Ecosystem Modeling for Gulf Menhaden Management

David Chagaris[1], Skyler Sagarese[2], Kim de Mutsert[3], Matt Lauretta[2], Igal Beherenstein[2]

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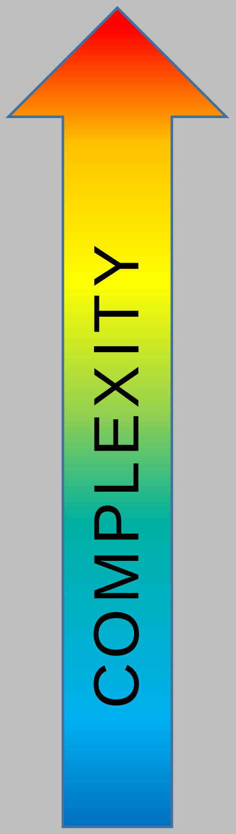
Gulf of Mexico Ecosystem Models

At least 45 ecosystem models developed over the last 35 years



- Bio-geo-chemical based ecosystem models (Atlantis)
- Aggregated or whole ecosystem models (EwE)
- Coupled and hybrid model platforms (OSMOSE)
- Dynamic multi-species models
- Single-species extensions
- Conceptual and qualitative models

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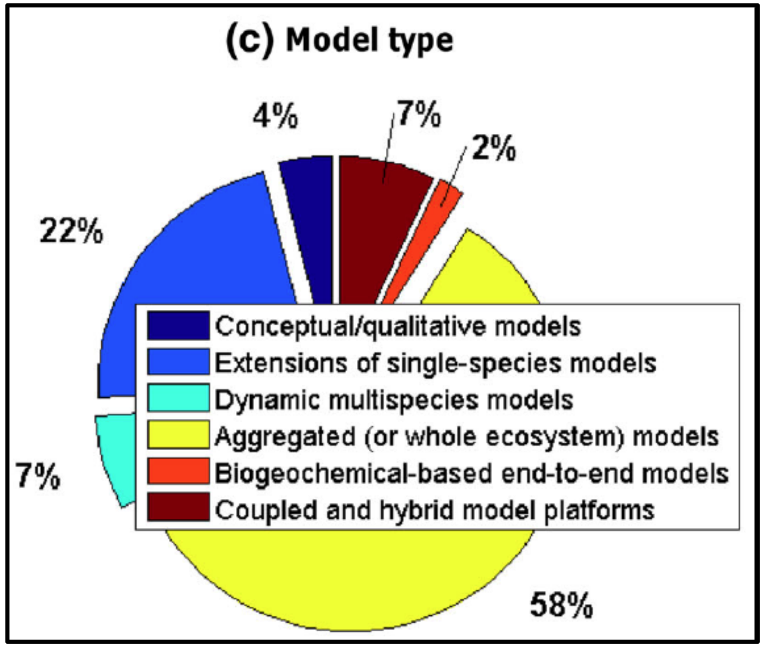
CrossMark

REVIEWS

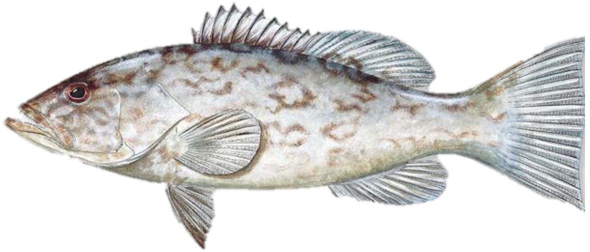
Ecosystem modeling in the Gulf of Mexico: current status and future needs to address ecosystem-based fisheries management and restoration activities

Halie O'Farrell · Arnaud Grüss · Skyler R. Sagarese · Elizabeth A. Babcock · Kenneth A. Rose

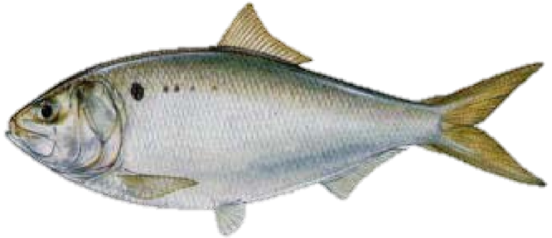


Ecosystem Modeling for Fisheries Management in the Gulf of Mexico

- 3 year project funded by NOAA RESTORE Round 2, decision-support tool priority
- Update and adapt multiple ecosystem models for the Gulf of Mexico
- Goal: Integrate information on ecosystem stressors and predator-prey interactions into the assessment and management of fisheries in the Gulf of Mexico



