NOAA FISHERIES

Perspectives on Modeling for EBFM

Howard Townsend, Ph.D.
NMFS Ecosystem Modeling Coordinator

SAFMC SSC
October 26, 2016

Overview

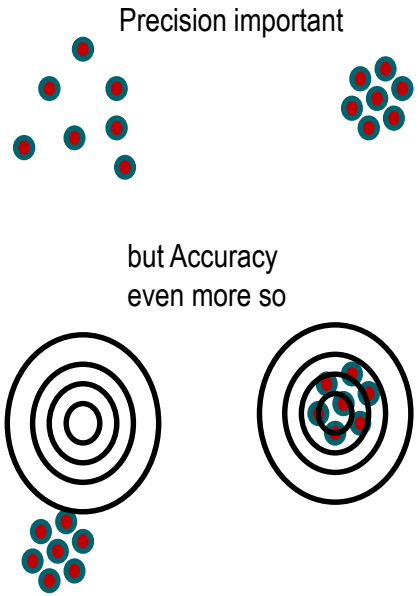
- Background on EBFM Road Map and the need for Ecosystem/Multi-species Models
- Where we've been
  - S&T efforts to coordinate Ecosystem Modeling
  - Science Center efforts to apply EM - highlights
- What's next for EM and EBFM
  - Broadly across NMFS
  - How we can help with SAFMC efforts

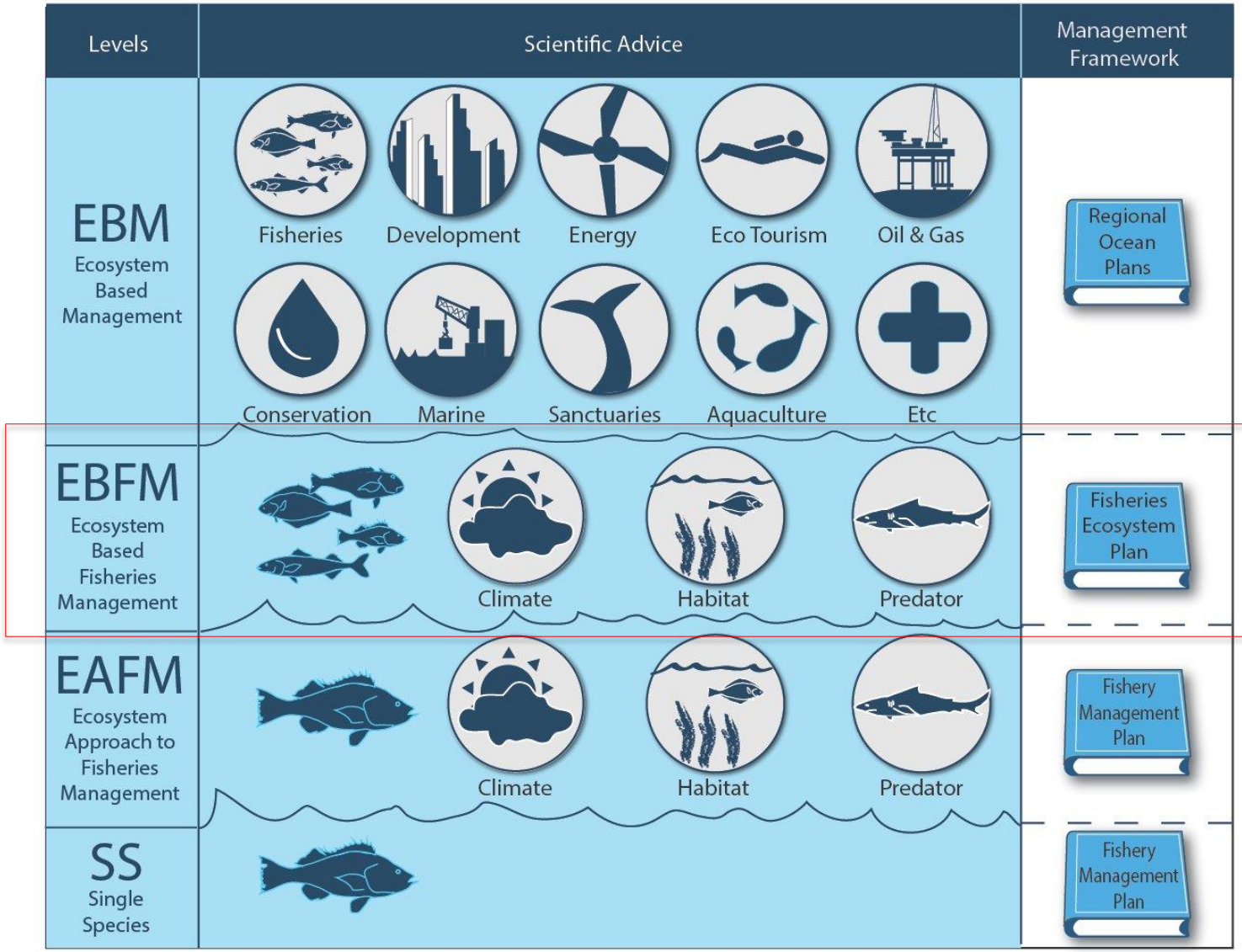
Background

EBFM Road Map and Ecosystem Modeling

Why EBFM

- Advice could suffer with Climate Change
- Triage & Prioritization
- Increased Stability
- Address Tradeoffs




Levels
Scientific Advice
Management Framework
EBM
Ecosystem Based Management
Fisheries
Development
Energy
Eco Tourism
Oil & Gas
Conservation
Marine
Sanctuaries
Aquaculture
Etc
Regional Ocean Plans
EBFM
Ecosystem Based Fisheries Management
Climate
Habitat
Predator
Fisheries Ecosystem Plan
EAFM
Ecosystem Approach to Fisheries Management
Climate
Habitat
Predator
Fishery Management Plan
SS
Single Species
Fishery Management Plan

Why an EBFM Road Map?

- Guides implementation of the Final EBFM Policy
- Incorporates the menu of options for implementation and benchmarks for NMFS

Key Questions:

- What does successful EBFM look like?
- What do we need for successful implementation of EBFM?
- How do we measure completion and success of EBFM?

Road Map

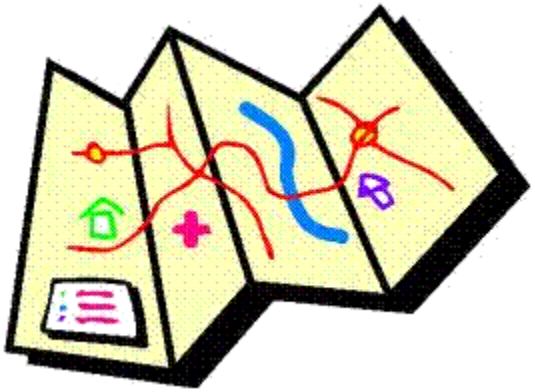
- Intended to build on current efforts
- Intended to guide the implementation of the EBFM Policy over the next 5-years
- Describes recommended Actions to address each of the Policy's six Guiding Principles for near-term work
- We will review our progress and revise road map after 5 yrs

6 Guiding Principles, with Core Components are:

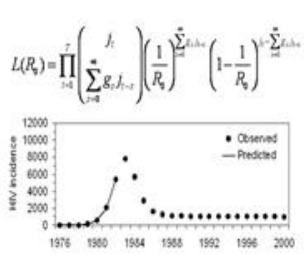
1. **Implement ecosystem-level planning**
- Engagement Strategy
- Fishery Ecosystem Plans
2. **Advance our understanding of ecosystem processes**
- Conduct Science to Understand Ecosystems
- Ecosystem Status Reports
3. **Prioritize vulnerabilities and risks of ecosystems and their components**
- Ecosystem-level Risk Assessment
- Managed Species, Habitats & Communities Risk assessment
4. **Explore and address trade-offs within an ecosystem**
- Modeling Capacity
- Management Strategy Evaluations
5. **Incorporate ecosystem considerations into management advice**
- Ecosystem-level Reference Points
- Incorporate Ecosystem Considerations for Living Marine Resources
- Systematic Advice for Other Management Considerations
6. **Maintain resilient ecosystems**
- Evaluate Resilience

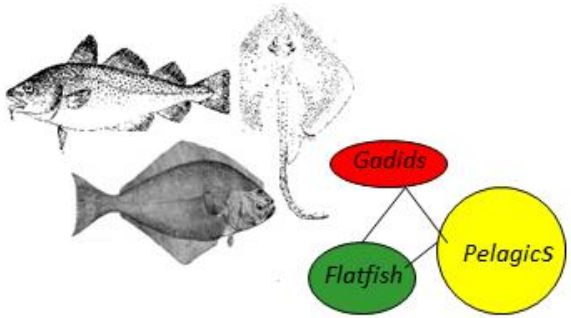
EBFM Road Map

- *2.4.a Analyze trade-offs for optimizing benefits from all fisheries within each ecosystem or jurisdiction, taking into account ecosystem-specific policy goals and objectives, cognizant that ecosystems are composed of interconnected components*



Ecosystem Modeling:
Living Marine Resource Management



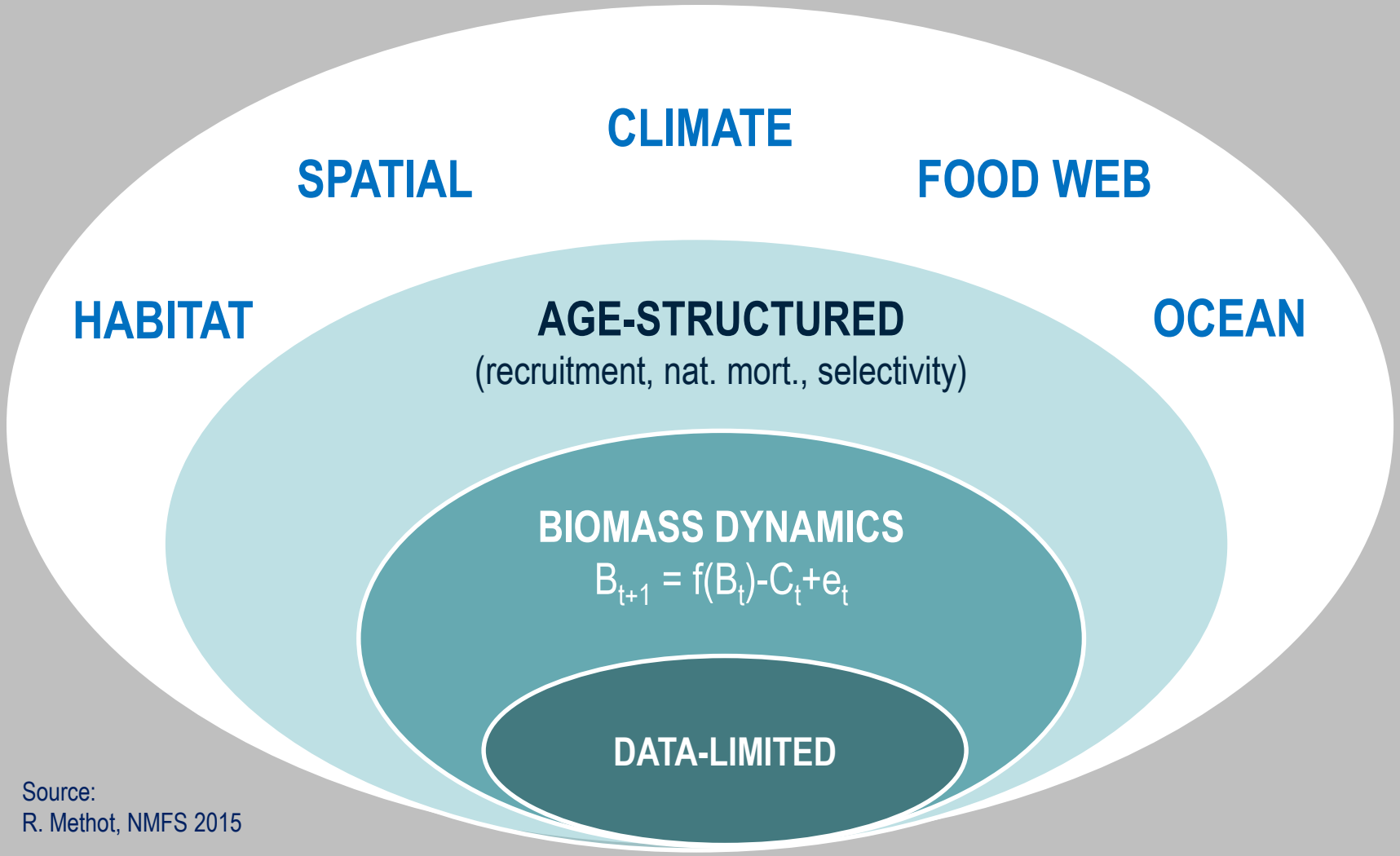


Data-limited Calculations | Biomass dynamics models | Age/Size Structured Models | Age/size Models w/ external factors | Multi-species Models | Biophysical Models | Aggregate Biomass Models | Food Web Models | Biogeo-chemical Models | Full System Models

