PICES-2012: Summary of Scientific Sessions and Workshops

BIO/MEQ/FUTURE Topic Session (S10)
Ecosystem responses to multiple stressors in the North Pacific

Co-Convenors: *Vladimir Kulik (Russia), Ian Perry (Canada) and Motomitsu Takahashi (Japan)*

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Background

Marine ecosystems of the North Pacific, both coastal and offshore, are influenced by multiple stressors, such as increased temperature, change in iron supply, harmful algal blooms, invasive species, hypoxia/eutrophication, ocean acidification, and intensive fishing. These multiple stressors can (but do not always) 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 session sought to understand the responses of various marine ecosystems to multiple stressors and to identify appropriate indicators of these effects. Contributions were invited which reviewed and defined categories of indicators to document the status and trends of ecosystem change at a variety of spatial scales (e.g., coastal, regional, basin) in response to multiple stressors. Emphasis was placed on empirical and theoretical approaches that forge links between ecosystem change and the intensities of multiple stressors. This session was a contribution to the work of PICES WG 28 on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors* (http://www.pices.int/members/working_groups/wg28.aspx).

Summary of Presentations
Session S10 was held on Friday, October 19, 2012 (half day). It was launched with an invited speaker, Natalie Ban (Australian Research Council Centre of Excellence for Coral Reef Studies, Australia) and included 5 other oral presentations, 8 poster presentations, and time for discussion. The titles of the presentations are listed at the end of this report.

In her invited presentation, Dr. Natalie Ban (Australian Research Council Centre of Excellence for Coral Reef Studies, Australia) discussed issues related to mapping cumulative impacts, including advances, relevance and limitations to marine management. She began by noting there is global concern about multiple stressors and currently a lot of interest in mapping where multiple stressors might be interacting. She identified the purpose of her presentation as providing examples of methods and data for mapping multiple stressors in a given region. She concluded that such approaches do provide informative uses of existing data and information, baselines for future mapping, new opportunities to improve mapping approaches, but cautioned that there is a need to ground-truth these mapping efforts. She also recommended caution when scores for the vulnerabilities of different habitats to different stressors developed in one region (*e.g.*, the California Current system) are applied to a different region (*e.g.*, the coast of British Columbia), without critical consideration of their 'transferability'. An important next step in these types of habitat vulnerability analyses is the use of Bayesian methods to assess multiple stressors, which are now being investigated in some coral reef regions. Discussion following her presentation included how to move from GIS analyses of multiple stressors to impacts; it was noted that some of this needs to come from directed studies of impacts, however such studies currently often examine only one stressor at a time.

Dr. Ian Perry (in his paper with Dr. Jennifer Boldt) provided an example of a study to identify multiple stressors on multiple habitats in a specific region, the Strait of Georgia, British Columbia, featuring the early work of Working Group 28. The objectives of this study were to develop a structured process to identifying multiple stressors in the Strait of Georgia, and the responses of selected (key) habitats to these stressors, to identify which habitats might be more vulnerable to which stressors, and to provide base information that is needed to develop indicators of ecosystem responses to multiple stressors in this area. He described a GIS-

based approach to identify which stressors occur in the Strait of Georgia and how they might impinge upon various habitats, and then described an expert-based project to identify the potential vulnerabilities of these habitats to which stressors. He concluded that considerable (but not complete) information is available for the Strait of Georgia on spatial patterns of important marine habitat features and human stressors, that we are beginning to understand the knowledge gaps concerning measures of habitat vulnerability and resilience, and that expert surveys are one method to obtain information but they need to be cross-linked with empirical data. Ecosystem models may provide useful 'platforms' to understand ecosystem responses to multiple stressors, but they also need to be supported and cross-checked with empirical data and expert surveys. This type of analyses does not permit inclusion of temporal trends in stressors, which can be important in assessing current conditions when the information base is from past conditions.

Dr. Vladimir Kulik provided a detailed and thorough statistical analysis of mapping cumulative human and natural impacts in the Sea of Okhotsk, based on the monitoring of energy emissions from fishing activities. He derived time series of this information and applied statistical analyses to extract the dominant underlying features and trends. Planned activities include additional stressors such as SST and sea ice, adding nearshore human activities (specifically small-scale fishing), involving experts in a survey to get weights for ecosystem vulnerability, clustering the bottom area by ground type and depth, and summarizing impact scores by clusters.

Dr. Motomitsu Takahashi and co-authors provided an initial comparative study of ecosystem responses to anthropogenic activities and natural stressors among inland, shelf and oceanic waters around Japan. They used the expert-based screening method developed by Working Group 28 to identify the impacts of human activities and natural stressors in each of these regions. They then compared the outcomes from the expert-based approach with observed data. They concluded that increasing sea temperatures affect all three ecosystems, that coastal development and engineering have strong impacts on the East China Sea and the Seto Inland Sea, that demersal and pelagic fishing impacts the East China Sea and the Kuroshio/Oyashio region, respectively, and that nutrient inputs have synergistic impacts to Harmful Algal Blooms and hypoxia. They also identified problems with the expert-based scoring method, including that the certainty of the experts on the impacts differ among ecosystems because of the quality and quantity of information available, that the evaluation of impacts can differ among experts with different experience and expertise, that more information in the intertidal and coastal waters along China are needed for the East China Sea region, and that for oceanic waters, a lack of information may preclude appropriate evaluation of ecosystem responses.

