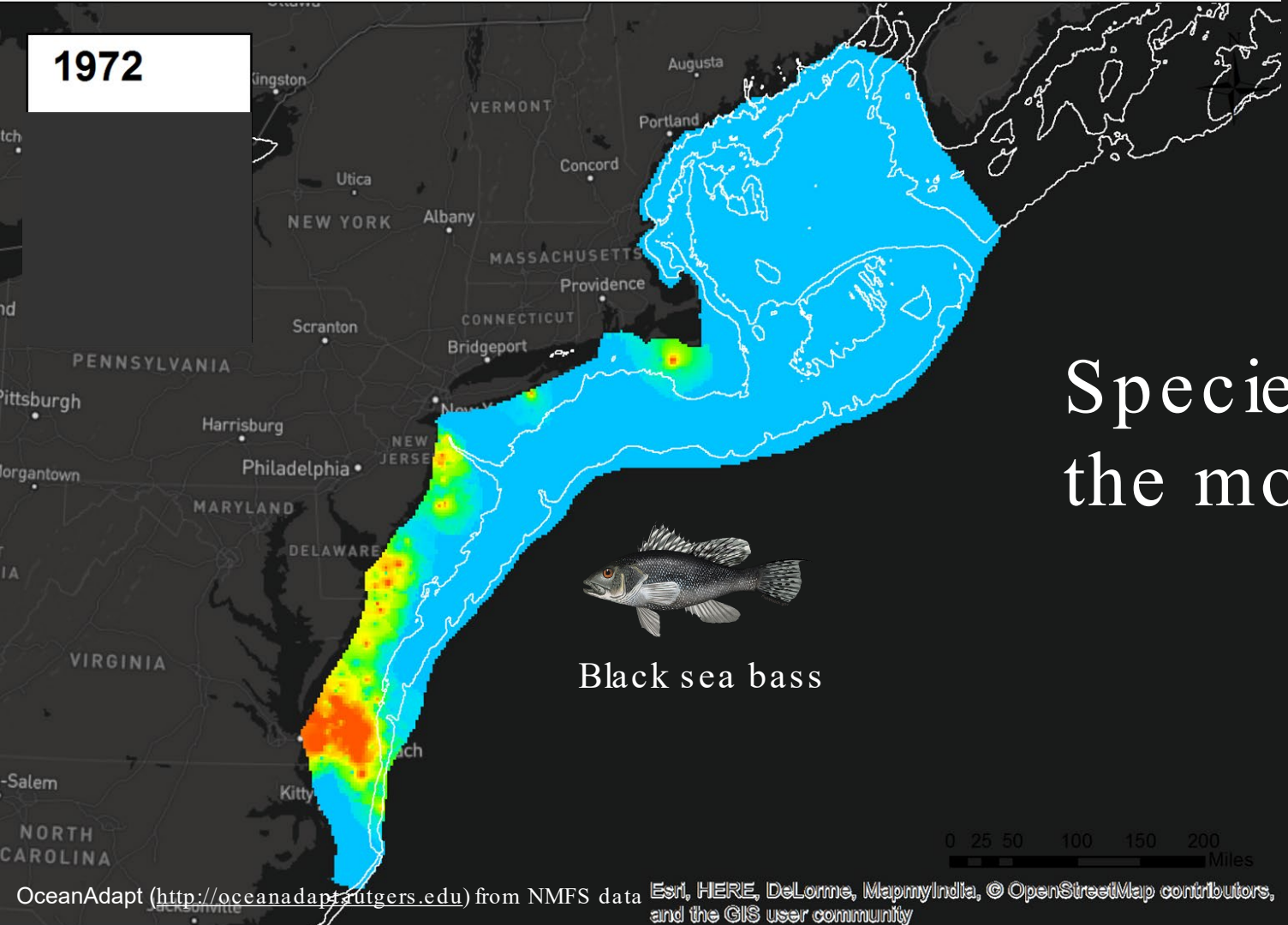
Short-term forecasts of species distributions for fisheries management

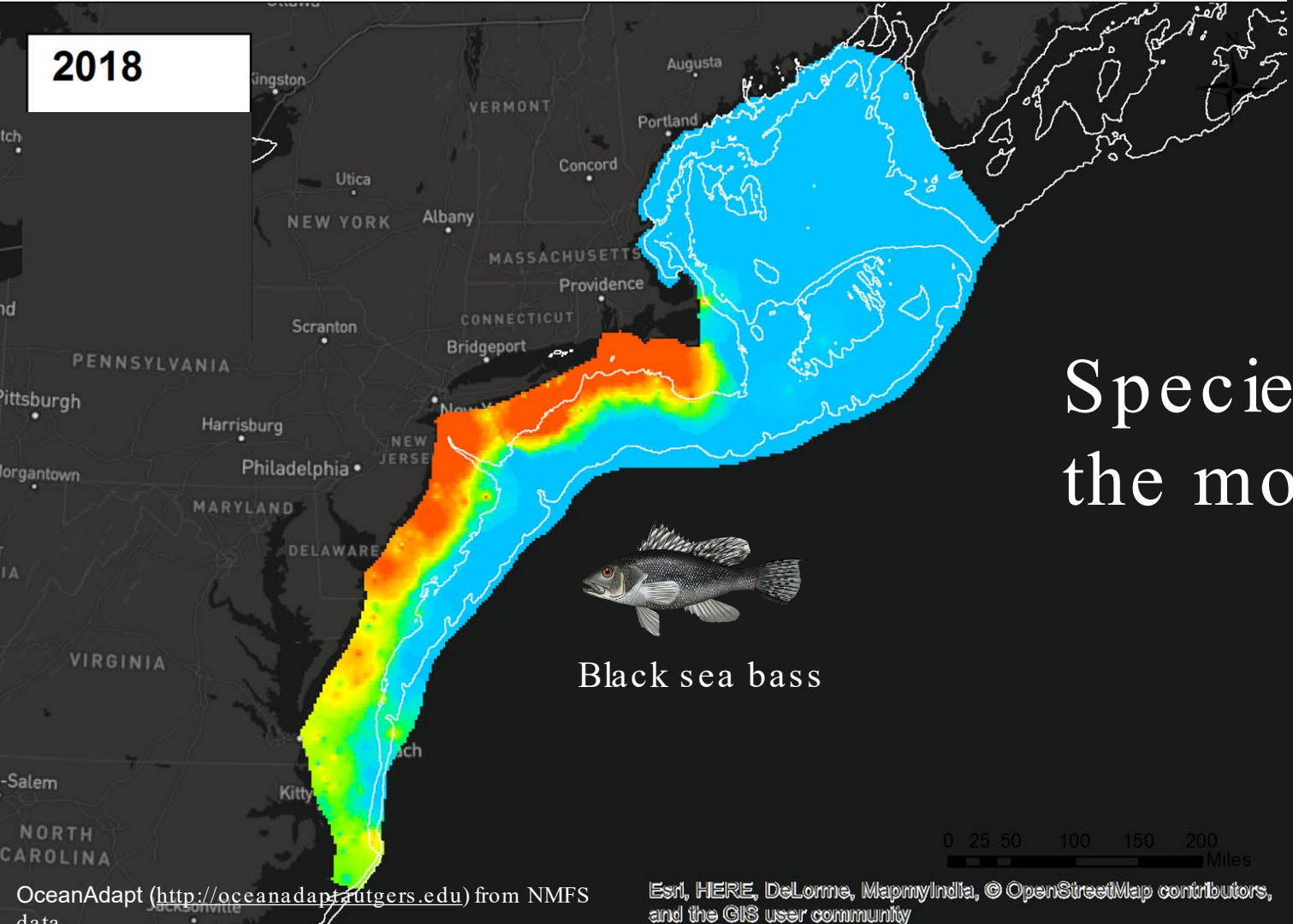
Malin Pinsky, Rutgers University
Alexa Fredston, University of California Santa Cruz
Brandon Muffley, Mid -Atlantic Fishery Management Council



