# Short-term forecasts of species distributions for fisheries management

Mid-Atlantic Fishery Management Council Meeting
April 4, 2023
Durham, North Carolina


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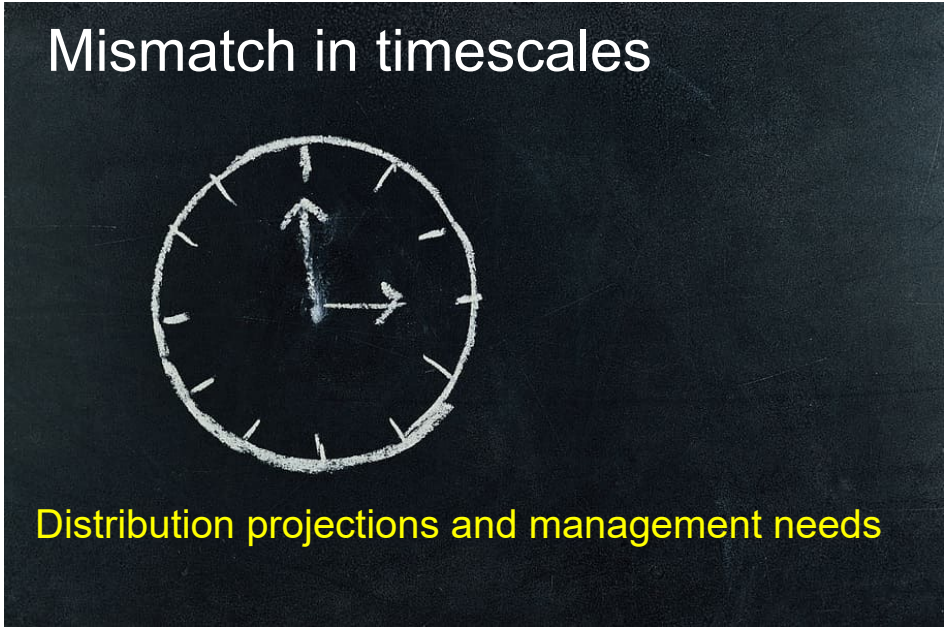
# Presentation Outline

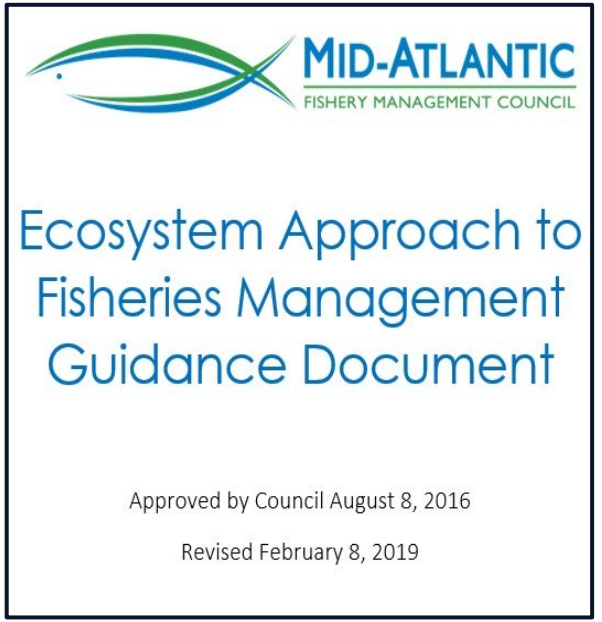
- Project Need & Goals
- Model Approach & Development
- Preliminary Results & Outputs
- Areas of Potential Management & Science Application
- EOP Committee, AP & SSC Feedback
- Council Discussion



# EAFM Guidance Document

## Example Climate-Related Policies and Recommendations

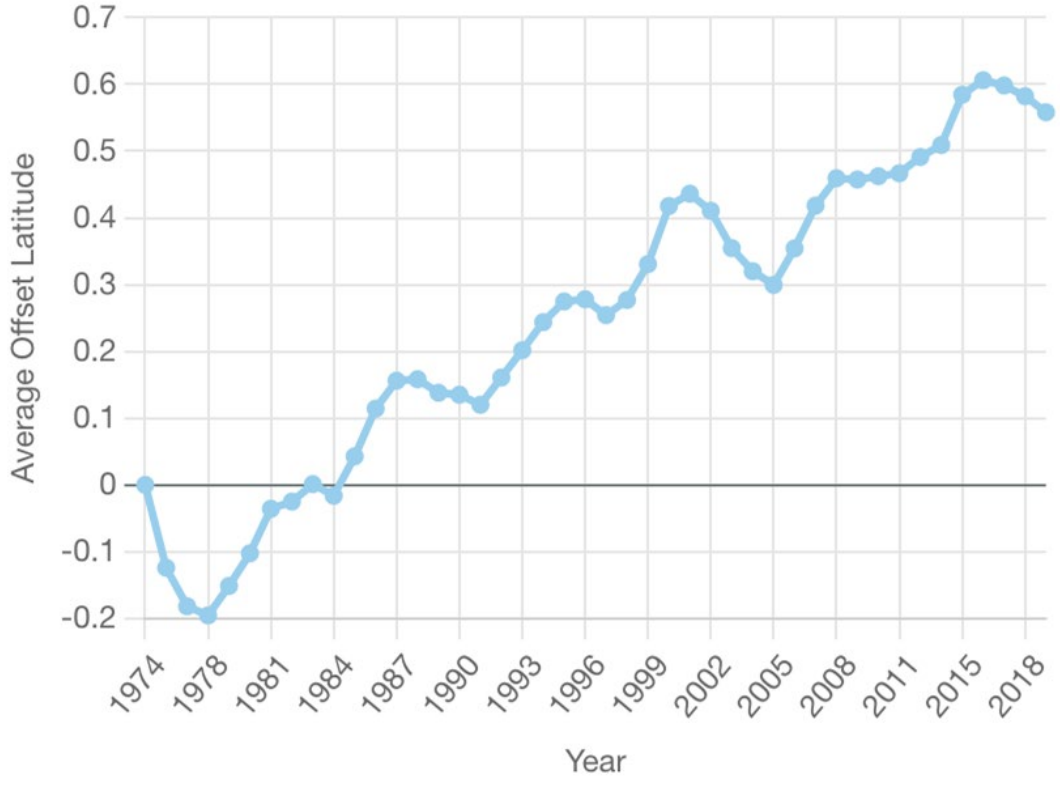
- Develop and evaluate approaches for MAFMC fisheries and their management to become more adaptive to change
- Use models to develop short-term forecasts and medium-term projections
- Identify new species likely to become established in the Mid-Atlantic (from the South Atlantic) and species likely to expand or shift distribution into waters under the jurisdiction of New England and Canada



# Species Distribution Shifts

- Collaborated with Morley et al. 2018 on *Projecting shifts in thermal habitat during the 21st century* project
- Highly informative and considered in a strategic way - i.e., EAFM guidance document
- This project allows Council to potentially consider distribution change in a more tactical way
  - Focus on Mid At. species, but interest in possible South At. changes

# Change in species distribution




NOAA DisMAP; Northeast US spring trawl survey

# Goals

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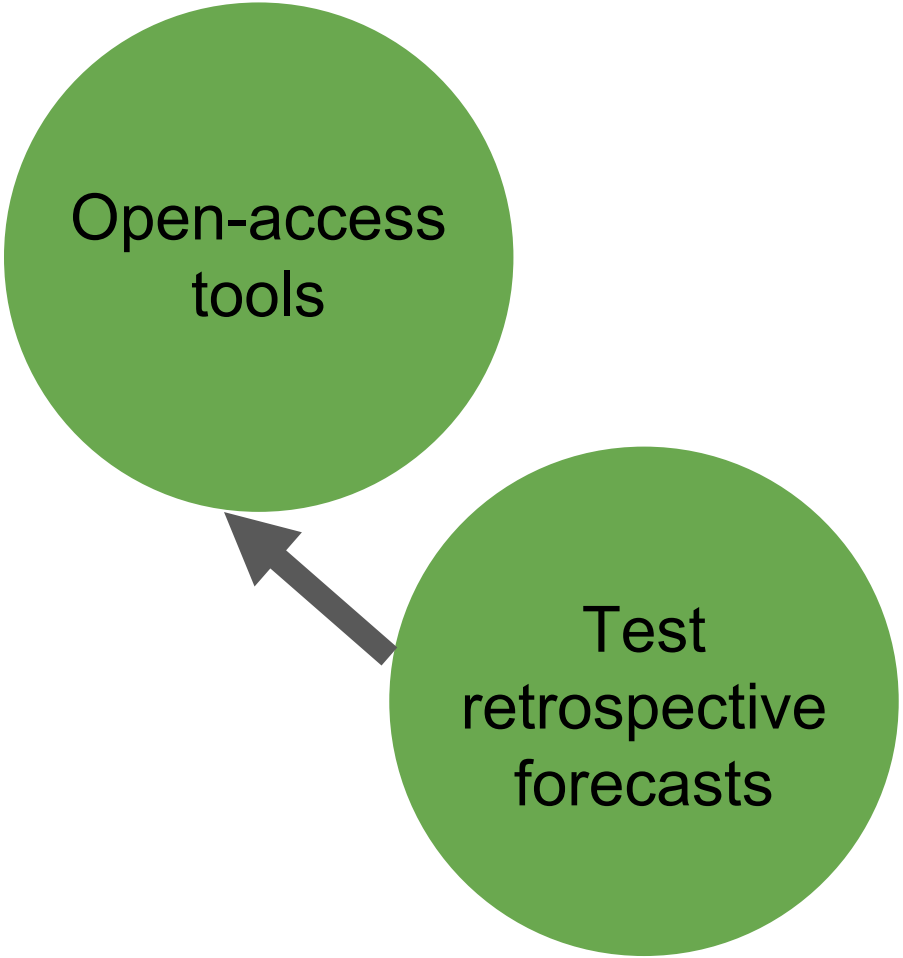

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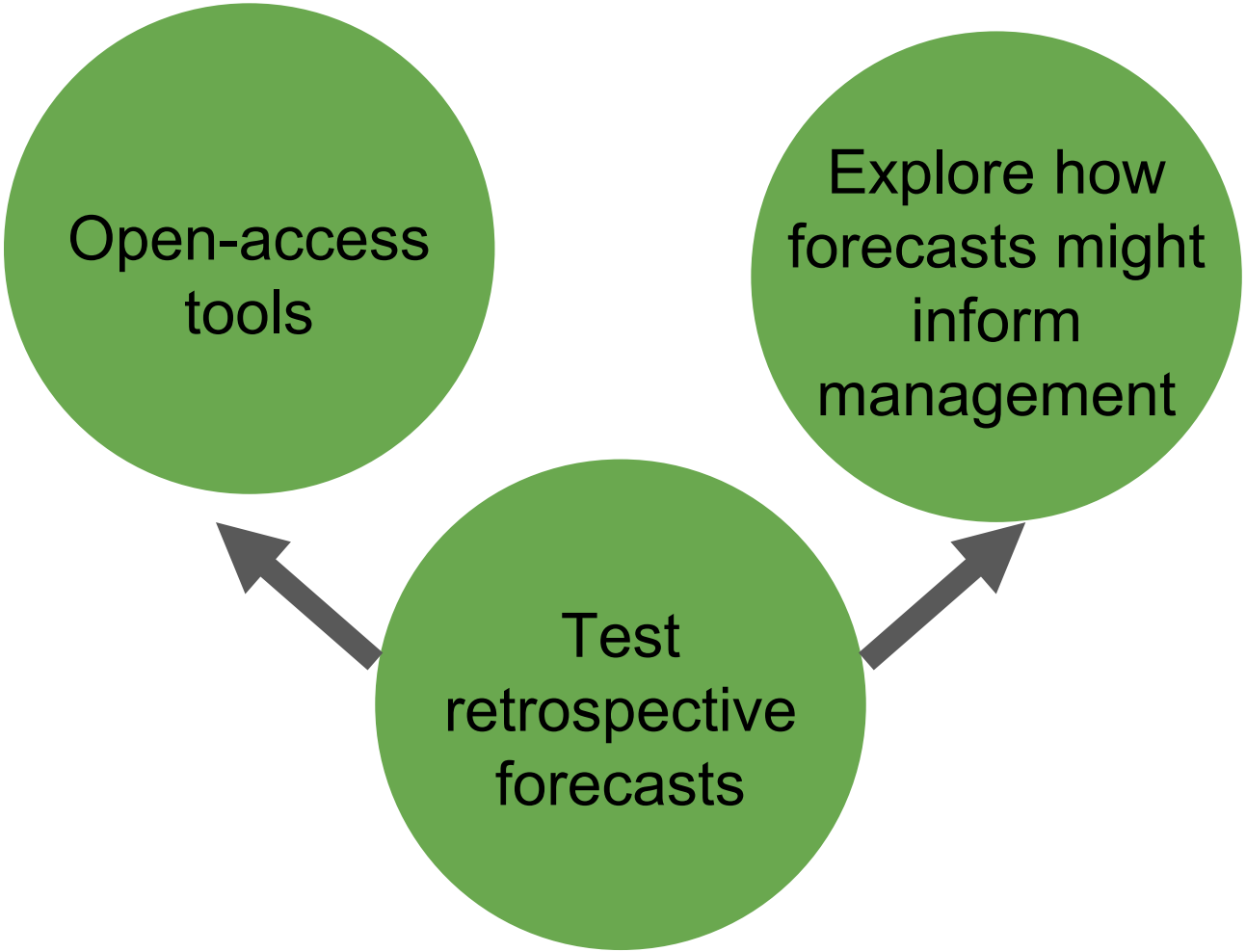
Open-access tools
Explore how forecasts might inform management
Test retrospective forecasts

