Summary of Scientific Sessions and Workshops
and List of Best Presentations at PICES-2016

Science Board Symposium (S1)
25 Years of PICES: Celebrating the Past, Imagining the Future

Co-Convenors: *Thomas Therriault (SB), Angelica Peña (BIO), Elizabeth Logerwell (FIS), Chuanlin Huo (MEQ), Jennifer Boldt (MONITOR), Kyung-Il Chang (POC), Toru Suzuki (TCODE), Steven Bograd (FUTURE), Hiroaki Saito (FUTURE), Igor Shevchenko (Russia)*

Invited Speakers:
Cornelius Hammer (International Council for the Exploration of the Sea (ICES))
Naomi Harada (Research and Development Center for Global Change (RCGC)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan)
Alan Haynie (NOAA Fisheries' Alaska Fisheries Science Center, USA)
Guido Marinone (Centro de Investigación Científica y de Eduación Superior de Ensenada (CICESE), Mexico)
Philip Munday (James Cook University, Australia)
Phillip Mundy (Alaska Fisheries Science Center, NMFS, NOAA, USA)
Essam Yassin Mohammed (International Institute for Environment and Development, London, UK)

Background

In its 25 years of existence PICES has achieved remarkable success in furthering our understanding of the North Pacific's natural and socioeconomic systems. Dedicated and tireless efforts of the many natural and social scientists from all its member countries have enabled us to understand basin-scale phenomena that we did not know about 25 years ago, such as regime shifts and their ecosystem impacts—from biogeochemistry, through phytoplankton production, to higher trophic levels including fisheries and coastal communities. Building on these foundational results, we now embark on the next 25 years of PICES that should lead to better observations, improved understanding of mechanisms of change, and ultimately better predictions of status and trends in North Pacific ecosystems. Forecasting the effects of natural and anthropogenic change, especially climate change, will allow adaptation based on the ecological, societal, and economic resilience of our coasts and oceans. Increasing resilience is a key societal challenge and will only be possible with increased scientific knowledge of the North Pacific and intergovernmental collaborations like those developed within PICES.

The founders of PICES saw the vastness of the North Pacific Ocean not as something that separates us, but rather as a factor that unites us. They knew that to unravel the inner workings of the North Pacific, PICES member countries would need to work together. To recognize the leadership that set us on this path, several speakers indicated how present day problems are being addressed with the science and tools that we have developed over the past 25 years. Looking forward, several presenters identified challenges that might be expected over the next 25 years. The list of past and future topics of interest in PICES is long, and includes basin- and regional-scale issues such as coastal ecosystem stressors (eutrophication, hypoxia, pollution, ocean acidification), loss or changes of marine biodiversity, changing productivity and species distributions in response to climate change, developing outlooks or forecasts of future ocean ecosystems, and examining climate change impacts on ocean ecosystems and human society. Presentations on these topics were provided in this session.

Summary of presentations

The keynote speaker was Ryan Rykaczewski who presented a talk titled "*Projecting ecosystem consequences of climate variability and change: Aspirations for the next 25 years of PICES*". Using studies in the California Current, he highlighted mechanisms linking physics, nutrients, zooplankton abundance and composition, to sardine and anchovy populations. An important message was that current empirical relationships that link physics to zooplankton to fish cannot necessarily be extended into the future. Mechanisms need to be understood to ensure more forecasts that are robust to climate change and long-term monitoring is needed to do this.

Five Invited Speakers presented in S1. The first was Philip Munday who discussed the need to include evolutionary potential (plasticity or genetic adaptation) in forecasting effects of climate change on ecosystems. Alan C. Haynie's talk summarized the increasing presence of human dimensions and interdisciplinary work in PICES. He also identified benefits and challenges of including human dimensions in large science projects and had recommendations for future projects. Cornelius Hammer described ongoing areas of collaboration between PICES and ICES and identified potential future areas of collaboration between the organizations. Guido Marinone summarized the importance of oceans for Mexico and provided an overview of research in Mexico. He also identified a future goal of trinational collaboration between the US, Canada, and Mexico. Naomi Harada provided a talk on potential environmental changes in the western Arctic and the western North Pacific in which she discussed a new technique to quantify the response of marine calcifiers to ocean acidification.

In contributed talks, Robert Blasiak discussed whether climate change will lead to more conflict and instability in fisheries. He assessed the vulnerability of countries, by examining exposure, sensitivity and adaptive capacity of countries across the world. Luis Valdés provided an overview of UN architecture for ocean knowledge and governance. He also summarized global efforts, such as Future Earth and the World Ocean Assessment. He identified the need for interdisciplinary science programs mobilizing the marine scientific community in a common spirit and goal. Jeffrey Polovina summarized tools and datasets for understanding climate impacts across all trophic levels. He also identified challenges and future directions, including developing an understanding of climate-informed reference points and robust management strategies, as well as spatial ecosystem models to provide short and long-range forecasts. Sanae Chiba provided an overview of the framework for ocean observing and the development of Essential Ocean Variables. She discussed the Biodiversity Indicators Partnership and biodiversity goals relative to Aichi Biodiversity Targets. Shang Chen's talk was on Marine Ecological Capital (MEC), which can have a direct or indirect contribution to human social and economic production and can provide benefits for humans, and summarized tool development for use in management. Maciej Telszewski discussed work toward the integration of ocean observation information into the GCOS Implementation Plan in support of the UNFCCC, the World Summit on Sustainable Development, the Group on Earth Observations, and other international and intergovernmental strategies. William Sydeman summarized the accomplishments of marine mammal and bird research in PICES, why marine mammals and seabirds provide Essential Ocean Variables, and the technological advances through tagging studies.

Overall, the Session provided an overview of the inter-disciplinary science that has been conducted within PICES over the past 25 years, how this work complements existing international efforts, and what challenges PICES is likely to face in coming years. A key message in these talks is the need for international collaboration to address these challenges and to arrive at a better understanding of the mechanisms linking climate variability and change to North Pacific marine ecosystems and human socieites. Ultimately, the ability to forecast climate change impacts on oceanic and coastal ecosystems will allow our governments to increase the ecological, societal and economic resilience of our ocean communities.

List of papers

Oral presentations

Projecting ecosystem consequences of climate variability and change: Aspirations for the next 25 years of PICES (Invited)
Ryan R. Rykaczewski

Predicting evolutionary responses to climate change in the sea: Progress and challenges (Invited)
Philip L. Munday

Why people matter: Past and future analysis of the role of humans in marine ecosystems (Invited)
Alan C. Haynie

Applying fractionalization indices to transboundary fish stocks to forecast future conflict hotspots
Robert Blasiak, Jessica Spijkers and Nobuyuki Yagi

PICES-ICES Cooperation: Where we are and where to go? (Invited)
Cornelius Hammer

Oceanography of the Mexican Pacific Ocean: An interactive region between north and south (Invited)
Guido Marinone

The UN role in for ocean science and ocean governance
Luis Valdés

Recent advances, ongoing challenges, and future directions in ecosystem approaches to fisheries management in the central North Pacific
Jeffrey Polovina, Anela Choy, Phoebe Woodworth-Jefcoats, and Johanna Wren

Can we use zooplankton diversity to fill the global indicator gap of the Aichi Biodiversity Target 10?
Sanae Chiba, Stephen Fletcher and Sonia D. Batten

Marine Ecological Capital: Assessment, management and investment
Shang Chen, Yongfu Sun, Tao Xia and Linhua Hao

Potential environmental changes in the western Arctic and the western North Pacific: Their impacts on lower trophic level organisms (Invited)
Naomi Harada, Katsunori Kimoto, Jonaotaro Onodera, Eiji Watanabe, Koji Sugie, Masahide Wakita and Tetsuichi Fujiki

Future Global Ocean Observing System – Built on requirements, promoting alignment, delivering relevant information
Maciej Telszewski, Toste Tanhua, Albert Fischer

Marine birds, mammals and PICES: History and roadmap for the future
William J. Sydeman, George L. Hunt Jr., Douglas F. Bertram, Yutaka Watanuki, Rolf Ream, Kaoru Hattori, Hidehiro Kato and Ken Morgan

Poster presentations

Highlights from 16 years of the North Pacific CPR program, a PICES MONITOR project
Sonia Batten, Sanae Chiba, Tomoko Yoshiki and Hiroya Sugisaki

Negotiating the international instrument on BBNJ: Long-term implications
Robert Blasiak, Jeremy Pittman and Nobuyuki Yagi

25 years history of ecosystem modeling related to PICES and myself
Michio j. Kishi

Increase in the toxic Alexandrium tamarense blooms with the climate regime shift to warming in the eastern Bering Sea shelf
Masafumi Natsuike, Rui Saito, Amane Fujiwara, Kohei Matsuno, Atsushi Yamaguchi, Naonobu Shiga, Toru Hirawake, Takashi Kikuchi, Shigeto Nishino and Ichiro Imai

BIO/TCODE/FIS Topic Session (S2)
Early life history stages as indicators and predictors of climate variability and ecosystem change

Co-Convenors: *Richard Brodeur (USA), Tony Koslow (USA), Ian Perry (Canada), Moto Takahashi (Japan)*

Invited Speakers:
Janet Duffy-Anderson (NOAA, USA)
Jon Hare (NOAA, USA)
Akinori Takasuka (National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency, Yokohama, Japan)

Background

As management strategies become more ecosystem-based and climate-driven, there is a need for more information on the influence of oceanographic variability and climate change in regulating fisheries resources and on marine communities more generally. Ichthyoplankton abundance provides proxies for adult spawning stock biomass, so insight into changing fish communities can be obtained from ichthyoplankton time series. The early life stages of fish may also be critical in determining year class success and subsequent recruitment to fisheries. This session examined changes in the abundance, distribution, and ecological relationships of early life stages (eggs to juveniles) of fish taxa in relation to environmental conditions, and in many presentations their use in management decision-making.

In general, the current use of early life stage information in fish stock assessments appears to be of two forms: use of abundance and distribution information of these early stages to hind-cast spawning biomass, or the use of abundances and distributions to forecast adult recruitment. This led to key questions, such as: what is the definition of a stock; what is the effect of climate variability and change on stock structure; and can early life stages be used to inform stock identification? Information about the early life stages of fish can help to define stock structure and its changes, but understanding what is driving these changes in apparent distributions and stock productivity is crucial to using this information in assessments. For example, it was reported that in the Northeast United States, most stocks are defined spatially but that currently over 50% of these stocks are experiencing changes in their distribution patterns. Similar important changes in distributions of small pelagic fishes were reported off the west coast of Baja California, Mexico. Identifying the causes of these distribution changes is a key question for how best to use this information in stock assessments. Assessing changes in spatial distributions as a tool for stock assessments is complicated by the fact that early life and adult stages often occur in different places. This means that recruitment forecasting can change within a region due to changing growth environments outside of that region. However, differences in distributions between early life and adult stages, particularly if driven by changes in environmental conditions, can result in strong recruitment success if, for example, adults are cannibalistic on their young. This was the case reported for two populations of Walleye Pollock around Hokkaido, Japan, in which changes in current patterns and resulting temperature changes controlled the extent of overlap, and therefore of cannibalism.

Summary of presentations

The somewhat ephemeral nature of fish distributions, and abundance fluctuations, was underlined by the study of McClatchie *et al*. who took a very long time perspective. They concluded that for small pelagic fishes off southern California, the paleo (500 year) record shows that "collapse" is a normal state repeatedly experienced by anchovy, hake and sardine in the absence of commercial fishing. The mean time to return to one-third of peak biomass was 22 years for sardine, but 8 years for anchovy and hake. The authors concluded this historical record indicates that, on average, we might expect 1−2 decades of fishable biomass followed by 1−2 decades of low biomass. The authors concluded that setting a high threshold below which fishing is prohibited may not prevent forage fish populations from collapsing, and that predators dependent on forage fishes are likely to experience repeated periods of forage scarcity.

Several presentations reported on advances in understanding the relationships between environmental conditions and early life stage species composition, abundance, and survival. Lu *et al.* studied the Strait of Georgia, Canada, and found that the composition of the larval fish assemblages in spring differed from the late 1960s, early 1980s, to the late 2000s. The authors concluded that these changes were likely related to changes in large-scale climatic conditions. In the California Current System, ichthyoplankton time series indicate coherent trends in mesopelagic fishes in relation to midwater O_2 concentrations, and a decline since 1969 of dominant cool-water and endemic fishes in relation to transport, upwelling, and heat content of the California Current. The authors of this study (Koslow *et al.*) also found that species richness positively correlated with warm-water mesopelagic fish abundance, indicating that movements of warm-water taxa occurred in and out of the southern California Bight but without apparent replacement of California Current endemic or cool-water species. The changes in distributions of early life stages due to the very warm conditions in the northeast Pacific from 2014 to 2016 also were featured in a number of presentations. One study off Japan illustrated the interconnections between larval mesopelagic fishes and their zooplankton prey. This study examined the distribution, growth, and mortality of the six numerically dominant mesopelagic fish larvae and their predatory impact on zooplankton in the Kuroshio Current waters off Japan. The authors concluded that the food requirement of these larvae was 1.33 mg C m^{-2} d^{-1}, and that the predatory impact of these six mesopelagic fish larvae on the production rate of the available prey was 5% d^{-1}.

The session concluded that different types of information on early life stages are needed for different types of management approaches and questions. Early life stage information can be used as proxies for how adult spawning stock biomass may respond to climate changes. However, Takasuka *et al.* demonstrated there can be discrepancies between egg and larval abundance and spawning stock biomass over longer terms, and that the processes causing these discrepancies need to be understood for early life stages to be used successfully as indicators and predictors of climate variability and ecosystem change. They suggested that maternal effects and early growth–survival dynamics may be keys to understanding these discrepancies. Early life stages can also contribute to holistic management approaches. For example, Duffy-Anderson *et al.* identified that single species assessments need abundance estimates of larvae to provide key indicators of spawning stock health and production of young. Information on production hotspots can be used to identify spawning grounds that may need protection and to observe range shifts and colonization of potential new habitats. For ecosystem-based fisheries management, they identified needs for information on fish community responses to environmental variability, the diversity and stability of species compositions (to understand ecosystem sustainability and resilience), and to identify potential thresholds and tipping points. For ecosystem-based management, they suggested that information on early life stages would help to identify ecological hotspots and environmentally sensitive areas, to inform more complex risk assessments, and to quantify risks of shipping routes, oil spills, algal blooms, *etc*. With newer and faster means to identify early life stages from plankton tows, this information may become more readily available on rapid time scales and therefore more useful to in-season and 'tactical' management decisions.

List of papers

Oral presentations
Climate change, stock identification, and the distribution of early life stages (Invited)
Jonathan A. Hare, Harvey J. Walsh, Katrin E. Marancik, and David E. Richardson

Climate-driven growth potential affects recruitment signals in coastal age-0 cod surveys from the Atlantic and Pacific
Benjamin J. Laurel, David Cote, Robert S. Gregory, Lauren Rogers, Halvor Knutsen, Esben Moland Olsen

Decadal-scale changes in larval fish abundance and composition in the Strait of Georgia (British Columbia, Canada)
Lu Guan, John Dower, Skip McKinnell, Pierre Pepin, Stephane Gauthier

The spring spawning habitats of small pelagic fish in northwestern Mexico
Jose A. Valencia and Timothy Baumgartner

Variability, collapse, and recovery of forage fish population
Sam McClatchie, Andrew R. Thompson, Ingrid L. Hendy and William Watson

Decadal changes in abundance and distribution of early life stages of fish in the Kuroshio Current system (Invited)
Akinori Takasuka, Hiroshi Kuroda, Takeshi Okunishi, Michio Yoneda, Chiyuki Sassa, Motomitsu Takahashi, Patricia Ayón and Yoshioki Oozeki

Two walleye pollock stocks around Japan under different recruitment control mechanism
Tetsuichiro Funamoto, Masamichi Watanobe, Tadashi Misaka, Takayuki Honma, Kazuhiko Itaya and Osamu Shida

Specific gravity measurements on mackerel eggs and larvae and implications for interannual variability in recruitment
Hwahyun Lee, Sukyung Kang, Kyungmi Jung, Suam Kim and Sukgeun Jung

Comparative larval growth and mortality of mesopelagic fishes and their predatory impact on zooplankton in the Kuroshio waters
Chiyuki Sassa and Motomitsu Takahashi

Effects of temperature and prey abundances on larval growth rates of Carangid fishes in the East China Sea
Motomitsu Takahashi, Chiyuki Sassa

Examining ichthyoplankton across spatial and temporal scales as an approach to promote understanding and management of fisheries across Large Marine Ecosystems (Invited)
Janet Duffy-Anderson, Toby Auth, Richard Brodeur, Peter Davison, Esther Goldstein, Tony Koslow, Lauren Rogers and Elizabeth Siddon

The influence of climate on the biodiversity and community structure of fishes in the southern California Current, 1969 – 2011
J. Anthony Koslow, Helena McMonagle and William Watson

Patterns and processes: Spatial and temporal variability in ichthyoplankton assemblages across the Gulf of Alaska
Esther D. Goldstein, Janet T. Duffy-Anderson and Ann C. Matarese

Basin-scale ichthyoplankton response to environmental change in the northeastern Pacific Ocean
Peter C. Davison, J. Anthony Koslow, J. Duffy-Anderson and R. Brodeur

Changes in the ichthyoplankton in the northern California Current during the 2015-16 warm 'blob' and El Niño phenomena
Toby D. Auth, Elizabeth Daly, Richard Brodeur and Jennifer Fisher

Poster presentations

Density dependent effects on growth and migratory rate during sockeye salmon early marine residency
Cameron Freshwater, Marc Trudel, Terry Beacham, Stewart Johnson, Chrys Neville and Francis Juanes

Interactive effect of thermal gradient and prey mismatch on thermal selection of juvenile Pacific cod (*Gadus macrocephalus*)
Zhe Li, Jun Yamamoto, Mitsuhiro Nakaya and Yasunori Sakurai

Climate-driven variability in forage fish biodiversity in the California Current
Jarrod A. Santora, Elliott L. Hazen, Isaac D. Schroeder, Steven J. Bograd, Keith Sakuma and John C. Field

Autumn ichthyoplankton assemblage in the Yangtze Estuary shaped by environmental factors
Hui Zhang and Weiwei Xian

Source water variability in the California Current System and implications to rockfish production
Isaac D. Schroeder, Jarrod A. Santora, Ellliott L. Hazen, Steven J. Bograd, Brian K. Wells and John C. Field

MEQ Topic Session (S3)
Source, Transport and Fate of Hydrocarbons in the Marine Environment

Co-sponsor: **GESAMP**

Co-Convenors: *Hideaki Maki (Japan), Staci Simonich (USA), Robert Duce (GESAMP, Texas A&M University)*

Invited Speaker:
Kenneth Lee (Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia)

Background

Following two successful sets of activities at PICES-2014 and PICES-2015 ('Microplastics' and 'Indicators of ocean pollution'), the Working Group on *Emerging Topics Marine Pollution* (WG 31) organized, convened and facilitated the third in its planned series of Special Sessions. The topic chosen for 2016 was to comprehensively address the science of 'Source, transport and fate of hydrocarbons in the marine environment'. This is timely for PICES as it followed up on the PICES-2015 short-term response workshop, "*Marine environment emergencies: Detection, monitoring and response*". This topic is also timely since oil and gas exploration, development and transport is taking place to varying degrees around the North Pacific Ocean. Thousands of different hydrocarbon compounds are found in fuels, each with different physical and chemical properties. The resulting complex interactions between these compounds and components of the marine environment highlight the importance of a multidisciplinary and up-to-date sharing of knowledge. This knowledge will provide insight into the consequent risks to biota, the design of monitoring programs, the choice of analytical methods, and management responses following leaks or spills.

Summary of presentations

The topic session, co-sponsored by GESAMP, focused on the behavior, fate and effects of hydrocarbons in the marine environment, as well as some logistic approaches for oil spills. While some examples of catastrophic oil spills were referred to, some discussions focused on chronic, low level releases of hydrocarbons from multiple sources that are far more evasive and widespread, and also some examples on physicochemical transformations of oil and/or hydrocarbons in marine environmental media.

Dr. Kenneth Lee, Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, gave us a comprehensive talk as invited speaker on various case studies of oil spills in terms of type of oil, environmental media, ecosystem response and counter measures. There is no universal and simple method to mitigate influences of oil spill without any adverse effect on marine ecosystems. The best possible way should be chosen for each case on the basis of scientific knowledge that has been obtained from previous examples. This was followed by some experimental studies on the influences of oil-accommodated fraction in seawater on phytoplankton and the effect of sunlight irradiation of oil slicks on marine crustaceans. The Korean research team reported experimental formation and influences of oiled particulate matter aggregates suspended in seawater. The Canadian groups reported some logistic approaches toward possible oil spill. To simulate the trajectory of spilled oil in channels in British Columbia coastal seas, many drifters have been released and simple statistical analysis of their behaviors in channels shows that it could be a useful tool to predict drifts of spilled oil. A framework has been made to assess the vulnerability of biota to oil spill in coastal areas of Canada, which identifies the areas that should be prioritized in terms of prevention of oil stranding and clean-up to mitigate potential risk of oil spills on habitats. Although the scientific contents of each presentation were rather diverse, they remind us of the importance of promoting science and technology to predict what happens in marine ecosystem after both accidental and chronic oil spills and what kinds of countermeasures should be prepared for future releases.

List of papers

Oral presentations

Sources, behaviour and environmental impacts of petroleum hydrocarbons released into the marine environment (Invited)
Kenneth Lee

Physiological responses of marine phytoplankton to oil exposure in the context of the 2015 oil spill in the Santa Barbara Channel
Tanika M. Ladd, Jessica A. Bullington, Andrea Valdez-Schulz, Paul G. Matson, and M. Debora Iglesias-Rodriguez

Photo-oxidation of crude fuel and its toxicity to marine amphipods
Hideaki Maki, Takehiko Hiwatari and Kunio Kohata

In situ formation of oil-suspended particulate matter aggregate during flushing activities
Andrew Loh, Un Hyuk Yim, Sung Yong Ha and Joon Geon An

How far will it go? The estimation of oil spill extents from surface drifter data
Charles Hannah, Hauke Blanken, Tamás Juhász and Stephen Page

A framework to assess vulnerability of biological components to oil spilled in the marine environment
Lucie Hannah, Kate Thornborough, Candice St. Germain and Miriam O

Poster presentations

Atmospheric concentration of petroleum derived polycyclic aromatic hydrocarbons after the Hebei Spirit oil spill
Joon Geon An, Un Hyuk Yim, Sung Yong Ha, Moonkoo Kim and Won Joon Shim

FIS Topic Session (S4)
Climate variability, climate change and the reproductive ecology of marine populations

Co-Convenors: *John Field (USA), Sandi Neidetcher (USA), Michio Yoneda (Japan), Sukgeun Jung (Korea)*

Invited Speakers:
Olav Kjesbu (Hjort Centre for Marine Ecosystem Dynamics, Institute of Marine Research, Bergen, Norway)
Richard McBride (NOAA Fisheries, Woods Hole Laboratory, USA)

Background

This topic session sought to expand the scope of understanding on both the mechanisms and consequences of environmental variability and climate change on the reproductive potential of marine fishes based on empirical or model-based studies. The intent was to distinguish reproductive ecology (egg and/or larval output) from recruitment processes (early life history and survival), as the two are presumed to be fundamentally different processes. Appreciation for the significance of age and size dependent factors that relate to reproductive potential was a key theme at this session, with a substantial number of talks and posters that explored such factors as size dependent energy allocation and fecundity, skipped spawning, multiple brooding and other maternal effects. Several other talks explored the contrasting examples of high turnover species, particularly indeterminate spawners, which may be more sensitive over short time scales to climate variability and change. The overall objective of the session was to begin to explore how the consequences of future climate change may interact with the effects of fishing to alter reproductive potential in exploited populations, recognizing that such impacts will likely occur in complex and unanticipated ways. The need to develop and maintain time series of data on reproductive metrics (maturity, fecundity, timing of reproductive activity) as well as to develop additional case studies on the interactions between climate and reproductive output were highlighted at the conclusion of the session.

Summary of presentations

The session included presentations that focused on a wide range of life history types but with the common theme of environmental influences on reproductive ecology and was well attended. The session included two invited speakers and twelve contributed papers (five of which were from early career scientists), as well as seven posters.

The first invited speaker, Dr. Olav Kjesbu, provided a thought provoking presentation entitled "*Crucial factors affecting reproductive investment of marine fishes in a changing climate.*" His talk focused on the need to understand the processes that function in response to environmental drivers of varying reproductive success. The talk highlighted the fact that the late oocyte stages and ovulation may represent the most constraining aerobic scope of the life history of marine fishes, yet there is very little emphasis in the literature about the potential impacts of climate change on such stages. He also suggested that studying the dynamics of fecundity allows researchers to observe the impacts of environmental fluctuations during a time when the reproductive organs require optimum conditions for development, pointing out that while oogonial proliferation might be expected to increase under climate change (increasing total fecundity), so too might atresia and comparable processes (decreasing potential fecundity). Thus, fecundity and other aspects of reproductive ecology are expected to exhibit high plasticity under future climate change scenarios. We will need improved sources of data and better conceptual models to better understand the likely direction and other consequences of change.

Dr. Richard McBride, the second invited speaker, next considered the effects of climate change by contrasting the energy storing ("capital") versus the "income" reproductive strategists, in his talk "*Fish responses to climate variation among capital-income breeders*". Noting first that reproduction is an energetically costly process, he highlighted the fact that capital breeders are able to spawn during periods of unfavorable conditions if energy stores are sufficient, but their reproductive effort may be limited by the amount of energy stored each seasonal cycle, an allometric constraint. In contrast, egg production by income breeders responds quickly as feeding conditions change, and income breeders are less restricted by allometric constraints during times of abundant resources. Examples were provided which show that many species exhibit characteristics of both strategies, and such conditional (non-genetic) plasticity, likely will buffer fish reproductive responses to climate change. For example, some fish exhibit remarkable variation in reproductive traits across environmental gradients: in American shad, annual fecundity decreases but repeat spawning increases with latitude, such that lifetime fecundity is roughly constant. Such examples of long term, intraspecific time series and case studies should be helpful in informing predictions of how current populations will respond to future climate change.

Two contributed papers in the morning presented case studies of climate impacts on the reproductive potential of specific populations. Dr. Hiroshige Tanaka presented a talk entitled "*Temperature related variability on the resource allocation to egg production in Japanese anchovy Engraulis japonicus as revealed by stable isotope approach.*" He found that changes in stable isotope ratios were effective at identifying the impacts of variable water temperatures to resource allocation and subsequent egg production. While the results were consistent with the idea that Japanese anchovy are largely income breeders, their resource allocation strategy could be more complicated than previously considered.

Next, Ms. Laura M. Slater presented a talk entitled "*Female reproductive potential of eastern Bering Sea snow crab (Chionoecetes opilio),*" which explored how exploitation of male crabs could influence female reproductive potential and stock productivity. She presented data from ongoing time series and research in this population indicating that demography has a strong influence on egg output and that there has been little evidence for sperm limitation in this.

The afternoon talks began with a presentation by Dr. Michio Yoneda, one of the session co-conveners, entitled "*Size dependent energy allocation to reproductive output of short-lived multiple-batch spawning Japanese anchovy Engraulis japonicus.*" This paper explored the flexibility of energy allocation to reproductive output between small and large Japanese anchovy using carbon and nitrogen stable isotope ratios as quantitative indicators. Results suggested some differences among the two size classes in the sources of energy used for

egg production: larger individuals took advantage of more "bet hedging" spawning strategies in response to variable climate conditions.

Next, Dr. Christina Conrath discussed the model impacts of skipped spawning on stock assessment biomass and catch limits for three species of rockfish in the North Pacific Ocean in a talk entitled "*Variability in spawning omission and the productivity of deepwater rockfish in the North Pacific Ocean.*" Her results indicated that skipped spawning varied among species. Very preliminary results indicated some potential for temporal variability in the fraction of mature females that may skip spawning in any given year, but more data are necessary to explore the extent of such variability and any linkages to climate.

Climate and seabird productivity was explored in a talk by Ms. Yutzil Lora-Cabrera entitled "*Impacts of recent environmental anomalies on seabirds of the Baja California Pacific Islands, Mexico.*" In this analysis, she described increased nest abandonment and low reproductive performance for brown pelicans and Brandt's cormorants in Baja California during 2014 and 2015, apparently in response to warm water temperatures anomalies.

Canary rockfish were the focus of a talk by Dr. Melissa Head entitled "*Assessing maturity, skipped spawning, and abortive maturation for fisheries managers: a case study of Sebastes pinniger.*" She presented efforts to incorporate accurate estimates of life history parameters into population models by including estimates of abortive maturation and skipped spawning. She suggested that a better understanding of how ocean conditions influence reproduction will aid in assessing the vulnerability of such population to climate impacts.

The afternoon's only mollusk case study was provided by Mr. Hyun-Sung Yang, whose talk was entitled "*Inter-annual variation in the reproductive pattern of Manila clam Ruditapes philippinarum and impacts of Perkinsus olseni infection on the reproduction observed from the west coast of Korea.*" His results indicated that spawning duration and frequency varied substantially from year to year, but that gonadosomatic indices were more variable in areas of greater disease infection intensity.

