accuracy of future predictions. Collection of data from multiple sources and stages during the salmon life cycle is an imperative factor for decreasing gaps in our understanding of salmon productivity and their activities on the high seas.
3. While many present were surprised with the low number of salmon caught, it was pointed out that the catches on this expedition were consistent with historical winter trawl surveys in the Gulf of Alaska. Low catches may indicate that the salmon were located elsewhere in the water column than where the net was deployed – deeper for example. The relative abundance of catches in the 2019 survey were not in accord with the known relative abundances of these species. Greater consideration of why this occurred is warranted.
4. The need for winter survival data when most of the variance in future adult returns can be obtained (in some locations) from coastal summer and fall surveys of outmigrating age x.0 fish was also questioned. For some major stocks, one of the main hypotheses of the 2019 cruise relating to abundance can be rejected without leaving the dock. Cohort abundance was mostly explained by events that occurred between freshwater and summer/fall surveys. It may not apply to all fisheries or species but in the few areas where effort has been expended to get these data the result is pretty clear. It was suggested that a review of what species/locations might benefit the most from winter survival data be conducted.
5. The final point brought up in discussion was the representative sampling of salmon on the high seas was age composition. After ocean entry, the abundance of a cohort can only decrease unless there is zero ocean mortality. That means that the most abundant age-classes are the youngest. If repeated sampling does not reflect this, then sampling is biased in some way that needs to be addressed.

List of papers

Oral presentations

The challenges to understand how rapid climate warming impacts marine ecology of Pacific salmon
Ed Farley

2019 Gulf of Alaska Expedition
Richard Beamish

Overview of methodology and high-level results of Russian salmon research and comparison with obtained results in 2019 GoA salmon expedition (Invited)
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Overview of preliminary findings during the February-March 2019 International Gulf of Alaska expedition
Evgeny A. Pakhomov, Christoph Deeg, Svetlana Esenkulova, Gerard Foley, Brian P.V. Hunt, Arkadii Ivanov, Hae Kun Jung, Gennady Kantakov, Albina Kanzeparova, Anton Khleborodov, Chrys Neville, Vladimir Radchenko, Igor Shurpa, Alexander Slabinsky, Alexei Somov, Shigehiko Urawa, Anna Vazhova, Perumthuruthil S. Vishnu, Charles Waters, Laurie Weitkamp, Mikhail Zuev and Richard Beamish

Pacific salmon ecosystems on the high seas: Initial findings from the Winter 2019 Gulf of Alaska Expedition (Invited)
Laurie A. Weitkamp

Hydrochemical study in open part of the Gulf of Alaska in the winter 2019
Anna S. Vazhova

Winter dynamics of phytoplankton biomass in the Gulf of Alaska derived from Sentinel 3 Imagery
V.P. Suseelan and Maycira Costa

Mega-swarm of northern sea nettles (*Chrysaora melanaster*) in the Gulf of Alaska in the winter of 2019
Brian P.V. Hunt, Alexei Somov, Albina Kanzeparova, Evgeny A. Pakhomov and Vladimir Radchenko

Pacific salmon abundance and biomass as estimated by trawl survey in the Gulf of Alaska in February-March 2019
Vladimir I. Radchenko and Aleksey A. Somov

Changes in our thinking of the ocean life of sockeye salmon
Chrys M. Neville, Richard J. Beamish and Aleksey Somov

Origins and status of chum salmon caught in the Gulf of Alaska in the winter of 2019
Shigehiko Urawa, Shunpei Sato and Motoyasu Kuwaki

Condition of Pacific salmon stocks in the summer Bering Sea
Kentaro Honda, Tomoki Sato and Shunpei Sato

Occurrence of non-salmonid species in the Northwestern Pacific Ocean and the Gulf of Alaska during the 2019 winter survey
Albina N. Kanzeparova, Alexey A. Somov, Anna S. Vazhova, Mikhail A. Zuev and Arkadiy M. Ivanov

