Ecosystem modeling for fisheries management in the Gulf of Mexico

David Chagaris, Skyler Sagarese, Matt Lauretta,
Kim de Mutsert, Rob Ahrens

Gulf of Mexico Fishery Management Council SSC meeting
March 13, 2019
Tampa, FL

Objectives and Outline

Objectives

1. Provide an update on current modeling efforts
2. Demonstrate potential utilities of ecosystem models
3. Receive feedback from SSC on future directions

Outline

1. Background on recent EBFM activities
2. Overview of NOAA RESTORE ecosystem modeling project
3. Ecosystem model applications
4. Discussion

Ecosystem models as a research and management tool

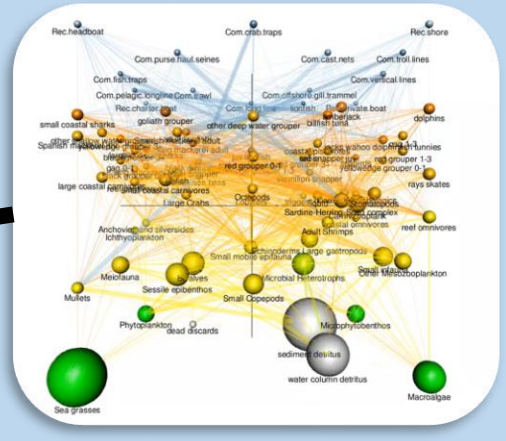
Stock assessment

Regulation development

Stakeholder input

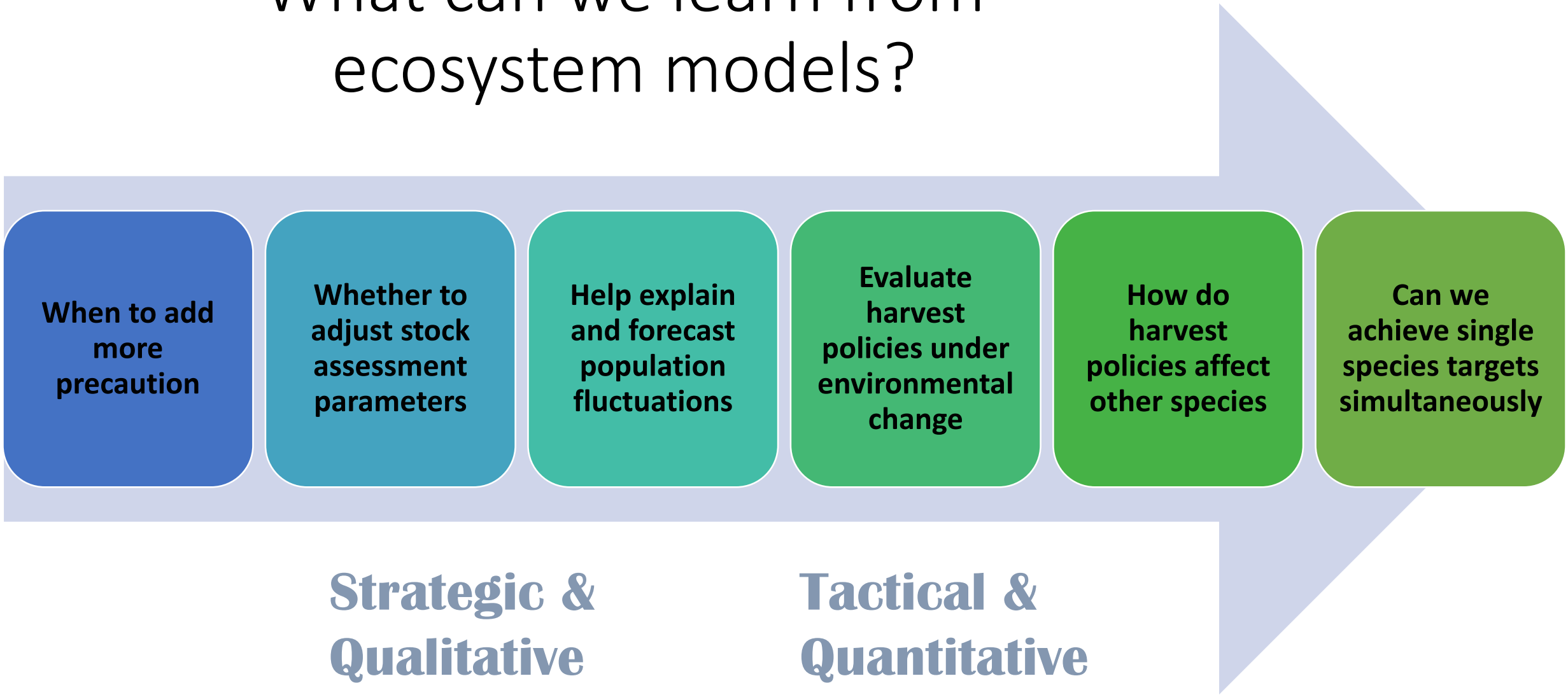
Data collection

Management Action

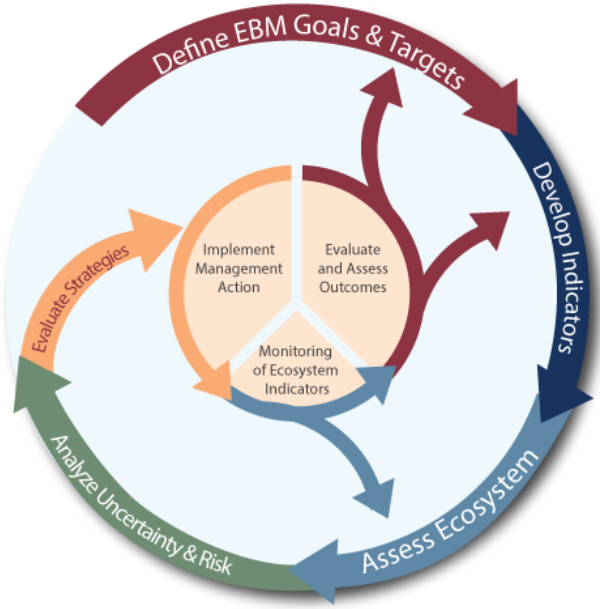


Ecosystem models

What can we learn from ecosystem models?



National EBFM Efforts



IEA DIPSER framework

- NOAA EBFM Policy and Road Map
- Regional EBFM Implementation Plans
- Integrated Ecosystem Assessments (IEA)
- Ecosystem Status Reports
- Fisheries Ecosystem Plans (FEP)
- Climate vulnerability assessments

- Management Strategy Evaluation (MSE)
- National Ecosystem Modeling Workshops (NEMOW)
- Ecosystem modeling toolbox
- Data repositories

U.S. Regional EBFM Activities

Pacific FMC

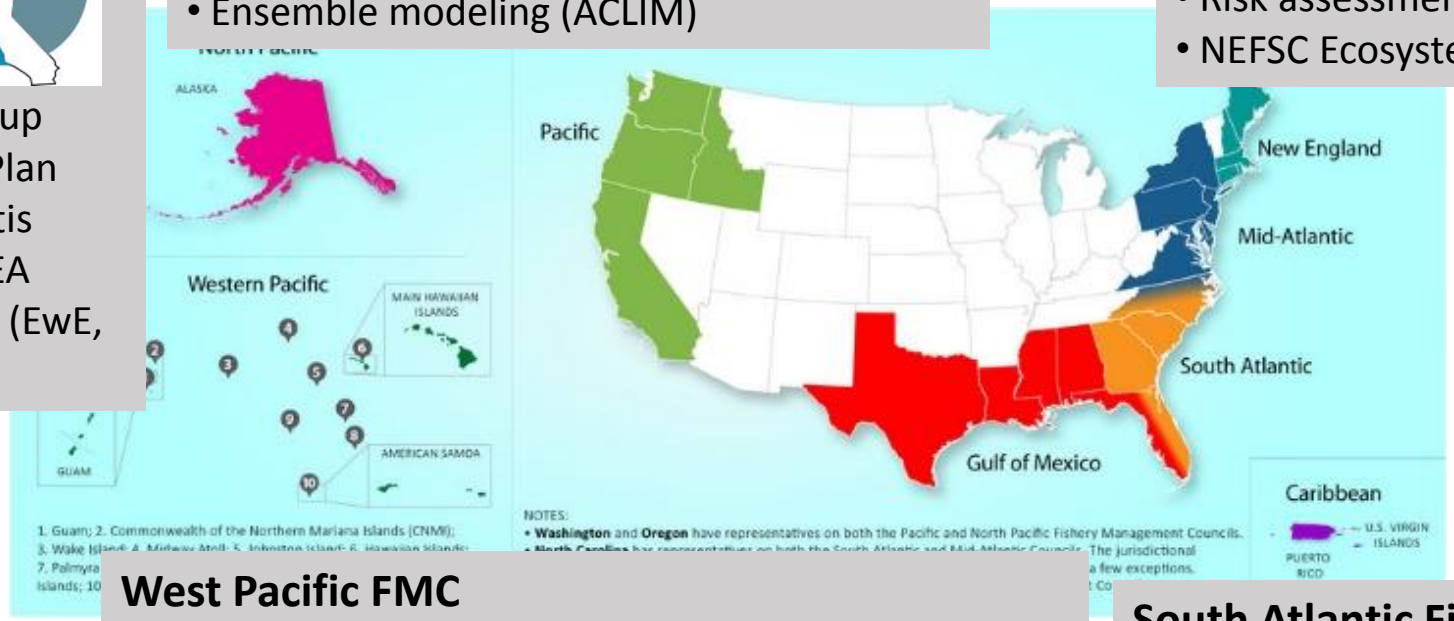
- Ecosystem Workgroup
- Fishery Ecosystem Plan
- SSC review of Atlantis
- California Current IEA
- Ensemble modeling (EwE, Atlantis, MICE)

North Pacific FMC

- Ecosystem committee
- 2 Fishery Ecosystem Plans
- Alaska Marine Ecosystem Forum
- Alaska IEA
- Ensemble modeling (ACLIM)

New England Fishery Management Council

- EBFM committee
- Georges Bank FEP under dev.
- Northeast IEA
- Risk assessment, MSE
- NEFSC Ecosystem Dynamics Program



MID-ATLANTIC FISHERY MANAGEMENT COUNCIL

- Ecosystem & Ocean Planning Committee
- EAFM Guidance Document
- EAFM risk assessment
- Habitat, forage, protected spp.

