Appendix 5

PICES Press Articles Related to WG 28

Workshop on Marine Biodiversity Conservation and Marine Protected Areas in the Northwest Pacific

by Vladimir Kulik

Fig. 1 The participants of the NOWPAP/NEASPEC workshop on "Marine biodiversity conservation and marine protected areas in the Northwest Pacific", March 13–14, 2013, in Toyama, Japan. The photo was provided by the Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (CEARAC) of NOWPAP.

The beautiful city of Toyama, Japan, 300 km northeast of Tokyo, was the setting on March 13–14, 2013, for a workshop on "*Marine biodiversity conservation and marine protected areas in the Northwest Pacific*". The workshop was convened by NOWPAP (Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region; part of the Regional Seas Program of the United Nations Environment Program; http://www.nowpap.org/) and NEASPEC (North-east Asian Sub-program for Environmental Cooperation; http://www.neaspec.org/). The objectives of the workshop were: (1) to share information on methodologies for marine environment assessment and the current status of Marine Protected Areas (MPAs) in member states of NOWPAP, and (2) to discuss the programs and operations of the proposed North-east Asian MPA network. PICES was invited to participate in this workshop, and was represented by Dr. Vladimir Kulik, a member of the PICES Working Group 28 on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors*. In addition to PICES, other participants at the workshop included experts from all NOWPAP member states (Japan, People's Republic of China, Republic of Korea and the Russian Federation) and from international organizations such as the Helsinki Commission (HELCOM; http://www.helcom.fi/) and the IOC Sub-Commission for the Western Pacific (IOC/WESTPAC; http://www.unescobkk.org/westpac). In total, more than 20 people attended the workshop (Fig. 1).

The motivation for the workshop was responsibilities to contribute to marine biodiversity conservation and sustainable use of marine ecosystem services in the NOWPAP region. The meeting had presentations and shared information on details of MPAs in the region, including definition, categories and monitoring/management status in each member state of NOWPAP. An information sheet was developed and will be finalized based on additional information provided after the workshop. The meeting discussed the similarities and differences in the definitions of MPAs among the member states and recognized the usefulness of such information for future considerations to improve the management of MPAs. Information was also shared on the challenges of maintaining and managing MPAs, as well as future plans to design and expand these areas, including the possible application of the Ecologically or Biologically Significant Sea Area (EBSA) concept developed by the United Nations (UN) Convention on Biological Diversity (CBD; http://www.cbd.int) and other organizations.

The meeting learned about ongoing related activities for assessing the marine environment being conducted by PICES, HELCOM and IOC/WESTPAC, which were recognized as being useful for the conservation of marine biodiversity in the NOWPAP region. The necessity of Ecological Quality Objectives for the NOWPAP region was stressed as a basis for setting targets for assessment and appropriate management. Collaborations among the NOWPAP member states and other regional organizations such as PICES towards the conservation of marine biodiversity were acknowledged as being crucial. Of special interest to PICES was a presentation by Dr. Maria Laamanenof (HELCOM) on "*Comprehensive ecosystem assessment for marine biodiversity conservation*". She noted that they have reached the 10 % target set by the UN CBD for a regional network of MPAs in the Baltic Sea. However, the present network may not be entirely ecologically coherent if adequacy, representativity, replication and connectivity are the primary criteria used for its assessment. The most important problems they have encountered in evaluating the effectiveness of this network of MPAs are nonlinearities and thresholds in the ecosystem recovery process. Therefore, reaching some of the targets did not lead to convergence with other targets from the same domain. As a result, widely used simplifications in the models of ecosystem assessment such as linearity and additivity must be reconsidered. HELCOM member states are in the process of summarizing their achievements in assessing the progress towards reaching HELCOM objectives for a healthy Baltic Sea, which are available at http://www.helcom.fi/BSAP_assessment/en_GB/main.

At its conclusion, the NOWPAP/NEASPEC workshop recommended the following:

- The regional monitoring centre for NOWPAP to assess the availability of data and to consider the collection of metadata and the development of assessment tools based on the available data for marine biodiversity conservation in the NOWPAP region;
- Recognizing that the indicators employed by HELCOM and those being studied by PICES are useful references for the NOWPAP region, to consider the availability of data and different conditions in the marine environment in the NOWPAP region when selecting indicators;
- Strengthen collaboration with relevant partners, for example, PICES, HELCOM and IOC/WESTPAC, when conducting the above tasks.

