Ocean acidification explored using a suite of end-to-end ecosystem models covering ecosystems from the tropics to the arctic

By: Dr. Erik Olsen, Head of Research, Demersal Fish Research Group
Institute of Marine Research, Norway – www.hi.no

@erikjsolsen
Based on a recent paper in Frontiers in Marine Science

Ocean Futures Under Ocean Acidification, Marine Protection, and Changing Fishing Pressures Explored Using a Worldwide Suite of Ecosystem Models

Erik Olsen 1*, Isaac C. Kaplan 2, Cameron Ainsworth 3, Gavin Fay 4, Sarah Gaichas 5, Robert Gamble 6, Raphael Girardin 6, Cecilia H. Eide 7, Thomas F. Ihde 7, Hem Nalini Morzaria-Lung 8,9,10, Kelli F. Johnson 11, Marie Savina-Rolland 12, Howard Townsend 13, Mariska Weiherman 14, Elizabeth A. Fulton 15,16 and Jason S. Link 17
Overview of talk

• Background and rationale for using End-to-end ecosystem models in EBM
• Common scenarios
• The models
• Analyzing the results: guilds and emergent ecological properties
• Ocean Acidification
• Marine Protection
• Fisheries
• Ecosystem responses
• Conclusions
Background

• EBM requires evaluating effects of multiple stressors at once on the entire ecosystem
  • Need trade-off analyses illustrating the ecosystem-wide effects of management actions
• To address global issues we need to understand and compare how stressors and management actions work in different regions to tease out the common as well as unique responses
• Only feasible using modelling approaches
Atlantis end-to-end model framework

- Complex ecosystem model covering everything from energy input to human activities
- Full MSE capability, while taking into account fisheries, climate and environmental variability, and multi-sectoral dynamics
- >26 extant models (more in development)
Common scenarios - 50 years into the future

1. **BASE CASE** (the one all the others were compared to)
   1. Calibrated and published model
   2. Fisheries continue at constant rate

2. Increased **OCEAN ACIDIFICATION**
   1. 0.5% or 1% added mortality per day for calcifying algae, corals, coccolithophores, echinoderms, and mollusks

3. Increased **MARINE PROTECTION**
   1. MPAs were extended from shore to 250m until 10, 25, and 50% of the continental shelf was closed to all fishing

4. Changing **FISHING PRESSURES**
   1. Fishing mortality rates ($F$) on species fished in the base-case scenario were doubled, halved, and eliminated
The eight Atlantis models
Analyzing the results

• Species were aggregated to **Guild Level** – since the biological components (species) differed between the models:
  • Marine Mammals
  • Seabirds
  • Sharks
  • Demersal fish
  • Squid
  • Filter feeders
  • Epibenthos
  • Zooplankton
  • Primary production
  • Infauna

• Emergent ecosystem properties analyzed through indicators:
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Results
Ocean Acidification (1% added mortality per day)
Marine Protection, 50% closures of continental shelf
2X fishing mortality on small pelagic fish
0.5X fishing mortality on demersal fish
Guild level responses to OA over time

Filter Feeder

Dem. Fish

Biomass response

year

Biomass response

year
OA results explained

• Most models showed an overall decline in guild biomass under OA scenarios

• Regime shifts apparent in:
  • Guam
    • Corals and CCA decline massively, but soft corals (& other filter feeders) move in coupled with increase in detrivores. This provides more food for the fish
  • SE Australia
    • Reducing scallops, benthic filter feeders and benthic grazers, but microfauna and detritus increase providing food for red prawns (2000X increase) which in turn provides food for shallow demersal fish that increas 20X
  • NE US
    • Weaker impacts than Fay et al (2017) predicted, because Fay added OA mortality to deposit feeders
Indicators and emergent system properties

(a) Ocean acidification

(b) Marine Protected Area

(c) Double F on small pelagics

(d) Double F on invertebrates

(e) Halve F on demersals
(a) Ocean acidification
Further developments

• Combining the drivers – current analysis looks at each driver separately.
• Adding more drivers (temperature increase, petroleum activities, pollution)
• Sensitivity testing (difficult, but needed)
• Socioeconomic effects of displacing fishing effort (caused by changes in species distribution and MPAs)
Conclusions

• Stronger impacts from ocean acidification and MPAs than fishing
  • Regime shifts happened in Guam and SE Australia
  • Sensitive to what species are defined to be impacted by OA

• Vast majority of impacts are moderate

• Managing at the guild level, taking advantage of greater stability there, merits further consideration

• Removing fishing causes larger impacts than doubling fishing effort

• Clearly illustrate how ecosystem modelling can be used to highlight the most interesting management action among a suite of possible alternatives
Thanks to all my coauthors, and thank you for your attention!

E-mail: eriko@hi.no