Gag Grouper
Mycteroperca microlepis



Gulf Menhaden
Brevoortia Patronus

NOAA RESTORE SCIENCE PROGRAM

NATURE COAST BIOLOGICAL STATION | UF IFAS UNIVERSITY of FLORIDA

NOAA Southeast Fisheries Science Center
NATIONAL MARINE FISHERIES SERVICE

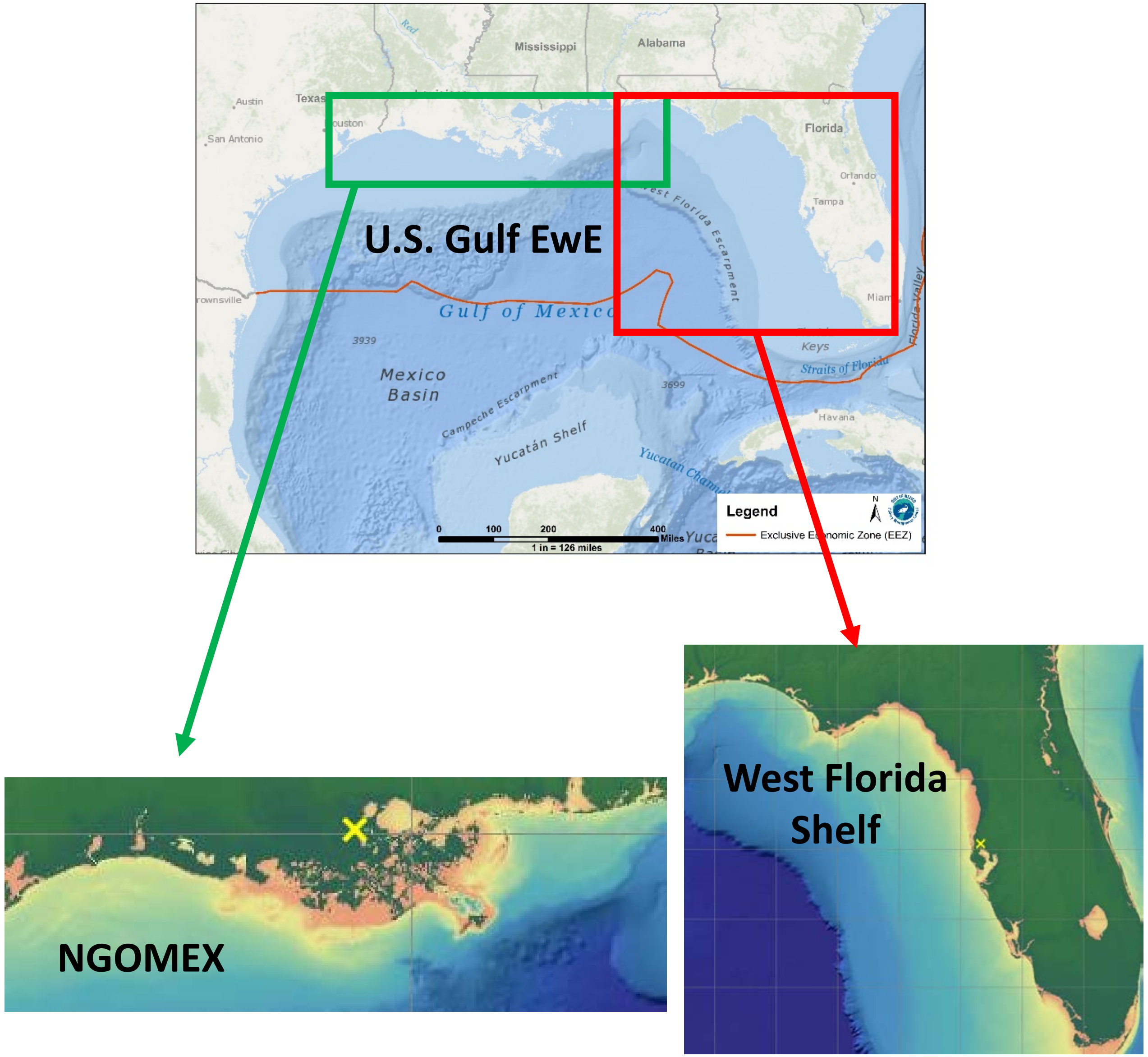
GEORGE MASON UNIVERSITY | ENVIRONMENTAL SCIENCE AND POLICY

Ecosystem Model Updates

Re-designed to meet needs
for fisheries management

1. West Florida Shelf EwE (UF)
2. U.S. Gulf EwE (NOAA SEFSC)
3. NGOMEX (GMU)

- Updates include:
  - Additional functional groups
  - New and updated datasets
  - Model recalibration
  - Ecospace spatial-dynamic
  - New Ecospace functionality



Ecopath with Ecosim

www.ecopath.org

No fish is an island

Ecopath

- Mass-balanced snapshot of the food web
- Inputs: biomass, mortality, consumption rates, diet composition, fishery catches
- Outputs: ecosystem indicators, network analysis, trophic levels, transfer efficiencies, etc.

Ecosim

- Time dynamic simulator of ecosystem and predator prey abundances
- Foraging arena theory
- Calibrated to time series
- Flexible simulation tool
- Modules:
  - Batch runs
  - MSE
  - Policy optimization
  - Equilibrium analysis (MSY)

Ecospace

- Spatial dynamic model
- Additional inputs: movement rates, habitat preferences, fishing effort, environmental forcing
- Spatially-explicit harvest policies and environmental forcing

U.S. Gulf of Mexico EwE

Skyler Sagarese & Matt Lauretta, SEFSC

- U.S. Gulf of Mexico waters, continental shelf out to 400 m
- 78 functional groups, 16 fleets
  - Focus on federally managed & HMS species
  - Integrate dynamics from stock assessments
- Attempts to alleviate concerns of previous “Gulf” models
  - More representative of entire Gulf
  - Improved data inputs - diet matrix, discards
  - Calibrated to appropriate time series

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Progress towards a next-generation fisheries ecosystem model for the northern Gulf of Mexico

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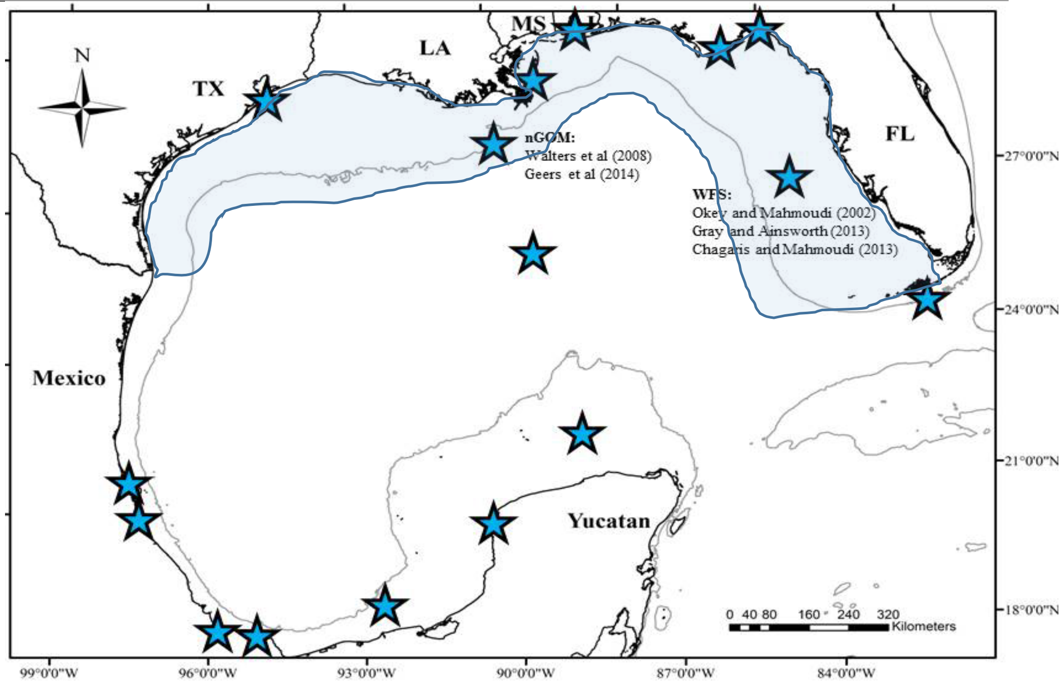


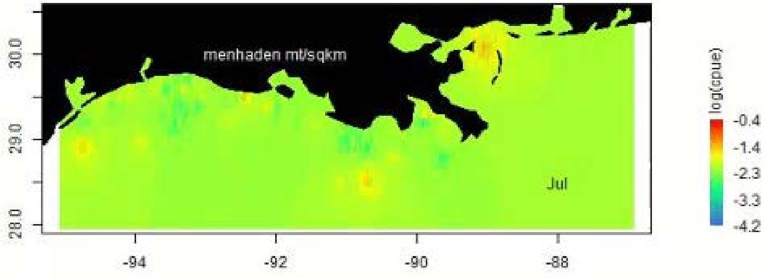
NGOMEX EwE Model

Kim de Mutsert, George Mason University

- Primarily supported by NCCOS Northern Gulf of Mexico Ecosystems & Hypoxia Assessment
  - Designed to study hypoxia effects
- Adapted to inform menhaden management
  - Supported by NOAA RESTORE
  - Included Menhaden ages 0-3+
- Focus on spatial dynamics
  - Links to ROMS model
  - Uses output from coupled physical-biological model to get DO and Chl-a drivers

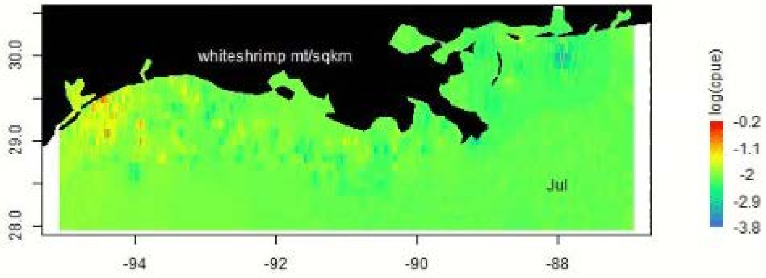
Visualizations

The gif below shows monthly distribution of Gulf menhaden biomass in log of metric tonnes per square kilometer from the SEAMAP data set for 2000-2016. Spatial interpolation was performed in R using kriging. Not all months were sampled on a consistent basis.



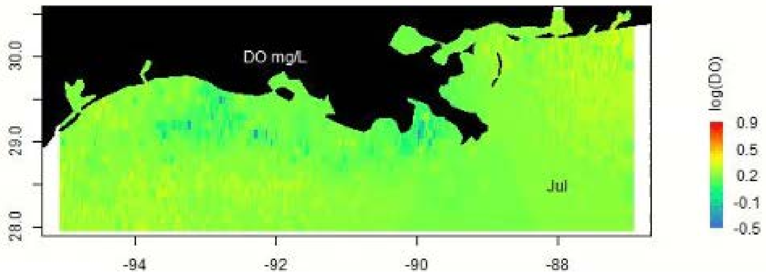
Menhaden biomass

This gif shows Gulf of Mexico white shrimp biomass from the SEAMAP data set for 2000-2016. Not all months were sampled on a consistent basis.