Fig. 2 PICES WG 28 presentation at the NOWPAP/NEASPEC workshop.

The full meeting report, with details from each NOWPAP member state, and all presentations (including that given by the author of this article (Fig. 2) on behalf of PICES WG 28) are available on the workshop website at http://www.cearac-project.org/NOWPAP_NEASPEC_Workshop/NOWPAP_NEASPEC_Joint_Workshop.htm.

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OSM Session on "*Identifying multiple pressures and system responses in North Pacific marine ecosystems*"

by Ian Perry

Marine ecosystems of the North Pacific, both coastal and offshore, are impacted by multiple pressures, such as increased temperature, change in iron supply, harmful algal bloom events, invasive species, hypoxia/eutrophication and ocean acidification. These multiple pressures can act synergistically to change ecosystem structure, function and dynamics in unexpected ways that differ from single pressure responses. It is also likely that pressures and responses will vary geographically. A key objective of the PICES FUTURE science program is the identification and characterization of these pressures to facilitate comparative studies of North Pacific ecosystem responses to multiple stressors and how these systems might change in the future. This session had two primary objectives: 1) identify key stressors and pressures on North Pacific marine ecosystems, including comparisons as to how these stressors/pressures may differ in importance in different systems and how they may be changing in time; and 2) identify ecosystem responses to these multiple stressors and pressures. Objective 2 includes understanding how natural and human perturbations may cascade through ecosystems, and whether there may be amplifiers or buffers which modify the effects of perturbations on marine systems. The overall goal of this session was to contribute to the work of PICES Working Group 28 on *Developing Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors* and to obtain an overview of the pressures being experienced by North Pacific marine ecosystems and their impacts on the marine ecosystems of the North Pacific.

In total, 15 papers were presented in session S1, plus one by Isabelle Rombouts in a plenary session (Fig. 1). All presentations demonstrated that multiple stressors are common, and that single stressors are rare (*e.g.*, Fig. 2). Literature analyses of multiple stressors usually list between 25 to 50 multiple stressors (Working Group 28 has been working with an integrated list of about 20 stressors for its comparative studies). Several presentations by Working Group 28 members (Takahashi *et al*., Martone *et al*., Kulik, Samhouri *et al*., Zador and Renner, Perry *et al*.) provided descriptions of multiple stressors in North Pacific marine ecosystems. The presentation by Perry *et al*. concluded that the scientific community is beginning to understand issues of sensitivity and exposure of habitats to multiple stressors (Fig. 3), but there is also consensus that a lot of questions remain. Early analyses from Working Group 28 suggest that there are more stressors, and greater impacts, in coastal than offshore areas. However, comparative studies also suggest there may be a shorter list of important stressors at regional scales. In analysis of scenarios of cumulative impacts along the coast of British Columbia, Canada, Clarke-Murray *et al*. found climate change impacts overwhelmed all other stressors.

Fig. 1 Plenary speaker, Dr. Isabelle Rombouts addressing the audience.

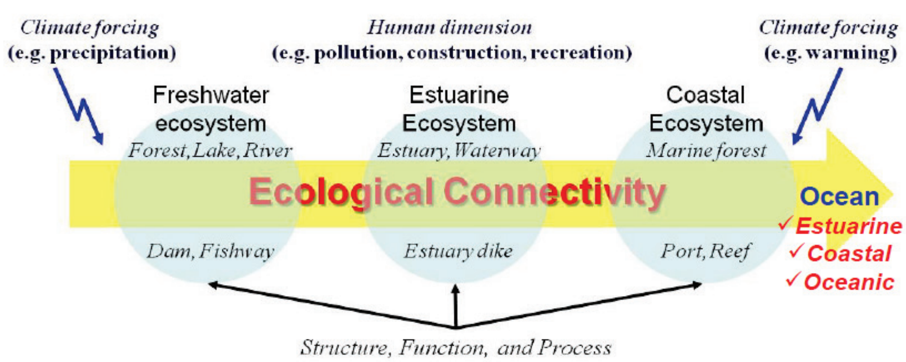

Fig. 2 Example of multiple and cumulative stressors along an ecological gradient from freshwater to marine systems. From Won et al.