Species are on the move

Black sea bass

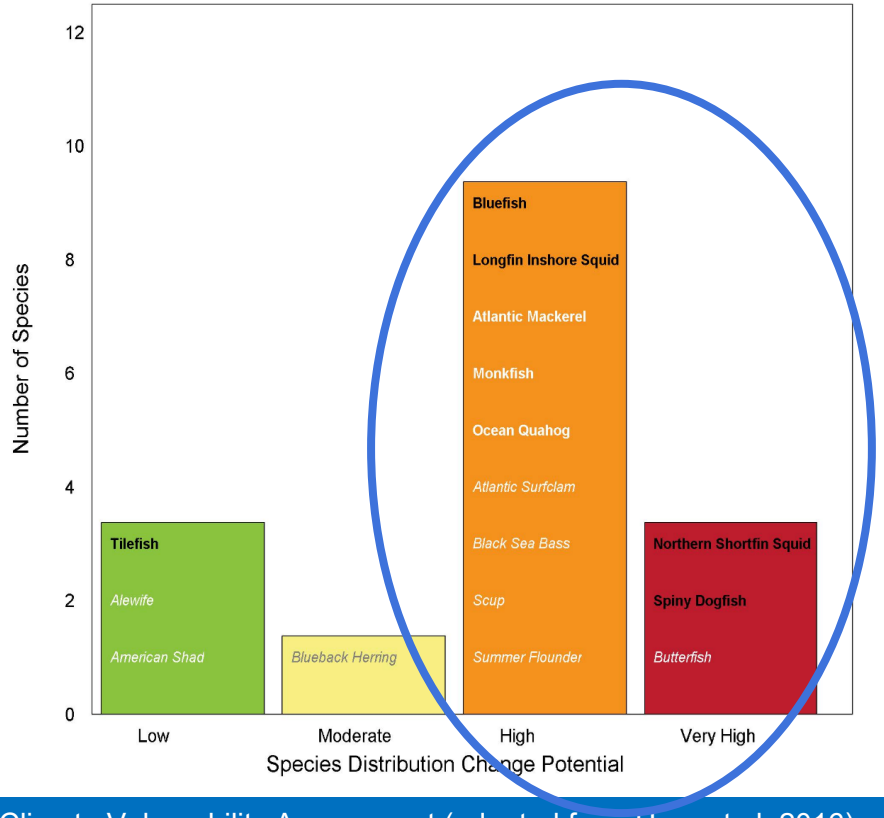
OceanAdapt (http://oceanadapt.rutgers.edu) from NMFS data