Rockfish returned back to the main stage in the final talk before the afternoon break, presented by Ms. Sabrina Beyer's talk entitled "*Interannual variability in larval production of rockfishes (Sebastes* spp.*) in the California Current.*" Her talk focused on a growing time series of fecundity estimates of chilipepper (*Sebastes goodei*) and yellowtail (*S. flavidus*) rockfish, and indicated that even after accounting for regional and size-dependent influences on total fecundity, significant differences in reproductive output (including the frequency of multiple brooding) could be attributed to environmental variability.

To assess the impacts of environmentally induced variability on reproductive reference points, Dr. Loretta O'Brien developed a suite of models relating maturity to age and bottom temperatures in a talk entitled "*Evaluating environmental effects on maturity, spawning stock biomass, and biological reference points of Georges Bank Atlantic cod using state-space models.*" Her results suggested that changes in temperature or other environmental processes influence maturation, that biological reference points appear to be more robust to environmental variability while spawning stock estimates are more sensitive, and that state space models provide a robust approach for including environmental effects in stock assessments.

Ms. Peng Sun used both simulation and experimental methods to evaluate changes in fish phenotypic traits in a talk entitled "*Fisheries-induced evolution effects on fish populations in the East China Sea and its management implications.*" These results suggest important implications for fishery management references points and contribute to the basic theoretical development of studies on phenotypic life history plasticity and the potential for fisheries-induced evolution.

Walleye pollock in the Western Pacific were the subject of the talk by Ms. Moojin Kim entitled "*Differences in biological characteristics and recruitment variability of walleye pollock (Gadus chalcogrammus) off the eastern Korean Peninsula during 1960s–2000s.*" Ms. Kim found shifts in both the size structure and length of 50% maturity for Korean pollock between early stages of the fishery (in the 1950s) and more recent time periods, likely in response to forage (euphausiid) availability.

Ms. Sandra Neidetcher, a session co-convener, concluded the session with the second talk to focus on walleye pollock, entitled "*Fecundity estimates for walleye pollock during varying climate conditions,*" in which she analyzed fecundity data and the occurrence of atresia in this species in the Eastern Bering Sea and Gulf of Alaska over a 20+ year time period. Results indicated both interannual and regional variability in fecundity over the duration of the time series; the effects were enhanced by increased levels of atresia during years of unusually warm water temperatures in the Gulf of Alaska.

List of papers

Oral presentations

Crucial factors affecting reproductive investment of marine fishes in a changing climate (Invited)
Olav Sigurd Kjesbu

Fish responses to climate variation along a capital-income breeding continuum (Invited)
Richard S. McBride

Temperature-related variability in the resource allocation to egg production in Japanese anchovy *Engraulis japonicus* as revealed by stable isotope approach
Hiroshige Tanaka, Michio Yoneda, Hajime Kitano, Kohei Kawamura, Michiya Matsuyama and Seiji Ohshimo

Female reproductive potential of eastern Bering Sea snow crab (*Chionoecetes opilio*)
Laura M. Slater, Joel B. Webb, Gordon Kruse, Franz J. Mueter, Bernard Sainte-Marie, Ginny L. Eckert and Douglas Pengilly

Size dependent energy allocation to reproductive output of short-lived multiple-batch-spawning Japanese anchovy *Engraulis japonicus*
Michio Yoneda, Satoshi Katayama, Naoaki Kono, Masayuki Yamamoto, Tatsuo Tsuzaki and Hiroshige Tanaka

Variability in spawning omission and the productivity of deepwater rockfish in the North Pacific Ocean
Christina L. Conrath and Peter-John F. Hulson

Impacts of recent environmental anomalies on seabirds of the Baja California Pacific Islands, Mexico
Yutzil Lora-Cabrera, D. Martínez-Cervantes, E. Rojas-Mayoral, A. Hernández-Ríos, E. Bravo-Hernández, A. Fabila-Blanco, M. Corrales-Sauceda, A. Aguilar-Vargas, A. Aztorga-Ornelas, M. Félix-Lizárraga, Y. Bedolla-Guzmán, A. Aguirre-Muñoz and F. Méndez-Sánchez

Challenges associated with assessing maturity, skipped spawning, and abortive maturation rates for fisheries managers: a case study of *Sebastes pinniger*
Melissa A. Head, Peter H. Frey, Jason M. Cope and Aimee A. Keller

Inter-annual variation in the reproductive pattern of Manila clam *Ruditapes philippinarum* and impacts of *Perkinsus olseni* infection on the reproduction observed from the west coast of Korea
Hyun-Sung Yang, Do-Hyung Kang and Kwang-Sik Choi

Interannual variability in larval production of rockfishes (*Sebastes* spp.) in the California Current
Sabrina G. Beyer, Susan M. Sogard, E.J. Dick, David M. Stafford, Lyndsey S. Lefebvre, Neosha S. Kashef and John C. Field

Evaluating environmental effects on maturity, spawning stock biomass, and biological reference points of Georges Bank Atlantic cod using state-space models
Timothy J. Miller, Loretta O'Brien and Paula Fratantoni

Fisheries-induced evolution effects on fish populations in the East China Sea and its management implications
Peng Sun, Zhenlin Liang, Rong Wan and Yongjun Tian

Differences in biological characteristics and recruitment variability of walleye pollock (*Gadus chalcogrammus*) off the eastern Korean Peninsula during 1960s–2000s
Moojin Kim, Sukyung Kang and Suam Kim

Fecundity estimates for walleye pollock during varying climate conditions
Sandra Neidetcher

Poster presentations

Plasticity in reproductive strategies for rockfish in the Southern California Current and linkages to maternal characteristics and climatic variability
Lyndsey S. Lefebvre, Sabrina G. Beyer, Neosha S. Kashef, David M. Stafford, Susan M. Sogard and John C. Field

Ovarian development, energy storage, and skipped spawning in female sablefish in Alaska
Cara Rodgveller, Katy Echave, Peter-John Hulson and Karson Coutré

Effects of the North Pacific Current on productivity of 163 Pacific salmon stocks
Michael J. Malick, Sean P. Cox, Franz J. Mueter, Brigitte Dorner and Randall M. Peterman

Influence of environmental factors and density dependence on variability in reproductive output and growth of Atka mackerel (*Pleurogrammus monopterygius*)
Susanne McDermott and Morgan Arrington

Temperature effects on the reproductive traits of walleye pollock *Gadus chalcogrammus*
Hiroshige Tanaka, Toru Nakagawa, Takashi Yokota, Naoto Murakami, Masayuki Chimura, Yuuho Yamashita and Tetsuichiro Funamoto

Identifying robust model selection tools for including environmental links to recruitment in North Pacific groundfish stock assessments
Ashley E. Weston, Carey R. McGilliard and Gavin Fay

BIO/MONITOR/MEQ Topic Session (S5)
Understanding our changing oceans through species distributions and habitat models based on remotely sensed data

Co-Convenors: *Patrick O'Hara (Canada), Elliott Hazen (USA), Sei-Ichi Saitoh (Japan), Yutaka Watanuki (Japan)*

Invited Speakers:
Robert Suryan (Oregon State University, OR, USA)

Background

In this session we identified and explored processes underlying or driving distributions and abundances of marine organisms. Satellite remote sensing oceanography products directly measured habitat characteristics such as bathymetric features or ice-extent/coverage or were used as proxies for features such as convergent fronts or water masses. Increasingly Species Distribution Models (SDM) are based on Regional Ocean Modelling System (ROMS) data assimilation models – this is proving to be a very powerful development for accurately predicting species distributions and/or abundances particularly with respect to climate change and changing ocean conditions.

Summary of presentations

The talks were diverse yet shared key characteristics – they all discussed how species distributed themselves and explored the how and why (as per Robert Suryan's plenary talk) they distribute themselves the way they do, with the help of remote sensing and remote sensing based oceanography products as indices of potential distribution drivers. The talks varied in that they explored relationships among species abundance/distributions, or aggregations within and/or among species, with a variety of remotely sensed variables as predictors including but not limited to SST, SSH, bathymetry, and Chl$_a$. These relationships were explored over a range of spatial and temporal scales, from basin level to mesoscale and from decadal to daily. In some cases, relationships were explored to better understand factors driving species distributions and abundances, and in other cases, model output had direct applications such as fisheries management and threat mitigation. Talks focused on a range of taxa from planktonic to squid/saury to top predators.

There were participants from Japan (5), China (1), USA (10), Russia (1), Canada (1) and Mexico (1) in this session. Several talks explored the relationship between at-sea distribution/abundances or movement data with remotely sensed data and/or oceanography products based on these data (often refered to as biophysical parameters). Palacios *et al.* used remotely sensed variables as proxies for mechanisms favoring krill aggregations to model blue whale movement behaviour, and Santora *et al.* discussed the importance of remotely sensed bathymetry and in particular shelf incising canyons for modeling krill aggregations themselves. Others explored seasonal patterns in these relationships such as distributions of Short-tailed

Shearwater and their prey with SST in the in the Bering and Chukchi Seas (Nishizawa *et al.*), the Laysan Albatross off Mexico (Munguía-Cajigas *et al.*), salmon prey assemblages in the California Current (Friedman *et al.*), and gonate squid in the Northwest Pacific (Kulik *et al.*). Some of the talks explored these relationships over longer term variation such as ENSO (Joyce *et al.*), and climate change effects in the Bering Sea on ice and seabirds (Hunt *et al.*) and bioclimatic velocity for Walleye Pollock (Alabia *et al.*), and in the northwest Pacific on gonate squid (Kulik *et al.*). There was an even mixture of talks that looked at single species response to oceanography or multiple species. Of note, Joyce *et al.* discussed seabird-tuna-dolphin aggregations and ENSO, Friedman *et al.* relate salmon prey assemblages with oceanographic conditions, Dick *et al.* predicted seabird assemblages, and Baker *et al.* used environmental thresholds to predict changes in species interactions to inform multispecies models. There were two talks from the Southwest Fisheries Science Center (NOAA) that described developments towards dynamic ocean management – Becker *et al.* explored the utility of ROMS as a basis for near real time cetacean SDMS and Hazen *et al.* used Earth Observation data as a basis for habitat modeling and ultimately bycatch mitigation for a number of species including leatherback turtles, sea lions, and blue sharks. Two talks from Japan also had direct applications in that they described modeling projects oriented to support and manage fishing industries such as Pacific Saury (Syah *et al.*) and flying squid (Igarashi *et al.*). IPCC scenarios and habitat models were used to predicted distribution changes for saury in the Northwest Pacific by Syah *et al.* and a suite of seabird species in the California Current Ecosystem by Dori Dick *et al.*

There was a brief discussion near the end of the session during the time slot for a talk that was cancelled at the last minute. During this discussion, we explored interest in submitting the talks as papers in a special edition of a primary publication. Only half of the authors were present, but all agreed that they would be interested in submitting, including – Daniel Palacios, Daniella Munguía-Cajigas, Dori Dick Irene Alabia, Matthew Baker, Vladimir Kulik, and Sei-Ichi Saithoh (on behalf of Syah). The convenors will follow up with these authors and those remaining (Elizabeth Becker, Jarrod Santora, Brian Wells, Trevor Joyce, Bungo Nishizawa, and George Hunt) to further solidify this interest as well as draft up plans to move forward on this.

List of papers

Oral presentations

Making the most of satellite-derived oceanographic data and habitat use models to understand species distributions
Robert M. Suryan

Moving towards dynamic ocean management: How well do modeled ocean products predict species distributions?
Elizabeth A. Becker, Karin A. Forney, Paul C. Fiedler, Jay Barlow, Susan J. Chivers, Christopher A. Edwards, Andrew M. Moore and Jessica V. Redfern

Spatio-temporal patterns of potential fishing zones for Pacific saury in a warming climate
Achmad Fachruddin Syah, Sei-Ichi Saitoh, Irene D. Alabia and Toru Hirawake

Modeling blue whale movement behavior in relation to environmental conditions in the California Current from satellite tracking and remote sensing
Daniel M. Palacios, Ladd M. Irvine, Bruce R. Mate, Elliott L. Hazen, Karin A. Forney, Elizabeth A. Becker, Monica L. DeAngelis, Steven J. Bograd and Helen Bailey

Foraging patterns of Laysan Albatross from Guadalupe Island, Mexico and their relation to oceanographic variables from the California Current System
Daniela Y. Munguía-Cajigas, Julio César Hernández-Montoya, Evaristo Rojas-Mayoral, Yuliana Bedolla-Guzmán, Federico Méndez-Sánchez and Alfonso Aguirre-Muñoz

Submarine canyons and essential krill habitat: Implications for modeling distribution patterns under climate change
Jarrod A. Santora, Jeffrey G. Dorman, Ramona Zeno and William J. Sydeman

Forecasting bycatch and ship strike risk for dynamic ocean management in the California Current
Elliott L. Hazen, Kylie L. Scales, Dana K. Briscoe, Steven J. Bograd, Larry B. Crowder, Rebecca Lewison and Sara Maxwell

Seasonal distribution of short-tailed shearwaters and their prey in the Bering and Chukchi seas
Bungo Nishizawa, Kohei Matsuno, Takashi Yamamoto, Elizabeth A. Labunski, Kathy J. Kuletz, Atsushi Yamaguchi and Yutaka Watanuki

Relationships between seabird, tuna, and dolphin foraging aggregations and El Niño-Southern Oscillation in the oceanic eastern tropical Pacific
Trevor W. Joyce, Robert L. Pitman and Lisa T. Ballance

Climate change impacts on distribution patterns of boreopacific gonate squid (*Boreoteuthis borealis*) in the Northwest Pacific
Vladimir V. Kulik, Oleg N. Katugin, Mikhail A. Zuev

Salmon prey assemblages and oceanographic conditions along the California Current Shelf Ecosystem
Whitney Friedman, Brian Wells, Jarrod Santora, John Field, Richard Brodeur, David Huff and Isaac Schroeder

Eastern Bering Sea seabirds shift distributions in response to timing of sea-ice retreat
George L. Hunt, Jr, Jarrod Santora, Martin Renner, Lisa Eisner, Sigrid Salo and Kathy Kuletz

Bioclimatic velocity for walleye pollock in the Bering Sea
Irene D. Alabia, Jorge Garcia Molinos, Sei-Ichi Saitoh and Toru Hirawake

Forecasting the flock: Using species distribution models to evaluate the effects of climate change on future seabird foraging aggregations in the California Current System
Dorothy M. Dick, Jaime Jahncke, Nadav Nur, Julia Howar, Jeanette E. Zamon, David G. Ainley, Ken H. Morgan, Lisa T. Ballance and David Hyrenbach

Adaptive improvement of habitat suitability index (HSI) model for neon flying squid in central North Pacific by using ocean forecasts and real-time fishery reports
Hiromichi Igarashi, Yoichi Ishikawa, Tsuyoshi Wakamatsu, Yusuke Tanaka, Masafumi Kamachi, Norihisa Usui, Mitsuo Sakai, Sei-ichi Saitoh and Yutaka Imamura

Integrating species environmental thresholds to explore species interactions and parameterize multi-species models
Matthew Baker, Kirstin Holsman and Anne Hollowed

Poster presentations

Impacts of climate change on suitable region for Japanese scallop aquaculture in Shandong, China and southern Hokkaido, Japan, using RS/GIS
Yang Liu, Sei-Ichi Saitoh1, Yongjun Tian and Rong Wan

Integrating habitat, prey and predators over space and time to assess distributional responses to environmental variability and climate change
Caren Barceló, Lorenzo Ciannelli, Ryan Rykaczewski, Bryan Wright, Richard D. Brodeur and Leigh Torres

Distribution of Arctic and Pacific copepods and their habitat in the northern Bering and Chukchi Seas
Hiroko Sasaki, Kohei Matsuno, Amane Fujiwara, Misaki Onuka, Atsushi Yamaguchi, Hiromichi Ueno, Yutaka Watanuki and Takashi Kikuchi

POC/MEQ/MONITOR/BIO Topic Session (S6)
What factors make or break trophic linkages?

Co-Convenors: *Elliott L. Hazen (USA), Jameal Samhouri (USA), Shin-Ichi Ito (Japan), Jennifer Boldt (Canada)*

Invited Speakers:
Masashi Kiyota (National Research Institute of Far Seas Fishereis, Fishey Resarch Agency, Japan)
Kenneth Rose (College of the Coast & Environment, Louisiana State University, USA)

Background

Mechanistic linkages from physics to phytoplankton to zooplankton to fish remain a central goal of understanding climate forcing on marine ecosystems. Thus, this session aimed to understand how ecosystem linkages and species distributions are influenced by ocean features and how these linkages translate through the food web. Specifically, what information can be gained from moving beyond a single linkage (*e.g.*, phytoplankton to zooplankton) towards a comparison across trophic levels across different North Pacific ecosystems. We had chosen three study areas, the California, the Kuroshio Current, and the Bering Sea to examine from physics to phytoplankton, phytoplankton to zooplankton, zooplankton to fish, birds and

mammals, and fish to birds and mammals but received talks from many more ecosystems. By looking particularly across multiple ecosystems and trends and anomalies at multiple trophic linkages, we can better understand how climate variability and anthropogenic forcing may cascade through these marine ecosystems. S6 presentations included topics that (a) examine how physical oceanography in both study areas lead to long term trends or anomalous responses in primary production, zooplankton, fish, and top predators (b) assess how primary productivity results in spatial patterning of mid and high trophic levels, (c) how trophic relationships may respond to physical forcing, changes in spatial distribution, and species abundances, and (d) test for threshold responses (non-linearity) across trophic levels to changes in physical oceanography and the abundance of other species (competitors, prey, and predators).

Summary of presentations

Masashi Kiyota (Invited) gave a talk titled "*Response of commercial fisheries and a top predator to long-term ecosystem fluctuations in the western North Pacific Ocean off northeastern Japan*". Dr. Kiyota presented general concepts overarching four main topics: the classification and characterization of oceanic ecosystems using scientific survey data/samples, top predators as indicators of ecosystem change, commercial fisheries as consumers in marine food webs, and information feedback to the commercial market and general public.

Charles Stock presented information on trophodynamic drivers of global fisheries catch in which he combined three observational and modeling advances to examine whether primary production could explain fishery catches. He showed that processes may amplify projected trends under climate change. Jennifer Boldt examined bottom-up, top-down, and competitive factors that might affect juvenile Pacific herring abundance and condition in the Strait of Georgia, British Columbia. George Hunt discussed the variation in ice retreat timing and its effects on zooplankton abundance, size composition, and pollock survival. Sonia Batten compared trophic linkages across the PICES region, based on Continuous Plankton Recorder (CPR) data. She gave an overview of three projects that have used CPR data to show mechanistic linkages between plankton and higher trophic levels.

Kenneth A. Rose (Invited) presented on "*Linear and non-linear responses of marine and coastal fish populations to habitat: a view from the virtual world*" in which he talked about how we sometimes confuse model inputs and emergent properties. He summarized three examples of modeling and showed that the capabilities for assessing habitat effects on upper trophic level dynamics is limited and behavioural movement drives model results.

Konstantin Rogachev examined the effects of freshwater discharge and tidal currents on zooplankton aggregations in the coastal Sea of Okhotsk. He showed that changes in freshwater and coastal circulation altered the abundance of zooplankton. In Julie E. Keister's presentation on cryptic trophic connections to juvenile salmon survival revealed by a zooplankton time series, she examined factors, including copepod abundance and community composition that might control Coho Salmon survival. Anela Choy talked about trophic diversity of pelagic "forage species" in the central North Pacific and northern California Current ecosystems.   She showed that marine fish sampling methodologies have biases. She examined long-nosed lancetfish as samplers of the fish community and that different sampling methodologies may reveal different perspectives on trophic food webs. Hitomi Oyaizu investigated the spatio–temporal variability in growth and migration of Pacific saury (*Cololabis saira*) associated with environmental conditions using an individual-based model. Kelly Kearney's talk used a modeling approach to compare primary production pathways in warm and cold years in the Bering Sea. She also examined the effects of mesozooplankton and benthos to different food pathways. Brian Wells examined the effects of upwelling, prey, and seabirds on Chinook salmon. Yoichi Miyake looked at how Japanese eels, a top predator in river ecosystems, accomplish cross-shelf migration using warm water intrusions of the Kuroshio current.

Adam J. Schlenger presented on the temporal variability of net primary production driving global patterns of structure and function across multiple marine ecosystems in which he examined holistic approaches to complex systems. He looked at temporal variability of net primary production and patterns across multiple

indices of structure and function. In her presentation, Kirstin Holsman used a regional downscaled model and bioenergetics model to project climate change effects on pollock. Brian Hunt talked about salmon as integrative samplers of high seas food web. He used isotope data to understand food-web dynamics and life history conditions that Sockeye salmon experience at sea.

Overall, the session covered a suite of topics across multiple PICES interests. There were 10 talks that primarily used data, and 5 that primarily used models. The talks focused on phytoplankton (1), zooplankton (8), fish (13), top predators (4), and humans (1) as well as ecosystem linkages to these groups, highlighting the cross-disciplinary nature of the session. In addition, the session highlighted that, in moving forward, there is a need to include both the top and bottom of the food web. There were some unique topics focusing on trophic methodologies, such as Dr. Rose's talk on how animal behavior may drive trophic interactions in an individual-based model. In addition, the comparison of diet studies to shipboard-surveys, as presented by Dr. Choy, highlighted some of the methodological limitations in understanding trophic interactions. The idea of a review paper was brought up at the end of the session and discussions may continue via email. The attendance was high throughout the day, so a follow-up topic session in the future would likely be just as successful.

<u>List of papers</u>

Oral presentations

Response of commercial fisheries and a top predator to long-term ecosystem fluctuations in the western North Pacific Ocean off northeastern Japan (Invited)
Masashi <u>Kiyota</u> and Shiroh Yonezaki

Trophodynamic drivers of global fisheries catch
Charles A. <u>Stock</u>, Jasmin G. John, Ryan R. Rykaczewski, Rebecca G. Asch, William W.L. Cheung, John P. Dunne, Kevin D. Friedland, Vicky W.Y. Lam, Jorge L. Sarmiento and Reginald A. Watson

Juvenile Pacific Herring (*Clupea pallasi*) trophic linkages in the Strait of Georgia, British Columbia
Jennifer <u>Boldt</u>, Matthew Thompson, Chris Rooper, Chrys Neville, Doug Hay, Jake Schweigert, Rusty Sweeting, Jaclyn Cleary and Marc Trudel

Life at the ice edge: Does the timing of ice retreat set the table in the eastern Bering Sea?
George L. <u>Hunt</u>, Jr., Lisa Eisner, Edward Farley and Janet Duffy-Anderson

A comparison of trophic linkages across the PICES region, based on Continuous Plankton Recorder data
Sonia <u>Batten</u>, Mark Hipfner, Steve Moffitt and Scott Pegau

Linear and non-linear responses of marine and coastal fish populations to physics and habitat: A view from the virtual world (Invited)
Kenneth A. <u>Rose</u>

Effects of freshwater discharge and tidal currents on zooplankton aggregations in the coastal Sea of Okhotsk
Konstantin <u>Rogachev</u> and Natalia Shlyk

Cryptic trophic connections to juvenile salmon survival are revealed by a zooplankton time series
Julie E. <u>Keister</u>, Marc Trudel, Jennifer L. Boldt, Bethellee Herrmann, Mara S. Zimmerman and Matthew Thompson

New insights on the trophic diversity of pelagic "forage species" in the central North Pacific and Northern California Current ecosystems
C. Anela <u>Choy</u>, Jeffrey J. Polovina and Bruce H. Robison

Modeling recruitment variability of Pacific saury (Cololabis saira) using an individual-based model
Hitomi <u>Oyaizu</u>, Satoshi Suyama, Shin-ichi Ito, Daisuke Ambe, Takahiko Kameda, Takeshi Terui, Michio J. Kishi and Sachihiko Itoh

A comparison of Bering Sea ecosystem energy pathways in warm versus cold years
Kelly <u>Kearney</u>, Al Hermann, Ivonne Ortiz, and Kerim Aydin

Caught in the middle: Top-down impact of seabirds on Chinook salmon (*Oncorhynchus tshawytscha*) is dependent on bottom-up mechanisms
Brian K. <u>Wells</u>, Jarrod A. Santora, Mark Henderson, Peter Warzybok, Jaime Jahncke, Russell W. Bradley, David D. Huff, Isaac D. Schroeder, Peter Nelson, John C. Field and David G. Ainley

Shoreward intrusions of Kuroshio waters may influence the recruitment of a top predator in river ecosystems
Yoichi <u>Miyake</u>, Aigo Takeshige, Hikaru Itakura, Akira Yoshida and Shingo Kimura

Temporal variability of net primary production drives global patterns of structure and function across multiple marine ecosystems
Adam J. Schlenger, Simone Libralato and Lisa T. Ballance

Suboptimal thermal conditions and spatial mismatch between predators and prey and may limit walleye pollock growth under climate change
Kirstin Holsman, Anne Hollowed, Kerim Aydin, Jim Ianelli and André Punt

Integrating stable isotope analyses of zooplankton and returning adult salmon tissues to inform high seas North Pacific food web dynamics
Brian P.V Hunt, Evgeny A. Pakhomov and Sonia D. Batten

Poster presentations

Anomalous ocean conditions in 2015 and the impact on spring Chinook salmon and their prey field
Elizabeth A. Daly, Richard D. Brodeur and Toby D. Auth

Interannual variation in phytoplankton blooms and its biological impacts in the Sea of Japan
Taketoshi Kodama, Taku Wagawa, Ken-ichi Fukudome, Haruyuki Morimoto, Naoki Iguchi, Seiji Ohshimo and Tohya Yasuda

Developing marine food web models to evaluate blue whale, Cassin's auklet and salmon responses to long- and short-term changes in oceanography in the California Current
Ryan J. Hartnett, Karina Nielsen, Frances Wilkerson, Meredith Elliott, Nadav Nur and Jaime Jahncke

Fine scale oceanography and the ecology of juvenile Chinook salmon in the Salish Sea
William D. P. Duguid and Francis Juanes
Presented by Francis Juanes on behalf of William D. P. Duguid

Impact of physiological flexibility of phytoplankton on modeled primary production in the western North Pacific
Yoshikazu Sasai and S. Lan Smith

Climate events and recruitment dynamics of anchovy in the California Current: A mechanistic understanding using a climate-to-fish model
Dimitris V. Politikos, Enrique N. Curchitser and Kenneth A. Rose

Deepening thermocline displaces salmon catch on the Oregon coast
Peter Lawson, Cheryl Harrison and Lorenzo Ciannelli

Biogeography of seabird assemblages in the Bering Sea: spatial assessment of oceanographic drivers and multispecies aggregation hotspots
Jarrod A. Santora, Lisa Eisner, Kathy Kuletz, Carol Ladd, Martin Renner and George L. Hunt Jr

Winter phytoplankton blooms and trophic implications on copepod and krill biomass and egg production in the northern California Current
Xiuning Du, William Peterson, Tracy Shaw, Jennifer Fisher and Jay Peterson

Jellyfish - fish trophic interactions in the Bering Sea: ecosystem impacts of jellyfish population fluctuations
James J. Ruzicka, Richard D. Brodeur, Mary Beth Decker and Kristin Cieciel

Sim-turtle: biophysical interactions in the mesoscale
Cheryl S. Harrison

POC/TCODE/MEQ Topic Session (S7)
New stage of ocean acidification studies: Responses of oceanic ecosystem including fisheries resources

Co-sponsor: ICES

Co-Convenors: *Tsuneo Ono (Japan), Jun Kita (Japan), Debby Ianson (Canada), John Pinnegar (ICES / UK)*

Invited Speakers:
John Pinnegar (Centre for Environment, Fisheries & Aquaculture Science, UK)
George Waldbusser (Oregon State University, USA)
Steve Widdicombe (Plymouth Marine Laboratory, UK)

Background

Considering over 20 years of progress on ocean acidification studies, our knowledge on biological responses in response to acidified ocean environments has accumulated to some extent. WGII report of IPCC AR5 illustrates a sensitivity matrix of ocean life to acidification among a wide range of species and pCO$_2$ levels, showing our present terminus of this scientific topic. However, our progress simultaneously awakes various new questions, such as the response of biology to temporally-varied pCO$_2$, inter-species interactions under acidified environments, and biological adaptation. Also, we have gradually come to realize the existence of ocean acidification by eutrophication, as well as by anthropogenic CO$_2$, in coastal regions. Emergence of these new questions reveals that we are now moving into a new stage of understanding on the ocean acidification problem, in which we may be able to make more realistic and quantitative predictions about future biological/ecological responses to an acidified ocean, and socio-economic response of humans to changes in ocean conditions. In this session, diverse studies on biological/ecological responses to ocean acidification, including fisheries resources, both in coastal and open ocean environments were presented.

Summary of presentations

Thirteen oral presentations, including three invited talks (Steve Widdicombe, George G. Waldbusser and John Pinnegar), as well as seven poster presentations, attracted over 100 participants. Several sessions in past PICES Annual Meetings had treated ocean acidification, but these had tended to focus mainly on changes in carbon chemistry and its consequences in lower trophic ecosystem. In this session, therefore, we tried to enhance the scope to the OA response of higher trophic level species such as fishes and large benthos, and their consequence to fisheries. Results of various cultivation studies for clubs, mussels and fishes were presented as this result, and moreover, many of these treated advanced topics such as multi-stressor response and biological adaptation / acclimation. The acclimation issue was especially highlight throughout the session, as it largely changes the future projection of population model for each OA-affected species. The importance of the effect of short-term variation of environmental pH (or Ω) was also emphasized by many presentations. Despite all this bountiful information on higher-trophic level biological studies, however, it was disappointing that a very limited number of reports was presented on their economical / social consequences. This may be a most significant difference between PICES and ICES at the present stage, as many economical / social assessments were made for OA in ICES communities. We plan to re-visit this topic session within the next few years to encourage more economical / social studies as well as oceanology / fisheries studies at that time.