White shrimp biomass

The below gif shows bottom dissolved oxygen (mg/L) from SEAMAP stations from 2000-2016.



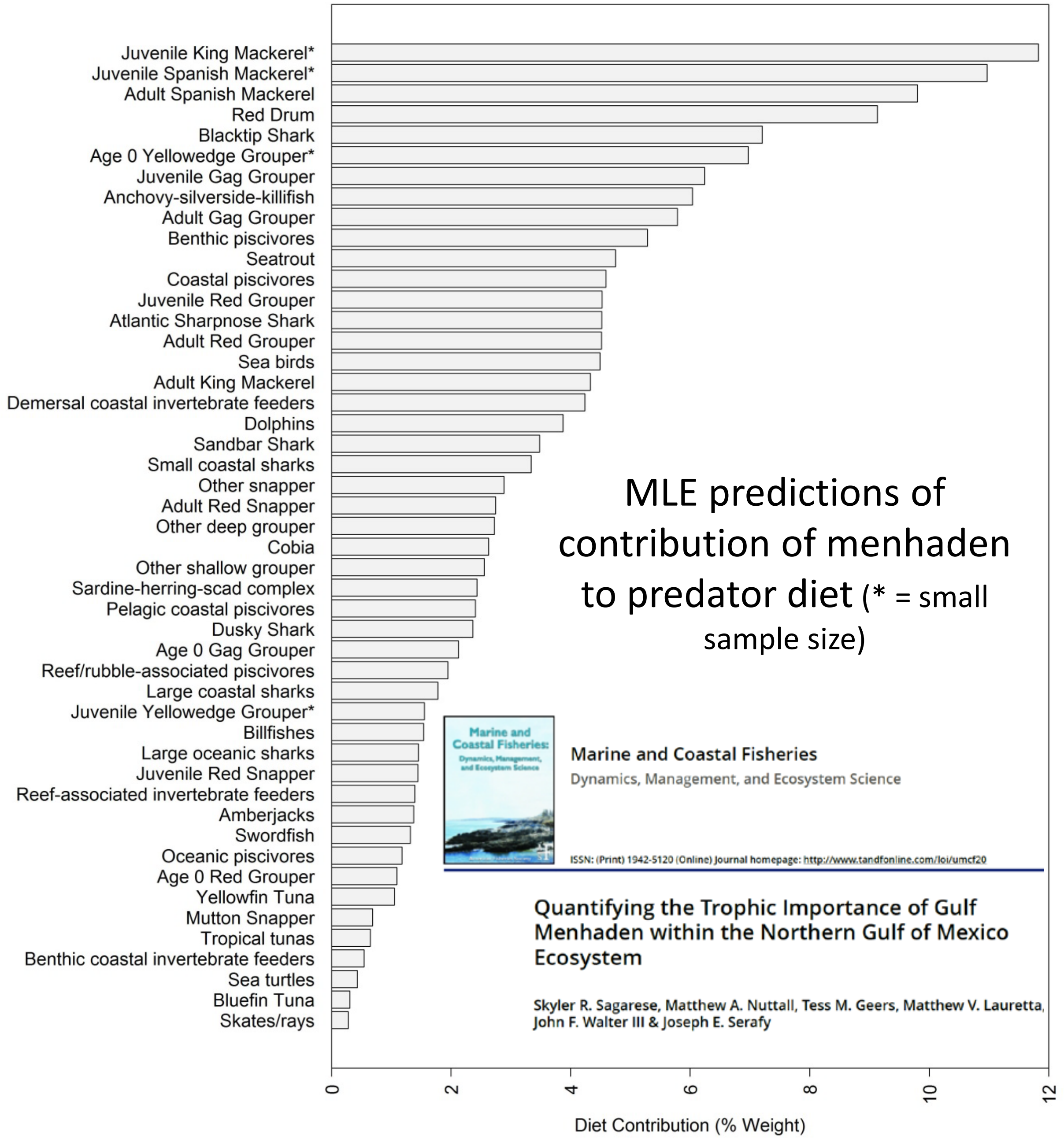
Dissolved Oxygen

https://demutsertlab.wordpress.com/ngomex/

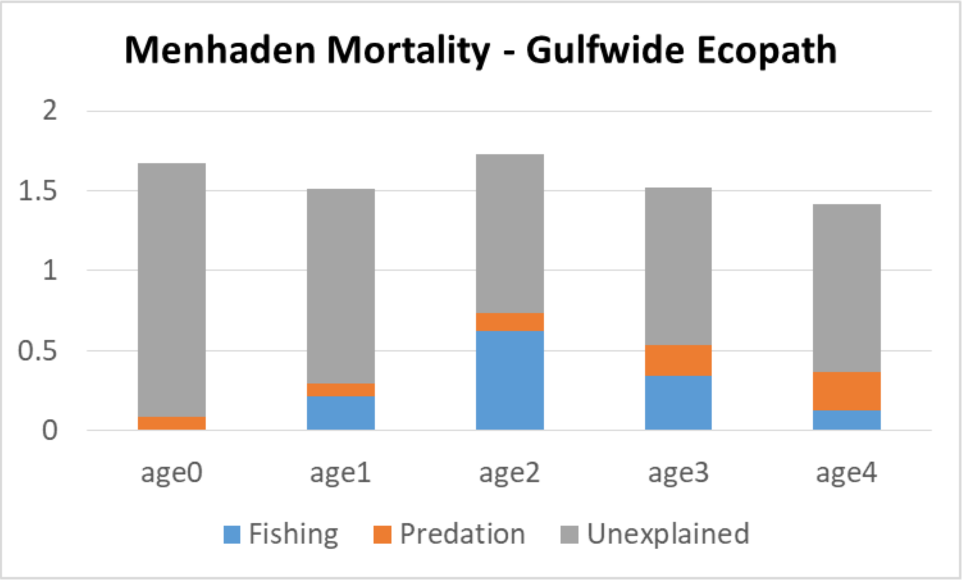
Identification of Important Gulf Menhaden Predators

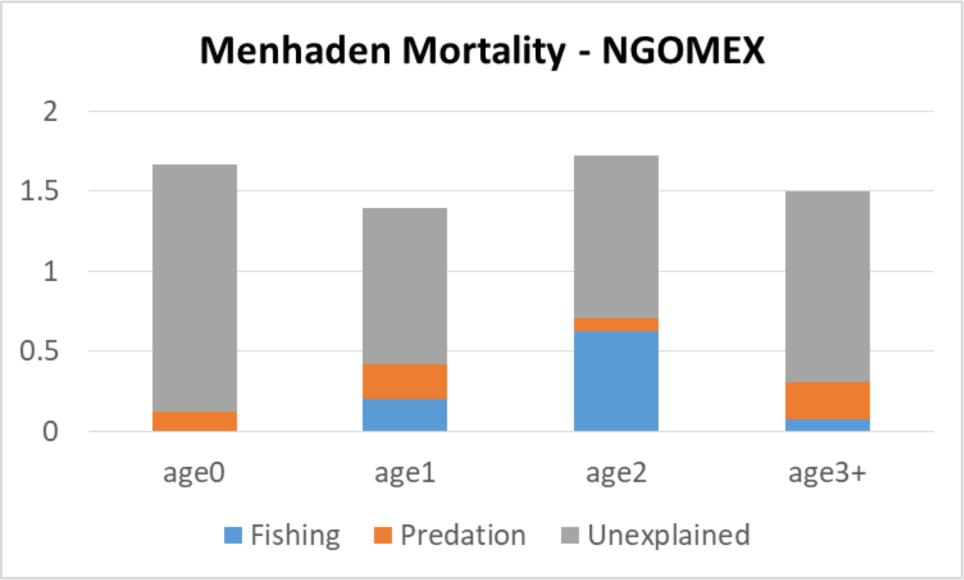
- Considered diet data and bycatch
- Identified 17 Likely Predators
  - Dolphins, birds, 6+ shark species, cobia, 2 mackerels, red drum, sea trout, other inshore and coastal piscivores
- 14 less likely predators
- Fish prey not always identified to species