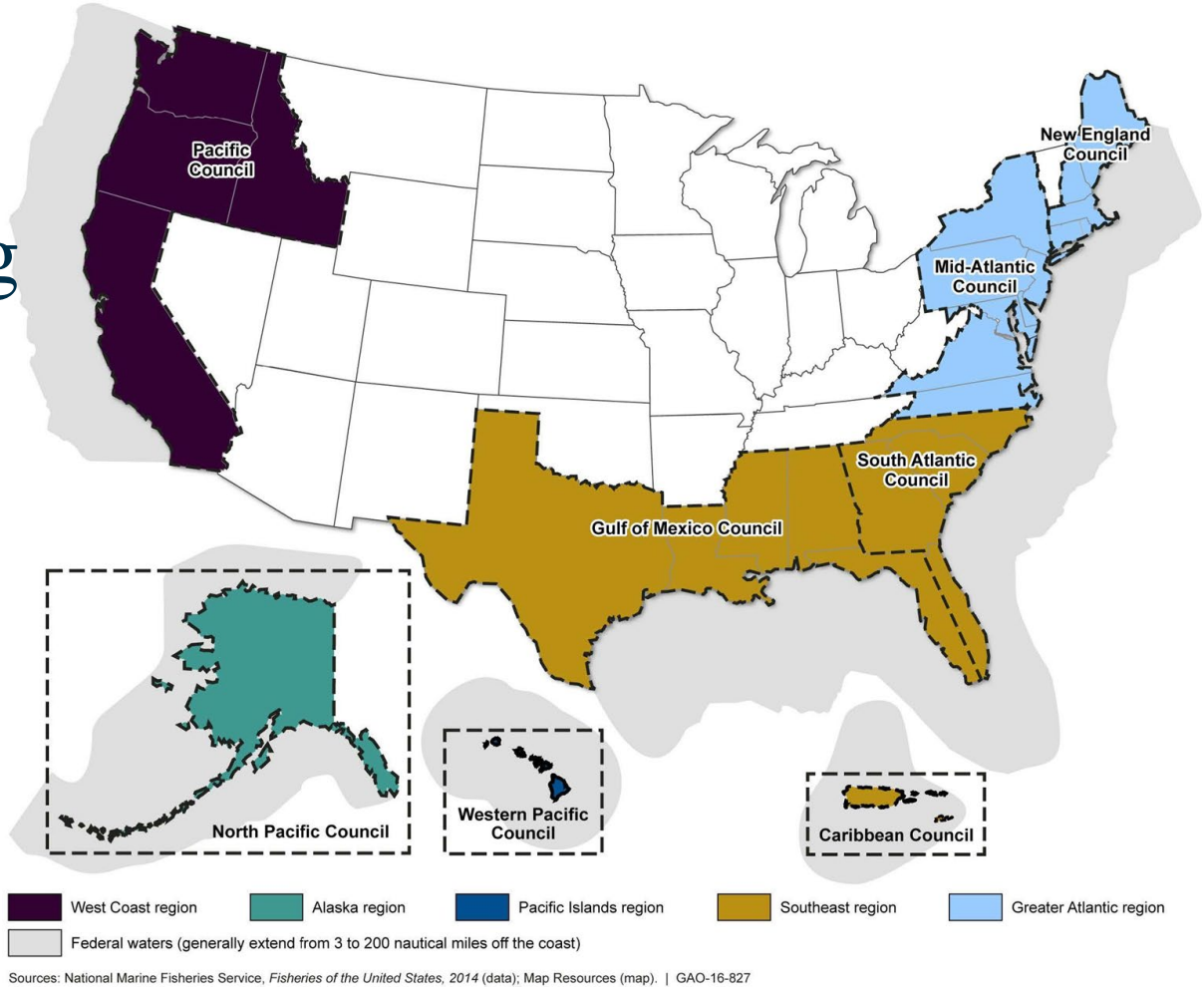
Species are on the move

OceanAdapt (http://oceanadapt.rutgers.edu) from NMFS

Potential change in species distribution

