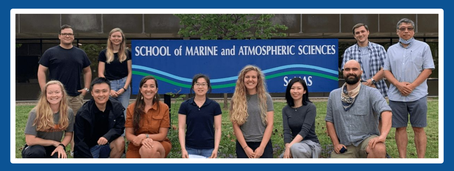
Developing Modelling Capacity for Understanding Population Dynamics and Habitat Interactions for Commercial Fisheries in a Changing Gulf of Maine



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Introduction

Climate change, exploitation, and ecosystem shifts are causing uncertainty with current and future status of Gulf of Maine (GOM) species. To combat this, the Chen Lab develops modelling tools to quantify and project spatiotemporal dynamics of habitat and abundance distributions of these stocks. Here we highlight current research.

American Lobster

Through the use of an individual-based simulator, a delta-GLMM framework (VAST), a length-structured stock assessment model, and a habitat suitability model, hypothesized climate effects and subsequent fishery impacts are being projected.

Figure 1. Lobster habitat suitability in the GOM today (left), where red areas represent high suitability and blue represent low suitability and changes to this suitability over the next 80 years (right), where red represents increases in suitability and blue represents decreases.

Lobster habitat will continue to decline in the GOM, but appear to exhibit spatial nonstationarity and changes to growth and size-at-maturity may alter population biomass. These changes may shift the timing of the fishery to occur earlier in the season.

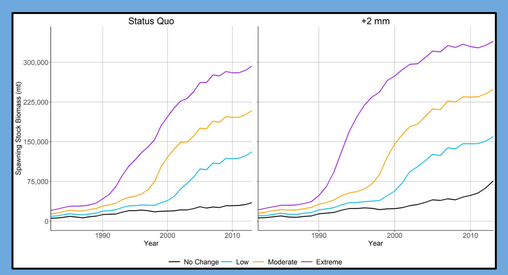

Figure 2. Simulated spawning stock biomass under low (blue), moderate (orange), and extreme (purple) changes to maturity and growth, for both status quo and a +2 mm minimum legal size alternative.

Right Whales

Federal Right Whale risk reduction rules have increased the minimum trawl lengths for lobster fisheries in the GOM. We modeled the change to loads on vertical lines used across the GOM. The new rules may limit the capacity of lobster fishers to operate safely and incur adaptation costs.

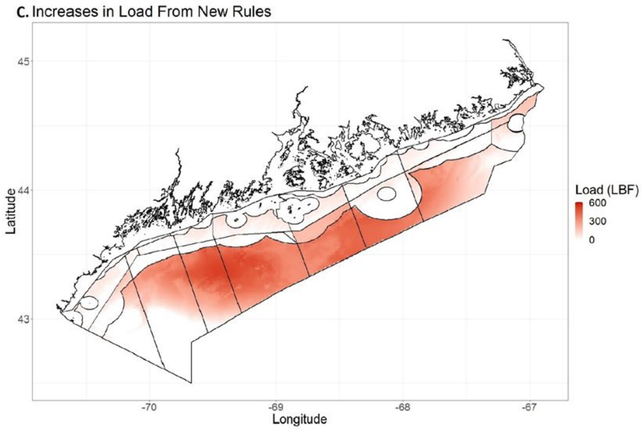

Figure 3. The increases in load on vertical lines from a base case scenario for lobster fishers in the GOM under new federal trawl minimum rules (in foot-pounds).

Atlantic Sea Scallops

Figure 4. An Atlantic sea scallop shell with the first three visible rings marked showing the size of the organism when it was that old.

Table 1. Asymptotic maximum size (L_∞) in millimeters (mm) and the brody growth coefficient (k) in 1/year for each of three geographic regions.

Area	L_∞ (mm)	k (1/year)
Northern Gulf of Maine	154	0.457
Georges' Bank	144	0.427
Mid-Atlantic Bight	133	0.508

We develop models to estimate individualistic growth rates for Atlantic sea scallops. We compare these models across regions and times, and infer environmental influences. Scallops in the GOM appear to grow larger than those on Georges' Bank or the Mid-Atlantic Bight, but at similar rates. Future research will look at fine-scale environmental effects.

Northern Shrimp

We developed statistical regression models and spatial indicator metrics to examine hypotheses of environmental effects on northern shrimp reproduction and distribution. Decreased habitat suitability and high predator pressure appear to have exacerbated collapse of shrimp.

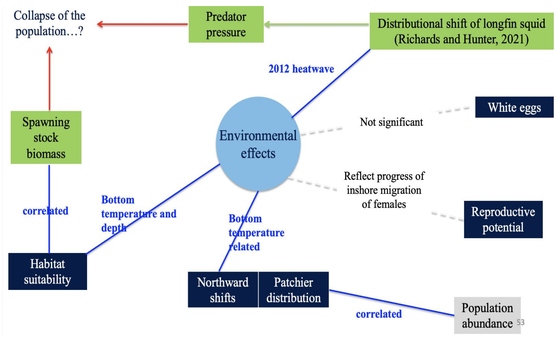

Figure 5. Hypotheses tested in this study. The graph shows statistically significant and nonsignificant effects on the response variable. Blue solid lines denote significant, gray dashed lines denote nonsignificant, green and red solid lines are inferences.