Distribution patterns of squid in the upper epipelagic Gulf of Alaska in winter 2019
Oleg N. Katugin, Vladimir V. Kulik, Mikhail A. Zuev and Svetlana Esenkulova

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

Genomic science tools being implemented on samples from the first Gulf of Alaska expedition in 2019
Kristina M. Miller (presented by Christoph M. Deeg)

Food habits of Pacific salmon in the North Pacific Ocean in winter 2019
Alexey Somov

At sea genetic stock identification of overwintering coho salmon in the Gulf of Alaska: Evaluation of nanopore sequencing for remote real-time deployment
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Spatial distribution and abundance of floating macro-and microplastics based on visual observations and neuston net survey in the Gulf of Alaska in February-March 2019
Gennady A. Kantakov, Vladimir I. Radchenko, Evgeny A. Pakhomov and Brian Hunt

Live fish trap for pelagic trawl and problems of its use for salmon revealed at the international Gulf of Alaska expedition in winter 2019
Alexander A. Pavlenko, Vladimir I. Radchenko, Gennady A. Kantakov, Andrey Yu. Likhograev and Artem A. Likhoshapko

Juvenile salmon and ocean ecosystem studies in the Northern California Current
Kym C. Jacobson, Richard D. Brodeur, Brian J. Burke and Mary E. Hunsicker

Annual surveys for juvenile Pacific salmon in the coastal waters of British Columbia
Chrys M. Neville

How does sea-entry condition of juvenile chum salmon affect their subsequent survival/ growth? A case study in eastern Hokkaido, Japan
Kentaro Honda, Kotaro Shirai, Shinji Komatsu and Toshihiko Saito

Chum salmon monitoring using electronic tags in Yeongok River of mid-eastern coast, Korea
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IESSNS – International ecosystem survey in the Northeast Atlantic (Invited)
Kjell Rong Utne, Anne Olafsdottir, Jan Arge Jacobsen, Teunis Jansen, Kai Wieland and Leif Nøttestad

Non-anadromous species in the Subarctic North Pacific
Aleksandr Zavolokin

Integrating salmon ocean research results into a management framework
Brian K. Wells, David D. Huff, Brian J. Burke, Steven T. Lindley and Richard W. Zabel

BIO Workshop (W17)
Scoping an IEA of the Northern Bering-Chukchi Seas LME

Convenors: *Libby Logerwell (USA, FIS), Kirstin Holsman (USA, NOAA IEA Program), Raychelle Daniel (USA, Pew Trusts), Yutaka Watanuki (Japan)*

Background

Preparing an Integrated Ecosystem Assessment for the Northern Bering-Chukchi Seas Large Marine Ecosystem (LME) is necessary to provide scientific advice on issues such as the prospect for future fisheries in the Arctic, vulnerability to increased shipping activities, impacts of oil and gas development, and consequences of climate change. The potential impacts of climate change on Arctic marine mammals and seabirds, many of which provide subsistence resources for local and indigenous communities is also a growing concern. A workshop focusing on scoping an IEA of the Northern Bering-Chukchi Seas LME was held to:

1. Review recent research, activities and priorities related to an IEA of Arctic Ecosystems;
2. Review the scientific interest, data availability and overall feasibility of conducting such an IEA for the Northern Bering-Chukchi Sea region;
3. Assess the opportunities to partner with other organizations to address the issues identified above;
4. If the above activities demonstrate the feasibility of conducting an IEA of the NBS-Chukchi Seas LME, then Terms of Reference for a Study Group or possibly a Working Group would be developed for PICES consideration.

Contributions were invited on ecosystem surveys and research activities in the Northern Bering-Chukchi Seas LME as well as on IEA in other ecosystems, lessons learned and best practices.