West Pacific FMC

- Regional Ecosystem Advisory Committees
- 5 Fishery Ecosystem Plans
- West Hawaii IEA
- #1 Ecosystem research priority: expand/update/develop food web models to assess impacts of climate & fisheries

South Atlantic Fishery Management Council

- Habitat & EBFM committee
- Fishery Ecosystem Plan (II)
- Habitat focus
- Supported ecosystem model development

Gulf of Mexico EBFM and Ecosystem Modeling Activities

2005-2010 **GMFMC Ecosystem Pilot Project**

- 4 modeling workshops
- Established Ecosystem SSC

2010 **Gulf of Mexico IEA**

- Data synthesis, ecosystem status reports
- Ecopath and Ecosim, OSMOSE, Atlantis modeling

2010-2013 **West Florida Shelf model development**

- Reef fish management focus

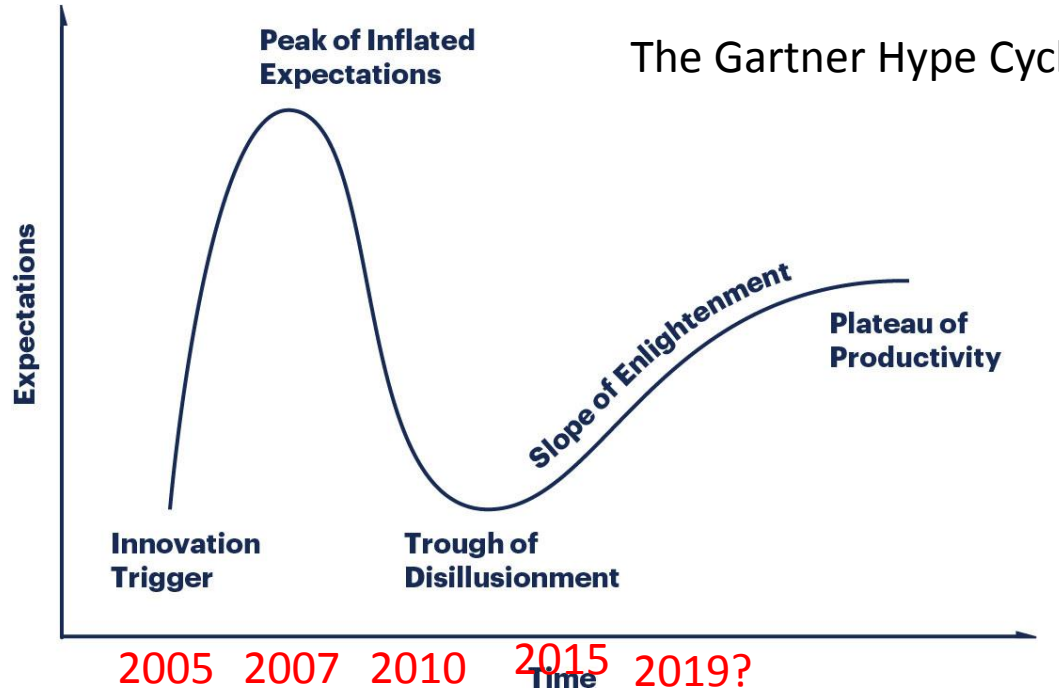
2013-present **RESTORE Act**

- Enhanced data collection
- Atlantis and EwE modeling

2018 **Gulf of Mexico EBFM Road Map**

- stock assessment, monitoring, climate, habitat, species interactions, connectivity, human dimensions

The Gartner Hype Cycle



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

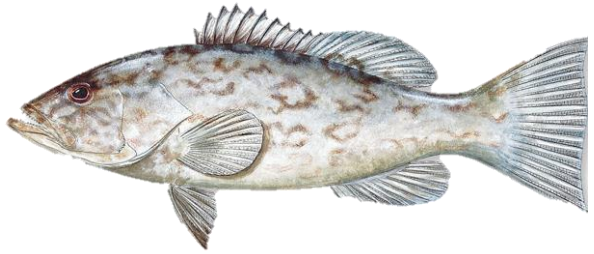
RESTORE SCIENCE PROGRAM

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



Gag Grouper
Mycteroperca microlepis

Gulf Menhaden
Brevoortia Patronus

Investigators & Collaborators

Modeling Team

- Skyler Sagarese – SEFSC Miami
- Matt Lauretta – SEFSC Miami
- Kim de Mutsert - GMU
- Rob Ahrens - UF
- Matt Nuttall – Univ. of Miami
- Daniel Vilas – UF PhD Student
- Behzad Mahmoudi – FWC FWRI
- Carl Walters – UBC
- Jeroen Steenbeek – Ecopath International

End Users

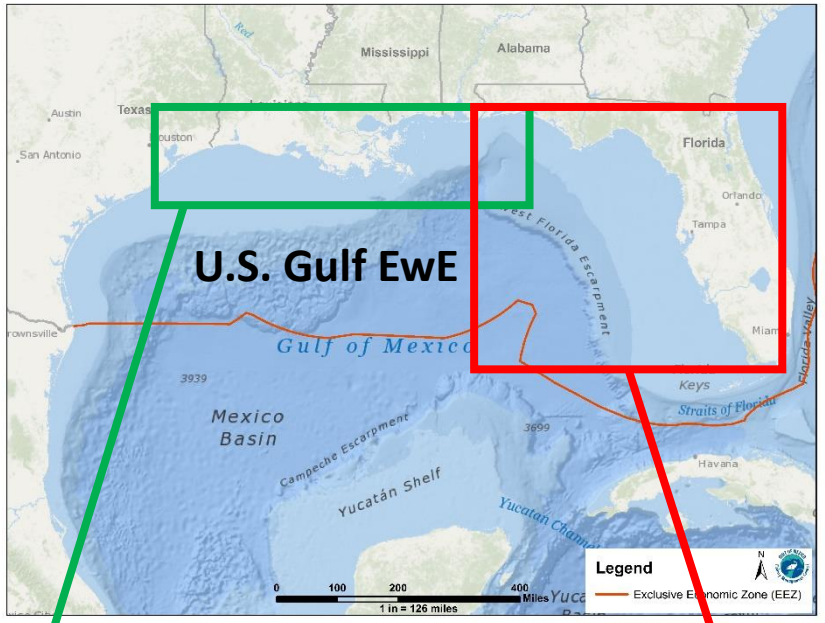
- Nick Farmer – NOAA SERO
- Steven Vanderkooy – GSMFC
- Will Patterson – GMFMC SSC
- Morgan Kilgour – GMFMC Staff
- Amy Schueller – SEFSC Beaufort
- Jim Estes – FWC DMFM
- Martha Guyas – FWC & GMFMC
- Howard Townsend – NOAA OST
- Tom Frazer - GMFMC

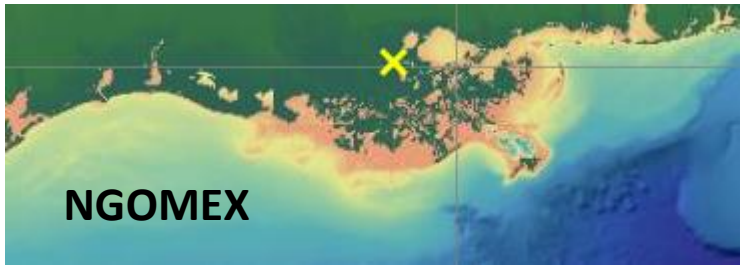
Ecosystem Model Updates

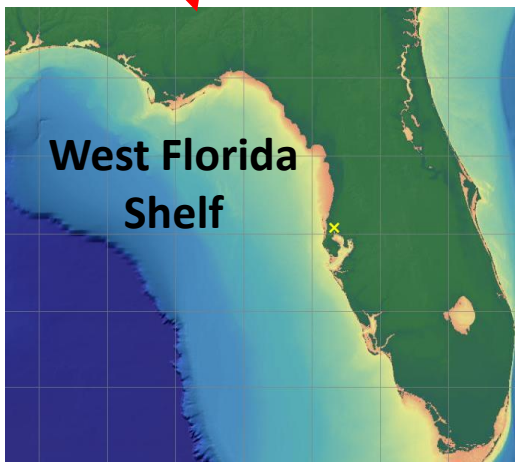
Re-designed to meet needs
for fisheries management

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

- Updates include:
  - 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

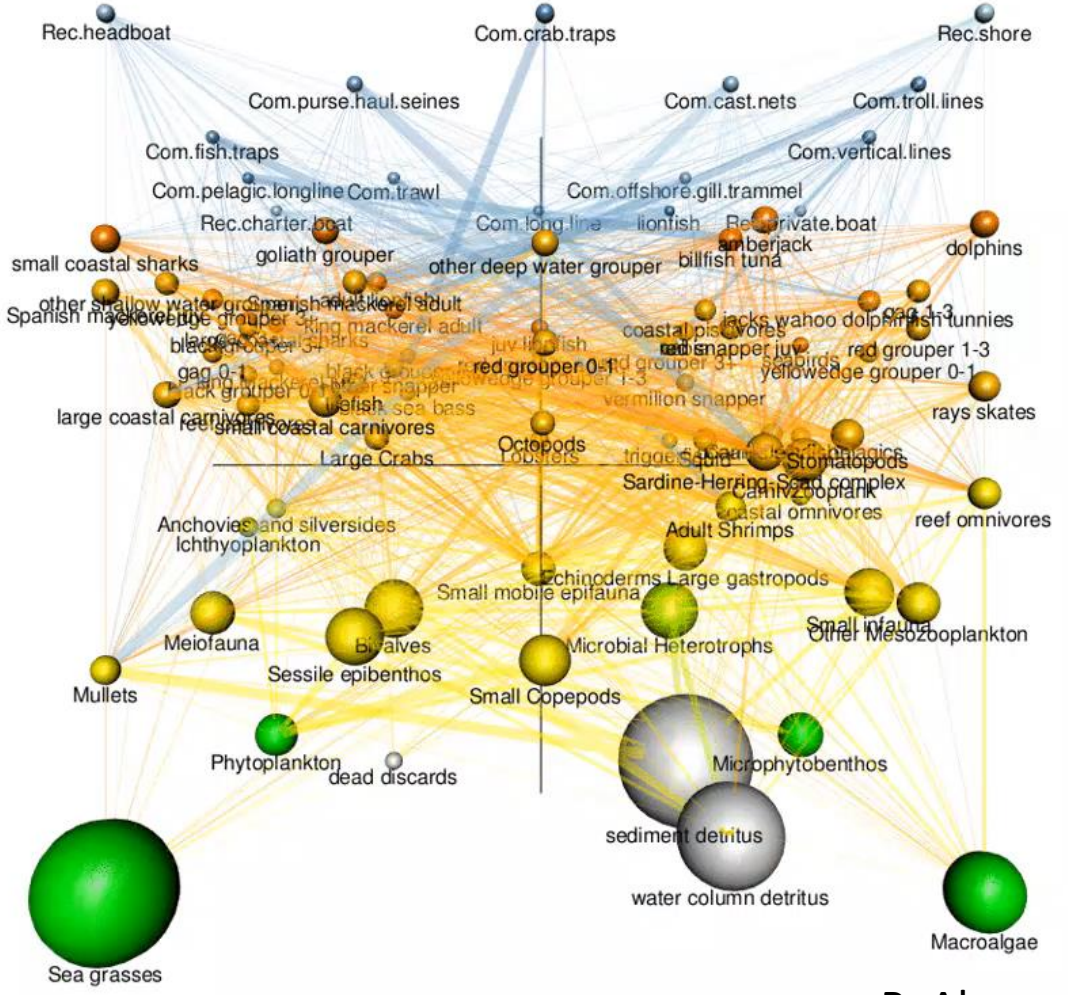
- Spatial dynamic model
- Additional inputs: movement rates, habitat preferences, fishing effort, environmental forcing
- Spatially-explicit harvest policies and environmental forcing

West Florida Shelf EwE model

Chagaris, University of Florida

- 83 functional groups and 18 fishing fleets

- Emphasis on managed reef fish in FMP
  - Snappers – red (3 ages), vermilion, gray, others combined
  - Groupers – red (6 ages), gag (6 ages), black, scamp, yellowedge, goliath, other SWG, other DWG
  - Tilefish – blueline and golden
  - Greater amberjack, gray triggerfish, hogfish, lionfish, black seabass, red porgy
  - 6 other reef fish functional groups



