Young-Gyu Park, Jae-Hun Park, Ho Jin Lee, Hong Sik Min and Seon-Dong Kim
The effects of geothermal heating on the East Sea circulation

Andrey G. Andreev and Igor A. Zhabin
Origin of the mesoscale eddies and year-to-year changes of the chlorophyll *a* concentration in the Kuril Basin of the Okhotsk Sea

Aigo Takeshige, Tetsuya Takahashi, Hideaki Nakata and Shingo Kimura
Long-term trends in seawater temperature in Omura Bay, Japan

Masanori Konda, Tamami Ono, Kazuyuki Uehara, Kunio Kutsuwada, Osamu Tsukamoto, Fumiyoshi Kondo and Naoto Iwasaka
Ocean mixing layer variation as indicated by the measurement of the dissipation rate in the Kuroshio Extension region

Poster presentations

Igor Rostov, Vladimir Rostov, Natalia Rudykh, Elena Dmitrieva and Andrey Golik
Components of oceanographic and marine environment management information support in the Far Eastern region of Russia

Valentina V. Moroz
Thermohaline structure peculiarities formed by tides in the Kuril Straits archipelago and adjacent areas

Valentina V. Moroz
Thermohaline structure peculiarities formed in the Kuril Islands area and climate change

Yosuke Igeta, Tatsuro Watanabe, Akira Okuno and Naoto Honda
Strong coastal currents associated with winter monsoon around the Noto Peninsula, Japan

Sachihiko Itoh, Ichiro Yasuda, Masahiro Yagi, Satoshi Osafune, Hitoshi Kaneko, Jun Nishioka, Takeshi Nakatsuka and Yuri N. Volkov
Strong vertical mixing in the Urup Strait, Kuril Islands

Hiroshi Kuroda, Daisuke Takahashi, Takashi Setou, Tomonori Azumaya and Humio Mitsudera
Hindcast experiment for the Okhotsk Sea using the sea-ice-coupled Regional Ocean Modeling System

Tatsuro Watanabe and Koji Kakinoki
Interannual variation in the volume transport through the Sado Strait in the Japan Sea

BIO Workshop (W1)
Identifying critical multiple stressors of North Pacific marine ecosystems and indicators to assess their impacts

Co-Convenors: *Jennifer Boldt (Canada), Vladimir Kulik (Russia), Chaolun Li (China), Jameal Samhouri (USA), Motomitsu Takahashi (Japan) and Chang-Ik Zhang (Korea)*

Background

Multiple natural and human stressors on marine ecosystems are common throughout the North Pacific, and may act synergistically to change ecosystem structure, function and dynamics in unexpected ways that can differ from responses to single stressors. Further, these stressors can be expected to vary by region, and over time. This workshop seeks to understand responses of various marine ecosystems to multiple stressors, and to identify and characterize critical stressors in PICES regional ecosystems including appropriate indicators of their impacts. The goal is to help determine how ecosystems might change in the future and to identify ecosystems that may be vulnerable to the combined impacts of natural and anthropogenic forcing. Contributions are invited which identify and characterize the spatial and temporal extent of critical stressors in marine ecosystems (both coastal and offshore regions) of PICES member countries, and in particular the locations at which multiple stressors interact. Contributions will include a review and identification of broad categories of indicators which document the status and trends of ecosystem change at the most appropriate spatial scale (*e.g.*, coastal, regional, basin) in response to these multiple stressors. This workshop is linked with the Topic Session titled "*Ecosystem responses to multiple stressors in the North Pacific*" but is designed to provide more in-depth examination and discussion of the spatial and temporal extents of critical marine ecosystem stressors and their potential indicators. It will assist with progress towards the goals of PICES WG 28 on Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors.

Summary of Workshop

The BIO Workshop (W1) was held on Friday, October 12, 2012 (full day), and was launched with a talk by invited speaker, Dr. Natalie Ban (Australian Research Council Centre of Excellence for Coral Reef Studies, Australia) and included 6 other oral presentations.: Olga Lukyanova (TINRO-Centre, Russia), Stephani Zador (NMFS, USA), Christopher Mulanda Aura (Hokkaido University, Japan), Elliott Hazen (University of Hawaii and NMFS, USA), Jameal Samhouri (NMFS, USA), and Jennifer Boldt (Fisheries and Oceans Canada). In addition, there were general discussions after the morning presentations, and in-depth discussions in the afternoon.