Summary of presentations

The purpose of the workshop was to assemble experts in the Northern Bering-Chukchi Sea LME and also in Integrated Ecosystem Assessment in other systems (such as ICES areas (*e.g.*, Barents Sea, Norwegian Sea), the SE Bering Sea and the California Current). The experts reviewed the interest, data availability and overall feasibility of conducting an IEA in the proposed ecosystems. We discussed ecosystem surveys and research activities in the Northern Bering-Chukchi Seas LME. We also discussed IEA in other ecosystems, lessons learned and best practices. We decided that conducting an IEA in the proposed area was timely, relevant and feasible. We proposed Terms of Reference and deliverables for a new PICES Working Group (possibly joint with ICES and the Joint EA-EG led by PAME), parented by FUTURE, to conduct the IEA.

List of papers

Poster presentations

Pacific Arctic seabird communities in a time of change
Kathy Kuletz, Daniel Cushing, Erik Osnas, Franz Mueter, Elizabeth Labunski and Adrian Gall

Applying NPRB Arctic IERP (2016-2019) research to inform an IEA in the Northern Bering Sea and Chukchi Sea
Matthew Baker, Danielle Dickson, Edward Farley, Seth Danielson, Carol Ladd, Kate Stafford and Henry Huntington

Sensitivity of Alaska marine food webs to mortality-based perturbations
George A. Whitehouse and Kerim Aydin

Synoptic meteorological controls on declining seasonal sea ice in the Bering and Chukchi Seas
Matthew G. Asplin, Todd Mudge, David Fissel, Dawn Sadowy and Keath Borg

MEQ Workshop (W18)
GlobalHAB: Evaluating, reducing and mitigating the cost of harmful algal blooms: A compendium of case studies

Co-sponsors: *SCOR, ISSHA, NOWPAP, Greig Seafood Ltd., IOC UNESCO, GlobalHAB, AXA XL insurance*

Convenors: *Vera L. Trainer (USA), Keith Davidson (ICES, WGHABD), Kazumi Wakita (Japan)*

Invited Speakers:
Leif Anderson (NOAA, USA)
Alejandro Clément (Chile)
Keith Davidson (SAMS, Scotland)
Dan Holland (NOAA, USA)
Sunny Jardine (UW, USA)
Di Jin (WHOI, USA)
Jorge Mardones (Chile)
Charles Trick (Canada)

Background

Over the last 2 decades, several reports have compiled what is known about the economic effects of harmful algal blooms. However, both the type and amount of available data are limited, and these reports largely have been compiled by marine scientists rather than economic experts. Most coastal states have neither conducted economic analyses of HABs nor collected data that can be used to generate reliable quantitative estimates of

net economic losses and economic impacts. Proposals submitted to NOAA for economic impact studies demonstrate this lack of coordination; they are strong either in the HAB science or economic assessments, but not both.

Summary of presentations

To strategize how specific economic studies can be used to assess the economic impacts of HAB and mitigate their risks, a workshop (W18) was held on October 17–19 at PICES-2019. During this workshop, over 48 international experts on economics and the science of HABs from Australia, Canada, Chile, China, France, Japan, Korea, Norway, the United Arab Emirates, Scotland, Spain, UK and USA discussed a compendium of case studies that highlight the economic impacts of HABs on farmed salmon and shellfish and on wild-caught, reef-based fisheries.

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

Day 1 (½-day) was devoted to looking at the net impacts and cost analysis of U.S. west coast HABs, focusing on the example from a massive 2015 *Pseudo-nitzschia* bloom. Day 2 (full day) was devoted to presentations addressing the net impacts, costs, coastal resilience to HABs worldwide using examples of wild fisheries, recreational fisheries and aquaculture losses, and human wellbeing. On Day 3 (full day), breakout groups were formed to discuss the value of information from better or more refined forecasts and best practices for economic assessment, including economic costs and net economic losses. Questions addressed included: Can contingency planning reduce loss? How do we open areas more quickly? How do we make closures shorter? What is the value of information from better forecasts? What is the cost benefit analysis of monitoring programs? How much should be spent on monitoring? For insurance purposes, how do we reduce the cost of HABs?