# What we are **not** doing in this project

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- Operationalizing the forecasts for routine management use
- Producing a stock assessment
- Providing management advice

# Research questions

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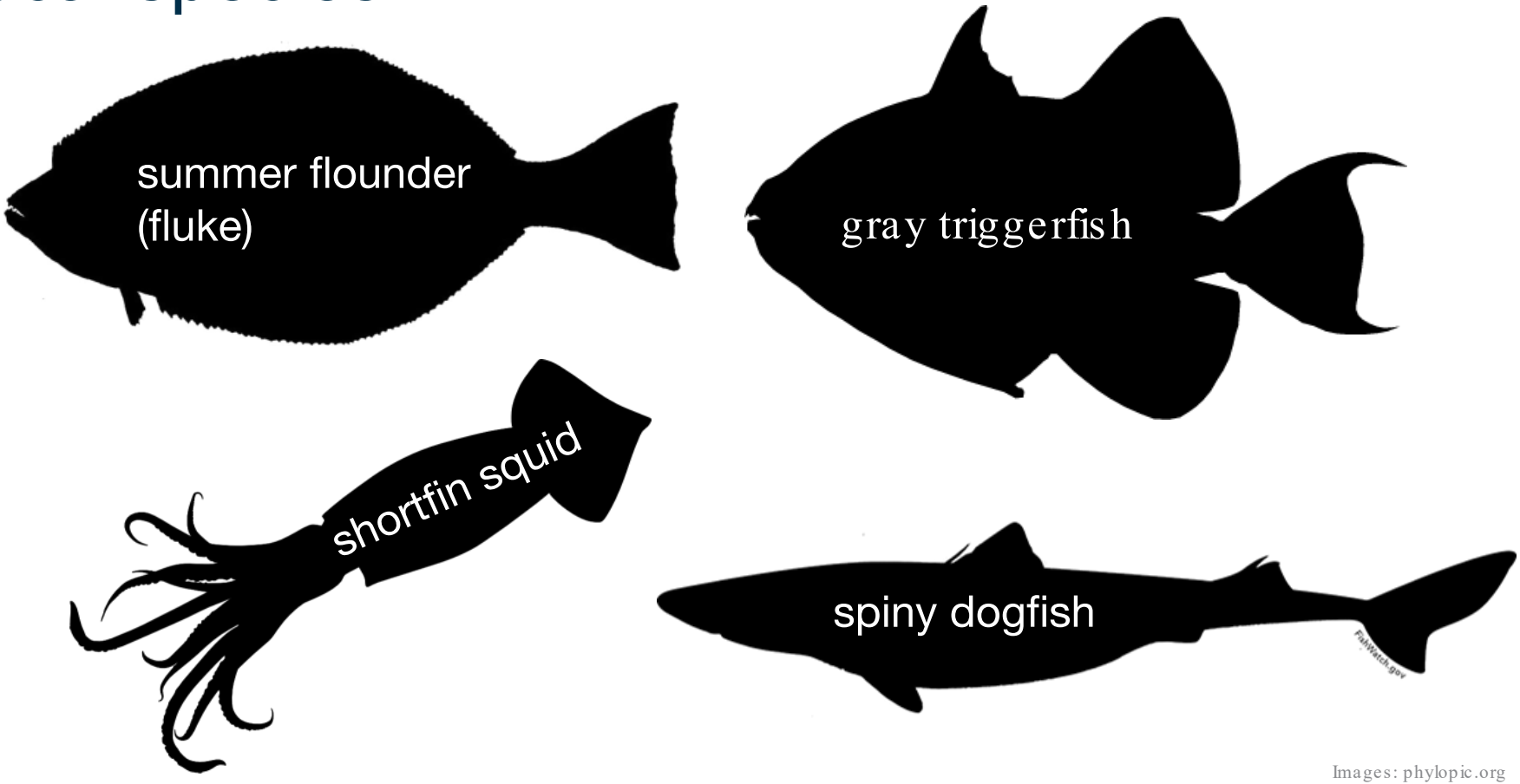
3. Does information on **fishing** pressure improve forecasts of species distributions?

# Focal species



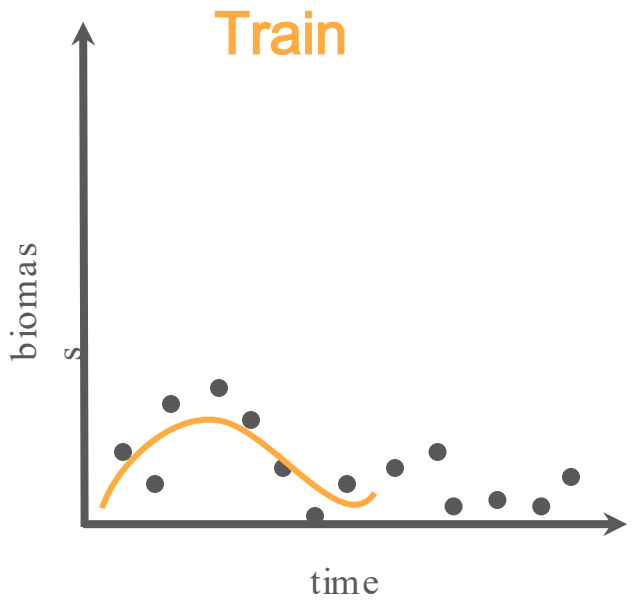



Images: phylopic.org
FishWatch.gov

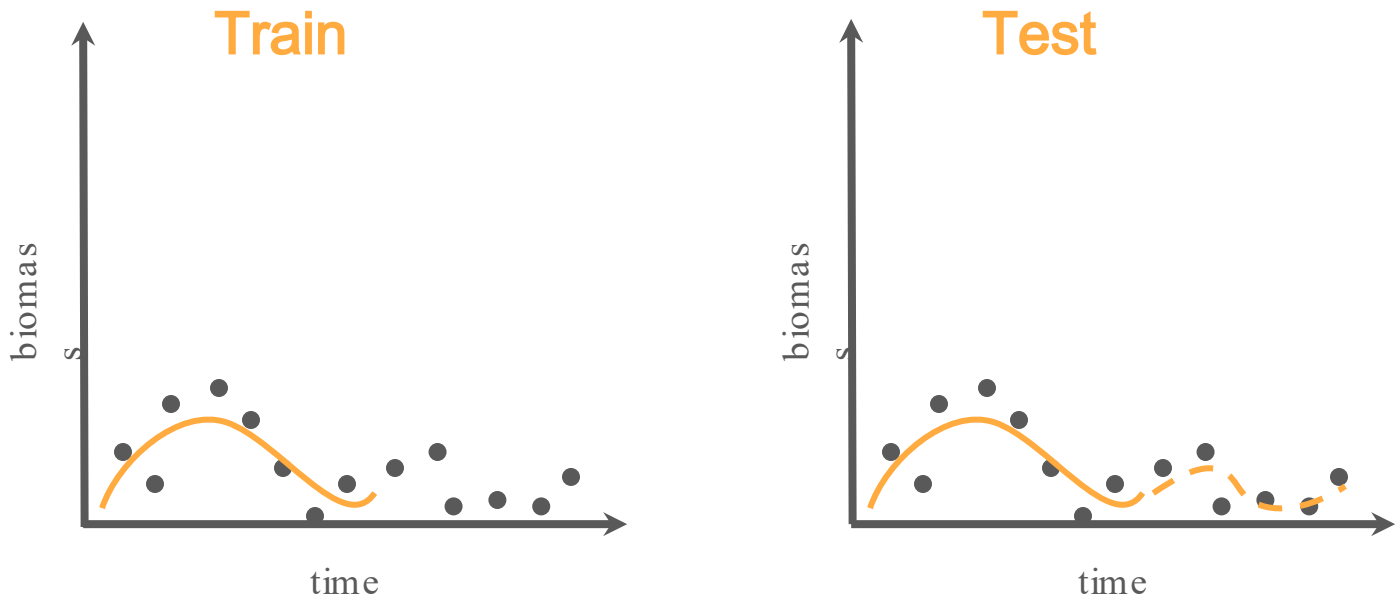
# Spoiler alerts: summer flounder models

1. Non-climate factors (fishing, dispersal) influence species distributions
2. Species distributions are highly variable, not marching up the coast
3. Dynamic range models can forecast distribution shifts with some skill

# Summary of work



# Work plan



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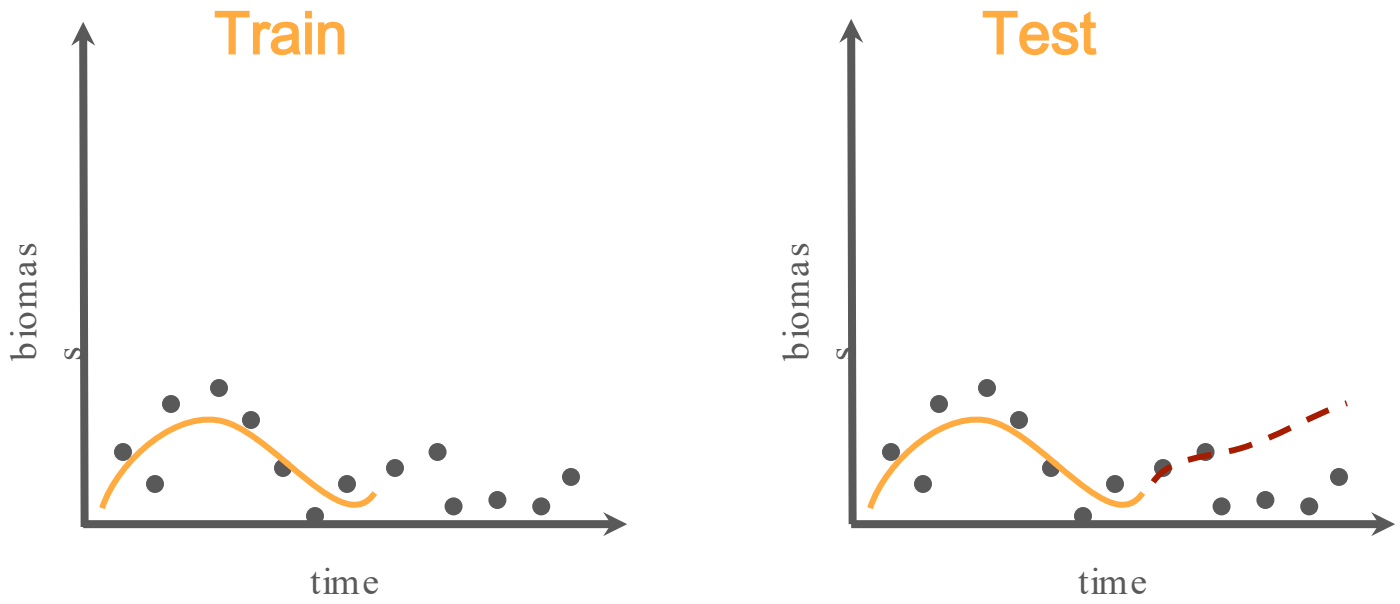