List of papers

Oral presentations

Ocean acidification: What can species responses tell us about ecosystem consequences? (Invited)
Steve Widdicombe

Coastal zone acidification and bivalves: Carbonate chemistry complexity, high frequency variability, and organism interactions, oh my! (Invited)
George G. Waldbusser, Iria Gimenez, Stephanie R. Smith and Burke HAles

Effects of Ocean Acidification on Temperate Coastal Marine Ecosystems and Fisheries in the Northeast Pacific
Rowan Haigh, Debby Ianson, Carrie A. Holt, Holly E. Neate and Andrew M. Edwards

The 2016 NOAA west coast ocean acidification cruise
Richard A. Feely, Simone R. Alin, Nina Bednarsek, Wiley Evans, Debby Ianson, Dana Greeley, Brendan Carter, Julian Herndon and J. Martin Hernandez-Ayon

Respiration and enhanced ocean acidification in the hypoxic zone off the Changjiang estuary
Jinwen Liu, Minhan Dai, Xu Dong and Hongjie Wang

Ocean acidification and increased temperatures reduce young-of-the-year red king crab (*Paralithodes camtschaticus*) survival, but not growth or morphology
Katherine M. Swiney, W. Christopher Long and Robert J. Foy

Interactive effects of ocean acidification and ocean warming on Pacific herring (*Clupea pallasi*) early life stages
Cristina Villalobos, Brooke Love, Brady Olson and Leo Bodensteiner

Nutritional and ocean acidification effects on larval growth of a north Pacific flatfish
Thomas P. Hurst, Benjamin J. Laurel, Eric Hanneman, Scott A. Haines and Michele Ottmar

Identifying potential ecosystem effects of ocean acidification using size structured food web models
Jonathan Reum, Kirstin Holsman, Kerim Aydin, Anne Hollowed and Julia Blanchard

Ocean acidification research in the United Kingdom: Scaling from chemistry to commercial fisheries
John K. Pinnegar, Silvana Birchenough, Clare Ostle and Phil Williamson

Effects of ocean acidification on growth of juvenile Japanese surf clam *Pseudocardium sachalinense*
Masahiro Hayashi, Ryota Suwa, Chiho Kishida, Yusuke Watanabe, Yasushi Minowa, Kozue Nishida, Atsushi Suzuki and Yukihiro Nojiri

Sustainability of crab fisheries with ocean acidification uncertainty in Alaska
Robert J. Foy, W. Christopher Long, Katherine M. Swiney, Andre Punt, Michael Dalton and Shannon Meseck

Anticipated impacts of ocean acidification on local societies in Japan
Masahiko Fujii

Poster presentations

Is there decadal change in shell morphology of planktonic foraminifera due to ocean acidification?
Minoru Kitamura, Katsunori Kimoto, Yuriko Nakamura, Masahide Wakita, Sanae Chiba and Sonia Batten
Presented by Sanae Chiba on behalf of Minoru Kitamura

Frequent column observations revealed low pCO_2 water under the sea ice melt in the Canada Basin of the Arctic Ocean
N. Kosugi, D. Sasano, M. Ishii, S. Nishino, H. Uchida and H.Y. Inoue

The combined effect of high pCO_2 and warming on reproduction of Japanese whiting *Sillago japonica*
Ryota Suwa, Yuzo Yamamoto, Masahiro Hayashi, Takashi Kikkawa, Yusuke Watanabe, Yasushi Minowa and Yukihiro Nojiri

Dynamic of aragonite saturation horizon depth in waters of Baja California, Mexico
Norma L. Oliva, J. Martín Hernández, Reginaldo Durazo, Simone R. Alin, Eduardo Santamaría and J. Augusto Valencia

Development of communication tools on ocean acidificaton
Tomohiko Tsunoda and Keita Furukawa

Seasonal variations of pH and aragonite saturation at oyster culture beds in Tongyeong & Geoje Bays, southeast coast of Korea
JeongHee Shim, Jeong-Min Shim, Jung-No Kwon and Yong-Hwa Lee

Physiological responses of coastal and oceanic diatoms to diurnal fluctuations in seawater carbonate chemistry under two CO_2 concentrations
Futian Li, Yaping Wu, David A. Hutchins, Feixue Fu and Kunshan Gao

MoE/MEQ/TCODE Topic Session (S8)
The effect of marine debris caused by the Great Tsunami of 2011

Co-sponsor: PICES MoE ADRIFT Project

Co-Convenors: *Cathryn Clarke Murray (Canada), Nancy Wallace (USA), Hideaki Maki (Japan), Thomas Therriault (Canada)*

Invited Speakers:
James Carlton (Professor of Marine Sciences Emeritus, Williams College, USA)

Background

The Great Tsunami of 2011 washed an estimated five million tons of debris into the Pacific Ocean. The Government of Japan estimates that 70% of that debris sank close to shore, leaving 1.5 million tons floating in the North Pacific with the potential to arrive on North American and Hawaiian coastlines. While shorelines worldwide already endure marine debris from terrestrial and aquatic sources there may be additional impacts from the increase in abundance and differing debris types associated with the tsunami. Aside from the impacts of additional marine debris itself, there is the possibility of debris carrying coastal Japanese species to new habitats. An event of this magnitude offers unique opportunities to investigate the transport of non-native species, oceanographic processes and impacts of marine debris in general. With Working Group (WG 21) on *Non-indigenous Aquatic Species* completed in 2012 and Working Group (WG 31) on *Emerging Topics in Marine Pollution* formed in 2013, PICES members are well-placed to contribute to research on the potential impacts of Japanese tsunami marine debris. Funded by the Ministry of Environment of Japan, research on the effect of tsunami marine debris is ongoing under the PICES project ADRIFT (Assessing the Debris-Related Impact From Tsunami). Session presentations covered the surveillance and monitoring of tsunami-generated marine debris, modeling the movement of marine debris in the North Pacific, the impacts of tsunami debris and the risk from potentially invasive species to coastal ecosystems.

Summary of presentations

During the session, 15 oral presentations and seven poster presentations were given. The invited speaker, James Carlton of Mystic College opened the session with a plenary presentation entitled "Life rafts on the open sea" which reviewed the state of knowledge on the coastal Japanese and oceanic species associated with tsunami debris from the 2011 tsunami in Japan. Project co-chair Nancy Wallace continued the session with an overview of the tsunami event and the response activities that occurred in the eastern Pacific in the wake of the event.

Contributed talks covered the three core themes of the ADRIFT project: modeling the drift of debris, surveillance and monitoring of debris landings, and the risk from potential invasive species associated with debris. Two papers covered the oceanographic drift models developed in response to the event. Masafumi Kamachi described the JAMSTEC model of tsunami debris drift and its correlation with sightings in the eastern Pacific. Nikolai Maximenko compared and contrasted three models of drift: JAMSTEC, GNOME and SCUD and their relationship to observations of tsunami debris vessels in the Eastern Pacific.

Five papers were presented on the surveillance and monitoring of incoming debris in North America and Hawaii. Sherry Lippiatt presented the results of the NOAA Marine Debris Monitoring and Assessment Project and the types of debris most commonly observed in surveys. Cathryn Clarke Murray showed that while incoming debris trends varied by region of the eastern Pacific, debris arrivals increased 10-fold in the years after the tsunami event. Shin'ichiro Kako presented research on debris arrival using a webcam system in Oregon and the relationship of arrival to onshore winds. Tomoya Kataoka presented a case study of marine debris accumulation on the western coast of Vancouver Island, Canada measured using aerial surveys, shoreline surveys and image analysis. Atsuhiko Isobe estimated quantities of marine debris washed ashore using the webcam system and a particle tracking model.

The biological community associated with tsunami debris poses an unknown risk to coastal ecosystems in the eastern Pacific. Seven papers investigated aspects of invertebrate and algae species that drifted across the North Pacific with tsunami debris. John Chapman revealed the crustacean species associated with debris and size-structure results that suggest some species were reproducing and self-recruiting to debris objects. Hiroshi Kawai presented genetic diversity studies and the biogeography of the macroalgae species of tsunami debris. Nancy Treneman showcased the incredible diversity of shipworms associated with lumber from the tsunami-hit region of Japan landing in the eastern Pacific. Jonathan Geller demonstrated the value of DNA barcoding for biodiversity accompanying tsunami debris.

Finally, two presentations sought to address the risk of these species to the recipient ecosystems and detect any possible incursions. Jocelyn Nelson applied a species screening tool, CMIST, to the species observed on tsunami debris and showed the most risky invertebrate species for each of the affected ecoregions. A number of well-known invasive species were observed with tsunami debris and further monitoring is warranted. Gregory Ruiz presented the results of a wide-scale detection effort from Alaska to California and Hawaii to search and detect introductions of tsunami debris species. No species introductions were detected and these survey efforts provide essential baseline data for future monitoring of tsunami debris species (or other species incursions).

Conclusions

- The interdisciplinary research presented integrates physical oceanography, taxonomy, ecology, and risk management tools to understand this unique event, while making contributions to the broader pure and applied research fields.
- The session showcased the incredible breadth and depth of research accomplished in association with the PICES ADRIFT project and its outcomes will contribute to the 3-year report to the Ministry of Environment of Japan in 2017.

List of papers

Oral presentations

Life rafts on the open sea: successful long-term transoceanic transport of coastal marine organisms by marine debris
James T. Carlton, John W. Chapman, Jonathan B. Geller, Jessica A. Miller, Gregory M. Ruiz4, Deborah A. Carlton, Megan A. McCuller, Rebecca Barnard, Nancy Treneman and Brian Steves

Responding to the debris generated by the Great Tsunami of 2011
Nancy Wallace

Drift simulation of Japan Tsunami Marine Debris (JTMD) as an application of data assimilation
Masafumi Kamachi, Hideyuki Kawamura, Yoichi Ishikawa and Norihisa Usui

Modeling the drift of marine debris generated by the 2011 tsunami in Japan
Nikolai Maximenko, Amy MacFadyen and Masafumi Kamachi

The NOAA Marine Debris Monitoring and Assessment Project: Four years of effort in the U.S. Pacific States
Sherry Lippiatt, Carlie Herring and Nancy Wallace

The influx of marine debris to North American shorelines after the Great Tsunami of 2011
Cathryn Clarke Murray, Sherry Lippiatt and Nikolai Maximenko

Sequential monitoring of marine debris washed ashore on a western US beach using a webcam system
Shin'ichiro Kako, Tomoya Kataoka, Kei Yufu, Atsuhiko Isobel, Charlie Plybon, Thomas A. Murphy and Nir Barnea

Accumulation of beach litter in Vancouver Island, Canada
Tomoya Kataoka, Cathryn Clarke Murray and Atsuhiko Isobe

An estimate of the tsunami-debris quantity washed ashore on the US and Canadian beaches, based on a webcam monitoring and a particle tracking model experiment
Atsuhiko Isobe, Shinsuke Iwasaki, Shin'ichiro Kako and Tomoya Kataoka

Crustaceans Adrift: Multiyear observations of Asian marine amphipods, isopods, and tanaids arriving in North American shores on open ocean drift objects generated by the 2011 Japanese Tsunami
John W. Chapman, Ralph A. Breitenstein, James T. Carlton, Jessica A. Miller, Toshio Furota, Michio Otani, Ichiro Takeuchi, Jessica Porquez, Andrea Burton and Maria Barton

Genetic diversity and biogeography of the macroalgal species associated with the Japanese tsunami marine debris
Takeaki Hanyuda, Gayle Hansen and Hiroshi Kawai

The fate of wood at sea: shipworms (Bivalvia: Teredinidae) in woody debris from the 2011 Japanese tsunami
Nancy Treneman, James T. Carlton, J. Reuben Shipway, Luisa Borges, Michael J. Raupach and Bjorn Altermark

DNA barcoding of potential Japanese tsunami marine debris-associated invaders of U.S. and Canadian waters
Jonathan B. Geller, Gregory Ruiz, John Chapman, Hideki Takami, Hisatsugu Kato, Michio Otani and James T. Carlton

The invasion risk of invertebrate species associated with Japanese tsunami marine debris in North America and Hawaii
Jocelyn C. Nelson, Cathryn Clarke Murray, James T. Carlton, Michio Otani, Gregory M. Ruiz and Thomas W. Therriault

Detection of non-native species in North America: Effects of the large-scale arrival of biota on Japanese tsunami marine debris (JTMD)?
Gregory Ruiz, J. Geller, L. McCann, K. Larson, L. Ceballos, M. Marraffini, B. Tracy, S. Havard, K. Newcomer, B. Steves, A. Chang, R. DiMaria, K. Lohan, R. Barnard, P. Fofonoff, J. Miller, J. Chapman, C. Murray, T. Therriault and J. Carlton

Poster presentations

Marine algae carried across the North Pacific on Japanese Tsunami Marine Debris (JTMD) and their invasion threat to the coasts of Oregon and Washington, USA
Gayle I. Hansen, Takeaki Hanyuda and Hiroshi Kawai

Marine algae carried across the North Pacific on Japanese Tsunami Debris: how have they survived the journey?
Gayle I. Hansen, Hiroshi Kawai and Takeaki Hanyuda

Aerial surveillance for tsunami debris in British Columbia, Canada
Cathryn Clarke Murray, Vickie Jackson, Nicole de Greef and David Bayne

Synthesizing the state of debris in Hawaii from 2015 aerial imagery and spatial analysis data
Stephanie Kung, Kirsten Moy, Miguel Castrence, Amber Meadows, Alexi Meltel, Andy Omori, Anne Rosinski, Brian Neilson, Kelsey Barrow, Stephen Ambagis, Michael Hamnett and Kristine Davidson

Contamination of hexabromocyclododecanes (HBCDs) in styrofoam marine debris from Asia and Pacific region and the Great Tsunami
Won Joon Shim, Mi Jang, Sang Hee Hong, Manviri Rani, Gi Myoung Han and Young Kyoung Song

An undescribed species of Japanese Pyropia appeared on the coast of British Columbia in 2015
Sandra Lindstrom

Trends in arrival and deposition of Marine Debris generated by the March 2011 Japan Tsunami on Eastern Pacific Shorelines
Amy MacFadyen and Glen Watabayashi

Life history and environmental requirement analyses of Japanese tsunami marine debris (JTMD) biota
Jessica A. Miller, Reva Gillman, Cathryn Clarke Murray, James T. Carlton, Gregory M. Ruiz, Michio Otani, Jocelyn Nelson and Janson Wong

FIS/TCODE Topic Session (S9)
Resilience, transitions and adaptation in marine ecosystems under a changing climate

Co-sponsor: ICES

Co-Convenors: *Franz Mueter (USA), Ken Drinkwater (Norway), Sei-Ichi Saitoh (Japan), Emanuele Di Lorenzo (USA)*

Invited Speakers:
Benjamin Planque (Institute of Marine Research, Tromsø, Norway)

Background

Marine ecosystems respond to climate variability and anthropogenic forcing at a variety of spatial and temporal scales. While there is a growing literature on the capacity of social-ecological systems to cope with climate change, the resilience of physical and ecological marine systems to climate change remains poorly

understood. In the context of ongoing climate change, resilience refers to the capacity of a system to absorb disturbances and to reorganize so as to maintain its essential structure, function, identity and feedbacks. This concept presumes the existence of alternative stable states or regimes that are separated by reversible transitions. The concept also presumes the possibility of thresholds or tipping points that may be irreversible and are associated with the loss of essential structure and function. In an ecological context, tipping points occur if key organisms are no longer able to adapt to changes in their environment. This session explored the concepts of resilience, tipping points (including early warning signals) and adaptation in marine ecosystems from plankton through fish.

Theoretical studies and applied case studies were presented that help refine our understanding of resilience in a marine ecosystem context, provide practical approaches to measuring resilience, define "essential structure and function" of marine ecosystems, and explore the phenotypic and evolutionary adaptive capacity of marine organisms to deal with gradual changes and transitions. This session contributed to the development of more plausible scenarios for future physical and biological changes in marine ecosystems, which are needed to facilitate climate change adaptation in socio-economic systems that depend on marine resources.

Summary of presentations

The session included 14 oral and 5 poster presentations.

The invited speaker, Benjamin Planque, set the stage for the session by reviewing the concept of resilience, which is broadly defined as "the ability of a system to absorb disturbance and maintain structure and function". Three features can contribute to the resilience of a system: resistance, flexibility and reorganisation. Resistance implies low sensitivity to external pressures. Flexibility refers to the capacity of a system to return to its original configuration after being exposed to a perturbation. Reorganisation defines the capacity of a system to constantly reconfigure itself in order to maintain its functions in the presence of perturbations. Dr. Planque presented results from the BarEcoRe project that investigated specific features of the resilience of the Barents Sea ecosystem based on data from long term monitoring of the Barents Sea ecosystem. The presentation highlighted the need for a null model of ecosystem dynamics in order to evaluate temporal changes in ecosystem structure and function.

Resilience may also be measured as the ability of a community to persist, or remain stable, in the face of a changing environment. Barceló *et al.* used diversity measures to identify a region off central and southern Washington in the California Current ecosystem where the pelagic fish community displayed both high species diversity (high alpha diversity) and low turnover over a 17-year survey period (low beta diversity). In contrast, the offshore region was characterized by low alpha diversity and high beta diversity. They suggest that the wide shelf in this region creates refugia that buffer the pelagic community against high environmental variability in the offshore region.

Devising a practical approach to identifying species that are more or less resilient to climate change is challenging, but Spencer *et al.* provide a worked example to evaluate the vulnerability of individual fish stocks to climate change based on their sensitivity at various life stages to environmental changes and their expected exposure to changing conditions. The approach relies on expert opinion to rank sensitivity and exposure based on a set of agreed-upon criteria and is being applied in the U.S. to all managed stocks within several management regions. Such analyses of vulnerability depend on the distribution of different life stages, as each life stage is exposed to a different suite of environmental conditions. Ciannelli *et al.* show that across a number of systems and species, earlier life stages tend to be more constrained in their spatial distribution, suggesting higher vulnerability. This highlights the need for surveys at different life stages, which are often lacking, but the approach could be expanded to data-poor stocks if spatial constraints can be linked to life history strategies to identify the most vulnerable stages.

A common observation of biological responses to ocean warming is a poleward shift in populations. García Molinos *et al.* took a broad-scale, meta-analytical approach to show that predictions of distributional shifts

across many taxa could be improved by accounting for the directional agreement between ocean currents and warming. Depending on the agreement between current direction and spatial gradients of temperature flow direction could either facilitate or hinder shift responses to warming. Contrary to expectations, Vega-García *et al.* (presented by Salvador Lluch-Cota) documented the presence of a fixed center of high abundance of benthic macroinvertebrates off the central coast of Baja California, suggesting a limited distributional response to ocean warming. In contrast, the distribution of semi-demersal walleye pollock in the eastern Bering Sea is highly variable and appears to shift in response to zooplankton availability (Stepanenko and Gritsay). When the abundance of large zooplankton, the preferred prey of walleye pollock, is low on the southeastern Bering Sea shelf, pollock may migrate into Russian waters in the northwestern Bering Sea and vice versa, suggesting some degree of resilience to changing environmental conditions.

The Arctic and its marginal seas are experiencing some of the most dramatic changes associated with climate warming, due to changes in sea ice cover, and the future of fish populations in these regions is of great interest to fisheries managers due to the potential for commercially important stocks to expand from the Subarctic into the Arctic. Hollowed *et al.* show that the magnitude of expected changes in temperatures and production strongly depends on assumptions about future CO_2 emissions, but sub-zero temperatures are expected to persist into spring in most regions even under a high-emissions scenario. Subarctic commercial stocks may be limited by light and temperature from expanding into the Arctic, but the responses are likely to vary across regions.

In examining the responses of fish populations to climate change the evolution of critical traits is rarely considered. Using a simple but elegant approach, the capacity of organisms to adapt to climate change through the evolution of a trait such as intrinsic growth rates was explicitly modeled by Ken Denman. Based on a published laboratory study of about 1,000 generations of the coccolithophore *Emiliania huxleyi*, genetic mutations of intrinsic growth rate in response to an abrupt temperature increase were modeled over many generations, but could not replicate results from laboratory experiments adequately. Specifically, there was an unrealistic lag time of about 100 generations after a shift to warmer temperatures before growth rates started increasing through adaptive evolution. The lag time could be eliminated by introducing a plastic response to warming, which can maintain a population from approaching extinction until favorable mutations can become significant and lead to genetic adaptation to higher temperatures.

Evaluating the utility of early warning signals computed from survey data to predict abrupt ecosystem shifts was the goal of a study by Litzow and Hunsicker, presented by Mary Hunsicker. A literature review and empirical analyses suggest that systems that display non-linear dynamics are more likely to show the expected behavior of early warning signals, such as a rise in temporal or spatial variance and autocorrelation prior to an observed shift.

The structure of oceanic communities at several trophic levels and their responses to climate variability and change or fishing were examined in several presentations and posters. Sugie *et al.* examined effects of climate change on phytoplankton community composition, which strongly affects production at higher trophic levels, and found that very high pCO_2 levels could depress the growth of diatoms, while high pCO_2 and temperature synergistically enhanced the growth of pico-sized phytoplankton (*e.g.*, *Synechococcus*), hence their growth could ameliorate the negative impacts of high CO_2 and temperature conditions. Tomiyama et al. (presented by Atsushi Yamaguchi) compared the structure of zooplankton communities among four contrasting regions around Hokkaido Island. Results suggested marked differences in bottom-up vs. top-down forcing among areas, with bottom-up control dominant in the planktonic food web of the southern Okhotsk Sea, top-down control dominant in the Japan Sea, and the other regions showing intermediate characteristics. Tian *et al.* presented evidence of increases in cephalopods in the China Sea, including several coastal species, in spite of heavy fishing. These increases parallel worldwide increasing trends in cephalopods and suggest that these changes are environmentally driven. There was some evidence that changes coincided with ENSO events and with basin-wide regime shifts, but trends also differed among species, presumably as a result of differences in their biological traits. Mass-balance models provide an approach to examining the impact of anthropogenic effects, including climate change, on the trophic dynamics of marine communities and were applied by Du *et*

al. in subtropical Xiamen Bay to quantify the impacts of a fishery and of changes at various trophic levels on the ecosystem.

The importance of ecological monitoring to assessing changes in biological communities and in the resilience of these communities to change or their capacity to adapt was highlighted in Kurilova and Kulbachnyi, but their study also showed the difficulty of separating other anthropogenic impacts, particularly in developed coastal or inshore regions, from the effects of climate change. Many existing datasets remain underutilized for addressing questions relevant to monitoring and understanding resilience, transitions and adaptation in marine ecosystems. For example, Khoruzhiy analyzed seasonal variability in the pelagic fish community of the Northwest Pacific Ocean based on extensive pelagic trawl surveys conducted from at least 2004–2015. This is one of many rich datasets available to examine the response of populations to climate variability and change.

Several presentations addressed the human dimensions of adapting to climate change. Seung and Ianelli evaluated the performance of different management strategies for walleye pollock in the eastern Bering Sea under a changing climate using dynamic computable general equilibrium models that considers both biological and economic impacts. They showed that harvest control rules that dynamically adjust a lower threshold for biomass below which fishing is prohibited to protect Steller sea lions performed best. The threshold was adjusted based on recent recruitments and their expected contribution to spawning biomass.

The ability of a fishing community in South Korea to respond to the collapse of the pollock fishery provides an instructive example of a linked socio-ecological system. Yoo and Lee show that changes in the fishing community of Goseong can be understood in the context of Holling's (2001) "adaptive cycle" of four phases: exploitation, conservation, release, and reorganization. In Goseong, exploitation increased after the fishery was re-established following the Korean war and led to a massive influx of people. During the second phase, the pollock fishery and processing capacity stabilized, followed by a crisis due to the collapse of the pollock stock and the reliance of the community on a single resource. Currently, the community is undergoing the fourth phase of reorganization, primarily through diversification and active crisis management, while trying to maintain their identity as a main production area of pollock.

Morrison and Termini reviewed the literature to identify options for managing fisheries in a changing climate. They suggest that management actions that seek to increase management flexibility and provide incentives to the fishing industry to try new approaches, while preserving genetic diversity of the fished populations, are beneficial to increasing resilience. Management may respond to climate change at various levels by taking measures to increase the resilience of individual stocks, whole ecosystems, fishing businesses, or coastal communities.

List of papers

Oral presentations

Marine Ecosystem resilience, what is it and how can we measure it? (Invited)
Benjamin Planque, Michaela Aschan, Grégoire Certain, Padmini Dalpadado, Lis Lindal Jørgensen, Raul Primicerio and Mette Skern-Mauritzen

Early warning signals of declining resilience and abrupt transitions in ocean ecosystems
Michael A. Litzow and Mary E. Hunsicker

Status and trend of four commercially important coastal cephalopods in China Seas: An overview with implications for climate change
Yongjun Tian, Yumeng Pang, Yanli Tang, Yiping Ren and Rong Wan

Effects of high-CO_2 and temperature on the dynamics of plankton communities in the subarctic Pacific
Koji Sugie, Sohiko Kameyama, Takeshi Yoshimura, Hiroshi Uchida, Jun Nishioka, Naomi Harada and Akihiko Murata

A model simulation of the adaptive evolution through mutation of the coccolithophore *Emiliania huxleyi* based on a published laboratory study
Kenneth L. Denman

Detection of a geographically fixed center of high abundance of macroinvertebrates along the west coast of Baja California
Pablo David Vega-García, Fiorenza Micheli, Héctor Reyes-Bonilla and Salvador E. Lluch-Cota

Identifying climatically resilient or sensitive locations in the Northern California Current using partitioned beta-diversity
Caren Barceló, Lorenzo Ciannelli and Richard D. Brodeur

Climate vulnerability analysis of eastern Bering Sea fish and invertebrate stocks
Paul D. Spencer, Anne B. Hollowed, Mark W. Nelson, Michael F. Sigler and Albert J. Hermann

Resilience and adaptation of marine ecosystems in Vanina Bay, Sea of Japan: Past, present and scenarios for the future
Ekaterina P. Kurilova and Sergey E. Kulbachnyi

Are Arctic and sub-arctic fish stocks more prepared for a changing climate?
Anne B. Hollowed, Wei Cheng, Harald Loeng, Libby Logerwell, Franz Mueter and James Reist

Going with the flow: Ocean currents modify the coupling between climate change and biogeographical shifts
Jorge García Molinos, Michael T. Burrowsb and Elvira S. Poloczanska

Life history spatial constraints and species adaptability to climate change
Lorenzo Ciannelli, Anna Neuheimer, Leif Christian Stige and Mary Hunsicker

Assessment of management strategies for eastern Bering Sea walleye pollock fishery with climate change
Chang Seung and James Ianelli

Fisheries collapse and social changes in a fishing-dependent community: The case of Goseong
Chaewon Yoo and Dowon Lee

Poster presentations

Fluctuations of the Bering Sea pollock recruitment, abundance, distribution as impacts on environmental changes
Mikhail A. Stepanenko and Elena V. Gritsay

Seasonal shifts of compound and structure of the nekton community in the Northwestern Pacific Ocean
Alexey A. Khoruzhiy

Inter-oceanic differences in macrozooplankton biomass and community structure in four regions around Hokkaido Island, Japan: Consequences for marine ecosystem structure
Kosuke Tomiyama, Kohei Matsuno, Yoshiyuki Abe, Hiroshi Shimada and Atsushi Yamaguchi

Literature review of management approaches that improve resilience for species, ecosystems, and/or fishing businesses
Wendy Morrison and Valerie Termini

Food sources and trophic structure of fishes and benthic macroinvertebrates in a tropical seagrass meadow revealed by stable isotope analysis
Jianguo Du, Xinqing Zheng, Teguh Peristiwady, Jianji Liao, Petrus Ch. Makatipu, Xijie Yin, Wenjia Hu, Wulan Koagouw and Bin Chen

FUTURE Topic Session (S10)
The response of marine ecosystems to natural and anthropogenic forcing: Past, present and future

Co-Convenors: *Steven Bograd, NOAA (USA)*, *Hiroaki Saito (Japan)*, *Jacquelynne King (DFO, Canada)*, *Sukyung Kang (NFRDI, Korea)*

Invited Speakers:
Masaka Miya (Natural History Museum and Institute, Chiba, Japan)
Ryan Rykaczewski (University of South Carolina, Columbia, SC, USA)
Samantha Stevenson (National Center for Atmospheric Research, Boulder, CO, USA)
Jennifer Sunday (University of British Columbia, Vancouver, BC, Canada)

Background

'Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems' (FUTURE) is an integrative Scientific Program undertaken by the member nations and affiliates of PICES to understand how marine ecosystems in the North Pacific respond to climate change and human activities, to

forecast ecosystem status based on a contemporary understanding of how nature functions, and to communicate new insights to its members, governments, stakeholders and the public. One of the principal aims of FUTURE is to improve our understanding of how marine ecosystems respond to natural and anthropogenic forcing, and how marine ecosystems will change in the future. In this session, we (a) reviewed our state of knowledge on how climate variability and change affect the processes underlying ecosystem structure and function, (b) identified critical gaps in our understanding, and (c) provided an assessment of our capacity to forecast climate-driven marine ecosystem changes. Advances in the understanding of climate impacts on marine ecosystems, and a broad dissemination of this information, is essential for preserving a healthy and sustainable North Pacific for FUTURE generations.