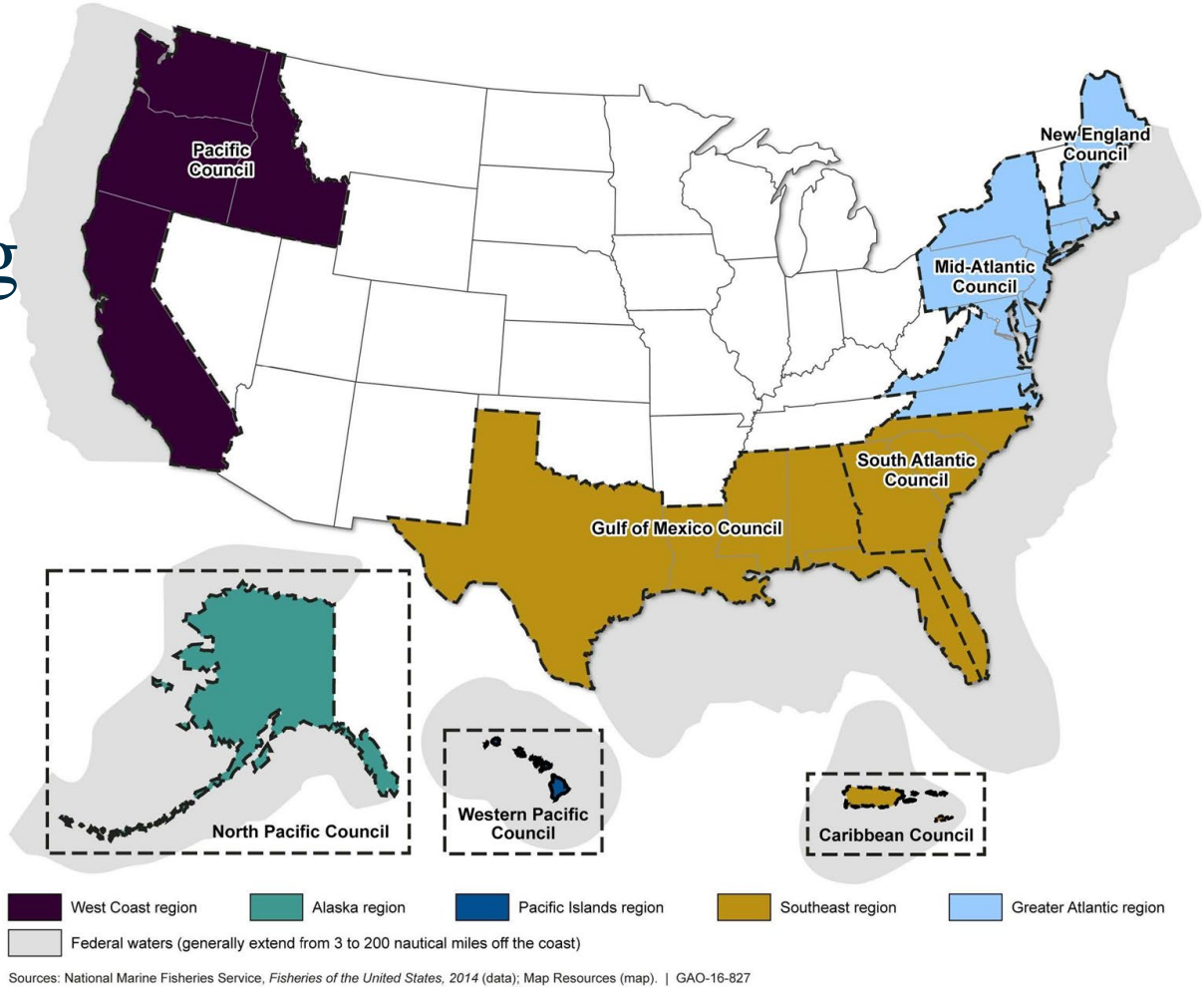


Fisheries management requires knowing where fish are



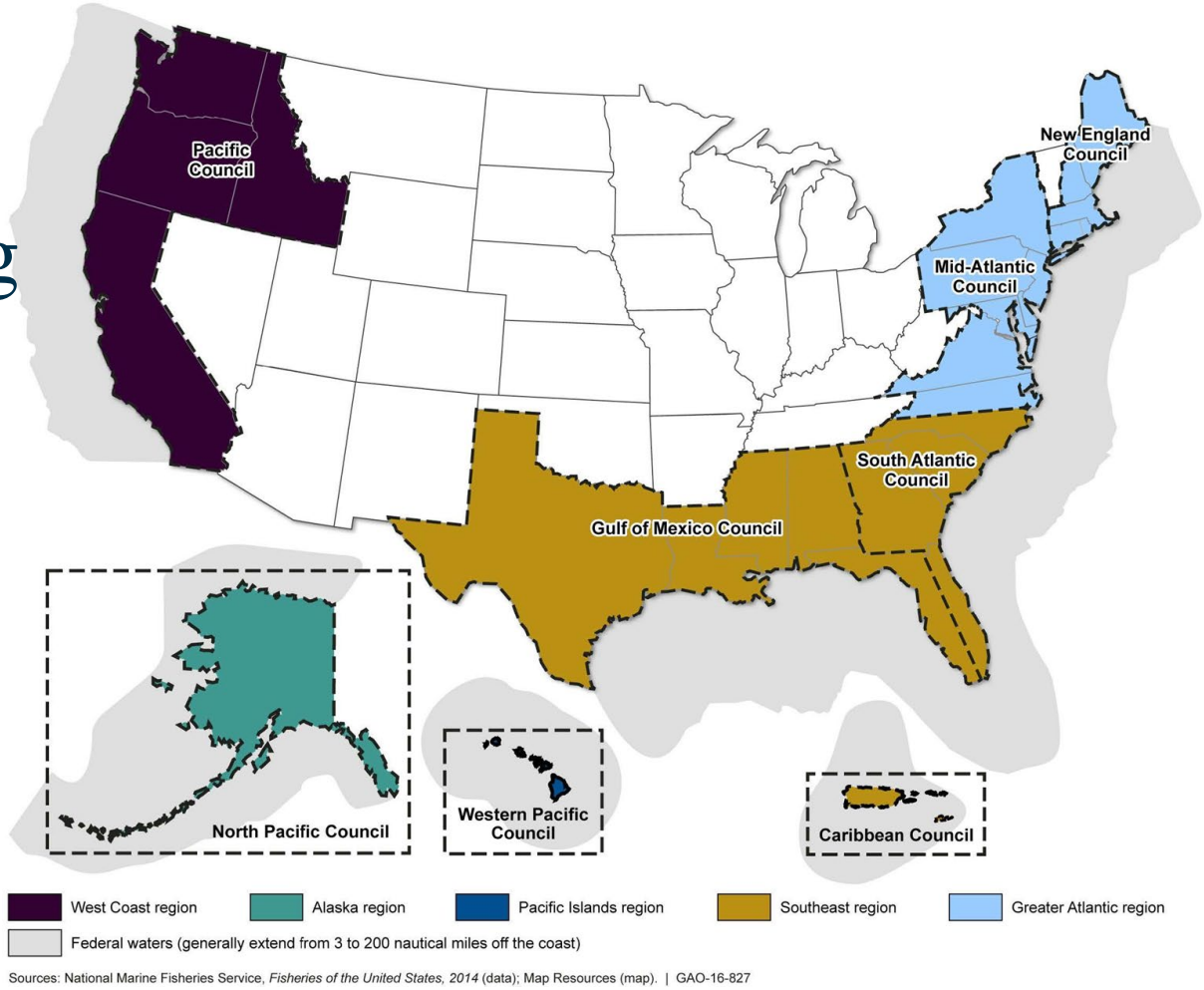
Fisheries management requires knowing where fish are