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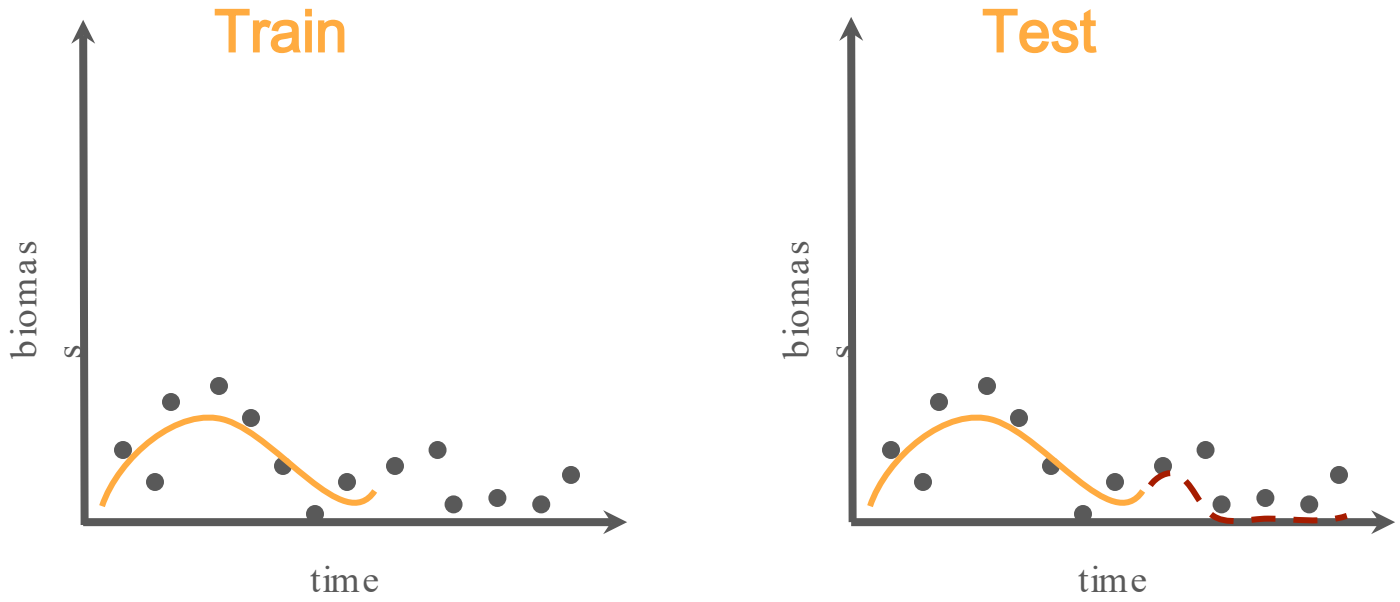
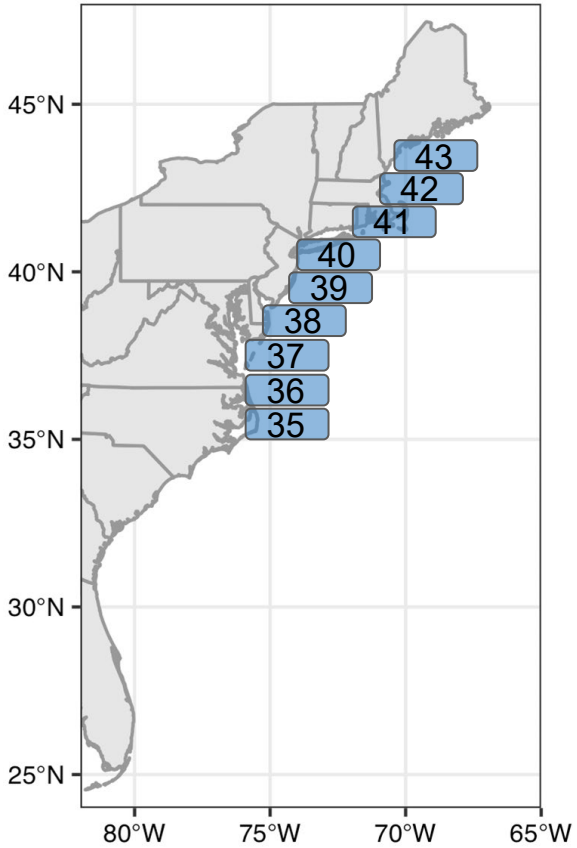


# Summary of approach

**Fit** to data from bottom trawl survey, 1972-2006



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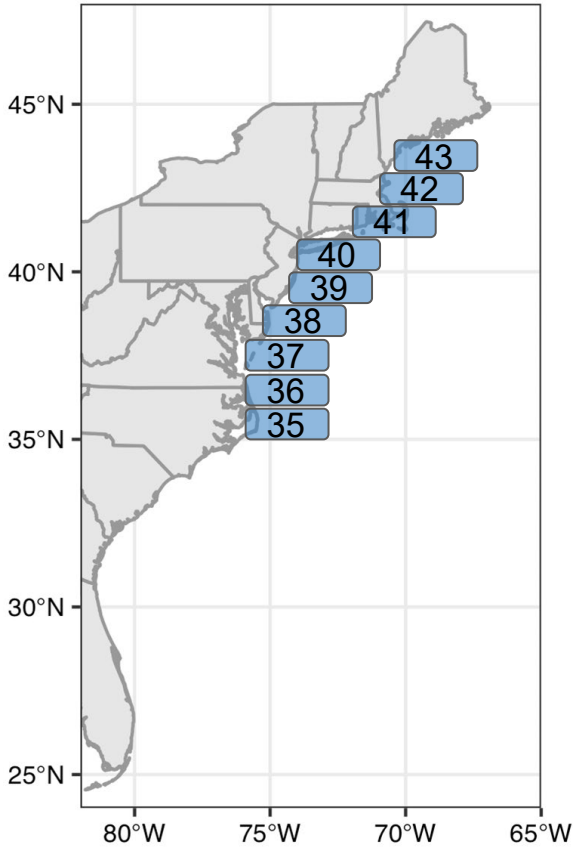


**Test** the forecast 2007-2016

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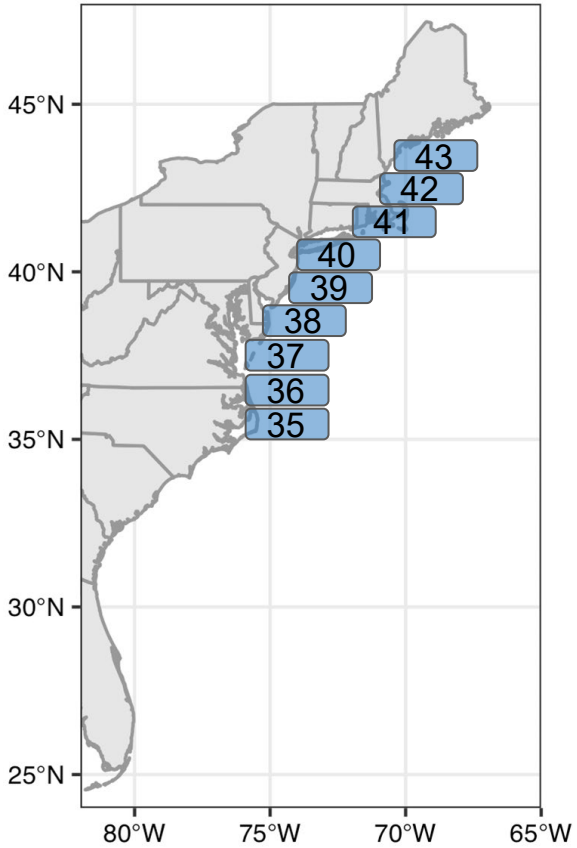
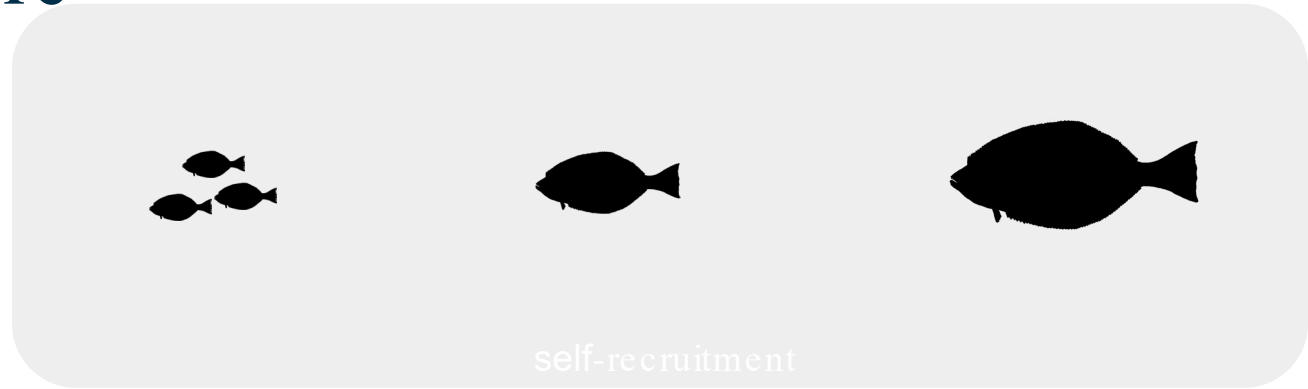



**Test** the forecast 2007-2016

**This is a proof of concept, not a future forecast!**

# Model structure



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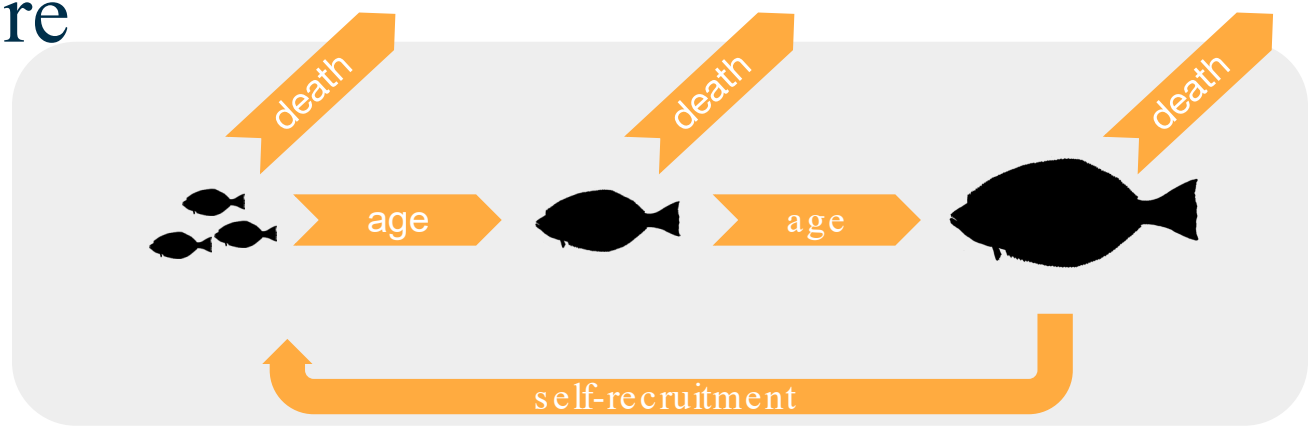

