OSM Workshop on "*Climate change and ecosystem-based management of living marine resources: Appraising and advancing key modeling tools*"

by Tim Essington, Anne B. Hollowed and Myron A. Peck

The workshop (W3), co-sponsored by the ICES/PICES Strategic Initiative (Section) on the *Impacts of Climate Change on Marine Ecosystems* (SICCME/S-CCME), was convened by the co-authors of this summary on April 14, 2014, as part of the PICES FUTURE Open Science Meeting. Ten scientists representing 6 nations participated in the meeting.

Overview

Climate variability and climate change interact with other pressures to affect the productivity and dynamics of marine ecosystems. Managers charged with the stewardship of sustainable living marine resources are challenged to deal with the consequences of this variability, and better tools are needed to inform them. The workshop was convened to discuss state-of-the-art tools for: (1) calculating biological reference points under changing climate conditions that recognize that equilibrium states no longer apply; (2) assessing the relative ecological and economic costs and tradeoffs of different ecosystem-based management scenarios, and (3) estimating the vulnerability and stability of ecosystems (and their key components) required to make informed, ecosystem-based fisheries management decisions. The workshop was intended to provide a critical review of modeling tools available for fisheries management needs and to understand what advancements are required to address climate-driven changes in ecosystem dynamics.

Objectives

The three main objectives were to discuss state-of-the-art tools for:

1. Calculating biological reference points under changing climate conditions that recognize that equilibrium states no longer apply,
2. Assessing the relative ecological and economic costs and tradeoffs of different ecosystem-based management scenarios, and
3. Estimating the vulnerability and stability of ecosystems (and their key components) required to inform ecosystem-based fisheries management.

Summary

Two invited speakers provided a strong conceptual backdrop on the current status and important avenues for future progress in state-of-the-art ecosystem modeling. In the first talk, Icarus Allen (PML, UK) presented an overview of the current state of lower trophic level (LTL) models with emphasis on examining links between physics, biogeochemistry and the production of phytoplankton and zooplankton. He compared the pathways utilized to represent food web connections within LTL models highlighting the fact that these are fairly rigid and different pathways. Many of these nutrient-phytoplankton-zooplankton-detritus (NPZD) models were never designed to represent zooplankton dynamics, although many are being utilized to estimate biomass and productivity of that component. An important advancement of these LTL models includes more mechanistic (physiological-based) representation of life history and trait-based approaches allowing evolution and adaptation to environmental conditions to take place (and emergent properties of communities), and more widespread inclusion and increased complexity in representing benthic processes. Modular models with flexible components are needed. Furthermore, the talk stressed the importance of broad-scale patterns (consistent features of groups which are independent of habitat characteristics) that allow one to better validate models.

In the second invited talk, Beth Fulton (CSIRO, Australia) provided an overview of her experience constructing complex (parameter-rich) end-to-end models and ongoing improvements in model structure and parameterization that help represent real-world complexity. Her talk stressed how ecosystems are moving targets with respect to the features of key components. One example was the inability to examine temporal development in fish groups without explicitly accounting for fishery-induced changes in size during the early portion of the time series and both fishery effects and climate-induced changes. She also highlighted the importance of exploring scenarios in end-to-end models that include consideration of the full extent of (potentially surprising) human responses within multiple interacting sectors. When used in this manner, it is possible to assess the importance of various attributes of ecosystems (such as the presence or absence of adaptation of key species to change). Her work with these complex models also highlighted the importance of collecting new information on key groups such as mesopelagic fish and forage species, which are a rarely studied but possibly are a critically important component in many marine food webs. Understanding and modeling the adaptive capacity of both biological (food web components) and social systems are important challenges that need to be overcome.

Alan Haynie (NOAA NMFS, USA) provided a (recorded) talk introducing FishSET, a spatial economics toolbox to better incorporate fisher behavior into fisheries management and ecosystem modeling. The model attempts

to understand how fishers respond to various aspects such as fish or fuel prices, changes in habitat and the environment, bycatch regulations, catch shares, and marine reserves or other closures. This location-choice model uses various types of available data to evaluate what factors explain where vessels fish (and related questions). The fishing area is chosen as a function of key economic indicators such as expected catch/revenue in the area, travel costs (fuel, time, wages, the opportunity cost of not using the boat elsewhere) and vessel characteristics (*e.g.*, horsepower), as well as biological and environmental characteristics of areas. FishSET is a stand-alone Matlab application and the presentation outlined the 7 primary features of the model. An upcoming pilot project in the Northeast/Mid-Atlantic will examine the interactions between fishers and potential wind energy projects.

In the final talk, Myron Peck (University of Hamburg, Germany) briefly introduced the EU VECTORS program which is attempting to examine the ecological and economic costs and tradeoffs of changes in the distribution and productivity of outbreak forming species (such as jellyfish) and alien invasive species. Three European regional seas are in focus (North Sea, Mediterranean Sea, and Baltic Sea). This presentation summarized efforts to build consistent future scenarios that allow one to not only incorporate physical and biological changes projected under different greenhouse gas emission scenarios but also the key economic (fish price, fuel price, gear investment, *etc*.) and policy decisions regarding spatial utilization of ocean habitats (from fisheries, renewable energy, conservation, *etc*.). An important take-home message was that future policy mechanisms may be as important as potential climate-driven changes in the distribution of fish stocks. The talk also summarized how distributional changes, as detected using different approaches (bioclimate envelop models, dynamic energy budget models) under common scenarios, were being assessed using a spatially explicit bio-economic model (FishRent).

A wide ranging discussion followed these talks which was facilitated by a 1-hour combined session with workshop W2 focusing on communicating science and effective stakeholder engagement. Key findings from the workshop were:

- Models should be flexible to accommodate shifting selectivity, growth, natural mortality, and availability. Zooplankton and mesopelagic species, as well as the adaptive capacity of food web components need to be better represented.
- Fisher choice models provide insight into functional responses which will be critical to use within end-to-end models of marine systems, which include management evaluation frameworks. Stock assessment and fisheries scientists should partner to conduct retrospective studies of fisher responses to changing conditions.
- Setting biological reference points without knowing the trajectory to a new equilibrium state will be challenging. Management evaluation frameworks are needed to identify robust harvest strategies.
- Projections of the effects of climate change on future fish and fisheries must consider also the responses of fishers and managers. Developing future scenarios must be done in conjunction with stakeholders. A set of candidate alternative futures is needed to set the stage for discussion of scenarios.

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