Stock Assessment/Single Species Models

Ecosystem Assessment/Multi-species model

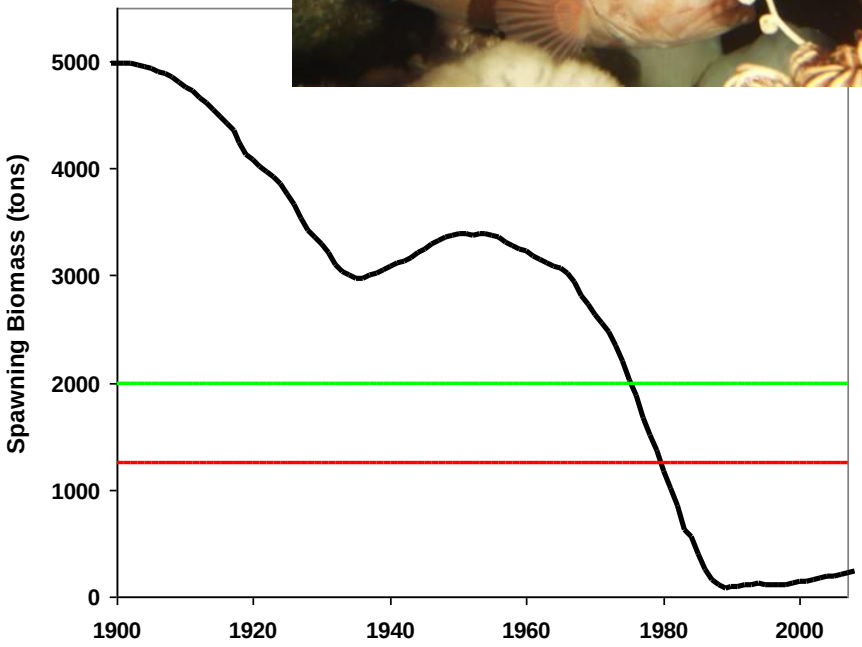
Onion of **Model Simplifications**



Source:
R. Methot, NMFS 2015

Single Species Models in Fisheries

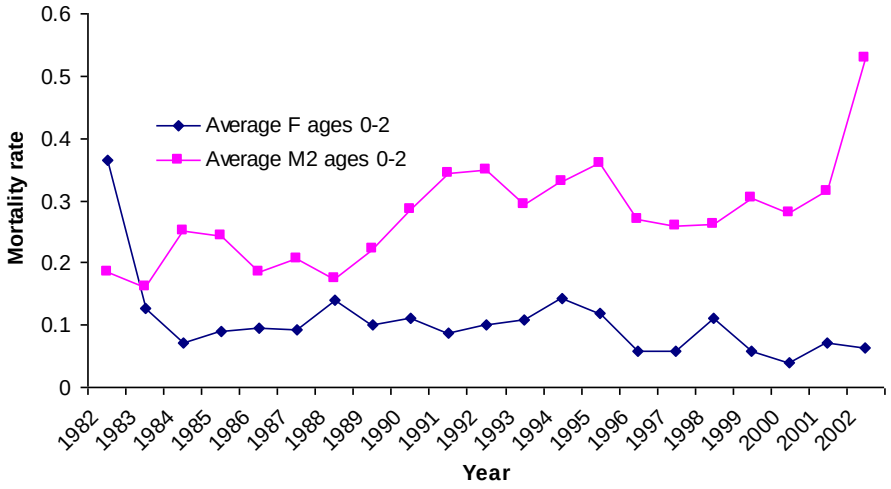
- **Intended Purpose:**
  - Assess the status of fishery stocks
- **Pros:**
  - Classical approach in fisheries
  - Well established models & approaches
- **Cons:**
  - "Precision v. Accuracy" issue- may miss other influencers on stocks
- **Data Needs:**
  - Standard- (i.e. landings, bycatch, survey abundance/biomass; maybe size/age structure)



Cowcod (*Sebastes levis*) stock assessment- a very data poor stock

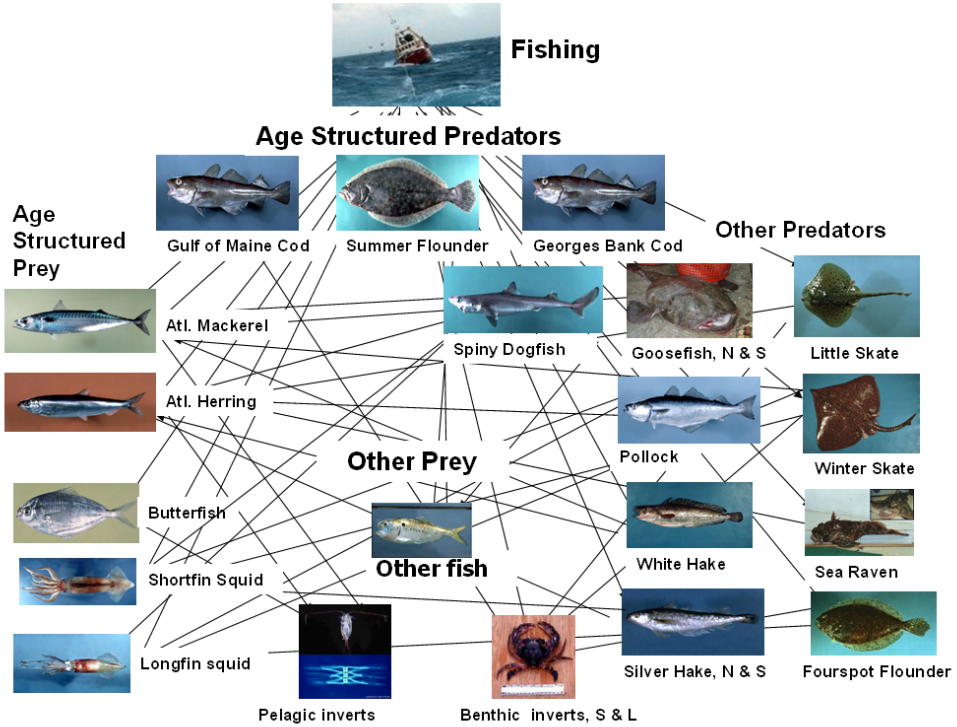
Single Species with Add-ons Models in Fisheries

- **Intended Purpose:**
  - Assess the status of fish stocks with additional factors added in
  - Aka MRMs
- **Pros:**
  - Enhanced biological/ecological/ environmental realism
  - Same model outputs as std fisheries models
- **Cons:**
  - Extra data requirements
  - Harder to insert into mgt process
- **Data Needs:**
  - Standard plus stomach or environmental



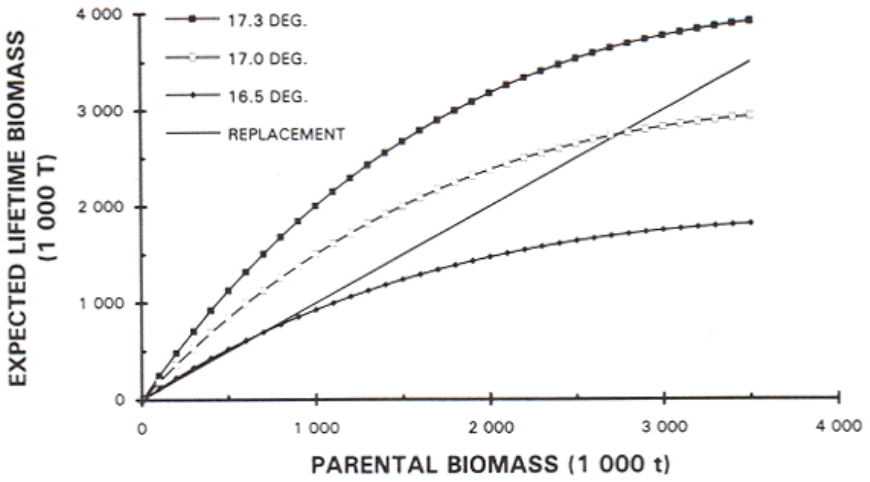
Multi-Species Models in Fisheries

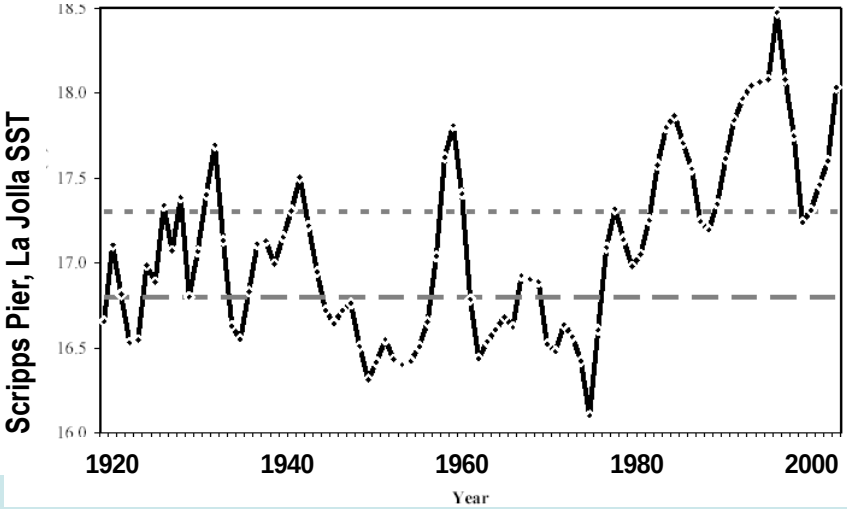
- **Intended Purpose:**
  - Assess the status of stocks simultaneously, usually with some form of interactions amor spp, gear, etc.
- **Pros:**
  - Improvement over MRMs as additional factors are modeled concurrently
  - Model outputs are still in familiar form
- **Cons:**
  - Functional form of several interactions debated
  - Even additional data requirements
  - May still miss other key factors
- **Data Needs:**
  - Standard plus stomach