Topic Session 10 was sponsored by the FUTURE Scientific Steering Committee, with the aim of providing a platform to showcase recent advances in the FUTURE science program and to identify key challenges and new paths forward for doing inter-disciplinary marine science in the North Pacific. A total of 14 oral presentations were given over two days (November 10 and 11), including morning Plenary Sessions on both days. Four invited speakers contributed to the session, and half of the speakers were early-career scientists (including three of the invited speakers). One of the speakers (Petrik) was awarded a Best Oral Presentation (see list of Award recipients at the end of the Summaries report). There were also 8 poster presentations in addition to the oral presentations. The oral presentations, summarized below, provided a broad sampling of the excellent science on climate-ecosystem interactions that is being carried out within the PICES community.

Summary of presentations

The first morning (November 10) Plenary had talks by Richard Rivkin, Colleen Petrik, Michael Litzow, and Ivone Ortiz. Rivkin's talk, "*Influence of phytoplankton-bacterial coupling on the export of biogenic carbon in the ocean: Insights from iron enrichment experiments*", demonstrated that ways in which bacteria and phytoplankton have co-evolved and how their interactions can influence ocean biogeochemical processes. Petrik's award-winning talk, "*The response of fisheries production to natural and anthropogenic forcing: Past, present and future*", described results from a global size-based fish model that show the relative contributions of fishing and climate change to total mean biomass of fishes. Litzow's talk, "*Non-analogue ecosystem states in the Gulf of Alaska*", described regime-dependent temperature effects on ecosystem components in the Gulf of Alaska and showed that SST effects on the biology are nonlinear and state-dependent. Ortiz's talk, "*Applications of downscaled regional ocean biophysical models: Forecasting indicators and fish habitat*", described efforts to forecast ecosystem indicators and fish habitat in the Bering Sea from downscaled regional models.

Session 10 continued with three more morning talks out of plenary. As a late substitute for a cancelled talk, Jake Rice gave a presentation on "*Climate change and ocean uses ... Adaptation from what?*" in which he discussed his experiences in considering ecosystem based management under a changing climate. Youngji Joh's talk, "*Extreme ocean temperature events in the North Pacific under greenhouse forcing*", addressed the question of whether the characteristics of marine heat waves change over time and are sensitive to climate change. This was followed by a talk from Christina Folger, presenting for Henry Lee II on "*The Icarus challenge - Predicting vulnerability to climate change using an algorithm-based species' trait approach*", in which she described recent efforts to assess the impacts of various climate stressors on near-coastal species along the North American west coast.

The following morning (November 11) Session 10 continued with 7 plenary talks, including the 4 invited speakers. Samantha Stevenson's (Invited) talk, "*An ensemble approach to understanding climate change in the Pacific*", described analyses of an ensemble of earth system models to investigate how Pacific climate variability responds to various anthropogenic forcing and how climate mitigation strategies affect projected climate variability. Ed Gregr's talk, "*Marine habitats in a changing world: Looking beyond correlation*", provided a methodological comparison of habitat modeling approaches, concluding that simpler models are likely better for strategic forecasts and providing more guidance on process. Ryan Rykaczewski's (Invited) talk, "*Wind stress, stratification, and source waters: How will eastern boundary current upwelling processes*

respond to climate change", provided an overview of recent observational and modeling studies that investigated changes in the intensity, spatial structure and phenology of coastal upwelling.

Haruka Nishikawa's talk, "*Simulated influence of the 1976-77 regime shift on anchovy and sardine in the California Current*", described a newly developed fully coupled end-to-end fish model that has been used to explore changes in small pelagic fish abundance in the California Current through the 1976–77 regime shift. Masaki Miya's (Invited) talk, "*Environmental DNA metabarcoding from fish (and other invertebrates) using universal primers MiFish: A data-driven approach for fish community research*", gave an overview of the recent advances and remaining challenges of eDNA, which provides a new frontier for fish biodiversity research. Desiree Tommasi's talk, "*Seasonal climate predictions to improve fisheries management decisions*", reviewed recent advances in using management strategy evaluations (MSEs) to improve fisheries management in the context of changing ocean conditions. Finally, Jennifer Sunday's (Invited) talk, "*The mechanics of range shifts in a warming world*", reviewed the factors that determine species distributions and described the relative roles of species traits and ecological interactions in mediating climate-driven range shifts.

Overall, Topic Session 10 provided a fascinating and diverse overview of new methods and approaches to investigate the impacts of climate variability and change on marine ecosystems. It was particularly encouraging to see the excellent new science being driven by early-career scientists from the PICES community, which bodes well for FUTURE and PICES.

List of papers

Oral presentations

Influence of phytoplankton-bacterial coupling on the export of biogenic carbon in the ocean: Insights from iron enrichment experiments
Richard B. Rivkin, M. Robin Anderson and Michelle Hale

The response of fisheries production to natural and anthropogenic forcing: Past, present and future
Colleen Petrik, Charles Stock, Ken Andersen, James Watson and Jorge Sarmiento

Non-analogue ecosystem states in the Gulf of Alaska
Michael Litzow, Lorenzo Ciannelli, Ryan Rykaczewski, Emanuele Di Lorenzo, Michael Opiekun, Patricia Puerta and Megan Stachura

Applications of downscaled regional ocean biophysical models: forecasting indicators and fish habitat
Ivonne Ortiz, Al Hermann, Chris Rooper, Ned Laman, Stephani Zador and Kerim Aydin

Climate change and ocean uses – Adaptation from what?
Jake Rice

Extreme ocean temperature events in the North Pacific under greenhouse forcing
Youngji Joh and Emanuele Di Lorenzo

The Icarus challenge - Predicting vulnerability to climate change using an algorithm-based species' trait approach
Henry Lee II, Christina Folger, Deborah A. Reusser, Patrick Clinton and Rene Graham
Presented by Christina Folger on behalf of Henry Lee II

An ensemble approach to understanding climate change in the Pacific (Invited)
Samantha Stevenson, Antonietta Capotondi, John Fasullo and Bette Otto-Bliesner

Marine habitats in a changing world: Looking beyond correlation
Edward J. Gregr, Rowenna Gryba, Daniel M. Palacios and Kai M. A. Chan

Wind stress, stratification, and source waters: How will eastern boundary current upwelling processes respond to climate change? (Invited)
Ryan R. Rykaczewski

Simulated influence of the 1976–77 regime shift on anchovy and sardine in the California Current System
Haruka Nishikawa, Enrique N. Curchitser, Jerome Fiechter, Kenneth A. Rose and Kate Hedstrom

Environmental DNA metabarcoding from fishes (and other vertebrates) using universal primers MiFish: A data-driven approach for fish community research (Invited)
Masaki Miya

Seasonal climate predictions to improve fisheries management decisions
Desiree <u>Tommasi</u> and Charles Stock

The mechanics of range shifts in a warming world
Jennifer M. <u>Sunday</u>

Poster presentations

The exploration for system stability in the coastal marine ecosystem of northern Yellow Sea of China
Zhongxin <u>Wu</u>, Xiumei Zhang, Hector M. Lozano-Montes and Neil R. Loneragan

Effects of climatic stressors on behavioral and physiological response of marine animals
Taewon <u>Kim</u> and Jung-Ah Lee

Species-specific responses of demersal fishes to near-bottom environmental conditions within the California Current large marine ecosystem
Aimee A. <u>Keller</u>, L. Ciannelli, W. Waldo Wakefield, Victor H. Simon, John A. Barth and Stephen D. Pierce

Detection of anthropogenic impacts on ocean biogeochemical cycles
James <u>Christian</u>, Sarah Schlunegger and Keith Rodgers

Potential responses of phytoplankton community structure to future global warming
Taketo <u>Hashioka</u>

Statistical downscaling of global projections to the Bering Sea, based on an ensemble of regional model output
Albert J. <u>Hermann</u>, Wei Cheng, Georgina A. Gibson, Ivonne Ortiz and Kerim Aydin

Upwelling-induced changes in the structure of plankton assemblages and role of heterotrophic bacterioplankton in biogeochemical carbon cycles in the Ulleung Basin, East Sea
Jung-Ho <u>Hyun</u>, Eun-Jin Yang, Jae-Hoon Noh, Kyeong-Hee Kim, Sung-Han Kim, Jin-Sook Mok, Dongseon Kim and Sinjae Yoo

Estuarine ecology and environment: in response to long-term variations of Changjiang (Yangtze River) runoff input and sediment load
Weiwei <u>Xian</u> and Hui Zhang

POC Topic Session (S11)
Advances in understanding and modeling of physical processes in the North Pacific in the past 25 years of PICES and future directions

Co-Convenors: *Steven Bograd (USA), Charles Hannah (Canada), Shin-Ichi Ito (Japan), Hiromichi Ueno (Japan)*

Invited Speakers:
Michael Foreman (Scientist Emeritus, Fisheries and Oceans Canada, Canada)
Jerome Fiechter (Institute of Marine Sciences, University of California-Santa Cruz, USA)
Vyacheslav Lobanov (V.I. Il'ichev Pacific Oceanological Institute (POI), Russia)
Ichiro Yasuda (The University of Tokyo, Japan)

Background

Since its birth in 1992, the Physical Oceanography and Climate Committee (POC) have promoted and coordinated physical and chemical oceanography, atmospheric science, and interdisciplinary research in the northern North Pacific. Impacts of climate variability and physical dynamics in coastal, shelf and open ocean areas are considered with emphasis on processes that are related to living marine resources and environmental quality. POC addressed the following topics in order to achieve the goals of PICES through its expert groups: ocean circulation, the Okhotsk Sea and the Oyashio region, modelling physical processes, carbon cycling, connection between ocean variability and climate change, exchange between continental shelf waters and the nearby ocean, and future climate projections in regional-basis. POC can continue to contribute to PICES and PICES scientists by deepening our understanding of physical and chemical processes in ocean and climate in the North Pacific and also by providing leadership in identifying key issues associated with a central issue of PICES, understanding and projecting the long-term variability of the North Pacific ecosystems. The session

will review the advancement of processes that POC has identified and consider new challenges that POC should target to improve understanding of marine ecosystems in the North Pacific.

Session 11 was sponsored by the Physical Oceanography and Climate (POC) Committee, with the aim of showcasing advances in the understanding and modeling of physical processes in the North Pacific over the first 25 years of PICES, and recommending future directions. A total of 20 oral presentations were given over two days (November 8 and 9), in addition to 9 poster presentations. Four invited speakers contributed to the session, and 5 of the speakers were early-career scientists, one of who received Best Presentation award for an early career scientist (see list of award recipients at the end of Session Summaries report). The presentations, summarized below, provided the PICES community with a good overview of the evolution and continued development of POC-related science.

Summary of presentations

Ichiro Yasuda (Invited): "*Ocean mixing processes: Impact on biogeochemistry, climate and ecosystems*" reviewed the importance of mixing processes for the biogeochemistry and biology of marine ecosystems, and reviewed recent Japanese projects aimed at studying ocean mixing.

M. Debora Iglesias-Rodriguez described the oceanographic conditions and coupling to biology that resulted in an unusual phytoplankton bloom in the southern California Current. Olga Trusenkova described empirical orthogonal function analyses of sea level anomalies to investigate modes of variability in the Japan/East Sea. Sayaka Yasunaka described decadal trends in key surface nutrients in relation to large-scale climate patterns associated with the PDO and NPGO. Makoto Kashiwai presented a new method for identify the forcing mechanisms of observed water mass changes of the Okhotsk Sea Intermediate Water.

Vyacheslav Lobanov's invited talk, "Recent advances and future perspectives in the understanding of mesoscale water dynamics in the Japan/East Sea" reviewed PICES-driven scientific advances in the Japan/East Sea, focusing on the work of AP-CREAMS.

Hanna Na's presentation on "*Mesoscale-eddy-induced variability of flow through the Kerama Gap between the East China Sea and the western North Pacific*" received the Best Oral Presenation award for a POC-sponsored session. She gave analyses of altimeter-derived volume transports through the Kerama Gap and discussed the relationship between the Kerama Gap throughflow and the Kuroshio.

Hiromichi Ueno provided an overview of studies of mesoscale eddies in the subarctic North Pacific and provided avenues for future research on the topic. William Crawford gave an overview of the large, westward-propagating eddies observed over the past two decades in the Gulf of Alaska, and reviewed knowledge gaps about their dynamics and biological impacts. Cheryl Harrison presented results from an earth system model used to investigate the dynamics and carbon flux associated with mesoscale circulation features (FTLE) in the North Pacific. Hally Stone described results from a ROMS hindcast of the northern California Current region, including differentiating the importance of local and remote wind forcing and the origin of slope and shelf waters.

Michael Foreman's (Invited) talk on "*Linking technological and POC advances over the past 25 years*" described the technological advances that have been made in physical oceanographic research over the lifetime of PICES, and how these advances have improved our understanding of North Pacific climate and ecosystems.

Fangli Qiao described recent field experiment results aimed at quantifying wave-turbulence interaction, which could help improve vertical mixing schemes in ocean circulation models. Chanhyung Jeon's presentation on "*Distribution of near-inertial waves in the mixed and deep layers of the East/Japan Sea using a high-resolution wind-forced ocean model*" summarized results from a high-resolution model study aimed at investigating the characteristics of near-inertial wave energy distribution in the East/Japan Sea. Daji Huan presented results from a high-resolution model to investigate the response of sea surface height and circulation

in the Bohai, Yellow and East China Seas. Jerome Fiechter's (Invited) paper on "*Regional and climate forcing on forage fish and apex predators in the California Current: New insights from a fully coupled ecosystem model*" described results from a fully coupled end-to-end ecosystem model (ROMS + NEMURO) of the California Current, which was used to investigate interactions between an apex predator and forage fish. Romeo Saldivar-Lucio analyzed low-frequency signals in California Current upwelling, and compared this variability with biological signals for the North American west coast. Andrey Andreev described analyses of altimetry and *in situ* observations, including interannual changes in Alaskan Stream flow and its downstream effects on plankton biomass in the eastern and western Okhotsk Sea. Nicholas Bond reviewed the anomalous atmospheric forcing and ocean response related to the 2013–16 warm "blob" in the northeast Pacific. Anomalous conditions in the northeast Pacific in recent years were also described by Alexander Kurapov who provided estimations from a high-resolution ocean circulation model.

Overall, Topic Session 11 demonstrated the significant advances in technology and modeling that has contributed to enhanced understanding of physical processes in the North Pacific, and how these processes impact marine ecosystems. It is clear that many of these advances would not have been possible without the collaborations and structure provided by PICES.

List of papers

Oral presentations

Ocean mixing processes: Impact on biogeochemistry, climate and ecosystems (Invited)
Ichiro Yasuda

Oceanographic conditions facilitating the formation and propagation of a novel coccolithophore bloom in the Santa Barbara Channel
Paul G. Matson, Chris Gotschalk, Tanika M. Ladd, David A. Siegel, Libe Washburn and M. Debora Iglesias-Rodriguez

Long-term sea level variation in the Japan/East Sea from two decades of altimetry data
Olga Trusenkova and Dmitry Kaplunenko

Long-term variability of surface nutrient concentrations in the North Pacific
Sayaka Yasunaka, Tsuneo Ono, Yukihiro Nojiri, Frank A. Whitney, Chisato Wada, Akihiko Murata, Shin-ichiro Nakaoka and Shigeki Hosoda

Mechanism of warming the Okhotsk Sea Intermediate, from consideration on the seasonal cycle
Makoto Kashiwai

Recent advances and future perspectives in the understanding of mesoscale water dynamics in the Japan/East Sea (Invited)
Vyacheslav B. Lobanov

Mesoscale-eddy-induced variability of flow through the Kerama Gap between the East China Sea and the western North Pacific
Hanna Na, Jae-Hun Park, Mark Wimbush, Hirohiko Nakamura, Ayako Nishina and Xiao-Hua Zhu

Studies on mesoscale eddies in the subarctic North Pacific
Hiromichi Ueno

Mesoscale eddies of the Northeast Pacific Ocean
William Crawford

The effect of mesoscale circulation on biological production and carbon export in the North Pacific
Cheryl S. Harrison, Nikki Lovenduski, Fred Castruccio and Matthew Long

Reconciling perspectives of upwelling system dynamics and basin-scale drivers on shelf water variability in the Pacific Northwest coastal ocean
Hally B. Stone, Neil S. Banas, Barbara M. Hickey and Parker MacCready

Linking technological and POC advances over the past 25 years (Invited)
Michael Foreman

Wave turbulence interaction induced vertical mixing and its effects in ocean and climate models
Fangli Qiao, Yeli Yuan, Jia Deng, Dejun Dai and Zhenya Song

Distribution of near-inertial waves in the mixed and deep layers of the East/Japan Sea using a high-resolution wind-forced ocean model
Chanhyung Jeon, Jae-Hun Park, Young-Gyu Park and Hong Sik Min

Synoptic variability of wintertime wind-driven circulation in the Bohai, Yellow and East China seas
Daji Huang and Zhiyuan Li

Regional and climate forcing on forage fish and apex predators in the California Current: New insights from a fully coupled ecosystem model (Invited)
Jerome Fiechter, Luis Huckstadt, Kenneth Rose, Daniel Costa, Enrique Curchitser and Katherine Hedstrom

Macro-scale patterns in upwelling/downwelling activity along the North American west coast
Romeo Saldívar-Lucio, Emanuele Di Lorenzo, Miguel Nakamura, Héctor Villalobos, Daniel Lluch-Cota and Pablo Del Monte-Luna

The seasonal and interannual variability of circulation in the eastern and western Okhotsk Sea and its impact on plankton biomass
Andrey G. Andreev, Sergey V. Prants, Maxim V. Budyansky and Michael Yu. Uleysky

The response of Northeast Pacific Ocean circulation to recent atmospheric forcing
Nicholas A. Bond, Phyllis J. Stabeno

Anomalous oceanic conditions along the US West Coast in 2014: Inferences from a high resolution regional ocean model
Aleaxnder L. Kurapov

Poster presentations

Rapid Freshening of the Kamchatka and Oyashio Currents
Konstantin Rogachev and Natalia Shlyk

Spreading of Antarctic Intermediate Water in the Philippine Sea
Nan Zang and Fan Wang

A long-term reference for detecting oceanic variations in the western North Pacific: JMA 50-year long 137°E repeat hydrographic section
Toshiya Nakano, Hiroyuki Inoue, Kiyoshi Murakami, Yusuke Takatani, Atsushi Kojima, Yoshiteru Kitamura, Masao Ishii, Eitarou Oka, Shusaku Sugimoto and Toshio Suga

Comparison of chlorophyll-a responses to climate change in the tropical western Pacific marginal seas
Rong-shuo Cai, Hai-xia Guo, Di Fu, Hong-jian Tan and Xiu-hua Yan

Time interpolation of surface winds and its impact on the modelling of inertial currents in the North Pacific
Yukiharu Hisaki

Vertical mixing observed on the continental slope of the southwestern East/Japan Sea
Seongbong Seo, Young-Gyu Park, Jae-Hun Park, Chang-Soo Hong and Dong Guk Kim

Mapping of the air–sea CO_2 flux in the Arctic Ocean and its adjacent seas: Basin-wide distribution and seasonal to interannual variability
Sayaka Yasunaka, Akihiko Murata, Eiji Watanabe, Masao Ishii, Naohiro Kosugi, Shigeto Nishino, Daisuke Sasano and SOCAT-Arctic contributors

Evaluation surface winds over the Korean Peninsula and its surrounding seas
Wonkeun Choi, Ho-Jeong shin and Chan Joo Jang

Approach of dynamic physical thresholds on spatial-temporal phytoplankton variability in NE Pacific
Eliana Gómez-Ocampo and Gilberto Gaxiola-Castro

MONITOR/BIO/TCODE Topic Session (S12)
Causes and consequences of 25 years of variability in ocean conditions on the ecosystems of the North Pacific

Co-Convenors: *Bill Peterson (USA), Jack Barth (USA), Sanae Chiba (Japan), Yury Zuenko (Russia)*

Invited Speakers:
Emanuele Di Lorenzo (Earth & Atmospheric Sciences, Georgia Institute of Technology, USA)
Art Miller (Scripps Institution of Oceanography, University of California-San Diego, USA)

Background

Climate change is upon us in terms of both slow chronic change and increased physical and ecosystem variability. Slow increases in SST, ice melting, sea level, hypoxia, ocean acidification and northward shifts in species are cause for concern. However, for many scientists, climate variability at the seasonal-to-interannual time scale is of greater interest. This is especially true for the North Pacific where PICES scientists have been leaders in showing how increased variability in physical forcing at the basin scale (*e.g.*, the PDO, NPGO and ENSO) affects productivity of marine ecosystems. Indeed, recognition of the impact of physical forcing at the basin scale on local ecosystems was among the earlier focal points of PICES research and clearly opened our eyes to the need to look at the physical forcing across the entire basin, not just local drivers of ecosystem variability. In the 25 years since PICES was established, many unusual oceanographic events have occurred in the throughout North Pacific that have affected the physics, plankton and fisheries: change in the PDO from 20–30 year cycles to the 5–10 year cycles seen at present, the extended "warm ocean" period of 1993–1998 that resulted in the listing of many salmon species as threatened or endangered, the really big El Niño events of 1997–98 and 2015–16, the 2002 sub-Arctic intrusion, the smaller 2003–2005 and 2009–10 El Niño events, the cold North Pacific in 2008, and of course the warm Blob in 2014. Analysis and synthesis papers on regional variations in recent climate variability and ecosystem response in coastal waters off Asia as well as the Sea of Okhotsk, Bering Sea, and the major current systems: Kuroshio, Oyashio, North pacific and California Currents were encouraged.

Summary of presentations

This session included presentations from atmospheric scientists, physical oceanographers, and biological oceanographers and was attended by over one hundred PICES participants. The speakers discussed a wide range of variability in ocean wind forcing, ocean temperatures and sea ice cover, and the consequences of that variability on components of the marine ecosystem including phytoplankton, zooplankton, fish, marine mammals and seabirds. Presentations included those that covered the entire North Pacific and related physical phenomena from the equator to high latitudes. Other talks focused on either the western or eastern North Pacific and there were two contributed posters on studies from the western North Pacific.

The session started with two invited talks on the large-scale climate variability across the North Pacific, including a discussion of the existence, predictability and potential consequences of this variability on marine ecosystems. The invited talks did a nice job of explaining the interannual and interdecadal variability in the atmosphere and ocean, including the El Niño Southern Oscillation, the Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation. It was pointed out that the PDO is not a physical mode, but rather a sum of several physical processes including a "reddened ENSO," the re-emergence of the deep warm anomalies to extend the PDO across several years, and the role of oceanic Rossby waves in affecting the Kuroshio Extension region. A correlation between the PDO and ecosystem drivers was noted and that the correlation is getting stronger and that this has led to an increase in ecosystem synchrony. There was a nice talk showing how El Niño may or may not result in warming in the California Current System, showing the importance of understanding the entire state of the North Pacific winds and temperatures since changes are not solely driven by equatorial processes.

The remainder of the talks included further discussion of climate variability and how it manifests itself in various geographic regions across the North Pacific from the Sea of Okhotsk, across Hawaii and the Bering Sea, to the California Current. The influence of this climate variability on many trophic levels was examined including phytoplankton community composition, zooplankton size and species assemblages, fish size and species composition, marine mammal reproductive success, and seabird breeding cycles. Although climatic forcing of ecosystem changes is indicated by correlations between observed ecosystem changes and climatic indices and/or associated physical environmental parameters, the presenters suggested that the mechanisms that cause those ecological consequences vary case by case. For example, direct influence of temperature changes on physiological conditions mainly impacts some species while advection control is the major cause for other species.

At the conclusion of the session there was discussion about whether we really are seeing "extreme events" like the 2014-2016 warm blob or the large amounts of Japanese sardine found on the coast along Tartar Strait, or that these events have happened in the past too and our records are not long enough to have the proper historical context. There are studies that show variability is increasing and/or the return time between large events is shortening under global warming. All agreed that we must keep our time series of physical, chemical and biological variables in the North Pacific going and that we should all endeavor to place our observations of unusual or extreme events in historical context.

Below is a table showing how each talk in this session discussed causes and consequences of climate variability, and about the nature of that variability, whether the variability was stable or increasing, and if there was any predictability for the variability.

Presentation	Nature		Tendency of variability		Predictability	
	Internal	External	Strengthening	Stable	Deterministic	Stochastic
Causes of environmental changes						
Miller	+	ENSO	+			+
Di Lorenzo	+	ENSO	+		+	+
Ustinova		AO, ENSO	+		+	+
Felder	+	ENSO				+
Barth	+	ENSO	+		+	
Mantua	+	+				
Consequences of environmental changes for marine ecosystems						
Di Lorenzo	+		+		+	+
Woodworth	+	+			+	
Lowry		+			+	
Jahncke	+	+		+	+	
Barth		+		+	+	
Petersen		+	+			+
Show		+		+		
Li	+					+
Pena	+					
Brandt						

List of papers

Oral presentations

Changes in climate and changes in concepts: Physical-biological interplay in the Pacific Ocean over the PICES years (Invited)
Arthur J. Miller

Increasing variance and synchrony in North Pacific climate and ecosystems (Invited)
Emanuele Di Lorenzo, Giovanni Liguori and Bryan A. Black
Presented by Art Miller on behalf of Emanuele Di Lorenzo

Relationships between climate variability and fisheries catch in the central North Pacific
Phoebe A. Woodworth-Jefcoats, Jeffrey J. Polovina and Jeffrey C. Drazen

Climate variability and changes in the marginal Far-Eastern Seas
Elena I. Ustinova and Yury D. Sorokin

Warm and cool years in the California Current: Relation to ENSO
Paul Fiedler and Nate Mantua

California sea lions: Historical diet patterns in relation to environmental changes in the California Current*
Mark S. Lowry, Stephanie E. Nehasil, Alan R. Jackson and Robert Holland

Mid- and upper trophic level responses to variability in ocean conditions off central California
Jaime Jahncke, Russell Bradley, Pete Warzybok, Meredith Elliott, Jan Roletto and Danielle Lipski

The subsurface and inner-shelf structure of 25 years of variability in the Northern California Current
John A. Barth, Stephen D. Pierce and Scott M. Durski

Effects of the Blob on phytoplankton and copepod species composition, community structure and biodiversity off the central Oregon coast
William T Peterson, Xiuning Du, Jennifer Fisher and Jay Peterson
Presented by Tracy Shaw on behalf of William T. Peterson

Euphausiid responses to recent warming events in the coastal upwelling zone off the Oregon Coast, USA
C. Tracy Shaw and William T. Peterson

Historical context for the atmospheric forcing of record high SSTs in the NE Pacific Arc in 2014-16
James Johnstone and Nathan Mantua

The impacts of climate variability on the distribution of groundfish along the Northeast Pacific coastal shelf
Lingbo Li, Anne Hollowed and Steve Barbeaux

A decade of phytoplankton composition and environmental measurements along Line P in the NE subarctic Pacific
Angelica Peña, Nina Nemcek and Marie Robert

Variability in North Pacific Ocean conditions: Assessing habitat-specific vital rates and thresholds for fishes
Stephen B. Brandt and Cynthia E. Sellinger

Poster presentations

Reponses of marine primary productivity (PP) to the future climate change scenario: The role of the subsurface chlorophyll maximum (SCM) in the mid-latitudinal marginal seas
Christina Eunjin Kong, Sinjae Yoo, Chanjoo Jang and Jisoo Park

Interannual variation of ocean environment in the Kuroshio Extension, Oyashio, and their transition area correlated with the recruitment of chub mackerel (*Scomber japonicas*)
Hitoshi Kaneko, Takeshi Okunishi, Takashi Setoh, Hiroshi Kuroda, Sachihiko Itoh, Shinya Kouketsu and Daisuke Hasegawa

MONITOR/TCODE Topic Session (S13)
Understanding the changing coastal ocean: Advances and challenges in multi-parameter observations

Co-Convenors: *Vyacheslav B. Lobanov (Russia), Matthew Baker (USA), Sung Yong Kim (Korea), John Barth (USA), Daisuke Ambe (Japan)*

Invited Speaker:
Hidekatsu Yamazaki (Department of Ocean Sciences, Tokyo University of Marine Science and Technology, Japan)

Background

Major changes in coastal ocean ecosystems occur across the North Pacific and its marginal seas on a variety of time scales, from weeks to years. Examples include warming events associated with low (*e.g.*, El Niño) and high latitude ("warm blob") forcing, and coastal hypoxia influenced by both natural and anthropogenic forcing. These major changes involve physical, chemical, and biological processes and their interaction. Sustained, high-quality, multi-parameter coastal observations are required to discern changes from normal seasonal patterns and to detect long-term trends. Contributions that address the role of coastal ocean observations in advancing our understanding of these major physical-biological changes in North Pacific coastal oceans were encouraged. These included techniques for sustaining multi-sensor time series and the use of new measurement platforms, as well as new measurements and understanding of regional interactions and coastal-deep ocean interactions at various areas of PICES region.

Summary of presentations

The session's invited speaker, Dr. Hidekatsu Yamazaki (Department of Ocean Sciences, Tokyo University of Marine Science and Technology, Japan), introduced some recent results on his coastal observation systems which includes a free-fall multi-parameter profiler, a cable observatory system and autonomous underwater vehicle to measure various physical, chemical and biological parameters simultaneously, including microstructure and plankton.