- Stock definitions



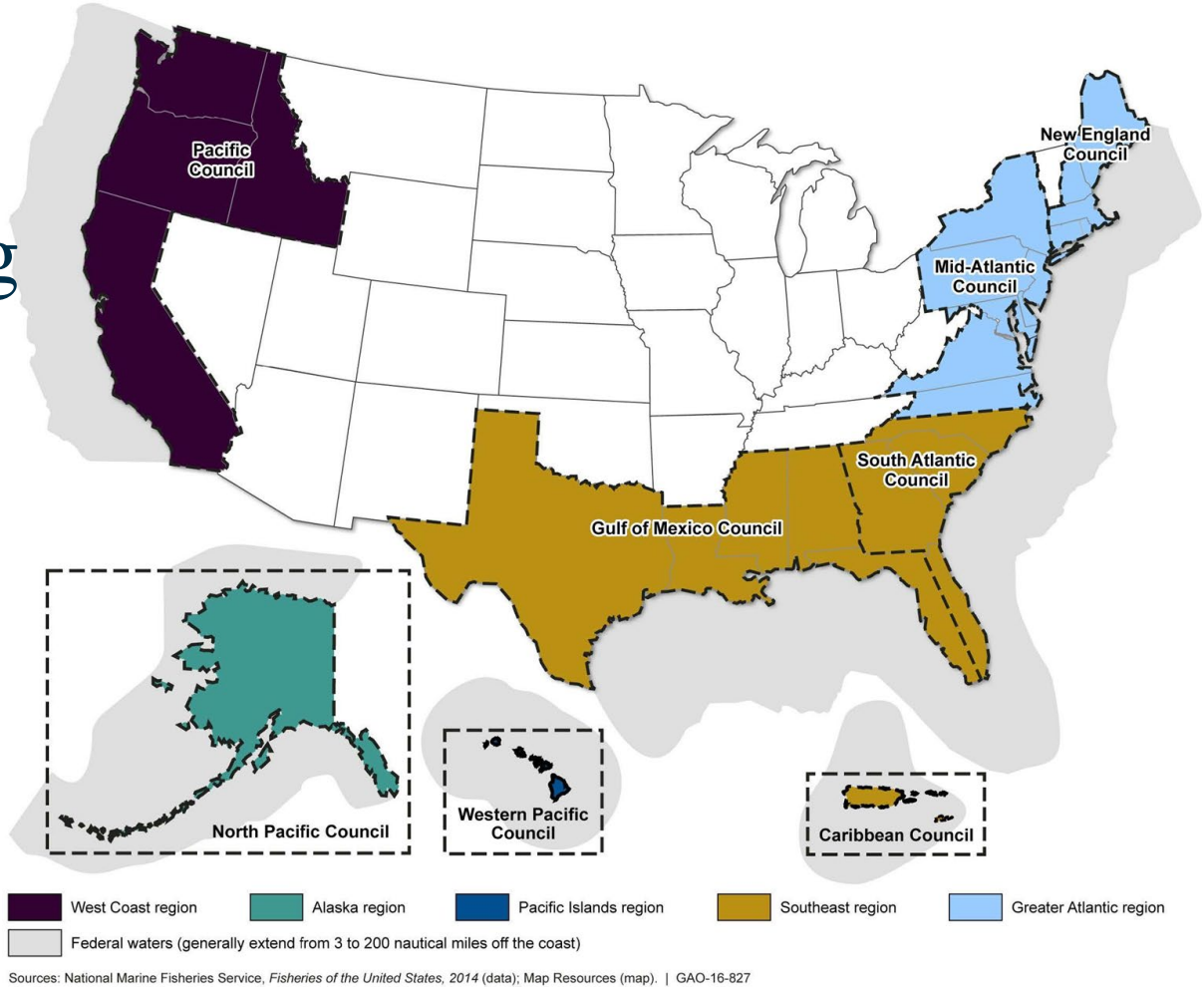
Fisheries management requires knowing where fish are

- Stock definitions
- Stakeholder representation



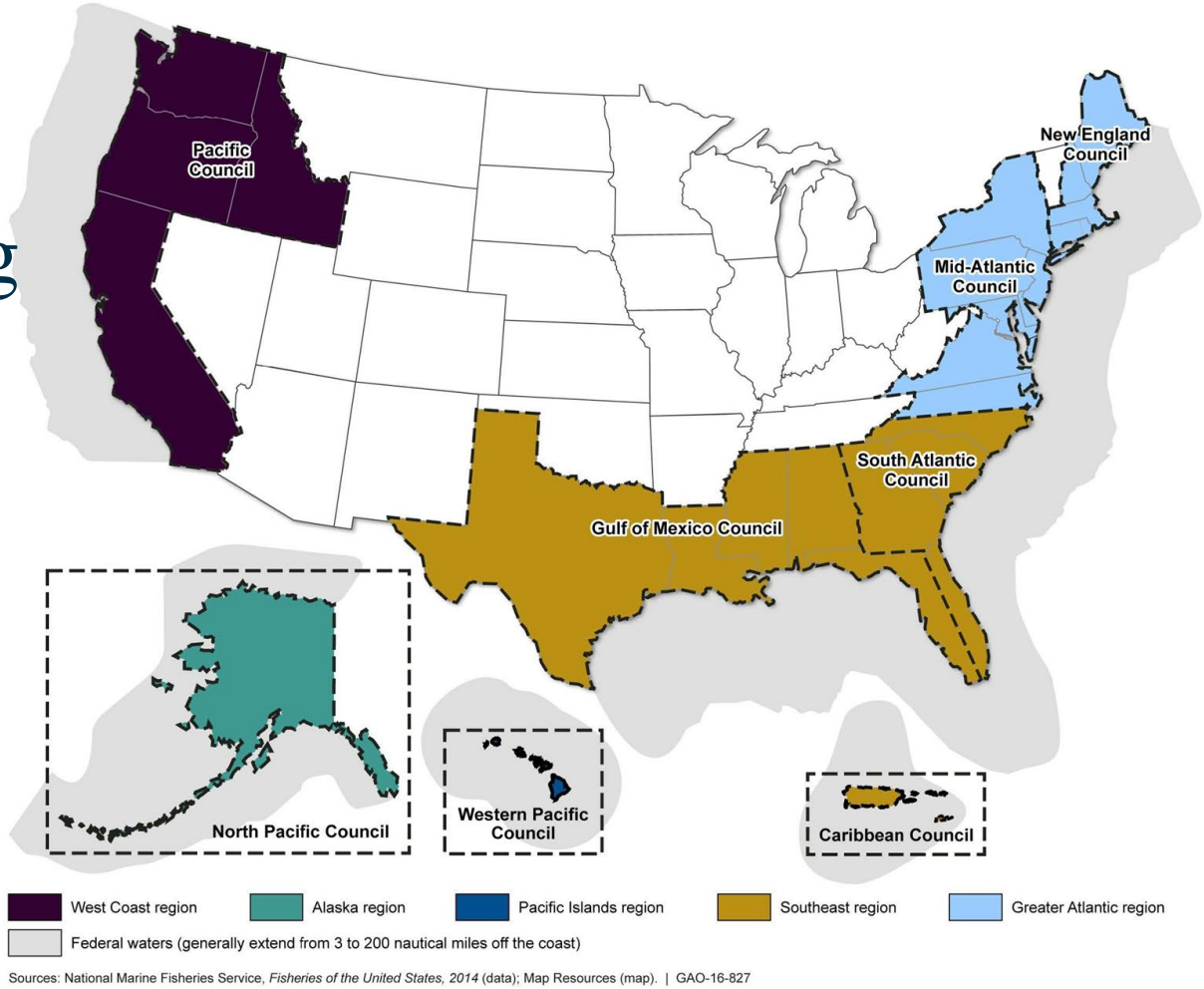
Fisheries management requires knowing where fish are

