PICES-2019 Annual Meeting

Book of Abstracts

October 16-27, 2019, Victoria, BC, Canada

Prepared by the PICES Secretariat

Table of Contents

Abstracts

Sessions, Poster Presentations

Workshops, Poster Presentations

*for current list of registrants, please check PICES-2019 website (Registration Summary)
https://pices.int/meetings/annual/PICES-2019/PICES_2019_reg_summary.aspx

Please report all errors to PICES Secretariat (secretariat@pices.int)

List of Sessions and Workshops

Plenary	Oct. 22, 24	
S1	Oct. 21	Connecting science and communities in a changing North Pacific
S2	Oct. 22	Marine heatwaves in the North Pacific: Predictions and impacts in coastal regions
S3	Oct. 24	Coastal ocean modelling in the North Pacific
S4	Oct. 23	The impacts of marine transportation and their cumulative effects on coastal communities and ecosystems
S5	Oct. 22, 23	Trends in ocean and coastal ecosystems and their services and its future
S6	Oct. 24	Identifying thresholds and potential leading indicators of ecosystem change: The role of ecosystem indicators in ecosystem-based management
S7	Oct. 24	Environmental indicators of plastic pollution in the North Pacific
S8	Oct. 24	Creating more effective Integrated Ecosystem Assessments (IEAs) in PICES countries
S9	Oct. 24	Coastal Ocean Observing Systems, Essential Biological Variables, and community-based monitoring
S10	Oct. 23	Linking changes in climate, nutrient distribution, phytoplankton ecology, and production of algal exudates in the North Pacific
S11	Oct. 23	Incorporating ecosystem variability and climate change into fisheries management: Progress and challenges for EBFM in the 21st century
S12	Oct. 22, 23	Impacts of meso-/submeso-scale processes on heat/material transport and on marine ecosystems
S13	Oct. 22, 23	Implications of prey consumption by marine birds, mammals, and fish in the North Pacific
S14	Oct. 22	Integrating economic and social objectives in marine resource management
S15	Oct. 22	Advances in North Pacific marine ecosystem prediction

BIO-P	Oct. 25	Biological Oceanography Committee contributed paper session
FIS-P	Oct. 25	Fisheries Science Committee contributed paper session
MEQ-P	Oct. 25	Marine Environmental Quality Committee contributed paper session
POC-P	Oct. 25	Physical Oceanography and Climate Committee contributed paper session
GP	Oct. 24	General Poster Session (part of the Poster Session)

Salon A Level 2	Oct. 24	**POSTER SESSION / RECEPTION**

W1	Oct. 19	Learn to effectively communicate your science
W2	Oct. 18	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
W3	Oct. 18	Let's play the GAME! (to achieve sustainable fisheries development in the PICES regions)
W4	Oct. 18	Circulation, biogeochemistry, ecosystem, and fisheries of the western North Pacific marginal seas: Past and future of CREAMS (Circulation Research of East Asian Marginal Seas)
W5	Oct. 18	Celebrating two decades of North Pacific CPR sampling, and future directions
W6	Oct. 19	Assessing marine ecosystem services: A comparative view across the North Pacific
W7	Oct. 17	PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment (Third)
W8	Oct. 17	Synthesis of bioacoustics programs for monitoring zooplankton and fisheries in the North Pacific
W9	Oct. 17	Monitoring non-indigenous species in PICES member countries: Towards best practices
W10	Oct. 16	PICES/ICES collaborative research initiative: Toward regional to global measurements and comparisons of zooplankton production using existing data sets
W11	Oct. 16	PICES/NPFC collaborative research: The influence of environmental changes on the potential for species distributional shifts and population dynamics of Pacific saury
W12	Oct. 18	Potential food competition between top predators and fisheries in the North Pacific
W13	Oct. 17	Common ecosystem reference points
W14	Oct. 16	New frontiers: The application of molecular approaches in marine ecology and fisheries science
W15	Oct. 17, 18	Application of machine learning to ecosystem change issues in the North Pacific
W16	Oct. 19, 20	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
W17	Oct. 16	Scoping an IEA of the Northern Bering-Chukchi Seas LME
W18	Oct. 17, 18, 19	GlobalHAB: Evaluating, reducing and mitigating the cost of harmful algal blooms: A compendium of case studies
W19	Oct. 19	Impacts of mariculture on coastal ecosystems

KeyNote

Connecting science to management, policy and people

Jackie **King**

Fisheries and Oceans Canada. E-mail: Jackie.King@dfo-mpo.gc.ca

The cumulative impacts of human stressors on coastal ecosystems are increasingly exacerbated by climate change. As scientists, we are called upon to provide scientific evidence and advice to support sustainable resource and ecosystem management of coastal ecosystems. Yet public distrust of science is increasing, which creates a new challenges for us. I will highlight 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. In doing so these programs build trust, relevance and accessibility for their science. The challenge to connect beyond our traditional science roles and relationships is a difficult one, and personal, but a challenge that each of us should attempt to undertake in some capacity.

Abstracts

PLENARY SESSION

S3-Plenary

Challenges and progress in the development of a circulation model for the central west coast of Vancouver Island

Michael **Foreman**[1], Peter Chandler[1], Di Wan[1], Pramod Thupaki[2], Maxim Krassovski[1], and Laura Bianucci[1]

1 Institute of Ocean Sciences, Fisheries and Oceans Canada, P.O. Box 6000, Sidney, B. C., V8L 4B2, Canada
E-mail: mike.foreman@dfo-mpo.gc.ca
2 Hakai Institute, Pruth Harbour, Calvert Island, BC V0P 1H0, Canada

Some of the challenges encountered in developing coastal circulation models will be illustrated with a case study for the central west coast of Vancouver Island. Though the motivation for this particular model is simulating the dispersion of parasites and pathogens emanating from salmon farms in Clayoquot and Nootka Sounds, grid resolution and forcing field (e.g., atmospheric, open boundary, river discharge) requirements and limitations should be typical of other coastal models in the North Pacific. Simulations for the spring of 2016 will be described and their accuracy will be assessed through comparisons with observations from acoustic Doppler current profilers, coastal tide gauges and bottom pressure sensors, and near-surface salinities and temperatures from as many as 21 salmon farms. Overall model performance, circulation features relevant to dispersion, and a wish list that should lead to future improvements, not only for this but all coastal circulation model applications, will be discussed.

S5 Plenary

Community shifts from macroalgae to corals under climate warming: Underlying processes and adaptation strategies

Naoki H. **Kumagai**[1], Jorge García Molinos[1,2,3], Hiroya Yamano[1], Shitaro Takao[3,4,5], Masahiko Fujii[3] and Yasuhiro Yamanaka[3]

1 Center for Environmental Biology and Ecosystem Studies, National Institute for Environmental Studies, Tsukuba, Japan
E-mail: nh.kuma@gmail.com
2 Arctic Research Center, Hokkaido University, Sapporo, Japan
3 Graduate School of Environmental Science, Hokkaido University, Sapporo, Japan
4 Bioscience Group, National Institute of Polar Research, Tachikawa, Japan
5 Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Japan

Global degradation of coral reefs and macroalgal beds can have ecosystem wide implications for biodiversity, ecological functioning, and ocean resources. However, opposing the well-known shifts from corals to algae, recent studies in warm temperate zones have documented community shifts from macroalgae to corals, signaling a potential mechanism for coral conservation at the expense of macroalgae under climate warming. Here, we present evidence that ocean warming, aided by the dominant poleward-flowing current system, is 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. Our results also suggest that future climate change may exacerbate this process, potentially compromising the long-term stability of these communities. Furthermore, we introduce our ongoing field surveys on the transient communities from temperate macroalgae to tropical corals on the southwestern Japanese coasts. We discuss future conservation of these communities, which might require of a more proactive management toward climate adaptation including abundance control of herbivorous fishes, artificial assistance for thermal adaptation through selection of thermal-tolerant lineages, or relocation and translocation into cooler areas.

(Kumagai, N. H., J. García Molinos, H. Yamano, S. Takao, M. Fujii, and Y. Yamanaka 2018. Proceedings of the National Academy of Sciences of the United States of America 115: 8990–8995; doi: 10.1073/pnas.1716826115)

S6-Plenary

How can we develop suitable indicators to inform management of ecosystems under multiple pressure?

Saskia A. **Otto**

Institute of Marine Ecosystem and Fishery Science, University of Hamburg, Germany
E-mail: saskia.otto@uni-hamburg.de

Indicators are effective tools for assessing and communicating key aspects of ecosystem state with multiple indicator roles and features emerging. Some operational indicators trigger management action when a threshold is reached, while others play an interpretive, or surveillance, role in informing management. In Europe, the Marine Strategy Framework Directive (MSFD), intended to lead to a 'good environmental status' of the marine waters, requires indicators to also respond to manageable anthropogenic pressures. But 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. For instance in the Baltic Sea, recent studies show that trophic interactions can shape trade-offs between management targets by modifying and mediating effects of pressures on ecosystems. In some cases, effects of nutrient load and climate scenarios counteracted each other, altering how management measures manifested in the indicators. Incorporating climate change, or other regionally non-manageable drivers, is thus necessary for an accurate interpretation of indicators and thereby of EBM measure effects. Developing a set of meaningful indicators calls for iterative indicator validations, accounting for natural processes such as trophic interactions and for trade-offs between management objectives, to enable learning and setting target levels and action thresholds in an adaptive manner. A thorough screening based on indicator selection criteria can help further identify particular weaknesses in any given indicator, which could then be addressed to improve the indicator's usefulness in a management context.

S7-Plenary

Past progress and future opportunities: Seabirds as biological monitors of microplastic pollution in the Pacific

Stephanie **Avery-Gomm**

University of Queensland, Brisbane, Australia. E-mail: s.averygomm@uq.net.au

Marine plastic pollution occurs from the Arctic to the Antarctic, with several areas of significant concentrations in regions where ocean currents converge in gyres. To date, over 2000 organisms have been documented to interact with plastic via ingestion or entanglement. Research to document the extensive distribution of marine debris and interactions with wildlife has usefully raised the profile of the plastic pollution problem and motivated policy changes. Now, cost-effective approaches to detect changes in the density and composition of plastic pollution are needed to establish monitoring programs that can trigger state-dependent management actions and/or detect the outcomes of waste-reduction policies. A seabird, the Northern fulmar, is the only environmental indicator of microplastic pollution that has been used in a formal, long-term program to monitor spatial and temporal trends. Why is this species suitable? What can this indicator tell us how the North Pacific compares to other regions? How has studying plastic ingestion in Northern fulmar contributed to the maturation of the field of wildlife plastic ingestion overall? I will give an overview of progress made over the past 20 years and discuss some of the challenges and opportunities for monitoring plastic pollution in the future.

S10-Plenary

Micro- and macro-nutrient supply from the marginal seas to the North Pacific Ocean and its changing

Jun **Nishioka**[1], Hajime Obata[2] and Ichiro Yasuda[2]

1 Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan
E-mail: nishioka@lowtem.hokudai.ac.jp
2 Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan

It is well known that phytoplankton growth is broadly limited by iron (Fe) availability in the subarctic Pacific. To investigate which Fe source control the amplitude of seasonal variation in biogeochemical parameters in the subarctic Pacific, we examined the spatial variation in the west-to-east distribution of dissolved Fe (DFe) across the western and eastern subarctic Pacific through the GEOTRACES-Japan program. The vertical section profile of the western subarctic Pacific gyre showed high dissolved Fe concentrations in intermediate water, suggesting that Fe-rich intermediate water is transported laterally. This is well explained by external sedimentary Fe sources and water ventilation systems from a subpolar marginal sea, the Sea of Okhotsk. While, extremely rich in macro-nutrient (nutrient) and low in dissolved oxygen water is discharged from the western Bering Sea and spread in wide density range of the intermediate layer of the whole subarctic area. The spatial pattern of Fe to nutrient stoichiometry supplied from the intermediate water to the surface, in comparison with reported Fe and nutrient demand in surface phytoplankton, quantitatively explains the differences in surface macronutrient consumption between the western and eastern gyre as well as the formation of the high nutrient and low chlorophyll region in the whole subarctic Pacific. Whereas, the sub-polar marginal seas are changing under the influence of climate change, such as weakening of ventilation and intermediate water circulation with decreasing sea ice formation. Therefore, our findings have important implications for predicting the impact of climate change on the global nutricline, biological productivity and the carbon cycle.

S15-Plenary

Decadal predictions of ocean biogeochemistry in the North Pacific

Nicole **Lovenduski**[1], Stephen Yeager[2], Kristen Krumhardt[2], and Riley Brady[1]

1 Department of Atmospheric and Oceanic Sciences and Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado, USA. E-mail: nicole.lovenduski@colorado.edu
2 Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, Colorado, USA

The pressing need for societally-relevant information about the climate system in the near-future (the coming years to decades) has generated extensive research in the field of decadal climate prediction. Here, we explore the potential to make predictions of near-term ocean biogeochemistry in the North Pacific using the Community Earth System Model Decadal Prediction Large Ensemble (CESM-DPLE). CESM-DPLE initiates 40 decade-long forecasts of the coupled Earth system each year from 1954 to 2015. Each forecast is initialized slightly differently, but all forecasts are subject to a common set of historical external forcings. The benefit(s) of forecast initialization are explored by comparing the ensemble mean forecast with that generated by the un-initialized CESM Large Ensemble. Our results suggest the potential to predict the evolution of biogeochemically important quantities such as air-sea CO_2 flux, phytoplankton primary productivity, and surface ocean pH variations in the North Pacific several years in advance. The production and analysis of decadal ocean biogeochemical predictions has the potential to serve society and advance scientific research in this field. Those designing ocean biogeochemical observational programs can benefit from a robust quantification of regional predictability.

SESSION 1
Connecting science and communities in a changing North Pacific

(S1-14278) INVITED

How the Kuroshio enriches the southern coast of Japan and its downstream regions

Takeyoshi **Nagai**[1], Silvana Duran[2], Diego Otero[2], Yoshie Naoki[3], Kazuki Ohgi[3], Daisuke Hasegawa[4], Sophie Clayton[5], Yusuke Uchiyama[6]

1 Tokyo University of Marine Science and Technology, Japan. E-mail: tnagai@kaiyodai.ac.jp
2 Facultad de Pesquería, Universidad Nacional Agraria La Molina, La Molina, Peru
3 Center for Marine Environmental Studies, Ehime University, Ehime, Japan
4 Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Miyagi, Japan
5 Ocean, Earth and Atmospheric Sciences Department, Old Dominion University, Norfolk, VA, USA
6 Department of Civil Engineering, Kobe University, Hyougo, Japan

The Kuroshio, a western boundary current in the North Pacific, has been influencing the local weather, physical oceanography, biogeochemistry and marine ecosystem in the northwestern Pacific regions. Previous studies have revealed that the Kuroshio Extension region is the one of the largest net carbon sinks, “carbon hotspot” for the atmosphere on the Earth. Also, many fish species are populated in the Kuroshio regions, despite that the surface Kuroshio water is known to be nutrient depleted. The comprehensive understandings of the role of the Kuroshio in forming the net carbon sink and modulating the marine ecosystem are, therefore, vital for better predictions of the ocean responses to the climate changes. Recent studies have suggested that the subsurface layers of the Kuroshio carry a large amount of nutrients, transporting them to the downstream Kuroshio regions, similar to the Gulf Stream. Furthermore, the subsurface nutrient concentrations along these western boundary currents are elevated compared to that in the ambient waters of the same density. However, it has still been unclear how these elevated nutrient concentrations are formed, whether and how these nutrients along the Kuroshio in the dark subsurface layers are supplied to the southern coast of Japan, how the mesoscale eddies and filaments influence the nutrient supply, and how the nutrients are supplied in the downstream Kuroshio Extension regions. In this study, recent field observations of nutrients and microscale turbulence using a state-of-the-art tow-yo turbulence profiler in the upstream Kuroshio regions and the numerical simulation results are discussed, to address these issues.

(S1-14318) INVITED

Better understanding of socioeconomic impacts of climate change in fisheries

Dohoon **Kim**

Pukyong National University, Busan, R Korea. E-mail: delaware310@pknu.ac.kr

Needless to say, understanding climate variability and its impacts on fisheries and fishing communities is important. In particular, the interactions among climate change, ecosystem, fisheries, and coastal communities have been intensively conducting by researchers and especially, FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems) program in PICES. The SEES (Social-Ecological-Environmental Systems) framework has been considered and applied in PICES and found to be applicable. I introduced one case that shows socioeconomic and ecological impacts of climate change in fisheries in the Republic of Korea. I also considered analytical methods for estimating socioeconomic impacts of climate change in fisheries for more effective strategies of management and governance.

(S1-14158)

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

Aoi **Sugimoto**

Japan Fisheries Research & Education Agency, Japan. E-mail: aois@affrc.go.jp

It has been pointed out that there is a lack of scenario approach studies in Asia despite that this approach is recognized beneficial for the better governance of Ecosystem Services (ES) or Nature's Contribution to People (NCP) (Saito et al. 2018). Furthermore, scientists are globally facing the challenge to incorporate cultural dimensions in the assessment and governance of ES/NCP (Diatz et al. 2015; Chan et al. 2018). Given this circumstances, this work proposes a novel approach which integrates cultural dimensions in the national-scale future scenarios for ES/NCP governance under the rapid natural/social environmental changes (e.g., depopulation, immigration, and climate change).

I use a case study of Ishigaki island, Okinawa, Japan to demonstrate this approach, under a national level ecosystem scenario building project: Predicting and Assessing Natural Capital and Ecosystem Services (PANCES). By combining the past ecological/biological works with ethnographic works both of which have been carried out in the same island for many years, this work explores the way how traditions/customs of the island could interact with rapid changes of socio-ecological systems. This work also shows the possibilities and challenges of participatory scenario building method which engages local community in the 'scientific' process. Discussions will be welcomed among PICES member countries following the presentation, which even will lead a future collaboration to develop this approach in wider North Pacific context.

(S1-14376) INVITED

An automated synopsis of the state of Pacific Canadian groundfish and climate impacts

Sean C. **Anderson**[1], Elise A. Keppel[1], Andrew M. Edwards[1], Philina A. English[1], Eric J. Ward[2]

1 Pacific Biological Station, Nanaimo, British Columbia, Canada
E-mail: sean.anderson@dfo-mpo.gc.ca
2 Northwest Fisheries Science Center, Seattle, WA, USA

Modern survey and fishery monitoring programs generate vast quantities of biological and environmental data. However, translating the data into measures of population and ecosystem health that are useful to fellow scientists, the public, resource managers, and the Indigenous people and fishing-industry collaborators who help collect the data remains a challenge. In British Columbia, Canada, survey- and commercial-monitoring programs produce data on over 100 groundfish species, but limited capacity has historically left the majority of such data unreported. To address this, we developed an automated data-synopsis report for 113 groundfish species in Pacific Canadian waters. Our report includes visualizations of temporal trends and spatial distributions of commercial catches and survey indices, and data on age and length frequencies, maturity, and growth, presented in a standardized format for each species. The report facilitates discussions on stock-assessment and survey-program prioritization, increases transparency about our data holdings, and makes the data available for regular review by all interested parties. We describe lessons learned while developing this report, insights the project has yielded thus far, and how ongoing work will further enhance the utility of this reporting tool. One important next step is to incorporate environmental data in the form of climate velocities—the speed and direction with which a population would have to shift to maintain consistent climatic conditions—to provide a window into potential climate impacts on Pacific Canadian groundfish species.

(S1-14209)

The Winter 2019 Gulf of Alaska Expedition: Studying salmon ecosystems on the high seas

Laurie A. **Weitkamp**

Northwest Fisheries Science Center, NOAA Fisheries, Newport, OR, USA
E-mail: laurie.weitkamp@noaa.gov

This past winter an international team of scientists representing Japan, Korea, Russia, Canada, and the U.S. spent a month in the Gulf of Alaska studying salmon on the high seas. The primary goal of the study was to determine if winter is indeed a critical period for salmon survival, which determines subsequent adult abundances. To achieve this goal, the expedition study design was holistic and included physical and chemical ocean oceanography, plankton, and nekton including salmon. This talk will provide an overview of the initial results of the expedition. Because the study area covered roughly 10° latitude (47-57°N) and longitude (138-148°W) and straddled the North Pacific and Alaska currents, we observed clear spatial variation in water conditions and catches across the study area. However, the spatial distributions and abundances of species had some unexpected surprises, including supposedly coastal species far from shore. Genetic analyses to determine the origins of salmon conducted during and after the expedition indicate many salmon originated from around the Pacific Rim. Furthermore, 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 increases our understanding of a region (Gulf of Alaska) and time (late winter) which has received little attention, and provides an important baseline for future studies, including proposed research in 2021.

(S1-14392)

An assessment of climate change impacts on polar ecosystems

Anne B. **Hollowed**

Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, USA.
E-mail: Anne.Hollowed@noaa.gov

The Intergovernmental Panel on Climate Change commissioned a Special Report on Oceans and Cryosphere under a Changing Climate (SROCC). This report will be published this fall. The report provides a comprehensive assessment of the evidence for climate change on marine ecosystems of the world. This talk will describe the key findings of the report with respect to trends, impacts and the scope for adaptation for polar regions. The talk will contrast the observed responses of marine species and humans to changing climate conditions in the Bering Sea and Barents Sea and will elucidate the key threats to these marine ecosystems in the future. The report provides a comprehensive assessment of the physical, biogeochemical, biological and societal changes occurring in polar regions. This talk will present the assessment of options for human responses to changing climate conditions in the far north.

(S1-14075)

Top predators as climate and ecosystem sentinels

Elliott L. **Hazen**[1,2], Briana Abrahms[1], Stephanie Brodie[1,2], Gemma Carroll[1,2], Michael Jacox[1,2,3], Matthew S. Savoca[1,4], Kylie L. Scales[5], William J. Sydeman[6], and Steven J. Bograd[1,2]

1 NOAA Southwest Fisheries Science Center, Environmental Research Division, USA. E-mail: elliott.hazen@noaa.gov
2 University of California Santa Cruz, Institute of Marine Science, USA
3 NOAA Earth Science Research Laboratory, Physical Sciences Division, USA
4 Stanford University, Hopkins Marine Station, USA
5 University of the Sunshine Coast, School of Science and Engineering, AUS
6 Farallon Institute, Petaluma, USA

The presentation is a culmination of our workshop at the 2014 PICES FUTURE meeting. The rapid pace of environmental change in the Anthropocene necessitates a new suite of tools for measuring changes in ecosystem dynamics. From birds to invertebrates, sentinel species have been used to provide insight into ecosystem function, hidden risks to human health, and as harbingers of future change. Here we propose that marine top predators offer a unique ability to assess ocean processes as they can transit across ocean basins and amplify food web processes across multiple spatio-temporal scales. To better facilitate the use of top predators as sentinel species, we provide a clear definition of 'climate and ecosystem sentinels', review the attributes of species identified as sentinels, and describe how a suite of sentinels could strengthen our understanding and management of marine ecosystems. We conclude that using marine predators as ecosystem sentinels enables rapid response and adaptation to ecosystem variability and environmental change in part because they are easier to observe, and in part because they may serve as a leading indicator of ecosystem change. While oceanography and predator ecology are often two disparate fields, we need to continue to forge interdisciplinary collaborations to understand what top predator behavior, distribution, abundance, and demography may tell us about how climate variability and change are affecting ocean ecosystems. Choosing a suite of appropriate sentinels will both give insight into ecosystem processes and can help manage changing ecosystems into the future.

(S1-14418) INVITED

Connecting science and communities under a changing climate: The role of boundary organizations

Anna Milena **Zivian**

Ocean Conservancy, Santa Cruz, USA. E-mail: azivian@oceanconservancy.org

The ocean affects all aspects of our lives – history, culture, health, well-being. We need to do better to ensure we can continue to rely on the ocean, and that the vast biodiversity in the ocean can persist and thrive. For this, we need to reduce the multiple stressors on the ocean, and in particular to act on climate – by mitigating CO2 and other greenhouse gas emissions; adapting; and increasing ecological resilience as well as people's ability to withstand change. To act on climate and address change, we need to bring together science, knowledge, governance, advocacy, and action for success; and as the title of this session indicates, to connect science and communities.

Organizations that work across sectors and domains – boundary organizations – are important actors in making these connections and in providing a networked approach to bring different skills and knowledge to issues facing the ocean. By bringing different areas together – both geographic and sectoral or disciplinary – we can facilitate transdisciplinary research; diversify and strengthen ocean governance; and provide useful knowledge in the right format and at the right time to decision makers. This presentation will discuss examples of how boundary organizations like the Ocean Knowledge-Action Network can contribute to knowledge synthesis, transfer, and support for action, especially in the context of the upcoming UN Decade of Ocean Science for Sustainable Development and its goal of reversing the cycle of decline in ocean health and creating improved conditions for the ocean and all of us who rely on it.

(S1- 14517)

The North Pacific Ecosystem Status Report 2009-2015

Peter **Chandler**

Institute of Ocean Sciences, Sidney, BC, Canada. E-mail: Peter.Chandler@dfo-mpo.gc.ca

This is the third in a series of North Pacific Ecosystem Status Reports (NPESR) produced by the North Pacific Marine Science Organization (PICES), and is commonly referred to as NPESR3. The purpose of this report is to provide an integrated view of the status and trends in North Pacific marine ecosystems, and the vulnerability and resilience of these ecosystems to pressures from climate and human activities. The intended audience includes those interested in the science of climate and marine ecosystems of the North Pacific Ocean, and the governments that deal with issues of policy and management of North Pacific ecosystems.

(S1-13915)

The UN Decade of Ocean Science for Sustainable Development and PICES: For the perspective of a predicted ocean

Fangli **Qiao**

First Institute of Oceanography, Ministry of Natural Resources, Qingdao, 266061, PR China
E-mail: qiaofl@fio.org.cn

The UN Decade of Ocean Science (20121-2030) will build upon 60 years of ocean science leadership at the United Nations to create a global process and movement to unlock the body of ocean science and knowledge the world needs to achieve its goals for a healthy and sustainable planet. The decade has 6 social goals including a clean ocean, a healthy and resilient ocean, a predicted ocean, a safe ocean, a sustainably harvested and productive ocean, and a transparent and accessible ocean. PICES, as one of the most important regional international organizations in the north Pacific, has implemented long-term FUTURE program in which predicted ocean is one of the key parts. This presentation will mainly focus on the challenge and possible solution for ocean models, Typhoon models and climate models. Improved physical processes understanding can dramatically improve model performance. Surface wave-tide-circulation coupled model can much improve the forecasting ability of ocean model in upper ocean which has been a challenge for half century; the inclusion of surface wave in Typhoon model can reduce the systematic forecasting error of Typhoon intensity which has been a challenge for several decades; and the inclusion of surface wave in climate models can much reduce the tropical biases which are common problem for all climate models. All above suggests that the point of view of complex system or interdisciplinary research is a key to understand and predict the world.

(S1-14331)

Participatory system modelling to increase climate resilience of seafood availability in Tla'amin Nation

Patricia T. **Angkiriwang**[1], Sachiko Ouchi[2], Tiff-Annie Kenny[3], Anne Salomon[2], Laurie Chan[3], and William Cheung[1]

1 University of British Columbia, Vancouver BC, Canada. E mail: p.angkiriwang@oceans.ubc.ca
2 Simon Fraser University, Vancouver BC, Canada
3 University of Ottawa, Ottawa ON, Canada

Fish and other seafoods are integral to the traditional diet and culture of many indigenous First Nations on the west coast of Canada. However, the availability and access of traditional foods for these communities have been declining, and shifting fish distributions due to projected climate change—among other factors— may pose further challenges to the food security, nutritional health and culture of coastal First Nations.

Through a collaborative effort with the Tla'amin Nation, we aim to identify and explore adaptation options to reduce potential climate risks on the Nation's fisheries and food system, and assess their effectiveness and possible trade-offs. We develop and apply a participatory modelling approach, first by co-organizing a workshop with legislators, community members, and experts from Tla'amin Nation to synthesize a shared multi-disciplinary complex systems understanding of factors and dynamics relating fisheries, environmental change, food security, culture and well-being. The resulting systems model will subsequently be used to test potential impacts of community-proposed adaptation options and strategies under various socio-ecological and climate change scenarios.

Ultimately, we hope the outputs from this study will help increase community resilience to human and climate impacts on fish availability in the area. This research highlights interdisciplinary systems framework approaches, with key components informed by community focus groups and participatory systems mapping workshops.

(S1-14378)

The Local Environmental Observer Network for inclusive documentation and understanding of unusual environmental / ecological changes that matter to communities

Thomas A. **Okey**[1,2], Michael Y. Brubaker[3,4] and Michael J. Brook[3,4]

1 University of Victoria, British Columbia, Canada. E-mail: Thomas.Okey@gmail.com
2 Ocean Integrity Research, Victoria, British Columbia, Canada
3 Alaska Pacific University, Anchorage, Alaska, USA
4 Alaska Native Tribal Health Consortium, Anchorage, Alaska, USA

The Local Environmental Observer (LEO) Network (leonetwork.org) can be utilized by regional marine science organizations and communities such as PICES to showcase and integrate multiple dimensions of existing knowledge about ecological and social changes. This increases the general understanding of these unusual changes as well as the capacities of communities to adapt. The LEO Network is a global community of citizens and other experts documenting unusual environmental changes, understanding those changes, and finding solutions. It features a growing online database of quality-assured first-person observations that can be queried topically, geographically, and temporally. These observations integrate local, indigenous, and scientific knowledge, and they become published collaborative posts with attribution. Each posted observation can be linked to powerful resources related to the topics of each observation. The concentration of first-person observations and news articles along northeast Pacific coastlines is one pattern that emerged from the LEO data. That pattern is distinct in that region because the LEO Network originated in Alaskan Native communities through the Alaskan Native Tribal Health Consortium. New developments in LEO such as the incorporation of (geo-referenced) peer-reviewed journal articles and other historical scientific publications are advancing the power of this surveillance and knowledge platform to integrate existing scientific knowledge with local and indigenous knowledge. This and other advancements will to continue to improve our general understanding of ecological and social-ecological changes. Furthermore, the LEO Network facilitates solutions to serious environmental / ecological problems faced by communities by providing a safe and transparent space for knowledge sharing and collaboration.

(S1-14429)

Capacity building in Indonesian fishing communities using smartphone technology to monitor the environment and fisheries: The FishGIS project

Mitsutaku **Makino**[1], Mark L. Wells[2], Suhendar I. Sachoemar[3], Naoki Tojo[4], Shion Takemura[5], Shigeharu Kogushi[6], Vladimir Kulik[7], Joo-Soo Lee[8], Charles Trick[9], Chang-an Xu[10] and Alexander Bychkov[11]

1 AORI, The University of Tokyo, Kashiwa, Japan; E-mail: mmakino@aori.u-tokyo.ac.jp
2 School of Marine Sciences, University of Maine, Orono, USA
3 Agency for the Assessment and Application of Technology, Jakarta, Indonesia
4 Faculty of Fisheries Sciences, Hokkaido University, Hakodate, Japan
5 National Research Institute of Fisheries Science, FRA, Yokohama, Japan
6 Greenfront Research Laboratory Co., Ltd., Aichi, Japan
7 Russian Research Institute of Fisheries and Oceanography, Pacific Branch, Vladivostok, Russia
8 National Institute of Fisheries Science, MOF, Busan, Korea
9 Western University, London, Canada
10 Third Institute of Oceanography, SOA, Xiamen, China
11 PICES Secretariat

Fisheries management is often challenged by the limitations in survey data, and this weakness is particularly intense for developing nations. The overall goal of the PICES-MAFF FishGIS project is to enhance the capacity of local small-scale fishers in Pacific Rim developing countries to monitor their local coastal ecosystems and coastal fisheries. The project uses smartphone GIS-based technology (applications) to enable Indonesian fishing communities to quantify some aspects of water quality, the presence of toxic (red-tide) phytoplankton, fish landings accompanied by information on fishing operations (including illegal, unreported or unregulated fishing activities), and floating garbage. Fishers and other community members are acting as citizen scientists to transmit these coastal ecosystem and fisheries data to the relevant Indonesian agencies. This type of citizen sampling is proving to provide greater temporal and spatial data coverage than conventional scientific monitoring. Furthermore, feedback from local community members has been used to refine the FishGIS applications, including cultural design aspects such as translating the application steps into the Indonesian language. Perhaps most importantly, this integration has created a collaborative enterprise between PICES, Indonesian researchers and government, and the local communities, with new synergies that are improving knowledge and awareness of sustainable fisheries practices and food safety. The primary outcomes of the FishGIS project activities are: 1) local community members have developed a sense of ownership and are taking pride in their monitoring activities; 2) the Indonesian government is including these citizen scientist data into its National Ocean Data Center; and 3) the autonomous data streams provided by the fishing communities are now laying a foundation for the Indonesian government to scientifically manage and predict the future of its coastal ecosystems and fisheries. Two training workshops on the new smartphone technologies for fishers, community leaders, as well as for Indonesian researchers and central and local government officers, have been conducted in Indonesia in July 2018 and July 2019. The final workshop of this project is scheduled for February 2020 when reports prepared based on the collected data will be delivered to the participating communities. Future plans are to continue assessing the changing perceptions in local communities, and to include broader range of Indonesian stakeholders, such as NGOs.

SESSION 2
Marine heatwaves in the North Pacific: Predictions and impacts in coastal regions

(S2-14299) INVITED

Historical and Future Projected Changes in Global Marine Heatwaves

Eric **Oliver**[1], Markus Donat[2], M. T. Burrows[3], P Moore[4], D Smale[5,6], L Alexander[7,8], J Benthuysen[9], M Feng[10], A Sen Gupta[7,8], A Hobday[11], N Holbrook[8,12], S Perkins-Kirkpatrick[7,8], H Scannell[13,14], S Straub[6], M Thomsen[15] and T Wernberg[6]

1 Department of Oceanography, Dalhousie University, 1355 Oxford Street, Halifax, Nova Scotia B3H 4R2, Canada
E-mail: eric.oliver@dal.ca
2 Barcelona Supercomputing Center (BSC), Barcelona, Spain
3 Scottish Association for Marine Science, Scottish Marine Institute, Oban, Argyll, PA37 1QA, Scotland, UK
4 Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, Aberystwyth SY23 3DA, UK
5 Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK
6 UWA Oceans Institute and School of Biological Sciences, The University of Western Australia, Crawley, Western Australia 6009, Australia
7 Climate Change Research Centre, University of New South Wales, Gate 11 Botany Street, Library Walk, Level 4, Matthews Building, Sydney, New South Wales 2052, Australia.
8 Australian Research Council Centre of Excellence for Climate Extremes, University of New South Wales, Gate 11 Botany Street, Library Walk, Level 4, Matthews Building, Sydney, New South Wales 2052, Australia
9 Australian Institute of Marine Science, PMB 3, Townsville MC, Queensland 4810, Australia
10 CSIRO Oceans and Atmosphere, Perth, Western Australia, Australia
11 CSIRO Oceans and Atmosphere, Hobart, Tasmania 7000, Australia
12 Institute for Marine and Antarctic Studies, University of Tasmania, 20 Castray Esplanade, Battery Point, Private Bag 129, Hobart, Tasmania 7001, Australia
13 School of Oceanography, University of Washington, Seattle, Washington, USA
14 NOAA Pacific Marine Environmental Laboratory, Seattle, Washington, USA.
15 Marine Ecology Research Group, School of Biological Sciences, University of Canterbury, Christchurch 8041, New Zealand.

Marine heatwaves are important events in oceanic systems that can have devastating consequences for ecosystems, causing ecological changes and socioeconomic losses. Prominent marine heatwaves have occurred recently and attracted scientific and public interest, but comprehensive assessments of how these events have been changing globally is missing. Using daily satellite observations, daily in situ measurements, and gridded monthly in situ-based sea surface temperatures we identify significant increases in marine heatwaves over the past century. We further estimate future changes in marine heatwaves to the end of the 21st century, as simulated by CMIP5 global climate model projections. We find that from 1925 to 2016, global averages of marine heatwave frequency and duration have increased by 34% and 17%, respectively, resulting in a 54% increase in annual marine heatwave days. Importantly, these trends can largely be explained by the increase in mean ocean temperatures, rather than a change in variability. Future projections show significant, and accelerating, increases in MHWs properties into the 21st century with many parts of the ocean reaching a near-permanent MHW state by the late 21st century, regardless of emissions scenario considered (RCP4.5, 8.5). Comparison with simulations of a natural world, without anthropogenic forcing, indicate that these trends have emerged from the range of natural variability within the first two decades of the 21st century. This implies that the climate system has departed significantly from natural marine heatwave conditions under which ecosystems evolved, and therefore impacts on marine ecosystems can be expected to be widespread, significant and persistent.

(S2-14120)

Predicting the evolution of the 2014-16 California Current System marine heatwave from an ensemble of coupled global climate forecasts

Michael G. **Jacox**[1,2], Desiree Tommasi[3,4], Michael Alexander[2], Gaelle Hervieux[2,5], and Charles Stock[6]

1 Environmental Research Division, Southwest Fisheries Science Center, National Oceanic and Atmospheric Administration, Monterey, CA, USA. E-mail: michael.jacox@noaa.gov
2 Physical Science Division, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO, USA
3 Fisheries Resources Division, Southwest Fisheries Science Center, National Oceanic and Atmospheric Administration, La Jolla, CA, USA
4 Institute of Marine Sciences, University of California Santa Cruz, Santa Cruz, CA, USA
5 University of Colorado Boulder, Boulder, CO, USA
6 Geophysical Fluid Dynamics Laboratory, National Oceanic and Atmospheric Administration, Princeton, NJ, USA

Throughout 2014-2016, the California Current System (CCS) was characterized by large and persistent sea surface temperature anomalies (SSTa), which were accompanied by widespread ecological and socioeconomic consequences that have been documented extensively in the scientific literature and in the popular press. This marine heatwave and others have resulted in a heightened awareness of their potential impacts and prompted questions about if and when they may be predictable. Here, we use output from an ensemble of global climate forecast systems to document which aspects of the 2014-2016 CCS heatwave were predictable and how forecast skill, or lack thereof, relates to mechanisms driving the heatwave's evolution. We focus on four prominent SSTa changes within the 2014-2016 period: (i) the initial onset of anomalous warming in early 2014, (ii) a second rapid SSTa increase in late 2014, (iii) a sharp reduction and subsequent return of warm SSTa in mid-2015, and (iv) another anomalous warming event in early 2016. Models exhibited clear forecast skill for the first and last of these fluctuations, but not the two in the middle. Taken together with the state of knowledge on the dominant forcing mechanisms of this heatwave, our results suggest that CCS SSTa forecast skill derives from predictable evolution of pre-existing SSTa to the west (as in early 2014) and the south (as in early 2016), while the inability of models to forecast wind-driven SSTa in late 2014 and mid-2015 is consistent with the lack of a moderate or strong El Niño or La Niña event preceding those periods. The multi-model mean forecast consistently outperformed a damped persistence forecast, especially during the period of largest SSTa, and skillful CCS forecasts were generally associated with accurate representation of large-scale dynamics. Additionally, a large forecast ensemble (85 members) indicated elevated probabilities for observed SSTa extremes even when ensemble mean forecasts exhibited limited skill. Our results suggest that different types or aspects of marine heat waves are more or less predictable depending on the forcing mechanisms at play, and events that are consistent with predictable ocean responses could inform ecosystem-based management of the ocean.

(S2-14277)

California Niño/Niña

Chaoxia Yuan[1], Doi Takeshi[2], Jing-Jia **Luo**[1], Jiaqing Xue[1] and Toshio Yamgata[2]

1 Nanjing University of Information Science and Technology, Nanjing, PR China. E-mail: chaoxia.yuan@nuist.edu.cn
2 Japan Agency for Marine-Earth Science and Technology

The sea surface temperatures (SSTs) in the coastal ocean along California and Baja California are mainly influenced by the strength of local upwelling, the advection of California Current and the exchange of surface heat flux with the overlying atmosphere. In some years, the coastal SSTs are much warmer/cooler than normal and significantly impact the local marine ecosystem. The anomalous warming/cooling has been largely attributed to the tropical ENSO through its atmospheric and oceanic teleconnections. However, our research shows that the local air-sea interaction between the alongshore surface winds and the coastal SSTs also plays an important role in the coastal SST variations. When the climatological southward alongshore surface winds are weaker than normal, they will reduce the coastal upwelling, weaken the California Current and raise the coastal SSTs. The higher-than-normal SSTs then heat the overlying atmosphere, decrease the sea level pressure, and generate an anomalous seaward pressure gradient, which can further weaken the alongshore surface winds. The positive feedback is analogous to the Bjerknes feedback in the tropical oceans responsible for ENSO generation, and thus is named as the coastal Bjerknes feedback. The resultant coastal air-sea coupled phenomenon is thus called the California Niño/Niña. Some California Niño/Niña co-occur with the tropical ENSO and can be predicted at least two seasons ahead by the SINTEX-F prediction system. For those independent to ENSO, the prediction skills are low, partly owing to the coarse model resolution that can not resolve well the coastal Bjerknes feedback.

(S2-14091)

Effects of a prolonged marine heatwave on middle and upper-trophic level biota in the California Current

Jennifer **Fisher**[1] and Richard D. Brodeur[2]

1 Cooperative Institute for Marine Resources Studies, Newport, OR, USA. E-mail: Jennifer.fisher@oregonstate.edu
2 NOAA, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR 97365, USA. E-mail: rick.brodeur@noaa.gov

The Northern California Current is a highly productive region that has undergone substantial interannual and decadal-scale variability in recent decades. Forage taxa play a central role in the transfer of energy from lower to higher trophic levels. Ocean conditions may influence this energy pathway in the northern California Current (NCC) ecosystem. The recent unprecedented prolonged warming in the NCC provided unique opportunities to examine connections between ocean conditions and forage taxa abundance and distribution patterns and feeding. Findings from several studies that suggest that the recent warming period associated with the 'Warm Blob' and El Niño affected zooplankton and forage fishes over the last several years resulting in dramatic changes in species composition and phenology. Spawning times for several dominant forage fishes occurred several months prior to normal conditions and over a broad geographic area. Trawl surveys found significantly different assemblages of pelagic micronekton during 2015 and 2016 compared to three normal years. Food habits of forage fishes examined from June during recent warm years were found to be significantly different compared to previous average or cool years. Crustaceans were the main prey items of the forage fishes in cool years, but gelatinous zooplankton were consumed in higher quantities in warm years, resulting in poorer body condition. This substantial reorganization of the pelagic forage community has the potential to lead to major alterations in trophic functioning in this normally productive ecosystem, which were exhibited in reproductive failures and decreased productivity of top predators.

(S2-13882)

The 2014-16 North Pacific marine heatwave's impacts on the marine ecosystem in central California, USA

Meredith L. **Elliott**[1], Jaime Jahncke[1], Danielle Lipski[2] and Jan Roletto[3]

1 Point Blue Conservation Science, Petaluma, CA, USA. Email: melliott@pointblue.org
2 Cordell Bank National Marine Sanctuary, Point Reyes, CA, USA
3 Greater Farallones National Marine Sanctuary, San Francisco, CA, USA

The ACCESS (Applied California Current Ecosystem Studies) program (a partnership among Point Blue Conservation Science, Cordell Bank National Marine Sanctuary, and Greater Farallones National Marine Sanctuary) has been conducting at-sea surveys in central California since 2004, helping to track and monitor changes in this region, including the North Pacific marine heatwave of 2014-16 and its impacts to the marine environment in central California, USA. This marine heatwave was characterized by high PDO and low NPGO values for the North Pacific basin. In the central California Current ecosystem, high sea surface temperatures, weak winds, weak upwelling conditions, and high sea level heights (indicating downwelling conditions) were observed. Surface water samples showed anomalously low concentrations of nutrients (nitrates, nitrites, phosphates, and silicates) during these years. Zooplankton data from our Tucker trawl samples showed higher proportions by wet weight of younger age classes of *Euphausia pacifica* (the most common euphausiid species in the region), and adult *E. pacifica* were smaller in size (which is consistent with other warm water years). Lower euphausiid densities in the region led to more humpback whale (*Megaptera novaeangliae*) sightings in nearshore areas and more entanglements in crab pot gear.

(S2-13868) INVITED

Marine heat wave impacts on lower trophic levels in the northern Gulf of Alaska

Sonia **Batten**[1], Pierre Helaouet[2] and Anthony Walne[2]

1 CPR Survey, Marine Biological Association, Nanaimo, Canada. E-mail: Sonia.batten@mba.ac.uk
2 CPR Survey, Marine Biological Association, Plymouth, UK

The 2014-2016 marine heat wave in the Northeast Pacific had noticeable impacts, widely reported, on many organisms in the Gulf of Alaska. Plankton are the base of most marine food chains supporting fish, marine birds and mammals in the region. Here we use time series of plankton abundance data from Continuous Plankton Recorder transects in the Gulf of Alaska to show how the plankton communities on the shelf and in the open ocean were impacted during this event. CPR data have been collected in the region since 2000, with sampling encompassing other periods of warmer (as well as cooler) than average conditions, facilitating such comparisons. We found that, in general, both phytoplankton and zooplankton communities decreased in mean size with different groups of organisms benefitting from, or adversely impacted by, the warmth in 2014-2016. In some groups the impacts were as predicted from sampling during previous warm years (an increase in the number of warm water species for example) but in other groups impacts were not as expected, suggesting that not all the changes were caused directly by temperature and indirect effects on water properties also likely influenced the communities. In addition, responses by plankton to the heat wave were more evident in the open ocean than in the shelf communities which may hinder our understanding of how impacts pass up the food chain here. We also assess whether, as 2017 and 2018 returned to more typical (though still relatively warm) ocean conditions, the plankton communities also responded.

(S2-14371)

Influence of Temperature and the 2014-2016 Heat Wave on Regional Zooplankton Community Structure in the eastern North Pacific

Brian **Hoover**[1], Marisol García-Reyes[1], Sonia Batten[2], Chelle Gentemann[3], Kathleen Dohan[3], William Sydeman[1]

1 Farallon Institute, Petaluma, CA, USA. E-mail: bhoover@faralloninstitute.org
2 CPR Survey, Marine Biological Association, Nanaimo, Canada
3 Earth & Space Research, Seattle, WA, USA

Two decades of Continuous Plankton Recorder (CPR) surveys in the North Pacific now enable comparisons of zooplankton community structure under a wide range of environmental conditions, including the marine heatwave in 2014-2016. Using summer CPR data collections over 17 years (2000-2016), we tested the hypothesis that zooplankton community structure and distribution varies interannually in relation to oceanographic and topographic considerations. Using 16 abundant taxa, we used spatial ordinations and hierarchical clustering within “cold” and “warm” environmental periods to: i) identify and characterize the “typical” community structures associated with particular regions of the Northeast Pacific, and ii) describe how regional community structure varied with temperature and current flows of the North Pacific Current, Alaska Current, and Alaskan Stream. We identified 3 clusters in cold years, and 5 regional clusters in warm years including the 2014-2016 MHW with each representing distinct combinations of zooplankton taxa. Temperature alone did not exert a significant effect on community structure across the entire study domain, however, we observed a significant interaction between temperature and geographic domain, i.e. temperature effects varied by domain. Temperature variation resulted in significant shifts in community structure on the Aleutian shelf and within coastal regions in the eastern GoA, in which biodiversity and spatial range of clusters increased during warm years. In the central Gulf of Alaska, temperature appeared to have little influence. The Bering Sea and Gulf of Alaska did not persistently covary in interannual temperature and current patterns, emphasizing the confounding effect between temperature and regional variability throughout the study domain.

(S2-14220)

Reduced energy transfer through forage fish disrupted marine food webs during the North Pacific marine heatwave

Mayumi **Arimitsu**[1], John Piatt[1], Rob Suryan[2], Dan Cushing[3], Scott Hatch[4], Kathy Kuletz[5], Caitlin Marsteller[1], John Moran[2], Scott Pegau[6], Matt Rogers[2], Sarah Schoen[1], Jan Straley[7], and Vanessa von Biela[1]

1 U.S. Geological Survey Alaska Science Center, Juneau, Alaska, USA. E-mail: marimitsu@usgs.gov
2 NOAA Alaska Fisheries Science Center, Auke Bay Lab, Juneau, Alaska, USA
3 Pole Star Ecological Research, LLC, Anchorage, Alaska, USA
4 Institute for Seabird Research and Conservation, Anchorage, Alaska, USA
5 U.S. Fish and Wildlife Service, Anchorage, Alaska, USA
6 Prince William Sound Science Center, Cordova, Alaska, USA
7 University of Alaska Southeast, Sitka, Alaska, USA

The Gulf of Alaska (GOA) forage fish community includes a few key species with diverse migration habits, spawn timing, and seasonality of growth and lipid storage. Diversity in life history strategies among forage species is important for resilience in marine food webs because it buffers the effects of extreme variability in abundance of small pelagic fish populations. During the prolonged North Pacific marine heatwave, the availability and quality of forage fish were reduced in the system. An abrupt decline in capelin and sand lance occurrence in predator diets was observed, and herring spawning biomass was historically low. Changes in age structure, growth, and energy content of capelin, sand lance, and herring were also associated with warming during the heatwave but not all species responded in the same way. Migratory capelin reached length at maturity earlier than normal while resident sand lance in Prince William Sound experienced anomalously low growth over the winter of 2015-2016. Changes in forage fish populations were immediately reflected in predator populations in 2015-2016, when seabirds and marine mammals experienced shifts in distribution, mass mortality, and reproductive failures in the GOA. The persistence of marine heatwave conditions was coincident with the collapse of multiple forage fish populations and reduced the efficiency of energy transfer through the middle trophic level. Low energy transfer between plankton and predators across multiple years was a key mechanism underlying a large-scale disruption in the GOA marine food web during the marine heatwave.

(S2-14359)

Predicting physical drivers of marine ecosystems in the Northeast Pacific using a Linear Inverse Modeling approach

Antonietta **Capotondi**[1,2] and Prashant D. Sardeshmukh[1,2]

1 University of Colorado/CIRES, Boulder, CO, USA. E-mail: antonietta.capotondi@noaa.gov
2 NOAA/Earth System Research Laboratory, Physical Sciences Division, Boulder, CO, USA

A Linear Inverse Model (LIM) is a stochastically forced damped linear dynamical model whose dynamical evolution operator and stochastic forcing amplitudes are estimated using the observed lag-covariances of the system state vector. We construct a LIM over a spatial domain extending from 30ºS to 70ºN and from 100ºE to 70ºW, including the entire tropical and North Pacific. Our system is described by monthly averages of sea surface temperature (SST) and sea surface height (SSH), two quantities that play a key role in ecosystem dynamics. In particular, SSH is dynamically linked to thermocline depth, and provides information on upper-ocean heat content and thermocline displacements related to upwelling.

In this study, we use the LIM approach to examine the predictability of the extreme and persistent warming that occurred in the northeast Pacific from the Winter of 2013/14 to the Winter of 2015/16, conditions that were poorly captured by operational forecast systems. Our LIM results confirm that the sequence of events during 2014/15 in the northeast Pacific was indeed "unusual" and hard to predict, but the presence of an El Niño event toward the end of 2015 improved significantly the LIM skill. The nature of these unusual conditions is further investigated using long LIM integrations.

(S2-14316)

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**[1], Mayumi Arimitsu[1], Sarah Schoen[1], Vanessa Von Biela[1], Julia Parrish[2], Heather Renner[3], Kathy Kuletz[4] and William Sydeman[5]

1 Alaska Science Center, Anchorage, AK, USA. E-mail: jpiatt@usgs.gov
2 University of Washington, Seattle, WA, USA
3 Alaska Maritime National Wildlife Refuge, Homer, AK, USA
4 Migratory Bird Management, U.S. Fish and Wildlife Service, Anchorage, AK, USA
5 Farallon Institute, Petaluma, CA, USA

More than 60,000 common murres, the dominant breeding seabird of the northern hemisphere, washed ashore during fall and winter of 2015-2016 along the west coast of North America. Starvation was the apparent cause of most mortality, which was centered in the Gulf of Alaska and likely exceeded one million birds. In addition, breeding failures were observed at many colonies in the region before and years after the mass mortality. The magnitude of these events is globally unprecedented and was associated with the northeast Pacific marine heat wave that developed during winter 2014 and intensified through 2015-2016. This prolonged heating of ocean habitat changed the distribution of prey taxa both vertically in the water column and geographically, which affected availability to predators. More importantly, many forage populations declined markedly during the heat wave. Why? Primary production declined, and zooplankton communities were restructured in favor of lower calorie species. This in turn reduced the quality and survival of forage fish; an effect exacerbated by the increase in food requirements of ectothermic forage fish in response to increased temperature. Simultaneously, the metabolic rates and food requirements of large ectothermic groundfish almost certainly shot upwards as well, greatly magnifying competition with seabirds and mammals for the same distressed forage fish stocks. Together, these bottom-up and top-down forces created an "ectothermic vise" on forage fish leading to a system-wide scarcity of food and mass mortality of murres and at least eight other upper-trophic-level fish, bird and mammal species in the region between 2015 and 2018.

(S2-14375)

Are marine heatwaves causing an increase in seabird breeding failures globally?

William J. **Sydeman**[1], Sarah Ann Thompson[1], David S. Schoeman[2], Marisol Garcia-Reyes[1], and the *Seabird-Climate Working Group*

1 Farallon Institute, Petaluma, CA, USA. E-mail: wsydeman@faralloninstitute.org
2 University of Sunshine Coast, Queensland, Australia

As the world warms, extreme climate events and "marine heatwaves" are becoming more frequent and intense, but the global-scale consequences of these events on marine ecosystems are not well known. Well-understood and actively monitored ecological indicators are needed to assess changes across marine ecosystems at the global scale. Seabird productivity (i.e., breeding success female$^{-1\ -yr}$). is such an indicator; mostly, climate affects seabird breeding success indirectly through the availability of mid trophic level food resources (fish and zooplankton), so variation in seabird breeding success mostly reflects changes in local food webs. Food webs are also affected by natural ecosystem processes and climate variability, as well as fisheries which may alter the flow of energy between ecosystem components. In this study, test the hypothesis that food web functions have become more variable through time by examining systematic change in the variance structure of seabird mean breeding success, and rates of breeding failure. On the global scale, seabird breeding success became more variable and the rate of breeding failure increased, especially in the past decade, suggesting global-scale changes in coastal food webs which can be attributed to recent marine heatwaves, especially in the Northern Hemisphere. Seabird breeding success is one of few variables measured similarly by almost all researchers globally. This study demonstrates how meta-analyses of key "process indicators" of sentinel species may be used to understand variable and complex climate-ecosystem interactions.

(S2-14056) INVITED

Effects of the North Pacific marine heatwave and El Niño events of 2013–2016 on the biogeochemistry of the southern Salish Sea

Simone **Alin**[1], Jan Newton[2], Richard Feely[1], Dana Greeley[1], and Beth Curry[2]

[1] NOAA Pacific Marine Environmental Laboratory, Seattle, WA, USA. E-mail: simone.r.alin@noaa.gov
[2] Applied Physics Laboratory, University of Washington, Seattle, WA, USA

A decade of carbon, oxygen, and nutrient observations from cruises have characterized water column biogeochemistry in the southern Salish Sea before, during, and after the paired extreme heat events of the North Pacific marine heatwave of 2013–2015 and the 2015–2016 El Niño. Since 2014, the Washington Ocean Acidification Center has supported cruises each April, July, and September, allowing comparison of seasonal conditions throughout Puget Sound across this multi-year event. The North Pacific marine heatwave hit the Pacific Northwest coast in fall 2014. Temperatures remained higher throughout the water column everywhere in Puget Sound through 2016. Although water column temperatures had returned to pre-heatwave conditions at the time of the July 2017 cruise, subsequent cruises revealed deep-water temperatures that were again substantially elevated relative to pre-heatwave conditions. During 2015 and 2016, deep water July pCO_2 values in parts of Puget Sound were as high or higher than during pre-heatwave years. However, marine intrusions flushed out high-pCO_2 deep water earlier than normal in both years, resulting in September conditions with anomalously low pCO_2. Similar patterns manifested for oxygen concentrations and aragonite saturation state. In contrast, after cooler 2017 summer conditions, two fall cruises revealed the highest pCO_2 values and lowest aragonite saturation states seen to date in different parts of the southern Salish Sea. Recent years have shown profound warming and carbonate chemistry anomalies in the southern Salish Sea that were decoupled from each other and present in-situ opportunities for studying biological impacts of ocean stressors.

(S2-14146)

Marine heatwave alters abundance, structure and virulence of *Vibrio* populations associated with the Pacific oyster resulting in a mass mortality event

Timothy **Green**[1*], Malcolm Cowan[2,3], Gurdit Khatkar[1], Natalie Khtikian[1], Allister Clisham[1], Andrew Robinson[2], Chris Pearce[3] and Gary Meyer[3]

[1] Vancouver Island University, Centre for Shellfish Research and Department of Fisheries and Aquaculture, Nanaimo, BC, Canada, V9R 5S5. E-mail: timothy.green@viu.ca
[2] University of Victoria, Biology Department, Victoria, BC, Canada, V8P 5C2
[3] Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, V9T 6N7

The Pacific oyster, *Crassostrea gigas*, is cultured in many regions of the world. In cultivation, adults are prone to mass mortality events during the summer months. A complex combination of environmental and biological parameters has been suggested as the cause of this disease. In recent years, summer mortality has had a significant economic impact on oyster farms in British Columbia, Canada. From late July 2018 to August 2018, up to 87 % mortality was reported in adult Pacific oysters cultivated in Baynes Sound, BC. Farmers in this area first observed mortalities of adult oysters on July 24, which coincided with a spike in sea surface temperatures (SST) in the Sound above the 90th percentile for three days (SST = 20.9^{o}C, 2.7^{o}C above climatology). Histological examination of moribund *C. gigas* collected during the mortality event revealed early-stage tissue necrosis combined with systemic bacterial infections comprised of bacteria with uniform short-rod-shape morphology. Microbiological characterization – combining 16S rRNA amplicon sequencing, bacterial culture, qPCR, and multilocus sequence typing – revealed the microbiome of moribund oysters were dominated by bacteria related to *Vibrio aestuarianus* and *V. harveyi*. The effect of temperature on *Vibrio* pathogenicity is currently been investigated using laboratory challenge trials, proteomic analysis, and bioassays. Our preliminary findings indicate that marine heatwaves can alter the abundance, structure, and virulence of *Vibrio* populations associated with the oyster resulting in summer mortality events. The increasing frequency of marine heatwaves in Baynes Sound is a threat to sustainable oyster production.

(S2-14083)

Characterizing marine heatwaves in British Columbia waters

Charles **Hannah**, Peter Chandler, and Stephen Page

Fisheries and Oceans Canada, Sidney, BC, Canada. E-mail: charles.hannah@dfo-mpo.gc.ca

Since the Blob event in 2013-2015, 'warmer than normal' seems to have become the norm for the surface waters of the Gulf of Alaska. However dramatic warming of the surface waters of the shelf and coastal regions of British Columbia does not seem to have occurred. We use the Marine Heatwave classification of Hobday et al (2018) as a framework for analysis of sea surface temperature statistics for the nearly 30 years of sea surface temperature data from 13 weather buoys around British Columbia. We also explore the use of the Heatwave classification to the coastal sea surface temperature from the BC Lighthouse program; many of these records start in the 1930s. The goal is to characterize the spatial and temporal patterns of Marine Heatwave statistics for British Columbia waters. We also introduce the analogous Coldwave classification.

(S2-14261)

A tale of three fjords: A comparison of marine heatwave impacts on the British Columbia mainland coastal systems

Jennifer M. **Jackson**[1], Eddy Carmack[2] and Jessy Barrette[1]

[1] Hakai Institute, Victoria, BC, Canada. E-mail: jennifer.jackson@hakai.org
[2] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada

Coastal British Columbia is lined by numerous fjords that were carved out by glaciers and whose bathymetry (length, maximum depth, sill depth) varies with specific geologic history. Some fjords, such as Bute, Knight, and Rivers Inlets, are still influenced by headwater glaciers whose seasonal runoff strongly influences the physical, chemical and biological properties in these inlets. In recent years, warm anomalies in the Eastern Pacific atmospheric system have led to enhanced glacial melt and a prolonged marine heatwave. Physical (temperature and salinity) and chemical (oxygen) profile data have been collected in these three fjords since 1951, yet this nearly 7 decade-long time series hasnever been examined in the context of climate change. In June 2019, all three fjords were concurrently sampled by the Raincoast Foundation's R/V Achiever (Bute and Knight Inlet) and by the Hakai Institute's small boat (Rivers Inlet). Data from these three inlets show the striking impacts of glacial melt and the 2014 to 2016 marine heatwave on the internal structure of temperature, salinity and oxygen within these fjords.

SESSION 3
Coastal ocean modelling in the North Pacific

(S3-14196) CANCELLED

Physical and biogeochemical variability in Yellow and Bohai Seas from joint analysis of model simulations and observations

Hao **Wei**[1], Liang Zhao[2], Guisheng Song[1], Haiyan Zhang[1], Hongtao Nie[1], Xiaofan Luo[1] and Youyu Lu[3]

1 School of Marine Science and Technology, Tianjin University, Tianjin, PR China. E-mail: hao.wei@tju.edu.cn
2 College of Marine and Environmental Science, Tianjin University of Science and Technology, Tianjin, PR China
3 Bedford Institute of Oceanography, Fisheries and Oceans Canada, Dartmouth, NS, Canada

The ecosystem of Yellow and Bohai Seas are undergoing significant changes in the past few decades due to natural factors of climate change and human factors such as pollution, coastal development and aquaculture activities, etc. The complicated space-time variations in physical and biogeochemical variables in the region are first revealed through analysis of multi-disciplinary observations conducted during recent years. Key aspects of the observed variations are reproduced reasonably well by high-resolution physical-biogeochemical models under realistic atmospheric and lateral ocean boundary forcing. Joint analyses of the observed and modelling results lead to better understanding of the forcing mechanisms and predictability of the variability. Results of key process studies will be presented. For example, the observed spatial distribution of pH in the Yellow Sea shows a northward decrease at the same depth, with the lowest values in the lower layer of the northern Yellow Sea being related to strong influences of aquaculture; while at 35°N, the westward spreading of low pH water in summer is related to cross topography up-welling in spring.

(S3-13961)

Queen Charlotte Strait FVCOM modeling development

Yuehua **Lin**[1], Laura Bianucci[2], Maxim Krassovski[2], and Mike Foreman[2]

1 ASL Environmental Sciences Inc., Victoria, BC, Canada. E-mail: alin@aslenv.com
2 Institute of Ocean Sciences, Sidney, BC, Canada

An application of the unstructured grid, Finite-Volume, primitive equation Community Ocean Model (FVCOM) is under development for Queen Charlotte Strait, Canada, as part of a Program for Aquaculture Regulatory Research (PARR) project. The objective is to provide a high-resolution hydrodynamic model of the region to assist in finfish farm siting and assess particle/pathogen dispersal from the farms to the environment as well as farm-to-farm interactions. Currently, the horizontal resolution of the model grid ranges from 50 m at the Port Hardy region to 2000 m at the open ocean. At the open ocean boundary (Queen Charlotte Sound), the model is one-way nested within the operational largescale Coastal Ice Ocean Prediction System for the West coast (CIOPS-W). The latter is developed by the Canadian Operational Network of Coupled Environmental PredicTion Systems (CONCEPTS), with 1/36° horizontal resolution (~2.0 to 2.5km). At surface, the FVCOM model is forced by the operational High-Resolution Deterministic Prediction System (HRDPS) from Environment and Climate Change Canada (ECCC), which provides surface winds and heat flux with a 2.5 km spatial resolution. In this presentation, we will describe the model in detail and provide preliminary results from the undergoing detailed evaluation of the model performance.

(S3-14110)

Sea level and meso-scale eddy variations in the Northeast Pacific during 2007-2016 simulated with a high-resolution regional ocean model

Youyu **Lu**[1], Li Zhai[1], Xianmin Hu[1], Rachel Horwitz[1], Jean-Philippe Paquin[2], Charles Hannah[3] and William Crawford[3]

[1] Bedford Institute of Oceanography, Fisheries and Oceans Canada, Dartmouth, NS, Canada. E-mail: Youyu.Lu@dfo-mpo.gc.ca
[2] Environment and Climate Change Canada, Dorval, QC, Canada
[3] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada

A regional ocean model with a horizontal resolution of ~2.5 km has been recently developed for short-term forecasting through the joint efforts of two Canadian government departments. A decade-long (2007-2016) hindcast simulation has been carried out to evaluate the model's capability of reproducing past changes in the region. The hindcast results are extensively evaluated with various *in situ* and satellite remote sensing observations. The sea level variations show distinct differences between the shelf and offshore deep waters, in terms of the seasonal cycle, and the sub-seasonal and inter-annual variations. Beyond monthly time scales, the sea level variations can be mostly accounted for by the steric effects (density variations). The analysis further quantifies the thermal and haline contributions to density changes, and the similarity and difference of these two effects in their relation to local and remote atmospheric forcing and ocean dynamic processes. With the seasonal cycle removed, the sea level anomalies on the shelf at time scales less than 20 months are strongly influenced by remote winds offshore centered near 38° N and 130ºW, while variations beyond 20 months are related to the Trade Wind in the central tropical Pacific Ocean. Thus, remote wind forcing is a key driver of sea level variations for the shelf waters of British Columbia. The model results also reveal seasonal and inter-annual variations of meso-scale eddy activity in offshore waters that agree reasonably well with satellite altimeter observations. Potential applications of the hindcasting and forecasting results of the model will be discussed.

(S3-14128)

Modelling the riverine coastal domain along the Central Coast of British Columbia, Canada

Pramod **Thupaki**[1], Di Wan[2], Mike Foreman[2], Maxim Krassovski[2]

[1] Hakai Institute, Victoria, BC, Canada. E-mail: pramod.thupaki@hakai.org
[2] Institute of Ocean Sciences, Sidney, BC, Canada

The coastal ocean off the Central Coast of British Columbia, which includes the Great Bear Rainforest, is home to rich biodiversity in marine life. The hydrodynamics in the region is strongly influenced by the large amount of fresh water entering the domain and its interactions with circulation on the shelf. Some of the rivers are gauged, however, the majority of the rivers and streams are seasonal, transient and/or ungauged. Long-term estimates of the effects of climate change also predict a reduction in the amount of freshwater entering the ocean due to loss of glaciers, changes to precipitation patterns and changes in land-use.

In this paper, we present the results from a three-dimensional unstructured-grid hydrodynamic model developed using the FVCOM (Finite Volume Community Ocean Model) to simulate the circulation along the Central Coast of British Columbia. The hydrodynamic model is validated against current observations made using acoustic Doppler current profilers and current meters deployed off the coast of Calvert Island and CTD profiles. The validated hydrodynamic model has been used to identify the extent of the riverine coastal domain in this region and assess the sensitivity of the circulation to the amount of fresh water discharge entering the domain.

(S3-14162)

Role of river inflows from the Kamchatka Peninsula in the Okhotsk Sea

Toru **Miyama**[1] and Humio Mitsudera[2]

1 Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan. E-mail: tmiyama@jamstec.go.jp
2 Hokkaido University, Sapporo, Japan

The Okhotsk Sea is a unique ocean in that sea ice forms at the lowest latitude in the world. The sea ice formation plays important roles in ventilation through a dense water mass formation not only in the Okhotsk Sea but also in the North Pacific Ocean. The river inflows from the surrounding coasts affect the dense formation by changing stratification. While the contribution from the river inflow from the Amur River on the western side of the Okhotsk Sea has been widely discussed, the role of the river inflows from the Kamchatka Peninsula on the eastern side of the Okhotsk Sea is not well known. In this study, we simulated the northern part of the Okhotsk Sea to investigate the roles of river inflows from the Kamchatka Peninsula. FVCOM (Finite-Volume, Primitive equation

Community Ocean Model) was used. The comparison with and without the river inflows shows that the inflows lower the salinity more than 1 unit at a maximum. The effect of river inflows from the Kamchatka Peninsula also spreads toward the western Okhotsk Sea. The freshening reaches deeper levels through the dense shelf water formation. The impact on the deeper levels by the river inflows from the Kamchatka Peninsula is greater than those from the Amur river.

(S3-14017)

A coupled physical-biogeochemical FVCOM model for the Discovery Islands (BC, Canada)

Laura **Bianucci**[1], Mike Foreman[1], Hayley Dosser[2,3], Maxim Krassovski[1], Pramod Thupaki[2], Peter Chandler[1], and Jen Jackson[2]

1 Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada. E-mail: laura.bianucci@dfo-mpo.gc.ca
2 Hakai Institute, Victoria, BC, Canada
3 The University of British Columbia, Vancouver, BC, Canada

The Discovery Islands region is a network of deep fjords and narrow channels north of the Strait of Georgia. The complex interaction of fresh water inputs, bathymetry, and marine and atmospheric forcing leads to rich marine ecosystems, making the region suitable for finfish aquaculture. Hydrodynamic models of this area are useful tools for the aquaculture industry and management in many ways (they can assist in farm siting decisions, assess the connectivity between farms, evaluate the risk of spread of disease onto wild fish populations, etc.). Furthermore, biogeochemical ocean models (not yet applied in the region for aquaculture purposes) can also be useful, since finfish aquaculture operations can affect and be affected by changes in seawater oxygen concentrations. For instance, farms decrease oxygen in their vicinity both directly by the respiration of the fish and indirectly when organic matter (such as fish feces) gets decomposed by oxygen-consuming bacteria. Moreover, variations in oxygen concentrations due to natural physical processes (e.g., stratification and mixing) can affect aquaculture, especially in times of climate change and ocean deoxygenation (e.g., if waters with less oxygen than usual inundate areas with farms). In this project, we examine oxygen concentrations in the Discovery Islands by coupling a Finite Volume Community Ocean Model (FVCOM) hydrodynamic application with a biogeochemical module (FVCOM-ICM). With this coupled model, we aim to understand the dominant mechanisms that determine the distribution of dissolved oxygen in the region and how they may change along with climate. Here, we will discuss preliminary results and future work.

(S3-14227)

Modelling the interannual variability of biogeochemical conditions along the British Columbia coast

Angelica **Peña**, Isaac Fine and Wendy Callendar

Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, Canada. E-mail: Angelica.Pena@dfo-mpo.gc.ca

The British Columbia shelf is at the northern end of the California Current System and is influenced by summer coastal upwelling, mesoscale eddies, and freshwater inputs. Previous studies have shown significant interannual to decadal variability in oceanographic conditions related to ENSO (El Niño Southern Oscillation) events. In this study, a 33-year hindcast simulation (1979-2011) of a regional circulation-ecosystem model is used to examine interannual variability of primary production and biogeochemical conditions along the British Columbia coast. Linkages between simulated variability and forcing are explored through correlations to local upwelling winds, outflow from the Juan de Fuca Strait estuarine circulation, and two indices of Pacific Ocean basin-scale variability, the Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation (NPGO). The dominant time and space patterns of interannual variability of simulated primary production was found to be significantly correlated with the NPGO. On the shelf, negative primary production anomalies appear to be primarily associated with strong El Niño events.

(S3-13976)

Projecting climate change impacts for Canadian Northeast Pacific waters

Amber M. **Holdsworth**, James R. Christian, and Youyu Lu

Fisheries and Oceans Canada. Email: Amber.Holdsworth@dfo-mpo.gc.ca

A high resolution regional model of the Northeast Pacific Ocean incorporating the Cana- dian Ocean Ecosystem Model (CanOE) has been developed using NEMO (v3.6). The North- east Pacific (NEP36) model has a resolution of 1⁄36° (2–3) km and includes the effects of tidal mixing. The ocean is forced with atmospheric fields from the Canadian Regional Cli- mate Model (CanRCM4) for historical 1986–2005 and future 2046–2065 periods under the RCP4.5 emissions scenario. We found that high frequency wind speed variability was re- quired to produce a realistic distribution of freshwater in the model. We examine changes in stratification, productivity, acidification, oxygen content, and the distribution of nutrients in the diverse regions of the Canadian Pacific Coast including Juan De Fuca Strait, Queen Charlotte Sound, and the oceans surrounding Haida Gwaii.

(S3-13990)

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

National Marine Environmental Forecasting Center, Beijing, PR China. E-mail: liugm@nmefc.cn

A lagrangian-particle-tracking experiment coupled with biological process has been conducted to analyze the trajectories and blooms of green macroalgae along the southern coast of the Shandong Peninsula (SP) in 2016 and 2017, using sea surface temperature and current of Regional Ocean Modeling System (ROMS), 10m sea surface wind and down-upward short-wave radiation of NCEP Climate Forecast System Reanalysis data. The pathway of particles are impacted by sea surface wind and current in the lagrangian-particle-tracking model, meanwhile the sea surface temperature and photo-synthetically Active Radiation (PAR) are also factors of the green macroalgae growth and death during day and night. The numerical results revel matching performance with MODIS observed satellite image, including occurrence, rapid growth, going ashore and disappear along the northern region of Changjiang River (western coast of the Jiangsu Province) and the southern coast of the Shandong Peninsula. Furthermore, this lagrangian-particle-tracking experiment coupled with biological process has been applied to analyze and predict the bloom and migration of the green macroalgae in 2019. The numerical results suggest that the main part of green macroalgae concentrating in the northern offshore of Yancheng, Jiangsu province before June. Massive green macroalgae would drift northward rapidly in the early of June, move northeastward by wind and current in the middle of June, and then shift ashore near the south coast of Shandong Peninsula in the end of June. The southeastern sea area of Shandong Peninsula, such as Yantai and Weihai would be influenced more seriously than the southern sea area of peninsula, such as Rizhao and Qingdao during the end of June and the early of July. Due to temperature increasing in July, the mortality rate of green macroalgae begin to rise, so that the net growth rate decrease. Starting from mid-July, green macroalgae would no longer grow, but enter into a period of extinction, and then disappear from late July to early August.

(S3-13938)

Using SalishSeaCast, a coupled bio-chem-physical model of the Salish Sea, to evaluate interannual variability in the Strait of Georgia

Susan E. **Allen**[1], Elise Olson[1], Nancy Soontiens[1,2], Michael Dunphy[1,2], Doug Latornell[1], Ben Moore-Maley[1], Tereza Jarnikova[1] and Jie Liu[1]

1 University of British Columbia, Vancouver, BC, Canada. E-mail: sallen@eoas.ubc.ca
2 now at Fisheries and Oceans, Canada

The Strait of Georgia (SoG) is a semi-enclosed deep coastal basin with a strong estuarine circulation. It is part of the corridor for out-migrating juvenile salmon and is hypothesized to be a critical area for mortality. Observations show that the SoG is a productive region with strong temporal and spatial gradients that are chronically under-sampled. Here we present the SalishSeaCast system: a three-dimensional biochemical model coupled to a NEMO-based physical model of the Salish Sea. The biological model: Salish Sea Model Ecosystem - Lower Trophic (SMELT) was developed specifically for the SoG. We will describe the model and its evaluation. The coupled model is run daily in real-time and we now have a time series of more than 4 years allowing us to assess the interannual variations in physics, biology and chemistry in the SoG and the drivers of those variations using the model. Equally interesting is that part of the seasonal cycle that is robust and remains relatively unchanged year to year. Key issues, ultimately impacting juvenile salmon, include transport, nutrient availability in the surface waters, primary productivity, zooplankton grazing success and near surface changes in pH and aragonite saturation state. We will summarize with a comparison to interannual observational data that is available and a critical analysis of the model's strengths and weaknesses.

(S3-14189)

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

University of British Columbia, Vancouver, BC, Canada. E-mail: eolson@eoas.ubc.ca

Salish Sea Model Ecosystem - Lower Trophic (SMELT) is a three-dimensional biogeochemical model coupled to a NEMO-based physical model of the Salish Sea, run operationally at UBC as part of the SalishSeaCast system. In this presentation, we will discuss semiperiodic nitrate supply to the surface waters of the northwest Strait of Georgia diagnosed from SalishSeaCast output. The nutrient supply pattern is identified as a region of elevated mean (March-November) and standard deviation (April-September) of surface nitrate stretching from Discovery Passage to Baynes Sound in a monthly climatology based on simulations from fall 2014 to present. We will describe the relative contributions of southward advection of nitrate supplied through tidally-enhanced mixing in and near Discovery Passage, transport of nitrate from the northeastern Strait under eastern upwelling conditions, and local upwelling. We will discuss the importance of the phenomenon as a source of nutrients to the euphotic zone, fueling primary production in the northern Strait of Georgia. Finally, we will interpret our study within the context of the susceptibility of the Northern Strait of Georgia ecosystem to climate change.

(S3-13914)

Modelling the energy flow structures and interannual dynamics of Yangtze estuary and its adjacent waters in China

Yuanchao **Wang**[1,2], Cui Liang[2,3], Weiwei Xian[1,2,3,4]

1 University of Chinese Academy of Sciences, Beijing 100049, PR China. E-mail: wangwoncho@163.com
2 Key Laboratory of Marine Ecology and Environmental Sciences, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, PR China
3 Laboratory for Marine Ecology and Environmental Science, Qingdao National Laboratory for Marine Science and Technology, Qingdao 266237, PR China
4 Center for Ocean Mega-Science, Chinese Academy of Sciences, Qingdao 266071, PR China

An Ecopath model is constructed with comprehensive assessments of accuracy and sensitivity, based on the quarterly survey of the Yangtze estuary and its adjacent waters in February, May, August and November 2014. The entire community are divided into 23 taxa groups. In 2014, the trophic level of each taxa group of the estuarine ecosystem was between 1-4.361. The average ecotrophic efficiency of the fishery functional group was 0.845. The total energy flow of the ecosystem was 12217.660 $t{\cdot}km^{-2}{\cdot}a^{-1}$, and the total biomass without detritus was 94.336 $t{\cdot}km^{-2}{\cdot}a^{-1}$. Based on EcoTroph, we found that functional groups whose TLs > 3.1 were more sensitive to fishing pressures. In the functional groups with TLs > 3.1, 71.43 % of them tended to the primary production requirements of debris. The Q/TST of this estuary was very higher, which would be considered as a trophic signature. The dynamic evolution of taxa groups' structure and their energy flow networks in the three periods (1985-1986, 2004 and 2014) are compared and analyzed. In 2004, the huge fishing pressure faced by the marine ecosystem caused great changes in the ecosystem structure, the ecosystem became immature, and the ability to resist external disturbances declined. In 2014, the situation was relieved compared with 2004, nevertheless the fishery output capacity was far lower than the previous level. This research supply energy flows details of the estuarine ecosystem aiming to the better understanding of ecosystem structures and functions, and policy developments of fishery protection.

(S3-14014)

Future changes of the coastal waters in the California Current System

Mercedes **Pozo-Buil**[1,2], Michael G. Jacox[1,2], Jerome Fiechter[1] and Michael A. Alexander[3]

[1] University of California Santa Cruz, Santa Cruz, CA, USA. E-mail: mercedes.pozo@ucsc.edu
[2] NOAA Southwest Fisheries Science Center, Monterey, CA, USA
[3] NOAA Earth System Research Laboratory, Boulder, CO, USA

Future changes of the coastal waters in the California Current System (CCS) are investigated by dynamically downscaling CMPI5 climate projections using the Regional Ocean Modeling System (ROMS) with 0.1˚ horizontal resolution. To capture the spread of projections, we select three global climate models (GCMs) that span the CMIP5 range for future changes in both the mean and variance of physical and biogeochemical CCS properties: GFDL-ESM2M, HadGEM2-ES, and IPSL-CM5A-MR. To debias the model forcing obtained from the GCMs (i.e., correct for their systematic offsets with observed climate), we apply a "time-varying delta" method in which the regional model's surface and lateral boundary conditions are constructed by adding the transient (1980-2100) GCM anomalies to the observed historical (1980-2010) climatology. Relative to a "fixed delta" method that compares a historical period to a future one, the time-varying delta method has advantages of (1) capturing projected changes in interannual variability, and (2) resolving intermediate time frames (e.g., 2010-2070), when climate changes will have considerable impacts on the CCS ecosystem. We investigate spatial differences between the downscaled projections as well as differences between downscaled projections and the GCM projections that force them. This analysis sheds light on the uncertainty that results from insufficient resolution in GCMs relative to the uncertainty due to spread among the GCMs themselves. Until large ensembles of eddy-resolving global or regional models are computationally feasible, we suggest that a fruitful approach is to combine coarser resolution large ensembles with dynamical downscaling of select runs informed by analyses like the one here.

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. Therefore, this session aims to bring together researchers interested in learning and discussing about the challenges and advances in coastal ocean models. We welcome contributions about any aspect related to these models, from applications in specific regions to regional intercomparisons, including hydrodynamics-only as well as coupled models (physical-biogeochemical, -ice, -sediments, etc.).

(S3-14328)

Importance of simulating coastal biogeochemical processes for projections of ocean acidification on the Bering Sea shelf

Darren J. **Pilcher** [1,2], Jessica N. Cross [2], Albert J. Hermann [1,2], Samuel Mogen [2,3], Kelly Kearney [1,4], Wei Cheng [1,2]

[1] Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA
E-mail: darren.pilcher@noaa.gov
[2] NOAA Pacific Marine Environmental Laboratory, Seattle, WA, USA
[3] University of Virginia, Charlottesville, VA, USA
[4] NOAA Alaska Fisheries Science Center, Seattle, WA, USA

The Bering Sea is highly vulnerable to ocean acidification (OA) due to naturally cold, low carbonate concentration waters. Expected negative impacts of OA to marine organisms therefore pose a significant threat to this highly productive marine ecosystem, which supports critical commercial and subsistence fisheries. Carbonate chemistry and oxygen cycling were recently added to a regional ecosystem model of the Bering Sea at 10km horizontal resolution. A decadal hindcast illustrates considerable spatial variability in the biogeochemistry and vulnerability to OA of Bering Sea shelf water. Substantial summer-fall biological productivity maintains highly supersaturated carbonate saturation states (Ω) on the outer shelf, whereas freshwater runoff from major river systems with relatively corrosive water decrease Ω to values below 1 on the inner shelf. Conversely, bottom water corrosivity and relatively lower oxygen concentrations are more prevalent on the outer shelf compared to the inner. These results highlight how vulnerability to future environmental changes can vary substantially within a coastal shelf system. However, coastal ecosystem projections are typically produced from global-scale Earth System Models (ESM), which generally do not contain the spatial resolution and coastal biogeochemical processes required to capture these shelf features. Thus, we use our regional model to produce dynamically downscaled projections of OA for the Bering Sea shelf, using multiple global ESMs and emissions scenarios. These projections provide information on OA risk at high spatial resolution, which is critical to addressing emerging stakeholder needs.

(S3-14015)

The value of the greenhouse gas monitoring system for climate change in the China Sea

Dan **Wang**, Honggang Lv, Yifei Jiang and Shan Gao

Key Laboratory of Research on Marine Hazards Forecasting, National Marine Environment Forecasting Center, Beijing, PR China
E-mail: saisaiwang@163.com

CO_2 is one of the most important greenhouse gases that cause global warming. After the sea absorbs excessive CO_2, the composition of carbonate system will change. Consequently, the pH of the seawater will decrease and in result damage the marine ecological environment.

In this study, the authors developed a assimilation system of Carbon in Global and Chinese coastal areas based on CarbonTracker-China, which adopts the real-time observation data from the four WMO greenhouse gas monitoring stations in China and the global carbon monitoring satellites (GOSAT, OCO-2, Tansat) with the encryption capacity of data assimilation, in order to improve the prediction accuracy of CO_2 concentration and flux in the Chinese coastal areas. At present, this system is in quasi-operational state in National Marine Environmental Forecasting Center, which plays an important role in regular collection and assimilation of the real-time data in CO_2 concentration and flux. Otherwise, based on the ROMS regional ocean dynamic model, coupled with the ecological dynamic model of marine carbon cycle, the air-sea CO_2 fluxes numerical forecasting system in the coastal China Sea is set up, utilizing the real-time observation data from the four WMO greenhouse gas monitoring stations in China and the global carbon monitoring satellites. The production of this system includes total alkalinity of seawater, total inorganic carbon and pCO_2 on the air-sea interface in the next 120 hours.

SESSION 4
The impacts of marine transportation and their cumulative effects on coastal communities and ecosystems

(S4-13949) INVITED

Ship antifouling biocides used in Japan and their environmental risk

Hideo **Okamura**

Research Center for Inland Seas, Kobe University, Japan. E-mail: okamurah@maritime.kobe-u.ac.jp

International convention on the control of harmful antifouling system (AFS) on ships has banned specific organotin compounds since 2008 and could regulate other harmful biocides in the future. The Japan Paint Manufacturers' Association commenced a self-control program of AFS in Japanese market has been updating a list of registered paint products since 2005. The latest 2019 list tells us 14 biocides registered in 344 products, and the biocides are arranged in order with higher usage rate; cuprous oxide (Cu_2O, 76%), copper pyrithione (51%), zinc pyrithione (18%), Sea-Nine 211 (17%), triphenylborane pyridine (11%), diuron, zineb, Irgarol 1051, tralopyril, and so on. There are limited data available on the dissolved copper (D-Cu) levels in Japanese coastal seawater despite cuprous oxide is the most frequently formulated biocide. We, therefore, measured D-Cu concentrations in seawater (79 samples in total) collected at three zones (marina/harbor, Seto Inland Sea, and offshore) and estimated environmental risk using a copper marine Biotic Ligand Model (BLM) proposed by USEPA. Copper in a 0.4 (micro)m-membrane filtered seawater, extracted by chelating resin and quantified by FLAAS or ICPMS, was regarded as D-Cu. The 90th percentiles of D-Cu were 0.5 µg/l at offshore, 1.4 µg/l at inland sea, and 5.0 µg/l at marina. The measured D-Cu concentration was compared with the criterion continuous concentration (CCC) calculated with four seawater parameters (temperature, pH, salinity and dissolved organic carbon) using copper marine BLM, suggesting five seawater samples (6.3 % in total) collected at marina/inland sea pose environmental risk because they exceeded the CCC.

(S4-13960)

Unwanted networks: Vessel traffic heightens the risk of invasions in marine protected areas

Josephine C. **Iacarella**[1], Lily Burke[1], Ian C. Davidson[2,3], Claudio DiBacco[4], Thomas W. Therriault[5] and Anya Dunham[5]

1 Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada
E-mail: Josephine.Iacarella@dfo-mpo.gc.ca
2 Smithsonian Environmental Research Centre, Edgewater, MD, USA
3 Cawthron Institute, Nelson, New Zealand
4 Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada
5 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada

Nonindigenous species (NIS) pose a significant threat to a primary objective of marine conservation, protecting native biodiversity. To-date, research quantifying invasion risk to marine protected areas (MPAs) is limited despite potential negative consequences. By applying graph-theoretic concepts to vessel traffic data for 1,346 vessels that connected invasion nodes along the Northeast Pacific coast to MPAs within Canadian waters in 2016, we identified invaded areas that are high-risk sources of NIS and MPAs that are at risk of receiving those NIS via ballast or biofouling. Twenty-nine percent of MPAs overlapped with invasion nodes and 70% were connected to invasion nodes via vessel traffic. Vessel connections increased in summer and with spatial extent and dock area at nodes, but did not differ among MPA protection strengths. A notable absence of NIS and vector management in most MPA management policies could be addressed by targeting vessels transiting from high-risk NIS nodes.

(S4-13861)

Ship strike management in priority regions of the U.S. West Coast: Effectiveness of past efforts and potential for new strategies

R. Cotton **Rockwood**[1], Jeff Adams[2], John Calambokidis[3], Greg Silber[2] and Jaime Jahncke[1]

1 Point Blue Conservation Science, Petaluma, CA, USA. E-mail: crockwood@pointblue.org
2 National Marine Fisheries Service, Office of Protected Resources, Silver Springs, MD, USA
3 Cascadia Research Collective, Olympia, WA, USA

Ship strikes are a major source of death for endangered whales on the U.S. West Coast. Quantifying ship strikes is an important step to ensure the recovery of whale populations. We used an encounter rate model based on ship data from AIS and whale habitat models to examine ship strikes in waters off Los Angeles/Long Beach and San Francisco Bay. We estimated ship strike deaths and their spatial patterns over five years and modeled the effect of past voluntary and incentivized programs on whale mortality. Next, we simulated scenarios of increased cooperation with speed limits to examine the effect of improvements to existing speed limits or instatement of mandatory regulations. Finally, we identified areas not currently managed that show the greatest mitigation potential and evaluated the hypothetical reduction in mortality from adding speed limits. Cooperation with voluntary speed limits increased moderately with management efforts and maximum reduction of modeled mortality in the managed areas was about 13% compared to before speed limits were implemented. Some of that reduction was from management efforts, but some stemmed from a long-term decline in ship speeds as companies employ ‘slow steaming’ to decrease costs and lower emissions. Off San Francisco, high compliance (80-90%) similar to that achieved with mandatory regulations on the U.S. East Coast could be approximately twice as effective as current management. To effectively address one of the top human threats to whales, managers need to consider pursuing greater cooperation with speed limits and expanding those limits to key areas of risk.

(S4-14298)

Environmental impacts and mitigation of grey water discharges from ships

Sarah **Bobbe**[1] and Andrew **Dumbrille**[2]

1 Ocean Conservancy, Anchorage, AK, USA. E-mail: sbobbe@oceanconservancy.org
2 World Wildlife Fund Canada, Ottawa, ON, Canada

Grey water is drainage from dishwater, shower, laundry, bath and washbasin drains. Most vessels that produce grey water will discharge it into the sea untreated. While dumping of many other vessel-generated discharges like sewage is internationally regulated in coastal waters, grey water is not. However, like sewage, grey water discharges contain bacteria, metals, chemicals, pathogens, food waste and high concentrations of nutrients such as nitrogen and phosphorus. This can lead to oxygen depletion, spread pathogenic bacteria and viruses, and increase nutrient levels in the surrounding ecosystem, possibly leading to toxic algal blooms and eutrophication. As more and more ships operate in Canada and Alaska, some coastal communities have voiced concern about the ramifications of untreated grey water discharges in the region. Discharges from cruise ships are of particular concern as they carry many more passengers and therefore generate much more sewage and grey water than other ship types. One of the few places in the world to recognize the need to treat grey water to the same extent as sewage, the State of Alaska requires vessels carrying 250 passengers or more to not only meet higher sewage discharge standards than most places in the world, it also requires grey water to meet those same standards, and enables strict monitoring and enforcement. The concerns of coastal communities, the potential threats of untreated grey water and the need to expand treatment and enforcement regimes similar to the State of Alaska should be recognized and further explored.

(S4-14326)

Influences of wind, sea state, and oil type on oil dispersion in the Salish Sea

Rachael D. **Mueller**[1], Shihan Li[2], Ashutosh Bhudia[1], Krista Cawley[1], Doug Latornell[1], Ben Moore-Maley[1], Susan E. Allen[1], Haibo Niu[2] and Stephanie Chang[1]

[1] University of British Columbia, Canada. E-mail: rmueller@eoas.ubc.ca
[2] Dalhousie University, Canada

Over 26 million m3 of oil is transported within the Salish Sea each year, and this volume may increase by approximately 4 million m3/yr as a result of three, proposed terminal expansion projects. The fate of oil spilled by this transport will vary by quantity, location, weather conditions and oil type. For example, ~40% of light crude oil is likely to evaporate within 7 days (and most in the first 3 days) compared to an evaporation of <5% of heavy crude and ~15% of dilbit, within the same time period. Weathering of oil begins immediately after spill and can vary by the type of spilled oil and by environmental conditions. Oil recapture by skimmers, the primary and only non-chemical option for recovery in the Salish Sea, is also influenced by environmental conditions and is reported to be 75% less effective in 10-15 m/s winds. In this talk, we discuss the environmental conditions that will affect oil spill impacts. We also present a newly developed modeling platform that utilizes the NEMO-based SalishSeaCast and WaveWatch III® model results to predict the weathering of spilled oil with a revised version of the oil algorithms developed in a MOHID water model. We refer to this combined SalishSeaCast and oil spill model as SOILED. SOILED will provide the first open-source modeling platform of oil spills in the Salish Sea using a rigorously tested hydrodynamic model. Preliminary results of the SOILED-estimated fate of spilled oil in the Salish Sea are presented.

(S4-13854)

Marine eco-damage assessment methods based on the eco-restoration cost in China

Keliang **Chen**, Fenggui Chen, Jiwei Zhang, Jinkeng Wang and Bingkun Wang

Third Institute of Oceanography, MNR, Xiamen, China. E-mail: klchen@tio.org.cn

The marine eco-damage situation is very serious in China due to the project construction, oil spillage, dumping, discharge of pollutants, enclosing and reclamation of sea areas, overfishing, destruction of coral reefs and mangroves, habitat destruction, etc. As well as the marine eco-damage assessment in China is less without a set of scientific, systemic, reasonable and unified evaluation methods and standards currently. The ecological cost of this series of activities has not been effective evaluated as well as the stakeholders didn't get reasonable compensation which leaded to irreparable damage of fishery, aquaculture and marine ecosystem. The paper proposed a set of suitable methods to assess marine eco-damage under China's national conditions according to the eco-restoration theory through the analysis of relevant international conventions, the eco-damage assessment methods and related researches in China and other countries. The methods would be analyzed from assessment principles and procedure, preparation stage, investigation contents and requirements, determining objects, scope and degree, value assessment contents and methods of marine eco-damage, and making plan of marine eco-restoration project. It put forward the value of natural resources and eco-damage should be calculated by the reasonable cost of restoration on the damaged ecosystem according to the eco-restoration plan and quantitative assessment methods. Two cases between sea reclamation project and oil spillage in China are analyzed according to the guideline. It will provide a scientific reference for establishing the compensation mechanism of marine eco-damage activities.

(S4-13912)

Research on the application level of marine ecosystem services economic valuation in decision-making in China

Jingmei **Li**; Na Wang and Jin Hua

Ocean University of China, Qingdao, PR China. E-mail: jingmeili66@163.com

The ecosystem services economic valuation (ESV) is an important means for marine ecosystem management and biodiversity conservation. Compared with the fruitful ESV research results, its application level in China's decision-making is still unknown. A questionnaire survey was conducted to staffs working in China's coastal government department and marine scientific research institutions, to find out their cognitive level on ESV and the application level of marine ecosystem services economic valuation (MESV) in China's decision-making. And 126 valid questionnaires were collected, the statistical analysis results show: 1) most respondents have a knowledge of ESV and believe that ESV is useful in China's government decision-making; 2) respondents generally believe that MESV is less used in China's decision-making. The regression results of ordered logit model and ordered probit model indicated: 1) the application level of MESV was significantly positive correlated to the application value of MESV, and significantly negative correlated to the restricting factors of MESV; 2) unreasonable valuation methods is the main restricting factor in the application of ESV in decision-making in marine ecosystem. Based on the analysis results, suggestions increasing the application level of marine ecosystem services economic valuation in decision-making in China were put forward from three aspects: improve the rationality of valuation method, increase the reliability of valuation results and increase the awareness of decision makers.

(S4-14173)

The variability of Japanese eel body larval length concerning the environmental factors of the migration route

Kuan-Mei **Hsiung**[1], Chi Ma[2], Yu-San Han[2], Chia-Ying Ko[2]

1 School of Oceanography, Shanghai Jiao Tong University, Shanghai, PR China. E-mail: km-hsiung@sjtu.edu.cn
2 Institute of Fisheries Science, National Taiwan University, Taipei, Taiwan R.O.C.

The Japanese eel (*Anguilla japonica*) is distributed in the western Pacific Ocean that is of commercial importance in East Asia. Its' recruitment has declined dramatically in most habitats since the 1970s and exhibited large interannual fluctuations. Previous studies have demonstrated how climate events, such as El Niño–Southern Oscillation (ENSO) events and the Philippines–Taiwan Oscillation (PTO) changed the ocean physical conditions and further affect the recruitment of the Japanese eel by using particle modelling. However, effects of biological and environmental factors, such as water temperature, salinity and the chlorophyll concentration on wild eel larvae have less been discussed. In this study, a recent 8–year body length data of Japanese glass eel was used to represent the larval conditions, and the migration route of eel larvae was estimated by numerical simulation. As the spatial and temporal distribution of ocean currents and eel larvae were analyzed, the environmental conditions of the migration route were obtained from satellite telemetry. Finally, the relationship between biological/environmental factors and body length variation was analyzed by a generalized additive model (GAM). The results from the GAM showed that eel larvae has larger body length when the temperature and salinity in the spawning area is around 21-24.5°C, 35.1-35.3 psu and the chlorophyll concentration is about 0.03-0.07 mg/m^3, and the temperature of the migration route should be higher than 24°C and the chlorophyll concentration should be higher than 13 mg/m^3 at the same time.

SESSION 5
Trends in ocean and coastal ecosystems and their services and its future

(S5-14018)

Interannual variability in stratification, nutrients, and water mass structure in the Chukchi Sea

Carol **Ladd**[1], Calvin Mordy[2], and Phyllis Stabeno[1]

1 Pacific Marine Environmental Laboratory, NOAA, Seattle, WA, USA. E-mail: carol.ladd@noaa.gov
2 University of Washington, Seattle, WA, USA

Striking changes in the physical environment of the Chukchi Sea have been observed over the past decade. As a seasonally ice-covered sea, the advance and retreat of sea ice plays a dominant role. This seasonal evolution of ice is linked to variability in stratification and water mass structure, which have been shown to influence the ecosystem from phytoplankton to fishes and seabirds. Using hydrographic mooring and profiling float data, we quantify variability in the seasonal and interannual evolution of transport, water mass structure, and stratification and illustrate the seasonal transition (spring and fall) between Winter Water and Summer Water. Timing of the transitions is correlated with the timing of ice retreat in spring and ice arrival in fall. When initially formed, Winter Water is relatively fresh and nutrient poor with replenishment occurring through the winter. While transport of water masses from the south is likely important to water mass transitions, transport at the Icy Cape line is not significantly correlated with the timing of Summer Water arrival or the timing of ice retreat. However, the strongest average spring transport (March to May) in our record was observed in 2017, the same year that both ice retreat and Summer Water arrival were more than a month earlier than average. The open water season in 2017 and the amount of time that Summer Water was present were both unprecedented in our record. The summer of 2018 also exhibited an extremely long period of open water.

(S5-13898)

Shifts in the physical environment in the Pacific Arctic and implications for ecological timing and structure

Matthew **Baker**[1], Kirill Kivva[2], Jordan Watson[3], Maria Pisareva[2] and Julia Selivanova[2]

1 North Pacific Research Board, 1007 West Third Avenue, Anchorage, AK, 99501 USA
2 VNIRO, Russian Federal Research Institute of Fisheries and Oceanography, 17 V. Krasnoselskaya, Moscow 107140 Russia
3 NOAA, Alaska Fisheries Science Center, Auke Bay Laboratories 17109 Pt. Lena Loop Road, Juneau AK 99801 USA

The northern Bering Sea and Chukchi Sea form the gateway from the Pacific to the Arctic. Many processes in the region appear to be changing with important implications for hydrography and ecology in both Pacific and Arctic systems. Our analyses access remote and local data sources in US and Russian waters to characterize oceanographic conditions and to analyze the implications of the dramatic shift in environmental conditions in recent years. Previously, this region appeared resilient to shifts apparent in the greater Arctic. Now, the Pacific Arctic appears to be in rapid transition. The conditions observed in 2017-2019 are unprecedented. We note important shifts in the phenology and magnitude of physical variables including sea ice extent, concentration and residency, and the extent and intensity of the related Bering Sea cold pool. We also document a convergence of water temperatures in the southern and northern Bering Sea. This has important implications for connectivity and transport between Pacific and Arctic systems, as the thermal barrier that had previously distinguished these systems is now absent. Shifts in oceanographic conditions appear to have influence on the timing and volume of primary production. Research in this important region is complicated by international borders but may be enhanced through international collaboration. This analysis represents an attempt to integrate data across both Russian and US waters to more fully represent processes important to the region as a whole. It also aims to inform means to contrast and integrate trends across subregions to understand processes governing this linked system.

(S5-14344)

Resolving drivers of microbial community variability in the Strait of Georgia over multiple time scales

Colleen **Kellogg**[1], Rebecca Piercey[2], Caterina Giner[3], Justin Del Bel Belluz[1], Brian Hunt[3], and Jennifer Jackson[1]

1 Hakai Institute, Heriot Bay, British Columbia, Canada. Email: colleen.kellogg@hakai.org
2 University of New South Wales, Sydney, Australia
3 University of British Columbia, Vancouver, British Columbia, Canada

Microorganisms play integral roles in carbon and nutrient cycles, constituting critical components of marine ecosystems globally. Given their vast diversity and variable responses to environmental change, it is challenging to determine how the microbial component of marine ecosystems will respond to changing ocean conditions. Therefore, it is crucial to characterize microbial community composition and function in marine systems, establishing a baseline from which to detect change. Understanding microbial responses to ecosystem change is especially challenging in dynamic coastal marine systems where changes on land make their way seaward into an ocean system simultaneously undergoing widescale change. In 2014, the Hakai Institute began a weekly oceanographic time series in the northern Strait of Georgia (SoG) in an effort to better resolve physical, chemical, and biological (including microbial) variability in the waters of coastal British Columbia. Weekly microbial sample collection and subsequent molecular characterization of bacterial and archaeal populations provides a unique opportunity to finally characterize this often-overlooked component of the SoG food web. Our collection rate is approaching the turnover time of marine prokaryotes, facilitating a better understanding of their response time to changing environmental conditions. We observe clear weekly changes in SoG prokaryotic communities from spring into early fall, something that would be overlooked with less frequent sampling. Over longer timescales, we are working to resolve drivers of observed seasonality and interannual shifts in timing of boom and bust cycles in SoG microbes.

(S5-14102)

Constraining along-coast surface seawater CO_2 system variability and changeability from an Alaskan ferry

Wiley **Evans**[1], Geoffrey T. Lebon[2,3], Christen D. Harrington[4], and Allison Bidlack[5]

1 Hakai Institute, Heriot Bay, BC, Canada. E-mail: wiley.evans@hakai.org
2 Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, Seattle, WA, USA
3 Joint Institute for Study of the Ocean and Atmosphere, University of Washington, Seattle, WA, USA
4 Alaska Department of Transportation, Ketchikan, AK, USA
5 Alaska Coastal Rainforest Center, University of Alaska Southeast, Juneau, AK, USA

In the Northeast Pacific near-shore zone, marine CO_2 system variability and changeability due to anthropogenic CO_2 uptake has been largely under-characterized. Since October 2017, the Alaska Marine Highway System M/V *Columbia* has served as a platform for surface underway data collection to help fill this information gap while conducting twice weekly ~1300-km transits between Bellingham, Washington and Skagway, Alaska. This effort provided the first characterization of the variability, severity, and timing of severe pH and aragonite saturation state (Ω_{arag}) conditions across this region. Lowest pH was seen in confined tidally-mixed zones in autumn; whereas lowest Ω_{arag} was seen in areas of high glacial melt in summer. Time-of-detection estimates revealed the tidally-mixed zones to be potential sentinel observing sites with a ~decade time span to capture seawater pCO_2 increase equivalent to the atmospheric CO_2 trajectory. Anthropogenic CO_2 estimates elucidated the monthly along-track changes in pH and Ω_{arag} since 1765, revealing a greater degree of winter pH change and a greater degree of summer Ω_{arag} change. Areas of diverging patterns of severe pH and Ω_{arag}, and the differential response to anthropogenic CO_2, have implications for species vulnerability to ocean acidification and must be considered within the scope of tracking ocean climate change.

(S5-13966)

The role of temperature in determining how marine fish will be differentially affected by climate change

Phoebe A. **Woodworth-Jefcoats**[1,2], Julia L. Blanchard[3], and Jeffrey C. Drazen[2]

[1] Pacific Islands Fisheries Science Center, NOAA Fisheries, Honolulu, HI, USA
E-mail: Phoebe.Woodworth-Jefcoats@noaa.gov
[2] Oceanography Department, University of Hawaii at Manoa, Honolulu HI, USA
[3] Institute for Marine and Antarctic Science, University of Tasmania, Hobart, TAS, Australia

The central North Pacific's pelagic ecosystem supports fisheries for high trophic level billfish and tuna species. In fact, more the half the tuna landed in the United States are caught in these waters. Climate change is expected to have a large impact on this ecosystem and the fisheries which it supports. A primary driver of ecosystem change is rising ocean temperature, due to its role in defining pelagic habitat and influencing physiological rates. Yet few studies have examined how marine species will be differentially affected by ocean warming. Here, we present a size-structured food web model with species-level resolution that includes the physiological effects of ocean temperature. We examine temperature across species' full vertical range, and in doing so see that different species may be affected very differently as the ocean warms. These differential effects have the potential to alter the species composition, and in turn value, of commercial fisheries' catch. Additionally, we find that rising ocean temperatures and declining primary productivity are projected to reduce both the size of fish caught and overall yield. However, our simulations also suggest that future levels of fishing mortality will strongly influence the magnitude of these changes. Proactive fisheries management, which takes climate change into account, can help limit its fishery and ecosystem impacts.

(S5-14343)

Synchrony between phytoplankton and zooplankton phenology in the Strait of Georgia, Canada

Karyn **Suchy**[1,2], Maycira Costa[1], Moira Galbraith[3], Kelly Young[3] and Ian Perry[3,4]

[1] Department of Geography, University of Victoria, Victoria, BC, Canada. E-mail: ksuchy@uvic.ca
[2] Pacific Salmon Foundation, Vancouver, BC, Canada
[3] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada
[4] Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, Canada

The Strait of Georgia (SoG) is a dynamic coastal region with substantial temporal and spatial variability at lower trophic levels. This variability, in turn, may directly impact resident and migratory fish populations in the region. The main goal of this research is to examine the link between phytoplankton and zooplankton phenology in the SoG from 2003-2016. Analysis of region-specific MODIS-Aqua chlorophyll *a* (Chl a) satellite products showed that the average spring bloom start date in the SoG occurs in late March. Earlier than average spring blooms occurred in 2005 and 2015, whereas later than average blooms occurred in 2007 and 2008. Cluster analysis revealed that zooplankton community composition was significantly related to both spring bloom timing and SST. Further, positive anomalies in spring Chl a corresponded with earlier peak timing of juvenile calanoid copepods and euphausiids, which are important food items for juvenile herring and salmon. In contrast, later than average peaks in these taxa coincided with negative anomalies in spring Chl a. Annual abundance and biomass of these taxa were influenced by the magnitude of the spring bloom, with positive anomalies occurring during years with the highest bloom magnitude. The exception to this was found for juvenile euphausiid biomass, which was unrelated to bloom magnitude yet showed positive anomalies during years with later bloom timing. Results from this study will provide insight into how changes in the seasonal patterns of phytoplankton and zooplankton may ultimately influence higher trophic levels.

(S5-13984)

Community species identities, diversity, and patterns across the Salish Sea: Metagenomic analyses of zooplankton and eDNA

Carol A. **Stepien**[1], Julie Keister[2], Elizabeth Slikas[1,3] Christopher Paight[1], Emily Norton[1,3] and Ellen Lee[1,3]

1 Genetics and Genomics Group, NOAA Pacific Marine Environmental Lab, Seattle, WA, USA
E-mail: carol.stepien@noaa.gov
2 School of Oceanography, the University of Washington, Seattle, WA, USA
3 JISAO, the University of Washington, Seattle, WA, USA

Ecological sampling depends on accurate taxon identification, delineation, and abundances, yet is time consuming, expensive, involves considerable taxonomic expertise, and often is thwarted by lack of diagnostic morphological characters. Targeted metagenomic analyses entailing field sampling, multiple gene metabarcoding, high-throughput sequencing, and bioinformatics offer means to rapidly and accurately simultaneously characterize the species diversity and compositions of entire communities, including rare and cryptic taxa, along with their relative representation and population genetics. We present results of diagnostic high-throughput Illumina MiSeq assays developed to analyze communities of invertebrates and fishes for environmental (e)DNA water samples from the field and zooplankton net tows, collected through the Washington Ocean Acidification Center's cruises in the Salish Sea. These analyses are especially useful for assessing species diversity responses of marine communities to changing conditions, including ocean acidification, temperature, and hypoxia. We also present examples of their use to discern population genetic variation, in context of temporal and special patterns. In our procedure, samples are quantified using synthetic internal standards for representative key taxa during PCR, and used to establish thresholds for potential error. Our custom bioinformatic pipeline assesses sequence read quality and output, and matches with database taxa reference sequences. Results from these metagenomic analyses demonstrate considerable application across marine ecosystems at a scale, accuracy, complexity, and capacity for automation not otherwise feasible.

