Modeling population-scale responses of iconic fisheries to OA

Sarah Cooley, Jennie Rheuban, Dvora Hart, Victoria Luu, David Glover, Jon Hare, Scott Doney

Ocean Acidification Principal Investigators’ Workshop, Woods Hole, MA • June 11, 2015
Real-world context

- Will OA affect my resource?
- When will it happen?
- How bad will it be?
- What can we do about it?
Problem

- Mismatch between global change, marine resource use & management timescales
- Few tools exist to explore both
- Decision-relevant information is lacking
- What to do for specific resources?
2 studies trying to change that

An Integrated Assessment Model for Helping the United States Sea Scallop (*Placopecten magellanicus*) Fishery Plan Ahead for Ocean Acidification and Warming

Sarah R. Cooley¹,²,*, Jennie E. Rheuban², Deborah R. Hart³, Victoria Luu⁴, David M. Glover², Jonathan A. Hare⁵, Scott C. Doney²

PLOS One, 2015

Evaluating the impact of ocean acidification on fishery yields and profits: The example of red king crab in Bristol Bay

André E. Punt¹,*, Dusanka Poljak¹, Michael G. Dalton², Robert J. Foy³

Ecological Modelling, 2014
Sea Scallop Fishery

- One of most valuable single-species, wild-caught fishery in US
- Currently a ~500 million USD industry
- Considered “overfished” in mid-1990s

Data source: NMFS
Sea Scallop Habitat

- Found abundant along the northeastern Atlantic shelf at depths 40 – 100 m
- US fisheries located Mid-Atlantic Bight, Georges Bank, and Gulf of Maine
- Tolerate water temperatures ~ 6 – 18 °C

Hart and Chute 2004
Sea Scallop Management Success

Managed through regulations on:
- Limited access fishery
- Fishing location
- Effort allocated by vessel
- Minimum gear size – 4in. ring (~90 mm scallop)
- Crew size limited to 7

Limited Access fishery and area closures

Rotational management

Restrict gear from 3.5” to 4”

Data source: NMFS 50th SAW 2010
Integrated Assessment Model

Two-box biogeochemical model, driven by seasonal thermal stratification

Biogeochemical Model

Ambient conditions

Emissions

Environmental quality

Fishery management

Harvest quantities/Revenue

Sea Scallop Model

Population dynamics from NOAA NMFS management models

Economic Model

Economic decisionmaking and relationships from NOAA NMFS Economics data
IAM with full detail

Scallop submodel

Biogeochemical submodel

Socio-economic submodel

\( \Delta t = 0.1 \) year

Cooley et al. 2015. PLOS One
OA’s effect on sea scallops

Likely growth/survival impacts, based on other species studied
OA’s effect on sea scallops

- OA affects scallop growth in deep water
- T affects scallop growth in deep water
- OA affects recruitment in surface

Meta-analysis of bivalve growth response

\[ \Delta G = 1.272\Delta\Omega + 0.075 \]

\[ r^2 = 0.557 \quad p < 0.0001 \]

8 species, 6 studies

Cooley et al. 2015. PLOS One
Modeled CO$_2$ chemistry

Surface pCO$_2$

Deep pCO$_2$

Cooley et al. 2015. PLOS One
Landings

Not significantly different

Cooley et al. 2015. PLOS One
Socioeconomic Data

A. Revenues

B. Landings

Cooley et al. 2015. PLOS One
Cooley et al. 2015. PLOS One

Deep pH

Biomass

Revenue

Deep Ω

Landings

% U10
Red King Crab in Bristol Bay

~$115M/yr first wholesale value
8.5M lb/yr finished products

Red King Crab in Bristol Bay

- Juvenile % survival data at pH 8.0, 7.8, 7.5 from experiments
- Recruitment changes into stage-structured population model linked to bioeconomic model
Bioeconomic models for OA

- Potential for integrating short, long term influences
- High-yield single species fisheries
  - Lots of data, lots of $, cultural importance
- Sticking point: how to link OA (and other drivers) and population-scale processes.
  - So far: growth, juvenile survival.
  - Yet to come: Fecundity? Multiple stressors?