R. Ahrens

U.S. Gulf of Mexico EwE

Skyler Sagarese & Matt Lauretta, SEFSC

- Northern Gulf 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

Contents lists available at ScienceDirect

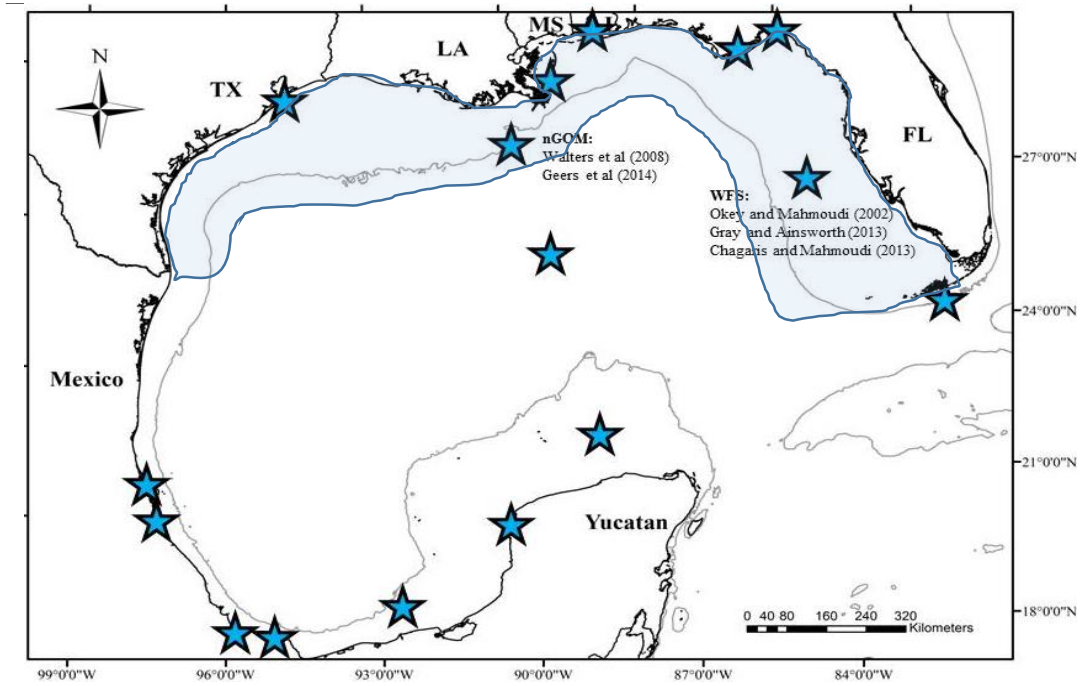
Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

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

Skyler R. Sagarese[a,*,1], Matthew V. Lauretta[b], John F. Walter III[b]

[a] Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, USA
[b] Southeast Fisheries Science Center, National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, FL 33149, USA



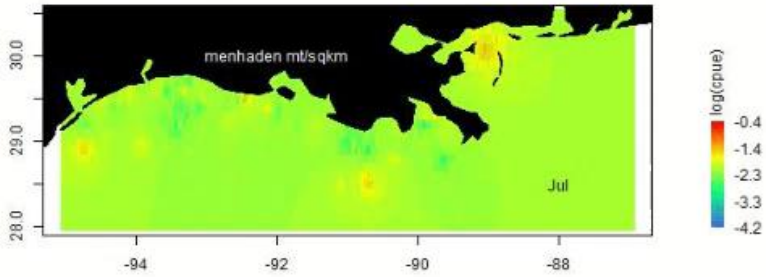
NGOMEX EwE Model

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

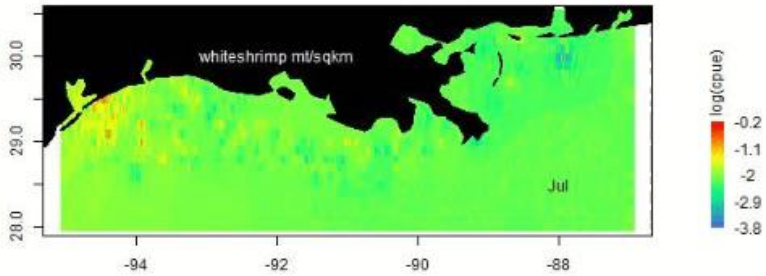
Visualizations

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.



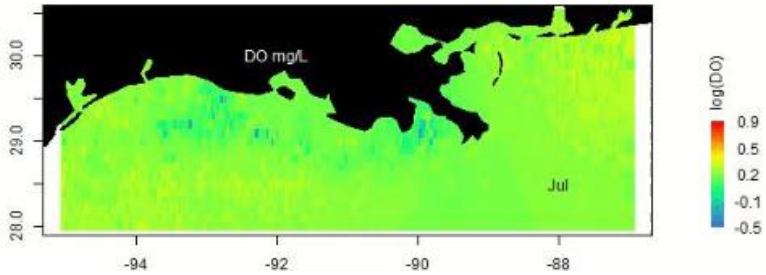
Menhaden biomass

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/

Ecosystem Modeling Scoping Workshop

Purpose:

Identify and prioritize issues and challenges that would benefit from an ecosystem modeling approach

September 6-7, 2017
St. Petersburg, FL

https://doi.org/10.1016/j.marpol.2018.11.033

Contents lists available at ScienceDirect

Marine Policy

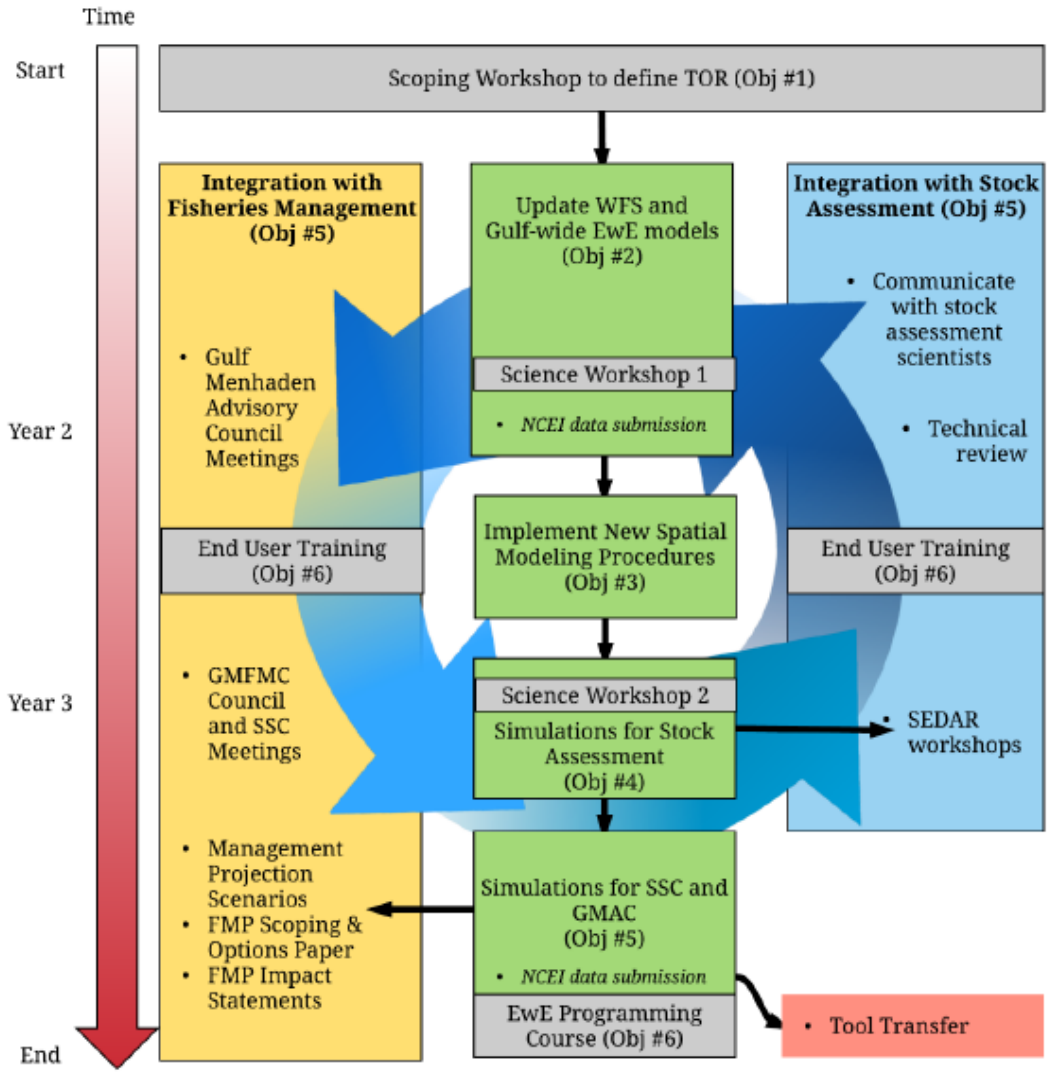
journal homepage: www.elsevier.com/locate/marpol

Management challenges are opportunities for fisheries ecosystem models in the Gulf of Mexico

David Chagaris[a,*], Skyler Sagarese[b], Nick Farmer[c], Behzad Mahmoudi[d], Kim de Mutsert[e], Steven VanderKooy[f], William F. Patterson III[g], Morgan Kilgour[h], Amy Schueller[i], Robert Ahrens[g], Matthew Lauretta[b]

- What are the effects of environmental stressors on exploited fish stocks?
- Do multi-species reference points lead to better management outcomes?
- What are the impacts of invasive lionfish and how do we mitigate them?
- How does habitat contribute to fisheries productivity?
- Can spatial management enhance sustainability and recovery of exploited species?
- How to account for ecosystem services when managing forage fisheries?
- Can ecosystem models help improve stock assessments?
- How can we effectively communicate ecosystem modeling to stakeholders?

Incorporating Input from Managers into Ecosystem Model Development & Outputs



- Scoping Workshop
  - Managers & assessment scientists
  - Develop a Terms of Reference for ecosystem models
- Engage in assessment & management activities
  - Gulf menhaden advisory committee (GMAC)
  - GMFMC SSC
  - SEDAR assessment workshops
- Contribute to FMP Scoping and Options Papers

Potential Applications of Gulf of Mexico Ecosystem Models

Example Applications

When to add more precaution

Whether to adjust stock assessment parameters

Help explain and forecast population fluctuations

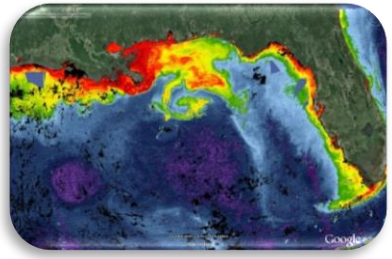
Do harvest policies perform well under environmental change

How do harvest policies affect other species

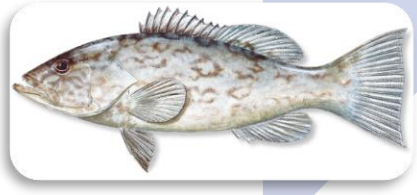
Can we achieve single species targets simultaneously

Red tide mortality

Multiple stressors

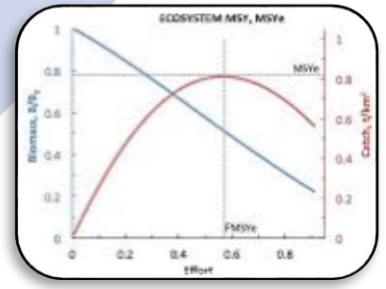


Non-stationary changes in primary production



Stock Rebuilding

Forage fisheries



Multispecies reference points; MSE

Red Tides

Red tides have become more frequent and severe

What are the impacts on grouper populations?