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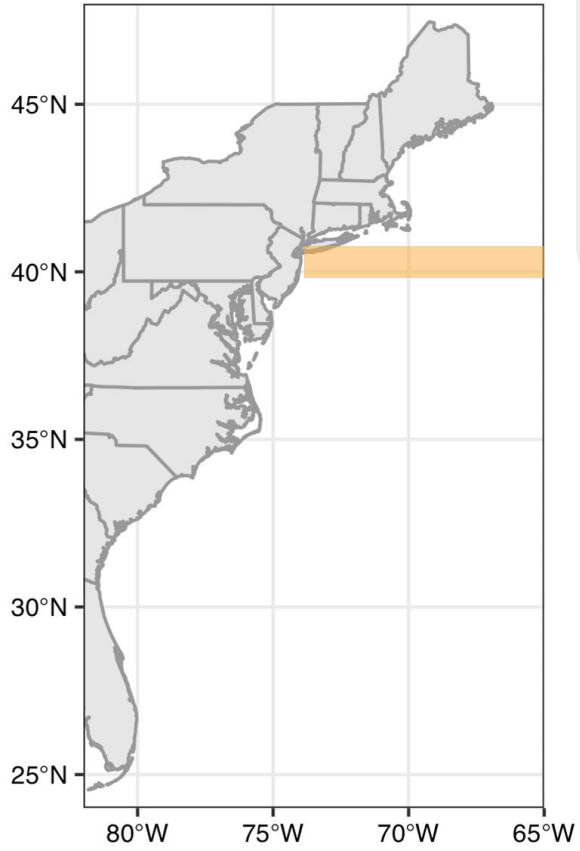


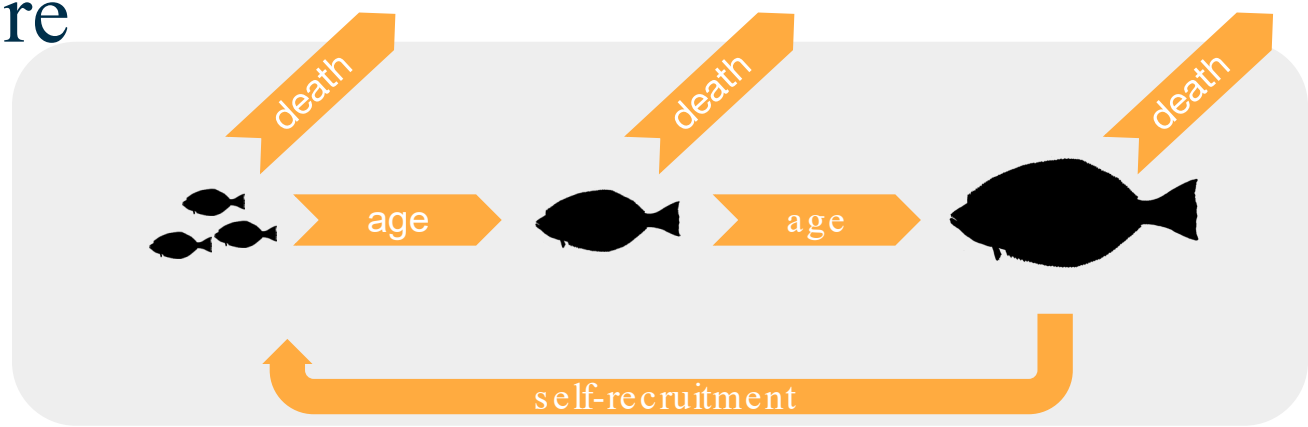

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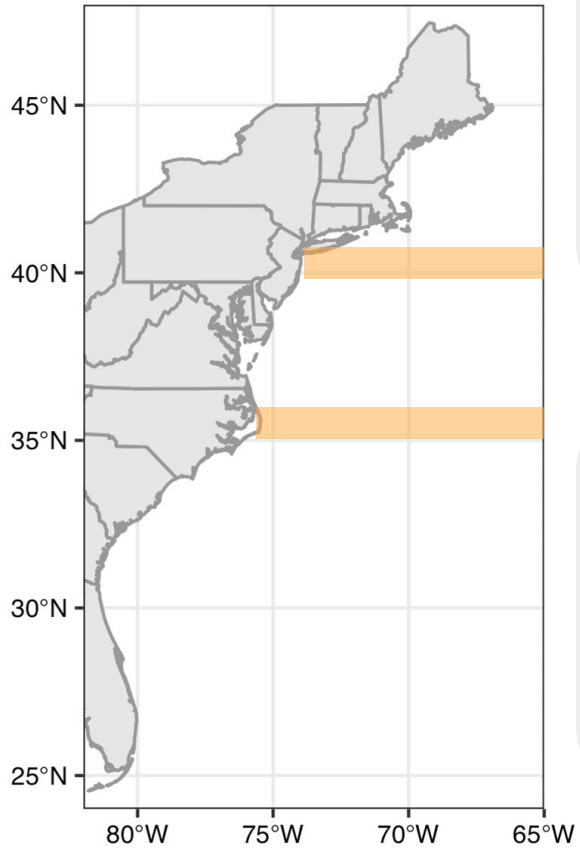


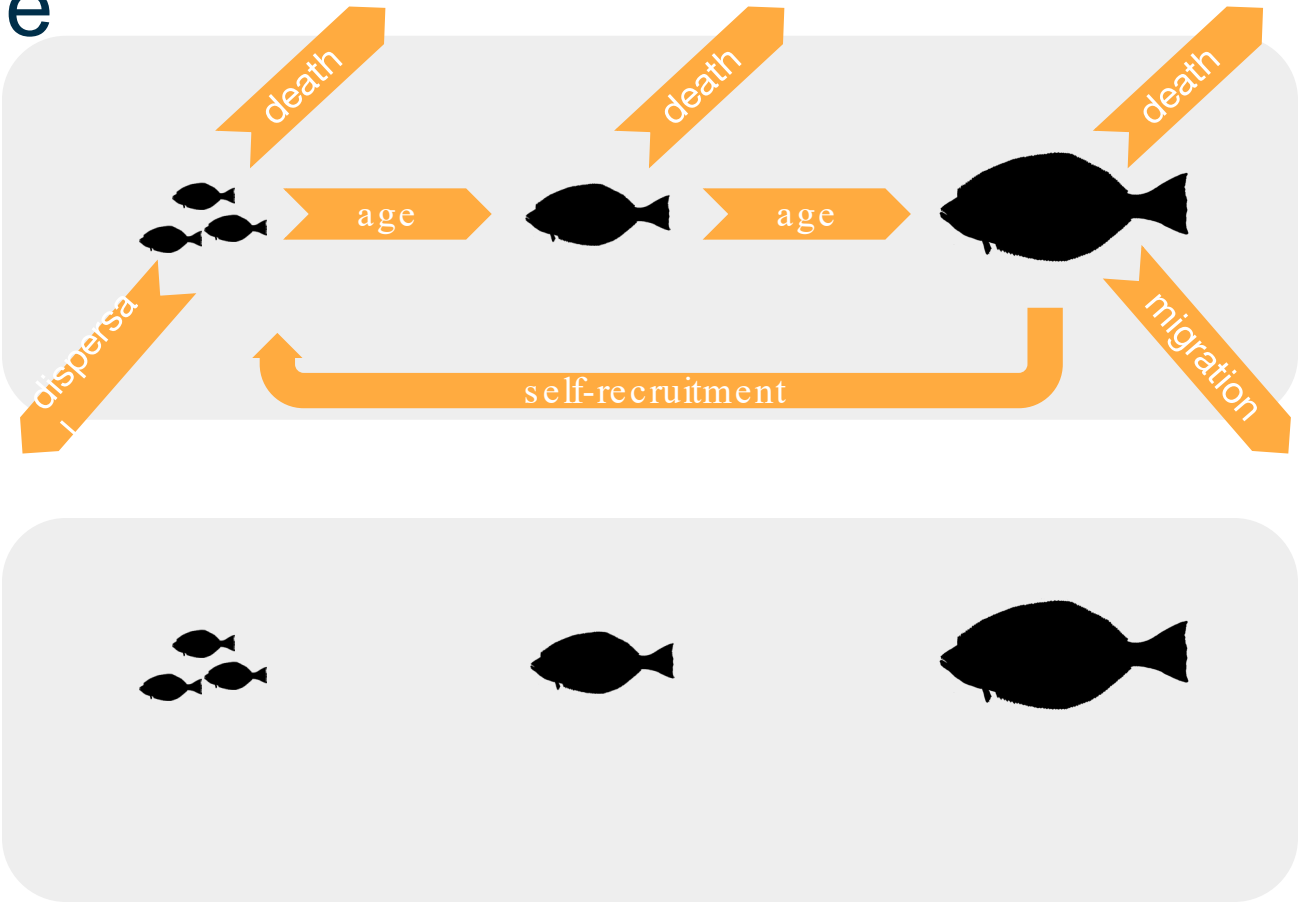

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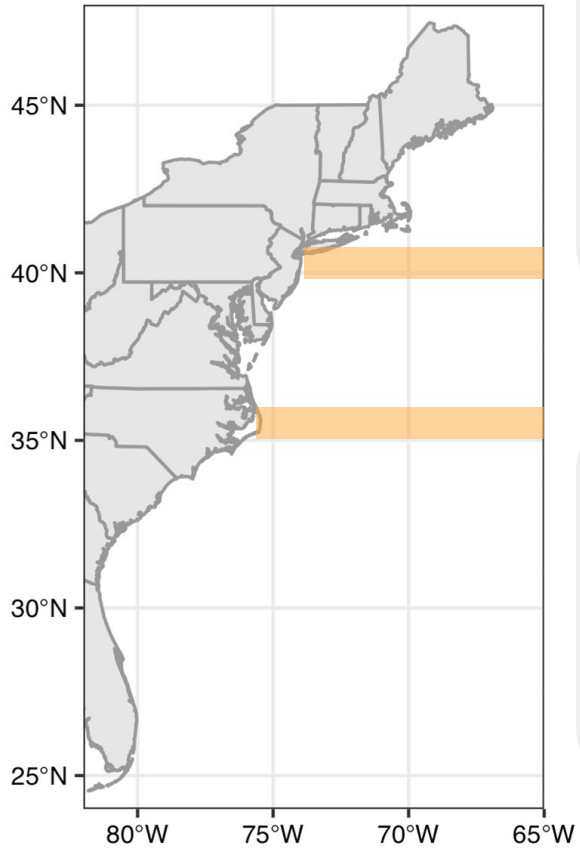