Workshop presentations and discussion focused on three apparent approaches to evaluating stressors: (1) expert-based surveys, (2) model-based analyses, and (3) empirical/data based analyses.

The invited presentation was given by Dr. Ban who provided a view of cumulative human impacts in the marine environment, using an expert-based survey approach as well as combinations of all approaches. Utilizing the empirical analyses approach, Dr. Lukyanova introduced her research showing that eggs, embryos and larvae of marine fish and echinoderms may be used as bioindicators of early disturbances due to multiple stressor interactions in vulnerable ecosystems, in particular from hydrocarbons in water. Dr. Zador (presented by Ms. Patricia Livingston) summarized indicator-based ecosystem assessments in the Bering Sea and Aleutian Islands regions, utilizing a team-based approach, thereby addressing the expert-based survey approach. Three broad conclusions from this study were provided: (1) the physiological and biological nature of the ecosystem, the extent of scientific knowledge about the ecosystem, and the particular expertise of team members will influence the final assessment product; (2) team discussion of assessment structuring themes should occur before indicator selection, and (3) developing assessments should be an iterative process with frequent review by fisheries managers. Dr. Aura's presentation highlighted a model-based approach to evaluating stressors and features suitable for aquaculture sites in northern Japan. Dr. Aura's research included the development of a site suitability model, conducted using geographic information system (GIS)-based, multi-criteria evaluation (MCE) with weighted linear combinations to assess suitable scallop culture sites. For scallop culture, requisite biophysical (sea temperature, chlorophyll-*a*, secchi disk depth and bathymetry) and social infrastructure (distance to pier and town) parameters formed thematic layers that were limited by a constraint layer, and results were consistent with existing scallop culture locations. Dr. Hazen's presentation focused on the data-based analytical approach. He developed a quantitative indicator selection framework by looking for composite indices and links between pressure and state variables for the California Current region. Dr. Samhouri highlighted expert-based survey approaches to evaluating stressors. He compared and contrasted results from multiple efforts to elicit the opinions of regional experts about the vulnerability of coastal habitats along the U.S. west coast. These assessments encompass stressors as varied as pollution, climate change, invasive species, and overharvest in relationship to habitats from rocky shorelines and sandy beaches to the deep sea. Dr. Aseeva's presentation highlighted a data-based analytical approach to evaluating environmental stressors that explain fluctuations in flounder species composition on the shelf of West Kamchatka. Dr. Boldt gave an overview of the Indicators for the Seas 2 (IndiSeas2) research program, which uses all three approaches (data-based, model-based, and expert surveys) to evaluating stressors. The goal of IndiSeas2 is to evaluate the status of marine ecosystems in a changing world using a suite of indicators that reflect effects of multiple drivers on the states and trends of exploited marine ecosystems.

Morning Discussion

During the discussion after the morning presentations, workshop participants discussed the pros and cons of the three alternative approaches for evaluating stressors: (1) expert elicitation, (2) model-based simulation, and (3) empirical analysis (Table 1), as well as a general discussion on indicators.

Main discussion points:

- Some pros and cons derived from the presentations were listed by the group. There was general agreement that, despite pros and cons of each approach (Table 1), there is a need to use multiple approaches due to data availability and, where data are available, constraints and assumptions of analyses, *e.g.*, the constraint that

Principal Components Analyses represent only linear relationships, and that most approaches conducted to date of the impacts of multiple stressors assume their effects to be additive.

- The pros and cons of the three approaches depend on the objectives. For example, is the objective to know the state of ecosystems or to identify management interventions? WG 28 is looking at the state of ecosystems and ecosystem responses; linking that to management actions could be a next step.
- The selection of indicators and stressors will be affected by the behaviour of species and ecosystem properties (surroundings and hydrodynamics).
- The goal of WG 28 is not to forecast future indicator responses, but rather, to choose indicators (or at minimum to develop a process for choosing indicators of ecosystem responses to multiple stressors) that will be of interest in the future. One goal of WG 28 is to understand if ecosystems are responding to human activities (and climate), so that management actions can control human impacts. Separating human and climate effects is very difficult; can we identify indicators of interactions (*e.g.*, fishing and climate) that will help us identify deteriorating ecosystem conditions?