Atlantic Cod

The current management unit for Atlantic cod in the GOM is likely to have two separate biological units, the eastern GOM (EGOM) and western GOM (WGOM). When applying a Habitat Suitability Index (HSI) model to the GOM management unit, unique spatial trends in habitat suitability between the two biological areas are lost, often aligning only with WGOM preferences, due to greater federal survey coverage, and overlooking those distinctive to the EGOM.

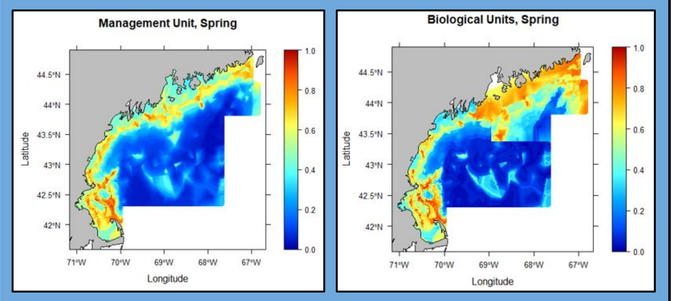

Figure 6. Mean Habitat Suitability Indices (HSIs) for cod caught on the NEFSC Bottom Trawl Survey in the spring from 2000-2017 when modeled over the GOM management unit and the WGOM and EGOM biological units.

Relevant Manuscripts

Behan, J., Hodgdon, C.T., and Chen, Y. *Submitted*. Scale-Dependent Assumptions Influence Habitat Suitability Estimates for the American Lobster (*Homarus americanus*): Implications for a Changing Gulf of Maine.

Behan, J., Li, B., and Chen, Y. 2021. Examining Scale Dependent Environmental Effects on American Lobster (Homarus americanus) Spatial Distribution in a Changing Gulf of Maine. Frontiers in Marine Science. DOI: 10.3389/fmars.2021.680541.

Chang, H.-Y., R. A. Richards, and Y. Chen. 2021. Effects of environmental factors on reproductive potential of the Gulf of Maine northern shrimp (Pandalus borealis). Global Ecology and Conservation. 30(7): e01774. DOI: 10.1016/j.gecco.2021.e01774.

Chang, H.-Y., R. Klose, and Y. Chen. 2020. Possible climate-induced environmental impacts on parasite-infection rates of northern shrimp *Pandalus borealis* eggs in the Gulf of Maine. Dis. Aquat. Organ. 140, 109-118. doi: 10.3354/dao03495.

Chang, H.-Y., and Y. Chen. 2020. Evaluating sampling strategies for collecting size-based fish fecundity data: an example of Gulf of Maine northern shrimp *Pandalus borealis*. J. Northw. Atl. Fish. Sci. 51, 33–43. doi: 10.2960/J.v51.m730.

Hodgdon, C.T., Shank, B., and Chen, Y. *In Prep*. Developing a Framework to Calculate Dynamic Reference Points using a Thermally Explicit Spawning Stock Biomass / Recruitment Relationship.

Hodgdon, C.T., Khalsa, N., and Chen, Y. *In Prep*. Implications of Climate Driven Changes on Growth and Size-at-Maturity for Size Structured Stock Assessments.

Hodgdon, C.T., Mazur, M., Friedland, K., Willse, N., and Chen, Y. *Accepted*. Consequences of False Assumptions when Projecting Habitat Suitability: A Caution of Forecasting under Uncertainties. ICES Journal of Marine Science. 78(6): 2092-2101. https://doi.org/10.1093/icesjms/fsab101.

Hodgdon CT, Tanaka K, Cao J, Runnebaum J, Chen Y. 2020. A framework to incorporate environmental effects into stock assessments informed by shery-independent surveys: a case study with American lobster (*Homarus americanus*). Canadian Journal of Fisheries and Aquatic Sciences. 77(10): 1700-1710. https://doi.org/10.1139/cjfas-2020-0076.

Hodgdon, C.T, Torre, M., and Chen, Y. 2020. Spatiotemporal variability in Atlantic sea scallop (*Placopecten magellanicus*) growth in the Northern Gulf of Maine. J. Northw. Atl. Fish. Sci. 51: 15-31. 10.2960/J.v51.m729.

Khalsa, N., Hodgdon, C.T., Mazur, M., and Chen, Y. *In Prep*. Climate-Driven Shifts in Maturity and Growth Induce Dramatic Changes to Population and Fishery Dynamics of a High-Value Crustacean.

Kim, J., Hodgdon, C.T., Chen, Y., and Evans, K. *In Prep*. Understanding Impacts of Climate Induced Distributional Change of Fishery Landings in the Maine Lobster Fishery.

Linner, R. M and Chen, Y. *In Prep*. Implications of Stock Structure in Understanding Juvenile Atlantic Cod (*Gadus morhua*) Habitat Suitability in the Gulf of Maine.

Willse, N., Summers, E., and Chen, Y. *Submitted*. Analysis of Gear Requirements for the Fixed Gear Lobster Fishery in the Gulf of Maine, With Potential Risk Reduction Benefits for the North Atlantic Right Whale.

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