Jinyong Jeong *et al*. introduced an 'Integrated Coastal Monitoring System'program of Korea based on the Ocean Research Stations (ORS) located at open Yellow Sea and East China Sea such as The Ieodo, Gageocho and Socheongcho ORSs. Equipped with more than 30 different types of instruments, the ORSs are observing a wide range of different variables of the ocean and atmosphere (wind, wave, temperature and salinity, air-sea fluxes, *etc*.). This operational information is used for many on-going research programs to investigate typhoons, air-sea interactions, transportations of air pollutant particles, sea-fog formations, changes of the biological eco-environment, *etc*.

David M. Anderson *et al*. reported on observation of record-warm temperatures in California coastal waters in 2015, and unprecedented levels of domoic acid during the summer 2015 harmful algal bloom and other extreme events by the Central and Northern California Ocean Observing System. CeNCOOS supports an array of 14 continuously streaming multi-parameter shore stations, 27 current-sensing high frequency radars, and two autonomous gliders that traverse the California Current to 500 km offshore. CeNCOOS is one of eleven regional ocean observing system (IOOS) regional associations that maintain real-time, multi-parameter observing systems. Salinities in estuaries remain elevated as the California drought enters its fifth year. These and other extreme events are recorded by Data acquisition at periods ranging from minutes to hours produces a high-velocity stream useful in a range of applications including mobile apps and assimilation into coastal models. Ninety percent of CeNCOOS' observations are in the surface layer, underscoring the challenge of siting, maintaining, and telemetering observations from multiple depths. IOOS data are made available in a variety of formats, served to distributed catalogs, and contributed to long-term archives. Best practices are documented in quality assurance manuals and reports, enabled by the use of existing standards, and further developed in test-beds and exploratory programs.

Sung Yong Kim *et al*. discussed a feasibility and capability of integrated coastal ocean observations to monitor multiscale oceanic geophysical signals and variability in open ocean and coastal regions. An observation system includes sea surface heights obtained from satellite altimetry, tide gauges and coastal radar-derived surface currents, as well as temperature and salinity profiles sampled by Argo floats, long-term hydrographic surveys and shore station CTD casts. While discussing and comparing various means of observation of ocean parameters, he had enhanced awareness and matured efforts to examine the physical view on the ocean ecosystem-related issues.

Richard Dewey *et al*. presented an investigation of anomalous conditions in the Salish Sea, Strait of Georgia, and Juan de Fuca Strait during 2015 in the context of large scale North Pacific Warm Blob using multiplatform observations (*in-situ* observations, ferries) of dissolved oxygen, sea water temperature, salinity, and density.

Yang Luo *et al*. talked about water quality comparison and ecological environment assessment during major and minor tides in the nearshore area of Fujian Province based on four surveys on water quality, marine sediments and marine biological quality at 20 monitoring sites carried out during the spring and neap tides in the autumn of 2010 and the spring of 2012. The community structure of phytoplankton in the spring was unstable, and the marine environment in the autumn was more suitable for the growth of a variety of phytoplankton.

Brian Hunt *et al*. presented the potential marine-terrestrial interactions to the recent warm blob in a view of land-sea-ocean interactions using coastal observatory network.

Tetjana Ross *et al*. reported on multi-parametric observations of marine mammal (*e.g*., whales), a potential trophic level of marine ecosystem (*e.g*., zooplankton), and hydrography off the west coast of Vancouver Island using subsurface gliders.

David Welch *et al*. presented the technical challenges and advances to monitor and track the juvenile fish in the ocean.

List of papers

Oral presentations

Coastal observation systems to monitor physical, chemical and biological parameters (Invited)
Hidekatsu Yamazaki, Eiji Masunaga, Scott Gallager, Mamoru Tanaka, Marika Takeuchi, Kazuo Amakasu, Kunihisa Yamaguchi and Hayato Kondo

Introduction to the Ocean Research Stations (ORSs) in Korea and application activities
Jinyong Jeong, Jooyoung Lee, Jae-Seol Shim, Do-Seong Byun and In-Ki Min

Recording extreme events in the multi-parameter Central and Northern California Ocean Observing System (CeNCOOS)
CeNCOOS Investigators and David M. Anderson

Probing multi-scale oceanic signals from the coast
Hyun Sup Soh, Jang Gon Yoo, and Sung Yong Kim

Using multiple platforms to assess a potential link between the North Pacific warm anomaly (the 'Blob') and anomalous conditions in the Salish Sea during 2015
Richard Dewey, Akash Sastri, Jeremy Krogh, Steve Mihaly and Kim Juniper

From marine terrestrial interactions to the "warm blob": Integrating land-ocean-atmospheric research in a coastal observatory framework
Brian Hunt, Ian Giesbrecht, Margot Hessing-Lewis, Jennifer Jackson, Colleen Kellogg and Kira Krumhans

Water quality comparison and ecological environment assessment during major and minor tides in near sea area of Fujian Province
Yang Luo, Wanmin Ni, Liping Jiao, Haining Huang and Youyin Ye

Multi-parameter observations of whales, zooplankton and hydrography on the west coast of Vancouver Island using ocean gliders
Tetjana Ross, Rianna Burnham, Tara Howatt, Dave Duffus and Stephanie Waterman

Advances in the science and technology underlying measurement of survival of juvenile fish in the ocean
David W. Welch, Erin L. Rechisky and Aswea D. Porter

Poster presentations

Multifactor effects of near-bottom processes in the coastal ocean
Vadim Navrotsky

Submarine groundwater discharge (SGD) and SGD-driven nutrient fluxes in Geoje Bay, Korea
Tae-Hoon Kim, Dong-Woon Hwang and Minkyu Choi

Biochemical composition of surface sedimentary organic matter and material fluxes at the sediment-water interface of Jaran Bay, Korea
Semi Jeong, Jung-Hyun Park, Hyung-Chul Kim, Won-Chan Lee and Seok Jin Oh

Typhoon storm surges observed by Chinese HY-2A satellite radar altimetry
Jingsong Yang, Xiaohui Li, Guoqi Han, Nan Chen and Dake Chen

The Present and Future of Ocean Research Stations (ORSs) of the Korea Hydrographic and Oceanographic Agency (KHOA)
Chungho Lee, Jooyoung Lee, Jinyong Jeong, Do-Seong Byun and Eunil Lee

Multivariate Ocean Climate Indicator (MOCI): Describing the California Current
Marisol García-Reyes, Sarah Ann Thompson and William J. Sydeman

Non-market value of marine ecosystem service in Saemangeum open sea in Korea
Seul-Ye Lim and Seung-Hoon Yoo

New light for time series: international collaboration in ship-based ecosystem monitoring
Luis Valdés and Kirsten Isensee

Integration and duplication remove of the oceanographic and marine meteorological data at CMOC/China
Yulong Liu, Fangfang Wan, Dongsheng Zhang and Mingmei Dong

POC Workshop (W1)
Acidification of the North Pacific Ocean: A basin-wide assessment

Co-Convenors: *James Christian (Canada), Tsuneo Ono (Japan)*

Invited Speaker:
Karen Kohfeld (Simon Fraser University, Vancouver, Canada)

Background

Ocean acidification has been proceeding for a century, at an accelerating rate, and its impacts are beginning to be felt in many corners of the North Pacific. The workshop brought together scientists from all of the PICES countries to synthesize our observations and projections of acidification processes and impacts in our respective countries' waters and adjacent international waters. This workshop is the culmination of a two-year long process of collation of relevant information, and synthesis of data collected in each of the countries of the North Pacific basin. The workshop proceedings will form the basis for subsequent assessments, with improved understanding of which ocean regions are most vulnerable to acidification impacts, and how additional resources might best be deployed to predict or detect changes likely to produce significant impacts.

Summary of presentations

The workshop on "*Acidification of the North Pacific Ocean: a basin-wide assessment*" was held on November 3, 2016 at the PICES Annual Meeting in San Diego, CA. It was well attended, with representation from all PICES countries. There were several topical presentations, as well as individual national updates and extensive discussion of the contents of the proposed Assessment and strategies for completing it. The discussions covered both the open ocean and coastal waters, and roles of observing systems on both sides of the Pacific.

One key point that was noted was that locally secular trends in pH and other carbon system indicator variables often differ from the global mean trend, and it is often difficult to know whether this is simply a result of inadequate data or whether there are local influences that themselves have long-term secular trends. These deviations can be used to build a case for construction and maintenance of observing systems as necessary and interactive factors in decision-making. The driving factors will vary among regions, and we can use scientific understanding of these to guide design of observing systems, as well as mitigation and adaptation policies. Overall the workshop was highly productive and the assessment activity is on track to be completed in 2017.

List of papers

Oral presentations

Assessing vulnerability to ocean acidification in the Strait of Georgia along the Canadian Pacific Coast (Invited)
Karen E Kohfeld, Debby Ianson, Susan E. Allen, Ellie Simpson, Ben Moore-Maley, Chris Harley, Paul Covert, Marty Davelaar, Kenny Scozzafava, Yves Perrault, Andre Comeau, Keith Reid and Terry Learmonth

Variations of carbon uptake and ocean acidification in the Bering Sea and Western Arctic Ocean from 1999 to 2014
Zhongyong Gao, Heng Sun, Liqi Chen and Di Qi

Reconstructing ocean acidification in deep coastal and estuarine waters of the northeastern Pacific Ocean (Cascadia Margin): A crab's eye view
Simone Alin, Beth Curry, Meghan Shea, Wendi Ruef, John Mickett, Richard A. Feely, Jan Newton, Allan Devol, Liam Antrim, Kathy Hough, Christopher Krembs and Samantha Siedlecki

MEQ Workshop (W2)

Conditions promoting extreme Pseudo-nitzschia events in the eastern Pacific but not the western Pacific

Co-Convenors: *Vera Trainer (USA), Polina A. Kameneva (Russia)*

Invited Speaker:
Inna Stonik (Zhirmunsky Institute of Marine Biology, Vladivostok, Russia)

Background

There is clear evidence of contrasting occurrence and impacts of the toxin-producing diatom, *Pseudo-nitzschia*, between the western and eastern Pacific. In 2015, a massive bloom spanning from California to Alaska, had major impacts on the shellfish industry economic viability and on wildlife health. In contrast, *Pseudo-nitzschia* are not highly toxic and do not cause economic losses in the western Pacific. These data provide a unique opportunity for east-west Pacific comparisons to identify and rank those environmental factors that promote harmful algal bloom (HAB) success at different times. A recent PICES-funded workshop on HABs and Climate Change emphasized the importance of studying such extreme events to enhance our understanding of climate impacts. This workshop focused on *Pseudo-nitzschia*, a diatom that historically has had massive economic impacts in the eastern PICES member countries, with low or no impacts in the western Pacific. The workshop foundation was an extension of the current dataset to the 1990s and earlier where available, with PICES participants pre-submitting available data on: HAB species presence, maximum abundance, toxicity, optimal conditions for growth, time of year, temperature range, salinity range, water clarity, nutrients, wind, river flow (flooding), and upwelling indices.

Summary of Presentations

Inna Stonik (Invited) posed the question that if *Pseudo-nitzschia multiseries* reaches concentrations and toxicity in Russia similar to those seen in eastern Pacific, why was there no shellfish toxicity in the western Pacific when Russian and eastern Canadian strains of *P. multiseries* are genetically the same? There appear to

be correlations between water temperature and *Pseudo-nitzschia* species abundance. Dr. Stonik highlighted the differences between the eastern and western Pacific including a shift in community composition possibly due to warming. For example, a shift from *P. multiseries* (colder) to *P. calliantha* (warmer) has been observed in Denmark. A decreasing abundance of diatoms and corresponding increase in raphidophytes has been observed over the last decade in Russia. Greater warming in the western Pacific (more intense) vs. eastern Pacific may be the reason for this shift.

Vera Trainer (USA) reported on the typical toxic *Pseudo-nitzschia* blooms in the Pacific Northwest of the U.S. that originate from hotspot sites – the Juan de Fuca eddy, Heceta Bank, Monterey Bay and the Santa Barbara Channel. Trinidad Head, at the border of Oregon and California, is a new hotspot site that was first identified in 2015. Physical factors that contributed to toxic *Pseudo-nitzschia* advection to the coast include moderate upwelling (average cumulative upwelling index) followed by storms bringing cells to the coast. The Columbia River plume can block the advection of *Pseudo-nitzschia* to the coast by forming a barrier (salinity gradient). The most typical toxigenic *Pseudo-nitzschia* on the coasts of Oregon and Washington are *P. pseudodelicatissima, P. cuspidata*, and *P. australis*. Higher abundances of the small cells (>1 million cells/L) are required to toxify shellfish compared to larger cells (>30,000-50,000 cells/L). These are the threshold abundances used to alert managers of toxic blooms. Environmental factors believed to induce *Pseudo-nitzschia* blooms in the Pacific Northwest include low Fe, the type of nitrogen, a pulse of N to the coastal environment after a period of nutrient starvation. The economic losses due to domoic acid (DA) are great and were estimated at $24 million USD lost income in Washington State alone after a 1-year closure of the razor clam fishery. The Dungeness and rock crab fishery closures in 2015 were estimated to cost $50 million USD. This does not take into account the social and cultural losses due to DA closures.

Nicola Haigh *et al*. (Canada) reported that an unprecedented amount of DA was observed on the west coast of British Columbia in 2015. In Esperanza Inlet in mid June, 75 ppm DA was measured in a mussel sample. In Saanich Inlet, 54 ppm DA in shellfish was observed in November 6, coincident with observations of *P. australis*.

Tamara Russell (Canada) summarized data of domoic acid events in Haida Gwaii from 2004–2016, from the Marine Biotoxin Monitoring Program of the Canadian Food Inspection Agency. Salinity and sea surface temperature data were compared to historical means (1936–2016) during years with domoic acid events. The only DA event which surpassed the 20 µg/g regulatory limit was in northeastern Haida Gwaii in September 2012 (41.7 µg/g); DA persisted at lower levels in this area for several months. This followed the ocean fertilization experiment of July–August 2012, where 120 tons of iron sulphate were dumped off western Haida Gwaii. DA events below the regulatory limit were also seen in northern Haida Gwaii in 2004 (14.7 µg/g) and 2005 (14.2 µg/g), and southern Haida Gwaii in 2006 (12.6 µg/g) and 2015 (12.2 µg/g). Decreased salinity was present throughout 2006 (>1 ppt below the mean), 2005 (~2 ppt below the mean), and 2004 (~2 ppt below the mean). Increased sea surface temperature was present throughout 2015 (> 2°C above the mean), and in 2005 (> 2°C above the mean). It is unknown whether phytoplankton taxonomic data from Haida Gwaii exist for the periods with DA events, so *Pseudo-nitzschia* spp. present during these events are unknown.

Devan Johnson (Canada) discussed results of a follow up study of *Pseudo-nitzschia* sp. and concentrations in and around Saanich Inlet, Vancouver Island, following the Amnesic Shellfish Poisoning closure in November 2015. A mixture of *Pseudo-nitzschia* species was identified across the six sampling sites, including *Pseudo-nitzschia australis*, the species determined to be responsible for the high DA levels in 2015. *Pseudo-nitzschia australis* was found at every site sampled and was eventually found all the way to the northern tip of Vancouver Island in samples taken by the Harmful Algae Monitoring Program (HAMP). No DA was detected by the Canadian Food Inspection Agency during the sampling period along the east coast of Vancouver Island.

Yuichi Kotaki (Japan) noted that Japan has never had an amnesic shellfish poisoning event. In 1994, DA was measured in shellfish in Ofunato Bay at 3 ppm maximum. However, most shellfish were negative for DA. *P. multiseries* has been present in Ofunato Bay, and appears to be a common *Pseudo-nitzschia* species. Batch experiments with *P. multiseries* by Kotaki *et al*. published in 1999 in *Toxicon* showed a linkage between low

Fe with an increase in DA content in cells in culture. Samples chelated with EDTA or natural depletion of Fe showed increasing DA. Experiments using dialysis were used to expose axenic *P. multiseries* to bacteria with no increased DA observed. A large porphyrin-like compound may be produced by bacteria. The Great Tsunami of 2011 impacted Ofunato and Okirai bays. Concentrations of DA at the pg/L level were detected in plankton. *P. multiseries* was cultured with a maximum of 317 ng/ml observed in culture. However, DA was not detected in any shellfish in 2011. It is speculated that rivers washed *P. multiseries* out of the bays resulting in low residence time of these cells so that bloom proportions could not be reached.

Meredith Elliott (USA) reported on monitoring of *Pseudo-nitzschia* in California using a relative abundance scale. This is part of the Applied California Current Ecosystem Studies, research that supports marine wildlife conservation and healthy marine ecosystems to inform management, policy, and conservation in central California. Samples are collected during 3–4 cruises per year, including water samples, nutrients and zooplankton along with environmental parameters.

Hao Guo (China) presented for Lin Yang. Sixteen blooms of *Pseudo-nitzschia* have been observed in China since 1987. No marine life mortality or economic loss due to *Pseudo-nitzschia* has been apparent. Species observed include *P. delicatissima, P. pungens* and an unknown *Pseudo-nitzschia* sp. Li Dazhi (2001) detected DA in scallops at 5 ppm.

Weol-Ae Lim (Korea) noted that *Pseudo-nitzschia multiseries* isolated from Korean waters has been shown to produce up to 1 pg DA per cell during its stationary phase. Many species of shellfish have been analyzed for DA resulting in no detectable or very low concentrations of toxin. Time series data have shown a decrease in *Nitzschia* and *Pseudo-nitzschia* species over the last decade with a subsequent increase in *Cochlodinium polykrikoides* and other flagellates. *Pseudo-nitzschia* blooms in some areas appear to have a tight linkage to rainfall events. Many species of *Pseudo-nitzschia* are observed in Korea. *Pseudo-nitzschia calliantha, P. multiseries, P. calliantha* are the only three species that have been shown to produce DA at concentrations of 3.5, 0.1 and 0006 pg/cell, respectively.

Anthony Odell (USA) provided a review of 2016 Washington outer coast *Pseudo-nitzschia* spp. blooms and subsequent razor clam closures along Washington's south coast. The outer coast of Washington State has regions of strong upwelling and primary productivity which often originate harmful algal blooms; the Juan de Fuca Eddy located off the northwest tip of the Olympic Peninsula and Heceta Bank located off of the central Oregon coast. Recent R/V *Bell M. Shimada* cruise observations and data, weather hindcasts from NOAA, LiveOcean model (UW/NOAA) particle tracks, buoy data from multiple offshore buoys and CODAR data from along Oregon's coastline indicated possible bloom origination sites as the Juan de Fuca Eddy in September and Heceta Bank in October. It was shown that there are 3 fairly distinct regions of Washington's outer coast which are affected by various large scale oceanographic features such as: The Juan de Fuca Eddy along the north coast, strong seasonal upwelling along the central coast, and the Columbia River plume and estuarine output along the south coast. It was also observed that coastal sample sites along the extreme north coast of Washington may be reliable sentinel sites which could possibly provide insight in HAB formations within the Juan de Fuca Eddy due to their proximity to the eddy. It was also observed that phytoplankton taxonomic information from coastal sampling may be used as a possible biometric to indicate the physical oceanography of the region.

Workshop discussion was productive and resulted in the identification of several themes that will be examined for submission in the PICES Scientific Report series.

BIO Workshop (W3)
Distributions of habitat-forming coral and sponge assemblages in the North Pacific Ocean and factors influencing their distributions

Co-Convenors: *Kwang-Sik Choi (Korea), Janelle Curtis (Canada), Masashi Kiyota (Japan), Chris Rooper (USA)*

Invited Speaker:
Hiroya Yamano (Center for Environmental Biology and Ecosystem Studies, NIES, Japan)

Background

Changes in the marine environment influence global and regional distribution patterns of marine organisms including corals and sponges in shallow, mesophotic, and deepwater ecosystems. The biogenic habitats formed by these organisms support a broad range of biodiversity, and provide critical habitats for some socio-economically important fishes and invertebrates that attract commercial fishing and other anthropogenic activities. The aim of this workshop was to improve understanding of factors influencing the distributions of corals and sponges in the North Pacific Ocean, improve habitat models predicting their distribution, and predict how their distributions are likely to shift in response to natural and anthropogenic forcing, including climate change.

Summary of presentations

The 2-day workshop was held on November 2 and 3, 2016. It was co-convened by Drs. Kwang-Sik Choi (Korea), Masashi Kiyota (Japan) and Chris Rooper (USA). The invited speaker was Dr. Hiroya Yamano (Japan). The workshop comprised three sessions of oral presentations in the morning and early afternoon of the first day, with a total of 10 papers presented. It was followed by species distribution modelling session during the rest of the first day and throughout the second day. The workshop was attended by more than 20 researchers.

The oral session 1 covered recent topics in habitat-forming shallow-water corals including direct and indirect impacts of environmental changes, case studies of future projection modeling, and field monitoring of annual reproductive cycles of coral species expanding their geographical ranges to higher latitudes. H. Yamano highlighted that the current level of CO_2 emission enhances seawater temperature warming, ocean acidification and sea level rise in global scale and increases precipitation and sediment discharge from land to sea in regional scale, and these processes affect the distribution and condition of shallow-water corals in a complex manner.

In Session 2, deep water coral and sponge distributions were summarized in three talks. A significant difference in water mass characteristics in the North Pacific was considered important to predict the presence of deep water octocorals, and the existence of three bathyal biogeographic provinces in the North Pacific was suggested. Understanding the factors that contribute to the distribution of corals and sponges in deep water may be elucidated using a modeling approach. The major glass sponge habitats confirmed were those forming reefs along the British Columbia coast.

Session 3 focused on technical aspects of the species distribution modeling, including the best-practices for generating input data, creating models and evaluating the results, data driven approach to define bioregions, a multi-scale assessment of species distribution models, and an assessment of the model transferability. In addition to the research focus of each presentation, these talks elicited excellent discussions concerning the selection of informative variables, the most appropriate methods for evaluating models, and lessons learned from currently unpublished work in progress.

Building on the information presented during the oral presentation sessions, the late afternoon and second day of the workshop was devoted to the exercise of building some preliminary models of corals and sponges for data limited taxa. The goals of the modeling session were: 1) to evaluate existing environmental variables/mechanisms effecting basin-wide distribution of coral and sponge, 2) to construct preliminary basin-wide habitat models for taxa including glass sponges and corals in the North Pacific Ocean and 3) to provide model-based information for predicting potential changes in distributions of coral and sponge with climate change.

Currently available environmental layers and species distributional data were presented, and subsequent fruitful discussion suggested avenues for improving these datasets, including the addition of new data (*e.g.*, PAR, SST, current direction, storm surge, and new terrain metrics). In addition, workshop participants evaluated the appropriate taxonomic resolution to use in modeling efforts, and generated a preliminary list of taxa to model (shallow-water corals, glass sponges, stony corals, gorgonian corals and sea pens). After the habitat variables and response data were compiled, cleaned and discussed, the initial models were developed for shallow water corals and glass sponges.

It was particularly beneficial to have the combined experience of both modelers and biologists in order to be able to standardize and refine the modeling approach based on the expert understanding of species taxonomy, biology, and ecology. Preliminary models and data sets were shared among the WG-32 members and will provide common basis to iteratively discuss and develop the best methods inter-sessionally for overcoming issues that arose during the modeling process.

List of papers

Oral presentations

Environmental factors affecting the distribution of habitat-forming shallow-water corals (Invited)
Hiroya Yamano

First report on the annual gametogenesis of high-latitude corals *Alveopora japonica* (Eguchi, 1968) and *Oulastrea crispta* (Lamarck, 1816) on Jeju Island, Korea
Jin-Soo Park, Sang-Yul Park, Shashank Keshavmurthy, Chang-Keun Kang and Kwang-Sik Choi

Biogeographic patterns and hypotheses relating deep-sea coral distributions to water masses
Les Watling

Factors affecting the large scale distribution of deep sea corals and sponges in the Alaskan ecosystems of the North Pacific Ocean
Christopher N. Rooper, Rachel Wilborn and Pamela Goddard

Seascape ecology of glass sponge reefs: Fine scale measurements of habitat heterogeneity and its relationship to community structure
Stephanie K. Archer, Jannet Mossman and Anya Dunham

Resolving biogeographic patterns in the deep sea using species distribution modeling
Samuel E. Georgian and Erik E. Cordes

Data-driven bioregions for local ecosystem context in species distribution models
Andrew McMillan and Anders Knudby

Selection of the proper spatial resolution for habitat modeling of cold-water corals
Mai Miyamoto, Masashi Kiyota, Hiroto Murase, Takeshi Nakamura and Takeshi Hayashibara

Testing the transferability of species distribution models between shallow seamounts in the North Pacific Ocean
Dana Haggarty, Janelle Curtis and Cherisse Du Preez

FIS Workshop (W4)
Methods relating oceanographic conditions to the distribution of highly migratory species

Cosponsoring Organization: International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC)

Co-Convenors: *Gerard DiNardo (USA), Chi-lu Sun (Chinese Taipei)*

Invited Speaker:
Barbara Muhling (NOAA, USA)

Background

This workshop was convened by the joint PICES-ISC Working Group on *Ocean Conditions and the Distribution and Productivity of Highly Migratory Fish*, as identified in the Working Group's Terms of Reference (first workshop – PICES-2016). The distribution and productivity of many commercial pelagic fish populations in the North Pacific are determined by large-scale oceanographic processes and climate variability. One hypothesis is that highly migratory pelagic species, such as albacore (*Thunnus alalungus*), have environmental thresholds and preferences that drive their distribution and productivity. The workshop's focus was on statistical modeling approaches that link spatially explicit environmental data (*e.g.*, satellite derived SST) to distributional fish data (*e.g.*, commercial catch per unit effort data, CPUE) for highly migratory species.

List of papers

Oral presentations

Ecology and management of Atlantic bluefin tuna under climate variability and change (Invited)
Barbara A. Muhling, John T. Lamkin, G. Walter Ingram Jr., John F. Walter, Sang-Ki Lee, Yanyun Liu, Ricardo Domingues, Mitchell A. Roffer, Frank E. Muller-Karger, Joseph Quattro and David Lindo Atichati

Population dynamics of fish species in marine ecosystem: A case study in the Bohai Sea, China
Xiujuan Shan, Xianshi Jin, Fangqun Dai, Yunlong Chen, Tao Yang and Jianping Yao

The impact of climate change on Pacific Bluefin (*Thunnus orientalis*) tuna distribution in the Eastern Pacific Ocean
Rosa Runcie, Gerard DiNardo, Toby Garfield, Elliott Hazen, Steven Bograd, Kylie Scales and Jordan DiNardo

Crossing the line: Albacore actively exploit submesoscale fronts to enhance foraging success
Stephanie Snyder, Suzanne Kohin, Yi Xu, Lynne D. Talley and Peter J.S. Franks

FIS Workshop (W5)
Modeling effects of climate change on fish and fisheries

Co-Convenors: *Anne B. Hollowed (USA), Shin-ichi Ito (Japan)*

Invited Speaker:
Michio Kawamiya (JAMSTEC, Japan)

Background

S-CCME convened a workshop in August 2015 to discuss the details needed to establish an international effort to project the response of fish and fisheries to different climate change scenarios and fisheries management strategies. Several regional modeling teams were identified that would form the core of the S-CCME projection modeling research effort. S-CCME members were tasked with working with modelers within each of the modeling nodes to initiate projections in 2016. This workshop provided an opportunity for S-CCME investigators and collaborating modelers in each of the regional nodes to meet to discuss the current status of their regional integrated modeling teams. Specific goals of this workshop were to: a) identify analytical approaches that are being used in each of the regional nodes; b) review methods for comparing projections derived from different suites of single species climate enhanced projection models, multispecies climate enhanced projection models, full food web (*e.g.*, EcoSIM), and dynamic spatially explicit ecosystem models; and c) preliminary inspection of the implications of future climate change on commercially important marine fish stocks in the northern hemisphere.

Summary of presentations

Michiyo Kawamiya (Invited, Japan) reviewed on-going research in Japan to evaluate and improve Global Climate Models and Earth System Models for use in the next Climate Model Inter-comparison Project (CMIP6). A new activity, the ocean model inter-comparison project (OMIP), is focused on evaluating the performance of global models in resolving ocean features. Four MIROC models are under development, 3 of these have 0.5° resolution, the fourth model has 0.25° resolution. Some of these new models include Earth System Model capabilities. Japanese modelers have adopted the tri-pol grid. Modeling experiments started in 2016 with a target completion date of in 2018. Preliminary results suggest marked similarities with CMIP5 and CMIP6.

As a special project, analysts are focusing effort on responses for 1.5°C trends (the HAPPI-MIP project). This modeling experiment focuses on the implications of a half a degree additional warming prognosis and projected impacts. Time slice ensembles from several models (MIROC, NCAR, CAM4,5, HadGemx, CanAM4, *etc*.) will be examined. This provides information needed to extend ISI-MIP to include the RCP 2.6 scenarios. Warming trends projected by Miroc5 are close to 1.5°C.