(S5-14116)

Drivers of interannual and decadal-scale variability in the lower trophic levels of the marine ecosystem off Vancouver Island, Canada

R. Ian **Perry**[1,2], Moira Galbraith[2], Kelly Young[2], Roy Hourston[2], Richard Thomson[2], Ken Fong[1], and Brenda Waddell[1]

1 Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, Canada. E-mail: Ian.Perry@dfo-mpo.gc.ca
2 Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada

The marine ecosystem west of Vancouver Island, Canada, is known for experiencing warm and cool conditions related to ENSO and other occasional events. These changing conditions influence the species composition and biomass of the zooplankton and fish in this region. In this presentation, we use nearly four decade-long time series of zooplankton and small demersal invertebrates and finfish to explore the decadal patterns of biomass when the interannual variability of these warm-cool episodes is removed. Results from initial analyses suggest that taxa significantly related to changes in water temperature include southern-affinity copepods, northern-affinity copepods, and northern-affinity gelatinous zooplankton. In contrast, variables that are significantly different at decadal scales pre- and post-1999 include the North Pacific Gyre Oscillation (NPGO) index, upwelling-favourable wind stress, southern gelatinous zooplankton, and small demersal invertebrates and finfish. In particular, the NPGO appears to be an important driver of upwelling wind stress and zooplankton biomass when the ENSO-influence is removed. We hypothesise that an increase in zooplankton and small demersal invertebrates and finfish off the west coast of Vancouver Island in recent decades may have been driven by increased nutrients from enhanced climate-driven upwelling in this region.

(S5-14419)

Climate-related variability in assemblage and size- structure of euphausiids in coastal waters off northern California

Eric **Bjorkstedt**[1,2] and Roxanne Robertson[2,3]

1 NOAA Fisheries, Southwest Fisheries Science Center, Santa Cruz, CA, USA. E-mail: eric.bjorkstedt@noaa.gov
2 Department of Fisheries Biology, Humboldt State University, Arcata, CA, USA
3 Cooperative Institute for Marine Ecosystems and Climate, Humboldt State University, Arcata, CA, USA

We analyzed an 11-year time series of zooplankton collections made at roughly biweekly to bi-monthly intervals along the Trinidad Head Line (41°N) to assess effects of climate forcing on coastal euphausiids off northern California, with specific attention on the effects of the 2014-16 marine heat wave. Cold-water species (*Thysanoessa spinifera* and *T. inspinata*) both declined during warming events while warm-water species (e.g., *T. gregaria*) increased in abundance. *Euphausia recurva* and *Nyctiphanes simplex* occurred exclusively during the marine heatwave, and the timing of their arrival of northern California corroborates anomalous onshore transport during the early 'Warm Blob' phase of the heatwave and strong poleward transport following the onset of the 2015-16 El Niño. In contrast to many other taxa, the dominant species *Euphausia pacifica* exhibited relatively little variability in numerical abundance over the course of our study. However, length of adult and juvenile *E. pacifia* in coastal waters off northern California declined sharply during years affected by unusual warming events. Early life history stages exhibited an opposite response, in which warming shifted the population towards larger size classes. Changes in body size suggest dramatic declines in biomass of this critical and dominant forage species. Results from this work suggest that time series of euphausiid community composition and size have strong potential to serve as informative ecosystem indicators.

(S5-14383)

Development of an ecosystem-based assessment approach for the northwestern Pacific mullet (*Mugil cephalus*) fishery

Sheng-Yuan **Teng**[1], Shin-ichi Ito[2], Nan-Jay Su[1] and Ming-An Lee[1,3]

1 Department of Environmental Biology Fisheries Science, National Taiwan Ocean University, Keelung, Taiwan R.O.C.
E-mail: yuan22365041@gmail.com
2 Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba, Japan
3 Taiwan Group on Earth Observations, Zhubei City, Hsinchu County 30274, Taiwan, R.O.C.

Grey mullet (*Mugil cephalus*) is one of the most important commercial species in the coastal fisheries of Taiwan. It is a cosmopolitan species that is distributed in tropical and temperate zones at latitudes 42˚N-42˚S. The feeding grounds of juveniles and adults are located in the coastal and estuarine waters of China at 25-30˚N. It migrated to the coastal waters of the southeastern Taiwan Strait for spawning in winter. The purpose of this study is to develop a fisheries assessment framework approach that integrates ecosystem and socio-economic considerations into the fishery assessment process. Therefore, we collected fisheries data from Taiwan, Japan, and Korea from 1970 to 2010. The regions of the data from each country are 14, 38, and 1 respectively. The annual production of Japan and Taiwan also have the highest value in the 1980s and it rapidly declined. However, the annual production of Korea has an increasing trend in recent years. Through the cluster analysis, we can separate 9 groups of all regions by setting 65 of the similarity. The results show the 2 groups of Taiwan's data. One is located in the spawning ground which in the coastal waters of western south Taiwan and the other is located in Chan-Yun Rise which is the main fishing ground for Taiwanese fishermen. Lack of an effective cooperative fishery management institution and the strong demand for mullet, the intent is to facilitate the realization desire of the Taiwanese government and relevant management institutions to improve management of its fishery resources.

(S5-14095)

Large multi-decadal space and time shifts in Pacific herring spawning in the Gulf of Alaska

David W. **McGowan** and Trevor A. Branch

University of Washington, Seattle, WA, USA. E-mail: mcgowand@uw.edu

The effects of long-term changes in climate on coastal ecosystems may be more pronounced and detected earlier in marine organisms with life stages that are sensitive to environmental perturbations, such as spawning in small pelagic fishes. Variability in the location and timing of Pacific herring (*Clupea pallasii*) spawning within Prince William Sound (PWS) was examined using aerial survey data collected between 1980-2017. Spatial shifts in spawning in the 1980s preceded by 2-3 years an abrupt increase and later decrease in population size. In more recent decades, herring spawning grounds have contracted to areas used infrequently prior to the population collapsing in 1993. Spawn timing trends were also different between hydrologically distinct areas of PWS: peak spawning shifted 3 weeks earlier between 1980-2006 in eastern PWS where oceanographic exchange with the Gulf of Alaska (GOA) is weaker and freshwater inputs from glaciers is lower, whereas there was no clear trend in other areas during this period. Starting in 2007, the peak spawn date shifted later in the season across all PWS areas by 2-3 weeks during a 7-year period of relatively cold temperatures in the GOA. To determine if these patterns occurred more broadly, ongoing work is quantifying coherence in spawn timing among PWS herring and other coastal herring populations in the GOA. In addition, we are assessing the relative influence of environmental processes operating at local (10s of km) and larger (100s-1000s of km) scales on spawn timing for each population to provide a mechanistic understanding driving these patterns.

(S5-14395)

Depressed condition and growth of juvenile sockeye salmon (*Oncorhynchus nerka*) during early migration

J. **Garzke** and BPV Hunt

Institute for the Ocean and Fisheries, University of British Columbia, Vancouver, Canada. E.mail: j.garzke@oceans.ubc.ca

The years 2015 and 2016 were reported as two of the hottest years since recorded, the Blob hit the coast of British Columbia in 2015 and a strong El Niño was observed in winter 2015/2016. Observations showed warmer water temperatures, changes in plankton abundance and composition affecting migrating juvenile sockeye salmon. We measured RNA-DNA ratio and fatty acid composition as a parameter of fish fitness and nutritional condition to identify spatial and temporal fitness changes and connected observed changes to environmental changes and related changes in the lower trophic levels. We found that temperature not directly lead affected juvenile fitness and nutritional condition but rather indirect effects at the base of the food web: differences in prey species composition, food quantity and quality lead to low fish fitness and nutritional condition. Additionally, results showed that juvenile salmon had higher recovery from starvation phases when fed on higher quality food suggesting that higher survival rates of juvenile fish can be expected when food quality is high. Considering that the early marine stage in fish is the most vulnerable, and migrating species are world-wide distributed, this study showed that small changes at the base of the food web can lead to major effects on top predators and their survival. We found that a single extreme event can affect fish fitness and nutritional condition but when two independent but shortly after each other occurring events can lead to much stronger effects on fish condition and decrease the change of recovery in the open ocean.

(S5-14163)

Quantifying the role of estuaries in Oregon Coast coho salmon production

Caitlin L. **Magel**[1], Mark D. Scheuerell[2], Eric R. Buhle[3] and Sally D. Hacker[1]

1 Oregon State University, Corvallis, OR, USA. E-mail: whitecai@oregonstate.edu
2 USGS Cooperative Fish and Wildlife Research Unit, School of Aquatic and Fisheries Sciences, University of Washington, Seattle, WA, USA
3 Biomark Applied Biological Services, Boise, ID & Northwest Fisheries Science Center, NOAA Fisheries, Seattle, WA, USA

Pacific salmon (*Oncorhynchus* spp.) are important ecologically, economically, and culturally, but approximately one-half of their populations in the continental U.S. are currently listed as threatened or endangered under the U.S. Endangered Species Act. Of these, the Oregon Coast coho (*O. kisutch*) evolutionarily significant unit (ESU) is currently less than 20% of its historical size. Compared to other species of salmon, coho may rely more heavily on estuarine habitats, however little has been known about the factors limiting coho salmon and the potential role of estuaries in their recovery. Therefore, we used an integrated population model (IPM) to evaluate key factors, including estuarine marsh habitat, that mediate coho salmon abundance. Using 22 years of available data for 21 independent coho salmon populations, our Bayesian hierarchical IPM allowed us to examine population dynamics, important habitat needs, and possible restoration approaches within the ESU and across independent populations. Significant differences in intrinsic productivity and carrying capacity among populations indicated that local-scale factors, such as estuarine habitat size and quality, can contribute to coho salmon production. This critical information can be used to make projections about Oregon Coast coho salmon populations under future management or restoration scenarios, and findings are being linked to an economic model that will quantify the broader value of ecosystem services derived from estuarine habitat restoration.

(S5-14103)

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

Cecilia A. **O'Leary**[1], J.T. Thorson, J. Hoff, S. Kotwicki, and A. Punt

1 1UW, Seattle, U.S.A. E-mail: cecilia.oleary@noaa.gov

The Bering Sea region is transitioning from an arctic to subarctic region as climate changes, and there is evidence that some Bering Sea groundfish stocks, such as walleye pollock *Gadus chalcogrammus* and Pacific cod *Gadus macrocephalus*, are undergoing distributional shifts from the Eastern Bering Sea into the Northern Bering Sea. Scientists and managers aim to understand how these distributional changes are influencing fish abundance and spatial distribution in the Bering Sea over time, as this information is essential for the successful management of the Bering Sea fisheries. The proportion of the total fish stock captured in the available fisheries-independent surveys is important information to determine and use in stock-assessments. There are multiple fishery-independent bottom trawl surveys conducted in the Bering Sea that use different gears and cover different regions. The relative efficiencies of these surveys and their overall coverage were analyzed to understand the spatial availability of groundfish stocks to the Alaska Fisheries Science Center (AFSC) fisheries-independent bottom trawl survey. We use these multiple surveys to explore the availability of groundfish to the AFSC bottom trawl survey, compare fishing powers of surveys, and develop alternative indices of abundance for use in stock-assessment models. The spatiotemporal approaches we used provided us with information about trends in fishing power and population abundance over time and space as groundfish distributions change across survey boundaries in the Bering Sea. Overall, the vessels used in the western Bering Sea had a lower fishing power, and local variance estimators provided a reduced abundance index uncertainty. Based on these calculated indices and the availability of groundfish to the Eastern Bering Sea survey, a portion of the studied Bering Sea groundfish observed are moving north. We used model-based indices of abundance to explore the role of environmental covariates in the movement of these fish stocks north in recent years. These methods can be extended to other fisheries stocks and management frameworks.

(S5-14415)

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

State Fisheries Genetics Lab, Coastal Oregon Marine Experiment Station, Department of Fisheries and Wildlife, Hatfield Marine Science Center, Oregon State University, Newport, Oregon, USA. E-mail: elizabeth.lee@oregonstate.edu

Understanding species connectivity between marine ecosystems is important when considering how future changes in ocean conditions may impact fishery harvests. The Dungeness crab (*Cancer magister*) is the most valuable single-species commercial fishery within the California Current Ecosystem (CCE), and historically, the annual harvest has fluctuated by an order of magnitude. Variation in the abundance and timing of megalopae recruitment has been extensively studied for over two decades in Coos Bay, Oregon. These studies have shown that survival and dispersal during the larval stage is influenced by ocean conditions, and successful recruitment of larval megalopae can be used to predict Dungeness crab harvests four years later in the CCE. Here, we used a genotyping-by-sequencing (GBS) approach to examine genetic variation among recruiting Dungeness crab megalopae. Larval megalopae recruits were monitored daily and collected for genetic analyses throughout three recruitment seasons (2014, 2017, and 2018). Intra-annual and inter-annual genetic differentiation was tested for among recruiting megalopae, based on variation at both neutral and putatively adaptive genetic markers. The findings suggest there is high genetic connectivity among Dungeness crab larval recruits in the CCE with evidence for local adaptation. This study improves our understanding of how ocean conditions influence larval dispersal and population connectivity of Dungeness crab.

(S5-14051)

Multiple facets of marine biodiversity in the Pacific Arctic under future climate

Irene D. **Alabia**[1], Jorge Garcia Molinos[1], Sei-Ichi Saitoh[1], Takafumi Hirata[1], Toru Hirawake[2] and Franz J. Mueter[3]

1 Arctic Research Center, Hokkaido University, Sapporo, Japan. E-mail: irenealabia@arc.hokudai.ac.jp
2 Faculty of Fisheries Sciences, Hokkaido University, Hakodate Japan
3 University of Alaska Fairbank, Juneau, Alaska, USA

Climate change triggers species distributional shifts, affecting biogeography in marine ecosystems. Here, we explored the potential ecological impacts of projected changes in species habitat due to elevated temperature and sea ice loss in the Pacific Arctic continental shelves. In particular, we examined the contemporary and future structures of species richness (alpha-) and community composition (beta-diversity) of benthic assemblages across the taxonomic, functional, and phylogenetic biodiversity facets. Our data were composed of multi-ensemble projections for present (1993-2017) and future (2026-2100) habitat distributions of 20 fish and invertebrate species and their respective functional (9 biological traits) and phylogenetic information. Prominent changes relative to contemporary biodiversity patterns were observed during the late-century (2076-2100) under high warming scenario. Specifically, alpha diversity structure was characterised by the poleward increases in taxonomic richness and functional trait redundancy, along with a reduction in phylogenetic distances. In terms of community composition, the subarctic (Arctic) region exhibited community homogenisation (heterogenisation) as seen from the significant declines (increases) in taxonomic, functional and phylogenetic beta-diversity between the present and future periods. We found that the projected poleward shifts of boreal species in response to warming were modifying the taxonomic and functional biogeography of the Arctic communities as larger, longer-lived and more predatory taxa were expanding the leading edges of their distribution. Our results show that looking at multiple diversity facets can yield critical insights into the link between species composition, ecosystem functioning, and environmental drivers across biogeographic domains under the rapidly emerging threats of climate change.

(S5-14147)

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

Haruka **Nishikawa**[1], Shiro Nishikawa[1], Tsuyoshi Wakamatsu[2,3], and Yoichi Ishikawa[1]

1 Japan Agency for Marine-Earth Science and Technology. E-mail: harukan@jamstec.go.jp
2 Nansen Environmental and Remote Sensing Center
3 Bjerknes Centre for Climate Research

The Kuroshio Extension (KE), which includes the Kuroshio-Oyashio transition zone (KOTZ) and the Kuroshio southern recirculation gyre (KR) is an important fishing ground in the western North Pacific. It is known that the interannual variation of primary production in KE strongly depends on perturbation of the Kuroshio path. Due to narrowness of the Kuroshio path, the eddy resolving ocean state products are required for future projection of the primary production in this region. However, the spatial resolutions of the current climate projection products, CMIP5, are generally of about 1 degree. The resolutions are too coarse to reproduce the narrow Kuroshio path. Recently, we have succeeded at dynamical downscaling of multiple CMIP5 ocean products to 0.1º horizontal resolution products. In this study, we estimate the primary production in KOTZ and KR until 2100 by using the high resolution products based on empirical relationships between physical variables and primary production. For example, spring primary production in KOTZ is related to the distribution of the Kuroshio-Oyashio layered structure. Preliminary analysis using the downscaled MRI-CGCM3 data shows that extremely low production sometimes occurs in the RCP2.6 and 8.5 scenarios. Spring primary production in the KR depends on winter mixed layer depth. There is no significant trend in the winter mixed layer time-series in RCP2.6 scenario, and 43m of decrease from 2010 to 2100 appears in RCP8.5 scenario. This mixed layer shoaling links to 18% reduction of primary production in spring.

(S5-14043)

Reconstructing and projecting trends in a Northeast Pacific ecosystem

Szymon **Surma**

University of British Columbia, Vancouver, BC, Canada. E-mail: s.surma@oceans.ubc.ca

This paper uses a mass-balanced food web model to reconstruct and project trends in the marine ecosystem surrounding Haida Gwaii (an archipelago in the southeastern Gulf of Alaska). The model was built in Ecopath with Ecosim, initialized with data on the ecosystem state existing *circa* 1950, and fitted to a comprehensive set of biomass and catch time series extending to 2015. The fitting procedure permitted an evaluation of the relative importance of top-down versus bottom-up forcing (i.e. fishing and predation versus primary productivity) in historical ecosystem dynamics. Trends in mean ecosystem trophic level, Shannon-Wiener biodiversity, and a “fishing down the food web” index were also reconstructed for 1950-2015. Future impacts of continued whale recovery, as projected by surplus production models, were then simulated in the fitted ecosystem model, under twenty different primary productivity scenarios obtained by randomized resampling from a historical dataset. Reconstructed ecosystem dynamics since 1950 revealed that trends in fishing mortality, trophic interactions (especially marine mammal population recovery), and primary productivity (positively correlated with the Pacific Decadal Oscillation) are all necessary to explain historical ecosystem behavior. These interacting drivers yielded a mosaic of top-down, bottom-up, and intermediate trophic control. The reconstruction also revealed that a biodiversity decline and “fishing down the food web” had occurred since 1950. Simulated effects of future whale recovery were substantial, though somewhat sensitive to the primary productivity scenarios. This paper illuminates the complex drivers of Northeast Pacific ecosystem dynamics and illustrates an approach capable of reconstructing past and projecting future ecosystem trends.

(S5-13994)

Developing a community-based resilience assessment model to extreme ocean-climate events

Samuel **Akande**[1], Adekunle Osinowo[2], Olajumoke Jejelola[3], Olabanji Olajire[4] and Oluwaseun Apenuwa[5]

1 Department of Meteorology and Climate Sciences, Federal University of Technology, Akure, Nigeria
E-mail: soakande@futa.edu.ng
2 Department of Marine Science and Technology, School of Earth and Mineral Sciences Federal University of Technology, Akure, Nigeria
3 School of Earth and Mineral Sciences Federal University of Technology, Akure, Nigeria
4 African Regional Cebtre for Space Science and Technology Education-English, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria
5 Department of Urban and Regional Planning, School of Environmental Technology, Federal University of Technology, Akure, Nigeria

Though the advancement of earth observation technology in ocean environment monitoring has greatly improved globally, but an important determinant of adaptation to climate change and extreme events of sea level rise, storm surges and ocean warming is institutional capital, or the assistance provided by government, civil society and private organization through programs and policy. The study assessed future climate change scenarios and associated impacts along the Gulf of Guinea, particularly for vulnerable populations along the West-African coastal communities. The study area is home to a large number people with a projected population of 55 million in 2020. In order to ensure the preservation and conservation of coastal cities from environmental degradation, a modified methodological approached was developed to assess both the natural and the anthropogenic risks. The long term inter-seasonal, inter-annual and multi-decadal timescale analyses of sea level data, sea surface temperature and ocean heat flux from a 3-D coastal ocean circulation model indicate long-term threats to low lying areas on the final risk map. However, the methodology of this study is being broadly applied in the Gulf of Alaska, with a view of achieving community-based resilience. Therefore, adopting climate change adaptation measures must be transparent and participatory since they aim at both short-term and long-term objectives. Recommendations from the study would enhance the capacity and knowledge of global policy makers to prepare for and provide sustainable adaptation strategies in accordance with the United Nation’s Sustainable Development Goals (SDGs 1,2,13 & 14).

(S5-14154)

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

National Taiwan Ocean University, Taiwan, R.O.C. E-mail: rogershiao@gmail.com

The Taiwan Bank (TB) is located in the southern Taiwan Strait, the marine environments are affected by China Coastal Currents, South China Sea Warm Current and Kuroshio Branch Current. In summer, the surface current is predominantly wind driven, and the bottom current flows upwards from the continental slope with four major upwelling regions, and formed an important fishing ground in TB. The purpose of the study investigated the relationship between the variations of upwelling intensity and marine environment, and the climatic phenomenon, and related to the ecosystem structure using primary production required (PPR). Two upwelling indices of sea surface temperature divergence and Ekman pumping showed the upwelling were strongest in June and weakest in August. The El Niño Southern Oscillation (ENSO) events had significant effect on the strength of upwelling in TB, and have shown a time lag of a 3~6 months. The PPR is convert the catch weights to the same value of primary productivity (PP) and used to revealed the fishery intensities. The PPR showed the extremely high value in 2011 in TB caused by the high catch of Scombridae species, and also had seasonal variations. There is no significant correlation between PPR and upwelling indices, but had negative correction with CHL-a. The relationship between PPR and PP in different habitat regions (upwelling areas, marine frontal areas, and non-upwelling areas) will leave for further study and discussion.

SESSION 6
Identifying thresholds and potential leading indicators of ecosystem change: The role of ecosystem indicators in ecosystem-based management

(S6-14104)

Are Canadian Pacific groundfishes shifting their distribution in response to local climate velocities?

Philina A. **English**[1], Sean C. Anderson[1], Eric J. Ward[2], Brendan M. Connors[3], Andrew M. Edwards[1], Robyn E. Forrest[1], Karen L. Hunter[1], and Christopher N. Rooper[1]

1 Pacific Biological Station, Fisheries and Oceans Canada (DFO), Nanaimo, BC V9T 6N7, Canada
E-mail: philina.english@dfo-mpo.gc.ca
2 Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanographic and Atmospheric Administration, Seattle, WA 98112, USA
3 Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC V8L 5T5, Canada

The impacts of climate change can manifest at local scales in heterogeneous ways. In the ocean, currents, winds and depth can influence the rate of change in temperature, dissolved oxygen, and salinity, while species characteristics and habitat preferences limit the degree to which species can shift their distributions in response to these changes. As a result, species distribution shifts might not be accurately represented by regionally aggregated trends in climate and population that do not account for local variability in climate, abundance, and habitat. We assessed the degree to which changes in distributions of groundfish populations within Canada's Pacific waters can be explained by locality-specific climate velocities—the distance and direction of movement required to maintain similar climatic conditions through time—which incorporate species-specific physiological thresholds and habitat limitations. We constructed geostatistical spatiotemporal fish density models using maturity-specific biomass data from biennial random-stratified surveys and compare these to local climate velocity predictions derived from *in situ* temperature, salinity, and dissolved oxygen measurements. For species that track local climate velocities, our models will help anticipate changes in species interactions and fishing pressures, identify barriers to future movement, and to predict when a species might to become more locally concentrated and therefore more vulnerable to exploitation and density-dependent effects. Where changes in species distributions do not track climate velocity, our models differentiate among populations that are less sensitive to climate, and populations that are limited by a lack of nearby analogous climatic conditions, and therefore no longer operating in their optimal environment.

(S6-14153)

Identifying drivers and their thresholds for piscivorous fishes in the exploited China Seas under climate change

Dan **Liu**[1], Yongjun Tian[1,2*], Caihong Fu[3], Shuyang Ma[1], Jianchao Li[1], Peng Sun[1], Zhenjiang Ye[1] and Shijie Zhou[4]

1 Fisheries College, Ocean University of China, 5 Yushan Road, Qingdao, 266003, PR China
E-mail: FOL_DanLiu@163.com
2 Laboratory for Marine Fisheries Science and Food Production Processes, Qingdao National Laboratory for Marine Science and Technology, Aushanwei, Qingdao, 266071, PR China. E-mail: yjtian@ouc.edu.cn
3 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia V9T 6N7, Canada
4 CSIRO Oceans and Atmosphere, P.O. Box 2583, Brisbane, QLD 4001, Australia

Marine fisheries have undergone significant variations over the past six decades as a result of exploitation and climate change. Long term variability of Chinese fisheries has rarely been investigated, especially for piscivorous fishes, which are ecologically important due to their top-down controls on ecosystem structures, but are also susceptible to overfishing owing to their economic values. To identify 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 in the China Seas, we selected over 20 species from pelagic to demersal fishes inhabiting either cold or warm water to represent two distinct groups. Catches of both groups increased until the 2000s and then

declined slightly; however, the proportion of piscivorous fishes in the total marine fish catch decreased rapidly from the early 1970s and then fluctuated below 25%. Gradient forest analyses indicated that among all biotic and abiotic drivers explored in this study, prey assemblage had the greatest impact on variations in piscivorous fish catch. In addition, the cold-water group was more responsive to changes in SST with a threshold response around 24°C. Principal component analysis showed evident interannual-decadal variabilities in both groups with step changes occurring in 1988/89 and 1996/97, corresponding well to the step changes in prey assemblage around 1986/87 and 1993/94 with a lag of about 2-3 years. This study sheds light on the drivers of piscivorous fishes in the exploited China Seas, which would facilitate sustainable management of Chinese fisheries.

(S6-14187)

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

David G. **Kimmel**

Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, USA
E-mail: david.kimmel@noaa.gov

A two-step, multivariate approach was used to analyze spring (May) zooplankton abundance in the Shelikof Strait, western Gulf of Alaska: 1) Dynamic Factor Analysis (DFA) was used to estimate if common trends were present; 2) non-linear, generalized additive models (GAM) were used to relate environmental factors to zooplankton abundance. DFA of environmental data found one underlying trend linked to the Pacific Decadal Oscillation. DFA of zooplankton time-series also indicated one underlying trend where the positive phase was characterized by increases in the abundance of *C. marshallae* C5, *C. pacificus* C5, *E. bungii* C4, *Pseudocalanus* spp. C5, and *L. helicina* and declines in the abundance of *N. cristatus* C4 and *Neocalanus* spp. C4. A positive trend in the abundance of *C. pacificus* C5 and a negative trend in the abundance of *N. cristatus* C3/C4 and *Neocalanus* spp. C4 abundance was also detected. GAM models varied by species; however, the most important variables correlating with zooplankton abundance were water temperature, strength of upwelling, and Julian day of sampling. Unsurprisingly, the zooplankton community responds strongly to environmental variability. A novel finding is that the decline or increase in abundance of several species appears to reflect a shift in phenology related to temperature effects on development rate as the sample timing has remained constant over time. This is inferred by the correlation between Julian day and abundance for these species. The result can be applied to ecosystem-based fisheries management as shifting phenology impacts the match-mismatch between zooplankton and their predators.

(S6-14117)

Evidence for ecosystem overfishing in North Pacific marine ecosystems

Jason S. **Link**

National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Woods Hole, MA, USA
E-mail: Jason.Link@noaa.gov

Fisheries are an important driver of the North Pacific economy, contributing billions of dollars and millions of jobs. We know that overfishing a fish stock erodes those socio-economic contributions. We have not, however, examined whether entire systems of fisheries have been overfished. Here I present novel indices of ecosystem overfishing (EOF), providing a brief summary and theoretical background of each, with thresholds not to exceed analogous to single-species biological reference points. I then estimate values of these indices over time for all the major large marine ecosystems in the North Pacific. From these I show that there has indeed been EOF at points in time in many of these marine ecosystems. I also demonstrate 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. I conclude by posing recommendations of these EOF thresholds moving forward to detect and avoid any drastic changes to North Pacific fisheries systems.

(S6-14427) CANCELLED

Biological threshold application for forecasting future sustainability of estuarine calcifiers in the Salish Sea

Nina **Bednaršek**[1], Greg Pelletier[2], Richard Feely[3], Simone Alin[3], Anise Ahmed[2], and Teizeen Mohamedali[2]

1 Southern California Coastal Water Research Project, Costa Mesa, CA, 92626 USA. E-mail: ninab@sccwrp.org
2 Washington State Department of Ecology (DOE), PO BOX 47600, Olympia, WA, 98504 USA
3 NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA, 98115 USA

Ocean acidification is projected to have profound impacts on marine ecosystems and resources, especially in the estuarine habitats. Here, we describe biological effects of current and future ocean acidification in the Salish Sea, an estuarine system that already experiences inherently low OA conditions. We used a PNNL/DOE Salish Sea biogeochemical model informed by a selection of OA biological sensitivity thresholds for pelagic and benthic calcifying taxa (pteropods, echinoderms, crabs) to investigate the effects of combined nutrient loading and atmospheric CO_2 uptake on the magnitude, duration, and severity of exposure below the biologically relevant thresholds with implication for biological risks across different functional groups. Varying sensitivity to projected pH and omega allows discrimination of the varied levels of vulnerability of diverse calcifiers, each with specific carbonate parameter sensitivity (add info). Regarding future sustainability of pelagic calcifiers in the Salish Sea, exposure below CO_2-system thresholds for reproduction and survival could lead to population level effects expected during late summer to early fall in stratified embayments under RCP8.5 scenario by 2100. Echinoderms are projected to be affected the least by exposure to harmful pH levels, with only physiological impairments in larval and shallow water species observed under future OA scenario, due to their diverse responses to changing pH. Our results provide a set of projections that set the stage to guide future OA risk assessment in estuarine habitats of the Salish Sea on ecologically and economically important species.

(S6-14293)

Ecological thresholds in forecast performance for key United States West Coast Chinook salmon stocks

William H. Satterthwaite[1], Kelly S. **Andrews**[2], Brian J. Burke[3], Jennifer L. Gosselin[4], Correigh M. Greene[3], Chris J. Harvey[2], Stuart H. Munsch[5], Michael R. O'Farrell[1], Jameal F. Samhouri[2] and Kathryn L. Sobocinski[3,6]

1 Fisheries Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Santa Cruz, CA USA. E-mail: kelly.andrews@noaa.gov
2 Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA USA
3 Fish Ecology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA USA
4 School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA USA
5 Ocean Associates Inc., Under Contract to Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA USA
6 Long Live the Kings, Seattle, WA USA

Preseason abundance forecasts heavily influence management of ocean salmon fisheries off the U.S. West Coast, yet little is known about how environmental variability influences forecast performance in comparison to current approaches (i.e., sibling-based, production-based, or averaged over recent years). We investigated forecast performances for key California/Oregon ocean fishery stocks in (Sacramento and Klamath Fall Chinook), and high priority stocks of prey for endangered Southern Resident Killer Whales (multiple stocks in Puget Sound). We explored how well environmental indices (at multiple locations and time lags) explained variation in forecast performance, and tested for nonlinearities and thresholds. For the California stocks, no environmental index could explain >50% of the variation in forecast performance, but spring PDO and winter NPI of return year had R^2>40% for the sibling-based Sacramento Fall Chinook forecast, with nonlinearity and apparent thresholds. This suggests that conditions experienced after jacks return have the most impact on sibling-based forecast performance. For Puget Sound stocks employing various forecast methods, we detected nonlinear and threshold relationships (with R^2>50%) with multiple indices and time lags. These 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.

(S6-14129)

The changing physical and ecological meanings of North Pacific Ocean climate indices

Michael **Litzow**[1], Mary Hunsicker[2], Nicholas Bond[3], Brian Burke[4], Curry Cunningham[5], Jennifer Gosselin[6], Emily Norton[3], Eric Ward[4] and Stephani Zador[7]

1 University of Alaska Fairbanks, Kodiak, AK, USA. E-mail: mlitzow@alaska.edu
2 National Marine Fisheries Service, Northwest Fisheries Science Center, Newport, OR, USA
3 Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA
4 National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA, USA
5 Alaska Pacific University, Anchorage, AK USA
6 University of Washington, Seattle, WA, USA
7 National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA, USA

Climate change is likely to change the relationships between commonly used climate indices and underlying patterns of climate variability, but this complexity is rarely considered in studies using climate indices. Here we investigate 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. This event was accompanied by changes in the statistical behavior of the PDO and NPGO indices, including declining autocorrelation in the PDO, increasing variance and autocorrelation in the NPGO, and increasing correlation between the two indices. The spatial patterns of sea level pressure and surface temperature patterns associated with each climate index also changed after 1988/89, indicating that identical index values reflect different states of basin-scale climate over time. Finally, the PDO and NPGO showed time-dependent skill as indices of regional northeast Pacific ecosystem variability. Both indices have become less relevant to physical-ecological variability in northern ecosystems (Bering Sea and Gulf of Alaska), while the NPGO has shown strengthening association with variability in southern (California Current) ecosystems. Accounting for changing relationships between these climate indices and underlying physical variables may help to improve our understanding of North Pacific ecosystem variability.

(S6-14373)

Traits-based tools to account for the effect of shifting predator-prey interactions on the distributions of tunas under climate change

Stephanie J. **Green**[1], Natasha A. Hardy[1,2], Michael Jacox[3], Elliott L. Hazen[3], Steven J. Bograd[3], Larry B. Crowder[2]

1 Department of Biological Sciences, University of Alberta, Edmonton, AB, T6E4R4, Canada
E-mail: stephanie.green@ualberta.ca
2 Hopkins Marine Station, Stanford University, Monterey, CA, 93940, Canada
3 NOAA Southwest Fisheries Science Center, Monterey, CA, 93940, Canada

Climate change is shifting fisheries resources across jurisdictional boundaries, with potential consequences for communities that depend on these fisheries. When and where will shifts occur? While many analytical approaches are developing to link changing abiotic conditions and species distribution under future climate scenarios, there is also a need to account for the potential influence of dynamic trophic interactions on species' distribution and abundance. Here we outline an initiative that seeks to address this gap by using insights into species' foraging and anti-predation traits to flexibly incorporate the effect of climate-mediated range shifts on predator-prey interactions, and ultimately community structure and biomass. We describe the framework for this approach, and illustrate the process by which we are applying it to model the distribution of tunas and their prey in the California Current system. These are key fisheries species for which trophic interactions are variable and uncertain, and for which distributions are likely to change across multiple regional and international jurisdictions in the coming decades due to climate change. The project is occurring in three phases of work: (1) identifying the traits basis of foraging interactions, (2) integrating traits-based approaches into spatially explicitly food web models, and (3) coupling food web models with projections of species redistribution from regional ocean modeling in the CCLME.

(S6-14363)

Trait-based modeling for albacore tuna predator-prey interactions under climate change in the NE Pacific

Natasha **Hardy**[1,2], Elliott Hazen[2,3], Michael Jacox[3,4], Steven Bograd[3], Larry B. Crowder[2], Stephanie J. Green[1]

1 Department of Biological Sciences, University of Alberta, Edmonton, AB, Canada T6E4R4
E-mail: nahardy@ualberta.ca
2 Hopkins Marine Station, Stanford University, Monterey, CA, USA 93940
3 Southwest Fisheries Science Center, National Oceanic and Atmospheric Administration, Monterey, CA 93940
4 Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO 80305

Climate change is driving shifts in marine species to maintain their preferred habitat, decoupling food web components and resulting in fisheries production shifting across jurisdictional boundaries. Novel combinations of species are giving rise to new trophic dynamics, which will in turn shape species redistributions in changing oceanic habitats. Our team is investigating the role of functional trait metrics in predicting how predator-prey relationships may mediate climate-induced shifts of highly-migratory pelagic predators. Here, we test 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. We then aim to apply trait-based parameters to models that predict shifts in predator diets as a response to changing environmental conditions. We highlight 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. Analytical tools that incorporate predictive traits to evaluate the effect of predation on species abundance will add salient and cost-effective information to existing species distribution and ecosystem-based models. Our team hopes to foster international collaborations on tuna diet data to produce predictive tools for predator-prey interactions across jurisdictional boundaries and gradients of environmental change.

(S6-14265)

Dynamics of the planktonic food-web of the Strait of Georgia (northeast Pacific) and implications for zooplanktivorous fish.

David **Costalago**[1], Brian P. V. Hunt[1,2,3], Chrys Neville[4], Ian Perry[4], Kelly Young[5] and Ian Forster[6]

1 Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada. E-mail: d.costalago@oceans.ubc.ca
2 Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, Canada
3 Hakai Institute, Heriot bay, BC, Canada
4 Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, Canada
5 Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada
6 Centre for Aquaculture and Environmental Research, Fisheries and Oceans Canada, Vancouver, BC, Canada

The growth and survival of fish is conditioned by the nutritional content of their food. Since zooplankton is the principal dietary group for juvenile salmon and herring, variations in the nutritional composition and abundance of zooplankton are key modulators of the fishes' growth and survival. Here, we describe the pathways and connections between plankton food-web components, the seasonal development of these pathways and their spatial variation in the Strait of Georgia (SoG). We used fatty acid (FA) biomarkers and stable isotope analyses of particulate organic matter (POM) and zooplankton from 2017/18. We also measured the ratio of the essential FAs docosahexaenoic acid (DHA) to eicosapentaenoic acid (EPA) (DHA/EPA), as this is an indicator of the nutritional value of food for fish. We found that the FA composition and the C and N isotopic values of POM and zooplankton were highly variable between seasons and between zooplankton size classes, and to a lesser extent, between different regions within the SoG. Fish larvae and the copepod *Paraeuchaeta elongata* had the highest DHA/EPA of all analyzed taxa, while the lowest DHA/EPA values were measured in the copepods *Eucalanus bungii* and *Calanus marshallae*. Compared to other regions at similar latitudes (i.e. west coast of Vancouver Island and the North Sea), zooplankton DHA/EPA in the SoG was up to 100% lower. In all zooplankton size classes, DHA/EPA was significantly lower in spring than in summer, which suggests herring and out-migrating juvenile salmon might be encountering poor nutritional conditions in spring in the SoG.

(S6-14094)

Characterizing spatial coherence of copepods as regional indicators in the Northern California Current

Michael J. Dumelle[1], Jesse F. Lamb[2], Kym C. **Jacobson** [3], Mary E. Hunsicker [3], Cheryl A. Morgan[4] , Brian J. Burke[5], and William T. Peterson[3]

1 Oregon State University, Corvallis, Oregon, USA
2 National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA, USA
3 National Marine Fisheries Service, Northwest Fisheries Science Center, Newport, OR, USA. E-mail: kym.jacobson@noaa.gov
4 Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, Oregon State University, Newport, OR, USA
5 National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA, USA

Ecosystem indicators track information about states and trends in ocean systems and are a valuable tool for ecosystem assessment and management. To ensure that indicators are used appropriately it is important to understand the extent to which they represent broader spatial patterns. In the northern California Current (NCC) ecosystem, copepod metrics derived from a well-sampled station on the Newport Hydrographic (NH) Line ('NH05', five nmi offshore from Newport, OR, USA) are commonly used as indicators of regional ocean conditions. Here, we use the biomass of cold-water and warm-water copepods from this station as a test case for determining how well this sentinel station represents broader regional patterns in the NCC. We applied correlation analyses and statistical models to 14 years of survey data to 1) quantify spatial coherence of copepod biomass measured throughout the central Oregon and Washington shelf, and 2) identify regional and basin-scale environmental drivers that may influence copepod distributions. In general, our results provide evidence of a strong similarity between the biomass of cold-water copepods at NH05 and other sampling stations of similar bathymetry. We found that cold-water copepod biomass is spatially autocorrelated up to a distance of approximately 45 km, while warm-water copepod biomass is spatially autocorrelated up to 75 km. Deep temperature, station depth, and the PDO were the main drivers of the distribution of copepod biomass along the shelf. Together, our findings support the continued use of copepod metrics from a sentinel station, NH05, as representative of a broader region of the NCC.

SESSION 7
Environmental indicators of plastic pollution in the North Pacific

(S7-14323) INVITED

Main Advances in Marine Microplastics Research in China

Daoji **Li**

East China Normal University, Shanghai, PR China. E-mail: daojili@sklec.ecnu.edu.cn

In the past two years, China's research on marine microplastics has focused on the dynamics of marine microplastics from source to sink and their ecological effects. Significant progresses have been made in many different aspects of marine microplastics, such as research methodology, ecological and environmental effects, and the flux into the sea and transport. Including "Marine Microplastics Monitoring Guideline" were employed for trial monitoring of microplastics along China's coasts, revealing distribution characteristics of marine microplastics in several different environmental matrix of China including surface seawater, sediments and marine organisms in estuaries and coastal areas, and a Material Flow Analyze model has been established to estimate the annual input of marine plastic waste from China. Furthermore, numerical simulations model of marine microplastics transport pathways in the marginal seas around China, South Korea, and Japan were established, revealing the aggregation of marine microplastics and their transport pathways to the West Pacific Ocean. The vertical transport mechanism of microplastics in the ocean surface and new ways of microplastics transference in the food chain were discovered. It was confirmed that marine snow could promote the transfer of microplastics to the marine food web. Meanwhile, the temporary storage of microplastics of wild fish in the East China Sea and the pathway along the trophic level was studied and a novel method for collecting microplastics in marine water layers was established and For the first time, using large volume in-situ filtration and revealing the true vertical concentration distribution of microplastics unknown before in deep sea.

(S7-14166)

Fast fragmentation rate of secondary nano- and microplastics from foamed polystyrene by sunlight exposure

Young Kyoung Song[1,2], Won Joon **Shim**[1,2], Sang Hee Hong[1,2], and Soeun Eo[1,2]

1 Korea Institute of Ocean Science and Technology, Geoje, R Korea
E-mail: wjshim@kiost.ac.kr
2 Korea University of Science and Technology, Deajeon, R Korea

The secondary microplastic production by photochemical weathering is expected one of major input sources of microplastics in marine environments. Fragmentation process and rate of nano- and microplastic production, however, are largely unknown. Our previous study revealed that foamed plastic, such as expanded polystyrene (EPS) was highly susceptible to UV as well as mechanical weathering due to the unique foamed structure compared to polyethylene and polypropylene. In addition, foamed plastics including EPS are one of common marine plastic debris items in the ocean worldwide. In this study, we aimed to identify micro- (0.8-500 mm) and nanoparticles (2-800 nm) of EPS produced by sunlight exposure for 2 years including size distribution. The abundance of produced particles increased by increasing sunlight exposure time (micro particles: 3.4×10^6 - 6.7×10^7 particles/cm^2 and nanoparticles: 4.0×10^7 - 5.7×10^8 particles/cm^2), and the average size of fragmented EPS particles were in range of 2.03-2.88 mm for microparticles and 138-189 nm for nanoparticles, respectively. The abundance of microparticles increased by decreasing size, but nanoparticles showed bimodal size distribution based on 100 or 80 nm. The estimated fragmentation rate was 2.6×10^8 particles/year·cm^2 by sunlight exposure according to linear regression equation ($y = -16295045 + 55231x$, $r^2 = 0.94$, $p < 0.01$). Any EPS litter directly exposed to sunlight in the environment can be a kind of factory for continuously producing secondary nano- and microplastics within relatively short time span.

(S7-13876)

Microplastic accumulation patterns in sand at three Hawaiian beaches

Nicolas **Vanderzyl**, Steven Colbert and Tracy Wiegner

University of Hawai'i at Hilo, Hilo, HI, USA. E-mail: nvanderz@hawaii.edu

Microplastics (< 5 mm) are a pervasive contaminant in the ocean, and global concentrations are anticipated to increase. Microplastic concentrations are greater in sediment than water, and highest in backshore and subtidal zones. Yet, no comparative study across cross shore zones has been conducted to date on Hawai'i Island, HI. A comprehensive analysis along six shore zones at: 1) Hapuna Beach State Park, 2) Hilo Bay, and 3) Pohoiki, investigated if a cross shore microplastic concentration gradient existed. Samples were collected from the: 1) berm crest, 2) high-tide line, 3) swash zone, 4) low-tide line, 5) surf zone, and 6) shore break zone. Recent volcanic activity has formed a new beach, Pohoiki, permitting an investigation into the pervasiveness of microplastics four months after its conception. Microplastics were extracted via density flotation, and visually sorted by: 1) fragment, 2) fiber, and 3) nurdle. Sediment grain size was also quantified to investigate any association with microplastic concentrations. Microplastic concentrations were similar at Hapuna and Hilo Bay, while significantly lower at Pohoiki. Fibers had the highest concentrations among all shore zones and sites. Overall, microplastics were evenly distributed among all shore zones at Hapuna and Pohoiki, while a cross shore gradient was found at Hilo Bay. Although microplastic concentrations were highly variable among zones, this study documented higher concentrations backshore at Hilo Bay, suggesting an area of focus during future beach clean-ups. This study also found microplastics present at a newly formed beach. This further emphasizes the extent of global microplastic pollution.

(S7-14121)

Microplastic pathways into the ocean: Lessons learned from Vancouver, Canada

Peter S. **Ross**, Katerina Vassilenko, Mathew Watkins, Stephanie Wang and Anna Posacka

Ocean Wise Conservation Association, Vancouver BC Canada. E-mail: Peter.Ross@ocean.org

Microplastics represent a new and emerging pollutant category in the marine environment, with significant questions outstanding regarding source, transport and fate pathways in the marine environment. We have devised a dual strategy that encompasses forensic 'source to sink' and 'sink to source' evaluations. In the former, our 'Microfiber Partnership' with industry and government is tracking microplastics from homes through wastewater treatment plants and into the marine environment. In the latter, we are identifying and enumerating microplastics particles in seawater, sediments, shellfish, zooplankton, fish and marine mammals. In both approaches, we employ microscopic image analysis and subsequent Fourier Transform Infra Red (FTIR) spectrometry so as to inform on environmental pathways and putative sources. We estimate that trillions of microplastic particles enter Vancouver wastewater treatment plants every year, with as much as 98% being retained in biosolids. Of this, the majority are fibers, and these are dominated by polyester. The traditional indicator matrices of sediments and mussels appear to provide a poor reflection of microplastic pollution, with microplastics typically being neutrally buoyant, and found preferentially in seawater. Our studies of Arctic seawater reveal a similar pattern; 91% of microplastic particles are fibers, and 54% of these are polyester. These latter findings in the remote Arctic bring us back to our studies in Vancouver (Canada), where we estimate that a single load of laundry releases up to 18 million microfibers, and billions of particles are released into the ocean. We feel that the solution to this growing ocean pollution crisis lies in a team approach where innovation trumps everything, and industry, governments and civil society work together on blue design, best practices, waste management, consumer education and regulations.

(S7-13844)

Impacts of environmentally-relevant concentrations of polypropylene rope on Pacific Mole crab *(Emerita analoga)* development and lifespan

Dorothy **Horn**[1], Elise Granek[1] and Clare Steele[2]

1 Environmental Science and Management, Portland State University
E-mail: dhorn@pdx.edu
2 Environmental Science and Resource Management, California State University Channel Islands

Microplastics are increasingly recognized as widespread in marine systems, however, the effects of these particles on marine fauna are not well known. Ocean-borne plastic debris accumulates in littoral ecosystems around the world, and invertebrate infauna inhabiting these systems can ingest small plastic particles, mistaking them for food items. We examined the effect of microplastics on physiological and reproductive outcomes in a nearshore organism by exposing Pacific mole crabs (*Emerita analoga*), collected from Newport, Oregon, to environmentally relevant concentrations of polypropylene rope for 71 days. We compared crab mortality, reproductive development, and larval stages of eggs on gravid females between control and treatment groups. We found that Pacific mole crabs exposed to polypropylene rope had decreased larval development rates and displayed marginal differences in mortality and reproductive success. These effects of microplastic ingestion on a nearshore prey item have implications for food webs, as plastic use, and resultant microplastics presence in nearshore environments increases.

Keywords: *Microplastic, Food Web, Sandy Beach, Reproductive Success, Larval Development*

(S7-13931)

The vertical distribution and biological transport of marine microplastics across the epipelagic and mesopelagic water column

C. Anela Choy[1,2], Bruce H. Robison[1], Tyler O. Gagne[3], Benjamin Erwin[1], Evan Firl[3], Rolf U. Halden[4], J. Andrew Hamilton[1], Kakani Katija[1], Susan E. Lisin[3], Charles Rolsky[4], and Kyle S. **Van Houtan**[3,5]

1 Monterey Bay Aquarium Research Institute. Moss Landing, CA, USA. E-mail: kyle.vanhoutan@gmail.com
2 Scripps Institution of Oceanography, University of California, San Diego, CA, USA
3 Monterey Bay Aquarium, Monterey, CA, USA. E-mail: kvanhoutan@mbayaq.org
4 Arizona State University, Tempe, AZ, USA
5 Nicholas School of the Environment, Duke University, Durham, NC, USA

Plastic waste has been documented in nearly all types of marine environments and has been found in species spanning all levels of marine food webs. Within these marine environments, deep pelagic waters encompass the largest ecosystems on Earth. We lack a comprehensive understanding of the concentrations, cycling, and fate of plastic waste in sub-surface waters, constraining our ability to implement effective, large-scale policy and conservation strategies. We used remotely operated vehicles and engineered purpose-built samplers to collect and examine the distribution of microplastics in the Monterey Bay pelagic ecosystem at water column depths ranging from 5 to 1000 m. Laser Raman spectroscopy was used to identify microplastic particles collected from throughout the deep pelagic water column, with the highest concentrations present at depths between 200 and 600 m. Examination of two abundant particle feeders in this ecosystem, pelagic red crabs (*Pleuroncodes planipes*) and giant larvaceans (*Bathochordaeus stygius*), showed that microplastic particles readily flow from the environment into coupled water column and seafloor food webs. Our findings suggest that one of the largest and currently underappreciated reservoirs of marine microplastics may be contained within the water column and animal communities of the deep sea.

(S7-13982)

Microplastics in pelagic food webs: Initial insights from a study on microplastic contamination in the Beaufort Sea beluga whales and its prey

Rhiannon **Moore**[1,2], Peter Ross[2], Leah Bendell[1], and Lisa Loseto[3]

1 Simon Fraser University, Vancouver, BC, Canada. E-mail: rhiannon.moore@ocean.org
2 Ocean Wise Conservation Association, Vancouver, BC, Canada
3 Department of Fisheries and Oceans, Winnipeg, MB, Canada

Frequent reports of microplastic pollution (plastic particles of < 5mm) in the environment have attracted widespread public and scientific interest. While data on microplastics in the digestive systems of marine species continue to mount, their movement through the food web and availability to upper trophic levels is poorly understood. This study measured microplastics (in the size range of 50 µm – 5 mm) in beluga whales (*Delphinapterus leucas*, *n*= 7) from the Beaufort Sea, and in digestive tracts of beluga prey including arctic cod (*Arctogadus glacialis*, n=20), arctic cisco (*Coregonus autumnalis,* n=20), saffron cod (*Eleginus gracilis*, n=20) and capelin (*Mallotus villosus,* n=15). Contents from the entire digestive tracts of the whales and prey were chemically digested (10% KOH for 2 weeks) and all suspect microplastics were analyzed in terms of their size, type and polymer identity using light microscopy coupled to Fourier-transform infrared spectrometry (FTIR) analysis. Our preliminary results show that beluga whales are vulnerable to microplastic contamination, despite inhabiting waters far removed from anthropogenic activities/populated areas. Our study provides both a baseline assessment of microplastic contamination within the beluga food web and contributes to a currently narrow understanding of plastic pollution in toothed cetaceans.

(S7-14068)

Sea Turtles as indicators of plastic marine debris quantities and types in the Central Pacific

Jennifer M. **Lynch**[1,2], Melissa R. Jung[2], George H. Balazs[3], Thierry M. Work[4], Shandell Brunson[5], Alexander Gaos[5], and T. Todd Jones[5]

1 National Institute of Standards and Technology, Chemical Sciences Division, Waimanalo, HI, USA
E-mail: Jennifer.Lynch@nist.gov
2 Hawai'i Pacific University, Center for Marine Debris Research, Waimanalo, HI, USA
3 Golden Honu Services of Oceania, Honolulu, HI, USA
4 U.S. Geological Survey, National Wildlife Health Center, Honolulu Field Station, Honolulu, HI, USA
5 NOAA Pacific Islands Fisheries Science Center, Honolulu, HI, USA

Sea turtles are excellent bioindicators of plastic marine debris because they inhabit all tropical and subtropical oceans, are charismatic with conservation concerns, have a propensity to ingest plastic debris, and have long guts with slow gut transit times. A recent global meta-analysis reviewed 131 studies on plastic ingestion in sea turtles. After standardizing published data, the critically endangered hawksbill sea turtle was found to ingest more than other sea turtle species. Furthermore, turtles sampled in the Central and Northwest Pacific ingested the most. Only 82 hawksbill turtles globally, and just two from the Central Pacific, have been examined for plastic ingestion. Monitoring efforts for species and regions are disproportionate to the problem's extent. We examined gastrointestinal tracts of 15 hawksbills from the Central Pacific. Color, type, size, and mass were recorded for each plastic piece. White and fragments were the most common. Debris sizes ranged from 1X1X0.5 mm to 14X0.5X0.1 cm. 66.7% of the turtles ingested plastic (means including non-detects: 9.13 pieces/turtle, 0.256 g/turtle, 1.76 g/kg). The updated average plastic ingestion in Central Pacific hawksbills, 2.58 g/kg, remains the highest globally, exceeding green turtles from Northwest Pacific (1.9 g/kg) and post-hatchlings from Florida (2.07 g/kg). Younger, more pelagic, turtles ingested more than larger turtles (means: 3.64 g/kg for 4-9 cm straight carapace length turtles; 2.96 g/kg for 28-41 cm; 0.010 g/kg for 46-71 cm), so monitoring and mitigation should focus on earlier life stages, particularly post-hatchlings, of this critically endangered species in hotspot regions, like the Central Pacific.

(S7-14374)

BIOPs: Towards seabird bioindicators of North Pacific plastic pollution

K. David **Hyrenbach**[1], Lauren Chamberlain[1], Michelle Hester[2], Paula Hartzell[3], Meg Duhr[3], Jenn Lynch[4]

1 Marine Science Program, Hawai'i Pacific University, Waimanalo, HI, USA, khyrenbach@hpu.edu
2 Oikonos Ecosystem Knowledge, Kailua, HI, USA
3 U.S. Fish and Wildlife Service, Honolulu, HI, USA
4 National Institute of Standards and Technology, Waimanalo, HI, USA

The BIOPs network studies plastic ingestion by North Pacific seabirds following three approaches: (1) assessing community-wide patterns; (2) developing local pollution metrics using species with restricted foraging distributions; and (3) comparing regional pollution using far-ranging species. In the Northwestern Hawaiian Islands, we necropsied 350 specimens of 16 species from French Frigate Shoals, and documented plastic ingestion in 11 species (69%), belonging to 7 families and representing 5 feeding guilds: albatrosses, tuna-birds, nocturnal petrels, plunge divers, and frigatebirds. Plastic ingestion varied within species, with chicks having significantly higher incidence and mass than adults. More recently, we focused on identifying potential regional bioindicators: Bonin Petrels from Midway, and Laysan / Black-footed Albatrosses from Kure Atoll. In particular, we contend that Bonin Petrels are ideal bioindicators for the central North Pacific due to: (i) their winter-time breeding, (ii) high plastic ingestion, and (iii) availability of naturally-deceased birds at colonies. An analysis of hatch-year (97.5% occurrence, n=40) and after-hatch-year (95.0% occurrence, n=40) birds revealed no significant differences in plastic incidence or loads between these two age classes. Overall, fragments were the most abundant plastic type by mass (HY:51%, AHY:58%), followed by line (HY:27%, AHY:23%), sheet (HY:22%, AHY:4%) and foam, which only occurred in AHY birds (15%). Bonin petrels ingested buoyant plastic, with low-density polyethylene accounting for most mass (42%), followed by polypropylene (14%), high-density polyethylene (14%), polypropylene/polyethylene (12%), polyethylene (11%), polystyrene (5%), and unknown (2%). These results underscore the value of seabirds as bioindicators and provide insights into the composition of floating plastic debris.

(S7-14141)

The feeding preference for the color of plastic debris in the hawksbill turtle, *Eretmochelys imbricate*

Taewon **Kim**[1], Seonmyeong Choo[1], Jibin Im[1], and Sujin Jang[2]

1 Department of Ocean Sciences, Inha University, Incheon, R Korea. E-mail: ktwon@inha.ac.kr
2 Ewha Womans University, 52 Ewha-ro, Seodaemun gu, Seoul, R Korea

Plastic debris which accounts for the largest percentage of marine Debris, can cause damage to marine animals and finally lead them to death. Sea turtles are frequently reported to eat plastic bags floating in the sea by mistaking them as food. To test what color of plastic debris are preferred by sea turtles, we presented Hawksbill turtles (*Eretmochelys imbricata*) in the aquarium with combinations of 2 randomly selected colored floating plastics from 4 different colors of (Yellow, Black, White, Transparent) plastics. They preferred the yellow colored plastics to the other ones and reaction speed was the highest for the yellow plastics. We suggest that the hawksbill sea turtles are more likely to eat the yellow colored plastics than the transparent or white ones because they are easy to recognize. Therefore, it is highly recommended to refrain from using yellow colored plastics in order to protect the Hawksbill turtles.

(S7-14063)

Quantities and characteristics of plastic debris ingested by sea turtles in the Korean coastal waters

Yelim Moon[1,2], Sang Hee **Hong**[1,2], Gi Myung Han[1], Won Joon Shim[1,2], Youna Cho[1,2], Mi Jang[1,2], Il-Hun Kim[3] and Min-Seop Kim[3]

1 Oil and POPs Research Group, Korea Institute of Ocean Science and Technology, Geoje, R Korea. E-mail: shhong@kiost.ac.kr
2 Department of Marine Environmental Sciences, University of Science and Technology, Daejeon, R Korea
3 National Marine Biodiversity Institute of Korea, Seochun-gun, R Korea

Plastic debris is now ubiquitous in the marine environment affecting an extensive variety of taxa. As six out of seven species are listed from vulnerable to critically endangered on the International Union on the Conversation of Nature Red List, assessing the impact of marine plastic debris on sea turtle is a worldwide research priority. All seven species of sea turtles were reported to have ingested plastic debris. This study investigated the amount, shape, color, and polymer type of ingested plastics in the gastrointestinal tracts of 20 turtles: 15 loggerhead turtles, 4 green turtles, and 1 olive ridley turtles. The turtles were stranded or captured by fishing gears from 2017 to 2018 in the Korean coastal waters where the quantities of marine debris ingestion by sea turtle have never been reported. All loggerheads, greens, and olive ridleys had ingested plastics. In all species, fiber and film were dominant shapes. Regarding color, white and transparent plastics accounted for the majority of the debris. PE and PP comprised a large portion of polymer types, of which density are low enough to float on the sea surface. Green turtles ingested more debris (0.14±0.07 g/kg, 31.0±16.9 pieces/turtle), however not significantly due to a lack of turtle numbers, than loggerheads (0.09±0.18 g/kg, 25.9±55.5 pieces/turtle) or olive ridleys (0.002 g/kg, 1.00 pieces/turtle). This study demonstrates that sea turtles distributed near South Korea are seriously affected by marine plastic debris, recommending further studies on evaluating the exposure levels and impacts of plastic debris on marine turtles in this region.

(S7-14313)

Microplastic ingestion by seabirds in South Korea

Miran **Kim**[1], Mijin Hong[2], Hee Young Kim[1], Sang-moon Cho[3], Ki-Baek Nam[2], Ha-na Yoo[2], A-hyeon Lim[1] and Youngsoo Kwon[1]

1 Korea National Park Research Institute, Wonju, Gangwon, R Korea. E-mail: mirankim318@gmail.com
2 Kyung Hee University, Seoul, R Korea
3 Sahmyook University, Seoul, R Korea

Plastic pollution on seabirds has been reported in the North Pacific Ocean. It is unknown how many seabirds ingested microplastics in South Korea. This study was conducted to investigate microplastic contamination level on seabirds of South Korea. We collected total 192 corpses of 11 seabird species in 21 places in 2009, 2016, 2018 and 2019. Dead seabirds were dissected to collect stomach contents and the contents had been analyzed by a fourier transforms infrared (FTIR) spectrometer. As results, 5.2% of 192 corpses had microplastics (1 to 11 plastics per individual). Swinhoe's storm-petrels (*Oceanodroma monohis*) (1 out of 3), Red-breasted merganser (*Mergus serrator*) (1 out of 6), Pacific divers (*Gavia pacifica*) (2 out of 16) and Black-tailed gulls (*Larus crassirostris*) (4 out of 38), Ancient murrelets (*Synthliboramphus antiques*) (1 out of 112) were contaminated by microplastics. While we did not find microplastics in Great grebes (*Podiceps cristatus*), Streaked shearwaters (*Calonectris leucomelas*), Red-throated loons (*Gavia stellata*), Black-throated loons (*G. arctica*), Pacific loons (*G. pacifica*) and Herring gulls (*L. argentatus*). The microplastics were mainly composed by polyethylene (40.0%) followed by mixture of polypropylene and poly (ethylene: propylene) (25.7%), polypropylene (2.9%) and poly (ethylene: propylene) (2.9%). Fragment types were most frequently found (63.6%) than filament (31.8%) and pallet (4.5%) types. This is the first assessment of microplastic contamination on seabirds in South Korea. For the future, identifying the foraging area and diet of seabirds will be useful to understand the ingestion pathway of microplastics in this region.

(S7-14205)

Ingestion of plastics by seabirds and its potential effects

Yutaka **Watanuki**[1], Naya Sena[1], Kosuke Tanaka[2], Rei Yamashita[3], Mami Kazama[1], Ken Yoda[4], and Hideshige Takada[3]

1 Hokkaido University, Faculty of Fisheries Sciences, Japan. E-mail: email:ywata@fish.hokudai.ac.jp
2 Hokkaido University, Faculty of Veterinary Sciencesv
3 Tokyo University of Agriculture and Technology, Agricultural Research Institute, Japan
4 Nagoya University, Graduate School of Environmental Studies, Japan

The occasion of ingestion of plastics by marine birds is increasing since 1960's so its biological influence has been a concern. Plastics in their digestive tract, mainly in the gizzard, may block the tract or injure epidermis, occupy the space of digestive tract and hence deteriorate digestive ability, and work as vectors of pollutants (POPs) from the environment to the bird tissue. To better understand the consequences of plastic ingestion on the growth of their chicks, we carried out does-response experiment in streaked shearwaters (*Calonectris leucomelas*) under natural condition. 0.4g plastic pellets (c 5mm size) were fed to 11 chicks at 37-day-age (around 500g body mass). Pellets remained in the gizzard. Parents of this experimental and control group (10 chicks) raised chicks normally. No significant effects on the growth (mass and size) were detected. We review the previous works exploring the effects of ingested plastics on the digestive ability and body condition, including the observations of wild birds and the experiment of caged birds. Excluding studies basing on carcasses presumably dead from starvation, the effects of plastics were detected in samples where mass of plastics in the stomach was greater than 0.25% of body mass. Although our experiment dosing small amount of plastics (0.08% of body mass) did not show apparent effects, further experimental study has to be done as the amount of marine plastic is increasing to be a critical level deteriorating the digestive ability of marine birds.

(S7-14459)

AMAP's Microplastics and Marine Litter Expert Group

Peter **Murphy**

7600 Sand Point Way NE, WA, U.S.A. E-mail: peter.murphy@noaa.gov

Concern about microplastics and litter in the environment has been raised at global (CBD, UNEP, etc.) and regional (Arctic Council Ministerial, EU, OSPAR, Nordic Council) level. The Arctic Council Working Group *Protection of the Arctic Marine Environment* (PAME) conducted a desktop study on marine litter in the Arctic region. The report recommends developing a regional action plan on marine litter in the Arctic which will be planned and implemented in the coming years. Developing a monitoring program as part of, or parallel to, the development of a regional action plan is of great importance in gaining knowledge and information. Despite the significant increase in available data on microplastic pollution and litter debris globally, including in the Arctic, status reports lack standardization in methodology and reporting consistency. How the extreme environmental conditions of the Arctic might affect plastic transport and degradation processes is not yet known. Importantly, emerging knowledge from lower latitudes may not be transferable to the Arctic environment, so studies specific to Arctic conditions are needed. The purpose of the AMAP Microplastics and Marine Litter Expert Group is to review existing knowledge and give advice on what an Arctic monitoring programme needs to cover and to design this. This includes understanding how global programmes may or may not be applicable in the Arctic environment. Since plastic pollution is also very much a local problem in Arctic communities, monitoring guidelines and references will include community-based monitoring projects, to enable communities to do their own plastics monitoring and allow for the results to be comparable across the Arctic. This Expert Group was formed in 2019 and the work will be carried out over the next 2 years.

SESSION 8
Creating more effective Integrated Ecosystem Assessments (IEAs) in PICES countries

(S8-14414) INVITED

Connecting Science and Communities through Integrated Ecosystem Assessments

Phillip S. **Levin**

University of Washington, Seattle, WA, USA. E-mail: pslevin@uw.edu

Integrated Ecosystem Assessments (IEAs) provide a structured approach to ecosystem evaluation that serves as an integrative complement to single-species and single-sector assessments. Here, I critically examine the 10-year history of IEAs. I highlight ways in which IEAs are useful in informing ocean management over a range of spatial scales. I emphasize the need to engage local communities to co-create scientific products that can be implemented. Critically, IEAs consider sectoral trade-offs that may emerge or be amplified as a consequence of climate change and thus force interdisciplinary and cross-sectoral thinking. Consequently, IEAs require that e broaden participation in marine resource management, including expertise often ignored in more conventional analyses. The challenge for IEAs to inform the multitude of ocean uses against a backdrop global change is great; however, sustainable resource management requires that we bring science to the fore to confront this challenge.

(S8-14105)

A brief history of the California Current Integrated Ecosystem Assessment: How we got here, what we've learned, and where we're headed

Chris **Harvey**[1] and Toby Garfield[2]

[1] NOAA Fisheries, Northwest Fisheries Science Center, Seattle, WA, USA. E-mail: chris.harvey@noaa.gov
[2] NOAA Fisheries, Southwest Fisheries Science Center, La Jolla, CA, USA

The NOAA California Current Integrated Ecosystem Assessment (CCIEA) effort originated in 2010, with the goal of using the NOAA IEA framework to support management and conservation of marine resources and ecosystem services in the California Current ecosystem. Early efforts focused on developing science tools (robust ecosystem indicators; models and analytical methods; data visualizations) and building relationships with management and stakeholder partners, especially the Pacific Fishery Management Council. Focused research efforts, strong collaboration and supportive leadership enabled great progress in tool development, but actual application of these tools to address societal needs was hindered by several factors, notably the lack of clear ecosystem-oriented management objectives or legislative mandates, and also a loss of funding for continued development of social science tools and research capacity. However, implementation of CCIEA tools subsequently accelerated due to two major factors: (1) the North Pacific marine heatwave of 2013-2016, which greatly increased managers' and stakeholders' appreciation of linkages between valuable resources and ecosystem drivers; and (2) CCIEA efforts to establish partnerships with other entities, such as individual states and the National Marine Sanctuaries network. We will review this history and also describe lessons we have learned and how we plan to apply them so that uptake and implementation of CCIEA products is both efficient and effective. These lessons relate to early and purposeful engagement with management partners and stakeholders; building and leveraging research collaborations across multiple disciplines; and adapting the IEA framework to spatial and temporal scales that are consistent with specific management needs.

(S8-14347)

Potential vulnerability of the Arctic marine ecosystem due to environmental changes

Takafumi **Hirata**[1], Yoshio Masuda[1], Jorge García Molinos[1], Irene Alabia[1], Toru Hirawake[1,2], and Sei-Ichi Saitoh[1]

[1] Arctic Research Center, Hokkaido University, Sapporo, Japan. E-mail: tahi@arc.hokudai.ac.jp
[2] Faculty of Fisheries Sciences, Hokkaido University, Hakodate, Japan

While recent changes in the Arctic marine environment, as represented by the drastic decrease of sea ice, may increase socio-economic opportunities, such as natural resource exploitation and the consolidation of northern-route shipping, they may also cause a degradation of the present marine ecosystems and their ecological services; directly or indirectly. Therefore, assessment of the potential impacts of these environmental changes on marine ecosystem is desired for both deliberate socio-economic development and conservation of the Arctic oceans. Using Planetary Boundaries as thresholds for proposed processes regulating the stability and resilience of the Earth system, and assuming that larger environmental change increase the potential impacts, we have developed the Potential Vulnerability Index (PVI) of the Arctic marine ecosystems. The PVI is based on statistical analysis that identifies geographical regions where (1) the large variance of the selected Planetary Boundaries components is found (larger exposure to environmental forcing), (2) a response of marine ecosystems to the environmental forcing is larger (larger sensitivity), and (3) an adaptive capacity of the ecosystems is smaller (smaller resiliency). Our results highlight regions in the Arctic oceans where the potential vulnerability is large and may require further attention. Our work is expected to contribute to ecosystem management and conservation including the establishment of marine protected areas for example.

(S8-14098)

The Bering Sea fishery ecosystem plan as a guidance tool for ecosystem-based fishery management in Alaska

Kerim **Aydin**[1] (by Kirstin Holsman) and Diana Evans[2]

[1] NOAA Alaska Fisheries Science Center, Seattle WA USA. E-mail: kerim.aydin@noaa.gov
[2] North Pacific Fishery Management Council, Anchorage, AK, USA

In December 2018, the North Pacific Fishery Management Council (NPFMC) adopted a Fishery Ecosystem Plan (FEP) for the eastern Bering Sea, home to some of the world's largest fisheries. This was the result of a four-year scoping and development process that included repeated, regular engagement between scientists, NPFMC members, fishers, NGOs, local and native communities, and other stakeholders. The resulting FEP is a "living" document that outlines and structures the methods through which other components of the IEA process – in particular Ecosystem Status Reports and climate-focuses Management Strategy Analyses – will continue to inform the NPFMC's ecosystem approaches to fishery management in the region. Further, the Bering Sea FEP includes an emphasis on bring local knowledge (LK) and traditional knowledge (TK) into the fishery management process. Here, we discuss the FEP and its role as a guiding structure for Bering Sea IEA activities, along with lessons learned along the way for implementing FEPs in a management setting.

(S8-13952)

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

Third Institute of Oceanography, Ministry of Natural Resources, PR China. E-mail: xuchangan@tio.org.cn

Net cage fish culture in Sandu bay Fujian China has developed rapidly, but with the increasing scale and density of net cage farming, there are many problems occurring subsequently, including frequent occurrence of diseases, increased mortality, decreased production, reduced production efficiency and so on. Based on the investigation of the current situation of net cage culture here in Sandu bay and the analysis of relevant data, a series of measures are put forward by applying the concept of ecosystem management in order to make the net cage fish farming industry here enter the track of sustainable development.

(S8-13979)

Evaluating management strategies for ecosystem services in a Hawaiian Islands coral reef IEA

Mariska **Weijerman**[1], Jeffrey Polovina[1], Jamison Gove[1], Ivor Williams[1], William Walsh[2] and Dwayne Minton[3]

1 Pacific Islands Fisheries Science Center, NOAA, Honolulu, HI, USA. E-mail: mariska.weijerman@noaa.gov
2 Division of Aquatic Resources, Dept. of Land and Natural Resources, Kailua-Kona, HI, USA
3 The Nature Conservancy, Honolulu, HI, USA

Pacific tropical oceans are home to vibrant corals, fish, green sea turtles, spinner dolphins, whales, and manta rays. This wide array of ocean life makes it incredibly important for marine biodiversity and human society. The coastal ocean and coral reefs provide seafood, resources for tourism and recreation, protection from wave and storm impacts, and the preservation of cultural practices. But this ecosystem is also particularly vulnerable to the pressures of an increasing population, coastal development, fishing, pollution, and climate change. Using an ecosystem model we integrated the detrimental effects of ocean warming and land-based sources of pollution on corals, fisheries, and the food web and we linked the biological components to ecosystem services we rely on. We simulated a range of management options to protect and restore this valuable marine ecosystem for the future and evaluated how six alternative management strategies would benefit (1) ecosystem structure and resilience, (2) dive tourism and (3) nearshore fisheries. Since these ecosystem services inherently have conflicting goals finding the “best” management strategy depends on the desired balance between enhancing ecological benefits (i.e., improved ecosystem structure and resilience) and improving socio-economic benefits to fishermen and dive tourists. Allowing only line fishing generated the most balanced trade-off between stakeholders, with positive gains in both ecosystem resilience and dive tourism, while only moderately decreasing fishery value within the area.

(S8-14125)

A Bayesian decision network model for ecosystem-based management of the Georges Bank social-ecological system

Robert P. **Wildermuth**[1,2], Gavin Fay[1], Sarah Gaichas[3] and Geret DePiper[3]

1 Department of Fisheries Oceanography, School for Marine Science and Technology, University of Massachusetts Dartmouth, New Bedford, MA, USA. E-mail: rwildermuth@umassd.edu
2 NOAA National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA, USA

Integrated ecosystem assessment requires decision tools that can use multiple datasets, account for uncertainties, and assess tradeoffs among ecological, social, and economic objectives. Several environmental stressors and human activities affect fisheries on Georges Bank, USA. Tradeoffs among multiple ocean uses and the multitude of benefits provided to the Georges Bank socio-ecological system are difficult to assess with extant quantitative models due to imbalanced data availability across system components. We developed a Bayesian network model for the Georges Bank social-ecological system that integrates monitoring data and expert knowledge to estimate direct and indirect effects of multiple human uses of living natural resources for a set of management objectives. We used maximum likelihood methods and a survey of social science experts to fit our model to a 58-year time series for Georges Bank and evaluated the model’s predictive ability. With three alternate network structures, we assessed the influence of structural uncertainty on the perceived ability to meet 12 management objectives. Altogether, the consensus model correctly predicted component states greater than 70% of the time, though it poorly anticipated component state transitions. Our evaluation revealed potential leading indicators for habitats and managed functional groups, as well as unexpected outcomes for seafloor and demersal habitat. Alternate fishery structures influenced perceived tradeoffs among outcomes. We demonstrate 1) how to integrate expert knowledge in the development and evaluation of Bayesian network models, and 2) how these methods can provide strategic management advice for complex marine social-ecological systems, even when few data exist for key components.

(S8-13983)

Cloud computing of key NASA oceanographic data: Implications for automating aspects of ecosystem status reports

Marisol **García-Reyes**[1], Chelle Gentemann[2], Jeffrey Dorman[1], and William Sydeman[1]

1 Farallon Institute, Petaluma, CA, USA. E-mail: marisolgr@faralloninstitute.org
2 Earth and Space Research, Seattle, WA, USA

Comparative analyses of essential environmental data are key to describe variability within and between North Pacific LMEs and form a basic component of IEAs. Processing multi-ecosystem data in a similar manner will make comparisons easier, timelier and more robust, but is challenging. Satellite-based data is now of sufficient duration to construct meaningful time series amenable to analyses of interannual variability. However, acquiring, processing and constructing time series for multiple LME or mesoscale regions with at least monthly or seasonal resolution is complicated, time consuming and requires proficiency in programming that is not in the toolbox of all PICES members. These issues limit the availability and accessibility of these key data for comparative ecosystem analyses. As part of NASA's plan to make their data available on the cloud and make analysis of data reproducible and sharable, we developed an online tool based on Python and Jupyter notebooks that allows one to generate spatially-explicit time series of available online SST, winds, SSH, and currents data, for all of the PICES regions. These notebooks run fully online, but can be downloaded and run in personal computers if need be, and it can be modified to customize data or zones but also to further develop said scripts. Here, we present this project and scripts as an option of easily acquiring and comparing similar key satellite oceanographic data for the PICES domain. We show how this approach could be used to enhance the timeliness and utility of the PICES NPESR documents.

(S8-14185)

Developing a placed-based participatory IEA framework for coastal communities in the Gulf of Alaska

Judith Rosellon-Druker[1], Kerim Y. Aydin[2], Curry J. Cunningham[1], Stephen Kasperski[2], Gordon H. **Kruse**[1], Jamal H. Moss[3], Melissa Rhodes-Reese[3], Ellen Spooner[4], Marysia Szymkowiak[3] and Ellen M. Yasumiishi[3]

1 College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, USA
E-mail: jrosellondruker@alaska.edu
2 Alaska Fisheries Science Center, NMFS, NOAA, Seattle, WA, USA
3 Alaska Fisheries Science Center, NMFS, NOAA, Juneau, AK, USA
4 NOAA Fisheries, Silver Spring, MD, USA

Integrated Ecosystem Assessment (IEA) is a framework that organizes science to aid in the transition from traditional single species management towards ecosystem-based management. The US NOAA IEA National Program currently has five active regional plans, including the Gulf of Alaska. Within this large marine ecosystem, we identified coastal fishing communities based on geographic location and relevance for Alaska's federally managed fisheries, to allow us to develop localized, smaller-scale IEA frameworks with active engagement of local stakeholders. We completed the first stage of the IEA loop for Sitka, a Southeast Alaska community, which included the following steps: (1) project scoping (definition of a spatiotemporal scale and focal species), (2) identification of local ecosystem components and threats, and (3) development of socio-ecological conceptual models. These conceptual models were co-produced between scientists and local stakeholders using data gathered from two participatory workshops and an extensive literature review of ecosystem attributes driving the abundance of four focal species: Pacific halibut (*Hippoglossus stenolepis*), Pacific herring (*Clupea pallasii*), Chinook salmon (*Oncorhynchus tshawytscha*), and sablefish (*Anoplopoma fimbria*). We also operationalized these models using qualitative network models, which are mathematical representations of conceptual models in which perturbations of individual variables can be assessed for their qualitative impact on the entire system. A series of simulations were conducted to test different environmental scenarios while evaluating tradeoffs across human well-being components. Several potential sustainable local management strategies have resulted from this integrated approach involving transdisciplinary knowledge, a participatory stakeholder process, and modeling.

(S8-14240)

Human activities - Developing indicators that can translate costs and benefits across the human dimension and ecological domains of the socio-ecological system

Kelly **Andrews**, Karma Norman and Chris Harvey

Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, USA. E-mail: kelly.andrews@noaa.gov

The conceptual model of NOAA's Integrated Ecosystem Assessment (IEA) for the California Current consists of three primary domains. The ecological and human dimensions domains are on either side of the conceptual model with human activities centered in the middle. The ecological and human dimensions domains describe the status, trends and interactions of important physical, biological and socio-economic components of the system (e.g. stock abundance, sea surface temperature, fisheries revenue and vulnerability of coastal communities). However, changes in these individual components or interactions among components are often affected by human activities, which thus serve as the primary management levers that can be altered to affect change in the ecological and human dimension components that we care about. Many IEAs around the globe monitor and report the status and trends of human activity indicators, but these indicators are not necessarily capable of translating how changes in these activities will affect ecological and human dimensions components simultaneously – one of the primary goals of IEAs. Additionally, most human activity indicators are related to pressures on the ecological domain, while the integration of 'positive' indicators (e.g. restoration efforts, citizen science participation) have not been incorporated into the IEA framework. Here, we describe 1) the importance of developing a suite of indicators across all three domains that allows for meaningful translation of costs and benefits to ecological and human dimensions components when changes in human activities occur; and 2) the importance of creating interdisciplinary teams of researchers to develop a fully-complementary set of indicators.

SESSION 9
Coastal Ocean Observing Systems, Essential Biological Variables, and community-based monitoring

(S9-14118) INVITED

The Hakai Institute: Supporting community-based science in British Columbia with global frameworks for biological Essential Ocean Variables (EOVs)

Eric **Peterson**[1], Ray Brunsting[1], Luba Reshitnyk[1], Rebecca Martone[2,3], Markus Thompson[2] and Margot Hessing-Lewis[1]

[1] Hakai Institute, Quadra Island, BC, Canada. E-mail: eric@tula.org
[2] Marine Planning Partnership for the North Coast (MaPP)
[3] Ministry of Forest, Lands, Natural Resource Operations and Rural Development (FLNRO)

A clear imperative has been identified for standardized biological and ecological Essential Ocean Variables (EOVs) to inform societal needs and governance at local, regional and global scales. The consensus EOVs include many declining, yet critical, foundation species, such as seagrass, mangroves, and coral reefs. Supported by international ocean observing initiatives (i.e., GOOS, MBON), research communities are building consensus for EOV sub-variables. Concurrently, to advance adoption of biological EOVs at the local and regional level within the Canadian Integrated Ocean Observing System (CIOOS), the Hakai Institute is supporting data producers by linking international standards with community-based coastal science in British Columbia. We illustrate EOV science and technology transfer through the case study of seagrass and kelp monitoring conducted by Indigenous coastal communities and the Provincial Government (MaPP; the Marine Planning Partnership for the North Pacific Coast). Here, Hakai is developing the remote sensing tools (drones, planes and satellites) to map habitats at multiple scales across the BC Coast. These tools provide information on critical EOVs for seagrass and kelp that can be ground-truthed and refined by local communities. In partnership with MaPP, Hakai also builds capacity for local seagrass/kelp monitoring, by facilitating information exchange on EOVs standards and methodologies (i.e. drone mapping). The seagrass/kelp example shows that biological EOVs are primed for adoption across a range of scales, from local to global, and provide a framework for prioritized data collection and standardized data management necessary to address human impacts on coastal ecosystems.

(S9-14225) INVITED

Essential ocean variables for biology and ecosystem to inform policy in the decade of ocean science for sustainable development

Sanae **Chiba**[1] Patricia Miloslavich[23], Nic Bax[4], Daniel Dunn[5], and members of the GOOS Biology and Ecosystems Panel

[1] Japan Agency for Marine-Earth Science and Technology (JAMSTEC) Yokosuka, Japan. E-mail: chibas@jamstec.go.jp
[2] Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia
[3] Departamento de Estudios Ambientales, Universidad Simón Bolívar, Caracas, Venezuela
[4] Commonwealth Scientific and Industrial Research Organisation, Hobart, Australia
[5] Duke University Marine Laboratory, Beaufort, NC, USA

There is a gathering momentum to integrate ocean observing systems at basin and global scales to help understand how marine ecosystems are responding to increasingly rapid environmental changes. Establishing an integrated coastal observing system is yet challenged because local, regional and national projects are conducted for very specific purposes, from fisheries and biodiversity conservation to environmental assessment. International initiatives are needed to develop networks and coordinate these projects so that they can collect observations in ways that they can be shared and aggregated making the data interoperable. The Global Ocean Observing System Biology and Ecosystem Panel (GOOS-BEP) has developed Essential Ocean Variable (EOVs) based on societal demand, and practical readiness of the observation to assist the community in coming together to develop common and/or comparable approaches of observation and data management. This talk will overview how the GOOS-BEP has developed its EOVs and established its partnership with the Marine Biodiversity Observation Network (MBON) of the Group of Earth Observation (GEO) to implement EOVs. Harmonizing the collection and reporting of coastal observations will increase scientists' capacity to deliver the goals of the Post 2020 Global Biodiversity Framework and the Decade of Ocean Science for Sustainable Development, e.g. by developing the official indicators for a healthy and resilient ocean. Through the discussion, we would like to review how the ocean science community could use the EOVs to inform national and international policy, and identify the opportunities and challenges for the coastal observing systems in the PICES countries in implementing the GOOS-BEP EOVs.

(S9-14203)

Developing a biological Global Ocean Observing System: Qualities, attributes, and readiness of existing biological Essential Ocean Variable networks

Erin **Satterthwaite**[1], Patricia Miloslavich[2], Nic Bax[3], Daniel Dunn[4], and members of the GOOS Biology and Ecosystems Panel and PEGASuS project

1 National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara, CA, USA
E-mail: satterthwaite@nceas.ucsb.edu
2 Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia and Departamento de Estudios Ambientales, Universidad Simón Bolívar, Caracas, Venezuela
3 Commonwealth Scientific and Industrial Research Organisation, Hobart, Australia
4 Duke University Marine Laboratory, Beaufort, NC, USA

A globally coordinated and sustained ocean observing system is needed to systematically assess and manage global marine ecosystems. Biological essential ocean variables (EOVs) are designed to address scientifically and societally relevant questions and inform policy and management decisions. More reliable and consistent monitoring of the effects of climate change and human-use on marine ecosystems will increase the ability of the global community to effectively predict, manage and sometimes mitigate impacts on our global ocean. A first step is to identify current observing networks meeting the desired qualities and common attributes of a Global Ocean Observing System. We use the criteria established by the Observations Coordination Group (OCG) and identify the level of maturity according to the Framework for Ocean Observing (FOO) for the major biological EOV "networks". Criteria include: appropriate spatial scale, temporally sustained, globally coordinated, clear mission and targets, agreed-upon best practices, data standards, technological readiness, and other desired attributes identified by experts across the scientific and observing community. The biological EOV networks are heterogenous in their level of maturity in terms of capacity, implemented technologies, and data availability, especially across geographic regions. Differences in readiness of biological EOV networks may be related to inequalities in the requirement levels (e.g. technological, spatial and temporal scales, long term stability), in the coordination of the observations (e.g. data-collection networks and communities of practitioners, characteristics of the taxa, sampling techniques, calibration) and in the data management and information products (e.g. QA/QC processes, data availability, interoperability). This indicates that there are cultural as well as technological steps to be taken in developing a Global Ocean Observing System for biology and ecosystems. We invite conference participants who are affiliated with a biological monitoring network to verify that their network is included in the Biological Global Ocean Observing Network.

(S9-14034)

Incorporating multiple community perspectives in development of essential ocean variables for monitoring port ecosystems

Paul A. **Covert**[1], James P. Mortimor[2], Spencer **Taft**[3], John Konovsky[3], Natasha Salter[1] and Janet Mossman[2]

1 Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada. E-mail: Paul.Covert2@dfo-mpo.gc.ca
2 Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, Canada
3 Treaty, Lands and Resources, Tsleil-Waututh Nation, North Vancouver, BC, Canada

Given the reliance of much of the global population upon marine ecosystems, a fundamental understanding of these ecosystems, their health, and how they are changing with time is certainly a societal concern. It has been proposed that a key component of understanding long-term ecosystem changes is the establishment of monitoring programs that record a suite of "essential ocean variables" (EOVs) that reflects both biological and societal importance; the process of determining these EOVs has been described in a couple of recent publications. During the development of the scientific scope of the Coastal Environmental Baseline Program (an initiative within Canada's Oceans Protection Plan) we have had the opportunity to compare, contrast and integrate the results of two independent efforts to establish EOVs; one by Fisheries and Oceans Canada scientists and one by Tsleil-Waututh First Nation scientists. In comparing the results of the two processes, we found that there is considerable overlap between the two sets of EOVs. However, differences between the two sets manifest themselves in a way that clearly reflects differences in community perspective. In this presentation we describe the two different processes by which the EOVs were chosen and the ecological and community values that each set reflects. As a result of this analysis, we argue that any effort to establish a long-term monitoring program with a broad ecological and societal context must include community perspectives beyond that of government and academia.

(S9-14210)

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**[1], Brian P.V. Hunt[1,2,3], Stephanie Waterman[2] and Jennifer M. Jackson[3]

1 Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada, V6T 1Z4
Email: a.margolin@oceans.ubc.ca
2 Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, Canada, V6T 1Z4
3 Hakai Institute, PO Box 309, Heriot Bay, BC, Canada, V0P 1H0

Biogeochemical data from various organizations (e.g., Fisheries and Oceans Canada, Hakai Institute, National Oceanographic and Atmospheric Administration) are compiled, including temperature and salinity, and dissolved oxygen, nutrient and chlorophyll concentrations where available. Data are utilized to characterize regions of British Columbia's coastal waters, considering short-term variability and long-term trends, as well as the 'riverine coastal domain' (RCD). The RCD supports diverse marine ecosystems that have high economic, environmental and social value (e.g., salmon and shellfish fisheries), which are vulnerable to climate change. Sustaining such biodiversity depends on the predictability of the water's biogeochemical properties, such as nutrients at the very base of the food chain, and the foundation for that predictability is coherent observations. Utilizing data collected over the course of nine decades, we examine regional differences in biogeochemical properties in BC's coastal ocean. This regionalization of BC's waters will serve to improve spatial management of the province's fisheries, water quality and Marine Protected Areas, ensuring that they are sustained in the face of climate change and our mitigation pathways. Biogeochemical indicators will be necessary for adequately predicting the consequences of climate anomalies that have cascading effects on the food web, and this work establishes such indicators via a regionalization approach.

(S9-14342)

Development of Information Service for Set Net fisheries using Satellite and numerical data

Sei-Ichi **Saitoh**[1], Takashi Hosokawa[2], and Fumihiro Takahashi[3]

1 Arctic Research Center, Hokkaido University, Sapporo, Japan. E-mail: ssaitoh@arc.hokudai.ac.jp
2 Hakodate Branch, NITTO SEIMO CO., LTD., Hakodate, Japan
3 Green & Life Innovation, Inc., Hakodate, Japan

It's said that the origin of a set net was spread all over Japan more than 400 years ago and three historically originated by three prefectures such as Yamaguchi, Toyama and Miyagi. This fishing method has some advantages, i.e. almost of the nets are installed in the depth of less than 100m, located in the short distance from the coast, and short traveling to a fishing ground. Only about 20 % of a school of fish in the net is fished because it's a passive fishing method, and it's said to be the resource management type fishing method. Recently, species of catching by set net were changed due to sea temperature increasing. At present, there are 4,100 set net fisheries management entities in coastal region of Japan, and 1,400 management entities in Hokkaido coast. Under changing climate, it is necessary for fisher to manage the sustainable set net fisheries and one of solutions is to develop the information service including prediction of when and what kind of fish will be trapped in the set net. We challenge to have co-working and co-designing with a set net fisheries company to develop of information service in southern Hokkaido coast, along Cape Esan. This fisheries company has been archiving over ten years daily catch data including fish species and amount and we apply those data coupled with satellite and reanalysis numerical model data to develop probability model of fishes entering to set net using machine learning method. The provability model presents trend of entering fish species and amount. We will introduce preliminary result in this presentation.

(S9-13887)

Experience in developing and operating a marine Citizen Science Program in the Strait of Georgia, Canada

Isobel **Pearsall**[1], Terry Curran[1], Svetlana Esenkulova[1], Rich Pawlowicz[2], Ryan Flagg[3] and Colin Novak[1]

1 Pacific Salmon Foundation, Vancouver, BC, Canada. E-mail: pearsalli@psf.ca
2 University of British Columbia, Vancouver, BC, Canada
3 Ocean Networks Canada, Victoria, BC, Canada

The PSF Citizen Science program began in 2015 as a partnership between the Pacific Salmon Foundation, Fisheries and Oceans Canada, and Ocean Networks Canada. The brainchild of Dr. Eddy Carmack – a retired scientist from the Institute of Ocean Sciences, DFO – it involves volunteers using a "mosquito fleet" of their own fishing vessels to do oceanographic surveys in ten overlapping areas of the Strait of Georgia approximately every two weeks. In one day, these citizen scientists collect CTD data, plankton and water samples from more than 100 sites with automatic transmission of CTD data via a mobile app called *Community Fishers*. The app, developed by ONC, allows fishers and volunteer citizens to upload CTD data to ONC's world-leading data management system, Oceans 2.0. From there, the data are archived, processed and visualized for scientists and the public around the world. This collaborative program is continuing for a fifth year, providing oceanographic information at a temporal and spatial scale not easily achieved with large traditional research vessels. The data collected are allowing us to assess annual variation in physical/chemical oceanography, develop ecosystem models, validate satellite imagery, and understand spatial and temporal changes in productivity of the Strait of Georgia. This presentation will discuss the value of the Citizen Science program, with information provided on program design and implementation, the value of training modules and audits, the development of formal data handling protocol, program validation, and key lessons learned.

(S9-14145)

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

Lynn **Lee**[1] and Chantal Vis[2]

1 Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site, Skidegate, BC, Canada
E-mail: lynn.lee2@canada.ca
2 Natural Resource Conservation Branch, Parks Canada, Gatineau, QC, Canada

Coastal and marine ecosystems are as complex and interrelated as the social systems they interact with. Securing sustained funding and capacity for integrated long-term monitoring programs that operate on decadal scales remains an ongoing challenge. Parks Canada is well positioned to spearhead place-based long-term marine monitoring programs that monitor the health of Canada's National Marine Conservation Areas (NMCAs). To be successful, Parks Canada will require monitoring programs to be implemented in collaboration with Indigenous organizations, other government departments, non-government organizations and academia. Gwaii Haanas is a NMCA Reserve and Haida Heritage Site in northern British Columbia, Canada, that is cooperatively managed by the Council of the Haida Nation, Parks Canada and Fisheries and Oceans Canada. As part of Parks Canada's national marine monitoring program, Gwaii Haanas is in the process of designing and implementing a long-term marine monitoring program that includes ecosystem Essential Ocean Variables (eEOVs) and their linkages to coastal ecosystem monitoring metrics. These metrics include indicators of eelgrass, kelp forest, and rocky intertidal community health and resilience. We provide our perspectives and lessons learned to date as discussion points with the broader ocean condition monitoring community to contribute to future development of long-term marine monitoring programs including for Gwaii Haanas.

(S9-14115)

Community-based monitoring to support cumulative effects assessment in coastal BC

Rebecca G. **Martone**[1], Quinton Ball[2], Kyle Clifton[3], Maria Faria[4], James Herbert[5], Heather Johnston[4], Melissa Lucchetta[1], Kim Lutz[6], Maya Paul[3], Janine Pittman[7], James Prsala[4], Carmen Tattersfield[8], and Nicole Wallace[3]

1 Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Province of British Columbia, Victoria, BC, Canada E-mail: Rebecca.Martone@gov.bc.ca
2 Kitsumkalum Environment, Lands & Referrals Department, Terrace, BC, Canada
3 North Coast Skeena Stewardship Society, Prince Rupert, BC, Canada
4 Ministry of Energy, Mines and Petroleum Resources, Province of British Columbia, Victoria, BC, Canada
5 Gitxaala Environmental Monitoring Department, Prince Rupert, BC, Canada
6 Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Province of British Columbia, Terrace, BC, Canada
7 Gitga'at Oceans and Lands Department, Hartley Bay, BC, Canada
8 Kitselas Lands and Resources Department, Terrace, BC, Canada

The North Pacific Coast of BC, a region of significant ecological diversity and cultural richness, is subject to intensive development pressure from a variety of industrial uses. To address the potential cumulative effects of current and potential future development on ecosystems and human well-being, two different collaborative government-to-government initiatives, the Environmental Stewardship Initiative (ESI) and the Marine Plan Partnership (MaPP), are working to monitor, assess and manage cumulative effects on key coastal and marine values in this area, including: aquatic habitats: estuaries; salmon; food security and access to resources. The goal is to co-develop a system of indicators, metrics, and management triggers that will enable implementation of sound management decisions. Monitoring programs are underway in the North Coast at various scales: (1) Skeena estuary ecological state indicator monitoring; (2) North Coast MaPP water quality monitoring; and (3) MaPP regional kelp monitoring. Sites are selected to meet the program objectives but with a common key interest to understand the scope, scale and rationale for variations resulting from gradients of cumulative effects. A master sampling design has been developed to ensure statistically robust analysis. Key biological indicators include eelgrass, fish communities, soft-sediment macrofauna and meiofauna, and canopy kelps. Abiotic indicators include water physical and chemical, and sediment quality metrics. The programs are developed collaboratively with the aim to utilise and enhance capacity in the communities for long-term monitoring in support of ecosystem-based management. We describe key lessons learned from these collaborative efforts and challenges and opportunities for data collection, storage, and management.

(S9-14215)

Identifying forage fish beach spawning habitat in British Columbia – "To conserve and protect"

Jacklyn **Barrs**[1] and Haley **Tomlin**[2]

1 World Wildlife Fund – Canada, Victoria, BC, Canada. E-mail: jbarrs@wwfcanada.org
2 Mount Arrowsmith Biosphere Regional Research Institute (MABRRI), Vancouver Island University, Nanaimo, BC, Canada

Forage fish play a critical role in the marine food web by transferring energy from the base of the food web to higher trophic levels. In the Salish Sea, forage fish are an important prey item for Chinook salmon, which in turn are a key diet component of the federally listed Southern resident killer whale. As such, variations in forage fish productivity, distribution, and biomass can alter the function and structure of marine ecosystems.

The Salish Sea is home to multiple forage fish species, including Pacific sand lance and surf smelt, which spawn directly on beaches. Beach spawning habitats are undergoing a "coastal squeeze", where climate change impacts (e.g., rising sea levels) combined with shoreline development (e.g., seawalls) are diminishing the quantity and quality of spawning habitats. Building on existing work, WWF-Canada and MABRRI are coordinating a network of citizen scientist groups to monitor beach spawning habitat along the Salish Sea coastline. Citizen scientists follow a set method to collect data on physical aspects of the beach and sediment samples (bulk and eDNA) for egg identification. All data collected is submitted to the Strait of Georgia Data Centre. The data will be used to identify beaches needing restoration and protection and provide the scientific basis for regulation and policy change, ensuring the resilience of forage fish spawning habitat in the face of climate change. Moving forward, as beaches are sampled routinely, this data will provide a valuable source of information on changes to coastal habitats in the Salish Sea.

(S9-14300)

Using an underwater glider to detect acoustically-tagged green sturgeon

John A. **Barth**[1], Mary Moser[2], Steve Corbett[2], Daniel Erickson[3], Stephen D. Pierce[1], and Anatoli Erofeev[1]

1 [1]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 104 CEOAS Admin Bldg, Corvallis, OR, 97331-5503, USA. E-mail: jack.barth@oregonstate.edu
2 Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, USA
3 Ocean Associates Inc., Contractor, West Coast Region, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, USA

Underwater gliders can measure many physical, chemical and bio-optical Essential Ocean Variables (EOVs) from the sea surface to near the sea floor. We tested whether a glider could contribute to the measurement of biological EOVs, in particular fish distribution and abundance. We used an autonomous underwater vehicle (Slocum glider) with two integrated VEMCO receivers to detect acoustically-tagged green sturgeon (*Acipenser medirostris*) at sea. Identifying essential fish habitats in nearshore marine environments is needed for adequate management. However, monitoring marine species is typically time-consuming and expensive. Two, 3-week missions were completed in spring and fall 2018 along the coast of Oregon, USA, to the 300-m contour. In both surveys the glider flew a zig-zag course southward as it transited the water column and collected water quality information. This information, glider position/performance data, and sturgeon detections were transmitted in near-real time during each mission. A conventional fixed array of acoustic receivers with sentinel transmitters was also maintained to compare detection efficiencies of the two platforms. Green sturgeon and sentinels were successfully detected by both the fixed array and the glider. The detection range from the glider was up to about 700m. While detection efficiency was higher for the fixed array, the glider detected green sturgeon outside of the array and provided clues to sturgeon behavior during hypoxic events. This application of the Slocum underwater glider shows promise for identification of sturgeon aggregation areas in the marine environment, as well as opportunities for public engagement, teaching, and outreach.

(S9-14235)

Identifying fish sounds of British Columbia with an autonomous audio and video array

Xavier **Mouy**[1], Morgan Black[2,3], Kieran Cox[2,3], Jessica Qualley[2], Francis Juanes[2] and Stan Dosso[1]

1 University of Victoria, School of Earth and Ocean Sciences, Victoria, BC, Canada. E-mail: xaviermouy@uvic.ca
2 University of Victoria, Biology department, Victoria, BC, Canada
3 Hakai Institute, Calvert Island, BC, Canada

Among the ~400 marine fish species of British Columbia, only 22 have been reported to be soniferous. However, it is likely due to the lack of examination, as more species are suspected to produce sound. Here we describe how an autonomous audio and video array can identify fish sounds *in situ*. The array is composed of a collapsible 2m x 2m x 3m PVC frame, an AMAR acoustic recorder, six omnidirectional hydrophones, and two custom-made wide-angle autonomous video cameras mounted on the top and side of the array that collect data continuously for up to 10 days. Fish sounds are automatically detected in the acoustic recordings, the time difference of arrivals between pairs of hydrophones is measured by cross correlation, and the 3D sound-source location and its uncertainty are estimated using linearized inversion. Simulated annealing optimization was used to define the hydrophone configuration that provides the smallest localization uncertainties. The video recordings are used to assign the species of sound-producing fish localized within the array. The array was deployed at several locations around Vancouver Island and used to define the species, sound characteristics, and source levels of several fish sounds. This new information will help making passive acoustics a viable way to monitor fish in the wild.

(S9-14311)

Estimation of the biodiversity of fish and invertebrates using video and acoustics

Xavier Muoy[1], Fabio Fabio Cabrera De Leo[2], Stan Dosso[1], and Francis **Juanes**[1]

1 University of Victoria, Victoria, BC, Canada. Email: juanes@uvic.ca
2 Ocean Networks Canada, Victoria, BC, Canada

The increase in climate and anthropogenic stressors in the marine environment can lead to important losses in habitat for fishes and invertebrates. Consequently, monitoring marine biodiversity has become a critical task for ecologists. Traditional biodiversity measurements are costly and logistically challenging and there is an increasing need to develop new techniques that are more suitable for long-term and large-scale monitoring. The objective of this work is to assess the efficiency of underwater video, and active and passive acoustics to monitor the presence and diversity of fish and invertebrates. This work uses a multi-instrument platform, deployed on Ocean Networks Canada's VENUS cabled observatory in the Strait of Georgia (British Columbia, Canada), comprised of a high-definition video camera with a pair of LED lights, a dual-frequency imaging sonar and a hydrophone. Fish and invertebrates are automatically counted and identified using the data from the video camera and sonar. Several acoustic indices such as acoustic complexity indices and similarity sound clusters are computed from the hydrophone data. The time series of these indices estimated from the passive acoustic data are then compared to the camera and sonar recordings to assess the ability of passive acoustics alone to determine the presence and diversity of fish and invertebrates.

(S9-14384)

Development and observational examples of measuring vertical turbulent nitrate flux using sensors

Daisuke **Hasegawa**[1], Takahiro Tanaka[1], Takeshi Matsuno[2], Tomoharu Senjyu[2], Eisuke Tsutsumi[2], Hirohiko Nakamura[3], Ayako Nishina[3], Toru Kobari[3], Naoki Yoshie[4], Xinyu Guo[4], Takeyoshi Nagai[5], Takeshi Okunishi[1] and Ichiro Yasuda[6]

1 Tohoku National Fisheries Research Institute, Shiogama, Miyagi, Japan. E-mail: daisukeh@affrc.go.jp
2 The Research Institute for Applied Mechanics, Kyusyu University, Kasuga, Fukuoka, Japan
3 Faculty of Fisheries, Kagoshima University, Kagosima, Japan
4 Center for Marine Environmental Studies, Ehime University, Matsuyama, Ehime, Japan
5 Tokyo University of Marine Science and Technology, Tokyo, Japan
6 Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Chiba, Japan

Vertical nutrient transport plays an important role in supporting primary production in the upper ocean. Nutrients are supplied to surface euphotic layer from deeper, nutrient-rich layers via vertical advection and turbulent mixing. Due to a limited number of observations, our understanding of the spatiotemporal variability of turbulent nutrient fluxes remained poorly resolved. Here, we developed a novel system to measure turbulent nitrate flux by attaching a small nitrate sensor on a turbulence profiler. In this presentation, we explain the instrument setup, the data processing method; demonstrate the capability of the developed system by using observational examples. The simplicity of our system is enabling a greater number of in situ observations to help elucidate the importance of this phenomena in aquatic ecosystems.

This work was supported by a Grant-in-Aid for Scientific Research on Innovative Areas (MEXT KAKENHI Grant Number: 15H05818, 15H05821, 16H01590, 18H04914, 18H04917, 18H04920).

(S9-14379)

High-resolution carbonate dynamics of Netarts Bay, OR from 2014-2019

William **Fairchild** and Burke Hales

Oregon State University, Corvallis, OR, USA. E-mail: fairchiw@oregonstate.edu

Netarts Bay is a shallow, temperate, tidal lagoon located on the northern coast of Oregon and site of the Whiskey Creek Shellfish Hatchery (WCSH). Data collected with an automated flow-through system installed at WCSH capable of high-resolution (1 Hz) pCO2 and hourly TCO2 measurements, with combined measurement uncertainties of <2.0% and 0.5%, respectively, is analyzed over the 2014-2019 interval. These measurements provide total constraint on the carbonate system, allowing calculation of derived variables such as pH, alkalinity, and carbonate mineral saturation states. Nearly 70% of the bay's volume is drained during each tide cycle, and in-bay freshwater sources are limited to small perennial streams or direct precipitation via high-rainfall events. Summer upwelling, wintertime downwelling, and in-situ bay biogeochemistry represent significant drivers of the observed variability in carbonate dynamics. Summer upwelling is associated with large amplitude diel pCO2 variability but weak variability in water-source dynamics. Wintertime downwelling is associated with bay freshening by both local and remote sources, a strong tidal signature, and pCO2 values near atmospheric gas-solubility equilibrium. Using piecewise linear regressions of salinity and alkalinity allows identification of mixing end-members associated with direct precipitation, small coastal rivers, southward displacement of the Columbia River plume, California Current surface and deep upwelled waters. Further, the importance of non-conservative in-bay processes during intervals of high productivity is apparent. This research has proved useful to local hatchery owners who have historically faced seed-production failures related to high-CO2 conditions exacerbated by ocean acidification.

(S9-14400)

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

Oregon State University, Corvallis, OR, USA. E-mail: bhales@coas.oregonstate.edu

We participated in two cruises, Nome-Barrow-Nome in September of 2016 and Seward-Nome-Barrow-Nome in August 2017, where we operated systems for continuous, high-speed analysis of carbonate chemistry (pCO_2 and TCO_2), nutrients (nitrate+nitrite, ammonia, phosphate, and silicate), and biological O_2 unsaturation (derived from O_2/Ar ratios) in the ship's flow-through seawater system. Data rates were sufficiently high (~1-Hz data collection rate with ~10-second response times) that even with significant data reduction tens of thousands of synchronized tracer vectors result. The combination of synchronized pCO_2 and TCO_2 allows the calculation of the full suite of carbonate-system parameters, including alkalinity, pH, and mineral saturation states (Ω). Alkalinity-salinity relationships show the influence of several established regional mixing lines, along with those due to local source waters. Despite persistently low pCO_2 and high pH at in situ temperatures, Ω values were persistently low, below values known to be impactful to larval bivalves, showing clear decoupling of these parameters often thought to be tightly correlated. Nutrient distributions showed a northward increase in nitrate deficiency, relative to phosphate, presumably reflecting the influence of denitrification in the Bering Sea. Silicate distributions strongly reflected local freshwater inputs, and showed the varying contributions of Pacific and Atlantic source waters along the W-E transect in the Chukchi Sea. O_2/Ar distributions showed clear instances of net autotrophy and heterotrophy, but with varying nutrient and carbon coherence, reflecting differential timescales of O_2 and CO_2 gas-exchange, and the absence of a definable 'equilibrium' state for nutrients with respect to net community metabolism.

SESSION 10
Linking changes in climate, nutrient distribution, phytoplankton ecology, and production of algal exudates in the North Pacific

(S10-14315)

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

Yellow Sea fisheries Research Institute, CAFS, Qingdao, PR China. E-mail: liqf@ysfri.ac.cn

The coastal area around Laoshan Mountain, a worldwide famous scenic spot, is also habits of several rear seafood and an important maricultural area of Qingdao City. So, it is essential for tourism and aquaculture to keep its high-quality eco-environment, we continuously monitor and assess the coastal eco-environment quality in an integrative way for about 10 years in order to grasp the status and change of coastal eco-environment quality in time. The results indicated that the quality of eco-environment of Laoshan coastal area keeps good for the 10 years, the temperature and salty were stable without obviously impacted by climate change, the concentration of heave metals keep lower than the standard of first-class seawater quality. The concentrations of nutrients were over the standard of first-class seawater quality but lower than the second-class seawater quality, meeting the requirement of mariculture. However, the concentration of DIN and N/P showed decline trend in recent years, the EI varies between 0.1 to 0.5, means a lower nutritive level. Therefore, the diversity and biomass of phytoplankton and zooplankton also deceased. So, the ecosystem health in this area is not as good as we thought, which needs attention.