We need information that is…

- Timely and contemporary
- Quantitative
- Accounts for bloom extent, duration, & severity, species distributions, and food web impacts

Estimating Red Tide Mortality

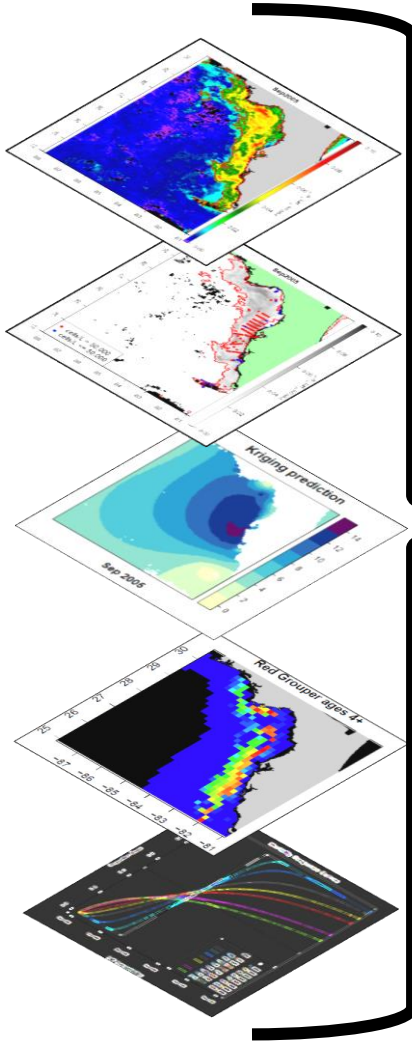
Flourescent Line Height satellite imagery (extent, duration)

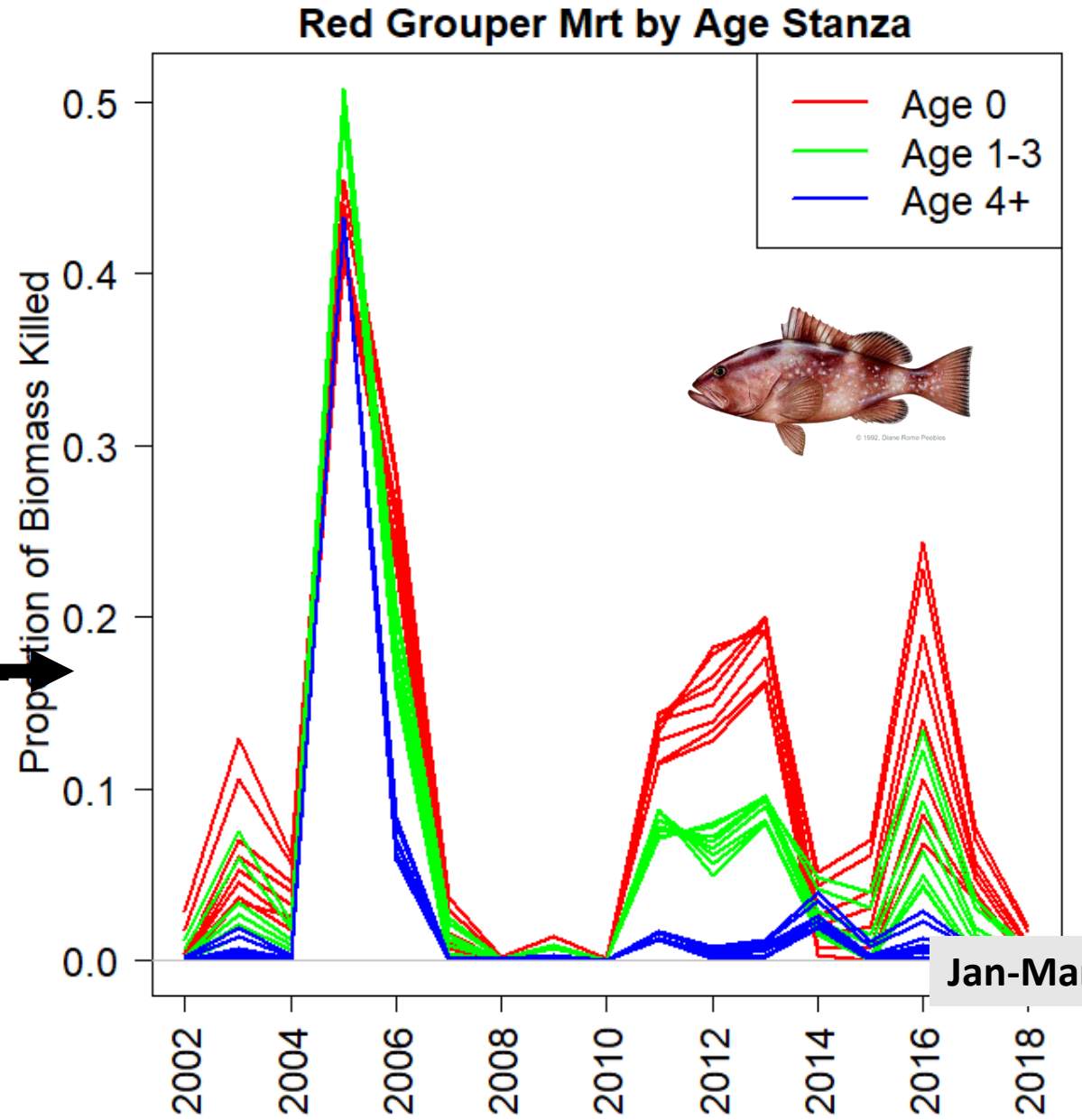
FWRI K. brevis concentrations (severity)

Kriged red tide maps

Species distributions from Ecospace

Logistic mortality function





SEDAR 61 Working Paper 6

Estimating Red Tide Mortality

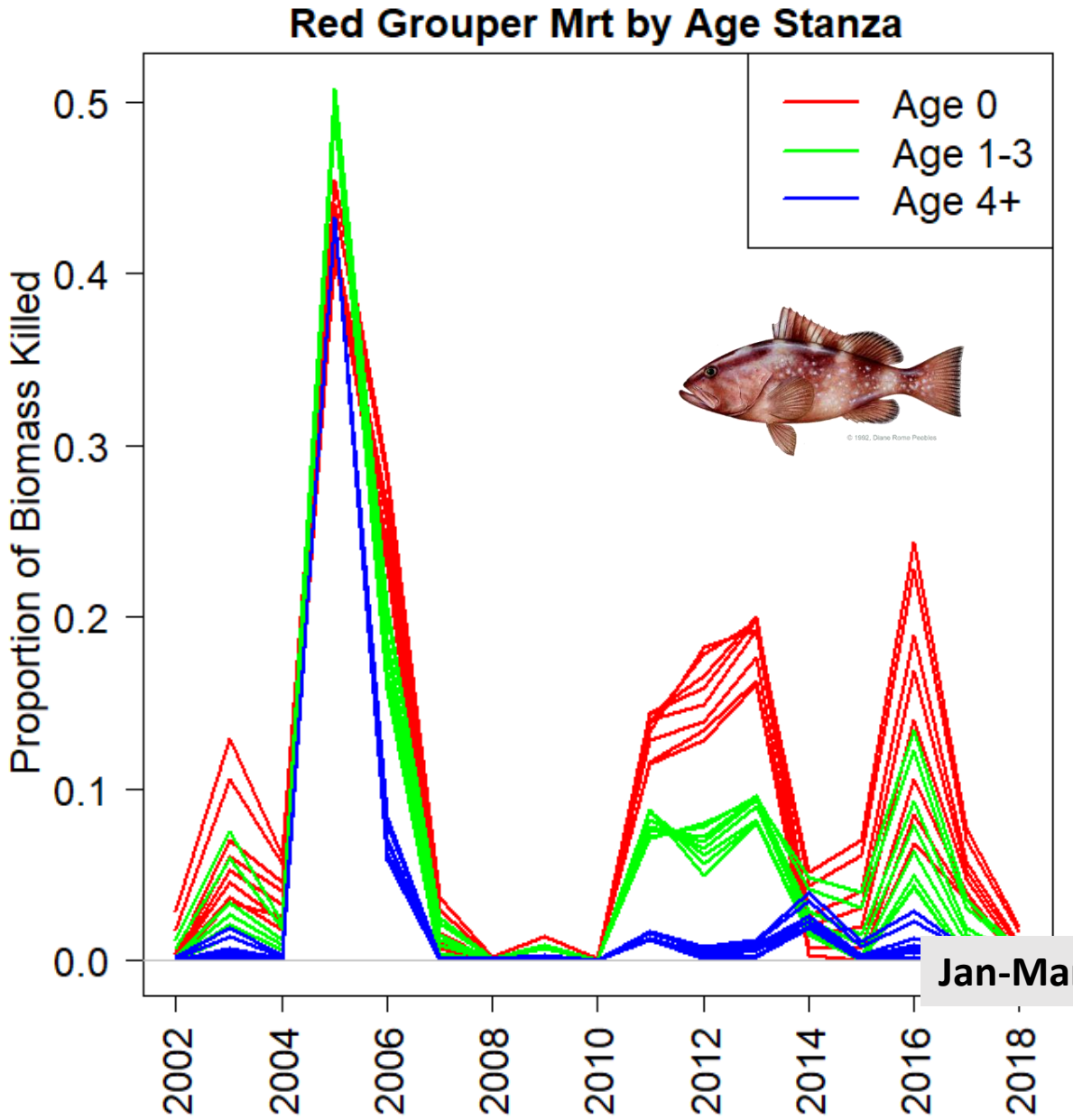
Red Grouper Trends in M_{rt}

Total Biomass

- 2005: 43.8%
- 2006: 7.5-10.5%
- all other years: 0.3 - 3.5%

Impacts on Juveniles

- Age-0 M_{rt} = 10-20% in 5 of last 8 years
- Age 1-3 M_{rt} = 5-13% in 5 of last 8 years