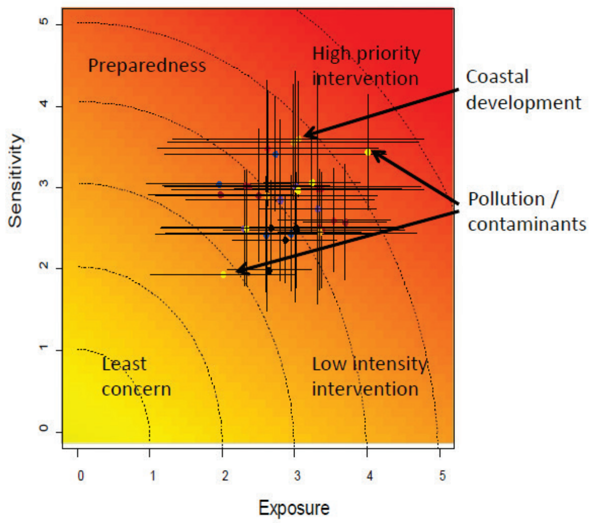

Fig. 3 Example of a risk plot (Exposure by Sensitivity) of multiple stressors (20 stressors by 22 habitats) for the Strait of Georgia, Canada. Color coding represents degrees of inferred relative risk. Horizontal and vertical bars represent uncertainties derived across multiple experts. From Perry et al.

Several presentations discussed options for developing ecosystem indicators to characterise ecosystem responses to multiple stressors. Boldt *et al*. outlined a number of requirements for such indicators. These include the need to define strategic goals and ecological or management objectives for these indicators, and the need for a suite of integrative indicators that would cover key components and gradients at the appropriate spatial scales. It was also recognised that mechanistic approaches can give insights into how pressures are likely to interact and how impacts may become observable. The synthesis of indicator status across multiple trophic levels may reveal broad-scale changes in the environment that may have important biological and management implications. For example, upper trophic level organisms such as seabirds and halibut may serve as integrative indicators that can provide near-real time cues of environmental state (Zador and Renner presentation).

Multiple stressors might interact in additive, synergistic, or antagonistic ways. An analysis of interaction type from 171 studies that manipulated 2 or more stressors found that 26% identified additive interactions, which are most commonly used in model studies of stressor interactions, but that 36% and 38% of the studies identified synergistic or antagonistic interactions, respectively (Crain *et al*. 2008, Ecology Letters). Examples presented during this session included the paper by Jung, who concluded that intensive fishing activities by Korean trawlers could have aggravated the potential resilience of the filefish stock, causing it to collapse when the climate changed; and the paper by Polovina and Woodworth-Jefcoats, who concluded that top-down responses in the Central North Pacific ecosystem means that fishing and potentially bottom-up climate impacts are likely to have stronger negative impacts on the larger fishes than on smaller fishes, causing the ecosystem size structure to shift towards smaller sizes. Their study, based on two ecosystem models, indicated that impacts from bottom-up stressors could range from moderate (–20%) to severe (–60%) depending on changes in phytoplankton. Del Raye and Weng identified a need for physiological models that use aerobic scope for activity to understand interactions between temperature and O_2 at discrete $p\mathrm{CO}_2$.

Based on the presentations and discussions, the session reached the following conclusions:

- Ecosystem responses to multiple stressors are non-uniform: a suite of indicators is best to capture a diversity of ecosystem responses.
- Because a diversity of ecosystem responses is expected, it is essential to clarify which types of ecosystem changes matter to a pre-specified group of people.
- Interactions between multiple stressors more often appear to be non-additive (synergistic or antagonistic); there is the need to understand how predicted ecosystem responses vary with different assumptions about interactions between stressors (noting, however, that there is no substitute for data).
- Climate and fishing provide good examples of how interactions between stressors can act non-additively in some cases and additively in others to change the dynamics of exploited fish populations.

Different approaches may be needed for situations with different degrees of complexity. For example, data-driven evaluations are obviously to be preferred for situations where data are available (in space, time, and types of variables). Expert opinion may be necessary when the focus is on broad spatial scales, although care should be taken to verify these opinions with data or other experts when possible.