- Stock definitions
- Stakeholder representation
- Spatial management



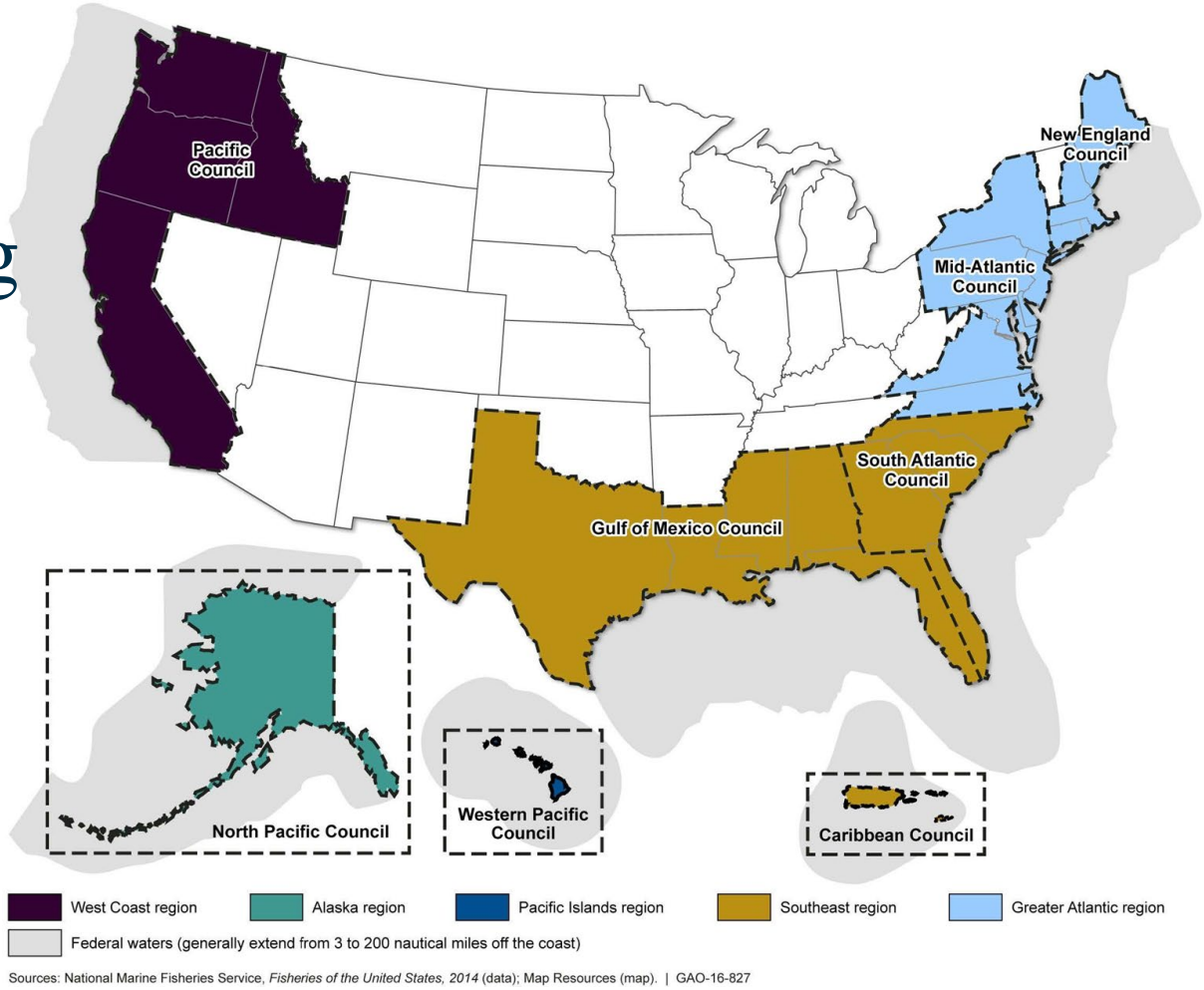
Fisheries management requires knowing where fish are

- Stock definitions
- Stakeholder representation
- Spatial management
- Incidental catch



Fisheries management requires knowing where fish are

- Stock definitions
- Stakeholder representation
- Spatial management
- Incidental catch
- Allocations



Research questions

1. Can dynamic range models **forecast** changes in species distributions?

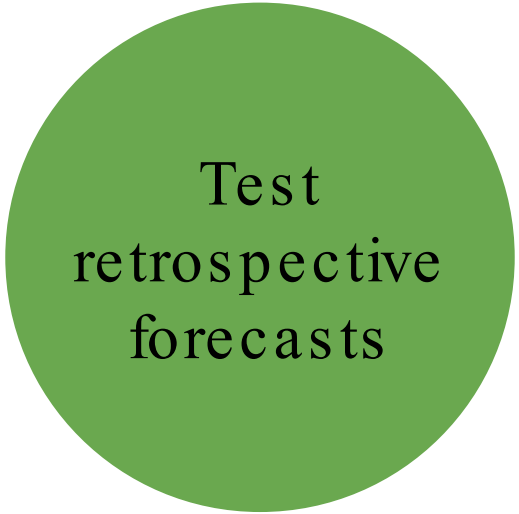
Research questions

1. Can dynamic range models forecast changes in species distributions?
2. At what **time-scales** do forecasts have skill (1- 10 years)?

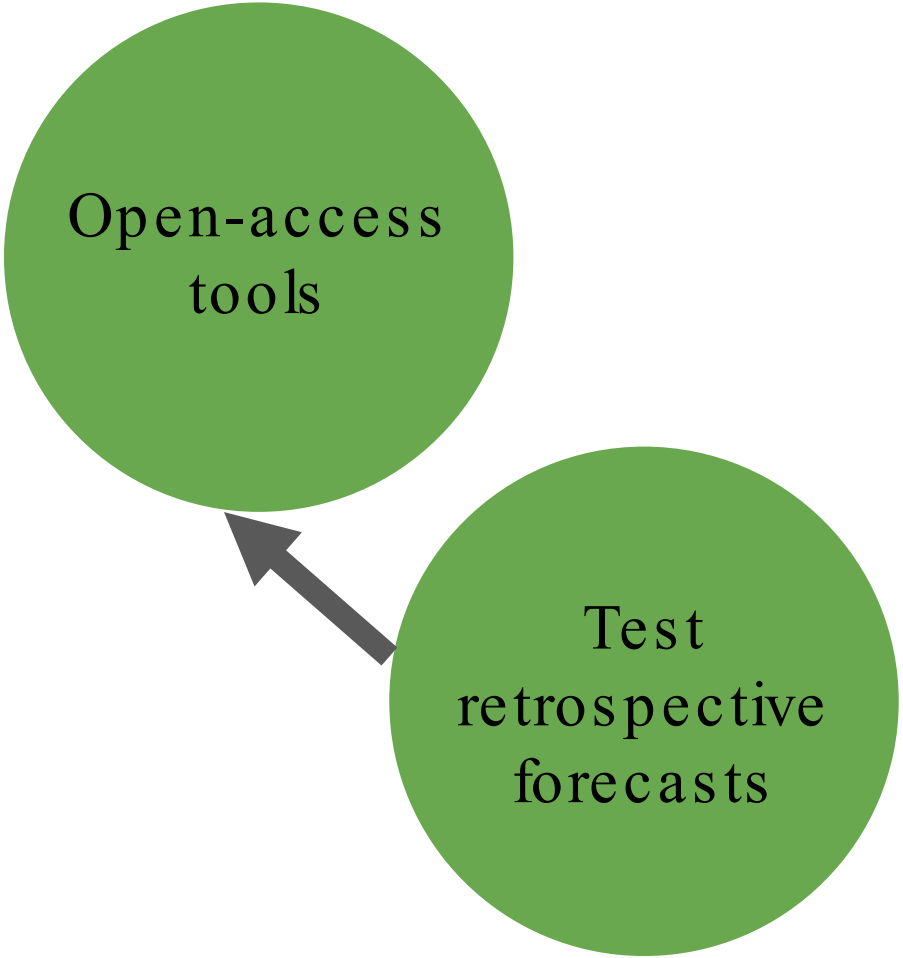
Research questions

1. Can dynamic range models forecast changes in species distributions?
2. At what time-scales do forecasts have skill (1- 10 years)?
3. Does information on **fishing** pressure improve forecasts of species distributions?