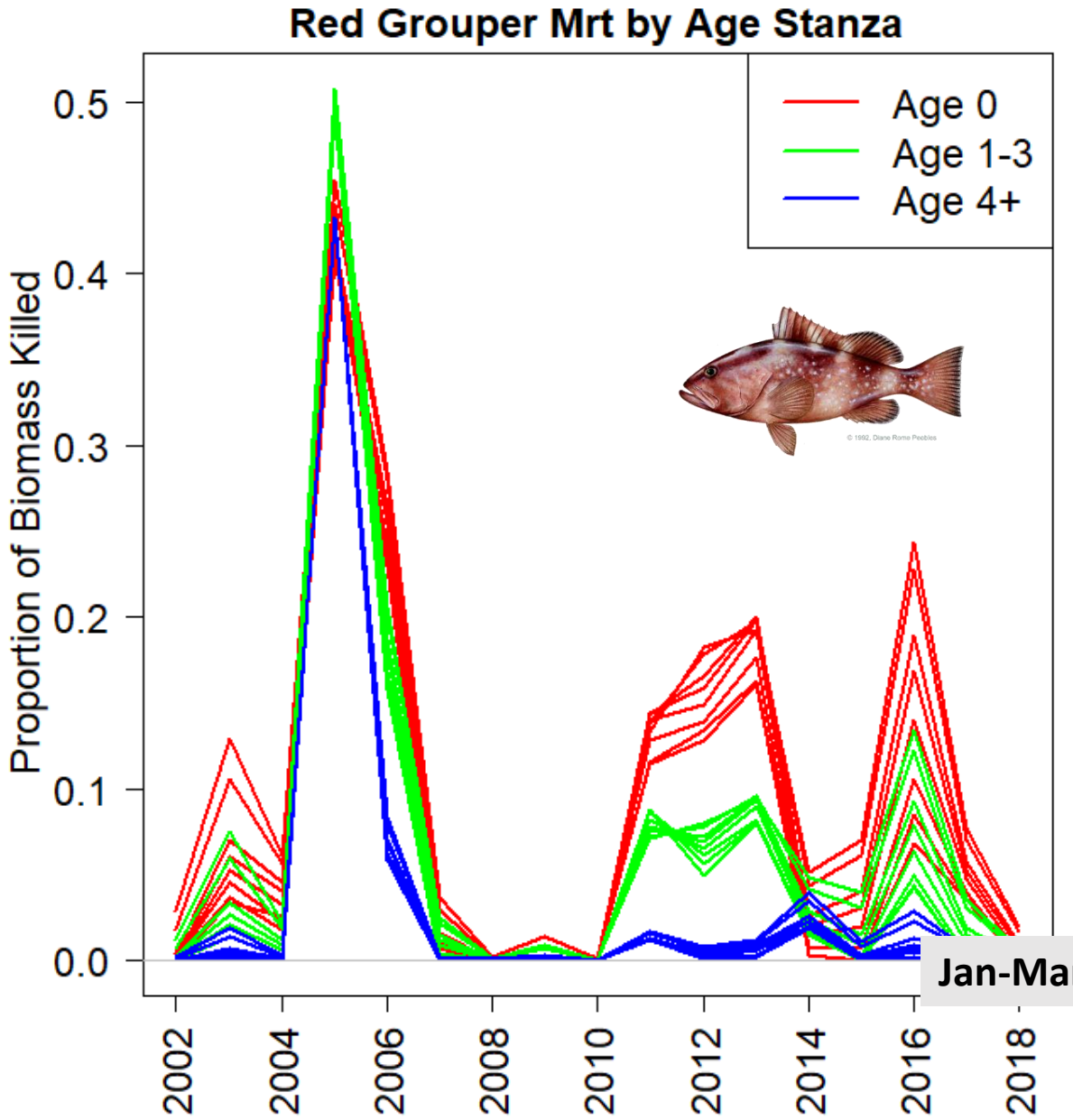
SEDAR 61 Working Paper 6

Estimating Red Tide Mortality

Red tide has likely had an impact on recruitment of red grouper

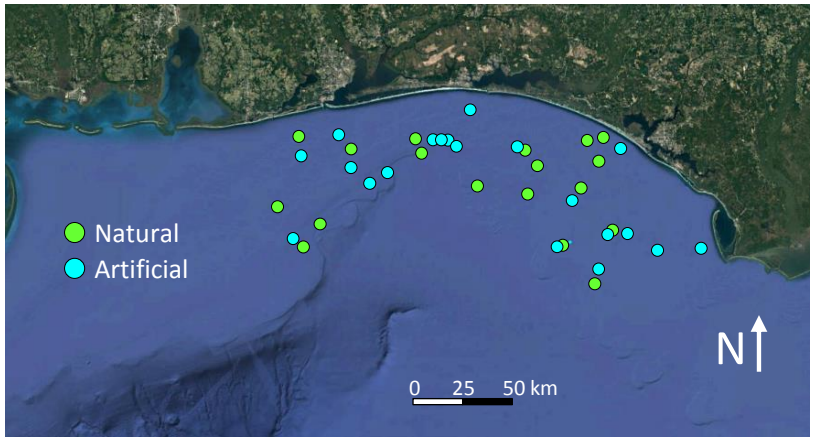
<u>Practical Implications:</u>

- lower survival of juveniles in stock assessment
- Below average recruitment in ACL projections
- More precautionary management



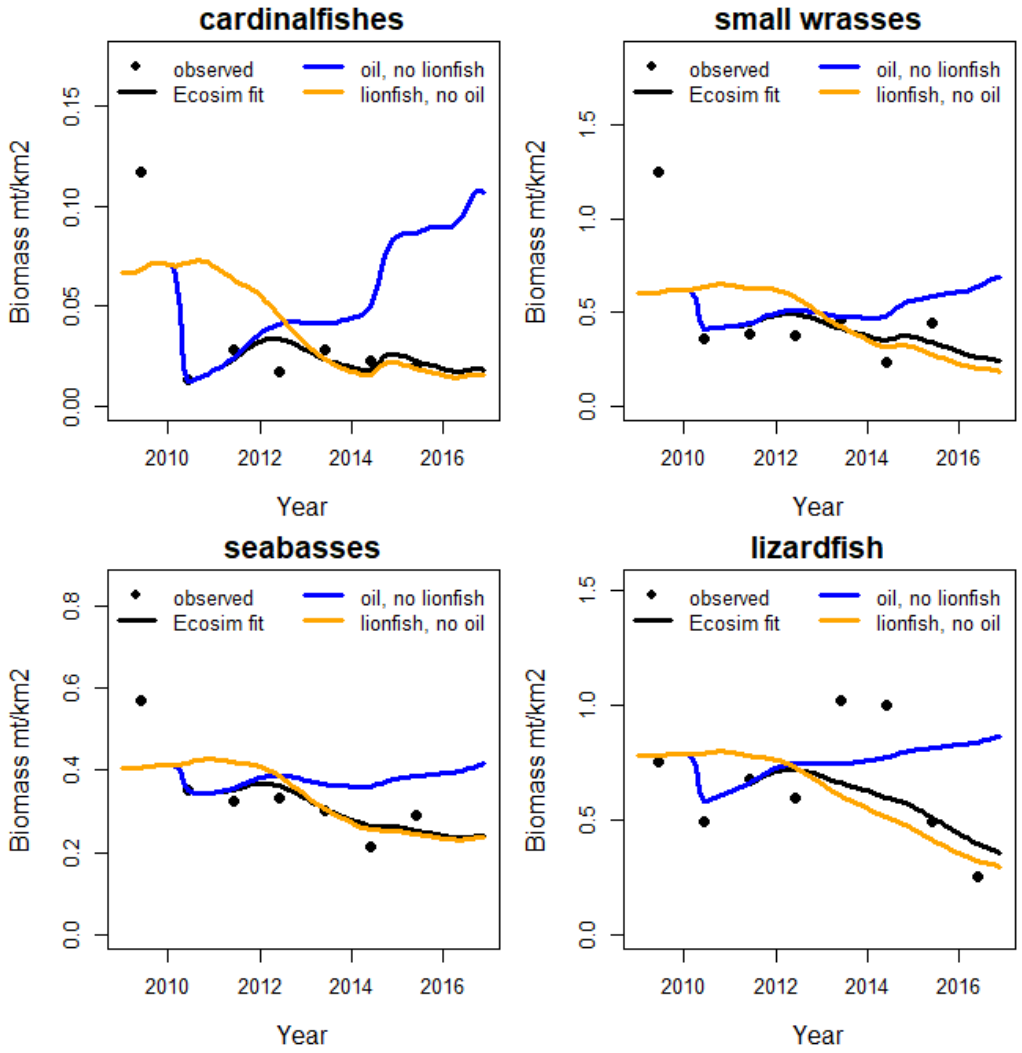
SEDAR 61 Working Paper 6

Teasing apart effects of multiple stressors



Lionfish and DWH Impacts in the NGoM

- Lionfish impacted the recovery of small reef fishes following DWH
- Also predicted indirect & positive effects on secondary prey items
  - declines in predation mortality by meso-predators due to lionfish
  - Trophic cascades – increase in benthic inverts



Teasing apart effects of multiple stressors

Potential causes for slow recovery of Red Snapper in eastern Gulf

Fishing

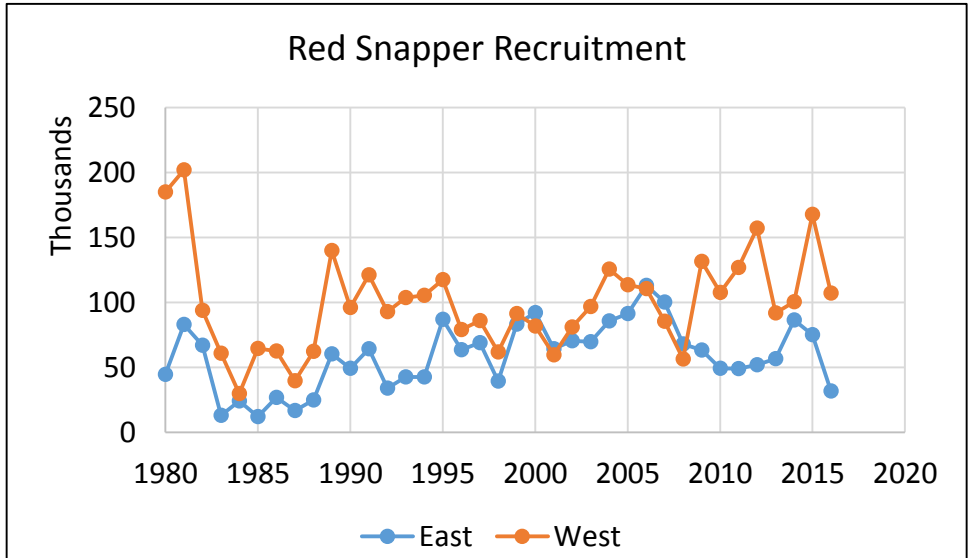
Episodic mortality

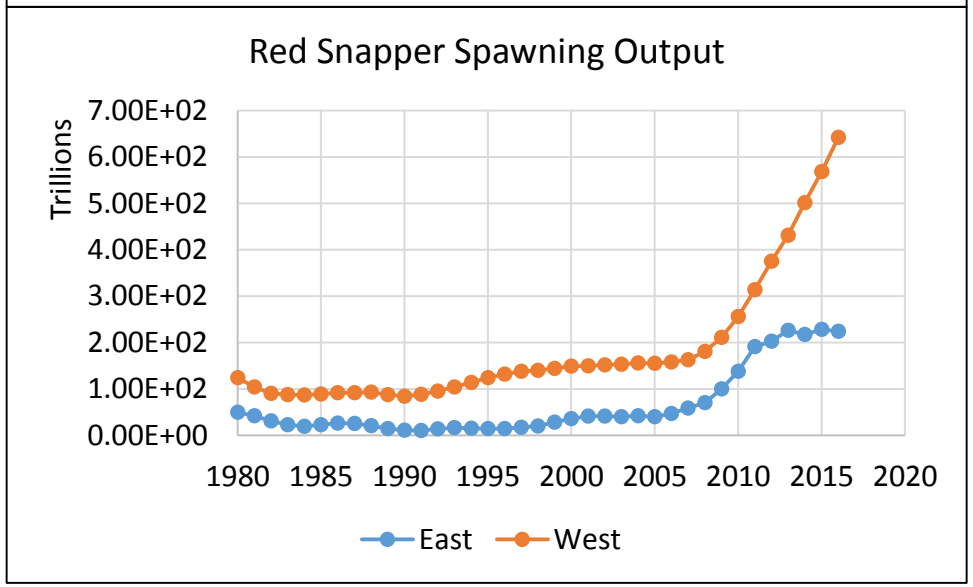
Predation & competition

Direct & Indirect (food web) effects

Growth & Survival

Stock Assessment





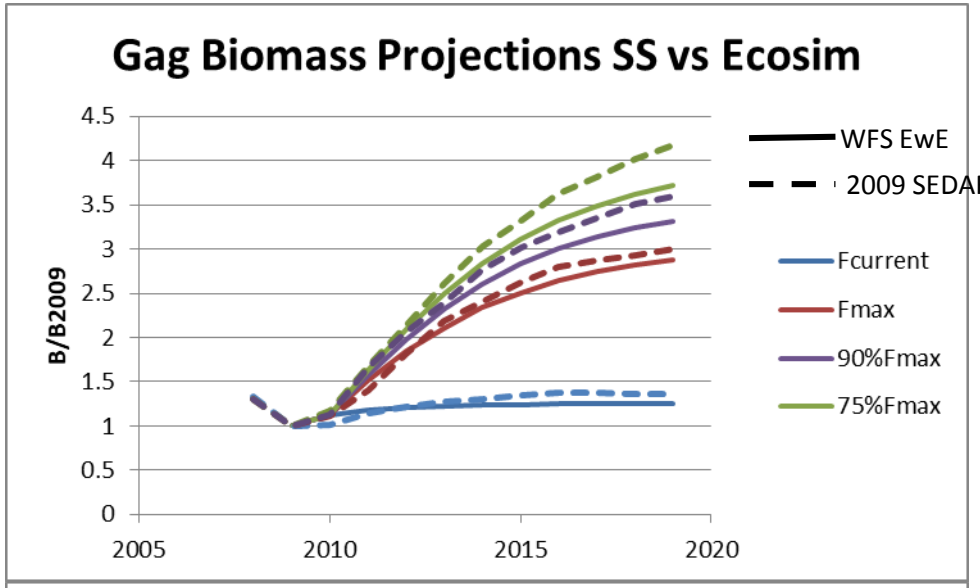
Stock Projections

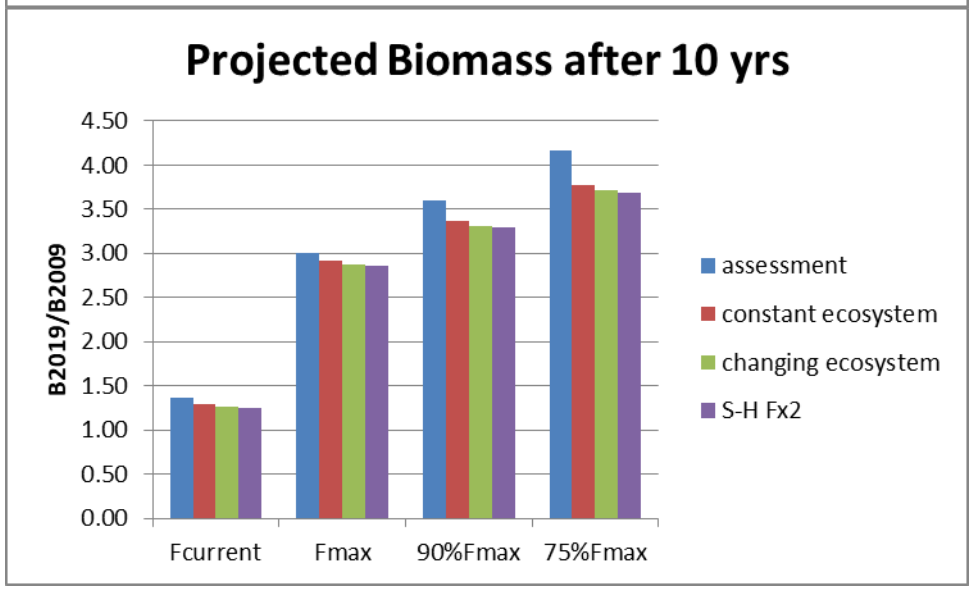
Project future stock conditions under a range of fixed *F* scenarios