Key words: ecosystem health, coastal sea area around Laoshan, nutrient level, eco-environemnt monitoring

(S10-13905)

Variations in spring and summer phytoplankton communities across water mass gradients in the Chukchi Sea

Lisa B. **Eisner**[1], Michael W. Lomas[2], and Jens M. Nielsen[1]

[1] NOAA Fisheries, Alaska Fisheries Science Center, Seattle, WA, USA. E-mail: Lisa.Eisner@noaa.gov
[2] Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

Marine phytoplankton composition and size are important to carbon cycling (e.g. sinking of particles and subsequent regeneration) and trophic energy transfer to zooplankton, fish and marine mammals (large taxa such as diatoms allow a shorter food web and more efficient energy transfer to higher trophic levels). Phytoplankton community composition, and consequently also the quality and quantity of dietary resources for higher trophic level consumers, varies considerably between oligotrophic, eutrophic and ice-influenced water masses, between surface and subsurface depths in Arctic seas. Accordingly, the phytoplankton population size structure also varies by region and water mass with strong implications for trophic transfer of primary production. Changes in climate (increased freshening, warming, and open water area, all of which affect stratification and nutrient supply) are likely to alter phytoplankton community size structure and composition. Phytoplankton taxonomic information was collected during fisheries oceanography surveys in the Chukchi Sea in 2017 as part of Arctic ecosystem projects: Arctic Shelf Growth, Advection, Respiration & Deposition (ASGARD) and the Arctic Integrated Ecosystem Survey (Arctic IES) in June and August-September, respectively. Variations in phytoplankton communities are evaluated using Flow Cam analysis of live phytoplankton (large taxa), flow cytometric analysis (small taxa) and size-fractionated chlorophyll a across the Chukchi shelf in spring and summer. We explore relationships of phytoplankton communities to water mass and latitudinal region, and potential impacts on higher trophic levels.

(S10-14332)

High temporal resolution phytoplankton compositions and environmental drivers in the northern Salish Sea, British Columbia, Canada

Justin A. **Del Bel Belluz**[1], Angelica Peña[2], Jennifer M. Jackson[1], and Nina Nemcek[2]

1 Hakai Institute, PO Box 309, Heriot Bay, BC, V0P 1H0, Canada. E-mail: Justin.belluz@hakai.org
2 Institute of Ocean Sciences, Fisheries and Oceans Canada, P.O. Box 6000, Sidney, BC, Canada V8L 4B2

Understanding phytoplankton dynamics is essential for assessing ecosystem health as they form the base of the marine food web, are a key component in nutrient cycling and play a vital role in CO_2 uptake. In the Salish Sea, a highly productive inland sea on the British Columbia coast, contemporary research on phytoplankton compositions is limited. In this work, we present a four-year (2015-2018) high temporal resolution (weekly) timeseries of phytoplankton compositions in the northern Salish Sea utilizing a pigment-based (CHEMTAX) approach. This method has the advantage of resolving pico-sized species typically underestimated via traditional methods. Through the timeseries, we observed considerable temporal variability driven by episodic events, but also a clear seasonal trend emerged characterized by: 1) low biomass (TChla < 1 mg m^{-3}) flagellate dominated winter conditions; 2) high diatom biomass spring bloom conditions; 3) flagellate dominated summer conditions and; 4) autumn conditions with increased diatom contributions, but flagellates still important. Regardless of season, prasinophytes and cryptophytes were consistently the greatest contributors to the flagellate community. Of the environmental drivers, stratification and nutrient limitation played an important role in the determination of phytoplankton compositions. For instance, spring-summer transitions were characterized by increased stratification and nutrient limitation in each year of the timeseries. Furthermore, highly stratified summer seasons were associated with fewer episodic bloom events and flagellate based communities. These findings are pertinent considering the importance of the region to juvenile salmon migration and shellfish aquaculture, both of which are sensitive to ecosystem changes driven by phytoplankton.

(S10-14228)

Evidence for the production of copper-complexing ligands by marine phytoplankton in the Canadian Arctic and subarctic NE Pacific

Andrew R.S. **Ross**[1,2], Richard L. Nixon[2], Jasper George[2], David J. Janssen[3], Sarah L. Jackson[3], Jay T. Cullen[3], Kyle G. Simpson[1] and Marie Robert[1]

1 Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada. E-mail: Andrew.Ross@dfo-mpo.gc.ca
2 Department of Biochemistry and Microbiology, University of Victoria, Victoria, BC, Canada
3 School of Earth and Ocean Sciences, University of Victoria, Victoria, BC, Canada

Organic complexation affects the uptake of copper and other bioactive metals by phytoplankton, with important implications for marine productivity and climate change. However, relatively little is known about the origin and identity of marine copper-complexing ligands. We used immobilized copper(II)-ion affinity chromatography (IMAC) to isolate dissolved (< 0.2 µm) copper ligands from seawater samples collected during the 2015 Canadian Arctic GEOTRACES expedition and recent Line P cruises. UV detection at 254 nm was employed to monitor elution of the compounds retained by IMAC. The areas of the resulting peaks were used to generate depth profiles showing the distribution of marine copper ligands in the Canadian Arctic and alone Line P. The depth of highest ligand concentration was generally found to coincide with the chlorophyll maximum depth. Correlations between ligand concentration and *in situ* chlorophyll-a fluorescence further suggest that marine phytoplankton or cyanobacteria could be an important source of copper ligands. Spectroscopic analysis of fractions collected during IMAC provides additional information about the composition and structure of these ligands. Use of this information to better understand and predict how copper complexation and bioavailability might affect or be influenced by plankton ecology and climate change will be discussed.

(S10-14005) **CANCELLED (presented only in a Workshop)**

The monthly wet depositional fluxes of Organic Matter in Precipitation of Jeju Island

Min-Young **Lee**, Tae-Hoon Kim, and Na-Yeong Song

Department of Earth and Marine Sciences, Jeju National University, Jeju, R Korea. E-mail: thkim@jejunu.ac.kr

In order to evaluate the distributions and fluxes of organic matter in the atmosphere, particulate organic carbon (POC) and dissolved organic carbon (DOC) were measured in Jeju Island, Korea, from January to December 2018. The concentrations of POC and DOC were in the range of 0.62-1567 µM (AVG = 76 µM, VWA = 36 µM) and 14.8-991 ìM (AVG = 102 ¼M, VWA = 53 ¼M). The highest concentration of POC and DOC were found in January 2018. This result seems to be associated with incomplete combustion of fossil-fuel during winter. According to back-trajectories (HYSPLIT model), The groups consist of events with air mass originated from the continent of Asia (40%), Ocean (51%), and Local (9%). The monthly wet depositional fluxes of POC and DOC at Jeju varied from 0.01-1.23 mmol cm^{-2} $month^{-1}$ and 0.24-1.31 mmol cm^{-2} $month^{-1}$. The highest flux of POC was found in March, due to the highest concentration of POC, and that of DOC was observed in September, owing to the highest amount of precipitation. The lowest flux of POC was found in July due to the lowest concentration of POC, and that of DOC was observed in November, owing to the lowest amount of precipitation. The annual flux of POC was relatively higher than that in other regions, while that of DOC was relatively lower than that in other regions. In order to understand the behavior of organic matter in the atmosphere, extensive studies are necessary in the future over greater time-scale using various chemical tracers.

(S10-14168)

An algicidal bacteria secreted natural compound induces mortality in the marine phytoplankton

Ruoyu **Guo**[1], Ruize Xie[2] and Yongyu Zhang[2]

[1] Second Institute of Oceanography, Ministry of Natural Resources of the People`s Republic of China
E-mail: dinoflagellate@sio.org.cn

[2] Key Laboratory of Biofuels, Shandong Provincial Key Laboratory of Energy Genetics, Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences, PR China

Phytoplankton and bacteria numerically dominate the ocean ecosystem with intimately interaction relationship and effect on the global biogeochemical cycling of the ocean ecosystem. The interaction of phytoplankton and bacteria can be beneficiary or detrimental. In the detrimental interaction relationships, the bacteria could kill the phytoplankton via producing the algicidal compound. In the present study, an algicidal bacterium *Microbulbifer* sp. RZ01 and its excreted algicidal compound were identified. The structure analysis revealed that this algicidal compound was 3,3,5,5-tetrabromo- 2,2-biphenyldiol (4-BP), belongs to bromophenol. Algicidal activity test showed that it could kill various phytoplankton including diatoms, dinoflagellates, chlorophyta, and cyanobacteria. The further physiological analysis of 4-BP on diatom *Phaeodactylum tricornutum* revealed that the 4-BP could strongly inhibit the photosynthesis efficiency, decrease the pigments contents, and increase the ROS production. The transcriptomic analysis revealed that the 4-BP largely inhibited the chlorophyll *a* synthesis pathway, and disturbed photosynthesis, chorismate related pathways, TCA cycle, glycolysis/gluconeogenesis, and pentose phosphate pathway. Both physiological and transcriptomic results indicated that the photosynthetic electron transport chain might be key target of 4-BP, and the superfluous ROS production might be the direct reason that cause the cell death. This study pointed out the potential ecological roles of 4-BP in the ecosystems, and provided the insight of algicidal bacteria action mechanism on phytoplankton, and provided the evidence of interaction of bacteria and phytoplankton could regulate the carbon cycling in the marine ecosystem.

(S10-14099)

Linking harmful algal blooms and oceanographic conditions in the Strait of Georgia, Canada

Svetlana **Esenkulova**[1], Karyn Suchy[2,1], Rich Pawlowicz[3], and Isobel Pearsall[1]

1 Pacific Salmon Foundation, Vancouver, BC, Canada. E-mail: svesen@uvic.ca
2 Department of Geography, University of Victoria, Victoria, BC, Canada.
3 Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, Vancouver, BC, Canada

Based on a high resolution monitoring in the Strait of Georgia, we present complex linkages between harmful algae bloom (HAB) dynamics and oceanographic conditions. About 80 stations were sampled ~bi-monthly from February to October, 2015-2019 with harmful algae identified and enumerated: *Alexandrium* spp., *Chaetoceros convolutus* and *C. concavicornis, Cochlodinium fulvescens, Dictyocha* spp., *Dinophysis* spp., *Heterosigma akashiwo, Noctiluca scintillans, Pseudo-nitzschia* spp., and *Rhizosolenia setigera.* Physical parameters (temperature, salinity, density, turbidity) were also measured at ~80 stations, while nutrients (nitrate+nitrite, silicate, phosphorus) were measured at ten of these stations. We suggest that relationship between HAB dynamics and coastal water conditions are convoluted and long term results are needed to establish links to climate change.

(S10-13864)

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**[1,2], Brian D. Bill[2], Nicolaus G. Adams[2], Urban Tillmann[3], Catherine Sloan[2], Douding Lu[1] and Vera L. Trainer[2]

1 Key Laboratory of Marine Ecosystem and Biogeochemistry, State Oceanic Administration, Second Institute of Oceanography, Ministry of Natural Resurces, Hangzhou, 310012, PR China. E-mail: xinfengdai@sio.org.cn
2 Environmental and Fisheries Science Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, Washington, 98112, USA
3 Alfred Wegener Institute for Polar and Marine Research, Am Handelshafen 12, D-27570 Bremerhaven, Germany

Azaspiracids (AZA) are novel lipophilic polyether marine biotoxins associated with azaspiracid shellfish poisoning (AZP). Azaspiracid-59 (AZA-59) is a new AZA that was recently detected in strains of *Azadinium poporum* from Puget Sound, Washington State. In order to understand how environmental factors affect AZA concentrations in Puget Sound, a laboratory experiment was conducted with two local strains of *A. poporum* to estimate the growth rate and AZA-59 (both intra- and extracellular) cell quotas along temperature and salinity gradients. Both strains of *A. poporum* grew across a wide range of temperatures (6.7 °C to 25.0 °C), and salinities (15 to 35). Growth rates increased with increasing temperature up to 20.0 °C, with a range from 0.10 d^{-1} to 0.42 d^{-1}. Both strains of *A. poporum* showed variable growth rates from 0.26 d^{-1} to 0.38 d^{-1} at salinities from 15 to 35. The percentage of intracellular AZA-59 in both strains was generally higher in exponential than in stationary phase along temperature and salinity gradients, indicating higher retention of toxin in actively growing cells. Cellular toxin quotas varied by strain in both the temperature and salinity treatments but were highest at the lowest growth rates, especially for the faster growing strain, NWFSC1011.

Consistent with laboratory experiments, field investigations in Sequim Bay, WA, during 2016–2018 showed that *A. poporum* was detected when salinity and temperature became favorable to higher growth rates in June and July. Although current field data of *A. poporum* in Puget Sound indicate a generally low abundance, the potential of local *A. poporum* to adapt to and grow in a wide range of temperature and salinity may open future windows for blooms. Although increased temperatures, anticipated for the Puget Sound region over the next decades, will enhance the growth of *A. poporum*. These higher temperatures will not necessarily support higher toxin cell quotas. Additional sampling and assessment of the total toxicity of AZA-59 will provide the basis for a more accurate estimation of risk for azaspiracid poisoning in Puget Sound shellfish.

(S10-14010)

Studies on *Prorocentrum* (Dinophyceae) in the coastal water of China

Pengbin **Wang**, Ruoyu Guo, Xinfeng Dai, Ruifang Wang, and Douding Lu

Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, 310012, PR China. E-mail: algae@sio.org.cn

Prorocentrum is a kind of dinoflagellate with cosmopolitan distribution. Many species of *Prorocentrum* can produce the diarrhetic shellfish poison (DSP), which can enter the food web through the prey of fish and shellfish. So far, there are many studies only on serval main species of *Prorocentrum* in Chinese coastal water, such as *Prorocentrum donghaiense* (pelagic) and *Prorocentrum lima* (benthic). To this big genus with about 80 species, it is apparently that there is not sufficient on the study of *Prorocentrum* biodiversity and geographical distribution. Based on our previous work, samples will be taken by collecting the surface water and using vacuum collection, artificial substrates as well as other methods. The targeted species and strains will be isolated and cultured in lab condition. Normal light microscope, laser scanning confocal microscope, SEM and TEM will be used for morphological study. The molecular identification will be also performed by amplifying and sequencing for specific genes. So far, we have isolated more than 30 strain of *Prorocentrum* spp., including *Prorocentrum concavum*, *Prorocentrum donghaiense*, *Prorocentrum koreanum*, *Prorocentrum lima*, *Prorocentrum micans*, etc.. Also, several unknow species of *Prorocentrum* have been isolated and cultured successfully. For these work, the biogeographic distribution pattern of *Prorocentrum* in typical coastal habitats of China will be constructed, which will also be contributed to improving global distributive pattern of these important species. In addition, it will be beneficial for further study on deep research of marine biotic resources, maintaining marine ecosystem health and monitoring or early warning of harmful algal blooms.

(S10-14012)

Light triggered the hemolytic toxin production of fish-killing Raphidophyte: *Heterosigma akashiwo*

Robert Jay Nerit **Ramos**, Channimol Ky, Jingyao Zhang and Mengmeng Tong*

Ocean College, Zhejiang University, Zhoushan City, China. E-mail: mengmengtong@zju.edu.cn

Light plays a critical role for various photosynthetic microalgae such as the fish-killing raphidophytes *Heterosigma akashiwo* by utilizing the radiant energy for their growth, migration, and even toxin production. However, the research on physiological and toxicological responses of the ichthyotoxic alga on different wavelengths within the visible spectrum are still limited. Therefore, the present study focused on the mechanism of hemolytic toxin production and to investigate the light color effect on the growth, photosynthetic efficiency (Fv/Fm), pigment compositions and hemolytic activity of *H. akashiwo* under red (632 nm), orange (596 nm), green (526 nm), blue (464 nm), violet (453 nm) and white (control) light. The results showed that *H. akashiwo* grew significantly faster under blue, violet and red, followed by white, than orange and green. Likewise, hemolytic activity had the same response to the light color as the growth rate, suggesting that the hemolytic compound might be related to the active growth of the cells. When exposed to blue and violet, photosynthetic efficiency of *H. akashiwo* got lower when cells aged, while zeaxanthin was remarkably higher than in the longer light wavelengths (red, orange and green) and control (white), indicating the unhealthy status of *H. akashiwo* and protection against photo-oxidative damage by dissipating the excess light energy, which in return, possibly leading to the hemolytic toxin production. These findings suggested that light wavelengths have a direct effect on the physiology and may regulate the fish-killing potential of *H. akashiwo*.

(S10-14179)

Role of dissolved nitrate/ammonium and phosphate in isolates of *Mesodinium rubrum* and toxin-producing *Dinophysis acuminata*

Chenfeng **Hua**[1], Ramos R.J. Nerit[1], Han Gao[1], Mengmeng Tong[1] and Patricia M. Glibert[2]

[1] Ocean College, Zhejiang University, No 1 Zheda Road, Zhoushan 316000, Zhejiang, PR China
E-mail: mengmengtong@zju.edu.cn
[2] Horn Point Laboratory, University of Maryland Center for Environmental Science, Cambridge, Maryland, USA

Dinophysis acuminata, a producer of toxins associated with diarrhetic shellfish poisoning and/or pectenotoxins, is a mixotrophic species that requires both ciliate prey and light for growth. Linkages have been described in the literature between natural abundances of the predator *Dinophysis* and its prey, *Mesodinium rubrum*, and culture experiments have demonstrated that prey, in addition to light, is required for toxin production by *D.acuminata*; together these suggest *Mesodinium* is a critical component for *Dinophysis* growth and toxicity. However, little is known about the role of dissolved inorganic nutrients on *Mesodinium* growth or that of toxin producing *Dinophysis*.

Accordingly, a series of experiments were conducted to investigate the possible uptake of dissolved nitrate/ammonium and phosphate by 1) *Dinophysis* starved of prey, 2) *Dinophysis* feeding on *M.rubrum*, and 3) *M. rubrum* grown in nutritionally-modified medium. All single-clone or mixed cultures were monitored for dissolved and particulate nutrient levels over the growth cycle, as well as growth rate, biomass, and toxin production.

D.acuminata didn't utilize dissolved nitrate or phosphate in the medium under any nutrient regime, but may can utilize dissolved ammonium. *M.rubrum*, on the other hand, rapidly assimilated dissolved nitrate/ammonium and phosphate into its particulate nutrient fraction. Obviously, limitation of nitrate or phosphate did not impact the growth of *D.acuminata* (0.339±0.026, 0.268±0.060 respectively).The result of toxin is analyzing now.

SESSION 11
Incorporating ecosystem variability and climate change into fisheries management: Progress and challenges for EBFM in the 21st century

(S11-14305) INVITED

Merging contextual ecosystem advice with single-species stock assessment to inform fisheries managers in times of extreme environmental changes

Stephani **Zador**[1], Elizabeth Siddon[2], and Martin Dorn[1]

[1] NOAA Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, Seattle, WA, USA
E-mail: Stephani.zador@noaa.gov
[2] NOAA Alaska Fisheries Science Center, Auke Bay Lab, Juneau, AK, USA

Scientists have been providing contextual ecosystem information to federal fisheries managers in Alaska to support the quota-setting process for 25 years. This information is supplemental to the stock assessment process and largely consists of ecosystem indicators that track physical and biological changes in the ecosystem. These indicators are integrated into ecosystem assessments presented annually to managers immediately preceding their review of stock assessments. Lessons learned largely follow themes of communication, collaboration, and transparency. Regular communication among scientists, managers, and fisheries practitioners of information tailored to specific needs increases uptake into management processes. Ecosystem information must be timely and at relevant scales. To achieve this also requires collaboration, which is encouraged by trust in the management system and transparency. In 2018, this type of collaboration built on trust allowed for communication of reports of strong impacts on the northern Bering Sea ecosystem, which did not freeze over during the preceding winter for the first time, to stock assessment scientists and fisheries managers before stock assessments were completed. The rapid availability of this information informed a re-evaluation of stock assessment assumptions regarding the geographic shift of fish stocks from the eastern to the northern Bering Sea. Also in 2018, several stock assessments included a new risk table that identified and ranked ecosystem, population dynamics, and assessment concerns. Summarizing myriad data into simple risk tables allowed stakeholders to compare management recommendations among stocks, increasing their understanding of assessment concerns. The outcome was greater engagement in the development of management advice by stakeholders.

(S11-14391)

National Oceanic and Atmospheric Administration's Climate Fisheries Initiative: Long-term projections

Anne B. **Hollowed**[1], Charles Stock[2], Alan Haynie[1], Albert Hermann[3,4] and Kirstin Holsman[1]

[1] Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, USA. E-mail: Anne.Hollowed@noaa.gov
[2] Geophysical Fluid Dynamics Laboratory, Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration, Princeton, NJ, USA
[3] Joint Institute for the Study of Atmosphere and Oceans, University of Washington, Seattle, WA, USA
[4] Pacific Marine Environmental Laboratory, Oceanic and Atmospheric Research, National Marine Fisheries Service, Seattle, WA USA

Understanding and assessing the impacts of changing climate and identifying and testing adaptation options for management of fish and fisheries requires multidisciplinary research teams. In 2019, the National Oceanic and Atmospheric Administration agreed to explore its options for the creation of a permanent research enterprise composed of experts from across the agency. Interdisciplinary research teams were formed to develop an implementation plan for a Climate Fisheries Initiative. This talk will describe the implementation plan and it's research components and illustrate how each agency within NOAA will contribute to deliver the following climate projection modeling products: 1. A flexible modeling framework that will adapt to improvements in our scientific understanding of mechanisms underlying responses of living marine resources and fishers to changing climate conditions. 2. A flexible modeling framework that continues evolve to improvements in our scientific understanding of greenhouse gas accumulation in the atmosphere on the earth including its role on ocean atmosphere coupling and biogeochemical connectivity. 3. A projection modeling framework that incorporates a high – resolution modeling capability for use on US coastal shelves that will continue to evolve in response to

ever changing high-speed computing capacity and innovations in functional representations of the human-natural system. 4. Continued adaptation of global shared socio-economic pathways for use in developing scenarios for regional management of living marine resources. 5. Interdisciplinary research teams that include stakeholder input that are responsible for proposing, vetting and developing functional representations of adaptation options under regional socio-economic pathways for fisheries. 6. Projected impacts of climate change under alternative representative concentration pathways on the distribution and abundance of living marine resources using models of different levels of complexity. Multi-model ensembles will be needed to fully address different sources of uncertainty – structural, initiation, scenario, and parameter. 7.Identification of management strategies that are robust to climate change (to the extent possible) and acknowledgement of cases where management is incapable of preserving a species/or species complex. This initiative may serve as an example for other nations as a framework for the long-term delivery of climate ready harvest advice.

(S11-14044)

Towards ecosystem-based management of Northeast Pacific herring fisheries

Szymon **Surma**

University of British Columbia, Vancouver, Canada. E-mail: s.surma@oceans.ubc.ca

This paper investigates potential ecosystem-based management strategies for northeast Pacific herring fisheries, as well as ecological and socioeconomic impacts of candidate strategies, under current and projected ecosystem and climate conditions. The operating model was constructed in Ecopath with Ecosim (EwE) for the marine ecosystem surrounding Haida Gwaii (an archipelago in the southeastern Gulf of Alaska). Ecological impacts of multiple herring fishing strategies were comparatively examined with a powerful management strategy evaluation (MSE) algorithm available as a plugin for EwE. This tool accounts for ecosystem model parameter uncertainty along with stock assessment and strategy implementation errors. Furthermore, MSE runs in the built-in EwE MSE tool were employed to evaluate the performance of the current Canadian management strategy under three primary productivity scenarios. The MSE results indicate that herring and predator biomasses are moderately impacted by the management strategies currently employed in Canada and Alaska. More precautionary strategies could substantially mitigate these impacts, albeit at the cost of reduced catches and frequent fishery closures. The tradeoff between herring and predator biomasses on the one hand, and catches and fisheries openings on the other, could be resolved by reducing target fishing mortality within existing management strategies. However, full consideration of uncertainty reveals that herring and predator biomasses could decrease naturally under all strategies. In particular, reduced primary productivity may greatly exacerbate the impacts of the current Canadian management strategy. This study identifies ecosystem-based management strategies and compromise solutions for northeast Pacific herring fisheries while accounting for numerous sources of ecosystem and management uncertainty.

(S11-14136)

Emperor Chain Research Project of the NSCMB FEB RAS – Key animal groups in the vulnerable marine ecosystems and natural resources management in the Pacific High Seas

Tatiana N. **Dautova**

National Scientific Center of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok, Russia. E-mail: tndaut@mail.ru

The Emperor Chain of seamounts provides the high seas fisheries resources in the North Pacific (NP) along with a testimony of the intriguing wonders of the deep-sea coral world. The Convention on the Conservation and Management of the High Seas Fisheries Resources in the NP and NP Fishery Commission (NPFC) aim to ensure the long-term conservation and sustainable use of fisheries resources while protecting the vulnerable marine ecosystems. In the case of possible mining of mineral resources and overfishing, there is a problem of environmental assessment of the impact on vulnerable marine ecosystems of the seamounts, including coral gardens and reproductive accumulations of commercial fish and others. Recognizing the necessity to collect scientific data in order to understand the marine biodiversity and ecology in the region, the National Center of Marine Biology (Russia) created the Emperor Chain Survey Project as one of the environmentally focused multidisciplinary projects of the Russian Academy of Sciences. It focuses on the functional structure of the deep-water ecosystems and their key indicative groups – corals and sponges biodiversity. Modern non-contact monitoring is applied using the ROV video survey along with the efforts of the biologists, geochemists and marine geologists. Developing international scientific cooperation in the region, the project is planned to attract university students and NPFC observers/managers from all countries of the North Pacific region.

(S11-13904)

Fragile ecosystems, robust assessments? Performance testing stock assessments for the California Current and Nordic and Barents Seas under climate change

Isaac C. **Kaplan**[1], Sarah K. Gaichas[2], Patrick D. Lynch[3], Christine C. Stawitz[3], Cecilie Hansen[4]

1 Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, WA, USA
E-mail: Isaac.Kaplan@noaa.gov
2 Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA, Woods Hole, MA, USA
3 Office of Science and Technology, National Marine Fisheries Service, NOAA, Silver Spring, MD, USA
4 Institute of Marine Research, Bergen, Hordaland, Norway

The California Current and Nordic/Barents Seas are experiencing rapid global change, fundamentally altering the productivity of ecosystems and fish stocks. To facilitate the development of fishery management advice that is robust to climate change, we tested the performance of stock assessment modeling approaches under climate scenarios across these two ecosystems. As 'operating models' or virtual testbeds, we applied Atlantis ecosystem models of the California Current and Nordic/Barents Seas, forced with scenarios for warming ocean temperature. These scenarios project conditions in the 2060's, with associated impacts on fish growth, trophic interactions, and predation mortality. These ecosystem models are spatially explicit and include biological groups ranging from primary producers to top predators; here we focus primarily on key harvested species including Pacific sardine (*Sardinops sagax*), Pacific hake (*Merluccius productus*), Northeast Arctic cod (*Gadus morhua*) and Norwegian spring spawning herring (*Clupea harengus*). Using a new R package, *AtlantisOM*, we simulate survey and fishery sampling from Atlantis output, including the uncertainty and bias associated with survey and catch observations, before passing data to a Stock Synthesis assessment. Within Stock Synthesis, we evaluated the efficacy of different modeling assumptions (e.g., time-varying, empirical, or constant) on growth and natural mortality parameters to account for changing productivity driven by climate change. We evaluated stock assessment performance 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 assessment.

(S11-14279)

Spatiotemporal interannual variabilities of Swordfish Catch in relation to Fronts and Eddies in the Northwestern Pacific

Gloria S. **Duran**[1], Takeyoshi Nagai[2] and Kotaro Yokawa[3]

1 Agraria La Molina National University, Lima, Peru. E-mail: 20130368@lamolina.edu.pe
2 Tokyo University of Marine Science and Technology, Tokyo, Japan
3 National Research Institute, Far Seas Fisheries, Fisheries Research Agency

The previous study of the authors, has found that swordfish can be targeted more effciently in the northeastern side of anticyclonic eddies during unstable period at the northern area of the Kuroshio Extension system. These results suggested that the interannual variabilities in the North Pacific not only affect the physical and biogeochemical oceanography but also modulate the fish abundance of marine species. Even though oceanographic modulations can have a large impact on fishery resources, the effects of mesoscale eddies on swordfish population in the western North Pacific is still unclear. In this study, eddy detection analysis in relation to the interannual Kuroshio path modulations are analyzed to provide implications to the pelagic swordfish catch from 2004 through 2010. During this period, the Kuroshio path modulations presented two dynamic states: stable period (2004, 2005 and 2010) and unstable period (2006-2009). Analysis for northern (37-45◦N) and southern (25-37◦N) region has been given as well.

(S11-14040)

Ideas on how to incorporate EBFM into a pelagic longline tuna fishery

Phoebe A. **Woodworth-Jefcoats**[1], Justin Hospital[1], Johanna L.K. Wren[1], and Sarah Medoff-Wong[2]

1 Pacific Islands Fisheries Science Center, NOAA Fisheries, Honolulu, HI, USA. E-mail: Phoebe.Woodworth-Jefcoats@noaa.gov
2 Joint Institute for Marine and Atmospheric Research, University of Hawaii, Honolulu, HI, USA

More than half the tuna landed in the United States are caught by the Hawaii-based longline fishery and landings have steadily increased over the past decade as the fishery has moved into lightly exploited waters farther from Hawaii. These increased landings have led to the fishery reaching its regional quota in the late summer or early autumn with growing frequency. Yet despite the current trend, climate change is expected to reduce this fishery's yield over the long term. The current management framework in place for this fishery may not provide adequate incentives for the industry to consider seasonal or annual timing of catch. Therefore, we are interested in exploring alternative management strategies that would take environmental drivers of catch composition and economic performance into account, in turn allowing fishers to better time their catch and improve efficiency. For example, rights-based management alternatives could allow fishers to fish less in the spring when target catch rates are lowest, and focus efforts later in the year when catch rates are higher and seasonal demand peaks. Such a shift could also have ecosystem benefits as well, potentially shifting fishing effort to seasons and waters where catch rates of over-exploited species like striped marlin are lowest. We also present possible ecosystem-based metrics that could be used to place current catches in the broader context of climate change. Implementing such an approach could help limit projected climate-driven declines in this fishery's yield while simultaneously addressing contemporary concerns.

(S11-14119)

An evaluation of dynamic and static spatial management in a swordfish fishery: Balancing economic and bycatch concerns

James A. **Smith**[1,2], Desiree Tommasi[1,2], Michael Jacox[3], Elliot Hazen[1,3], Heather Welch[1,3] and Stephanie Brodie[1,3]

1 University of California Santa Cruz, Santa Cruz, USA. E-mail: jsmith35@ucsc.edu
2 NOAA Southwest Fisheries Science Centre, La Jolla, USA
3 NOAA Southwest Fisheries Science Centre, Monterey, USA

The dynamic distributions of many marine species complicate their spatial management. Management strategies for minimizing fisheries bycatch, for example, can include static closures during periods of high bycatch risk. But the changing distributions of both target and bycatch species can greatly affect the success of these closures, and dynamic ocean management (DOM) is considered a valuable alternative to static approaches. We conducted a simulation evaluating spatial management strategies for a U.S. swordfish fishery to: 1) quantify the impact of existing static closures on catch and bycatch; and 2) compare this impact to a multi-species DOM tool (EcoCast) used in the simulation to indicate bycatch risk. We found that using EcoCast instead of the static closures increased fleet-wide swordfish catch by 15-30%, while also achieving a reduction in turtle bycatch. The economic benefits varied greatly among fishing ports, depending on their proximity to closures. A clear advantage of DOM was that fishers could take better advantage of years with generally lower bycatch risk, through increased fishing opportunity and catches of target species. Because DOM was better able to redistribute fishing effort (rather than remove it), its performance was particularly sensitive to uncertainty in the expected presence and catchability of rare bycatch species.

(S11-13884)

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

National Taiwan Ocean University, Keelung, Taiwan (R.O.C). E-mail: mir19951224@gmail.com

Tuna are globally critical to fisheries because of their broad distribution and high market value. The yellowfin tuna *(Thunnus albacares*; YFT*)* is one of the most crucial tuna species. In this study, we analyzed records of YFT catch rates globally to determine the effects of climate indices on the monthly catch of YFT. Multiple regression indicated that multidecadal climate indices—the Atlantic Mulitdecadal Oscillation (AMO), North Pacific Gyre Oscillation (NPGO), and Pacific Decadal Oscillation (PDO)—were associated with the catch rate and longitudinal center of gravity of YFT. Two interannual climate indices, the Indian Ocean Dipole (IOD) and Oceanic Nino Index (ONI), were significantly correlated with the center of gravity of fishing grounds.

The climate indices pattern with the annual catch rate anomalies and percentage variation in the center of gravity had similar time period results to the wavelet analysis. The effects of the multidecadal climate indices AMO, PDO, and NPGO on the catch rate globally had approximately 4–8-year coherence from 1986–1991 until the end of the 2010s. However, the IOD and ONI exerted effects only in the western Pacific Ocean and Indian Ocean. This study provides preliminary insights into some of the climate indices driving the global abundance and migration of YFT and associated variability in fishery catches. In the future, we will attempt to integrate comprehensive data on YFT to perform more advanced research.

(S11-14182)

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

National Oceanic and Atmospheric Administration, Pacific Islands Fisheries Science Center, Honolulu, Hawai'i, USA
E-mail: johanna.wren@noaa.gov

The Hawai'i-based longline fishery is the 7th largest fishery by value in the US, with ex-vessel landings exceeding $100 million. The longline fleet operates across 13 million km^2 in the subtropical North Pacific Ocean. The majority of the fishery targets bigeye tuna, but only one-third of the catch consists of the target species. Catch composition varies with location and time of year and exhibits a long-term shift from larger species (i.e., tunas and billfishes) towards smaller species (i.e., pomfrets and mahimahi). Using data collected by fisheries observers over a 24-year time-series, we identify spatiotemporal changes in species associations of fisheries catch. Co-occurrence matrices, cluster, and network analysis methods allow us to identify specific associations with species of interest, as well as commercially valuable non-target catch. For example, in the northeast part of the fishing grounds, bigeye is often associated with pomfrets and mahimahi, while billfishes are caught together. To the south of Hawai'i early in the time series, we see multispecies networks, while during the latter part, associations are between bigeye and one other species. By better understanding which species are caught together, and in what area at what time of the year, managers and fishers can make informed decisions to optimize target species and commercially valuable catch while minimizing protected species interactions and bycatch discard. In addition, species co-occurrence in fisheries catch can shed light on potential environmental and ecosystem drivers of understudied species and allow us greater insight into the subtropical North Pacific ecosystem.

(S11-14275)

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

Desiree **Tommasi** and Barbara Muhling

University of California Santa Cruz and NOAA Southwest Fisheries Center, La Jolla, USA. E-mail: desiree.tommasi@noaa.gov

Catch limits for highly migratory species, such as tunas and billfish, in the North Pacific are based on stock status estimates that compare the current biomass and/or fishing mortality to benchmark levels defined by reference points. Reductions in harvest are required if current biomass exceeds these management thresholds with a specific probability. Such probabilities are computed by projecting the stock forward in time for a period of 10 years using current life history, current fishing mortalities, and future recruitment randomly sampled from historical levels and calculating the probability that biomass or fishing mortality would fall below a reference point. For stocks that are overfished (already below a reference point) the same projections are used to assess the probability of rebuilding to a pre-specified level. Climate, the environment, and ecosystem interactions can affect future stock productivity, and uncertainty in future recruitment is a major source of uncertainty in estimates of future stock status or rebuilding timeframes. For fish species with robust environment-recruitment relationships, integration of skillful multiannual climate predictions in projections of future stock biomass may help improve reliability of stock status and rebuilding estimates. Here, we use a recently published recruitment-sea surface temperature relationship for Pacific Bluefin Tuna and probabilistic multi-annual SST projections to 1) produce a 35-yr hindcast of recruitment forecasts and assess their probabilistic skill under varying levels of error in climate forecasts and the environment-recruitment relationship, and 2) compare probabilistic forecast skill of stock status and rebuilding probabilities computed when considering future climate information and when not.

(S11-14290)

Accounting for shifting distributions and changing productivity in U.S. marine fisheries management: Challenges and recommendations

Melissa **Karp**[1], Jay Peterson[2], Patrick Lynch[2], and Roger Griffis[2]

1 ECS Federal, LLC, Fairfax VA, 22301 on behalf of NOAA Fisheries, Office of Science & Technology, 1315 East-West Highway, Silver Spring MD, USA. E-mail: melissa.karp@noaa.gov

2 NOAA Fisheries, Office of Science & Technology, 1315 East-West Highway, Silver Spring MD, USA

There is growing evidence that the distribution and productivity of many marine fish and fisheries are changing in response to changing environmental conditions. Shifting species distributions and changing productivity may have significant impacts on the effectiveness of a variety of fishery management decisions including allocation of catch, spatiotemporal closures, stock status, and catch limits. Shifting distributions across management boundaries can make the process of fishery management particularly challenging. Fisheries managers are increasing interested in using climate and ecosystem data to develop proactive management strategies to address the effects of changing ocean and ecosystem conditions on the fisheries in their regions. A national working group of NOAA Fisheries scientists identified specific issues, needs, and recommendations to better understand and respond to shifting species distributions and changing productivity throughout the science-to-management process. These recommendations are provided under six key steps in the science-to-management process where increasing our capacity to account for these changes is important. These key steps include detecting and anticipating changes, understanding mechanisms of changes, evaluating priorities and risks, conducting assessments and developing forecast, communicating to managers, and taking management actions. Case studies from U.S. experiences with shifting distributions and changing productivity of marine species will be discussed in the context of these recommendations.

(S11-13911)

Regime shift and early warning signals of Atlantic cod and American plaice on Grand Bank off Newfoundland

Fan **Zhang**[1], Paul Regular[2] and Eric Pedersen[3]

[1] Fisheries and Marine Institute, Memorial University of Newfoundland, St. John's, NL, Canada. E-mail: fan.zhang@mi.mun.ca
[2] Northwest Atlantic Fisheries Centre, Fisheries and Oceans Canada, St. John's, NL, Canada
[3] Department of Biology, Concordia University, Montreal, QC, Canada

Ecological systems may shift to contrasting states under disturbance, which is often difficult to reverse even if external drivers return to conditions before disturbance. This type of hysteretic response is common to many fish populations that showed little signs of recovery after collapse. Based on case studies of Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) populations on Grand Bank off Newfoundland, we detected hysteretic response of their population states to climate and fishing effects. A Hidden Markov Model indicated that two regime shifts may have occurred in each of the two populations, around 1970 and 1990. The detected shifts towards lower population size and earlier maturation coincided with periods of high fishing pressure and cold ocean condition. We tested the performance of multiple early warning signals (e.g. variance, autocorrelation, skewness, kurtosis and heteroscedasticity), but each metric failed to predict the incipient regime shift. Therefore, cautions should be taken when applying early warning signals to indicate regime shifts of ecological systems, and more research should focus on mechanistic understanding of regime shifts.

(S11-14164)

A multi-model approach to better understanding the robustness of management of Pacific hake to environmental variability

Kristin N. **Marshall**[1], Isaac C. Kaplan[1], Kirstin Holsman[2], Grant Adams[3] and Nis Jacobsen[4]

[1] NOAA National Marine Fisheries Service, Northwest Fishery Science Center, Seattle, WA, USA
E-mail: kristin.marshall@noaa.gov
[2] NOAA National Marine Fisheries Service, Alaska Fishery Science Center, Seattle, WA, USA
[3] School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA
[4] National Research Council Research Associate at NOAA National Marine Fisheries Service, Northwest Fishery Science Center, Seattle, WA, USA

Management Strategy Evaluation (MSE) is one tool to examine how changing ocean conditions affect fisheries management. MSE explores the effects of uncertainty on the performance of management decision-making processes. Here, we use MSE to explore the consequences of structural uncertainty in the modeled dynamics of the most abundant groundfish in the California Current Ecosystem, Pacific hake. We approach this question using three operating models, 1) a single species spatial operating model with temperature-dependent movement of fish between the US and Canada, 2) a non-spatial single species operating model with prey- and temperature-dependent growth, and 3) a spatial end-to-end ecosystem model. We use simple scenarios to evaluate the consequences of changing temperature and prey dynamics on the performance of three harvest strategies: fixed fishing mortality, the default harvest control rule used for hake management, and a more precautionary harvest control rule. Performance is evaluated using metrics describing the status of the Pacific hake stock, average catch, and average annual variability in catch. Our results show that while ecosystem metrics are not strongly influenced by climate change, temperature-dependent changes in somatic growth could affect the performance of management strategies. This work demonstrates the utility of exploring multiple operating models in MSEs by showing that the robustness of the current management approach for hake to future climate depends on the assumptions used to model the response of the fish population to climate change.

(S11-13847)

Environmental indicators to reduce loggerhead turtle bycatch offshore of Southern California

Heather Welch[1,2], Elliott L. **Hazen**[1,2], Dana K. Briscoe[1,3], Steven J. Bograd[1,2], Michael G. Jacox[2,4], Tomoharu Eguchi[5], Scott R. Benson[6,7], Christina C. Fahy[8], Toby Garfield[5], Dale Robinson[1,9], Jeffrey A. Seminoff[5], and Helen Bailey[10]

1 Institute of Marine Sciences, University of California, Santa Cruz, Santa Cruz, CA 95064, USA. E-mail: heather.welch@noaa.gov
2 National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center, Monterey, CA 93940, USA
3 Stanford University, Hopkins Marine Station, 120 Oceanview Blvd, Pacific Grove, CA 93950 USA
4 National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Boulder, CO, 80305, USA
5 National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center, La Jolla, CA 92037, USA
6 Marine Mammal and Turtle Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Moss Landing, CA 95039 USA
7 Moss Landing Marine Laboratories, Moss Landing, CA 95039 USA
8 Protected Resources Division, West Coast Regional Office, National Marine Fisheries Service, Long Beach, CA 90802 USA
9 National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center, Santa Cruz, CA 95060, USA
10 Chesapeake Biological Laboratory, University of Maryland, Solomons, MD 20688, USA

Extreme climatic events are expected to become more frequent under current conditions of increasing global temperatures and climate variability. A key challenge of fisheries management is understanding and planning for the effect of anomalous oceanic conditions on the distributions of protected species and their interactions with fishing gear. Environmental indicators can serve as early warning signals that allow for proactive management responses before significant bycatch occurs. Marine heatwaves in the Pacific have caused shifts in the distributions of endangered loggerhead turtles (*Caretta caretta*), increasing overlap with California's Drift Gillnet fishery and thereby the risk of turtle bycatch events. To reduce bycatch, a fishery closure offshore of Southern California is enacted when an El Niño event has been declared. However, this regulation was based on qualitative assessment of a limited bycatch dataset. Providing a quantitative indicator could help to refine future decisions. Our objectives were to: 1) develop a suite of thermal indicators, and 2) hindcast closure scenarios based on these indicators to evaluate efficacy in terms of opportunity costs to fishers and turtle interaction avoidance. The best indicator was an SST anomaly derived indicator with closures enacted above a threshold of 0.77 °C. This result can improve upon the current closure guidelines by providing a quantified and spatially-explicit indicator. Our analysis seeks to demonstrate the feasibility of the explicit incorporation of an environmental metric into fisheries regulation, thereby aiding a movement towards fisheries management strategies that are responsive to climate variability and change.

(S11-14021)

The only constant is change: Incorporating socioecological variability into protected species management

Briana **Abrahms**[1], Hannah Blondin[2], Steven J. Bograd[1,3], Blake Feist[4], Mary Fisher[5], Arjun Hausner[6], Elliott L. Hazen[1,3] and Jameal Samhouri[4]

1 NOAA Southwest Fisheries Science Center, Monterey, CA, USA. E-mail: Briana.abrahms@noaa.gov
2 Stanford University, Palo Alto, CA, USA
3 University of California Santa Cruz, Santa Cruz, CA, USA
4 NOAA Northwest Fisheries Science Center, Seattle, WA, USA
5 Cornell University, Ithaca, NY, USA

Identifying management strategies for mobile species that account for environmental variability is crucial for supporting marine ecosystems that are both inherently variable and undergoing unprecedented change. Here we present two case studies on blue whales (*Balaenoptera musculus*), an Endangered species threatened by both ship strikes and entanglement with fishing gear in the California Current Ecosystem. Using fine-scale vessel movement data and a species distribution model derived from whale tag data, we show how intraannual and interannual variability in the physical environment, species distributions, and human activity patterns (cargo shipping and commercial fishing) dramatically alter the spatiotemporal patterns of human-wildlife conflict. We further quantify the potential for spatial management measures to reduce both the ecological vulnerability of whales and the social vulnerability of human industries under different environmental conditions. We find that dynamic management strategies can substantially improve the efficiency of management strategies for both biological and socioeconomic outcomes, particularly in anomalous environmental conditions such as marine heatwaves. These trade-off and scenario analyses are laying the foundation for how forecasts of oceanographic conditions, whale distributions, and human activities can be used to inform proactive, rather than reactive, ocean management approaches.

(S11-14022)

Assessing the vulnerability of marine life to climate change in the Pacific Islands Region

Donald R. Kobayashi[1], Jonatha Giddens[1,2,3], Mark Nelson[4] and Johanna **Wren**[1]

1 NOAA Fisheries Pacific Islands Fisheries Science Center, Honolulu, HI, USA. E-mail: donald.kobayashi@noaa.gov
2 Joint Institute for Marine and Atmospheric Research, University of Hawaii at Manoa, Honolulu, HI, USA
3 National Geographic Fellow, Washington D.C., USA
4 NOAA Fisheries Office of Science & Technology, Silver Spring, MD, USA

Our changing climate poses growing challenges for the effective management of marine life, ocean ecosystems, and the human communities that depend upon them. Which species are most vulnerable to climate change and where should science and management focus efforts to reduce these risks? To address these questions, the NOAA Fisheries Climate Science Strategy called for vulnerability assessments in each of NOAA's ocean regions. The Pacific Islands Vulnerability Assessment (PIVA) project assessed the vulnerability of 83 marine taxa to the impacts of climate change over a 37-year period (to 2055). In a Rapid Vulnerability Assessment framework, the PIVA project utilized expert knowledge, literature review, and climate projection models to synthesize the best available science towards answering these questions. Here we: (1) provide a relative climate vulnerability ranking across species; (2) identify key attributes and factors that drive this vulnerability; and (3) identify key data gaps in understanding and mitigating climate change impacts to living marine resources. The invertebrate group ranked as most vulnerable to climate change impacts, and pelagic and coastal groups ranked as least vulnerable to climate change impacts. Sea surface temperature, ocean acidification, and oxygen concentration were the three main exposure drivers of vulnerability. Early life history and settlement requirements were the most data deficient of all sensitivity attributes in the assessment. The sensitivity of many coral reef fishes ranged between Low and Moderate, which is likely an underestimate given that reef species depend on a biogenic habitat that is itself extremely threatened by climate change. Within its limitations, this project advances our understanding of the research needs and the management options to sustain both marine life and seafood security in the Pacific Ocean and beyond.

(S11-13945)

Incorporating climate, oceanographic and ecological change considerations into population assessments in Canada: A review and recommendations

Pierre Pepin[1], Jacquie King[2], **Carrie Holt**[2], Helen Gurney-Smith[3], Nancy Shackell[4], Kevin Hedges[5], Alida Bundy[4]

1 Northwest Atlantic Fisheries Centre, Fisheries and Oceans Canada, 80 White Hills Road, St. John's, NL Canada
2 Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Road, Nanaimo, BC, Canada
E-mail: Carrie.Holt@dfo-mpo.gc.ca
3 Saint Andrews Biological Station, Fisheries and Oceans Canada, 531 Brandy Cove Road, Saint Andrews, NB, Canada
4 Bedford Institute of Oceanography, Fisheries and Oceans Canada, 1 Challenger Drive, Dartmouth, NS Canada
5 Freshwater Institute, Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, MB, Canada

Ecosystem approaches to fisheries management (EAFM), where ecosystem variables are considered in management decisions for individual fisheries, are widely recognized as an important step towards ecosystem-based management. However, the incorporation of climate and ecosystem considerations into stock assessments and resulting management decisions are inconsistent across fisheries. We reviewed the use of climate, oceanographic and ecological considerations in Fisheries and Oceans Canada's stock assessment processes for 178 stocks. We evaluated whether climate, oceanographic and ecological information was considered in several ways: in the development of hypotheses or general context, through quantitative or qualitative analyses, and to inform the recommendations concerning current or future stock status. These ecosystem considerations appeared in hypotheses or general context in 46% of assessments; quantitative inclusions occurred in 21% of assessments while qualitative interpretations appeared in 31% of assessments; and 27% of assessments included them in the advice. Assessments of salmonids, invertebrates and pelagic taxa were more likely to make use of climate, oceanographic and ecological data than groundfish and elasmobranch. The influence of oceanographic factors and ecological interactions were considered more often than the effects of climate variables, although the latter were of particular importance in the Pacific and Arctic regions. We provide several recommendations to address Canada's challenges in achieving a nationally coherent, ecosystem-based responsible approach to managing for changes in climate, oceanographic and ecological conditions.

(S11-13850)

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**

Habitat and Ecosystem Process Research program, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, WA, USA. E mail: James.Thorson@noaa.gov

Oceanographers have spent decades developing annual indices that summarize physical conditions in marine ecosystems. Examples include the Pacific Decadal Oscillation, summarizing annual variation in the location of warm waters in the North Pacific, or cold-pool extent (CPE), summarizing the area with cold near-bottom waters in the eastern Bering Sea. However, these indices are rarely included in the species distribution models that are used to identify and forecast distribution shifts under future climate scenarios. I therefore review three interpretations of spatially varying coefficient models, explain how they can be used to estimate spatial patterns of population density associated with oceanographic indices, and add this option to the multivariate spatio-temporal model *VAST*. I then use a case-study involving bottom trawl data for seventeen fish and decapod species in the eastern Bering Sea 1982-2017 to answer: does a spatially varying coefficient model for CPE explain variation in spatial distribution for species in this region? and (2) does a spatially varying effect of CPE remain substantial even when local temperature is also included as a covariate? Results show that CPE and local bottom temperature are both identified as parsimonious by AIC for 13 of 17 species, jointly explain nearly 9-14% of spatio-temporal variation on average, and CPE does explain variation in excess of local temperature alone. I therefore conclude that spatially varying coefficient models are a useful way to assimilate oceanographic indices within species distribution models, and hypothesize that these will be useful to account for decadal-scale variability within multi-decadal forecasts of distribution shift.

(S11-14048)

Environmental effects on reproductive traits in cold/warm-water squids: Implications on catch fluctuation

Yumeng **Pang**[1], Chin-Shin Chen[2], Tomohiko Kawamura[1], and Yoko Iwata[1]

[1] Atmosphere and Ocean Research Institute, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8564, Japan
E-mail: yumeng.pang@aori.u-tokyo.ac.jp

[2] Institute of Marine Affairs and Resource Management, National Taiwan Ocean University, Keelung, 20224, Taiwan (R.O.C.)

Reproductive traits of coastal squids (mostly one-year life span) are influenced by environmental changes, which might lead to resource fluctuation. In the Sea of Japan, catch of cold-water squid (*Heterololigo bleekeri*) showed positive relationship with water temperature in spawning ground, while catch of warm-water squid (*Uroteuthis edulis*) in the opposite way. Those different responses to water temperature change might be associated with their reproductive traits. In this study, we compared reproductive traits of *H. bleekeri* and *U. edulis* to understand effects of water temperature on reproductive traits and consequently on their catch fluctuation. We sampled *H. bleekeri* in the Sea of Japan in 2017-2019, and *U. edulis* in the Sea of Japan and north coast of Taiwan in 2017-2018. Reproductive traits including oocytes number and size in the ovary, ova number and size in the oviduct were measured for mature females. The oocytes number was used as an index of the fecundity, and ova number as batch fecundity, respectively. In *H. bleekeri*, when water temperature was high, its fecundity was high with small oocytes, and batch fecundity was low with large ova. However, exactly the opposite reproductive traits of *U. edulis* were found in a warmer environment: fecundity was low with large oocytes, and batch fecundity was high with small ova. Therefore, as for a warmer spawning ground, great catch of *H. bleekeri* could benefit from higher fecundity level; while bad catch year of *U. edulis* in the Sea of Japan might result from lower fecundity.

(S11-14177)

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

Department of Marine Biology and Ecology, National Marine Environmental Monitoring Centre, Dalian, PR China
E-mail: xtyuan@nmemc.org.cn

Ocean acidification and warming are now identified as major threats for marine species and ecosystems. Sea cucumbers play an important role in ecosystem functioning (as ecosystem engineer) and the economy (fisheries), and hence their fate has been of concern in a changing ocean. Here, we evaluated the impact of ocean acidification and warming on the development of the sea cucumber *Apostichopus japonicus,* an ecologically and economically important holothurians in eastern Asian coast. Results showed that a 0.34 unit decrease in pH delayed the developmental time by prolonging the stage duration from auricularia to doliolaria. However, a 2.8 ºC increase in seawater temperature would eliminate the negative influence of pH decrease on the development. The transcriptional responses of the gene families related to skeletogenesis and biomineralization in early stages of *A. japonicus* were also tested under the above conditions, and showed a complex pattern. Our finding illustrated that seawater warming would minimize the harmful impacts caused by lowered seawater pH and sea cucumbers hence could survive in CO_2-induced ocean acidification and greenhouse warming at the end of the century.

(S11-13869)

Environmental determinants of spatiotemporal variability in salmon forage and its direct and indirect effects on salmon recruitment

Brian K. **Wells**[1], Whitney R. Friedman[2], and Megan Sabal[3]

1 Fisheries Ecology Division, SWFSC, NOAA Fisheries, Santa Cruz, CA, USA. E-mail: brian.wells@noaa.gov
2 National Center for Ecological Analysis and Synthesis, Santa Barbara, CA, USA
3 University of California Santa Cruz, Department of Ecology and Evolutionary Biology, Santa Cruz, CA, USA

It is believed that the first period at sea for salmon is a critical period during which the magnitude of recruitment is set. Recent work from the California Current demonstrates that variability in forage availability is related to early salmon survival. When available, lipid-rich salmon prey taxa promote improved condition and growth. The composition of the prey assemblage along the coast is linked to broad seascape conditions such as early upwelling and preconditioning of the shelf ecosystem. Typically, reduced stratification and nutrient introduction in late winter leads to robust krill populations and abundant lipid-rich forage fishes (e.g., rockfishes, sand lance) during spring when salmon emigrate to sea. The distribution of prey during spring is largely dependent on fine- and meso-scale processes such as those resulting from wind and transport dynamics interacting with coastal geography (e.g., upwelling shadows, fronts). Salmon foraging success and condition are dependent on the overall abundance of forage as well as its local accessibility. Fullness of salmon is dependent on forage abundance and is greatest in the vicinity of fronts and during recent periods of increased upwelling; both processes aggregate prey. Improved foraging opportunities increase salmon growth which may allow the salmon to escape predator gapes. Predation on juvenile salmon can have significant effects on recruitment especially during years when there is limited alternative forage. We provide a full life-cycle model that represents the sensitivity of recruitment of salmon to these dynamics.

(S11-14107)

Shifting distributions of fisheries for juvenile albacore in the eastern North Pacific

Barbara **Muhling**[1,2] and Desiree Tommasi[1,2]

1 University of California – Santa Cruz Cooperative Institute for Marine Ecosystems and Climate, San Diego, CA, USA
E-mail: Barbara.Muhling@noaa.gov
2 NOAA Southwest Fisheries Science Center, San Diego, CA, USA

Variability in the ocean environment can lead to distribution shifts in managed species. These movements can cause problems if stock assessment and management frameworks are not robust to changes in availability among different fleets. Here, we describe how distribution and migration paths of juvenile albacore (*Thunnus alalunga*) respond to decadal-scale oceanographic variability in the eastern North Pacific. Latitudinal shifts in favorable fishing areas for the U.S. and Canadian surface fleets in the California Current System have implications for transboundary management, and exploitation of a shared resource. In contrast, apparent longitudinal shifts in east-west migration patterns can cause large fluctuations in fishing costs for both fleets. This can limit the utility of albacore as an open access "insurance" fleet, which west coast fishers rely on when other species are depleted or subject to closures. Our results have relevance for the prediction of albacore movements across international boundaries, and for their effective management as climate change continues to result in novel environmental conditions in the North Pacific.

(S11-14085)

Prospects for environmental prediction of annual fishery range expansion and contraction: A case study in the Northwest Atlantic

Kisei R. Tanaka[1], Fernando G. Taboada[1], Charles A. Stock[2], Desiree **Tommasi**[4], Malin L. Pinsky[3], Vincent S. Saba[2] and Jorge L. Sarmiento[1]

1 Princeton University, Princeton, NJ, USA. Email: kiseit@princeton.edu
2 NOAA Geophysical Fluid Dynamics Laboratory, NJ, USA
3 Rutgers University, New Brunswick, NJ, USA
4 NOAA Southwest Fisheries Science Center, La Jolla, CA, USA

Fluctuations and trends in sea surface temperature (SST) drive major shifts in the spatial distribution of living marine resources (LMRs). Management strategies for many commercial fish stocks have lagged behind such biogeographical changes. Skillful forecasts of changing species distribution metrics could allow managers to formulate adaptive management strategies. We demonstrate that an empirical thermal-habitat model combined with multi-annual (1-5 year) SST anomaly predictions can skillfully forecast range expansions and contractions for numerous Northwest Atlantic fisheries over the period 1982-2017. Forecast skill was verified by comparing retrospective forecasts with historical survey-based species range estimates. The results showed that a simple, non-parametric SST-based range model can predict short-term changes in effective area occupied by species with an average correlation coefficient of 0.57 (SD 0.18) for 1-year lead forecast and 0.81 (SD 0.15) for average area occupied over the next 5 years. Forecasts were particularly skillful for species at the edges of the ranges which are at risk of extirpation or present opportunities for new fisheries. Our analysis supports the potential strategic utility of multi-year SST forecasts for the proactive management of shifting fish distributions in the data-rich Northwest Atlantic. We argue that the relative simplicity of the approach may also make it amenable to application in data-poor regions.

(S11-14455)

Dynamics of Pink Salmon (*Oncorhynchusgorbuscha*) abundance in the Tatar Strait rivers (Sea of Japan)

A.A. Dulenin and T.V. **Kozlova**

Khabarovsk branch of VNIRO, 680000, Russia, Khabarovsk, Amursky Blvrd, 13A, Russia. E-mail: uch_khvtinro@mail.ru

Pink salmon is the most abundant salmon species in the rivers of the western coasts of the Tatar Strait. This species is an object of commercial, sport and traditional (indigenous) fishing.

Pink salmon is a short life cycle species. Its abundance is vulnerable to meteorological and climate changes; therefore, this species has the most wide maximal and minimal abundant ranges among other Pacific salmon species.

During more than a century fishing period on the Tatar Strait rivers, pink salmon abundant and less abundant populations regularity is constantly changing, as well as a value of pink salmon returns to spawning streams.

For example, the maximum historical catch was recorded in 2016 - more than 10 thousand tons, the minimum in 2001 - 7.5 tons. The average catch value for more than a century of observations remains constant: 2430 ± 236 tons. However, we observe short periods of a steady growth of pink catches, as well as periods of catch decreases. Correlation to 11-year cycles of a solar activity is regarded as one of the reasons to catch fluctuations. Maximal catch values and Wolf number peaks are coincide in 80% frequency.

Local hydro meteorological conditions also influence pink salmon abundance.

Earlier we found that rivers of the northern and southern parts of the Strait have a different role in a pink salmon reproduction process. In common the most abundant pink approaches were observed in the mouth of the northern Tumnin river basin. We marked less abundant migrations of this species to the southern small coastal river basins. However, since 2010, there has been a decrease in pink salmon abundance migrating for spawning to the northern rivers. The Tumnin river spawning grounds are scarcely filled, number of juveniles are decreasing. The ratio of pink salmon migrating to spawning grounds in the Tumnin river has recently declined from 50 to 20 % from total pink abundance in the north-western part of the Tartar strait (for even-year populations).

A cyclical decline in pink stocks, exacerbated by an increased anthropogenic pressure is observed today.

SESSION 12
Impacts of meso-/submeso-scale processes on heat/material transport and on marine ecosystems

(S12-14431) INVITED

Submesoscale observations in the Northeast Pacific

Jody M. **Klymak**

University of Victoria, Victoria BC, Canada. E-mail: jklymak@uvic.ca

Oceanography is at an exciting time where numerical predictions and at-sea observations are approaching similar scales of resolution. This is an opportunity for synergy between the two approaches, but a challenge because traditional numerical parameterizations, developed for coarser models, need to be rethought as the resolution of models becomes finer. A particular challenge is accounting for processes that cause lateral mixing in the ocean, thought to be dominated by eddy stirring. The mixing acts on large-scale gradients on the scale of ocean basins, is driven by instability of the ocean currents, and finally cascades to turbulence at scales of centimeters, scales that will always be parameterized. This problem is important for predicting not just the heat and salt content of the ocean, but also biological tracers that are harder to include in data assimilation.

In this talk I outline efforts my group has participated in to observe both the processes that drive lateral mixing, and to quantify lateral turbulence using statistical approaches. Observationally, this is a difficult problem because the scales we measure are hard to cover quickly with a ship, and because the signatures of lateral stirring are often overwhelmed by internal wave signals. Our 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. I will also briefly discuss plans to augment these ship-based studies with glider observations on the west coast.

(S12-14352)

Glider observations of downwelling processes and zooplankton distributions in Clayoquot Canyon

Tara **Howatt**[1], Tetjana Ross[2] and Stephanie Waterman[1]

1 University of British Columbia, Vancouver, BC, Canada. E-mail: thowatt@eoas.ubc.ca

2 Institute of Ocean Sciences, Sidney, BC, Canada

Submarine canyons are often regions of increased biological activity due to enhanced mixing, upwelling, and other dynamic processes. However, few observational surveys of these processes have been conducted, especially during stormy downwelling seasons. A survey of Clayoquot Canyon conducted between January 30 and February 18 2017 using three autonomous underwater gliders provides highly resolved spatial-temporal information on temperature, salinity, oxygen, and zooplankton backscatter. The observed strong, northward current preconditions the region for downwelling, and a downwelling feature is observed at the head of the canyon. Further exploration into whether the downwelling feature is canyon–driven or eddy-driven will be discussed. Two storms were observed during this sampling period, the first storm resulted in a shoaling of the downwelling feature at the head of the canyon, the second storm had minimal effect. Vertically migrating zooplankton were limited to above the oxycline/pycnocline and similar shoaling patterns were observed in the zooplankton volume scattering strength, indicating that the physical processes in the region influence the distribution of zooplankton.

(S12-14159)

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

Vadim **Navrotsky**

V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, Vladivostok, Primorsky Kray, Russia. E-mail: vnavr@poi.dvo.ru

Complex structure of physical, biological, geomorphologic and other processes in the coastal ocean is defined, first of all, by bottom relief: steep continental slope and shelf boundary (outer shelf); maximum curvature at the shelf break (depths about 100-200 m); small bottom slope from the shelf break till the shoreline. Over the continental slope before the shelf break, all large-scale processes having vertical scale more than 200 m must transform and give up their energy to smaller-scale processes (eddies, internal waves, turbulence). As opposed to the deep ocean, in the shelf area, especially in the near-shore region (internal shelf) processes in the near-bottom layers can considerably affect internal processes. From the point of heat, momentum, and energy fluxes and their role in oceanic ecosystems the most important are interconnections between processes in outer and internal shelves. Besides tidal currents and eddies, the continuous flux of large-scale motions energy from the outer shelf to small-scale motions in the inner shelf is performed by internal waves (IW). Maximum of terrestrial material, including nutrients and contaminants, comes from land into near-shore waters and concentrates in sediments. IW and boluses in many cases have trapped cores of cold water from the coastal upwelling, and their breaking leads simultaneously to augmenting nutrients concentrations and to near-shore water ventilation. In our paper are presented theoretical and observational results of IW generation over the continental slope, their breaking and specific IW-turbulence interactions, revealed with the help of detailed spectral analysis of heat, momentum and energy fluxes.

(S12-14112)

Impacts of the Loop Current associated mesoscale processes on zooplankton communities in the northern Gulf of Mexico

Jillian Gilmartin and Hui **Liu**

Texas A&M University at Galveston, Galveston TX, USA. E-mail: liuh@tamug.edu

Mesoscale processes consist of the primary mechanism for dispersal of planktonic species in the ocean. The upper ocean mesoscale features in the Gulf of Mexico are primarily influenced by fluctuations in the spatial configuration and intrusion of the Loop Current, which irregularly sheds anticyclonic (warm core) and cyclonic (cold core) eddies in the region. While it is well known that the zooplankton abundance and distribution are tightly linked with ocean circulation, our knowledge on the relationship between zooplankton and the Loop Current associated mesoscale features in the northern Gulf of Mexico still remains insufficient. In this study we examined the spatio-temporal distribution of chaetognaths and zooplankton communities in terms of mesoscale oceanographic conditions in the northern Gulf of Mexico in 2015, 2016, and 2017. Copepods are dominant among the zooplankton communities, accounting for 49% to 91% of the total abundance. Higher zooplankton abundance and diversity appear in the region strongly associated with the Mississippi River plume, while the lower abundance occurs at stations within the Loop Current domain. Our findings show that salinity, dissolved oxygen, and distance to the Loop Current front are significant indicators of species-specific abundance of chaetognaths and zooplankton communities. This study highlights the importance of the Mississippi River plume, and Loop Current front on the distribution and abundance of zooplankton in the northern Gulf of Mexico.

(S12-14078)

Role of submesoscale circulations in vertical transport within and across the mixed-layer

Guangpeng Liu and Annalisa **Bracco**

School of Earth and Atmospheric Sciences, Georgia Tech, USA. E-mail: abracco@gatech.edu

We will discuss how vertical transport within/across the mixed-layer is affected by submesoscale circulations in coastal areas as function of mixed-layer depth and season. We will focus on the patterns of downwelling from the surface to the base of the mixed-layer and below, and from immediately below the mixed-layer upward, near the surface. Additionally, we will present results highlighting the submesoscale circulations' role in accelerating the sinking of particulates. We will do so using sediment trap data and comparing them to numerical simulations.

Our study would contribute to better understand how nutrients and plankton are distributed across the euphotic layer in various seasons in regions of elevated submesoscale and mesoscale activity.

(S12-14038)

Eddy yield in the North Pacific

Hiromichi **Ueno**[1], Isao Fujita[1], Tetjana Ross[2] and Carol Ladd[3]

1 Hokkaido University, Hakodate, Japan. E-mail: ueno@fish.hokudai.ac.jp
2 Fisheries and Oceans Canada, Sidney BC, Canada
3 Pacific Marine Environmental Laboratory, NOAA, Seattle, WA, USA

In the North Pacific, many eddies have been observed and named based on their formation area. For example, in the Gulf of Alaska, Haida, Sitka, and Yakutat eddies form off Haida Gwaii, off Sitka and off Yakutat, respectively. In this study, we discuss the relative contribution of each eddy formation area from the perspective of eddy-formation frequency and/or eddy lifetime using eddy dataset from January 1, 1993 to January 18, 2018 (~25 years). In this discussion we estimate "eddy yield", that is, the sum of lifetime of eddies formed in each 2°×2° box over 25 years divided by 25 years, as a way to statistically quantify the relative contribution of each eddy formation area. The geographical distributions of eddy yield were different from eddy formation rate in some areas, indicating that frequent eddy formation in an area does not always correspond to "important" eddy formation in an area.

(S12-14388)

Kuroshio variability and its relationship with mesoscale eddies in the southern East China Sea

Hanna **Na**[1], Hong Sik Min[2], Dong Guk Kim[2], Jae-Hun Park[3], Chanhyung Jeon[3], Hirohiko Nakamura[4], Ayako Nishina[4] and Xiao-Hua Zhu[5]

1 Seoul National University, Seoul, R Korea. E-mail: hanna.ocean@snu.ac.kr
2 Korea Institute of Ocean Science and Technology, Busan, R Korea
3 Inha University, Incheon, R Korea
4 Kagoshima University, Kagoshima, Japan
5 Second Institute of Oceanography, Hangzhou, China

The Kuroshio transports heat and material from south to north in the western North Pacific. Current velocity of the Kuroshio was observed in the southern East China Sea from June 2015 to June 2017. Based on the 2-year *in situ* observation data, Kuroshio transport was estimated and its temporal variability is examined associated with mesoscale eddy activity over the region. Stronger Kuroshio accompanied by offshore shift of the current axis is related to anticyclonic eddies on the eastern side of the observation line, whereas weaker Kuroshio accompanied by onshore shift of the current axis is associated with cyclonic eddies from the east. Temporally extended time series of the Kuroshio transport by using satellite altimetry data for longer than 20 years exhibits spectral peaks on 60–100 days, which is related to mesoscale eddy variability. It turns out westward propagating eddies from the North Pacific to the Ryukyu Island region modify Kuroshio transport depending on their size, strength, location, etc. Spatio-temporal characteristics of the eddies in the western North Pacific are discussed focusing on their relationship with the Kuroshio variability in the East China Sea.

(S12-14006)

Meridional heat transport variability induced by mesoscale processes in the subpolar North Atlantic

Xiaopei **Lin**[1], Jian Zhao[2], Amy Bower[2] and Jiayan Yang[2]

1 Physical Oceanography Laboratory/CIMST, Ocean University of China and Qingdao National Laboratory for Marine Science and Technology, Qingdao 266100, PR China. E-mail: linxiaop@ouc.edu.cn

2 Woods Hole Oceanographic Institution, Woods Hole, MA, USA

The ocean's role in global climate change largely depends on the meridional heat transport carried by the ocean circulation. Therefore, understanding the ocean processes responsible for the meridional heat transport (MHT) variability is a fundamental issue. Prevailing observational and modelling evidence suggests that MHT variability is primarily determined by the large-scale ocean circulation[1-3]. Here, using new *in-situ* observations in the eastern subpolar North Atlantic Ocean and an eddy-resolving numerical model, we show that energetic mesoscale eddies with horizontal scales of about 10-100 kilometers profoundly modulate MHT variability on time scales from intra-seasonal to interannual in the Iceland Basin. Our results reveal that the velocity change due to mesoscale processes in the subpolar ocean produce substantial variability for the MHT regionally (within sub-basins) and the subpolar North Atlantic as a whole. The findings have important implications for understanding the mechanisms for poleward heat transport variability in the subpolar North Atlantic Ocean, a key region for heat and carbon sequestration, ice-ocean interaction and biological productivity.

(S12-13917)

Water dynamics in the western Bering Sea and its impact on chlorophyll concentration and chum salmon abundance

Andrey G. **Andreev**[1], Maxim V. Budyansky[1], Gennady V. Khen[2], Michael Yu. Uleysky[1] and Sergey V. Prants[1]

1 Pacific Oceanological Institute, Vladivostok, Russia. E-mail: andreev@poi.dvo.ru

2 Federal Institute for Fisheries and Oceanography, Vladivostok, Russia

The water dynamics in the western Bering Sea are characterized by a significant seasonal and interannual variability. In January, the southwestern geostrophic current is related to the continental slope and anticyclonic movement of waters is observed on the shelf. In July, the surface flow is oriented to the northeast along the continental slope and cyclonic water movement prevails on the shelf. The formation of mesoscale anticyclones in late winter – early spring is due to the supply of low-temperature and low-salinity northern Bering Sea shelf water. The temporal variability of the direction and current velocity in western part of the Bering Sea during the summer period is associated with the wind and coastal upwelling. The presence of coastal upwelling and eddies should be considered as one of the factors leading to the formation of a region with a high concentration of chlorophyll along the shelf margin and creation of the favorable conditions for the chum salmon feeding in summer.

(S12-14346)

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

Pacific branch of Russian Federal Research Institute of Fisheries and Oceanography (TINRO), Vladivostok, Russia
E-mail: elena.ustinova@tinro-center.ru

This study focuses on the impact of mesoscale processes on saury (*Cololabis saira*), sardine (*Sardinops melanostictus*), and mackerels (*Scomber japonicus* and *Scomber australasicus*) fishery in the national and open waters against the backdrop of large-scale water circulation. The region of the Russian fishery of these subtropical migrants is characterized by strong mesoscale variability associated with the Oyashio branches, anticyclonic and cyclonic eddies, and related processes of frontrogenesis and frontolysis. The “Oceanography” and “Marine Biology” databases of TINRO R/Vs complex surveys, materials obtained by scientific groups in the fisheries expeditions, surface currents from the Ocean Surface Current Analyses Real-time (OSCAR) project and NEAR-GOOS gridded SST are used. In summer and autumn 2014-2018 significant part of the populations of these species migrated actively to the feeding area within the cyclonic Western Subarctic Gyre. Oceanographic TINRO surveys allowed us to estimate its general state during the pre-fishing and fishing season. In recent years the currents field of the Gyre consisted of several smaller-scale vortex formations, especially in the second half of summer. The characteristics of the subsurface layer and the state of the seasonal thermocline are also important to the fishery. So, the areas with gradient in the seasonal thermocline ≥0.19°/m are favorable for the formation of higher concentrations of feed phytoplankton and zooplankton. The delay and accumulation of shoals occurs in areas where the thickness of the upper mixed layer is sufficient for maneuvering schools of fish (≥6 m for saury and 10 m for sardines), as well as high feed plankton concentration.

(S12-13890)

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

Réka **Domokos**

Pacific Islands Fisheries Science Center, NOAA, USA. E-mail: reka.domokos@noaa.gov

The North Pacific Subtropical Frontal Zone seasonally aggregates economically important fish and protected species, considered in response to convergence and the prominent Transition Zone Chlorophyll Front (TZCF) via assumed bottom-up forcing. Our understanding of factors affecting TZCF dynamics is based mostly on largescale sea-surface data, but recent works indicate that mesoscale forcing and vertical processes might play an important role. The present study investigates the role of TZCF and another prominent front in the region, the Subtropical Front (STF), in micronekton characteristics that are the major forage for top predators that link primary productivity to top predators via secondary and tertiary consumers. Results indicate the importance of mesoscale variability from eddies and storms via horizontal Ekman transport and vertical mixing on frontal position and acoustically-derived relative micronekton biomass. Micronekton biomass peaked at the STF with differing composition to the south and north, with a northward extent relating to the position of the TZCF. Relative biomass of the shallow scattering layer (SSL) showed positive correlation to temperature of the epipelagic zone while the deep scattering layer primarily to the STF and secondarily to the TZCF. The large-scale 2014-2017 warming influenced micronekton composition and positively corresponded with its relative biomass. Results of this work highlight the importance of subsurface and mesoscale processes and the need to further our understanding of the role of micronekton in the region’s ecosystem to improve management of our living marine resources in a changing climate.

(S12-14291) CANCELLED

Yellow Sea Cold Water Mass multiple ocean process and their impacts on Pacific cod life history and Yellow Sea ecosystem

Jianchao **Li**[1], Feng Jiang, Rui Wu, Chi Zhang, Yongjun Tian*, Guangxue Li, Qinfeng Gao

[1] Ocean University of China, Fishery College, 5 Yushan Rd., 266003, PR China. E-mail: lijianchao@ouc.edu.cn

Yellow Sea as a representative shelf sea, its summer hydrological and hydrodynamic structure is dominated by a significant mesoscale process, Yellow Sea Cold Water Mass (YSCWM). And thanks to YSCWM, cold water fish such as Pacific cod could survive in this temperate ocean. However, the mechanism of its fluctuated resource is still unsolved issuse. The early life history of Pacific cod is greatly influenced by the forming of YSCWM and its accompanied ocean process. YSCWM boundary, near-inertial oscillation (NIO) and spatially different tidal current are key impact factors among them. And we carry out this contrast with otolith daily increment data from sampled Pacific cod juveniles during seasonal fisheries investigation. The boundary's spatial variation along the formation of YSCWM could impact the settling of juvenile Pacific cod. The NIO existing in the west cold core of YSCWM and strong tidal current provide ample dissolved oxygen and nutrients from upper mixed layer to the YSCWM below, making YSCWM still an adequate habitat for demersal cold water fish despite of stratification in summer. Meanwhile, the fortnightly spring tidal current can trigger the daily growth of Pacific cod, especially in the eastern cold core area. Besides, the formation and strength of YSCWM is originally related with the Yellow Sea Warm Current, which is also vital for the status of Pacific cod spawning ground. Therefore, the mesoscale structure and variation of YSCWM and its derived ocean process influence the local ecosystem environment, and further impact on the early life process of Pacific cod.

(S12-14178)

Diel vertical migration of zooplankton and micronekton on the northern slope of the South China Sea observed by a moored ADCP

Chenghao Yang[1], Dongfeng **Xu**[1], Zuozhi Chen[2] et. al.

[1] Second Institute of Oceanography, Ministry of Natural Resources, PR China. E-mail: xudongfengsio@sio.org.cn
[2] South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, 231 Xingang Road West, PR China

Acoustic Doppler current profiler (ADCP) echoes can be transformed into mean volume backscattering strength (MVBS), which is positively proportional to the biomass of zooplankton and micronekton. A mooring with an upward-looking 75-kHz ADCP was deployed on the northern slope of the South China Sea to monitor diel vertical migration (DVM) and vertical distributions of zooplankton and micronekton under general conditions and extreme conditions such as typhoons. DVM occurs throughout the year, with the maximum migrating speed reaching 9.0 cm/s. It had some cyclic variation, which was in response to marine environment and astronomical influence. Light initiates the ascents and descents of the migrators, and migration intensity may be proportional to the solar altitude. Neap-spring tidal cycle and full moon phase influences are prominent, and the peak at 112 d may be driven by variation of currents. In addition, 270 m is the demarcation between upward and downward migrations; some organisms living below this layer, especially zooplankton and micronekton, migrate to the surface to obtain nutrients and energy; other marine mesopelagic organisms also survive in this manner. Super and severe typhoons reduced vertical migration, having less influence on the deep scattering layer. As Super Typhoon Rammasun passed by the mooring station, current speed increases and temperature decreases were synchronous with changes in the deep scattering layer; the migrators swam downward to evade the influence of a higher-speed current rather than swam upward to compensate for the decrease of temperature.

(S12-14039)

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**[1], Alexander Ostrovskii[2], Alexander Lazaryuk[1], Vyacheslav Dubina[1], Svetlana Ladychenko[1], and Vyacheslav Lobanov[1]

[1] V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, Vladivostok, Primorsky Kray, Russia
E-mail: trolia@poi.dvo.ru

Infrared images from the NOAA and Suomi/NPP satellites, visible images from the COMS satellites, and CTD data from the moored Aqualog profiler deployed off the Primorye (Russian) coast in the northwestern Japan/East Sea were analyzed for the warm season 2015. The Aqualog data cover the depth range of 64–300 m, with the depth step of 1 m, and the period from mid April through mid October 2015, with the time step of 6 hours. Patterns observed from satellite imagery were linked to the Aqualog data in order to reveal vertical extent of surface mesoscale and submesoscale dynamic structures and accompanied thermohaline anomalies. Considered are the cases of the offshore excursion of the Primorye (Liman) Current in April, passage, from northeast to southwest, of a large anticyclonic eddy in late May – early June, offshore advection of coastal warm fresh water at this eddy rear edge, advection of subtropical water from the southwest, south, and east in late June through early September, and wind upwelling in October. Anomalies of temperature, salinity, density, and Brunt frequency linked to the surface dynamic structures were detected in the Aqualog data down to the depths of 100–150 m, with the exception of upwelling when these anomalies were detected down to the depth of 70 m only. The latter can be explained by the strong seasonal pycnocline persisting in the studied area in early October, despite the surface cooling. Waters of different origins also differ in bio-productivity, as revealed by COMS data.

SESSION 13
Implications of prey consumption by marine birds, mammals, and fish in the North Pacific

(S13-13928)

Development of a predation index to assess spatiotemporal variation in consumption of Walleye Pollock in the Gulf of Alaska

Cheryl L. **Barnes**[1], Anne H. Beaudreau [1], Martin W. Dorn [2], Kirstin K. Holsman [2], and Franz J. Mueter [1]

1 College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, USA. E-mail: cheryl.barnes@alaska.edu
2 Alaska Fisheries Science Center, National Oceanographic and Atmospheric Administration, Seattle, WA, USA

Predation can have substantial and long-lasting effects on the population dynamics of ecologically important prey. Diverse predator assemblages, however, may provide stabilizing (*i.e.,* 'portfolio') effects on prey abundance, as long as biomass or consumption rates vary asynchronously among predators. We developed an index of predation to quantify portfolio effects and better understand diversity-stability relationships in a system that has undergone considerable shifts in community composition. We selected Walleye Pollock (*Gadus chalcogrammus*) as our focal species because they comprise some of the largest and most valuable commercial fisheries while also serving as essential prey for a variety of taxa. Predation indices included spatially-explicit estimates of predator biomass, bioenergetics-based annual rations, and age-specific proportions of pollock consumed by five key groundfishes in the Gulf of Alaska (1990 to 2015). Arrowtooth Flounder (*Atheresthes stomias*) was, by far, the dominant predator – though asynchronous consumption among species and areas may have helped buffer intense top-down control on pollock. The degree of asynchrony, potential for portfolio effects, and estimates of community stability tended to increase from broad (*e.g.,* central subregion) to fine (*e.g.,* Chirikof and Kodiak statistical areas) spatial scales as well as throughout the time series. However, total consumption of pollock was highly variable and often exceeded assessment-based estimates of productivity for the Gulf of Alaska. We assert that relative changes in predation intensity can be used as a modifier of constant natural mortality, thereby providing a practical method for incorporating ecological information into single species stock assessments to improve estimates of biomass and yield.

(S13-13906)

Rorqual ingestion estimates for the Eastern North Pacific based on direct measures of feeding rates and prey quality

Matthew S. **Savoca**[1], Shirel R. Kahane-Rapport[1], Dave E. Cade[1], Max F. Czapanskiy[1], James A Fahlbusch[1,2], Paolo S. Segre[1], John Calambokidis[2], Douglas P. Nowacek[3], Dave W. Johnston[3], K.C. Bierlich[3], Julian Dale[3], Elliott L. Hazen[4], Ari S. Friedlaender[5], and Jeremy A. Goldbogen[1]

1 Hopkins Marine Station, Stanford University, Pacific Grove, CA, USA. E-mail: msavoca@stanford.edu
2 Cascadia Research Collective, Olympia, WA, USA
3 Duke University Marine Laboratory, Duke University, Beaufort, NC, USA
4 Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Monterey, CA, USA
5 Institute of Marine Sciences, University of California – Santa Cruz, CA, USA

As ecosystem engineers, rorqual whales have oversized impacts on marine food webs by ingesting vast quantities of low-trophic level prey while also aiding in nutrient cycling. However, evaluating the biomass of prey consumed by rorqual whales is challenging in large part because prey densities are difficult to quantify, lunge-feeding rates have been intractable to measure, and measuring both concurrently is extremely challenging. The majority of published estimates on rorqual prey consumption have been calculated via extrapolations of metabolic rate rather than by measuring foraging rates and prey concentrations directly. Using high-resolution biologging technology (130 deployments on humpback, fin, and blue whales), drone photogrammetry, and active acoustic prey mapping, we report estimates of prey consumption in four lunge-feeding rorqual species. Our results indicate prior estimates of maximum daily and annual consumption are likely underestimated by a factor of five. The implications of our findings are wide-ranging. This includes re-evaluations of the net primary productivity and krill biomass required to sustain rorqual whale populations in the California Current Ecosystem, the amount of nutrient recycling and redistribution (e.g. Fe, N, P) due to fecal deposition, and food-web interactions with other krill predators. These estimates increase rorquals' considerable ecological role in the Eastern North Pacific, and globally, particularly as their populations continue to recover from industrial whaling.

(S13-13878)

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**[1], Tsutomu Tamura[2], Takashi Hakamada[2], Koji Matsuoka[2], Hiroto Murase[3], and Toshihide Kitakado[3]

[1] National Research Institute of Far Seas Fisheries, Japan Fisheries Research and Education Agency, Yokohama, Japan
E-mail: hirosasaki@affrc.go.jp
[2] Institute of Cetacean Research, Tokyo, Japan
[3] Tokyo University of Marine Science and Technology, Tokyo, Japan

In 2016, the MBM workshop on "Consumption of North Pacific forage species by marine birds and mammals" recommended undertaking detailed analysis of prey consumption of sei, Bryde's and common minke whales. To estimate prey consumption in a spatial context, a reliable estimation of spatial abundance as a function of environmental covariates with an appropriate spatiotemporal scale is required. In 2017 and 2018, we applied a density surface model (DSM) to sighting data of sei and Brydes's whales to estimate abundance in a spatial context. This year, we applied a DSM to sighting data of common minke whale. The data were obtained in the Japanese Whale Research Program under Special Permit in the western North Pacific-Phase II (JARPNII) conducted in 2008 and 2009. The DSM consisted of two levels. At the first level, detection function (probability of detecting a school of common minke whale given its distance from the transect) was modeled with visibility and Beaufort scale as covariates. Density surface (*i.e.* spatial abundance estimation) was estimated using a generalized additive model (GAM). We used daily water temperature (derived from FRA-ROMS) and depth as covariates of GAM. We constructed GAM to estimate the amount of prey consumed by whales with the weight of main prey derived from the stomach contents sampling conducted in JARPN II as a response variable and the environmental covariates as explanatory variables. This result will be applied for assessment of predation impact by baleen whale species in the western North Pacific.

(S13-14037)

Daily food requirements of Steller sea lion, spotted seal and ribbon seal distributed along the coast of the Nemuro Strait, Hokkaido, Japan

Yoko **Goto**[1] and Andrew W. Trites[2]

[1] Wakkanai Fisheries Research Institute, Hokkaido Research Organization, Wakkanai, Japan. E-mail: goto-yoko@hro.or.jp
[2] Marine Mammal Research Unit, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada

Three species of pinnipeds (Steller sea lion, spotted seal, and ribbon seal) occur along the coast of Rausu, Nemuro Strait, Hokkaido, Japan during winter and spring. This Strait separating Hokkaido and Kunashiri Island is just 17 km at its narrowest point. Having several higher trophic level species living in such a limited area at the same time suggests this is a highly productive place during winter and spring. However, it also raises the question of how much are pinnipeds removing from the Nemuro Strait. We answered this using a new method to estimate food requirements of marine mammals (Trites, in prep), which we compared to a previous method (Perez et al. 1990). We also used pinniped biological data from research conducted in the 1990s for all three species, with the addition of data from research conducted in the 2000s for Steller sea lions. The average body weight used for calculation was 301 kg (1990s) and 286 kg (2000s) for the Steller sea lion, 132 kg for the spotted seal, and 129 kg for the ribbon seal. Daily requirements averaged 22.0 kg (1990s) and 21.2 kg (2000s) per Steller sea lion, 6.1 kg per spotted seal, and 6.0 kg per ribbon seal. These new values are ~13-17% higher than previous estimates and shows that the average Steller sea lion consumes ~3.5 times more than a seal, despite being just twice the size of a seal. The major prey consumed in Nemuro Strait is walleye pollock and other gadids.

(S13-14135)

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

Andrew W. **Trites**

Marine Mammal Research Unit, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada
E-mail: a.trites@oceans.ubc.ca

In general, smaller species of marine mammals have higher mass-specific energy requirements than bigger species (e.g., 4-5% for dolphins and 2-3% for large whales). However, closer inspection of energetic requirements of different sized species reveals that many consume significantly more or less than predicted by generalized models of consumption. This implies that the simple models currently used to determine daily rations are ineffective to estimate the food requirements of marine mammals, and that new means are required to yield better estimates of prey consumption. Using well-supported estimates of energy requirements for 28 species of marine mammals, I found the energy requirements of all pinnipeds and cetaceans can be predicted using three generalized equations that estimate consumption as a function of body mass and their costs of living (high, medium and low). The relationship between cost of living and food requirements likely reflects differences in evolutionary pathways that shaped predator-prey interactions and resulted in specialized and generalist foragers targeting high and low quality species of prey. These new equations that incorporate cost of living are superior to existing generalized equations that have been previously used to estimate energetic needs, and can be used to derive estimates of prey consumption for species of marine mammals with unknown energy requirements.

(S13-14045)

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

Szymon **Surma**

University of British Columbia, Vancouver, Canada. E-mail: s.surma@oceans.ubc.ca

Prey quality (energy content) is known to strongly affect both individual and population health in endothermic predators. Pacific herring is a forage fish supporting numerous marine mammal and seabird populations in the coastal Northeast Pacific. Moreover, its importance as prey is likely substantially enhanced by its high average energy content. Thus, ecosystem models based on energy rather than biomass may illuminate the importance of herring to endothermic predators in the Northeast Pacific. A mass-balanced food web model constructed in Ecopath with Ecosim for the marine ecosystem surrounding Haida Gwaii (an archipelago in the southeastern Gulf of Alaska) was utilized, together with published energy content for each model functional group, to generate a set of energy-balanced models. Predator diet compositions employed in these models were calculated by weighting the proportion of each prey by its energy content. Potential impacts of herring depletion on predator populations were then examined through parallel ecosystem simulations in mass- and energy-balanced models. Results suggest that dietary contributions of herring to numerous marine mammals (minke and humpback whales, dolphins and porpoises, seals, and sea lions) and piscivorous seabirds are likely underestimated when considered in terms of biomass. They also indicate that impacts of herring depletion on numerous marine mammals (humpback, fin, and minke whales, dolphins and porpoises, and sea lions) and piscivorous seabirds may be substantially stronger than suggested by mass-balanced model outputs. These findings demonstrate the potential for improved representation of endothermic predator foraging ecology through explicit inclusion of interspecific prey quality differences in ecosystem models.

(S13-14309)

Variability in the energy density of prey and its consequences for growth in juvenile Chinook Salmon

Jacob **Weil**, Will Duguid and Francis Juanes

University of Victoria, Victoria, BC, Canada. E-mail: juanes@uvic.ca

To understand how energy is transferred through organisms, the energy content or energy density (ED) of both consumers and prey must be determined. To ease ED measurement across taxa, we developed a model to estimate the ED of organisms with broad taxonomic, temporal and spatial coverage using percent ash-free dry weight (AFDW). AFDW was the superior predictor of ED relative to previous metrics for a broad range of taxonomic groups including aquatic invertebrates, aquatic vertebrates, aquatic plants and terrestrial invertebrates. We then apply the AFDW method to the diet of juvenile Chinook Salmon to determine the effect of variable prey ED on growth. To do so, we collected monthly zooplankton and fish samples of importance in the diet of juvenile Chinook Salmon to examine fine-scale taxonomic, temporal and spatial differences in ED. Decapod zoeae and megalopae differed from each other and showed family level variability in ED. Amphipods also showed species-level variability in ED. Temporal differences were observed, but did not reveal a consistent pattern among groups.

Spatial variability was not significant. Finally, we used bioenergetics models to assess the effect of using fine-scale ED on growth of juvenile Chinook Salmon. The difference between using coarse- and fine-scale estimates was not substantial on average, but in some cases represented more than a two-fold difference in growth over a 180day time period. These results highlight the importance of determining how processes at the fine-scale, such as energetic content, affect broader-scale patterns such as growth for early life history of fishes.

(S13-14274) INVITED

Ontogenetic shifts in the trophic role and consumption demand by Chinook salmon and Pacific herring in Puget Sound

David **Beauchamp**

U.S. Geological Survey, Western Fisheries Research Center, Seattle, WA, USA. E-mail: fadave@usgs.gov

The trophic role of fishes change through their ontogeny as does the magnitude of their consumption of various prey resources. In Puget Sound, Washington, USA, subyearling Chinook salmon enter the epi-pelagic marine habitat in June and feed heavily on larval crab during an approximately month-long critical growth period that strongly influences overall marine survival. Pacific herring and other juvenile salmon exhibit considerable diet overlap with Chinook during this critical growth period, and Herring consume greater than 10-fold higher biomass of the key shared prey than Chinook. The subyearling Chinook become progressively more piscivorous later in the summer and become important predators on Herring for the remainder of their foraging time in Puget Sound. Emigration by the ocean-bound component of the Chinook population out of Puget Sound is underway during September; however, approximately 30% of the population remains resident in or around Puget Sound for the remainder of marine life and continue feeding heavily on Herring throughout and seasonally on other prey fishes, crab larvae, and other invertebrates. The per capita and “population” level consumption rates of juvenile and resident forms of Chinook salmon in Puget Sound and Pacific Herring will be presented during ecologically-significant periods to quantitatively demonstrate the shifting roles and magnitudes of Chinook and Herring from competitors to predators and prey through the marine ontogeny of Chinook salmon.

(S13-14219)

Environmental drivers of variation in energy intake by Pacific bluefin tuna over 15 years

Gemma **Carroll**[1,2], Stephanie Brodie[1,2], Steven Bograd[2], Elliott Hazen[2], Rebecca Whitlock[3], and Barbara A. Block[4]

1 Institute of Marine Science, University of California Santa Cruz, Santa Cruz, CA, USA. E-mail: gemma.carroll@noaa.gov
2 Environmental Research Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Monterey, CA, USA
3 Institute of Freshwater Research, Swedish University of Agricultural Sciences, Drottningholm, Sweden
4 Hopkins Marine Station of Stanford University, Pacific Grove, CA, USA

Monitoring patterns of prey consumption by large vertebrate predators can give insight into variation in the abundance and quality of the forage base across space and time. Here we examine changes in energy availability in the California Current Large Marine Ecosystem through the lens of an apex predator, Pacific bluefin tuna (*Thunnus orientalis*). We first examine spatio-temporal variability in physical ocean conditions in the California Current from 2002 – 2017. We then use experimentally validated heat increment of feeding (HIF) values obtained from visceral temperature loggers to estimate patterns of daily energy intake by 242 bluefin tuna over the same period. We link the spatial distribution of tuna and their energy intake to dynamic ocean conditions over 15 years. We highlight the striking temperature anomalies in the California Current system in 2014 – 2016, and show that spatially-explicit energy intake by tuna was low in these years compared to the long term mean. However, tuna exhibited behavioural plasticity under anomalously warm conditions, shifting their distribution and migration timing to exploit northerly waters that are usually too cold to be accessible. Understanding the physical drivers regulating prey consumption is important for predicting both species-specific and ecosystem responses to environmental change in dynamic systems like the California Current.

(S13-14134)

Shifts in prey consumption by seals and sea lions in the North Pacific

Andrew W. **Trites**

Marine Mammal Research Unit, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada
E-mail: a.trites@oceans.ubc.ca

Seals and sea lions are an important component of the North Pacific ecosystem that consume many important commercials species of fish and invertebrates. Significant increases and decreases have occurred in pinniped numbers since the 1990s when prey requirements were last estimated (Hunt et al. 2000). However, changes in amounts consumed and the potential impacts on North Pacific ecosystems are unknown. I compiled recent (2010-2017) dietary information and population estimates in PICES sub-regions for 3 species of otarids (Steller sea lion, northern fur seal, California sea lion) and 6 species phocids (bearded seal, harbor seal, ribbon seal, ringed seal, spotted seal, northern elephant seal). I then applied new generalized models based on the cost of living for each species (low, medium and high; Trites unpubl. data) to predict the amounts of food that each consumed annually by region. Comparing these estimates with those from 35 years earlier shows 2-3 fold increases in amounts of prey consumed by pinnipeds between California and Southeast Alaska—and 2-3 fold decreases in consumption further north. These significant changes have implications for commercial and recreational fisheries, as well as for management of marine mammals.

(S13-14297)

Prey switching and consumption by seabirds in the central California Current upwelling ecosystem: Implications for forage fish management

Pete Warzybok[1], Jarrod A. Santora[2], David G. Ainley[3], Russell W. Bradley[1], John C. Field[4], Phillip J. Capitolo[5], Ryan D. Carle[6], Meredith **Elliott**[1], Jessie N. Beck[6], Gerard J. McChesney[7], Michelle M. Hester[6], Jaime Jahncke[1]

1 Point Blue Conservation Science, Petaluma, CA, USA. E-mail: pwarzybok@pointblue.org
2 Center for Stock Assessment Research, Santa Cruz, CA, USA
3 H.T. Harvey & Associates Ecological Consultants, Los Gatos, CA, USA
4 National Marine Fisheries Service, Santa Cruz, CA, USA
5 Institute of Marine Sciences, Santa Cruz, CA, USA
6 Oikonos Ecosystem Knowledge, Santa Cruz, CA, USA
7 U.S. Fish and Wildlife Service, Fremont, CA, USA

Effective ecosystem-based fishery management involves assessment of foraging interactions among consumers, including upper level predators such as marine birds and humans. Of particular value is information on predator energetic and consumption demands and how they vary in response to the dynamics of forage populations. We examined the prey requirements of common murre (*Uria aalge*), Brandt's cormorant (*Phalacrocorax penicillatus*), and rhinoceros auklet (*Cerorhinca monocerata*) in the central California Current over a 30-year period, 1986–2015. We developed a bioenergetics model that incorporates species-specific values for daily basic energy needs, diet composition, energy content of prey items and assimilation efficiency, and then projected results relative to stock size and levels of commercial take of several species. The most common forage species consumed were juvenile rockfish (*Sebastes* spp.), northern anchovy (*Engraulis mordax*), smelt (*Osmeridae*), and market squid (*Doryteuthis opalescens*). Total biomass of forage species consumed during the breeding season varied annually from 8500 to >60,000 metric ton (t). Predator population size and diet composition had the greatest influence on overall prey consumption. The most numerous forage species consumed in a given year was related to abundance estimates of forage species derived from an independent ecosystem assessment survey within the seabird foraging range. The energy density of dominant prey consumed affected predator energy expenditure during chick rearing and whether prey switching was required. Increased forage species take by predators, as revealed by seabirds, may be adding consumptive pressure to key forage fish populations, regardless of the potential additional impacts of commercial fisheries.

(S13-14032)

Estimation of prey consumption by marine mammals in the PICES regions - Update of Hunt *et al.* (2000)-

Tsutomu **Tamura**[1], Kenji Konishi[1], Koji Matsuoka[1] and Takashi Hakamada[1] and Andrew W. Trites[2]

1 Institute of Cetacean Research, 4-5 Toyomi, Chuo-ku, Tokyo 104-0055, Japan. E-mail: tamura@cetacean.jp
2 Marine Mammal Research Unit, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada

Hunt *et al*. (2000) estimated prey consumption for 135 species of seabirds and 47 species of marine mammals in the PICES region by some simple equations with estimated energy requirement based on a function of body mass. Recent abundance estimates and dependency of estimated value are needed for the assessment of the ecosystem in the PICES region. In 2016, S-MBM in PICES recommended that the Hunt *et al*. (2000) report be updated with data collected over the past 2 decades to answer the overarching question, "how much do marine mammals consume." In this study, the assessment of prey consumption by marine mammals in PICES region was based on 1) recently available abundance estimates of marine mammals (after 2000), 2) daily prey consumption rates of marine mammals estimated by simple models, 3) estimated biomass of cetaceans by use of average body weight and abundance, and 4) composition of prey species of marine mammals. These new results can be used to assess the feeding impact by marine mammals in the PICES region.

(S13-14212)

Assessing decadal changes in prey consumption by marine mammals and forecasting the impacts of marine mammals off western Canada

Caihong **Fu**[1], Thomas Doniol-Valcroze [1], Strahan Tucker[1], Jennifer Boldt[1], Norm Olsen[1], Yi Xu[2], Huizhu Liu[3], Philippe Verley[4] and Yunne-Jai Shin[4]

[1] Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia, V9T 6N7, Canada E-mail: Caihong.Fu@dfo-mpo.gc.ca
[2] Fisheries and Oceans Canada, Fraser and Interior Area, 3-100 Annacis Parkway, Delta, British Columbia, V8L 6A2, Canada
[3] Vancouver Island University, Nanaimo, Canada
[4] Institut de Recherche pour le Développement, UMR MARBEC (IRD, University Montpellier, Ifremer, CNRS), Montpellier, France

Marine mammals, including humpback whale (*Megaptera novaeangliae*), harbour seal (*Phoca vitulina*), Steller sea lion (*Eumetopias jubatus*), have been increasing in abundance over the past decades in waters off western Canada. It becomes increasingly important to evaluate the impacts of marine mammals on the dynamics of their prey species and the marine ecosystem. Individual-based spatially- and temporally-explicit ecosystem models, such as OSMOSE, are valuable tools for simulating predator-prey interactions within an ecosystem with the entire life histories of modelled species being explicitly modelled. In this study, using OSMOSE and incorporating the data recently collected on humpback whale, harbor seal, Steller sea lion, and their prey species such as Pacific herring (*Clupea pallasi*), we assess the historical consumption and predation mortality of prey species by marine mammals off western Canada. We also project forward for the next five and ten years, based on the current growth rate of marine mammals and potential future oceanographic conditions, to obtain the dynamics of modelled species and the future state of the ecosystem in terms of its biodiversity, resilience and productivity. This study provides insight for recommending fisheries management strategies that would achieve best trade-offs between economic benefit and ecosystem health.

(S13-14046)

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

Szymon **Surma**

University of British Columbia, Vancouver, Canada. E-mail: s.surma@oceans.ubc.ca

This paper employs mass-balanced ecosystem models constructed in Ecopath with Ecosim to evaluate prey consumption and competition with fisheries by Northeast Pacific marine mammals. The study area surrounds Haida Gwaii (an archipelago in the southeastern Gulf of Alaska). Three models were constructed representing ecosystem states in 1900, 1950, and currently. Each model estimated total annual prey consumption by marine mammals and consumption relative to prey production. Results suggest that marine mammals (particularly harbor seals, Steller sea lions, humpback whales, and small odontocetes) are currently important predators in the southeastern Gulf of Alaska, consuming substantial quantities of forage fish (notably herring), squid, krill, groundfish, and salmon. In 1950, due to whale depletion, pinnipeds accounted for most marine mammal trophic demands. In 1900, unexploited baleen whales appropriated notable amounts of forage fish and krill, as did sperm whales for squid and demersal fish, while pinniped trophic requirements were lower. Whale consumption of commercially fished species exceeded fisheries catch in 1900, unlike in 1950 or currently. Whales now appropriate more herring production than fisheries, as in 1900, due to strong humpback whale population recovery, while the reverse was true in 1950. Dynamic simulations of ecosystem impacts of whale prey consumption since 1950 indicate that whale competition with fisheries was limited to one herring stock. However, further baleen whale population recovery could intensify competition with herring fisheries, although this result is somewhat sensitive to simulated trends in future primary productivity. Furthermore, coming sperm whale recovery will likely yield competition with rockfish and sablefish fisheries.

SESSION 14
Integrating economic and social objectives in marine resource management

(S14-14390) INVITED

Integrating economic and social objectives in marine resource management: Australian experiences

Sean **Pascoe**, Toni Cannard, Natalie Dowling, Cathy Dichmont, Trevor Hutton

CSIRO Oceans and Atmosphere, St Lucia, Queensland, Australia. E-mail: sean.pascoe@csiro.au

Fisheries management is often characterised by the need to achieve multiple objectives. In Australia, this need is explicit, with most fisheries jurisdictions including the need to satisfy economic and social objectives as well as resource sustainability objectives when designing management or harvest strategies. These objectives are often poorly defined in the enabling legislation, creating challenges for managers, industry and other stakeholders, who often have different perceptions of what achieving these objective entails. In this paper, we outline recent attempts to integrate social and economic considerations when determining the most appropriate harvest and management strategy for two key Australian fisheries. One fishery is multisector, with the commercial, recreation and charter sector active participants in the decision process. The other is a multi-fleet, multi-species trawl fishery with a primary focus on achieving maximum economic yield. We use quantitative, qualitative and participative approaches to derive and measure objectives, assess management options and develop harvest strategies, taking into account the different objectives of the different stakeholder groups.

(S14-14093) (CANCELLED)

Using an open-access information platform and expert elicitation to prioritize management actions for salmon in the face of uncertainty

Charlotte **Whitney**[1], Katrina Connors[1,2], Eileen Jones[1], Eric Hertz[1], Katy Kellock[1], Lia Chalifour[3,4], and Tara Martin[3]

1 Salmon Watersheds Program - Pacific Salmon Foundation, Vancouver, BC, Canada. E-mail: cwhitney@psf.ca.
2 School of Environment and Sustainability, Royal Roads University, Victoria, BC, Canada
3 Department of Forest Science and Conservation, University of British Columbia, Vancouver, BC, Canada
4 Department of Biology, University of Victoria, Victoria, BC, Canada

In British Columbia (BC), the lack of centralized, standardized, and easily accessible information on the state of Pacific salmon populations, and threats to them, limits the ability to make informed, transparent, and evidence-based management and conservation decisions. In an effort to provide broader public understanding of salmon data in BC, the Pacific Salmon Foundation is developing a collaborative initiative to synthesize the best available information on salmon populations and their freshwater habitats in BC, and make these data publically available. Using an interactive data visualization platform called the Pacific Salmon Explorer (www.salmonexplorer.ca), we provide standardized, reproducible, and open-access information on a suite of biological indicators including assessments of current biological status. We couple these biological indicators with habitat assessments that quantify the geographic extent and intensity of both individual and cumulative pressures on freshwater salmon habitats. Our novel approach provides a timely synoptic overview of the status of salmon populations and the risks to their freshwater habitats in BC, while highlighting data deficient areas where more research is necessary. We provide an example from BC's Fraser River illustrating the application of this tool within a structured expert elicitation process called Priority Threat Management to identify management efforts that are most likely to lead to positive conservation outcomes for salmon. Overall, evidence-based decision-making relies on continuous, reliable, and informative data. We demonstrate how the synthesis, analysis, and sharing of decision-relevant information can be brought to bear on complex environmental problems that demand timely and pragmatic solutions.

(S14-14160)

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**[1], Daniel S. Holland[2] and Andre E. Punt[1]

[1] University of Washington, Seattle, WA, USA. E-mail: okenk@uw.edu
[2] NOAA Northwest Fishery Science Center, Seattle, WA, USA

Diversification of fishing portfolios of individuals, vessels, and communities can stabilize interannual variability of income at each level of organization. This portfolio effect is stronger when the populations within a portfolio respond in different ways to environmental changes. However, many modern management policies may be reducing the diversity of fishing portfolios as access to multiple permits becomes infeasible. A detailed understanding of these processes is limited by the complexity of the systems which makes experimentation impossible. Empirical research instead is correlative in nature or relies on "natural experiments" that quantify metrics before and after major changes occur. Here, we instead simulate fisheries linked by cross-participation, loosely based around Dungness crab (*Metacarcinus magister*), Chinook salmon (*Oncorhynchus tshawytscha*), and groundfish (Sablefish; *Anoplopoma fimbria*) fisheries on the U.S. West Coast, and explore the dynamics of the system under various ecological and regulatory scenarios. Specifically, we look at how access to multiple permits and population synchrony interact to influence revenue stability. Asynchronous population dynamics do stabilize revenue, but only when the biomass available to the fishery undergoes large year-to-year fluctuations. Increasing the number of vessels with access to multiple permits decreases their temporal revenue variability, but also decreases average revenue per individual as the same amount of biomass is divided among a larger group. Limited access fisheries have many ecological and social benefits, but in forcing individuals to commit to a smaller portfolio of fisheries, reduces individuals' resilience to declines in certain populations that may arise due to factors such as climate change.

(S14-14399)

How fisheries portfolio diversification can enhance social-ecological resilience along the Sanriku Coast of Japan

Raphael K. **Roman**[1,2], Tomoaki Goto[1] and Gakushi Ishimura[1,2]

[1] Iwate University, Morioka, Japan. E-mail: raphgenf@iwate-u.ac.jp
[2] National Institute for Environmental Studies, Tsukuba, Japan

Extreme events have been increasing in frequency and intensity over the last few decades, and Japan's coastal communities are particularly vulnerable to them. In 2011, the Great East Japan Earthquake and tsunami wreaked havoc along the Sanriku Coast, devastating local economies and negatively impacting the ecological balance and health of valuable marine ecosystems. The ensuing challenges remind us of how important building resilience in affected communities and natural ecosystems is to buffer against unpredictable risks. Dampening such risks can be accomplished by adapting and diversifying fisheries management strategies in the face of environmental and economic changes. Tapping into the unique features of Japanese multispecies fisheries, we investigated long-term species-specific catch and revenue patterns in the three prefectures that suffered the most in 2011, Iwate, Miyagi and Fukushima, and assessed the various social-ecological benefits of diversifying fishing opportunities. By considering each species as an "asset", we transferred the concepts of financial portfolio theory to ecosystem-based fishery management (EBFM), showing how species richness and composition, as well as inter-species symbiosis, could affect the performance of fisheries portfolios at the prefecture level. Looking at pre- and post-2011 earthquake figures, we identify and recommend catch diversification strategies to buffer against environmental and market fluctuations, deliver multiple benefits and enhance the resilience of unique social-ecological systems along the Sanriku Coast of Japan.