Biophysical Models in Fisheries

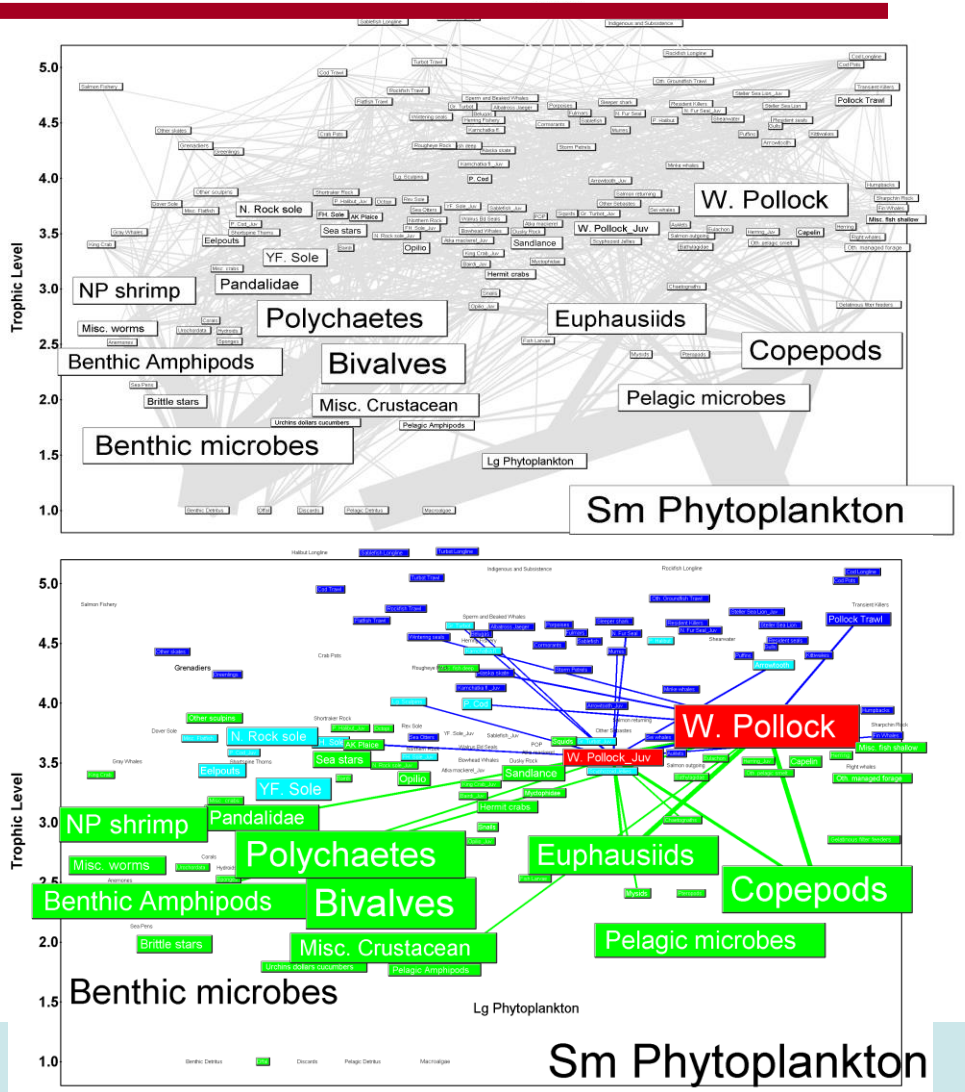
- **Intended Purpose:**
  - Evaluate how physical conditions alter stocks (more than SS add-ons)
- **Pros:**
  - Enhanced environmental realism
- **Cons:**
  - Often uncertain or solely correlative relationship between env. and stocks
  - How to handle model outputs
- **Data Needs:**
  - Physical oceanographic or limnological conditions
  - Known or estimated responses of fish to env. conditions





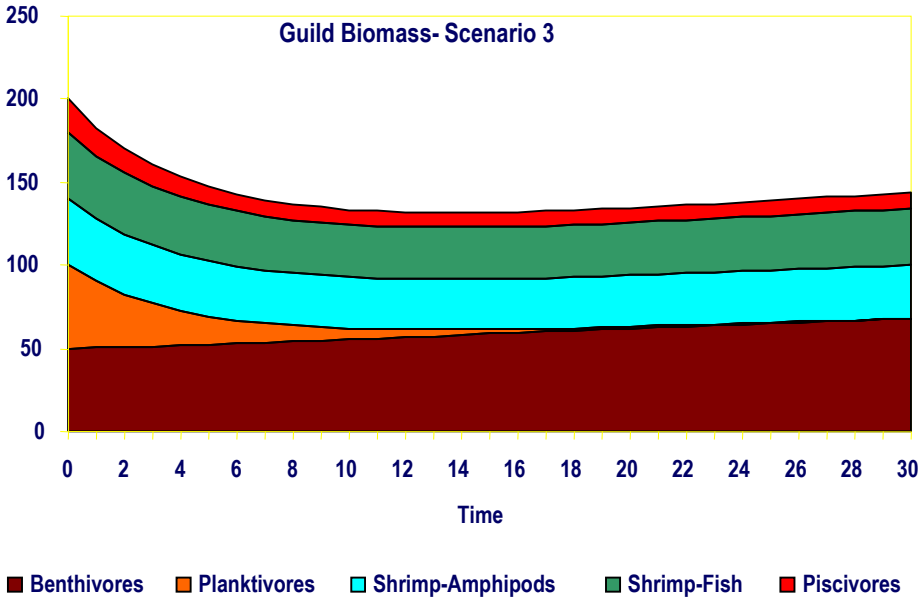
Food Web Models in Fisheries

- **Intended Purpose:**
  - Evaluate species interactions, energy flows, and network structure of system surrounding fishery stocks
- **Pros:**
  - Enhanced ecological realism
  - Establishes ability to address trade-offs among fisheries
  - Often serves as a catalog for future work
- **Cons:**
  - Transparency of models
  - Assumptions of functional forms
  - Model outputs atypical for historical fisheries context
- **Data Needs:**
  - Std plus stomach, many vital rates, many more taxa groups than just targeted spp
  - Flows among compartments and rates within compartments



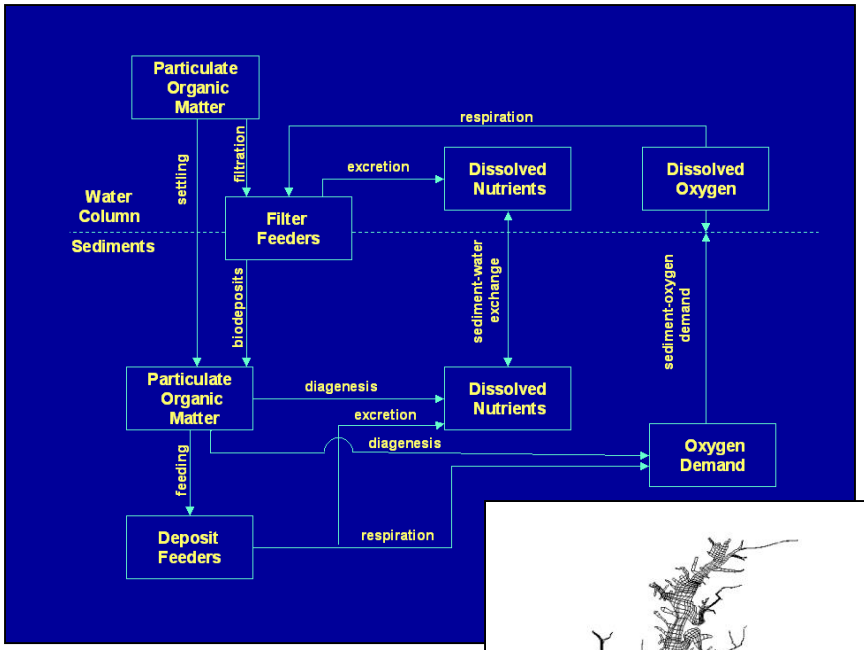
Aggregate Biomass Models in Fisheries

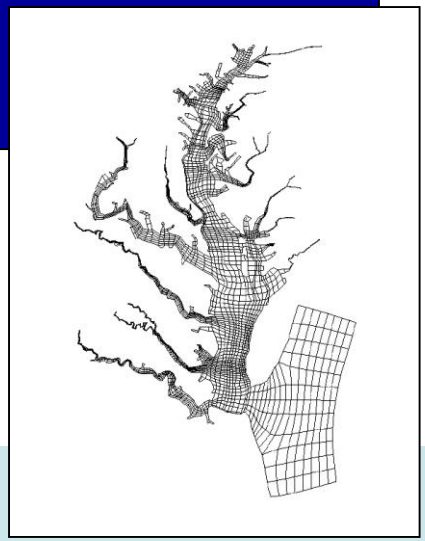
- **Intended Purpose:**
  - Assess the status of resources as major groups or clusters (e.g. guilds, taxa, etc.), not as individual stocks
- **Pros:**
  - Establishes ability to address trade-offs among fisheries
  - Built in precautionary approach
  - Model outputs are still in familiar, albeit aggregated, form
- **Cons:**
  - Minimizes stock specific information
  - Assumptions of amalgamated vital rate parameters across groups of diverse spp & life histories
- **Data Needs:**
  - Std, maybe some stomach, but clustered
  - Some flows among groups



Biogeochemical Models in Fisheries

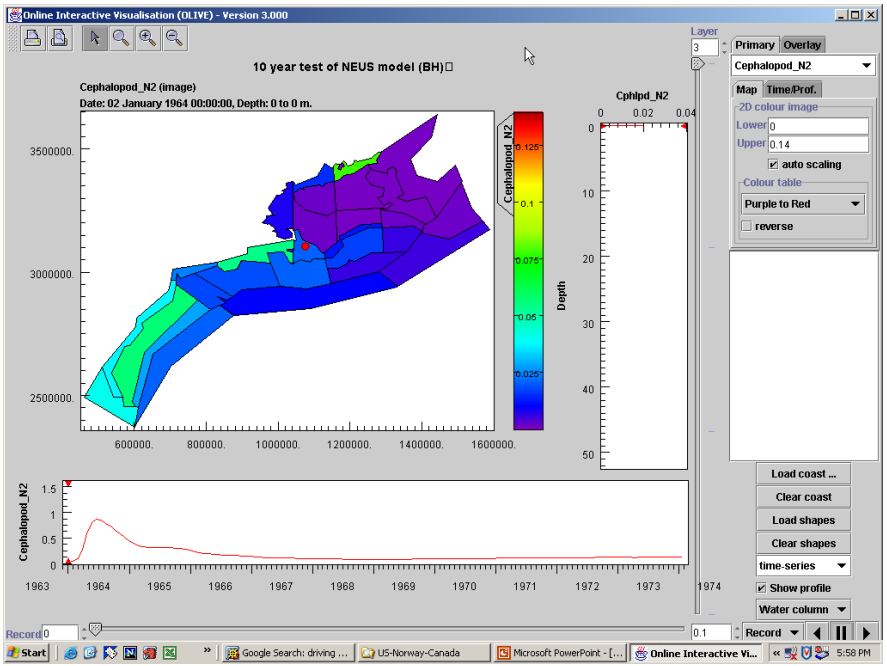
- **Intended Purpose:**
  - Evaluate fish in the context of broader material/elemental fluxes in a system
- **Pros:**
  - Places fish in broader systemic context
  - Particularly helpful for chemical (heavy metal or organic toxin) accumulation modeling
- **Cons:**
  - Not routinely used in typical fishery modeling contexts
- **Data Needs:**
  - Elemental composition, flows among compartments and rates within compartments





Full System Models in Fisheries

- **Intended Purpose:**
  - Evaluate fish in context of all the potential uses of an ecosystem
- **Pros:**
  - Inclusive of effectively every possible factor that can influence fish stocks
  - Excellent for strategic, multiple sector mgt
- **Cons:**
  - Models quickly become unwieldy
  - Multiple functional forms to choose from
  - Model outputs may or may not be familiar
- **Data Needs:**
  - Std plus stomach, many vital rates, many more taxa groups than just targeted spp
  - Flows among compartments and rates within compartments
  - Economic, socioeconomic and governance drivers



Ecosystem Modeling:

Living Marine Resource Management

The primary reason to use **Ecosystem Modeling (EM)** is to better account for ecosystem and systemic, cumulative features when providing advice for stock, protected resource, habitat or Integrated Ecosystem Assessments

- Application as operating models for Management Strategy Evaluation and skill assessment.
- Application of a range of models for multiple model inference to deal with uncertainty
- Application for risk assessment and trade-off evaluation in a bioeconomic context.