- Evaluated alongside stock assessment projections
- Includes changes to other species and environment
- Feedback into SS projections (M, rec dev, etc.)

Ecosim predicts lower biomass than assessment when $F<90\%F_{msy}$

- Density dependent foraging
- Inter-specific competition effects are low at small stock sizes

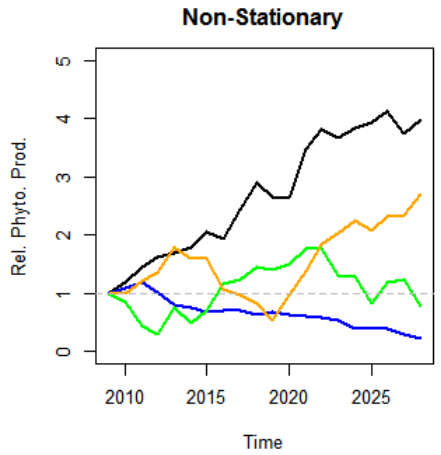




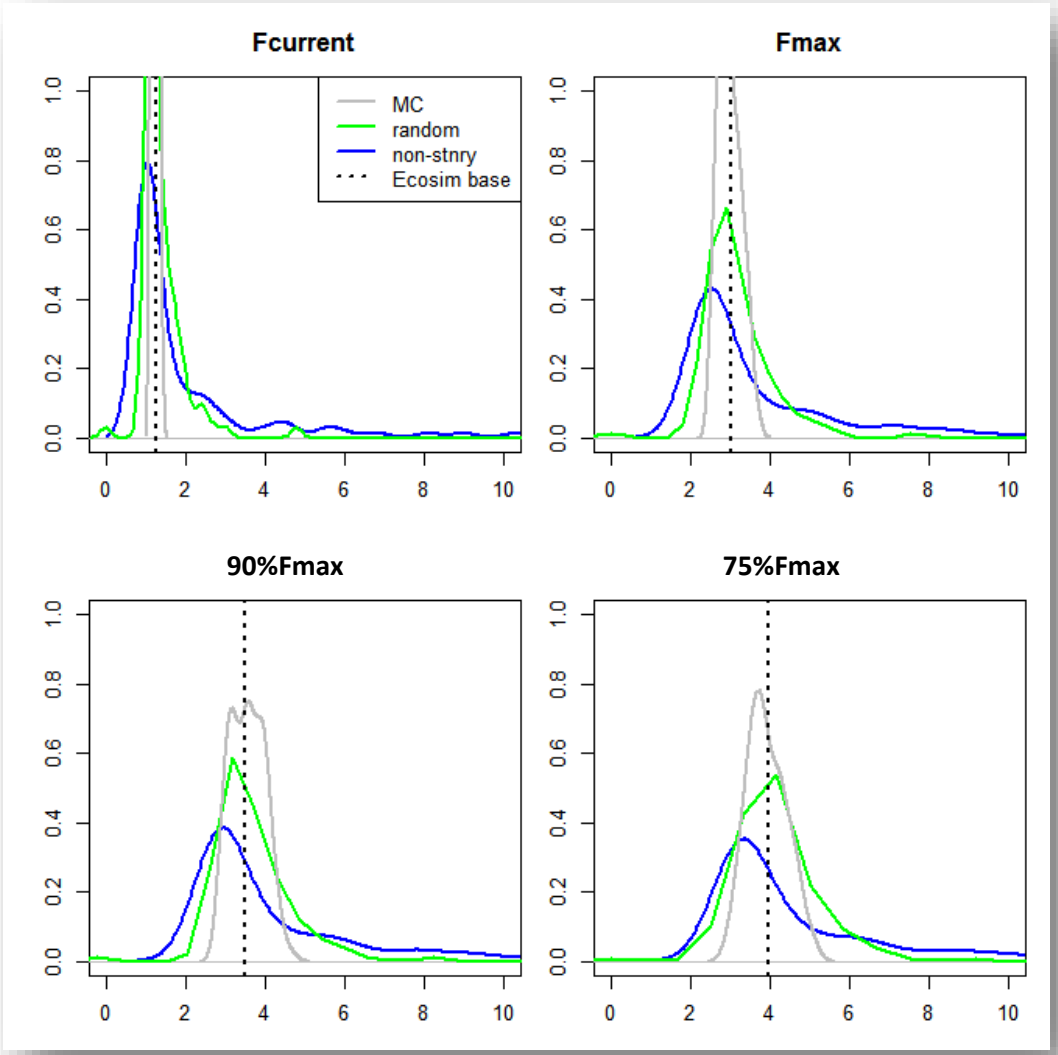
Stock Projections

Scenarios with non-stationary change in primary production lead to largest uncertainty in projected biomass

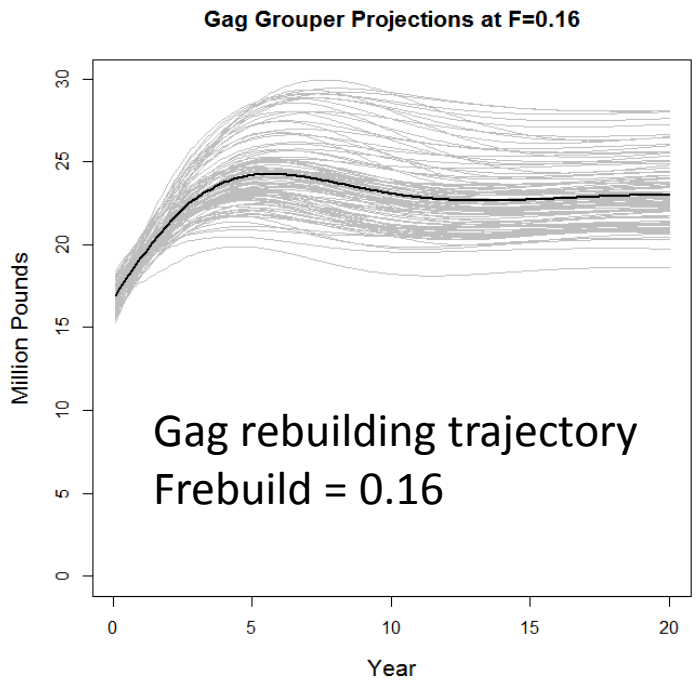
Higher proportion of projections fall below baseline prediction



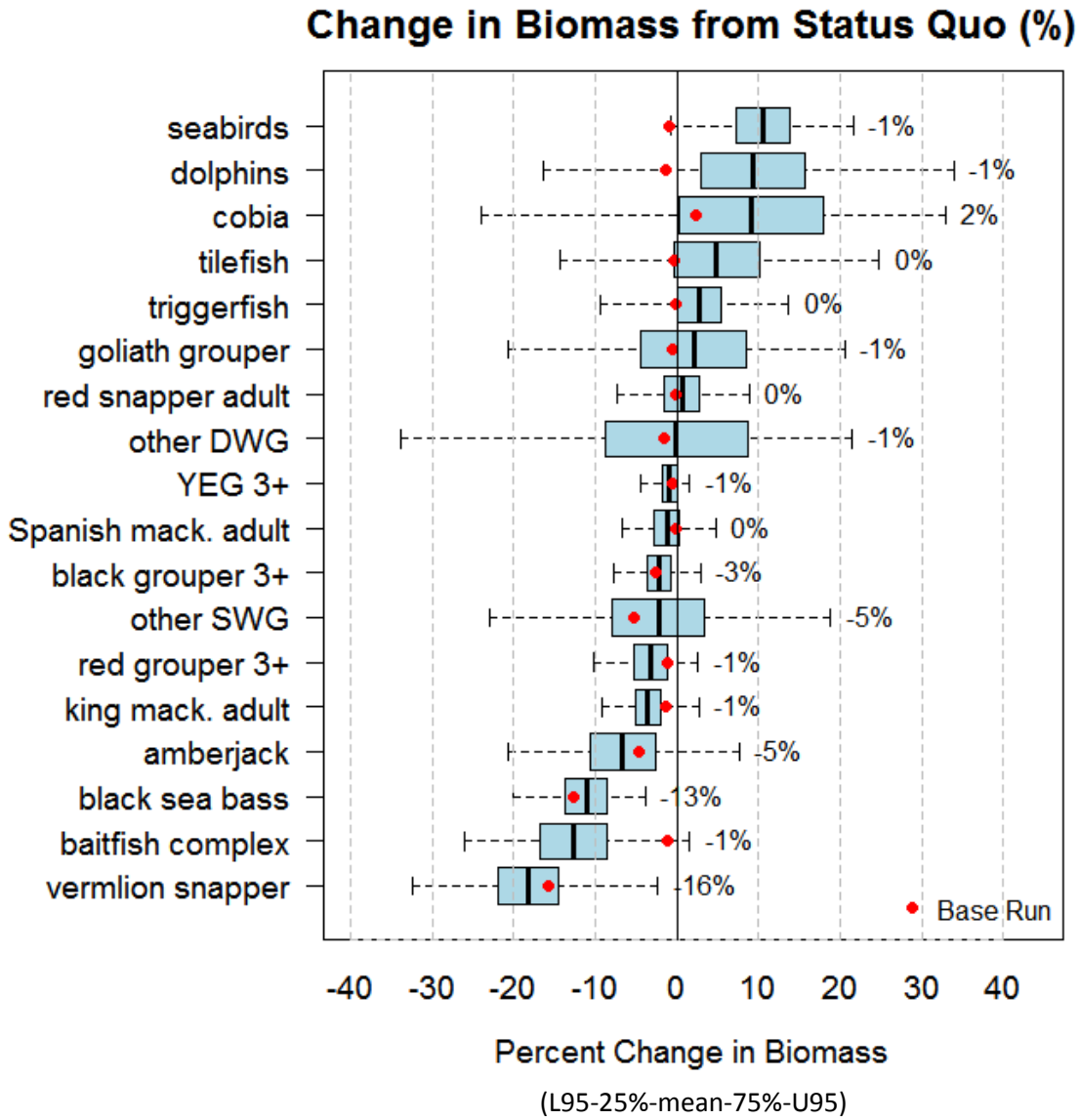
Examples of randomly generated non-stationary PP patterns