(S14-14386)

Infrastructuring big data of multi-species fishery catch for agile-up fishery strategy

Hiroaki **Sugino** and Nobuyuki Yagi

The University of Tokyo, Bunkyo-ku, Japan. E-mail: a-sugino@mail.ecc.u-tokyo.ac.jp

In Japan after the Great East Japan Earthquake, fish catch status has been temporally different from usual one and lost its trend which is critical for resource management. In such situation, smarter solutions aiming to give a decent quality of fish catch prediction have been called for. Recently, there is a trend of fish catch and resource stock prediction utilizing a huge data set with boosted computer calculation. However, mono-variate auto regression for one specific species cannot be well-utilized when the data lost its long-term trend. Also, the required data of landing markets in small regions is basically not appropriately aggregated for statistical analysis yet. Therefore, this research aims to 1) obtain a huge data set of multi-species fish catch by web scraping, and 2) analyze how each fish catch data is correlated with others in order to develop an alternative data infrastructure for adaptive strategy for fishery development. In this research, the landing markets in Iwate prefecture, Japan, were took as study targets. The multi-species fish catch data of each landing market was recurrently obtained throughout the internet. As an initial result of time-series clustering analysis and vector auto regression model, it was found that bluefin tuna(*Thunnus orientalis*)'s catch can be explained by several other species' catch data including Japanese horse mackerel(*Trachurus japonicus*), ocean sunfishes(*Mola mola*) and spear squid (*Lokigo bleekeri*). This research demonstrated that multi-species catch data enables detection of the latent but important information that is not recognizable if only one species catch data is analyzed.

(S14-14296)

Recent changes to the structure and function of the North Pacific albacore fishery

Timothy **Frawley**[1], Barbara Muhling[2], Gwendal Le Fol[2], Megan Cimino[1], Steven Bograd[1], Elliott Hazen[1] and Michael Jacox[1]

1 NOAA Southwest Fisheries Science Center, Monterey, CA, USA. E-mail: Tim.Frawley@noaa.gov
2 NOAA Southwest Fisheries Science Center, La Jolla, CA, USA

The North Pacific albacore fishery is an important component of diverse harvesting portfolios for many commercial fishers operating off the west coast of North America. As one of the last remaining open access fisheries, albacore represents an important 'insurance fishery', capable of absorbing effort when the productivity of other regional fisheries is limited by environmental change, resource scarcity and/or regulatory reform. Though by many accounts the target stock is considered robust and sustainably managed, in recent years changes in species distribution and market structure have had a significant impact upon fisheries operations by shifting the locus and means of production. Using diverse data sources (logbook entries, fisheries landings, vessel registration information and career-history interviews) we characterize recent ecological and economic trends across the albacore fishery and assess their distributional effects. Preliminary results indicate that whereas historic landings were dominated by large vessels operating out of California and Hawaii, in recent years small-boat fishermen in Oregon, Washington, and British Columbia have captured an increasingly large portion of resource revenues by targeting coastal waters, developing local markets, and minimizing operating costs. By describing the modern structure and recent evolution of the North Pacific albacore fishery, we intend to explore the links between marine resource licensing and allocation regimes, social-ecological change, and the resilience and adaptive capacity of coastal fishing communities.

(S14-13972)

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

The Ocean Policy Research Institute of the Sasakawa Peace Foundation, Tokyo, Japan.
E-mail: i-fujii@spf.or.jp or iwao.fujii.india@gmail.com

Capacity building is an essential element for the management of biodiversity in areas beyond national jurisdiction (BBNJ). Its potential providers include not only States, but also NGOs, which are highly represented at BBNJ intergovernmental conferences. However, what capacity building exists and what capacity building is needed remain unknown. This study examines the gap between providers and recipients to facilitate effective capacity building, with a focus on NGOs. Having studied nearly 50 NGOs that participated in the BBNJ conferences, this study revealed that about 80 % of them provided capacity building in a variety of forms ranging from workshops to joint research. Most of their efforts pertained to law, governance, or science. However, less than 10 % of them directly focused on the high seas. These results imply that NGOs have potential to strengthen the capacity of States in areas of law and science, for both of which there are capacity shortages among developing countries. The remaining task is how the skills and experience of NGOs can be applied to the high seas, bearing in mind the unique characteristics of BBNJ. Embracing the world's largest ocean, the Pacific region should build a strong network of NGOs through North-South cooperation. Furthermore, involvement of other sectoral bodies, such as PICES, would strengthen capacity building for the successful management of the high seas.

(S14-13877)

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

Yu-San **Han**

Institute of Fisheries Science, National Taiwan University, Taipei 10617, Taiwan. E-mail: yshan@ntu.edu.tw

The Japanese eel *Anguilla japonica* is an important aquaculture species in East Asian countries. Large-scale commercial artificial propagation of the glass eel is still unavailable, and so the fry used in aquaculture can only be obtained by capture in estuarine and coastal waters during their upstream migration. Before 1970s, the potential annual catch of Japanese glass eel could exceed 1000 tons. It has been declining significantly to only 20-30 tons per year nowadays. The rapid decline of the eel resource between year 1970 and 1990 is mainly due to river/estuary habitat destroy caused by industrialization of East Asia countries. After 1990s, the overfishing becomes an important cause for the continuously declining of the eel resource. The shortage of eel fry becomes the bottle neck of eel aquaculture industry. In response to this crisis, the Red List of IUCN listed *Anguilla anguilla* as a "critically endangered" species in 2010. In 2014, the Japanese and American eels were also listed in IUCN as an "endangered" species. In order to perform an effective resource management measure, better understanding the recruitment patterns of the glass eel is important. Here, we combine information from larval durations based on otolith increments, simulated drifting paths on the East Asian Continental Shelf, and main fishing seasons of the glass eel in each location of East Asia. We identify five main recruitment blocks: (1) The main Kuroshio, (2) The Taiwan Strait Warm Current, (3) The Taiwan Warm Current, (4) The Yellow Sea Warm Current and (5) The branch of Yellow Sea Warm Current. This study clarifies the eel's transport mechanisms in the East Asia Continental Shelf, providing important information for establishing suitable protection range.

Keywords: Japanese glass eel; larval duration; Kuroshio; recruitment; sustainability

(S14-13859)

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

Meng **Su**

College of Economics, Ocean University of China, Qingdao 266100, PR China. E-mail: sumengouc@qq.com

Jimo became a district of Qingdao in 2017, that is located in the east of the Qingdao and the southeast of the Shandong Peninsula. In 2016, the city ranked 9th among the top 100 counties in China. The eastern part of the city faces the Yellow Sea and encompasses 2517km^2, with a coastal extent of 183km. There are seven natural bays, 28 large and small islands, 15 fishing port docks in the area. Jimo user rights management has based on the fishery licenses system from the fishery input aspect, which certifies the type of operation, territorial area, the time limit, the quantity and the specifications of fishing gear, fishing species, etc. Fisherman's qualification certificate is a threshold for fishing production. There are also some other marine fishery management policies which support the user rights management. The rights-based approach has contributed to the sustainable use of resources, economic adaptability and social equity. However, there are still many challenges to face, such as the IUU fishing, policy conflict, and inter industry contradiction. Finally, we offered some recommendations for improving current fishery management practices. The output control will be taken to improve Jimo fishery management system in the future.

(S14-14314)

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

Pukyong National University, Busan, R Korea. E-mail: delaware310@pknu.ac.kr

The amount of catch in Korea has been decreasing since 1986. Especially, the catch amount of 2017 was only 54% of the catch in 1986. For the implementation of fisheries resources management policy, it is needed to evaluate stock level with a reliable model. Many studies have indicated that Bayesian state-space model could give relatively reliable results because it could reduce the uncertainty of process-error and observation-error. But stock assessment using Bayesian state-space model is still limited in Korea. This study is aimed to compare stock assessment models depending on how the models fit to the observed data for finding which model is relatively appropriate to estimate potential yield in the West Sea. Observation-error and Bayesian state-space model were conducted with the same catch-effort data of Korean Western coast fisheries which were already analyzed by Process-error, ASPIC, and Maximum Entropy model in the previous study for comparison. Analytical results showed that there was the least error between the estimated CPUE and the observed CPUE with Bayesian state-space model and consequently, the result of the Bayesian state-space model would be the most reliable. According to the Bayesian state-space model, potential yield of fishery resources in the West Sea in Korea was estimated to be 231,949 ton per year. However, the results also showed that the fishery resources of the West Sea have been decreasing since 1967. The amounts of stock in 2013 were assessed to be only 36% of the Bmsy level.

SESSION 15
Advances in North Pacific marine ecosystem prediction

(S15-13948) INVITED

Seasonal-interannual prediction of sea surface height using an ocean-atmosphere dynamical model "SINTEX-F"

Takeshi **Doi**, Masami Nonaka, and Swadhin K. Behera

APL/VAiG/JAMSTEC, Yokohama, Japan. E-mail: takeshi.doi@ jamstec.go.jp

Extreme sea level rise seriously impacts the habitation and processes of primary production. In addition to the rising sea level trend owing to the global warming, extreme sea level events are shown to be influenced by the El Nino/Southern Oscillation (ENSO), the ENSO Modoki and the Indian Ocean Dipole (IOD) on global as well as regional scales. To reduce the risks, therefore, skillful seasonal-interannual forecast of sea level is necessary.

Some previous studies already applied dynamical coupled ocean–atmosphere models for the prediction of seasonal sea level anomalies globally for up to 7 months in advance. They showed that the prediction skill is derived from the models' ability to predict ENSO. The prediction skill drops outside of the oceanic waveguides of the equatorial Pacific region.

In this study, we have revisited the predictability study trying to access the seasonal sea level anomalies up to 24 months in advance by a dynamical coupled ocean–atmosphere model "SINTEX-F". We newly found that 1) it is skillful to predict regional sea level anomalies up to about 18-month ahead in a region in the North Pacific (30-40N, 180W-160W), and 2) sea level prediction skill is higher relative to that of sea surface temperature (SST) at least for some regions and for some seasons. This suggests that sea level prediction should be considered as a new type of information with better prediction skills beyond the common climate prediction information such as SST.

We will also introduce and compare the skills of the newly developed seasonal prediction system "SINTEX-F2" for the sea level prediction.

(S15-14276)

Seasonal forecast skill for the Bering Sea cold pool

Kelly **Kearney**[1,3], Al Hermann[1,2], Wei Cheng[1,2], and Kerim Aydin[3]

1 University of Washington, Seattle, WA, USA. E-mail: kelly.kearney@noaa.gov
2 NOAA Pacific Marine Environmental Laboratory, Seattle, WA, USA
3 NOAA Alaska Fisheries Science Center, Seattle, WA, USA

The formation of seasonal sea ice in the Bering Sea leaves behind a footprint of cold, dense bottom water that persists through the early summer months. This "cold pool" is associated with high nutrient concentrations and productivity, and can influence the spatial distribution and recruitment of higher trophic level species, including key commercial target species. A metric of the cold pool's extent (cold pool index) is part of the Ecosystem Status Report (ESR) for Bering Sea groundfish and crab fisheries. It is presented to the North Pacific Fisheries Management Council annually (during the fall) immediately prior to quotas being set for the following year; as the cold pool has a noted biological relationship with groundfish and crab recruitment, its forecast has been used alongside other ESR indicators for determining appropriately-precautionary quotas that take into account anticipated biological production.

The cold pool index mentioned above is calculated using a regional ocean model for the Bering Sea (i.e. the Bering10K ROMS model). When constrained by historical surface heat and freshwater fluxes, the model has shown considerable skill in reproducing summer bottom temperatures across the Eastern Bering Sea shelf. But does this translate into the short-term forecast skill needed to be useful for fisheries management purposes? Here, we present the preliminary results of a short-term forecast skill assessment, using a series of seasonal (1- to 9-month) retrospective forecasts over the period of 1982-2016.

(S15-14301)

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**[1], Samantha Siedlecki[2], Isaac Kaplan[3], Albert Hermann[1,4], Jennifer L. Fisher[5], Cheryl A. Morgan[5], Suzanna Officer[6], Casey Saenger[1], Simone A. Alin[4], Jan Newton[7], Nina Bednarsek[8] and Richard A. Feely[4]

1 Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA. E-mail: emilyln@uw.edu
2 University of Connecticut, Storrs, CT, USA
3 Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle WA, USA
4 Pacific Marine Environmental Laboratory, NOAA, Seattle, WA, USA
5 Cooperative Institute for Marine Resources Studies, Oregon State University, Newport, OR, USA
6 Whitman College, Walla Walla, WA, USA
7 Applied Physics Laboratory, University of Washington, Seattle, WA, USA
8 Southern California Coastal Water Research Project, Costa Mesa, CA, USA

The Dungeness crab (*Metacarcinus magister*) fishery is consistently one of the highest value fisheries in the US Pacific Northwest. Although adult crabs are demersal, their pelagic larvae encounter a range of ocean conditions during their dispersal period. Because environmental exposure history is important for some pelagic organisms and recent field studies show impaired condition of megalopae in their natural habitat, we hypothesized that exposure history affects the occurrence of *M. magister* megalopae. We combined observations of megalopae and simulated ocean conditions to model megalopae occurrence using generalized linear models (GLM). The modeled ocean conditions were extracted from J-SCOPE, a high-resolution coupled physical-biogeochemical model. The extracted environmental variables had been identified in the literature as being important for larval crabs: temperature, salinity, dissolved oxygen concentration, nitrate concentration, phytoplankton concentration, aragonite and calcite saturation state, and pH. GLMs were calibrated with either *in situ* conditions or environmental exposure histories from particle tracking experiments. We found that inclusion of exposure history significantly improved the ability of the GLMs to predict megalopae occurrence. Of the five swimming behaviors used to simulate megalopae-like dispersal, more than one behavior generated GLMs that fit the observations best, so a biological ensemble of these models was created. The biological ensemble identified several significant predictors of megalopae occurrence. These results highlight the importance of including exposure history in larval occurrence modeling, and this work is a step toward quantifying pelagic megalopae occurrence to build a forecast tool for the fishery.

(S15-13978)

Skill and uncertainty of environmentally driven forecasts of Pacific hake distribution

Michael J. **Malick**[1], Mary Hunsicker[2], Melissa Haltuch[1], Sandy Parker-Stetter[1], Isaac Kaplan[1], Aaron Berger[2], Samantha Siedlecki[3], Nicholas Bond[4], Albert Hermann[4], and Emily L. Norton[4]

1 NOAA Northwest Fisheries Science Center, Seattle, WA, USA. E-mail: michael.malick@noaa.gov
2 NOAA Northwest Fisheries Science Center, Newport, OR, USA
3 Department of Marine Sciences, University of Connecticut, Groton, CT, USA
4 Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA

Changing ecosystem conditions present a challenge for the monitoring and management of living marine resources, where decisions are often made with lead-times of weeks to months. Improvements in the skill of regional ocean models to predict physical ocean states at seasonal time scales provides opportunities to develop early warnings of the biological responses to changing environments and distribution shifts that impact fishery management practices. In this study, we illustrate how regional ocean model predictions can be used in an ecological context using Pacific hake (*Merluccius productus*) summer distribution in the California Current Ecosystem. We used the J-SCOPE regional ocean model to develop 6-8 month lead-time forecasts of thermal conditions at depth, which were then used to force environmentally driven species distribution models for Pacific hake. Using retrospective skill assessments, we show good agreement between hake distribution forecasts and historical observations. Finally, we discuss the utility of using seasonal lead-time ocean predictions in an ecological context to address research questions that can inform current resource management.

(S15-14133)

Marine heatwave of sea surface temperature of the Oyashio region in summer since 2010

Toru **Miyama**[1], Shoshiro Minobe[2] and Hanako Goto[2]

1 Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan. E-mail: tmiyama@jamstec.go.jp
2 Hokkaido University, Sapporo, Japan

The sea surface temperature of the Oyashio region in boreal summer has abruptly increased from 2010. Observations and reanalysis data using an ocean prediction model in JAMSTEC show that this marine heatwave occurred not only at the surface but also at greater depths. Downward air-sea heat flux is not a major factor because the increase of the heat flux did not collocate with the SST increase and cannot explain subsurface warming. Salinity in summer also increased in parallel with the temperature in the Oyashio region. The rises in the temperature and salinity suggest the strengthening of the Kuroshio influence. The sea surface height and the velocity show that the first intrusion of the Oyashio in summer weakened from 2010 because of the stronger anticyclonic warm eddy. The rise of the water temperature may have affected an abrupt increase of yellowtail, a warm water fish species, around northern Japan. Thus, predicting changes of balance between Oyashio and Kuroshio influences is essential for ecosystem and fisheries in the western North Pacific Ocean.

(S15-14004)

The impact of atlantic multi-decadal oscillation on the North Pacific subtropical mode water

Baolan **Wu**[1], Xiaopei Lin[1] and Lisan Yu[2]

1 Physical Oceanography Laboratory/Institute for Advanced Ocean Studies, Ocean University of China and Qingdao National Laboratory for Marine Science and Technology, Qingdao 266100, PR China. E-mail: wubaolan@stu.ouc.edu.cn
2 Department of Physical Oceanography Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA

North Pacific Subtropical Mode Water (mode water hereafter) is a vertically homogeneous thermocline water mass, formed in the south of the Kuroshio Extension and occupying the whole subtropical Western Pacific Ocean. It transports mass, heat and nutrient from surface into subsurface ocean and provides memory of climate variability for climate prediction. Previous studies attributed decadal variability of the mode water to the Pacific Decadal Oscillation (PDO). Using available observations and reanalysis data, here we show that decadal to multi-decadal variability of the mode water mean temperature is controlled by the Atlantic Multi-Decadal Oscillation (AMO) rather than the PDO. During the AMO positive phase, warm sea surface temperature (SST) in the north Atlantic Ocean weakens the subtropical North Pacific westerlies by inducing anomalous easterlies in the subtropical west Pacific, which produce an enhanced northward Ekman transport of warm water into the Kuroshio Extension. This increases the mode water mean temperature through a subduction process and controls the upper-layer ocean heat content as well as the fish catches variability in the Northwestern Pacific. This mechanism is supported by a long-term pre-industrial model simulation and a pace-maker model experiment. Our finding suggests that the AMO is an important forcing of decadal climate and ecosystem variability and memory of prediction in the Kuroshio Extension region.

(S15-14061)

Climate variability patterns and their ecological effects on ecosystems in the northwestern North Pacific

Shuyang **Ma**[1], Yongjun Tian[1,2], Jianchao Li[1], Haiqing Yu[1], Jiahua Cheng[3], Caihong Fu[4] and Yoshiro Watanabe[1,5]

1 Fisheries college, Ocean University of China, Qingdao, PR China. E-mail: mashuyang1992@163.com
2 Laboratory for Marine Fisheries Science and Food Production Processes, Pilot National Laboratory for Marine Science and Technology, Qingdao, PR China
3 East China Sea Fishery Research Institute, Chinese Academy of Fishery Sciences, Shanghai, PR China
4 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, Canada
5 Atmosphere and Ocean Research Institute, University of Tokyo, Chiba, Japan

It is widely known that the Aleutian Low forced Pacific Decadal Oscillation (PDO) is the leading pattern of interannual-decadal climate variability in the North Pacific (NP) with considerable ecological effects on marine ecosystems especially in the central-northeastern NP. However, previous studies suggest that there may be different climate-ecosystem linkages in the northwestern NP in comparison with the central-northeastern NP. Unraveling the ecological effects of potential climate variability patterns in the northwestern NP is vital for forecasting ecosystem variations and ecosystem-based management. For this purpose, we integrate multiple time-series data involving biology, oceanography and climatology in the China Seas, Sea of Japan and Kuroshio Current region to identify potential climate variability patterns and their crucial effects on ecosystems in the northwestern NP. Our results show that, compared with the PDO, the Siberian High, El Niño-Southern Oscillation, East Asian Monsoon (EAM) together with Arctic Oscillation (AO) achieve higher correlations with regional sea surface temperature, inducing great ecological responses. In particular, a climatic regime shift indicated by the AO and EAM in the late 1980s led to the simultaneous abrupt ecosystem shifts. It reveals that the AO and EAM play vital roles on the regional thermal variability in the northwestern NP and then have critical effects on ecological variability in the species-, community- and ecosystem-levels. The relatively robust AO/EAM-ecosystem relationship would benefit ecosystem forecast targeting on the northwestern NP under future climate scenarios. This study facilitates the understanding of the different responses between ecosystems in the northwestern and central-northeastern NP to basin-scale climate variability.

(S15-14321)

Basin-scale Relations between Marine Ecosystem Indices and Physical Environment in North Pacific

Shoshiro **Minobe**[1,2], Emiyati[1,6], Nathan Mantua[3], Shin-ichi Ito[4], Emanuele Di Lorenzo[5]

1 Department of Natural History Sciences, Graduate School of Science, Hokkaido University, Japan. E-mail: minobe@sci.hokudai.ac.jp
2 Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University.
3 Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanographic and Atmospheric Administration, California 95060, USA
4 Atmosphere and Ocean Research Institute, University of Tokyo
5 School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia, USA
6 Remote Sensing Application Center, Indonesian National Institute of Aeronautics and Space, Indonesia

To understand how marine ecosystem varies and how that variability is related to physical climate conditions, it is useful to conduct a multivariate analysis using large number (several tens) of marine ecosystem indices (e.g., Hare and Mantua 2000) and this type of analysis is referred to as large multivariate analysis (LMA). In this study we conduct a LMA for the marine ecosystem for whole North Pacific, for the first time to the authors' knowledge, using the marine ecosystem indicators both in the eastern and western side of the basin. The main analysis method is Empirical Orthogonal Function (EOF) of marine ecosystem indicators and the relation of the marine ecosystem EOFs and physical climate condition is examined. The EOFs are calculated for marine ecosystem indicators in the western and eastern basin separatory or combined. The results indicate that the first EOF mode is characterized by a long-term trend, irrespective of the EOF domain. The second mode varies on multi-decadal timescale in the eastern North Pacific, and on somewhat shorter timescale in the western North Pacific. It appears that the first mode is related to the overall warming over the North Pacific, but the second modes are closely related to decadal climate modes, i.e., the Pacific (inter-)Decadal Oscillation and North Pacific Gyre Circulation modes. The implications of the present results for marine ecosystem predictability will be discussed.

(S15-13862)

Applying empirical dynamic modelling to identify intraspecific spatial scales of dynamics and improve in-sample predictability in the CalCOFI ichthyoplankton survey

Peter T. **Kuriyama**[1,2], Brice X. Semmens[2] and George Sugihara[2]

1 Southwest Fisheries Science Center, La Jolla, CA, USA. E-mail: peter.kuriyama@noaa.gov
2 Scripps Institution of Oceanography, La Jolla, CA, USA

Empirical dynamic models are a group of equation-free models that provide accurate out-of-sample predictions and identify causal relationships in marine and terrestrial ecosystems. These methods can identify nonlinear relationships for chaotic systems in which time series may appear to be uncorrelated. Here, we apply simplex and s-map prediction to the California Cooperative Fisheries Investigation (CalCOFI) survey data to identify intraspecific shared dynamics across space. The CalCOFI survey is among the longest running oceanographic surveys in the United States, and the original intent of the survey was to better understand the collapse of Pacific sardine populations in the 1940s. Specifically, we seek to identify the spatial scales of dynamics, and quantify improvements of in-sample forecast skill that leverage identified spatial dynamics. We found that for species like northern anchovy and Pacific hake, EDM methods identified shared dynamics that improved in-sample forecast skill. Correlation identified a greater number of related stations, but in some cases decreased in-sample forecast skill. We conclude by discussing future research identifying causality between ichthyoplankton and physical covariates like sea surface temperature and improving out-of-sample forecasts.

(S15-14406)

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

Albert J. **Hermann**

Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA
E-mail: albert.j.hermann@noaa.gov

While coupled global models of the atmosphere and ocean have demonstrated significant skill in predicting broad-scale SST patterns on seasonal timescales, they typically lack the fine resolution necessary to capture biophysical details which strongly impact fish recruitment (for example, regional prey biomass and regional subsurface temperatures). Dynamical downscaling - the use of coarse-scale global predictions to force fine-scale regional dynamical models - can be used to bridge this gap, and to generate useful predictions for biogeochemical variables not included in the global simulations. However, the computational expense of dynamical downscaling has strongly limited its wider use. Indeed, at present, readily available ensembles of coarse-scale global output are far larger than what can be affordably downscaled. Given this computational barrier, statistical relationships derived from a limited set of downscaling output can be used as a proxy to generate a much larger ensemble of regional predictions from the global forcing. Here we review several related hybrid statistical-dynamical methods to expand dynamically-generated regional ensembles on both seasonal and multi-decadal timescales. These methods are based on dominant spatial/temporal correlations between the global forcing and the regional response, and can include correlations across different biophysical variables. Depending on the spatial and temporal scale of the target predictand, time-lagged correlations may be a crucial element in these hybrid methods. Examples include the use of hybrid methods for projecting the short- and long-term future of the Bering Sea cold pool, a feature with strong connections to major fisheries of the Bering Sea.

(S15-14425) INVITED

Exploring the determinants of ecological predictability

Stephanie **Brodie**[1,2]

1 Institute of Marine Science, University of California Santa Cruz, Monterey, California, USA
2 Southwest Fisheries Science Centre, National Oceanic and Atmospheric Administration, Monterey, California, USA
E-mail: sbrodie@ucsc.edu

The development and application of ecological forecasts have greatly increased in recent years. Ecological forecasting and predictability are often reliant upon empirical statistical modelling. With a myriad of model types, methods, and parameterization options available, it is challenging to make informed decisions about how to build robust models appropriate for ecological prediction. One clear first step is to identify what role the environment plays across different temporal scales of ecological prediction. Using two case studies from the North Pacific, this talk explores the attribution of spatiotemporal and environmental variation across a suite of species distribution models. The results reveal trade-offs between accurately estimating species abundance, accurately estimating spatial patterns, and accurately quantifying underlying species-environment relationships. These comparisons between model types and parameterization options can help model users better understand sources of bias and estimate error. The determinants of ecological predictability were further explored by temporally decomposing model covariates to determine how different temporal scales of environmental variability relate to species distributions. The results are discussed with respect to seasonal-to-interannual forecasting and climate projections designed to aid marine resource management.

(S15-14072)

Regime shifts in the fish assemblages around Japan over the last century and their early warning signals

Yongjun **Tian**[1,2], Shuyang Ma[1], Kazuhisa Uchikawa[2], Jiahua Cheng[3], Yoshiro Watanabe[4], Jürgen Alheit[5] and Caihong Fu[6]

1 Ocean University of China, Qingdao, PR China. E-mail: yjtian@ouc.edu.cn
2 Japan Sea National Fisheries Research Institute, Japan Fisheries Research and Education Agency (FRA), Niigata, Japan
3 East China Sea Fishery Research Institute, Chinese Academy of Fishery Sciences, Shanghai, PR China
4 Atmosphere and Ocean Research Institute, the University of Tokyo, Chiba, Japan
5 Leibniz Institute for Baltic Sea Research, Warnemünde, Germany
6 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia V9T 6N7, Canada

The marine ecosystems around Japan, one of the most productive regions in the North Pacific, are under the impact of the warm Tsushima and Kuroshio currents and the cold Oyashio current. They are typical wasp-waist ecosystems dominated by small pelagic species such as sardine and anchovy exhibiting large low-frequency fluctuations in biomass. Most studies have hitherto been on the variability of individual species such as sardine and anchovy; only a few have focused on the long-term variability of the fish assemblages. In this study, thirteen species ranging from small forage to large predatory species and from warm to cold water species were selected as indicators, and essential characteristics of the fish assemblages were analyzed based on fishery, oceanographic and climate datasets during the period from 1901 to 2010. Principal component analysis (PCA) of the catch of 13 indicator species showed evident decadal variation patterns with step changes in the first principal component (PC1) in the early-1910s, mid-1930s, early-1960s and late-1980s, and in the PC2 around the late-1920s, early-1940s and mid-1970s. PC3 showed abrupt changes around the early-1910s and mid-1930s, mid-1950 and mid-1960s, closely resembling those in PC1. The tipping points in PC1 and PC3 corresponded well with those of the Arctic Oscillation (AO) (mid-1930s and late-1980) and the Monsoon Index (MOI) (early-1910s, mid-1960s and late-1980s), while PC2 seemed associated with Pacific Decadal Oscillation (PDO) (early-1940s and mid-1970s). These regime shifts revealed by PC analysis indicated that the dominant variation modes in the fish assemblages of waters surrounding Japan were forced by decadal climate variability as inherent in AO, MOI and PDO. Ecological indicators such as mean trophic level showed decadal variation patterns which were influenced to a large degree by small pelagic species. The potential possibility of using ecological indicators to detect early warning signals of future regime shifts in the fish assemblages is discussed.

(S15-13936)

Interactive effects of fishing, ocean acidification and ocean warming on a marine ecosystem off western Canada

Chuanbo **Guo**[1], Caihong Fu[1], Robyn E. Forrest[1], Norm Olsen[1], Huizhu Liu[2], Philippe Verley[3] and Yunne-Jai Shin[4]

1 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia V9T 6N7, Canada
E-mail: chuanbo.guo@dfo-mpo.gc.ca
2 Vancouver Island University, Nanaimo, Canada
3 Institut de Recherche pour le Développement, UMR AMAP (IRD, Cirad, INRA, CNRS, Univ Montpellier), Montpellier, France
4 Institut de Recherche pour le Dévelopement, Sète, France and Université de Montpellier, Montpellier, France

Marine ecosystems are subjected to multiple stressors that have impacted their dynamics both individually and/or cumulatively. Quantitative understanding of ecosystem responses to these multiple stressors is challenging, though of paramount importance for predicting future ecosystem state and for conserving marine living resources. In this study, an end-to-end ecosystem model OSMOSE was parameterized for the marine ecosystem off British Columbia (referred to as OSMOSE-BC), Canada, based on time series data during 1941 to 2018. With the calibrated OSMOSE-BC model, we investigated the individual and interactive effects of fishing, ocean acidification and ocean warming on the marine ecosystem. Different scenarios of fishing mortality of exploited stocks, mortality of benthic invertebrates, and larval mortality of exploited stocks were simulated in the OSMOSE-BC model to mimic the impacts of fishing, ocean acidification and ocean warming, respectively. We predicted the individual and cumulative effects (synergistic, additive or antagonistic) of the three stressors by evaluating the variations of the community and ecosystem level indicators (e.g. system biomass, catch, productive capacity, mean length, and mean trophic level) to understand the ecosystem response to multiple future changes. The results provide not only insights toward understanding the interactive impacts of multiple stressors on marine ecosystems, but also guidelines for adaptive fisheries management strategies and marine protection policies in the face of climate change.

(S15-14360)

Winter preconditioning, mesoscale variability and geomorphology influence the distribution and abundance of krill in the California Current System

Megan A. **Cimino**[1,2*], Jarrod Santora[4], Isaac Schroeder[1,2], Michael Jacox[1,2,3], Elliott Hazen[1,2] and Steven Bograd[1,2]

1 Institute of Marine Science, University of California Santa Cruz, Santa Cruz, CA, USA. E-mail: mecimino@ucsc.edu
2 Environmental Research Division, NOAA Southwest Fisheries Science Center, Monterey, CA, USA
3 Physical Sciences Division, Earth System Research Laboratory (NOAA), Boulder, CO, USA.
4 Department of Applied Math and Statistics, Center for Stock Assessment Research, University of California Santa Cruz, CA, USA

Krill are important prey for many marine organisms due to their global distribution, high biomass and energy content. Krill form large, dense aggregations that move both passively and actively, making them extremely patchy in space and time. Understanding krill habitat associations is essential for forecasting range shifts or variability in the future, and for determining the response of krill predators. In the central California Current Ecosystem, we used a boosted regression tree statistical model to relate 16 years (2002-2018) of krill data collected from a shipboard mid-water trawl survey conducted during May/June to environmental variables to identify the factors related to the two dominant krill species (*Thysanoessa spinifera* and *Euphausia pacifica*). Their distribution and abundance were influenced by geomorphic features (e.g., depth and rugosity), coastal upwelling dynamics during the prior winter, and mesoscale oceanographic features at the time of the trawl, and revealed the nearshore distribution of *T. spinifera* compared to the offshore, slope distribution of *E. pacifica*. Both species were influenced by mesoscale variability with *E. pacifica* being especially negatively impacted by offshore transport. Both species also responded negatively (positively) to warm (cold) climate events, which corresponded to changes in seabird and whale distributions. Our framework demonstrates species-specific habitat relationships for keystone species and their response to large-scale climate events, which can inform ecosystem-based management of krill hotspots and conservation strategies for their predators. We provide recommendations for developing and improving future near real-time forecasts of krill occurrence and intensity, which would likely also be indicative of predator distributions.

(S15-14165)

A downscaling approach to predict climate change effects on forage fish abundance and distribution in the California Current

Jerome **Fiechter**[1], Michael G. Jacox[2], Mercedes Pozo-Buil[1,2], and Michael A. Alexander[3]

1 University of California Santa Cruz, Santa Cruz, CA, USA. E-mail: fiechter@ucsc.edu
2 NOAA Southwest Fisheries Science Center, Monterey, CA, USA
3 NOAA Earth System Research Laboratory, Boulder, CO, USA

We present a modelling framework to dynamically downscale physical and biogeochemical variability in the California Current and project the effects of changing climate conditions on the distribution and abundance of key forage fish species, namely sardine and anchovy. We use a combination of Eulerian models for the physics (ROMS) and biogeochemistry (NEMURO) and a Lagrangian individual-based model (IBM) for fish, and contrast results from a historical simulation for 1985-2010 and a downscaled climate projection for 2075-2100. The impact of changing physical and biogeochemical conditions on sardine and anchovy abundances and distributions are further compared to those associated with small variations in the species' intrinsic traits and responses to environmental cues constraining bioenergetics and behavior in the model. The results presented here, albeit preliminary, offer a way forward toward characterizing sources of variability and uncertainty in projections for forage fish and, ultimately, higher trophic level species in the California Current and other Eastern Boundary Current Upwelling Systems.

(S15-14207)

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

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17, Verkhnyaya Krasnoselskaya, Moscow, 107140, Russia
E-mail: akrovnin@vniro.ru

The fluctuations in abundance of most commercial stocks at different time scales are closely related to the corresponding climate variations within the whole Northern Hemisphere. Thus, for the long-range forecast of their state it is necessary to have idea about the climate change during the next 2-3 decades. The observed climate warming is not uniform in time because of the existence of 50-70 – year cycle. Some studies show that at time scales of 15-30 years this cycle is now more important than greenhouse gas effects. Against the background of the above cycle the quasi-decadal climatic fluctuations of 8-15 years are often observed. The similar variations with periods from 50-60 years to 10-20 years are revealed for many commercial fish species both in the Northwest Pacific and Northeast Atlantic. During the last 2-3 decades the changes in temporal structure of climatic variations were noted. These changes were associated with an increase in short-term variability, first of all, in the North Pacific climate that caused, for example, a sharp growth of catches of Far East salmons during the last 5 years. Our results show that this could be associated with changes in character of interaction between the North Atlantic and North Pacific climatic systems. This was accompanied by changes in sign of correlations between the biological and climatic parameters. The climatic tendencies in the Northern Hemisphere under the natural processes and their effects on fish stocks during the next 2-3 decades will be discussed.

BIO-PAPER SESSION

(BIO-P-13881)

Body size, light intensity and nutrient supply determine plankton stoichiometry in mixotrophic plankton food webs

Pei-Chi **Ho**[1], Chun-Wei Chang[2], Fuh-Kwo Shiah[2], Pei-Ling Wang[1], Chih-hao Hsieh[1,2,3,4] and Ken H. Andersen[5,6]

1 Institute of Oceanography, National Taiwan University, Taipei, Taiwan. E-mail: bookwormpageho@gmail.com
2 Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan
3 Institute of Ecology and Evolutionary Biology, Department of Life Science, National Taiwan University, Taipei, Taiwan
4 National Center for Theoretical Sciences, Taipei, Taiwan
5 VKR Centre for Ocean Life and 6. National Institute of Aquatic Resources, Technical University of Denmark, Kgs. Lyngby, Denmark

Trophic strategy determines stoichiometry of plankton. In general, heterotrophic zooplankton have lower and more stable C:N and C:P ratios than photoautotrophic phytoplankton whereas mixotrophic protists, which consume prey and photosynthesize, have stoichiometry between zooplankton and phytoplankton. As trophic strategies change with cell size, body size may be a key trait influencing eukaryotic plankton stoichiometry. However, the relationship between body size and stoichiometry remains unclear. Here, we measured plankton size-fractionated C:N ratios under different intensities of light and nutrient supply in subtropical freshwater and marine systems. We found a unimodal body size-C:N ratio pattern with a maximum C:N ratio at ~50 µm diameter in both marine and freshwater systems. Moreover, the variation in C:N ratios is mainly explained by body size, followed by light intensity and nutrient concentration. To investigate the mechanisms behind this unimodal pattern, we constructed a size-based plankton food web model in which the trophic strategy and C:N ratio is an emergent result. Our model simulations reproduce the unimodal pattern with C:N ratio of photoautotrophs ≤ 51 µm increasing with body size due to increase of photosynthetic carbon, whereas C:N ratio of organisms > 51 µm decreases with size due to decreasing photoautotrophic but increasing heterotrophic uptake. Based on our field observations and simulation, we extend the classic "light-nutrient" theory and how luxury uptake determines plankton C:N ratio to include size and trophic strategy dependency.

(BIO-P-14157)

Comparison of phytoplankton growth and mortality in oligotrophic subtropical North Pacific and Eastern Indian Ocean

Siyu **Jiang**[1], Fuminori Hashihama[2] and Hiroaki Saito[1]

1 Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Chiba, Japan
E-mail: jiangsiyu@aori.u-tokyo.ac.jp
2 Department of Ocean Sciences, Tokyo University of Marine Science and Technology, Tokyo, Japan

The major pathway for phytoplankton production engaging in the marine food web is microzooplankton grazing. In the subtropical North Pacific, high growth rates of phytoplankton community dominated by *Prochlorococcus* were observed under a severe nitrogen limitation (DIN < 10 nM) (Jiang et al. submitted). The extremely small size of *Prochlorococcus* and the capability of utilizing various organic nitrogen made them grew faster and dominated the community under a low nutrients condition. We speculated that growth and mortality of picophytoplankton are crucial factors to dynamics of phytoplankton community in the oligotrophic oceans. Thus, we conducted size-fractionated dilution experiments in the subtropical and equatorial Eastern Indian Ocean (16.5°N to 20°S, along 88°E) to examine growth and mortality rates of phytoplankton of different size classes (< 1 µm, 1-3 µm, 3-10 µm and >10 µm) . Results were similar with which in the subtropical Pacific. Picophytoplankton (< 3 µm) dominated the community and their higher growth was not limited by nutrient scarcity (DIN < 60 nM) severely. The daily consumption of phytoplankton production by microzooplankton was generally lower than 50%. However, two stations around the equator influenced directly by the Wyrtki Jet showed distinct characteristics, including more than twofold phytoplankton biomass and microzooplankton grazing pressure higher than 100%. The picophytoplankton still dominated the community but showed low growth limited by nutrient (DIN of 14 and 34 nM). In contrast to the steady Pacific, the complex physical activities in the Indian Ocean could lead to distinct geographical variations of picophytoplankton.

(BIO-P-14194)

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**[1], Jim Greenwood, Martin Lourey, Christine E. Hanson, Nagur Cherukuru, Peter A. Thompson, Paul Branson and Charitha Pattiaratchi

1 Oceans & Atmsophere, CSIRO, Level 4, Indian Ocean Marine Research Centre
E-mail: james.mclaughlin@csiro.au

The continental shelf of the South Kimberley region of Western Australia is wide (~300 km) and interactions with the Indian Ocean culminate in extreme tides. This results in some of the largest tropical tides in the world (reaching 11m on spring tide) measured in King Sound (KS), a large embayment which opens to the Indian Ocean. This remote area of Australia is very rich in natural resources and under increasing developmental pressures, but despite this the marine environment has been poorly studied. In Austral autumn (April/May) 2010, we examined phytoplankton biomass and production across four onshore-offshore transects from coastal waters (also within KS) to the 1000m isobath, and their responses to physical and chemical environmental variables associated with tidal forces during a four week voyage aboard the *RV Southern Surveyor*. Using temperature and salinity relationships we found three distinct water masses; KS, Kimberley Shelf, and Kimberley Shelf break waters. The highest chlorophyll-a biomass in the study area was measured in a band along the 200m isobath (27–46 mg Chl a m^{-2}), and associated with greater concentrations of nutrients (332–392 mmol NO_3 m^{-2}, 650–823 mmol Si m^{-2}, 21–39 mmol PO_4^{3-} m^{-2}). Phytoplankton biomass inside KS was dominated by large diatoms (as determined from accessory pigment analyses), shifting to a community largely comprised of picophytoplankton offshore. Rates of primary production (PP) on the shelf, via measurements of phytoplankton carbon (^{14}C) uptake from photosynthesis versus irradiance incubations, decreased from coastal areas (222–560 mg Cm^{-2} d^{-1}) to offshore waters (45–78 mg mg Cm^{-2} d^{-1}). In KS, PP was highest (1692 mg mg Cm^{-2} d^{-1}) despite low standing stock nutrient concentrations (0.02–1.5 mmol NO_3 m^{-2}) and relatively higher concentrations of suspended particulate material reducing light availability (Kd = $0.27m^{-1}$). We examined phytoplankton photo-physiological response to natural light in closer detail at different phases of the spring-neap (MS_f) 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.

(BIO-P-14090)

Copepod community dynamics across a shelf and oceanic gradient in the northeast Pacific from 1998-2016

Samantha M. **Zeman**[1], Jennifer L. Fisher[1], William T. Peterson[2], and Cheryl A. Morgan[1]

1 Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, Oregon State University, 2030 SE Marine Sciences Dr. Newport, OR, 97365, USA. E-mail: zemans@oregonstate.edu
2 NOAA, Northwest Fisheries Science Center, Hatfield Marine Science Center, 2030 SE Marine Sciences Dr. Newport, OR, 97365, USA

In the Northern California Current large marine ecosystem, hydrographic and zooplankton data have been collected monthly along the same transect (44.6°N) for the past 23 years. This effort, specifically at a shelf station NH-5 (9 km from shore), has shown that 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. Using this high frequency time series, we will examine the cross-shore variations in the copepod community from 1- 200 nm miles offshore of Newport, Oregon over 18 years. We will examine seasonal and inter-annual trends in the copepod communities across this habitat gradient, determine how the community responds to basin-scale forcing and investigate the possible role of local environmental factors. Initial analyses suggests that the community dynamics nearshore are in synch with those offshore (65 km from shore) 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.

(BIO-P-14126)

Population dynamics of the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera*, with notes on *Thysanoessa inspinata,* off of Newport, Oregon, USA

C. Tracy **Shaw**[1] and Jennifer L. Fisher[2]

1 University of South Florida College of Marine Science, 140 7th Ave S, MSL 119, St. Petersburg, FL 33701, USA
E-mail: ctshaw@usf.edu
2 Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, OR 97365, USA

Euphausiids were collected in nighttime bongo samples from 2001-2016 on the Newport Hydrographic line to investigate the population dynamics (abundance, biomass, total length) of *Euphausia pacifica, Thysanoessa spinifera,* and *T. inspinata*. All three species occurred throughout the study period, with *E. pacifica* by far the most abundant (n=28945 adults, n=24561 juveniles), followed by *T. spinifera* (n=5350 adults, n=3852 juveniles). *T. inspinata* was present throughout the study period but was never abundant (n=63 females, n=80 males, n=672 adults/juveniles). The maximum (average) total lengths of females and males, respectively, were 26.2 (17.3) mm and 25.9 (16.6) mm for *E. pacifica*, 28.9 (21.7) mm and 27.2 (18.6) mm for *T. spinifera*, and 14.9 (10.6) mm and 13.2 (8.6) mm for *T. inspinata*. 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 are discussed for *E. pacifica* and *T. spinifera* in the context of environmental conditions (PDO phase, spring transition, upwelling season, anomalous cold and warm water events) during this 16-year time period.

(BIO-P-14097)

Comparison of condition metrics and lipid content between *Euphausia pacifica* and *Thysanoessa spinifera* in the northern California Current, USA

Jennifer L. **Fisher**[1], Jennifer Menkel[1], Louise Copeman[1,2], C. Tracy Shaw[1], Leah R. Feinberg[1] and William T. Peterson[3]

1 Cooperative Institute for Marine Resources Studies, Newport, OR, USA. E-mail: Jennifer.fisher@oregonstate.edu
2 College of Earth, Ocean and Atmospheric Science, Newport, OR, USA
3 NOAA-Fisheries, Northwest Fisheries Science Center, Newport, OR, USA

Krill are a key component of pelagic food webs where they play a vital role for the transferring of energy from phytoplankton to higher trophic levels. Krill also form dense aggregations making them important prey for higher trophic level fish, seabirds and marine mammals. The two dominant euphausiid species in the northern California current (NCC) are *Euphausia pacifica* and *Thysanoessa spinifera*. While *E. pacifica* is the most abundant euphausiid in the NCC, *T. spinifera* have a larger body size and appear to have a higher lipid density, leading to vastly higher realized energetic content in *T. spinifera*. Cross-shelf and alongshore differences in the biomass of these two species result in localized hotspots where predators might encounter krill with species-specific differences in lipid content. Most studies have inferred differences in the lipid content and body condition between the two species, but few studies have quantified these differences in the NCC. Here, we report on the differences in body condition, elemental composition and total lipids, which strongly differed between the two species. *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.

(BIO-P-14420)

Developing a mechanistic understanding of ocean acidification sensitivity in marine bivalves: Experimentally decoupling pH and saturation state and reproducing natural variability

Iria **Giménez**[1,2], Burke R. Hales[3], George G. Waldbusser[3], Wiley Evans[1], and Helen Gurney-Smith[4]

[1] Hakai Institute, Quadra Island, BC, V0P 1H0, Canada Email: iria.gimenez@hakai.org
[2] Department of Zoology, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada
[3] College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR, 97331, USA
[4] Fisheries and Oceans Canada, St. Andrews, New Brunswick, E5B 0E4, Canada

Ocean acidification (OA) alters carbonate chemistry variables such as PCO_2, pH and mineral saturation state (Ω). Although these parameters normally co-vary in open-ocean settings, they often decouple in dynamic coastal margins and estuaries, habitat to many sensitive marine organisms, including important cultured species. Most OA experiments rely on fixed levels of co-varying PCO_2, pH or Ω therefore preventing the empirical identification of the carbonate parameter driving sensitivity and the evaluation of organismal responses to observed natural carbonate chemistry variability. Building on a previous prototype, we installed an improved design of a feed-forward, flow-through carbonate chemistry control system capable of decoupling PCO_2, pH or Ω and producing dynamic treatments by independently manipulating total alkalinity and total inorganic carbon. Our system can manipulate source seawater with stable or variable carbonate chemistry, and simultaneously produce multiple stable or dynamic experimental treatments, including off-set treatments that impose an estimated anthropogenic ΔPCO_2 on naturally variable conditions. 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. We will present results of viability testing on marine organisms, including results from experiments decoupling pH and $\Omega_{aragonite}$ on larval and post-larval stages of Pacific oyster (*Crassostrea gigas*). We will also discuss further applications including the incorporation of multi-stressors.

(BIO-P-14263)

Climate controls on zooplankton composition and ocean-estuary exchange in the Strait of Juan de Fuca, USA

Julie E. **Keister**, Bethellee Herrmann, Andrew Mondavi and Parker MacCready

University of Washington, Seattle, WA, USA. E-mail: jkeister@uw.edu

In the Northeast Pacific, the Strait of Juan de Fuca (SJF) connects the North Pacific to the Salish Sea between the U.S. and Canada. Multiple physical influences including advection from three hydrographically different regions—the Strait of Georgia, Puget Sound, and the Northern California Current upwelling system—create a complex environment, strongly influenced by ocean-estuary exchange. Climate influences on the physics are reflected through changes in temperature, river flow, and circulation; factors which also affect zooplankton community structure in the SJF. 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 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 interannual variability. We 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.

(BIO-P-14106)

The quality of juvenile salmon prey during early marine residence in Puget Sound, WA, USA

Minna **Hiltunen**[1,2], Ursula Strandberg[1], Julie Keister[3], David Beauchamp[4], Miika Kotila[1], and Michael T. Brett[3]

1 University of Eastern Finland, Joensuu, Finland
2 University of Jyväskylä, Jyväskylä, Finland. E-mail: minna.m.hiltunen@jyu.fi
3 University of Washington, Seattle, USA
4 Western Fisheries Research Center, U.S. Geological Survey, Seattle, USA

Puget Sound is a large, fjord-like estuary in WA, USA, that has suffered from declining Pacific salmon stocks. Prey composition and quality are critically important to the growth of juvenile salmon and their survival to adult. Aquaculture studies show that essential fatty acids (EFAs) are particularly important for somatic growth, reproduction, immune responses, and osmoregulation of fish. However, the EFA content of juvenile salmon prey in Puget Sound is poorly known. We evaluated patterns in zooplankton EFA content from samples collected in March through September 2017 from multiple regions of Puget Sound. 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.

(BIO-P-14350) CANCELLED

Cloning and characterization of the insulin and glucagon genes in short-beaked common dolphin (*Delphinus delphis*), and analysis of its islet architecture

Liyuan **Zhao**, Yufei Dai, Fuxing Wu, Yila Re, Mingyu Li

The Third Institute of Oceanography, Ministry of Natural Resource, Xiamen, PR China. E-mail: zhaoliyuan@tio.org.cn

Insulin and glucagon are two kinds of hormones secreted by pancreatic β and α cells, which regulating the glucose homeostasis together. The disorder of these two hormones will result in hyperglycemia or hypoglycemia. To better understand the endocrine physiology of dolphins, we cloned and characterized the insulin and glucagon genes from short-beaked common dolphin. We obtained the complete coding sequences of the insulin and glucagon genes, which encoding insulin protein of 110 amino acid (aa) residues and encoding glucagon protein of 180 aa residues respectively. Sequence comparison, phylogenetic analyses and synteny analyses indicated that their protein structures were similar to other mammalian orthologs. Moreover, we performed immunofluorescence staining using insulin, glucagon and somatostatin antibodies for analysis of short-beaked common dolphin islet architecture. Our resulted showed that the α, β and δ cells of the dolphin were irregularly shaped and intertwined, which were highly similar to the shape and distribution of human islet. These results will provide new information about the structural and functional conservation of the insulin and glucagon genes in dolphins.

FIS-PAPER SESSION

(FIS-P-14190)

Revisiting Lasker's stable ocean hypothesis: The influence of wind events on larval fish mortality in the southern California Current Ecosystem

Brendan D. Turley[1] and Ryan R. **Rykaczewski**[2]

[1] School of the Earth, Ocean, and Environment, University of South Carolina, Columbia, SC, USA. E-mail: bturley@email.sc.edu
[2] NOAA Pacific Islands Fisheries Science Center, Ecosystem Sciences Division, Honolulu, HI, USA

Lasker's stable ocean hypothesis is one of the founding concepts of fisheries oceanography. The hypothesis seeks to explain variability in the morality of larval fish by considering the influence of wind-driven mixing on the vertical distribution of planktonic prey. Periods of calm winds are hypothesized to facilitate development of dense plankton concentrations, allowing successful foraging by larval fish. Conversely, storm events dilute concentrations of planktonic prey and lead to reduced foraging success. Here, we investigate the stable ocean hypothesis by comparing larval fish mortality rates estimated from 37 years of ichthyoplankton data against metrics of wind events. Contrary to expectations, we found that mortality for Pacific hake (*Merluccius productus*) significantly decreased as storm events increased in the southern portion of the California Current Ecosystem. Mortality rates for northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), Pacific mackerel (*Scomber japonicus*), and jack mackerel (*Trachurus symmetricus*) had no relationships to storms, and none of the species' mortality rates exhibited a significant relationship with the number of calm events. Investigation of the influence of wind events on the vertical structure of chlorophyll in the water column does indicate that such events reduces concentrations of plankton below thresholds thought to be required for successful feeding, but this process does not clearly control variability in larval mortality. Temporal and spatial variability in the composition of the planktonic prey field (among other sources of environmental variability) are likely critical factors that require consideration to reconcile the relationships among water-column stability, plankton distributions, and larval mortality.

(FIS-P-14272)

Impacts of environmental changes on ichthyoplankton assemblages in the northern Bering Sea

Yuki **Takemuro**[1], Yukari Kurihara[2], Yui Kono[3], Atsushi Yamaguchi[1], Hisatomo Waga[1], Atsushi Ooki[1], Toru Hirawake[1] and Orio Yamamura[1]

1 Hokkaido University, Hakodate, Japan. E-mail: yuki-takemuro_kyoto@eis.hokudai.ac.jp
2 ECONiXE Co., Sapporo, Japan
3 Fisheries Distribution Division, Kochi Department of Fisheries, Kochi, Japan

Bering Sea ecosystems are changing dramatically as the results of rapid climate changes including the reduction of sea ice cover which alter the oceanographic processes and adult fish distributions. Ichthyoplankton are susceptible to the environmental stress from the changes because of their sensitivity and fragility, so the structure of the assemblage is expected to promptly reflect the environmental variability. In this paper, we investigated the impacts of environmental changes on the ichthyoplankton assemblages in the northern Bering Sea. Ichthyoplankton surveys were carried out during summers in cold years (2008, 2009 and 2013) and warm years (2017 and 2018). A total of 1275 individuals were collected by 57 tows of a 70cm Bongo net. Cluster analysis classified into the three assemblages: i) cold years assemblages in south of St. Lawrence Island, ii) cold years assemblages in Norton Sound, and iii) warm years assemblages. Different species dominated in each group: i) Arctic cod (43.1%) and shannies (31.1%), ii) Northern Rock Sole (84.3%), iii) Bering flounder and/or flathead sole (50.0%). This result indicates that the ichthyoplankton assemblages were distinct in different environmental conditions. BIO-ENV procedure was used to relate between ichthyoplankton assemblages and environmental factors. The structures of the assemblages were accountable by the following four factors: bottom temperature, integrated water column temperature, the duration from sea ice retreat timing (dSRT) and zooplankton biomass (Spearman rank coefficient, $\rho = 0.52$). Our results indicate that the environmental conditions, especially sea ice conditions, have a potential to alter the early life stages and recruitments.

(FIS-P-14338)

Distributional changes of NE Pacific groundfish owe more to ontogeny than to temperature change

Lingbo **Li**[1,2], Anne Hollowed[1], Edward Cocket[3] and Michelle McClure[3]

1 NOAA Alaska Fisheries Science Center, Seattle, WA, USA. E-mail: lingbo.li@dfo-mpo.gc.ca
2 present address: Fisheries and Oceans Canada, Delta, BC, Canada
3 NOAA Pacific Marine Environmental Laboratory, Seattle, WA, USA

Fish distributional changes in depth and location (longitude and latitude) have been documented extensively as climate-induced shifts and sometimes as ontogenetic shifts. However, the two types of movements are likely confounded, and the relative importance of types and directions of fish movements remains unknown. Here we present the first attempt to partition the groundfish movements and compare the two types of movement at different size classes by species within a subregional spacial scale. We examined large quality-controlled datasets of depth-stratified, random bottom trawl surveys conducted during summer in the Gulf of Alaska and along the west coast of Canada and the U.S. over the period 1996-2015. Our estimation of centroids of groundfish distribution, weighted with catch per unit effort and stratum area, show that most groundfish shifted to deeper habitat as they grew. Furthermore, widely distributed species were found deeper in warmer waters as the subregions transition from the Gulf of Alaska to the southern west coast of U.S. Thermal windows are likely specific to life stage and subregion in addition to species. Using standardized movements, Principal Component Analyses further suggest that ontogenetic shifts in depth, rather than any temperature responses, represent the primary movement pattern for all aggregated species of all sizes and subregion. Groundfish demonstrated subregional differences in responses to warm temperatures while different sizes of fish had different ontogenetic shifts. We show that without accounting for spatial scales and life stages, interpreting species movements as responses to temperature changes can be problematic.

(FIS-P-14349)

Environmental variables effects on the early growth of largehead hairtail (*Trichiurus japonicus*) in China Seas

Peng **Sun**[1,2], Qi Chen[1], Jianchao Li[1], Haiqing Yu[1], Zhenjiang Ye[1], Yang Liu[1] , Chi Zhang[1], Yongjun Tian[1,3*]

1 Fisheries College, Ocean University of China, Qingdao
2 Department of Biological sciences, University of Bergen, Bergen
3 Laboratory for Marine Fisheries Science and Food Production Processes, Pilot National Laboratory for Marine Science and Technology, Qingdao. E-mail: sunpeng@ouc.edu.cn

Largehead hairtail (*Trichiurus japonicus*) is an important commercial marine fish species in China Seas, characterized by wide distribution, extensive migration and long spawning period. The catch of largehead hairtail has been on the rise with increasing water temperature since the 1990s, suggesting that the environmental variables have an important influence on recruitment dynamics of fish populations. In this study, we aim to explore linkages between the early growth of largehead hairtail and associated environmental variables on both spatial and temporal scales. Young-of-the-Year (YoY) largehead hairtail were collected from three regions: Dalian, Qingdao, Zhoushan in China seas. Results showed that the common spawning cohorts (i.e. March-spawned cohort and July-spawned cohort) were found to show obviously different growth patterns indicated by the changes of daily increment width in three regions. The gradient forest method identified that environmental factors, particularly sea bottom temperature (SBT), temperature difference (TD) and sea surface salinity (SSS), have great importance in determining the early growth of largehead hairtail by affecting the quantity and distribution of food availability. This study highlights the importance of understanding the early growth response to environmental variables and has important implications for the fishery management of largehead hairtail in China Seas.

(FIS-P-14256)

Estimation of the potential fisheries production in the Korean waters based on ecosystem approach

Hyunjoo **Lee**, Seonggil Go and Sukgeun Jung

Department of Marine Life Sciences, Jeju National University, 102, Jejudaehak-ro, Jeju-si, R Korea. E-mail: hyunjoo920216@gmail.com

Recently, the annual catch from the Republic of Korea's marine-capture fisheries has dropped below one million ton for the first time in 44 years, urging fisheries scientist and policy makers to reliably estimate the potential fisheries production for sustainable fisheries. We utilized the satellite-derived ocean-color data from the Geostationary Ocean Color Imager (GOCI) to estimate the potential fisheries production- by applying the Ryther's ecosystem approach and the biomass-size spectrum (BSS) approach, in which we constructed the BSS of phytoplankton by size class from pico- to micro- plankton. The derived estimate of potential fisheries production in the Korean waters for the year 2014 was 2.5×10^6 tons based on the Ryther's approach, which is compatible with the global exploitation rate of ca. 40% suggested by Ryther(1969)(100 to 240×10^6 tons vs. 1.0 to 2.4×10^6). However, the estimate derived from the BBS approach was 5.3×10^6 tons, which is grater by a factor of 2than the estimate based on the Ryther's method. Because it was suggested that the dominant small fish species, anchovy(*Engraulis japonica*), alone can produce more than 10×10^6 tons in a year in the Korean waters, further refinements are required in the applications of the two approaches, especially for the resilient and productive small-pelagic species.

Key words: biomass size-spectrum, potential fisheries production, ocean-color data

(FIS-P-14026) presented by Roman Novikov

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**

Kamchatka branch of the Russian Federal Research Institute of Fisheries and Oceanograph (VNIRO) («KamchatNIRO»), Petropavlovsk–Kamchatsky, Russia. E-mail: Novikova.o.v@kamniro.ru

On the basis of long-term data (1971-2018), including biological statistics and series of observations of 10 climate indices, a direct correlation analysis and a stepwise multidimensional regressive analysis was carried out, which allowed to identify the most meaningful climatic factors affecting the numbers of cod and saffron cod in the Eastern part of the sea of Okhotsk at different stages of ontogenesis.

In direct correlative analysis the prolific generations of saffron cod appeared with increasing temperature anomalies of the surface of sea of Okhotsk near the Western coast of Kamchatka (SSTa) (r = 0,58). Highly reliable positive correlation was obtained between the number of fish generation reached mass puberty and the ice coverage of the Okhotsk sea (Ice OkhS) (r = 0.85). With a lag of 1 year cod was noted high reliable correlation with Ice OkhS (r =0.84). With a long-term lag (4 years), the strongest dependence was obtained with phase change Pacific decadal oscillation (PDO) (r = 0.69).

Stepwise multivariate regression analysis has showed the greatest impact the indices PNA on saffron cod, and the indices PDO on cod. All the obtained results showed the presence of true relationships with the number of generations of fish in the second year of life and with the number of generations of fish that have reached more than 50% of maturation. On the basis of the obtained equations of multiple regression of the relationship between the numbers of fish with the selected most active climatic indices, three-dimensional regression models were constructed.

(FIS-P-13891)

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

Olga **Zikunova**

Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO), Petropavlovsk-Kamchatsky, Kamchatka, Russia
E-mail: topkam@mail.ru

Chinook salmon is not abundant species of Pacific salmon in Kamchatka peninsula. Chinook salmon target fishing does not exist here, but chinook salmon individuals can be in the catches of sockeye salmon commercial fishing as a bycatch, although in sport fishing it is the main adorable object.

In the rivers of the west coast of Kamchatka chinook salmon commercial fishing has been stopped since 2010 due to extremely low stock abundance; fishing can occur in scientific or artificial rearing purposes, or as sportiv or amateur.

Current stock of chinook salmon in Kamchatka persists in two big river basins on the *east coast* of Kamchatka — Kamchatka river (Kamchatsky Gulf) and Apuka river (Olyutorsky Gulf). The state of the stock of chinook salmon in these river basins now is intermediate between lower and upper limits and can provide target catch at the low stratum level. In previous decade the biomass of Kamchatka river chinook salmon stock was decreasing, what can be explained by increased part of four-years-old individuals 1.2 in spawning runs, having small body weight and length, and decreased number of six-years-old individuals 1.4. Modal age group in the runs of both populations 1.3, the second abundant in the Apuka river is older group 1.4 and in the Kamchatka — younger 1.2. If earlier in the catches in Kamchatka the fish with the body weight 15 kg and more werefrequent, now big individuals can be found only in the North of peninsula, whence in the other places the body weight is hardly over 6 kgs.

The determinants of similar structural processes of stocks include climate changes and biotic interactions. Fishery management plays an important role as well. In the river basins where basis of fishing is well managed, fishing is the main factor limiting stock abundance and forming the age, gender and length-weight composition of salmon population.

(FIS-P-14250)

High resolution Sockeye salmon (*Oncorynchus nerka*) early marine growth a response to environmental conditions

Yuliya **Kuzmenko**[1], Tymofiy Spesivy[1], Evgeny Pakhomov[1,2,3], and Brian Hunt[1,2,3]

1 Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, BC, Canada. E-mail: ykuzmen@eaos.ubc.ca
2 Institute of the Oceans and Fisheries, University of British Columbia, BC, Canada
3 Hakai Institute, BC, Canada

Since 1990 many North Pacific Sockeye salmon population have experienced declines in productivity. There is a strong evidence that this decline is related to higher mortality during the early marine stage and that it is size dependent. Several previous studies have pointed to certain critical areas where conditions for growth on ocean entry may have worsened due to climate change, leading to reduced fish condition and lower survival rates. Data on size at entry, growth rate and feeding condition from these critical regions might allow improved estimate of year class strength and contribute to the prediction of survival and returns. For this study fish otoliths have been selected as a proxi to the environmental conditions and fish growth, which considered to be the most reliable method to reconstruct fish life history up to date(Campana, 2005; Izzo et al., 2016). Based on the data on visual and chemical markers received from the controlled conditions two stocks of sockeye salmon have been evaluated on early marine growth patterns as a response to environmental conditions during the outmigration in the Strait of Georgia and Johnston Strait (2015 and 2016 outmigration years).

MEQ-PAPER SESSION

(MEQ-P-14171)

Occurrences of Microplastics in surface water of Bisunumati and Bagmati Rivers, and on the Roads in Kathmandu city, Nepal

Moemi **Okamoto**[1], Shuhei Tanaka[1], Satoru Yukioka[1], Shigeo Fujii[1], Sangeeta Singh[2] and Hideshige Takada[3]

1 Kyoto University, Kyoto, Japan. E-mail: okamoto@eden.env.kyoto-u.ac.jp
2 Tribhuvan University, Kathmandu, Nepal
3 Tokyo University of Agriculture and Technology, Fuchu, Japan

Recently, microplastics attract a growing concern worldwide, because of their potential for environmental negative effects. However, the surveys of the occurrences of microplastics are mainly conducted in developed countries, and the knowledge in developing countries is still insufficient. In this study, we collected MPs (>100 µm) samples of surface water in Bisunumati River and Bagmati Rivers (*n*=5), and road dust in Kathmandu City (*n*=4), Nepal. These collected samples were subjected to decomposition of organic matter with H_2O_2 (30 %) and density separation with NaI (5.3 M). Stereoscopic microscope and FTIR-ATR were used for size measurement and composition identification. The results showed the density of microplastics in river water were 600-45,000 pieces/m^3 in Bisunumati River, and 3,200-6,800 pieces/m^3 in Bagmati River. No trend was observed depending on the sampling location. In road dust, the density of microplastics ranged 25.7-340 pieces/m^2. The density of microplastics per unit area tended to increase as the road scale got smaller. It was revealed the dominant composition of microplastics in river water was polyacrylate (70 %) followed by polyethylene (13 %), vinyl polymer (7 %), polypropylene (4 %). On the other hand, in road dust in Nepal, polyethylene occupied 40 % of microplastics, followed by rubber type plastic (18 %), polyacrylate (16 %). These results suggested that microplastics in river surface water mainly came from other sources than road dust. It was assumed that one of the possible sources was the direct discharge of greywater from households.

(MEQ-P-14007)

Long-term changes of nutrient regimes and their ecological effects in Bohai Sea, China

Ming Xin, Baodong **Wang**, and Linping Xie

The First Institute of Oceanography, Ministry of Natural Resources, Qingdao, PR China. E-mail: wangbd@fio.org.cn

The nutrient regime has changed significantly in the Bohai Sea during the past six decades because of anthropogenic perturbations. The concentration of DIN increased by 7-fold from the end of the 1950s to the mid-2010s, whereas the concentrations of DIP and DSi decreased from the end of the 1950s to the beginning of the 1990s, and since then have increased again. Unsynchronized changes in nutrients levels have led to changes in the nutrients structure, and subsequently caused a series of ecological effects. Phytoplankton biomass increased by 6-fold from the 1960s to the mid-2010s. The phytoplankton composition shifted from a diatom-dominated system to a dinoflagellate-dominated one, and the dominant species of macrozoobenthos changed also. Red tides rarely occurred before the 1980s, but have occurred periodically and frequently since the 1990s. In a word, the Bohai Sea ecosystem has shifted from an N-limited oligotrophic state before the mid-1990s to a potential P-limited eutrophic state after.

(MEQ-P-13888)

Marine debris as bycatch: Using fishery observer data to estimate trends over time in the North Pacific Subtropical Convergence Zone

Amy V. **Uhrin**[1], William A. Walsh[2], and Jon Brodziak[3]

1 NOAA Office of Response and Restoration, Marine Debris Division, Silver Spring, MD, USA. E-mail: amy.uhrin@noaa.gov
2 Walsh Analytical Service, Kailua, HI, USA
3 NOAA Pacific Islands Fisheries Science Center, Honolulu, HI, USA

Marine debris is abundant across the remote North Pacific Ocean, accumulating in convergence zones that coincide with the fishing grounds of the Hawai'i-based pelagic longline fishery. Longlines are prone to snagging marine debris, providing a mechanism for debris reporting by fishery observers. Here, we consider marine debris as bycatch, and apply a zero-inflated negative binomial model used in standardizing catch per unit effort (standardized CPUE) for biological bycatch species in this fishery, to estimate debris trends in the North Pacific Subtropical Convergence Zone (STCZ). During 2008-2016, observers reported 1326 debris items, half of which were derelict nets. Our modeling results suggest that the relative abundance of marine debris caught by longlines is declining over time. Standardized CPUE of debris was highest in the STCZ and increased moving toward the Great Pacific Garbage Patch. Despite substantially less effort in the shallow-set sector of the fishery (~50-100 m depth), standardized CPUE was four-fold greater than that of the deep-set sector (~250 m). Observations from this fishery provide an opportunistic, yet regular, mechanism for assessing distribution, abundance, and trends of marine debris. Some longline fishermen voluntarily haul snagged debris from the ocean. Incentivizing at-sea debris removal may elicit further cooperation.

POC-PAPER SESSION

(POC-P-14151)

Pacific water in the northeastern Chukchi Sea

Miaki **Muramatsu**[1], Hiromichi Ueno[1], Motoyo Itoh[2], Eiji Watanabe[2], and Jonaotaro Onodera[2]

[1] Hokkaido University, Hakodate, Japan. E-mail: hoku-h3@eis.hokudai.ac.jp
[2] Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan

In the Pacific sector of Arctic basin, sea ice retreat during summer has been enhanced over the past few decades. Previous studies suggested that the Pacific water entering to the Chukchi Sea from the Bering Sea contributed to the sea ice retreat. The Pacific water flowing northward through the Bering Strait is transported to the Arctic basin mostly via Barrow Canyon; part of the water is suggested to be transported west-northwestward as the Chukchi slope current. In this study, we investigated the Pacific water along the Chukchi slope using mooring temperature, salinity and velocity time series data, located around 73°*N* and 161°*W* from August 2003 to September 2004 and from September 2015 to September 2017. The Pacific water was observed at ~40 m depth mooring data in October 2003, 2004, 2015 and 2016, when the flow direction was mostly west-northwestward. A temperature lag-correlation analysis between mooring site of this study and Barrow Canyon suggests that it takes a few months for the Pacific water to be transported to the mooring site from the Barrow Canyon.

(POC-P-14144)

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

Seoul National University, Seoul, R Korea. E-mail: jiwonk503@gmail.com

The northward flowing Kuroshio shifts shelf-ward in the East China Sea (ECS) as its strength is weakened, which is called as "Kuroshio shelf intrusion". The Kuroshio shelf intrusion induces exchange of different water masses and thus plays a crucial role in a local ecosystem and climate of marginal seas. The intrusion mostly occurs in winter rather than in summer, but it has been reported that non-seasonal variability is as significant as the seasonal variability. In this study, therefore, spatial and temporal variability of the Kuroshio shelf intrusion is analyzed in the ECS focusing on the non-seasonal variability during 1993-2017. It is revealed that when the intrusion is strong, shelf warming in sea surface temperature, northeasterly wind, mesoscale eddy kinetic energy and upward surface heat flux are strengthened northeast of Taiwan. In addition, we present intrusion-associated subsurface cooling, contrary to the surface warming during strong Kuroshio shelf intrusion events. We also discuss changes in sub-mesoscale eddy activity by using surface drifter tracks from Global Drifter Program.

(POC-P-14262)

Global distribution and interannual variation of winter halocline

Masato Oda[1], Hiromichi **Ueno**[2], Katsura Yasui[1], and Humio Mitsudera[1]

1 Hokkaido University, Sapporo, Japan
2 Hokkaido University, Hakodate, Japan. E-mail: ueno@fish.hokudai.ac.jp

The distribution and interannual variation of the winter halocline in the upper layers of the world ocean were investigated via analysis of hydrographic data from the World Ocean Database 2013 using a simple definition of the halocline. The halocline was observed in the tropics, equatorward subtropical regions, North Pacific subarctic region and Southern Ocean. A strong halocline tended to occur in areas where the sea surface salinity (SSS) was low. The interannual variation in halocline strength was also correlated with variation in SSS. The correlation coefficients were usually negative: the halocline was strong when the SSS was low. However, in the Gulf of Alaska in the northeastern North Pacific, the correlation coefficient was positive. There, the halocline strength as well as SSS was influenced by the interannual variation of Ekman pumping.

(POC-P-14405)

Dynamic biogeography of the subarctic North Pacific

Kathleen **Dohan**[1], William Sydeman[2], Chelle Gentemann[1], Marisol Garcia Reyes[2], Brian Hoover[2], and Sonia Batten[3]

1 Earth & Space Research, Seattle, WA, USA. E-mail: kdohan@esr.org
2 Farallon Institute, Petaluma, CA, USA
3 Marine Biological Association, Nanaimo, BC, Canada

Large Marine Ecosystems (LME) (often > 200,000 km^2) are structured by similar atmospheric and oceanographic conditions and often contain similar biotic communities. However, LME are stationary coastal regions that lack information on mesoscale variability that can drive productivity across trophic levels. The idea of Meso-Marine Ecosystems (MME) has been introduced for sub-regions of the subarctic North Pacific defined by analyses of phytoplankton and zooplankton community composition. MMEs are tied to fixed boundaries but also to nonstationary oceanographic features such as eddy formation locations and oceanographic currents.

In this presentation we describe the changing physical properties of the subarctic North Pacific (SNP) using more than 25 years of satellite data. The goal is to better understand the connection between ocean dynamics and the dynamic structuring of MMEs in the SNP. We are using satellite fields (surface currents, SST, winds, salinity) together with data from the North Pacific Continuous Plankton Recorder (CPR) program.

The focus here is on a detailed description of the SNP circulation and its evolution throughout the last 25 years. We observe dramatic shifts in the gyre position and location of the bifurcation line between flow into the Alaska Current and the California Current. The stability and position of the currents and eddies in the SNP varies significantly with season and between years. In addition, this region has experienced extreme temperate events in recent years. Knowledge of these physical conditions will be crucial for interpreting the CPR data used to define MMEs.

(POC-P-13922)

Impact of surface waves on wind stress under low to moderate wind conditions

Sheng **Chen**, Fangli Qiao, Wenzheng Jiang, Jingsong Guo and Dejun Dai

First Institute of Oceanography, Ministry of Natural Resources, Qingdao, PR China. E-mail: Rain@fio.org.cn

The impact of ocean surface waves on wind stress at the air-sea interface under low to moderate wind conditions was systematically investigated based on a simple constant flux model and flux measurements obtained from two coastal towers in the East China Sea and South China Sea. It is firstly revealed that the swell-induced perturbations can reach a height of nearly 30 m above the mean sea surface, and these perturbations disturb the overlying airflow under low wind and strong swell conditions. The wind profiles severely depart from the classical logarithmic profiles, and the deviations increase with the peak wave phase speeds. At wind speeds of less than 4 m/s, an upward momentum transfer from the wave to the atmosphere is predicted, which is consistent with previous studies. A Comparison between the observations and model indicates that the wind stress calculated by the model is largely consistent with the observational wind stress when considering the effects of surface waves, which provides a solution for accurately calculating wind stress in ocean and climate models. Furthermore, the surface waves at the air-sea interface invalidate the traditional Monin-Obukhov similarity theory (MOST) and this invalidity decreases as observational height increases.

(POC-P-14073)

Effects of the non-breaking surface wave induced vertical mixing on winter mixed layer depth in subtropical regions

Siyu **Chen**[1,2], Fangli Qiao[1,2,3], Chuanjiang Huang[1,2,3] and Zhenya Song[1,2,3]

1 First Institute of Oceanography, State Oceanic Administration, Qingdao, PR China. E-mail: chensiyu@fio.org.cn
2 Laboratory for Regional Oceanography and Numerical Modeling, Qingdao National Laboratory for Marine Science and Technology, Qingdao, PR China
3 Key Laboratory of Marine Sciences and Numerical Modeling, State Oceanic Administration, Qingdao, PR China

Compared with observations, the simulated multi-model mean zonally averaged surface oceanic mixed layer depth (MLD) during winter in the subtropical regions (20°-40°) of both hemispheres shows 24% and 43% deep bias from 45 CMIP5 climate models in the Southern and Northern hemispheres, respectively. Our twin numerical experiment and in one CMIP5 model results from two numerical experiments using one of CMIP5 models show that the non-breaking surface wave-induced vertical mixing can serve as a remedy. This summer build up lead to stronger stratification in the upper ocean, which is hard to break in the winter and resulted in shallower mixed layer. As the result, this fixes the deeper bias in the model run without Bv for subtropical regions. The enhanced vertical mixing increases the upper ocean temperature and reduce the potential density in winter which then stabilize the upper ocean and shallow the simulated MLD depth in winter in subtropical regions. The increase of temperature in winter is not due to the air-sea interface fluxes; instead, it is the legacy of the summer temperature increase attributable to the additional vertical mixing from surface wave. The simulation biases of the annually averaged water temperatures in the upper 400 m reduced by 43% and 28% in south and north latitude bands between of (20°-and 40°), respectively. The non-breaking surface wave induced vertical mixing shallows both boreal and austral winter MLDs by 2-11 m (a change of 5-20%) in both northern and southern subtropical regions.

(POC-P-14453)

The 2019 Alaskan Heatwave and recent changes in North Pacific climate

Emanuele **Di-Lorenzo**[1] and Dillon Amaya[2]

1 School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia, USA. E-mail: edl@gatech.edu
2 Scripps Institution of Oceanography, University of California, San Diego, USA. E-mail: djamaya@ucsd.edu

Over the last 5-10 years the North Pacific has experienced a sequence of extreme events associated with the consecutive occurrence of land and marine heatwaves affecting the US West Coast and the Alaskan peninsula. The physical and ecological consequences of these extremes include unprecedented record high temperatures and a dramatic alteration of the marine food web that led to die offs of birds and mammals. While several studies point to a link between these trends in extremes and the rising temperature associated with climate change, the role of internal climate variability on decadal and multi-decadal timescales is still debated. Several large-ensembles of climate models forced with anthropogenic forcing scenarios reveal that internal variability can influence substantially not only regional trends (e.g. warming/cooling, drying/wetting) but also the distribution of extreme events. By combining available observations with a 100-member ensemble of a climate model simulation of the SPS8.5 warming scenario, we explore the role of internal modes of variability in the occurrence of the extreme events over the Northeast Pacific during the last decade. Specifically, we show evidence that prolonged co-occurrence of the warm phases of both Pacific Decadal Variability (PDV) and the Atlantic Multi-decadal Oscillation (AMO) have had a key influence in determining the probability distribution of extremes events over the Northern Hemisphere. While part of these fluctuations are natural, some of the recent trends in the AMO may be related to changes in aerosol forcing. Better understanding the influence of the AMO and aerosol forcing on the dynamics and PDFs of North Pacific temperature may provide a more robust estimate of how the Alaskan peninsula and the US West Coast are responding to forced and natural climate variability.

(POC-P-14258)

An evaluation of the short-term prediction skill of FIO-ESM in the North Pacific

Yajuan **Song**[1,2] Yiding Zhao[1,3], and Xunqiang Yin[1,2]

1 First Institute of Oceanography, Ministry of Natural Resources, Qingdao 266061, PR China
Technology (Qingdao), Qingdao 266071, PR China. E-mail: songyj@fio.org.cn
2 Key Laboratory of Marine Science and Numerical Modeling, Ministry of Natural Resources, Qingdao 266061, PR China
3 College of Oceanic and Atmospheric Sciences, Ocean University of China, Qingdao 266100, PR China

This work evaluates the seasonal prediction skill of the First Institute of Oceanography short-term climate prediction system for SST and precipitation in the North Pacific. The daily-averaged SST and SLA data of satellite observation are assimilated by using the Ensemble Adjusted Kalman Filter assimilation scheme to get the reliable initial field. We analyze the FIO-ESM 6-month hindcast results starting from each month of 1993–2019. Compared with the observations, the model exhibits high SST prediction skills over most of the North Pacific for two seasons in advance. It remains skillful at long lead times for mid-latitudes. The average skill of the North Pacific variability (NPV) index from 1 to 6 months lead is as high as 0.72 (0.55) when El Niño-Southern Oscillation and NPV are in phase (out of phase) at initial conditions. Furthermore, FIO-ESM shows significant high predictive skills in ENSO variability based on ensemble mean results. The reliable prediction of SST can transfer fairly well to precipitation prediction via air-sea interactions in the North Pacific.

WOKSHOP 1
Learn to effectively communicate your science

W1-14440 INVITED

Communicating science through social media 101: The art of speaking nerdy

Cherisse **Du Preez**

Fisheries and Oceans Canada, Institute Of Ocean Sciences, Sidney, BC, Canada. E-mail: Cherisse.DuPreez@dfo-mpo.gc.ca

Why add another thing to your already packed schedule? When speaking about the scientific process, Mark Walport famously said, "Science is not finished until it is communicated." At the time, Sir Walport was the Chief Scientific Advisor to the UK. He added, "'Communication to wider audiences is part of the job of being a scientist, and so how you communicate is absolutely vital." In this session, you will hear an overview of my own experience in sharing marine science messages through social media—and how important social media can be for expanding the impact of your research. As a deep-sea ecologist, I use social media posts to engage with broad audiences, increasing ocean literacy while inspiring people to care and to act to protect the oceans. As an international and interdisciplinary group of scientists, our messages will all vary, but the social media platforms available to us—and their best practices, tips and tricks, dos and definite-do-nots—will be the same. Together, we will work through several hands-on, fun, and interactive activities, each of you developing your own research social strategy and a PICES meeting post. Unlike most presentations, movie theatres, and airplanes, I invite you to bring your phones and keep them on and connected, especially if you have Twitter, Facebook, and/or Instagram.

W1-14450 INVITED

Be your own newsroom: How to make your science engaging

Alison **Morrow**

KING 5 News, Seattle, WA, USA. E-mail: Amorrowtv@gmail.com

I am an Environmental Reporter and one of Seattle's first solo video journalists, which means I shoot, write, edit and deliver my stories on-air and online. I have recently entered the YouTube world, as well. Everyone should see themselves as their own newsroom, regularly providing content to their audiences. This session will help scientists do exactly that, as well as bridge the worlds of science and news media. Attendees will learn how to get their science in headlines, avoid common pitfalls when dealing with reporters, and develop their own content for social media. We will cover tips to make science storytelling compelling, to overcome fears of public speaking, and to have fun engaging with the world outside your lab!

WORKSHOP 2
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

(W2-14096) INVITED

The International Pacific Halibut Commission: Approaching 100 years of science-based fishery management decision making

David T. **Wilson**

International Pacific Halibut Commission, Seattle, WA, USA. E-mail: david.wilson@iphc.int

The International Pacific Halibut Commission (IPHC) is an intergovernmental organization established by a Convention between Canada and the United States of America. The IPHC Convention was concluded in 1923 and entered into force that same year. The Convention has been revised several times since, to extend the Commission's authority and meet new conditions in the fishery. In early 2019, the IPHC turned 96, making it the oldest regional fisheries management body in existence. The IPHC conducts an annual stock assessment that includes the Pacific halibut resource in the IPHC Convention Area, covering the Exclusive Economic Zones of Canada and the United States of America. Data sources used for stock assessment include data from the fishery-independent setline survey, the commercial Pacific halibut sector and other fisheries sectors, as well biological information generated by the 5-yr Biological and Ecosystem Science Research Program that conducts studies on migration, growth, reproduction, discard mortality and genetics and genomics of Pacific halibut (*Hippoglossus stenolepis*). These data sources for stock assessment are updated each year to reflect the most recent scientific information available for use in management decision making. Furthermore, the IPHC is also conducting a Management Strategy Evaluation process to evaluate the consequences of alternative management options.

(W2-13977)

Accounting for temporal variability in productivity and dynamic reference points in tactical and strategic decision-making

Allan **Hicks**, Piera Carpi, and Ian Stewart

International Pacific Halibut Commission, Seattle, USA. E-mail: Allan.Hicks@iphc.int

Different models are used for different purposes which span a continuum among three general categories: broad conceptual understanding, strategic planning, and tactical decision making. These types of models are used at the International Pacific Halibut Commission (IPHC) to investigate and understand the temporal variability in the population dynamics of Pacific halibut, and to provide advice for the management of Pacific halibut. Conceptual models are currently being used to investigate temporal changes in productivity, which is primarily driven by changes in weight-at-age and recruitment dynamics. Strategic models are used to investigate the robustness of management procedures to that temporal variability. Tactical models are being used to understand past trends in productivity and to supply short-term advice given current understanding of productivity. All three types of models are being used to investigate variability in reference points (e.g., maximum sustainable yield, MSY) in relation to productivity regimes. High recruitment and high weight-at-age occurred jointly for a short period of time in the late 1990s and early 2000s, resulting in high yields. However, strategic models show that this is not common and management procedures need to perform well in periods of low productivity to meet management objectives.

(W2-14150)

Features Pacific halibut fishery in the western part of the North Pacific Ocean

Roman **Novikov**[1] and Igor Glebov[2]

[1] Kamchatka branch of VNIRO (Research Institute of Fisheries and Oceanography), KamchatNIRO, Petropavlovsk- Kamchatsky, Russia. E-mail: novikov.r.n@kamniro.ru

[2] Pacific branch of VNIRO (Research Institute of Fisheries and Oceanography), TINRO, Vladivostok, Russia

Pacific halibut is one of the most valuable commercial fish species, and it is in high steady consumer's demand. It is distinguished by its large size, extended habitat, stretching along the Asian and American coasts. It can be a target fish species or can be caught as a bycatch. Currently, the annual catch of the Pacific halibut in the North Pacific is more than 20 thousand tons.

We described the significance of the Pacific halibut for the Russian fishery, history of the Pacific halibut fishery development in Asian part as well as the dynamics of catch (interannual and seasonal) for different type of fishing gear in accordance with fishing regions in 2009-2018.

Over the past decade, the Pacific halibut catch in Asian waters varied from 2,0 to 5,8 thousand tons with most of it occurring in the Western Bering Sea (more than 80%).

Bottom longline was the main fishing gear used for Pacific halibut fisheries in 2009-2018. The contribution of longline fisheries varies considerably with the fishing regions. The maximum was in the Western Bering Sea, while minimum was in Pacific waters of Eastern Kamchatka water area. In these areas Pacific halibut was mostly fished from May to September, and in the eastern part of the Sea of Okhotsk from January to July. The highest average catch per vessel day (3,05 tons) in the Western Bering Sea was observed in 2010. Subsequently, this figure decreases. Medium-sized fishing vessels were the most commonly used vessel type for the Pacific halibut fisheries.

(W2-13865)

Fully subscribed: Evaluating yield trade-offs among sectors utilizing the Pacific halibut resource

Ian **Stewart** and Allan Hicks

International Pacific Halibut Commission, Seattle, USA. E-mail: Ian.Stewart@iphc.int

The Pacific halibut (*Hippoglossus stenolepis*) stock in the waters of the exclusive economic zones of Canada and the United States of America has been actively managed by the International Pacific Halibut Commission since its formation in 1923. Fisheries have varied over both time and space, supporting an average yield of 28,500 mt (~63 million pounds) over the last 100 years. All geographical areas are currently exploited by a diverse user group including mortality from directed fisheries: commercial longline (60%, over the last five years), recreational (18%), subsistence harvests (3%), and discards in these directed fisheries (3%, primarily due to the use of a minimum size limit), as well as discarded bycatch in fisheries that cannot legally retain Pacific halibut (17%). Understanding the effects of the magnitude and spatial distribution of available yield allocated among fishery sectors is a high priority for managers and participants in these fisheries. This analysis uses the current stock assessment for Pacific halibut to compare the yields over the period 1991-2018 under alternative hypothetical distributions of mortality. Specifically, we vary the magnitude and size structure of discarded bycatch while holding the Spawning Potential Ratio (a measure of fishing intensity) constant in each year, in order to estimate the equivalent yield to the directed fisheries. We find that yields larger than a simple reallocation and spread across the entire stock, may have been possible under reduced discarded bycatch, due to the differences in the size and age structure of the mortality among sectors.

(W2-14191) INVITED

Reducing Pacific halibut bycatch in groundfish bottom trawl fisheries: A Review of trawl modifications

Mark J.M. **Lomeli**[1], W. Waldo Wakefield, and Bent Herrmann

[1] Pacific States Marine Fisheries Commission, Newport, OR, USA. E-mail: mlomeli@psmfc.org

Implementing practices that enhance utilization of fishery quotas, and provide for an economically sustainable fishery are objectives of the U.S. West Coast groundfish bottom trawl fishery catch shares program. Catch accountability has encouraged fishers to fish more selectively to improve the utilization of their catches of individual fishing quota (IFQ) species such as Dover sole (*Microstomus pacificus*), petrale sole (*Eopsetta jordani*), rockfishes, (*Sebastes* spp.), sablefish (*Anoplopoma fimbria*), and lingcod (*Ophiodon elongatus*). However, bycatch of Pacific halibut (*Hippoglossus stenolepis*, a prohibited species), often constrain some fishers from fully utilizing their IFQs of productive groundfish stocks, as relatively limited individual bycatch quota of Pacific halibut is available to the groundfish fishery. Thus, identifying and testing gear modifications that can provide fishers increased access to target groundfish stocks while reducing Pacific halibut bycatch would be beneficial to fishers, management, and the resource. In this presentation, a review of trawl gear modifications tested to reduce Pacific halibut bycatch in the Pacific Coast groundfish bottom trawl fishery will be presented. Regional and international potential applications of the gear modifications tested will also be discussed.

(W2-14131)

Model-based discard mortality rates of Pacific halibut from covariates in the North Pacific trawl fishery

Geoffrey M. **Mayhew** and Jennifer A. Cahalan

Pacific States Marine Fisheries Commission, Seattle, WA, USA. E-mail: gmayhew@psmfc.org

The Pacific Halibut is one of the most economically important species in the north Pacific with an ex-vessel value of over $100 million U.S. dollars. The International Pacific Halibut Commission (IPHC) sets catch limits to ensure the long-term welfare of the stock and in the United States, NOAA Fisheries enforces these limits by closing fisheries when limits are exceeded. In non-IFQ fisheries, halibut are prohibited from being retained and estimates of post- capture mortality are based on the product of estimated discard weight and discard mortality rates (DMRs). Currently, DMRs are derived from observers' assessments of discarded halibut. However, this task is time consuming, may be affected by observer experience, and data collection might be hampered by commercial fishing operations. This study evaluates the relative efficacy of model-based DMR estimates that incorporate covariates that have been previously demonstrated to predict halibut mortality: time out of water, haul size, fish length, and temperature. Using observer data collected on trawl catcher vessels targeting Pacific cod near Unimak Island, AK in 2016-2017, an ordinal logistic model was used to predict mortality rates of individual halibut and calculate DMRs that are compared to estimates generated using current methods. Although the dataset in this study is limited, the model-based approach shows promise. With additional data, well-trained models may provide reliable DMR estimates that can replace the need for observers to assess the condition of discarded halibut and may be applied to larger commercial fisheries.

(W2-14192)

Alaska's approach to estimating recreational discard mortality of Pacific halibut

Sarah **Webster** and Scott Meyer

Alaska Department of Fish and Game, Division of Sport Fish, Anchorage, AK, USA E-mail: sarah.webster@alaska.gov

Estimation of all sources of Pacific halibut removals is essential for the stock assessment and for fishery management. Estimates of removals include commercial, recreational, and subsistence harvest, bycatch mortality, and commercial and recreational discard mortality. In 2017, Alaska's recreational fisheries accounted for an estimated 5.8 million pounds (13.7%) of the coastwide removals. The Alaska Department of Fish and Game (ADF&G) estimates recreational harvest and discard mortality for regulatory areas in Alaska from a mandatory logbook for the charter (for-hire) sector and a mail survey for the unguided sector. Size of discarded fish are not collected for fiscal and logistical reasons. ADF&G developed an approach to estimate mortality using assumed mortality rates corresponding to hook types used in the fishery and modeling to estimate the sizes of released fish. Logistic curves representing the probability of retaining (or releasing) halibut as a function of their length are used to estimate the size distribution and average weight of released halibut in each sector and IPHC area. Without data on discarded halibut, the curve is fit to two empirical data points derived from fisheries for other species where both retained and released fish were measured. This approach could be applied to other recreational halibut fisheries (or fisheries for other species) with similar available data as an interim approach until sufficient data on discarded fish are available to provide more robust estimates of discard mortality.

(W2-14082)

Improving discard mortality rate estimates of Pacific halibut (*Hippoglossus stenolepis*) in the directed longline fishery

Claude L. **Dykstra**[1], Timothy Lohe[1], Ian J. Stewart[1], Allan C. Hicks[1], Nathan Wolf[2], Bradley P. Harris[2] and Josep V. Planas[1]

[1] International Pacific Halibut Commission, Seattle, WA, USA. E-mail: claude.dykstra@iphc.int
[2] Alaska Pacific University, Anchorage, USA

Regulations require that all sublegal size Pacific halibut in the directed fishery be returned to the sea with minimal injury. Accurate understanding of the types and relative levels of injuries and stresses that Pacific halibut are exposed to during the capture and discarding process can be instrumental in helping better estimate the probability of resultant mortality, and to inform the development of best discard practices. In the fall of 2017, we conducted a field study to begin investigating injury severity resulting from different hook release techniques (careful shake, gangion cut, and hook stripper) along with associated physiological condition measures. Physiological parameters collected included condition status at capture (round weight, fat reserves) and blood samples to evaluate post-handling levels of stress indicators (glucose, lactate, and cortisol). Additionally, we tagged and released 79 Pacific halibut with accelerometer pop-up archival transmitting tags to assess near term (96 days) survival, and 1,048 fish with wire tags to investigate longer term survival. Preliminary results and relationships will be presented. Results of this study will be used to further refine the estimation of discard mortality rates (DMRs) by hook release method. Furthermore, injury profiles developed from this work could then be used to calculate DMRs on vessels carrying electronic monitoring (EM) systems rather than observers.

(W2-14237)

Controlled experiments to explore the use of a multi-tissue approach to characterizing stress in wild-caught Pacific halibut (*Hippoglossus stenolepis*)

Anita C. **Kroska**[1], Nathan Wolf[1], Josep V. Planas[2], Matthew R. Baker[3], T. Scott Smeltz[1] and Bradley P. Harris[1]

1 Fisheries, Aquatic Science, and Technology Laboratory, Alaska Pacific University, Anchorage, AK, USA
E-mail: akroska@alaskapacific.edu
2 International Pacific Halibut Commission, Seattle, WA, USA
3 North Pacific Research Board, Anchorage, AK, USA

Multi-tissue approaches to commonly used physiological and ecological analyses can increase both interpretability and temporal resolution. Previously, most investigations of the stress response in fish have focused on single tissue, primarily blood plasma, cortisol levels. While informative, interpretations of plasma cortisol levels are confined to a short temporal frame of reference. Epidermal mucus has been proposed as a secondary sampling tissue that may provide a longer temporal window for comparative assessment. Here, we compared cortisol kinetics in Pacific halibut (*Hippoglossus stenolepis*) plasma and mucus with the aims of increasing our understanding of the Pacific halibut stress response and potentially broadening the scopes of application and interpretation of cortisol analyses. We examined relative rates and magnitudes of free-cortisol levels in plasma and mucus after a) inducing cortisol synthesis using adrenocorticotropic hormone (ACTH1-24) injections and b) inducing cortisol metabolism/ elimination using cortisol (hydrocortisone, 98%) injections. The ACTH treatment elicited a peak plasma cortisol response 2-4 hours post-injection, while mucus cortisol concentrations peaked at 21 hours and later. Exogenous cortisol treatment indicated that cortisol took longer to clear in plasma (7.4 and 4.3 hours) than in mucus (3.2 and 3.5 hours). Differences in the magnitudes of cortisol responses were consistent between tissues regardless of treatment group, suggesting the potential for comparative analysis. Our results demonstrate the efficacy of mucus as a sampling tissue with a longer frame of interpretation than plasma, with application to applied fisheries research, such as the augmentation of qualitative post-release condition assessments.

(W2-14188)

The visual system of flatfish: How retinal studies can help assess and reduce fisheries bycatch mortality

Inigo **Novales-Flamarique**

Simon Fraser University, Burnaby, BC, Canada. E-mail: inigo@sfu.ca

Conservation of halibut stocks requires policies that both assess and prevent fisheries bycatch of this species. It is presently unknown the survival percentage of fish that get returned to the ocean, or the factors that may be crucial to survival. As such, the conservative policy has been to suspend the fishery after a threshold bycatch has been attained, though accurate estimates of survival could potentially allow for an extended fishery. The occurrence of halibut bycatch by other fisheries could also potentially be reduced if signals were generated that alerted the halibut but not the targeted species. Our research on the visual system of flatfishes may help to identify factors that affect bycatch survival and the properties of light signals that could be used to reduce bycatch. In this presentation, I will give a brief overview of the visual system of flatfishes and present results on the functional properties of photoreceptor cells present in the retina of Atlantic halibut. These cells capture light to begin the process of vision and, thus, set a spectral limit on what Atlantic halibut can see. I will also present results on incidence of detached retinas in soles kept alive in water tanks for 14-18 hours after catch on a boat. As most flatfishes are visual predators, detached retinas are a major detriment to localizing prey and long term survival after release. I will finish the presentation by identifying areas for further research that should help to estimate bycatch mortality and devise ways to prevent it.

(W2-14200) INVITED

Process and mechanistic studies of Pacific halibut early life stages can inform management strategy and decision making in the North Pacific

Janet **Duffy-Anderson**[1], Esther Goldstein[1], Josep Planas[2], Lauri Sadorus[2], Ian Stewart[2], and Ray Webster[2]

1 NOAA Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115, USA
E-mail: Janet.Duffy-Anderson@noaa.gov
2 International Pacific Halibut Commission, 2320 W Commodore Way, Suite 300, Seattle, WA 98199, USA

Pacific halibut (*Hippoglossus stenolepis*) are high value flatfish that support commercial, recreational, and subsistence fisheries in the North Pacific. They also play a key role in the ecosystem's trophic structure and transfer of energy, serving as prey for a number of demersal piscivorous species when they are at smaller sizes and consuming fish and invertebrates as adults. Yet despite their economic and ecological importance much of the life history of Pacific halibut remains unknown, affecting the development of comprehensive management strategies and the advancement of sustainable fishing efforts. Moreover, rapidly changing atmospheric and oceanographic conditions in the North Pacific compound inherent biological and ecological uncertainties and heighten the urgency for improved understanding, better scientific approaches, and the development of climate-sensitive management tools. Ecology and dynamics of pre-recruit Pacific halibut are little studied topics but potentially important contributions to the comprehensive effort to understand climate influences on recruitment variability, stock structure, population connectivity, and habitat use. Here we present cross-disciplinary research undertaken from a fish early life history perspective, to illustrate how directed research on little studied life history stages can inform comprehensive Pacific halibut management practices and be used to develop sensitivity metrics to forecast future perturbations to the halibut population in the face of climate shifts.

(W2-14029)

Early life connectivity of Pacific halibut (*Hippoglossus stenolepis*) within and between the Bering Sea and Gulf of Alaska

Lauri L. **Sadorus**[1], Esther Goldstein[2], Raymond Webster[1], Josep V. Planas[1], and Janet Duffy- Anderson[2]

1 International Pacific Halibut Commission, Seattle, WA, USA. E-mail: lauri.sadorus@iphc.int
2 National Oceanic and Atmospheric Administration, Seattle, WA, USA

Pacific halibut (*Hippoglossus stenolepis*) spawn during winter along the continental shelf edge throughout the Gulf of Alaska (GOA) and Bering Sea (BS). Eggs and larvae are carried by the prevailing westward-flowing currents during the six month pelagic phase followed by demersal settlement and subsequent migration away from settlement habitat. Field observations provide some indication of larval dispersal and distribution of young fish that are 2+ years old, but there are significant gaps in the understanding of pathways taken, and of the degree of connectivity within and between the BS and GOA. This study utilizes two separate modelling approaches examining dispersal during the pelagic and early life demersal phases of the 2005 and 2009 year classes. These two years represent production of strong and weak cohorts as well as "warm" and "cold" environmental regimes, respectively. Results from larval advection modelling indicated strong connectivity between the eastern and western BS, and between the eastern and western GOA. Additionally, an estimated 12-51% of the larvae spawned in the western GOA are advected through Unimak Pass into the eastern BS prior to settlement. Results from spatial modelling of 2-6 year old fish suggest significant ontogenic migration from the eastern BS to Unimak Pass, supporting earlier tagging evidence that Pacific halibut actively migrate from the BS to the GOA. There is no conclusive evidence that differences in advection or active distribution are related to environmental regimes or year class strength, but both approaches indicated annual variability.

(W2-14242)

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**

International Pacific Halibut Commission, Seattle, WA, USA. E-mail: tim.loher@iphc.int

Pacific halibut (*Hippoglossus stenolepis*) in North American waters have traditionally been managed as single panmictic stock, within which harvest rules are applied within Regulatory Areas that reflect both political and geographic boundaries. The stock can be viewed as occupying two distinct oceanographic basins (i.e., the Gulf of Alaska (GOA); and the eastern Bering Sea and Aleutian Islands (BSAI) region) in which variations in behavior, connectivity, and productivity have been observed. As such, current management has begun to adopt the notion of describing the stock within broad Biological Areas that roughly correspond to basin- level population structure. Here, we present data from electronic archival tagging studies focused in the BSAI that demonstrate patterns of movement within the region and relative isolation/connectivity with between the BSAI, GOA, and Asian waters that are not currently considered in the management of this stock. Analyses of seasonal redistribution demonstrate regional variance in the timing and duration of spawning migrations and likely spawning periods, which can have implications for both recruitment and fishery-induced mortality. In particular, different components of spawning stock are likely to deliver their larvae into different conditions with respect to primary productivity and larval advection, and adults may be subject to differential rates of fishing mortality depending relationships between their movements and seasonal fishery dynamics. Both processes have bearing upon population-level redistribution that may be induced by climate change – especially in an ecosystem historically structured by winter sea ice formation – and upon ongoing discussions regarding the potential to establish 12- month fishing periods.

(W2-13980) CANCELLED

Genomics of Atlantic Halibut: Parallels and contrasts with Pacific Halibut

Anthony **Einfeldt**, Tony Kess, Paul Bentzen, Daniel E Ruzzante, Iand an R Bradbury

Dalhousie University, Halifax, Nova Scotia, Canada. E-mail: t ony.einfeldt@gmail.com

Atlantic and Pacific Halibut are thought to have diverged less than 5 million years ago, sharing extensive morphological and ecological similarities, but differing in their sex determination mechanisms. We investigated population structure and the evolution of sex determination in Atlantic Halibut using a chromosome-level genome assembly and >500,000 SNPs from >700 samples. We found subtle population structure in the Northwest Atlantic, and a chromosomal inversion that may play a role in maintaining ecotypes despite high gene flow. Sex-linked markers demonstrate that the sex chromosomes in Atlantic Halibut (XY) are different than those in Pacific Halibut (ZW), suggesting recent evolutionary changes to the pathway regulating sexual development. Linkage and heterozygosity patterns indicate a single putative gene controlling the male pathway in Atlantic halibut, with potential structural changes to the chromosome that controls sexual development in Pacific Halibut. Our results suggest that genomic architecture may be important to maintaining divergence within each of these closely related species, and provide a first look at the structural changes underlying their different mechanisms of sexual development.

(W2-13863)

Assessing the potential for competition between Pacific Halibut and Arrowtooth Flounder in the Gulf of Alaska

Cheryl L. **Barnes**[1], Anne H. Beaudreau[1], Mary E. Hunsicker[2], and Lorenzo Ciannelli[3]

[1] College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, USA. E-mail: cheryl.barnes@alaska.edu
[2] Northwest Fisheries Science Center, National Oceanographic and Atmospheric Administration, Newport, OR, USA
[3] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

Pacific Halibut (*Hippoglossus stenolepis*) support culturally and economically important fisheries in the Gulf of Alaska. However, recent decreases in size-at-age have reduced fishery yields, generating concerns among stakeholders and resource managers. A prevailing hypothesis for decreased size-at-age is intensified competition with Arrowtooth Flounder (*Atheresthes stomias*), which have exhibited nearly fivefold increases in biomass between the 1960s and mid- 2010s. To assess the potential for competition between Pacific Halibut and Arrowtooth Flounder in the Gulf of Alaska, we evaluated spatiotemporal and dietary overlap from bottom trawl survey and food habits data provided by the Alaska Fisheries Science Center (NOAA; 1990 to 2017).

We used delta models to quantify species-specific presence-absence and catch-per-unit-effort as a function of survey year, tow location, depth, and bottom temperature. We then calculated spatial overlap by multiplying standardized predictions of species' abundance across a uniform grid. Dietary overlap was calculated using Schoener's similarity index. Finally, we assessed the relationship between spatial and dietary overlap as a measure of resource partitioning. We found that spatial overlap increased from east to west. Dietary overlap was generally low throughout the study area. No correlation between spatial and dietary overlap suggests an absence of resource partitioning along the niche dimensions examined. Thus, our findings provide little indication that competition with Arrowtooth Flounder was responsible for changes in Pacific Halibut size-at-age in the Gulf of Alaska; however, we do not rule out competitive interactions that may have impacted resource use prior to the start of our time series or at finer spatial scales.

(W2-14186)

Environmental, ecological, and fishery effects on size-at-age of Pacific halibut

Jane Y. Sullivan[1,2], Gordon H. **Kruse**[1], Steven J.D. Martell[3,4] and Franz J. Mueter[2]

[1] College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, USA. E-mail: ummjane@gmail.com
[2] Current address: Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, AK, USA
[3] International Pacific Halibut Commission, Seattle, WA, USA
[4] Sea State, Inc., Bainbridge Island, WA, USA

Size-at-age of Pacific halibut (*Hippoglossus stenolepis*) declined significantly since the 1980s. For instance, the average weight of 20-year-old females declined from 55 kg in 1988 to 20 kg in 2014. Causes of these changes are poorly understood. We investigated several hypotheses related to declines in size-at-age, including the effects of environmental and ecological variability and the cumulative effects of fishery harvest and size-selective fishing. Generalized additive models (GAMs) were used to explore potential effects of environmental covariates, such as the Pacific Decadal Oscillation and summer sea surface temperatures, as well as ecological variables, such as annual biomass estimates of arrowtooth flounder (*Atheresthes stomias*) and Pacific halibut as indicators of inter- and intraspecific competition, respectively. Although we found no relationship between size-at-age and environmental variables, negative correlations were found between halibut size-at-age and arrowtooth flounder biomass and, to a lesser extent, halibut biomass. Our best-fitting GAM explained only 28% of the observed variability in halibut size-at-age. A population modeling approach was used to simulate the effects of fishing on halibut size-at-age. We found that harvest and size-selective fishing can explain 30-65% of observed declines in size- at-age since the 1980s in the Gulf of Alaska, and up to 100% of the declines in Southeast Alaska and British Columbia where harvest rates were high in the 1990s and 2000s. Our findings suggest the importance of considering the effects of size-selective fishing and ecological interactions when developing harvest policies.

(W2-14238)

Exploring the role of diet in driving declining size-at-age in pacific halibut in the Gulf of Alaska

Brian **Ritchie**[1], Nathan Wolf[1*], Ian Stewart[2], Josep V. Planas[2], and Bradley P. Harris[1]

1 Fisheries, Aquatic Science, and Technology (FAST) Laboratory, Alaska Pacific University, Anchorage, AK, USA
E-mail: nwolf@alaskapacific.edu
2 International Pacific Halibut Commission (IPHC), Seattle, WA, USA

Characterizing the mechanisms driving the observed decline in the mean size-at-age of adult Pacific halibut in the eastern North Pacific Ocean has remained challenging because of inherently high individual variability in Pacific halibut size-at-age, and the large spatial and temporal scales at which processes affecting the mean size-at-age operate. Here, we present the results of research designed to address both of these challenges by a) increasing our understanding of the influences of one important variable, diet, on growth and consequent size- at-age of individual Pacific halibut using d13C and d15N analysis, and b) characterizing both the spatiotemporal variability of Pacific halibut size-at-age and the spatial variability of Pacific halibut diet in IPHC Regulatory Area 3A in the Gulf of Alaska. Results demonstrate size-based patterns in dietary strategy and composition in both males and females and persistent spatial structure in size-at-age within the region for the years 1998-2018. Preliminary results on the spatial variability of diet within Regulatory Area 3A demonstrate high levels of correspondence between areas of persistently small size-at-age and dietary strategies associated with smaller size-at-age fish. In addition to implicating diet as a potential driver of the observed decreases in size-at-age, our results suggest additional complexity in the patterns of Pacific halibut movement and migration than is captured in our current understanding.