Levels of Information Use in Fisheries Mgt

- Heurism
- Tactical
- Strategic

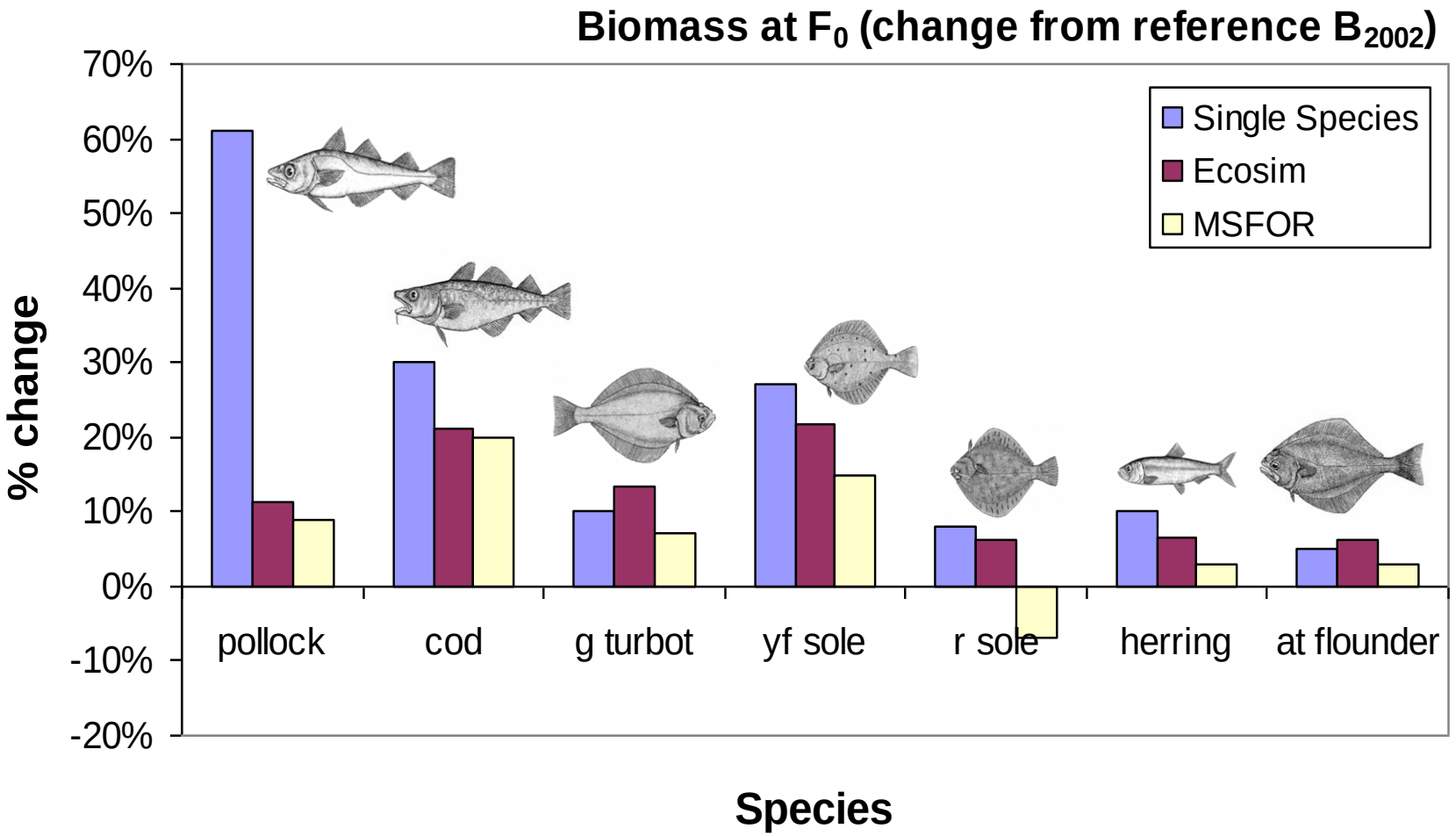
Heurism

- Understanding Ecosystem Functioning
- Relative Importance of Different Processes
- Advancing Scientific Theory

Tactical Management

- Revised Stock Assessments
  - Yield Adjustments
  - Altered Biological Reference Points, etc.
- Specific Impacts on Non-Target Species, Habitat
- Specific “What If” Scenarios and Gaming
- BINDING IN SCOPE

What difference does it make? Tactically: BRPs



From Aydin et al

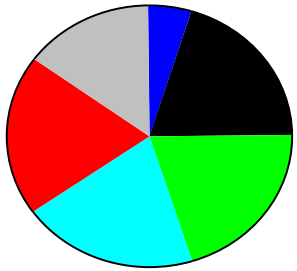
Strategic Management

- Assessing Biomass Tradeoffs
  - System Level Emergent Properties & RPs
  - Evaluating Alternate Stable States
- Cumulative Impacts on Non-Target Species, Habitat
- General “What If” Scenarios and Gaming, Long Term Trends
- BOUNDING IN SCOPE

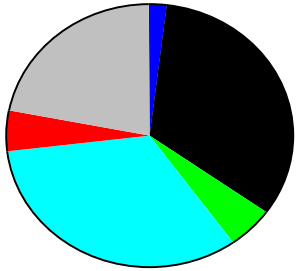
What difference does it make? Strategically: Tradeoffs

$$\sum MSY_{SS} > MSY_{System}$$

Option 1-
Balance

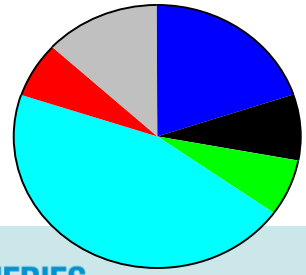


Option 2-
GB Now

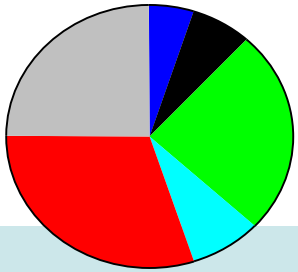


- Mammals
- Elasmobranchs
- Groundfish
- Pelagics
- Decapods & Molluscs
- Junk Fish

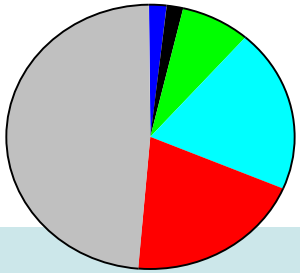
Option 3-
Whale Hugger



Option 4-
GB 1950s



Option 5-
Rape & Pillage



Where we've been

S&T and Science Center Efforts to Apply EM

(Finding) NEMoW

A proposal for a:

National Ecosystem Modeling Workshop

Jason Link, Howard Townsend, Kerim Aydin

EM Coordination Efforts To Date

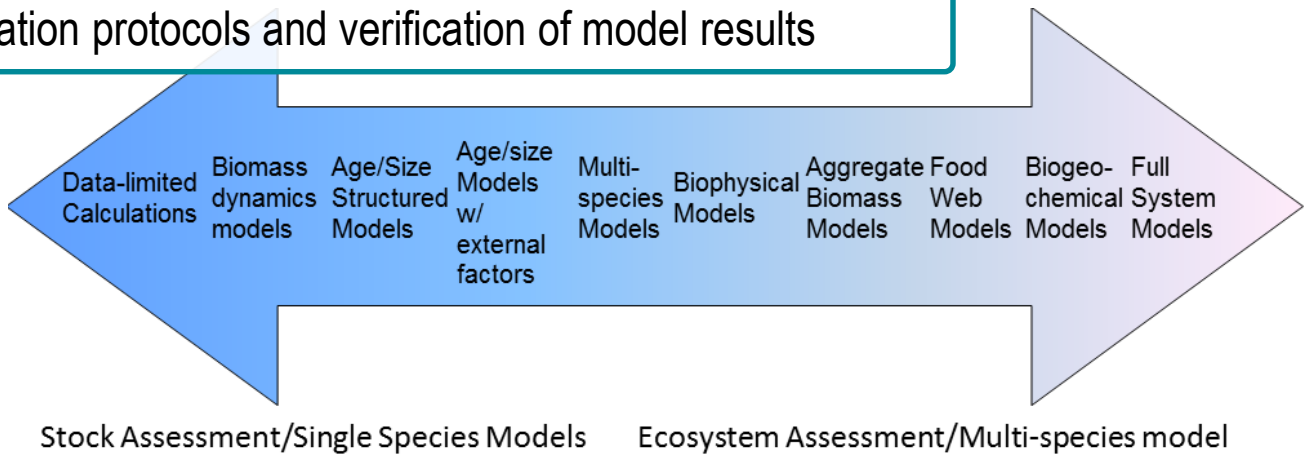
Primarily effort
has been through National Ecosystem Modeling Workshops (NEMoWs) in 2007, 2010, 2014, and 2017.

NEMoW was designed as a NMFS-wide, national workshop to examine NMFS ecosystem, bio-physical and multispecies modeling approaches to explore the establishment of ecosystem modeling standards of use and review for living marine resource management applications.

1st National Ecosystem Modeling Workshop

Initiate development of a standardized approach
for EM across NMFS and examine:

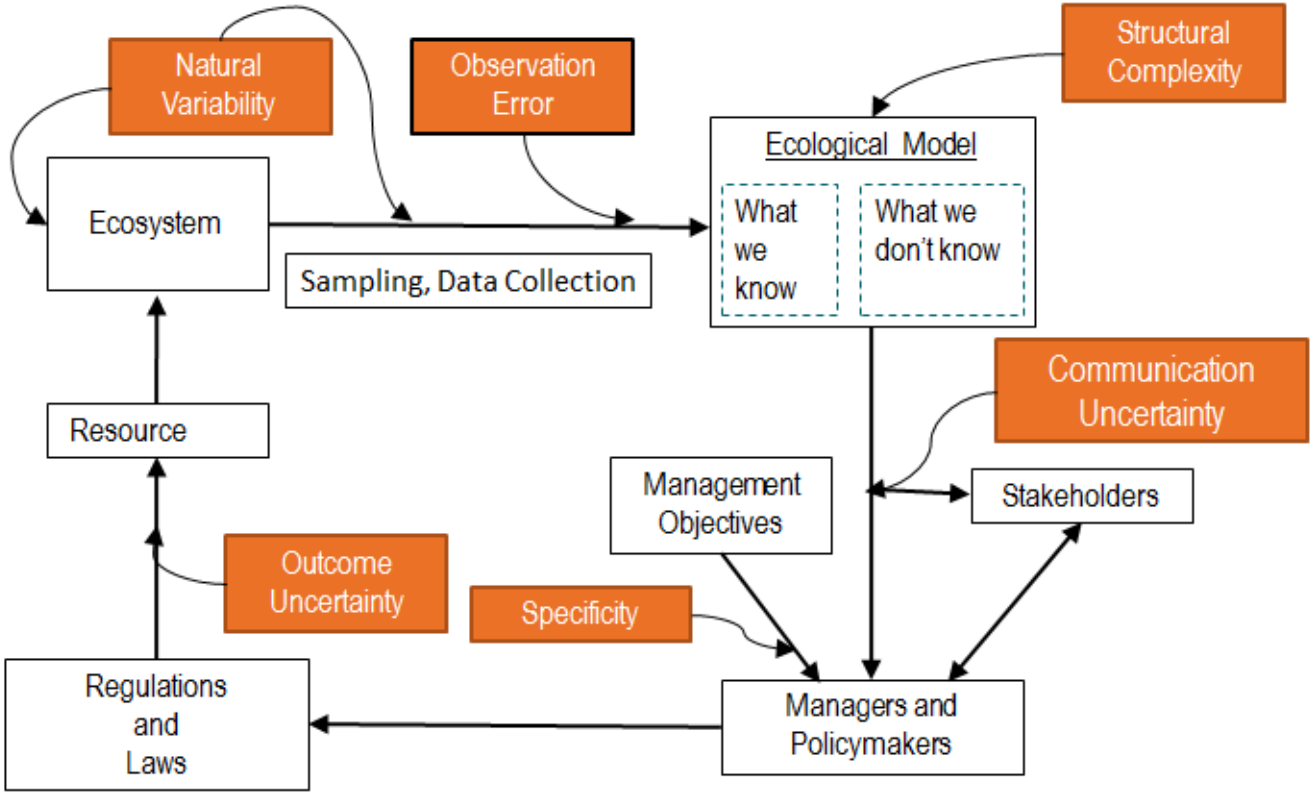
- Software packages
- Recommendations for use and data requirements
- Parameterization protocols
- Validation protocols and verification of model results