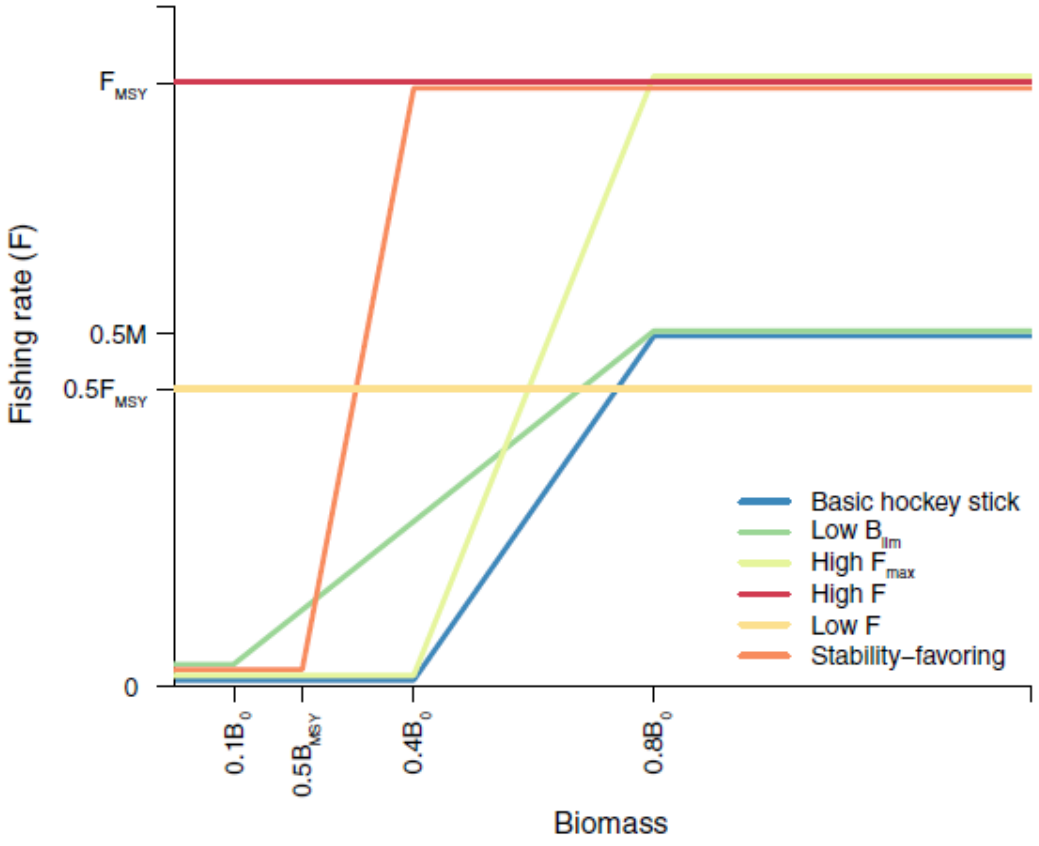
Ecological Sensitivities: Rebuilding Predators



- Year 10 biomass ≈ 23 mp
- Projected biomass from single species model is 22-30 mp under F of .14-.19
- Potential for impact on vermilion snapper, black sea bass, and GAJ
- Modest impacts on other species



Ecological Sensitivities: forage fisheries



GSMFC menhaden reference points workshop - Feb 12-13, 2019

- Define management objectives and reference points
- Evaluate harvest control rules using MSE
- Use EwE to develop HCRs and screen them for impacts on predators

Multispecies Reference Points

- European Commission policy is to achieve MSY for all stocks

- Case study for North Sea demersal stocks:
  - MSY for whiting (prey) is lower when cod (predator) is at Bmsy
  - Mixed fisheries cannot be divorced from dynamics of other system components

Fig. 2. Predictions of maximum sustainable yield (MSY) when F_{MSY} predicted by single species are applied in a single-species (open bars), mixed-fishery (stippled bars), and ecosystem (solid bars) context.

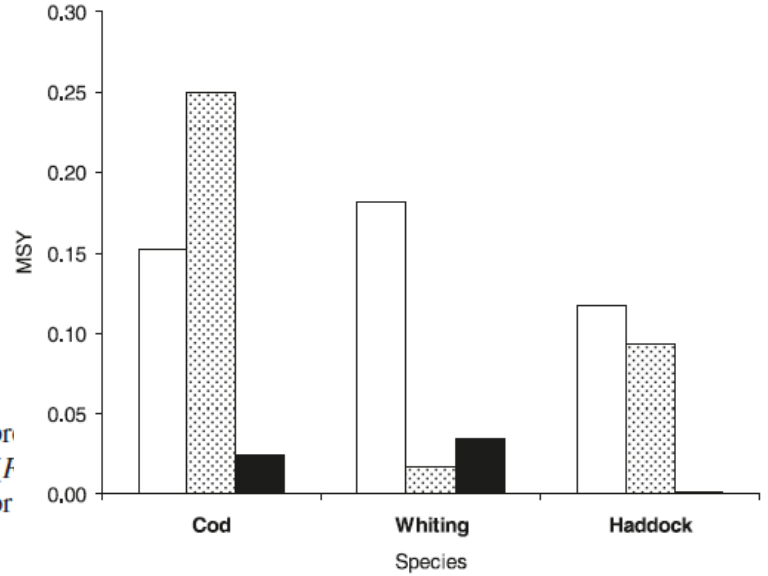
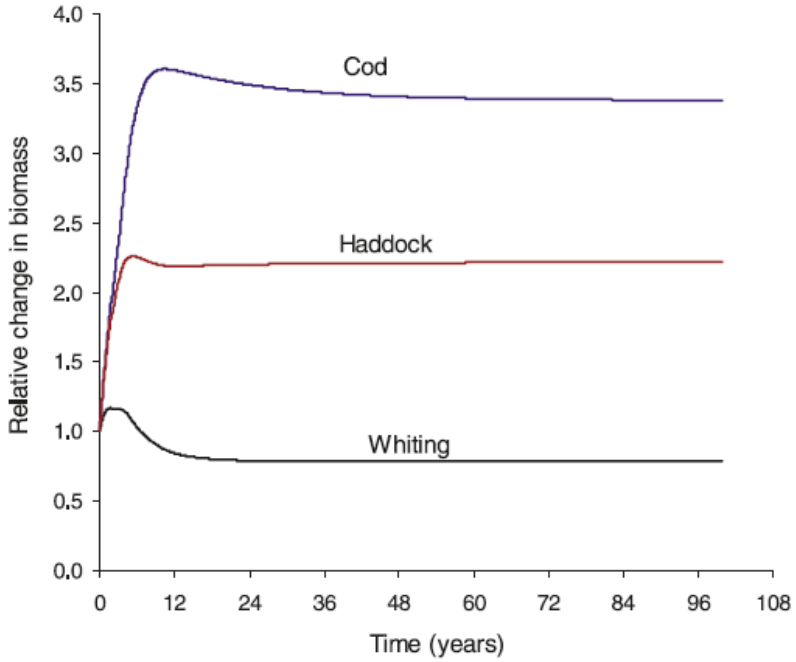


Fig. 3. Biomass trajectories when EC F_{MSY} pr
simultaneously to cod ($F = 0.201$), haddock (F
ing ($F = 0.3$) for a sufficiently long period for
catches to reach equilibrium.



Mackinson, S., B. Deas, D. Beveridge, and J. Casey. 2009. Mixed-fishery or ecosystem conundrum? Multispecies considerations inform thinking on long-term management of North Sea demersal stocks. CJFAS 66:1107-1129.

Constraints and Targets on Total System Yield

Ecosim Policy Optimization

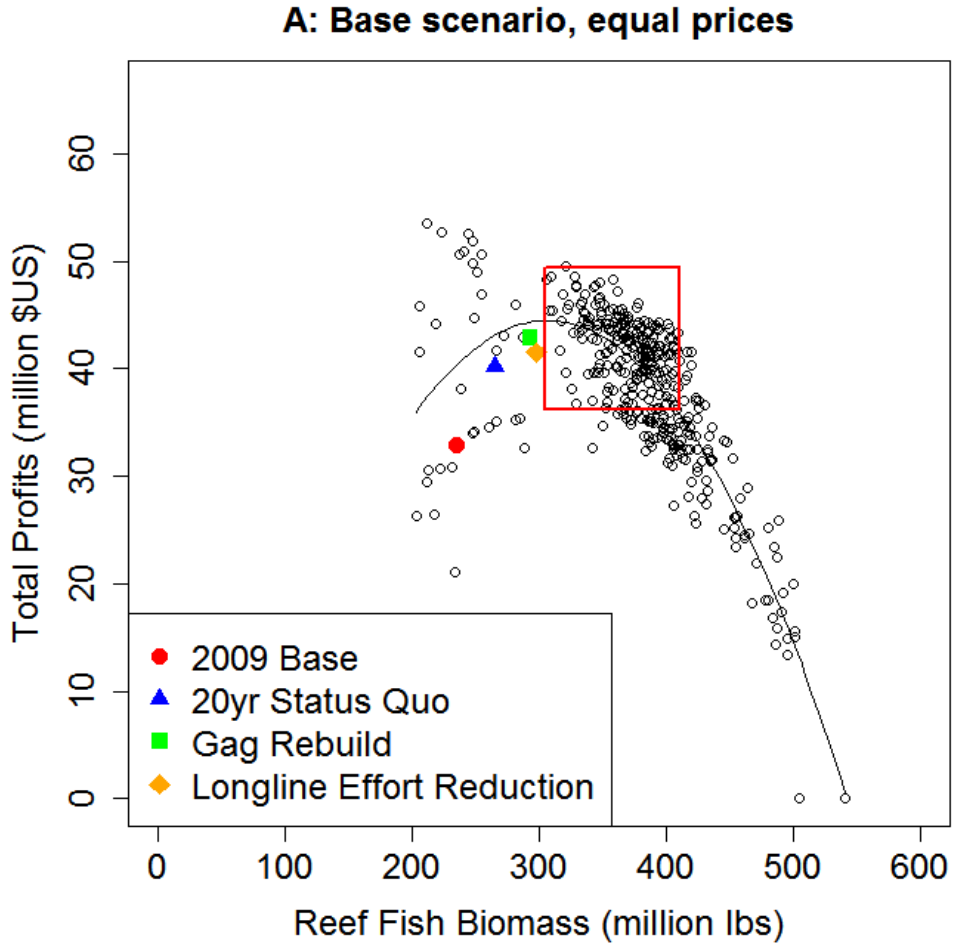
Productivity of fleets are linked through trophic interactions