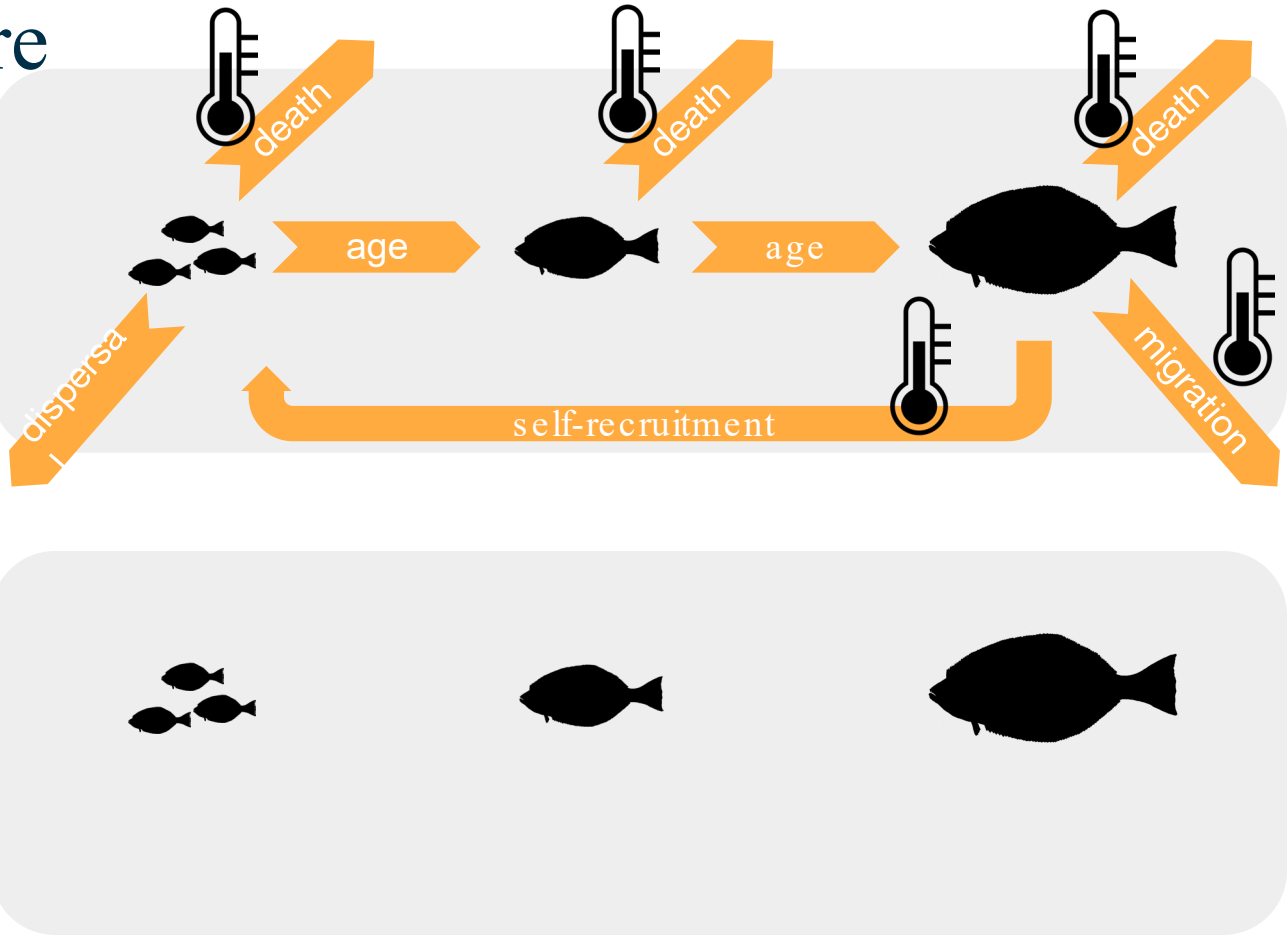

# Model implementation for summer flounder

**Stochastic recruitment**

yes/no

**Temperature affects…**

recruitment

dispersal

mortality

nothing

**Known Fover time**

yes/no

**Fit to length data**

yes/no

**Stock-recruit relationship**

yes/no

# Candidate model for summer flounder

| **Model structure decision** | Yes | No |
|---|---|---|
| Fishing values from stock assessment inform mortality rate | | ✓ |
| Stochastic recruitment process | ✓ | |
| Length data informs age structure | | ✓ |
| Stock-recruit relationship | | ✓ |
| Temperature affects recruitment | | ✓ |
| Temperature affects mortality | | ✓ |
| Temperature affects migration | ✓ | |

# Research questions

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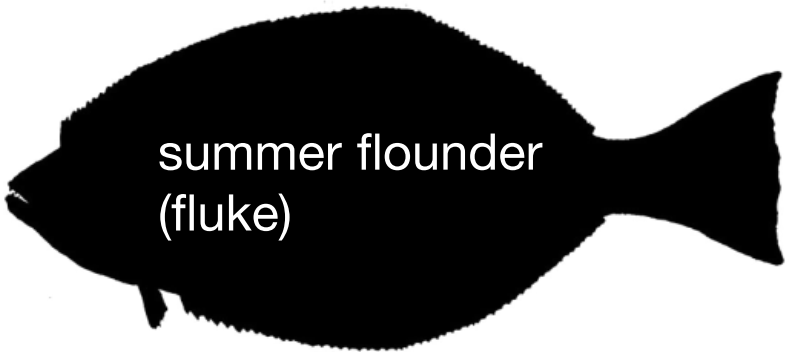
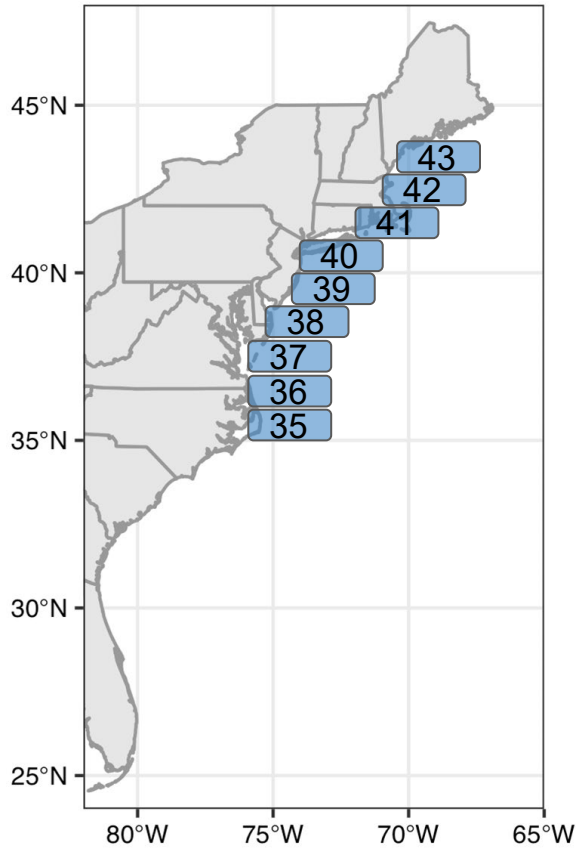
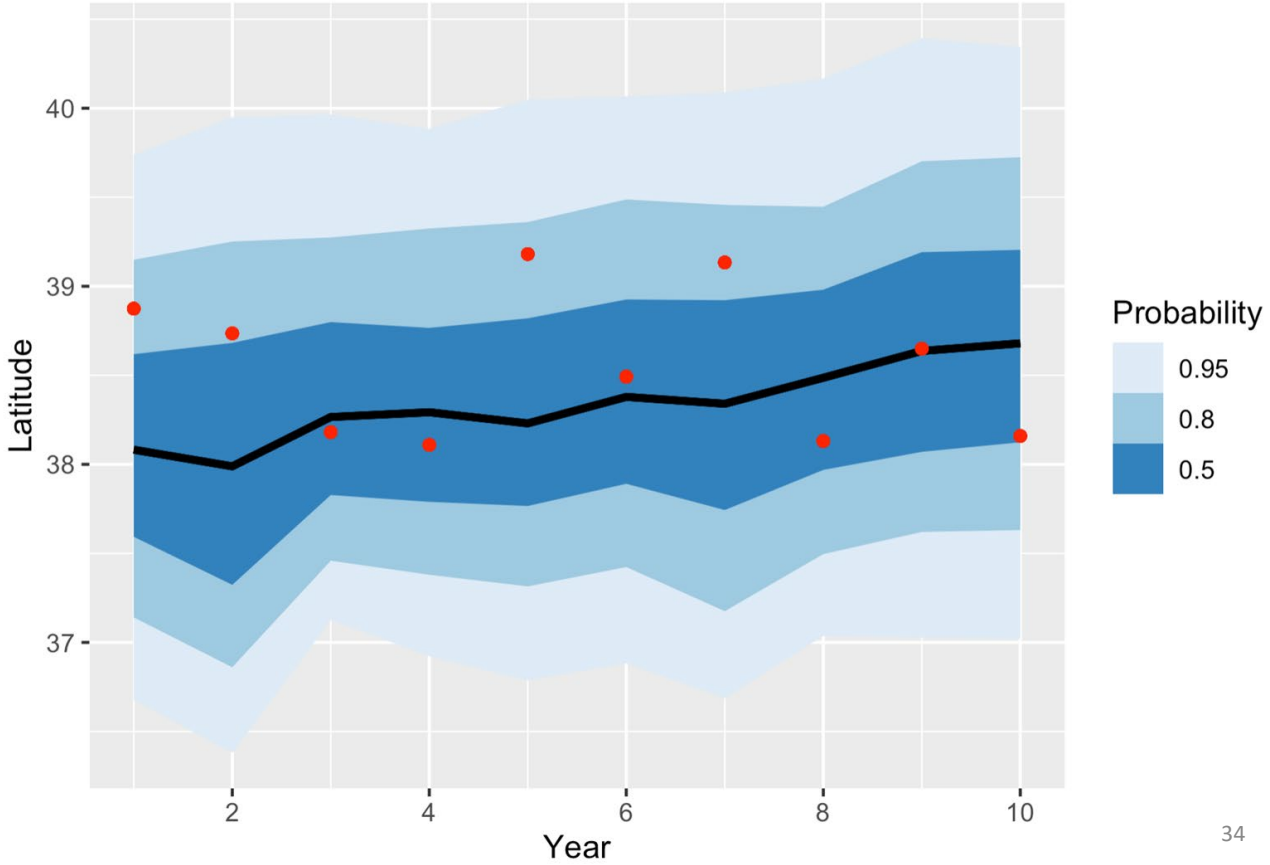
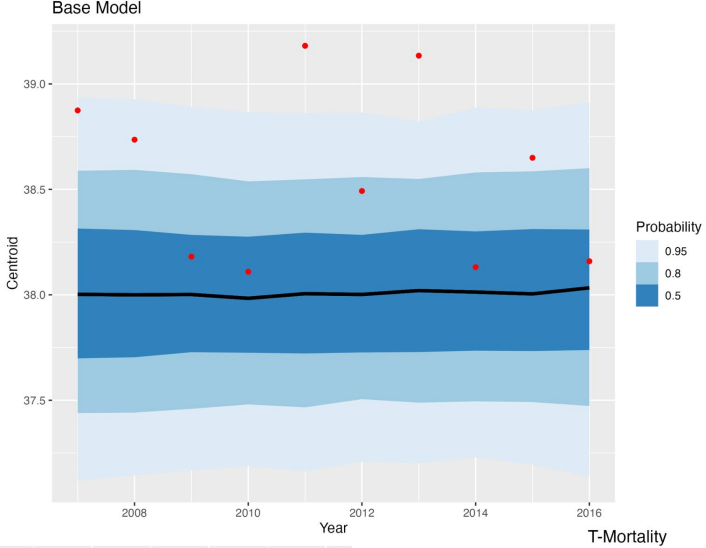


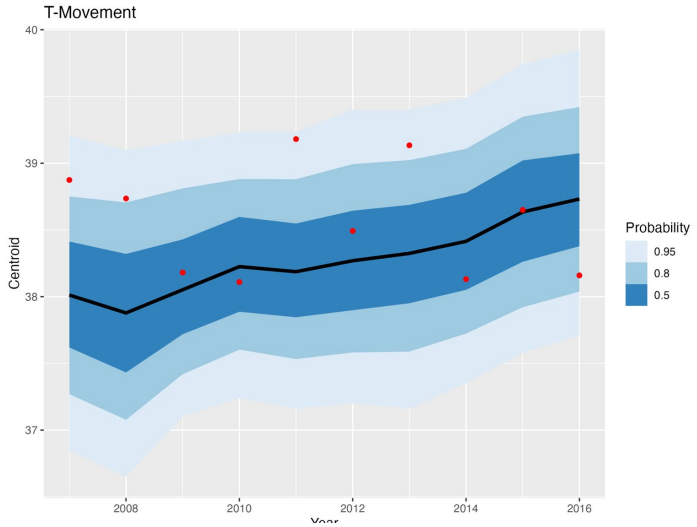
# Forecast vs. reality: centroid position