Table 1. Some pros and cons of three alternative approaches for evaluating stressors: (1) expert elicitation, (2) model-based simulation, and (3) empirical analysis.

Approach	Pros	Cons
Expert elicitation	Solution to the no data problem	Difficult to validate responses
	Appropriate for global and regional visualization	
Empirical analysis	Track emerging stressors where expert input is untested or models are unavailable	Difficult to find data at appropriate scales
	Appropriate indicators can be tailored to the physical and biological nature of ecosystem	Least common denominator issue (shortest time series, smallest common spatial domain)
	Remotely sensed data available for many physical variables	
Model based analyses	Can generate as much data as you need	Must have a model
	Can create an ensemble of models using different frameworks	Outputs are only as good as the data that go into the model

Afternoon discussion

After presentations in the afternoon, workshop participants discussed and compared indicators that are used in different regions to characterize the spatial and temporal extents of critical stressors and understand responses of ecosystems to multiple stressors.

Main discussion points:

- There was acknowledgement that indicators are collected and used for varying temporal and spatial scales, thereby making it difficult to combine indicators. One solution is to leave indicators disaggregated and ensure discussions around the indicator responses are framed within the varying response-times (and scales). Composite indices need to preserve enough information so that the driving factors of index variability are understood. Another related point raised was that what we see is how ecosystems respond to multiple stressors, and as part of our analyses we attempt to separate these responses into effects of individual stressors. We may not need to disaggregate individual effects of each stressor in order to choose appropriate indicators of ecosystem responses; however, we will need to tease these effects apart if we want to ensure a process-based understanding that can be used for forecasting the future.

- The group then discussed and identified four groups of indicators, stressors, and activities: environmental, biological, human activities and stressors, and sociopolitical-economic. Broad categories of indicators were then listed for each of three of these groups (environmental, human activities and stressors, and sociopolitical-economic); this was *not* meant to represent a complete list, and could be supplemented with existing knowledge in the literature. For each country and each category of indicators (Table 2), member countries established the existence of data, and the temporal and spatial extent of the data (3 responses for each indicator). The tables were not filled out completely (indicators or data availability), but this could be a WG 28 activity. For the biological indicators, some information can be acquired from the work of PICES Working Group 19 on *Ecosystem-based Management Science and its Application to the North Pacific*, in their Ecosystem-Based Fisheries Management 2010 report (PICES Scientific Report 37, Table 3.1.3). Note that this table would not include information about data availability for habitats.

Table 2. Some broad-scale indicators identified in the workshop to address three main categories (environmental, human activities and stressors, and sociopolitical-economic). The tables were not filled out completely, but this could be a WG 28 activity. Biological indicator information can be acquired from the EBFM 2010 PICES Scientific Report 37, Table 3.1.3. Each cell contains three responses for the existance of data, availability of time series data, and spatial extent of data. Y = Yes, N = No, S = Some, N/A = Not applicable

Indicators, Activities, and Stressors	Canada	Japan	Russia	U.S.A.	High Seas
Environmental stressors/indicators					
Temperature					
Sea Ice					
Chla					
Nutrients	Y,Y,N	Y,Y,S	Y,Y,N	Y,Y,N	
River discharge	Y,Y,Y	Y,Y,Y	S,Y,N	Y,Y,Y	N/A
Toxic contaminants	Y,N,N	Y,N,N	Y,N,N	Y,N,N	S,N,N
Large scale climate index (e.g., PDO, ENSO)					
pH	Y,N,N	Y,N,N	Y,N,N	Y,N,N	Y,N,N
Oxygen	Y,Y,N	Y,Y,S	Y,Y,N	Y,Y,N	
Human activities & stressors					
Fishing	Y,Y,Y	Y,Y,Y	Y,Y,Y	Y,Y,Y	S,S,S
Oil and Gas					
Military Activity	N,N,N	N,N,N	N,N,N	N,N,N	N,N,N
Wave/Wind/Tidal					
Shipping					
Coastal engineering	Y,S,S	Y,S,S	Y,N,S	Y,N,S	N/A
Aquaculture					
Ecotourism					
Land-based pollution					
Socio-economic-political					
Seafood demand					
Coastal population trends	Y,Y,Y	Y,Y,Y	?,?,?	Y,Y,Y	N/A
Marine Employment	S,Y,Y	Y,Y,Y	N?,N?,N?	S,Y,Y	S,S,S
Marine Revenue					
Marine exports/domestic consumption					
Participation/stakeholder involvement					
Governance					
Happiness					
Satisfaction with ocean status					
Community vulnerability					
Coastal infrastructure					