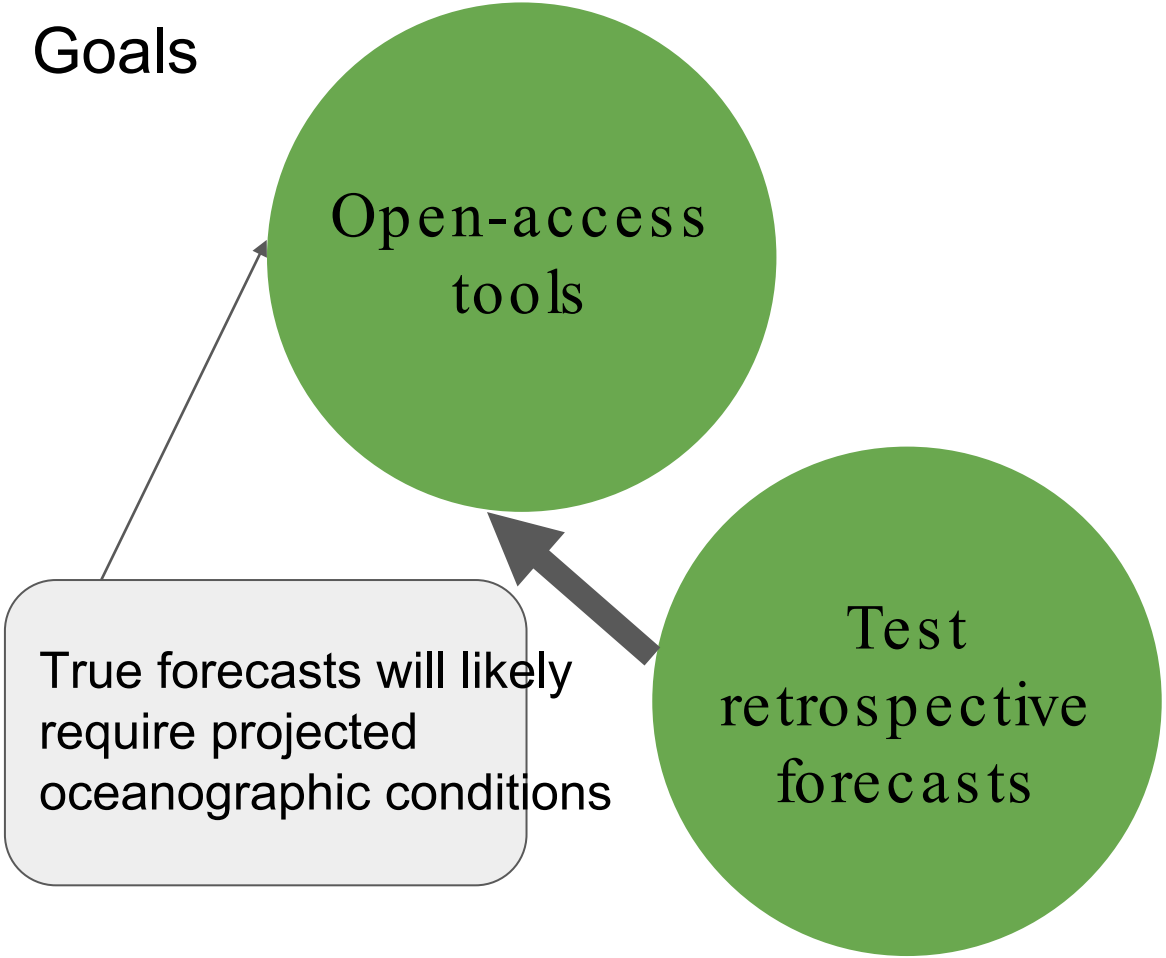
Goals



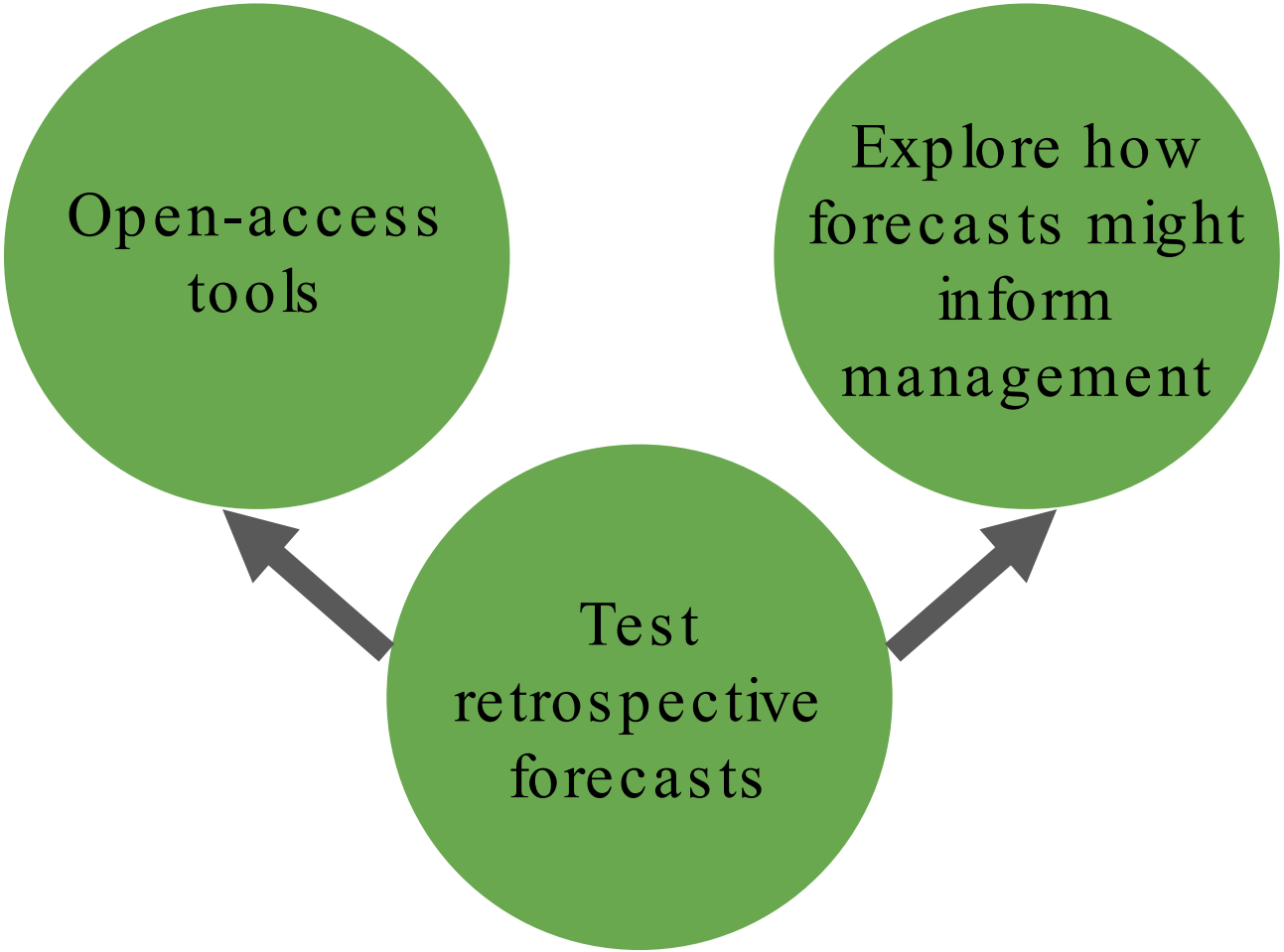
Goals



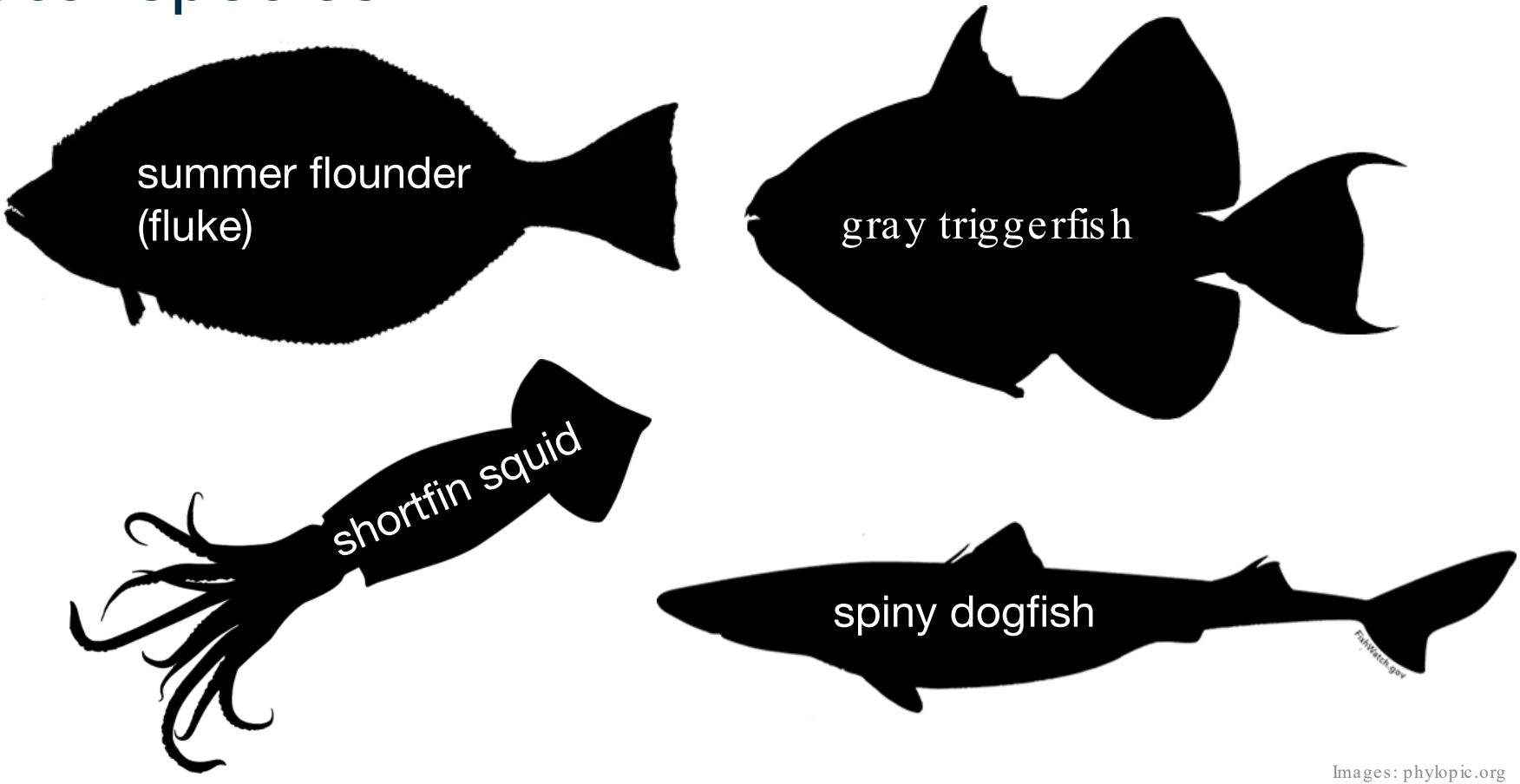
Goals


Open-access tools
Test retrospective forecasts
True forecasts will likely require projected oceanographic conditions