Prey item	% of studies
UNID clupeid	38
Brevoortia sp.	29
Brevoortia patronus	20
Brevoortia tyrannus	13



Menhaden Mortality Components in Ecopath

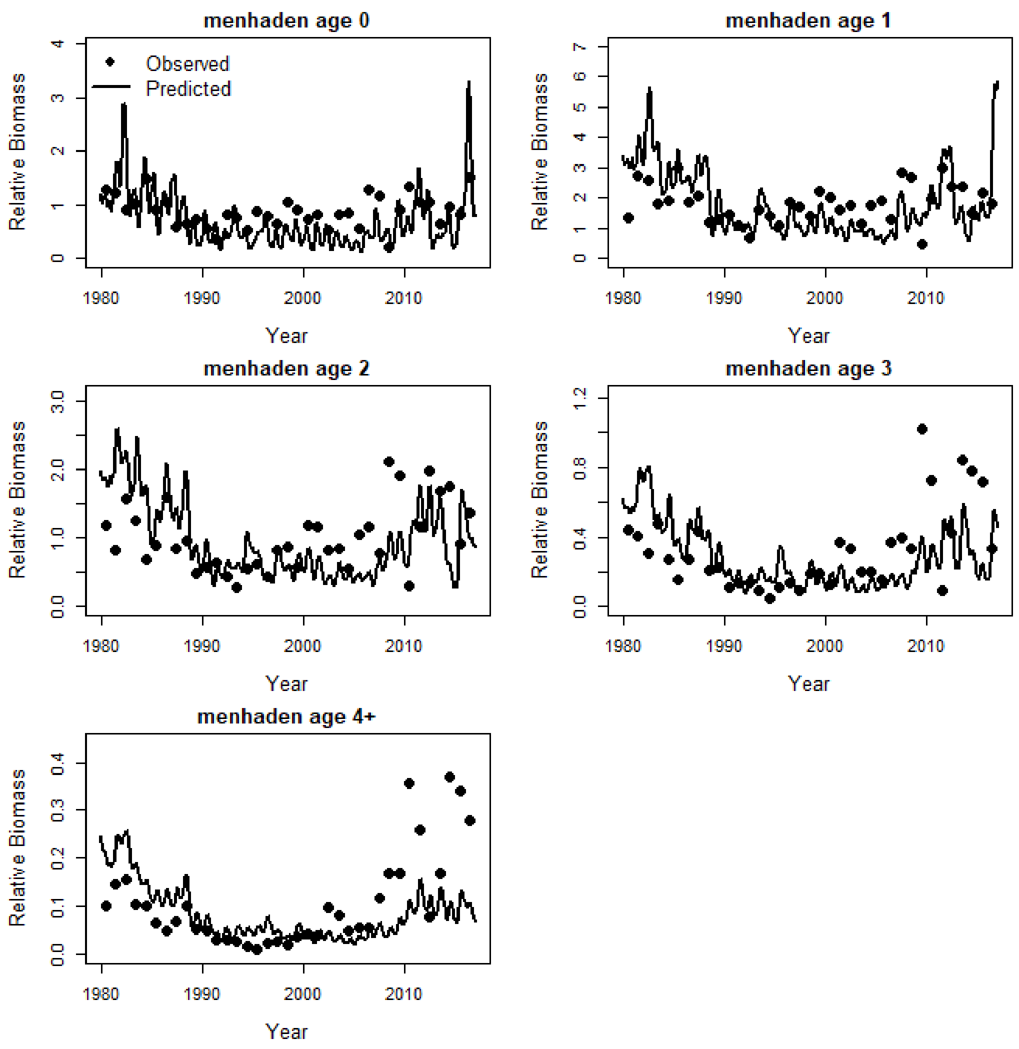


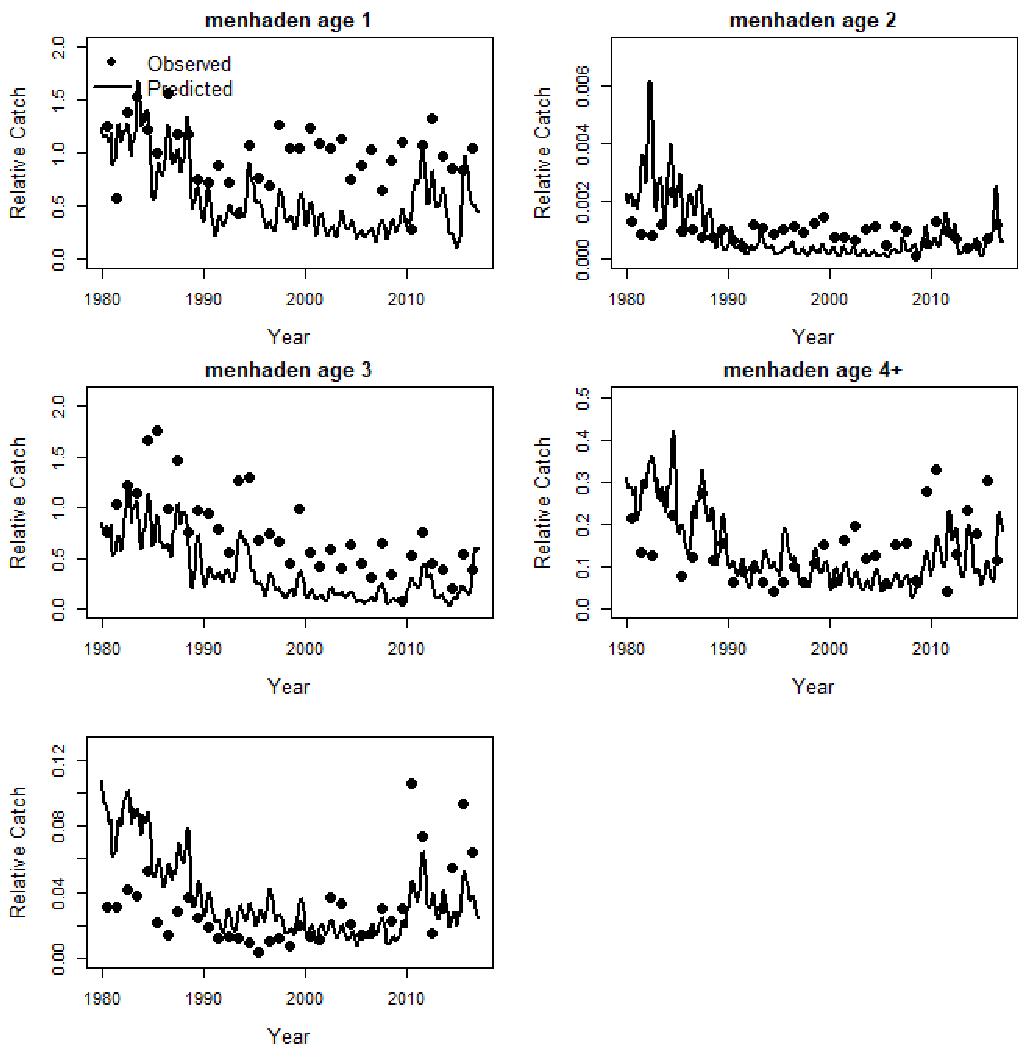


$$M2_i = \frac{\sum B_j QB_j DC_{ij}}{B_i}$$

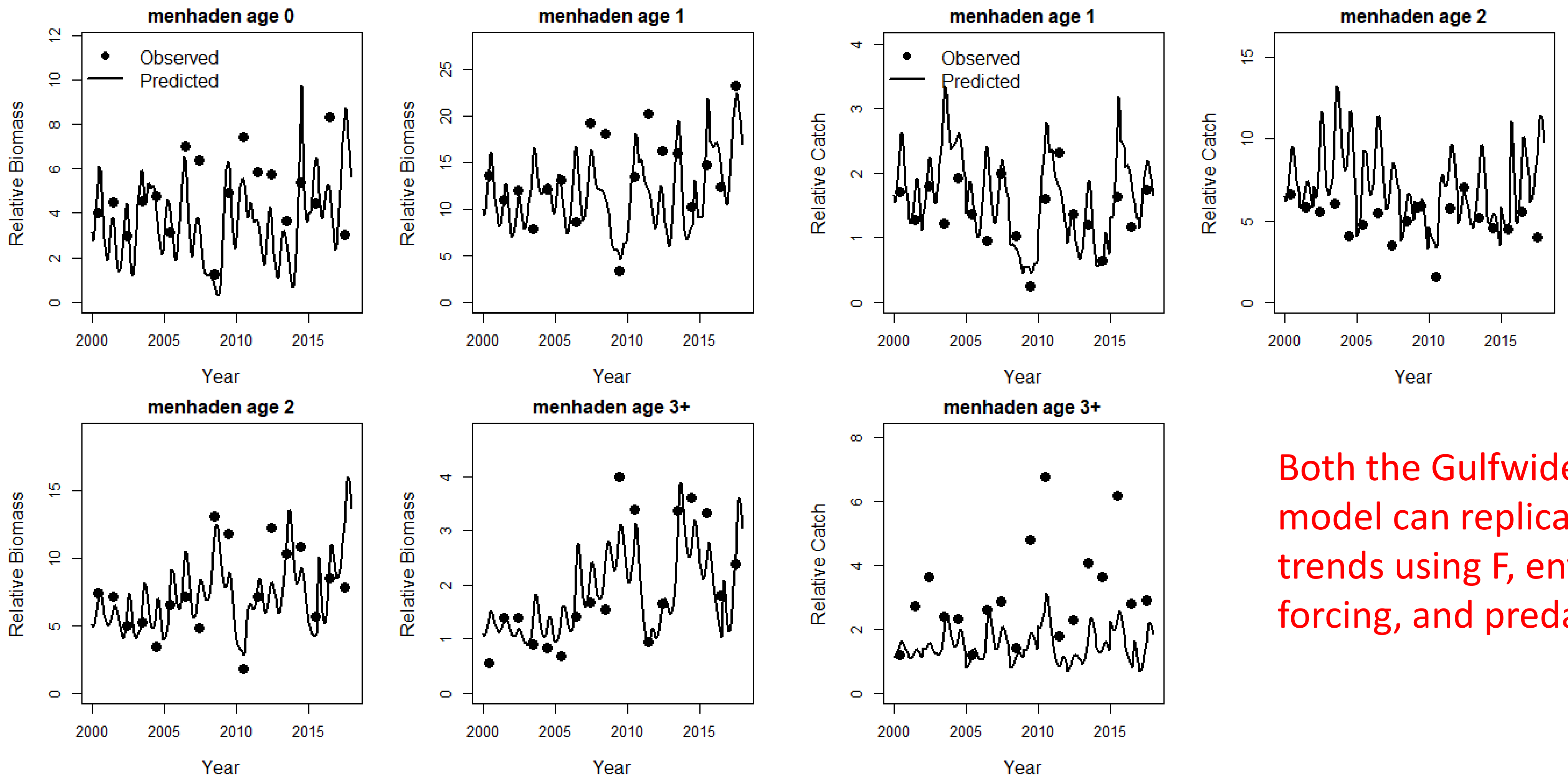
- Modeled predation only accounts for a small percentage of total mortality