WORKSHOP 3
Let's play the GAME! (to achieve sustainable fisheries development in the PICES regions)

(W3-14413) INVITED

Let's play the fishing village revitalization game to achieve sustainable fisheries development in the PICES regions

Yuuki **Terada**[1,2], Hiroaki Sugino[1,2], Osamu Imai[1], Aoi Sugimoto[3] and Takaaki Matsuki[1]

1 Pine Tree Institute, Tokyo, Japan. E-mail: yuukiterada@gmail.com
2 The University of Tokyo, Tokyo, Japan
3 National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency, Yokohama, Japan

As an introduction of our workshop, this talk will show you the aim, scope, and structure of "Sustainable Fishing Community Development Game" (hereinafter, Game).

Serious games (or gamification, gaming communication) have increasingly proven their value in contributing to the analysis and design of complex social or social-ecological problems. Even though sustainable fisheries development has been one of the most critical issues for marine sciences among PICES countries, it's been challenging to achieve ecologically/economically/socially balanced fisheries development in the region. Given the complexity of above three pillars when considering the issues related to the sustainability of socio-ecological systems, we suggest a serious game approach as a tool to explore the pathway to sustainable fisheries development in North Pacific Ocean. We developed this Game through a series of workshops in Japan involving fisheries scientists, policy makers, and community members, including fishers. By doing so, this Game reflects the reality of Japanese fishing communities and industries. Today, however, we will play this Game among multi-national participants. We expect the participants to gain greater understanding for the perspectives of fishers, managers or community members, and to experience the difference between this Game's setting (a Japanese fishing village) and the ecological/economic/social context of their own countries/regions. This is the objective of this Game. Following the gaming experience, participants will discuss the priorities of sustainable fisheries development in different countries/regions. Thus, we hope this workshop can enhance the mutual understandings among PICES members for how best to achieve sustainable fisheries development in the North Pacific.

WORKSHOP 4
Circulation, biogeochemistry, ecosystem, and fisheries of the western North Pacific marginal seas: Past and future of CREAMS (Circulation Research of East Asian Marginal Seas)

(W4-14286) INVITED

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

Kuh **Kim**

School of Earth and Environmental Sciences, Seoul National University, R Korea. E-mail: kuhkim@gmail.com

Marine scientists from China, Japan, Korea and USA met at the First JECSS (Japan and East China Seas Study) Workshop which was held at Tsukuba University in 1981 to share recent findings on these seas with a hope to promote multi-national collaborative researches. Later JECSS changed to PAMS (Pacific-Asian Marginal Seas) as scientists from Thailand, the Phillipines and Russia participated in recognition of active exchange and interactions between Asian marginal seas and the North Pacific. As a result of the biennial workshops CREAMS (Circulation Research of the East Asian Marginal Seas) was initiated in 1993 focusing first on understanding the circulation in the East (Japan) Sea. Comprehensive field observations were carried out for five years at sea, producing new findings on the vertical structure of temperature and salinity and the dissolved oxygen concentration which are very different from common understandings based upon Uda's historical work in 1932. Moorings were deployed at several locations which reveal strong deep currents for the first time in the sea. Extensive chemical measurements were very crucial to date water masses. CREAMS-II followed in 1998-2002 to trace water formation and fast turnover of water masses in cooperation with JES (Japan/East Sea) program supported by the Office of Naval Research of the US. CREAMS has been expanded including ecosystem studies as PICES established CREAMS-AP in 2005.

(W4-14334)

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**

V.I. Il'ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russia
E-mail: lobanov@poi.dvo.ru

CREAMS (Circulation Research of the East Asian Marginal Seas) successfully started in 1993 was the first international program in the Japan/East Sea organized by oceanographers of Japan, Korea and Russia. Its second phase, CREAMS-II (1998-2001) was supported by marine scientists from USA and other countries provided significant findings in physical, chemical and biological aspects of the sea. It was also supported by PICES. To oversee and facilitate further international research and permanent observation and data exchange networks in this region the advisory panel (AP) CREAMS was established by PICES in 2005. Its main activity was focused on organization of joined cruises to study climate and long term-changes of circulation, ventilation, mesoscale water dynamics and biogeochemical processes of the sea and their effect on changes in the biotic environments, as well as preparation of the status reports, workshops and summer schools. More ecosystem and human dimensions components required by PICES were added. Important achievement of the CREAMS activity is an establishment of good network between marine scientists in the region which is a base for efficient further development. The CREAMS 3.0 program should continue previous efforts by closer collaboration with other national and international projects such as NEAR-GOOS, NOWPAP, WESTPAC-WG06, GEOTRACES, CSK-II and contribute greatly to the UN Decade of Ocean Science for Sustainable Development.

(W4-14172)

Material exchanges between land and the open ocean — A framework for cooperative studies in the western North Pacific Marginal Seas (WESTPAC WG06)

Jing **Zhang**

University of Toyama, 3190 Gofuku, Toyama, 930-8555, Japan. E-mail: jzhang@sci.u-toyama.ac.jp

Marginal seas in the western North Pacific and western boundary current area are constantly and intermittently exchanging energy and materials between land and the open ocean. In these marginal seas, lack of evidence from field work, such as origin identification parameterization and process explanation, limits the improvement of numerical modeling. A nine-country Working Group, “A framework for cooperative studies in the Western Pacific Marginal Seas: Energy and materials exchange between land and open ocean”, was established by the IOC Sub- Commission for the Western Pacific (WESTPAC) in 2017. It is building a framework for interdisciplinary and joint studies of the East and Southeast Asian marginal sea environment. Three workshops have been held: Fukuoka, Japan 2017; Qingdao, China 2018; and Seoul, Korea 2019. Research activities are categorized into five groups: Okhotsk Sea; Marginal Seas surrounding Japan, Korea and Russia; East China Sea; South China Sea, and material exchange and transport with the Kuroshio, eddies and mixing. The long-term monitoring areas, named PEACE (Program of the East Asian Cooperative Experiments) were set; 15 international cooperative cruises were carried out, three international cooperative research programs have been approved and six early career scientists are associate Steering Committee members. Some current scientific results will be introduced. Using chemical tracers, e.g., rare earth elements, neodymium isotopic composition, 137Cs that originated from the Fukushima Dai-ichi Nuclear Power Plant accident, is an excellent means to analyze the multiple water masses and to estimate fluxes while coupling with salinity and temperature.

(W4-14067)

NOWPAP activities and cooperation with PICES

Takafumi **Yoshida**

Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (CEARAC), Northwest Pacific Action Plan (NOWPAP). E-mail: yoshida@npec.or.jp

NOWPAP was adopted by the People’s Republic of China, Japan, the Republic of Korea and Russian Federation in September 1994 as a part of the Regional Seas Programme of the United Nations Environment Programme. NOWPAP members adopted the Medium- term Strategy (MTS) 2012-2017 with five thematic areas: integrated coastal and river basin management; regular assessments of the state of the marine environment; pollution prevention and reduction including harmful substances, hazardous waste and marine litter; biodiversity conservation including alien invasive species; and climate change impacts were focused. Four Regional Activity Centres in each member state implemented various activities to achieve the goal of MTS 2012-2017. In 2018, new MTS 2018-2023 was adopted, which aims to advance regional progress towards achieving ocean-related Sustainable Development Goals of the 2030 Sustainable Development Agenda. New MTS has four core areas: support ecosystem-based integrated coastal and river basin management; assess status of the marine and coastal environment; prevention and reduce land- and sea-based pollution; and conservation marine and coastal biodiversity. MTS 2018-2023 highlights the importance of a holistic approach for preventing and reversing environmental degradation by focusing on the economic and social dimensions of sustainable development as well.

PICES and NOWPAP established “Joint PICES-NOWPAP Study Group on Scientific Cooperation in the North Pacific Ocean” in 2014, and have discussed possibilities of cooperation in common working areas. Now, with active cooperation in AP-CREAMS, AP-NIS, WG 35, WG 42, S-HAB and MEQ, it is expected that our collaborative effort can contribute to resolution of global marine environmental issues.

(W4-14026) CANCELLED

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**

Kamchatka branch of the Russian Federal Research Institute of Fisheries and Oceanograph (VNIRO) («KamchatNIRO»), Petropavlovsk–Kamchatsky, Russia. E-mail: Novikova.o.v@kamniro.ru

On the basis of long-term data (1971-2018), including biological statistics and series of observations of 10 climate indices, a direct correlation analysis and a stepwise multidimensional regressive analysis was carried out, which allowed to identify the most meaningful climatic factors affecting the numbers of cod and saffron cod in the Eastern part of the sea of Okhotsk at different stages of ontogenesis.

In direct correlative analysis the prolific generations of saffron cod appeared with increasing temperature anomalies of the surface of sea of Okhotsk near the Western coast of Kamchatka (SSTa) (r = 0,58). Highly reliable positive correlation was obtained between the number of fish generation reached mass puberty and the ice coverage of the Okhotsk sea (Ice OkhS) (r = 0.85). With a lag of 1 year cod was noted high reliable correlation with Ice OkhS (r =0.84). With a long-term lag (4 years), the strongest dependence was obtained with phase change Pacific decadal oscillation (PDO) (r = 0.69).

Stepwise multivariate regression analysis has showed the greatest impact the indices PNA on saffron cod, and the indices PDO on cod. All the obtained results showed the presence of true relationships with the number of generations of fish in the second year of life and with the number of generations of fish that have reached more than 50% of maturation. On the basis of the obtained equations of multiple regression of the relationship between the numbers of fish with the selected most active climatic indices, three-dimensional regression models were constructed.

(W4-13992)

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

Xinzheng **Li**

Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, PR China E-mail: lixzh@qdio.ac.cn

1. Long-term variations of macrobenthic community in three regions (defined according to the 40 m depth and 70 m depth) in the southern Yellow Sea were analyzed. The community structure showed significant differences among periods, especially between 1950s and the year after 2000. For the relative number of species, polychaetes were increasing from 1950 to 2014, but echinoderms were stable. Polychaetes were decreasing in the relative abundance in the Eastern Region, and increasing in the Western Region, while echinoderms opposed this situation.

2. Long-term variations of the species distribution pattern in the Yellow Sea and East China Sea and the influence of the region in 32°~33°N were assessed. The total abundance of polychaetes increased obviously from 1950s to 2010s, while the abundance of echinoderm decreased. From 1950s to 2010s, most opportunistic polychaete species with small size increased in abundance and distribution range. Large size polychaetes like *Onuphis geophiliformis* also increased in distribution range, but decreased in abundance. From 1950s to 2010s, most echinoderm species decreased in abundance and distribution range. *Ophiura sarsii vadicola* decreased in distribution range, but increased obviously in abundance. We found the distribution area of some macroalgaes moving northward, which may be related to the increase of the sea water temperature (climate change). The region in 32°-33°N obstructed the distribution of some macrobenthos, and it may be useful for studying the distribution of macrobenthos.

3. Long-term variations of macrobenthic community in the Yangtze river estuary and its adjacent area were also assessed. Number of species had low values during 1990- 2000, increased gradually during 2004-2009, and increased rapidly during 2013-2015. Abundance had low value in 2002, increased significantly since 2005, and had highest value in 2012 (perhaps because of the increase of small size polychaetes). In late 1990s, biomass decreased sharply (because of human activity and climate change) and increased gradually during 2000. Most increased species were polychaetes, and they contributed little to the biomass. From 1958 to 2015, the macrobenthic community structure changed significantly; diversity decreased with the increase of disturbance.

(W4-13941)

Long-term variations in nutrient concentrations in the upper ocean of the East/Japan Sea

Ji Hyun **Kim** and Guebuem Kim

Seoul National University, Seoul, R Korea. E-mail: gkim@snu.ac.kr

In the surface East/Japan Sea (EJS), long-term decline of dissolved inorganic phosphorus (DIP) has been documented in association with the strengthening of stratification (Kodama et al., 2016), while some studies showed increases in dissolved inorganic nitrogen (DIN) owing to the fallout of anthropogenic N (Kim et al., 2011; Kim et al., 2014). However, the change in vertical distributions of nutrients in this region has been poorly understood. Thus, approximately 40-year data of nutrient concentrations were compiled to examine long-term variations in the vertical nutrient concentrations of the EJS. Following outlier removal and weighting adjustments, the data was divided into different depth layers according to the physical characteristics of the EJS for statistical testing. In the surface layer, disproportionate trends were observed between DIN and DIP; an increasing trend existed for DIN ($p < 0.01$) whereas no significant trend ($p > 0.05$) was observed for DIP. Despite the DIN increase in the surface layer, total inventory of both DIN and DIP from 0 to 500 m demonstrated statistically significant declining trends ($p < 0.05$). No significant temporal trends ($p > 0.05$) were observed for deeper layers (depth layers below 500 m). Possibilities of climate change, including global warming, acting as drivers of the trends were considered. This research highlights potential consequences of climate change in terms of nutrient availability, which may result in repercussions on ocean productivity and carbon cycles.

(W4-13909)

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

KyungJae **Lee**[1] and SungHyun Nam[1,2]

1 Seoul National University, Seoul, R Korea. E-mail: browneyed1221@gmail.com
2 Research Institute of Oceanography, Seoul National University, Seoul, R Korea

In spite of importance of mesoscale eddies in the East Sea (ES), also referred to Sea of Japan, and their significant impacts on circulation and environments, quantitative parameters of them have not statistically well characterized. Here, statistical characteristics of ES mesoscale eddies were estimated from long-enough satellite altimetry data (1993-2017) and in-situ data obtained from four cruises conducted between 2015 and 2017, and a total of 1,008 mesoscale eddies were identified and classified into 27 groups (16 anticyclonic and 11 cyclonic eddy groups) yielding 25-year mean parameters of lifetime (L) of 95±104 days, amplitude (H) of 3.5±1.5 cm, radius (R) of 39±6 km, intensity per unit area (or Eddy Intensity, EI) of 0.023±0.017 cm2 s-2 km2, ellipticity of 0.72±0.07 (zero for circle), eddy kinetic energy (EKE) of 20±21 TJ, and available potential energy (APE) of 590±250 TJ. The quantitative parameters might be over- estimated as relatively small and shortly lived eddy groups are hardly identified, particularly ones in the Japan Basin due to the sampling issues of the satellite altimetry data. The southern groups found in the south of subpolar front are more energetic and tend to move a longer distance following surface currents. This study suggests that the ES eddies 1) include newly identified groups such as the Hokkaido and the Yamato Rise warm eddies; 2) have a shorter L; smaller H, R, and EKE; and stronger EI and larger APE than those of the global ocean and move following surface mean currents rather than propagating westward, and 3) show large spatial heterogeneity among groups.

(W4-14144)

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

Seoul National University, Seoul, R Korea. E-mail: jiwonk503@gmail.com

The northward flowing Kuroshio shifts shelf-ward in the East China Sea (ECS) as its strength is weakened, which is called as "Kuroshio shelf intrusion". The Kuroshio shelf intrusion induces exchange of different water masses and thus plays a crucial role in a local ecosystem and climate of marginal seas. The intrusion mostly occurs in winter rather than in summer, but it has been reported that non-seasonal variability is as significant as the seasonal variability. In this study, therefore, spatial and temporal variability of the Kuroshio shelf intrusion is analyzed in the ECS focusing on the non-seasonal variability during 1993-2017. It is revealed that when the intrusion is strong, shelf warming in sea surface temperature, northeasterly wind, mesoscale eddy kinetic energy and upward surface heat flux are strengthened northeast of Taiwan. In addition, we present intrusion-associated subsurface cooling, contrary to the surface warming during strong Kuroshio shelf intrusion events. We also discuss changes in sub-mesoscale eddy activity by using surface drifter tracks from Global Drifter Program.

(W4-13926)

Observations on the cyclonic circulation semi-persistently formed in the northern East China Sea

Hojun **Lee**, Kyungjae Lee, SungHyun Nam, and Jae-Hak Lee

Gwanak-ro, Gwanak-gu, Seoul 08826, R Korea. E-mail: generalhojun@gmail.com

A subsurface thermohaline front semi-persistently formed in association with near-bottom cyclonic circulation in the northern East China Sea was newly found from detailed hydrographic data collected during the two cruises in February 2017 (winter) and April 2018 (spring) along with supplementary satellite remote sensing and historical hydrographic data. An intruding structure near the bottom in water properties was observed across the cyclonic circulation in both seasons as generated by two contrasting water masses – low temperature and low salinity (thus low spiciness) water transported by Chinese Coastal Current (CCC) and high temperature and high salinity (high spiciness) water transported by Tsushima Warm Current (TWC). Consistent structures were confirmed from current observations (after removing tidal currents) during the two cruises, historical hydrographic observations, and satellite altimetry-derived sea surface height though surface frontal structure was deemed by seasonal development of thermal stratification in spring. Our results suggest that the transports of heat, materials, and energy could be significantly affected by the front and cyclonic circulation in the northern East China Sea and neighboring seas.

(W4-14005)

The monthly wet depositional fluxes of Organic Matter in Precipitation of Jeju Island

Min-Young **Lee**, Tae-Hoon Kim, and Na-Yeong Song

Department of Earth and Marine Sciences, Jeju National University, Jeju, R Korea. E-mail: thkim@jejunu.ac.kr

In order to evaluate the distributions and fluxes of organic matter in the atmosphere, particulate organic carbon (POC) and dissolved organic carbon (DOC) were measured in Jeju Island, Korea, from January to December 2018. The concentrations of POC and DOC were in the range of 0.62-1567 µM (AVG = 76 µM, VWA = 36 µM) and 14.8-991 µM (AVG = 102 µM, VWA = 53 µM). The highest concentration of POC and DOC were found in January 2018. This result seems to be associated with incomplete combustion of fossil-fuel during winter. According to back-trajectories (HYSPLIT model), The groups consist of events with air mass originated from the continent of Asia (40%), Ocean (51%), and Local (9%). The monthly wet depositional fluxes of POC and DOC at Jeju varied from 0.01-1.23 mmol cm-2 month-1 and 0.24-1.31 mmol cm-2 month-1. The highest flux of POC was found in March, due to the highest concentration of POC, and that of DOC was observed in September, owing to the highest amount of precipitation. The lowest flux of POC was found in July due to the lowest concentration of POC, and that of DOC was observed in November, owing to the lowest amount of precipitation. The annual flux of POC was relatively higher than that in other regions, while that of DOC was relatively lower than that in other regions. In order to understand the behavior of organic matter in the atmosphere, extensive studies are necessary in the future over greater time-scale using various chemical tracers.

(W4-14033)

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

Yong **Xu** and Xinzheng Li

Institute of Oceanology, Chinese Academy of Sciences, Qingdao, PR China. E-mail: xuyong@qdio.ac.cn

To detect large scale spatial pattern of the benthic macroinvertebrate communities and the relationship with environmental variables in the East China Sea shelf, forty sites were investigated for benthic macroinvertebrates and environmental variables during August and September 2015. A total of 12529 benthic macroinvertebrate individuals and 274 species were collected, with crustaceans being predominant, followed by mollusks. Four communities (Inshore community (IC), Transitional community (TC), Northern offshore community (NOC) and Southern offshore community (SOC)) were identified by hierarchical agglomerative cluster (HAC) and cross-verified by non-metric multidimensional scaling (NMDS) ordination. Significant differences in community structure of the four communities were also observed by permutational multivariate analysis of variance (PERMANOVA). The indicator species varied among the four communities, with *Solenocera crassicornis*, *Sternaspis scutata* and *Virgularia* sp. dominating IC, *Solenocera koelbeli*, *Trachysalambria curvirostris* and *Nitidotellina valtonis* dominating TC, *Parapenaeus fissuroides*, *Onustus exutus* and *Drachiella morum* dominating NOC, and *Heikeopsis japonica*, *Solenocera pectinulata* and Actiniaria dominating SOC. Significant differences among communities were detected for species number (S), Margalef's index (d), Pielou's index (J'), Hill's number ($N\infty$), total taxonomic distinctness ($S\Delta^{+}$), average phylogenetic diversity (Φ+), total phylogenetic diversity ($S\Phi$+) and abundance through statistical analyses. The redundancy analysis (RDA) model revealed that turbidity, silicate and depth were significant environmental variables influencing the benthic macroinvertebrates. Variation partitioning (VPA) showed that water characteristics had a greater impact than sediment conditions on the distribution of benthic macroinvertebrates in the East China Sea.

(W4-13942)

Estimating the vertical fluxes of nutrients using ^{228}Ra as a tracer in the East/Japan Sea

Yongjin Han and Guebuem **Kim**

Seoul National University, Seoul, R Korea. E-mail: gkim@snu.ac.kr

The vertical fluxes of nutrients and organic carbon were measured using ^{228}Ra-based eddy diffusivities in the Ulleung Basin of the East/Japan Sea. Radium samples were collected by attaching MnO2- impregnated fiber (Mn-fiber) to a mooring system at 22 depths from surface to 2300 m. The ^{228}Ra/^{226}Ra activity ratio was measured using RaDeCC (Radium delayed coincidence counter) and a gamma counter. The ^{228}Ra concentration was then calculated by multiplying the ratios by ^{226}Ra concentrations measured independently in seawater. Using the ^{228}Ra profile, a one-dimensional diffusion model was established by assuming steady state. The eddy diffusion coefficient of the surface layer (100-500 m) was calculated to be 9.64 cm^2 s^{-1}. The vertical fluxes of dissolved organic carbon, dissolved inorganic nitrogen and dissolved inorganic phosphorus were then estimated by applying the eddy diffusivities to the corresponding concentration gradients (0.45 mol m^{-2} yr^{-1}, -1.40 mol m^{-2} yr^{-1}, and -0.11 mol m^{-2} yr^{-1} respectively). In addition, seawater ages were calculated using the rapid decay of ^{228}Ra relative to ^{226}Ra from the surface to 1000 m. Then, export production (5.0 mol m^{-2} yr^{-1}) was estimated based on the relationship between the apparent oxygen utilization and the seawater age. Our results suggest that high resolution measurements of ^{226}Ra and ^{228}Ra obtained by Mn-fiber mooring are useful for determining the water ages and vertical fluxes of dissolved materials through the oceanic interface (pycnocline).

(W4-13997)

Effects of strong turbulent mixing on phytoplankton around the Tokara strait

Kazuki **Ogi**[1,] Naoki Yoshie[1], Anri Kabe[1], Toru Kobari[2], Daisuke Hasegawa[3] and Joji Ishizaka[4]

[1] Center for marine environmental studies, Ehime University, Matsuyama, Matsuyama, Japan. E-mail: leeogi.sea@gmail.com
[2] Facalty of Fisheries, Kagoshima University, Kagoshima, Japan
[3] Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Miyagi, Japan
[4] Institute for Space-Earth Environmental Research Nagoya University, Nagoya, Japan

Kuroshio provides many benefits to human despite its low productivity and oligotrophic environment. In recent years, the effects of strong turbulent mixing on the lower-trophic level ecosystem have studied around the Tokara strait, where many seamounts and small islands exist within the route of the Kuroshio in the East China Sea. We conducted Lagrangian observations along the Kuroshio from the upstream of the Tokara Strait to the downstream in autumn of 2016, 2017 and 2018. We also investigated responses of phytoplankton assemblages to various nutrient supplies by nutrient enrichment experiments. The incubation experiments showed significant growth of phytoplankton with the nutrient supply by the turbulent mixing. Although phytoplankton biomass observed in the downstream of the Tokara Strait were higher than those in the upstream, the phytoplankton assemblages in the downstream were affected by not only the turbulent mixing but also intrusion of coastal water. Therefore we estimated coastal water fractions in each water column using salinity differences with assuming isopycnal mixing, and excluded the effects of the coastal water intrusion to find net effects of turbulent mixing. The phytoplankton assemblage affected the turbulent mixing in the downstream decreased after passing the Tokara Strait while these decreases in phytoplankton biomass were different from the results expected from the incubation experiments without meso-zooplankton grazing. This result suggested these decreases might be due to rapid grazing by meso-zooplankton in the downstream, and the nutrients supplied by the turbulent mixing might be a driving force behind the relatively high zooplankton productivity in oligotrophic region.

(W4-14001)

Intraseasonal abyssal current variability of bottom-trapped topographic Rossby waves in southwestern East Sea (Japan Sea)

JiYun **Shin**[1] and SungHyun Nam[1,2]

1 School of Earth and Environmental Sciences, Seoul National University, Seoul, R Korea E-mail: jyshin.ocean@gmail.com
2 Research Institute of Oceanography, Seoul National University, Seoul, R Korea

Deep water exchange through the Ulleung Interplain Gap (UIG) between the Ulleung Basin (UB) and Japan Basin (JB) in the East Sea (Sea of Japan) is important for better understanding the sea's vigorous circulation and material cycles. The exchange features an asymmetric flow structure across the UIG: broad and weak inflow (into UB) in the western UIG and narrow and strong outflow (out of UB) in the eastern UIG, where the latter is closely associated with variability in abyssal current near Dokdo, i.e. Dokdo Abyssal Current (DAC). Here, linear theory of bottom-trapped topographic Rossby waves (TRWs) is applied to account for an intraseasonal (defined as period of 30–50 days) DAC variability by analyzing multi-year long observational and reanalysis data. The bottom-intensified DAC variability is characterized with TRW parameters of vertical trapping scale of 1110–1820 m, horizontal wavelength of 54–86 km, propagating speed of 1.44–2.30 km day^{-1}, and propagating direction aligned into the isobaths within 2–23° (with shallower water on the right). A departure angle between the waves' energy-propagating direction and the isobath direction is estimated in two different ways and compared to examine the significance of bottom-trapped TRW dynamics: from spectra of along-slope and cross-slope abyssal currents (θe) and from the theoretical dispersion relation of TRWs for given buoyancy frequency and bottom slope (θt), yielding a small (<16°) difference. Our results support the significance of bottom-trapped TRWs on intraseasonal abyssal current variability near steeply sloped UIG and other areas.

(W4-14178)

Diel vertical migration of zooplankton and micronekton on the northern slope of the South China Sea observed by a moored ADCP

Chenghao Yang[1], Dongfeng **Xu**[1], Zuozhi Chen[2] et al

1 Second Institute of Oceanography, Ministry of Natural Resources, PR China. E-mail: xudongfengsio@sio.org.cn
2 South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, 231 Xingang Road West, PR China

Acoustic Doppler current profiler (ADCP) echoes can be transformed into mean volume backscattering strength (MVBS), which is positively proportional to the biomass of zooplankton and micronekton. A mooring with an upward-looking 75-kHz ADCP was deployed on the northern slope of the South China Sea to monitor diel vertical migration (DVM) and vertical distributions of zooplankton and micronekton under general conditions and extreme conditions such as typhoons. DVM occurs throughout the year, with the maximum migrating speed reaching 9.0 cm/s. It had some cyclic variation, which was in response to marine environment and astronomical influence. Light initiates the ascents and descents of the migrators, and migration intensity may be proportional to the solar altitude. Neap-spring tidal cycle and full moon phase influences are prominent, and the peak at 112 d may be driven by variation of currents. In addition, 270 m is the demarcation between upward and downward migrations; some organisms living below this layer, especially zooplankton and micronekton, migrate to the surface to obtain nutrients and energy; other marine mesopelagic organisms also survive in this manner. Super and severe typhoons reduced vertical migration, having less influence on the deep scattering layer. As Super Typhoon Rammasun passed by the mooring station, current speed increases and temperature decreases were synchronous with changes in the deep scattering layer; the migrators swam downward to evade the influence of a higher-speed current rather than swam upward to compensate for the decrease of temperature.

WORKSHOP 5
Celebrating two decades of North Pacific CPR sampling, and future directions

(W5-14454) INVITED

60 years of plankton community in the northern North Atlantic Ocean

Pierre **Helaouet**

Marine Biological Association of the U.K., Plymouth, Devon, United Kingdom. E-mail: pihe@MBA.ac.uk

The northern North Atlantic Ocean is one of the most studied oceanic area in the world due to its economic role, as well as its role in the Global Ocean Circulation. Its extensive latitudinal extent, coupled with an intricate topography has lead to a very complex set of environmental parameters varying in time (from season to decade) and space (from local to basin). This variability provides a large variety of habitats for its biota, in turn leading to a high diversity with a complex dynamic.

Mainly driven by climate variability and ocean warming, extensive changes in plankton ecosystems in the northern North Atlantic Ocean over the last 60 years including production, biodiversity and species distributions have had effects on fisheries production and other marine life. The Continuous Plankton Recorder (CPR) Survey is an international non-profit organisation collecting data from the North Atlantic and the North Sea on biogeography and ecology of plankton since 1931. With a stable methodology since 1958, the CPR database contains almost 260000 samples gathering crucial information on almost 700 planktonic taxa. With its large spatio-temporal coverage coupled with an impressive taxa resolution, this unique dataset allows us to use multidimensional techniques (e.g.

PCA, PCOA, dbMEM, etc.) to perform comprehensive community analyses. Results depict all the complexity of the plankton dynamic in a fast changing Ocean.

(W5-14031)

Defining isoscapes in the Northeast Pacific as an index of ocean productivity

Boris Espinasse[1,2], Brian P.V. **Hunt**[1,2,3], Sonia D. Batten[4] and Evgeny A. Pakhomov[1,2,3]

1 Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, 2020 – 2207 Main Mall, Vancouver, BC, Canada, V6T 1Z4. E-mail: b.hunt@oceans.ubc.ca
2 Institute for the Oceans and Fisheries, University of British Columbia, AERL, 2202 Main Mall Vancouver, BC, Canada, V6T 1Z4
3 Hakai Institute, PO Box 309, Heriot bay, BC, Canada, V0P 1H0
4 Marine Biological Association UK, CPR Survey, c/o 4737 Vista View Cr, Nanaimo, BC, Canada, V9V 1N8

This study modeled zooplankton isoscapes in the Northeast Pacific using in situ zooplankton stable isotope (SI) data and satellite data. Our objectives were to develop a tool for tracking top predator foraging locations and a simple proxy for secondary productivity. Approximately 280 summer zooplankton samples were analyzed for Carbon ($\delta^{13}C$) and Nitrogen ($\delta^{15}N$) stable isotope (SI) ratios. Samples were obtained from the North Pacific CPR survey and Line P (1998 to 2017). Corresponding environmental conditions were extracted from satellite, in situ sensor, and model databases. Generalized additive models were used to explain the spatial variability of $\delta^{13}C$ and $\delta^{15}N$ and predict isoscapes. Sea surface temperature (SST), sea level anomaly (SLA) and chlorophyll-a were the significant SI predictors. Modelled isoscapes reproduced patterns observed in $\delta^{13}C$ and $\delta^{15}N$ value distribution, including a decrease in SI values from the coast to offshore and elevated SI values associated with eddies, reflecting enhanced local production. In the central part of the NE Pacific higher SI values were correlated with higher large copepod biomass. However, adjacent to the British Columbia coast high $\delta^{15}N$ variability appeared associated with episodic intrusions of coastal waters demonstrating that caution is needed when interpreting sharp changes in SI ratios. While the mechanisms driving SI ratio variability are complex, we demonstrated that a few parameters were able to successfully produce isoscape models. This approach was proven useful to provide a qualitative estimate of the secondary production, which can be particularly valuable in a region where few data are available.

(W5-14050)

Interannual variation in regional zooplankton community structure in the eastern North Pacific

Brian **Hoover**[1], Marisol García-Reyes[1], Sonia Batten[2], Chelle Gentemann[3], Kathleen Dohan[3], and William Sydeman[1]

1 Farallon Institute, Petaluma, CA, USA. E-mail: bhoover@faralloninstitute.org
2 CPR Survey, Marine Biological Association, Nanaimo, Canada
3 Earth and Space Research, Seattle, WA, USA

Two decades of Continuous Plankton Recorder (CPR) surveys in the North Pacific now enable comparisons of zooplankton community structure under a wide range of environmental conditions, including the marine heatwave in 2014-2016. Using summer CPR data collections over 17 years (2000-2016), we tested the hypothesis that zooplankton community structure and distribution varies interannually in relation with oceanographic condition and topographic considerations. Using 16 abundant taxa, we used spatial ordinations and hierarchical clustering to: i) identify and characterize the "typical" community structures associated with particular regions of the Northeast Pacific, and ii) describe how regional community structure changed with temperature and current flow. We identified 7 regional clusters throughout the study domain, each representing distinct combinations of zooplankton taxa. This approach illustrated coastal clusters off the shelf waters near Vancouver Island; a single cluster southeast of Unimak Pass associated with strong currents; a cluster of generally low abundance located along the eastern arm of the subarctic gyre where ocean conditions are dominated by eddy activity; and a set of clusters in the pelagic Gulf of Alaska (GoA) that are associated with stable temperature and current conditions. These results are consistent with previous studies based on single years of data. Temperature variation resulted in significant shifts in community structure on the Aleutian shelf and within coastal regions in the eastern GoA, whereas temperature appeared to have little influence on community structure in the central GoA.

(W5-14076)

Extending the North Pacific CPR Survey pole-ward into the Arctic and potential future investigations

Clare **Ostle**[1], Sonia Batten[2], Jon Fisher[3], David Johns[1], Humfrey Melling[4], Doug Moore[4], John Nelson[4] and Rowena Stern[1]

1 CPR Survey, Marine Biological Association, Plymouth, UK. E-mail: claost@mba.ac.uk
2 CPR Survey, Marine Biological Association, Nanaimo, BC, Canada
3 Centre for Fisheries Ecosystems Research Fisheries and Marine Institute of Memorial University of Newfoundland, St. John's, Canada
4 Institute of Ocean Sciences, Ocean Science Division, West Saanich Road Sidney, BC, Canada

In recent years the Arctic Ocean has seen significant warming trends and changes in circulation, which are likely to have implications for the carbon pump and plankton community composition. Trans-Arctic migrations are likely to become more prevalent as warming continues, and could have large impacts on the ecosystem and biodiversity. The northern boundary of the Pacific Ocean is likely to move pole-ward under climate change; this may cause a shift in areas of the Arctic Ocean to resemble Pacific conditions. By providing the coverage of both the North Pacific and now the boundary conditions between the Arctic, the CPR is ideally suited to tracking these changes. Such gradients of change need to be monitored over a large geographical area and using consistent time-series, in order to understand the implications within the marine ecosystem, and any possible impacts on marine resources. Following the successful completion of a number of summer voyages towing a CPR from western and eastern Canada into the Arctic Ocean, we will present some of the initial preliminary analyses and findings. This presentation will also highlight some of the key interest areas within the North Pacific/Arctic for potential future investigations, such as pollution monitoring and sea-surface carbon flux. These results not only have implications for plankton-dynamic biogeochemical models, but also likely influence carbon export, as different phytoplankton communities have different carbon export efficiencies. Extending and maintaining such datasets is critical to improving our understanding, and monitoring of carbon cycling in the surface ocean and improving climate model accuracy.

WORKSHOP 6
Assessing marine ecosystem services: A comparative view across the North Pacific

(W6-14408) INVITED

Coastal ecosystem services in the Temperate Northern Pacific: An emphasis on beneficiaries

Chanda J. **Littles**[1], Chloe Jackson[2], Theodore DeWitt[2], and Matthew Harwell[3]

1 Army Corps of Engineers, Portland, OR, USA. E-mail: chanda.j.littles@usace.army.mil
2 Western Ecology Division, Environmental Protection Agency, Newport, OR, USA
3 Gulf Ecology Division, Environmental Protection Agency, Gulf Breeze, FL, USA

Understanding the portfolio of beneficiaries relying on coastal ecosystem goods and services (EGS) in a given area can facilitate better land-use planning. Within the scientific community, identifying end-users at the onset of EGS studies means that results are more relevant to decision-makers and communities. We used the Final Ecosystem Goods and Services Classification System (FEGS-CS) in a comprehensive review of beneficiary groups represented in existing coastal EGS literature. We focused on peer-reviewed journal articles published prior to 2018 that linked coastal landscape features with human beneficiaries. Of just under 450 articles that were identified worldwide, less than 50 were based in ecoregions of the Temperate North Pacific. These articles contributed 186 lines of evidence linking EGS to specific coastal users within ecoregions of the Temperate North Pacific. The Cortezian and Yellow Sea Ecoregions had the greatest amount of literature evidence for coastal beneficiaries. Conversely, there were no studies identified linking beneficiaries to coastal features in seven of the 17 ecoregions of this realm. The majority of literature evidence addressed indirect EGS (e.g., climate regulation, biodiversity value, etc.), even when specific beneficiaries were also considered. Additionally, zero-inflated linear models and post-hoc comparisons revealed industry, recreational, and subsistence users with significantly more literature evidence than other beneficiary groups. Overall, results provide a snapshot of prominent users of coastal EGS within the Temperate North Pacific, while shedding light on the disparity in knowledge among ecoregions and opportunities for future work.

(W6-14011)

Valuation of marine ecosystem services: Misunderstandings and lessons

Shang **Chen**, Linhua Hao, Wei Liu, Tao Xia and Shuai He

Research Center for Marine Ecology, First Institute of Oceanography, State Oceanic Administration. 6 XianXiaLing Road, LaoShan District, Qingdao, 266061, PR China. E-mail: schen@fio.org.cn

Marine ecosystem services (MES) are the benefits human beings obtain from marine ecosystem, which consist of the four services, i.e. the provisioning, regulating, cultural and supporting services. Some cases on valuation of MES all around the world have been checked and analyzed. The total value per square kilometer of MES ranks from million USD to ten millions USD. The provisioning services are the major of MES in the near-shore sea area at medium spatial scale while cultural services play the major role in the onshore sea area at the small spatial scale. The value of MES shows the decreasing pattern from onshore to offshore. The value of MES highly depends on the sea use manners. There are some lessons from existing MES valuation cases. Firstly, there is misunderstanding on constituent of each ecosystem service in some cases. Secondly the identification process of each service is sometimes neglected in many cases. Thirdly, the method of reference, esp. The unit price or value per area or weight, is sometimes mis-used in many cases. The paper suggests the comprehensive understanding of MES valuation methods and their application conditions before conducting valuation studies.

(W6-14389)

Developing a system of Environmental-Economic Accounting for oceans: A Chinese perspective

Peng **Zhao**[1,] Feixue Li[2] and Yunlan Zhang[3]

1 Fourth Institute of Oceanography, Ministry of Natural Resources, PR China. E-mail: zp-zp@163.com
2 Nanjing University, Nanjing, Jiangsu, PR China
3 Guangxi Finance College, Nanning, Guangxi, PR China

The System of Environmental-Economic Accounting 2012-Central Framework (SEEA Central Framework) and Experimental Ecosystem Accounting (SEEA EEA) was released for accounting the environmental assets and ecosystem services by the United Nations Statistical Commission. They are widely accepted by international society, but mostly limited to terrestrial assets and services accounting. The natural resources accounting and balance sheets are two important mechanisms for realizing eco-civilization in China, and demand a comprehensive spatial coverage of SEEAs. To extend their application to oceans and ocean ecosystems, it is necessary to connect oceanic assets and services to SEEAs. This study aims at reviewing the stakeholders and needs for SEEAs for oceans in China, connecting oceanic assets and services to SEEAs, assessing the data availability and gaps and providing suggestions on extending SEEAs to oceans.

WORKSHOP 7
PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment (Third)

(W7-14451) INVITED

WGIBAR activities and development integrated ecosystem assessments for the Barents Sea with prospect for connecting WGICA activities

Elena **Eriksen**

Institute of Marine Research, Bergen, Norway. E-mail: elena.eriksen@hi.no

The integrated assessment for the Barents Sea (WGIBAR) is a multidisciplinary group of scientists, seeking to describe the state of and changes in the ecosystem. The BS undergo dramatic changes from cold climate condition with larger part of the BS covered by ice and colder temperature conditions during 1960-1980, oscillating period with both warm and cold years during 1990, to record warm temperature condition and loss of half of areas with winter ice during 2000s. Warming in the BS was associated also with increased net primary production, abundance of meso- and macroplankton and good fish recruitment. Capelin stock collapsed twice during the recent warming due to increased overlap with cod and predation pressure. However, good recruitment and feeding condition benefit to recover faster and tolerate a record high cod between their collapses. High cod stock increased occupation area into the northern area and preyed on alternative food items in addition to polar cod while capelin was at low level.

The Atlantic water that flows through the BS forms the Barents branch of Atlantic water in the CAO. Variability of these branches of Atlantic water monitored and assessed by WGIBAR and is important information for WGICA. Transport of Calanus species into the CAO and expansion of distribution of fish in the Atlantic gateway area is also essential for the WGICA. While information on circulation in CAO e.g. Beaufort Gyre can be of value for WGIBAR.

(W7-14151)

Pacific water in the northeastern Chukchi Sea

Miaki Muramatsu[1], Hiromichi **Ueno**[1], Motoyo Itoh[2], Eiji Watanabe[2], and Jonaotaro Onodera[2]

1 Hokkaido University, Hakodate, Japan. E-mail: hoku-h3@eis.hokudai.ac.jp
2 Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan

In the Pacific sector of Arctic basin, sea ice retreat during summer has been enhanced over the past few decades. Previous studies suggested that the Pacific water entering to the Chukchi Sea from the Bering Sea contributed to the sea ice retreat. The Pacific water flowing northward through the Bering Strait is transported to the Arctic basin mostly via Barrow Canyon; part of the water is suggested to be transported west-northwestward as the Chukchi slope current. In this study, we investigated the Pacific water along the Chukchi slope using mooring temperature, salinity and velocity time series data, located around 73°*N* and 161°*W* from August 2003 to September 2004 and from September 2015 to September 2017. The Pacific water was observed at ~40 m depth mooring data in October 2003, 2004, 2015 and 2016, when the flow direction was mostly west- northwestward. A temperature lag-correlation analysis between mooring site of this study and Barrow Canyon suggests that it takes a few months for the Pacific water to be transported to the mooring site from the Barrow Canyon.

(W7-13905)

Variations in spring and summer phytoplankton communities across water mass gradients in the Chukchi Sea

Lisa B. **Eisner**[1], Michael W. Lomas[2], and Jens M. Nielsen[1]

1 NOAA Fisheries, Alaska Fisheries Science Center, Seattle, WA, USA. E-mail: Lisa.Eisner@noaa.gov
2 Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

Marine phytoplankton composition and size are important to carbon cycling (e.g. sinking of particles and subsequent regeneration) and trophic energy transfer to zooplankton, fish and marine mammals (large taxa such as diatoms allow a shorter food web and more efficient energy transfer to higher trophic levels). Phytoplankton community composition, and consequently also the quality and quantity of dietary resources for higher trophic level consumers, varies considerably between oligotrophic, eutrophic and ice-influenced water masses, between surface and subsurface depths in Arctic seas. Accordingly, the phytoplankton population size structure also varies by region and water mass with strong implications for trophic transfer of primary production. Changes in climate (increased freshening, warming, and open water area, all of which affect stratification and nutrient supply) are likely to alter phytoplankton community size structure and composition. Phytoplankton taxonomic information was collected during fisheries oceanography surveys in the Chukchi Sea in 2017 as part of Arctic ecosystem projects: Arctic Shelf Growth, Advection, Respiration & Deposition (ASGARD) and the Arctic Integrated Ecosystem Survey (Arctic IES) in June and August-September, respectively. Variations in phytoplankton communities are evaluated using Flow Cam analysis of live phytoplankton (large taxa), flow cytometric analysis (small taxa) and size-fractionated chlorophyll a across the Chukchi shelf in spring and summer. We explore relationships of phytoplankton communities to water mass and latitudinal region, and potential impacts on higher trophic levels.

(W7-14254)

Spatial changes of phytoplankton community in the northern Bering Sea during summers of 2017 and 2018

Yuri **Fukai**[1], Yutaka Fukai[1], Yoshiyuki Abe[2], Kohei Matsuno[1], Atsushi Yamaguchi[1]

1 Hookaido University, Hakodate, Japan. Email: y.fukai@fish.hokudai.ac.jp
2 The University of Tokyo, Chiba, Japan

In the northern Bering Sea, changes in the timing of sea ice retreat and the hydrographic condition during summer are reported in recent years. However, the influence of the environmental changes on the phytoplankton community is not fully understood. In this study, we investigated spatial changes on phytoplankton community in the northern Bering Sea during the summers of 2017 and 2018. Also, we evaluated the effects of the environmental changes to the phytoplankton community during summer. The cell density of phytoplankton community ranged from 3.6×10^2 to 1.6×10^6 cells L^{-1} in 2017 and 8.5×10^2 to 3.4×10^5 cells L^{-1} in 2018, particularly with a high density near the Bering Strait in 2017. From cluster analysis, based on cell density, phytoplankton communities were separated into four communities, and their distributions changed with spatially and temporally. In the Chirikov Basin and the Bering Strait, phytoplankton communities greatly varied between 2017 and 2018. The phytoplankton communities near the Bering Strait showed high cell densities dominated by *Chaetoceros socialis* and *Chaetoceros* spp. (subgenus *Hyalochaete*) in 2017, while low cell densities (mean cell density = 3.4×10^4 cells L^{-1}) with pennate diatoms and *Chaetoceros* spp. (subgenus *Phaeoceros*) were observed in 2018. Non-metric multidimensional scaling indicated that phytoplankton communities correlated with some environmental factors such as nutrients. This study revealed that the community structure of phytoplankton in the northern Bering Sea, especially near the Bering Strait, was affected by the annual changes of environmental conditions during summer.

(W7-13929)

Spatial and inter-annual changes in zooplankton community structure in the western Arctic Ocean during summers of 2008−2017

Yoshiyuki **Abe**[1], Kohei Matsuno[2], Amane Fujiwara[3], Atsushi Yamaguchi[2] and Toru Hirawake[2]

[1] Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan. E-mail: y.abe@aori.u-tokyo.ac.jp
[2] Graduate School of Fisheries Science, Hokkaido University, Hakodate, Japan.
[3] Japan Agency for Marine-Earth Science and Technology, Yokosuka, Kanagawa, Japan

Reduction of summer sea ice coverage has occurred in the western Arctic Ocean recently. Changes in the coverage and retreat timing of sea ice are expected to have a great impact on the marine ecosystem. Under such situation, inter-annual changes in the spatial distribution of the zooplankton community structure have also occurred. However, most previous studies that report on the community structure focus on particular limited region and limited years. In this study, we evaluated inter-annual changes in the spatial distribution of zooplankton communities in the western Arctic Ocean during the summers of 2008, 2010, 2012–2017. A total of 339 casts were conducted to collect zooplankton by vertical hauls at 22−63 stations in the western Arctic Ocean during 26 August−13 October of 2008, 2010, 2012–2017. Based on cluster analysis, four zooplankton communities were identified. Horizontal distribution of each zooplankton community corresponded with the depth. Shelf community was characterized by high abundance of the Pacific species, especially copepod *Metridia pacifica,* which transported from the Bering Sea. The group D located between the shelf and the Slope, which showed low species diversity and low abundance, was occurred in 2012, 2015 and 2017 when the melt day of sea ice was a significantly earlier than the other years. These results suggest that the earlier sea ice reduction may cause a small phytoplankton bloom and this change can also possibly lead to the increase in the area with low species diversity and low zooplankton abundance during summer in the western Arctic Ocean.

(W7-14051)

Multiple facets of marine biodiversity in the Pacific Arctic under future climate

Irene D. Alabia[1], Jorge Garcia Molinos[1], Sei-Ichi **Saitoh**[1], Takafumi Hirata[1], Toru Hirawake[2] and Franz J. Mueter[3]

[1] Arctic Research Center, Hokkaido University, Sapporo, Japan. E-mail: irenealabia@arc.hokudai.ac.jp
[2] Faculty of Fisheries Sciences, Hokkaido University, Hakodate Japan
[3] University of Alaska Fairbank, Juneau, Alaska, USA

Climate change triggers species distributional shifts, affecting biogeography in marine ecosystems. Here, we explored the potential ecological impacts of projected changes in species habitat due to elevated temperature and sea ice loss in the Pacific Arctic continental shelves. In particular, we examined the contemporary and future structures of species richness (alpha-) and community composition (beta-diversity) of benthic assemblages across the taxonomic, functional, and phylogenetic biodiversity facets. Our data were composed of multi-ensemble projections for present (1993-2017) and future (2026-2100) habitat distributions of 20 fish and invertebrate species and their respective functional (9 biological traits) and phylogenetic information. Prominent changes relative to contemporary biodiversity patterns were observed during the late-century (2076-2100) under high warming scenario. Specifically, alpha diversity structure was characterised by the poleward increases in taxonomic richness and functional trait redundancy, along with a reduction in phylogenetic distances. In terms of community composition, the subarctic (Arctic) region exhibited community homogenisation (heterogenisation) as seen from the significant declines (increases) in taxonomic, functional and phylogenetic beta-diversity between the present and future periods. We found that the projected poleward shifts of boreal species in response to warming were modifying the taxonomic and functional biogeography of the Arctic communities as larger, longer-lived and more predatory taxa were expanding the leading edges of their distribution. Our results show that looking at multiple diversity facets can yield critical insights into the link between species composition, ecosystem functioning, and environmental drivers across biogeographic domains under the rapidly emerging threats of climate change.

WORKSHOP 8
Synthesis of bioacoustics programs for monitoring zooplankton and fisheries in the North Pacific

(W8-14283) INVITED

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

Stéphane Gauthier

Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada. E-mail: stephane.gauthier@dfo-mpo.gc.ca

Mobile surveys are routinely used to assess fish populations, but are prone to errors or biases when assumptions of synopticity are violated and fish migrate or move significantly through the survey domain. Moreover, migration of highly mobile species can be influenced by many ecological factors and oceanographic conditions. These movements and behaviors are subject to change over time, introducing further uncertainty in survey estimates. In this presentation, I will illustrate how strategically-positioned moored echosounders can help characterize the temporal aspect of fish population migration using two examples from the west coast of Canada. The first study uses Acoustic Zooplankton and Fish Profilers (AZFP) to monitor the outmigration of juvenile Pacific salmon to the open ocean through Discovery Passage. This work indicated that the migration of juvenile salmon was characterized by a series of high density pulses over a total period of 6-8 weeks, suggesting fast movement through the area. In the second example, AZFPs were deployed on the continental shelf off the west coast of Vancouver Island to intercept Pacific Hake during their northward feeding migration. Sampling combined with analytical approaches, including multi-frequency methods, was used to interpret the acoustic data and characterize ecosystem components. Results indicate highly variable local abundance and a more extended migration period than previously anticipated. In both studies, distinct migration patterns were observed at high temporal resolution for discrete periods of time, offering a unique view of these dynamic processes.

(W8-13920) INVITED

Development of monitoring techniques for zooplankton using multi-frequency profilers moored in Yamada bay, Tohoku, Japan

Kouichi **Sawada**[1], Tohru Mukai[2], Tomohiko Matsuura[1], and Yoshiaki Fukuda[2]

1 National Research Institute of Fisheries Engineering, Japan Fisheries Research and Education Agency, Kamisu, Japan
E-mail: ksawada@fra.affrc.go.jp
2 Hokkaido University, Hakodate, Japan

The salmon production in Iwate, which is next to Hokkaido in Japan, has declined after 1995- and 2006-year class, drastically. In this situation, the Tohoku Earthquake happened in March 11, 2011. Sanriku coast which faced to the Pacific Ocean suffered severe damage from the earthquake and tsunami. Fisheries facilities including hatchery stations were seriously damaged. After the earthquake disaster, new research programs, which were planned by Agriculture, Forestry and Fisheries Research Council, were carried out to rebirth food supply region by developing advanced technologies. In Iwate prefecture, the new program, the development of release techniques of juvenile salmons to improve return rate in Sanriku area, had been conducted from 2013 to 2017. The objectives of the program included the prediction of suitable release timing, development of release and monitoring techniques, feeding habit, and physiological state of released juvenile salmons. In this program, we developed techniques to confirm the release timing based on the marine environment including zooplankton condition in a bay. As it is known that juvenile salmons prefer large zooplankton, monitoring systems were developed to observe distribution density of zooplankton by size using echo sounders with multiple frequencies. Two systems were moored at near the mouth of Yamada bay faced Pacific Ocean from January to June 2014 to 2017. In 2017, one of the systems was connected to cellular system and observed data could be delivered to fishermen every day. In this presentation, developed systems, comparisons between net sampling of zooplankton and profiler observations are introduced.

(W8-13939)

Vertical distribution and density of Antarctic silverfish (*Pleuragramma antarcticum)* in the Ross Sea, Antarctic using multi-frequency

Wooseok **Oh**[1], Huoungsul Na[2], Wuju Son[3], Inwoo Han[1], Geunchang Park[1] and Kyounghoon **Lee**[4]

1 Department of Fisheries Science, Chonnam National University, Yeosu, R Korea. E-mail: owsnice@gmail.com
2 Division of Polar Ocean Sciences Korea Polar Research Institute, Incheon, R Korea
3 Division of Polar Ocean Sciences Korea Polar Research Institute, University of Science and Technology Daejeon, R Korea
4 Department of Marine Technology, Chonnam National University, Yeosu, R Korea. E-mail: khlee71@jnu.ac.kr

The Ross Sea is known as a sea area with the highest primary productivity out of the Antarctic where lots of species inhabit in the sea. To protect the Ross Sea, where the pristine natural environment has been preserved, the Commission for the Conservation of Antarctic Resources (CCAMLR) designated the Ross Sea as one of the Marine Protected Areas (MAPs) at the 35th Conference for protection of the marine ecosystem of the Antarctic in 2016. We carried out acoustic survey during the period from January 16 to January 21 in 2019 by the R/V Araon, a research vessel from the Korea Polar Research Institute. Acoustic data were collected by the scientific echosounder (Simrad EK60, Norway) mounted on the polar research vessel, RV Araon. The collected frequencies were 38 kHz, 120 kHz and 200 kHz, and they were analyzed by Echoview software Ver. 9.0 (Myriax, Australia). In the Ross Sea where various marine life live, Antarctic silverfish (*Pleuragramma antarcticum*) is a dominant fish species playing a very important role in the relation of food chain as the intermediate link. As the results from a towed survey fishing gear, about 92 % of the collected species was Antarctic silverfish (*Pleuragramma antarcticum*). Some fish shoals were detected to the max. 150-m depth, and they were distributed within the 50-m depth on this survey.

(W8-14000)

Assessment of fishery resources around Set-net using acoustic methods for sustainable fishery

Yanhui **Zhu**[1], Kenji Minami[2], Yuka Iwahara[3], Kentaro Oda[3], Koichi Hidaka[3], Osamu Hoson[3], Kouji Morishita[3], Sentaro Tsuru[3], Masahito Hirota[3] and Kazushi Miyashita[4]

1 Graduate School of Environmental Science Hokkaido University, N10W5, Sapporo, Hokkaido, Japan
E-mail: zhuyanhui0817@eis.hokudai.ac.jp
2 Estuary Research Center, Shimane University, 1060 Nishikawatsu, Matsue, Shimane, Japan
3 Marine Fisheries Research and Development Center (JAMARC), Japan Fisheries Research and Education Agency, 2-3-3 Minatomirai, Yokohama, Kanagawa, Japan
4 Field Science Center for Northern Biosphere, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido, Japan

Japan is one of the top producers of fishery products in the world, and it is also widely known in positive fisheries management. Up to the present, Japanese fishery industries put great effort into sustainable fishery by using the scientific methods to quantify. We are considered that taking scientific approaches to assess fishery resources is the main principle for sustainable fishery. In our study, we conducted the assessments in Suzu of the Kochi coastal area, where the Set-net fishery is the main industries. Our data were collected in each season from Aug. 2016 to Feb.2018 at surrounding area of Set-net by fishing boat (9.91 gross tonnage). Fish abundance and the environmental characteristic of fish distribution around current Set-net were examined predominantly by quantitative echo sounder (KSE300 SONIC, 38kHz). Furthermore, statistical analysis was performed to identify the relationship of acoustic index and marine environment, such as generalized additive model (GAM). As a result, every season showed a strong tendency that the fish concentrated near the bottom.

However, whether the fish echoes were present in the middle layer or not differs depending on the season. The distribution changes were likely reflected in ecology of different dominant fish species in each season. Additionally, the fish composition was affected in marine environmental dynamics, caused by intrusion of the Coastal Kuroshio Meander. Therefore, it is suggested that currents changes alter fish abundance and distribution, and are critical for determining annual variation between multiple currents and fish composition.

(W8-13951)

Estimating the species identification and abundance of Antarctic Krill (*Euphausia superba*) Using 2-frequency difference method

Inwoo **Han**[1], Seokgwan Choi[2], Sangdeok Chung[2] Wooseok Oh[1], Geunchang Park[1] and Kyounghoon **Lee**[3]

1 Department of Fisheries Science, Chonnam National University, Yeosu, R Korea
2 Division of Fisheries Resources Research Division, National Institute of Fisheries Science, Busan, R Korea
3 Department of Marine Technology, Chonnam National University, Yeosu, R Korea E-mail: Khlee71@jnu.ac.kr

This study aimed to understand the frequency characteristics of krill using the two frequencies; 38 kHz and 120 kHz and conducted sampling survey to identify krill species. The scientific echosounder (Simrad EK 60, Kongsberg, Norway) consisting of two frequencies; 38 kHz and 120 kHz was used to apply the 2-frequency difference method based on its backscattering strength characteristics of the target species. To identify Antarctic krill as target species in the sound scattering layer, various analysis methods were utilized in this survey. The processing of background and other noise can be increased to discriminate and estimate Antarctic krill's distribution inhabiting in neighboring waters off the South Shetland Island (Subarea 48.1). Acoustic data were collected with the frequency of 38 kHz and 120 kHz in 2016 and 2019. A. Krill was collected by the commercial mid-water trawl gear. The data were processed and analyzed following the CCAMLR standard protocols using interval integration based on a transect-based survey. The weighted krill's density was estimated to be 3.00 g/m^2 in 2016 and 4.17 g/m^2 in 2019, respectively.

(W8-14086)

Zooplankton acoustic surveys of Korea Polar Research Institute in the Polar Oceans

Hyoung Sul **La**[1], Wuju Son[1,2], Eun Jin Yang[1], Kyoung-Ho Cho[1], Tae-Wan Kim[1], Jinyoung Jung[1], Youngju Lee[1] and Sung-Ho Kang[1]

1 Korea Polar Research Institute, Incheon, R Korea. E-mail: hsla@kopri.re.kr
2 Korea University of Science and Technology, Daejeon, R Korea

Polar marine ecosystems are considered as sentinels of global change. Zooplankton are an essential link in polar marine ecosystems between primary producers and higher trophic levels. Sustained observations and long-term data are needed in the population changes and process controls. However, zooplankton surveys are still scarce to provide a general description of the spatio-temporal variability of zooplankton in the seasonally ice-covered areas due to the logistic difficulty. Korea Polar Research Institute (KOPRI) has conducted multidisciplinary oceanographic surveys with icebreaking research vessel, *Araon*, in the Pacific side of Arctic and Antarctic Oceans. During expedition, acoustic systems consisting of vessel-mounted and mooring-based were used to observe and understand the zooplankton distribution and behavior related to environmental changes. Vessel-mounted acoustic system (EK60 scientific echosounder) is the primary tool to observe the spatial distribution of zooplankton biomass covering a large open water area, whereas the mooring-based acoustic system such as an acoustic Doppler current profiler is useful to observe the vertical behavior of zooplankton at high temporal resolution under sea ice. In this presentation, an introduction of zooplankton acoustic surveys that we have done in the biological hotspots in the Polar Oceans is provided, and a case will be made for collaborative scientific research with a definite Arctic focus to accommodate future needs.

(W8-14236)

Bio-acoustic monitoring with the Acoustic Zooplankton Fish Profiler

Steve **Pearce**[1], Jan Buermans[1], Stephane Gauthier[2], Alireza Rezvanifar[3], Tunai Porto Marques[3], Melissa Cote[3], Alexandra Branzan Albu[3] and David Lemon[1]

1 ASL Environmental Sciences Inc., Victoria, BC, Canada. E-mail: spearce@aslenv.com
2 Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada 3University of Victoria, Victoria, BC, Canada

Bio-acoustic monitoring with the Acoustic Zooplankton Fish Profiler (AZFP) is typically accomplished via tautline or bottom frame mooring, where this autonomous and calibrated echosounder may operate continuously for 12 months at a time. Such deployments of this multifrequency instrument provide excellent temporal coverage. Recently the multifrequency AZFP has been integrated into the Slocum glider, facilitating increased spatial coverage during typical multi-week glider deployments. Deployment locations for the AZFP/Slocum have so far included the Gulf of St. Laurence, Gulf of Mexico, and the Southern Indian Ocean. This presentation highlights user data from moored deployments and from glider-based deployments featuring the AZFP. A recent study off the coast of Vancouver Island has contributed to these data, which are part of an ongoing collaboration between ASL, DFO/IOS, and the University of Victoria to apply computer vision and machine learning to multifrequency AZFP data. This collaboration explores novel ways of detecting visual patterns from echosounder data using computer vision techniques. Switching from the more traditional acoustic data processing paradigm to computer vision algorithms may provide new insights into echosounder data and robust automatic classification rates for patterns such as schools of herring.

(W8-14422)

Long-term bio-acoustics monitoring of zooplankton dynamics in Saanich inlet (British Columbia, Canada)

Lu **Guan**[1], Mei Sato[2], Akash Sastri[3], Chih-hao Hsieh[4], and Richard Dwey[1]

1 Ocean Networks Canada, University of Victoria, Victoria, BC, Canada. E-mail: lguan@uvic.ca
2 Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, Canada
3 Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, Canada
4 Institute of Oceanography, National Taiwan University, Taipei, Taiwan

Ocean Networks Canada (ONC) operates underwater cabled observatory networks to deliver real-time data for monitoring the NE Pacific and Arctic. For example, zooplankton in the Saanich inlet, an inverse estuary at the southeastern end of Vancouver Island (British Columbia, Canada), have been monitored by acoustic profiler mounted on Network Under the Sea (VENUS ONC) cabled observatory system platform since 2006. A single-frequency Zooplankton Acoustic Profiler (ZAP, 200kHz) and a multi-frequency Acoustic Zooplankton Fish Profiler (AZFP, 38, 125 and 200 kHz) have been deployed during 2006-2016 and 2016-present, respectively. Measurements of environmental and oceanographic indices (e.g. temperature, salinity, oxygen and tide height) are collected via multiple observatory system sensors concurrently. Two case studies based on these thirteen-year (2006-2019) high-resolution time-series will be discussed: 1) quantification of the seasonal variability in migration timing of euphausiids; and 2) characterization of zooplankton dynamical features and exploration of the driving forces/processes on multiple time scales using Empirical Dynamic Modeling. In addition, potential of applying AZFP in fish monitoring in Saanich inlet will also be demonstrated.

(W8-14247)

"Seeing" prey provides insights into the decline of southern resident killer whales

Mei **Sato**[1], Andrew W. Trites[1] and Stephane Gauthier[2]

1 Marine Mammal Research Unit, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada
E-mail: m.sato@oceans.ubc.ca
2 Institute for the Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada, V8L4B2

The decline of southern resident killer whales may be due to a shortage of prey. However, there are few observations to test the hypothesis that prey are less numerous and accessible to this population of killer whales. Acoustics provide a means to "see" beneath the surface, and unravel fine-scale details about the distribution, numbers and behaviors of prey species. We compared the availability of prey sought by two populations of killer whales feeding in the waters off Vancouver Island—one that is small in numbers and declining in Juan de Fuca Strait (southern resident killer whales) and one that is four times larger in population size and increasing in Johnstone Strait (northern resident killer whales). Both populations of killer whales primarily feed on Chinook salmon. We used ship-based multifrequency echosounders and direct sampling to identify differences in the prey fields that may explain the dynamics of these two whale populations. We found that the frequency of occurrence of large fish targets (> 60 cm) was 1.6 –

3.5 times higher in Johnstone Strait than in Juan de Fuca Strait. Those large targets were located significantly deeper in Johnstone Strait, which may reflect differences in bathymetries of the two regions. Our study addresses a critical knowledge gap in predator-prey interactions, and provides insights into the future management options that might be implemented to facilitate recovery of the southern resident killer whales.

(W8-14294)

Mapping prey fields of foraging humpback whales in British Columbia, Canada

Rhonda **Reidy**[1], Stéphane Gauthier[2], Laura Cowen[1], and Francis Juanes[1]

1 University of Victoria, Victoria, B.C., Canada. E-mail: rreidy@gmail.com
2 Fisheries and Oceans Canada, Sidney, B.C., Canada

Developing a cost-effective sampling framework for obtaining time-series data on prey composition and spatiotemporal dynamics of baleen whale feeding remains a major challenge. We investigate a sampling method that measures a variety of surface and deep-water prey characteristics in North Pacific Humpback Whale feeding areas near northern and southern Vancouver Island, British Columbia (B.C.), Canada. The vertical distribution of prey is continuously recorded near feeding Humpback Whales from a small vessel using an Acoustic Zooplankton and Fish Profiler (AZFP), following fine-scale transects to map three-dimensional prey fields. The surveys are conducted in daylight hours in regions with and without foraging Humpback Whales to describe prey in the areas used by the whales. Regional mid- water prey sampling informs the species composition of acoustic signal data, while humpback fecal sampling provides information about which prey species are actually consumed. Results show consistent differences between feeding regions, with Humpback Whales targeting shallow Pacific Herring aggregations off northern Vancouver Island but deep layers of Walleye Pollock and euphausiids in southern Vancouver Island waters. Fecal samples from surveyed whales in southern waters comprise mainly bones from juvenile Walleye Pollock or Pacific Cod, while surface observations document juvenile herring as the dominant humpback prey in northern waters, thus linking Humpback Whale foraging to concurrent measures of prey from the AZFP.

(W8-13845)

Spatial distribution of fin (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales in relation to environment and acoustically measured prey distribution

Abigail **McCarthy**[1], Alex De Robertis[1], Stan Kotwicki[1], Kathy Hough[2], Paul Wade[1] and Chris Wilson[1]

1 Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE Seattle, WA, 98115, USA. E-mail: Abigail.McCarthy@noaa.gov
2 National Marine Sanctuary Foundation *for* Olympic Coast National Marine Sanctuary, National Ocean Service, National Oceanic and Atmospheric Administration, 115 East Railroad Avenue, Port Angeles, WA, 98362, USA

Fin and humpback whales share foraging areas and may be competing for the same prey, but little is known about the extent to which they partition prey. Visual cetacean surveys and simultaneous acoustic-trawl surveys of prey were conducted around two submarine canyons off Kodiak Island in 2004 and 2006. A combination of univariate and multivariate statistical models were used to examine the associations between sightings of fin and humpback whales and measures of their potential prey and environment. Observations and models indicate that fin whales were disproportionately abundant in areas with the highest observed euphausiid concentrations, while humpback whales were abundant at lower euphausiid concentrations and in areas where juvenile walleye pollock were abundant. Fin whales were disproportionately abundant in the areas where krill biomass was deepest and in the deepest areas surveyed (>150 m depth). In contrast, humpback whales primarily occurred in shallower areas and near more shallowly distributed krill. The different depth and prey affinities of fin and humpback whales suggest niche and habitat partitioning between these two co-occurring species. Abundance models built using acoustic estimates of prey density are a useful tool for further understanding of distribution, abundance, and behavior of these animals, and will aid future conservation efforts.

(W8-14009)

Correlation analysis between fish and zooplankton in cold water mass using acoustic survey

Wooseok **Oh**[1], Insung Han[2], Ujin Ko[2], Geunchang Park[1], Inwoo Han[1] and Kyounghoon **Lee**[3]

1 Department of Fisheries Science, Chonnam National University, Yeosu, R Korea. E-mail: owsnice@gmail.com
2 Climate Change Research Division, National Institute of Fisheries Sciences, Busan, R Korea
3 Department of Marine Technology, Chonnam National University, Yeosu, R Korea. E-mail: khlee71@jnu.ac.kr

The cold water mass is defined that waters have water temperature differences, more than 3 to 5 Celsius degrees, compared to near waters. The phenomenon of cold water mass has seasonal variation. However, every time from June to August, the phenomenon of cold water mass is occurred frequently in the southeast part of the East Sea. The duration of this phenomenon might be approximately one to two weeks and it happens repeatedly. The cold water mass has a high level of nutrients and high productivity of Food Organisms. Also, the biomass of zooplankton would be increased due to the cold water. The purpose of this study is to identify the relationship between fish and zooplankton in the cold waters from Pohang to Gijang regions. 2018 In summer season; June 25-29, July 9-13, July 23-27, and August 27-31, the acoustic survey was conducted using the frequency 38 kHz and 120 kHz in the southeast waters of East Sea, Korea. The separation between fish and zooplankton was based on the results of acoustic survey and their correlation was identified. The NASC of zooplankton and fish had the lowest value in July 9-13 as 351 m^2/n.mile^2, 1865 m^2/n.mile^2. In June 26-29, August 22-25 The NASC of zooplankton had the highest value as 760 m^2/n.mile^2, 750 m^2/n.mile^2. The NASC of fish had the highest values in June 26-29, August 22-25 as 4573 m^2/n.mile^2, 4537 m^2/n.mile^2. The NASC correlation between fish and zooplankton showed a positive value (R^2=0.67).

(W8-14284)

Interoperating ocean sonar data of heterogeneous sources using echopype

Wu-Jung **Lee**, Valentina Staneva and Kavin Nguyen

University of Washington, Seattle, WA, USA. E-mail: wjlee@apl.washington.edu

The recent broader availability of commercial autonomous echosounders has created a surge in deployment and produced a deluge of data. However, these new data remain significantly under- utilized, despite their promising potential in advancing our understanding of the marine ecosystem. One of the root causes of this problem is the lack of interoperable data format and scalable analysis workflows that adapt well with the rapidly increasing data volume. At present, most echosounder data are stored in manufacturer-specific formats and analyzed using software packages that are mostly closed-source or written in proprietary languages. Many are GUI-based, which facilitates visual data exploration but hinders reproducibility. Furthermore, none of the existing packages supports parallel computation with random-access file formats. The sheer tedium in data wrangling has significantly diverted efforts of the research community away from answering scientific questions. To address these issues, we developed a Python software package "echopype" to leverage existing distributed computing libraries in the scientific Python stack, such as Xarray and Dask, for large-scale echosounder data processing. echopype provides tools to convert manufacturer-specific sonar data files to netCDF, which enables explicit and scalable computation of echo data in a labeled, multi-dimensional format that is familiar to the wider oceanography and earth science communities. We envision the continued development of echopype as a catalyst to an open, community-driven effort in establishing best practices for analyzing large echosounder data sets.

(W8-14562)

Spatial organization and abundance indicators of euphausiids across the California Current ecosystem

Jeffrey G. **Dorman**[1], William J. Sydeman[1], Jarrod A. Santora[1,2], Brian Hoover[1], and Sarah Ann Thompson[1]

1 Farallon Institute, 101 H Street, Suite Q, Petaluma, California, 94952, USA. E-mail: jdorman@faralloninstitute.org
2 Department of Applied Mathematics, University of California Santa Cruz, 1156 High Street, Santa Cruz, 95060, California, USA

The spatial distribution and inter-annual variability of krill in the California Current is import to understanding the flow of energy throughout the food web up to commercially important top predators. We present acoustic data across the entire California Current Ecosystem (CCE) from Mexico to Canada, testing for differences in relative abundance and spatial organization across nine ecological regions of the CCE. We summarize euphausiid backscatter, expressed as areal density using the Nautical Area Scattering Coefficient (NASC; m^2 nmi^{-1}) based upon data collected during 33 cruises from 2000 through 2018 (missing 2007). Time-space averaging was used to quantify the "spatial climatologies" of the euphausiid prey fields within and across regions. Interannual and regional variation in NASC was examined using analysis of variance; we used kernel density smoothing to illustrate mesoscale aggregations and the Getis-Ord Gi* statistic within the core sampling region (central-northern California) to test for sub-mesoscale interannual variation in spatial structuring. In the core region, NASC corresponded with the numerically dominant species *Euphausia pacifica*, but for shelf habitats represented positive densities of both *E. pacifica* and *Thysanoessa spinifera*. For years, with nearly complete coast-wide coverage, the highest NASC values were found in the southern and northern regions of the CCE, with intermediate values in the central regions. Sub-mesoscale aggregations within the central-northern California region showed both increasing as well as oscillating persistence. Aggregations along the coastline from Monterey Bay to immediately south of San Francisco, California, appear to have become more persistent over the past decade. Understanding the spatial structure of euphausiids on multiple scales across the CCE provides a major step in determining consumer-prey relationships and marine ecosystems functions in this dynamic seascape.

WORKSHOP 9
Monitoring non-indigenous species in PICES member countries: Towards best practices

W9-P-13907 INVITED

Community science to capture the leading edge of an invasion: European green crab on Washington State's inland shorelines.

Emily W. **Grason**[1], Jeff Adams[1], P. Sean McDonald[3], and Kate Litle[1]

1 Washington Sea Grant, University of Washington, Seattle, WA, USA E-mail: egrason@uw.edu
2 Program on the Environment and School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA

The spread of the globally-damaging invasive European green crab, *Carcinus maenas*, into the Salish Sea has been viewed with concern by managers. Following the detection, in 2012, of an established population of green crab in Sooke Basin, B.C., Washington Sea Grant launched Crab Team, a volunteer-based monitoring program in 2015. Crab Team currently engages 250 volunteer, tribal, and agency monitors in surveying a network of 54 sites along Washington's inland shorelines. This multi-stakeholder approach has enabled a much broader scope of early detection than would otherwise be possible. In addition, close advisory partnerships with management entities, including tribes, US federal and state agencies, facilitate communication and coordination of response and assessment efforts.

Since 2016, 236 green crabs have been captured at a handful of monitoring sites along Washington's inland shorelines, the majority concentrated at a single site. Based on size, these are believed to be initial colonizing individuals, arrived via larval dispersal in 2015 and/or 2016. Though most of these populations are not yet fully established, there is potential for rapid growth without intervention. Yet the low numbers and apparent isolation of current populations indicate that the invasion is still in its early stages, providing a unique opportunity for effective early intervention. While physical oceanographic modeling and genomic research are ongoing in an attempt to better understand the dispersal dynamics of green crab in the Salish Sea, continued monitoring efforts and cross boundary collaboration are imperative to protect ecosystems and natural resources.

(W9-14367)

Developing spatially explicit tools to minimize costs and maximize benefits of marine invasive species control

Alexandra C.D. **Davis** and Stephanie Green

University of Alberta, Edmonton Alberta, Canada. E-mail: acdavis@ualberta.ca

Invasive species are a global economic and ecological problem and are responsible for billions of dollars in environmental damages annually. Invaders transmit disease, prey on and outcompete native species, and are one of the leading causes of recent extinctions leading to alterations in native communities. The effects of invasive species can vary, so understanding and thus managing species invasions requires ecological and socio-economic information at multiple spatio-temporal scales. Management plans should include (a) accurate mapping of the invasive species' range, (b) assessment of the effects of invasive species on native species, (c) quantification of micro-habitat selection and use by invasive species, and (d) assessment of removal efforts and suppression costs.

The aim of this project is therefore to create a modeling framework that can be modified for various invaded marine systems. Using information on removal efforts, population densities, environmental and habitat conditions, and efficiency of gear and personal we can predict cost and efficacy of removal efforts. With these model outcomes integrated with management goals (i.e. preservation of habitat or economically important species) we can create conservation management tools designed to prioritize sites of value for focused population control. Tools such as these allow managers to input details directed towards their priorities and create conservation plans that have the lowest socioeconomic strain. Currently, we are modeling for management of invasive lionfish (*Pterois spp.*) in US Atlantic and Caribbean territories, but plan to expand to the spreading invasion of European green crab (*Carcinus maenas*) on the West Coast of North America.

(W9-14484)

Development of an aquatic invasive species monitoring program: Past, present & next steps

Claudio **DiBacco** and J. Benjamin Lowen

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, B2Y 4A2, Canada. E-mail: claudio.dibacco@dfo-mpo.gc.ca

The overarching objective of Fisheries and Oceans Canada's (DFO) National Aquatic Invasive Species Program is to protect the health and productivity of aquatic ecosystems by minimizing the risk of new introductions and managing or mitigating the impact of already established species. From its inception in 2005-06, key components of DFO Science activities have included

development of an AIS monitoring strategy to collect data and characterize the status of AIS in nearshore marine communities. This data was subsequently shared locally, nationally and internationally through (ii) data management systems in support of (iii) research and (iv) risk assessment objectives and strategies. Over time, this initial (linear) approach has become more integrated with feedback between components where monitoring, data management, research and risk assessment activities influence seasonal, annual and inter-annual activities. An overview and timeline on how each component was initiated, developed and matured, and how they have been integrated over the past 14 years to help address overarching project objectives, including invasion biology (e.g., AIS distributions), ecology (e.g., climate change) and management issues (e.g., risk assessment), will be discussed.

(W9-14479)

A collaborative science-based approach to non-indigenous species monitoring on British Columbia's North Coast

Thomas W **Therriault**[1], Jason Scherr[2], Natasha Lebedick[3], and Caitlin Smith[2]

1 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada. E-mail: Thomas.Therriault@dfo-mpo.gc.ca
2 Port of Prince Rupert, Prince Rupert, BC, Canada
3 Coast Mountain College, Prince Rupert, BC, Canada

Non-indigenous species (NIS) pose a significant threat to coastal marine ecosystems and commercial ports have been identified as invasion hotspots primarily due to commercial (and recreational) vessels that can introduce new species. Further, port environments are often modified and contain substantial artificial structures that can enhance NIS establishment. Since NIS management is most effective when new invaders are detected early when populations are small and contained, effective early detection monitoring is critical. On the North Coast of British Columbia, several partners have formed a science- based collaboration to monitor for new NIS and track changes in existing ones. The Port of Prince Rupert, Department of Fisheries and Oceans, Coast Mountain College and Smithsonian Environmental Research Center, as well as other members of the Aquatic Invasive Species working group that includes representatives from First Nations and industry, work together on the design and implementation of this NIS program. Monitoring efforts have established critical baseline data, including a registry of species in the region (both native and non-native), that has improved our understanding of invasion dynamics in British Columbia. The network also allows for inclusion of experts and greater engagement around potential management strategies. Although the current focus has been on tunicates and the European Green Crab (both with limited distributions in Northern BC), the program is well positioned to detect and track a suite of species. Through this unique monitoring program that includes settlement plates, plankton tows, and targeted trapping surveys, port partners are working collaboratively in Prince Rupert and across the west coast of North America to better understand how we can collectively ensure healthy ecosystems free from potentially harmful organisms.

WORKSHOP 10
PICES/ICES collaborative research initiative: Toward regional to global measurements and comparisons of zooplankton production using existing data sets

(W10-13964) INVITED

Zooplankton production in temperate coastal waters: From individual to community level

Shin-ichi **Uye**

Hiroshima University, Higashi-Hiroshima, Japan. E-mail: suye@hiroshima-u.ac.jp

Zooplankton, as secondary and tertiary producers, play pivotal roles in energy and carbon flux in marine ecosystems, many of which are currently stressed by global climate change and various anthropogenic impacts. Accurate estimation of their production rates is essential for understanding the functional roles of zooplankton, but there is no established method that can be routinely applied to natural zooplankton populations and communities. As I have been studying the zooplankton production rates in temperate coastal waters for some 40 years, I review my previous works, mainly on copepods. First, I established the body length and carbon weight relationships for major zooplankton taxa, which facilitates the conversion to zooplankton carbon biomass. Second, I determined the specific growth rates for 9 copepod species, based on laboratory rearing experiments under excess phytoplankton supply, and used them to estimate the production rates of their natural populations. The average specific growth rate of copepods (g, d^{-1}) increases with increasing temperature (T, °C), as expressed by $g = 0.078e^{0.062T}$, and varies roughly from ca. 0.1 d^{-1} in winter to ca. 0.4 d^{-1} in summer. Third, I used specific growth rates that had been previously determined for individual taxa to estimate the secondary and tertiary production rates of the total zooplankton community (i.e., micro-, meso-, and macro- zooplankton). I applied this in the Inland Sea of Japan, where the plankton community built a very efficient food chain (i.e., the transfer efficiencies from primary to secondary production and from secondary to tertiary production were 28 and 25%, respectively).

(W10-13879)

Prey stoichiometry, primary production, and plankton composition influence production of marine zooplankton

Pei-Chi **Ho**[1], Esther Wong[2], Fan-Sian Lin[1], Akash R. Sastri[3,4], Carmen García-Comas[5,6], Noboru Okuda[7], Fuh-Kwo Shiah[8], Gwo-Ching Gong[9,10], Rita S.W. Yam[11] and Chih-hao Hsieh[1,8,12,13]

1 Institute of Oceanography, National Taiwan University, Taipei, Taiwan
2 Division of Life Science, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong
3 Department of Biology, University of Victoria, Victoria, BC, Canada
4 Ocean Networks Canada, University of Victoria, Victoria, BC, Canada
5 Aquatic Ecology Group, University of Vic – Central University of Catalonia, Vic 08500, Catalonia, Spain
6 Institute of Marine Sciences (ICM-CSIC), Barcelona, Spain
7 Research Institute for Humanity & Nature, Kyoto, Japan
8 Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan
9 Institute of Marine Environment and Ecology, National Taiwan Ocean University, Keelung, Taiwan
10 Center of Excellence for the Oceans, National Taiwan Ocean University, Keelung, Taiwan
11 Department of Bioenvironmental Systems Engineering, National Taiwan University, Taipei, Taiwan
12 Institute of Ecology and Evolutionary Biology, Department of Life Science, National Taiwan University, Taipei, Taiwan
13 National Center for Theoretical Sciences, Taipei, Taiwan. E-mail: chsieh@ntu.edu.tw

Manipulative laboratory studies have shown strong evidence that phytoplankton stoichiometry and taxonomic composition, in addition to phytoplankton carbon (C) biomass and primary production (PP), affects zooplankton biomass production (ZP). However, field observations investigating the simultaneous effects of prey stoichiometric quality, PP, and community composition on ZP remain relatively scarce. Here, we examined how in situ ZP is affected by carbon:nitrogen:phosphorus (C:N:P) molar ratios of prey, PP, and plankton composition in the East China Sea. To obtain field estimates of ZP, we measured zooplankton biomass using net samples and in situ

growth rates using artificial cohort incubation experiments. Our focus was on copepods as they are biomass-dominant in mesozooplankton community. We found that ZP was low when prey C:N and C:P ratios were high (i.e. prey carbon exceeds the need of zooplankton consumers), but the variation of ZP was large when prey C:N

and C:P ratios were low. ZP did show a weak positive relationship with PP; however, removing high PP condition (PP > 100 mg C m^{-3} d^{-1}) renders the association non-significant. Multivariate regression also indicates that prey C:N ratio explains most of the variation of ZP, followed by prey and zooplankton compositions, while PP exerts a weak influence on ZP. Our findings suggest that ZP is affected by prey stoichiometry, with further modification by consumer and prey compositions in marine food webs. However, the total explained variance by those key factors is less than 50 %, indicating that marine zooplankton biomass production is influenced by complex factors in nature.

(W10-14397)

What have we learned from 13 years of chitobiase-based measurements of crustacean zooplankton productivity along Canada's west coast?

John F. **Dower**[1], Theresa A. Venello[1], Karyn D. Suchy[2,1] and Akash R. Sastri[3,1]

1 University of Victoria, Victoria, BC, Canada. E-mail: dower@uvic.ca
2 Pacific Salmon Foundation, Vancouver, BC, Canada
3 Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada

The chitobiase method is one of several methods for estimating secondary production in planktonic ecosystems. Chitobiase is an enzyme released by crustaceans during moulting, in an amount that scales with individual body size. The decay rate of this enzyme provides *in situ* estimates of community-level productivity by crustacean zooplankton. Whereas some other methods estimate secondary productivity via numerical manipulation of zooplankton biomass data (e.g. empirical models à la Huntley and Lopez, the biomass size-spectrum approach), the chitobiase method generates estimates that are independent of zooplankton biomass data.

We present an overview of chitobiase-based secondary productivity measurements along Canada's west coast from 2005 to 2018. Our data show considerable interannual variability, with productivity being generally higher (but also more variable) from 2005-2011 relative to 2015- 2018. Intra-annual spatial variability was also evident, with on-shelf productivity often (but not always) higher than values measured seaward of the shelf-break. With respect to community composition, chitobiase-based productivity was generally higher in cooler years dominated by larger boreal copepods, than in warmer years when smaller, southern, copepod species were abundant.

As it provides near-instantaneous *in situ* measurements, chitobiase-based productivity estimates can also be coupled with primary production rates to calculate trophic transfer efficiency (TTE). From several years of data, we show that unlike the oft-cited average value of 10%, *in situ* estimates of TTE display a high level of spatiotemporal variability. We conclude by considering the utility of this approach for parameterizing food-web models with actual field-based (as opposed to literature-based) values of TTE.

(W10-13965)

Seasonal population dynamics, biomass, production, and feeding of the chaetognath *Aidanosagitta crassa* in a temperate eutrophic inlet

Shin-ichi **Uye**[1] and Liang Dong[2]

[1] Hiroshima University, Higashi-Hiroshima, Japan. E-mail: suye@hiroshima-u.ac.jp
[2] JC Environment LCC, Higashi-Hiroshima, Japan

The seasonal population dynamics (i.e., numerical abundance, generation structure, time to sexual maturity, life span, clutch size, and mortality), biomass, production and feeding of the chaetognath *Aidanosagitta crassa* were studied for a year in a eutrophic inlet of the Inland Sea of Japan. The abundance of this species ranged from 1.0 ind m^{-3} (or 0.0029 mg C m^{-3}) to 3,370 ind m^{-3} (or 14.69 mg C m^{-3}), with a small blunter peak in winter and a large sharper peak in summer. The population consisted of 3 subpopulations, each of which produced at least 6–7 generations, yielding a total of 19 generations. The time from egg to sexual maturity varied from 32 to 71 d and the life span from 34 to 96 d; both were negatively correlated with mean water temperature at which each generation had developed. The mean body length of mature adults, whose clutch size was uniform (mean: ca. 15 eggs ind^{-1}), was also a negative function of temperature. The population production rate also showed a bimodal seasonal variation ranging from 0.72 to 2.61 mg C m^{-3} d^{-1} with an annual integrated production rate of 91.49 mg C m^{-3} y^{r-1}. Gut contents analysis revealed that *A. crassa* exhibited prey size preferences, which shifted from microzooplankton to mesozooplankton with growth. We also determined average numbers of prey in the gut (range: 0.09–0.80 prey ind-1) and digestion times at different temperatures, and estimated feeding rates (0.69–11.4 prey ind^{-1} d^{-1}) and carbon weight-specific feeding rates (0.01– 0.81 d^{-1}).

(W10-14111)

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

Hui **Liu**

Texas A&M University at Galveston, Galveston TX, USA. E-mail: liuh@tamug.edu

While a set of traditional approaches (e.g. natural cohort, artificial cohort, molting rate, egg production etc.) has been applied for estimating zooplankton rate processes, until now no method has been accepted as a standard in the field. Given that most traditional methods are time consuming and labor intensive and often require careful handing during deployments, which may limit the methods to be broadly implemented for estimating zooplankton production. Modeling provides an alternative to the estimation of vital process rates of zooplankton. Jellyfish frequently exhibit seasonal population blooms in response to environmental triggers, and rapidly produce enormous biomass that impacts the marine ecosystems and fisheries. To date, a set of concepts and methods has been used to study the growth of jellyfish, but few generalities have emerged in predicting the growth patterns in a changing world. We develop a phase-structured population model for a common jellyfish species (*Aurelia aurita*), which includes benthic (polyp) and pelagic phases (ephyra, juvenile medusa, and adult medusa). In this study, we conduct the simulation experiments to estimate the growth and production of the species at environmental settings and explore the utility of the approach for estimating zooplankton production in the ocean.

(W10-14433)

Chitobiase-based estimates of developing biomass, growth rate, biomass production rate for a synchronous cohort of *Pseudodiaptomus inopinus* in culture

Akash **Sastri**[1,2], John Dower[2] , Alex Clancy[2] , Yuichiro Yamada[3], Tomonari Kotani[4] , Toru Kobari[4] and Yuka Matsuura[4]

1 Fisheries and Oceans Canada, Sidney, British Columbia, Canada. E-mail: Akash.Sastri@dfo-mpo.gc.ca
2 Department of Biology, University of Victoria, Victoria, BC, Canada
3 School of Marine Biosciences, Kitasato University, Kanagawa, Japan
4 Faculty of Fisheries, Kagoshima University, Kagoshima, Japan

The chitobiase method is a biochemical method which has been used to measure community-level rates of crustacean zooplankton production in the field. The method is unique among all other methods because production rates may be calculated without handling animals or indeed without an independent estimate of biomass (i.e. using nets); instead, it relies on measurements of the activity and rate of production of the crustacean moulting enzyme, chitobiase, in the water. Thus, chitobiase-based measurements are capturing growth of only the actively developing animals rather than assuming that all animals sampled in the water column are growing and contributing to production. This quality is also of practical value because multiple types of sampling gear are typically required to adequately census the entire zooplankton size spectrum. Here we evaluate the performance of the chitobiase method as a measure of three productivity- related metrics: developing biomass; specific growth rate; and biomass production rates. Chitobiase activity and decay rates were measured daily using water subsampled from a 200 L synchronously- developing culture of *Pseudodiaptomus inopinus*. Overall, we found a strong positive relationships between daily chitobiase-based production rates and developing biomass, life-table estimates of production and growth rates.

(W10-13986)

Application of the physiological model to the existing data sets for estimating zooplankton production rates

Toru Kobari[1], Kazuaki **Tadokoro**[2], Megu Iwazono[1] and Debbie Steinberg[3]

1 Aquatic Sciences, Faculty of Fisheries, Kagoshima University, Kagoshima, Japan. 4-50-20 Shimoarata, Kagoshima, Kagoshima 890-0056, Japan. E-mail: kobari@fish.kagoshima-u.ac.jp
2 Stock Productivity Section, Tohoku National Fisheries Research Institute, 3-27-5 Shinhama-cho, Shiogama, Miyagi 985-0001, Japan
3 Virginia Institute of Marine Science, 1208 Greate Rd., Gloucester Point, Virginia 23062, USA

Zooplankton production rate represents trophodynamics integrated materials from lower trophic levels of marine ecosystems. While many methodologies for measuring zooplankton, production have been developed in the last half century, their applications to zooplankton population and community in nature remain limited due to the specific disadvantages and assumptions. Here we demonstrate an application of the physiological model (the Ikeda-Motoda model) to some zooplankton data sets for estimating their production rates. The physiological model represents a reasonable applicability due to the variables to be available in the existing data sets (i.e., individual body mass and ambient temperature) and wide applicability to various locations and taxonomic groups. Application the physiological model revealed the similar production rates even with the different biomass among the sites due to the high growth rates for the small individuals under the warm thermal regime. The production rate estimates were more associated with biomass than growth rates. According to the sensitivity analysis on the assimilation (AE) and gross growth efficiencies (GGE) within their 10% variations, the production rates were variable from 72 to 147% of the estimates with the average combinations and more sensitive to the lower AE and higher GGE. The physiological model might be applicable for the large-scale comparison of production rates which their standing stocks are more variable than their growth rates.

(W10-14339)

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[1,2], Karyn D. **Suchy**[1,3], Lian E. Kwong[4], and Moira Galbraith[2]

1 University of Victoria, Victoria, BC, Canada. E-mail: asastri@uvic.ca
2 Fisheries & Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada
3 Pacific Salmon Foundation, Vancouver, BC, Canada
4 University of British Columbia, Vancouver, BC, Canada

PICES working group (WG37) seeks to evaluate growth and production rate measurement methods. Among secondary production rate estimates, is the approach of applying empirical models of specific growth rate to copepod community biomass. The empirical models used for this approach relate direct field estimates of specific growth rates to a variety of biological and physical factors such as individual body size, food concentration and temperature. The relative ease with which these factors are measured makes this approach particularly appealing. Furthermore, long-term time series for biomass are relatively common whereas similar observations of in situ growth or production rates are rare since rate estimates in the field are logistically difficult to apply routinely. An important advantage of modeling production rate is that empirical growth rate models may be applied retrospectively to long-term time-series of biomass to estimate production rate (product of specific growth rate and biomass). On the other hand, this approach assumes that all animals in the community are in fact growing and at rates predicted by each growth rate model. Thus, variation of modelled production rate tends to vary entirely with biomass. Here we present spatial patterns of production rates from time series of modelled rates along the west coast of Vancouver Island (1982-2018) and the Strait of Georgia, BC, Canada (2003-2016). We also explore: 1) the value of using the range of modelled rates as quasi-bounds within which we might expect production rates to vary; as well as 2) recent attempts to improve sensitivity by retrospectively addressing food-limited growth.

(W10-14077)

A global collaboration for the worldwide mapping of marine zooplankton biomass and production

Lidia **Yebra**[1] and Todd D. O'Brien[2]

1 Instituto Español de Oceanografía, Centro Oceanográfico de Málaga, Fuengirola, Málaga, Spain. E-mail: lidia.yebra@ieo.es
2 NOAA Fisheries, Silver Spring, Maryland, USA

This talk will address several goals of the workshop by proposing expanding the work of WG37 to become a global collaboration between ICES, PICES, the International Group for Marine Ecological Time Series (IGMETS), and the Coastal & Oceanic Plankton Ecology, Production, and Observation Database (COPEPOD). For example, including interested participants from the IGMETS and ICES Working Group on Zooplankton Ecology (WGZE) could add 60 zooplankton biomass time series to the PICES existing effort, and by integrating with COPEPOD, even more data, tools and capabilities could be added almost immediately. COPEPOD has been collaborating with the plankton research community since 2004, providing data analytical and visualization support to groups in ICES (WGZE/WGPME/WGIMT), SCOR (WG125/WG137/WG157), and IOC-UNESCO

(IGMETS/TrendsPO). Over these past 15 years, all of these groups have found that maximum participation (especially in global studies) comes from readily accommodating the broadly different technical capabilities and data policy requirements of those groups' data providers and participants. We will show how these issues were addressed by these other groups, will present examples of existing tools and data to support the proposed global collaboration, and will then discuss what tools can be developed to support the goal of a worldwide mapping of marine zooplankton biomass and production.

WORKSHOP 11
PICES/NPFC collaborative research: The influence of environmental changes on the potential for species distributional shifts and population dynamics of Pacific saury

(W11-14312) INVITED

Results of stock assessment on Pacific saury by NPFC

Technical Working Group on Pacific Saury Stock Assessment[1] and Kazuhiro **Oshima**[2]

[1] North Pacific Fisheries Commission (NPFC), Tokyo, Japan. E-mail: secretariat@npfc.int
[2] National Research Institute of Far Seas Fisheries, Japan Fisheries Research and Education Agency, Yokohama, Japan

The presenter reports the results of the latest stock assessment conducted at the 4th meeting of the Technical Working Group on Pacific saury stock assessment in March 6-9, 2019. Biomass for 1980-2017 were estimated through a Bayesian state-space production model using 1980-2017 catch series and seven time series of abundance indices submitted by the NPFC Members. A total of six base cases were set according to three different assumptions on catchabilities of the Japanese fishery-independent biomass survey index and two scenarios where Japanese early CPUE was either used or not used. China, Japan and Chinese Taipei independently conducted the stock assessment analysis. The results of the six base case models by the three Members were averaged with equal weight to account for uncertainty in time-varying catchability in the models and differences in assumptions of prior distributions. The stock assessment results for each Member were similar, so outcomes of MCMC runs were aggregated over for the 18 models. Based on combined model estimates, B was below Bmsy (average B/Bmsy during 2016-2018 = 0.82) and F was below Fmsy (average F/Fmsy during 2015-2017 = 0.82). Results indicate that the stock declined from near carrying capacity in the mid-2000's after a period of high productivity to current levels. Exploitation rates were increasing slowly during this period but remained lower than Fmsy. Point estimates indicate that stock biomass fell to the lowest value since 1980 (B/Bmsy = 0.63) in 2017, then increased to Bmsy in 2018. Biomass estimates show long-term fluctuations and interannual variability.

(W11-13871) INVITED

Aggregation habitat variation of Pacific saury and its influence factors based on HSI model

Chuanxiang **Hua**, Qingcheng Zhu, Siquan Tian, Fei Li and Yongchuang Shi

Shanghai Ocean University, Shanghai, PR China. E-mail: cxhua@shou.edu.cn

Pacific saury is one of the important fisheries resources which was believed affected by climate- ocean variation due to its short-lived lifespan in the Northwest Pacific. Based on China's Pacific saury logbook data and oceanography data (sea surface temperature, SST and sea surface temperature gradient, SSTG), a weighted mean habitat suitability index model for aggregation (HSIa) was developed, to discuss the potential aggregation habitat area (PAa) variation and its response to climate-ocean changes. The result indicates that: (1) The high HSIa (≥0.6) sea area was mainly distributed in the south of 40°N in Winter and Spring, and in the north of 40°N in Summer and Autumn, and reaching the northernmost in August; (2) The annual mean SST in saury habitat sea area had no evident fluctuation, however, the annual mean SSTG fluctuated sharply during 2014 and 2017, in which annual average SSTG at each latitude in 2016 was higher than other years; (3) The annual mean HSIa and PAa fluctuated drastically during 2014 and 2017, the HSIa and PAa were significantly lower in 2016; (4) The annual mean HSIa and PAa were significantly negatively correlated with the annual mean SSTG in each sea area ($p<0.01$), and all had the negative relationship with the annual mean Niño 3.4 index and/or PDO index in last year; It is suggested that the regime shift seemed to have occurred in 2016, in which El Nino and La Nina events were both take placed.

(W11-13858)

Habitat of Pacific saury *Cololabis saira* is affected by the distributional change of other small pelagic fishes in the North Pacific

Taiki **Fuji**[1], Yasuhiro Kamimura[2], Sho Furuichi[2], Hiroomi Miyamoto[3], Midori Hashimoto[1], Shin-ichiro Nakayama[2], Kazuhiro Oshima[1] and Satoshi Suyama[3]

1 National Research Institute of Far Seas Fisheries Japan Fisheries Research and Education Agency, Yokohama Japan E-mail: tfuji114@affrc.go.jp
2 National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency, Yokohama, Japan
3 Tohoku National Research Institute, Japan Fisheries Research and Education Agency, Hachinohe, Japan

Several pelagic fishes (Japanese sardine, Japanese anchovy, Chub mackerel, Spotted mackerel) as well as Pacific saury are distributed in the transitional domain of North Pacific. These species change their own distributional ranges along with their periodic stock fluctuations. The surface trawl net survey has been conducted to estimate the biomass of Pacific saury for over 15 years. This survey successfully covers the area and period of multi-species distributional change. We used the results of this survey to examine the distributional changes of these fishes in the North Pacific every early summer. Pacific saury was characterized by wider distribution than the other species; it was found continuously from ca. 150°E to 165°W. On the other hand, distributions of the other species were limited west of 180°. Basically, Pacific saury prefer cooler water than the others. Japanese anchovy showed partially overlapped distributional range with Pacific saury. On the other hand, distributional range of other three species rarely coincide with Pacific saury, because they apparently preferred warmer water. However, after 2013, mackerels and Japanese sardine have expanded their distributions to the region with temperature <15°C possibly because their stock biomass increased. Distribution of Pacific saury also changed after 2013; habitat temperature was lower than the past in the waters west of 180°, where mackerels and sardine coexisted. These results implied that habitat of Pacific saury would be changed due to expansion of the other species to cooler waters in the western side of the North Pacific.

(W11-14143)

The impact of water temperature on the Pacific saury catch distribution

Vladimir **Kulik**, Aleksei Baitaliuk, Oleg Katugin and Elena Ustinova

Pacific Branch of VNIRO (“TINRO”), Vladivostok, Russia. E-mail: vladimir.kulik@tinro-center.ru

The Pacific saury, *Cololabis saira,* is widely distributed in the North Pacific, and is harvested commercially in the area between 140ºE and 172ºE. We used environmental daily information from Meteorological Research Institute multivariate ocean variational estimation (MOVE) system for the area between 140ºE and 159ºE. About 95% of total catches provided to the North Pacific Fisheries Commission (NPFC) by its Members and 100% of Russian catches were distributed in that area in 1994-2017. Positions of saury aggregated catches with a 1 km resolution from Russian vessel monitoring system (VMS), and sea surface temperature (SST) from Multi-scale Ultra-high Resolution analysis were used. Overall spatial resolution for the models was upscaled to MOVE system. First, we estimated variable contribution and permutation importance of 184 possible combinations of SST and MOVE daily products with 0 to 7 days lags and moving average window from 0 to 7 days in MaxEnt. SST, water temperature (WT) and its gradient (WTG) at 50 m depth for the current day of catch and up to 2 previous days for SST and from 3 to 7 days for WT and WTG at 50 m depth contributed the most of all. We further tried different configurations of GAMs and Random Forest with those variables. The latter outperformed MaxEnt and GAMs by accuracy. Annual sum of the predicted areas with conditions preferred by saury in the EEZ show significant correlation (0.96) with total catches of saury in the last extreme years (2008, 2014, 2017 and 2018) of pacific saury catch.

(W11-13866) INVITED

Estimating spatial non-stationary environmental effects on the distribution of Pacific saury in the Northwest Pacific Ocean

Bai **Li**

School of Marine Sciences, University of Maine, Maine, 04469, USA. E-mail: bai.li@maine.edu

Pacific saury (*Cololabis saira*) is one of the major target species in the Northwest Pacific Ocean and is managed as one of the priority species by the North Pacific Fisheries Commission (NPFC). While a body of literature has quantified the effects of environmental factors on the distribution of saury using the fishery data from a single Member of the NPFC, studies examining the relationships between saury and environmental factors using joint data from Members over large spatial-temporal scales are scarce and the relationships remain unclear. Moreover, conventional analysis of environmental effects on Pacific saury using global models, such as generalized additive model and generalized linear regression model, is faced with the challenging task of studying complex patterns over large spatial scales. The implicit assumption of global models is that the ecological relationships between species and environmental variables do not vary within study areas. Given the dynamic spatial interactions between biological and environmental factors in a large area of the Northwest Pacific Ocean, the strength of environmental effects may exhibit spatial non-stationarity on saury distribution. The relationships between environmental factors and saury distribution may be clear on a finer spatial scale. In this study, we will use joint data with large spatial scales from 2001-2017 and geographically weighted regression model to detect spatially varying relationships between environmental factors and catch per unit effort of saury by estimating a set of local parameter coefficients at observation locations. The environmental factors include sea surface temperature, sea surface temperature gradient, and sea surface height. The patterns of the strength and direction of the estimated local relationships will be presented in this study. The estimated local relationships could be used to forecast fishing grounds and improve regionally informed management plans.

(W11-13908)

Ensemble forecasting of spatial distribution of Pacific Saury (*Cololabis saira*) in the Northwestern Pacific Ocean

Jin-Ying Lee[1], Yi-Jay Chang[1], Wen-Bin Huang[2], and Chih-hao **Hsieh**[1]

1 Institute of Oceanography, National Taiwan University, Taipei, Taiwan. E-mail: chsieh@ntu.edu.tw
2 Department of Natural Resources and Environmental Studies, National Dong Hwa University, Hualien, Taiwan

Species distribution modeling has been widely used to predict how species distribute depending on environmental factors. However, there is no single superior modeling method; the results from various modeling methods can differ, leading to model uncertainty for prediction. To address model-based uncertainties, consensus modeling approach incorporating and ensembling predictions from individual models are thought to provide a more reliable prediction. Here, we used fishery data (i.e. spatial-temporal CPUE) of Pacific Saury (*Cololabis saira*) and environmental variables from the fishing ground in the Northwestern Pacific Ocean during the main fishing season of 2002-2017. We chose five models, including Habitat Suitability Index, Boosted Regression Tree, zero-inflated GLM, zero-inflated GAM, and Maxent. We then adopted two consensus modeling approaches: Mean and Weighted Average methods. Finally, we calculated the area under the curve (AUC) value to assess performances among models. Results indicate that AUC of individual models ranged from 0.709 to 0.792 and AUC of consensus models ranged from 0.719 to 0.794. For individual models, the best modeling method differed among months. Although consensus models did not always outcompete individual models, they showed a more robust predictive performance in most cases, especially for the mean method, when comparing to the average of AUC values from all individual models. Overall, our results support that no single modeling method dominates and suggest that applying ensemble forecasting helps reduce predictive bias.

(W11-14152)

Pattern transition of age-specific distribution for Pacific saury *Cololabis saira* in the Northwestern Pacific Ocean

Midori **Hashimoto**[1], Taiki Fuji[1], Shin-Ichiro Nakayama[2], Satoshi Suyama[3] and Kazuhiro Oshima[1]

1 National Research Institute of Far Seas Fisheries, Japan Fisheries Research and Education Agency, Yokohama, Japan
E-mail: mhashimoto@affrc.go.jp
2 National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency, Yokohama, Japan
3 Tohoku National Research Institute, Japan Fisheries Research and Education Agency, Hachinohe, Japan

Pacific saury (*Cololabis saira*) is one of the commercially important small pelagic fish with a short lifespan of two years and widely migrates at least in the Northwestern Pacific Ocean. Fishery-independent survey extensively covering the habitat of the saury stock has been conducted since 2003 to acquire ecological information of this stock when northward migration towards foraging ground in June and July. Fish density observed with sea surface trawl nets have served the forecast of Japanese fishing ground after westward migration in the main fishing season from August to December as well as the estimation of stock biomass as an essential abundance index for stock assessments. Moreover, this survey provided knowledge on the historical changes in the age-specific distribution patterns during early summer: for instance, apparent high density of age 0 fish has recently been recognized around the eastern survey area. However, the distribution change over time has not been quantified yet and the effect of environmental factors remains unclear. Therefore, statistical models with spatial structure were applied to the age-specific density data to investigate the relationship between saury distribution and environmental factors such as sea surface temperature through the standardization of fish density. We will present the historical transitions of age-specific standardized density for 15 years and then describe their characteristics in terms of the occupied area and the high-density region. These results could provide effective information to develop a stock assessment model incorporating the large-scale migration of Pacific saury.

(W11-14280)

Property of Pacific saury recruitment in the North Pacific Ocean

Shin-Ichiro **Nakayama**[1], Satoshi Suyama[2], Taiki Fuji[1], Midori Hashimoto[1], and Kazuhiro Oshima[1]

1 National Research Institute of Far Seas Fisheries, Japan Fisheries Research and Education Agency, Yokohama, Japan
E-mail: shinichironak@affrc.go.jp
2 Tohoku National Research Institute, Japan Fisheries Research and Education Agency, Hachinohe, Japan

Pacific saury (*Cololabis saira*, PS) is a small pelagic fish species that shows large scale migration across the North Pacific Ocean. Following the recent start of the PS fishery by several countries, the North Pacific Fishery Commission has conducted stock assessment using a production model. The problem of the current PS stock assessment is the poor future prediction skill, and therefore the NPFC is now moving toward the application of age-structured models for accurate future prediction and sustainable use of this stock. As a first step for the age-structured model application, we extracted the indices of PS abundance for each age, based on Japanese fishery data. In this presentation, we introduce the overview of the indices focusing on the stock-recruitment relationship and the effect of sea surface temperature on recruitment. Since the structure and properties of PS stock are poorly known, the knowledge obtained through the process of abundance indices extraction can be useful for a sound stock assessment by age structured models and to enhance the understanding of the characteristics of this stock.

(W11-14208)

The climate impact on Pacific saury (*Cololabis saira*) stock dynamics

Andrey Krovnin, Sergey Melnikov, Kirill **Kivva** and George Moury

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17, Verkhnyaya Krasnoselskaya, Moscow, 107140, Russia
E-mail: akrovnin@vniro.ru

Pacific saury has a large importance for Russian fishery (with annual catches up to 119,433 t in 2007). However, its long-term fluctuations and their relation to changes in environmental conditions and, in a broader sense, with climate, are not well-studied. The aim of this research is to reveal connection of catches and CPUE dynamics of Pacific saury in 1950-2015 with climatic patterns. The dynamics of both saury catches and CPUE is characterized by clear quasi-decadal variability. We found strong statistical relationship between CPUE and winter NPGO index, when the latter leads CPUE by 5 years. This relationship is manifested in the large-scale modes of variability in both ocean and atmosphere. CPUE increases with warming of surface waters east and northeast of Japanese Islands. At the same time, saury catches in 1950-1990 did not reveal statistically significant correlation with the NPGO index with lags from 0 to 5 years. The structure of correlation pattern between saury catch and climatic fields with a 5-yr lag has some similarity with that for CPUE. However, the area of positive correlations before 1990 was located northward by 10-15 degrees of latitude compared to the period after 1990. It is clear that both total abundance and distribution of saury are controlled largely by climate. However, the catch volumes may be strongly influenced by distribution patterns and therefore do not correlate well with climate indices. On the other hand, CPUE reflects the density of saury concentrations. Correlation of CPUE with NPGO index allow for making projections of saury catch for the nearest future.