Recommendations

- Use multiple approaches (expert elicitation, model-based simulation, and empirical analysis) to identify and evaluate critical multiple stressors of North Pacific marine ecosystems and indicators to assess their impacts.
- Finish filling out the tables with help from other PICES working groups, sections, and committees. For example, the Section on *Human Dimensions on Marine Ecosystems* could provide expertise on socio-economic indicators. The FIS and BIO committees could provide help on biological indicators and the MONITOR committee could provide expertise environmental indicators and stressors.
- A next step might be to identify the gaps in the tables and those that are important for which to get information.

List of papers

Oral presentations

Natalie C. Ban, Stephen S. Ban and Hussein M. Alidina (Invited)
Combining stressor information – Experiences from Canada's Pacific waters and Australia's Great Barrier Reef

Olga N. Lukyanova, Elena V. Zhuravel, Sergey A. Cherkashin, Denis N. Chulchekov, Viktor A. Nadtochyi and Olga V. Podgurskaya
Bioindicators of multiple stressors interaction in the North-Eastern shelf of Sakhalin Island (Sea of Okhotsk)

Stephani Zador, Kirstin Holsman, Sarah Gaichas and Kerim Aydin
Developing indicator-based ecosystem assessments for diverse marine ecosystems in Alaska

Christopher Mulanda Aura, Sei-Ichi Saitoh, Yang Liu and Toru Hirawake
Spatio-temporal model for mariculture suitability of Japanese scallop (*Mizuhopecten yessoensis*) in Funka and Mutsu Bays, Japan

Elliott L. Hazen, Jameal F. Samhouri, Isaac D. Schroeder, Brian K. Wells, Steven J. Bograd, David G. Foley, Nick Tolmieri, Phillip S. Levin, Greg Williams, Kelly Andrews, Sam McClatchie, William T. Peterson, Jay Peterson, Jessica Redfern, John C. Field, Ric Brodeur and Kurt Fresh
Ecosystem indicators for the California Current: A quantitative approach towards indicator development

Jameal F. Samhouri
Much ado about everything: Comparison of expert-based vulnerability assessments for coastal habitats along the U.S. west coast

Jennifer Boldt, Alida Bundy, Caihong Fu, Lynne Shannon and Yunne Shin
An overview of IndiSeas2: Evaluating the status of marine ecosystems in a changing world

Poster presentation

Nadezhda L. Aseeva
Reconstructions of flounder community on the shelf of West Kamchatka (Okhotsk Sea) under influence of environmental changes and interspecies relationships

BIO Workshop (W2)
Secondary production: Measurement methodology and its application on natural zooplankton community

Co-conveners: *Toru Kobari (Japan) and William Peterson (USA)*

Background

Zooplankton communities play important roles on the transfer of primary production to higher trophic levels of marine ecosystems. In the past two decades, the quantitative evaluation of the energy flow has been emphasized for better understanding how marine ecosystems respond to climate change and global warming. To date, primary production can be globally estimated with remote sensing techniques and validated with *in situ* experiments using radio or stable isotope. Although secondary production has been estimated with various methods (natural cohort, artificial cohort, molting rate, egg production, nucleic acids ratio, enzyme activity and empirical models), there is little information which method is relevant for natural zooplankton population or community. Thereby, we have little knowledge or confidence of secondary production measurements