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I would like to thank the other S1 co-convenors, Vladimir Kulik, Rebecca Martone, Jameal Sambouri and Motomitsu Takahashi for their contributions in organizing and chairing this session.

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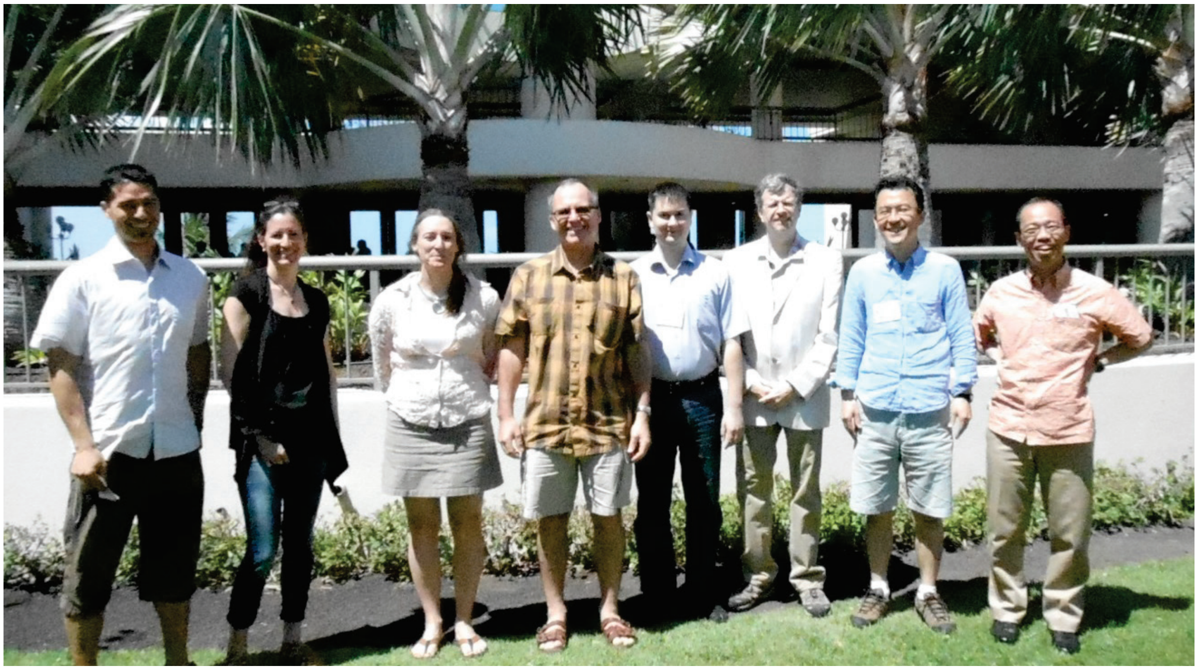
OSM Workshop on "*Bridging the divide between models and decision-making: The role of uncertainty in the uptake of forecasts by decision makers*"

by Edward J. Gregr



Convenors and invited speakers (left to right): Kai M.A. Chan (Canada), Lee Failing (invited speaker, Compass Resource Management Ltd., Canada), Georgina A. Gibson (invited speaker, International Arctic Research Center, University of Alaska Fairbanks), Edward J. Gregr (Canada), Vladimir Kulik (Russia), Hal Batchelder (PICES Secretariat), Motomitsu Takahashi (Japan), Shin-ichi Ito (Japan), Missing: Naesun Park (Korea), Ian Perry (Canada), Jameal Samhouri (USA).

The FUTURE science program recognizes the need to more directly address uncertainty in products such as ocean climate forecasts, and to improve how the knowledge produced by PICES is disseminated. In a series of presentations and discussions, our workshop (W2), held April 14, 2014, examined both the nature of uncertainty in model systems, and how uncertainties can be included in the decision making process. The workshop was well attended, with broad representation from PICES member countries. We identified a number of opportunities for the PICES community to improve how uncertainty is characterized, and to highlight several advantages that would emerge from tailoring model outputs, including uncertainties, for diverse audiences.