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

List of papers

Oral presentation

Case study 1: U.S. West Coast *Pseudo-nitzschia* - market analysis and responses
Sunny Jardin and Stephanny Moore

Case study 2: Evaluating the cost of harmful algal blooms in coastal waters of British Columbia, Canada
Svetlana Esenkulova, Isobel Pearsall and Chris Pearce

Case study 3: *Cochlodinium polykridoides* effects on wild and aquacultured fish in Asia
Weol Ae Lim

Case study 4: Chile *Pseudochattonella* impacts on aquacultured fish and Alexandrium impacts on shellfish
Alejandro Clément and Jorge Mardonez

Case study 5: Ciguatoxin impacts on wild fisheries
Charles Trick

Poster presentations

Dynamics of Amoebophrya parasites during recurrent blooms of the ichthyotoxic dinoflagellate *Cochlodinium polykrikoides* in Korean coastal waters
Bum Soo Park, Sunju Kim, Joo-Hwan Kim, Jin Ho Kim and Myung-Soo Han

CoCliME: Investigating the socio-economic impacts of HABs through co-development with stakeholders in European marine coastal areas
Jennifer Joy West, Muriel Travers, Véronique Le Bihan, Gildas Appéré, Patrice Guillotreau, Jérémy Thomas, Baptiste Morineau, Sophie Pardo, Gregor Vulturius, Caroline Cusack and Elisa Berdalet

MEQ Workshop (W19)
The impacts of mariculture to coastal ecosystems

Convenors: *Zengjie Jiang (China), Xianshi Jin (China), Michael Graham (USA), Kristi Miller (Canada), In-Kwon Jang (Korea), Mi Young Cho (Korea), Igor Sukhin (Russia)*

Invited Speaker:
Qingli Zhang (Yellow Sea Fisheries Research Institute, China)

Background

Mariculture, especially large-scale mariculture, is an important factor affecting coastal ecosystems. In PICES Scientific Report No. 44, a previous PICES expert group (Working Group 24 on Environmental Interactions on Marine Aquaculture) provided analyses and overviews of the following: (1) Environmental Interactions of Marine Aquaculture, (2) Marine Aquaculture Legislative Frameworks and Environmental Interactions Research and (3) Pathogens of Aquatic Animals: Detection, Diagnosis and Risks of Interactions Between Wild and Farmed Population. While this was an important contribution and a sound basis on which to proceed, there is much more research needed to characterize the effects of pathogenic and harmful organisms derived from or associated with mariculture on coastal marine ecosystems, consistent with FUTURE Research Theme 3. The Study Group will leverage the international expertise within PICES and partner organizations to "identify the impacts in coastal ecosystems that arise from regional- and large-scale mariculture". The rather cautious "Study Group leading to a Working Group" approach was selected in response to previous challenges and recommendations from Working Group 24, specifically: i) any future marine aquaculture-related PICES expert group should be more narrowly focused to not only allow for more directed work, but also to increase the

likelihood of experts from all PICES member countries being able to participate and contribute, and ii) it is clear that active participation from all PICES member countries is key to realizing a complete analysis of sustainable marine aquaculture issues.

Goals of the workshop were to (1) review recent research, activities and priorities related to the effects of pathogenic and harmful organisms derived from mariculture on coastal marine ecosystems in PICES nations, (2) assess the opportunities to partner with other organizations to address the issues identified above, and (3) prepare Terms of Reference for a Working Group to address the issues identified.