(W11-14267) CANCELLED

Spatial and temporal dynamic of fishing boats for Pacific saury and environmental changes in Northwestern Pacific using remote sensing

Yang **Liu**, Yongjun Tian, Hao Tian and Shigang Liu

College of Fisheries, Ocean University of China, Qingdao, PR China. E-mail: yangliu315@ouc.edu.cn; yangliu315@hotmail.co.jp

Pacific saury (*Cololabis saira*) are widely distributed in northwestern Pacific, The abundance of Pacific saury shows large annual-interannual variations which are largely affected by environmental conditions in the fishing grounds of Oyashio and Kuroshio region. Therefore, spatial and temporal dynamic monitoring of fishing boats and environmental changes will be important for understanding the distributional dynamics of fisheries. In this study, we used visible infrared imaging radiometer suite (VIIRS) day / night band (DNB) nighttime remote sensing images and GIS tools to extract and analyze the fishing boat position and operation status in the Oyashio region, whereas the effect of environmental variations in the spawning ground of Pacific saury in Kuroshio region were analyzed using CPUE data and MODIS satellite data. The results suggest that large-scale climatic influences played important roles in the variability of SST in the Kuroshio region, resulted in large variation in the recruitment accordingly. The method proposed in this study can effectively identify the location and operation status of Pacific saury fishing boats, and provide useful information for assessment of fishery resources of Pacific saury in the northwest Pacific region.

WORKSHOP 12

Potential food competition between top predators and fisheries in the North Pacific

(W12-14089) INVITED

Steller sea lions and Atka mackerel in the Aleutian Islands; Abundance and spatial patterns in fish distributions — A tale of scale

Susanne **McDermott**, Kimberly Rand, and Elizabeth **Logerwell**

NOAA, NMFS, Alaska Fisheries Science Center, 7600 Sandpoint Way, Seattle, WA 98115, USA. E-mail: Susanne.Mcdermott@noaa.gov

Two general components that result in foraging success for a large marine mammal are prey availability and high prey density at a scale relevant to the predator. The Aleutian Island western Steller sea lion (SSL) stock, or Western Distinct Population Segment (WDPS), is showing signs of slow recovery only in the eastern portion of their range ("eastern Aleutian Islands"), whereas in the western portion of their range ("western Aleutian Islands") the stock continues to decline for unknown reasons. The dominant prey in SSL diets across the Aleutians Islands is Atka mackerel. We examined small-scale abundance, local exploitation rate, and essential habitat of Atka mackerel with a focus on the western Aleutian Islands. Atka mackerel abundance and exploitation rates were estimated with a mark-recapture study.

Species composition and local (<20 nautical miles) fish densities were estimated using fishery- independent trawl catch per unit effort (CPUE). Although fish abundance estimates between the eastern and western Aleutian Islands were comparable, and fisheries exploitation rates were low, the distribution of these prey resources were significantly different. Atka mackerel CPUE significantly decreased from the eastern to western Aleutian Islands; the eastern Aleutian Islands, where SSL population trends have stabilized, supported dense Atka mackerel aggregations close to rookeries. In contrast, Atka mackerel distributions were diffuse and further away from rookeries in the western Aleutian Islands, where SSL are still in decline. In addition, northern rockfish, which comprise a small portion of the SSL diet but occupy similar habitat as Atka mackerel, increased in densities in the western Aleutian Islands compared to the eastern Aleutian Islands, making the prey field more diverse. All these factors could influence Steller sea lion foraging success and contribute to the continued lack of recovery for SSL in the western Aleutian Islands. These results will be discussed in the context of fisheries management measures to enable the recovery of this endangered animal.

(W12-14385)

Northern fur seals and competing pollock fish predators in the eastern Bering Sea: Variability in prey size availability and spatial overlap

Ivonne **Ortiz**[1], Elizabeth McHuron[1] and Jeremy Sterling[2]

1 University of Washington, Seattle, WA, USA. E-mail: ivonne@u.washington.edu
2 Alaska Fisheries Science Center, NMFS, NOAA, Seattle, USA

About half of the world's northern fur seal population breeds or haul-out in the Pribilof Islands. The majority of seals forage on the Bering Sea shelf and consume pollock as their primary prey. We used newly updated maps of aggregated foraging grounds for northern fur seals and overlapped them with year-specific maps of pollock availability by size (<20 cm and >30 cm in length) and bottom temperature using data from annual summer bottom trawl surveys from 1982 to 2018. We then added the spatial overlap with Pacific cod and Arrowtooth flounder –both known pollock predators, particularly arrowtooth flounder which has tripled its biomass since the late 1970s and early 1980s. Pollock's cannibalism as well as pollock's preferred sizes by fish predators were estimated from stomach samples collected annually, also as part of the bottom trawl surveys. While interannual variability of pollock abundance and distribution on its own changes the availability of pollock as prey to fur seals, the interplay of abundance and spatial overlap with fish predators can further change its availability. Warmer bottom temperatures shift/extend spatial overlaps further onto the shelf, with high fish predator abundances further exacerbating such overlap and potential competition. This study is part of a larger project that integrates bioenergetics and spatial approaches for quantifying relationships between northern fur seals, their prey, fisheries, and climate.

(W12-14193)

Evaluating competition between marine mammals and fisheries: A case study of the southern resident killer whales

Andrew W. **Trites**

Marine Mammal Research Unit, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada
E-mail: a.trites@oceans.ubc.ca

Southern resident killer whales are endangered and currently number 76 individuals (June 2019). Poor body condition suggests this small population of whales may simply be not getting enough to eat due to competition with fisheries for their primary prey – Chinook salmon. Concern about potential fishery impacts on southern resident killer whales prompted the Canadian government to close all fisheries targeting Chinook salmon during June and July in parts of British Columbia. However, many have questioned the rationale underlying this management action. In this talk, I will review the conditions that should be met to infer resource competition, as well as discuss the types of data that need to be collected to monitor ecosystem interactions and test whether fisheries outcompete marine mammals. I will use this conceptual framework to evaluate the impact of fisheries on southern resident killer whales and assess whether competition is occurring.

(W12-13845)

Spatial distribution of fin (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales in relation to environment and acoustically measured prey distribution

Abigail **McCarthy**[1], Alex De Robertis[1], Stan Kotwicki[1], Kathy Hough[2], Paul Wade[1] and Chris Wilson[1]

1 Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE Seattle, WA, 98115, USA. E-mail: Abigail.McCarthy@noaa.gov

2 National Marine Sanctuary Foundation *for* Olympic Coast National Marine Sanctuary, National Ocean Service, National Oceanic and Atmospheric Administration, 115 East Railroad Avenue, Port Angeles, WA, 98362, USA

Fin and humpback whales share foraging areas and may be competing for the same prey, but little is known about the extent to which they partition prey. Visual cetacean surveys and simultaneous acoustic-trawl surveys of prey were conducted around two submarine canyons off Kodiak Island in 2004 and 2006. A combination of univariate and multivariate statistical models were used to examine the associations between sightings of fin and humpback whales and measures of their potential prey and environment. Observations and models indicate that fin whales were disproportionately abundant in areas with the highest observed euphausiid concentrations, while humpback whales were abundant at lower euphausiid concentrations and in areas where juvenile walleye pollock were abundant. Fin whales were disproportionately abundant in the areas where krill biomass was deepest and in the deepest areas surveyed (>150 m depth). In contrast, humpback whales primarily occurred in shallower areas and near more shallowly distributed krill. The different depth and prey affinities of fin and humpback whales suggest niche and habitat partitioning between these two co-occurring species. Abundance models built using acoustic estimates of prey density are a useful tool for further understanding of distribution, abundance, and behavior of these animals, and will aid future conservation efforts.

(W12-14206)

Potential competition between fish and seabirds: A case study in the Bering Sea

Yutaka **Watanuki**

Graduate School of Fisheries Sciences, Hokkaido University, Japan E-mail: ywata@fish.hokudai.ac.jp

In marine ecosystem, large fish is the most important predator, while marine mammals and seabirds are the second and the third. These three groups share common prey groups including zooplankton, forage fish, and squids and therefore can compete each other. Bering Sea case study of pink salmon *Oncorhynchus gorbuscha* (PKS) that is the most abundant Pacific salmon species and short-tailed shearwater *Puffinus tenuirostris* (STSH) that is spending nonbreeding summer period there. Both species feed mainly on krill, followed by forage fish and squid is a good example. Biomass of PKS shows more than 10 times biennial fluctuation that gives a unique opportunity to explore species interaction. As expected, body and liver masses of STSH related negatively with the pink salmon biomass (Toge et al. 2011 PRSB). Body mass of Tufted Puffins *Fratercula cirrhata* feeding mainly on fish and squids showed no apparent responses. Thus PKS seemed to negatively impact the foraging success of seabird species that shared prey species. Review studies (Springer and Vliet 2014 PNAS, Springer et al. 2018 PNAS) also indicate competition between PKS and seabirds. Biennial change of PKS stock affected hatch date, clutch size, success in some seabird species breeding in the Bering Sea and further gave carry over effects on the productivity and population of STSH breeding at the Tasmanian islands in the southern ocean. All these indicate directional and negative impact of PKS on seabirds when PKS is super abundant.

(W12-14221)

Assessing food competition between marine mammals and fisheries off western Canada over the past six decades

Caihong **Fu**[1], Thomas Doniol-Valcroze[1], Strahan Tucker[1], Jennifer Boldt[1], Norm Olsen[1], Yi Xu[2], Huizhu Liu[3], Philippe Verley[4] and Yunne-Jai Shin[4]

1 Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7, Canada
E-mail: Caihong.Fu@dfo-mpo.gc.ca
2 Fisheries and Oceans Canada, Fraser and Interior Area, 3-100 Annacis Parkway, Delta, BC, V8L 6A2, Canada
3 Vancouver Island University, Nanaimo, BC, Canada
4 Institut de Recherche pour le Développement, UMR MARBEC (IRD, Université Montpellier, Ifremer, CNRS), Montpellier, France

In marine ecosystems off British Columbia (BC), Canada, Pacific herring (*Clupea pallasi*) is an ecologically important species serving as a food source for many predatory fish and marine mammals, including humpback whale (*Megaptera novaeangliae*), harbour seal (*Phoca vitulina*), Steller sea lion (*Eumetopias jubatus*). Pacific herring has also high economic and cultural value to First Nations and the commercial fishing industry. Over the past two decades, Pacific herring fisheries closures in some regions of BC as a result of population decline coincided with the increasing abundance of marine mammals. This has raised concern about food competition between marine mammals and fisheries. While it is challenging to address this concern by using empirical data alone, individual-based spatially- and temporally-explicit ecosystem models, such as OSMOSE, provide valuable avenues by simulating physical and ecological processes as well as human activities for modelled species. In this study, using OSMOSE that models the dynamics of multiple marine species including Pacific herring and their predators such as humpback whales, harbor seals, and Steller sea lions, we assess Pacific herring historical predation mortality, fishing mortality, and mortality due to other causes in order to understand the impacts of marine mammals and fisheries on Pacific herring under changing environment. This study provides insight for recommending fisheries management strategies that would achieve best trade-offs between economic benefit and ecosystem health.

WORKSHOP 13
Common ecosystem reference points

W13-14362 INVITED

Beyond singular driver-response tipping points and thresholds, recent examples and emerging approaches

Kirstin **Holsman**

NOAA Fisheries, Alaska Fisheries Science Center, Seattle, USA. E-mail: Kirstin.holsman@noaa.gov

Ecosystem based management (EBM) specifically addresses compound outcomes of multiple interacting pressures and responses of coupled social-ecological systems. Increasingly, EBM is predicated on actionable advice regarding ecological thresholds and tipping points. While identifying compound, nonlinear, or contextual tipping points that are still policy relevant is challenging, there are multiple emergent approaches that advance this objective. Here I will review some recent innovations in tipping point analyses and threshold detection, and discuss a few case study applications including assessing impacts of and adaptation to climate driven-change in marine social-ecological systems.

WORKSHOP 14
New frontiers: The application of molecular approaches in marine ecology and fisheries science

(W14-14232) INVITED

Using environmental DNA (eDNA) to track changes in species and ecosystems

Ryan P. **Kelly**[1], Ramón Gallego, and Emily Jacobs-Palmer

[1] University of Washington, Seattle, WA, USA. E-mail: rpkelly@uw.edu

It has become relatively straightforward to track hundreds or thousands of species by sequencing DNA recovered from samples of water, soil, or air ("environmental DNA" or "eDNA").

Here, I present highlights of several projects we have carried out using eDNA sampling in nearshore environments, using both qPCR and amplicon sequencing. These include efforts to count endangered salmonids in the field, to track ecosystem shifts over time, and to detect harmful algal species that threaten human health. I will also describe a statistical technique for making eDNA work more quantitative, and show the ways in which these kinds of data likely do — and do not — accurately track species' biomass.

(W14-14324) INVITED

Environmental DNA for fish monitoring in the wild

Hitoshi **Araki**, Hiroki Mizumoto and Takashi Kanbe

Hokkaido University, Sapporo, Japan. E-mail: arakih@res.agr.hokudai.ac.jp

Environmental DNA (eDNA) is increasingly recognized as a new molecular tool for detecting organisms in the wild. However, how efficiently it can be applied for monitoring migratory fish species, such as salmonid, is largely unknown. In this study, we conducted eDNA surveys on fish species in various environments. Experimental settings in aquarium tanks with flowing water allowed us to evaluate associations between biomass and the eDNA concentration, suggesting a potential of eDNA for indirectly estimating biomass in freshwater systems. We could also trace the migration patterns of salmonid fish in freshwater environments when an appropriate spatio-temporal scale for their distributions was adjusted, suggesting that the eDNA can be used for monitoring migration of fish species in the wild. In the ocean, the relationship between biomass and the eDNA concentration is seemingly much more complex, although we found eDNA metabarcoding being quite efficient to estimate fish fauna at least along shorelines.

(W14-14071)

Evaluation of infauna community structure through microscopy and eDNA

Joanna **Strzelecki**[1], Sarah Stephenson[2], Mick Haywood[3], John Keesing[1], Lydiane Mattio[1], Damian Thomson[1] and Melanie Trapon[1]

1 CSIRO, Oceans and Atmosphere, Crawley, Western Australia, Australia. E-mail: Joanna.strzelecki@csiro.au
2 CSIRO, Oceans and Atmosphere, Lucas Heights, New South Wales, Australia
3 CSIRO, Oceans and Atmosphere, Brisbane, Queensland, Australia

Marine sediments cover most of the ocean bottom and the infauna dominates biomass in this habitat. The number of species is estimated to range from 500,000 to 10,000,000. These organisms are microscopic and difficult to identify using traditional taxonomic methods.

Environmental (eDNA) metarbarcode surveys of DNA extracted from sediment samples are increasingly popular for surveying biodiversity. This study compares infaunal taxonomic composition revealed through metabarcoding of the cytochrome oxidase I (COI) and 18S rRNA genes to traditional morphological identification by microscopy. Four sediment cores for eukaryotes DNA and microscopy were collected at each station haphazardly along transect of approximately 10 m length. For each transect two cores were collected close together but sufficiently apart as to always sample undisturbed sediment. Stations were separated 100s of meters apart. This allowed comparison of results on three spatial scales: 1, 10 and 100s of meters. We will show the taxonomic composition, species richness and functional diversity based on 18S rDNA, COI and morphological taxonomy. Morphological and molecular techniques both detected a large variety of taxa and provided different insights into biodiversity of infauna. Each of identification techniques yielded somewhat different taxonomic composition. Metarbarcoding was affected by limitations of database and many OTUs could not be named therefore e-DNA will become progressively more accurate as genetic databases become more enriched.

(W14-14113)

A census of coastal biodiversity through DNA Barcodes

Matthew **Lemay**, Gillian Sadlier-Brown, and Kyle Hall

Hakai Institute, Victoria, BC, Canada. E-mail: matt.lemay@hakai.org

Species extinction, the introduction of invasive species, and pole-ward migration in response to climate change all have a dramatic impact on biodiversity, yet we often lack sufficient baselines to track these processes in real-time. To facilitate improved biodiversity monitoring, we are constructing a comprehensive genetic database of species on the central coast of British Columbia. We use intensive collection events that target large numbers of marine species from a variety of habitats. All specimens are identified by taxonomic experts, photographed, accessioned in public collections for long-term preservation, sequenced to obtain a DNA barcode, and the associated metadata are deposited in the Barcode of Life Database (BOLD).

Using this pipeline, we have identified previously undescribed species and have documented range shifts for many others. On average, we find that 20% of our invertebrate specimens have not been previously sequenced before — this number dramatically increases when we restrict our analysis to subtidal organisms. Beyond the intrinsic value of accurately quantifying biodiversity, these data provide a powerful tool for ecological monitoring when observation-based research is not possible. For example, we can now reconstruct and monitor entire ecosystems by sequencing the free environmental DNA (eDNA) present in the seawater and matching those sequences to our database. Tracking eDNA has become a common approach for biodiversity monitoring, yet the benefits of this approach are only as good as the underlying genetic database. Therefore, we suggest that curating a local genetic catalogue can provide a powerful tool for modern biodiversity research.

(W14-14113)

Multi-species quantitation with eDNA – Is it possible?

Kristina M. **Miller**, Shaorong Li, Tobi Ming, Angela Schulze, Amy Tabata, and Christoph Deeg

Pacific Biological Station, Fisheries and Oceans, Canada, 3190 Hammond Bay Rd, Nanaimo, BC, Canada
E-mail: Kristi.saunders@dfo-mpo.gc.ca

Under climate change, our ocean ecosystems are experiencing unprecedented declines in abundance of many species, shifting of predator and prey distributions, increased exposure to opportunistic pathogens and more frequent and toxic harmful algal blooms. At the same time, in North America, resources to support stock assessments and monitor ecosystem changes supporting commercially or ecologically important species has been impacted by decreasing budgets and limited ship time. There has never been a more important time to develop and implement large-scale non-invasive technologies to inform fisheries management. Environmental (e)DNA is now well established as an ideal non-invasive tool to survey species biodiversity and ecosystem health, but there is still more progress to be made in the development of applications in species quantitation. Thus far, quantitative PCR has proven to be the most reliable means to assess species abundance/biomass, as unlike amplicon sequencing, where competition for binding and amplification of assays that are not perfect matches to all species can impede accurate quantitation of individual species, species-specific assays can be applied individually.

However, most applications to date have been limited to quantitation of one species at a time. Microfluidics qPCR is set to change this limitation by enabling simultaneous quantitation of individual assays to dozens of species at once. This presentation will outline some of the key developments underway to evaluate the strengths and limitations of this approach to applications in salmon health, biosecurity monitoring, plankton monitoring, and stock assessment.

(W14-14130)

Assessing the seasonality of the planktonic protists in the Northern Strait of Georgia, British Columbia (Canada)

Caterina R. **Giner**[1,2], Rebecca Piercey[2], Colleen Kellogg[2] and Brian P.V. Hunt[1,2,3]

1 Institute for the Oceans and Fisheries, University of British Columbia, AERL, 2202 Main Mall, Vancouver, BC, Canada, V6T 1Z4
E-mail: c.giner@oceans.ubc.ca
2 Hakai Institute, PO Box 309, Heriot bay, BC, Canada, V0P 1H0
3 Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, 2020 – 2207 Main Mall, Vancouver, BC, Canada, V6T 1Z4

Protists (i.e., unicellular eukaryotes) are recognized as fundamental components of marine ecosystems, playing a wide range of ecological roles. Autotrophic protists carry out primary production and contribute to phytoplankton biomass, whereas heterotrophic cells play a key role in the marine food webs consuming primary producers and being the main bacterivores in the microbial food web. Yet, despite their importance, fundamental gaps persist in our understanding of their temporal dynamics, environmental drivers and trophic interactions. Obstacles to resolving protistan dynamics include low sampling frequencies and historic reliance on microscopy, which only allows identifying larger protists. In order to advance understanding of protist assemblages we conducted high frequency (weekly) sampling in the northern Strait of Georgia, British Columbia. This region is of particular ecological interest as it is a critical rearing ground for plankton dependent forage fish and juvenile salmon. Microbial communities were sampled from November 2014 to December 2018 at five depths through the water column (from 0m to 260m deep). Their taxonomic composition was determined by high-throughput amplicon sequencing (Illumina sequencing) of the 18S rDNA gene. Preliminary results showed differences between surface and deep communities, and a temporal pattern indicating a recurrent succession of the planktonic community through time. Here, we examine these changes with respect to concurrently measured environmental conditions. Increasing our knowledge of how microbial community structure behaves and responds to changes in the environment is essential to resolving pelagic food web function, and predicting the impact of changing ocean conditions.

(W14-14364)

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**[1], Ian Giesbrecht[1], Brian Hunt[2], Bill Mohn[2], and Steven Hallam[2]

1 Hakai Institute, Heriot Bay, British Columbia, Canada. Email: colleen.kellogg@hakai.org
2 University of British Columbia, Vancouver, British Columbia, Canada

Microbial communities play integral roles in mediating global nutrient and carbon cycles. Their importance is especially acute in productive coastal ecosystems, like the coastal temperate rainforest of British Columbia (BC), where large amounts of organic matter (OM) can be rapidly exported from land to sea. A key pathway for the incorporation of this terrestrial OM into marine systems is through its incorporation into marine microbial biomass, but the processes by which this occurs and the key microbial players involved remain unresolved along this continental margin. As part of interdisciplinary research program on Calvert Island, BC working to quantify the seaward flux of terrestrial materials and its impact on coastal food webs, we are characterizing microbial community composition and function from land to sea. Here, we highlight the first year of community sequencing data to show the distinctness of microbial communities across this land-sea continuum. Seasonal variability in marine community composition appears to be driven by physical processes, such as upwelling, and OM source, especially in surface waters, where the balance between terrestrial- and phytoplankton-derived OM is constantly in flux. To this end, we are employing microbial source tracking methods to quantify the flux of terrestrial microbes into coastal waters as a means to assess variability in marine-terrestrial linkages. The presence of soil microbes in coastal waters highlights the close connection between land and sea and the importance of terrestrial subsidies to marine food webs along the BC coast.

(W14-14100)

Metabarcoding, qPCR, and microscopy identification of taxa associated with harmful algal blooms

Svetlana **Esenkulova**[1], Amy Tabata[2], Ben J.G. Sutherland[2], Nicola Haigh[3], Christopher M. Pearce[2], and Kristina M. Miller[2]

1 Pacific Salmon Foundation, Vancouver, BC, Canada. E-mail: svesen@uvic.ca
2 Department of Fisheries, Oceans and the Canadian Coast Guard, Nanaimo, BC, Canada 3Microthalassia Inc., Nanaimo, British Columbia, Canada

We applied microscopic observational methods, quantitative real-time polymerase chain reaction (qPCR), and metabarcoding with multiple markers on cultured (n=30) and field (n=24) samples containing suspected harmful algae, including *Alexandrium* spp., *Chattonella* sp., *Chrysochromulina* spp., *Dictyocha* spp., *Heterosigma akashiwo*, *Protoceratium reticulatum*, *Pseudochattonella verruculosa, Pseudo-nitzschia* sp., and *Pseudopedinella* sp. Overall, the multiple marker metabarcoding results were superior to the morphology-based method for detection and identification of harmful taxa, with the notable exception of taxa from the Silicoflagellate group, which had better detection by morphology. This work is the first HAB species identification in Canada using a combination of morphological, metabarcoding, and qPCR approaches.

(W14-13930)

Metabarcoding diet analysis for revealing predator-prey relationships during the spawning period of Japanese sardine and Pacific round herring in Tosa Bay

Junya **Hirai**[1], Yoko Hamamoto[2,3], Daiske Honda[3,4], Kiyotaka Hidaka[5], Satoshi Nagai[5] and Tadafumi Ichikawa[5]

1 Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan E-mail: hirai@aori.u-tokyo.ac.jp
2 Graduate School of Natural Science, Konan University, Kobe, Japan
3 Institute for Integrative Neurobiology, Konan University, Kobe, Japan
4 Faculty of Science and Engineering, Konan University, Kobe, Japan
5 National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency, Yokohama, Japan

Successful feeding on preferred prey could be important for the survival of fish larvae. However, high taxonomic resolution of prey types from damaged gut contents is difficult to achieve through morphological classification, especially for fragile organisms or immature stages. Here, we applied 18S metabarcoding diet analysis to total 64 early post-larvae (< 10 mm) of Japanese sardine *Sardinops melanostictus* and Pacific round herring *Etrumeus teres*, which were collected from Tosa Bay (Japan) during their main spawning periods. There were no clear differences in the diets of the co-existing fish species, and copepods comprised the majority of the prey items. Among the copepods, the OTU derived from the large copepod *Calanus sinicus* was most consumed, followed by the OTU identified as small *Paracalanus* sp. Considering a body size of copepods, the fish larvae actively consumed nauplii of *C. sinicus*, suggesting that both food availability and developmental stages of copepods determined prey preference. Additionally, we applied the same technique to 40 adult female *C. sinicus*. The majority of prey items were small crustaceans and diatoms, taxa that are dominant in the environment and have been previously reported as important prey items of *Calanus*. Aplanochytrids (Labyrinthulea) were detected for the first time as a major prey of *C. sinicus*, and high proportions of unclassified eukaryote material were also observed. These results suggest that further investigation into a novel predator-prey relationship is recommended to understand the complex food web structures and population dynamics of commercially important fish species in marine ecosystems.

(W14-14123)

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**[1,3], Brian P. V. Hunt[1,2,3], Colleen Kellogg[1,3] and Vera Tai[4,3]

1 Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada. E-mail: j.maud@oceans.ubc.ca
2 Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, 2020 – 2207 Main Mall, Vancouver, BC, Canada, V6T 1Z4
3 Hakai Institute, PO Box 309, Heriot bay, BC, Canada, V0P 1H0
4 Departments of Biology and Statistical and Actuarial Sciences, Western University, 1151 Richmond St., London, ON, Canada, N6A 5B7

Molecular diet analysis of zooplankton species has so far tended to focus on single species at limited sampling stations. These have also tended to extract DNA from zooplankton guts and/or use blocking primers to limit the sequence reads generated from the predator. More recent work has attempted to use whole organisms (for ease of sample processing), without blocking primers (blocking primers may block DNA amplification of prey species that are highly similar to the predator, during intraguild feeding), and has yielded ample diet sequence reads to be able to characterise the diet. Here we aim to use the 18S rRNA V4 region as a marker to characterise the diets of the biomass-dominant mesozooplankton (both arthropod and gelatinous) of the Strait of Georgia (SoG) using whole organisms. The SoG is a seasonally productive coastal region between mainland British Columbia and Vancouver Island. We have ethanol-preserved zooplankton samples collected from 2015 to the present by the Hakai Institute from the northern SoG, and frozen samples from the central and southern SoG. Key arthropods include the calanoid copepods *Calanus pacificus*, *Eucalanus bungii* and *Neocalanus plumchrus*; the euphausiid *Euphausia pacifica*, and the amphipods *Cyphocaris challengeri* and *Themisto pacifica*. Important gelatinous species include the hydromedusa *Clytia gregaria*, the chaetognath *Parasagitta elegans* and the pteropod *Limacina helicina*. We will report on the success of attempts to use metabarcoding to obtain sufficient prey sequence reads from a variety of SoG species from different feeding-related functional groups.

(W14-14201)

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

Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan. E-mail: zhoufanyu@aori.u-tokyo.ac.jp

Euphausiids are one of the major micronekton with large biomass, and they play an important role in linking lower-higher trophic levels in the pelagic ecosystems. Although it is difficult to identify prey items of euphausiids by a conventional microscopic observation, a molecular approach using high-throughput sequencing could provide a ‘snapshot’ of the gut contents with high taxonomic resolution. In this study, we carried out 18S metabarcoding analysis to investigate prey of key euphausiid species in the North Pacific. Euphausiid samples were collected during the night in the California Current and the western/eastern North Pacific subtropical gyre, and gut contents were analyzed for dominant species in each region: *Euphausia pacifica* (n = 20), *E. brevis* (n = 26), and *E. hemigibba* (n = 30). Among the identifiable sequences, the most dominant and frequently-observed operational taxonomic unit (OTU) was identified as Hydrozoa in all three species. OTUs in copepods also showed relatively high proportions of sequences. In protists, dinoflagellates were highly dominant especially in subtropical species of *E. brevis* and *E. hemigibba*. Taxa in Stramenopiles including diatom were frequently observed in all species. These results suggested omnivorous diets of all euphausiid species which utilized various sources of prey in the environments. There were some issues including possible influence of cod-end feeding especially in metazoan taxa, high proportions of unclassified sequences, and possible symbiotic or parasitic taxa including fungii in our analysis. Thus, further investigations including comparisons with ambient plankton communities are recommended to clarify feeding ecology of euphausiids.

(W14-14019)

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

Department of Fisheries and Oceans Canada, Nanaimo, BC, Canada. E-mail: strahan.tucker@dfo-mpo.gc.ca

Pinniped populations, once intensively hunted, are rebounding in size and distribution. Concurrently, inter- and intra-specific interactions are increasingly shifting in response to climate change-induced alterations to ecosystems. Despite a paucity of data, pinnipeds are thought by some to have caused the decline or are impeding the recovery of a variety of fish species in British Columbia. Harbour seals, Steller and California Sea Lions overlap in foraging range having access to similar prey fields. To varying degrees, these species utilize both pelagic and benthic habitats from riverine estuaries to the oceanic zone beyond the continental shelf representing a broad range of foraging strategies. Each of the species tend to be opportunistic in their diets, exploiting seasonally abundant prey, feeding on a mix of pelagic forage fish such as herring and benthic fish such as gadids. However, explicit diet data for these species in BC are sparse, and taken opportunistically and irregularly. Little is known about how key prey are partitioned both within and between species over varying spatial and temporal scales. Scat samples are readily obtained and recent advances in DNA sequencing technology have revolutionized the field of molecular diet analysis with high resolution. Further, DNA from the animal itself can be extracted providing value added information such as sex and population structure. Over multiple years, we have undertaken systematic, repeat sampling of scats at key pinniped haul-outs where species co-occurred or were found exclusively. Novel high-throughput DNA techniques are providing accurate species composition, providing a comprehensive picture of diet.

(W14-14432)

Tracking seawater eDNA in British Columbia coastal waters

Jennifer **Sunday**[1], Ben Millard-Martin[1], and Matt Lemay[2]

[1] McGill University, Montreal, Canada. Email: Jennifer.Sunday@mcgill.ca
[2] Hakai Institute, Victoria, Canada

Observations of our oceans over the last half-century have collectively shown a global fingerprint of climate change, including species' range shifts towards higher latitudes, and changes in whole communities across time. Although environmental DNA (eDNA) presents a promising approach for tracking biodiversity change at unprecedented spatial and temporal scales, there remain many unknowns about accuracy and spatial level of inference from eDNA sampling and metabarcoding in coastal marine waters. Here we present results of environmental eDNA sampling in the central coast of British Columbia adjacent to visual and capture surveys. This work advances our knowledge of how much replication is required across space and habitat types to reveal a robust species assemblage, to be directly applied to monitoring program design.

WORKSHOP 15
Application of machine learning to ecosystem change issues in the North Pacific

(W15-14372) INVITED

AI and machine learning to improve understanding and prediction of complex ecosystem dynamics

Debra P.C. **Peters**, Heather Savoy, and Geovany Ramirez

USDA-ARS and Jornada LTER Program, Las Cruces, NM, USA. E-mail: deb.peters@usda.gov

Artificial intelligence (AI) and machine learning (ML) approaches are increasingly used with big data technologies and high-performance computing in scientific applications to improve scientists' ability to effectively analyze and comprehend large amounts of data in a short amount of time. Although these technologies are most commonly associated with computational methods to analyze satellite-, drone-, or ground-based imagery, the power of AI approaches in science-based applications reach far beyond image analysis and software-based approaches. My talk will show by example how AI, including ML and deep learning (DL), approaches can be used to improve understanding and predictions, and should be considered an integral part of the scientific method.

(W15-14442)

Where is machine learning going in the marine world

William L. **Michaels** and Cisco Werner

NOAA Fisheries, Silver Spring, MD, USA. E-mail: william.michaels@noaa.gov

Emerging Machine Learning (ML) technologies have enabled a better assessment and understanding of changes in marine ecosystems. At the same time, dramatic increases in data collection now exceed our capacity to process, analyze, and deliver scientific products in a timely manner. The application of ML can significantly reduce the time and costs to process data with automated detection and classification algorithms. Furthermore, ML has improved data assimilation and forecasting capabilities. Case studies will be presented to demonstrate recent progress in the application of machine learning (ML) and computer vision tools to improve data processing and analysis of data from the marine environment. While the present ML revolution provides higher quality and more timely scientific products, we must remain diligent in the rigorous independent testing of these models to maintain the integrity, reliability, and credibility of our science. Recommendations will be provided to improve organizational efficiencies and collaborative partnerships to more effectively utilize ML.

(W15-14069) CANCELLED

Can we predict the emergent properties of marine systems? Machine learning as way forward

Michael **St. John**

Danish Technical University Lyngby, Denmark. E-mail: mstjo@aqua.dtu.dk

Global change influences and is influenced by the composition and functioning of marine food webs, modifying biodiversity and ecosystem services such as greenhouse gas sequestration, biodiversity and production of living resources. Within marine food webs, the dynamics of these services are determined by complex non-linear interactions and feedbacks between physical, chemical and biological processes operating at a range of time and space scales ultimately feeding back to global climate. These characteristics define marine systems as complex adaptive systems (CAS) clarifying why the prediction of the future state of their services has proven elusive. In this presentation I propose a framework for developing a predictive understanding of the future states of the services provided by marine systems which with some modification could be applied in other (CAS) systems. The approach suggested merges outputs from our deterministic framework for understanding physical-chemical transport, mass flows and energy balances, as well as biological processes employing statistical and machine learning tools to better understand and increase the predictive capacity necessary to manage the emergent features of marine ecosystems.

(W15-14092)

What will influence Chilko Lake sockeye salmon as climate changes?

Yi **Xu**[1], Mike Hawkshaw[1], Caihong Fu[2], David Patterson[3], Roy Hourston[4], and Peter Chandler[4]

1 Fisheries and Oceans Canada, Fraser and Interior Area, 3-100 Annacis Parkway, Delta, BC, V8L 6A2, Canada
E-mail: yi.xu2@dfo-mpo.gc.ca
2 Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia, V9T 6N7, Canada
3 Fisheries and Oceans Canada, Science Branch, Pacific Region, School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC, V5A 1S6, Canada
4 Fisheries and Oceans Canada, Institute of Ocean Sciences, 9860 West Saanich Road, Sidney, British Columbia, V8L 4B2, Canada

Sockeye salmon (*Oncorhynchus nerka*) have a complex life cycle and the population dynamics are influenced by multiple environmental drivers including climatic, freshwater and marine conditions. Machine learning methods such as boosted regression trees (BRT) have great potential for unraveling relationships between sockeye salmon dynamics (recruitment, productivity and returning age proportion) and environmental drivers. Chilko Lake sockeye salmon is one of the most abundant (and well studied) sockeye stocks of the Fraser River watershed in British Columbia, Canada. In this study, we developed a suite of BRT models to examine linkage between sockeye population dynamics and multiple environmental drivers over the past 70 years. Results indicate (i) sockeye recruitment is mainly associated with juvenile abundance and also by the Pacific Decadal Oscillation (PDO) and summer sea surface temperature (SST) in the Gulf of Alaska; (ii) productivities at different life stages are affected by different environmental processes with freshwater-stage productivity being mainly negatively associated with an artificial spawning channel, while marine-stage productivity is most associated with wind stress around the Prince Rupert area and summer SST near Pine Island; (iii) while sockeye salmon predominantly return to river at age 4 associating with SST and, to a lesser degree, with wind stress, the proportion of returning at age 3 is negatively associated with river temperature during their parental migration. These findings improve our understanding of how sockeye salmon respond to environmental changes and suggest that multiple environmental drivers should be considered for sockeye salmon assessment and forecast, and fisheries management.

(W15-14213)

A machine learning approach to evaluating the impacts of multiple stressors on biotic indices at multiple trophic levels

Caihong **Fu**[1], Yi Xu[2], Jennifer Boldt[1], Cliff Robinson[1], Charles Hannah[3], Angelica Peña[3], Roy Hourston[3], and Richard Thomson[3]

1 Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
E-mail: Caihong.Fu@dfo-mpo.gc.ca
2 Fisheries and Oceans Canada, Fraser and Interior Area, 3-100 Annacis Parkway, Delta, BC, V8L 6A2, Canada
3 Fisheries and Oceans Canada, Institute of Ocean Sciences, 9860 West Saanich Rd., Sidney, BC, V8L 4B2, Canada

Anthropogenic activities (e.g. fisheries) in tandem with climate change have resulted in multiple stressors, threatening the biodiversity, integrity, and functioning of marine ecosystems.

Mechanistic understanding of the stressors' interactive effects is lacking, which hampers the prediction of ecosystem responses to multiple stressors and thus reduces the effectiveness of ecosystem-based fisheries management. Machine learning methods such as gradient forests have great potential for quantifying relative impacts of influencing stressors for a given set of response variables. In this study, applying the gradient forest method to the ecosystem off the Canadian West Coast, we explore how ecosystem components at different trophic levels, including primary productivity, biomasses at different trophic levels and ecosystem indicators respond to multiple environmental (e.g. local water temperature, salinity, sea level, upwelling as well as basin-scale indices of North Pacific Gyre Oscillation, Pacific Decadal Oscillation), ecological (e.g. predator- prey interactions), and human-induced stressors (e.g. commercial catches of different trophic levels). Results indicate that the degree ecosystem components are influenced by the various stressors depends not only on their specific trophic levels but also on their specific geographic regions. The understanding of the impacting factors of ecosystem dynamics obtained through the machine learning method is valuable for facilitating fisheries management under climate change. The results also suggest that region-specific management of fisheries continue to be advocated.

(W15-14516)

Application of machine learning to automated image analysis

Robert K. Cowen[1], Moritz S. **Schmid**[1], Christian Briseño-Avena[1], and Christopher Sullivan[2]

[1] Hatfield Marine Science Center, Oregon State University, Newport, OR, USA. E-mail: moritzsschmid@gmail.com
[2] Center for Genomic Research and Biocomputing, Oregon State University, Corvallis, OR, USA

Big data as generated from environmental modelling, genomics and novel instrumentation begets analytical techniques that are often beyond our typical statistical tools. Machine learning can reach broadly across these applications, as evidenced by its rapid rise across various disciplines and industries. The availability of machine learning allows for unique pattern/relationship seeking in model outputs, as well as for the rapid resolution of complex instrument outputs such as those from imaging systems or other observational sensors. Here we discuss the need for and application of machine learning and convolutional neural networks (CNNs) in automating the analysis of 100 millions of images generated in field studies using the In situ Ichthyoplankton Imaging system (ISIIS). We outline the instrument and its application to quantifying fine to mesoscale distribution of meso-plankton, the data/image analysis challenge, and the machine learning pipeline we have developed to address the image analyses required in a timely framework. We also discuss efforts to broaden the utility and availability of this image processing application to the ocean community.

(W15-14108)

Using machine learning techniques to estimate pelagic species distributions under novel environmental conditions in the California Current system

Barbara **Muhling**[1,2], Elliott Hazen[3], Stephanie Brodie[1,3], and Michael Jacox[3]

[1] University of California – Santa Cruz Cooperative Institute for Marine Ecosystems and Climate, San Diego, CA, USA
E-mail: Barbara.Muhling@noaa.gov
[2] NOAA Southwest Fisheries Science Center, San Diego, CA, USA
[3] NOAA Southwest Fisheries Science Center, Monterey, CA, USA

Machine learning techniques are gaining popularity for modeling the distributions of marine organisms, due to their flexibility and ability to represent complex relationships between a species and its environment. These statistical models often have high skill on training datasets, and can have good out-of-sample predictive power if overfitting is well controlled. However, they can behave in unexpected ways when confronted with strongly novel environmental conditions. As species distribution models are increasingly being used to project the potential impacts of climate change, it's important to understand how different models extrapolate, and consider whether projections based on these techniques are biological reasonable. In this study, we build species distribution models for several pelagic fishes in the California Current region using both machine-learning and more traditional techniques. We compare the skill of each method on training data, and then examine their behavior when applied to novel conditions experienced during a recent marine heatwave. Our results have implications for marine spatial management measures, developing climate change projections, and predicting future ecosystem change.

(W15-14302)

Computer vision-based detection of schools of herring from acoustic backscatter time series

Alireza Rezvanifar[1], Tunai Porto Marques[1], Melissa Cote[1], Alexandra **Branzan-Albu**[1], Alex Slonimer[2], Thomas Tolhurst[2], Kaan Ersahin[2], Todd Mudge[2], and Stéphane Gauthier[3]

1 University of Victoria, Victoria, BC, Canada. E-mail: aalbu@uvic.ca
2 ASL Environmental Sciences Inc., Victoria, BC, Canada
3 Fisheries and Oceans Canada - Institute of Ocean Sciences, Sidney, BC, Canada

The study of acoustic backscatter constitutes a thorough, non-invasive option employed in fisheries research to monitor underwater sites. Acoustic backscatter data gathered by multifrequency echosounders, such as the Acoustic Zooplankton Fish Profiler (AZFP), are commonly visualized as 2D images known as echograms. Visual structures in echograms indicate the presence of geological and biological elements. Biologists, acousticians, and other users of echosounders typically interpret echograms with manual or semi-automatic methods, which are time-consuming and prone to inconsistencies. This presentation discusses a collaborative project between the Computer Vision Research Laboratory at the University of Victoria, remote sensing specialists and acousticians at ASL Environmental Sciences Inc. (which develops the AZFPs), and biologists at the Institute of Ocean Sciences (IOS), aimed at exploring novel ways to detect visual patterns from echosounder data using computer vision and machine learning techniques. In particular, we focus on a case study involving the automatic detection of schools of herring from AZFP measurements collected in the Discovery Passage off Vancouver Island in 2015. Our proposed computational pipeline involves extracting regions of interest (ROIs) from echograms via denoising, adaptive thresholding, and filtering operations. The schools of herring are detected among these ROIs by using two parallel classification processes: one relying upon appearance and shape descriptors specific to herring schools, and the other using features automatically learned via a convolutional neural network (CNN) architecture. Preliminary results were computed over 100 images with 145 instances of schools of herring; both classification paradigms achieved an accuracy of over 85%.

(W15-14412)

Exploratory machine learning applications in oceanography

Di **Wan**[1], Pramod Thupaki[2] and Gregor Reid[3]

1 Institute of Ocean Sciences, Department of Fisheries and Oceans Canada, Victoria, Canada. E-mail: Di.Wan@dfo-mpo.gc.ca
2 Hakai Institute, Victoria, Canada
3 Government of Nova Scotia, Halifax, Canada

The non-linear nature of neural networks offer a great advantage over other empirical and statistical methods more traditionally used in oceanography. Being able to measure pH accurately is important to study ocean acidification. However, pH measurements were only improved in 1990s to be accurate enough to discern small changes. In this presentation, we will be discussing the application of neural network algorithm to estimate pH values of seawater using only temperature, salinity, oxygen, and chlorophyll observations.

(W15-14449) CANCELLED

A semi-automated method for measuring reef fish population density and biomass from stereo-video footage

Prospero C. **Naval**, Jr.[1] and Laura T. David[2]

1 Department of Computer Science, University of the Philippines. E-mail: pcnaval@dcs.upd.edu.ph
2 Marine Science Institute, University of the Philippines. E-mail: ltdavid@msi.upd.edu.ph

We propose a semi-automated process of performing fish census which otherwise requires high level of domain knowledge and expertise. Divers with minimal knowledge of fish can obtain high quality population and species distribution measurements using a stereo camera rig and fish video analyzer software that we have developed. Our system called Fish-i, has two major components: a camera rig and software for fish size, density and biomass estimation. The camera rig consists of a simple stand on which one to four pairs of stereo cameras are mounted to take videos of the benthic floor for a few minutes.

The stereo camera rig consists of a pair of stereo cameras mounted on a stand. When performing measurements, the stand is positioned at a suitable height above the benthic floor such that the stereo camera pairs can efficiently capture fish videos. We developed a fish video analysis software that calculates fish size, population density and biomass values from fish videos captured by the stereo camera pair through the following processing steps: Underwater camera calibration is performed by a diver that positions a camera calibration pattern for the purpose of determining the internal and external camera parameters of the stereo pair. The camera rig is then placed at the origin of the transect line while fish video is collected for a period of 2 minutes or longer. This process is repeated every 5 meters moving along the transect line until the entire 50 meter transect line is covered. When the data collection process is over, the camera rig is brought back to the surface and the collected video files are transferred to a computer for analysis. Fish video processing starts with conversion of collected videos into image frames on which an algorithm isolates the fish blobs which are the basis of the fish counts. Image stereo analysis is applied on corresponding stereo frames to measure the sizes of each detected fish. Fishes whose centroids are contained a specified volume are counted while those outside it are ignored. Population density is computed from the fish count within the volume. For species identification we used a Convolutional Neural Network to perform fish image classification. Experimental results for actual underwater video footages captured by the camera rig show promising results with fish counts accurate to within 7.7 % of actual counts and 97% species recognition accuracy for 121 fish species. The software produces video clips containing estimates of fish size, density and species biodiversity and a report in csv format containing information about the individual fishes for further end user analysis.

WORKSHOP 16
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

(W16-14470)

The challenges to understand how rapid climate warming impacts marine ecology of Pacific salmon

Ed **Farley**

NOAA Fisheries, Alaska Fisheries Science Center, Ted Stevens Marine Research Institute, 17109 Point Lena Loop Road, Juneau, AK, USA
E-mail: ed.farley@noaa.gov

As a changing climate and associated anomalous events in the large marine ecosystems of the North Pacific Ocean (NPO) progressively expose Pacific salmon to conditions that are outside the "normal" climate cycles, society will confront new resource management issues. These include the future of the cultures and subsistence lifestyles of local indigenous communities, potential impacts of industrial activities (e.g. commercial fishing), potential changes to regional ocean carrying capacity, and resilience of North Pacific marine ecosystems. In addition, the growing threat of illegal, unreported and unregulated high-seas fishing has increased the need for updated information regarding salmon distribution. This presentation provides updated information from integrated ecosystem surveys in Alaska's Large Marine Ecosystems on the response of Pacific salmon to rapidly changing ocean environments. The challenge is to understand how ocean conditions and potential competition during winter impacts distribution, migration, and survival of Pacific salmon in the North Pacific Ocean.

(W16-14469)

2019 Gulf of Alaska Expedition

Dick **Beamish**

Pacific Biological Station, Nanaimo, BC, Canada. E-mail: rabeamish@shaw.ca

Responsible stewardship of Pacific salmon in a future of changing ocean ecosystems requires an understanding of the mechanisms that regulate production during the period of ocean residence. Diversity and inclusion into international teams of researchers may be the most effective and efficient way to make the needed discoveries. The privately organized Gulf of Alaska expedition in the winter of 2019 on the Russian ship, Professor Kaganovsky, brought together 21 researchers from all five Pacific salmon producing countries to test hypotheses about the mechanisms that control salmon production in the ocean. The principle hypothesis was that brood year strength is mostly determined by the end of the first ocean winter, with the understanding that individuals that grow faster and quicker in the first months in the ocean survive better.

(W16-14393) INVITED

Overview of methodology and high level results of Russian salmon research and comparison with obtained results in 2019 GoA salmon expedition

Alexey A. **Somov**[1], Olga S. Temnykh[1], Svetlana V. Naidenko[1], Alexader N. Starovoytov[1], Igor I. Glebov[1], Vladimir I. Radchenko[2], Aleksander V. Zavolokin[3], and Vyacheslav P. Shuntov[1]

1 Pacific branch of Russian Federal Research Institute of Fisheries and Oceanography, «VNIRO» («TINRO»), Vladivostok, Russia E-mail: aleksey.somov@tinro-center.ru
2 North Pacific Anadromous Fish Commission, Vancouver, B.C., Canada
3 North Pacific Fisheries Commission, Tokyo, Japan

IYS GoA survey in February-March 2019 partially filled the spatial gap of salmon winter ecology study. Applying the identical methodology with previous Russian research allows to compare GoA with other regions of salmon marine habitat. Complex Russian studies of the Pacific salmon marine life period have been carried out since 1980s by TINRO including international programs (BASIS). Currently, the expeditions are directed and time-oriented on a pink salmon being the main commercial specie among salmon. High seas surveys cover three phases of salmon marine period. The first is fall trawl surveys on juveniles in Okhotsk and Bering seas (annualy) when they spread offshore. The second is winter-spring surveys in the western and central Subarctic zone (in particular years) to study salmon wintering. The third is early summer surveys on preanadromous salmon in the western Bering Sea (odd years) and Pacific waters off Kuril Islands and Kamchatka peninsula (annually). Integrated trawl survey includes complex of meteorological, hydrological, hydrochemical, acoustic, planktological, trophological and nektonic studies. The distance between stations is 40-60 nm. Using express methods allows to complete all the rough analysis on abundance, distribution, feeding, environmental conditions on board. To calculate total abundance, we apply catchability coefficient - 0.3 for adult and 0.4 for juvenile salmon. This data is used for forecast and assessing potential catch. Decades of regular observing allow to understand long- term abundance dynamic, limiting factors and carrying capacity of salmon marine feeding habitat.

(W16-14416)

Overview of preliminary findings during the February-March 2019 International Gulf of Alaska expedition

Evgeny A. **Pakhomov**[1, 2,3], Christoph Deeg[4], Svetlana Esenkulova[5], Gerard Foley[6], Brian P.V. Hunt[1,2,3], Arkadii Ivanov[7], Hae Kun Jung[8], Gennady Kantakov[9], Albina Kanzeparova[7], Anton Khleborodov[7], Chrys Neville[4], Vladimir Radchenko[10], Igor Shurpa[7], Alexander Slabinsky[7], Alexei Somov[7], Shigehiko Urawa[11], Anna Vazhova[7], Perumthuruthil S. Vishnu[12], Charles Waters[6], Laurie **Weitkamp**[13], Mikhail Zuev[7], Richard Beamish[4]

1 Department of Earth, Ocean & Atmospheric Sciences, UBC, Vancouver, BC, Canada E-mail: epakhomov@eoas.ubc.ca
2 Institute for the Oceans and Fisheries, UBC, Vancouver, BC, Canada
3 Hakai Institute, Heriot Bay, BC, Canada
4 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada
5 Pacific Salmon Foundation, Vancouver, BC, Canada
6 NOAA Alaska Fisheries Science Center, Auke Bay Laboratories, Juneau, USA
7 TINRO, Shevchenko Alley 4, Vladivostok, 690091, Russia
8 Gangneung-Wonju National University, Gangneung City, Republic of Korea
9 220-7 Babakina Street, Moscow, Russia
10 North Pacific Anadromous Fish Commission, Vancouver, B.C., Canada
11 Hokkaido National Fisheries Research Institute, Sapporo, Hokkaido, Japan
12 University of Victoria, Victoria, BC, Canada
13 NOAA Northwest Fisheries Science Center, Newport, USA

The first large-scale, integrated pelagic ecosystem scientific survey to the northeastern Pacific Ocean was conducted between February 16 and March 18, 2019 onboard R/V *Professor Kaganovskiy*. The expedition covered an area of approximately 700,000 km^2 of the potential open ocean habitat of Pacific salmonids. The international expedition was composed of 21 scientists from Canada, Japan, Korea, Russia and the United States of America and was a major contribution to the International Year of the Salmon Program. The intent of the expedition was threefold: (a) to demonstrate an effective international collaboration; (b) to provide baseline measurements of major pelagic ecosystem components including abundance of Pacific salmon during the winter season; and (c) to test key hypotheses on factors regulating salmon survival in the ocean during winter. In total, over 60 stations were completed at which physical and chemical parameters and productivity measured as well as zooplankton and micronekton collected and analysed. At each station, surface plastic particles were collected using the neuston net. In addition, 423 Pacific

salmon, including 223 chum, 93 coho, 73 sockeye, 31 pink, and 3 Chinook salmon, were caught using a midwater trawl. Two additional coho salmon caught with a live-box were tagged with NPAFC disc tags and released in the eastern Gulf of Alaska. Novel methodology of the 'at sea' Pacific salmon stock identification was tested. A summary of both physical and biological systems as well as the distribution patterns, condition and detailed biology of Pacific salmon species caught during the survey presented and discussed.

(W16-13962) INVITED

Pacific salmon ecosystems on the high seas: Initial findings from the Winter 2019 Gulf of Alaska Expedition

Laurie A. **Weitkamp**

Northwest Fisheries Science Center, NOAA Fisheries, Newport, OR, USA. E-mail: laurie.weitkamp@noaa.gov

In February, 2019, an international team of scientists and crew on board the Russian research ship *Professor Kaganovskiy* left Vancouver, BC, to study salmon in the Gulf of Alaska. While the focus of the expedition was the winter ecology of Pacific salmon, scientists from Japan, Korea, Russia, Canada, and the U.S. studied everything from water chemistry to plankton to salmon during the month-long cruise, providing a comprehensive understanding of the winter ecosystem in the region. A major goal of this privately-funded expedition was to test the hypothesis that winter is a critical time for salmon survival and ecosystem conditions in the region determine year class strength for many stocks. This talk will provide an overview of the initial results of the expedition, including physical oceanography, biological oceanography, and nekton including salmon. Because the study area covered roughly 10° latitude (47-57°N) and longitude (138-148°W) and straddled the North Pacific and Alaska currents, we observed clear spatial variation in water conditions and catches across the study area. However, the spatial distributions and abundances of species had some unexpected surprises, including supposedly coastal species 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 increases our understanding of a region (Gulf of Alaska) and time (late winter) which has received little attention, and provides an important baseline for future studies, including proposed research in 2021.

(W16-14148)

Hydrochemical study in open part of the Gulf of Alaska in the winter 2019

Anna S. **Vazhova**

Pacific Scientific Research Fisheries Center (TINRO), Vladivostok, Primorsky Kray, Russia. E-mail: anna.vazhova@gmail.com

The nutrients content in the upper quasi-homogeneous layer is the basis for the formation of the first trophic level. The dissolved oxygen content shows the intensity of photosynthetic processes and characterizes production-degradation processes in the water column. Hydrological and hydrochemical studies were conducted during the international expedition in February-March 2019 in the Gulf of Alaska and DO, DIN, DIP, silicates were determinate at 60 stations on standard horizons. It was revealed that on the surface during the period of research throughout the entire water area, the winter pre-vegetation content of biogenic substances and close to 100% DO was noted, with a slight oversaturation in the southern part of the water area, signaling the beginning of spring bloom. A weak subsurface maximum of dissolved oxygen, which is caused by the heating of water and the release of molecular oxygen from the ocean surface into the atmosphere, has been recorded. Two zones was stand out in the general background of the spatial distribution of hydrochemical parameters. There are the north-west with the influence of the cyclonic gyre of the Sub-arctic current and the south-east where mix of sub-arctic front and coastal flow transforming into Gulf of Alaska waters.

(W16-14132)

Winter dynamics of phytoplankton biomass in the Gulf of Alaska derived from Sentinel 3 Imagery

Vishnu **PS** and Maycira Costa

University of Victoria, Victoria, BC, Canada. E-mail: psvishnu2014@gmail.com

This study is a preliminary investigation of the data collected as part of the International Year of Salmon (IYS) expedition in the Gulf of Alaska (GoA) between February to March 2019. The objective of this study is to use satellite-derived phytoplankton biomass to define the habitat condition of Pacific salmon in the Gulf of Alaska. Surface water samples for the determination of HPLC pigment, total suspended matter concentration (TSM), particulate ap (λ) and phytoplankton aph (λ) absorption spectra, phytoplankton taxonomic analysis were collected from (~ 2 m depth) using the CTD/rosette system. An above-water hyperspectral radiometer (HyperSAS) was installed on the bow of the ship to measure the sea surface reflectance. The 8-day composite of Sentinel-3A imageries (300 m spatial resolution) are used to derive chlorophyll a (Chl a) concentration in the Gulf of Alaska. The satellite images indicate 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.

(W16-14382)

Mega-swarm of northern sea nettles (*Chrysaora melanaster*) in the Gulf of Alaska in the winter of 2019

Brian P.V. **Hunt**[1,2,3], Alexei Somov[4], Albina Kanzeparova[4], Evgeny A. Pakhomov[1,2,3], and Vladimir Radchenko[5]

1 Institute for Oceans and Fisheries, University of British Columbia, 2202 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada E-mail: c.graham@oceans.ubc.ca; b.hunt@oceans.ubc.ca

2 Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, 2207 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada

3 Hakai Institute, PO Box 25039, Campbell River, British Columbia V9W 0B7, Canada

4 TINRO, Shevchenko Alley 4, Vladivostok, 690091, Russia

5 North Pacific Anadromous Fish Commission, Suite 502, 889 West Pender Street, Vancouver, B.C., V6C 3B2, Canada

Between February 16 and March 18, 2019 the inaugural voyage of the International Year of the Salmon undertook a mesoscale survey of the Gulf of Alaska to research the winter ecology of the North Pacific salmon ecosystem. A total of 60 stations were sampled across an ~ 1 x 1 degree survey grid, covering an area of approximately 700,000 km^2. An integrated fisheries oceanography approach was used to sample all components of the pelagic food web, from the bottom up drivers of physics and chemistry, to biota spanning microbes to salmon. Nekton sampling was completed using a midwater trawl towed for one hour at ~ 4.5 knots. Here we report 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.km^{-2} and a standing stock biomass of 1.23 million tons wet weight. Here we report on the population structure of *C. melanaster* as a means to infer the origin of this typically shelf associated species. Furthermore, we estimate the potential predation impact of *C. melanaster* on zooplankton in the Gulf of Alaska ecosystem.

(W16-14306)

Pacific salmon abundance and biomass as estimated by trawl survey in the Gulf of Alaska in February-March 2019

Vladimir I. **Radchenko**[1] and Aleksey A. Somov[2]

1 North Pacific Anadromous Fish Commission, Vancouver, B.C., Canada. E-mail: vlrad@npafc.org
2 Pacific Branch of VNIRO (TINRO), Vladivostok, Russia

The international Gulf of Alaska expedition in February-March 2019 was the first large-scale, integrated winter pelagic ecosystem research survey in this region, with a particular focus on Pacific salmon. As a part of integrated survey, trawl survey consisted of 58 stations (59 trawl hauls) and covered an area of 697,500 km^2 between February 21 and March 15, 2019 (ship time). Biomass and abundance of every species or group of animals per trawled unit area (Voronoi polygon) were calculated by formula used in TINRO (Volvenko 2003). The area of calculated polygons ranged from 10,200 to 16,800 km^2, with an average of 12,000 km^2. The trawl catchability coefficient for maturing and immature Pacific salmon aged n.1+ or older, as well for quickly growing pink and coho salmon spending one year at sea, is 0.3; for other juvenile salmon of first marine year is 0.4. Total Pacific salmon numbers was estimated at 54.95 million fish, biomass – 51.33 thousand metric tons. In a day- time, Pacific salmon predominated among other fish and squid species in the upper 30-meter layer; in night-time, they contributed about 29% of total fish and squid biomass. Density of salmon distribution was comparable in the north-western and north-eastern North Pacific Ocean besides coho, which was more abundant, by an order of magnitude, throughout the Gulf of Alaska.

(W16-14475)

Changes in our thinking of the ocean life of sockeye salmon

Chrys M. **Neville**[1], Richard J. Beamish[1] and Aleksey Somov[2]

1 Pacific Biological Station, Nanaimo, BC, Canada. E-mail: Chrys.Neville@dfo-mpo.gc.ca
2 Pacific Research Fisheries Center, Vladivostok, Russia

During the winter of 2019 sockeye salmon were captured across the North Pacific using a trawl fished by the Russian ship, *Professor Kaganovskiy*. Seventy-nine sockeye were captured in the western Pacific in January and February and an addition 73 sockeye salmon were captured in the Gulf of Alaska in February and March. The majority of ocean age 1 sockeye from all countries were encountered in the central Pacific region with very few in the Gulf of Alaska or the coastal regions of Russia. The proportion of ocean age 1 sockeye was zero in the coastal region of Russia, 6% in the Gulf of Alaska and 49% in the central Pacific region. Additionally, the juveniles in the central Pacific originated from all countries and represented from 38-52% of the catch from each country. The information on stock specific distribution and age of sockeye salmon from all countries during the winter provides new insights into the ocean life of sockeye salmon.

(W16-14460)

Origins and status of chum salmon caught in the Gulf of Alaska in the winter of 2019

Shigehiko **Urawa**, Shunpei Sato and Motoyasu Kuwaki

Hokkaido National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Sapporo, Japan. E-mail: urawa@affrc.go.jp

The Gulf of Alaska is an important winter habitat for Pacific salmon, which originate from both Continents of North America and Asia. There are, however, limited knowledges for their stock- specific distribution, abundance and ecology in winter. An international cooperative survey was conducted in the Gulf of Alaska between February 16 and March 18, 2019 onboard the Russian R/V *Professor Kaganovskiy*. A total of 223 chum salmon were caught using a surface trawl, which was most abundant catch among Pacific salmon. Although chum salmon were widely distributed in the survey area (47-56ºN, 137-147ºW), they were relatively abundant in southern warm waters. The SST of chum salmon habitats averaged 6.7ºC, ranging between 5.0ºC and 7.5ºC Genetic stock identification (GSI) using a Pacific-wide 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 52ºN. Our otolith analysis detected 32 marked chum salmon, including 3 from eastern Hokkaido, Japan, 2 from western Sakhalin, Russia, 22 from Southeast Alaska, 1 from Southcentral Alaska, and 4 unknown marks. Fifteen % of chum salmon showed skinny condition (0.9 < Condition Factor), most of which were ocean age 2 or 3, originating from both Continents. It is unknown whether these skinny fish can recover their condition or not in the following spring/summer season.

(W16-14255)

Condition of Pacific salmon stocks in the summer Bering Sea

Kentaro **Honda**, Tomoki Sato, and Shunpei Sato

Hokkaido National Fisheries Research Institute, Sapporo, Japan. E-mail: fbmods@affrc.go.jp

Summer high-seas research cruise to monitor the condition of Pacific salmon stocks and their habitats have been conducted in the central Bering Sea annually since 2007 aboard Japanese research vessel, mainly using a surface trawl. In each survey between late July and early August, 2–4 thousands of Pacific salmon have been caught by trawls at 17 fixed stations. Most abundant species was chum salmon, occupied more than 80% every year, followed by sockeye salmon (12.9% on average) and Chinook salmon (2.9%). Chum salmon occurred more 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 (OA1) fish accounted for more than 50% in any given year. Proportions of older fish became 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 as 15–35%. Mean annual catch number per trawl for OA1- and OA2 chum salmon converted to Japanese stocks has been positively correlated with total adult returns to Japan. Thus, considerable attention has been paid to our results in the summer Bering Sea. Japanese chum salmon stay in the Gulf of Alaska during winter. We believe high- seas surveys in both areas are indispensable to understand mechanisms affecting salmon distribution and productivity throughout their entire ocean life.

(W16-14396)

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

Pacific branch of the Russian Federal Research Institute of Fisheries and Oceanography, «VNIRO» («TINRO»), Vladivostok, Russia
E-mail: albina.kanzeparova@tinro-center.ru

RV "Professor Kaganovsky" conducted winter salmon survey in January-March 2019 in the Northwestern Pacific Ocean (NWPO), Aleutian waters (AW) and Gulf of Alaska (GoA). Biomass of non-salmonid species was evaluated at 415 kg/km^2 in the NWPO, 212 kg/km^2 in AW, and 879 kg/km^2 in GoA. Species number, composition and abundance were different in those regions. In the NWPO, we identified 25 species (12 fishes, 3 squids, and 10 jelly macroplankton). Jellyfish biomass was the highest (200 kg/km^2), with *Aequorea* sp. accounting for 66% of biomass. Squid biomass was 65 kg/km^2, with *Boreoteuthis borealis* accounting for 72% of biomass. Fish biomass was 84 kg/km^2. Two epipelagic species, Japanese sardine and Chub mackerel, accounted for 76% of the fish biomass, of 31 and 45 kg/km^2, respectively. In the AW, we identified 11 species: 3 species of mesopelagic fishes, 3 squids, 4 jelly macroplankton and 1 lamprey. In AW, jellyfish biomass was the highest (160 kg/km^2) with *Aequorea* sp. accounting for 49%, and *Phacellophora camtshchatica* 40% of the biomass. Squid biomass was 52 kg/km^2, with *B. borealis* accounting for 92%, and fish biomass was 3.4 kg/km^2 with *Tarletonbeania crenularis* accounting for 53% of the biomass. The highest species diversity was recorded in the GoA: 32 species, of which there were 16 fishes, 11 squids and 10 jelly macroplankton. Biomass of jellyfishes was 780 kg/km^2, 62% of which was due to *Chrysaora melanaster*, Squid biomass was 73 kg/km^2 with *B. borealis* accounting for 67%, and *Onychoteuthis borealijaponica* 31%. Fish biomass was 26 kg/km^2, 74% of which was due to *T. crenularis*. Species composition was associated with water masses and the number of survey stations. In the NWPO and GoA, study area included both subarctic and mixed waters, whereas AW were characterized as subarctic.

(W16-14446)

Distribution patterns of squid in the upper epipelagic Gulf of Alaska in winter 2019

Oleg N. **Katugin**[1], Vladimir V. Kulik[1], Mikhail A. Zuev[1] and Svetlana Esenkulova[2]

1 Pacific branch of the Russian Federal Research Institute of Fisheries and Oceanography «VNIRO» («TINRO»), Vladivostok, Russia
E-mail: oleg.katugin@tinro-center.ru

2 Pacific Salmon Foundation, Vancouver, BC, Canada. E-mail: svesen@uvic.ca

A total of nine species of squid and one species of pelagic octopus occurred in net hauls during upper epipelagic trawl survey conducted by the RV "Professor Kaganovsky" in the Gulf of Alaska (GoA) in February-March 2019. Two squid species (*Boreoteuthis borealis* and *Onychoteuthis borealijaponica*) were the most highly abundant, and accounted for almost 98% of all assessed biomass of cephalopods in trawl catches in the GoA. The first one occurred across the entire research area, and the second one was captured mainly in the southern portion of the survey grid. Another two squid species (*Gonatus onyx* and *Abraliopsis felis*) occurred in relatively large numbers; however, they were represented by small-sized individuals and their biomass values were low. *Okutania anonycha*, which has been known as an abundant species in the northeast Pacific Ocean, were absent from trawl catches, and occasionally occurred only in stomach contents of three Pacific salmon species (*Oncorhynchus nerka, O. kisutch*, and *O. tshawytscha*). The observed patterns in distribution for different species of squid are associated with a number of factors, such as species-specific latitudinal and vertical occurrence, as well as differences in onthogenetic and diel vertical migrations, along with the ability of trawl net to catch squid.

(W16-14487)

Winter energetic status of Pacific salmon in the Gulf of Alaska

Charles D. **Waters**[1], Todd Miller[1], Emily Fergusson[1], Dion Oxman[2], and Edward Farley Jr.[1]

[1] Auke Bay Laboratories, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, Juneau, AK, USA
E-mail: Charlie.Waters@noaa.gov

[2] Mark Tag and Age Laboratory, Division of Commercial Fisheries, Alaska Department of Fish and Game, Juneau, AK, USA

It is widely acknowledged that overwinter survival of Pacific salmon is influenced by their ability to acquire sufficient lipid reserves in the preceding summer and fall. Additionally, while interactions among salmon species and stocks occur throughout their life history, winter is considered a period when competition for prey resources is highest due to low prey biomass. Competition may be further exacerbated by large-scale hatchery releases of pink and chum salmon in the North Pacific Ocean. To better understand this critical winter period, which may regulate the productivity of salmon in the high seas environment, we analyzed samples collected from the recent winter NPAFC-International Year of the Salmon Gulf of Alaska Expedition. Specifically, we assessed the winter fitness of Pacific salmon by estimating their lipid content, protein content, and energy density from samples of muscle tissue. We also compared energy density values obtained from two international labs to determine if and how results may differ across processing methods. Last, we differentiated hatchery- and wild-origin salmon using thermal marks and then compared the energetic status of these two groups. The results will be used to develop indices of winter fitness for Pacific salmon and will contribute to our understanding of intra- and inter-species competition that occurs during the critical winter period.

(W16-14472)

Genomic science tools being implemented on samples from the first Gulf of Alaska expedition in 2019

Kristina M. **Miller**

Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo BC Canada Department of Forest and Conservation Sciences, University of British Columbia, Vancouver, BC, Canada. E-mail: kristi.saunders@dfo-mpo.gc.ca

Genomic science has evolved from a field focused on genome sequencing and human medicine to applications supporting population genomics, environmental monitoring, and species and ecosystem health. Tracking this progression, complete genome sequences for multiple salmon species have been realized. Population genomics has resolved fine-scale demographic relationships, adaptation, and genetic impacts of anthropomorphic activities, as well as providing very fine scale stock identification tools.

Recently in my lab, we have developed 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". As well, given decreasing salmon stock abundances around the world, limited funds to support annual stock assessments, and a recognition of the importance of moving from single species/stock assessments characterizations of salmon ecosystems, the development and implementation of environmental (e) DNA tools to support salmon science has been an area of active research, including in Canada. We embarked on a collection of samples on the Gulf of Alaska Expedition to assess genetic stock identification, health and condition of salmon, and offshore oceanic ecosystems through eDNA of filtered water samples This talk will highlight these new technologies and what we have learned.

(W16-14473)

At sea genetic stock identification of overwintering coho salmon in the Gulf of Alaska: Evaluation of nanopore sequencing for remote real-time deployment

Christoph M. **Deeg**[1], Ben J. G. Sutherland[2], Tobi J. Ming[2], Collin Wallace[2], Kim Jonsen[2], Kelsey L. Flynn[2], Charlie D. Waters[3], Richard J. Beamish[2], Terry D. Beacham[2], and Kristi M Miller[1,2]

1 Forest and Conservation Sciences, University of British Columbia, Vancouver, BC, Canada. E-mail: chdeeg@mail.ubc.ca
2 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada
3 National Oceanic and Atmospheric Administration, Alaska Fisheries Science Center, Auke Bay Laboratories, Juneau, Alaska, USA

Genetic stock identification (GSI) by single nucleotide polymorphism (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. Sequencing platforms currently applied require large batch sizes and multi-day processing in specialized facilities to perform genotyping by the thousands. 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. Here we report and evaluate at-sea stock identification of coho salmon based on targeted SNP amplicon sequencing on the minION platform during the International Year of the Salmon Signature Expedition to the Gulf of Alaska in the winter of 2019. To compensate for the low number of extremely long sequence reads as well as the high error rate inherent to the nanopore platform, amplicon concatenation was performed to increase coverage and throughput. Nanopore sequencing at sea yielded stock assignment for 52 of the 75 assessed individuals.

Despite this, repeatability and concordance with Ion Torrent based sequencing is currently modest, highlighting inherent challenges of nanopore sequencing, such as homopolymer resolution and abundant indels. 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.

(W16-14307)

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[1], Vladimir I. **Radchenko**[2], Evgeny A. Pakhomov[3] and Brian Hunt[3]

1 Far-Eastern Ecological Centre, Ltd. (FEEC Ltd.), Yuzhno-Sakhalinsk, Russian Federation
2 North Pacific Anadromous Fish Commission, Vancouver, B.C., Canada. E-mail: vlrad@npafc.org
3 Institute for the Oceans and Fisheries (IOF), UBC, Vancouver, B.C., Canada

Spatial distribution and abundance of floating macro-and microplastics were estimated during the international Gulf of Alaska expedition in February-March 2019. The surface-floating macroplastics were estimated based on visual observations by The Ocean Cleanup (2018) method: during the one- hour observation watch, observer looked for debris floating within a 90-degree arc encompassing the area ahead of the ship and one side of the track-line within 50 m from the shipboard. Twenty observation watches were completed once a day between February 22 and March 15, 2019. Microplastics were sampled by deployment of handy sized neuston net from HydroBios, Kiel- Altenholz, Germany (surface 0–20 cm, opening area 40 x 70 cm, mesh size 300 µm) for 15 min at 2.5 knots after each of 58 midwater trawl hauls. Microplastic samples were kindly processed by Rein Nijhof and Matthias Egger, The Ocean Cleanup. Surface-floating macroplastics were spotted at 25% of observation, density of distribution on these areas raged from 1.1 to 2.3 per km^2. Among floating objects, packing materials (57.1%), food/drink containers (28.6%) and fishing gear parts (14.3%) were met. Two fishing net floats and kitchen appliance were spotted beyond the regular observation watch time. Microplastics including hard fragments and fibers were presented in neuston samples in small to moderate abundance. Survey results indicate a need to organise a regular floating macro-and microplastics monitoring in this area that is critically important for many commercial fishery stocks and microplastics contamination studies of main fisheries objects.

(W16-14308)

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[1], Vladimir I. **Radchenko**[2], Gennady A. Kantakov[3], Andrey Yu. Likhograev[1] and Artem A. Likhoshapko[1]

1 Polar branch of the VNIRO (PINRO), Murmansk, Russia
2 North Pacific Anadromous Fish Commission, Vancouver, B.C., Canada. E-mail: vlrad@npafc.org
3 Far-Eastern Ecological Centre, Ltd. (FEEC Ltd.), Yuzhno-Sakhalinsk, Russian Federation

The live fish trap is a pelagic trawl device that allows holding and lifting on board a research vessel of live, undamaged fish from the trawl catch for further study and/or tagging. For the international Gulf of Alaska expedition, the live fish trap was constructed at aluminium workshop in Murmansk, Russia under supervision of PINRO scientists, who have substantially modified the FISH-LIFT device (Holst and McDonald 1999) for local operating conditions. The net part of device ensures its connection with the trawl bag and the direction of fish caught and held by the trawl directly into the trap hull. Size and cutting shape of the net part of the live fish trap were made in accordance with the shape and size of the used trawl, in our case – Russian pelagic trawl of 80/396 m. Four trawl hauls with the live fish trap were conducted in 48º35 – 48º43 N 128º34–136º11 W on March 14-19, 2019. The live fish trap was towed at speed of 3.9-4.8 knots during 20 to 30 min with upper trawl panel kept on the surface. Many mesopelagic fish, jellyfish, macrozooplankton and two coho salmon specimens were sampled alive by the live fish trap in night-time. Coho salmon were tagged by disk tags and released. However, both coho had significant scale loss above recommended 10% while osmotic problems will cause fish with too high scale loss to die. Technical approaches to reduce a scale loss by salmon are discussed.

(W16-14109)

Juvenile salmon and ocean ecosystem studies in the Northern California Current

Kym C. **Jacobson**[1], Richard D. Brodeur[2], Brian J. Burke[3], and Mary E. Hunsicker[2]

1 National Marine Fisheries Service, Northwest Fisheries Science Center, Newport, OR, USA E-mail: kym.jacobson@noaa.gov
2 NOAA, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR 97365, USA
E-mail: rick.brodeur@noaa.gov
3 NOAA, Northwest Fisheries Science Center, 2725 Montlake Bvld. E., Seattle, WA 98112, USA

The distribution and ecology of juvenile salmon in their first critical summer at sea in the Northern California Current was relatively unknown prior to 1979, when juvenile salmon were first caught during a purse seine survey conducted by Oregon State University. From one to four surveys a year were conducted along the coasts of Oregon and Washington every year until 1985 and a substantial amount of information was gathered on distribution, migration, growth and feeding in the coastal environment for the dominant species, coho and Chinook salmon. There was a hiatus in sampling for 13 years until 1998, when juvenile salmon were collected in a National Marine Fisheries Service survey using fine-mesh surface trawl nets and this sampling has continued annually until the present. Broad-scale surveys were conducted mainly in May, June, and September off Washington and northern Oregon, with a higher level of effort off the mouth of Columbia River, the source of the juvenile salmon in this region. Biological data (length, condition, stock identification, growth, migration, parasites, diseases) have been collected on all salmon species, along with concurrent physical data and information on co- occurring plankton, nekton, and potential predators. In addition to these broad surveys, several process studies examined juvenile salmon fine-scale horizontal and vertical distribution, relationship to oceanographic features (fronts, eddies), and detailed predator-prey interactions.

We summarize some of the key findings of these sampling programs and discuss their contribution to management and ecosystem assessment of these culturally and economically important species in the Pacific Northwest.

(W16-14496)

Annual surveys for juvenile Pacific salmon in the coastal waters of British Columbia

Chrys M. **Neville**

Pacific Biological Station, Nanaimo, BC, Canada. E-mail: Chrys.Neville@dfo-mpo.gc.ca

Surveys of juvenile salmon and other small pelagic species in coastal waters of British Columbia (BC) are conducted annually by the Department of Fisheries and Oceans (DFO). The surveys are conducted using a mid-water trawls towed at variable head-rope depths. The net is towed at 4.5-5knots and typically has an opening of 13-15m deep and about 30m wide. There are multiple surveys and the timing of the surveys and survey design varies between coastal regions. We will provide an overview of the historic surveys as well as changes that have occurred over recent years. In addition, we will review other coastal sampling that has been conducted over recent years using alternative gear including purse seine, beach seine and rotary screw traps and discuss methodologies that are being used to assess the health and condition of these fish. We will demonstrate how these samples linked with samples collected during the Gulf of Alaska expedition in the winter of 2019 is providing new abilities to test key hypothesis on factors regulating marine survival of Pacific salmon.

(W16-14476)

How does sea-entry condition of juvenile chum salmon affect their subsequent survival/ growth? A case study in eastern Hokkaido, Japan

Kentaro **Honda**[1], Kotaro Shirai[2], Shinji Komatsu[1], and Toshihiko Saito[1]

[1] Hokkaido National Fisheries Research Institute, Sapporo, Japan. E-mail: fbmods@affrc.go.jp
[2] University of Tokyo, Kashiwa, Japan

Chum salmon *Oncorhynchus keta* is thought to experience considerable size-selective mortality during its early marine life stages. We examine favorable sea-entry conditions (i.e., timing and body size) of juvenile chum salmon that improve survival during their coastal residency. On 25 June 2013 off Konbumori, about 20 km east of the Kushiro river mouth, we sampled 365 juvenile chum salmon [57.5–98.6 mm fork length (FL)] originating from a hatchery in the Kushiro River, eastern Hokkaido. The sea-entry date, FL at sea entry, and post-sea-entry growth rate (mean daily growth in FL) of these Konbumori juveniles was back-calculated using otolith daily increment analysis, and then compared with data from 373 juveniles released from the same hatchery captured at the mouth of Kushiro river from April–July 2013. Most fishes sampled at Konbumori entered the sea between 25 May and 5 June, when coastal surface water temperatures constantly exceeded 5°C (conditions considered favorable for juveniles). The FLs of fish sampled at the Kushiro river mouth were significantly smaller than the back-calculated FLs at sea entry of Konbumori fishes during their main sea-entry period, suggesting size-selective mortality existed. As fishes entering the sea at or exceeding about 65 mm FL tended to grow faster among Konbumori fishes, release of larger-sized juveniles during favorable coastal temperature conditions might reduce post-release juvenile mortality.

(W16-14474) INVITED

IESSNS – International ecosystem survey in the Northeast Atlantic

Kjell Rong **Utne**[1], Anne Olafsdottir[2], Jan Arge Jacobsen[3], Teunis Jansen[4], Kai Wieland[5] and Leif Nøttestad[1]

1 Institute of Marine Research, Bergen, Norway. E-mail: kjell.rong.utne@hi.no
2 Marine and Freshwater Research Institute, Reykjavik, Iceland
3 Faroe Marine Research Institute, Torshavn, Faroe Islands
4 Greenland Institute of Natural Resources, Nuuk, Greenland
5 DTU AQUA – National Institute of Aquatic Resources, Hirtshals, Denmark

The international ecosystem survey in the Norwegian Sea and surrounding areas (IESSNS) is a collaboration between five countries where more than 3 million km2 are covered annually. The primary objective of the survey is an annual swept-area index used in stock assessment of NEA- mackerel, but the survey also targets herring and blue whiting acoustically and Atlantic salmon with surface trawling. Plankton and oceanographic sampling are also done during the survey. The survey has developed from a single vessel in 2007 to six vessels in 2018. The presentation will describe the survey methodology, sampling methods, data handling and storing, and how the data are applied in assessment. Examples will also be presented of how the data is used for hypothesis testing, of the critic against the survey and potential survey bias.

(W16-14310)

Non-anadromous Species in the Subarctic North Pacific

Aleksandr **Zavolokin**

North Pacific Fisheries Commission, Tokyo, Japan. E-mail: azavolokin@npfc.int

A pan-Pacific high seas ecosystem research survey planned as a part of the International Year of the Salmon (IYS) initiative provides an opportunity to collect valuable data on non-salmon species in the Subarctic North Pacific. The goal of this study is to review the past pelagic surveys conducted in the North Pacific with the emphasis on the period from January to March to get an idea which species of NPFC interest can be caught during the IYS survey. The study was mostly based on the review of Russian and Japanese research surveys (Ivanov&Zavolokin 2018), with the recent information from the 2019 expedition in the central Gulf of Alaska. It summarized the results of 151 pelagic surveys conducted entirely or partly in the North Pacific high seas, beyond exclusive economic zones, in 1969-2019. More than 900 species of fish, squids, crustaceans and other marine species, which are formally under the NPFC mandate, have been caught in the high seas from 1969. These include all eight priority species for the NPFC Scientific Committee: Pacific saury, chub and spotted mackerels, Japanese sardine, neon and Japanese flying squids, North Pacific armorhead and splendid alfonsino. Most catches of the priority species occurred in the western North Pacific although their distribution patterns were different. Potential outputs for NPFC from joining the pan-Pacific survey could include improved knowledge about distribution and migration of priority species, validation and adjustment of models, new biological information on priority and other species of fish and squids, and other data related to oceanography, fish diets, and zooplankton.

(W16-14441)

Integrating salmon ocean research results into a management framework

Brian K. **Wells**[1], David D. Huff[2], Brian J. Burke[2], Steven T. Lindley[1], and Richard W. Zabel[2]

1 NOAA Fisheries, SWFSC Fisheries Ecology Division, Santa Cruz, CA, USA. E-mail: brian.wells@noaa.gov
2 NOAA Fisheries, NWFSC Fish Ecology Division, Seattle, WA, USA

We review a number of recent and developing modeling approaches that can be parameterized using ocean survey data to improve management of salmon and the interactions with both their predators and prey. 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. Ocean environmental variability, predator demand, and for some stocks, salmon recruitment variability are increasing. 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. A few examples of applying these data to management include using ocean catches of juveniles and environmental covariates of early mortality to estimate later adult abundance at sea on which harvest control rules can be set. However, these are tactical and retrospective responses to estimated abundances of salmon at sea rather than a coordinated strategy to improve recovery and resilience of salmon. 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.

WORKSHOP 18
GlobalHAB. Evaluating, reducing and mitigating the cost of harmful algal blooms: A compendium of case studies

(W18-14139)

Case study: Evaluating the cost of harmful algal blooms in coastal waters of British Columbia, Canada

Svetlana **Esenkulova**[1], Isobel Pearsall[1], and Chris Pearce[2]

[1] Pacific Salmon Foundation, Vancouver, BC, Canada. E-mail: svesen@uvic.ca
[2] DFO - Pacific Biological Station

Coastal waters of British Columbia (BC), Canada is one of the most biologically productive ecosystems in the world, supporting large commercial and recreational fishing and aquaculture.

Effects of harmful algal blooms (HABs) in BC are profound resulting in fish kills of farmed fish and frequent harvest closures of shellfish. Here we present several local case studies of economic estimates of HAB impacts as wells as evidences of direct effects of HABs on wild juvenile salmon.

WORKSHOP 19
Impacts of mariculture on coastal ecosystems

(W19-14377) INVITED

Ecological risk of covert mortality nodavirus: From ponds to wild sea

Qingli **Zhang**[1,3,4] Shuang Liu[1,3], TingTing Xu[1,3], Jingwei Hao[1,3], Xiujuan Shan [1], Qiang Wu[1], Guangliang Teng [1], Xiaoping Li[1], Tao Yang [1], Chong Wang[1], Xiuhua Wang [1], Jie Huang [1], Xuan Dong [1], Zhongyi Li [1], Xiaoyuan Wan[1], Fanqun Dai[1], Chen Li[1], Songwen Sang[1], Jun Li[1,4], and Xianshi Jin [1,4]

1 Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Laboratory for Marine Fisheries and Aquaculture, Qingdao National Laboratory for Marine Science and Technology, Qingdao, China, Qingdao Key Laboratory of Mariculture Epidemiology and Biosecurity, Key Laboratory of Maricultural Organism Disease Control, Ministry of Agriculture, Qingdao, 266071, PR China
2 School of Sciences and Medicine, Lake Superior State University, Sault Ste. Marie, MI 49783, USA
3 These authors contributed equally to this work
4 These authors jointly directed this work
Correspondence should be addressed to Q.Z. (zhangql@ysfri.ac.cn) or J.L. (jli@lssu.edu) or X. S. (jin@ysfri.ac.cn)

Covert mortality nodavirus (CMNV), an emerging *Alphanodavirus*, is the pathogen of viral covert mortality disease (VCMD) and its widespread caused huge economic losses of shrimp aquaculture in Asia. High prevalence of CMNV in shrimp farming ponds in coastal provinces in China and CMNV infection in crustaceans from the outfalls of shrimp ponds caused increasing concerns to widely infection and spread of CMNV in wild marine crustaceans' populations. Surveys of presence and infection of CMNV in aquaculture and wild animals in farming ponds, drainage canals and wild marine were conducted to assess the ecological risk of CMNV spread from aquaculture ecosystem to wild ecosystem in present study. Firstly, analyses of molecular detection, virus purification, mass spectrometry, histopathology, in situ hybridization (ISH) and transmission electron microscope (TEM) revealed that the diseased ponds farming crustacean species in coastal provinces of the North China, including *Penaeus vanmamei*, *P. japonicus*, *P. monodon*, *Exopalaemon carinicauda*, and *Macrobrachium rosenbergii* were widely affected by CMNV and suffered VCMD from 2016 to 2017. The prevalence rate of CMNV was beginning to show a roughly downward trend in cultured crustaceans in coastal provinces of the North China. Further investigation demonstrated that eight invertebrates' species inhabiting crustacean farming ponds affected by VCMD were infected by CMNV, and might constitute new biological risk factors for CMNV spread. More extensive investigation indicated that species of mollusk, crustaceans, polychaetes and teleosteans in outfalls of shrimp ponds in coastal areas were infected by CMNV at high proportion. The results of systematic offshore surveys proved that crustaceans and teleostean from wide wild seas were seriously affected by CMNV with different infection rates. Meanwhile, the results of histopathology, ISH, and TEM revealed obvious histopathological lesion in the targets tissues in most CMNV positive samples from offshore seas. The results of correlation analysis between CMNV infection and population density dynamics in crustacean dominant species from the Bohai Sea, Yellow Sea and East China Sea indicated that the prevalence of CMNV was significantly negatively correlated with the number density of the population. It is speculated that the large-scale epidemic of CMNV led to the decline of the number density of the traditional dominant species of crustaceans in the above sea areas. Our studies revealed that CMNV can infect more than 40 species of cultured and wild animals and cause serious pathological damage to infected individuals, and its impact cannot be ignored both for the farming ponds ecosystems and the wild marine ecosystems.

Keywords: Ecological risk; viral covert mortality nodavirus; viral covert mortality disease (VCMD); farming ponds ecosystem; marine ecosystem.

(W19-14423) CANCELLED

Marine fish communities of First Nations' clam gardens

Morgan J. **Black**[1,2], Kieran Cox[1,2], Francis Juanes[1], Morgan Hocking[1,4] and Sarah Dudas [1,2,3]

1 University of Victoria, Victoria, Canada. E-mail: morganjb@uvic.ca
2 Hakai Institute, Calvert Island, British Columbia, Canada
3 Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, Canada
4 EcoFish Research, Victoria, Canada

Ancient First Nations' clam gardens on the west coast of North America provide a unique example of long-standing anthropogenic habitat modifications. Clam gardens are a rock-wall terrace in the intertidal that changes the beach slope, sediment composition, and structural complexity. They have been shown to support and increase clam populations, but their effects on other species that occupy the modified nearshore environment has not yet been quantified. To address this, we surveyed 18 sites up to four times over 2016 and 2017, collecting biodiversity and abiotic data including degree of structural complexity. Results suggest that the increased complexity of clam gardens increase abundance and species richness of fish and mobile invertebrates. This research serves to expand our understanding of drivers of diversity, impacts of habitat modification and supports creating common goals between indigenous peoples' land use rights and conservation objectives.

HAB-SECTION MEETING

(HAB-S-13842)

Morphology, Molecular Phylogeny and Toxicity Potential of a New *Prorocentrum* species, *P. thailandensis,* (Dinophyceae, Prorocentrales) from Phuket Island, Thailand

Berhane T. **Tesfai**[1,2] Pengbin Wang[2], Jiangning Zeng[2], and Mengmeng Tong[1]

1 Ocean College, Zhejiang University, Zhoushan, PR China. E-mail: berhina27@yahoo.com
2 Key Laboratory of Marine Ecosystem and Biogeochemistry, State Oceanic Administration (SOA), Hangzhou 310012, PR China

A new species, here called *Prorocentrum thailandensis*, of toxic benthic dinoflagellates is described morphologically and genetically based on established monocultures from Tritang bay, Phuket Island, Thailand collected in September 2018. The cells were 25-29 um long and 15-20 um wide with oval to oblong shape. The periflagellar area consists of 8 platelets, a wide flagellar pore and with smooth thecae ornamented with small and large pores. Unlike many *Prorocentrum* species, this new isolate lacks platelet 7 and apical pore. Morphologically *P. thailandensis* has similarities with *P. formosum* and *P. elegans* but unlike these closely related species, *P. thailandensis* has large, round posterior nucleus. It lacks a pyrenoid structure. Molecular phylogenetic analysis was carried out using maximum likelihood (ML) and Bayesian inference (BI) for both ITS and LSU sequences. In both ITS and LSU phylogeny, the isolate *P. thailandensis*, showed close relationships with clade of *Prorocentrum elegans*. The closely related species were from geographically different localities which indicate the potential of genetic divergence of sister species adapting to wider geographic range. In regard to toxicity potential, *Prorocentrum thailandensis* strain was found to be potentially toxic/ lethal to *Artemia salina* in both grazing nauplii and hatching cyst bioassays.

(HAB-S-13851)

2018 Red Tide in China

Hao **Guo**, Dongmei Li, Yubo Liang and Chunjiang Guan

National marine environmental monitoring Center, Dalian, PR China. E-mail: hguo@nmemc.org.cn

About 36 events of marine red tides with an affected area of 1,406 km^2 were witnessed along Chinese coastline. The events and the cumulative occurrence area of red tides decreased by 47% and 62% compared with that in 2017. The highest frequency was 23 times, with the largest cumulative area of 1,107 km^2 occurred in the East China Sea. High incidences of red tide mainly occurred in August. Red tides were caused by a total of 18 species. Among them, *Karenia mikimotoi* was the first dominant species, which caused the outbreak of as many as 7 red tides. The largest distribution area of green tides, *Enteromorpha prolifera*, was 38,050Km^2, increased nearly 30% than the previous year.

(HAB-S-13946)

New evidence for the role of oil-degrading bacteria in the formation of a *Prorocentrum* dinoflagellate bloom after an oil spill

Bum Soo **Park**[1,2], Deana L Erdner[1], Hernando Bacosa[1], Zhanfei Liu[1], and Edward J. Buskey[1]

1 Marine Science Institute, University of Texas at Austin, Port Aransas, TX 78373, USA. E-mail: parkbs@kiost.ac.kr
2 Marine Ecosystem Research Center, Korea Institute of Ocean Science and Technology, Busan, 49111, R Korea

There have been no studies on effect of altered bacterial communities due to crude oil exposure on phytoplankton growth, even though crude oil leads to change in bacterial communities, and this change can affect phytoplankton growth and community composition. Thus, we examined effect of change in bacterial communities due to oil exposure on dinoflagellate growth. For this study, free-living bacteria isolated from a *Prorocentrum texanum* culture were exposed to crude oil for a month, and the growth change in *P. texanum* after co-culture with oil-treated bacteria was investigated. Interestingly, the growth rate and yield of *P. texanum* in bacterial treatment was clearly enhanced. To gain more direct evidence, we investigated variation in dinoflagellates growth after co-culture with oil-degrading bacterial isolates from oil spilled soil after the Texas City "Y" oil spill. Two bacterial isolates (C1-T3 and E1-Gal-T2) clearly enhanced the growth rate and yield of six different dinoflagellates, including axenic cultures (*Amphidinium carterae* and *Peridinium sociale*). Lastly, to determine whether or not these isolates can enhance dinoflagellate growth by releasing nutrients, nutrient-limited medium was prepared by removing each one of the components (nitrogen, phosphorous, trace metals or vitamins), and the two bacterial isolates were inoculated into each nutrient limited media, containing *A. carterae* and *Pe. sociale*. These bacterial isolates enhanced the growth rate and yield of the two dinoflagellates, regardless of any nutrient-limited media. Together with these findings, oil-degrading bacteria may enhance the growth of dinoflagellates and this growth-enhancing activity may not be derived from nutrients released from the bacteria.

(HAB-S-14003)

20 years of HABs monitoring on the east coast of Russia: Results and lessons

Tatiana **Orlova**

National Scientific Center of Marine Biology, FEB RAS, Vladivostok, Primorsky Kray, Russia. E-mail: torlova06@mail.ru

The results of HAB monitoring program on the east coast of Russia during the period 1999-2019 were summarized. A total number of 43 potentially toxic and bloom-forming microalgae have been identified. The changes and trends in the composition, abundances and distribution of toxic microalgae are shown as follows: a decreasing of diatom component of phytoplankton; new bloom forming flagellate species were detected and new toxin producing species were revealed. For the last two decades some species of harmful algae (*e.g.*, toxic dinophyceae, prymnesiophyceae and pelagophyceae benefiting water column stratification, warm water benthic dinoflagellates and cyanobacteria responding to increased water temperatures) became common. The monitoring program aimed to analyze the presence of toxic species and screen for phycotoxins in shellfish was launched in 2007. Data of this monitoring program revealed the real threat of diarhetic shellfish poisoning in Primorye (the Sea of Japan). There are no practical methods for analyzing phycotoxins and as a consequence it is impossible to register poisons by any of these toxins in medical or sanitary organization. All of these are the reasons of not having data about real economic impacts and harm for people's health for Primorsky Krai and for the whole Far Eastern region of Russia. The question raised in the report is if Russia will fit into the HAB Pacific research strategy and what are the prospects for the next two decades?

This work was supported by the RFBR project 17-04-01394 and project FEB RAS "Far East" 18-5-074.

(HAB-S-14052)

Why massive blooms of the fish-killing harmful dinoflagellate *Cochlodinium polykrikoides* did not occur along the Korean coastal water in 2016

Seung Ho **Baek**[1], Young Kyun Lim[1], Minji Lee[1] and Bum Soo Park[2]

1 Risk Assessment Research Center, KIOST (Korea Institute of Ocean Science and Technology), Geoje 53201, R Korea
E-mail: baeksh@kiost.ac.kr

2 Marine Ecosystem Research Center, KIOST (Korea Institute of Ocean Science and Technology), Busan 49111, R Korea

For the past 20 years, blooms of *Cochlodinium polykrikoides* have been consistently present along the Tongyeong coast, Korea, but they abruptly disappeared in 2016. Despite extensive studies on this dinoflagellate, the cause of this abrupt decline remains largely unknown. To understand these phenomena, physico-chemical and biological data were collected along the Tongyeong coast through a biweekly field survey from June to September. Here, we focused the reason why the *Cochlodinium* bloom did not occur or spread to the Tongyeong coasts in 2016. The environmental differences between 2016 and previous years (1995-2015) were investigated. In 2016, the water temperatures (c.a.,30°C) and the salinity (c.a., 30) were outside the optimum ranges for *C. polykrikoides* growth in the study area. Moreover, the averages of these factors were significantly different from previous years (p<0.001). In particular, the amount of Changjiang River discharge in 2016, which can affect coastal environments via ocean currents, was relatively larger than in the past four years, reducing the salinity in August. Increased stratification and diatom dominance, both negatively associated with *C. polykrikoides* growth, were consistently observed during the study period. The combination of these environmental factors may have contributed to the decline of massive *C. polykrikoides* blooms in southern KCW in 2016. Our findings suggest that the amount of Changjiang River discharge may play an important role in the development or the decline of *C. polykrikoides* blooms in KCW, which resulted in abnormally low salinity and higher water temperatures in August in Korean coastal water.

(HAB-S-14053)

Field application and validity of a red-tide acoustic sensing system (RASS) for monitoring and alerting of harmful algal blooms (HABs) in Korean coastal waters

Jin Ho **Kim**[1], Seung Ho Baek[1], Young Kyun Lim[1], Hansoo Kim[2], Donhyug Kang[2], Seung Won Jung, and Bum Soo Park[3]

1 Risk Assessment Research Center, KIOST (Korea Institute of Ocean Science and Technology), Geoje 53201, R Korea
E-mail: baeksh@kiost.ac.kr

2 Maritime Security Research Center, KIOST(Korea Institute of Ocean Science and Technology), Pusan, R Korea

3 Marine Ecosystem Research Center, KIOST (Korea Institute of Ocean Science and Technology), Busan 49111, R Korea

Globally, harmful algal blooms (HABs) caused by marine microscopic algae pose a significant threat to human health and result in significant economic loss. Many strategies and instruments have been implemented for their detection, management and control, with the aim of minimizing the risk to seafood consumers and producers alike. One such instrument is the Red-tide Acoustic Sensing System (RASS) which utilizes a backscattered acoustic signal to detect microalgal cells in the water column, proving to be a cheap and easy tool for the detection of HABs. In the current study, five RASSs were deployed at fish-farms located in HAB-occurring areas throughout South Korea during the summer of 2018, and their performance examined for the early detection of HABs. From July 26th to 6th August 2018, the dinoflagellate *Cochlodinium polykrikoides* was the most abundant HAB species across all locations. A significant regression between the relative received acoustic intensity (dB) as measured by RASS and cell densities of HABs was observed (R^2 = 0.846) and was successfully applied to quantify the HAB cell density. The dB values noticeably increased from 25th July 2018 and decreased again from 1st August. Except on one occasion (13th August), the dB values corresponding to warning level of HABs (≥ 100 cells mL^{-1}) were not measured after 5th August. The highest 22 dB was recorded at St. R2 in 29th July, which corresponded to 2,782 cells mL^{-1}. To investigate any background interference, a significant correlation (R^2 = 0.997) between HAB cell abundance and backscattered acoustic signals was calculated. Results from our study show that the RASS can produce accurate, real-time bloom data, providing significant advantages for the warning of HABs.

(HAB-S-14054)

Succession phenomenon of two dinoflagellates *Cochlodinium polykrikoides* and *Alexandrium affine* in the southern sea of Korea in summer of 2017

Young Kyun **Lim**[1], Seung Ho Baek[1], Jin Ho Kim[1] and Bum Soo Park [2]

1 Risk Assessment Research Center, KIOST (Korea Institute of Ocean Science and Technology), Geoje 53201, R Korea
E-mail: baeksh@kiost.ac.kr

2 Marine Ecosystem Research Center, KIOST (Korea Institute of Ocean Science and Technology), Busan 49111, R Korea

We investigated the succession patterns of both HAB species in the southern sea of Korea and performed a bioassay using *C. polykrikoides* and *A. affine* to evaluate their competitive relationship. From June to August, the surface water temperature increased from 17.4°C to 27.9°C, the salinity decreased from 34.2 to 30.8. *C. polykrikoides* dominated in July; however, *A. affine* reached bloom levels in August. The growth experiments were carried out at six water temperature (15, 20, 22.5, 25, 27.5 and 30°C) and six salinity (20, 24, 26, 28, 30 and 32) levels. At 25°C, the maximum growth rate for *C. polykrikoides* (0.31 day^{-1}) was measured at a salinity of 32, and for *A. affine* (0.43 day^{-1}) at a salinity of 30. *C. polykrikoides* cells died within 2 days at 30°C, while *A. affine* maintained high growth rates (0.35 – 0.39 day^{-1}). Further, *C. polykrikoides* is salinity sensitive at low salinity of 20 in 25°C and 27°C, but *A. affine* did not respond sensitively to changes in salinity. In co-cultivation at a same inoculation ratio, *A. affine* had a competitive advantage over *C. polykrikoides* at all temperatures; however, when the inoculation ratios were varied, the species with a higher initial cell density showed a competitive advantage at all temperatures except 30°C. Combined the field and bioassay results indicated that *A. affine* may have an advantage over *C. polykrikoides* under higher temperature and low salinity conditions, which is important when evaluating the species succession and blooms in the southern sea of Korea during summer.

(HAB-S-14410)

Influence of eutrophication on dinoflagellate cyst distribution in Abu Dhabi coastal waters and future aspects

Anbiah **Rajan**[1], Barrie Dale[2], Rajasekhar Thankamony[1], Azza Al Raisi[1], Ponpandi Perumal[1] and Shaikha Al Hosani[1]

1 Environment Quality Sector, Environment Agency Abu Dhabi P.O. Box 45553, Abu Dhabi, UAE. E-mail: arajan@ead.ae

2 Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern, NO-0316 Oslo, Norway

The distribution and abundance of dinoflagellate cysts in a eutrophic area of Abu Dhabi coastal waters was investigated to determine how dinoflagellate cyst assemblages varied with nutrient loading. The study area is highly eutrophic due to the continuous flow of treated sewage (400,000m^3 L/Day) for the past several years and recorded maximum 53700 µg/L nitrate and 9330 µg/L phosphate concentrations. Sediments collected from surface and 45cm depth of randomly selected 10 sites in the study area were used for the present investigation. Fifty-one cyst morphotypes were recorded for the first time in Abu Dhabi coasts. Among them, six were bloom forming and most of the cysts were non- viable and concentrated in the surface of the sediment. The concentrations, assemblages and diversity recorded in the present observation clearly indicates the influence of high nutrient levels and extreme hydrographic parameters. The cyst concentrations were generally low compared with many other regions, though cysts were seen in all samples. The cyst assemblages showed both autotrophic and heterotrophic species, with heavy dominance by heterotrophs. Increased cyst concentrations in more heavily polluted sites, reflects a well-documented eutrophication signal; further supported by progressively lower cyst concentrations with distance from the main nutrient pollution source. In nine of 10 sites, cyst concentrations were higher in surface samples (90 - 4379 cysts/cm^3) than in lower samples (0-15 cysts/cm^3). The article also highlights the role of cysts as an indicator of the water quality changes and anthropogenic impact.

POSTERS

SESSION 1
Connecting science and communities in a changing North Pacific

S1-P1

Increasing input of anthropogenic nitrogen drives the East China and Yellow Seas to Phosphorus limitation

Kitack **Lee**[1], Ji-Young Moon[1], Eunil Lee[2], and In-Seong Han[3]

1 Division of Environmental Sciences and Engineering, Pohang University of Science and Technology, Pohang, 37673, R Korea
E-mail: ktl@postech.ac.kr
2 Ocean Research Division, Korea Hydrographic and Oceanographic Agency, Busan, 49111, R Korea
3 Division of Ocean Climate and Ecology Research, National Institute of Fisheries Science, Busan, 46083, R Korea

Increase in anthropogenic emissions of reactive nitrogen from China, Korea, and Japan, and its subsequent addition, via riverine input and atmospheric deposition, to the East China and Yellow Seas has led to an unprecedented increase in the nitrate (N) concentration of the upper ocean, without the proportional increase in phosphorous (P). The disproportional addition of anthropogenic N that persisting the past 4 decades has progressively driven the extensive regions of the East China and Yellow Seas from being N-limited to being P-limited. In 1980s, P limited area was small and mostly confined to the coastal areas near the mouth of Changjiang River, whereas the rest of East China and Yellow Seas remained severely deficit in N relative to P. After 1990s onward, the P-limited waters have rapidly expanded to the downstream of the Changjiang River, including the southern and eastern coastal waters of Korea. The areas located outside of downstream of Changjiang River remains still being N-limited relative to P but the magnitude of N deficiency has been less severe over time. Our results provide unique observational evidence pointing to a nutrient regime shift (i.e. N limitation transiting to P limitation), largely driven by anthropogenic N inputs, in extensive areas of East China and Yellow Seas in the vicinity of the largest source of anthropogenic N (northeastern Asian continent).

S1-P2

Spatio-temporal models provide new insights on the biotic and abiotic drivers shaping Pacific Herring (*Clupea pallasi*) distribution

Martin Godefroid[1], Jennifer L. **Boldt**[1], James Thorson[2], Robyn Forrest[1], Stéphane Gauthier[3], Linnea Flostrand[1], R. Ian Perry[1], Andrew R.S. Ross[3], and Moira Galbraith[3]

1 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada. E-mail: martin.godefroid@gmail.com
2 National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA, USA
3 Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada

Determining how fish respond to variation in biotic and abiotic conditions is a prerequisite to forecasting changes in productivity and spatial distribution of fish stocks. In the present study, we investigated physical and biological drivers of the spatio-temporal dynamics of Pacific Herring (*Clupea pallasi*). We fit multivariate spatio-temporal models to fisheries-independent trawl- and acoustics-based data collected off the West Coast of Vancouver Island (WCVI), Canada, 2006-2014. We evaluated the effects of environmental drivers of lower trophic level productivity, including sea surface temperature (SST), chlorophyll a, fluorescence, salinity, oxygen, transmissivity and zooplankton density on variation in Pacific Herring biomass. Models were also used to measure spatio-temporal covariation with other pelagic, semi-pelagic, and bottom-associated fish species to address potential competitive and predation interactions. Through application of spatio-temporal models we found: (i) Pacific Herring were distributed on the continental shelf (<185m); (ii) Pacific Herring biomass increased during 2006-2014, and was positively correlated with May and July SST; (iii) a positive covariation in spatio-temporal densities between Pacific Herring and its common zooplankton prey, supporting a potential bottom-up control hypothesis; (iv) a negative covariation in spatio-temporal densities between Pacific Herring and both Pacific Hake and Pacific Sardine; and (iv) a positive covariation in spatio-temporal densities between Pacific Herring and several groundfish predators (i.e., Arrowtooth Flounder, Sablefish, Pacific Halibut, Pacific Cod). Results suggest that the strongest drivers of Pacific Herring summer distribution and density are: i) zooplankton prey availability; ii) predator avoidance, particularly Pacific Hake; and iii) potentially competition with sardines.

S1-P4 CANCELLED

Recruiting anglers across Canada to build a nation-wide fisheries monitoring program that helps researchers fill their data gaps

Sean C. **Simmons**

Angler's Atlas, Prince George, BC, Canada. E-mail: sean@anglersatlas.com

Canada has over a million fish bearing lakes, streams, and saltwater destinations. However only a small number of these fisheries are monitored each year due to the high cost of surveying. As a result, the vast majority of fish bearing waters remain unmonitored and potentially at conservation risk. To address this issue we tested a new mobile app and website called MyCatch that encourages anglers to report their catch data. Anglers can also select local research projects that appeal to them, building a community of anglers eager to collect data for their favourite research projects.

In the first 14 months of the project anglers reported over 17,000 fishing trips, collecting catch rate data on over 3,000 waterbodies across Canada. Several waterbodies received enough reports to conduct comparisons with creel surveys from the same period. On the Bow River in Alberta, we compared results generated by MyCatch in 2018 with a large creel survey led by Alberta Environment and Parks. Catch rates and species compositions were strongly correlated (R values of 0.93 and 0.98 respectively), with no significant difference found between the distributions.