Understanding uncertainty

The first step in addressing uncertainty is to understand its source. Gregr and Chan (in review) consider three classes (Data, Scope, and Process) of uncertainty based on the assumptions necessary at various steps in the model design process. Assumptions about data relate to uncertainties about things such as sampling bias, representativeness, and the overall relevance of the data to the study under consideration. Decisions about model scope (*e.g.*, specification of spatial, temporal, and compositional extents) are central to model design and contain uncertainties about model boundaries and resolution, among other things. Once model data and scope are defined, decisions and assumptions about process must be made, for example, which ecosystem components interact and the nature of these interactions, some of which are also uncertain.

For the purposes of communication and decision-making, Gregr and Chan added two additional classes of assumptions, Communication and Relevance (Table 1). Assumptions around communication obscure uncertainties related to things such as language and disciplinary epistemology. Perhaps most importantly, the relevance of ecosystem model results to decision-making is often assumed to be quite high by model developers. However, this is far from certain, and evidence suggests that it is often quite low (Failing, this workshop). This class of assumptions thus relates to uncertainties about indicator selection and the context relevance. In many cases, comprehensive treatments of model uncertainties are not necessarily desirable (or tractable). However, Gregr and Chan argue that a more explicit recognition and discussion of model assumptions is necessary for improving our understanding and communication of model results, and the associated uncertainties.

Table 1 Assumption classes and the associated types of uncertainty.

Assumption class	Uncertainty
Data	Observational
Scope	Design uncertainty
Structure	
Process	Parameter estimation
	Natural variation
	Inherent randomness
Communication	Ambiguity
	Under-specification
	Vagueness
Relevance	Context dependence
	Relativism

Representing uncertainty

Several presentations illustrated methods for examining model uncertainties. Invited speaker, Georgina Gibson (USA), discussed the role of assumptions in the development of lower trophic level (LTL) ecosystem models. Describing how the complexity of model structure and parameterization can increase quickly, she emphasized the associated need for assumptions to manage this. She demonstrated how to use sensitivity analysis to identify critical parameters, but noted that the large computational demands limit the extent to which it can be applied. Gibson and Spitz (2011) used a one-dimensional lower trophic level model to examine a suite of 135 biological and 8 environmental factors, and ranked these factors according to their influence on model outputs. Although the approach identified parameters deserving closer scrutiny, similar analysis has not been applied to 2- or 3-dimensional models because of the computational limitations, leaving important parameters untested.

Exploring the parameter uncertainties in such simulation models is typically handled using established Monte Carlo methods. However, knowing the range over which to sample parameters is critical to such efforts. Unfortunately, such ranges (which are necessary to parameterize theoretical, mechanistic models) are not always known, and thus represent important design assumptions. Similarly, initial or starting conditions for models may be unknown, which can have a significant effect on the trajectory of model predictions (Gibson and Spitz 2011).

Rowenna Gryba (Canada) examined assumptions about the relevance and utility of data, and how this influences the evaluation of habitat suitability in models of North Pacific Right whales. Standard cross-validation approaches to evaluating models of habitat suitability are sensitive to potential biases in the data. Analytical methods typically assume unbiased data, but analyses often contain implicit, potentially false assumptions about the relevance or suitability of such data, which may contain geographic or seasonal sampling biases. Gryba also considered conceptual assumptions implicit in such models, where, for example, it is often assumed that mammal sightings are correlated with high prey concentrations. She showed how this conceptual assumption is testable using independent data on prey distributions, thus providing insights into the uncertainty associated with this key habitat modeling assumption.

The challenge of coupling models was discussed by Shin-Ichi Ito (Japan), who presented the results of a fisheries production model for Pacific saury forced using sea surface temperature predictions from 12 different global climate models developed by the Intergovernmental Panel on Climate Change (IPCC). While a number of correlations were found, uncertainty in fish growth projections were dominated by uncertainties in the physical forcing. This emphasizes the need for appropriate scaling methods when moving from global to regional study areas. Ito suggested that to effectively couple models across scales, more attention needs to be paid to key processes at the interfaces. For example, zooplankton dynamics play a key role in saury abundance. Thus, it is critical to appropriately capture the relationships between physics and zooplankton, and between zooplankton and higher trophic levels (HTLs). Given that HTLs typically respond to multiple drivers operating at different scales (*e.g*., Palacios *et al*. 2013), a better understanding is needed about how HTLs respond to short-term forecasts.