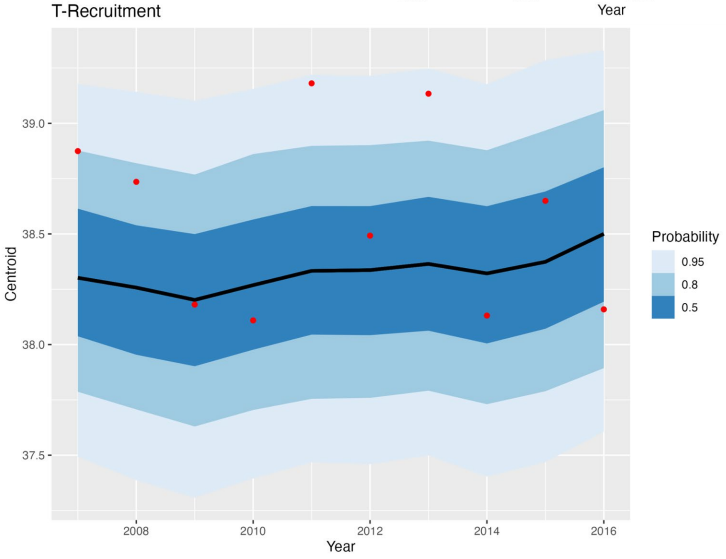


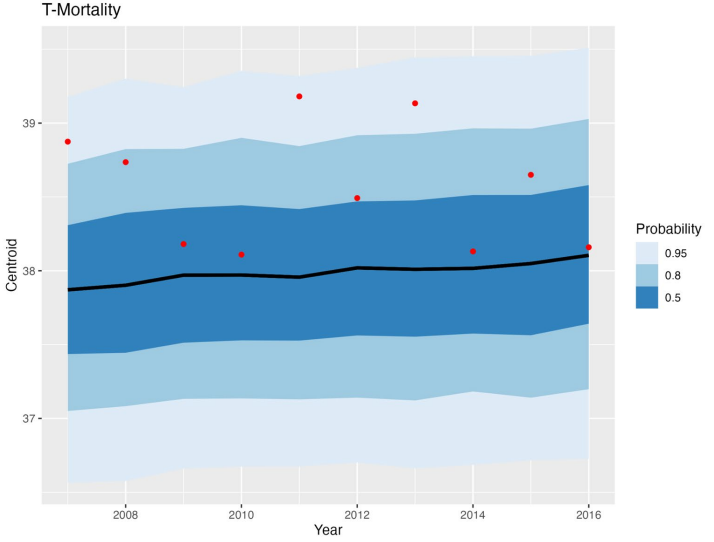



# Forecast vs. reality: model comparison

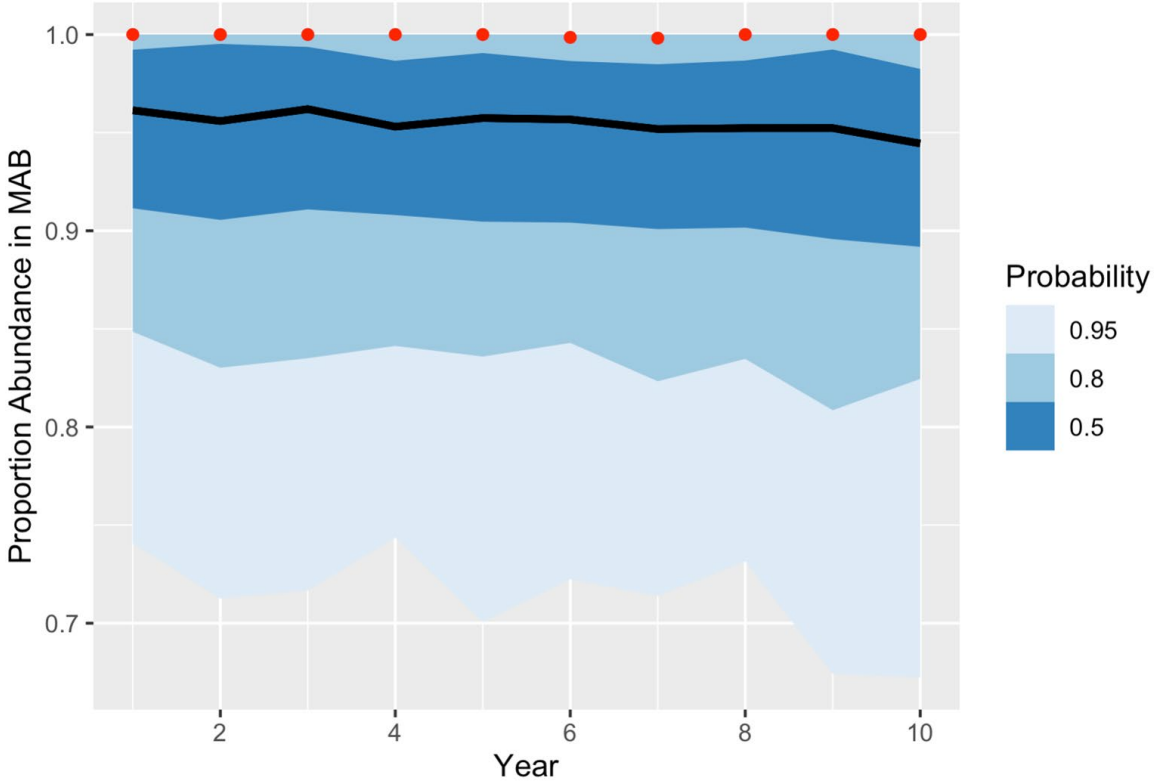


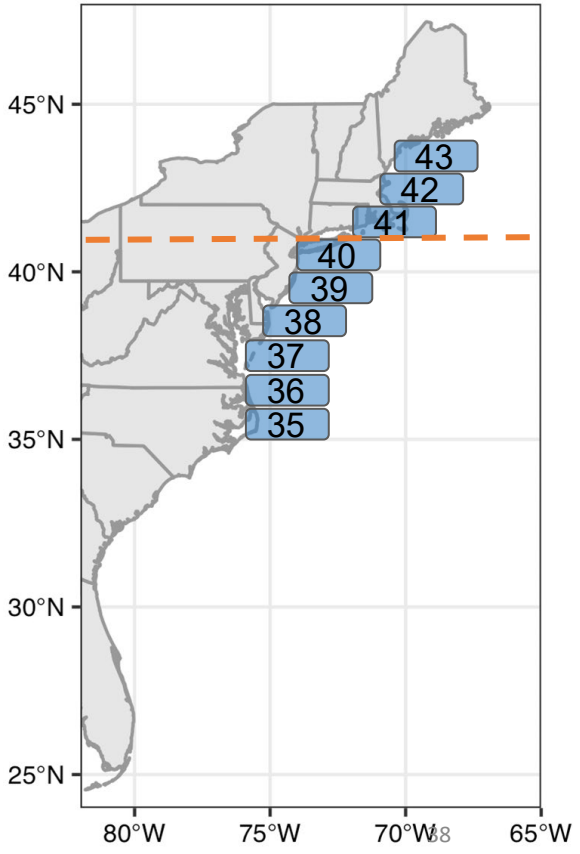



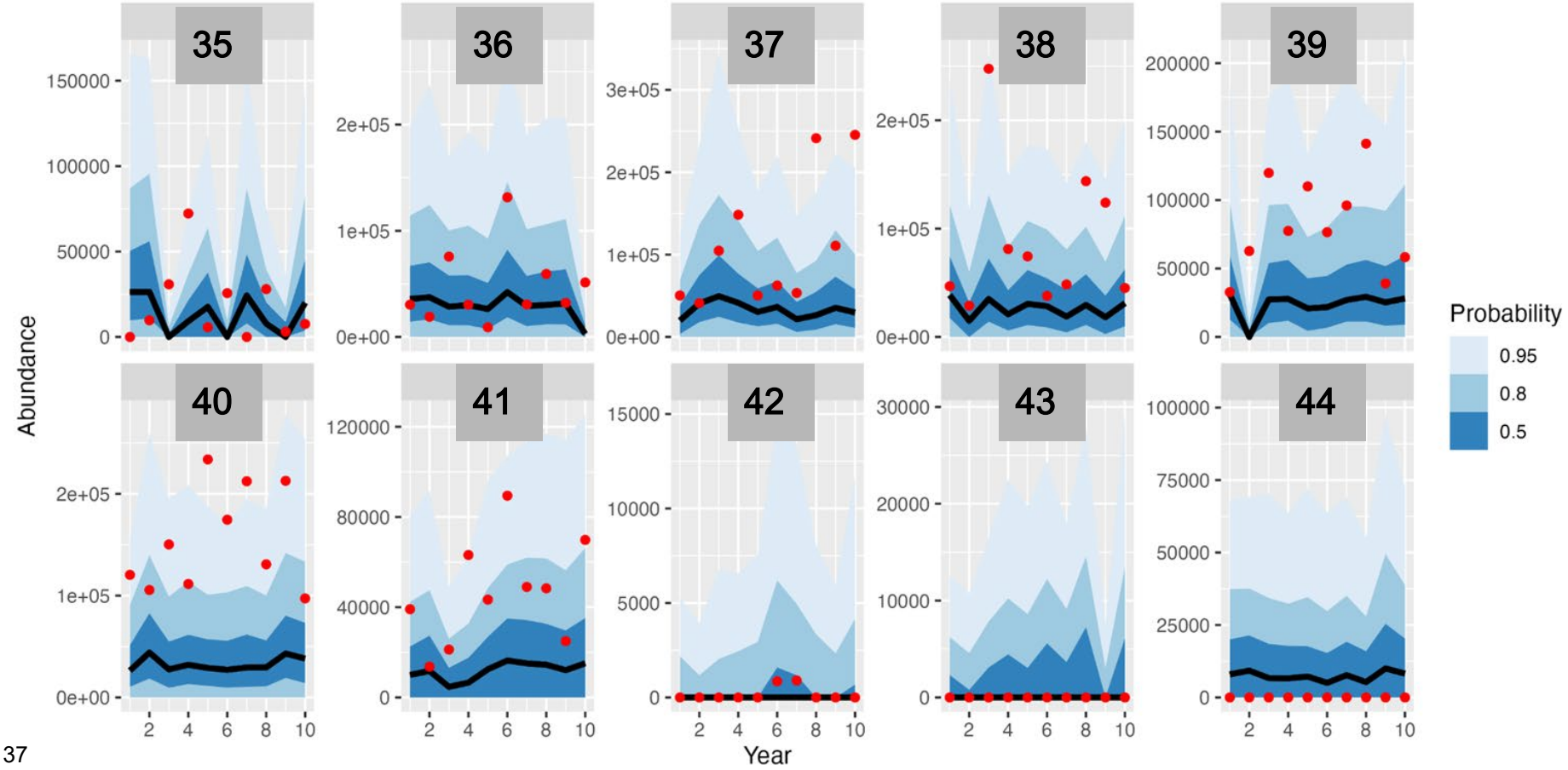



# Forecast vs. reality: Mid-Atlantic Bight vs Gulf of Maine / Georges Bank

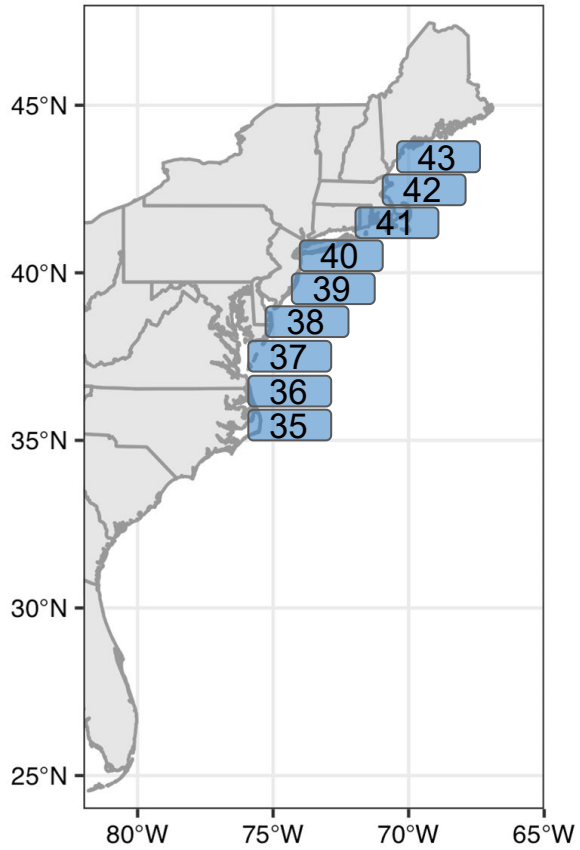


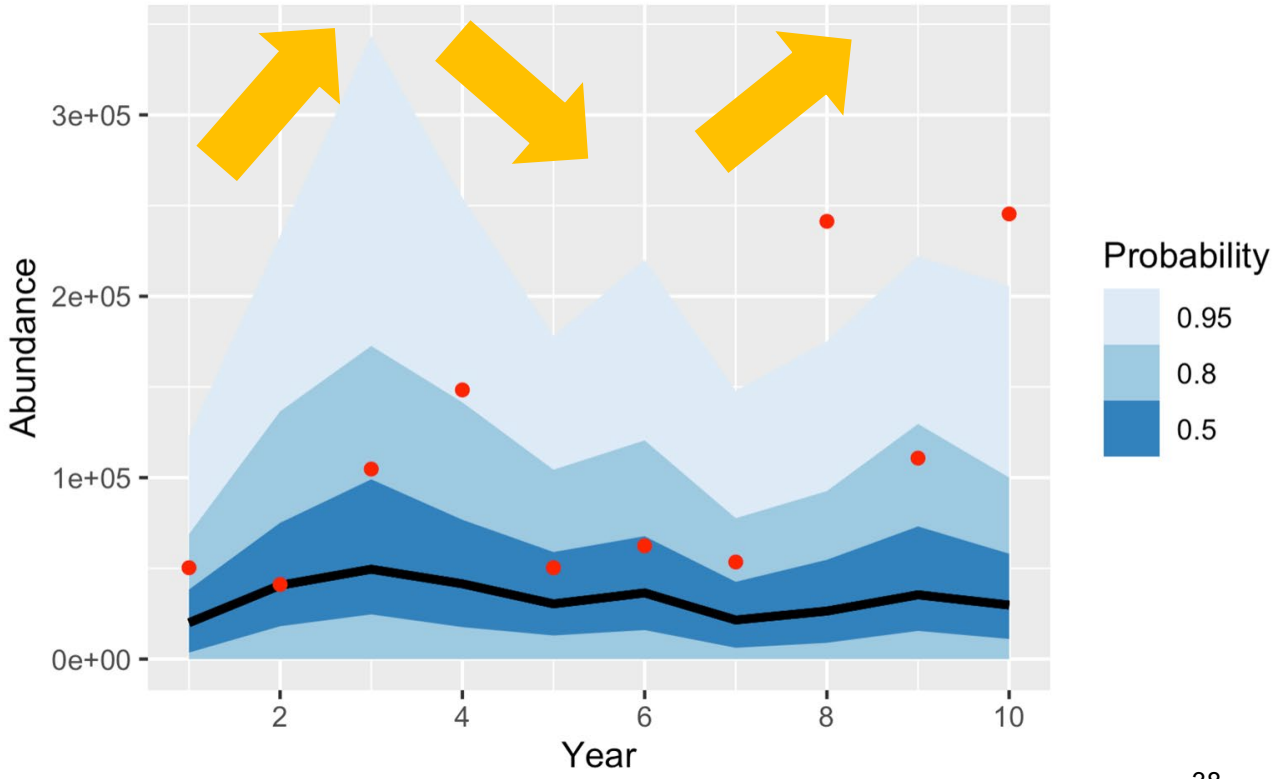