One of the most striking discoveries with the MyCatch project was the number of new research questions that can be answered by anglers collecting the data. In this presentation, new research questions will be presented, including an exciting new opportunity using anglers to help validate remote sensing data.

SESSION 2
Marine heatwaves in the North Pacific: Predictions and impacts in coastal regions

S2-P1

The Blob and its impacts on marine ecology in the Salish Sea

Matthew **Baker**[1,2], Jan Newton[1,3], Rebecca Guenther[1], Tara Wilson[1], Ryan McLaughlin[1], Emily Hamacher[1], Erin Horkan[1], Kali Williams[1], Jessica Thompson[1], Bryson Albrecht[1], Rayn Allen[1], Rachel Hale[1], Krista Nunnally[1], Ian Smith[1], Ye Tian[1], Gabriela Zayas del Rio[1]

1 Friday Harbor Laboratories, University of Washington, San Juan Island, USA. E-mail: mattbakr@uw.edu
2 School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA USA
3 Applied Physics Laboratory, University of Washington, Seattle, WA USA

Climate change is predicted to create more extreme and more variable conditions in the marine environment. Marine Heat Waves (MHW) are known to influence system production, energy flow, species distribution, recruitment, and survival. In 2014, climatologists documented a MHW, also known as “The Blob”. Sea surface temperatures in the northeast Pacific rose 1-4°C above average. Waters with elevated temperatures moved from the central Gulf of Alaska to coastal systems in fall with the seasonal shift to downwelling conditions. In the inland waters of the Salish Sea, the MHW had pronounced effects on the marine ecosystem with consequences that persisted several years after its dissipation. The Pelagic Ecosystem Function Research Apprenticeship examines patterns in oceanographic properties, the abundance of plankton, marine fish, seabirds, and marine mammals, and forage fish condition (2004-2019). Elevated seawater temperatures were noted during 2014-2016. Time series analyses reveal coincident shifts in N/P ratios, decreases in nitrate concentrations, and an increase in the abundance of amphipods relative to copepods. Also observed were significant decreases (30%) in mean condition in an important regional forage fish, Pacific sand lance, and reduced densities of marine birds and mammals. Laboratory analyses on Pacific sand lance provide further evidence for the effects of elevated temperature on fish condition. This synoptic view of the system provides insights into trends and linkages throughout the system. As marine heat waves become more prolonged and common, it is important to study these effects to better understand short and long-term impacts on local populations and ecosystems.

S2-P2

How unusual were ocean temperatures in the Northeast Pacific during 2014-2018?

Tetjana **Ross** and Howard Freeland

Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney BC, Canada. E-mail: tetjana.ross@dfo-mpo.gc.ca

Strongly positive sea-surface temperature anomalies developed in the Northeast Pacific Ocean during the winter of 2013/14. Sea-surface temperature anomalies near Station Papa, in the Gulf of Alaska, were more than 4.5 standard deviations above normal. Temperature anomalies in excess of 4 standard deviations were still present subsurface into 2017. Such departures from climatology raises this event from unusual to extraordinary. On the principle that an extraordinary observation needs extraordinary proof, in this presentation we examine three datasets that are completely independent of each other and examine how closely those datasets correspond with each other. The correspondence is found to be close. We also discuss the statistical interpretation of such large anomalies. We use the longest of the three timeseries to consider extreme value statistical distributions in addition to normal distributions and discuss the probability of a 4.5σ departure from normal.

S2-P3

Sharp reduction in nutrient concentrations in deep British Columbian strait linked to marine heatwave

Hayley V. **Dosser**[1], Stephanie Waterman[1], Jennifer Jackson[2], and Brian Hunt[1,2]

1 University of British Columbia, Vancouver, BC, Canada. E-mail: hayley.dosser@hakai.org
2 Hakai Institute, Victoria and Heriot Bay, BC, Canada

The marine heatwave known as The Blob impinged on the British Columbian coast from 2014 to 2016. From 2015 onwards, anomalously low levels of nutrients were recorded in Johnstone Strait, a 400m deep channel north of Vancouver Island. Low levels have persisted through 2018. The 2015-2018 mean concentrations of nitrate, phosphate, and silicate declined by roughly two standard deviations from their 1975-2014 mean values. Seasonal and other sampling biases cannot explain the discrepancy. Bottle samples were independently collected by scientists from both Fisheries and Oceans Canada and the Hakai Institute, providing an important comparison and validating the result. This dramatic reduction in nutrient concentrations is not observed in adjacent regions, including Queen Charlotte Sound, the Discovery Islands, and the Strait of Georgia. The occurrence of this low-nutrient water coincides with a reduction in the range of densities observed, a decrease in deep salinity, and an increase in temperature throughout the water column. We hypothesize that the mechanism behind this decline is the presence of anomalously warm, low-density water associated with The Blob depressing deep isopycnals on the continental shelf and preventing nutrient-rich upwelled water from transiting over the sill from Queen Charlotte Strait into Johnstone Strait. We explore the evidence supporting this hypothesis and examine the ramifications of this result for other straits and inlets along the British Columbian coast, with a focus on the role of upwelling and bathymetry in the seasonal replenishment of nutrients.

S2-P4

Regional case studies on marine heatwaves and their impacts on primary production

Hakase **Hayashida**[1,2], Richard J. Matear[3,2], and Peter G. Strutton[1,2]

1 Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia
E-mail: hakase.hayashida@utas.edu.au
2 Australian Research Council Centre of Excellence for Climate Extremes, University of Tasmania, Hobart, Tasmania, Australia
3 CSIRO Oceans and Atmosphere, Hobart, Tasmania, Australia

Ocean temperature extremes such as marine heatwaves are expected to intensify in coming decades due to anthropogenic global warming. Reported ecological and economic impacts of marine heatwaves include coral bleaching, local extinction of mangrove and kelp forests, and elevated mortalities of invertebrates, fishes, seabirds, and marine mammals. In contrast, little is known about the impacts of marine heatwaves on microbes that regulate biogeochemical processes in the ocean. Here we investigate the impacts on phytoplankton, the base of marine food web and the driver of biological carbon pump, by analysing the physical and biogeochemical output of a near-global eddy-resolving ocean circulation model simulation. By comparing with satellite and field observations, we show that the model realistically simulates some of the representative marine heatwave events of the recent past, such as the North Pacific Blob and the Western Australia Ningaloo Niño. We discuss the impacts of each event on modelled mixed layer depth, nutrient concentration, phytoplankton biomass and primary production.

S2-P5

Unexpected changes in zooplankton biomass and juvenile salmon growth during the 2015-2016 warm anomalies, Puget Sound, WA, USA

Julie **Keister**[1], Amanda Winans[1], Bethellee Herrmann[1], Julia Bos[2] and Iris Kemp[3]

1 University of Washington, Seattle, WA, USA. E-mail: jkeister@uw.edu
2 Washington Department of Ecology, Olympia, WA, USA
3 Long Live the Kings, Seattle, WA, USA

We use data from several monitoring programs in the Strait of Juan de Fuca and Puget Sound to explore spatial and interannual variability in ecosystem response to environmental change over 2014-2018, the period of the Pacific Warm Anomalies and beyond. We will show how the unprecedented temperatures observed in 2015 and 2016 related to zooplankton and juvenile salmon growth and survival. Interannual shifts in plankton phenology, biomass, and community structure were observed, with responses differing slightly across regions more, or less, connected to the coastal ocean. In contrast to predictions, zooplankton biomass and juvenile salmon growth were strongly elevated during the warm years. Furthermore, coho salmon that out-migrated from Puget Sound in 2015 during the peak of the warm anomalies survived at relatively high rates. This decoupling of previously-established relationships between temperature, salmon growth and survival, in which high temperature = poor growth and survival, suggests a challenge for fishery managers who seek ecosystem predictions based on simple metrics of physical properties.

S2-P6

Influence of *Vibrio* spp., temperature, reproductive development, and stocking density on Pacific oyster (*Crassostrea gigas*) summer mortality in Baynes Sound, British Columbia

M. **Cowan**[1,2,3], T. Green[3], P. de la Bastide[1], T. Finston[1], G. Meyer[2], B. McAmmond[4], J. Van Hamme[4], E. Bottos[4], W. Hintz[1], R. Marshall[5], C.M. Pearce[2]

1 University of Victoria, Department of Biology and Centre for Forest Biology, Victoria, BC, Canada, V8P 5C2
2 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, V9T 6N7
3 Vancouver Island University, Centre for Shellfish Research & Department of Fisheries and Aquaculture, Nanaimo, BC, Canada, V9R 5S5
4 Thompson Rivers University, Department of Biological Sciences, Kamloops, BC, Canada, V2C 0C8
5 SFCC Compliance Canada LTD., Nanaimo, BC, Canada, V9T 4N6

Cultured Pacific oysters (*Crassostrea gigas*) in Baynes Sound, British Columbia, have experienced summer mass mortality events in recent years with cumulative mortalities exceeding 90% at some sites in 2015 and 2016. In 2017, we isolated *Vibrio* spp. from oysters and putatively identified potentially pathogenic species, based on *recA* gene sequencing; among the 163 isolates, *V. aestuarianus* and *V. harveyi* were well represented. The objective of the present study was to identify factors influencing the onset of a mortality event in juvenile Pacific oysters during the summer of 2018. We recorded mortality, growth, gonad development, temperature, turbidity, dissolved oxygen, chlorophyll-*a*, plankton assemblages, and bacterial community composition. Our study site contained four replicate trays of four stocking densities: 150, 300, 450, and 600 oysters/tray. Mortality was first observed on July 30, which coincided with a marine heatwave. *Vibrio aestuarianus* and the proportion of *Vibrio* spp., quantified using qPCR and community 16S rRNA gene sequencing, respectively, increased with observed mortality rate. Mortality rates were at their highest on August 12 and we observed systemic mixed microbial infections in histological cross sections of oysters that otherwise appeared healthy. The final cumulative mortalities ranged from 34 to 75%, with the highest density trays having significantly lower mortality than the lowest density trays. Significant density-dependent effects were also observed for oyster size and gonad development. The long-term persistent ocean warming and increased frequency of marine heatwaves associated with climate change are likely contributing to the emergence of summer mortality and pathogenic *Vibrio* spp. in Baynes Sound.

S2-P7

Mediterranean marine heatwaves: Physical drivers and future evolution

Sofia Darmaraki

Dalhousie University, Halifax, Nova Scotia, Canada. E-mail: sofia.darmaraki@dal.ca

Episodes of extreme warm temperatures, termed as marine heatwaves (MHW), have been seen to intensify during the last decade in the Mediterranean Sea, a hotspot region for climate change. In fact, one of the first-ever documented events worldwide, occurred in the basin during the summer of 2003, with abnormal surface temperature anomalies of 2-3 ºC lasting over a month. However, only a few studies have dealt with the causal links behind this large-scale MHW, which resulted in extensive mass mortalities of endemic species in the northwestern part of the basin. Here, we first use the latest version of a dedicated, fully-coupled regional climate system (RCSM) model in hindcast mode, to study its dominant driving factors. A basin-scale analysis of the mixed layer heat budget during the MHW is performed, for the first time, using "online" diagnostics. The ocean and atmospheric components' contribution is investigated throughout the different phases of the event, indicating a key role of the wind forcing and the air-sea heat fluxes on its development. We then make use of an RCSM ensemble in scenario mode, to assess the MHW evolution in the basin in the 21st century and their characteristics relative to the 2003 event. Our results suggest longer and more severe MHWs with higher global-warming rates, with the MHW 2003-type events constituting a weak occurrence at the end of the period. This study contributes to a better and detailed understanding on the underlying factors of the 2003 MHW and provides an overview of future MHW conditions in the basin under different emission scenario.

SESSION 3
Coastal ocean modelling in the North Pacific

S3-P1

Methods for predicting short-term surface sea temperature and the forecasting service in Republic of Korea

Kwangnam Han[1], Byungmoon **Park**[1], Yong Huh[1], and Donghyeon Yu[2]

[1] Korea Hydrographic and Oceanographic Agency, Busan, PR Korea. E-mail: bmpark@korea.kr
[2] Inha University, Incheon, PR Korea

KHOA (Korea Hydrographic and Oceanographic Agency) predicts short-term (1~3 days) surface sea temperature prediction by applying harmonic decomposition and MOS (Model Output Statistics) method using G1SST (Global 1 km Sea Surface Temperature) satellite surface sea temperature data. However, there is a difference between G1SST and a observed sea temperature due to scattering effect by atmosphere and degradation of satellite sensor sensitivity. In this study, KHOA implemented a short-term prediction model of daily average surface sea temperature based on real-time ocean observation data. The model was considered the harmonic analysis and autoregressive error model. Also, sea water was predicted using long-short term memory artificial neural network. The short-term prediction results of surface sea were compared between 1 day, 2 days and 3 days. As a result of comparison of prediction results, the accuracy of prediction results is higher than MOS model ones at 13 points, and the proposed prediction models can predict the surface water temperature every hour. Using the developed surface sea temperature models, KHOA provides the forecasts of the short-term surface sea temperature and the possibility of the sea surface front, the high and low surface sea water. Also, the methods for predicting the surface sea temperature will be used for data assimilation to improve the accuracy of numerical model results.

S3-P2 (CANCELLED)

Numerical experiments on the summer distributions of water properties and nutrients in the East China Sea

Hyoun-Woo **Kang**, Ok Hee Seo, Jae Kwi So, and Chan Joo Jang

Korea Institute of Ocean Science and Technology, Busan, R Korea. E-mail: hwkang@kiost.ac.kr

The circulation of the East China Sea (ECS) is highly influenced by various forces such as Kuroshio and Taiwan Warm Currents (TWC), tide, wind and the Changjiang river discharge. In summer all these variabilities affect significantly on the distributions of water masses and nutrients. In this study, we have carried out a series of experiments using a coupled physical and biogeochemical model based on POLCOMS-ERSEM by simply excluding a specific forcing to find out the role of them on the distributions of nutrients and water properties especially in summer. Were it not for the tidal forcing, reduced vertical mixing increases the temperature and decreases the salinity in the upper layer resulting in stronger stratification in the middle area of ECS. It is noteworthy that the surface temperature increases much larger without the wind while subsurface temperature is not much influenced by the wind in summer. CDW spreads toward northwest of ECS as well as toward Korea Strait without the tide while it spreads toward southwest of ECS without the wind. Domain averaged nutrients and chlorophyll concentrations in the central ECS shallower than 200m in each case have compared each other. Contributions of biogeochemical processes depleting nutrients in the given domain during the summer are about 11% for nitrate and 8% for silicate. Chlorophyll concentration decreases about 35% due to the biogeochemical processes even though the phosphate concentration is not affected much.

S3-P3

Effects of ocean warming on potential habitat distribution of Japanese anchovy (*Engraulis japonica*) in the seas around Korea: A maximum entropy approach

Minkyoung **Bang**[1,2], Chan Joo Jang[1,2], Sukyung Kang[3], and Chang-Sin Kim[3]

1 Korea Institute of Ocean Science and Technology, Busan, R Korea
2 Ocean Science and Technology school, Korea Maritime and Ocean University, Busan, R Korea. E-mail: b910111@kiost.ac.kr
3 National Institute of Fisheries Science, Busan, R Korea

Ocean warming is affecting marine fish and these effects will continue in the future. Korean waters are one of the most rapid warming areas. In Korea, Japanese anchovy (*Engraulis japonica*) is commercially and biologically important small pelagic fish species sensitive to environmental changes. Thus, we try to investigate the effects of global warming on potential changes in habitat distribution of anchovy in the future by using a maximum entropy model (MaxEnt). The model was constructed based on seawater temperature at 10m depth, mixed layer depth (MLD), and sea surface height (SSH) in August 1983-2015, and predict spatial distribution in 2030, 2060, and 2090 by using the seawater temperature projections from the three climate change scenarios (RCP4.5, RCP6.0, and RCP8.5) in the NorESM1-M with keeping other environmental variables (SSH and MLD). Coastal regions from the eastern South Sea to the East Sea were within the range of optimal spawning temperature of anchovy during 1983-2015. However, in 2090, it moved to the north and located near the Vladivostok in Russia. Also, while the relatively high habitat suitability indices were limited to the South Sea in 1983-2015, it was extended prominent to the north in all the three scenarios in the future. We will apply several other CMIP5 models and consider primary production as an environmental factor. This study could contribute to the understanding of anchovy responses to climate change and offers basic information for application to complex models.

SESSION 4
The impacts of marine transportation and their cumulative effects on coastal communities and ecosystems

S4-P1

Effects of TBT on sinking rate and physiological parameters of marine planktonic diatom, *Thalassiosira pseudonana*

Mst. Ruhina Margia Khanam, Yohei **Shimasaki**, Koki Mukai, and Yuji Oshima

Faculty of Agriculture, Kyushu University, Motooka 744, Nishi-ku, Fukuoka 819-0395, Japan. E-mail: simasaki@agr.kyushu-u.ac.jp

Even after worldwide regulations for antifouling paints, TBT has been detected in sea water and sediment in coastal area of some countries, therefore the adverse impacts of TBT on marine ecosystem are still a matter of concern. Planktonic microalgae are important primary producers in aquatic environment and their sinking rate from surface layer to deep layer is a limiting factor for primary production by photosynthesis as light intensity changes depending on the depth. Thus present study investigated the effects of TBT on sinking rate in marine planktonic single-celled diatom, *T. pseudonana* by the SETCOL method and analyzed some physiological parameters. After exposure of TBT at 0 (control), 1 (EC10 for growth rate) and 1.7 µg L^{-1} (EC50) for 72 h (N=3), the sinking rates of *T. pseudonana* cells at EC50 (0.04–0.006 m day^{-1}) were significantly ($P < 0.05$) lower than that of control (0.13–0.08 m day^{-1}) at all measurement time (24 h, 48 h and 72 h). Protein content per cell decreased significantly ($P < 0.05$) at EC50 compared with control. The carbohydrate, neutral lipid contents per cell and cell diameter were not changed significantly. These results indicated that TBT could retard sinking rate of *T. pseudonana* and the retardation may induce the risk of photoinhibition by excessive light radiation for long time. Thus the decreased protein content may be one factor for sinking retardation by TBT because specific gravity of protein (ca. 1.33 g cm^{-3}) is higher than sea water (ca. 1.02 g cm^{-3}).

SESSION 5
Trends in ocean and coastal ecosystems and their services and its future

S5-P1 CANCELLED

Sea level variations in the East China Sea from merged altimetry data

Jilong **Chen**

Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, PR China. E-mail: cjl@mail.iap.ac.cn

The change trends of sea level height is in the East China Sea (ECS) were examined using merged altimetry data, and possible mechanisms were studied using Ishii data and ORAS5 assimilation data. The result shows that the mean sea level over the ECS has a rise rate of 3.62 mm/yr during 1993–2017, but sea level variations exhibits obvious decadal change and remarkable regional difference. The geographical distribution of the sea level variations over the ECS is asymmetric with a pronounced variation existing in the deep water. The analysis of thermosteric sea level variations indicate that thermal change of upper layer has a significant contribution to the sea level variations in the ECS. Heat budget analysis suggests that heat advection may be a key factor influencing the thermal change. Apart from thermal contribution, the contribution of precipitation and evaporation to sea level change were also investigated.

S5-P2

Carbon isotopic composition of clam shells along the Washington coast and the effects of ocean acidification

Yongwen **Gao** and Russell A. Svec

Makah Fisheries Management, P.O. Box 115, Neah Bay, WA 98357, USA. E-mail: gaoy@olypen.com

Carbon isotopic composition of clam shells have been used as a powerful tool in detection of climate change and ocean acidification, because these shells are composed of calcium carbonate ($CaCO_3$) and ocean acidification will affect the ability of clams to build protective shells and skeletons. Ocean acidification will also lead to a shift in DIC (dissolved inorganic carbon) equilibria and result in higher CO_2 and lower carbonate ion (CO_3^{2-}) concentrations. In this study, we report the results of stable isotope analyses on carbonate shells of Pacific razor clam (*Siliqua patula*), Pacific geoduck (*Panopea abrupta*), and Pacific sea scallop (*Patinopectin caurinus*) along the Washington coast, and using d^{13}C values in detecting the effects of ocean acidification. Among a large number of samples analyzed the d^{13}C values of the clam shells ranged from -2.9 to -0.3‰, whereas d^{18}O values of the same samples ranged from -2.2 to +1.4‰. As compared with the carbon isotope indicators reported previously, data from our study did not show a steady decrease in d^{13}C patterns. The d^{18}O values of the clam shells clearly showed life history that was consistent with the annual growth lines on the outside of the shell. Overall the isotopic results suggest that the carbonate shells are a good proxy for reconstructing the life history and environmental changes that a clam experienced, but the signatures of ocean acidification along the Washington coast (mainly from d^{13}C) are open to question.

S5-P3

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

Rebecca **Schijns**[1] and Daniel Pauly[2]

1 University of British Columbia, Vancouver, BC, Canada. E-mail: r.schijns@oceans.ubc.ca
2 University of British Columbia, Vancouver, BC, Canada

Canada's marine fisheries occur in three oceans, designated by Pacific, Arctic, and Atlantic Exclusive Economic Zones (EEZs), where management bodies utilize catch records in order to make decisions regarding the future of their fisheries. However, current catch reporting systems and stock assessment processes are flawed, as records are missing key fishery components and assessments can use time series that do not represent the full scale of change, known as shifting baselines. These shortcomings can directly impact the perception of fisheries and influence future management decisions. This research provides a comprehensive catch record for Canadian fish stocks in surrounding EEZs from 1950-2017 in order to estimate their current status and provide reference points useful for managers to secure future marine resources. Catch reconstructions initially done by the Sea Around Us group are improved and updated to 2017 using methodologies found through the Sea Around Us database. Using reconstructions, a new method called Catch Maximum Sustainable Yield (CMSY) allows reference points to be estimated from catch, resilience, and stock status priors in order to determine the current status of Canadian fisheries. As well, CMSY analysis is used to investigate truncation effects on stock assessments that exhibit shortened time series. Concealing historical trends leads to underestimating sustainable yields and stocks appear to be healthier than those assessed with expanded time series. Overall, this research enhances the scope of catch data and provides an approach to assess data-limited stocks, in order to gain better understanding of Canadian fisheries from a historical and managerial perspective.

S5-P4

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

Third Institute of Oceanography, Ministry of Natural Resources, PR China. E-mail: xuchangan@tio.org.cn

Zhulin Mangrove is located in Beihai Guangxi China. In the eyes of scientists, it has and has been providing a variety of goods and services, such as coastal protection, aquatic breeding grounds and larval shelters, carbon sequestration, pharmaceuticals as well as touring resource etc. With the development of local society and economy, Zhulin mangrove is being disturbed by human activities, and Its area is shrinking rapidly and the functions are damaged. By estimating the value of mangrove ecosystem, especially its total economic value, and demonstrating those figures to public quantitatively, we can arouse the attention of policy makers and local communities to protect it and exploit it in a sustainable way.

S5-P5

Constraining along-coast surface seawater CO_2 system variability and changeability from an Alaskan ferry

Wiley **Evans**[1], Geoffrey T. Lebon[2,3], Christen D. Harrington[4], and Allison Bidlack[5]

1 Hakai Institute, Heriot Bay, BC, Canada. E-mail: wiley.evans@hakai.org
2 Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, Seattle, WA, USA
3 Joint Institute for Study of the Ocean and Atmosphere, University of Washington, Seattle, WA, USA
4 Alaska Department of Transportation, Ketchikan, AK, USA
5 Alaska Coastal Rainforest Center, University of Alaska Southeast, Juneau, AK, USA

In the Northeast Pacific near-shore zone, marine CO_2 system variability and changeability due to anthropogenic CO_2 uptake has been largely under-characterized. Since October 2017, the Alaska Marine Highway System M/V *Columbia* has served as a platform for surface underway data collection to help fill this information gap while conducting twice weekly ~1300-km transits between Bellingham, Washington and Skagway, Alaska. This effort provided the first characterization of the variability, severity, and timing of severe pH and aragonite saturation state (Ω_{arag}) conditions across this region. Lowest pH was seen in confined tidally-mixed zones in autumn; whereas lowest Ω_{arag} was seen in areas of high glacial melt in summer. Time-of-detection estimates revealed the tidally-mixed zones to be potential sentinel observing sites with a ~decade time span to capture seawater pCO_2 increase equivalent to the atmospheric CO_2 trajectory. Anthropogenic CO_2 estimates elucidated the monthly along-track changes in pH and Ω_{arag} since 1765, revealing a greater degree of winter pH change and a greater degree of summer Ω_{arag} change. Areas of diverging patterns of severe pH and Ω_{arag}, and the differential response to anthropogenic CO_2, have implications for species vulnerability to ocean acidification and must be considered within the scope of tracking ocean climate change.

S5-P6

Effect of ocean freshening and acidification on amphipods and limpets of Antarctica

Taewon **Kim**[1], Jibin Im[1], Boongho Cho[1], Seojeong Park[1], Eunchong Sin[2], In-Young Ahn[2]

1 Department of Ocean Sciences, Inha University, Incheon, R Korea. E-mail: ktwon@inha.ac.kr
2 Division of Polar Ocean Sciences, Korea Polar Research Institute, Incheon, R Korea

Global warming induces glacier retreat and eventually salinity of seawater can decrease by melting water in the polar regions such as Antarctica. Also increased CO_2 induced by human activity can decrease the seawater pH in the Antarctica. Here we were interested in how the marine benthic ecosystems in the Marian Cove will change in response to freshening and acidification. We selected Antarctic amphipods (*Gondogeneis Antarctica*) living in the shallow water and limpets (*Nacella concinna*) living in the intertidal region as model animals to predict the fate of benthic animals in future. Following the first-year lab study, we did field survey on the distribution of amphipods and characteristics of limpets. Amphipods and limpets were quantitatively collected and water characteristics (e.g. pH, salinity, DO, temperature) were measured at 27 sites along the Marian Cove. As the collection site gets closer to the ice wall, the Shannon's diversity index(H) of amphipods decreased significantly. The number of the most dominant species, *Gondogenia antarctica*, decreased with declining salinity. Although there were no observations for low pH less than 7.9, each amphipod has appeared to have a special niche for pH ranges. Meanwhile, *N. concinna* did not have any significant difference in their distribution and condition index. Given the results, current pH and salinity condition of Antarctic ocean can shift the distribution of amphipods community but would not influence the population of limpets much.

S5-P7

Declining catch of Japanese sandeels

Shin-ichi **Ito** and Qinyao Li

Atmosphere and Ocean Research Institute, the University of Tokyo, Kashiwa, Japan. E-mail: goito@aori.u-tokyo.ac.jp

Sandeels are important fisheries target species in Japan. In addition, sandeels are important forage species for many piscivorous predators and key species in the coastal marine food web. Sandeels habitat on/in gravelly sand sediments and therefore their distribution shift is limited by the distribution of sandy sea floor. That unique characteristic might make sandeels vulnerable to climate variability and climate change. Recently, the catch of sandeels in Japan has decreased. To detect the geographical characteristics of sandeel catch decline, prefectural catch data from Statistics of Agriculture, Forestry and Fisheries was analyzed. Sandeel catches in 38 ocean-facing prefectures from 1956 to 2015 were used. The catch data was firstly log plus one transformed and then anomaly normalized by standard deviation was calculated in each prefecture to avoid the influence of fishery effort differences between prefectures. Since Kochi prefecture has no catch during the analyzed period, we applied principal component analysis to the normalized anomaly data of 37 prefectures. The contribution of the first principal component (PC1) was 28.6% and its score showed a decreasing trend since 1975. The contribution of the second principal component (PC2) was 12.2% and its score showed an increasing trend during 1956-1980 and a decreasing trend during 1995-2015. There are 12 prefectures (e.g. Okayama) which showed positive sing for PC1 and negative sing for PC2, hence sandeel catch drastically declined after 1975. There are 10 prefectures (e.g. Hyogo) which showed positive sings both for PC1 and PC2, hence sandeel catch gradually declined after 1975. Recently, it was reported three species of *Ammodytes* (*A. japonicus, A. heian and A. hexapteru*s) distributed around Japan. It was impossible to divide the three species in the historical fisheries catch data, however it is an urgent task to elucidate life histories and distributions of each *Ammodytes* species to develop sustainable management of sandeels in Japan.

S5-P8

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

Pacific Scientific Research Fisheries Center (TINRO-Center), Vladivostok, Russia. E-mail: denkurnos@mail.ru

Pacific herring *Clupea pallasii* consists of two ecological forms: sea and lake within the species range. The lake herring spawns and winters in small bays and lagoons and do not make extended feeding migrations. Sea herring spawns in the waters of sea bays, makes extended feeding migrations and winters in the open sea. At the moment there is no information about the formation of lake forms of herring and about the degree of their divergence, despite the studies conducted.

We used 683 DNA samples of Pacific herring collected from 2007 to 2017 from 18 locations in the Sea of Okhotsk, the Japan Sea, the Bering Sea and the Kara Sea, the Pacific Ocean, and the three lakes: Aynskoe (Sakhalin Island), Vilyui, Nerpichye (Kamchatka Peninsula). Were used for research 4 microsatellite loci and fragment of the mtDNA D-loop.

In the studied samples of Pacific herring in the D-loop fragment, were found 122 haplotypes. Three massive haplotypes found only in Lake Ainsky. Significant genetic differentiation was found between the samples from the Ainskoe, Vilyuy, Nerpichye lakes and all marine samples. The largest differences are observed between samples from different lakes.

Analysis of the results allows us to consider the Pacific herring *Clupea pallasii* from the lakes Aynskoe, Vilyuy and Nerpichye as separate genetic groups representing the lake form. Based on the geological features of the lakes and the obtained genetic data, it can be assumed that the formation of lake forms of herring occurred gradually, simultaneously with the formation of more desalinated lagoons 6 - 7 thousand years ago.

The reported study was funded by RFBR according to the research project № 18-34-00431.

S5-P9

Multi-decadal projections of biophysical conditions in the Bering Sea

Albert J. **Hermann**[1], Wei Cheng[1], Kelly Kearney[1], Georgina A. Gibson[2], Ivonne Ortiz[1], Kerim Aydin[3], and Kirstin Holsman[3], and Anne Hollowed[3]

1 Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA
E-mail: albert.j.hermann@noaa.gov
2 International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, AK, USA
3 NOAA/Alaska Fisheries Science Center, Seattle, WA, USA

Global climate projections for the 21st century suggest large increases in ocean temperature are likely in the Bering Sea (up to 5 degrees C on the northern shelf under "business as usual" emission scenarios). Here, using immersive 3D techniques, we present multi-decadal projections of biophysical conditions on the Bering Sea shelf, obtained through a dynamically downscaling regional model (with 10 km horizontal resolution) forced by coarse-scale global projections. The global projections used include members of both CMIP5 and the newly emerging CMIP6 experiments from the IPCC program. From each realization, temperature iso-surfaces are rendered to illustrate the relative volume and topology of the Bering Sea "cold pool" (shelf waters colder than 2 degrees C), which has strong impacts on the shelf ecosystem. Substantial differences in this metric are shown among results using different forcing global models (e.g. "structural uncertainty"), and among different emission scenarios (e.g. "scenario uncertainty"). The latter appears as the dominant source of uncertainty by the end of the 21st century.

S5-P10

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

Qingshan **Luan**, Yuande Kang and Jun Wang

Yellow Sea Fisheries Research Institute, CAFS, Qingdao, PR China. E-mail: luanqs@ysfri.ac.cn

Basing on the phytoplankton net samples that collected from 1959 to 2015 in the Bohai and Yellow Seas China, the long-term variations on species composition, cell abundance, community structure and diversity were analyzed. Dominant taxa changed dramatically in the Bohai Sea. Centric diatoms such as *Chaetoceros* spp. and *Coscinodiscus* spp. declined and were gradually replaced by *Paralia sulcata*, *Thalassionema* spp., *Noctiluca scintillans* and *Tripos* spp. Co-influenced by the absence of Huanghe river flow and strong El Niño event, the abundances and species diversities decreased to the lowest at the end of last century, while they had a 1.5 times and 15.0% recovery in this century. The persistent increasing on seawater N:P ratios has led to a phytoplankton succession from diatom-dominated communities to co-dominated by diatoms and dinoflagellates, with an increase of 2.82 times on the ratio of dinoflagellates to diatoms. However, species shifts were different in the Yellow Sea during this century, with *P. sulcata*, *Tripos* spp., *Chaetoceros* spp., *Coscinodiscus* spp., *Proboscia* spp., *Skeletonema costatum* and *Protoperidinium* spp. as the dominant forms. The ratio of dinoflagellates to diatoms and the species richness had 1.13 times and 78.9% increases, respectively. The species diversity maintained the same level in the Northern Yellow Sea while it increased 28.9% in the Southern Yellow Sea. This study provided with the basic references for discussing the effects of phytoplankton variations on the ecosystem food web structure and early recruitment of fishery resources in the crucial habitats of the important fisheries areas in the Bohai and Yellow Seas.

SESSION 6
Identifying thresholds and potential leading indicators of ecosystem change: The role of ecosystem indicators in ecosystem-based management

S6-P1

Using phytoplankton community index to assess water quality improvement in Hong Kong

Kedong **Yin** and Jianzhang He

Sun Yat-sen University, Guangzhou, PR China. E-mail: yinkd@mail.sysu.edu.cn

Water quality in Tolo Harbour and Channel (Tolo) has been improved since 1998 after the diversion of sewage effluent. However, it remains poorly understood how nutrient loading reduction has impacted the phytoplankton community. To evaluate this, we applied a Phytoplankton Community Index PI(mp) to the 23-year data (1991-2013) at inner (TM4) and outer (TM8) sites in Tolo, with the former being more eutrophic than the latter. The results show that 1) the phytoplankton community changed with time after sewage diversion; 2) "diatoms and dinoflagellates" were better indicators of nutrient impact than "autotrophic/mixotrophic and heterotrophic dinoflagellates"; 3) the rate of recovery differed between the two stations, but both reached a similar state at a similar time; 4) seasonality of the phytoplankton community showed greater disturbance in spring than in other seasons. Our findings indicate that the nutrient reduction in the Tolo resulted in a positive change in the phytoplankton community.

SESSION 7
Environmental indicators of plastic pollution in the North Pacific

S7-P1

Introduction of convergence cluster for human and environmental safety research of (nano)microplastics in Korea

Yunwi Heo and June-Woo **Park**

Korea Institute of Toxicology, Jinju, R Korea. E-mail: jwpark@kitox.re.kr

Microplastics are defined as plastic particles under 5mm in size. Microplastics are classified into two major categories: (1) artificially manufactured primary microplastics and (2) physically or chemically decomposed secondary microplastics. (Nano)Microplastics are universal throughout marine and terrestrial ecosystems. Microplastics are contaminating the air, the water, and the food we eat and can be a risk to human and environmental health. Ingestion of (nano) microplastics by marine organisms has impacts on major physiological functions (growth, behavior and respiration). In ecotoxicology, (Nano) microplastics may also play a role as vectors for toxic substances like persistent organic pollutants (POP) or hydrophobic organic chemicals (HOCs) etc.

With the support of National Research Council of Science and Technology (NST), (nano) microplastic convergence clusters project was launched in 2018 in the purpose of bring together experts from various fields to establish a community of researchers. It consists of three subcommitteesubcommittees: exposure, toxicity, and risk assessment. Experts from each subcommittee exchange ideas and expand research networks through regular meetings. In April, a workshop was held to examine the problems of (nano) microplastics faced by sharing the research trends and results with international experts and to find necessary technical and scientific solutions through expert discussions. Through this project, experts from various fields will gather knowledge and comprehensive research to solve problems of (nano) microplastics and lay the foundation for establishing safety in the environment and humans. Moreover, experts will try to seek required technical and scientific solutions against upcoming threats of (nano) microplastics, which are not yet problems.

S7-P2

Review of microplastic pollutions in captured and cultured seafood in China

Zuhao **Zhu**, Haibo Huang, Qiufeng Zhang and Jie Chen

Fourth Institute of Oceanography, Minstry of Natural Resources, Beihai, Guang'xi, PR China. E-mail: zuhaozhu@qq.com

Microplastic pollution in the oceans has been global concerns for several decades, not only its persisstant property, but also the potential toxicity to the marine organisms and human beings. Seafood has been an important nutrient and engergy source for human beings, now it is suffering the pollution of microplastics. China has the world's leading captured and cultured seafood productions, which are consumed by more than 1/5 world's populations. However, this world class seafood productivity is now facing the threat of microplastic pollution. Several studies have shown that high prevalance of microplastic pollution in captured and cultured bivalves (oysters, mussels, fish, etc.) from different coastal areas of China. More than eight different microplastics with varous compositions were found, the main types were cellophane (CP), polyethylene (PE) and polyethylene terephthalate (PET). The abundances of microplastics in studied seafood ranged from 0.62 to 57.2 items per individual, which positively related to abundances in the growth waters. The fibrous microplastics was being the dominat shape, while more than 50% of the microplastics' size were less than 1.5 mm. Seafood produced near urban areas contained significantly more microplastics than those near undeveloped areas, indicating the nature of anthrupogenic of microplastics. Based on these studies, more intensive research should be conducted to understand the fate, flux and toxicity of microplastic in the coastal areas of China, further more, effective measures should be taken to reduce the comsumption the plastics to deal with the increasingly serious of microplastic pollution in seafood.

S7-P3

Microplastic pollution in the Vancouver urban watershed: The role of Combined Sewer Overflows (CSOs)

Amir H. **Parizi**[1], Ryan Ziels[1], Stephanie Wang[2], Farida Bishay[3], Peter S. Ross[2], and Anna Posacka[2]

1 Department of Civil Engineering, The University of British Columbia, Vancouver, British Columbia, Canada
E-mail: Amirhossein.Parizi@ubc.ca
2 Plastic Lab, Ocean Wise, Vancouver, British Columbia, Canada
3 Metro Vancouver, Vancouver, British Columbia, Canada

Over the past few years, microplastics (MPs) have emerged as a significant global concern, but important questions remain regarding source, transport and fate of these synthetic particles. MPs can be released into the environment through degradation of larger plastic debris, with a variety of pathways in the urban watershed including combined sewer overflows (CSOs) and wastewater treatment plants (WWTPs). We are studying MPs in two phases. First, MPs discharged through selected Vancouver CSOs site are sampled and quantified over a 6-month period, allowing an assessment of seasonal variation. Second, we are investigating the fate of MPs in the Fraser River, the receiving environment for WWTPs and CSOs, as well as non-point sources. Our river sampling plan will capture three sampling events in October, November, and December. Sampling will be done from the CSOs, WWTPs and receiving environments in the river so as to generate a spatial depiction of microplastics in the Fraser River. A variety of microplastic particles were detected in CSO samples, with further efforts underway to identify these using FTIR spectrometry. Our study will shed light on the fate of MPs in the environment and evaluate the role of different sources of MPs into the environment.

S7-P4

Tackling microfiber pollution at source: An evaluation of washing-machine lint filters

Mathew J. **Watkins**[1], Katerina Vasilenko[1], José Gutiérrez-García[2], Farida Bishay[3], Peter Ross[1], and Anna Posacka[1]

1 Ocean Wise, Vancouver, BC, Canada. E-mail: Mathew.Watkins@ocean.org
2 UpGyres, Vancouver, BC, Canada
3 Metro Vancouver, Burnaby, BC, Canada

Microplastics (MPs, particles ranging from a few microns to 5 mm) are an emerging ocean-pollution concern. Locally, the Straight of Georgia is estimated to contain 3,200 MPs per m3, a number several orders of magnitude greater than in the coastal waters of southern California. Up to 95% of total MP particles in the nearshore zone have been shown to be MFs. Laundering textiles has been identified as a potentially important source, raising the prospects of intervention strategies that could reduce domestic inputs into the wastewater stream. We evaluated two lint filters and characterized the effectiveness of different filter pore sizes. Because lint retention may vary depending on fiber type, laundering was done with two different materials—nylon and polyester—washed separately while evaluating the Lint LUV-R© and Filtrol© brands. The polyester lint was more readily retained by both. A large mass of lint released by the tested polyester, and polyester's characteristic high-dimensional stability may have led to increased clumping and therefore increased retention on the surface of the lint filter. Our findings show that filter performance improves with decreased filter pore size; but once a small enough pore size is achieved, a further reduction results in similar retention. While a 200-µm filter is sufficient to retain the retain the majority of polyester fibers (87.1%), using a 100-µm filter may more than double nylon-fiber retention.

SESSION 8
Creating more effective Integrated Ecosystem Assessments (IEAs) in PICES countries

S8-P1

Sea ice reduction in the Arctic Ocean: Its impact on biogeochemical cycles

Naomi **Harada**, Jonaotaro Onodera, Eiji Watanabe and Katsunori Kimoto

Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan. E-mail: haradan@jamstec.go.jp

Sea ice reduction in the Arctic Ocean, which has progressed more rapidly than previously predicted, has the potential to cause multiple environmental stresses, such as warming, acidification, and strengthened stratification of the ocean. Observations and model simulations have both helped to clarify the impact of sea-ice reductions on the dynamics of biogeochemical cycles. Satellite analyses show that the reduction of sea ice has been especially great in the western Arctic Ocean. Thus, we focus on the western Arctic Ocean, which very importantly, has a higher rate of primary production than any other area of the Arctic Ocean owing to the supply of nutrient-rich Pacific water and report the impact of the current reduction of sea ice on marine biogeochemical cycles there, including lower-trophic-level organisms, and identify the key mechanism of changes in the biogeochemical cycles, based on published observations, and model simulations. The retreat of sea ice has enhanced primary production and has increased the frequency of appearance of mesoscale anticyclonic eddies in the coastal area. These eddies enhance the light environment and replenish nutrients, and they also represent a mechanism that can increase the rate of the biological pump in the Arctic Ocean.

S8-P2

Indicator of biocomplexity in assessing the state of environment

Ferdenant A. **Mkrtchyan** and Vladimir F. Krapivin

Fryazino Branch of Kotelnikov Institute of Radioengineering and Electronics, Russian Academy of Sciences, Fryazino, Moscow region, Russia. E-mail: ferd47@mail.ru

Biocomplexity refers to phenomena that result from dynamic interactions between the physical, biological and social components of the *Nature/ Society System* (NSS). The investigations of the processes of interaction between the *Society* and *Biosphere* are, as a rule, targeted at understanding and estimating the consequences of such interactions. The reliability and precision of these estimations depend on criteria founded on conclusions, expertise and recommendations. At present, there is no unified methodology for selection between the set of criteria due to the absence of a common science-based approach to the ecological standardization of anthropogenic impacts on the natural environment. After all, the precision of the ecological expertise for the functioning and planning of anthropogenic systems, as well as the representativeness of the global geoinformation monitoring data, depend on these criteria. We are introducing the scale of biocomplexity ranging from the state where all interactions between the environmental subsystems are broken to the state where they correspond to natural evolution. In this case, we have an integrated indicator of the environmental state including bioavailability, biodiversity and survivability. It reflects the level of all types of interactions among the environmental subsystems. In reality, specific conditions exist where these interactions are changed and transformed. For example, under the biological interaction of the type *consumer/producer* or *competition-for-energy-resources* there exists some minimal level of food concentration where contacts between interacting components cease. In the common case, physical, chemical and other types of interactions in the environment depend upon specific critical parameters. Environmental dynamics is regulated by these parameters and the main task is in the parametrical description of it. Biocomplexity reflects these dynamics.

SESSION 9
Coastal Ocean Observing Systems, Essential Biological Variables, and community-based monitoring

S9-P1

Statistical analysis of seasonal water pollutants affecting phytoplankton proliferation on the South Korean coasts

Young-Sug **Kim**, Tae-Young Heo, and Jung-No Kwon

National Institute of Fisheries Science, Busan, R Korea. E-mail: youngsugkim@korea.kr

An analysis of the water quality of South Korean coastal regions was conducted considering their geographical characteristics and including the major seasonal factors that determine water pollution, using a statistical method. The pollution indices of the South Korean coast generally indicate oligotrophy, but an indices value > 1 may occur during a red tide on west coast of the Korean Peninsula. The components of riverine water quality that affect the coastal water quality include total nitrogen (TN) > chemical oxygen demand (COD) > total phosphorus (TP), in this order of impact ($R2 \geq 0.55$). The primary factors affecting chlorophyll-a (Chl-a) were salinity (S) and pollutant load (COD, TN, and TP) as indicated by the factor analysis method. Temperature was considered a secondary factor. Furthermore, S and TP were indicated as regulatory components in the multiple regression model of Chl-a. The pollution indicators, TN and TP, were significant components of loading in accordance with river discharge, and TP, which was presented as the main component that controlled proliferation of phytoplankton during seasons such as spring and autumn, can be seen to have a great effect as well. Moreover, multiple linear regression results provided the smallest prediction error, and provided effective performance.

S9-P2

Estimation of temperature of seaweed bed vegetation boundary in the Bungo Channel of the Western Seto Inland Sea using satellite SST

Anri **Kabe**[1], Naoki Yoshie[1], Hiromori Shimabukuro[2,] and Goro Yoshida[2]

1 Center for Marine Environmental Studies, Ehime University, Matsuyama, Japan. E-mail: wa12ll27ll@yahoo.co.jp
2 National Research Institute of Fisheries and Environment of Inland Sea, Fisheries Research and Education Agency, Hatsuka-ichi, Hiroshima, Japan

Seaweed bed is algal community in the coastal region, and important for the coastal fisheries. It provides various ecosystem services to human society. However, it has been changing seriously, especially in the species and composition and habitat. Although several studies had reported the changes associated with the warming of sea surface temperature around Japan, they have some problems, such as low spatial-temporal resolution for the coastal region. Moreover, the boundary temperatures of the seaweed vegetation are not clear. In this study, I investigated the boundary temperature of seaweed vegetation in the Bungo Channel by using a satellite sea surface temperature data set which had enough resolution for the coastal region. The Bungo Channel has large gradient of sea surface temperature and various seaweed vegetation. I analyzed the time series of the temperatures of three southern limits of seaweed vegetation (the temperate kelps habitat, the other temperate seaweeds habitat and the transition region between temperate and subtropical seaweeds) both winter and summer. I found that the restrictive temperatures in winter were 14.3, 15.0, 15.6 degree, and also the restrictive temperatures in summer were 25.6, 26.1, 26.7 degree, respectively. The southern limit of temperate kelps moved northward by high water temperature in winter and summer. The southern limit of the other temperate seaweed was affected by the high winter temperature. Invasion of the subtropical seaweed seemed to be related with the disappearance of the temperate seaweed which lived in there.

S9-P3

Sensitivity analysis on zooplankton bioregionalization of British Columbia

Patrick **Pata**[1,2], Ian Perry[3], Brian P. V. Hunt[1,2,4], Moira Galbraith[5], and Kelly Young[5]

1 Institute for the Oceans and Fisheries, University of British Columbia, AERL, 2202 Main Mall, Vancouver, BC, Canada
E-mail: p.pata@oceans.ubc.ca
2 Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, 2020 – 2207 Main Mall, Vancouver, BC, Canada
3 Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, Canada
4 Hakai Institute, P.O. Box 309, Heriot bay, BC, Canada
5 Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada

Zooplankton are central to pelagic ecosystems in transferring energy from primary producers to higher trophic levels. Differences in zooplankton community composition reflect the spatiotemporal variability in environmental conditions and predict the recruitment success and biomass of higher trophic groups. Zooplankton biomass and diversity is an Essential Ocean Variable (EOV) that is continuously being measured by multiple observation programs around British Columbia (BC). The coastal waters of BC are composed of an array of habitat types associated with strong seasonality and inter-annual climate modes. Partitioning the BC coast into biological zones based on zooplankton biomass and diversity allows identifying spatial units bearing distinct ecological characteristics. This study compiled a database of zooplankton abundance and biomass from vertical net tows collected around BC from 1980 to 2016. Cluster analyses were applied on the database to derive emergent zooplankton bioregions. This data-driven approach required testing the robustness of bioregionalization to undersampling, data transformation, and assumptions in clustering algorithms. A sensitivity analysis on the consistency and number of significant clusters was assessed in relation to the choice in (1) temporal averaging, (2) beta diversity index, and (3) clustering method. Future work on understanding the role of other EOVs in driving zooplankton community composition will be discussed.

S9-P4

Coastal Monitoring using Ocean Observation Camera (OOC) on Micro Satellite RISESAT

Sei-Ichi **Saitoh**[1], Takafumi Hirata[1], Irene Alabia[1], Toru Hirawake[1,2], Jun-Ichi Kurihara[3], Yukihiro Takahashi[3], Yuji Sakamoto[4], Toshinori Kuwahara[4], Shinya Fujita[4], Hanyu Kosuke[4], Yu Murata[4], Morokot Sakal[4], Hannah Tomio[4], Yuji Sato[4], Ming-An Lee[5,] Kan-ichiro Mochizuki[6], Fumihiro Takahashi[7], and Hiroshi Murakami[8]

1 Arctic Research Center, Hokkaido University, Sapporo, Japan. E-mail: ssaitoh@arc.hokudai.ac.jp
2 Faculty of Fisheries Sciences, Hokkaido University, Hakodate, Japan
3 Space Mission Center, Hokkaido University, Sapporo, Japan
4 Department of Aerospace Engineering, Tohoku University, Sendai, Japan
5 National Taiwan Ocean University, Keelung, Taiwan
6 Specific Project Promotion Department, Corporate Strategy HQ, PASCO CORPORATION, Tokyo, Japan
7 Green & Life Innovation, Inc., Hakodate, Japan
8 Earth Observation Research Center, JAXA, Tsukuba, Japan

Micro Satellite RISESAT (Rapid International Scientific Experiment Satellite) / Hodoyoshi-2, which is directed by Tohoku University and Hokkaido University of Japan, successfully launched by Epsilon rocket of Japan Aerospace Exploration Agency (JAXA) on January 18 at 8:50 AM, GMT +9, 2019. RISESAT carry 8 scientific instruments with a total mass of 10 kg of total weight of 50 kg. We developed Ocean Observation Camera (OOC) as one of earth observation sensors onboard RISESAT. The OOC is a multi-band WFOV (Wide Field of View) camera system in the VIS range designed for ocean surface observation. The spatial resolution is about 100 m in a swath width of about 65 km. This camera system will sweep the ocean surface in a continuous image acquisition mode. The main target area of OOC will be in the Arctic Ocean and Asia around Japan and Taiwan. The OOC has three wave length of visible, 405nm, 490nm, 555nm, and one near-infrared, 867nm. Visible bands will apply to detect CDOM (Colored Dissolved Organic Matter), chlorophyll-a and sediment materials and near-infrared band will apply to atmospheric correction. After mission check of RISESAT, we started to observe coastal region in the Arctic and sub-arctic seas. We present a preliminary results of coastal monitoring using OOC and discuss on future application.

S9-P5

Developing a community-based coastal environmental monitoring system in Indonesia using smartphone app

Shion **Takemura**[1], MItsutaku Makino[2], Shigeharu Kogushi[3], Naoki Tojo[4] and Mark Wells[5]

1 National Research Institute of Fisheries Science, FRA, Yokohama, Japan. E-mail: shiontakemura@affrc.go.jp
2 AORI, The University of Tokyo, Kashiwa, Japan
3 Greenfront Research Laboratory Co., Ltd., Aichi, Japan
4 Faculty of Fisheries Sciences, Hokkaido University, Hakodate, Japan
5 School of Marine Sciences, University of Maine, Orono, USA

Citizen science is an effective research approach used to understand large-scale patterns of change in the distribution, abundance, and presence of organisms across time and space. There are many successful examples of citizen-based monitoring in developed countries. However, this approach has not been widely applied yet for collecting environmental and fisheries data in developing nations. The objective of this research was to develop a community-based coastal environmental monitoring system using a smartphone app in Indonesia where coastal ecosystems face various challenges due to ecological and social changes. In March 2018, based on discussions with fishers and other community members in several Indonesian villages, the FishGIS Project Science Team (PST), composed of scientists from all PICES member countries, identified five items to monitor in the local marine environment. Then, we created an initial version of a smartphone app and conducted two training workshops in Indonesia (in July 2018 and July 2019) for local fishers, community leaders, as well as for researchers and central and local government officers, on how to use this new technology for coastal monitoring. Finally, we developed an initial version of a data sharing system that provides immediate feedback to the fishers on the results of their monitoring efforts. Working on the smartphone app, we faced various challenges. However, these challenges proved to be an opportunity for the local fishers and government officers, and Indonesian and PICES researchers to learn from each other. For example, while the local fishers and government officers learned the concepts and importance of coastal monitoring from the PST, we learned the realities and needs of the local communities on how to implement the monitoring using smartphone technology. In this presentation, we will discuss effectiveness and difficulties of community-based coastal monitoring in Indonesia.

S9-P6

Preparing for a data intensive integrated oceanographic future

Di **Wan** and Charles Hannah

Institute of Ocean Sciences, Department of Fisheries and Oceans Canada, Victoria, Canada. E-mail: Di.Wan@dfo-mpo.gc.ca

Unprecedented volume of data are becoming available as technology advances. Oceanography is evolving to a data intensive, observatory-based approach. Information flows in near real-time from gliders, Argos, surface drifters, long-term and/or real-time moorings, satellite, and numerical models. This large volume of data and the integration of the physical, biological and chemical oceanography require us to re-examine the suitability and the efficiency of the current technology for the future. An initiative (CIOOS -- Canadian Integrated Ocean Observation System) led by the Department of Fisheries and Oceans Canada to ensure data are accessible from researchers and the general public will be discussed. We will also be talking about how data archiving, processing, and searching are handled at the Institute of Ocean Sciences and what are doing to get ready for a data intensive future.

S9-P7

Larval fish habitats and deoxygenation in the northern limit of the oxygen minimum zone off Mexico

Laura **Sánchez-Velasco**[1], Víctor M. Godínez[2], Erick D. Ruvalcaba-Aroche[1], Amaru Márquez-Artavia[1], Emilio Beier[3], Eric D. Barton[4] and S. Patricia A. Jiménez-Rosenberg[1]

1 Centro Interdisciplinario de Ciencias Marinas-Instituto Politécnico Nacional, Departamento de Plancton y Ecología Marina, Av. Instituto Politécnico Nacional s/n, Col. Playa Palo de Santa Rita. CP, La Paz, 23096, BCS, México. LSV, lsvelasc@gmail.com; EDRA, ruvalcaba.erick@uabc.edu.mx; AMA, tupac.marquez@gmail.com; SPAJR, adelheid1969@yahoo.com

2 CICESE, Departamento de Oceanografía Física, Carretera Ensenada-Tijuana 3918, Zona Playitas, Ensenada, 22860, Baja California, México. VMG, mxcali@cicese.mx

3 CICESE, Unidad La Paz, Miraflores No. 334 e/Mulegé y La Paz, CP, La Paz, 23050, BCS, México. EB, ebeier@cicese.mx

4 Departamento de Oceanografía, Instituto Investigaciones Marinas (CSIC), Eduardo Cabello 6, Vigo, 36208, España. DB, e.d.barton@iim.csic.es

The present state of deoxygenation in the northern limits of the shallow oxygen minimum zone off Mexico is examined in order to detect its effects on larval fish habitats and consider the sensitivity of fish larvae to decreased dissolved oxygen. A series of cruises between 2000 and 2017 indicated a significant vertical expansion of low oxygen waters. The upper limit of suboxic conditions (<4.4 µmol/kg) has risen ~ 100 m at 19.5 ºN off Cabo Corrientes and ~ 50 m at 25 ºN in the mouth of the Gulf of California. The larval habitat distribution was related to the geographic variability of dissolved oxygen and water masses between these two latitudes. One recurrent larval habitat, with Bregmaceros bathymaster larvae as indicator species, extended throughout the water column off Cabo Corrientes from Subtropical Subsurface Water (suboxic conditions) to the surface (220 µmol/kg). The second recurrent habitat was located between the oxycline (> 44 µmol/kg) and the surface in association with the Gulf of California Water, with Benthosema panamense as the indicator species. During the warm "El Niño" event of 2015-2016, a tropical larval fish habitat (Auxis spp.) associated with Tropical Surface Water appeared to change the larval habitat distributions. These results indicate that some species are resilient to changes of dissolved oxygen and temperature generated by "El Niño" events and by continuing deoxygenation, although other species with more limited environmental windows could be affected by the deoxygenation, probably leading in a change of the pelagic ecosystem over time.

Key words: Fish larvae; shallow Oxygen Minimum Zones; Eastern Tropical North Pacific; Deoxygenation.

SESSION 10
Linking changes in climate, nutrient distribution, phytoplankton ecology, and production of algal exudates in the North Pacific

S10-P1

Barrier effect of the Pearl River estuarine plume on wind-induced coastal upwelling of nutrients

Kuo **Wang** and Kedong Yin

Sun Yat-sen University, Guangzhou, PR China. E-mail: yinkd@mail.sysu.edu.cn

Coastal upwelling induced by prevail southwest monsoon occurs along the coast beyond the Pearl River estuary. It is usually thought that nutrient-rich water is brought up from the deep layer and little attention has been paid to whether the source of the upwelled water masses contains nutrients. However, the Pearl River plume may serve as a barrier for wind-induced upward movement of deep water and induce more horizontal advection instead. Here, we presented the in situ investigation to demonstrate a three layer structure in the water column: the nutrient-rich Pearl River estuarine plume in the surface layer, the deep water with low nutrients in the bottom layer and the oligotrophic subsurface water in the middle layer. High Pearl River outflow formed a large buoyant plume with abundant nutrients spreading over the shelf, while deep water with low nutrients is upwelled to the euphotic layer. The estuarine plume entrained the oligotrophic offshore surface water, which has undetectable nutrients and forms a middle layer beneath the plume. This unique structure weakened the intensity of upwelling and entrained the offshore surface water instead. Therefore, less nutrients are brought to the surface due to the barrier effect of the PRE plume than upwelling otherwise produced.

S10-P2

Spatio-temporal variability of surface water *p*CO_2 and nutrients in the tropical Pacific from 1981 to 2015

Sayaka **Yasunaka**[1], Shinya Kouketsu[1], Peter G. Strutton[2], Adrienne J. Sutton[3], Akihiko Murata[1], Shin-ichiro Nakaoka[4] and Yukihiro Nojiri[4]

[1] Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan. E-mail: yasunaka@jamstec.go.jp
[2] University of Tasmania, Hobart, Tasmania, Australia
[3] National Oceanic and Atmospheric Administration, Seattle, Washington, USA
[4] National Institute for Environmental Studies, Tsukuba, Japan

This study presents a synthesis of surface water partial pressure of CO_2 (pCO_2) and nutrient observations in the tropical Pacific (20°S–20°N) from 1981 to 2015 and characterizes the spatio-temporal variability. Using data from the SOCATv5, we developed gridded products of monthly means using a technique to interpolate measured pCO_2 values. The e-folding scale of pCO_2 is estimated to be 6° in latitude, 13° in longitude, and 2 months with a signal-to-noise ratio of 4. Large seasonal variation of pCO_2 appears in the cold tongue region corresponding to the seasonal variation of coastal upwelling, and in the off-equatorial region where the thermodynamic effect on pCO_2 dominates. pCO_2 along the equator declines during El Niño due to weakening of the easterly winds and therefore reduced upwelling of CO_2 rich subsurface water. We also quantified the spatial distribution of the long-term pCO_2 trend beyond the area-averaged trend presented previously. The long-term trend of pCO_2 is positive in all regions with an area average of 1.8 ± 0.1 µatm/yr. However, along the equator the trend is > 2 µatm/yr linked to the Pacific Decadal Oscillation forcing. Using the same methodology, we also analyzed about 20,000 surface nutrient measurements from the GLODAPv2, WOD2013, and VOS sampling by the NIES, Japan. We present the spatial patterns of reduced surface nutrient concentration in the central to eastern tropics along the equator during El Niño periods, but there are not enough data to characterize the trends of nutrients in the tropical Pacific.

S10-P3

Horizontal distribution and dominant species of phytoplankton in the Shengsi Sea Area of East China Sea

Min-Bo **Luo**[1] and Man-Man Liu[1,2]

1 Key Lab of East China Sea and Ocean Fishery Resources Exploitation and Utilization, Ministry of Agriculture, East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai,200090, PR China. E-mail: minbl@163.com
2 College of Marine Sciences, Shanghai Ocean University, Shanghai, 201306, PR China

This article discusses the horizontal distribution and dominant species of phytoplankton in the Shengsi Sea Area of East China Sea. The ecological characteristics of phytoplankton and their adaptability to the environment were also considered. Oceanographic investigation was carried out in the Shengsi Sea Area (30°34'-30°39'N and 121°37'- 122°37'E) in four seasons from 2016 to 2017. It was found that the total abundance showed obvious seasonal variations. It peaked in spring with a mean value of 96.00 × 10^3 cell·m^{-3}, followed by autumn (51.72 × 10^3 cell·m^{-3}). The lowest abundance occurred in winter (20.04 × 10^3 cell·m^{-3}). 4 seasons, the mean density of phytoplankton was 51.50× 10^3 cell·m^{-3}. For the horizontal distribution, abundance in spring, summer and autumn was higher in offshore than in nearshore areas of the Shengsi Sea Area. In winter, abundance in the nearshore was higher than in the offshore. The dominant species of the 4 seasons were Coscinodiscus oculus-iridis and Coscinodiscus jonesianus. Skeletonema costatum was the dominant species in spring, summer and autumn. The average species diversity of the 4 seasons was 1.73.

S10-P4

Long-term trend of the diatom *Thalassiosira nordenskioeldii* population dynamics from the northwestern Sea of Japan

Mariia A. **Shulgina**[1] and Olga G. Shevchenko[1,2]

1 A.V. Zhirmunsky National Scientific Center of Marine Biology, Far Eastern Branch, Russian Academy of Sciences, 690025, Vladivostok, Russia. E-mail: annekee@mail.ru
2 Far Eastern State Technical Fisheries University, 690087, Vladivostok, Russia

Thalassiosira nordenskioeldii is one of the most widely distributed species of planktonic diatoms, forming winter-spring blooms in temperate waters of the World Ocean. We provide data on seasonal and long-term dynamics in abundance of *T. nordenskioeldii*, as well as to discuss specific aspects of the ecology of the diatom from the northwestern Sea of Japan. A long-term study of phytoplankton was conducted from 2005 to 2015. In 2000s *T. nordenskioeldii* was noted to constitute a less significant part of planktonic communities as compared to 1970s and earlier years. From 2005 to 2010, the species comprised a substantial part of the phytoplankton in Amur and Paris Bays – up to 94% and 98% of the total phytoplankton population, respectively. In 2010-2012 the numbers of *T. nordenskioeldii* in Amur Bay were less than 50×10^3 cells/L. Since 2013 the species has not been a dominant one of the bay. In March 2014 the single bloom formed by *T. nordenskioeldii* had occurred in Paris Bay with the species reaching a concentration of 1.5×10^6 cells/L. In 2015 the diatom was absent from the plankton of the bay. For instance, the same trend observed from Narragansett Bay, where since 2014, the species has been completely absent.

S10-P5

Biogenic silica cycle of Planktonic Radiolarian in Western Pacific Ocean

Sonia **Munir**, Jun Sun, and Guicheng Zhang

Research Centre of the Indian Ocean, Tianjin University of Science and Technology, TEDA, Tianjin-300457, PR China
E-mail: soniaku2003@yahoo.com

Silica is one of the important nutrient elements in the biogeochemical cycle of marine ecosystem. This cycle is important for marine primary production. It is used by re-mineralized protozoa such as diatoms and some sponges, radiolarians, and other flagellates. Our study is related to silicon-containing radiolarians in the Western Pacific Ocean. Our results are based on net plankton samples collected during the voyage in the Western Pacific Ocean (120^{o}E- 130^{o}E and 0.6^{o}N-20^{o}N) in October 2016. This study was related to the content of silica in each radiolarian to estimate the production of silica in the euphotic zone of the study area. The SiO_3-Si [μmol/L] ranged from 0.65-4.2 μmol/L in this study area, the highest value > 3.1-4.2 μmol/L recorded at the 10- 5^{o}N degree in NECC area and lowest values < 0.65 μmol/L recorded at the 15-20^{o}N respectively. Compared with the Kuroshio area, the high abundance of radiolaria > 3240 cells m^{-3} and high silica recorded at NECC area. Therefore, NECC current and HE current together promote high nutrients to become a hot spot of silica. The biovolume $μm^3$ and silica content varied from (13 x 10^4 $μm^3$-162379 x $10^4 μm^3$) and (0.17–41.42 μg Si/cell) respectively. The high silica content (41.2 μg Si/cell is in NECC region, mainly due to the small shells <20um, and the high biovolume of the >500um size species were found at 125^{o} degree. There was a significant linear regression between the biovolume and silica content at P>0.004 so it was a powerful tool for silica budgeting in WPO.

S10-P6

Optimizing the PCR clean-up method for 18s amplicons generated from phytoplankton samples collected in Bellingham Bay

Tamisha **Yazzie**, Rachael Mallon, and Rachel Arnold

Northwest Indian College, Bellingham WA, USA. E-mail: tamishayazzie@stu.nwic.edu

Phytoplankton are the building blocks for the marine food web. These ecosystems are dynamic as they vary on multiple time scales and are influenced by many physical parameters. A massive reproduction of phytoplankton (bloom) can be instigated by natural biological processes and have been occurring with greater frequency with an increase in anthropogenic influence. Some blooms are known as harmful algal blooms (HABs), which have deleterious effects on the larger ecosystem and have been more frequent in recent years due to climate change and/or human influence.

HABs greatly affect the marine ecosystem of the Pacific Northwest; Native communities rely on the marine ecosystem and the effects of HABs (closures of shellfish hatcheries, fisheries, and traditional gathering grounds) have a significant impact on Coastal tribes of Washington State. These culturally and ecologically relevant marine food webs are heavily influenced by the dynamic nature of phytoplankton populations, which warrants frequent monitoring. To describe the community structure of phytoplankton in Bellingham Bay, water samples were collected weekly from the surface and a depth of 24m at the Se'lhaem Buoy. The small ribosomal subunit (a marker gene for species, 18S) was amplified using PCR. The primary goal of this study is to compare the effectiveness of PCR clean-up kit (Qiagen) to a bead clean-up (Ampure XP) method. Samples were collected in duplicate to compare the quantity and quality of PCR amplicons following the cleaning process. Optimizing PCR clean-up provides a more efficient protocol for future projects and more accurate sequence reads for downstream analysis.

S10-P7

Transparent exopolymer particle (TEP) production and aggregation by a marine plankton diatom (*Thalassiosira Weissflogll)* at different growth rates

Jie Chen, Haibo Huang, Qiufeng Zhang and Zuhao **Zhu**

Fourth Institute of Oceanography, Beihai, Guangxi, PR China. E-mail: carrie_ocean@sohu.com

Transparent exopolymer particles (TEP) play an important role in the ocean carbon cycle as they are sticky and affect particle aggregation and the biological carbon pump. We investigated the effect of growth rate on TEP production in nitrogen limited semi-continuous cultures of the diatom *Thalassiosira weissflogii*. Steady-state diatom concentrations and other indicators of biomass (chlorophyll *a*, total carbohydrate, particle volume concentration) were inversely related to growth rate. However, individual cell volume increased with growth rate. While there was no change in total TEP area with growth rate, individual TEP were larger at high growth rates and the number of individual particles was lower. SYTOX Green staining showed that < 5 % of the diatom population had permeable cell membranes, with the proportion increasing at low growth rates. However, TEP production rates were greater at high growth rates, indicating that TEP formation was not dependent on dying cells with compromised cell membranes. Measurements of particle size distribution (PSD) in the cultures using laser scattering showed that they were most aggregated at high growth rates. These data indicate that *T. weissflogii* is stickier at fast compared with slow growth rates and that stickiness is associated with a greater rate of TEP production.

S10-P8

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

Takafumi **Hirata**[1] and Koji Suzuki[2]

[1] Arctic Research Center, Hokkaido University, Sapporo, Japan. E-mail: tahi@arc.hokudai.ac.jp
[2] Faculty of Environmental Earth Science, Hokkaido University, Sapporo Japan

We investigated relationships between phytoplankton cell size and primary production in the Japanese waters (including the Kuroshio current), using remote sensing. The cell size and primary production were estimated for three major groups (i.e. diatoms, haptophytes and cyanobacteria). Our estimation showed that the regional averages of the cell sizes of diatoms, haptophytes and cyanobacteria were 20.1, 2.5 and 1.5m, respectively. A log-binormal distribution in the cell size was found over the region for diatoms, clearly separating a sub-arctic ecosystem from a sub-tropical ecosystem. However, a log-normal distribution was found for cyanobacteria across the ecosystems. Estimated primary production of diatoms, haptophytes and cyanobacteria were 134, 72 and 40 mg C m^{-2} day^{-1}, respectively. As a regional average, the primary production tended to increase with the increasing cell size but for diatoms and haptophytes only. If the biomass is proportional to the cell size, the result implies that the primary production of cyanobacteria is driven by a factor(s) other than their biomass, which is consistent with our previous result that the production by cyanobacteria is likely driven by their photophysiology rather than biomass/abundance while that by diatoms is driven by their biomass/abundance.

SESSION 11
Incorporating ecosystem variability and climate change into fisheries management: Progress and challenges for EBFM in the 21st century

S11-P1

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**[1], Brian P. V. Hunt[1,2,3], Chrys Neville[4], Ian Perry[4], Kelly Young[5] and Ian Forster[6]

1 Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada
E-mail: d.costalago@oceans.ubc.ca
2 Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, Canada
3 Hakai Institute, Heriot bay, BC, Canada
4 Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, Canada
5 Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada
6 Centre for Aquaculture and Environmental Research, Fisheries and Oceans Canada, Vancouver, BC, Canada

The causes for the decline in the populations of Pacific salmon and Pacific herring in Canada, which in some cases started in the 1980s-1990s, remain unknown. Fish that grow quickly during critical growth periods survive better because they can escape predators, outcompete competitors, or survive adverse conditions. Thus, food availability for herring and juvenile salmon in the Strait of Georgia (SoG) might determine their survival and their reproductive success. The quality of the food for fish is often defined by the ratio of the essential fatty acids (FAs) docosahexaenoic acid (DHA) to eicosapentaenoic acid (EPA) (DHA/EPA). Some studies on FA composition of zooplankton in the SoG suggest that the nutritional value of prey for juvenile salmon and herring has been consistently suboptimal (i.e. DHA/EPA < 2) in the last two decades. Our results show average DHA/EPA values of between 0.56-1.14 for zooplankton in 2017/18, depending on the season, region and size class, and with significant interspecific differences in large zooplankton. We are creating a FA-based food quality index of zooplankton, and we will apply this index to historic zooplankton community data to determine whether prey quality has changed over time. Should seasonal differences in DHA/EPA be less substantial than interspecific differences, our index will be useful to assess differences in phenology over the time series. Ultimately, we aim to resolve whether changes in prey quality may be a factor in the general decline in Pacific salmon smolt survival in Canada.

S11-P3

Traditional Intertidal Species Regression Study

Mikale **Milne**[1] and Amy Cline[2]

1 Northwest Indian College, Bellingham, Washington, USA. Email: mikalem@students.nwic.edu
2 Western Washington University, Bellingham, Washington, USA

Intertidal beaches have been part of First Nations Peoples' lives since time immemorial. These are food gathering places for chitons, limpets, urchins, clams, and cockles. These species have rich cultural, historical, and sustenance based importance to all peoples that harvest them. First Nations Peoples' from the Aleutian Islands in Alaska to the Coast Salish Peoples in Washington utilize these intertidal species often with the assistance of Indigenous clam gardens. Therefore, a better understanding of these intertidal species may allow for better scientific consensus on a variety of environmental effects such as climate change or pollution, and allows for better Tribal management of traditional species. In order to assist with studies such as these, calculating the biomass of a species remains a critical, yet time consuming, step. Biomass can roughly equate to food availability. The more biomass a species has, the more that it is likely to contribute to its environment as well as be available for sustenance. Therefore, these kinds of studies would benefit from the creation of a biomass regression table, as it will allow for more efficient field study of the sampled species. The purpose of this study is to create said regression equation for the sampled native and traditional food species, which can be utilized in future projects involving these species. The study took place during the summer of 2019 within the Salish Sea region. The results of this study can be used in numerous future projects as it provides a baseline for these sample species.

SESSION 12
Impacts of meso-/submeso-scale processes on heat/material transport and on marine ecosystems

S12-P1

Impact of ocean physics on marine ecosystems in the Kuroshio and Kuroshio Extension regions: A high-resolution coupled physical-biological model study

Yoshikazu **Sasai**[1], Makio C. Honda[1], Eko Siswanto[1], Sami Kato[2], Kazuyuki Uehara[2], Hideharu Sasaki[1,] and Masami Nonaka[1]

1 Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan. E-mail: ysasai@jamstec.go.jp
2 Department of Marine and Earth Science, Tokai University, Japan

A high-resolution coupled physical-biological ocean model is applied to investigate the physical transport of nutrients and the maintenance of biological production in the Kuroshio and Kuroshio Extension (KE) regions. The model captures the Kuroshio nutrient transport over the North Pacific; the seasonal and intraseasonal variability of biogeochemical distributions are associated with mesoscale eddies, fronts, flow filaments, Kuroshio meanders, convection, and upwelling/downwelling. The model also reproduces the observed interannual variability of sea surface height anomaly (SSHA) in the KE region from 2000 to 2012. The distributions of high (low) nitrate and phytoplankton concentrations correspond to negative (positive) SSHA. In terms of nutrient supply, the cyclonic eddies passing through the Kuroshio Extension Observatory station in the subtropical region cause uplifting of nutricline. These events lift nutrient-rich water into the euphotic zone and increase subsurface biological production during summer and fall. One eddy that was tracked from May to July 2004 off the east of Taiwan, contributed to the greatest vertical nutrient flux and enhancement of biological production.

S12-P2 CANCELLED

The role of submesoscale circulations in the population connectivity of deep-sea corals

Annalisa **Bracco**[1], Guangpeng Liu[1], Santiago Herrera[2], and Andrea Quattrini[3]

1 School of Earth and Atmospheric Sciences, Georgia Tech, USA. E-mail: abracco@gatech.edu
2 Department of Biological Sciences, Lehigh University, Bethlehem, PA 18015, USA
3 Department of Biology, Harvey Mudd College, 1250 N. Dartmouth Ave., Claremont, CA, USA

Deepwater corals are found on hard grounds of the continental shelf and slope of all ocean basins, where they enhance the abundance and biodiversity of invertebrates and fishes. Despite their essential role in deep-sea ecosystems, the knowledge of the factors that promote or impede connectivity among coral communities remains limited.

Here, we investigate the connectivity of a deepwater coral, Callogorgia delta, along the upper continental slope of the northern Gulf of Mexico. The circulation in the basin is simulated by a regional ocean model at 1 km horizontal resolution, which allows for the generation and evolution of submesoscale eddies and vorticity filaments, and for a reliable representation of major bathymetric features. Building upon data from four sites spanning about 250 km of distance and 400 m of depth, it is concluded that depth differences on scales of tens to at most few hundreds of meters are sufficient to limit *C. delta* connectivity among sites. This result has important implications in the development of restoration and preservation strategies of deepwater corals in the Gulf of Mexico and elsewhere, given that the formation of submesoscale circulations along continental shelves and slopes is likely a global phenomenon.

S12-P3

Regional differences in the impact of mesoscale eddies on Chlorophyll in the North Pacific

Isao **Fujita**, Ayumi Takeichi, Hiromu Ishiyama, and Hiromichi Ueno

Hokkaido University, Hakodate, Japan. E-mail: isao38@eis.hokudai.ac.jp

Mesoscale eddies, formed in the world ocean, play an important role in transporting not only heat and freshwater but also nutrients and biota. Several mechanisms have been suggested for the mesoscale eddies to influence the near-surface chlorophyll: e.g. stirring by rotational flows of eddies and trapping of nutrients and ecosystems. In this study, we evaluate the ratio of near-surface chlorophyll concentration in the eddy interior to that in the eddy exterior at each 0.25°×0.25°grid in the North Pacific from January 2002 to January 2018, using eddy data set based on satellite altimetry data and satellite chlorophyll data. The ratios were different among regions in the North Pacific. For example, the chlorophyll concentration in the anticyclonic eddies was 1.3 times as large as that outside eddies along the Alaskan Stream, and the value was 0.9 in the area north of Kuroshio Extension. In addition, the ratio was different among bearings. Along the Alaskan Stream, the ratios were 1.1–1.2 in the northern part of anticyclonic eddies while they were 1.3–1.4 in the southern part.

SESSION 13
Implications of prey consumption by marine birds, mammals, and fish in the North Pacific

S13-P1

A marine salmon diet database for the North Pacific

Caroline Graham[1,2], Evgeny A. Pakhomov[1,2] and Brian P.V. **Hunt**[1,2,3]

1 Institute for Oceans and Fisheries, University of British Columbia, 2202 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada E-mail: c.graham@oceans.ubc.ca
2 Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, 2207 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada
3 Hakai Institute, PO Box 25039, Campbell River, British Columbia V9W 0B7, Canada

Although the freshwater phase of the salmon life cycle has been studied in depth, there is much less information available on the marine phase, even though Pacific salmon can spend anywhere from 1 to 7 years of their life in the ocean. With rapidly changing ocean conditions, it is important to understand this phase of the salmon life cycle. One of the most significant factors for the survival of salmon is the presence and abundance of nutritious prey. Although it is difficult to measure prey occurrence across the scale of the Pacific Ocean basin, information on prey presence and abundance can be obtained by studying salmon diets. Diet data can give insight into food webs, niche overlap between species/stocks, health, and changing ocean conditions. Over the past century, there has been sporadic research on salmon diets in the ocean. There is an urgent need to consolidate available data to understand salmon habitat, identify knowledge gaps, and project future changes. We are constructing a database that will include historic diet information for salmon in the North Pacific Ocean, starting with stomach content data, in order to characterize the feeding biology of Pacific salmon. A product of this research will be a comprehensive, open-access database, containing available diet information that can be used as a research tool to address a variety of questions related to salmon marine survival. As changes in salmon abundance become increasingly unpredictable, it is critical to further our understanding of the ocean phase of the salmon life cycle.

S13-P2

Effects of ocean climate on forage fish condition in the Gulf of Alaska

Sarah Ann **Thompson**[1], Marisol García-Reyes[1], William J. Sydeman[1], Mayumi L. Arimitsu[2], Scott A. Hatch[3] and John F. Piatt[4]

1 Farallon Institute, Petaluma, CA, USA. E-mail: sathompson@faralloninstitute.org
2 U.S. Geological Survey, Alaska Science Center, Juneau, AK, USA
3 Institute for Seabird Research and Conservation, Anchorage, AK, USA
4 U.S. Geological Survey, Alaska Science Center, Anchorage, AK, USA

Forage fish are key mid-trophic level species in marine food webs and vital prey for top predators such as seabirds. Climatic drivers of the quality (represented by body condition) of forage fish in the North Pacific are poorly known. We hypothesized that forage fish body condition in the Gulf of Alaska (GoA) varies in relation to ocean temperature, and that interannual variability in forage fish condition relates to seabird productivity. To test these hypotheses, we analyzed morphometric data for capelin (*Mallotus catervarius*) and Pacific sand lance (PSL; *Ammodytes personatus*) sampled by a seabird in two regions of the GoA, and seabird reproductive success, from 1993–2016. We predicted that capelin body condition (Fulton's K) would be negatively related to the PDO and SST, whereas PSL condition would be positively related. Interannual variation in body condition was evaluated relative to seasonal values of ocean climate as well as annual seabird productivity. Forage fish condition varied interannually, between sampling regions, and was dependent on the size/age class of the fish sampled. As predicted, body condition of capelin was negatively related to the PDO and SST. Relationships with ocean climate for PSL varied by size/age class: positive for putative age-0 fish and negative for putative age-1+ fish. We conclude that our hypothesis was supported for capelin and partially supported for PSL. This study demonstrates that ocean climate determines key morphometric characteristics of forage fish that may relate to interannual variation in the energetic value of prey with bottom-up effects on predators.

SESSION 14
Integrating economic and social objectives in marine resource management

S14-P1

Impact and adaptation of coastal fisheries under climate change - A case study of set-net fishery in Taiwan

Ching-Hsien **Ho**

Department of Fisheries Production and Management, National Kaohsiung University of Science and Technology, ROC
E-mail: 20031005@ntou.edu.tw

The influence of climate change cannot be ignored since Taiwan is located in a hot-spot area impacted by climate change. In the future, as climate variability intensifies, the impact of climate change on the overall fisheries will be more far-reaching. When we face an unknown climate disaster, we must have sufficient scientific evidence and foundation to act as the reference, to develop suitable adaptive management measures to mitigate disasters and avoid losses caused by climate change. Hence, the purpose of this research project is to investigate comprehensive impact information of climate change and used TaiCCAT's support system for decision-making (TSSDA) to analysis climate risk on coast fishery in Taiwan. In the study, we select the set net as our target fishery. The set net fishery in Taiwan play important role in their coastal fishery and change of catch is mainly dependent on the natural factor. First, we focused on reviewing the characteristics of the natural environment and set net fishery in Taiwan. Simultaneously, we will conduct the on-site investigation on fishery manager or inspector of how they confronted with the impact of the climate, as well as different fishery managers or inspectors from diverse regional fishing villages and the local adaptive measurement they have taken. Ultimate, with a risk management analysis of Taiwan's fishery managers and local fishing villages adaptive tactics similarities and differences, together with Taiwan's current department insufficient adaptive measurements or tactics, we need to draft and plan for future feasible adaptive options, thereby reducing, averting and to lighten the influence of future intensification of climate change on the marine environment, society and economy.

S14-P2

Bioeconomic analysis of Small yellow croaker in the Republic of Korea

Minje **Choi**, Jaebeum Hong and Dohoon Kim

Pukyong National University, Busan, R Korea. E-mail: delaware310@pknu.ac.kr

Small yellow croaker is one of the most popular commercial species in the Republic of Korea, but the catch amount has been declining since 2011. There is no *direct* policy for restricting the amount of catch such as TAC. This study is aimed to assess the stock biomass of Small yellow croaker using a Bayesian state-space surplus production model in the Republic of Korea. An economic analysis was also additionally conducted for establishing management plans. In the analysis, a generalized linear model (GLM) was conducted for standardizing catch per unit effort (CPUE) data of three different fishing methods (Gill-net, Stow-net, and Pair-net) which took about 87% of the total catch (2013-2017). According to the Bayesian state-space surplus production model, MSY of Small yellow croaker was estimated to be 20,546 tons per year and the biomass has been decreasing after 2011. Especially, it is analyzed that the amount of stock in 2017 was only 59% of the Bmsy. From the bioeconomic analysis, it was analyzed that the amount of annual catch should be over 14,945 tons *at least* for ensuring profits.

SESSION 15
Advances in North Pacific marine ecosystem prediction

S15-P1

Potential predictability of interannual-to-decadal variability in eddy activity in the Kuroshio Extension

Masami **Nonaka**[1], Hideharu Sasaki[1], Bunmei Taguchi[2], and Niklas Schneider[3]

1 JAMSTEC, Yokohama, Japan. E-mail: nona@jamstec.go.jp
2 Univ. of Toyama, Toyama, Japan
3 IPRC, University of Hawaii, Honolulu, HI, USA

Eddies in the Kuroshio Extension have been shown to affect vertical stratifications and distributions of nutrients. It is therefore important to explore variability in the current and associated eddy activity in the region to improve our understanding of oceanic physical fields and ecosystem in the western North Pacific region. While interannual-to-decadal variability in the eddy activity in the Kuroshio Extension could be partly driven by atmospheric variability over the central/eastern North Pacific, it has also intrinsic variability independent from the atmospheric forcing. To separate the wind-driven and intrinsic components of the variability and to estimate potential predictability of eddy activity under realistic conditions, we analyze a ten-member ensemble, of fifty-year integration of an eddy-resolving OGCM driven by time-varying JRA55 reanalysis data. We consider the ensemble mean as the wind-driven, and the spread of ensemble members from their average as the intrinsic components. Focusing on interannual-to-decadal variability by the 13-month running mean, eddy activity in the downstream Kuroshio Extension region (32-38N, 153-165E) shows rather limited ensemble spread and ensemble mean has significant correlation with the observation (correlation coefficient r=0.58). Further the eddy activity has significant correlation with current speed variability that propagates westward from the central North Pacific. With the propagation, current speed variability in the central North Pacific (32-36N, 175-165W) correlates (r=0.59) with the eddy activity in the downstream Kuroshio Extension region four years later.

BIO-PAPER

BIO-P1

Seasonal dynamics of phytoplankton community using microscopic and Chemotax pigment analysis in Seomjin River Estuary, Korea

Minji **Lee** and Seung Ho Baek

Korea Institute of Ocean Science & Technology, Geoje, R Korea. Email: mjlee@kiost.ac.kr

Biotic and abiotic factors in estuaries have dramatic gradients due to the land-derived input and tide-induced exchanges with open seawater. To assess how environmental condition influences the spatio-temporal distribution of phytoplankton, we investigated the phytoplankton communities using microscopic and pigment analysis along a salinity gradient at 7 stations in the Seomjin River estuary, Korea. As a result, although marine planktonic diatoms generally dominated downstream in the high or middle salinity area, the differences in dominant species were associated with salinity gradient, which changed rapidly more than 10. In particular, pigments fucoxanthin and alloxanthin in late spring was high in upstream. In summer, peridinin pigment in downstream and diatoms in upstream was relatively high. In autumn, although cryptomonas were kept to high levels in microscopic analysis, fucoxanthin originated diatoms in the CHEMTAX analysis have contributed, implying that there was coexistent with non-identified small sized phytoplankton. In winter, diatoms groups have greatly occupied in both microscopic and pigment analysis in most stations. Therefore, the spatial distribution of phytoplankton has markedly changed along salinity gradients even though there were differences of seasonal total biomass and community composition of phytoplankton. In particular, the PPCs:PSCs was relatively low during four seasons, implying that there was suitable habitat for diatom owing to the high turbulence area of rapid water movement. In addition, we have a good agreement between microscopy and chemotaxonomy data that pigment analysis may have contributed to assess the complex estuarine phytoplankton community even lead to cell death and ultimately changes the species composition.

BIO-P2

Feeding ecology of chaetognaths in the Yellow Sea and the East Sea inferred from gut content and fatty acid analyses

Hyunjin **Yoon**[1,2] and Se-Jong Ju[2]

1 Department of Marine biology, Pukyong National University, Busan 48513, R Korea
2 Global Ocean Research Center, KIOST, Busan 49111, R Korea. E-mail: sjju@kiost.ac.kr

Chaetognaths are known to be not only an important planktivorous predators but also prey for high trophic level species such as fish larvae. However, even though they comprise high biomass, there are few study about their feeding ecology in the Korean coastal waters (KCW). To identify the diet of the most predominant chaetognath species (*Sagitta nagae, S. crassa* and *S. elegans*), we analyzed the gut content and fatty acids (FAs) of specimens sampled in April and August 2013, December 2015. In the KCW, about 10 ~ 20% of chaetognaths contained foods, which mainly consisted with small copepods in their guts. For FA composition, all species were dominated by 16:0, 18:1(n-9), 20:5(n-3) and 22:6(n-3). Unlike *S. nagae* and *S. crassa*, only *S. elegans* was characterized by significant amounts of 20:1(n-9) and 22:1(n-9), which are biosynthesized by calanoid copepods (i.e. cold water species). Based on the results, chaetognaths are carnivores and mainly feed on the copepod. Also, FA compositions of *S. nagae* between the YS and ES seems to reflect different prey including copepods. These results suggest that FA composition of chaetognaths are influenced by feeding environment rather than their biosynthesis. However, a lot of empty-gut species and gut content analysis could be misrepresented the prey items because different prey types may be digested at different rates. Therefore, it is possible to clearly understand the feeding ecology of chaetognaths in the KCW by using gene analysis for their gut contents and stable isotope analysis.

BIO-P3

Zooming in microbiome dynamics for short and intensive observation (replace) during *Akashiwo sanguinea* (Dinophyta) blooms

JunSu **Kang**[1,2], Hyun-Jung Kim[1], Taek-Kyun Lee[3], and Seung Won Jung[1]

1 Library of Marine Samples, Korea Institute of Ocean Science and Technology, Geoje 53201, R Korea. E-mail: diatoms@kiost.ac.kr
2 Department of Oceanography, Pukyong National University, Busan 48513, R Korea
3 Ecological Risk Research Division, Korea Institute of Ocean Science and Technology, Geoje 53201, R Korea

To understand micro-ecosystem changes during harmful algal blooms (HABs), we examined the variability of micro-environments and microbiome (virus to plankton) through short and intensive investigation during *Akashiwo sanguinea* blooms in Jangmok coastal waters of South Korea by metagenomics. The exudation of extracellular polymeric substances (EPS) by *A. sanguinea* markedly changed bio-geochemical cycles (in particular phosphorus and carbon sources). In *A. sanguinea*-associated bacteria communities, *Rickettsia rhipicephali* and *Polaribacter marinivivus* positively affect the HABs, while *Amylibacter ulvae*, *Mesonia algae*, and *Luminiphilus syltensis* negatively affect the HABs. An endoparasitic *Amoebophrya* sp., may importantly control bloom dynamics, as increase in their abundance lagged the HABs decline. In the dsDNA viruses, Pandoraviridae increased following increases in the HABs peaks, but Phycodnaviridae might not infect *A. sanguinea*. Thus, *A. sanguinea* blooms dramatically change the micro-ecosystem through their efficient autotrophic processes and exudation of EPS, followed by changes in the microbiome involving species-specific viruses, bacteria, and parasitoids

BIO-P4

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**[1], JunSu Kang[1,2], and Seung Won Jung[1]

1 Library of Marine Samples, Korea Institute of Ocean Science and Technology, Geoje 53201, R Korea. E-mail: diatoms@kiost.ac.kr
2 Department of Oceanography, Pukyong National University, Busan 48513, R Korea

To investigate the presence of *Anadara kagoshimensis* and *Tegillarca granosa* in the Boseong coastal waters of South Korea, samples of planktonic bivalve larvae were taken from the coastal waters from June to September 2018(this consisted of monthly sampling in June, July, and September with a three or four days interval sampling in August). The samples were analyzed using metagenomic next-generation sequencing methods (target gene: mitochondria COI region). In this study, a total of 21 bivalve OTUs were detected with the most abundant bivalve OTUs (relative mean abundance > 1%) belonging to *Crassostrea sikamea*, *Xenostrobus atratus*, *Musculista senhousia*, *Crassostrea gigas*, *Sinonovacula constricta*, *A. kagoshimensis*, *Kurtiella aff. Bidentate*, and *T. granosa*. In particular, *A. kagoshimensis* and *T. granosa* (the main fisheries resources on the Boseong coast) accounted for 0.51-12.5%(average 4.00%) and 0.01-12.50%(1.92%), respectively. The planktonic bivalve larvae were most abundant from July to August. *A. kagoshimensis* was most abundant in early August, but rare in the other investigated periods, while *T. granosa* was more abundant in late August. The bivalve larvae monitoring is important to predict the production of bivalve fisheries and intensive monitoring is needed to understand changes in planktonic bivalve larvae because potentially rapid turnover can respond to the ecological interaction of spawning bivalves.

BIO-P5

Description of new vessel hull fouling diatom *Olifantiella* (Naviculales, Bacillariophyceae) from the northwest temperate Pacific region

Joon Sang **Park**[1] and Seung Won **Jung**[2]

[1] Marine Biotechnology Research Center, Korea Institute of Ocean Science and Technology, Busan 49111, R Korea
[2] Library of Marine Samples, Korea Institute of Ocean Science and Technology, Geoje 53201, R Korea. E-mail: diatoms@kiost.ac.kr

Two elusive naviculoid diatoms with stigma-like structures on their valve face were observed on the hull of the R/V Onnuri from the Korea Institute of Ocean Science & Technology (KIOST) in South Korea. Under a scanning electron microscope, the morphological features, namely the buciniportula and the internal marginal chamber, were matched to the genus *Olifantiella*, which was recently described in tropical regions. Of these two Korean *Olifantiella* species, one is new to science and named as *Olifantiella onnuria* sp. nov., which can be distinguished from other *Olifantiella* species by an internally raised bean-like double processes and external T-shaped terminal raphe endings. These morphological features of *O. onnuria* resemble those of the genus *Labellicula*, however, the presence of an internal marginal chamber does not match the genus concept of *Labellicula*. The other Korean *Olifantiella* species is identical to *O. muscatinei* by the occluded macroareola on the valve face. These occurrences of two *Olifantiella* species are the first records from a temperate Pacific region and their presence on a ship's surface indicate that *Olifantiella* spp. may be widely distributed globally despite their periphytic habit.

BIO-P6

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**[1], Kei Sasaki[2], Kodai Yamane[3], Miwa Yatsuya[2], Yuichi Shimizu[3], Yoshitomo Nagakura[2], Tadahide Kurokawa[4], and Hideki Nikaido[2]

[1] Kitasato University, Sagamihara, Japan. E-mail: yyamada@kitasato-u.ac.jp
[2] Tohoku National Fisheries Research Institute, Miyako, Japan
[3] Iwate Fisheries Technology Center, Kamaishi, Japan
[4] Hokkaido National Fisheries Research Institute, Kushiro, Japan

The food availability of chum salmon fry is one of the principal factors affecting survival in their coastal residence period. The aim of this study was to better understand the quality and quantity of available food resources and the feeding habits of salmon fry in nearshore waters. We examined stomach contents of salmon fry and the zooplankton community structure of the water column during salmon fry's coastal residence period (April and May) over four years in Yamada Bay, a coastal embayment of the Pacific Ocean in northern Japan. The mean water temperatures during study period were low in 2014 and 2013 (6.7 and 8.3 °C, respecitively), and high in 2016 and 2015 (11.1 and 9.4 °C, respectively). *Neocalanus plumchrus* and *Themisto japonica*, typical cold-water zooplankton dominated the stomach contents of chum fry (except for 2016), however, they were not necessarily the most dominant in the water column, suggesting that chum fry selectively preyed upon these cold-water zooplankters. On the other hand, chum fry preyed primarily on decapod larvae in 2016 the warmest water year. Condition factor of chum fry were higher in cold-water years than those of warm-water years. Because these two cold-water zooplankton species are typically abundant in the Oyashio Current, the magnitude of Oyashio inflow may affect prey availability for chum salmon fry and their nutritional status. The relationship between the food environment at the coastal residence period of chum fry and the adult return rate after three years was also discussed.

BIO-P7

Population dynamics of marine cladocerans in the offshore area in Suruga Bay, Japan

Akiyuki **Kenmochi**[1], Hiroyuki Matsuura[1], Takashi Yoshikawa[1], Rumi Sohrin[2], Yumiko Obayashi[3] and Jun Nishikawa[1]

1 Tokai University, Shizuoka, Japan. E-mail: 8bkgm007@mail.u-tokai.ac.jp
2 Shizuoka University, Shizuoka, Japan
3 Ehime University, Ehime, Japan

Cladocerans have been reported more than 620 species around the world. While exhibiting high species diversity in freshwater, only 8 species are known in marine environment. In general, marine cladocerans are distributed in shallow coastal areas. However, we observed mass occurrence of cladocerans in offshore area (depth >1000 m) in Suruga Bay, Japan, during the summer 2014. To clarify whether outbrakes of cladocerans in offshore area regularly occur, population dynamics of marine cladocerans in the Bay was investigated. Mesozooplankton samples in the 0–100 m water column were collected at an offshore station once a month from June 2014 to December 2018. Additional samplings were also conducted at coastal areas in 2018. Cladocerans appeared at the offshore station from spring to summer every year, and their maximum abundance reached 193,542 inds. m^{-2}. The maximum abundance was observed in summer, and at that time cladocerans were the most dominant mesozooplankton, exceeding copepods. These results suggested that summer outbreaks of cladocerans at offshore Suruga Bay were periodic phenomenon rather than opportunistic event. Abundances of offshore populations were higher than those in the coastal areas, suggesting that the parthenogenetic reproduction and/or physical accumulation might occur at offshore area. Three species, *Evadne nordmanni*, *Penilia avirostris*, and *Pseudevadne tergestina*, were numerically dominant, and they showed clear seasonal transition: *E. nordmanni* dominated from February to April, while *Pe. avirostris* and/or *Ps. tergestina* dominated June to September. Ecological roles of cladocerans in the offshore food-web will be discussed.

BIO-P8

Basin-shelf connectivity of the zooplankton community in Bering Canyon, Alaska USA

Colleen **Harpold**[1], Carol Ladd[2], Wei Cheng[3], Janet Duffy-Anderson[1], and Phyllis Stabeno[2]

1 NOAA/NMFS Alaska Fisheries Science Center, Seattle, WA 98115, USA. E-mail: colleen.harpold@noaa.gov
2 NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, WA 98115, USA
3 JISAO University of Washington, Seattle, WA, USA

Transport of basin-origin zooplankton onto the Bering Sea shelf contributes to the high productivity characteristic of this region. Basin copepod species tend to be larger and more lipid rich than those originating from nearshore areas. Oceanographic exchange between the basin and the shelf is facilitated through submarine canyons along the Bering Sea slope, providing an advective conduit for zooplankton. Bering Canyon, in the southeast corner of the eastern Bering Sea shelf-break, is thought to be one such conduit. Depth-discrete and whole water column plankton sampling occurred across Bering Canyon and the Unimak Pass region in spring and fall of 2014 and 2015 to better describe zooplankton species composition, vertical distribution, and transport. Cluster analyses showed seasonal (spring vs. fall) as well as annual variation (2014 vs. 2015) between dominant zooplankton species groups. Key copepod species *Neocalanus* spp. (basin-origin) and *Calanus marshallae / glacialis* (shelf) were investigated further, as they are important prey for juvenile Walleye Pollock (*Gadus chalcogrammus*) entering their first winter. Results showed *Neocalanus* spp. had higher percent contributions to the overall zooplankton assemblages in the spring while *Calanus marshallae / glaciali*s had highest contributions in the fall. Spatial distribution of the assemblages coincided with flow patterns and vertical distribution of the most abundant zooplankton species were compared with depths of on-shelf flow. These results suggest Bering Canyon is an important pathway whereby zooplankton are being transported onto the shelf providing important prey for fish, seabirds and marine mammals.

BIO-P9

Plankton production in spring around the Izu Ridge, south of Honshu, Japan

Kiyotaka **Hidaka**[1], Shinji Shimode[2], Takashi Setou[1] and Tadafumi Ichikawa[1]

1 National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency, Yokohama, Kanagawa, Japan
E-mail: khidaka@affrc.go.jp
2 Graduate School of Environment and Information Sciences, Yokohama National University, Kanagawa, Japan

The slope water area south of Japan is an important area for the growth of forage fishes. The Izu Ridge is a prominent topographic feature in the area, affecting the Kuroshio flow-path and plankton productivity. Previous reports on plankton production around the ridge have been based on observation in the summer–early autumn and reports in spring, when forage fish species spawn, are scarce. In the present study, we examined plankton production in spring in the area based on satellite data and zooplankton data in the broad area south of the Japan. The Sea surface chlorophyll concentration (SSChl, MODIS-Aqua) was examined for the grids with depths of >500 m. Zooplankton samples were collected by vertical tow (0–150 m) of the NORPAC net with 0.335 mm mesh in February to March of 1963–2017 and copepod biomass was estimated in the laboratory by Bench-top Video Plankton Recorder. The relationships between plankton biomass and distance to the Honshu coast and to the Izu Ridge were examined. The SSChl declined as distance to the Honshu coast increased. But high SSChl was observed in several areas 150–250 km away to the coast and interpreted as caused by island-mass effect or enhanced production around the oceanic front. The copepod biomass was high around the Honshu coast (<50 km). Stations with high copepod biomass were observed in the 100–200 km north-east (downstream) of the Izu Ridge. They were located near the Honshu and thus cannot be distinguished as caused by island-mass effect.

BIO-P10

Life history and food-habit of a lophogastrid *Gnathophausia longispina* in Suruga Bay, Japan

Jun **Nishikawa**[1], Sohta Yonekubo[1], Takashi Yoshikawa[1], Hiroyuki Matsuura[1], Rumi Sohrin[2], and Yumiko Obayashi[3]

1 Tokai University, Shizuoka, Japan. E-mail: jun_nishikawa@tokai-u.jp
2 Shizuoka University, Shizuoka, Japan
3 Ehime University, Ehime, Japan

Lophogastrids are megazooplanktonic/micronektonic crustaceans living mainly in the meso and bathypelagic layers. Due to their low abundances and the difficulties to access their habitats, relatively little biological information is accumulated, except for a few species. We examined life history of a lophogastrid *Gnathophausia longispina* based on the monthly samplings in Suruga Bay, Japan. Among the 4 species found, *G. longispina* was dominant, comprising >90% of the total catch. Size distributions of this species exhibited bimodal patterns, suggesting two cohorts with different growth stages existed. A cohort with the smallest carapace length (CL) appeared in January/February, and then the CL increased until December. Estimated growth rate of the smaller cohort was 0.018 mm CL d^{-1} which was slightly higher than those reported in previous study. In contrast, the mode of the CL in larger cohort did not change throughout the year. Developmental stage of young (Mauchline 1980) brooded by the female was II until October, but it became II and III in November. Those results suggest that *G. longspina* has basically 2-year life cycle: young is released from brood of its mother in January, it grows to reach the sexual maturity in 11 months, and a matured female lay new young in her brood for a year until it is released in December. However, a large female carried with stage III young was collected in May, indicating some female may survive more than 2 years. Food habit analysis of *G. longispina* using stable isotope ratios will also be presented.

BIO-P11

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**[1], Satoru Suzuki[1] and Koji Hamasaki[2]

[1] Ehime University, Matsuyama, Japan. E-mail: obayashi.yumiko.nn@ehime-u.ac.jp
[2] The University of Tokyo, Kashiwa, Japan

Heterotrophic bacteria are important players of organic matter processing in marine biogeochemical cycles. They utilize dissolved organic molecules, however, intact biopolymeric substances such as proteins are too large for bacterial uptake and should be downsized by extracellular hydrolytic enzymes. Responses of seawater bacterial community with their extracellular enzyme production to dissolved polymeric organic molecules are not fully clarified. To investigate functional diversity of marine bacterial community in organic matter dynamics, incubation experiments testing the responses of bacterial community to addition of protein or free amino acids were conducted in the subtropical (Exp. S1) and subarctic (Exp. K2) North Pacific. In subtropical Exp. S1, addition of protein induced remarkable elevation of all tested extracellular protease (aminopeptidases, trypsin-type and chymotrypsin-type) activities and prokaryotes abundance from Day 2. The increased bacteria were Bacteroidetes on Day 2 and additionally Alphaproteobacteria on Day 5. Whereas, addition of free amino acids led immediate increase of prokaryotes abundance with high dominance of *Vibrio chagasii*, and ecto-aminopeptidase activities were elevated correspondingly with the increase of prokaryotes abundance. These variable responses imply that both inductive extracellular enzymes of polymer degraders and constitutive ecto-enzymes of fast growers contribute to organic matter dynamics in natural fluctuant organic matter conditions in the aquatic ecosystem. Contrastingly, in subarctic Exp. K2, significant changes of bacterial community and enzyme activities were not observed. Low temperature (3°C) seemed to suppress bacterial responses to addition of organic substances. Microbial activity in subarctic seawater might be controlled by temperature more strongly than by organic matter availability.

BIO-P12

Response of the ubiquitous pelagic diatom *Fragilaripsis doliolus* to manganese nodule exposure

Joon Sang **Park** and Kyun-Woo Lee

Marine Biotechnology Research Center, Korea Institute of Ocean Science & Technology, Busan, R Korea
E-mail: kyunu@kiost.ac.kr

Increasing in metal demand and rising in its commodity prices have aroused a shift of exploration and development expenditure to the marine mineral resources from deep seabed. Before starting the mining from deep seabed, the biological impact of tailing disposal of mineral should be evaluated for sustainable development of the marine environment. Diatoms are a good indicator of aquatic quality due to their sensitivity to pollutants. Most of ecotoxicity tests using diatom, however have been conducted to the fresh water or coasts, there was no candidate diatom for ecotoxicity test in the ocean environment. The primary objective of this study was to evaluate the effect of manganese nodule on the pelagic diatom *Fragilariopsis doliolus*. We tested the effects of the particles of manganese nodule and its leachate on the growth of the diatom. All cultures were able to survive in the presence of particle of manganese nodule and its leachate. The growth rate of diatom did not effect in exposure of the leachate, but it was inhibited with increasing of the particle concentration (96h EC_{50}=0.35 g L^{-1}). Although we only based on the growth rate of the diatom, *F. doliolus* may be a suitable organism to assess the effects of toxicity in ocean *in situ* bioassay because the diatom is ubiquity and suitability for use under laboratory conditions. In future works, the other endpoints such as gene expression and deformity of diatom will be provide an additional possibility of ecotoxicity test using *F. doliolus* in the ocean environment.

BIO-P13

Oceanological, hydrochemical and micronecton investigations in the upper epipelagic zone of the northeastern Pacific Ocean in march 2019

Anna S. **Vazhova**[1], Albina N. Kanzeparova[1], Alexey A. Somov[1], Denis S. Kurnosov[1], Svetlana Yu. Orlova[2], Mikhail A. Zuev[1], and Alexey M. Orlov[2]

[1] Pacific branch of Russian Federal Research Institute of Fisheries and Oceanography «VNIRO» («TINRO»), Vladivostok, Russia
E-mail: anna.vazhova@gmail.com

[2] Russian Federal Research Institute of Fisheries and Oceanography «VNIRO» Moscow, Russia

The northeastern Pacific Ocean is of interest because of rarely conducted comprehensive studies. Several stations were performed with oceanological, hydrochemical, and ichthyological studies in the open waters of the northeastern Pacific Ocean (between 143 and 161 W.) in march 2019. Each station was characterized by a different water structure. The salinity in the surface homogeneous layer increased and the thickness of the upper quasi-homogeneous layer decreased westward. The temperature in the upper homogeneous layer at the eastern stations ranged from 9.1 - 9.2°C, and at the western station it was 8.7°C with a subsurface temperature increased up to 10°C. The hydrochemical vertical structure at each station was different. In the western direction, the content of nutrients in the upper layer increased, oxygen supersaturation was observed from the subsurface layer up to 100 m. Each hour trawling was hauled at twilight at three horizons continually (90-60-30-0 meters). In total, 24 species (14 – fishes, 7 – squids, 3 – jellyfishes) were identified in the catches. *Abraliopsis felis* squid dominated in all catches (mean - 57%), number of mesopelagic fishes were abundant as well and consist in common 29% of total biomass. Species composition and ratio (especially among fishes) changed longitudinally. Moving westward, proportion of *Tarletonbeania crenularis*, *Nansenia candida* and *Stenobrachius leucopsarus* consistently decreased, whereas proportion of *Diaphus theta* and *Symbolophorus californiensis* increased. In general, oceanological characteristics in the open part of the Pacific Ocean determine hydrochemical composition of waters and species composition of micronekton and macroplankton, which showed longitudinal changes.

FIS-PAPER SESSION

FIS-P1

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

Pacific branch of VNIRO («TINRO»), 4 Shevchenko Alley, Vladivostok, 690091, Russia
E-mail: mikhail.stepanenko@tinro-center.ru; elena.gritsay@tinro-center.ru

Bering Sea ecosystem has undergene large change due to decadal-scale fluctuations in climate. Large interannual shift to warming had strong effects on plankton community structure and clear effects on the pollock behavior, migrations and spatial distribution in feeding period. Understanding of environmental driven changes in pollock distribution can be used to development of environmental- enchanced strategy of management explore. Seasonal pollock migrations and distributions in the northwestern Bering Sea have high anuual variability depends on bottom temperature and plankton (euphasiids and large copepods) abundance. The climate warms impacts to reduction abundance to large crustacean plankton with high lipid. In 2016-2018 bottom temperature was very high and small copepods with low nutritional value predominated entire Bering Sea. Resilience strategy of pollock behaviour in periods with low trophic level due low abundance of large plankton are big scale, early and fast active northward feeding migrations from winter habits and spawning grounds. Biomass pollock in the northwestern and northern Bering Sea in summer 2017 and 2018 was much higher as previous years. Some part of (as preliminary 0.5-1.0%) older pollock (7-10 years old) migrated northward and distributed through Bering Strait into southern Chukchi Sea based on TINRO summer 2018 bottom trawl survey. Some juvenile pollock was advected from northwesten Bering Sea into southern and central Chukchi Sea by general currents.