- Most likely due to incomplete sampling of predator diets (birds, sharks, migratory pelagics)

U.S. Gulf Ecosim – Preliminary Model Fits



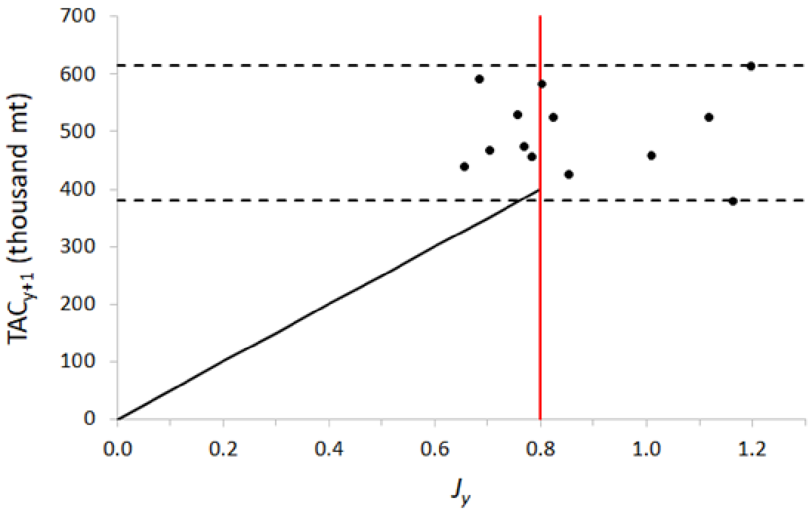


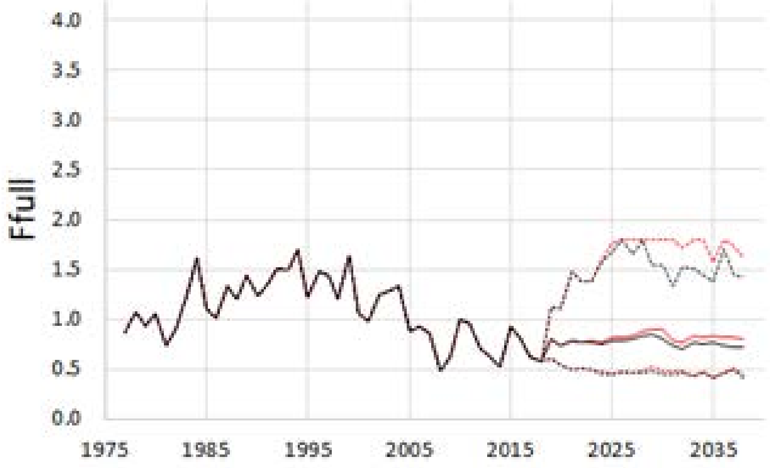
NGOMEX Ecosim – Preliminary Model Fits



Both the Gulfwide and NGOMEX model can replicate menhaden trends using F, environmental forcing, and predation

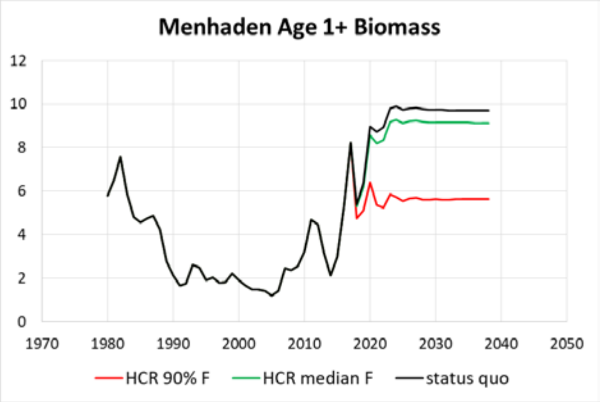
Ecosystem Sensitivities to Harvest Control Rule