The need to understand such processes and their interactions was nicely illustrated by Bill Peterson (USA), who showed how the correlation between the Pacific Decadal Oscillation (PDO) and Chinook salmon ocean survival, which had shown a robust negative correlation for 15 years, suddenly failed dramatically in 2011. The causal relationship appears mediated by copepods, which provide an index of the lipid richness at the base of the food chain. This 'lipid rich copepod index' is, in turn, correlated with Chinook survival. However, the decoupling of the relationship highlights new uncertainties about the scale and process of the presumed mechanism. Once again, this emphasizes the need to understand the process, though even so, surprises should be expected. For HTL models in particular, the need to transition from correlative to mechanistic model frameworks is increasingly relevant (Palacios *et al*. 2013).

Decision making and communication

Lee Failing (Canada), our second invited speaker, provided an important perspective on the role of research and uncertainty in decision making. Failing noted that while many frameworks exist to support integrated management, the process of actually making decisions and managing the risks arising from uncertainty are rarely emphasized. Rather, the decision-making components are often presented as *post-hoc* interactions with the principal science represented in prominent detail (*e.g.*, Figure 1). Treating decision-making as an afterthought introduces many implicit and likely false assumptions about the role of science in the decision-making process. Such perspectives are grounded in the information deficit model of science communication, an approach that is increasingly understood to be false (see http://en.wikipedia.org/wiki/Information_deficit_model). Only a small portion of science as currently practiced is typically salient to decision makers. To improve the relevance of science to policy and decision making, Failing emphasized the transformative power that comes from "making the decision" the goal of the scientific effort and analysis. This leads to immediate identification of what is important, and informs where science could best contribute to the process. The salience of such contributions would be greatest if they helped inform the trade-offs faced by decision-makers and their stakeholders.

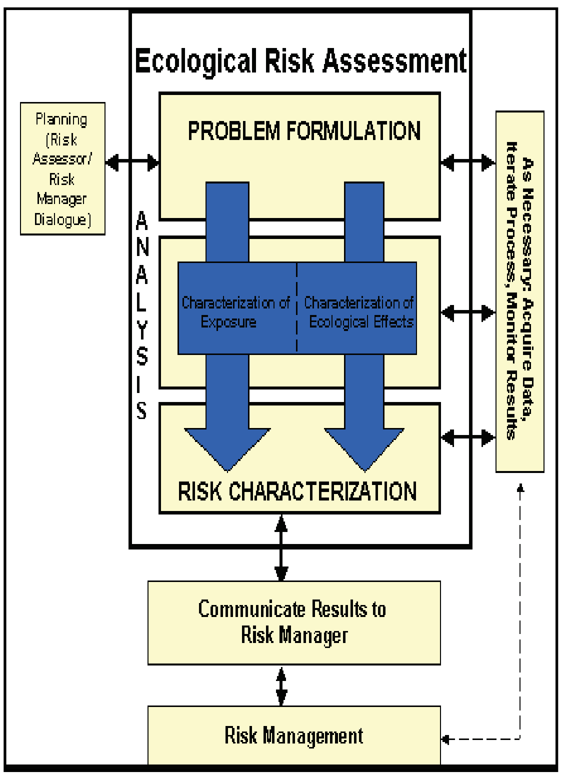


Fig. 1 Example risk assessment framework emphasizing (red oval, added) the implied post-hoc role for the decision making process.

This leads to the question of science communication, and Kai Chan (Canada) argued that this is as much a question of targeting as it is of understanding the science and the inherent uncertainties. Through various examples, Chan emphasized the need to focus on the complete decision scenario to identify what really matters and, equally important, what is at risk. From the perspective of the FUTURE program, this means identifying relevant metrics and understanding the distribution of inputs and outputs. It also means being explicit about unquantified assumptions to help understand the associated risk. And perhaps most importantly, it means recognizing that there is no single audience or stakeholder, but rather a diversity of interests for whom different metrics and presentation methods may be required. Targeting – identifying what matters, and how it is best measured, for each decision scenario – will be key to effectively communicating FUTURE products beyond the PICES scientific community.