# Forecast vs. reality: abundance by patch

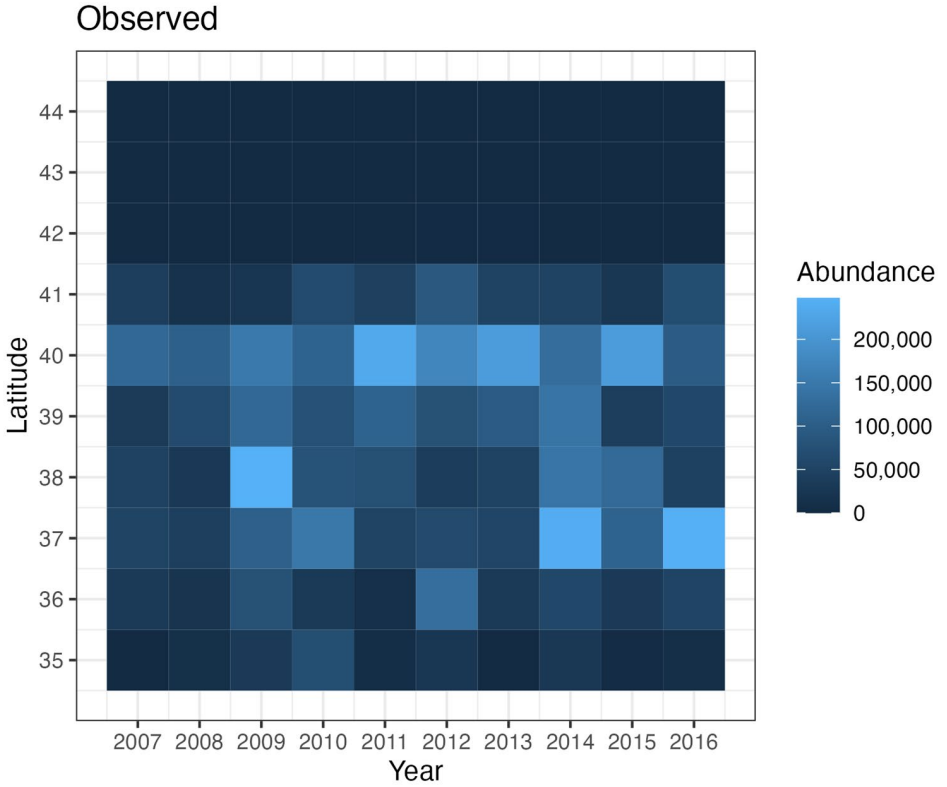


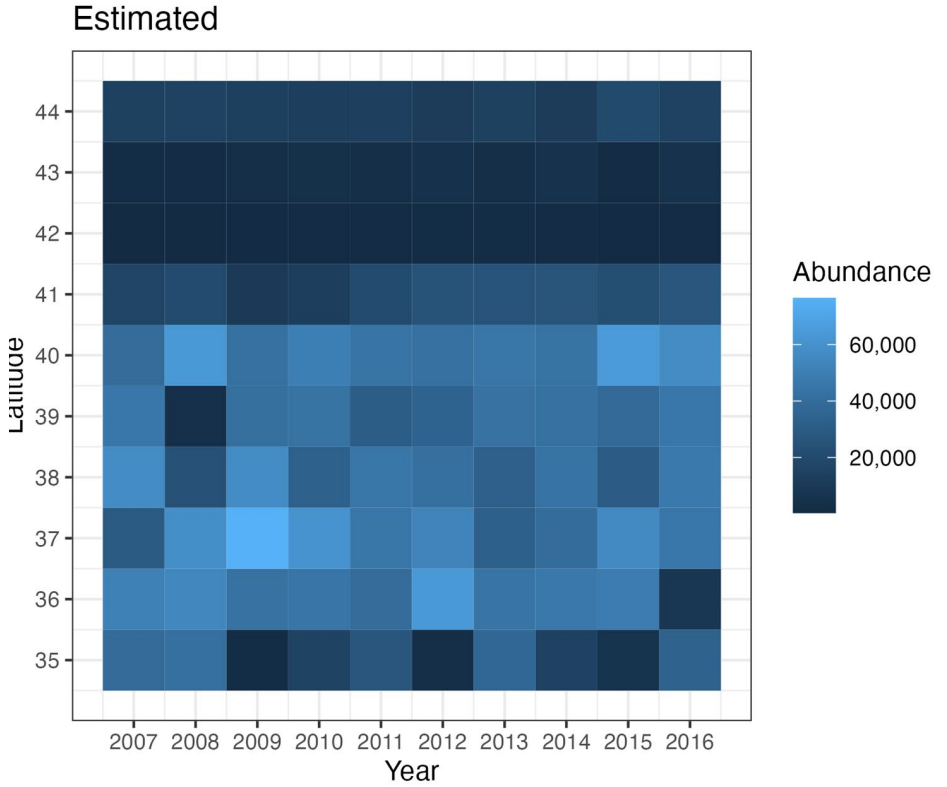
# Forecast vs. reality: 37-38 N



# Forecast vs. reality: best estimates



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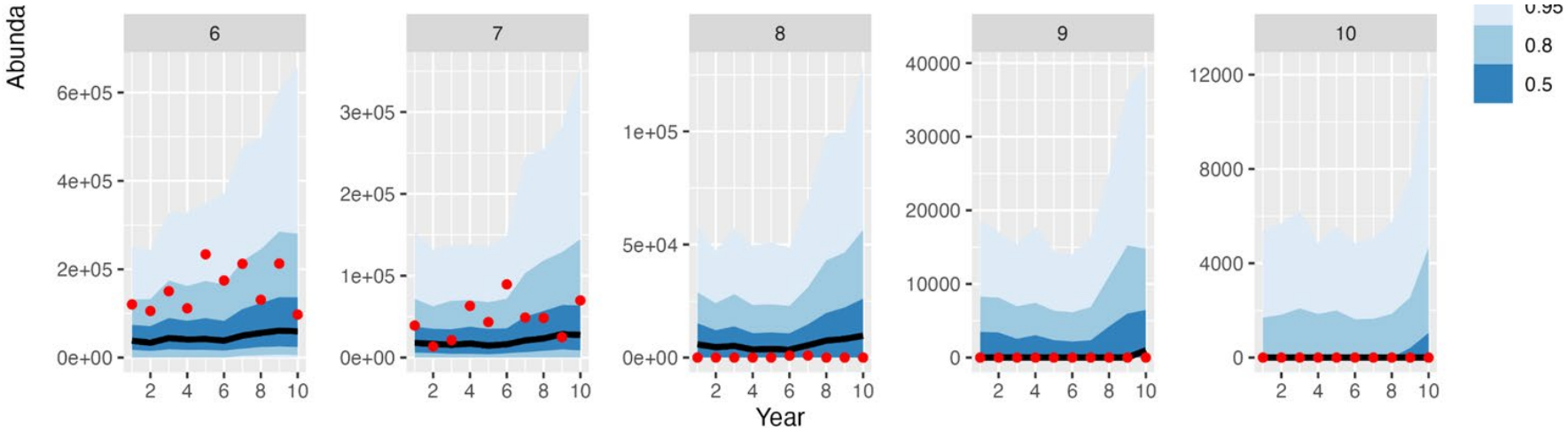

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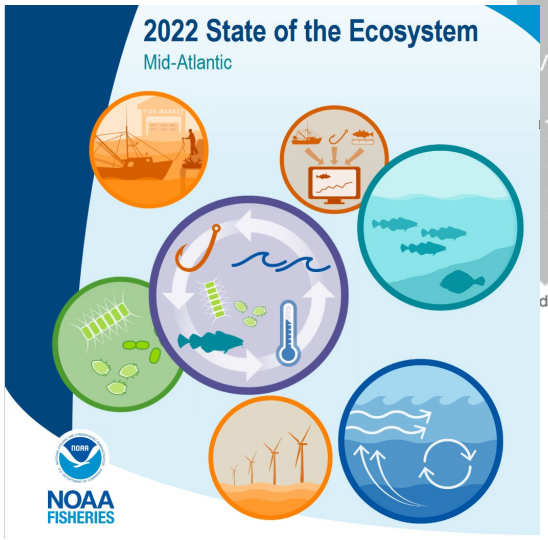
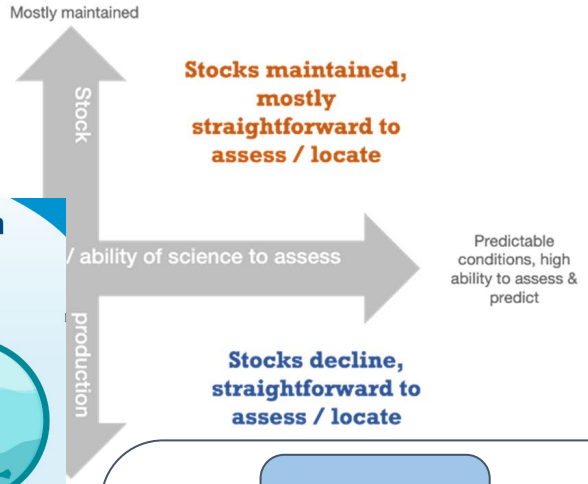
Yes!