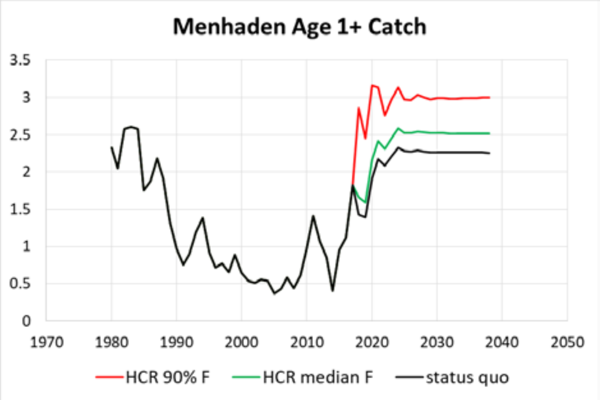


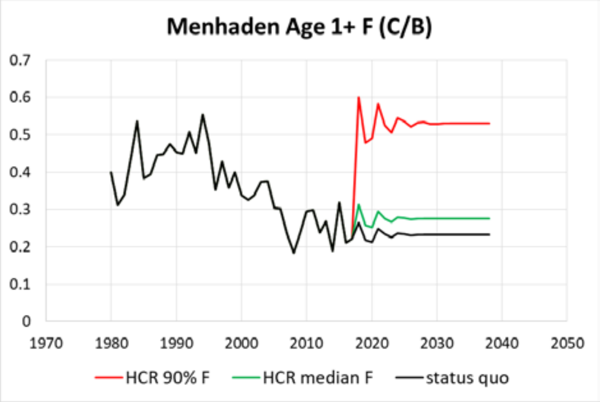


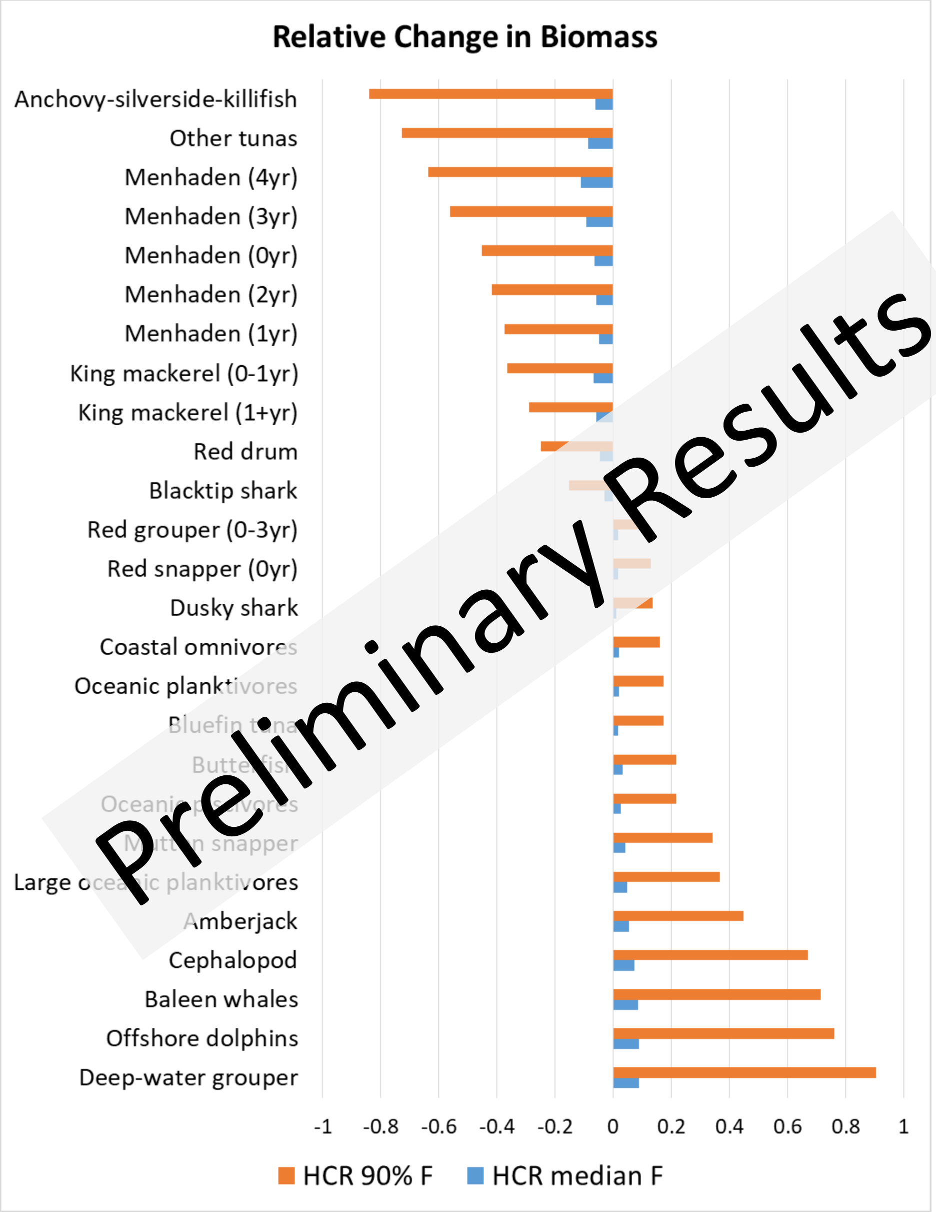
- Apply F rates from HCR in Ecosim to identify sensitive predators and quantify potential impacts
  - BAM 2017 F_{full} = 0.63
  - Median HCR F_{full} ≈ 0.75
  - Up. 90^{th} % HCR F_{full} ≈ 1.5
- Ratio approach, to modify F for all ages in Ecosim