Challenges and opportunities

In addition to the presentations, we devoted considerable time to discussion, including a joint session with the participants of workshop W3 on "*Climate change and ecosystem-based management of living marine resources: appraising and advancing key modeling tools*". The joint session acknowledged that the fundamental challenge for the modeling community is to identify what resonates with decision makers. Given the diversity of management and policy decisions that are regularly made, this emphasizes the need to develop communication strategies that can adapt effectively to diverse audiences. Decision makers would like to reduce risk and reduce surprises. This would presumably simplify the trade-offs inherent in policy and management decisions.

The role of reliable ecosystem forecasts in reducing risk and producing fewer surprises is recognized, although the risk of such forecasts being wrong and surprising decision makers will need to be carefully managed. Integrating data from regional Ocean Observing Systems, focusing on short-term forecasts, and predicting the responses of HTLs are essential components of such ecosystem forecast systems. The increasing risks faced by decision makers due to climate uncertainty provide an opportunity to advocate for ocean climate forecast services at regional scales, emphasizing that their utility for managing risk is as high as traditional short-term weather forecasts.

Uncertainties related to closure terms (*i.e.*, the parameters required to represent aspects not included in the model), model structure, and the downscaling of global models will continue to present challenges to the development of such short-term forecasts. Ensemble modeling is increasingly providing an opportunity to address the cumulative uncertainty in highly complex models, allowing the assessment of robustness (Knutti and Sedláček 2013). To demonstrate their relevance, a key performance challenge for such short-term forecasts is to achieve not only statistical accuracy, but to reasonably predict the phase (*i.e.*, timing) of climatic events. This will be best approached through regional models, which have already met with some success, such as the prediction of hypoxia events (Siedlecki *et al.* 2014). Accurate predictions of phase changes is critical (although emphatically not sufficient) for forecasting the HTL indicators important for many stakeholder groups.

Other opportunities are emerging due to the consequences of a changing ocean. As ecosystem boundaries shift, baselines on which stock assessment data are based will begin to expose the assumption of spatial stationarity. This provides an opportunity for fisheries scientists to reconsider how the science underpinning management decisions is conducted, and perhaps refocus it more directly on the decision and the risks to stocks in a more unpredictable ocean. This is particularly salient in light of recent research suggesting ocean conditions play a much stronger role in recruitment than previously believed (Szuwalski *et al*. 2014), re-enforcing the need for reliable ocean forecast systems.

The take-home message for FUTURE from the workshop is that broader uptake of our knowledge products will require clearly articulating the decision context to which they contribute. The extent to which we can explicitly inform the risks in the choices facing managers and policy makers will influence the uptake of our science into decision making. Casting our uncertainties as risks, and targeting these results at the appropriate audiences, will further increase our contribution to evidence-based decision making. Finally, by considering how we can contribute to decisions that will be made in the future, the ocean science community has an opportunity to move from a reactive, crisis-management role to proactive leadership where best available science provides timely, salient, and sound advice to support ocean management decisions.

References

Gibson, GA and YH Spitz. 2011. Impacts of biological parameterization, initial conditions, and environmental forcing on parameter sensitivity and uncertainty in a marine ecosystem model for the Bering Sea. Journal of Marine Systems 88: 214–231.

Gregr, EJ and KMA Chan KMA. 2014. Leaps of Faith: How implicit assumptions compromise the utility of ecosystem models for decision-making. BioScience. In review.

Knutti, R. and J. Sedláček. 2013. Robustness and uncertainties in the new CMIP5 climate model projections. Nature Climate Change 3, 369-–373.

Palacios, DM, MF Baumgartner, KL Laidre, and EJ Gregr. 2013. Beyond correlation: integrating environmentally and behaviourally mediated processes in models of marine mammal distributions. Endangered Species Research 22: 191–203. doi: 10.3354/esr00558

Seidlecki, SA, A Hermann, N Bond, S Alin, and R Feely. 2014. Hypoxia and ocean acidification of the coastal waters of the Pacific Northwest: evaluation of seasonal predictions of hypoxia and pH. Presentation at the 2014 Ocean Sciences Meeting, Honolulu, HI.

Szuwalski, CS, KA Vert-Pre, AE Punt, TA Branch, and R Hilborn. 2014. Examining common assumptions about recruitment: a meta-analysis of recruitment dynamics for worldwide marine fisheries. Fish and Fisheries 1467-2979. doi.org/10.1111/faf.12083.

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