Examining the Impacts of Climate Change and Fishing from Both Species-Based and Size-Based Modeling Perspectives

Phoebe A. Woodworth-Jefcoats,
Jeffrey J. Polovina,
Evan A. Howell,
and Julia L. Blanchard

Methods – Model Scenarios

NOAA GFDL prototype Earth System Model 2.1 – ESM2.1
- Coupled climate model (CM2.1; Delworth et al. 2006, Gnanadesikan et al. 2006) and biogeochemical model (Dunne et al. 2005)
- Forced by IPCC SRES A2 which projects CO2 concentrations reaching 850 ppm by 2100
- Projects increased stratification in North Pacific subtropical gyre, reducing nutrient input into the euphotic zone and leading to a decline in both small and large phytoplankton densities

Methods – Ecosystem Models

Species-Based Model: Ecopath with Ecosim – EwE
- Based on detailed diet and trophic interactions
- Consists of two components: static Ecopath component and dynamic Ecosim component
- Feeding interactions are a function of predator avoidance by prey (Christensen et al. 2008)
- Model used in this comparison is based on that of Howell et al. (2012), version 6.2.0.714

Size-Based Food Web Model – SBFW
- Based on the premise that predation in the pelagic environment is largely determined by body size
- Energy flow is driven by growth resulting from size-based predation
- Feeding kernel for predator of size m represented by a logarithmically decreasing probability function centered around prey size m
- Based on the pelagic component of model used by Blanchard et al. 2012

Primary producer (phytoplankton, consumer (black) spectra output by the SBFW model. Green circle denotes boundary between small and large phytoplankton. Blue circles indicate the sizes at which fish enter and are fully exploited by the fishery.

Fishing Scenarios
- Range of fishing mortality values: 0, 0.2, 0.4, 0.6, 0.8, 1.0, applied to fish > 1 kg
- Gear selectivity function: fish 1 kg experience one quarter the level of fishing mortality, fish > 15 kg experience one quarter the level of fishing mortality

Overview
- We compare a species-based and size-based ecosystem model forced by the same fishing and climate change scenarios
- Across models, climate change leads to ecosystem-wide declines in catch, though to differing extents
- Sensitivity to top-down and bottom-up forcing is linked, in part, to model structure
- Results highlight the need for integrated size- and species-based modeling approaches

Results

Long-Term Trends in Modeled Catch
- Including climate change leads to a gradual decline in catch in both models
- Both models project greatest large fish (> 15 kg) catch when F = 0.4 and least when F = 1.0
- Both models project smallest growth in fish (1 – 15 kg) catch when F = 0.4 and least when F = 0.2
- Model disparity on trends in and magnitude of interannual variability: -EwE: variability more closely follows that of small phytoplankton
- SBFW: variability more closely follows that of large phytoplankton
- Small fish catch: SBFW 2 – 3 times more variable than EwE
- Large fish catch: SBFW 7 – 27 times more variability than EwE

Food web used by EwE model. Circle size denotes relative biomass, circle lines represent trophic pathways. Species/fundamental groups subject to fishing mortality are shown in blue, with those subject to full levels of fishing mortality in bold.

Combined Fishing and Climate Impacts
- Model agreement on decline in large fish catch at all levels of fishing mortality when paired with climate change
- Model disparity in whether fishing exacerbates the impact of climate change
- EwE: Climate change impacts appear independent of level of fishing mortality and fish size
- SBFW: Magnitude of climate impacts increases with increasing fishing mortality and fish size

References


Discussion

Insights from Model Agreement
- Both models project similar negative trends in response to climate change and climate change in conjunction with fishing
- Lends confidence to our ability to project the broad ecosystem impacts of climate change
- Highlights the need for including these factors in comprehensive and forward-looking approaches to ecosystem-based fisheries management

Insights from Model Disparity
- Differences in the magnitude of interannual variability highlight the limitations of each approach
- EwE vulnerability parameter ultimately controls the relative strength of top-down vs. bottom-up effects, consequently has impacts on propagation of variability
- SBFW primary producer slope and intercept can be sensitive to small relative change in small and large phytoplankton densities, transmitting variability to consumer spectra

We thank Jeff Drazen and members of the Drazen lab for fruitful discussion of an earlier version of this comparison.
We also thank Frank Parrish and Melanie Abeccasis for helpful reviews of our study.
Deb Yamaguchi provided invaluable assistance in preparing and printing this poster.

Acknowledgements

1NOAA Fisheries, Pacific Islands Fisheries Science Center, 2570 Dole Street, Honolulu, HI 96822, USA
2Marine Biology Graduate Program, College of Natural Sciences & School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, HIG 132, 2525 Correa Road, Honolulu, HI 96822, USA
3Department of Plant and Animal Sciences, Alfred Denny Building, University of Sheffield, Western Bank, Sheffield, S10 2TN, UK