What effort combinations balance the tradeoffs in management objectives

- A ‘balanced’ solutions exist
- Not all species are above threshold

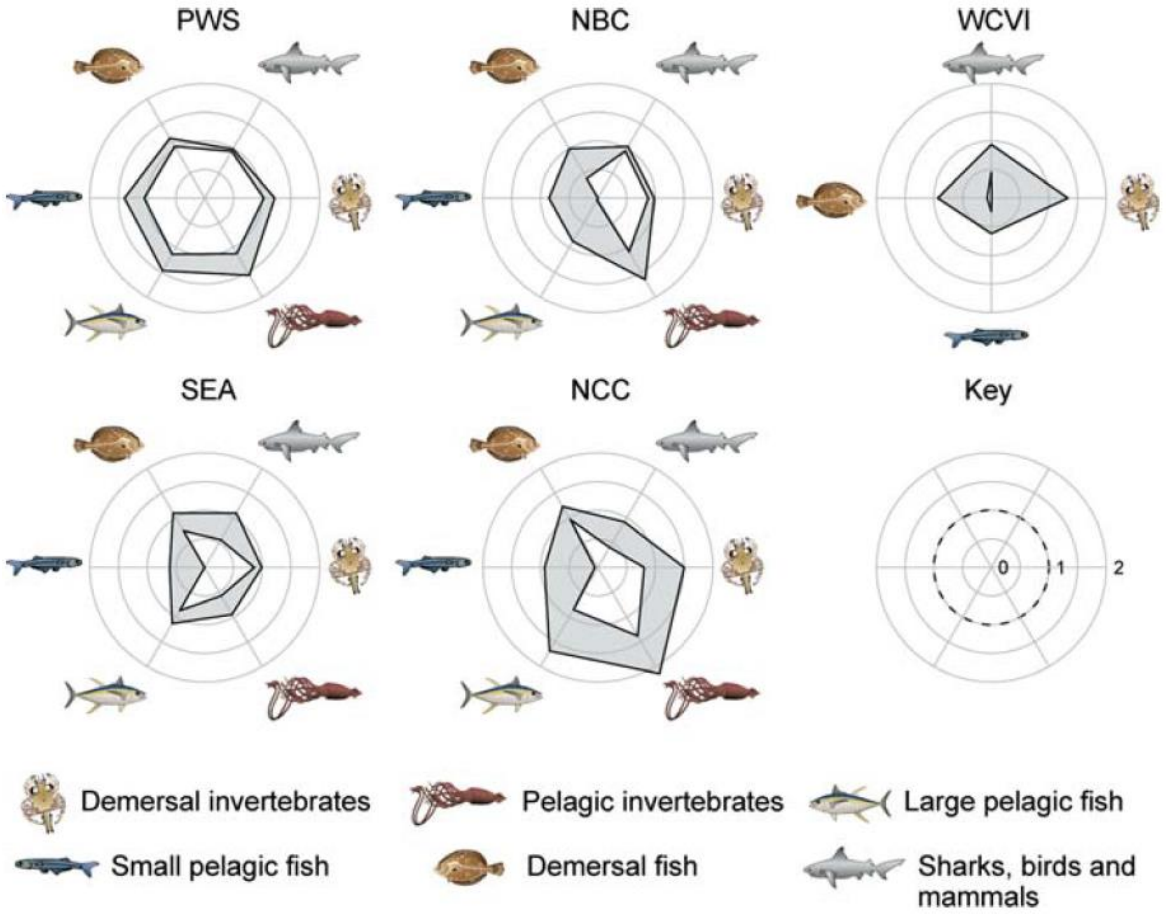
2009 (base) condition is suboptimal

- Rebuilding plans move system closer to the curve



Cumulative effects of fishing and environment

- Ecosim model of NE Pacific Ocean
- Evaluated climate effects:
  - primary productivity, species range shifts, zooplankton size structure, ocean acidification, ocean deoxygenation
- Predicted impacts on fisheries biomass, landings, and diversity
- Winners and losers
- Synergies
- Regional differences

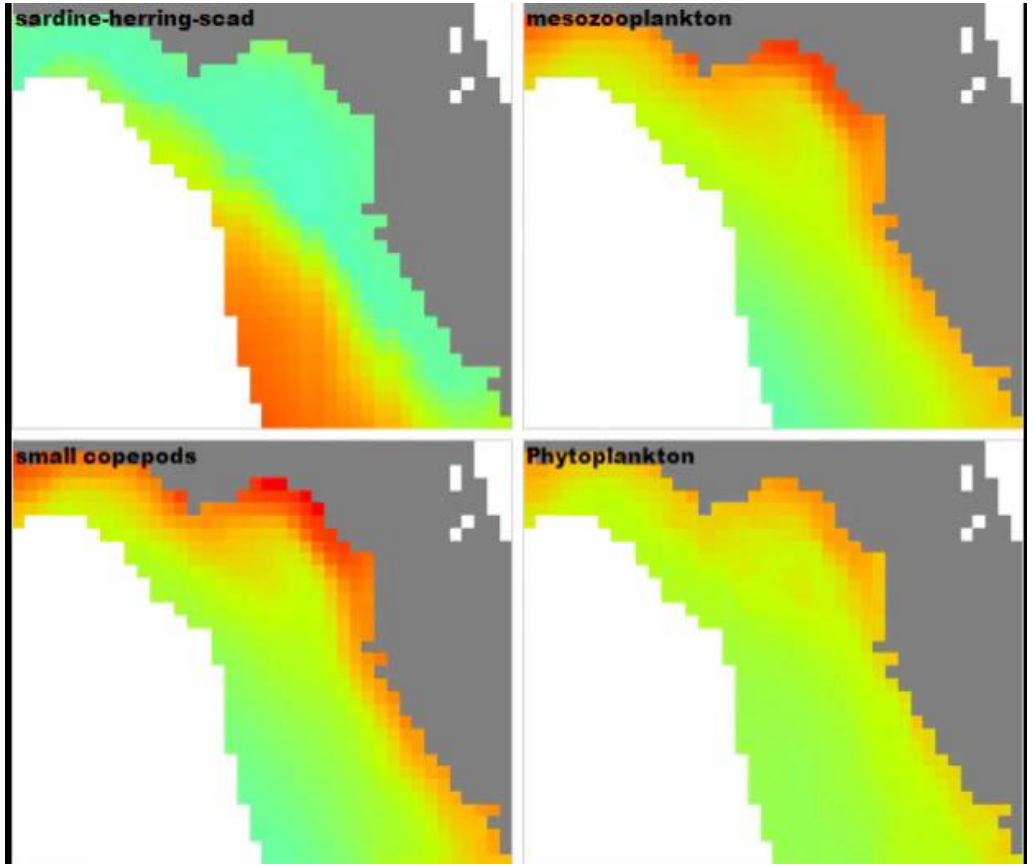


Ainsworth, C. H., Samhouri, J. F., Busch, D. S., Cheung, W. W. L., Dunne, J., and Okey, T. A. 2011. Potential impacts of climate change on Northeast Pacific marine foodwebs and fisheries. – ICES Journal of Marine Science, 68: 1217–1229.

Applications using Ecospace

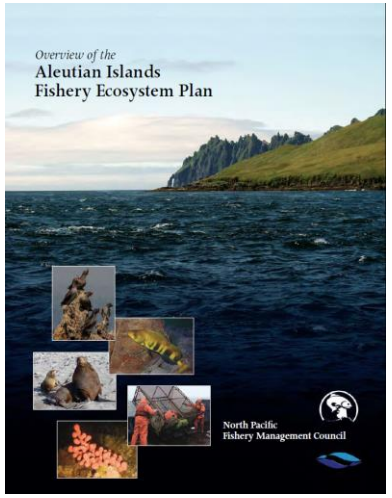
<u>Ecospace Spatial-Dynamic Framework</u>

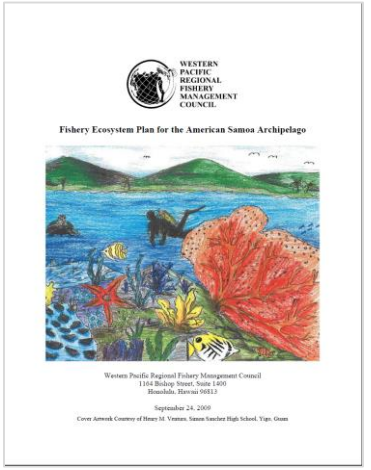
- Explore environmental change using spatial drivers
  - Remote sensing, oceanographic models
  - IPCC climate models
- Evaluate MPAs
- Simulate impacts of regional management on entire stock

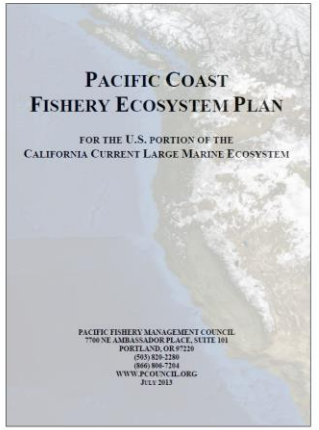


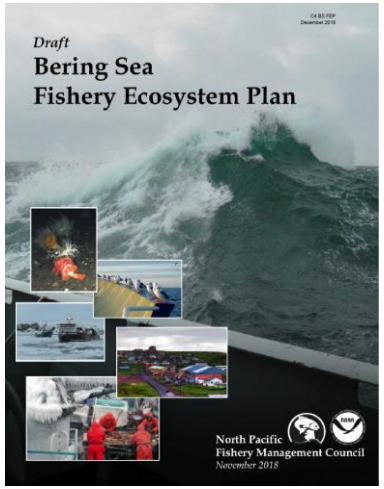
Informing Fishery Ecosystem Plans

- Context for biological interactions
- Provide catch advice
- Climate vulnerability analysis
- Risk analysis, ecological effects of harvest
- Evaluate ecosystem indicators
- Inform an EBFM research portfolio
- Feedback from FEP -> ecosystem models



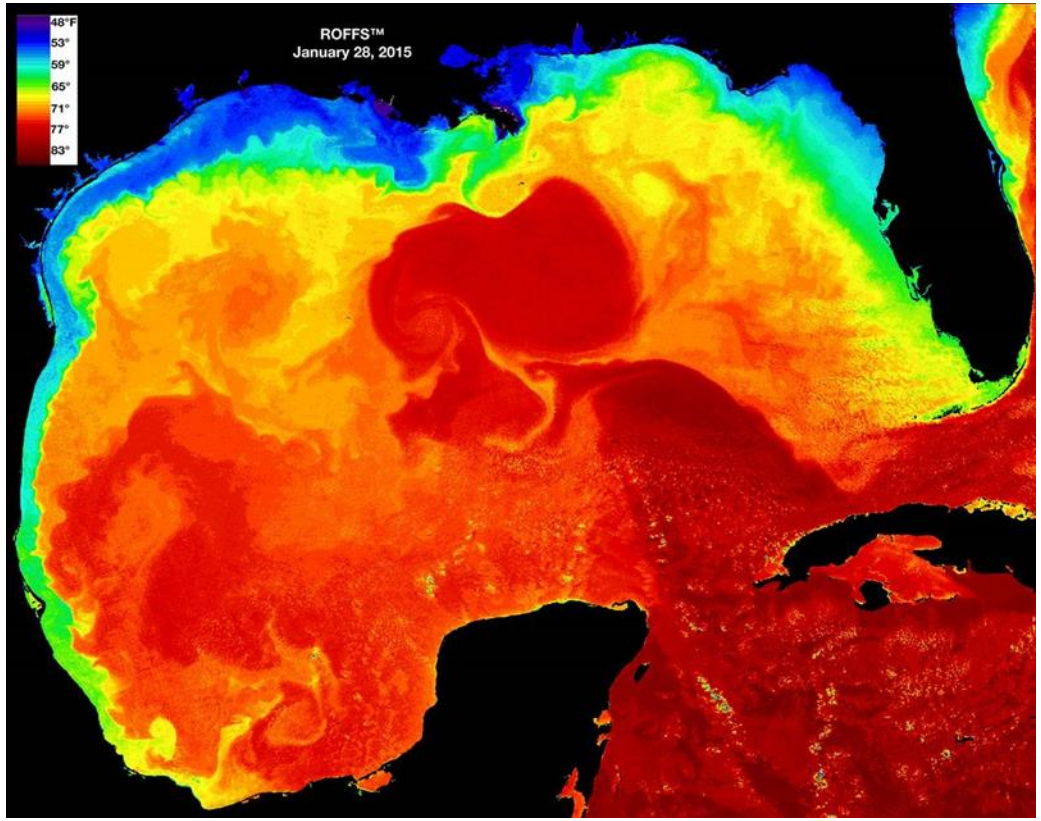






Summary

- Advice can be qualitative or quantitative, strategic or tactical
- Ecosystem models can contribute to single species assessment and management
- Particularly good at evaluating environmental perturbations
- Can aid in development of EBFM policies
- Tools are available now



Discussion Topics

How can ecosystem models help improve single species assessment and management?

What are the key management tradeoffs to be evaluated?

How can ecosystem models integrate into the management framework?

What are seen as major impediments?

Next steps…