John Pinnegar (Invited, United Kingdom) provided a brief overview of the CERES (Climate Change and European Aquatic Resources – H2020 BG2) project. The four-year (2016–2020) project has 26 European partners from 17 countries including 7 industry partners. The goal is to provide bottom-up (industry driven) and top-down (policy recommendations) solutions for how fisheries and aquaculture can adapt to from climate change. Physical projections (RCPs 4.5 and 8.5) will be downscaled using different regional models (POLCOMS-ERSEM from the NE-Atlantic to the Mediterranean Sea, NORWECOM in the Barents and Norwegian Seas, BSCOBI in the Baltic Sea, and E-Hype for European freshwater / rivers). Abiotic changes are linked to direct (physical) and indirect (*e.g.*, biological) impacts on the productivity of key aquaculture species (*e.g.*, salmon, shellfish, seabream, seabass, trout, cod, carp, *etc*.) and the distribution and productivity of target species of mixed pelagic, mixed demersal, and single species (bluefin tuna) fisheries. Biological consequences of climate change will feed into bioeconomic models and biological / socioeconomic vulnerability assessments (Figure 1).
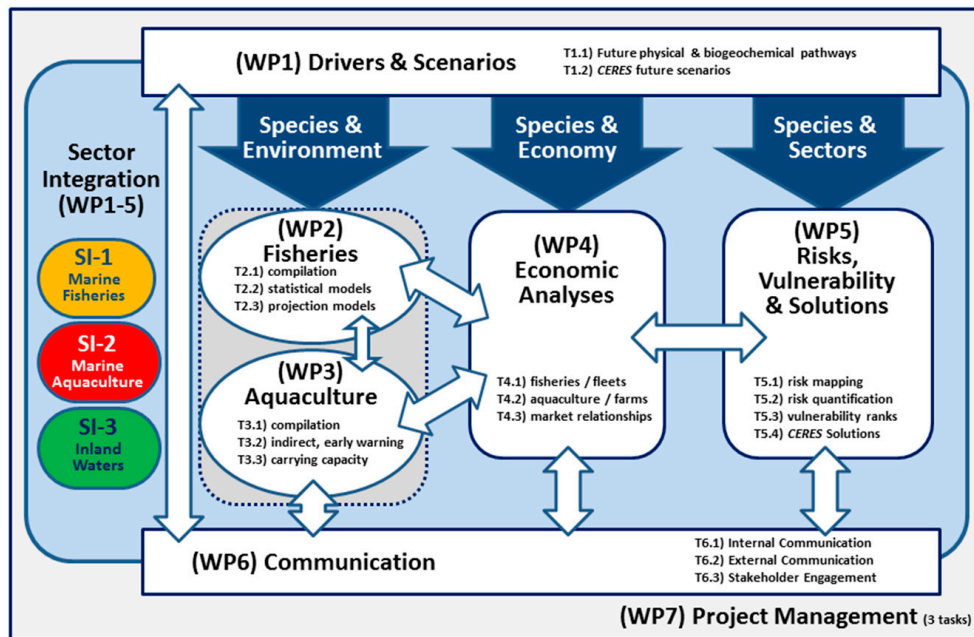

Figure 1 Diagram of the project structure of CERES. WP = work package, T = Task.

Stakeholder engagement includes both common-framing of future scenarios to be tested and mind-mapping (Bow-Tie analysis) to help envision perceived risks and mitigation strategies. The scenarios include four different "storylines" of the future (Figure 2). Vulnerability assessments by species/region will take into account the exposure, sensitivity and adaptive capacity of not only species targeted by aquaculture and fisheries but also the industry (farms and fishers).

Dr. Pinnegar focused his talk on methods for developing scenarios for governance, and socio-economic responses. CERES adopted a holistic "PESTLE" approach where PESTLE is a mnemonic denoting P for Political, E for Economic, S for Social, T for Technological, L for Legal and E for Environmental. CERES developed its socio-economic scenarios using a modification of the IPCC's Shared Socioeconomic Pathways (SSPs) see (Fujimori et al.). Four quadrants of potential outcomes representing possible futures where fisheries are managed as s: World Markets; National Enterprise; Global Sustainability or Local Stewardship (Figure 2). One of the challenges associated with characterizing these future scenarios was the task of working out how much fish Europeans would be eating under each scenario given the projected population numbers for the periods 2050 and 2100.

These draft socio-political storylines were elaborated by CERES partners and stakeholders

World Markets –
RCP 8.5 and SSP5 (A1F1)
- Fish obtained from the cheapest sources
- Decommissioning subsidies reduced
- Few legal and technical restrictions
- Only a few high-tech boats
- Sequentially depleted fish stocks
- More competition for resources globally
- Low taxes, strong private sector
- Europe outcompeted by Asia/China
- Use of cheap immigrant labour

Global Sustainability –
RCP 4.5 and SSP1 (B1)
- Fish from sustainable sources worldwide
- Equitable and ethical are important
- EU/international marine strategy
- Lower meat and fish consumption per capita
- Ecolabel certification schemes
- EIA required for new fisheries
- Traceability and quality standards
- Fisheries displaced by windfarms and MPAs
- Sustainable, low impact fishing gears

National Enterprise –
RCP 8.5 and SSP3 (A2)
- Maintaining national supply important
- Frequent 'cod wars'
- Decline in fish imports (import tariffs)
- Sport fisheries 'squeezed out'
- Higher fish prices and taxes
- Little new technology
- Food security more important than MPAs
- Individual Transferrable Quotas (ITQs)
- Increased disparity – rich and poor countries

Local Stewardship –
RCP 6.0 and SSP2 (B2)
- 'Bottom up' local/regional governance
- Self sufficiency viewed as important
- Large number of small/traditional vessels
- Improved opportunities for 'sport fisheries'
- Mosaic of different management measures
- Not worried about downstream impacts
- Equity and ownership are important
- Traceability standards important
- Individual Transferrable Quotas (ITQs)

Figure 2 Diagram of and adaptation of shared socio-economic pathways (SSPs) for use in projecting representative fishing pathways proposed by CERES.

Dr. Phoebe Woodworth–Jefcoats (USA) presented outcomes of a recent research project (Woodworth-Jefcoats *et al*., in press). In this study climate projections were used to assess the impact of climate change on epi-Pelagic habitats in the Hawaiian Islands and central Pacific. Projections based on RCP 8.5 were run using a variety of global earth system models including the Canadian CanESM2, GFDL – ESM26, GFDL – ESM 2M, and others.

Results showed trophic amplification where zooplankton declines phytoplankton declines. Results also showed a projected decline in potential carrying capacity which was related to metabolic demand coupled with reduction in zooplankton. These findings suggest that warming thermal habitat and declining food availability will re-shape North Pacific epipelagic habitat with up to 3–4 fewer tuna and billfish species in sub-tropics, with a similar increase in temperate latitudes.

Dr. Kirstin Holsman (USA) provided an overview of the Alaska Climate-change integrated Modeling (ACLIM) project activity currently occurring in the Bering Sea. The ACLIM project is half-way through its 3 year funding period. ACLIM strives to integrate physical, biological, and socioeconomic models to quantitatively project climate change impacts on fish and fishing communities through multi-model analysis of alternative management strategies under different climate change scenarios in the Bering Sea (AK). A collaboration of 19 scientists from NMFS, UW, PMEL, and IMR (Norway) the 3-year project is supported by

FATE (Fisheries and the Environment), SAAM (Stock Assessment Analytical Methods), and CREP (Climate Regimes and Ecosystem Productivity) – all NMFS Programs. The ACLIM project builds on a long history of research on the role of environmental forcing on the Bering Sea ecosystem. This body of research provided the foundation of observations and mechanistic linkages between environmental variability and ecosystem productivity. As part of the project, research scientists are projecting future environmental conditions using output from 5 Global Models under 11 representative concentration pathways (Figure 3). Projected climate change scenarios are downscaled to a regional ocean model to capture core physical and biological features governing ecosystem responses. Projections show considerable spread in temperature outcomes between the different scenarios. Of particular note was the observation that the differences in selected global models exceeded differences in RCPs, demonstrating the need to consider multiple models. Output from these projections was used to drive a multi-species model, CEATTLE which incorporated environmental impacts on bio-energetics, recruitment and predation. Preliminary projections show a wide range, however, the ensemble means suggest that of future pollock abundance based on a multi-species model will exhibit a declining trend in abundance.
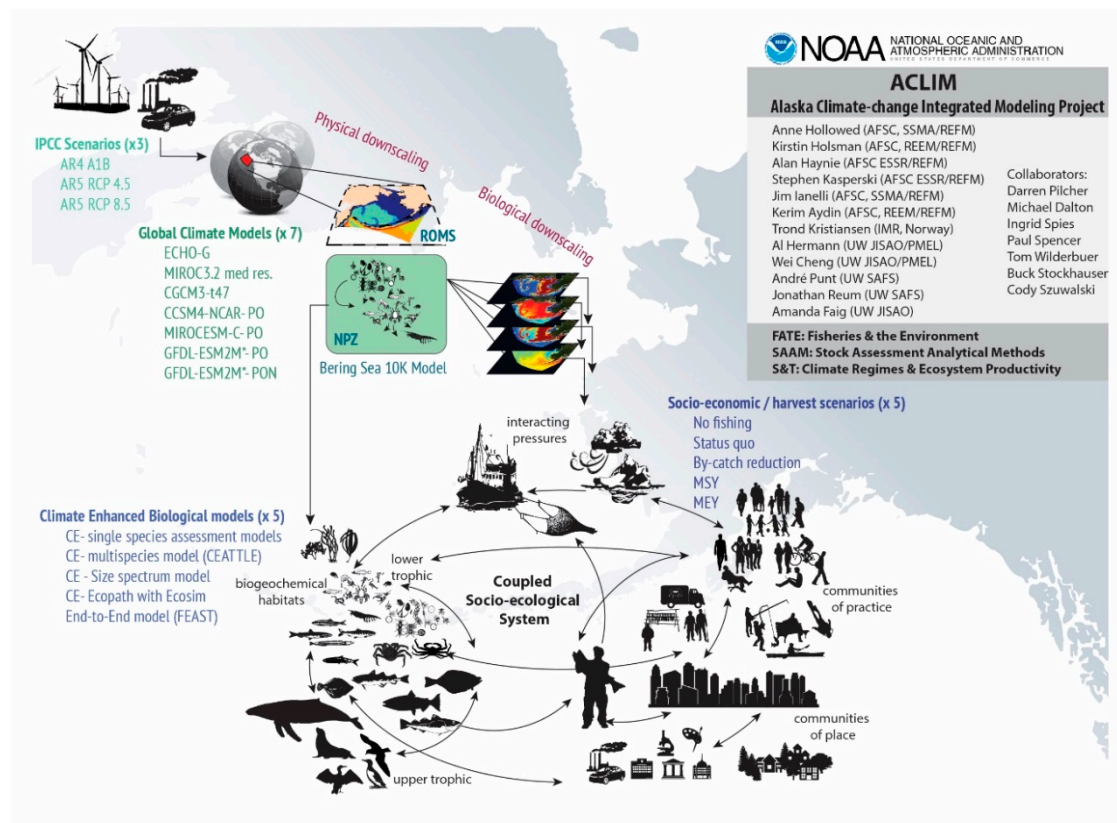

Figure 3 Schematic of the modeling framework for ACLIM.

Dr. Sukgeun Jung (Korea) presented updated analysis of climate change impacts on chub mackerel. Chub mackerel larval drift was simulated using an individual based model. Climate projections were downscaled to a regional ocean model for the region surrounding the Korean peninsula. When the model was driven in hind-cast mode, results suggest that shifts of the young-of-the-year mackerel biomass distribution to the north in the East Sea, and adult mackerel biomass distribution to the north, especially in the Yellow Sea.

Dr. Jung also reported recent findings of Dr. Sinjae Yoo. Dr. Yoo compared simulated ocean conditions against observations. Results show poor prediction of deep-layer or bottom water temperatures by the ocean circulation model.

Dr. Shin-ichi Ito (Japan) reviewed results from the Global Climate Change Effects on Fisheries and Aquaculture (GCCEFA) project (funded by MAFF). This integrated study also utilizes a long history of monitoring and process studies that inform the parameterization and selection of functional forms used in projection models. Of concern to S-CCME, the current project will end in 2017 with no clear funding source to support and update projections.

The goal of the GCCEFA project was to develop tools to track shifts in fish migration in response to climate change and to develop adaptation strategies to respond to projected changes. Target species included Pacific saury and sardine. Projections are based on the MIROC A2 scenario downscaled to a regional ocean model. Results show the southward migration of Pacific saury will be delayed and northward extent of the migration will be extended. Timing of maximum weight delayed may also be delayed. These factors suggest that the mean size of Pacific saury will decline under projected climate scenarios with strong implications to fisheries which target larger size groups.

Two new developments are emerging from this research effort. The first is the extension of NEMURO NPZ model to include smaller planktons (eNEMURO) or iron limitation (MEM) facilitated by introducing optimal uptake kinetics as nutrients. The second is the development of a multispecies IBM, NEMURO.SAN, as an end-to-end model. This model will allow modeling prey, predators, and fisheries as interacting units (Rose e*t al*., 2015). When completed this will be a remarkable improvement allowing IBMs to track the full life cycles of modeled species in a multi-species framework that incorporates fishing within a high resolution modeling environment.

Dr. Ito plans to adopt RCP 8.5 scenario, and use the FRA-ROMS model and coupling with eNEMURO using one-way nesting.

Tyler Eddie (Canada) discussed on-going efforts to compare global and regional model projections of climate impacts on fish and fisheries by FishMIP. FishMIP (ISI-MIP Marine Ecosystems and Fisheries Sector) is a component of ISI-MIP and represents a network of scientists studying 15 different models (10 global and 5 regional). FISH-MIP is using a standard selection of GCMs and RCPs (related to the overall ISI-MIP effort) and same shared socioeconomic pathways (SSPs) to: a) compare output of a range of global fisheries and ecosystem models, b) compare output of a range of regional fisheries and ecosystem models within and across regions, c) compare output of global and regional models in selected focus regions, and d) engage in inter-sectoral comparison activities within the ISI-MIP framework (longer term goal). Some of the specific global (*e.g.*, BOATS) and regional/global (*e.g.*, POEM2) and regional (EwE) modelling tools were presented.

Dr. Jonathan Hare (USA) discussed a number of research projects focused on projecting the implications of climate variability and climate change on the distribution and abundance of marine species along the Northeast U.S. Shelf Large Marine Ecosystem. The analytical methods ranged from qualitative vulnerability assessments (Hare *et al*., 2016) to quantitative Species Distribution Modeling (SDM) (Kleisner *et al*., 2016). Past and current species distribution modeling efforts were summarized with a focus on the statistical model used, the linkages to climate models, and the climate scenarios and time periods used in projections. The results showed that most SDMs focused on uncertainty resulting from climate models; yet most of the projection uncertainty was likely associated with the statistical functions used to describe biological distribution. Abundance, and by extension fishing, has a large influence on distribution. Comparison of qualitative and quantitative methods revealed that results based on expert opinion were generally comparable to statistical SDM outputs.

Dr. Hare showed essential next steps for future projection on species distribution shifts including seasonal migration, life history connectivity, process-based models, species interactions, high-resolution climate models or dynamical downscaling, social and economic effects, management/fishing scenarios, complicated fleet dynamics in the Northeast U.S.

Dr. Alan Haynie reported on the ICES/PICES Workshop on "*Economic modelling of the effects of climate change on fish and fisheries*" (WKSICCME_Econ) held in Brest, France on June 3–4, 2016 and an Alaska-

focused workshop held at the NOAA Fisheries Alaska Fisheries Science Center (AFSC) in August. The Brest workshop was associated with the larger ICES/PICES MSEAS Symposium, "*Understanding marine socio-ecological systems*". The workshop had the three following primary goals: a) Identify the socioeconomic data and features of the suite of representative future fishing and ecosystem scenarios identified in the August 2015 inter-sessional workshop that could be employed for use in evaluating climate change effects on fish and fisheries, b) Identify how fisheries management policies will interact with climate change and identify how researchers can best evaluate what management tools are most likely to be resilient to climate change effects on fisheries, and c) Identify suites of bio-economic and spatially explicit models of fishery behavior that can be used to project the implications different climate models on commercially important marine fish stocks in the northern hemisphere. Approximately 35 researchers from biological, economic, and other social science backgrounds participated. Efforts are on-going to write several papers that address these goals above and to standardize scenarios that will be used in regional projects.

Dr. Haynie also described a related workshop held in Seattle as part of the ACLIM Project. In addition to working to integrate ACLIM economic and biological models, the workshop focused on developing management scenarios that would map to the IPCC shared socio-economic pathways (SSPs), which are shown in Figure 4. The group is working to complete North Pacific scenarios by the end of 2017 and will report to SICCME members when work is complete.
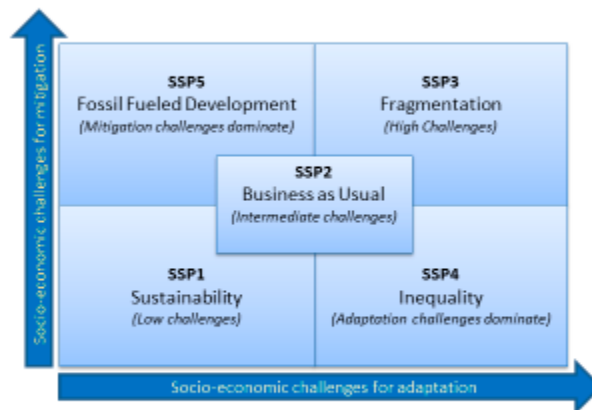
Figure 4 IPPC Shared socio-economic pathways (SSPs).

List of papers

Oral presentations

Earth system and climate modeling activities toward CMIP6 in Japan: A review (Invited)
Michio Kawamiya

CERES (Climate change and European Aquatic RESources): Socio-political scenarios for use alongside climate change projections
John K. Pinnegar

Climate change is projected to reduce carrying capacity in North Pacific pelagic marine ecosystems
Phoebe A. Woodworth-Jefcoats, Jeffrey J. Polovina and Jeffrey C. Drazen

The Alaska Climate-change Integrated Modeling project (ACLIM): Identifying impacts and management solutions for Eastern Bering Sea fisheries
Kirstin Holsman, Anne Hollowed, André Punt, Kerim Aydin, Jim Ianelli, Jonathan Reum, Paul Spencer, Wei Cheng, Al Hermann, Stephen Kasperski and Alan Haynie

Climate-change driven range shifts of exploitable chub mackerel (*Scomber japonicus*) projected by bio-physical coupling individual based model in the western North Pacific
Sukgeun Jung, Ig-Chan Pang, Joon-ho Lee, Hwa Hyun Lee and Suam Kim

Updated plan for modeling effects of climate change on fish and fisheries in the western North Pacific Ocean
Shin-ichi Ito, Takeshi Okunishi, Takashi Setou, Akinori Takasuka, Takahiko Kameda, Naoki Yoshie, Kazuyoshi Watanabe, Hiroshi Kuroda, Motomitsu Takahashi, Toru Hasegawa, Satoshi Kitajima, Michio Yoneda, Kosei Komatsu and Takaaki Yokoi

A review of species distribution modeling in the Northeast U.S. Shelf Large Marine Ecosystem
Jonathan A. Hare and Vincent S. Saba

Report on the 2016 ICES/PICES Workshop on economic modelling of the effects of climate change on fish and fisheries
Alan C. Haynie

BIO Workshop (W6)
Consumption of North Pacific forage species by marine birds and mammals

Co-Convenors:
Andrew Trites (Canada), Elliott Hazen (USA), Tsutomu Tamura (Japan), Yutaka Watanuki (Japan)

Invited Speaker:
Julie Thayer (Farallon Institute for Advanced Ecosystem Research, CA, USA)

Background

Marine birds and mammals (MBMs) are known to consume substantial amounts of prey species, and can impact their abundance and sometimes induce trophic cascades. Therefore, MBMs can have large impacts on forage fish populations, the broader ecosystem, and can compete with other top-predators and fisheries. Quantifying the effects of MBMs on marine ecosystem requires detailed knowledge of diets and abundance of prey species consumed. Such data are also needed to examine the influence of climate variability and change on trophic linkages in the North Pacific, as well as to understand how changes in prey quantity, quality, composition and distribution affect the abundance and distribution of marine birds and mammals. This workshop was a key priority of S-MBM's (2015–2020) goal to assess the climate and trophic ecology of marine birds and mammals.

Summary of presentations

The workshop was divided into two sessions. The morning session focused on case studies that 1) calculated food consumption for individual species of birds and mammals or 2) reviewed some of the methodological considerations that the S-MBM needs to consider when answering the question, "How much do marine birds and mammals consume in the North Pacific?" The afternoon session was led by S-MBM members and our invited speaker who made short presentations, and facilitated discussions and small group activities about the availability of data and methodological considerations. Topics covered included:
- Methodological considerations for estimating food consumption;
- Dietary data: What is available, and how should it be compiled and standardized?
- Population abundances and distribution: When and where are data available?
- Seasonality and decadal changes: What time(s) of year and what year(s) or decade(s) should be targeted?
- What is the desired spatial resolution for data to estimate consumption?
- Recommendation of workshop participants on how the S-MBM should proceed to answer the question, "How much do marine birds and mammals consume in the North Pacific?"

Workshop participants recognized that determining "How much marine birds and mammals consume" is a basic fundamental question that is relatively straight-forward to answer in terms of methodologies, but almost impossible to accurately answer due to data limitations. However, workshop participants also identified a number of other research questions that can be addressed on smaller scales, or for fewer species, using available data on diets and population numbers. They include:

- How much prey do marine birds and mammals need to support populations of different sizes and different growth rates?
- What are the implications for marine birds and mammals given the changes forecast to occur in the North Pacific in 20 years?
- What are the relative importance of different prey species to marine birds and mammals?
- What is the relationship between diets and populations trends and abundance?
- What is the relative importance of different marine birds and mammals in terms of the amount of energy they extract from the North Pacific?
- Are marine mammals and seabirds competing with fisheries, or are fisheries being out-competed by birds and mammals?
- What is the depth distribution over which marine birds and mammals feed?
- What is the relative distribution and densities of shelf feeders, shelf-break feeders, and open ocean feeders?
- What would a 5-fold increase in marine mammal abundance do to the flow of energy in the North Pacific?
- What consequence is the disappearance of ice likely to have on the population dynamics of marine birds and mammals in the North Pacific?
- What are the drivers of population increase or decrease?
- How do seabirds compete with fisheries?
- How does climate change link with interannual variation in prey consumption?
- How do the extreme climate conditions in recent years affect the population, diet and prey consumption of marine birds and mammals?

MAMMALS: Workshop participants recommended that the Hunt *et al.* (2000) report be updated with data collected over the past 2 decades to answer the over-arching question, "How much do marine mammals consume". The general approach proposed was to treat the Hunt *et al.* report as a living document, and have S-MBM members check and update tabulated data for species that they are familiar with over the next 12 months. S-MBM members will also assist in finding experts to verify and update tabulated data for species and areas where they cannot directly access the quality of needed information. This effort will be coordinated by Dr. Andrew Trites (Canada), with the intention of presenting and reviewing the tabulated findings at the next PICES Annual Meeting.

The workshop participants also recommended undertaking detailed analyses of the energy requirements and consumption of 3–4 species of marine mammals that have wide distributions and relatively good data that span decades to answer some of the other 10 questions listed above. The species identified as being the best candidates include sei whales (to be led by Hiroko Sasaki – Japan), gray whales (Seina Agabyani – Canada) and Steller sea lions (Andrew Trites – Canada). Other species with fair to good data that could be addressed in future years include common minke whales, Bryde's whale, Pacific white-sided dolphins, blue whales, northern fur seals, and harbor seals. The workshop participants recommended proceeding with the top 3 identified species, and that results be presented at PICES-2017.

BIRDS: Workshop participants felt that it would be useful to update Hunt *et al.* (2000), but were less inclined to do so at this time. They felt it will require considerable effort to accomplish. They are, however, interested in focusing on selected species in selected regions, and propose to target regions and species that have long time series data of population counts (mainly colony counts) and diets (mainly chick diets).

List of papers

Oral presentations

Consumption of forage fishes by marine birds in the Gulf of the Farallones, California
Pete Warzybok, Jaime Jahncke, Russell Bradley, Meredith Elliott, Jared Santora, Brian Wells, John Field, Ryan Carle and David Ainley

Consumption of salmon fingerlings by rhinoceros auklets breeding in Hokkaido, Japan
Junpei Ookado, Yutaka Watanuki, Motohiro Ito, Makoto Hasebe and Hideaki Kudo

The records of chum salmon fingerling predation by avian predators at the coastal
Motohiro Ito and Takaaki Abe

Spatio-temporal variations in the stable carbon and nitrogen isotopic compositions of Delphinidae species in the western North Pacific
Yu Kanaji, Hideyoshi Yoshida and Makoto Okazaki

Predator consumption of forage species in the California Current (Invited)
Julie A. Thayer, Amber I. Szoboszlai and William J. Sydeman

Spatial estimation of prey consumption by common minke, Bryde's and sei whales in the western North Pacific: A preliminary attempt
Hiroko Sasaki, Tsutomu Tamura, Takashi Hakamada, Koji Matsuoka, Hiroto Murase and Toshihide Kitakado

Simple models to predict daily energy requirements may not yield accurate estimates of prey consumption by marine mammals in the North Pacific
Andrew W. Trites

Prey consumption by marine birds in the eastern Bering Sea: Variability over time
George L. Hunt, Jr., Martin Renner, Jarrod Santora, Kathy Kuletz and John Piatt

MONITOR Workshop (W7)
Delivering quality multi-parameter data from the coastal ocean

Co-sponsor: Ocean Networks Canada

Co-Convenors: *Akash Sastri (Canada), Chuanxi Xing (China)*

Invited Speakers:
Rich Pawlowicz (University of British Columbia, Canada)
Zhifeng Zhang (National Marine Environmental Monitoring Center, SOA, PR China)

Background

The coastal ocean is a region with important fisheries and other ecosystem benefits, while at the same time being subject to human pressures. In order to assess coastal marine ecosystem status and changes, including any long-term trends, high-quality observations of a variety of physical, chemical and biological variables must be made and sustained. Sensor-based observations are critical to coastal observation programs and are used as part of ship-based sampling programs, fixed-point platforms (*i.e.*, long-term mooring and cabled deployments), mobile platforms (*i.e.*, gliders, ferries), and are necessary to ground-truth remote sensing observations (*i.e.*, turbidity, chlorophyll and CDOM). The quality of these observations depends on sensor choice, pre-deployment sensor preparation and calibration, platform and sensor deployment, post-deployment sensor calibration and data processing and dissemination. This workshop was a priority for the Advisory Panel on *North Pacific Coastal Ocean Observing Systems* (AP-NPCOOS) in fulfilling one of its terms of reference.

Summary of presentations

A 1-day workshop of talks and discussion was convened with the goal of comparing how different coastal observatory programs ensure the delivery of high-quality of data from multi-parameter systems. Workshop

presentations considered a variety of issues ranging from: i) descriptions of observatory systems and data assimilation techniques; ii) data quality concerns and methods; and iii) novel sensor applications and sensor fouling issues. A short discussion session was held following presentations grouped into each of these three themes. Since this workshop was intended to highlight issues relevant to AP-NPCOOS activities, the discussion sessions sought to identify similarities and differences in observatory systems practice and explore the need for developing 'best practices' related to each of the workshop themes. There were a total of 10 speakers from Canada, China, Japan, and Korea and a similar number of additional attendees were present and participated in discussions throughout the day.

The discussion following the morning talks started addressing differences in observatory systems, instrument maintenance practices, and the importance of certain data types for model assimilation. The first of the two invited speakers, Dr. Zhifeng Zhang from the National Marine Environmental Monitoring Center, China, noted that the Bohai Sea monitoring program employed periodic flushing techniques to resolve heavy sediment accumulation in their nutrient sensing packages, as well as biweekly maintenance by trained technical staff. Other groups (Japan) noted that in some instances the cost/effort of regular maintenance outweighed any benefit of automated instruments (nitrate sensors) since data quality was already considered poor. In some instances, it was even preferable to abandon automated approaches and focus on classical discrete sampling and laboratory analyses. Another aspect of this discussion session addressed how best to implement zooplankton abundance information from automated imaging systems for assimilation into NPZD models requiring biomass values. This discussion also stressed the necessity for assimilation of zooplankton diversity into models.

The second and third discussion sessions followed presentations by the second invited speaker, Dr. Rich Pawlowicz from the University of British Columbia, Canada, and subsequent talks on multi-parameter and single sensor data quality/assurance practices, novel methods for discrimination of algal groups using optical information, and potential correction methods for sensor fouling. A major point of discussion was the realization of several pitfalls which can arise with the rapid development of broad-scale, multi-platform, multi-parameter observatory systems. Significant data issues may escape standardized QA/QC protocols and ultimately demands careful oversight by a domain expert. Recommendations included: 1) developing and implementing quantitative testing techniques established by domain experts *before* installation of sensors; 2) and documenting an exhaustive list of "failures" in order to inform the continued development of observatory systems throughout the North Pacific. The afternoon discussion also addressed differences in QA/QC protocols among observatories with some adhering to formalized practices while others relying on site-specific protocols. Most approaches are similar but do not adhere to a single set of practices such as those defined by the Quality Assurance of Real Time Oceanographic Data (QARTOD - http://www.ioos.noaa.gov/qartod) group in the USA. Finally, discussion moved to identifying formalized practices for retrospective treatment of time-series for sensor fouling and 'calibration-slip'. Common experiences on the basis for relatively rapid deviation from manufacturer's calibration of dissolved oxygen optodes were discussed. The morning talks reviewed coastal observatory systems and protocols employed to ensure high-quality data by the countries represented by our speakers and started with our first invited speaker. The afternoon session was directed at methods used to identify and potentially resolve data quality issues and was started off by our second invited speaker.