Summary of presentations

On Saturday, October 19, 2019, a ½-day workshop (W19) on "The impacts of mariculture to coastal ecosystems" was convened. Approximately 15 participants joined the workshop. The invited speaker, Dr. Qingli Zhang, Professor of Yellow Sea Fisheries Research Institute, China Academy of Fishery Sciences, gave a presentation titled "Ecological risk of covert mortality nodavirus: from ponds to wild sea". The presentation focused on a covert mortality nodavirus (CMNV), an emerging *Alphanodavirus*, which is a pathogen of viral covert mortality disease (VCMD). It is widespread, causing huge economic losses in shrimp aquaculture in Asia. High prevalence of CMNV in coastal ponds is causing increasing concern that it is widespread in the marine environment. Comprehensive surveys of CMNV infection in organisms in farming ponds, drainage canals and wild sea were conducted to assess the virus' ecological risk. First, CMNV was revealed to be prevalent in the major crustacean farming areas in the coastal provinces of North China. Further analysis demonstrated that invertebrates inhabiting crustacean farming ponds constituted new biological risk factors for the spreading of CMNV. High ratio of CMNV infection in mollusks, crustaceans, polychaetes and teleosteans in the outfalls of ponds were uncovered by more extensive investigation. Moreover, serious CMNV infections were also identified from most wild offshore invertebrates, and the major decline of traditionally dominant crustaceans of the investigated seas was speculated to be related to the large-scale epidemic of CMNV. Our findings revealed the ecological hazard of CMNV spreads from farming ponds to the wild marine ecosystems.

The other invited speaker, Dr. Michael B. Rust, chair of aquaculture steering group of ICES, contribute to the workshop by sharing a valuable video presentation titled "Working towards an Ecosystem Approach to North Atlantic Marine Aquaculture". The presentation provided an overview of the ICES Aquaculture Steering group and recent progress of 7 working groups in aquaculture. It provided a very useful reference for the Study Group on *Impacts of Mariculture on Coastal Ecosystems*.

Dr. In-Kwon Jang of South Korea made a review of biofloc technology in shrimp farming. He summarized the development status, existing problems and challenges of shrimp culture in South Korea, and focused on the characteristics of biofloc technology and its application and industrialization in high-density intensive shrimp culture.

Dr. Zhuojun Ma, Director of China Academy of Fishery Sciences, provided an overview of fish meal and fish oil utilization in China, which introduced the current situation of fish meal and fish oil production in China and its application in aquaculture. He pointed out that aquaculture in China is characterized by low trophic level species and high rate of non-feeding, with high ecological transformation efficiency and input-output ratio. Compared with the high trophic species, the feed of the low nutrient species only needs to add less fish meal or oil.

In terms of suggested new Terms of Reference to upgrade from a Study Group to Working Group, the participants expressed different opinions. Some of them suggested that the new ToR were too narrow if only

focusing on the pathogen and disease aspects. Mariculture, in particular bivalves and seaweed mariculture, is a "green" industry and provides a positive ecological service function (such as food provision, climate regulation, *etc*.) if practiced in a scientific way. The disease issue is only part of the issue together with the rapid while not sustainable development of the mariculture industry. If we pay too much attention to the disease issue and its impact on the surrounding ecosystem, it will lead us in a wrong direction which will enhance the negative impact of mariculture. A Working Group should be more comprehensive so that we can find more collaboration opportunities with other organizations and attract more participants.

Other participants preferred to narrow the focus of Working Group to specifically address the impacts of mariculture pathogens on coastal ecosystems and specifically the need to address preparedness for emerging and re-emerging diseases/pathogens in PICES countries.

Considering the mismatch between the topic "Impacts of Mariculture on Coastal Ecosystems" and ToR of a new Working Group, the new ToR still need to be confirmed.

List of papers

Oral presentations

Ecological risk of covert mortality nodavirus: from ponds to wild sea (Invited)
Qingli Zhang, Shuang Liu, TingTing Xu, Jingwei Hao, Xiujuan Shan, Qiang Wu, Guangliang Teng, Xiaoping Li, Tao Yang, Chong Wang, Xiuhua Wang, Jie Huang, Xuan Dong, Zhongyi Li, Xiaoyuan Wan, Fanqun Dai, Chen Li, Songwen Sang, Jun Li and Xianshi Jin

Working towards an ecosystem approach to North Atlantic marine aquaculture
Mike Rust