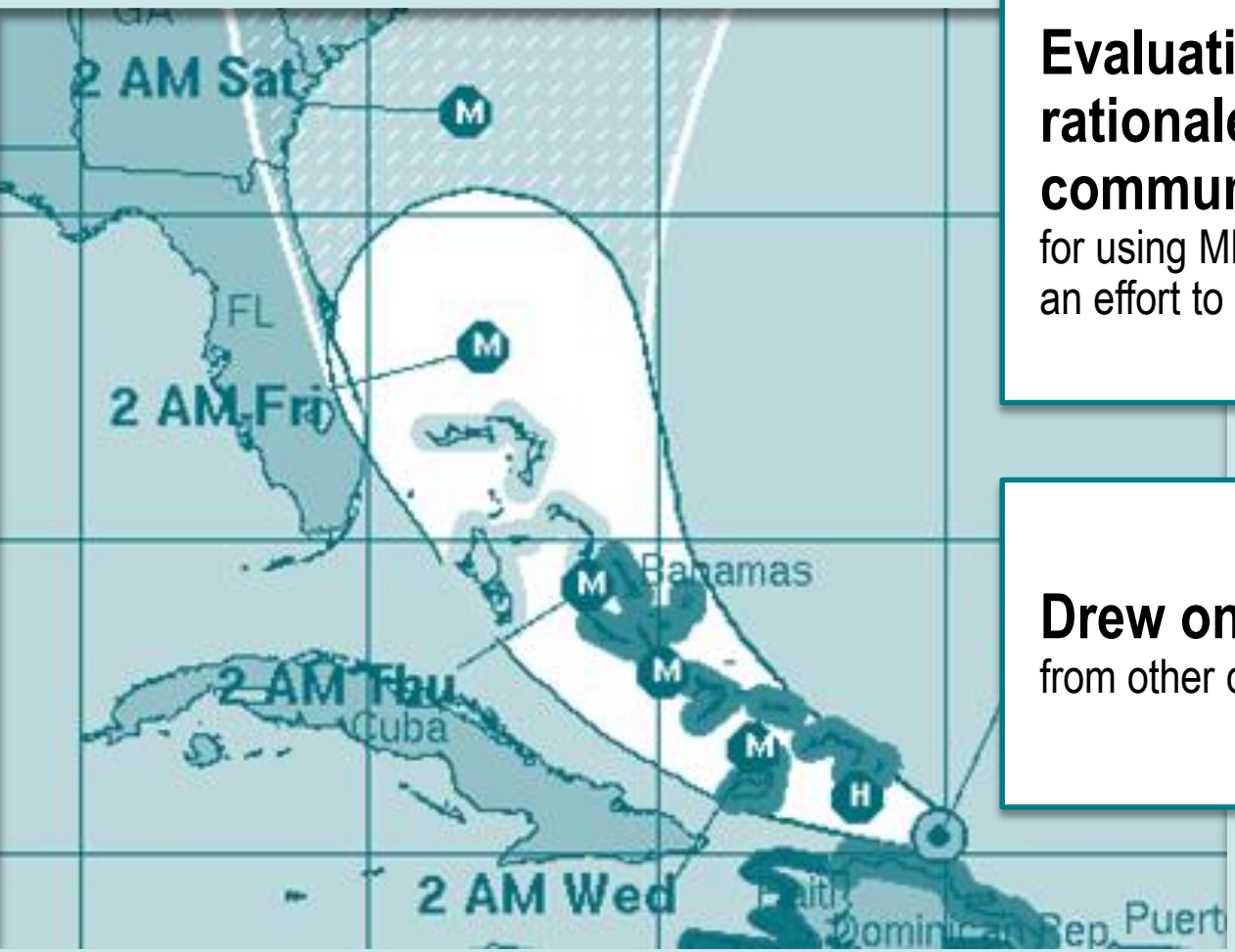
NEMoW 2 – Dealing with Uncertainty

Key for EMs to be used

in providing ecosystem-based LMR management advice is to ensure that all stakeholders, reviewers, managers and scientists using them have full confidence in what the models are doing in general and that the models have been applied appropriately in specific instances.



NEMoW 3 - Multiple Model Inference



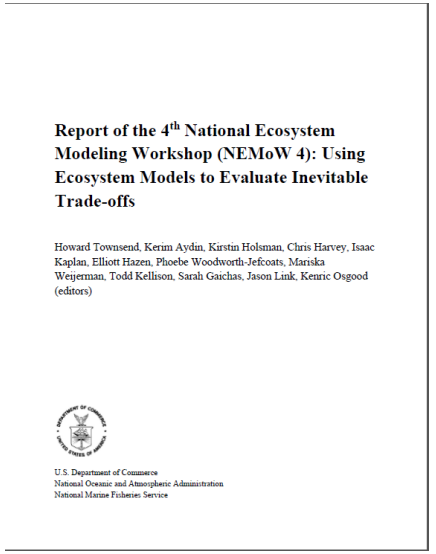
Evaluating methods, rationales, and communication methods
for using MMI in an LMR context in an effort to reduce uncertainty

Drew on expertise
from other disciplines

National Ecosystem Modeling Workshop 4

Evaluate best practices for using ecosystem models to address trade-offs inherent in ecosystem-based management of living marine resources

- Outline and review trade-offs being addressed
- Review common novel tools for modeling and communicating trade-offs
- Understand management implications for trade-offs
- Summarize best practices for addressing trade-offs using EM



Report of the 4th National Ecosystem Modeling Workshop (NEMoW 4): Using Ecosystem Models to Evaluate Inevitable Trade-offs

Howard Townsend, Kerim Aydin, Kirstin Holsman, Chris Harvey, Isaac Kaplan, Elliott Hazen, Phoebe Woodworth-Jefcoats, Mariska Weijerman, Todd Kellison, Sarah Gaichas, Jason Link, Kenric Osgood (editors)

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Major Recommendations from NEMoWs

Formally support/expand dedicated EM efforts at Centers

Adopt a National Standards of EM use

Establish regular NEMoWs

Identify and note sources of EM uncertainty as a must for EM use and review

Adopt Multiple Model Inference (MMI) best practices

Perform simulation studies to evaluate the skill of models to be used for MMI

Engage with stakeholders early and often

Major Outcomes from NEMoWs

Networking and swapping
of best practices

Vehicle to advance
ecosystem modeling and ecosystem-oriented efforts

During NEMoW
1, 2 out of 7 Centers (and Habitat Conservation Office) had **dedicated EM efforts/groups**, there are now 4.5(+) out of 7 such groups

At least 3 centers have had formal review
of ecosystem models so that Councils can use the EMs

Goals for Ecosystem Modeling Coordination

Conduct science to understand ecosystems

- Modeling the processes, drivers, threats, status, and trends of our ecosystems

Explore and address trade-offs within an ecosystem

- Establish sufficient EBFM modeling capacity to analyze trade-offs
- Develop Management Strategy Evaluation capabilities to better conduct ecosystem-level analyses to provide ecosystem-wide management advice

Incorporate ecosystem considerations into management advice

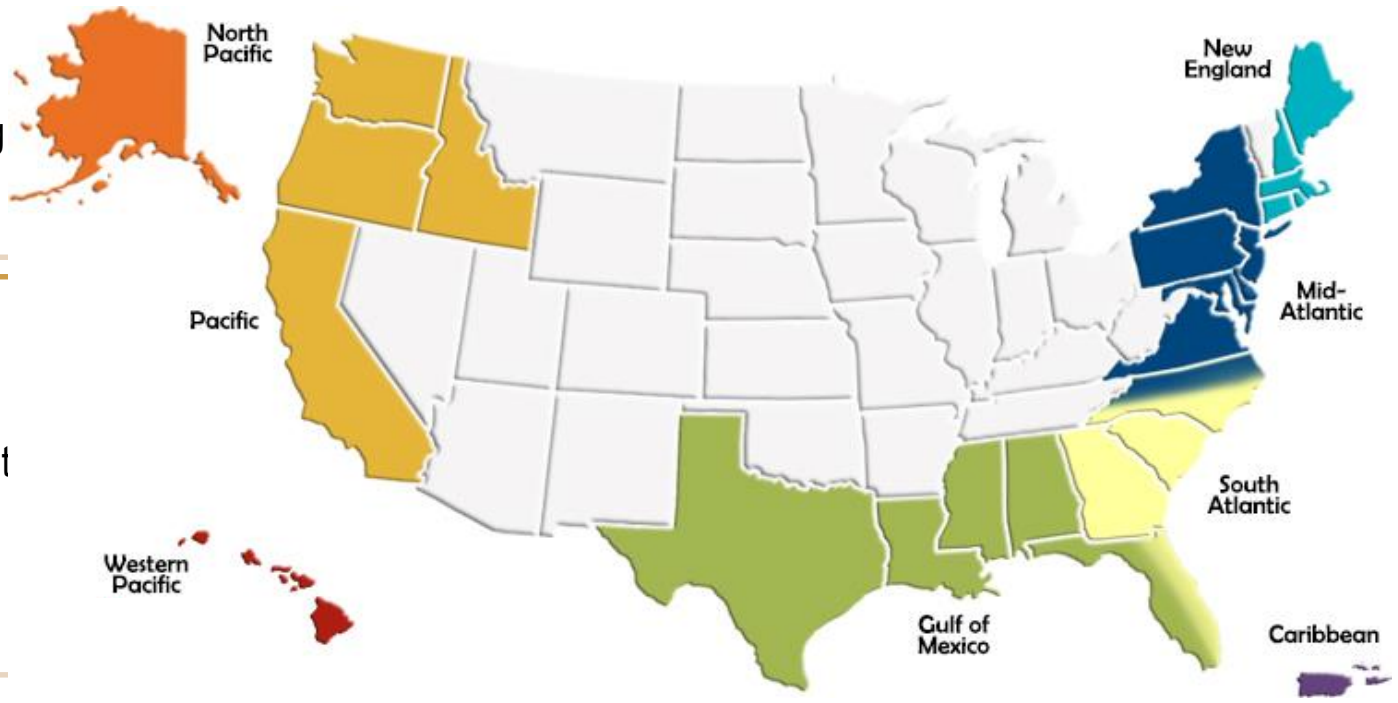
- Develop and monitor Ecosystem-Level Reference Points
- Incorporate ecosystem considerations into appropriate LMR assessments, control rules, and management decisions
- Provide systematic advice for other management considerations, particularly applied across multiple species within an ecosystem

Integration and Addressing Needs

MAJOR GOALS OF ECOSYSTEM MODELING COORDINATION

1 **Ensuring Centers have adequate capacity** for developing and applying models.

2 **Ensuring uptake** by regional management bodies.