Ecosystem Sensitivities to Harvest Control Rule





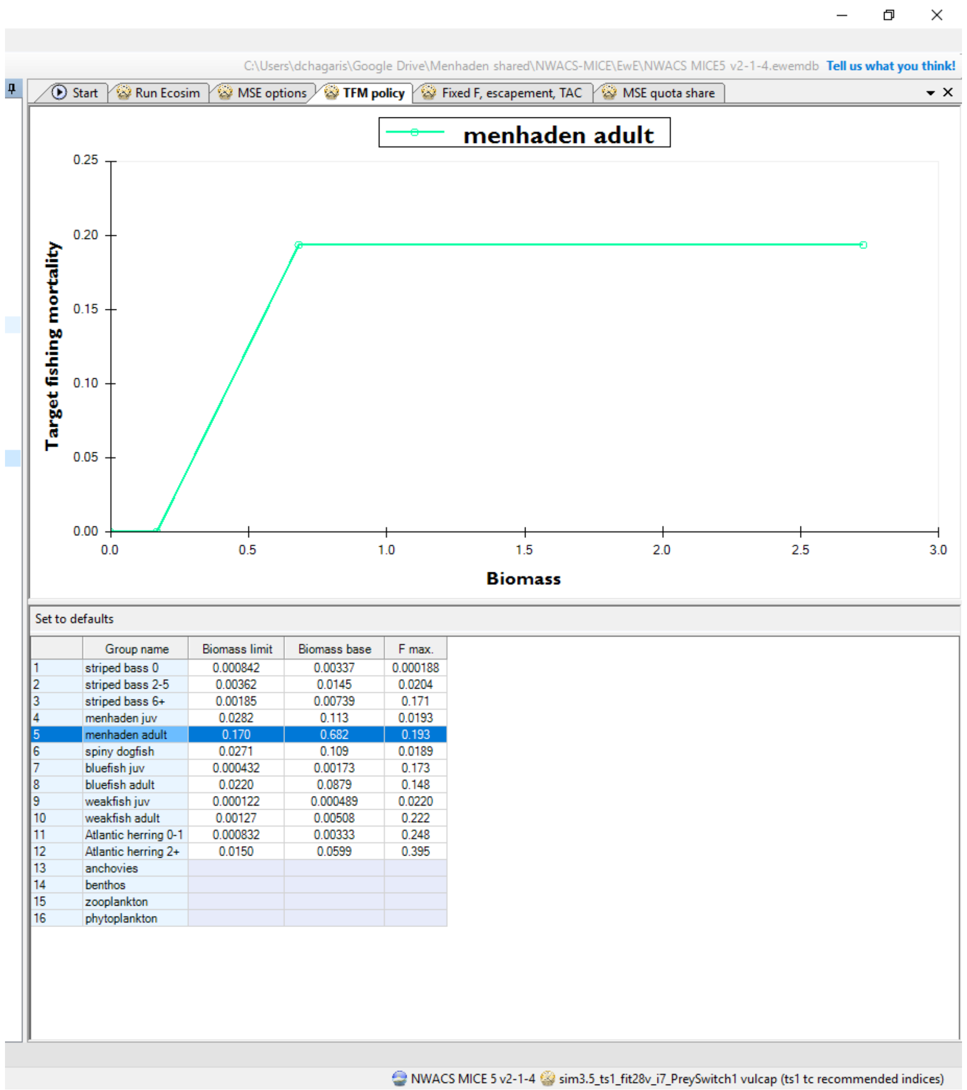




- Median F value from HCR does not cause major changes in food web
- Upper 90%ile from HCR resulted in negative and positive effects on the food web
- Most sensitive predators are tunas, mackerels, red drum, blacktip shark
- Indirect effects cause some groups to increase
- MORE DIAGNOSTICS NEEDED, THIS IS ONLY AN EXAMPLE!

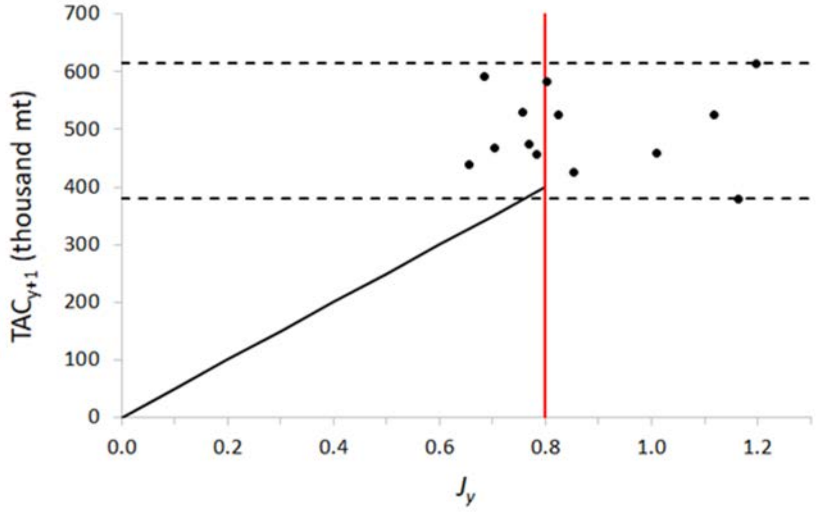
Ecosim Management Strategy Evaluation

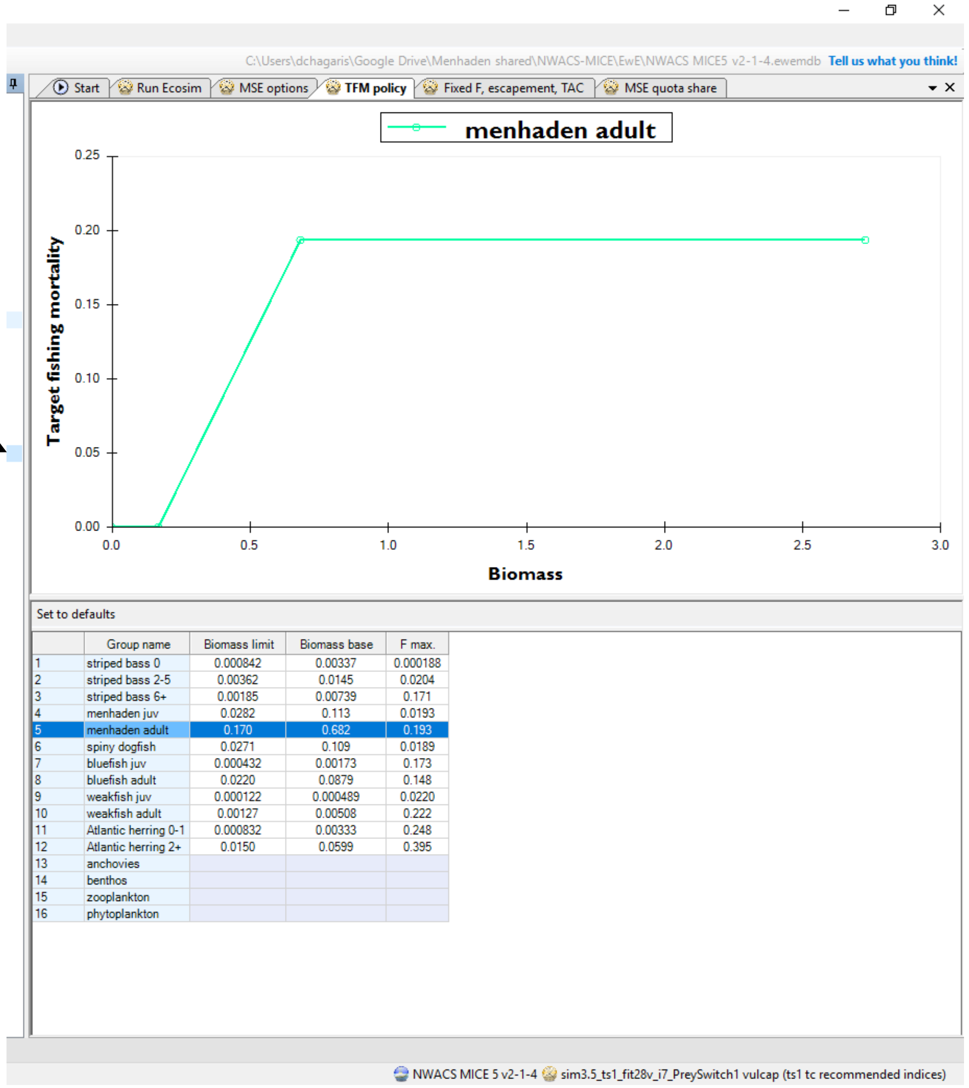
- Ecosim is the operating model
- Evaluate harvest control rules
  - Hockey-stick with B_{lim}, B_{max}, F_{max}
  - Fixed exploitation rate or TAC
  - Implements input (effort) or output (quotas) controls
- Simplified assessment model
- Options to account for
  - survey vs. population proportionality
  - Recruitment variability
  - catchability creep
- Ecosystem impacts of harvest control rule
- Multi-attribute HCR – i.e. HCR is applied based on other criteria



	Group name	Biomass limit	Biomass base	F max.
1	striped bass 0	0.000842	0.00337	0.000188
2	striped bass 2-5	0.00362	0.0145	0.0204
3	striped bass 6+	0.00185	0.00739	0.171
4	menhaden juv	0.0282	0.113	0.0193
5	menhaden adult	0.170	0.682	0.193
6	spiny dogfish	0.0271	0.109	0.0189
7	bluefish juv	0.000432	0.00173	0.173
8	bluefish adult	0.0220	0.0879	0.148
9	weakfish juv	0.000122	0.000489	0.0220
10	weakfish adult	0.00127	0.00508	0.222
11	Atlantic herring 0-1	0.000832	0.00333	0.248
12	Atlantic herring 2+	0.0150	0.0599	0.395
13	anchovies			
14	benthos			
15	zooplankton			
16	phytoplankton			