Dr. Zhifeng Zhang (National Marine Environmental Monitoring Center, SOA, China) was our first invited speaker. His presentation described an on-line monitoring network built in a semi-enclosed bay of the NW Pacific Ocean, the Bohai Sea. The goal of the program is to obtain real-time observations of nutrient input from the land to sea and for addressing biogeochemical processes resulting from this nutrient input. The on-line monitoring network is composed of shore-based stations and buoys. Shore-based stations are set near the mouths of the main rivers and sewage outlets and the buoys are set near the shore-based stations and along sections of the Bohai Sea deemed as important. Shore-based stations are used to measure nutrient fluxes and the buoys are used for measuring biogeochemical processes linked to nutrient input as well as measuring cross sectional nutrient transport. Dr. Zhang presented 'best practices' for measurements taken in the Liaohe River shore-based on-line monitoring station; these included calibration and adjustment of chemical sensors, and an introduction to river outfall measurements. He also discussed the establishment of a unified QA/QC protocol

with the Liaohe River shore-based on-line monitoring station example. The protocol is expected to be adopted for monitoring China's coastal Seas.

Dr. Hidekatsu Yamazaki (Tokyo University of Marine Science and Technology, Tokyo, Japan) spoke about the Joint Environmental Data Integration (JEDI) System with the project title "Novel technologies to evaluate multi-scale variations of pelagic marine communities and biodiversity under the influence of the Kuroshio and internal waves in coastal habitats". This project has two main goals: 1) to develop and apply advanced field methods to monitor dynamic changes, diversity and planktonic communities processes under the influence of strong physical forcing (Kuroshio and internal waves); and 2) to develop a new ecosystem model for open waters using a closure approach with validation using field observations. The unique monitoring system combines a cabled observatory (CO) and a new AUV which has been developed and deployed at the southern tip of Oshima Island where the Kuroshio flows near the coast. Both the CO and the AUV carry a new plankton imaging system (Continuous Plankton Imaging and Classification System, CPICS), and measures several physical/biological parameters simultaneously. The AUV also carries a microstructure package (TurboMAP). The multi-parameter nature of the monitoring system provides details on planktonic community abundance, annual variation, and the variation of environmental factors including PAR, chlorolphyll and turbidity. A physical model based on ROMS has been established and the oscillation of the waves around the Oshima Island was modeled. The model results are evaluated with observations from the monitoring system. The structure of the ecosystem model of Oshima Island is based on NPZD trophic levels and the parameters of the ecosystem model still need to be calibrated with observations.

Dr. Genki Terauchi (Northwest Pacific Action Plan & Special Monitoring & Coastal Environmental Assessment Regional Activity Centre), introduced the mission and activities of the Special Monitoring and Coastal Environment Assessment Regional Activity Centre (CEARAC) operating under the auspices of the Marine and Coastal Environment of the Northwest Pacific Region (NOWPAP). NOWPAP CEARAC has developed procedures for assessment of eutrophication status including the evaluation of land-based sources of nutrients for the NOWPAP region. The NOWPAP 'Common Procedures' include screening procedures to detect symptoms of eutrophication within the selected parameters; trends in Chemical Oxygen Demand (COD) or Total Organic Carbon(TOC), and frequencies of red tide and hypoxia events and trends in satellite derived chlorophyll-*a* concentration (Chl-*a*). A preliminary example of the NOWPAP CEARAC data products includes a frequency summary of red tide and hypoxia and climatological surface chlorophyll concentration in NOWPAP countries.

Dr. Naoki Yoshie (Centre for Marine Environmental Studies, Ehime University, Japan) discussed time-series' of fixed-point and ship-based observation programs starting in the early 2000's in the Western Seto Inland Sea, Japan. The effects of oceanic water intrusion on the coastal marine ecosystem have been intensively monitored with several thermistor-chain platforms that measure high-frequency, multi-depth water temperatures at low cost. The observation results indicated that the coastal marine ecosystem in the Western Seto Inland Sea is mainly supported by nutrient supply from periodic intrusions of Kuroshio high nutrient subsurface waters.

Dr. Chuanxi Xing (National Marine Environment Monitoring Center, State Oceanic Administration, China) presented ongoing observations of summertime coastal circulation in the western Bohai Sea as monitored with four sets of ADCP-equipped seabed-based observation systems. The observation data suggest that there seems to be a clockwise eddy-shaped circulation system during the observation period in the Qinhuangdao coastal area, where severe 'brown tides' frequently occur during the summer. The sea-bed observation system is specially designed for the environmental conditions of the China Seas which ensures a high retrieval rate. The coastal circulation system and its formation dynamics were then examined with the 3-D ocean circulation model ROMS. The simulation results suggested that coastal currents formed a clockwise eddy-shaped circulation system with the diameter of 65km and the tides and summer monsoon induced the circulation system. Sensitivity experiments are conducted to investigate the forming mechanism of the observed summertime coastal circulation. Both the tidal residual currents and wind currents induced by summer monsoon transported water northward, thus resulting in a higher water level in the north than that in the south

which then generated a southward pressure compensation current. Consequently, the northward coastal residual current and the offshore compensation current form the eddy-shaped circulation. More work is required to look into the sources of the nutrient supply of the 'brown tide' in the Qinhuangdao coastal area.

Dr. Rich Pawlowicz (Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada) gave a talk on his experiences as a user of observatory data. He started with a discussion of how the development of the internet made it possible to make coastal ocean observatory data widely available to everyone in real-time. This new approach, however, meant that the data gathering aspect of the research process was now consolidated and ostensibly out of the hands of the individual researcher. The result is a lack of expert oversight for data collection which can result in data issues which may not be realized until a domain expert devotes significant attention to a given time-series. Dr. Pawlowicz provided several case studies which explored how he identified and in some instances was able to resolve significant issues with instrument deployments, data processing issues, instrument calibration issues, and concerns with data acquisition for the end user. He noted that these challenges have been resolved for other data-sets which have been collected routinely for extended periods. Among the conclusions drawn were: data errors are likely unavoidable in complex systems; and that ultimately research scientists must be closely involved with data streams if the complex, multi-platform/parameter data is to prove useful.

Ms. Marlene Jeffries (Ocean Networks Canada – ONC) described data quality assurance/quality control approaches from the ONC coastal cabled observatory. These approaches included a detailed description of the necessity for data best practices, the workflow for the life cycle of a given device, and the QA/QC data model employed by ONC. Ms. Jeffries identified international standards ONC adheres to such as QARTOD best practices and ARGO data quality flags and steps moving ahead which include regular and systematic re-evaluation of historical data and following set standards for data-set publishing.

Dr. Wiley Evans (Hakai Institute, British Columbia, Canada) contributed a talk on monitoring ocean acidification (OA) in coastal systems using land-based Burke-O-Lator pCO_2/TCO_2 analyzers. Dr. Evans described data requirements for calculating aragonite saturation state and accepted recommendations for uncertainty of constituent measurements relative to research objectives. The presentation also outlined QAQC protocols adhered to by a network of land-based OA systems extending along the west coast of North America from Alaska to Washington State and described inter-site differences of OA variability occurring at multiple time-scales.

Ms. Yesuel Kim (Jeju International Marine Science Center for Research and Education, KIOST, Korea) presented an interesting approach for discriminating between the harmful algal bloom species (HABs), *Cochlodinium polykrikoides* and non-harmful phytoplankton blooms with analysis of water column optical properties. This presentation highlighted the need for monitoring of harmful algal blooms in Korean coastal waters given the adverse effects these blooms exert on fisheries. Ms. Kim outlined the current at-sea monitoring programs as well as the recognition that satellite remote sensing also plays a critical role for detecting blooms. The study described how identification of different sensing reflectance spectra using algal-culture specific absorption characteristics were used to clearly differentiate *C. polykrikoides* blooms from unspecified algal species.

Dr. Akash Sastri (Ocean Networks Canada) spoke about rapid biofouling-induced deterioration of signal quality for measurements of surface chromophoric dissolved organic matter (CDOM) in the Strait of Georgia as measured using ferry boxes. The presentation outlined two techniques used to derive correction factors which were applied retrospectively to the time series. The first approach employed a "benchmarking" approach using standard solutions for CDOM fluorescence and the second approach took and inter-sensor (salinity and CDOM) comparative approach to derive correction biofouling factors. Finally, he spoke about a new statistical approach (changepoint detection) being explored to identify (and eventually discriminate) between seasonal CDOM pulses, instrument failures and instrument cleaning events.

List of papers

Oral presentations

Delivering quality multi-parameter data from on-line monitoring network in estuaries and bays: A case study in Bohai Sea (Invited)
Zhifeng <u>Zhang</u>, Zhongsheng Lin, Qian Zhao, Lijun Wang, Zhanming Hu, Zhe Zhang and Dongmei Zhao

Joint Environmental Data Integration System: JEDI System in 2016
Hidekatsu <u>Yamazaki</u>, Scott Gallager, Mamoru Tanaka, Marika Takeuchi, Hayato Kondo and Kunihisa Yamaguchi

Identification of potential eutrophic zones in the Northwest Pacific region
Genki <u>Terauchi</u>, Zhiming Yu, Zaixing Wu, Changkyu Lee and Vladimir Shulkin

Monitoring of coastal ocean in the Western Seto Inland Sea, Japan
Naoki <u>Yoshie</u>, Miwa Nakagawa, Hidejiro Ohnishi, Akihiko Morimoto, Xinyu Guo and Hidetaka Takeoka

Analysis on the patterns and formation dynamics of the summertime coastal circulation system in the western Bohai Sea
Chuanxi <u>Xing</u>, Zhanming Hu, Qian Zhao and Wanlei Zhang

What do we do with observatory data? A user's perspective (Invited)
Rich <u>Pawlowicz</u>

Data quality assurance/ quality control approaches for coastal ocean multi-parameter data from a cabled observatory in the NE subarctic Pacific
Marlene <u>Jeffries</u>, Michael G. Morley, Reyna Jenkyns, Akash Sastri and Kim Juniper

Tracking ocean acidification in coastal settings using land-based Burke-O-Lator pCO2/TCO2 Analyzer
Wiley <u>Evans</u>, Burke Hales, Jan Newton, Simone Alin, Meghan Shea and Richard Feely

Optical discrimination of *Cochlodinium polykrikoides* blooms from non-harmful blooms in Korean coastal waters
Yeseul <u>Kim</u>, Sinjae Yoo and Young Baek Son

Real-time sea-surface measurements of coloured dissolved organic matter (CDOM) in the Strait of Georgia, Canada: Developing techniques to account for sensor fouling
Akash <u>Sastri</u>, Rowan Fox, Jeremy Krogh and Maycira Costa

POC Workshop (W8)
Mesoscale and submesoscale processes in the North Pacific: History and new challenges

Co-Convenors: *Kyung-Il Chang (Korea), Hiromichi Ueno (Japan), Annalisa Bracco (USA)*

Invited Speakers:
Sachihiko Itoh (The University of Tokyo, Japan)
Naomi M. Levine (University of Southern California, USA)

Background

Oceanic mesoscale structures like eddies, upwelling, and fronts at spatial scales of ~10–100 km have been extensively studied for their dynamics and various contributions to marine ecosystems. Motions at the submesoscales (~1 km) and their impacts on the marine ecosystem, however, are less understood. Submesoscale features involve larger vertical fluxes than those associated with mesoscale eddies which then have substantial effects on the phytoplankton productivity. Submesoscale processes also interact with mesoscale processes; for example submesoscale circulation cells are often found along the periphery of mesoscale eddies. Understanding the fundamental physics of these processes, their influence on lateral and vertical fluxes, and how they influence the functioning of the marine ecosystem is necessary in order to assess likely changes and shifts to the marine ecosystem under a changing climate. Faced with these important issues, however, observational capabilities, theoretical understanding, and modeling techniques are still immature. This workshop provided a forum to discuss the physics and biology of the ocean at the meso- and sub-mesoscales based on observations and modeling and to clarify our challenges in the next decade.

Summary of presentations

The 1-day workshop was held on November 4, 2016, as part of PICES-2016, in San Diego, USA. Among the co-convenors, Dr. Hiromichi Ueno attended the meeting, and led the morning/afternoon discussions and afternoon session. Dr. Annalisa Bracco attended the workshop via Skype. The morning session was led by Dr. Daisuke Hasegawa. More than 20 scientists attended the workshop with 7 oral presentations (including 2 invited talks) and 3 poster presentations.

In the morning session, the first (invited) speaker, Dr. Sachihiko Itoh, discussed the structure and seasonal fluctuation of isopycnal salinity in the California Current System using CUGN data, focusing on variations across the pycnocline in meso-submesoscale bands. Mr. Yasuhide Kobayashi talked about the mechanism determining an eddy trajectory under the influence of boundaries; Dr. Young-Gyu Park verified theories developed for 2D turbulence from the view point of power spectral density and seasonality; and Dr. Hiromichi Ueno discussed the spatiotemporal variation of mesoscale eddies in the North Pacific especially in the area of Kuroshio extension. In the afternoon, the second invited speaker, Dr. Naomi M. Levine, discussed the impact of submesoscale bio-physical interactions on ecosystem dynamics using a statistical description of the perturbations induced by submesoscale processes. Dr. Elena I. Ustinova followed with a talk on the role of mesoscale structures in the fishing grounds formation on the basis of observations of saury fishing implemented by TINRO-Center in the Northwestern Pacific, and Dr. Dongfeng Xu talked about the cross-shelf transport between the shelf and offshore waters in the Northern South China Sea (NSCS).

In the latter halves of the morning and afternoon sessions, we discussed the proposal for a new working group focused on mesoscale and submesoscale processes. First, Dr. Crawford gave a talk about mesoscale eddies in the northeast North Pacific; next, Dr. Hiromichi Ueno explained the terms of reference of the working group and participants discussed the purpose of such a working group. Some participants indicated that would be important to quantify the impact of mesoscale and submesoscale processes on fish and fisheries, while keeping in mind that observing submesoscale processes remains a challenge. The discussion provided helpful input to the proposal.

A poster session was held on November 8 and 10. Mr. Hiromu Ishiyama discussed oceanic mesoscale eddy mergers in the North Pacific, Mr. Elígio de Raús Maúre investigated the spring bloom initiation timing influenced by mesoscale eddies in the region around Yamato Basin, Japan Sea, in a period spanning 2002–2011, and Mr. Kyung-Jae Lee delivered a presentation entitled "*Mesoscale eddies in the East/Japan Sea: Detecting methods and characteristics of eddy properties*".

List of papers

Oral presentations

Finescale variability of isopycnal salinity in the southern California Current System (Invited)
Sachihiko Itoh and Daniel L. Rudnick

Eddy trajectory in a closed rectangular oceanic basin
Yasuhide Kobayashi and Atsushi Kubokawa

Mesoscale and submesoscale wavenumber spectra from the Geostationary Ocean Color Imager (GOCI)
Yeon S. Chang and Young-Gyu Park

Mesoscale eddies in the western subarctic North Pacific
Hiromichi Ueno, Hiromu Ishiyama, Yuki Okada and Yuka Karasawa

Competition in a patchy world: Submesoscale dynamics, phytoplankton growth, and carbon export in the oligotrophic North Pacific (Invited)
Naomi M. Levine and Xiao Liu

Mesoscale structures and Pacific saury fishing grounds in the northwestern Pacific
Elena I. Ustinova and Viktor N. Filatov

The cross-shelf transport by the eddy-pair in the Northern South China Sea in June 2015
Dongfeng Xu, Xianqiang He, Chenghao Yang, Jun Wang, Mingquan Xu, Hong Chen and Yaochu Yuan

Poster presentations

Global distribution of mergers and splits of oceanic mesoscale eddies
Hiromu Ishiyama, Hiromichi Ueno, Masaru Inatsu and Sachihiko Itoh

Impact of mesoscale eddies on spring bloom initiation in the Japan Sea
Elígio de Raús Maúre, Joji Ishizaka, Chiho Sukigara and Yoshihisa Mino

Mesoscale eddies in the East/Japan Sea: Detecting methods and characteristics of eddy properties
Kyung-Jae Lee and Kyung-Il Chang

POC Workshop (W9)
The role of the northern Bering Sea in modulating Arctic environments: Towards international interdisciplinary efforts

Co-sponsor: North Pacific Research Board

Co-Convenors: *Lisa Eisner (USA), Matthew Baker (USA), Kirill Kivva (Russia)*

Invited Speakers:
Seth Danielson (University of Alaska Fairbanks, USA)
Kirill Kivva (Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), Russia)
Alexander Zavolokin (North Pacific Fisheries Commission (NPFC))

Background

Despite the fact that the Bering Sea is outside the Arctic Ocean, in many ways it behaves as an Arctic sea. The northern Bering Sea influences the state of the southern Chukchi Sea ecosystem as well as the functioning of many other Arctic regions, including the central Arctic. The Pacific Arctic Region has received great attention during the past few years:

- RUSsian-American Long-term Census of the Arctic (RUSALCA) annual cruises and publications;
- Adaptation Actions for the Changing Arctic AMAP Report part C (in preparation);
- The Pacific Arctic Region synthesis (Grebmeier and Maslowski, Eds., 2014).

Yet, the scientific efforts in the Northern Bering–Southern Chukchi Sea region are conducted mostly at the national level, and would benefit from joint multinational coordination. The goal of this workshop was to bring together researchers representing multiple national and international institutions and multiple scientific disciplines (*e.g.*, oceanography, plankton, fisheries) to share data, share knowledge, build collaborations and conduct outreach. Scientists who interested in: 1) physical oceanography and chemical fluxes, 2) plankton distribution and ecology, 3) fisheries and ecosystem dynamics, and 4) modeling efforts across the northern Bering Sea region were invited to attend. Talks were followed by discussion periods.

Summary of presentations

The workshop consisted of three invited 30-minute talks and seven contributed 20-minute talks, summarized here in order of presentation. One poster was also included, "*Seasonal dynamics of dissolved inorganic nutrient in the Bering Sea*" by Kirill Kivva who received Best Poster Award by an early career scientist for POC-sponsored workshops and sessions.

Seth Danielson (Invited) from the College of Fisheries and Ocean Sciences (CFOS) at the University of Alaska Fairbanks (UAF) assessed the role of currents and water mass structure in and near the Gulf of Anadyr. He addressed the primary flow patterns in the NBS, baroclinic currents in the Gulf of Anadyr, when and where water mass modification occurs and how recent years compare to past decades. Key points include: there has been excellent CTD coverage across the entire NBS in since 2000; mean thermohaline fields reflect the

important regional drivers: Pacific–Arctic pressure head, Anadyr Current, river discharges, winter freezing and these data provide insight to the locations and roles of advection and mixing; recent thermal conditions appear to be outside the envelope (higher) of nearly the entire last century.

Alexander Zavolokin (Invited) from the North Pacific Fisheries Commission (NPFC) presented on the "*Impact of oceanographic fluctuations on the northwestern Bering Sea ecosystem*". His talk described the impacts of a change in water circulation for 2007–2011 that likely resulted in lower water inflow to the north. This change affected the distribution and abundance of highly migratory fish and might have caused biomass fluctuations of squids and mesopelagic fish. There were no pronounced changes in total zooplankton biomass in the western Bering Sea, but there was an increase in biomass of the cold water hyperiid amphipod *Themisto libellula* and a decrease in the small copepod *Oithona similis*. Finally, after the shift in water circulation, the intensity of trophic flows between different nekton species and zooplankton changed, while total food consumption by nekton remained at a similar level (2003–2006 compared to 2007–2010).

Ellen Yasumiishi from the NOAA Alaska Fisheries Science Center (AFSC) discussed "*Climate related changes in abundance and range shifts of fish and jellyfish in the eastern Bering Sea, 2002–2015*". Main findings included: in warm years, capelin were distributed farther north and juvenile sockeye salmon were distributed farther north and west, and there was no difference in the distribution of herring or jellyfish in warm and cold years; herring and juvenile sockeye salmon abundances increased with summer warming; and jellyfish biomass was negatively correlated with sea surface temperature (SST) at a 2-year lag (t-2).

Yury Zuenko from the Pacific Research Fisheries Center (TINRO-Center) reported on "*Environmentally driven variability of zooplankton composition in the northwestern Bering Sea and its influence on the pollock fishery*". This talk concluded that temperature and salinity conditions in the Navarin area from summer to fall depend on direction of advection controlled by the size and position of the Lawrence Cold Pool (very cold portion (< 0°C) of the Bering Sea cold pool situated southwest of St. Lawrence Island), determined by the severity of the preceding winter. For example, a strong along-slope current is formed after a relatively warm winter and provides heightened temperature and salinity. Environmental conditions favorable for high abundance of zooplankton in this area occur after both cold and warm winters, *e.g.*, high abundances can be seen in relatively cold years within warm periods or in relatively warm years within cold periods. Transport of euphausiids by currents from the Green Belt to the Navarin area is crucially important for pollock feeding. High annual landings of pollock in the Navarin area are possible only in years when pollock are able to continue feeding into fall (preying mostly on euphausiids).

Lisa Eisner from NOAA AFSC spoke on "*Spatial variations in late summer chlorophyll a and zooplankton distributions in the northeastern Bering Sea*". She concluded that between warm (2003–2005) and cold climate stanzas (2007–2012) changes in temperature, ice, chlorophyll *a* (Chl-*a*) and zooplankton composition are greater in the south than the north, although changes in the north are still significant for some regions. There is lower Chl-*a*, lower zooplankton biomass and more gelatinous zooplankton in the north than the south. High Chl-*a* and high abundance of large zooplankton occur in south Bering Strait and there is a negative relationship of Chl-*a* to temperature, unlike in the south Bering Sea. There are abrupt gradients in zooplankton composition from the north Bering Sea to the Chukchi Sea, related to water mass and latitude, with northward transport important.

Gennady Khen's (Invited, TINRO-Center), presentation was given by Kirill Kivva who described "*Summer water masses and fish communities in the northwestern Bering and western Chukchi Seas in 2003–2010*". The study area was classified into six water masses: Anadyr + Alaska Coastal Water (ACW), Diluted Gulf Water, Siberian Coastal Water, Bering Summer Water (BSW), Remnant Pacific Winter Water, and Newly Ventilated Winter Water. The Navarin (Anadyr) current (formed in spring due to changes in wind direction) is the main pathway for transport of relatively warm and salty BSW into the Arctic. Main aggregations of Pacific salmon, walleye pollock, Pacific cod, and Pacific herring in the Gulf of Anadyr occurred in ACW. In the Chukchi Sea (mainly within ACW), only mature chum, sockeye, and Chinook salmon were caught. In cold and normal years, Arctic cod feed near the Bering Strait within ACW, while in warm years, they move north and westward into BSW.

Jared Weems from UAF talked about the "*Early life history ecology of larval and juvenile blue king crabs in the US Subarctic*". Two study questions were posed: Are Pribilof Island blue king crab juveniles a bottleneck in stock recruitment processes? Will blue king crab populations contract with climate change? Preliminary results evaluated juvenile crab abundance and essential habitat; research is ongoing.

Ed Farley from NOAA AFSC presented on "*Defining critical periods for Yukon River Chinook salmon*" which focused on objectives to: extend an integrated ecosystem model into the NBS, develop annual indices (1970–2012) of size-selective mortality for Yukon River Chinook salmon during the first summer at sea (using models and data), identify key processes/mechanisms that affect the growth rate of salmon during critical periods, and test key processes/mechanisms in forecast models.

Al Herman from the Joint Institute for the Study of the Atmosphere and Ocean (JISAO), University of Washington examined the "*Statistical downscaling of global projections to the Bering Sea based on an ensemble of regional model output*". Twelve downscaling runs of global projections have been completed; a multivariate method yields promising results and analysis is underway; there are differences across modes derived from different IPCC models, especially for zooplankton; and there are hints at a negative relationship between SST and Chl-*a* in the NBS.

Matthew Baker from the North Pacific Research Board (NPRB) examined "Opportunities for data sharing in the northern Bering Sea – Research and data to support international and interdisciplinary analyses", providing an overview of current and future research efforts in the Pacific Arctic, including national research efforts, international research programs (*e.g.*, NPAFC, RUSALCA), and new efforts (*e.g.*, NPRB Arctic Integrated Ecosystem Research Program). He also reviewed existing ecological time series observations and the potential new mechanisms for data sharing and exchange to understand processes, structure, and interactions in the northern Bering Sea and associated ecosystems.

Discussion

During the morning discussion period, potential topics of interest for international collaboration included research on physical oceanography, biological oceanography and productivity, and fish and invertebrate ecology. In the afternoon, workshop participants discussed potential ways to encourage interdisciplinary and international collaboration and data sharing and dissemination. The Co-convenors suggested that a second workshop be held at PICES-2017 to engage more scientists working in the northwestern Bering Sea. This suggestion was met with approval by participants.

Recommendation

A follow-up workshop is recommended at PICES-2017 to promote synthesis and understanding of physical and biological interactions in the northern Bering Sea and international efforts towards data sharing, active research and increased collaboration at the international level. All scientists interested in these topics are welcome to attend.

List of papers

Oral presentations

Currents and water mass structure in and near the Gulf of Anadyr (Invited)
Seth L. Danielson, Gennady V. Khen and Phyllis J. Stabeno

Impact of oceanographic fluctuations on the northwestern Bering Sea ecosystem (Invited)
Alexander Zavolokin, Gennady Khen, Svetlana Naydenko and Alexey Somov

Climate related changes in abundance and range shifts of pelagic fishes and jellyfish in the eastern Bering Sea during late summer, 2002-2015
Ellen M. Yasumiishi, Ed V. Farley, Jr. and Kristin Cieciel

Environmentally driven variability of zooplankton composition in the northwestern Bering Sea and its influence on the pollock fishery
Yury I. Zuenko, Eugene O. Basyuk and Anatoly F. Volkov

Spatial and temporal variations in late summer chlorophyll a and zooplankton distributions in the northeastern Bering Sea
Lisa Eisner, Alex Andrews, Kristin Cieciel, Jeanette Gann and Ellen Yasumiishi

Summer water masses and fish communities in the north-western Bering and western Chukchi Seas in 2003-2010 (Invited)
Gennady V. Khen, Evgeny O. Basuk, Kirill Kivva and Vladimir I. Matveev

Crab larvae in the northeastern Bering Sea and southern Chukchi Sea: Abundance relative to water masses in 2012
Jared Weems, Franz Mueter, Alexei Pinchuk and Ginny Eckert

Defining critical periods for Yukon River Chinook salmon
Edward Farley, Ellen Yasumiishi, Kerim Aydin, Kelly Kearney, Albert Herman and Kathrine Howard

Statistical downscaling of global projections to the Bering Sea, based on an ensemble of regional model output
Albert J. Hermann, Wei Cheng, Georgina A. Gibson, Ivonne Ortiz and Kerim Aydin

Opportunities for data sharing in the northern Bering Sea – research and data to support international and interdisciplinary analyses
Matthew Baker and Lisa Eisner

Poster presentations

Seasonal dynamics of dissolved inorganic nutrient in the Bering Sea
Kirill Kivva

MEQ Workshop (W10)
Distribution and risk analysis of radionuclides in the North Pacific

Co-Convenors: *Yusheng Zhang (China), Kathryn A. Higley (USA)*

Invited Speaker:
Núria Casacuberta (ETH Zürich, The Laboratory of Ion Beam Physics and Environmental Physics, Switzerland)

Background

The Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident resulted in a large pulse of radioactive contaminants being released into the North Pacific. While radiation is recognized as a potential stressor in environmental systems, this workshop considered the data collected to date to determine if the radionuclides released have had significant impacts on ecosystems within the North Pacific. Presentations included radionuclide transport and fate, and any observed impacts from the FDNPP radionuclides on the marine ecosystem in the North Pacific. Participants were also encouraged to exchange information on new techniques and methodologies for monitoring environmental radioactivity and assessing the effects of radionuclides. The workshop also discussed any information gaps and research priorities in monitoring and assessment.

Summary of presentations

The session opened with a presentation by the invited speaker, Núria Casacuberta, on radionuclides distributions off the coast of Japan. Especially noteworthy was the analysis for ^{90}Sr, ^{129}I, ^{236}U and Pu isotopes, which are rarely reported due to the difficulty involved in separating and analyzing these radionuclides. At least two ^{90}Sr/^{137}Cs ratios were observed at different points in time (2011 *vs* 2013), suggesting the release pathway for ^{137}Cs detected in 2013 differed from 2011, or that they originated from separate sources. Following presentations by John N. Smith and Hideki Kaeriyama continued the theme of monitoring of seawater radionuclide levels. Smith's presentation highlighted the behavior of FDNPP-contaminated water on the Eastern side of the North Pacific, including its affiliation with the so-called Warm Blob. Kaeriyama's

presentation discussed both coastal areas along Japan, as well as the southward intrusion of FDNPP-contaminated water via central mode water.

The next two presentations by Takami Morita and Shizuho Miki discussed the concentrations of these radionuclides in biota. Morita's presentation discussed the ongoing monitoring of biota, showing that in recent years only a small fraction of sampled marine biota was found with substantial FDNPP contamination and the expectation that fish caught off of Fukushima prefecture are very close to being commercially viable. However, there was some uncertainty about interpreting these trends, as the number of species sampled has changed year by year and were not reported in an individual-species basis. The following presentation by Shizuho Miki specifically focused on ^{90}Sr levels in marine fish both away from Fukushima prefecture, near the prefecture as well as within the 20 km exclusion zone around FDNPP. No FDNPP influence was detectable on ^{90}Sr levels in fish collected away from the prefecture, while both fish collected near the prefecture and those within the 20 km zone showed ^{90}Srlevels that were often above background but had no increasing trend over the last several years. One of the posters submitted for W10 also looked at concentrations in biota, specifically in *Thunnus alalonga*, and that there were significant differences in ^{134}Cs levels depending on how far north or south US fishermen caught them.