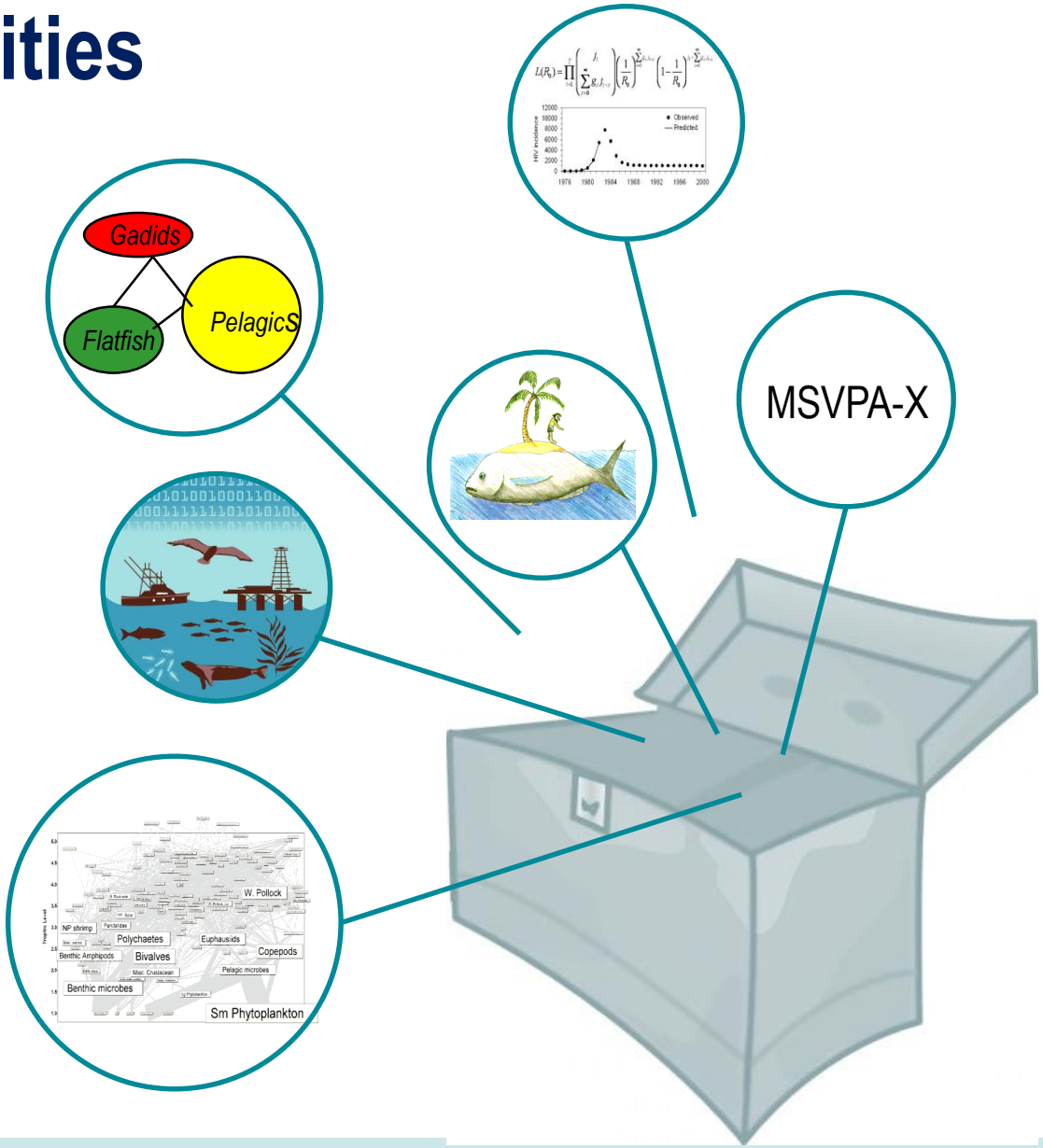


Addressing Priorities

Cataloging
EM activities
at Centers

Consulting
with Centers
on EM priorities

Developing Toolbox
so models can be
more readily
applied and reviewed




Regional Offices
Science Centers
Laboratories
LMEs
Fishery Management Councils
State Fisheries Commisions
US EEZ
AkSRG
NP
PaSRG
PS
P
Territories
WP
Antarctica
NE
MA
AS
GS
SA
AtSRG
GM
Ca

Ecosystem models by region

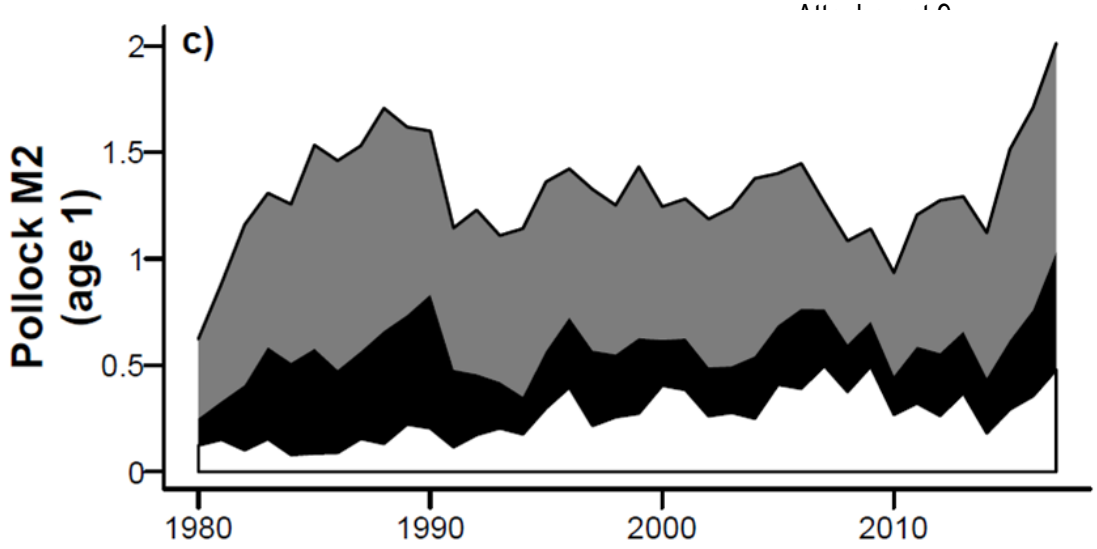
	EBS	GOA	AI	ARCTIC
ROMS/NPZ	*	o		?
Enhanced assessment	*	*	*	
Food web	*	+	+	o
Multispecies statistical	*	?	o	
FEAST-spatial	+			
Size Spectrum	o			
Qualitative network	o	o		

* Annual or biennial part of assessment, requested or required by Council.

+ Up-to-date for providing issue-specific advice.

O Under active development.

? Proposed.



SSC Comments – December 2016

"There are several reasons that justify taking a precautionary approach when setting the ABC […] Our current understanding of pollock early life dynamics suggests that recent survival from age-0 to age-1 may be low due to low availability of suitable prey. **Combined with increased predation, as suggested by the multi-species model CEATTLE** and other evidence, strength of the 2015 and 2016 year classes is expected to be lower than average."

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Alaska CLIMate Project

Anne Hollowed (AFSC, SSMA/REFM)
Kirstin Holsman (AFSC, REEM/REFM)
Alan Haynie (AFSC ESSR/REFM)
Stephen Kasperski (AFSC ESSR/REFM)
Jim Ianelli (AFSC, SSMA/REFM)
Kerim Aydin (AFSC, REEM/REFM)
Trond Kristiansen (IMR, Norway)
Al Hermann (UW JISAO/PMEL)
Wei Cheng (UW JISAO/PMEL)
André Punt (UW SAFS)

FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity

IPCC Scenarios (x3)

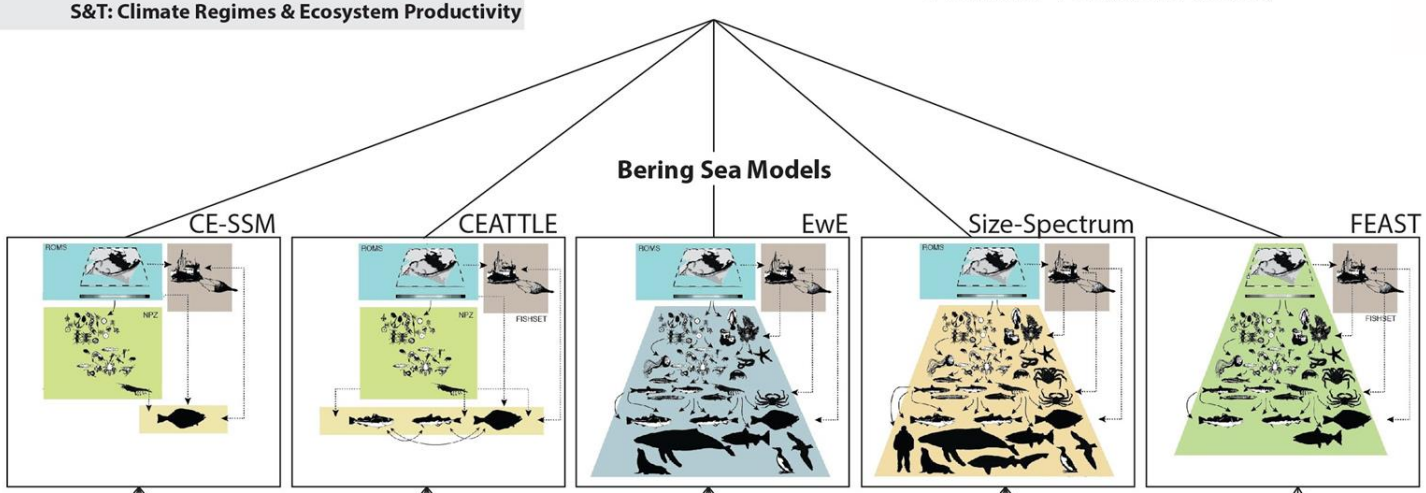
AR4 A1B
AR5 RCP6.0
AR5 RCP8.5

Global Climate Models (x 11)

ECHO-G (AR4 A1B)
MIROC3.2 med res. (AR4 A1B)
CGCM3-t47 (AR4 A1B)
CCSM4-NCAR- PO (AR5 RCP 6.0 & 8.5)
MIROCESM-C- PO (AR5 RCP 6.0 & 8.5)
GFDL-ESM2M*- PO (AR5 RCP 6.0 & 8.5)
GFDL-ESM2M*- PON (AR5 RCP 6.0 & 8.5)

Future Climate Scenarios

Bering Sea Models



multiple non-linear pressures

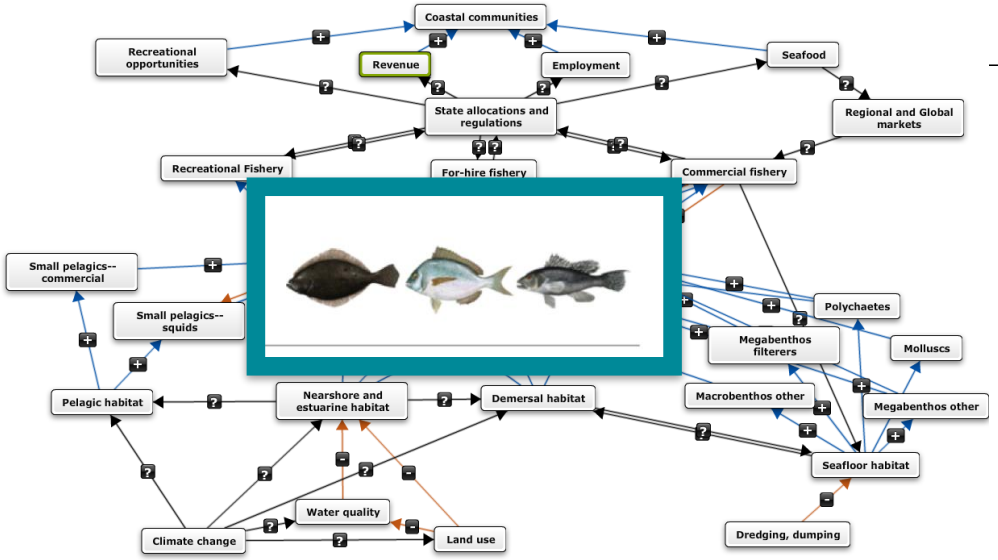
multiple non-linear interacting pressures

Climate-enhanced Biological Models

Fishing Scenarios

NEFSC: Multispecies/Ecosystem Models

Model name	Reference	Development
MS-PROD	Gamble and Link 2009, Gaichas et al. 2012	Published
Kraken	Gamble et al. In Prep, based on Gamble and Link 2009	Ongoing, Performance testing initiated
MS Delay Difference	In prep	Ongoing, Performance testing initiated
MS Statistical Catch-at-age	Curti et al. 2013	Published
MSVPA-X	Tyrell et al. 2008, Garrison et al. 2010	Published
Qualitative Network Model	DePiper et al accepted	Ongoing
EMAX	Link et al. 2006, 2007, 2008, 2009	Published
Rpath	Lucey et al. In Prep	Ongoing, Parameterizing GB
Hydra	Gaichas et al 2016, based on Hall et al. 2006	Ongoing
Atlantis	Link et al. 2010, 2011	V1.0 published, v1.5 in development