Ecosim Management Strategy Evaluation





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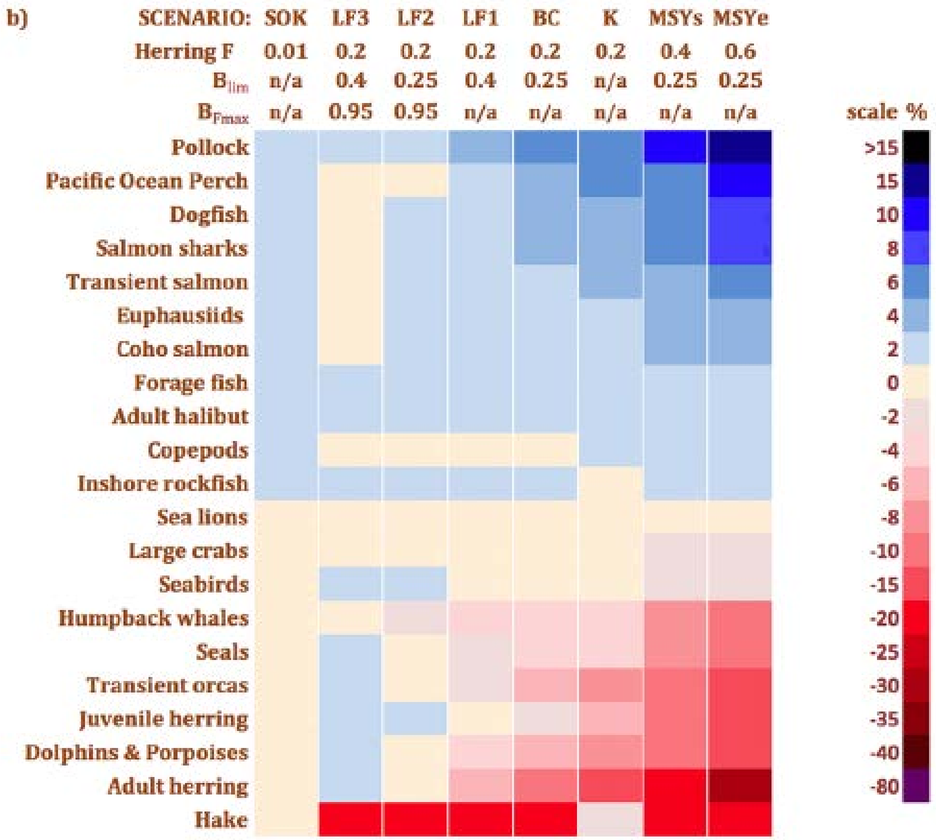
11	Atlantic herring 0-1	0.000832	0.00333	0.248
12	Atlantic herring 2+	0.0150	0.0599	0.395
13	anchovies			
14	benthos			
15	zooplankton			
16	phytoplankton			

- Convert rule to EwE units of biomass and TAC
- Similar to a fixed exploitation rate HCR

Ecosim MSE for Forage Fisheries – Pacific Sardine Case Study

- Evaluated 17 different MSEs
  - Alternative B_{lim}, B_{target}, and F_{target} values
  - 2 primary production scenarios (climate or oceanographic regime shifts)
- Performance Metrics
  - Herring and predator biomass
  - Probability of fishery closure and stock collapse
  - Catch trophic level, biodiversity
- Conclusions
  - Low F_{target}, high B_{lim} and hockey-stick HCRs performed best for precautionary EBFM objectives

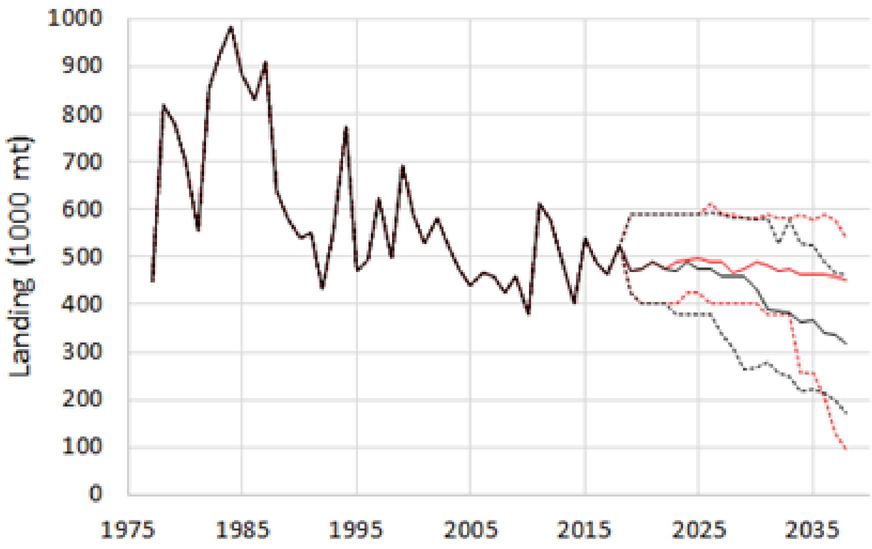


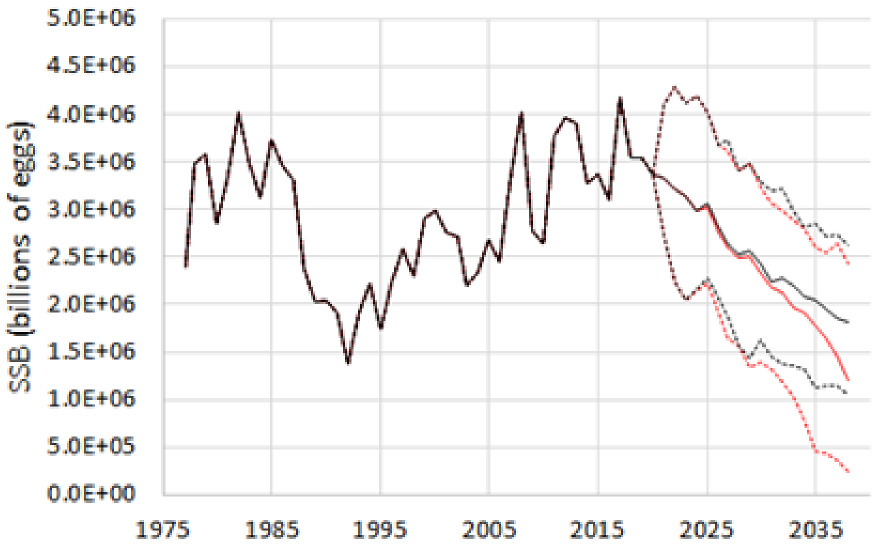
Surma S, Pitcher TJ, Kumar R, Varkey D, Pakhomov EA, Lam ME (2018) Herring supports Northeast Pacific predators and fisheries: Insights from ecosystem modelling and management strategy evaluation. PLoS ONE 13(7): e0196307. https://doi.org/10.1371/journal.pone.0196307

Plausible Changes in Predation Mortality

- MSE Robustness Tests 1.4 and 1.5 assume M increases linearly by 40% and 20% over next 20 years
- What is the most appropriate assumption?
- Project Ecosim model forward at menhaden Fcurrent with other groups' F reduced by half

Rob 1.5





Next Steps

- Further diagnostics needed for both the Gulfwide and NGOMEX models
- Obtain output from MSE for a more formal application with Ecosim
- Set up harvest control rule in Ecosim
- Requests from the GMAC?
- Provide update at Spring GSMFC Annual meeting