Next came a pair of presentations on FDNPP radionuclides in marine sediment. The first, presented by Daisuke Ambe, found that the sediment inventory along the East coast of Japan was largely determined by the initial FDNPP release, over time being transported southward and downward into the sediment, with significant differences depending on particle size in the sediment. The second presentation, by early career scientist Jinqiu Du, looked at opportunistically using FDNPP ^{137}Cs (as well as signals from weapons testing and Chernobyl) as a measure of sedimentation rate. Although there were disagreeing figures on sedimentation rates from the methods, experienced members of the workshop offered to work with Du after the session to correct the estimates.

The final four presentations did not have sub-topics in common with each other. The first, by Jianhua He, demonstrated further testing of a potentially fast prototype for separation of ^{137}Cs from seawater using AMP. Early indications suggest the device and method can allow for ^{137}Cs seawater measurements in just a few hours at sea rather than hours to days spent in a land-based lab for the same separation. This was followed by a presentation by Kyung Tae Jung of a new iteration of the POSEIDON series of compartment models, titled Multi-BURN POSEIDON, which tracked separate bone, flesh and organ compartments for the fishes and sharks in the model which showed much better agreement with measurements. Finally, Wu Men presented a computer system for environmental grading of marine radioactivity, which concluded all analyzed regions and species for China were of the safest two grades.

List of papers

Oral presentations
Assessment of the distribution of radionuclides (^{137}Cs, ^{134}Cs, ^{90}Sr, ^{129}I, ^{236}U and Pu-isotopes) in the coast off Japan derived from the Fukushima Dai-ichi nuclear accident (Invited)
Núria Casacuberta, Pere Masqué, Maxi Castrillejo, Marcus Christl, Christof Vockenhuber, Hans-Arno Synal and Ken Buesseler
Transport of the Fukushima radioactivity plume to the Eastern North Pacific
John N. Smith
Five years monitoring activity on radioactive cesium in seawater after the Fukushima Dai-ichi Nuclear Power Plant Accident
Hideki Kaeriyama, Daisuke Ambe, Yuya Shigenobu, Shizuho Miki, Tatami Morita, Hiroya Sugisaki, Manadu Shimizu and Tomoro Watanabe
Radioactive cesium in marine biota off Fukushima
Takami Morita, Ken Fujimoto, Yuya Shigenobu, Daisuke Ambe, Hideki Kaeriyama, Shizuho Miki, Tomowo Watanabe and Hiroya Sugisaki
Concentrations of strontium-90 in marine fishes after the Fukushima Dai-ichi Nuclear Power Plant accident
Shizuho Miki, Ken Fujimoto, Yuya Shigenobu, Daisuke Ambe, Hideki Kaeriyama, Kaori Takagi, Tsuneo Ono, Tomowo

Watanabe, Hiroya Sugisaki and Takami Morita

Spatio-temporal variation of radiocesium in sea sediment around off Fukushima
Daisuke Ambe, Shigeho Kakehi, Toru Udagawa, Kazuhiro Aoki, Yuya Shigenobu, Tsuneo Ono, Hideki Kaeriyama, Ken Fujimoto, Shizuho Miki and Takami Morita

Distribution of radionuclides in sediment and sedimentation rates in Dalian Bay
Jinqiu Du, Ziwei Yao, Hui Gao, Daoming Guan, Guangshui Na and Chuanlin Huo

Effect of settle time on absorption of AMP to ^{137}Cs in co-precipitation method
Jianhua He, Fangfang Deng, Jing Lin, Wen Yu, Wu Men and Yusheng Zhang

Preliminary results from modeling of radionuclide transfer through marine food web using a multi-organ fish model
Kyung Tae Jung, Roman Bezhenar, Vladimir Maderich, Kyeong Ok Kim and Fangli Qiao

Marine radioactive environmental quality assessment method of China
Wu Men, Wen Yu, Jianhua He, Yusheng Zhang, Fenfen Wang and Yiliang Li

Nuclear bombs and coral: Guam coral core reveals operation-specific radiocarbon signals from the Pacific Proving Grounds
Allen H. Andrews, Ryuji Asami, Yasufumi Iryu, Don Kobayashi and Frank Camacho

Poster presentations

Effect of migratory life history on North Pacific Albacore (*Thunnus alalunga*) uptake of radiocesium
Delvan R. Neville, A. Jason Phillips and Kathryn A. Higley

Application of environmental risk assessment for strategic decisionmaking in coastal areas: Case studies in China
Kankan Wu, Luoping Zhang, Jiwei Zhang and Jianwei Wu

BIO Contributed Poster Session 1
Recent progress in deep-sea research and conservation: Lessons from various parts of the globe

Co-Convenors: *Alexei Orlov (Russia), Tony Koslow (USA), Orio Yamamura (Japan), Evgeny Pakhomov (Canada)*

Background

In recent years, intensive study of deep-sea ecosystems (continental slope, seamounts, trenches, troughs, and mid-water layers) of the global ocean has received increased attention because of the high levels of endemism and extreme vulnerability of their biota to any impact, particularly due to human activities. In the past, deep-sea research was focused mainly on the qualitative and quantitative composition of particular species or component of deep-water ecosystem. Currently, studies of life cycles, evaluation of anthropogenic impact, conservation of biological and genetic diversity, safe and sustainable exploitation of biological resources and their protection from destruction during human activities (fishing, mining, shipping, *etc*.) have become increasingly important. Several projects under the "Census of Marine Life (CoML)" program were conducted during recent years, namely CeDAMar, Mar-Eco, CenSeam, ChEss, *etc*. There were also several local projects focused on deepwater biodiversity studies of the Sea of Okhotsk (SokhoBio), Japan/East Sea (SoJaBio) and Kurile-Kamchatka Trench (KuramBio). Protection of Vulnerable Marine Ecosystems (VME) in deep waters has received increasing attention, including data reporting requirements management action, in FAO, CCAMLR and a number of RFMOs such as NAFO, NEAFC, SEAFO, SPRFMO, *etc*. In the Southern Ocean German-led Antarctic Benthic Deep-Sea Biodiversity Project (ANDEEP) has provided critical new data that has been incorporated into the work of CCAMLR. For the Southern Indian Ocean, IUCN and SIODFA announced Benthic protected areas. Modern significant progress in deep-sea research became possible mainly due to development of new methodologies and technical equipment, including ROV's, landers, various recorders, *etc*. This poster session provided a forum for sharing recent advances in deep-sea research and conservation in various parts of the global ocean in the whole, and the North Pacific in particular.

List of papers

Poster presentations

Range-wide analysis of spatial distribution of Pacific flatnose *Antimora microlepis* in the North Pacific
Alexei M. Orlov and Alexei A. Baitaliuk

Spatial distribution, size composition, and dynamics of abundance of Okhotsk skate *Bathyraja violacea* in the North Pacific
Igor V. Grigorov, Alexei A. Baitaliuk and Alexei M. Orlov

A novel approach to estimating active carbon flux using the biomass size spectra
Lian E. Kwong, Evgeny A. Pakhomov and Brian P.V. Hun

Progress of Chinese deep sea research activities in recent 2 years
Yongling Zhu, Jiabiao Li and Yejian Wang

Georeferenced sensor, survey and sample data for the Endeavour Hydrothermal Vents Marine Protected Area
S. Kim Juniper, Karen Douglas and Reyna Jenkins

Biogeographical analysis of abyssal bottom habitats: Using an abiotic province scheme and metazoan occurrence databases
Brandon M. Genco

Data-driven bioregions for local ecosystem context in species distribution models
Andrew McMillan and Anders Knudby

A time-series of epibenthic community turnover along a dissolved oxygen gradient
Ryan P. Gasbarro, Jackson Chu and Verena Tunnicliffe

Joint German-Russian deep-sea expeditions in the NW Pacific
Angelika Brandt and Marina V. Milyutina
Presented by Alexei Orlov on behalf of A. Brandt and M. Milyutina

Endeavour Hydrothermal Vents Marine Protected Area conservation and management supported through institutional collaborations and interdisciplinary research
Benjamin Grupe, Janelle Curtis, Rachel Boschen, John Jamieson, Kim Juniper, Sheryl Murdock and Verena Tunnicliffe

BIO Contributed Poster Session 2

Co-Convenors: *Angelica Peña (Canada), Se-Jong Ju (Korea)*

Background

The Biological Oceanography Committee (BIO) has a wide range of interests spanning from molecular to global scales. BIO targets all organisms living in the marine environment including bacteria, phytoplankton, zooplankton, micronekton, benthos and marine birds and mammals. This session dealt with posters on biological aspects of marine science in the PICES region, except those covered by other Topic Sessions or Workshops sponsored by the Biological Oceanography Committee (BIO).

List of papers

Poster presentations

Spatial and temporal heterogeneity in distribution of euphausiid *Thysanoessa longipes* from the northern Gulf of Alaska
Alexei I. Pinchuk and Kenneth O. Coyle

Study on material cycling in the coastal waters and the role of the Kiritappu Wetland, in Hamanaka Town, Hokkaido: An analysis using surf clam (*Pseudocardium sachalinense*) as an environmental indicator
Xin Ba, Naoko Kouchi, Kentaro Watanabe and Masahiko Fujii

Temperature effects on the egg development time and productivity of *Acartia omorii* and *Acartia steueri*
Yang Jin Jo and Won Gyu Park

Application of end-pairing sequencing technique for the phytoplankton community analysis in East Sea
Tae-Ho Yoon, Hye-Eun Kang, Ah Ran Kim, Ji-Hyun Lee, Soo Rin Lee, Hyeon Jeong Hwang, Sun Young, Hyun Park and Hyun-Woo Kim

Boreopacific gonate squid (*Boreoteuthis borealis*) abundance and its relation to climate indices in the Northwest Pacific
Oleg N. Katugin, Vladimir V. Kulik, Gennady A. Shevtsov and Michael A. Zuev

Pilot application of a framework to assess vulnerability of biological components to oil spilled in the marine environment to the Canadian pacific region
Lucie Hannah, Candice St. Germain, Kate Thornborough and Miriam O

Geographical variation in the concentration and form of biogenic elements in the North Pacific Ocean
Hiroaki Saito, Fuminori Hashihama, Hideki Fukuda and Hiroshi Ogawa

The dietary response of the California sea lion population during the 2013 Unusual Mortality Event
Stephanie E. Nehasil and Mark S. Lowry

Density and distribution of seabirds on the Baja California Pacific islands, Mexico
David Martínez-Cervantes, Y. Bedolla-Guzmán, E. Rojas-Mayoral, M. Félix-Lizárraga, J.C. Hernández-Montoya, A. Fabila-Blanco, E. Bravo-Hernández, A. Hernández-Ríos and A. Aguirre-Muñoz

Synthesis of benthic macroinvertebrate diversity in coastlines of the Puget Sound before and after shoreline restoration
Timothy S. Lee and Jason D. Toft

Macromolecular compositions of phytoplankton in the Japan/East Sea
Keyseok Choe and Sang Heon Lee

FIS Contributed Poster Session

Co-Convenors: *Xianshi Jin (China), Elizabeth Logerwell (USA)*

Background

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

List of papers

Poster presentations

Application of an age-length structured population dynamics model to data for eastern Bering Sea tanner crab (*Chionoecetes bairdi*), Pribilof Island blue king crab (*Paralithodes platypus*), and Pacific cod (*Gadus macrocephalus*)
Caitlin I. Allen Akselrud and André E. Punt

Comparison of fish-killing activities of *Chattonella antiqua* and *Chattonella marina* against three fish species and possible mitigation effect of alginate oligomer on *Chattonella* sp.
Mikinori Ueno, Tomoki Nishiguchi and Tatsuya Oda

Reproduction and growth of the spiny lebbeid shrimp, *Lebbeus groenlandicus* (Fabricius, 1775) (Caridea, hippolytidae) in the East sea of Korea
Ho Jin Bae, Kyung Tae Lee, Seung Eun Kim, JungYeon Kim, Han Ju Kim and Chul-Woong Oh

Linking Pacific Ocean perch productivity to deep-sea corals and sponges in Alaska
Christopher N. Rooper, Jennifer L. Boldt, Christina Conrath and Matthew Baker

Annual changes in distributions and abundances of dominant myctophid fishes in the Pacific side of Hokkaido, Japan
Hiroki Yasuma, Rintaro Koide, Tetsuichiro Funamoto, Hiroshige Tanaka, Kazuyoshi Maekawa, Nobuo Kimura and Kazuhiro Sadayasu

Cumulative effects of size-selective fishing on size-at-age of Pacific halibut in the northeast Pacific Ocean
Jane Y. Sullivan, Steven J.D. Martell and Gordon H. Kruse

Age and growth of damselfish *Chromis notata* (Temminck & Schlegel, 1843) in the Jeju Island, Korea
Han Ju Kim, Ho Jin Bae, Seong Eun Kim, Jung Yeon Kim, Kyung Tae Lee and Chul-Woong Oh

Growth and reproduction of the Japanese mantis shrimp, *Oratosquilla oratoria* (De Haan 1844) in the coastal area of Tongyeong, Korea
Seong Eun <u>Kim</u>, Ho Jin Bae, Jung Yeon Kim, Han Ju Kim, Kyung Tae Lee and Chul-Woong Oh

Effects of submarine groundwater on feeding and growth of juvenile marbled flounder *Pseudopleuronectes yokohamae* in the Seto Inland Sea, Japan
Jun <u>Shoji</u>, Masaki Hata, Koji Fujita and Takeshi Tomiyama

First report on an annual gametogenesis of *Hyotissa hyotis* (Linnaeus 1758), the subtropical oyster in Jeju Island off the south coast of Korea
Hyun-Ki <u>Hong</u>, Hee-Do Jeung, Chang-Keun Kang and Kwang-Sik Choi

Spawning migration tracking of adult pacific herring (*clupea pallasii*) using supersonic telemetry
Makoto <u>Tomiyasu</u>, Hokuto Shirakawa, Yuki Iino and Kazushi Miyashita

Climate and feedback structures influence the population dynamics of small pelagic fish population off Chile
Mariella <u>Canales</u>, Mauricio Lima, Ursula Cifuentes and Antonio Aranis

Age validation and growth rate of *Mactra chinensis* (Bivalvia, Mactridae) by chondrophore
Jung-Yeon <u>Kim</u>, Ho Jin Bae, Han Ju Kim, Seong Eun Kim, Kyung Tae Lee and Chul-Woong Oh

Ontogenetic changes and interannual variations in diet of Japanese jack mackerel (*Trachurus japonicus*) juveniles in the East China Sea
Chiyuki <u>Sassa</u>, Satoshi Kitajima, Kou Nishiuchi and Motomitsu Takahashi

Changes in biomass of walleye pollock *Gadus chalcogrammus* in the East Sea: The late 1980s regime shift
Minkyoung <u>Bang</u>, Chan Joo Jang, Sukyung Kang and Suam Kim

Growth, migration and trophic interactions role of neon flying squid (*Ommastrephes bartramii*) in the North Pacific
Yoshiki <u>Kato</u>, Mitsuo Sakai, Makoto Okazaki, Maki Noguchi and Hiromichi Ueno

Importance of early life transports for recruitment of walleye pollock *Gadus chalcogrammus* in the Sea of Japan off Hokkaido Island
Mizuki Kuga, Shoko Abe, Yosuke Igeta, Hiroshi Kuroda, Tomonori Azumaya and Tetsuichiro <u>Funamoto</u>

Successive recruitment of age-0 jack mackerel (*Trachurus japonicus*) in coastal areas along the Kuroshio
Kazuo <u>Ishikawa</u>, Sachihiko Itoh, Chikako Watanabe, Manadu, Shimizu, Tsutomu Tokeshi, Masaharu Nishiguchi, Daisuke Hashida, Toshiyuki Ohkawa, Shigeo Harada, Masahiro Kuno, Yuki Suzuki and Shozo Takamura

Biodiversity patterns and changes in the fishery ecosystem of the Yellow Sea and the East China Sea
Shufang <u>Liu</u> and Zhimeng Zhuang

Bare hooks and other species interactions with benthic longline gear can influence hook-based abundance indices
Shannon G. <u>Obradovich</u>, K. Lynne Yamanaka and Murdoch K. McAllister

Disentangling the impact of regulation and climate on vessel productivity: A case study of the Leatherback Turtle Conservation Area Closure and the California drift gill net swordfish fisher
James R. <u>Hilger</u> and Kristin H. Roll

Does returning sockeye salmon (*Oncorhynchus nerka*) condition vary with climate in two BC rivers?
Angeleen M. Olson, Emma S. Pascoe, Jacob Weil, Elena Buscher, Will Duguid, Cameron Freshwater, Skip McKinnell and Francis <u>Juanes</u>

Pacific sand lance in the San Juan Islands: Synthesis of research 2010-2016
Matthew <u>Baker</u>, M. Beaulieu, N. Sisson, A. Tinnon, K. Cieri, L. Speed, O. Graham, A. Thomson, J.Lopez, M. Rood, A. Highland, N. Guilford, T. Pham, K. Bynum, M. Eisenlord, G. Greene, J. Aschoff, B. Matta, T. Helser, D. Lowry, P. Dionne and J. Selleck

Quantifying and evaluating implications for trawlable and untrawlable habitat
Matthew <u>Baker</u>, Wayne Palssson, Mark Zimmermann, Chris Rooper and David Somerton

MEQ Contributed Poster Session

Co-Convenors: *Chuanlin Huo (China), Darlene Smith (Canada)*

Background

Papers dealing with all aspects of marine environmental quality research in the North Pacific and its marginal seas, except those covered by other Topic Sessions or Workshops sponsored by the Marine Environmental Quality Committee (MEQ) were covered in this session.

List of papers

Poster presentations

Evaluation of organic matter and trace metal concentration in Korean coastal sediment using geochemical assessment techniques
Jung-No Kwon, Jae-Hyun Lim, Young-Sug Kim, Youngchul Park, Sang-Soo Kim, Kee-Young Kwon and Dong-Woon Hwang

Rapid determination of organochlorine pesticides in fish using selective pressurized liquid extraction and gas chromatography–mass spectrometry
Minkyu Choi, In-Seok Lee and Rae-Hong Jung

Estimation of carrying capacity for oyster farming in Korea and its economic benefits
Hyung Chul Kim, Sok Jin Hong, Won Chan Lee, Jeong Bae Kim, Jin Ho Kim and Woo Sung Jung

Sediment oxygen consumption rate and hydrogen sulfide release by dissolved oxygen depletion in hypoxic area of the Gamak Bay, Korea
Taehee Lee and Young Baek Son

Modelling pollution contribution rate for watershed management in Masan Bay
Won Chan Lee, Sokjin Hong, Hyung Chul Kim, Jinho Kim and Woo Sung Jeong

Estimate the contribution of submarine groundwater discharge to the biological productivity in coastal waters by the stable isotope signal recorded in the shell
Osamu Tominaga, Ryo Sugimoto, Saori Nishi, Nanami Horibe, Makoto Yamada, Jun Shoji, Hisami Honda, Shiho Kobayashi and Makoto Taniguchi

The design of an integrated Sino-Vietnam marine and island environment information management system deployed in Beibu Gulf
Jianwei Wu, Jiwei Zhang, Ling Cai, Keliang Chen, Yang Luo and Jinlong Jiang

POC Contributed Poster Session

Convenor: *Kyung-Il Chang (Korea), Michael Foreman (Canada)*

Background

Ten posters were submitted to this session and they covered a wide range of POC related topics. They were on display from Tuesday to Thursday and were featured (along with posters from other sessions, committees, and workshops) in the Wine and Cheese social events on Tuesday and Thursday evenings. Best Poster by an early career scientis for POC-sponsored sessions and workshops was awarded to Kirill Kivva for "*Seasonal dynamics of dissolved inorganic nutrient in the Bering Sea*" W9 in Workshop (W9) on "*The role of the northern Bering Sea in modulating Arctic environments: Towards international interdisciplinary efforts*".

Underline List of papers

Poster presentations

Ocean acidification on coast of the Korea
Ki-Hyuk Eom, In-Seong Han, Joon-Soo Lee, Young-Sang Suh and Kitack Lee

Enhanced responses of sea surface temperature in offshore China to Global Warming and Hiatus
Hong-jian Tan and Rong-shuo Cai

Cross-isobath Exchange in Bering Canyon
Carol Ladd, Wei Cheng, Janet Duffy-Anderson, Colleen Harpold, Kim Martini, Calvin Mordy and Phyllis Stabeno

Comparison between two types of Moored Vertical Profiler
Dong Guk Kim, Young-Gyu Park, Jae-Hun Park, Hong Sik Min, Chanhyung Jeon and Seongbong Seo

Mean sea level (MSL) trends around the Korea Peninsula with tide gauge and altimeter data
Kwang-Young Jeong, Eunil Lee and Seung-buhm Woo

Regional characteristics of global warming: Linear projection for the timing of unprecedented climate
Ho-Jeong Shin and Chan Joo Jang

Recent cooling trend in the Yellow and East China Seas and the associated North Pacific climate regime shift
Yong Sun Kim, Chan Joo Jang and Sang-Wook Yeh

Long-term changes of South China Sea surface temperatures in winter and summer
Young-Gyu Park and A-Ra Choi

Ferry based monitoring in the NEAR-GOOS Area
Hee Dong Jeong, Vyacheslav Lobanov, Sang Woo Kim, Jae Kyong Son, In Sung Han and Young Sang Suh

Nuclear bombs and coral: Guam coral core reveals operation-specific radiocarbon signals from the Pacific Proving Grounds
Allen H. Andrews, Ryuji Asami, Yasufumi Iryu, Don Kobayashi and Frank Camacho

MONITOR Contributed Poster Session

Co-Convenors: *Jennifer Boldt (Canada), Sanae Chiba (Japan)*

Background

This session conatined posters addressing general topics in monitoring and regularizing observations in the North Pacific and its marginal seas, except those covered by other Topic Sessions or Workshops sponsored by the Monitoring Committee (MONITOR).

List of papers

Poster presentations

Distribution of the CDOM (Chromophoric Dissolved Organic Matter) in spring of 2012-2014 at southwestern East (Japan) Sea
Hyeon-Sil Park and Mi-Ok Park

How ocean observations work for you: A perspective from the U.S. IOOS Regional Association serving Southern California
Clarissa Anderson and Julie Thomas

S-HD Contributed Poster Session

Co-Convenors: *Mitsutaku Makino (Japan), Keith Criddle (USA)*

<u>Background</u>

The Section on *Human Dimensions of Marine Systems* (S-HD) poster session was held to promote, coordinate, integrate and synthesize research activities related to the contribution of the social sciences to marine science, and to facilitate discussion among researchers from both the natural and social sciences.

<u>List of papers</u>

Poster presentations

Linking traditional knowledge and ecological studies to improve understanding of paralytic shellfish poisoning and enhance sustainability of shellfish harvest in Southeast Alaska
Elizabeth D. <u>Tobin</u>, Ginny L. Eckert and Thomas M. Leschine

Implementation of ecosystem-based fisheries management in U.S. Fisheries
Erin Schnettler, Michael <u>Waine</u> and Wesley Patrick

Alaska's sablefish fishery after Individual Fishing Quota Program implementation—A bioeconomic analysis
Keith R. <u>Criddle</u>, Stephanie Warpinski, Mark Herrmann and Joshua A. Greenberg

Evaluation of sustainability of fisheries products around Japan: Sustainable, Healthy and "*Umai*" Nippon seafood (SH"U"N) Project
Yoshioki <u>Oozeki</u>, Juri Hori, Toyomitsu Horii, Ryutaro Kamiyama, Ryo Kimura, Tatsu Kishida, Masashi Kiyota, Mitsutaku Makino, Keiichi Mito, Hiroyuki Shimada, Shinji Uehara, Hiroki Wakamatsu, Shingo Watari, Shiroh Yonezaki and Hiromu Zenitani

Best Presentations for Committee-sponsored Topic Sessions or Workshops at PICES-2016

PICES Best Presentation by an <u>early career scientist</u> for a Science Board sponsored Topic Session (S10) on "*The Response of Marine Ecosystems to Natural and Anthropogenic Forcing: Past, Present and Future*"

Colleen Petrik (Princeton University, Princeton, USA, colleenpetrik@gmail.com) on "*The response of fisheries production to natural and anthropogenic forcing: Past, present and future*" co-authored with Charles Stock, Ken Andersen, James Watson and Jorge Sarmiento.

PICES Best Poster by an <u>early career scientist</u> for a Science Board sponsored Topic Session (S1) on "*25 Years of PICES: Celebrating the Past, Imagining the Future*"

Robert Blasiak (The University of Tokyo, Toyko, Japan, a-rb@mail.ecc.u-tokyo.ac.jp) on "*Negotiating the international instrument on BBNJ: Long-term implications*" co-authored Jeremy Pittman and Nobuyuki Yagi.

BIO Best Oral Presentation by an <u>early career scientist</u> for the BIO/MONITOR/MEQ Topic Session

Dorothy M. Dick (Oregon State University, Corvallis, USA, doridick14@gmail.com) on "*Forecasting the flock: Using species distribution models to evaluate the effects of climate change on future seabird foraging aggregations in the California Current System*" co-authored with Jaime Jahncke, Nadav Nur, Julie Howar, Jeanette Zamon, David Ainley, Ken Morgan, Lisa Balance and David Hyrenbach.

BIO Best Poster Presentation by an <u>early career scientist</u> for the BIO Contributed Poster Session 1

Lian E. Kwong (Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada, lkwong@eos.ubc.ca) on "*A novel approach to estimating active carbon flux using the biomass size spectra*" co-authored with Brian Hunt and Evgeny Pakhomov.

FIS Best Oral Presentation by an <u>early career scientist</u> for the FIS/TCODE Topic Session

Caren Barceló (Oregon State University, Corvallis, U.S.A., cbarcelo@coas.oregonstate.edu) on "*Identifying climatically resilient or sensitive locations in the Northern California Current using partitioned beta-diversity*" co-authored with Lorenzo Ciannelli and Richard D. Brodeur.

FIS Best Poster Presentation by an <u>early career scientist</u> for the FIS/TCODE Topic Session

Michael J. Malick (School of Resource and Environmental Management, Simon Fraser University, Burnaby, Canada, mmalick@sfu.ca) on "*Effects of the North Pacific Current on productivity of 163 Pacific salmon stocks*" co-authored with Sean Cox, Franz J. Mueter, Brigitte Dorner and Randall M. Peterman.

MEQ Best Oral Presentation by an <u>early career scientist</u> for the MEQ Topic Session

Tanika Ladd (University of California, Santa Barbara, California, USA, tanika.ladd@lifesci.ucsb.edu) on "*Physiological responses of marine phytoplankton to oil exposure in the context of the 2015 oil spill in the Santa Barbara Channel*" co-authored with Jessica Bullington, Andrea Valdez-Schulz, Paul Matson and Debora Iglesias-Rodriguez.

MEQ Best Poster Presentation by an <u>early career scientist</u> for the MoE/MEQ/TCODE Topic Session

Kirsten Moy (Hawaii Coral Reef Initiative, University of Hawaii at Manoa, Honolulu, USA, kmoy@hawaii.edu) on "*Synthesizing the state of debris in Hawaii from 2015 aerial imagery and spatial analysis data*" co-authored with S. Kung, M. Castrence, A. Meadows, A. Meltel, A. Omori, A. Rosinski, B. Neilson, S. Ambagis, M. Hamnett and K. Davidson.

POC Best Oral Presentation by an <u>early career scientist</u> for the POC Topic Session

Hanna Na (Ocean Circulation and Climate Research Center, Korea Institute of Ocean Science and Technology (KIOST), Ansan, Republic of Korea, hanna@kiost.ac.kr) on "*Mesoscale-eddy-induced variability of flow through the Kerama Gap between the East China Sea and the western North Pacific*" co-authored with Jae-Hun Park, Mark Wimbush, Hirohiko Namakuma, Ayako Nishina and Xiao-Hua Zhu.

POC Best Poster Presentation by an <u>early career scientist</u> for the POC Workshop

Kirill Kivva (Climatic Bases of Biological Productivity Laboratory, Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, kirill.kivva@gmail.com) on "*Seasonal dynamics of dissolved inorganic nutrients in the Bering Sea*".

MONITOR Best Oral Presentation by an <u>early career scientist</u> for the POC/MEQ/MONITOR/BIO Topic Session
Kelly Kearney (Joint Institute for the Study of Atmosphere and Ocean, University of Washington, Seattle, USA, kelly.kearney@noaa.gov) on "*A comparison of Bering Sea ecosystem energy pathways in warm versus cold years*" co-authored with Al Hermann, Ivonne Ortiz, Kerim Aydin, Ed Farley and Ellen Yasumishi.

MONITOR Best Poster Presentation by an <u>early career scientist</u> for the POC/MEQ/MONITOR/BIO Topic Session
Ryan J. Hartnett (Point Blue Conservation Science, Romberg Tiburon Center for Environmental Studies, USA, ryan.j.hartnett87@gmail.com) on "*Developing marine food web models to evaluate blue whale, Cassin's auklet and salmon responses to long- and short-term changes in oceanography in the California Current*" co-authored with Karina Nielsen, Frances Wilkerson, Meredith Elliott, Nadav Nur and Jaime Jahncke.