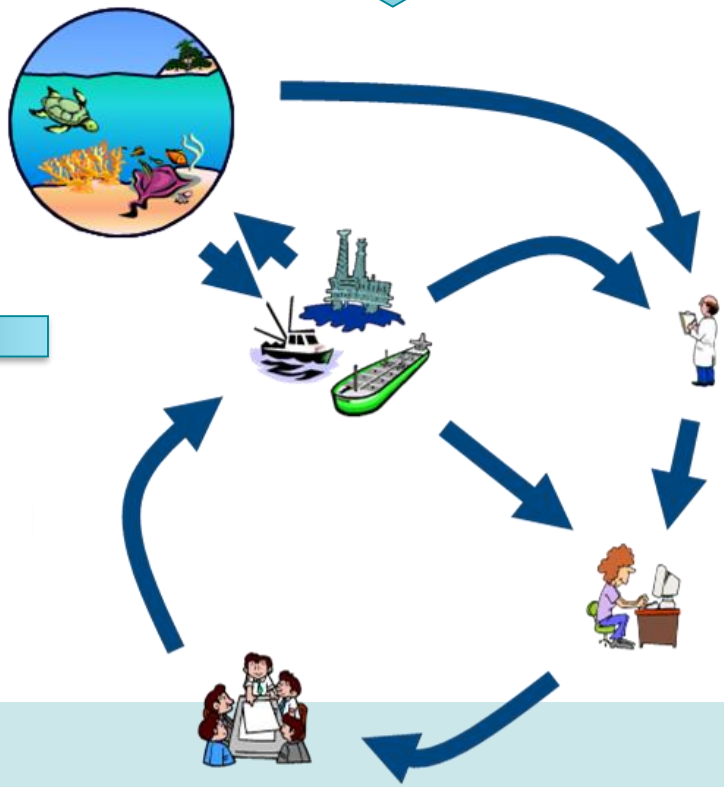
Council/stakeholder process
Specifies MSE objectives,
Performance measures,
Range of strategies

Scientists develop tools

Council Decision Support:

- **Tradeoffs** between objectives
- Potential management strategy **performance** considering
  - key interactions
  - risks
  - uncertainties

Performance measures

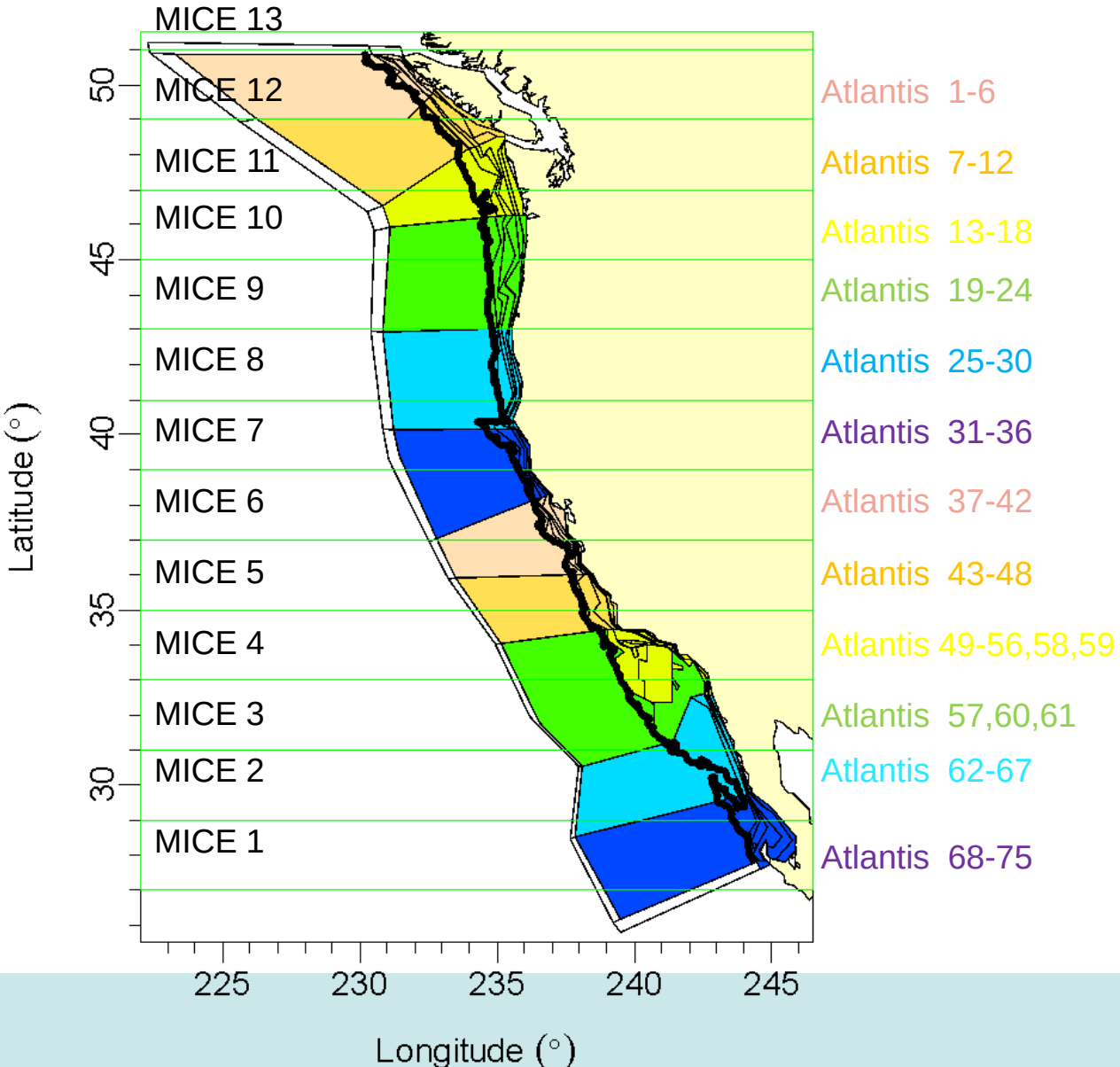


NWFSC: Multi-model approach: MICE, Atlantis, and Ecopath

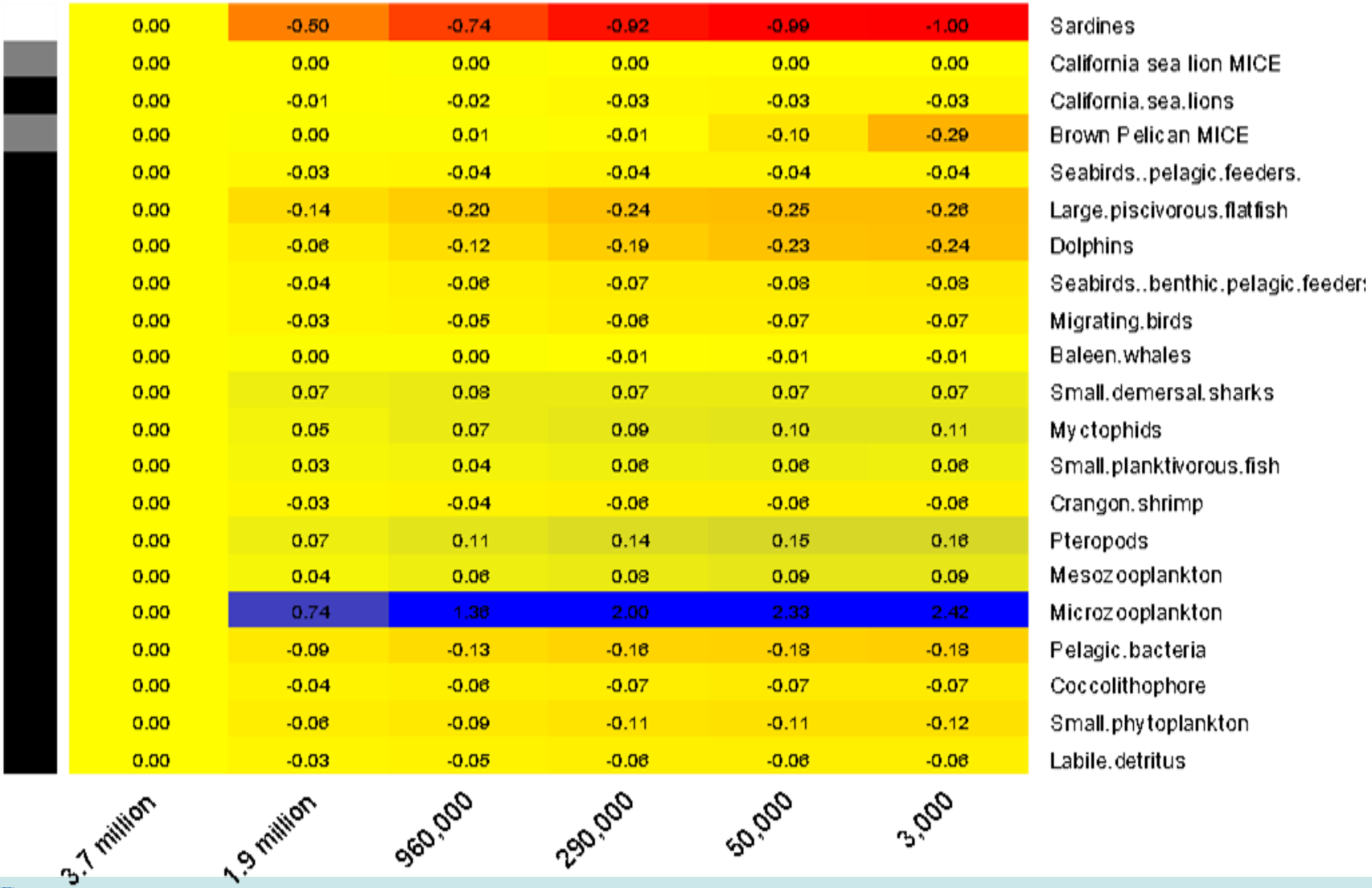
MICE *bins are divisions from 27-53N at 2 degrees of latitude.*

Atlantis *polygons are assigned to MICE latitudinal bins.*

EcoPath *domain: 2000 m isobath*

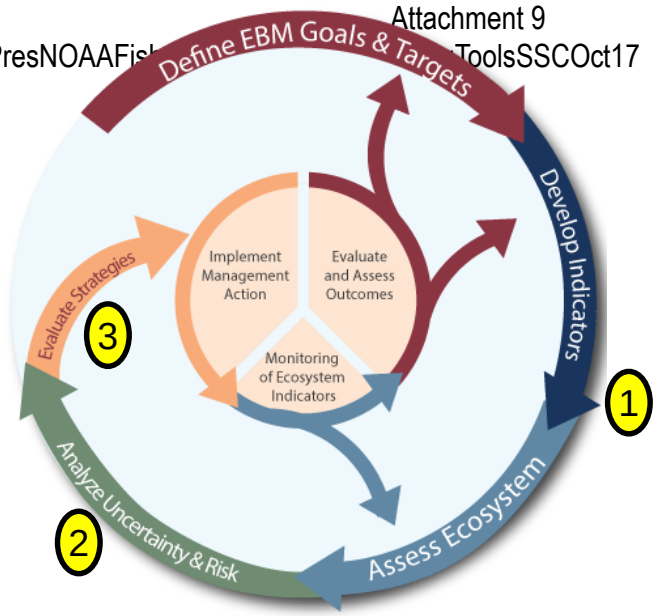


Models predict impacts on brown pelican; lesser impacts on sea lions; model structure dictates strength of response