FIS-P3

Age and growth of *Ceratoscopelus warmingii* (Myctophidae) in the South China Sea

Yan Wang[1,2,3], Jun Zhang[1,2], Zuozhi **Chen**[1,2], Yane Jiang[1,2], Shannan Xu[1], Yutao Yang[1], Wenming Yu[1]

1 South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Guangzhou, 510300, PR China
E-mail: zzchen2000@163.com
2 Key Laboratory of Open-Sea Fishery Development, Ministry of Agriculture and Rural Affairs, Guangzhou, 510300, PR China
3 Ocean College, Shanghai Fisheries University, Shanghai, 200090, PR China

Age and growth of a dominant species of lanternfish, *Ceratoscopelus warmingii* in the South China Sea was investigated based on the sagittal otolith microstructure. 75 individuals were collected from a midwater trawl in June, 2015. The length-weight relationship for the entire sample of fish was W=0.00000915 $SL^{3.0844}$, which showed positive allometric and no significant difference was found in *SL-W* relationship between sexes. Three regions of the otolith were clearly evident as the larval, post-larval and post-metamorphic zones. Age was estimated using counts by addition of daily growth increments in these three regions. The age of the sampled fish ranged from 78 to 298 days with corresponding standard body length ranged from 27 to 67 mm and body weight ranged from 0.23 to 4.2g. The von Bertalanffy model was fitted as: SL_t=77.4 [1-exp{-0.007 (t–13.3)}] and W_t = 5.62 [1-exp{-0.007 (t–0.002)}]$^{3.0844}$. The maximum rate of growth occurred at age 78 days after metamorphosis and 27 mm *SL* among the age determined samples, and the growth rate decreased with age.

Keywords: *Ceratoscopelus warmingii*, Age and Growth, Otolith microstructure, South China Sea

FIS-P4

Whole body energy density of juvenile Pacific Herring (*Clupea pallasii*) in the Strait of Georgia in the fall of 2012-2018

Hilari **Dennis-Bohm**, Jennifer L. Boldt, Matthew Thompson, Matthew H. Grinnell, and Jaclyn Cleary

Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC., Canada
E-mail: hilari.dennis-bohm@dfo-mpo.gc.ca

Forage fish are key prey species in marine ecosystems and their population abundance is subject to temporal and spatial variability, but these factors are not well understood. In British Columbia, one key forage species is Pacific Herring (*Clupea pallasi*). Herring eggs hatch in spring and larvae and juveniles need to store enough energy before fall to survive their first winter when less food is available. The objectives of this study were to improve the understanding of herring survival and recruitment by examining the size and condition of juveniles prior to their first winter and relating these measures to recruitment. Age-0 herring were collected with a purse seine from 10 transects within the Strait of Georgia (SOG) annually in September/October, from 2012-2018. Whole body energy density was measured and related to length, weight, condition (length-weight residuals), and percent dry weight. Preliminary energy density values varied among years and ranged from 4,861 calories per gram dry weight (cal/g) in 2012 to 5,331 cal/g in 2015. There were significant relationships between energy density and both condition (R^2=0.84, $p<0.01$) and percent dry weight (R^2= 0.17, $p<0.01$). Preliminary results indicate there is a positive relationship between age-0 herring energy density and age-2 recruit abundance (lagged by 2 years). This relationship has the potential to improve estimates of recruit abundance, which can be highly variable and comprise 50% or more of spawning stock biomass. Continued monitoring of age-0 herring could therefore improve stock assessment model projections of spawning stock biomass.

FIS-P5

Impact of a marine heat wave on Pacific salmon habitat

Steve **Lindley** and Nate Mantua

NOAA Fisheries, Santa Cruz, CA, USA. E-mail: Steve.Lindley@noaa.gov

The distribution of Pacific salmon has frequently been described based on sea surface temperatures, and the productivity of Pacific salmon populations is often related to fluctuations of sea surface temperature at regional or basin scales. Recently (2014-2016), the northeast Pacific was struck by an extensive and intense large marine heatwave, with SSTs 2-3 ºC above normal, in an event so notable that "the blob" became a household name. At the time, fisheries scientists and managers feared that this heatwave would have severe negative effects on Pacific salmon, and that it might be a preview of how salmon and salmon fisheries would fare in a warmer future. The linkages between SST and salmon are not simple however, involving not only direct effects of increased temperature on the salmon themselves, but bottom-up effects from changes in stratification and top-down effects from changes in predator distributions. In this paper, we examine how the heat wave affected mixed layer depths, primary production, the distribution of SSTs favorable for the various species of Pacific salmon, and the return rates of select salmon populations that experienced the heat wave to evaluate its impact on salmon and to increase our understanding of how ocean warming might impact salmon populations in the future.

FIS-P6

Early life history of Japanese horse mackerel *Trachurus japonicus* in the north Satsunan area, southern Japan

Kei **Nakaya**[1], Gen Kume[1], Toru Kobari[1], Tsutomu Takeda[1], Hiroumi Kuroda[1], Mutsuo Ichinomiya[2], Tomohiro Komorita[2], Junya Hirai[3], Maki Aita-Noguchi[4] and Fujio Hyodo[5]

1 Aquatic Sciences, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan
E-mail: k583889@kadai.jp
2 Faculty of Environmental and Symbiotic Sciences, Prefectural University of Kumamoto, Kumamoto, Japan
3 Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba, Japan
4 Research and Development Center for Global Change, Japan Agency for Marine-Earth Science and Technology, Kanagawa, Japan
5 Research Core for Interdisciplinary Sciences, Okayama University, Okayama, Japan

We examined the occurrence, growth and feeding habits of larval Japanese horse mackerel *Trachurus japonicus* in the north Satsunan area, southern Japan for five successive years (2015-2019). A total of 1,569 larvae were collected in this study. Larvae abundantly occurred during the winter season and their abundance greatly fluctuated among years. The growth was estimated based on the otoliths using the biological intercept method. The growth rates were generally higher than those in the East China Sea where is the main spawning and nursery ground for the species. In the study area, larval mesopelagic fish are abundantly cooccurring with larvae of *T. japonicus*. We compared their diet with larval mesopelagic species (*Sigmops gracilis*, *Myctophum asperum*) and explored the possibility of competition for prey resources among species groups. Based on the morphological and DNA meta-barcoding analyses for gut contents, main prey species were calanoid copepods for all species. Larvae of *T. japonicus* fed actively on Oithonidae spp. and Oncaeidae spp. as well as calanoid copepods. Meanwhile, appendicularians were substantially found in the guts of larval *S. gracilis* and *M. asperum* as well as calanoid copepods. The stable-isotope analysis showed that $\delta^{13}C$ values of appendicularians were lower than those of copepods. $\delta^{13}C$ values of larval *S. gracilis* and *M. asperum* were also somewhat lower than those of other species. The species-specific diet niche different from dominant mesopelagic species would enable larvae of *T. japonicus* to utilize the prey resources effectively in the study area.

FIS-P7

Seasonal occurrence pattern of leptocephali in the north Satsunan area, southern Japan

Gen Kume[1], Satoru Jinno[1], Toru Kobari[1], Kazuhiro Shiozaki[2], Atsushi Narumi[1], Shuya Ito[1], Kei **Nakaya**[1], Mutsuo Ichinomiya[3] and Tomohiro Komorita[3]

1 Aquatic Sciences, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan
E-mail: k583889@kadai.jp
2 Food and Life Sciences, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan
3 Faculty of Environmental and Symbiotic Sciences, Prefectural University of Kumamoto, Kumamoto, Japan

We examined the seasonal occurrence pattern of leptocephali in the north Satsunan area, southern Japan for four successive years. A total of 458 leptocephali were collected throughout the survey. Each leptocephalus was morphologically identified to the lowest possible level. It was impossible to identify 11 specimens to the family level. Therefore, they were genetically identified by PCR amplification and Sanger sequencing (DNA barcoding) of the mitochondrial 16S rRNA gene using the primer described by Kurogi et al. (2016). Sequences were compared against specie-level records in the Basic Local Alignments Search Tool (BLAST; https://blast.ncbi.nlm.nih.gov/Blast.cgi) for identification. Leptocephali abundantly occurred during the autumn season. Leptocephali were identified to 24 taxonomic groups. The most dominant species were *Gnathophis* spp., *Dysomma* spp. and *Muraenesox* spp. Most of larvae were thought to be dispersed from the East China Sea, where their main spawning grounds exist, to the study area by the Kuroshio Current. *Muraenesox* spp. are composed of *M. cinereus* and *M. bagio*, both of which are important fishery-targetting species. Leptocephali of *Muraenesox* spp. included a substantial number of small individuals (< 10 mm TL), suggesting that their spawning ground would exist adjacent to the study area.

FIS-P8

Potential habitat of skipjack tuna in the western North Pacific using HIMAWARI satellite data

Hiromichi **Igarashi**[1], Hiroshi Ishizaki[1], Masafumi Kamachi[1], Yoichi Ishikawa[1], Fumihiro Takahashi[2], Yoriko Arai[3], Shinichi Sekioka[3] and Sei-Ichi Saitoh[4]

1 Japan Agency for Marine-Earth Science and Technology, 3173-25, Showa-machi, Kanazawa-ku, Yokohama, Kanagawa, Japan
E-mail: higarashi@jamstec.go.jp
2 Green and Life Innovation, Inc., 16-3, Toyokawa-cho, Hakodate, Hokkaido, Japan
3 Remote Sensing Technology Center of Japan, 3-17-1, Toranomon, Minato-ku, Tokyo, Japan
4 Arctic Research Center, Hokkaido University, 3-1-1, Minato-cho, Hakodate, Hokkaido, Japan

An accurate estimate of a potential habitat of fish species enables us not only to understand the response of species to environmental changes but also to utilize it for an efficient use of fish resources. Skipjack tuna (*Katsuwonus pelamis*) is a highly migratory pelagic species inhabiting all tropical and subtropical waters of the world's oceans. It is commercially important, and a significant portion of the catches are from the Pacific Ocean, which has one of the most productive fisheries in the world. We developed the habitat suitability index (HSI) models for this species in the western North Pacific by applying MAXENT by Phillips et al. (2006), and used Japanese commercial fishery dataset including QRY report derived from Miyazaki Prefectural Fisheries Research Institute, and fishing points estimated from AIS fishing vessel position data. And as ocean environments, sea surface temperature (SST) derived from HIMAWARI satellite observation, and FORA-WNP30 ocean reanalysis dataset produced by JAMSTEC and MRI-JMA, which can provide realistic fields of 3-dimensional ocean environments, were used. In this study, we focused on an importance of oceanic fronts for the fishing ground formation, and investigated the HSI response of this species to oceanic front positions occurring in this area. The results show the close relationship between the SST front and the actual fishing location of the vessels, which suggests that oceanic fronts could affect the fishing ground formation in this area.

FIS-P9

Interalnual features of Walleye pollock distribution off the southern Kuril Islands

S. **Ovsyannikova**, E. Ovsyannikov, and A. Sheybak

Pacific Branch of VNIRO ("TINRO"), Vladivostok, Russia. E-mail: svetlana.ovsyannikova@tinro-center.ru

The trawl-acoustic, oceanological and planktonological surveys were carried out off the Pacific side of South Kuril Islands in spring 2017 and 2018. In general, pollock distribution was typical for the spawning period: 20% of pollock was distributed over depths of 175-250 m, 50% - over depths of 250-300 m and about 30% - deeper than 300 m. Pollock distribution difference was observed deeper than 400 m. 25% of pollock numbers were distributed deeper than 400 m in 2017, but almost not observed there in 2018.

Environmental conditions in these adjacent years were compared. Cold waters with low salinity enter to the Pacific Ocean from the Okhotsk Sea through the straits. Okhotsk Sea waters occupied almost the entire survey area in 2017, but their influence significantly reduced in 2018. The Oyashio current formed a coastal stream to the Iturup island shelf and relatively warm and saline waters occupied almost all the survey area in 2018. As a result, the water surface temperature was warmer by 0.1–1.6 °C in 2018. Zooplankton biomass exceeded the average values in 2017 and decreased by 1.5-2 times in 2018. The composition of zooplankton communities has also changed. Thus, water circulation features influenced the habitat conditions of plankton and pollock distribution off the southern Kuril Islands in 2017 and 2018.

FIS-P10

Construction and application of the Chinese Fishery DNA Barcoding System

Zhimeng **Zhuang**[1,2], Shufang **Liu**[1,2], and Jiongtang Li[3]

[1] Yellow Sea Fisheries Research Institute, CAFS, Qingdao, PR China. E-mail: zhuangzm@ysfri.ac.cn
[2] Qingdao National Laboratory for Marine Science and Technology, Qingdao, PR China
[3] Chinese Academy of Fishery Sciences, Beijing, PR China

DNA barcoding systems are efficient tools to standardize the management and sharing of barcode data. The construction of DNA barcode information platform combined with database technology and network technology, on the one hand, can standardize the storage and query of stored sample information and DNA barcode sequence, on the other hand, can provide the bioinformatics tools for species identification and analysis, which is of great significance to promote the research and application of DNA barcodes. On the basis of collecting the voucher specimens and corresponding DNA barcodes of important Chinese fishery species, the project team unified and standardized species and barcode information, established the relationships among species, voucher specimens, and DNA barcodes, and constructed the Chinese Fishery DNA Barcoding System (www.fishery-barcode.cn). This system comprises species, voucher specimen, and sequence databases. It includes the voucher specimen and corresponding DNA barcodes of 6020 fishery species. The platform offers convenient and fast web searches and provides a tool to identify unknown fishery species. This study constructed a DNA barcoding system aimed at Chinese fishery species for the first time, and achieved data sharing and collaboration, and will provide a useful resource for species classification, germplasm resource utilization, protection of endangered species, and aquatic product species identification.

Key words: f ishery species; database; DNA barcoding; species identification

FIS-P11

Spatio-temporal modelling of size distributions with incomplete survey data in a flat fish

Jin **Gao**[1], Noel Cadigan[1], Laura Wheeland[2] and Bob Rogers[2]

[1] Centre for Fisheries Ecosystem Research, Fisheries and Marine Institute of Memorial University of Newfoundland, Canada
E-mail: jin.gao@mi.mun.ca
[2] Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre, Canada

Good management relies on good assessment and good data. Abundance indices are fundamental inputs to stock assessment models. For species with almost no aging data, we rely on length compositions to infer cohort dynamics. Witch founder is an important commercial fish to Canadian fishing industry and Fisheries and Oceans Canada (DFO) has been conducting annual bottom trawl surveys since 1977. However, there are substantial changes in survey coverage due to reasons beyond control. Conventionally, the aggregated abundance indices for each length group is simply the strata area weighted average. In this study, we use a spatio-temporal model to analyze the joint dynamics of size distributions to account for variable survey coverage in 2J3KL witch flounder. By comparing the model estimated abundance indices and the DFO estimates, we find that ignoring the coverage changes produce biased estimates of abundance index especially for the smallest and largest sizes. The model approach also reduces the uncertainty by considering the correlation trends in spatial, spatio-temporal and adjacent length compositions.

FIS-P12

Forecasting chum salmon progenies on the North-East of Kamchatka with the method of juvenile salmon trawl surveying

Ekaterina **Voronova**, Mark Feldman, and Lidia Zavarina

Kamchatka Branch of «VNIRO» ("KamchatNIRO"), Petropavlovsk-Kamchatsky, Russia
E mail: voronova3875kate@mail.ru

This method was included into the system of Pacific salmon run forecasting as instrument for assessment of chum salmon abundance on the North-East of Kamchatka in 2017. The main idea of the method is to obtain correlation based on the pattern between juvenile chum salmon stock at the stage of migration from river estuaries and spawning returns of the migrants, when results allowing to forecast the runs of mature individuals of different ages of maturation in every given year. The logarithmic regression «juvenile escapement – spawning return» was used in the pattern with the confidence interval of 95%, minimizing the error of the forecast.

The abundance of chum salmon generations was evaluated on the results of observation of the Pacific salmon juvenile escapement in the south-west part of the Bering Sea for the period from 1986 to 2015. Results are provided with the pink salmon correction coefficient. The coefficient is required to improve chum salmon juvenile escapement in view of pink salmon return in next year and to reduce the data range and improve the regression. It is impossible to conclude ultimately that the results for chum and pink salmon are same highly authentic. The range, especially in the field of low meanings, is wide, and obtained results can differ several times in view of the wide range between the lower and the upper confidence intervals. Whether underestimation, possible difference in the time of the juvenile chum salmon outmigrance into the open waters or a high mortality of chum salmon after the first winter could explain it to some extent, no doubts that the pattern itself can work like the other prognostic methods applied.

FIS-P13

Reconstructing salmon runs to support sustainable fisheries management

Lingbo **Li**[1], Brittany Jenewein[1], and Pieter Van Will[2]

1 Fisheries and Oceans Canada, Delta, BC, Canada. E-mail: Lingbo.li@dfo-mpo.gc.ca
2 Fisheries and Oceans Canada, Port Hardy, BC, Canada

Sustainable fisheries management is challenging when and where multiple populations of varying productivity are harvested together. To reduce the likelihood of management errors that may cause serious conservation harm to those depleted populations and economic harm to the abundant population fisheries, salmon managers need to understand the expected abundance in each fishery. To fulfill management obligations outlined within the Pacific Salmon Treaty, a Quantitative Population Model (QPM) is being developed to model 10 co-migrating Chum Salmon (*Oncorhyncus keta*) stock groups with a large range of abundance returning to spawning grounds in southern British Columbia and Puget Sound. The model incorporates catch, escapement, and genetic stock identification (GSI) data using R statistical software and AD Model Builder. We applied a Bayesian approach incorporating available data and expert knowledge on arrival timing and run size of each stock group. We determined migration pathways for each stock based on GSI data. Each migration pathway spans from their initial arrival to the study area (top of Vancouver Island) to the terminal area near the spawning grounds. We present preliminary abundance estimates and sensitivity analyses. We will also discuss how model results can inform sustainable management decisions and how the model can be adapted to a variety of fisheries.

FIS-P14

Predicting spatially explicit growth potential and contribution to recruitment for Pacific Ocean perch in the Gulf of Alaska

Christopher N. **Rooper**[1], Jennifer L. Boldt[1], Sonia D. Batten[2], and Peter J. Hulson[3]

[1] Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, British Columbia, Canada E-mail: chris.rooper@dfo-mpo.gc.ca
[2] Sir Alister Hardy Foundation for Ocean Science, Nanaimo, British Columbia, Canada
[3] Alaska Fisheries Science Center, National Marine Fisheries Service, Juneau, Alaska, USA

Pacific Ocean perch (POP, *Sebastes alutus*) are a broadly distributed, abundant and commercially important species in the Gulf of Alaska (GOA). Species distribution models and a series of nursery habitat studies show that juvenile stages inhabit rocky habitats at depths from 85 – 245 m along the continental shelf and consume zooplankton species. We constructed a bioenergetics model for juvenile POP driven by monthly mean temperatures and the duration of the growing season inferred from continuous plankton recorder data. Spatially explicit growth potential was predicted for 1982-2018 and was found to be highest in the eastern GOA (where water temperatures are higher in the summer) and lowest westward of Kodiak. This spatial pattern was consistent across most years, but the temporal pattern was highly variable. The interannual variability is a combination of the interplay between the duration of the zooplankton bloom and water temperature during that bloom. For example, in 2005, there was an extremely short duration for the zooplankton bloom, yet water temperatures in the spring were the highest in the time series. This resulted in about average growth potential for the year. In contrast, 2002 and 2003 had two of the longest durations of the zooplankton bloom and about average water temperatures, which resulted in two years of very high growth potential across the Gulf of Alaska. A stock-recruit model was constructed that incorporated growth potential and growth explained a significant portion of the variability in POP recruitment (about four times the variability explained by spawning stock size alone).

MEQ-PAPER SESSION

MEQ-P1

Monitoring for radiocesium in sea-sediment around off Fukushima

Daisuke **Ambe**[1], Shigeho Kakehi[2], Yuya Shigenobu[1], Toru Udagawa[3], Daisuke Hasegawa[2], and Takami Morita[1]

[1] National Research Institute of Fisheries Science, Kanagawa, Japan. E-mail: ambe@affrc.go.jp
[2] Tohoku National Fisheries Research Institute, Miyagi, Japan
[3] National Research Institute of Fisheries Engineering, Ibaraki, Japan

Associated with the Great East Japan Earthquake (Mw 9.0) in March 2011, a large amount of radionuclides (mainly I-131, Cs-134, Cs-137) were released into the ocean from the Fukushima Daiichi Nuclear Power Plant (FDNPP) of the Tokyo Electric Power Company (TEPCO) of Japan. Fisheries Research and Education Agency (FRA) of Japan has been monitoring the radiocesium concentration in the sea-sediment around off Fukushima since 2012 with five-minutes spatial resolution. It was shown that the horizontal distribution of radiocesium concentration in the sea-sediment was determined during the early period after the FDNPP accident by the radiocesium distribution in bottom-seawater and the cesium adsorption which depends on the particle size of the sediment. The relatively high/low horizontal pattern of concentration has remained thereafter, but the inventory of the radiocesium has been decreased. The average Cs-137 concentration in the surface sediment layer (0-1 cm) in 2018 was less than 25% of that in 2012. This decline rate is much higher than the physical decay of Cs-137 (about 30 years of half-life). One of the main causes of this rapid concentration decrease could be the transport (of the sea-sediment) by the bottom current. Several results based on observation and numerical simulation suggested the southward and offshore transport of the sea-sediment.

MEQ-P2

Monitoring for radiocesium in sea-sediment around off Fukushima

Daisuke **Ambe**[1], Shigeho Kakehi[2], Yuya Shigenobu[1], Toru Udagawa[3], Daisuke Hasegawa[2], and Takami Morita[1]

[1] National Research Institute of Fisheries Science, Kanagawa, Japan. E-mail: ambe@affrc.go.jp
[2] Tohoku National Fisheries Research Institute, Miyagi, Japan
[3] National Research Institute of Fisheries Engineering, Ibaraki, Japan

Associated with the Great East Japan Earthquake (Mw 9.0) in March 2011, a large amount of radionuclides (mainly I-131, Cs-134, Cs-137) were released into the ocean from the Fukushima Daiichi Nuclear Power Plant (FDNPP) of the Tokyo Electric Power Company (TEPCO) of Japan. Fisheries Research and Education Agency (FRA) of Japan has been monitoring the radiocesium concentration in the sea-sediment around off Fukushima since 2012 with five-minutes spatial resolution. It was shown that the horizontal distribution of radiocesium concentration in the sea-sediment was determined during the early period after the FDNPP accident by the radiocesium distribution in bottom-seawater and the cesium adsorption which depends on the particle size of the sediment. The relatively high/low horizontal pattern of concentration has remained thereafter, but the inventory of the radiocesium has been decreased. The average Cs-137 concentration in the surface sediment layer (0-1 cm) in 2018 was less than 25% of that in 2012. This decline rate is much higher than the physical decay of Cs-137 (about 30 years of half-life). One of the main causes of this rapid concentration decrease could be the transport (of the sea-sediment) by the bottom current. Several results based on observation and numerical simulation suggested the southward and offshore transport of the sea-sediment.

POC-PAPER SESSION

POC-P1

Short-term forecasting for Korean coastal sea surface temperature and monitoring its levels based on Machine-Learning algorithms

Seunghwan Lee[1], Yoonsang Cho[1], Yong Huh[2], Gwangnam Han[2], and Donghyeon **Yu**[1]

1 Department of Statistics, Inha University, Incheon, R Korea. E-mail: dyu@inha.ac.kr
2 Oceanographic Forecast Division, Korea Hydrographic and Oceanographic Agency, Busan, R Korea

Sea surface temperature (SST) is one of the main physical characteristics of ocean and plays an important role to model other physical conditions within the ocean. In general, SST is obtained by either direct or indirect observation; a direct observation is the measurement by buoys and ships equipped with measurement instruments, whereas indirect observation is derived from remote sensing by merging measurements from satellites. Although remote sensing can cover whole areas of the ocean, it could contain large measurement errors caused by climate conditions such as clouds or reflected and scattered solar radiation. Especially, observations near the coastal areas by remote sensing usually have large measurement errors. In this study, we focus on short-term forecasting for SST of Korean coastal areas measured at tidal observatories. We developed daily and hourly SST forecasting methods based on the autoregressive error model. The averages of root mean squared errors (RMSE) of one-day and 24-hours predictions using the daily and hourly forecasting models for 13 Korean coastal locations are 0.3038 and 0.3723, respectively. In addition, we develop a monitoring procedure based on the prediction of the SST levels, where for each time point in a year, the SST levels are pre-determined based on the estimated normal SST. We predict the levels of the SST for a targeted time using the ensemble of machine-learning algorithms such as random forest and artificial neural network models.

POC-P2

Prediction of SST fronts using a recurrent neural network (RNN) in the South Sea of Korea

Eun-Joo **Lee**[1], Jeong-Yeob Chae[1], Jae-Hun Park[2], Yong Huh[3], and Kwang-Nam Han[3]

1 Department of Marine Science and Biological Engineering, Inha University, Incheon, R Korea
E-mail: eejlee29@gmail.com
2 Department of Ocean Sciences, Inha University, Incheon, R Korea
3 Korea Hydrographic and Oceanographic Agency, Busan, R Korea

The coasts of South Korea can be classified as east, west and south coasts. Each of them has different coastal shape and topography, which results in various oceanic physical phenomena along them. One of the physical processes representing the difference among the three coastal oceans is the sea surface temperature fronts (SST fronts). In the South Sea of Korea, the main focusing region in this study, the cold southern coastal waters and the Kuroshio-originated warm waters meet to form the fronts there. In addition, when the southwesterly wind prevails in summer, the upwelling fronts appear. SST fronts are known to be closely related to fishery resources especially in the southern coastal sea of Korea, which has spawning grounds and aquafarms for many species, so that the detection and prediction of SST fronts would be beneficial for better monitoring of the marine ecosystem. This study aims to identify the distribution of SST fronts and predict them using a RNN method in the South Sea of Korea. First, we apply a front detection method using line density index (LDI) to the SST daily data from OSTIA in the South Sea of Korea based on Choi et al. (2010). Then, the SST fronts represented by LDI are predicted utilizing the data set from OSTIA, KHOA(Korea Hydrographic and Oceanographic Agency), and HYCOM's data. The performance of the prediction will be presented in the meeting. The outputs from our on-going study are expected to provide benefits for industries of marine leisure as well as fishery.

POC-P3 CANCELLED

Linking North Pacific ventilation changes with surface outcrop variations

Sabine **Mecking** and Kyla Drushka

Applied Physics Laboratory/University of Washington, Seattle, WA, USA. E-mail: mecking@uw.edu

Some of the largest O_2 variations in the world have been observed in the North Pacific thermocline. These variations are strongest on subsurface isopycnals that outcrop into the mixed layer in the northwestern North Pacific, thus likely reflecting surface ocean ventilation and density variability. We examine the water transfer into the thermocline on these isopycnals by combining data from a variety of sources, including satellite, ARGO float, and hydrographic cruise data. A mid-1990's minimum in the outcrop area of base-of-thermocline isopycnals, indicating little to no ventilation, is found to correspond to a maximum in apparent oxygen utilization (minimum in O_2) in the northeastern North Pacific at a ~5 year lag. This supports the hypothesis that surface density variations in the northwestern North Pacific are linked to biogeochemical property variations in the east with a few year offset. In addition, subduction rates and long-term trends will be examined in this paper.

WORKSHOP 2
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

W2-P1

Genetic population structure of Pacific halibut: Progress to date

Lorenz Hauser[1], Daniel Drinan[1], Heather Galindo[1], and Tim **Loher**[2]

1 School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA. E-mail: lhauser@uw.edu
2 International Pacific Halibut Commission, Seattle, WA, USA

Population structure is generally subtle in marine fish species because of their wide distribution, large population sizes and high dispersal potential. These characteristics are especially prominent in Pacific halibut, which is distributed across the north Pacific, supports large commercial fisheries and has pelagic larvae that drift freely for up to three months. Indeed, genetic population structure studies have been challenging. Here, we summarize the state of knowledge on Pacific halibut population genetics.

Traditional microsatellite marker revealed little population structure across the US range of halibut, but revealed three out of 16 microsatellites that were linked to sex. This finding did not only show genetic sex determination, but was also used to develop high throughput sex identification markers that are now used routinely by the International Pacific Halibut Commission. Inclusion of 32 markers linked to expressed genes provided evidence of selective differentiation and led to the discovery of an apparently isolated population in the western Aleutians. Modern sequencing technologies including whole genome resequencing may provide further insights into population structure, and may be especially useful in identifying additional genes under selection. Such genes could be used to further test for spatial differentiation, but may also reveal temporal adaptation to a rapidly changing environment and increased fishing pressure.

W2-P2

Pacific halibut (*Hippoglossus stenolepis*) maturity status explored via histology and macroscopic maturity staging methods

Teresa **Fish**[1,2], Nathan Wolf[1], Bradley P. Harris[1], and Josep V. Planas[2]

1 Fisheries Aquatic Science and Technology (FAST) Laboratory, Alaska Pacific University, Anchorage, AK, USA
E-mail: tfish@alaskapacific.edu
2 International Pacific Halibut Commission (IPHC), Seattle, WA, USA

Accurate reproductive information is foundational to successful fisheries management. Presently, female Pacific halibut (*Hippoglossus stenolepis*) maturity stage assignments are derived from macroscopic assessment of ovaries sampled over a limited 2-3-month period during the fisheries- independent setline survey conducted by IPHC every year. This relatively narrow sampling window may not be adequate to describe the actual potential reproductive contribution of stages occurring over an annual cycle. Further, relative accuracy of macroscopic maturity assessments has yet to be compared to histologically-derived assignments, the highest standard of stage definition. The aims of this study are to

1) examine maturation stages over an annual cycle; 2) define female Pacific halibut maturity stages with histology; 3) compare staging results from histological and macroscopic assessment methods; and 4) update the female Pacific halibut maturity schedule using histology determined maturity status. From September 2017 to August 2018, ovaries from 30 female Pacific halibut (>90cm in length) were staged each month using the standard macroscopic approach and ovarian samples were prepared for histological assessment. Preliminary results include a characterization of Pacific halibut maturity classes throughout the annual cycle and the maiden histological description of Pacific halibut oocyte developmental stages. We expect histology stages will populate a more accurate maturity schedule as well as uncover any mismatches with the macroscopic staging method. The resulting refined gonadal staging process and maturity schedule will enhance our understanding of the species reproductive potential and accordingly allow for better management of the resource.

W2-P3

Genetic sex identification of Pacific halibut (*Hippoglossus stenolepis*) commercial landings

Anna **Simeon**[1], Dan Drinan[2], Lorenz Hauser[2], Timothy Loher[1], Lara Erikson[1], Ian J. Stewart[1] and Josep V. Planas[1]

1 International Pacific Halibut Commission, Seattle, WA, USA. E-mail: anna.simeon@iphc.int
2 University of Washington, School of Aquatic and Fishery Sciences, Seattle, WA, USA

Throughout the fishery's history, the sex ratio of commercially-caught Pacific halibut (*Hippoglossus stenolepis*) has remained unknown as landed individuals are eviscerated at sea and otherwise sexually monomorphic. Historically, the sex ratio from the International Pacific Halibut Commission's (IPHC) fishery independent setline survey (FISS) has been the only direct source of sex-ratio information, but differences in size between individuals landed commercially and on the FISS suggested a greater proportion of females in the fishery. To directly determine the sex ratio of commercial landings, two sex-linked single nucleotide polymorphisms (SNPs) were used to genotype 10,203 aged samples from the 2017 coast-wide commercial landings.

Results indicate that 82% of the commercially-landed stock from that year was female, varying from 65% in IPHC Regulatory Area 4B (Western Aleutian Islands) to 97% in IPHC Regulatory Area 4CDE (eastern Bering Sea). Additionally, 1.5% of samples genotyped indicated an alternate genotype not strictly corresponding to either sex. Monitoring of the commercial sex ratio will continue in order to inform the IPHC's stock assessment and harvest strategy development.

W2-P4

Identification of molecular growth signatures in skeletal muscle of juvenile Pacific halibut (*Hippoglossus stenolepis*) for monitoring growth patterns in wild fish

Josep V. **Planas**[1], Dana Rudy[1], Anna Simeon[1], and Thomas P. Hurst[2]

1 International Pacific Halibut Commission, Seattle, WA, USA. E-mail: josep.planas@iphc.int
2 Alaska Fisheries Science Center, NOAA Fisheries, Newport, OR, USA

The International Pacific Halibut Commission has reported changes in the size-at-age (SAA) of Pacific halibut (*Hippoglossus stenolepis*) for almost 100 years. However, our understanding of the potential causes for the long-term variability in SAA is limited. Although several factors could contribute to this variability, recent analyses have suggested that temperature variation may have been a contributing factor to the observed changes in SAA. Therefore, a better understanding of the physiological effects of temperature on growth in this species is needed. To address this issue, we investigated the effects of temperature-induced growth manipulations on white skeletal muscle in juvenile Pacific halibut. Two groups of juveniles were acclimated for 8 weeks at 2°C and 9°C, after which half of the individuals from the 2ºC group were gradually acclimated to 9ºC and held at that temperature for an additional 6 weeks. Initial acclimation at 2°C resulted in a significant reduction in the specific growth rate (SGR) of juvenile Pacific halibut when compared to fish acclimated only at 9°C. Following the first acclimation period, the group initially acclimated at 2ºC and subsequently acclimated to 9ºC displayed a significant increase in SGR when compared to fish that were constantly held at 9°C, demonstrating compensatory growth. We performed transcriptomic and proteomic analyses of white skeletal muscle collected from these experimental groups to identify growth-related genes and proteins that are regulated by temperature. The resulting molecular signatures of temperature-regulated growth will be useful to investigate potential changes in growth patterns in wild Pacific halibut.

W2-P5

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

International Pacific Halibut Commission, Seattle, WA, USA. E-mail: lauri.sadorus@iphc.int

In 2009, the International Pacific Halibut Commission (IPHC) commenced an annual coastwide environmental monitoring program. At each station surveyed during the IPHC's fishery- independent setline survey, water column profilers are deployed to collect pressure (depth), temperature, conductivity (salinity), dissolved oxygen, pH, and fluorescence. These data are used to monitor the conditions of Pacific halibut habitat in North American waters of the Pacific Ocean and Bering Sea. The data have led to a better understanding of the environmental conditions throughout Pacific halibut habitat, including spatial variability in environmental variables. The monitoring has also given scientists the ability to detect annual anomalies such as seasonal hypoxic zones that can greatly affect local Pacific halibut density. Incorporation of environmental covariates into the IPHC spatio-temporal modelling of density indices allows for the exploration of relationships between Pacific halibut density and environmental variables. As examples, we present results from modelling of data from surveys of the Bering Sea and the west coast of the United States of America.

W2-P6

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

International Pacific Halibut Commission, Seattle, WA, USA. E-mail: dana.rudy@iphc.int

The average size at age for both male and female Pacific halibut has significantly decreased during the last 25 years, particularly in the Gulf of Alaska. This has led to a decrease in the exploitable biomass of halibut stocks. Several factors, including environmental, fisheries-related, and even anthropogenic, could be responsible for the observed decrease in the growth potential of this species. Since the International Pacific Halibut Commission maintains a long-term, coast-wide otolith collection, we aimed to determine if otolith growth corresponds with somatic growth in Pacific halibut. Specifically, we looked at otoliths from the 1977, 1987, 1992, and 2002 cohorts from three different regions of biological significance within the Pacific halibut's range. Despite the significant decline in Pacific halibut size at age in these cohorts, we did not find a similar decline in otolith growth during this time period. For example, in 15-year-old females sampled in the Gulf of Alaska from the 1977 and 1992 cohorts, there was a 2.45% increase in mean otolith radius during that time period, despite a 14.97% decrease in mean body length for those fish. Additionally, we found that otolith accretion in male and female Pacific halibut does not reflect their large dimorphic size differences. Although factors regulating otolith growth in Pacific halibut are not well understood, otolith growth appears to be decoupled from somatic growth.

W2-P7

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

International Pacific Halibut Commission, Seattle, WA, USA. E-mail: joan.forsberg@iphc.int

The International Pacific Halibut Commission (IPHC) has collected otoliths for age determination since 1925. After otoliths are aged, they are stored and archived. The archived otolith collection at IPHC contains samples from over 1.6 million Pacific halibut. Age determination techniques used for Pacific halibut have changed over time; prior to 1992, all otoliths were surface aged. Beginning in 1992, otoliths that met certain criteria (high surface age, difficult pattern, etc.) were also aged by the break-and-burn or break-and-bake method in addition to surface aging. In 2002, the break-and-bake method was adopted as the standard technique for Pacific halibut age determination. To provide information on the bias and imprecision of historical surface ages relative to age data from the 1990s onward, subsets of otoliths from each decade from the 1920s to the 1980s were re-aged by both the surface and break-and-bake technique in 2014 and original surface ages were compared to the ages made in 2014. Results indicated that historical samples contained very few fish aged older than 15 years by either method. Based on simultaneous estimation of bias and imprecision for up to four unique ages per otolith, the properties of historical surface ageing methods were found to be very similar to current methods, becoming increasingly biased and imprecise beyond 15 years.

W2-P8

First records of killer whales *(Orcinus orca)* depredation on Greenland turbot (*Reinhardtius hippoglossoides)* and Pacific halibut (*Hippoglossus stenolepis)* fisheries in Western Bering Sea

O.A. Belonovich, R.N. **Novikov**, and D.A. Terentev

Kamchatka branch of Research Institute of Fisheries and Oceanography "KamchatNIRO", Petropavlovsk- Kamchatsky, Russia
E-mail: aizberg@gmail.com

Killer whales depredation on longline fisheries has been known worldwise. In Bering Sea and north Pacific first depredation cases occurred off Alaska and Hawaii Islands in 1960th. Currently killer whales and sperm whales depredate on longlines in eastern Bering Sea, Alaska, Pribilof Islands. At the same time, there is no information on toothed whales depredation on fisheries in western Bering sea. In 1995 4 vessel working on longline fisheries in western Bering Sea (from Olutorsky Gulf to Navarin cape) had a scientific observes on board. The longlines fished mostly for Greenland turbot and Pacific halibut on a continental slope (220- 450m) from June till October. In June killer whales were observed near the vessels, but did not depredated on its catch. Later in season, in August, killer whales started to take Greenland halibut from the longlines. To avoid depredation, fishing vessels moved from one place to another within the fishing area, but this tactic had limited effect: killer whales started to depredate again in a few days. Only when fishing vessels relocate south (to Karaginsky and Petropavlovsko-Komandorsky subzones), killer whales were not observed depredating anymore. Based on the interview data, killer whales were not observed depredating on bottom net fisheries in the same area in 1997-1999, when they were fishing for different species of halibut and other bycatch species. Sperm whales *(Physeter macrocephalus)* have not been observed depredation on longline fisheries in western Bering Sea.

WORKSHOP 4
Circulation, biogeochemistry, ecosystem, and fisheries of the western North Pacific marginal seas: Past and future of CREAMS (Circulation Research of East Asian Marginal Seas)

W4-P1

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

Kyushu University, Fukuoka, Japan. E-mail: simasaki@agr.kyushu-u.ac.jp

The shellfish culture is an important sector of the fisheries industry for food supply in Japan. In the Kariya Bay, north of Saga prefecture in Japan, shellfish poisoning due to *Alexandrium catenella* has frequently happened in the winter season. Thus, present study investigated the relationship between *A. catenella* bloom dynamics and environmental factors in Kariya Bay from October 2017 onward. The field survey observed *A. catenella* blooms in winter from December to February in 2017 – 2018 and 2018 – 2019. During bloom period, the temperature and salinity were measured at 10.5 – 17.5°C and 33.1 – 34.2 psu in 2017 – 2018 and 13.1 – 16.0°C and 32.9 – 34.3 psu in 2018 – 2019. Our laboratory experiments showed high growth rates (>0.59 divisions/day) of *A. catenella* strain isolated from Kariya Bay at the temperature range of 15 – 30°C and salinity range of 20 – 34 psu. Thus, temperature during the bloom period was thought to be around lower limit for active growth, especially temperature lowered down to 10.5°C at the end of bloom in former season. On the other hand, before bloom formation, nutrient concentrations increased gradually from November to December in both seasons and exceeded the values required for bloom formation (7.3 µM of nitrate nitrogen, 0.32 µM of inorganic phosphorus, Matsuda et al., 1999). Hence, we suggest that *A. catenella* bloom dynamics are mainly affected by the temperature and nutrient concentration in this area. Our study can contribute to the understanding of *A. catenella* growth characteristics to prevent serious economic losses in the Kariya Bay.

WORKSHOP 5
Celebrating two decades of North Pacific CPR sampling, and future directions

W5-P1

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**[1], Sanae Chiba[2], Sonia Batten[3], Yuka Sasaki[4], Hiroya Sugisaki[5], and Atsushi Yamaguchi[1]

1 Hokkaido University, Hakodate, Japan. E-mail: yutaka_fukai0411@eis.hokudai.ac.jp
2 Japan Agency for Marine-Earth Science amd Technology, Yokosuka, Japan
3 Sir Alister Hardy Foundation for Ocean Science, Nanaimo, Canada
4 Suidosha Co. Ltd., Kawasaki, Japan
5 Fisheries Research Agency, Yokohama, Japan

Seasonal abundance, population structure and diel changes in the abundance of five large copepods (*Neocalanus cristatus, Neocalanus flemingeri, Neocalanus plumchrus, Eucalanus bungii, Metridia pacifica*) were evaluated from CPR samples collected from ca. 7 m depth with 10 nautical mile intervals in the western subarctic Pacific (40˚20'–53˚46'N, 143˚53'–174˚02'E) during three seasons: spring (2 April–23 May), summer (5 June–19 July), and autumn (4 September–16 October) of 2001–2015. *N. cristatus* was abundant in summer, dominated by Copepodite V, and had a nocturnal abundance pattern. *N. flemingeri* was greater in spring, composed mainly of CII, and had no diel changes in abundance. *N. plumchrus* was abundant in summer, dominated by CII, and also had no diel changes in abundance. Thus, within the *Neocalanus* copepods, abundance by season varied with species: spring for *N. flemingeri* and summer for *N. cristatus* and *N. plumchrus*. It is known that the surface dwelling period of *N. flemingeri* is earlier than that of *N. plumchrus*. Species-differences in dominant stages may be related with their habitat depths. *E. bungii* was abundant in summer, dominated by CI, and had no diel changes. *M. pacifica* was greater in summer, all copepodite stages (CI–CVI) occurred in that season, and showed nocturnal abundance pattern. Since these two species are surface spawners, their reproduction and growth may be traceable using CPR samples. These species-specific patterns in seasonal abundance, population structure and diel changes in abundance may be a reflection of their ecologies: i.e. life cycle, habitat depth, and presence or absence of diel vertical migration.

WORKSHOP 7
PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment (Third)

W7-P1

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

Rebecca **Schijns**[1] and Daniel Pauly[2]

[1] University of British Columbia, Vancouver, BC, Canada. E-mail: r.schijns@oceans.ubc.ca
[2] University of British Columbia, Vancouver, BC, Canada

Canada's marine fisheries occur in three oceans, designated by Pacific, Arctic, and Atlantic Exclusive Economic Zones (EEZs), where management bodies utilize catch records in order to make decisions regarding the future of their fisheries. However, current catch reporting systems and stock assessment processes are flawed, as records are missing key fishery components and assessments can use time series that do not represent the full scale of change, known as shifting baselines. These shortcomings can directly impact the perception of fisheries and influence future management decisions. This research provides a comprehensive catch record for Canadian fish stocks in surrounding EEZs from 1950-2017 in order to estimate their current status and provide reference points useful for managers to secure future marine resources. Catch reconstructions initially done by the Sea Around Us group are improved and updated to 2017 using methodologies found through the Sea Around Us database. Using reconstructions, a new method called Catch Maximum Sustainable Yield (CMSY) allows reference points to be estimated from catch, resilience, and stock status priors in order to determine the current status of Canadian fisheries. As well, CMSY analysis is used to investigate truncation effects on stock assessments that exhibit shortened time series. Concealing historical trends leads to underestimating sustainable yields and stocks appear to be healthier than those assessed with expanded time series. Overall, this research enhances the scope of catch data and provides an approach to assess data-limited stocks, in order to gain better understanding of Canadian fisheries from a historical and managerial perspective.

W7-P2

Temporal changes of zooplankton community and population structure in the northern Bering Sea from June to September in 2017

Fumihiko Kimura[1], Yutaka **Fukai**[1], Yoshiyuki Abe[2], Kohei Matsuno[1], Russell R. Hopcroft[3] and Atsushi Yamaguchi[1]

[1] Hokkaido University, Hakodate, Japan. E-mail: f.kimura@fish.hokudai.ac.jp
[2] The University of Tokyo, Chiba, Japan.
[3] University of Alaska, Fairbanks, AK, USA

Zooplankton community structure in the northern Bering Sea may change significantly relatively short periods due to the inflow of different water masses and seasonal release of meroplankton, but details of these seasonal temporal changes are still unclear. Thorough this study, we investigated the zooplankton community in the northern Bering Sea from June to September of 2017, and revealed that the temporal changes of zooplankton community structure and population stage structure for its dominant species. Copepods were the dominant taxa, comprising 10–98% of zooplankton abundance, with benthic larvae such as bivalves most dominant at some of the stations during July and August. Cluster analysis of abundances divided the zooplankton community into seven groups, with the distribution pattern having a break-point around 172˚W. West of 172˚W, clear temporal changes were not observed possibly because the Bering Chukchi Winter Water persisted in the deep layer. In contrast, east of 172˚W the community structures differed every month due to inflowing water masses, meroplankton release, and copepod production associated with the phytoplankton bloom. Despite changes of water mass, growth for the dominant large copepods (*Calanus glacialis/marshallae, Eucalanus bungii* and *Metridia pacifica*) were revealed from their population structures. Temporal shifts in species within *Neocalanus* spp. and appendicularians were apparent driven by water mass exchanges. This study demonstrated that zooplankton community in the northern Bering Sea changes greatly every month, thus to evaluate the impact of climate change on zooplankton, it is important to consider both the observational time period and the dominant water masses present.

W7-P3

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[1], Yutaka **Fukai**[1], Yoshiyuki Abe[2], Kohei Matsuno[1], and Atsushi Yamaguchi[1]

[1] Hokkaido University, Hakodate, Japan. E-mail: a-yama@fish.hokudai.ac.jp
[2] Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan

Vertical and horizontal distribution of epipelagic ctenophores and scyphomedusae in the northern Bering Sea was evaluated by quantification underwater video camera during July of 2017 and 2018. Effect of environmental and biological parameters on their distributions was evaluated by Generalized Additive Model (GAM). Through the day and night observation, the dominant ctenophore *Bolinopsis infundibulum* was evaluated as they did not perform diel vertical migration.

B. infundibulum mainly distributed at north and west of St. Lawrence Island (SLI). Their vertical distribution varied with the region. Thus, *B. infundibulum* distributed upper pycnocline in the north of SLI, while they occurred below pycnocline in the west of SLI. As a possible cause of the regional differences in vertical distribution, biological interaction within the gelatinous zooplankton is considered. GAM analysis revealed that there was a negative interaction between

B. infundibulum and large scyphomedusa *Chrysaora melanaster*. Since *C. melanaster* occurred at the upper layer in the west of SLI, *B. infundibulum* may avoid that layer to reduce feeding competition. Standing stock of epipelagic ctenophores and scyphomedusae in 2018 was extremely fewer than that in 2017 with a factor of 1/20 (*C. melanaster*) – 1/90 (*Beroe* sp.). It might be due to year-to-year differences in water mass in this region. Since this drastic decrease of standing stock in 2018 was common for both ctenophores and scyphomedusae, food availability for them is also considered to be poor in this year.

WORKSHOP 8
Synthesis of bioacoustics programs for monitoring zooplankton and fisheries in the North Pacific

W8-P1 (CANCELLED)

Detecting wind-driven transport of planktonic biomass using moored acoustic instruments

Andrew **Majewski**[1], Christie Morrison[1], Jane Eert[2], Maxime Geoffroy[3], Bill Williams[2] and Andrea Niemi[1]

1 Fisheries and Oceans Canada, Winnipeg, MB, Canada. E-mail: andrew.majewski@dfo-mpo.gc.ca
2 Fisheries and Oceans Canada, Sidney, BC, Canada
3 Memorial University of Newfoundland, St John's, NL, Canada

Recent research on the ecological roles of large embayments in the Canadian Beaufort Sea suggests that they provide important spawning and rearing habitats for marine fishes. Net-validated hydroacoustic surveys indicate high relative biomass of ichthyo- and zooplankton forage species within Franklin Bay relative to the larger Amundsen Gulf, suggesting possible entrainment. Oceanographic surface drifters provide evidence that semi-distinct circulation patterns within Franklin Bay are broken down during strong wind events, providing a potential mechanism for transport of biota to the neighboring Canadian Beaufort Shelf and slope. This study aims to assess if mass export of planktonic organisms occurred from Franklin Bay in association with persistent westerly wind events during August and September in 2017 and 2018. Volume backscattering strength (S_v) is assessed from a moored Acoustic Zooplankton and Fish Profiler (AZFPs; 125, 200, 455 kHz) set at 50 m depth near Cape Bathurst at the western gateway of the Canadian Beaufort Shelf, which is downstream of Franklin Bay surface waters during westerly wind events. Mean daily S_v values during wind events, defined as westerly winds ≥15 knots persisting for a minimum of 72 hours, are compared to values during alternate wind conditions. Hourly S_v values are examined during a single pronounced wind event for a higher resolution examination of temporal patterns in relative planktonic density. This study is an initial step in the application of AZFPs to study biological-physical connectivities between Amundsen Gulf and the Canadian Beaufort Shelf and slope.

W8-P2

Acoustic reflection intensity of *Sargassum horneri*

Kenji **Minami**[1], Chihomi Kita[2], Makoto Tomiyasu[2], Hokuto Shirakawa[2], Takashi Kitagawa[3] and Kazushi Miyashita[2]

1 Shimane University, Matsue, Japan. E-mail: kminami@soc.shimane-u.ac.jp
2 Hokkaido University, Hakodate, Japan
3 The University of Tokyo, Otsuchi, Japan

A species of macroalgae, *Sargassum horneri*, with gas-filled vesicles, has recently emerged as a new fishery resource in Japan. However, its acoustic reflection intensity is unknown, rendering acoustic measurement via quantitative echo sounder for biomass estimation of *S. horneri* impossible. We measured the acoustic reflection intensity of *S. horneri* and clarified its characteristics. Measurements were taken using a 120 kHz quantitative echo sounder in an Iwate Prefecture fishing port in June and July 2014. Samples were collected by scuba diving in coastal waters surrounding the port. Each individual sample was suspended at a depth of about 4 m, and the acoustic reflection intensity was measured. Then, we divided *S. horneri* into vesicles and other parts. The vesicles and other parts were exsiccated at 80°C for over 10 hours. Vesicle and algal body dry weights were then measured. Vesicle dry weight increased with increasing algal body dry weight ($p < 0.01$) as did acoustic reflection intensity ($p < 0.01$). Reportedly, over 90 % of the acoustic reflection intensity of fish is the reflection of gas contained in the swim bladder. It was deduced that the contribution of the acoustic reflection intensity of the gas in the vesicles was high, and the intensity increased owing to the increase in vesicle weight accompanying that in algal body weight. Thus, *S. horneri* biomass can be estimated by measuring acoustic reflection intensity.

WORKSHOP 9
Monitoring non-indigenous species in PICES member countries: Towards best practices

W9-P1

Preliminary study on risk assessment of in-water cleaning method to remove the Ship's hull fouling organisms

Bonggil Hyun[1], Pung-Guk Jang[1], Jung-Hoon Kang[2], Min-Chul Jang[1] and Kyoungsoon **Shin**[1]

[1] Ballast Water Research Center, Korea Institute of Ocean Sciences & Technology, Geoje 53201, R Korea
E-mail: ksshin@kiost.ac.kr
[2] Risk Assessment Research Center, Korea Institute of Ocean Sciences & Technology, Geoje 53201, R Korea

The International Maritime Organization (IMO) has recognized the risk of hull fouling and announced '2011 Guidelines for the control and management of ship's biofouling to minimize the transfer of invasive aquatic species' and is planning international regulations to enforce them in the future. In this study, to effectively respond to future international regulation, we introduce the case of leading countries related to management of hull fouling and also investigate environmental risk assessment techniques for in-water cleaning. Australia and New Zealand, the leading countries in hull fouling management, have established hull fouling regulations through biological and chemical risk assessment based on in-water cleaning scenarios. Since in-water cleaning is accompanied by diffusion of alien species and release of chemical substances into aquatic environments, results from biological as well as chemical risk assessment are performed separately, and then evaluation of in-water cleaning permission is judged by combining these two results. Biological risk assessment created 40 codes of in-water cleaning scenarios, and calculated Risk Priority Number (RPN) scores based on key factors that affect intrusion of alien species during in-water cleaning. Chemical risk assessment was performed using the MAMPEC (Marine Antifoulant Model to Predict Environmental Concentrations), to determine PEC and PNEC values based on copper concentration released during in-water cleaning. Finally, if the PEC/PNEC ratio is >1, it means that chemical risk is high. Based on the assumption that the R/V EARDO ship performs in-water cleaning at Busan's Gamcheon Port, biological risk was estimated to be low due to the RPN value was <10,000, but the PEC/PNEC ratio was higher than 1, it was evaluated as impossible for in-water cleaning. We need to find ways to minimize the impact on the marine environment by using risk assessment of various in-water cleaning techniques for removing Ship's hull fouling organisms.

WORKSHOP 10
PICES/ICES collaborative research initiative: Toward regional to global measurements and comparisons of zooplankton production using existing data sets

W10-P1

Trophic sources and feeding impacts of microzooplankton on phytoplankton community in the Kuroshio

Takeru **Kanayama**[1], Toru Kobari[2], Fukutaro Karu[1], Koji Suzuki[3], Naoki Yoshie[4], and Gen Kume[2]

1 Aquatic Sciences, Graduate School of Fisheries, Kagoshima University, Kagoshima, Japan
E-mail: k7147399@kadai.jp
2 Aquatic Sciences, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan
3 Faculty of Environmental Earth Science, Hokkaido University, North 10 West 5 Kita-ku, Sapporo, Hokkaido 060-0810, Japan
4 Center for Marine Environmental Studies, Ehime University, 2-5 Bunkyo-cho, Matsuyama, Ehime 790-8577, Japan

Some foraging fishes spend their vulnerable life stages around the low food availability in the oligotrophic Kuroshio. Although small plankton are likely their energy source, there is limited knowledge on the trophodynamics of plankton food web in the Kuroshio of the East China Sea (ECS-Kuroshio). Here, we demonstrate trophic sources and feeding impacts of microzooplankton on phytoplankton community based on the size-fractionated chlorophyll measurements and UHPLC-CHEMTAX analyses for bottle incubations in the ECS-Kuroshio. Naked ciliates were the most predominant among microzooplankton biomass throughout the study area. Pico- to nanoplankton-sized autotrophs (hereafter pico-autotrophs and nano-autotrophs, respectively) like prochlorophytes, haptophytes and chrysophytes contributed to the total chlorophyll (Chl) *a* (i.e. divinyl Chl *a* plus Chl *a*) concentrations. Microzooplankton grazing rates were higher for nano-autotrophs (0.17-1.45 day^{-1}) compared with those for pico- (0.18-1.23 day^{-1}) and micro- autotrophs (0.06-0.92 day^{-1}). The microzooplankton community consumed 35 to 122% of primary production. The net growth rates in non-diluted bottles without nutrients enrichments were significantly negative for prochlorophytes, chrysophytes and haptophytes. These results suggest that pico- and nano- autotrophs to ciliates is a major trophic pathway in the plankton food web and they can support the trophodynamics to mesozooplankton and fish larvae in the ECS-Kuroshio.

W10-P2

Energy sources and feeding impacts of mesozooplankton community in the Kuroshio

Fukutaro **Karu**[1], Toru Kobari[2], Koji Suzuki[3], Naoki Yoshie[4], Taiga Honma[1], Takeru Kanayama[1] and Gen Kume[2]

1 Aquatic Sciences, Graduate School of Fisheries, Kagoshima University, Kagoshima, Japan. E-mail: k3131095@kadai.jp
2 Aquatic Sciences, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan
3 Faculty of Environmental Earth Science, Hokkaido University, North 10 West 5 Kita-ku, Sapporo, Hokkaido 060-0810, Japan
4 Center for Marine Environmental Studies, Ehime University, 2-5 Bunkyo-cho, Matsuyama, Ehime 790-8577, Japan

Early life stages of foraging fishes spending around the Kuroshio of the East China Sea (ECS-Kuroshio) risk encountering low food availability under the oligotrophic conditions. While mesozooplankton standing stocks and productivity equivalent to the continental shelf have been found in the Kuroshio path, there is limited information on trophic source and links to support the mesozooplankton community and fish larvae. Here, we demonstrate energy sources and feeding impacts of mesozooplankton community by bottle incubation experiments in the ECS-Kuroshio. Throughout the study sites across the continental shelf, Kuroshio path and the outside, pico- to nanoplankton-sized autotrophs (hereafter pico- and nano-autotrophs) contributed to the total chlorophyll (CHL) *a* (i.e. CHL *a* plus divinyl CHL *a*) concentrations, and calanoids and poecilostomatoids composed more than 85% of mesozooplankton biomass. Mesozooplankton ingestion rates showed significantly positive values for nano-autotrophs in the size-fractionated CHL, chrysophytes, dinoflagellates and prochlorophytes in the pigment-based phytoplankton and naked ciliates in microzooplankton. These ingestion rates increased with the mesozooplankton biomass during incubation, suggesting the underestimates of their ingestion rates. If the ambient mesozooplankton biomass is considered, their ingestion rates showed positive values for nano-autotrophs (2.1 μgCHL mgC^{-1} day^{-1}), chrysophytes (2.1 μgCHL mgC^{-1} day^{-1}), prochlorophytes (1.4 μgCHL mgC^{-1} day^{-1}) and naked ciliates (2.0 μgC mgC^{-1} day^{-1}). These results suggest that pico- and nano-autotrophs and ciliates to copepods are likely major trophic links to support mesozooplankton standing stocks and productivity in the ECS-Kuroshio.

W10-P3

Evaluation of protein synthetases activity as a proxy for zooplankton biomass and production rate using cultured copepod population, *Pseudodiaptomus inopinus*

Toru Kobari[1], Yuka Matsuura[1], Akash Sastri[2], Yuichiro Yamada[3], Megu **Iwazono**[1] and Tomonari Kotani[4]

[1] Aquatic Sciences, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan
E-mail: kobari@fish.kagoshima-u.ac.jp
[2] Ocean Networks Canada, University of Victoria, Victoria, BC, Canada
[3] School of Marine Biosciences, Kitasato University, Sagamihara, Kanagawa, Japan
[4] Fisheries Resource Sciences, Faculty of Fisheries, Kagoshima University, Kagoshima, Japan

Zooplankton productivity measurements are still ambitious since the contemporary methods are time-consuming and inapplicable to wide taxonomic groups. While biochemical approaches involve many advantages like simple and quick procedures, wide application to various groups and highly spatial and temporal resolutions. However, comparisons and validations of the biochemical proxies to the estimates with the traditional methodologies are necessary. Here, we demonstrate that aminoacyl-tRNA synthetases (AARS) activity can be a proxy for zooplankton biomass and productivity using the cultured copepod population, *Pseudodiaptmus inopinus*. *P. inopinus* exhibited subsequent development from early to middle naupliar stages and reached maximum biomass and production rate after 3 weeks when the artificial cohort was created. Protein-specific AARS activity was high before the increase of the population biomass and production rate. Total AARS activity accumulated with the population protein contents was high during the phase of high population biomass and production rate. Total AARS activity showed positive correlation to carbon- and protein-based mass and production rate. We propose that protein-specific AARS activity is growth potential and total AARS activity represents biomass and production rate.

WORKSHOP 14

New frontiers: The application of molecular approaches in marine ecology and fisheries science

W14-P1

Seasonal fish assemblage structure based on environmental DNA in the Yangtze Estuary as a primary study

Hui **Zhang** and Weiwei Xian

CAS Key Laboratory of Marine Ecology and Environmental Sciences, Institute of Oceanology, Chinese Academy of Sciences, Qingdao, 266071, PR China. E-mail: zhanghui@qdio.ac.cn
Laboratory of Marine Ecology and Environmental Science, Qingdao National Laboratory for Marine Science and Technology, Qingdao 266071, PR China
Center for Ocean Mega-Science, Chinese Academy of Sciences, 7 Nanhai Road, Qingdao, 266071, PR China

The fisheries resources of the Yangtze Estuary have undergone dramatic declines as a consequence of environmental changes and human activities, with traditional ecological investigations demonstrating progressive decreases in species diversity and annual numbers in the fisheries resource. We chose the Yangtze Estuary as a primary research area to investigate fish assemblages using eDNA technology. A total of 50 eDNA samples were collected in the estuary in 2018. The results showed that 41 operational taxonomic units were identified from three seasons, with 18, 12 and 33 fish species associated specifically with spring, summer and autumn, respectively. The fish assemblage differed significantly among seasons. C*anonical correspondence analysis* showed that water temperature, salinity, and dissolved oxygen were the main environmental factors affecting structure of the seasonal assemblages. Results of the present study indicate that eDNA technology can be an effective tool not only for fisheries monitoring, but might also importantly assist marine resources conservation, sustainable exploitation of fisheries, the aquatic products processing industry, eco-friendly development, and socioeconomic stability.

W14-P2

DNA barcoding: A potential tool for fishery biodiversity conservation

Shufang **Liu**[1,2] and Zhimeng Zhuang[1,2]

1 Yellow Sea Fisheries Research Institute, CAFS, Qingdao, PR China. E-mail: liusf@ysfri.ac.cn
2 Qingdao National Laboratory for Marine Science and Technology, Qingdao, PR China

The Earth's biodiversity are closely altered by a variety of human activities at all scale from local to global. These changes have a strong potential effect to biological communities, ecosystem properties, social affairs and economic development they provide. Fishery biodiversity is an important basis for human development and utilization of fishery biological resources, and a source of maintaining ecosystem stability and guaranteeing high-quality protein supply. Chinese fishery resources are characterized by high biodiversity which cover 10 percent of the total earth species because its role geographical position that occupies the eastern part of the Eurasian continent adjacent to the western Pacific Ocean. In recent years, it is a very realistic and important scientific problem to protect and rationally utilize the biodiversity of fisheries globally. In this paper, we put forward the idea of promoting the protection of fishery biodiversity by carrying out the research of DNA barcode of fishery biology was put forward. It reviewed how DNA barcode expounds the sustainable development in the fishery biological resources, species identification and classification, fishery biodiversity monitoring, foreign species evaluation, market and supervision, fishery information and so on. Besides that, it further discussed the recent prospects for the DNA barcode in the biologic study of fishery organisms, water ecological research, electronic classification technology and the new technology of meta-DNA barcoding. This research had appealed the continuous researches on construction of a fishery DNA barcode database and information platform of China which need to be constructed and shared nationally and globally.

Key words: fishery; biodiversity conservation; DNA barcode

WORKSHOP 16

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

W16-P1

Food habits of Pacific salmon in the North Pacific Ocean in winter 2019

Anton S. Khleborodov, Albina N. **Kanzeparova,** Alexander M. Slabinsky and Alexey A. Somov

Pacific branch of the Russian Federal Research Institute of Fisheries and Oceanography «VNIRO» («TINRO»), Vladivostok, Russia
E-mail: albina.kanzeparova@tinro-center.ru

RV "Professor Kaganovsky" conducted winter salmon survey in January-March 2019 in the Northwestern Pacific Ocean (NWPO), Aleutian waters (AW) and Gulf of Alaska (GoA). Feeding intensity of Pacific salmon species was similar in all studied areas; however, main food components were different. Pink salmon foraged mostly on amphipods; chaetognaths and euphausiids were less important as food items. In the GoA, euphausiids dominated stomach contents, and amphipods, pteropods and small fishes were significant as well. Chum salmon preyed mainly on copepods and amphipods in the NWPO, and on euphausiids and jellyfishes in the GoA. Sockeye salmon preferred copepods, amphipods and euphausiids in NWPO, and euphausiids, amphipods, fishes and squids in the AW and GoA. Sockeye forage intensity was the highest in the GoA. Coho and chinook salmon were caught only in the GoA. Coho showed the highest feeding intensity compared to other salmon species. Pteropods (*Clio pyramidata*) dominated stomach contents; and euphausids and squids were significant as food items as well. Chinook were occasionally captured, and only squids and fishes were found in their stomachs. Diet composition and range in all salmon species were associated with both fish size and dominant planktonic and micronektonic species. The intensity of salmon feeding in winter was lower, but not significantly, compared to summer and fall.

WORKSHOP 17
Scoping an IEA of the Northern Bering-Chukchi Seas LME

W17-P1

Pacific Arctic seabird communities in a time of change

Kathy **Kuletz**[1], Daniel Cushing[2], Erik Osnas[1], Franz Mueter[3], Elizabeth Labunski[1], and Adrian Gall[4]

1 U.S. Fish and Wildlife Service, Anchorage, AK, USA. E-mail: kathy_kuletz@fws.gov
2 Pole Star Ecological Research LLC, Anchorage, AK, USA
3 College of Fisheries and Ocean Sciences, University of Alaska, Juneau, AK, USA
4 ABR, Inc.- Environmental Research & Services, Fairbanks, AK, USA

Rapid changes are altering the Northern Bering-Chukchi Sea ecosystem, affecting upper trophic levels such as seabirds. Here, we summarize recent findings on Pacific Arctic seabirds derived primarily from at-sea visual surveys totaling 144,920 km of transects from 2007–2018. We compared seabird species richness, community composition, and abundance among sites and over time. Species richness (total = 59 species), as with abundance, was highest in the northern Bering Sea and peaked near Bering Strait, thus making this Arctic gateway a potentially high-risk area for seabirds as human activity increases. We identified six seabird community clusters, which were roughly associated with water mass systems (e.g., Alaska Coastal Current, Anadyr Current) or oceanographic domains, with some influence from locations of breeding colonies. Planktivorous auklets numerically dominate the region, but in the Chukchi Sea, only piscivorous species nest at colonies. For a subset of data in the Chukchi Sea, cross-community Mantel correlations suggest associations between planktivorous seabirds and zooplankton, but not between piscivorous seabirds and fishes, perhaps due to the influence of colony location for some birds. For most taxa, persistent habitat (or site) features appeared to be more influential than annual fluctuations in prey or environmental conditions; exceptions were late summer migrants not tied to colonies. However, in 2017 and 2018, with warm seas and changes in prey, several locally breeding seabird species had unusually low abundance. An assessment for risk will thus need to incorporate the different life histories, and patterns of distribution, diet, and foraging behavior among seabird taxa.

W17-P2

Applying NPRB Arctic IERP (2016-2019) research to inform an IEA in the Northern Bering Sea and Chukchi Sea

Matthew **Baker**[1], Danielle Dickson[1], Edward Farley[2], Seth Danielson[3], Carol Ladd[4], Kate Stafford[5], and Henry Huntington[6]

1 North Pacific Research Board, 1007 West Third Avenue, Anchorage, AK, USA. E-mail: Matthew.Baker@nprb.org
2 NOAA Auke Bay Laboratories, Alaska Fisheries Science Center, Juneau, AK (USA)
3 Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK, USA
4 NOAA, Pacific Marine Environmental Laboratory, Seattle, WA, USA
5 Applied Physics Laboratory, University of Washington, Seattle, WA, USA
6 Huntington Consulting, Eagle River, AK, USA

The North Pacific Research Board (NPRB) launched an Arctic Integrated Ecosystem Research Program (IERP) in partnership with BOEM, ONR and the Collaborative Alaskan Arctic Studies Program. The program examines how reductions in sea ice and the associated changes influence the flow of energy in the northern Bering Sea and Chukchi Sea. Research cruises were conducted 2017-2019. Research in the Bering Strait measured rates of growth, advection, respiration, and deposition of plankton at ice retreat. Research in the Chukchi shelf surveyed summer/fall conditions surveys with a focus on factors driving the abundance and distribution of fish—particularly Pacific and Arctic cod, walleye pollock, and salmon. Data was also collected from bio/physical moorings. A social science study integrates Local and Traditional Knowledge and examines the relative influence of environmental and socio-economic factors on food security. NPRB is coordinating with several national and international projects and new collaborations are welcome. Collaboration has been initiated with Hokkaido University, JAMSTEC, TINRO, and VNIRO. NPRB is also collaborating with the Nansen Legacy Program in Norway to compare processes in the Barents Sea and is interested in discussing additional opportunities for international collaboration. A synthesis is planned in 2022 to use existing data to improve understanding of ecosystem processes and explore local/regional results in the context of Arctic-scale change. This presentation will summarize findings and results of recent surveys and associated research activities in the Northern Bering-Chukchi Seas LME. The intent is to solicit new ideas and inform discussions on the development of an integrated Ecosystem Assessment.

W17-P3

Sensitivity of Alaska marine food webs to mortality-based perturbations

George A. **Whitehouse**[1] and Kerim Aydin[2]

1 University of Washington, Seattle, WA, USA. E-mail: gaw@uw.edu
2 NOAA Alaska Fisheries Science Center, Seattle, WA, USA

Ecosystem modelling is a useful tool for exploring the potential outcomes of policy options and conducting experiments that would otherwise be impractical in the real world. In this study we evaluate the sensitivity of the food webs in the eastern Chukchi Sea, eastern Bering Sea, and Gulf of Alaska to mortality-based perturbations and examine the response time of the food webs. We use a Monte Carlo approach to generate thousands of plausible ecosystems by drawing parameter sets from the range of uncertainty around the base model parameters. We subject the ensembles of ecosystems to a series of mortality based perturbations to identify which functional groups the food webs are most sensitive to, whether the food webs returned to their original configurations following a perturbation, and how long it took to return to that state. In all three study regions the number of disrupted ensemble food webs was positively related to the biomass and number of trophic links of the perturbed functional group, and negatively related to trophic level. The eastern Chukchi Sea was most sensitive to perturbations of benthic invertebrate groups, which are also important prey for marine mammals and seabirds. The eastern Bering Sea was most sensitive to shrimp and walleye pollock, and the Gulf of Alaska to shrimps, pelagic forage fish, and zooplankton. Response times were generally less than five years in all three ecosystems. The eastern Chukchi Sea had the slowest mean response time across all disrupted food webs.

W17-P4

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

ASL Environmental Sciences, Inc. Victoria, British Columbia, Canada. E-mail: masplin@aslenv.com

Seasonal sea ice freeze-up in the Bering Sea has been delayed into January – February since 2014, and essentially absent in 2018 and 2019. The warming trend in the Bering Sea has had trickle-down effects on ocean ecosystems ranging from the surface to the benthos, evidenced by shifting geographical ranges of Bivalves on the seafloor, a critical food source for walruses and seals. Populations of large, nourishing copepods are in decline, which in turn, has a negative impact on young fish that rely on them as a winter food source. These trends have been linked to increased winter storminess, strong southerly advection, and warmer water driven by atmospheric forcing and ocean heat anomalies.

Migratory atmospheric circulation patterns drive important dynamic and thermodynamic processes in sea ice through temperature advection, precipitation, wind-forcing, and ocean swells. Synoptic typing and compositing is a common technique used to identify a limited number of prevailing weather types that govern a region's climate (i.e. synoptic climatology). This study employs a previous synoptic climatology developed using principle components analysis and k-means clustering for the Beaufort, Chukchi and Bering Seas using NCEP-NCAR Reanalysis II gridded data. Trends in sea ice decline and subsequent impacts on ocean ecosystems are investigated using datasets from oceanographic moorings deployed at sites in the Chukchi Sea for 2010 – 2016. Trends in sea ice motion, thickness, ocean temperature and currents are compared with variability within the synoptic climatology. The observations of anomalous freeze-up in 2018 and 2019 are then discussed in the context of our results.

WORKSHOP 18
GlobalHAB: Evaluating, reducing and mitigating the cost of harmful algal blooms: A compendium of case studies

W18-P1

Dynamics of *Amoebophrya* parasites during recurrent blooms of the ichthyotoxic dinoflagellate *Cochlodinium polykrikoides* in Korean coastal waters

Bum Soo **Park**[1,2], Sunju Kim[3], Joo-Hwan Kim[1], Jin Ho Kim[1] and Myung-Soo Han[1,4]

1 Department of Life Science, Hanyang University, Seoul 04763, R Korea. E-mail: parkbs@kiost.ac.kr
2 Marine Ecosystem Research Center, Korea Institute of Ocean Science and Technology, Busan, 49111, R Korea
3 Department of Oceanography, Pukyong National University, Busan 48513, R Korea
4 Research Institute for Natural Sciences, Hanyang University, Seoul 04763, R Korea

During blooms of the harmful dinoflagellate *Cochlodinium polykrikoides* in August and October, 2012, infections by two different *Amoebophrya* species were observed in Korean coastal waters. To investigate the dynamics of the two parasites and their relative impact on the host populations, a quantitative real-time PCR (qPCR) method was applied to detect and quantify the parasites in the free-living and parasitic stages. Each specific primer set of the target species, *Amoebophrya* sp. 1 and sp. 2 was designed on the large subunit (LSU) and the first internal transcribed spacer (ITS1) of ribosomal RNA (rRNA) gene, respectively. Dynamics of the two *Amoebophrya* species via qPCR assay showed distinct patterns during blooms of *C. polykrikoides* in 2012. *Amoebophrya* sp. 1 showed peaks during both bloom events in August and October with relatively low copies (10^6−10^7 copies L^{-1}), while *Amoebophrya* sp. 2 appeared only during the bloom event in October with very high copies (10^9−10^{10} copies L^{-1}). Overall, the qPCR measurements for the dynamics of two *Amoebophrya* species in the parasitic stage were consistent with parasite prevalence through microscopic observations. *Amoebophrya* sp. 1 infections were observed during both bloom events in August and October with relatively low parasite prevalence (0.1−1.5%), while *Amoebophrya* sp. 2 infections were detected only during the bloom event in October with high prevalence (up to 45%). Taken together, *Amoebophrya* sp. 1 may be a generalist and *C. polykrikoides* may not be its primary host, while *Amoebophrya* sp. 2 may be a specialist which can substantially impact host population dynamics.

W18-P2

CoCliME: Investigating the socio-economic impacts of HABs through co-development with stakeholders in European marine coastal areas

Jennifer Joy West*[1], Muriel Travers[2], Véronique Le Bihan[3], Gildas Appéré[4], Patrice Guillotreau[3], Jérémy Thomas[2], Baptiste Morineau[3], Sophie Pardo[3], Gregor Vulturius[5], Caroline Cusack[6], and Elisa **Berdalet**[7]

* Corresponding author

1 Center for International Climate Research (CICERO), Norway
2 University of Nantes, France
3 University of Nantes, Lemna, France
4 University of Angers, France
5 Stockholm Environment Institute (SEI), Sweden
6 Marine Institute, Ireland
7 Institute of Marine Sciences (ICM, CSIC), Spain

The CoCliME project aims to co-develop climate services for adaptation to changing marine ecosystems. The focus is on how climate change will influence the marine environment and the likely response of harmful microorganisms in European seas (NE Atlantic, Baltic, Mediterranean, Black Sea, North Sea, Norwegian Sea). Working dynamically with key stakeholders and end-users in the different regional case studies, CoCliME's transdisciplinary team (including natural and social scientists, economists, statistical, numerical and climate modellers, biologists and chemists) along with our co-developers, decision-makers and users of climate services are identifying marine ecosystem vulnerabilities relevant to each case study, the common and particular needs of our stakeholders, and the challenges and solutions for adapting to climate change related ecological, social and economic impacts of target harmful marine microorganisms.

CoCliME's approach includes investigating stakeholder HAB risk perceptions and experiences and devising Marine Ecosystem Climate Impact Indicators (MECIIs), Climate Vulnerability and Adaptation Indicators (CVAIs), and Added-Value Indicators (AVIs). A further essential aspect of our approach is to analyse the environmental, human health and socio-economic impacts for selected events.

Here we will present our approaches on 1) HABs affecting shellfish and fish farmers in Norway and shellfish farming in the French Atlantic; an original database of trade bans for shellfish areas in the region of Pays de la Loire and southern Brittany (France) from 2004 to 2018, is used to quantify the frequency and duration of shellfish trade bans; secondly, a regional Input-Output model including a shellfish activity is designed to assess the direct and indirect of HABs on the regional economy. 2) HABs impacting residents and tourists in the French Mediterranean coast; qualitative and quantitative valuation of tangible effects (direct / indirect / induced impacts on market activities) and intangible effects of HABs on the well-being of tourists and local communities are being investigated.

GENERAL POSTER SESSION

GP-P1

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

Xuejuan **Ren** and Yating Xiong

School of Atmospheric Sciences, Nanjing University, Nanjing, 210023, PR China. E-mail: 443522240@qq.com

This study investigates the influence of El Niño events on atmospheric river (AR), water vapor transport and precipitation over the North Pacific region during winters of 1979/80 to 2016/17. During El Niño events, the westerly jet over the North Pacific extends southeastward. The Aleutian Low is deepened. More moisture is transported towards the northwestern Pacific and the west coast of North America. Meanwhile, the AR frequency over the northwestern Pacific and the northeast Pacific increases, the AR frequency over central North Pacific decreases. The magnitude of the water vapor transport of the AR days is markedly stronger than that of the non-AR days. The poleward transport is performed during the AR days, not during the non-AR days. In addition, ARs which landfall along the west coast of North America are detected basing on the 85th percentile of peak daily moisture flux. ARs which landfall north of 43°N significantly increases during El Niño. The hydroclimate effects of ENSO on anomalies in precipitation over North Pacific region are also discussed. Over the northwestern Pacific region, the precipitation anomaly during AR days contributes to 50% of the total precipitation anomaly. Over the central North Pacific, 90% of the total negative anomaly in precipitation is attributed to that during AR days. Over the northeastern Pacific, the positive anomaly in precipitation along the California coast is mainly attributed to that during AR days while the decreases in precipitation over the Gulf of Alaska is due to that during non-AR days.

GP-P2

Vulnerability of marine ecosystems to stressors

Jocelyn C. **Nelson**[1], Lucie C. Hannah[2], and Cathryn Clarke Murray[2]

1 Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada
E-mail: Jocelyn.nelson@dfo-mpo.gc.ca; jocelyn.nelson@alumni.ubc.ca
2 Fisheries and Oceans Canada, Institute of Oceans Sciences, Sidney, BC, Canada

Cumulative effects assessments are increasingly relied upon to inform ecosystem-based management. A key step in a cumulative effects assessment is to determine the vulnerability of ecosystem components to stressors, which can be achieved through a vulnerability assessment. However, as not all studies define vulnerability in the same way, this can lead to variable and incompatible results. For example, cumulative impact mapping used expert-derived scoring based on spatial scale, frequency, trophic impact, percentage change and recovery time (Teck et al 2010) while an Ecological Risk Assessment Framework (O et al 2014) used area, depth, temporal extent, intensity, frequency, acute change, chronic change, and recovery. In order to evaluate the sensitivity of outcomes to the vulnerability definition and criteria used, we synthesized vulnerability assessments, and compared rankings to examine commonalities and differences. We then explored how the definition and calculation of vulnerability and the goal of the assessment may have affected the rankings of habitats, species, and stressors. This comparison of vulnerability definitions and ranking across different assessments will advance the understanding of cumulative effects and the management of the risk of stressors. The refinement of vulnerability assessments will be a key component in cumulative effects assessments used to inform ecosystems-based management of ecosystems.

GP-P3

Jellyfish blooms in coastal waters nearby thermal discharges of nuclear power plant

Chunjiang **Guan**, Yongjian Liu, Chuan Jia, and Hao Guo

National Marine Environmental Monitoring Center, Dalian, PR China. E-mail: cjguan@nmemc.org.cn

There is one nuclear power plant, which was put into operation in 2013. In order to ensure the safety of the nuclear power plant cold source, long-term monitoring of marine organisms in this area with water outlet as the center and the radius of 4.0 km was carried out. In 2010, before the discharge of thermal waste water by the nuclear power plant, the maximum abundance of *Aurelia aurita* in this area, a common jellyfish species in the Bohai Sea, was recorded as 533 ind. /(net·h). Thereafter, the frequency of jellyfish bloom in this area has been increased. Inthis area, the maximum abundances from 2015 to 2018 were 12353, 16667, 380 and 9188 ind. /(net. h). The average results in the past 4 years showed that maximum abundance of *Aurelia aurita* was about 18 times of that in 2010. Long-term monitoring and comparatively analysis of the structure and function of marine organisms, biological communities and ecosystems, before and after the operation of nuclear power plant, are crucial for rectangle the relationship between the marine ecosystem and the thermal water discharge. And it may be an ideal 'stress-tests' system for studying the impacts of climate change on marine ecosystems. It is also an ideal place to study the relationship between harmful algae blooms and jellyfish blooms.

GP-P4

Population structure of *Ampithoe valida* (Amphipoda) in Cheongsapo, Busan of South Korea

Ye Ji **Lee** and Won Gyu Park

Dept. of Marine Biology, Pukyong National University, Busan, 48513, Korea. E-mail: lyj5181@gmail.com

Population structure of *Ampithoe valida* was investigated in Cheongsapo, Busan, Korea. Size distribution, life stages, and sex ratio of *A. valida* were analyzed. Sampling was conducted in March, April and May 2019. Up to 100 specimens were examined. The total length and cephalic length of *A. valida* were measured. The total length of *A. valida* was classified by 1 mm interval from 1 mm to 13 mm. In March and May, the minimum length was 2-3 mm while it was 1-2 mm in April. The largest length was 12-13 mm in April, 11-12 mm in May, and 9-10 mm in March. 3-4 mm in total length was most abundant in March and April, representing 24.2% and 31.7%, respectively while 4-5 mm in total length was most abundant in May, charging 32.7%. The life stages and sex ratio of *A. valida* varied by month. The maximum size class of juvenile was in 8-9 mm. The minimum size class of adult was ranged between 6 and 7 mm in March, while it was between 4 and 5 mm in April. Male ratio was higher in April than in March. Ovigerous females did not appear in March, but they appeared in April. The population structure of *A. valida* in Cheongsapo, Busanof South Korea was changed by month.

GP-P5

Development of a multi-target tissue approach for the prediction of non-uniform accumulation of radioactivity in fish

Kyeong Ok **Kim**[1], Roman Bezhenar[2], Vladimir Maderich[2], Hanna Kim[1], Mee Kyung Kim[1] and Kyung Tae Jung[1]

1 Korea Institute of Ocean Science & Technology, Busan, Korea. E-mail: kokim@kiost.ac.kr
2 IMMSP, Kiev, Ukraine

The present work is concerned with the development of a new dynamic modelling approach for the simultaneous calculation of concentration of a specific radionuclide accumulated in different tissues of fish. That is, as an extension of the previous single target tissue approach, the new model considers three-target tissues, flesh (muscle), bones (carcass), organs for each of fishes considered in the marine food web. The dynamic equation of concentration for each type of fish used in the single target tissue approach is then split into three independent equations having different values of assimilation efficiency parameter and biological half-life. The target tissues were chosen based on the large differences in cell renewal time, namely biological half-life. Organs include liver, kidney, stomach, gonads etc. assuming that dynamics of radionuclide accumulation and elimination is roughly similar. Unlike pharmacokinetic models the new model does not consider the interaction between targets, considering substantial difference in biological half-life between considered tissues. Such simplification then requires much less number of parameters. The assimilation coefficients were basically defined using the experimental ratios between concentration of radionuclide in whole body of marine fish and concentration in specific tissue (Yankovich et al., 2010). An additional requirement was the ratio between concentration of radionuclide in fish and in the surrounding water at equilibrium conditions should be equal to standard biological concentration factor value (IAEA, 2004). Summing up the contribution of different tissues leads to estimation of total concentration of a radionuclide in each of fish.

For the validation purpose the model has been applied to simulate experimental results described by Baudin et al (2000). In detail, concentrations of the radionuclides 60Co, 54Mn, and 137Cs accumulated in fish (juvenile trout) are calculated and compared. It is found that application of the model to reproducing the accumulation of three radionuclides in fish has given reasonable results, indicating that model can be used as a tool for assessment of the radiological consequences caused by the releases of radionuclides during normal operation from the various nuclear facilities or as a part of decision support system for the nuclear emergency response.

GP-P6

Submarine Groundwater Discharge (SGD) and coastal biogeochemistry in Jeju Island by Typhoon

Byung-Chan **Song** and Tae-Hoon Kim

Department of Earth and Marine Sciences, Jeju National University, Jeju, R Korea
E- mail: thkim@jejunu.ac.kr

To estimate submarine groundwater discharge (SGD) and nutrients by typhoon (Kong-rey) in a small coastal bay (Hwasun Bay) on volcanic Island, Jeju, the sampling was conducted from Oct. 04, 2018 (before typhoon) to Oct. 10, 2018 (after typhoon) in Hwasun bay. The discharges of submarine groundwater before/after typhoon in this bay, using DSi mass balance model, were 6.5×10^6 m^3 d^{-1} (before typhoon), 7.2×10^6 m^3 d^{-1} (the next day after typhoon), and 6.1×10^6 m^3 d^{-1} (3 days after typhoon), respectively. The relatively higher SGD was found in the next day after typhoon, due to heavy rain (precipitation: 340.8 mm) with typhoon. The SGD-driven nutrient fluxes, calculated by multiplying the SGD by average concentrations of groundwater, were 24-27 Mg yr^{-1} for DIN, 0.08-0.1 Mg yr^{-1} for DIP, and 16-20 Mg yr^{-1} for DSi, and were approximately 91-92%, 39-43%, and 98-99% of the total input fluxes for DIN, DIP, and DSi respectively. In addition, the removal rates of DIN, DIP, and DSi in this bay were estimated to be 65-93%, 96-99%, and 69-84%, respectively, due to biological production. Thus, nutrient fluxes through SGD can be readily utilized by marine plankton in coastal ocean and can be controlled by the natural events, such as typhoon.

GP-P7

Spatio-temporal variations of Dissolved Organic Matter (DOM) in coastal water of Jeju Island

Jin-Wook **Song** and Tae-Hoon Kim

Department of Earth and Marine Sciences, Jeju National University, Jeju, R Korea. E-mail: jwsong8534@jejunu.ac.kr

In order to estimate spatio-temporal variarions of dissolved organic matter (DOM) in the coastal environment of Jeju Island, samples for dissolved organic carbon (DOC), dissolved organic nitrate (DON), chlorophyll-a (Chl-a), and salinity were collected from 12 station every month from January to December 2017. The concentrations of salinity, DOC, DON, and Chl-a in the coastal environment of Jeju Island ranged from 30 to 35, 54 to 136 µM, 0.2 to 14 µM, and 0.04 to 4.2 µg/L respectively. The highest concentrations of DOC and DON were found in the northern area in summer. The DOC and DON concentrations showed significantly negative correlations with salinity in summer (DOC: $r^2 = 0.87$, DON: $r^2 = 0.48$). However, there was no significant correlation between Chl-a and DOC and DON. Thus, the origin of DOM in the coastal environment of Jeju Island seems to be mostly the external source (e.g, Changjiang diluted water) rather than autochthonous source in summer.

GP-P8

Persistency in the DMSLs of Sea Level in the Coast of Korea

Ho-kyun **Kim**

Korea Hydrographic and Oceanographic Agency, Busan, R Korea. E-mail: hokyun1001@ korea.kr

The changes of the sea level in a coast have an effect on the ecosystem of tidal zone and close relation with the safety of a human marine life. The temporal evolutions of DMSL (Daily Mean Sea Level) of sea level removed tide for 10 years (2009~2018) at 20 sites in the coast of Korea are studied by rescaled range(R/S) analysis to estimate the Hurst exponent. The result of the R/S yield consistent power laws for time scales up to 4 months. The time series of DMSLs are found to be fractional Gaussian noise (FGN) with Hurst exponents between 0.75 and 0.88. The time series of the DMSLs of sea level are not a random noise: it is a 'persistent' FGN. The FGN property of the DMSLs indicates that the DMSLs in future is somehow related with the present values. However, systematic prediction for a quantitative forecast of the DMSLs in the future is not available.

GP-P9

Separation of Pacific skipjack and bigeye tuna fishing grounds using public domain catch data

Shirley **Leung** and LuAnne Thompson

University of Washington, Seattle, WA, USA. E-mail: shirlleu@uw.edu

Skipjack and bigeye tuna are often caught together throughout the Pacific Ocean. Recent stock assessments indicate, however, that bigeye stocks may be overfished while skipjack stocks are still in healthy condition. It is therefore desirable to maximize skipjack catch while avoiding bigeye bycatch. In order to achieve this separation, it is important to better understand the environmental drivers of overlap between skipjack and bigeye, as well to illuminate the regions and/or times of year when large amounts of skipjack can be caught without many bigeye. Here we investigate the spatiotemporally variable environmental and fishing conditions controlling the extent of overlap between Pacific skipjack and bigeye catch using oceanographic measurements from World Ocean Database and satellites, along with publicly accessible, monthly mean purse seine catch data from the Western and Central Pacific Fisheries Commission (WCPFC) and Inter-American Tropical Tuna Commission (IATTC). We find that optimal regions of skipjack and bigeye catch separation vary with El Niño-Southern Oscillation (ENSO) phase. Ratios of bigeye bycatch to skipjack catch tend to be higher in El Niño years, for instance, especially within the warmest waters of the tropical Pacific.

GP-P10

Subtidal biodiversity on the central coast of British Columbia

Matthew **Lemay**[1], Gillian Sadlier-Brown[1], Kyle Hall[2], and Matthew Whalen[1,2]

[1] Hakai Institute, Victoria BC, Canada. E-mail: matt.lemay@hakai.org
[2] University of British Columbia, Vancouver BC, Canada

Biodiversity is declining at an accelerated rate, yet our ability to track these declines is hindered by incomplete data on the distribution and abundance of many species. To improve our ability to monitor changes in biodiversity, we are building a comprehensive genetic database of species on the central coast of British Columbia. We use intensive field collection events to catalogue marine species across a variety of habitats. All specimens are identified by taxonomic experts, photographed, accessioned in public collections for long-term preservation, sequenced to obtain a DNA barcode, and the associated metadata are deposited in the Barcode of Life Database (BOLD). Our previous work has shown that the number of unrecorded species dramatically increases in subtidal habitats, which have received less scientific attention than the shoreline. To address this lack of data, we conducted an intensive week-long subtidal biodiversity survey on the central coast of British Columbia in May, 2019. Specimens were collected to a depth of 40m by SCUBA, and a remotely operated vehicle (ROV) was used to target specimens down to 275m. In total, we collected ~1000 specimens from 17 phyla. These specimens include new records for the area, many species that previously lacked DNA barcodes, and likely a few undescribed species. In this poster, we present an overview of the species we observed, and use high-quality images to highlight the beauty of these understudied organisms.

GP-P11 CANCELLED

The impact of boat noise on aggression and territoriality of the plainfin midshipman fish, *Porichthys notatus*

Mackenzie B. **Woods**[1], Nicholas A.W. Brown[1,2], Sigal Balshine[2], and Francis Juanes[1]

[1] University of Victoria, Victoria, BC, Canada. E-mail: kenziew@uvic.ca
[2] McMaster University, Hamilton, ON, Canada

Anthropogenic noise has altered the underwater soundscape and studies have shown that it can negatively impact marine organisms and ecosystems. Many fishes are largely reliant on sound for communication, prey and predator detection, and navigation. The highly vocal plainfin midshipman fish, *Porichthys notatus*, has a long and energetically-costly parental care period, during which a male guards a nest and cares for his eggs. *P. notatus* relies on sound production and reception for mate attraction and agonistic encounters, including nest defence; therefore, alteration of the environmental soundscape has the potential to affect reproductive behaviour, including nest-guarding and parental care. We are conducting a two-part study to investigate the effect of boat noise on the behaviour of *P. notatus* guarder males during nest defence. Using a within-subjects design, we exposed guarder males to a nest-invading crab threat stimulus in the presence and absence of boat noise. We first conducted these experiments using fish housed in individual tanks; the captive fish exhibited more aggressive behaviours in trials during boat noise playback compared to trials with only ambient conditions. We then repeated the experiments *in situ* at an intertidal breeding site. Our results will help explain how boat noise affects fish behaviour and mediates parental care. As anthropogenic noise continues to increase, understanding how it affects aquatic organisms is crucial in order to appropriately mitigate such effects.

GP-P12

Forecasting the demand of extruded pellet feed in Korea

Juhyun **Yi** and Dohoon Kim

Pukyong National University, Busan, R Korea. E-mail: delaware310@pknu.ac.kr

Feed for the fish aquaculture in Korea highly relies on moisture pellet (MP) feed which may cause water pollution and overfishing. To minimize these problems, the Ministry of Oceans and Fisheries is trying to introduce the policy which forces the mandatory use of extruded pellet feed (EP). If the policy is implemented, it is obvious that the demand for EP feed will explode in Korea because the present portion of EP feed usage is about 15% of total. This study aimed to forecast future demand of EP feed in Korea when the use of MP feed is prohibited. Future demand of EP feed was forecasted by multiplying future production amount of fish aquaculture and the feed conversion ratio. Future production of fish aquaculture was calculated in three scenarios: 1) production will increase to the past maximum production level, 2) production will increase as it did in the past 20 years and 3) production will increase as it is predicted in FAO-OECD Agricultural Outlook 2018-2027. FCR was assumed to be constant because the aquaculture in Korea has been technologically stabilized. As a result, forecasted future demand of EP feed in Korea would be 340,759 tons on the past maximum production scenario, 231,816 tons on the CAGR scenario and 188,552 tons on the FAO-OECD scenario in 2026 when the policy is planned to be implemented. In addition, supply shortage problem seems to be occurred before 2022 on the first scenario, after 2026 on the second and after 2035 on the third, respectively.

GP-P13

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***[1,2], Mark Flaherty[1], Stephen F. Cross[3], and Christopher M. Pearce[1,2]

1 Department of Geography, University of Victoria, Victoria, BC V8P 5C2, Canada. E-mail: warren.emilym@gmail.com
2 Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC V9T 6N7, Canada
3 Department of Applied Research & Entrepreneurship, Conestoga College, Kitchener, ON N2G 4M4, Canada

Sea urchin aquaculture is a relatively new industry (especially in North America) and with the large demand for sea urchin gonads (roe or "uni" in industry parlance), it requires studies on its potential environmental impact, which have not been done before. When sea urchin population growth is uncontrolled, they can over-graze and decimate macroalgal beds, creating areas termed "urchin barrens". The sea urchins may stay in these barrens with little to no food for long periods of time, not only becoming unsuitable for the urchin gonad fishery due to low yields, but also preventing the re-growth of productive macroalgal ecosystems. Sea urchin gonad enhancement is a proposed method to both remove sea urchins from barren grounds and promote the re-growth of macroalgal beds. This would entail collecting empty sea urchins from barrens, placing them in captivity, and feeding them a prepared/natural diet for 8–12 weeks to produce high-quality gonads and then selling them to the market. This project aims to assess the effects of two prepared diets and a natural feed (bull kelp, *Nereocystis luetkeana*) and three seawater temperatures (8, 12, and 16°C) on gonad yield/quality and waste deposition for both the red (*Strongylocentrotus franciscanus*) and green (*S. droebachiensis*) sea urchin held under laboratory conditions for 12 weeks. Data on feeding, absorption, and faecal production rates, as well as faecal pellet size/shape and settling rate, will then be used in a waste deposition model (along with various oceanographic variables of a proposed site) to predict the potential environmental impact a commercial-scale sea urchin farm could have.

GP-P14

A traits-based approach to predict predator-prey uncoupling under climate change scenarios

Cole B. **Brookson**, Stephanie J. Green

Department of Biological Sciences, University of Alberta, Edmonton, Alberta, T6E 4R4 Canada

Climate change is driving major shifts in ocean species' geographic ranges around the globe. As ranges shift, predator and prey species with currently overlapping ranges might change asymmetrically, thus no longer occupying the same geographic area and reducing opportunities for interactions (i.e. 'uncoupling' predator-prey dynamics). While a variety of factors likely influence the magnitude of these range shifts, key species traits that influence predator-prey dynamics could aid managers in predicting the likelihood of uncoupling across systems. We focus on the development of a spatially-explicit individual-based model which explores how different species' trait typologies influence the coupling or uncoupling dynamics of predator-prey interactions. The model is parameterized with data from a literature review of morphological and behavioural traits (e.g. body size, foraging strategy, migratory behaviour) of marine pelagic fish species that influence diet specificity. We outline the application of the model to an important forage species in the NE Pacific (i.e. Pacific herring (*Clupea pallasii*)) and predators with differing life histories (e.g. Chinook salmon (*Oncorhynchus tshawytscha*) and lingcod (*Ophiodon elongatus*)). The goal of the model is to predict how predators may track prey, and how the ranges of both might shift in the face of changing climate conditions. This work will inform our understanding of how climate change could alter predator-prey interactions as species' ranges shift, and shed light on the repercussions for of these changes on fisheries and general ecosystem health.

GP-P15 CANCELLED

Sustainable fishing and farming strategy of Milkfish (*Chanos chanos*) under the influence of climate change in coastal communities in Indonesia

Takaaki Mori[1], Keitaroh Tao[2], Naoki Tojo[3]

[1] Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1, Minato Cho, Hakodate, Japan 041-8611
E-mail: takasawa0625@gmail.com
[2] School of Fisheries sciences, Hokkaido University, 3-1-1, Minato Cho, Hakodate, Japan 041-8611
[3] Faculty of Fisheries Sciences, Hokkaido University, 3-1-1, Minato Cho, Hakodate, Japan 041-8611

Fisheries production of Southeast Asian countries accounts for 20% of total amount in the world, and Indonesia has the largest production in the region. Many of the fishers in Indonesia are engaged in small-scale fisheries, and their communities are often vulnerable to changes in coastal climate and gaps with urban economies. Pabean Ilir village is one of the small coastal communities, and about 250 people are engaged in small-scale fisheries and fish farms. Milkfish (*Chanos chanos*) is economically one of the most important species in the village. Recently, residents have felt difficulty to sustain their households because of uncertainties from climate changes, especially rainfall pattern in rainy season recently. Not only on their fishing and farming activities, the survival of milkfish in the pond was most likely increased during the recent rainy seasons in the villages. Moreover, the villagers have been suffered with luck of capitals even for improvement of their fishing and aquaculture efficiencies with sustainable manners. This study aims to model optimal production scenario and fishing strategy in small-scale fisheries under the influence of local climate change. The analysis focuses on production model of milkfish culture in Pabean Ilir village as an associated research part of the ODA project, "Building capacity for coastal monitoring by local small-scale fishers (FishGIS)" committed by PICES since 2017. Developing optimal strategies with sustainable fishing and responsible aquaculture under environmental risks is important for sustainable fisheries in Indonesia and other countries awaiting contributions from PICES scientists.

GP-P16 CANCELLED

Sustainable production and household model with Mangrove forest and appropriate development assistances

Keitaroh **Tao**[1], Takaaki Mori[2], and Naoki Tojo[3]

1 School of Fisheries sciences, Hokkaido University, 3-1-1, Minato Cho, Hakodate, Japan 041-8611. E-mail: tarohdance12@gmail.com
2 Graduate School of Fisheries sciences, Hokkaido University, 3-1-1, Minato Cho, Hakodate, Japan 041-8611.
3 Faculty of Fisheries sciences, Hokkaido University, 3-1-1, Minato Cho, Hakodate, Japan 041-8611

Small scale fishers are vulnerable to environmental changes and disasters because of where they reside and capitals that generally they have. Especially in the present changes of climate and marine environment, it is important to study methodologies for adaptive improvements of their livelihoods and a variety of development assistances having been carried out with objectives of sustainability in coastal communities. However, it has been challenging to achieve the both financial and ecological sustainability in the community with small-scale fishing. For example, nearshore vegetations are often susceptive to direct exploitations despite of higher values in their indirect services. This study aimed to find optimum models for fishers' household and production with mangrove stands, in coastal areas of the southeastern Asia. Quantitative modeling of general household in local fishers and small scale aquacultures were carried out with functions of activities and capitals by applying collected data in field surveys and interviews. Parameters of the model were estimated from cases of the southern coast of Southeastern Asia and Java Island of Indonesia through the PICES project, "Building capacity for coastal monitoring by local small-scale fishers (FishGIS project)." Ecological sustainability was mainly discussed with services of mangrove stands to fishing and aquaculture targets. We discussed the optimum approach for sustainable households from model estimations and the best alternatives for sustainable development, including them with further official assistances to vulnerable small-scale fishery/aquaculture communities.

GP-P17

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

Shohei **Sasabe**[1], Naoki Tojo[2], Gordon H. Kruse[3]

1 School of Fisheries Sciences, Hokkaido University, 3-1-1, Minato Cho, Hakodate, Japan 041-8611
E-mail: sparrowclub18@eis.hokudai.ac.jp
2 Assistant Professor, Faculty of Fisheries Sciences, Hokkaido University, 3-1-1, Minato Cho, Hakodate, Japan 041-8611
3 Professor Emeritus, College of Fisheries and Ocean Sciences, 203 Lena Point Bldg., 17101 Point Lena Loop Rd. Juneau AK 99801-8344, USA

The spawning activity of Pacific herring (*Clupea pallasii*) in Bristol Bay, Alaska, is socio-economically important as both commercial and subsistence fisheries resources. Alaskan commercial herring harvests have averaged approximately 34,000 metric tons with a value of approximately $10 million. Pacific herring has been used by indigenous people in the coastal area of Alaska for more than 8000 years and have played a role in the local livelihoods and traditional cultures. The size of the herring spawning activities and the spatio-temporal pattern of them influence to the value of products as well as the efficiency of the fishing activity. However, Bristol Bay, which is a remote area, has limitations in its ongoing research activities, hence there have been only few studies in the dynamics of herring spawning. In this paper, we aimed to scientifically understand and conceptualize the spatial relationship between spawning activities and the environmental variables in Bristol Bay. There were three findings: (1) the activity was often started only the eastern areas in coastal area of Bristol Bay when the peak of spawning activities was small (S-Years), (2) the activity was often started from both areas in Bristol Bay when it was large (L-Years) and (3) the total concentration of sea ice(TC) in the area of pre-spawning migration passage in April was low in S-Years and high in L-Years. In the recent sea ice dynamics, it is meaningful to investigate changes in spatial dynamics of spawning activity in the given environmental change in the arctic and subarctic coasts.

GP-P18

Transecting the Riverine Coastal Domain – Observations of oceanographic properties on British Columbia's central coast from an estuary to the open ocean

Bryn **Fedje**[1], Emma Myers[1], Chris Mackenzie[1], Chris O'Sullivan[1], Eva Jordison[1], Jessy Barrette[2], Justin del bel Belluz[2], Eddy Carmack[3], and Jennifer Jackson[2]

1 Hakai Institute, Heriot Bay, BC, Canada. E-mail: jennifer.jackson@hakai.org
2 Hakai Institute, Victoria, BC, Canada
3 Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada

British Columbia's Central Coast, within the traditional territories of the Heiltsuk, Wuikinuxv, Kitasoo/Xai'Xais, and Nuxalk First Nations, spans from Smith Inlet south to Dowager Island and covers approximately 25000km^2. The Central Coast region, encompassing most of the Great Bear Rainforest, includes a diverse range of marine and terrestrial environments, from sub-alpine glaciers to watersheds surrounded by temperate rainforests to the coastal ocean. Steep mountains, long, deep coastal fjords, and islands dominate the terrain. Thousands of rivers and streams enter the coastal ocean, transporting freshwater and terrigenous material to the coastal ocean.

The riverine coastal domain (RCD) is a narrow (~< 15 km), shallow (~10 m) band along the coastline that acts as a main connector between terrestrial and marine environments. It is formed by multiple buoyant freshwater outflows held along the coast by the Coriolis force. In the context of global climate change and increased glacial melt, understanding the characteristics and behaviour of the RCD is crucial for understanding temperature fluctuations, nutrient dynamics, and corresponding ecosystem effects. Despite the importance of the RCD, very little information on its seasonal, spatial or interannual variability is known.

Using small boats, physical and biological oceanographic data were collected on BC's Central Coast over a 30km transect comprised of 5-13 stations, from Koeye estuary and Fitz Hugh Sound, through Hakai Pass, and into Queen Charlotte Sound. Oceanographic data (CTD, fluorescence, and oxygen) were collected consistently over the spring and summer of 2013-present, and fall and winter transects were collected (weather permitting) starting in 2015 and 2017, respectively. This multi-year, high resolution dataset will be examined to gain knowledge of how the RCD varies seasonally, spatially, and interannually in BC's Central Coast. This analysis will add detailed information on BC's coastal waters, which are often overlooked by large, infrequent offshore oceanography cruises.

GP-P19

Influence of Northern Pacific centres of atmospheric action on thermal regime of north-western coast of the Bering Sea

Yulia V. **Stochkute** and L.N. Vasilevskaya

FEFU, Vladivostok, Russia. E-mail: julias76@mail.ru,

The purpose of this work was to study the influence of the centers of atmospheric action in the northern hemisphere on the thermal regime of the Bering Sea coast of Russia for 1961–2012. The correlation analysis between the air temperature anomalies at 6 coastal meteorological stations and pressure anomalies at the surface of the earth (P0) and geopotential (H500) in the Aleutian low and P0 in the North-American high was performed.

Aleutian low. The dynamics of air temperature (except January), atmospheric pressure and geopotential are positive - linear trends are statistically significant (the coefficients of determination are 0.5-0.7). In the first half of the year asynchronous relations of air temperature with P0 were revealed in previous 1–4 months (the correlation coefficient reaches 0.4). The average geopotential value (H500) directly determines the temperature regime on the Bering Sea west coast the in June-October ($r = 0.29–0.39$) and the reverse in January and March. Asynchronous direct connections are significant from May to September with a shift of 1–4 months ($r = 0.42$).

North-American high. There is a negative relationship between air temperature and pressure P0. The closest dependence is manifested in December-January, in April-May and in August ($r = 0.27 - 0.32$). Pressure decrease in the North-American high leads to temperature increase on the west coast in these months.

GP-P20

Ocean Negative Carbon Emissions (ONCE)

Nianzhi **Jiao**

State Key Laboratory of Marine Environmental Science and Institute of Marine Microbes and Ecospheres, Xiamen University, PR China 361102

Global negative emissions provide an approach to the goal of the Paris Agreement to limit global warming to 2.0°C or even 1.5°C by the end of this century. The ocean has a large capacity to sequester carbon and has absorbed approximately 25% of the CO2 produced by fossil fuel combustion and cement production since the beginning of the industrial revolution. Understanding the mechanisms and processes involved in Ocean Negative Carbon Emissions (ONCE) is needed to achieve their potential contribution to the global negative emissions. The majority of the organic carbon in the ocean is in the form of dissolved organic matter (DOM), which contains an amount of carbon equivalent to the total inventory of atmospheric CO2 and whose refractory component is a form of sequestered carbon in the ocean. The previous PICES/ICES joint WG 33 on “Climate Change and Biologically-driven Ocean Carbon Sequestration” highlighted the importance of microbial processes in the production of refractory DOM in the ocean, and identified a potential ONCE technique based on the naturally occurring microbial carbon pump. However, there is a gap between this natural process and its potential application as negative emission. In addition, our knowledge of other ocean carbon sequestration mechanisms and processes, such as the solubility and carbonate pumps and the different components of the biological carbon pump, limit their potential application for mitigating climate change. The proposed new PICES/ICES joint Working Group ONCE will promote interdisciplinary exchange among different research communities by bringing together experts with backgrounds in science (biological, biogeochemical, chemical and physical oceanography) and engineering to develop theoretical bases, provide guidelines, and evaluate the implementation of ocean negative carbon emissions. The WG has the long-term objective of providing advice, through PICES and ICES, for climate policy and practical implementation of ocean negative carbon emissions to the scientific community, the public and governments.

Author Index

A

B

C

D

E

F

G

H

I

J

K

M

N

O

V

W

X

Y

Z