# Updates and next steps

1. All model features are programmed
2. Summer flounder 64 models are running on supercomputers at Rutgers this month
3. Ran traditional SDMs for comparison
4. Next up: formally evaluate and compare models
5. Other three species are in the works

# Potential Project Application(s)



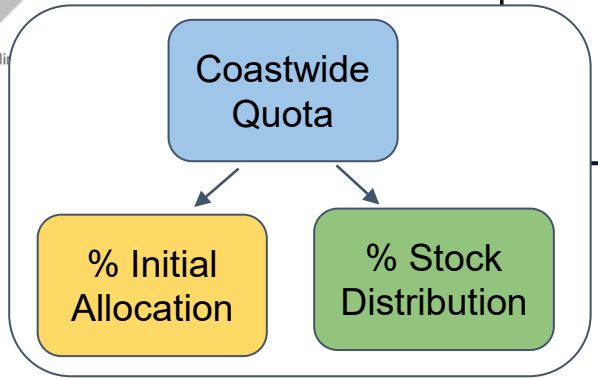



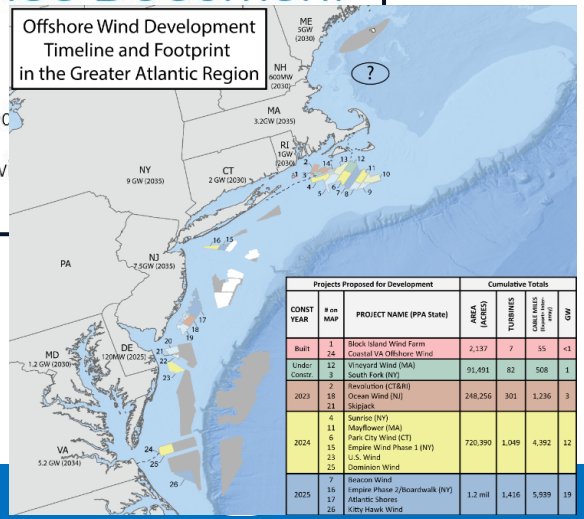

MID-ATLANTIC FISHERY MANAGEMENT COUNCIL

Ecosystem Approach to Fisheries Management Guidance Document

Approved

Rev



# Examples of Potential Council Application

- Work to help address priorities in the Council's 2020-2024 Strategic Plan
  - Specific strategies to evaluate and consider changes in stock distribution
- Continued development and implementation of EAFM guidance document

## Theme 4: Ecosystem

**Goal:** Support the ecologically sustainable utilization of living marine resources in a manner that maintains ecosystem productivity, structure, and function.

**Objective 13.** Collaborate with management partners to develop ecosystem approaches that are responsive to the impacts of climate change.[1]

*Risk Assessment Update 2020*

Table 4: Species level risk analysis results; l=low risk (green), lm= low-moderate risk (yellow), mh=moderate to high risk (orange), h=high risk (red)

| Species | Assess | Fstatus | Bstatus | FW1Pred | FW1Prey | FW2Prey | Climate | DistShift | EstHabitat |
|---|---|---|---|---|---|---|---|---|---|
| Ocean Quahog | | | | | | | | | |
| Surfclam | | | | | | | mh | mh | |
| Summer flounder | | | lm | | | | lm | mh | h |
| Scup | | | | | | | lm | mh | h |
| Black sea bass | | | | | | | mh | mh | h |
| Atl. mackerel | | h | h | | | | lm | mh | |
| Butterfish | | | | | | | | h | |
| Longfin squid | lm | lm | lm | | | lm | | mh | |
| Shortfin squid | lm | lm | lm | | | lm | | h | |
| Golden tilefish | | | lm | | | | mh | | |
| Blueline tilefish | h | h | mh | | | | mh | | |
| Bluefish | | | h | | | | | mh | h |
| Spiny dogfish | lm | | lm | | | | | h | |
| Monkfish | h | lm | lm | | | | | mh | |
| Unmanaged forage | na | na | na | | lm | lm | na | na | na |
| Deepsea corals | na | na | na | | | | na | na | na |

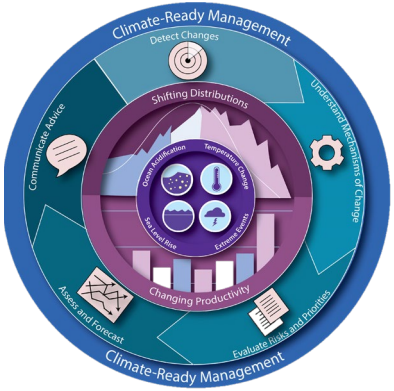
Table 5: Ecosystem level risk analysis results; l=low risk (green), lm= low-moderate risk (yellow), mh=moderate to high risk (orange), h=high risk (red)

| System | EcoProd | CommRev | RecVal | FishRes1 | FishRes4 | FleetDiv | Social | ComFood | RecFood |
|---|---|---|---|---|---|---|---|---|---|
| Mid-Atlantic | lm | mh | h | l | mh | l | lm | h | mh |

# Potential Management Applications (cont.)

- Council Actions
  - Dynamic allocation strategies/considerations (e.g. black sea bass)
- East Coast Climate Change and Distribution Shift Scenario Planning Project
  - Science needs to evaluate summit outcomes
  - Adaptive governance/management
- Marine Spatial Planning/Coordination
  - Offshore wind and aquaculture development
- NOAA Fisheries Climate Ready Fisheries Management
  - Tools to assess and forecast changes in stock distributions





# Examples of Potential Science Applications


- SOE risks to meeting management objectives
  - Linking ecosystem indicators to distribution changes
- Stock Assessments and projections
  - Ecosystem TORs and Ecosystem and Socio- economic Profiles for assessments

Less Uncertainty ⟹ More Uncertainty

| | | | |
|---|---|---|---|
| **Ecosystem factors accounted** | Assessment considered habitat and ecosystem effects on stock productivity, distribution, mortality and quantitatively included appropriate factors reducing uncertainty in short term predictions. Evidence outside the assessment suggests that ecosystem productivity and habitat quality are stable. Comparable species in the region have synchronous production characteristics and stable short-term predictions. Climate vulnerability analysis suggests low risk of change in productivity due to changing climate. | Assessment considered habitat/ecosystem factors but did not demonstrate either reduced or inflated short-term prediction uncertainty based on these factors. Evidence outside the assessment suggests that ecosystem productivity and habitat quality are variable, with mixed productivity and uncertainty signals among comparable species in the region. Climate vulnerability analysis suggests moderate risk of change in productivity from changing climate. | Assessment either demonstrated that including appropriate ecosystem/habitat factors increases short-term prediction uncertainty, or did not consider habitat and ecosystem factors. Evidence outside the assessment suggests that ecosystem productivity and habitat quality are variable and degrading. Comparable species in the region have high uncertainty in short term predictions. Climate vulnerability analysis suggests high risk of changing productivity from changing climate. |

From MAFMC Scientific and Statistical Committee OFL CV Guidance Document 20
– https://www.mafmc.org/ssc

# EOP Committee and AP feedback

## Comments/Feedback on Dynamic Range Model(s)

- Connect and share ideas, data, information with other research groups working on target species
- Potential spatial limitations and timing issues associated with the NEFSC bottom trawl survey data
  - Consideration of other data sources
- Model forecasts need to incorporate/respond to changes in temperature in either direction (i.e., warmer or cooler)

# EOP Committee and AP feedback (cont.)

Comments/Feedback on Potential Application of Project Results and Information

- Committee recommendation: bi-directional temperature function be considered in modeling framework is needed for management application
- Need to consider the development of these models for S.A. stocks to help management prepare for future availability
- Some expressed concern about any application of project in management, particularly for *Illex* and spatial considerations
  - Additional work and refinement needed before use
- Others felt this type of information is needed in management
  - EAFM risk assessment, sensitivity of leading/trailing edges of stocks

# *Short-Term Forecasts of Species Distributions for Fisheries Management*

- **The SSC:**
  - Encouraged continued development and potential utility for management decisions
  - Recommended additional validation including comparisons with simpler methods.
  - Encouraged further consideration of survey sampling issues and age-dependent responses to temperatures
  - Noted reasonably good correspondence between model predictions of Summer Flounder trends and spatial patterns for 2007-2016 period with observations from the bottom trawl surveys.
  - Noted variation of predictions increases with the length of the forecast.
  - Emphasized that true forecasts will require forecasts of oceanographic conditions on similar time scales.

# *Short-Term Forecasts of Species Distributions: Potential Applications*

- Could be linked to SOE indicators of vulnerability for coastal communities and various social and economic metrics.
- Could be compared with EAFM indicators of distributional shifts.
- Evaluate recreational fishing performance under various Harvest Control Rules.
- Evaluate feasibility of catch advice relative to the historical distributions.
- Potential tool for allocation decisions.
- Interpreting retrospective patterns observed in some species stock assessments.
- Interpreting changes in species distributions within and around offshore wind energy areas.

# *Short-Term Forecasts of Species Distributions: Research Recommendations*

- Consider changes in thermal preference that occur as fish age. Older fish prefer cooler water.
- Consider alternative patterns of spatial binning, i.e., East/West (depth) as well as latitudinal (north/south)
- Consider variations in the timing, duration, and execution of bottom trawl surveys since 1963.
- Check for confounding of such changes on detectability of trends due to climatic change.
- Species distribution forecasts should be confirmed by simpler methods.
- Adjust latitudinal boundaries to achieve more even distribution of samples among bins may be useful.
- Consider potential use of spring bottom trawl surveys along with the fall surveys.

# Questions to Think About for Discussion

## Potential Management Application

- If provided species-specific short term forecasts, how would you use that information?
  - Is this type of information helpful for management?
- Where/what types of Council actions, priorities, and/or projects would this type of information be informative or most appropriate?

## Future Model Development

- Is there different and/or additional information you would like see in order to make the model outputs more useful?
- Are there other/higher priority species that distribution forecasts would be most useful?
- Any thoughts on the future direction and development of these models (e.g., other environmental variables, coordination with NRHA products, stock dynamic information, cross research coordination/collaboration etc.)

# For Council Today

- No specific decisions today
- Looking for specific feedback and direction on next steps
  - Value and application for management
  - Future model development considerations

THANK YOU!!

RUTGERS THE STATE UNIVERSITY OF NEW JERSEY

UC SANTA CRUZ

MID-ATLANTIC FISHERY MANAGEMENT COUNCIL

LENFEST OCEAN PROGRAM