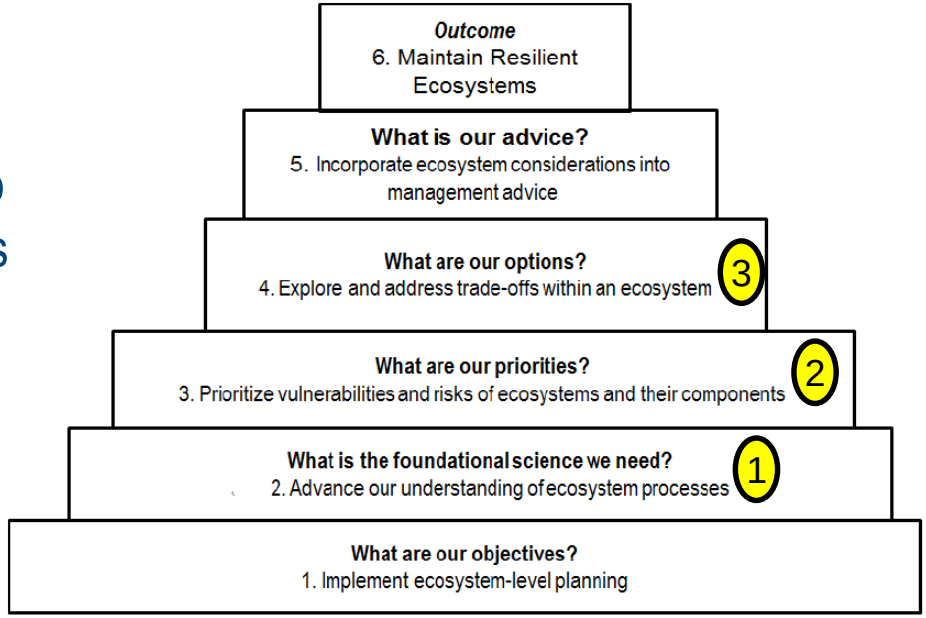


Using Ecosystem Models in EBM: Aims at NWFSC

- Ecosystem models can inform the IEA process (loop at upper right) and support NOAA EBFM efforts (pyramid at lower right) by:

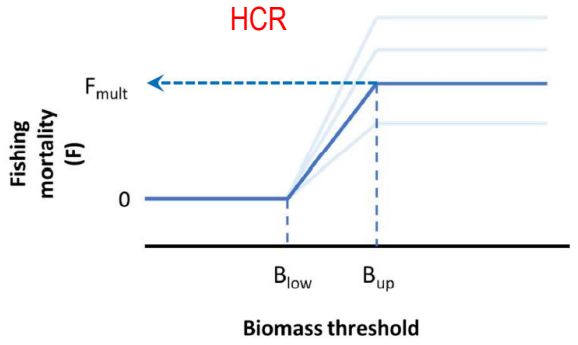


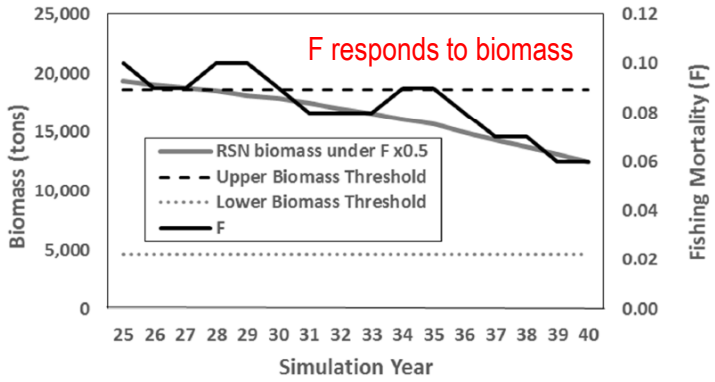
1. Synthesizing available data to help us understand and assess system dynamics
2. Scenario tests of the risk of key species to top-down or bottom-up mediated stressors
3. Scenario tests of the effectiveness and tradeoffs of management strategy alternatives

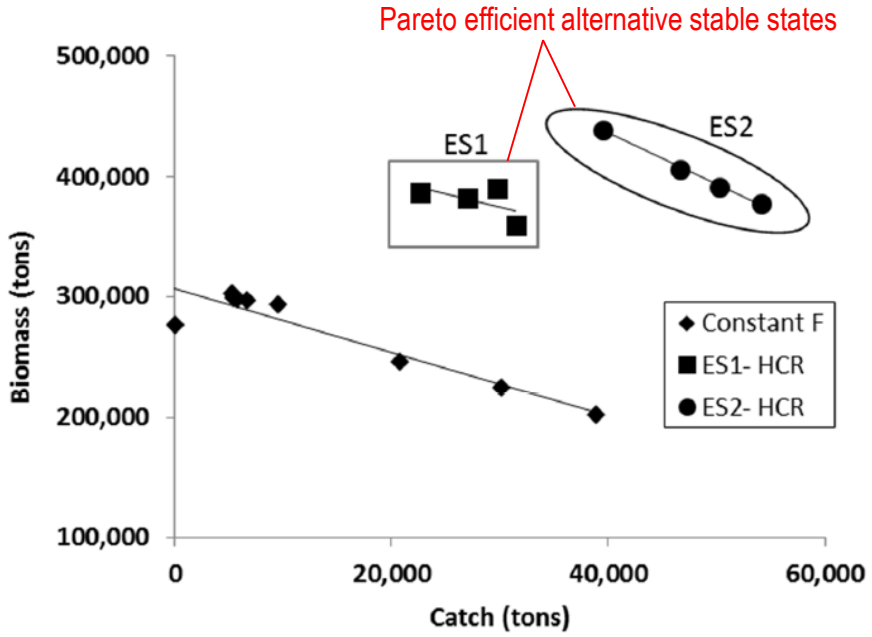


SEFSC/Gulf of Mexico MSE (Masi et al. In review)

- Compared 2 point harvest control rule with constant F
- Closed-loop management strategy evaluation
- HCR more Pareto efficient tradeoff; higher biomass, catch & biodiversity

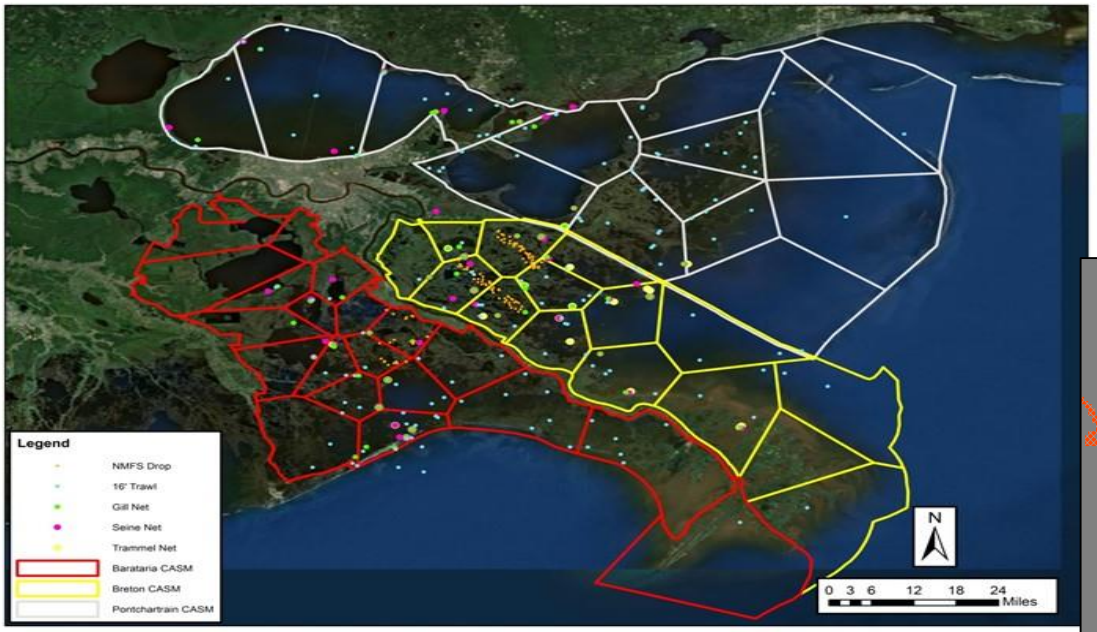






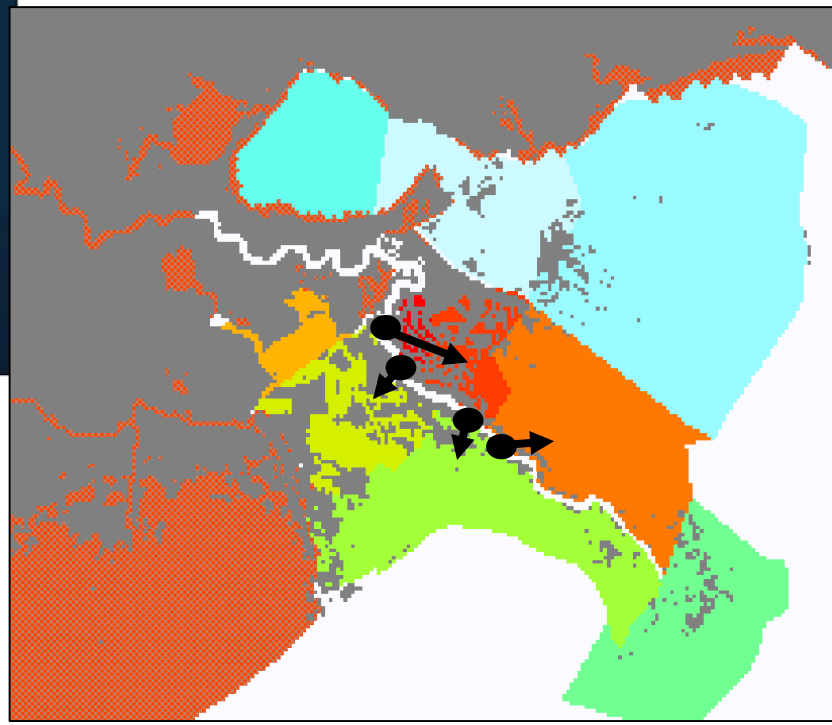
Masi, M., Ainsworth, C., Kaplan, I., Schirripa, M. Evaluation of robust single-species harvest control rules for managing reef fish in the Gulf of Mexico. Mar. Coast. Fish. (in review)

Coastal Louisiana Restoration – Multiple Ecosystem Models



Complex Aquatic System Model (CASM)

Ecopath with Ecosim (EwE)/Ecospace



Source: Sable – Dynamic Solutins, LLC ; de Mutsert - GMU

Where we've been

S&T and Science Center Efforts to Apply EM

Where we've been

S&T and Science Center Efforts to Apply EM

Where we're going with Ecosystem Modeling

- MSEs
- Quantitative tradeoff evaluations
- ELRPs
- Standardized tools, more operational use

- c.f. EBFM Road Map

Strengths

Strong ecosystem modeling programs at some Centers

NEMoW: History of collaborative and collegial interactions across Centers

Clear direction and goals in the EBFM Road Map

Broad Challenges and Possible Solutions

Challenges	Possible Solutions
Not all Centers have dedicated EM staff or Models in place to meet LMR management needs	Staff; S&T EM coordinator collaborations; coordination with existing programs
Few Councils and Regional Management Bodies have used EM for decision-making	**Focused effort** on developing ecosystem-level reference points; Development of FEPs; NEMoW to swap ideas on application & operational EMs to address LMR issues
Lack of standard peer-review process for EM	**Development** of EM Toolbox and review guidelines for tool

SA EwE Model is proceeding well

- Larger holistic ecosystem model, like EwE, can be useful for organizing the big picture of the ecosystem, answer heuristic and strategic questions, and "hanging" new data and research on
  - other more specific models may be more useful for specific tactical questions (Ecosystem Modeling Workgroup)
- Modeling for EBFM should be a guided by an iterative, two-way flow – often includes ecosystem “stuff” besides models (e.g., Ecosystem Status Reports)

As the SA EM efforts moves forward…

- NMFS can help with
  - Support from NMFS Ecosystem Modeling Coordinator
  - Draw on expertise from NMFS Science Centers
  - Assistance with EM model review
  - Other items in the EBFM Road Map