Dr. Mingyuan Zhu and co-authors examined ecosystem changes under multiple stressors in the Yellow Sea, including the natural environment of Yellow Sea and East China Sea, their multiple stressors, the resulting changes in pelagic and benthic communities, and the consequent response of the ecosystems. They concluded that multiple stressors on the ecosystems of these Chinese seas occur from both climate change and anthropogenic activities and that they are increasingly severe, that there are clear ecosystem changes as evidenced by loss of biodiversity, declines in living marine resources, increasing HABS, "green tides", jellyfish blooms, etc., and that further studies and management actions to reduce environmental stresses are urgently needed.

The presentation by Mr. Kyung-Su Kim and co-authors won the Best Paper award from the MEQ Committee. They examined the combined effects of elevated carbon dioxide concentrations and temperature on the development of olive flounder, the most important aquaculture species in Korea. It provided an example of the type of directed study that is needed to begin to understand the joint effects of more than one stressor. They concluded that larval growth was similar at the two lower CO_2 concentrations examined and within the range of seawater temperature range of 18~22℃, but that growth was enhanced at the highest CO_2 concentration at both temperatures. They also noted that the calcium component in larval bone was significantly increased at the highest CO_2 concentration. This study provided a nice example of the (often) non-linear relationships that can occur with multiple stressors interact.

General discussion considered whether these expert-based survey approaches should be done with a regional or global focus*, i.e.,* whether the respondents should be ask to consider just the range of values and experiences

in a particular geographic region or on a global comparison. No consensus was reach other than to note this question can be important and should be considered in such surveys and their questions. In addition, how can the impacts of multiple stressors on habitats be examined when more than two stressors are occurring. For example, Perry and Boldt found that the mode number of stressors on any 4 km^2 region in the Strait of Georgia was between 20 and 25. When developing indices for multiple stressors, they need to be "simple" but at the same time allow for users to 'drill down' to obtain more details about how particular sets of stressors might be driving particular responses in habitats. An important shortcoming in these approached was noted regarding temporal changes, and how to update the analyses. A stepwise process was recommended, involving identification of habitats, stressors, and their vulnerabilities, noting that these vulnerabilities of specific habitats to different stressors likely do not need to be updated on a regular basis. Updates for new time periods would then use the established vulnerabilities and simply update the stressor information.

List of Papers

Oral Presentations

Natalie C. Ban, Stephen S. Ban and Hussein M. Alidina
Mapping cumulative impact: Advances, relevance and limitations to marine management and conservation in Pacific Canada, and emerging Bayesian approaches (S10-8514), Invited

R. Ian Perry and Jennifer Boldt
Identifying multiple stressors and potential habitat responses in marine ecosystems of Pacific Canada (S10-8612)

Vladimir V. Kulik
Mapping cumulative human and natural impacts in the Sea of Okhotsk (S10-8559)

Motomitsu Takahashi, Sachihiko Itoh, Naoki Yoshie, Kazuhiko Mochida, Masakazu Hori and Shigeru Itakura
Comparative study on ecosystem responses to anthropogenic activities and natural stressors among inland, shelf and oceanic waters around Japan (S10-8568)

Mingyuan Zhu, Ruixiang Li and Zongling Wang
Ecosystem Changes under multi-stressors in the Yellow Sea (S10-8573)

Kyung-Su Kim, JeongHee Shim and Suam Kim
The combined effects of elevated carbon dioxide concentration and temperature on the early development stage of olive flounder Paralichthys olivaceus (S10-8429)

Poster presentations

Evgeniya Tikhomirova
Typical distributions of primary production at the surfaces of Peter the Great Bay (Japan Sea)

Kanako Naito, Setsuko Sakamoto, Mineo Yamaguchi, Ichiro Imai and Ken-ichi Nakamura
Iron as a triggering factor for harmful dinoflagellate blooms

Aya Morinaga and Kazumi Matsuoka
Eutrophication suggested by the heterotrophic signal of dinoflagellate cyst assemblages; Case of Omura Bay, West Japan

Yuta Inagaki, Tetsuya Takatsu, Masafumi Kimura, Yota Kano, Toyomi Takahashi, Yoshihiko Kamei, Naoto Kobayashi and Tatsuaki Maeda
Effects of hypoxia on annual changes in growth and somatic condition of flathead flounder *Hippoglossoides dubius* in Funka Bay, Japan

Tetsuya Takatsu, Koji Shinoda, Shoichi Inoue, Tomofumi Seta and Yuta Inagaki
Drastic reduction of demersal fish abundance by hypoxia in Mutsu Bay Japan in the fall of 2011

Stephani Zador and Kirstin Holsman
Identifying and comparing ecosystem stressors in the eastern Bering Sea and Gulf of Alaska

Yumiko Yara, Meike Vogt, Masahiko Fujii, Hiroya Yamano, Claudine Hauri, Marco Steinacher, Nicolas Gruber and Yasuhiro Yamanaka
Ocean acidification limits temperature-induced poleward expansion of coral habitats

Anastasiia Strobykina
Spatial and temporal variability of nutrients in the Okhotsk Sea shelf zone