Goals


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

Focal species

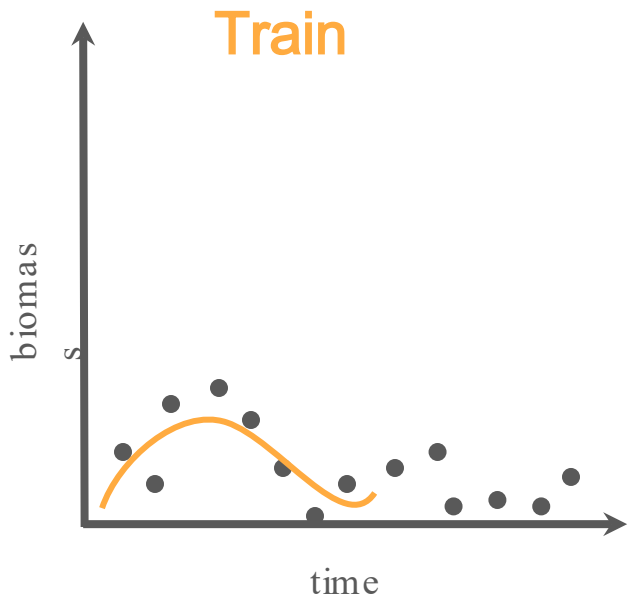


Images: phylopic.org
FishWatch.gov

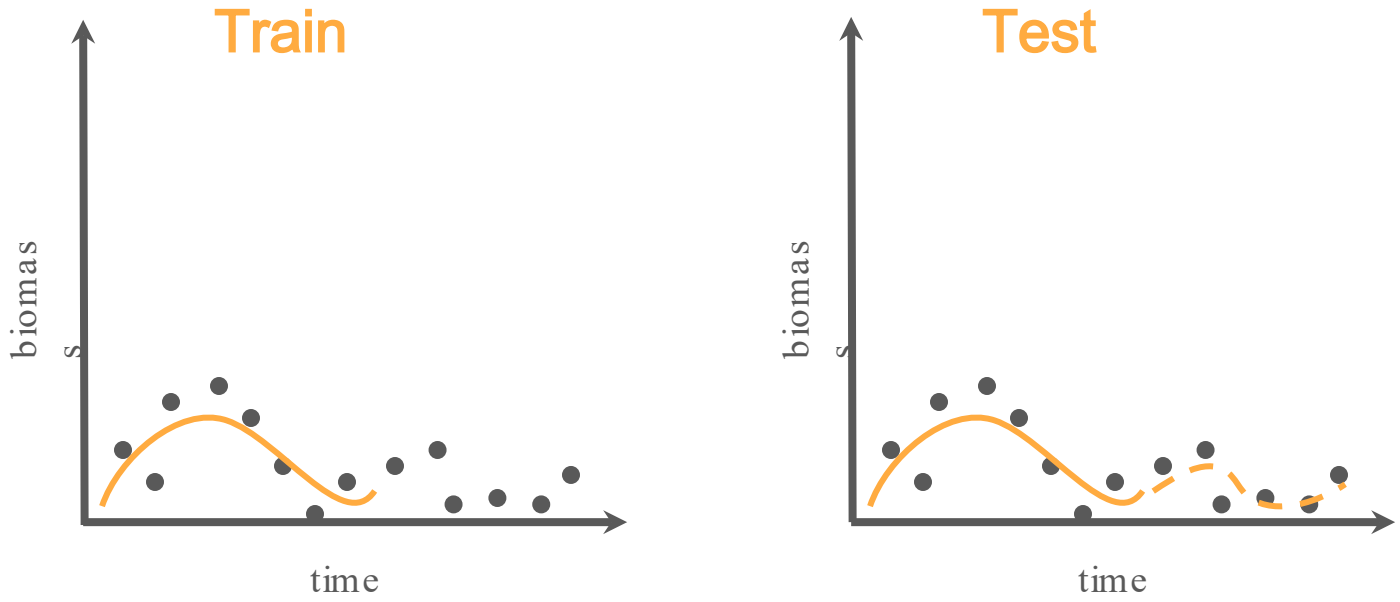
Spoiler alerts: summer flounder models

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

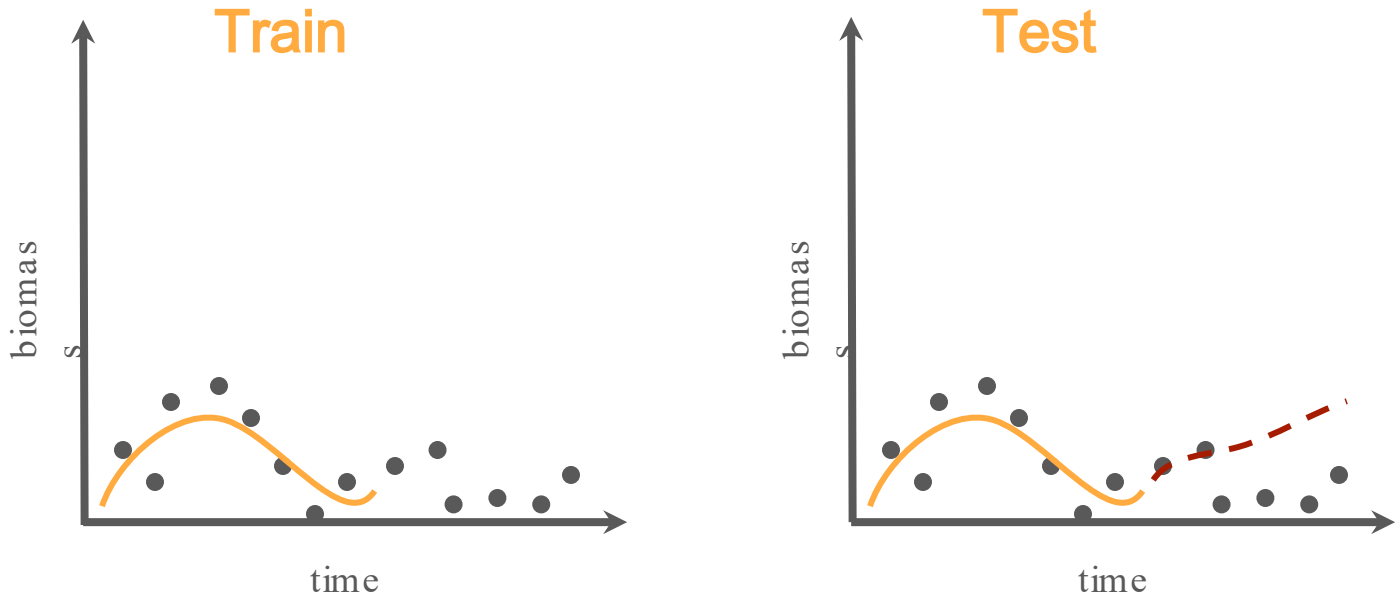
Summary of work



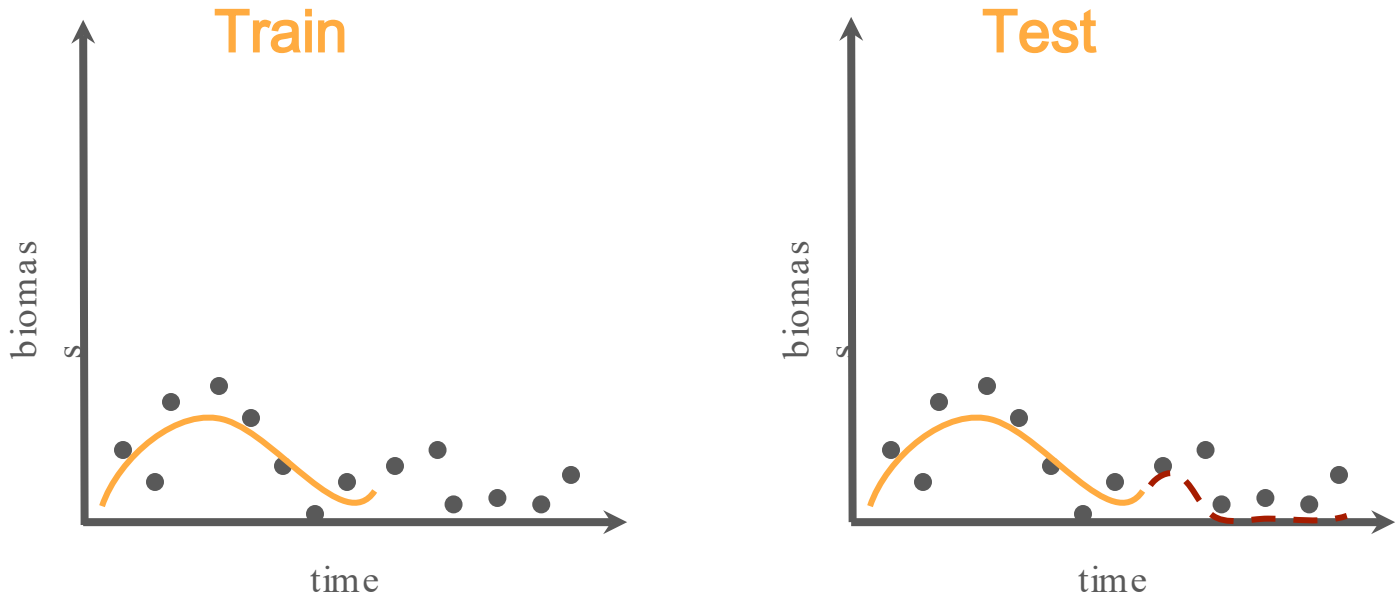
Work plan



Work plan

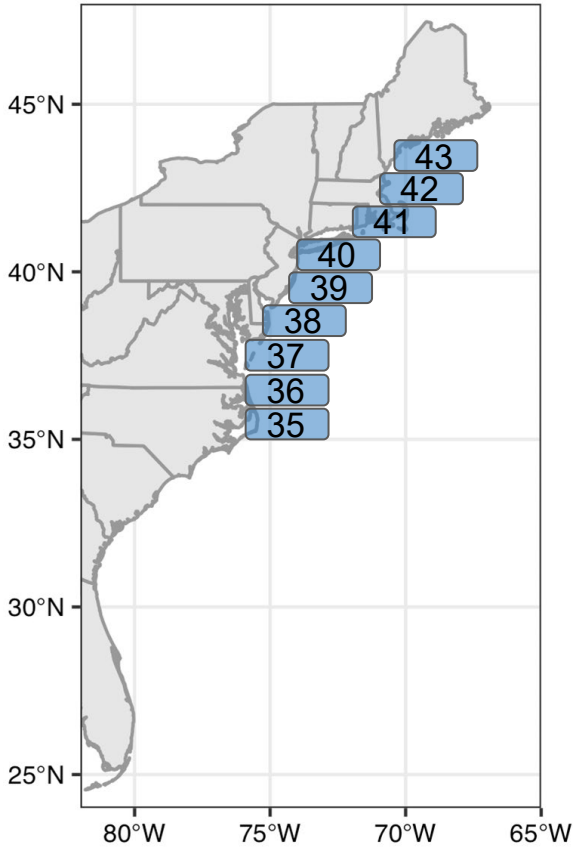


Work plan



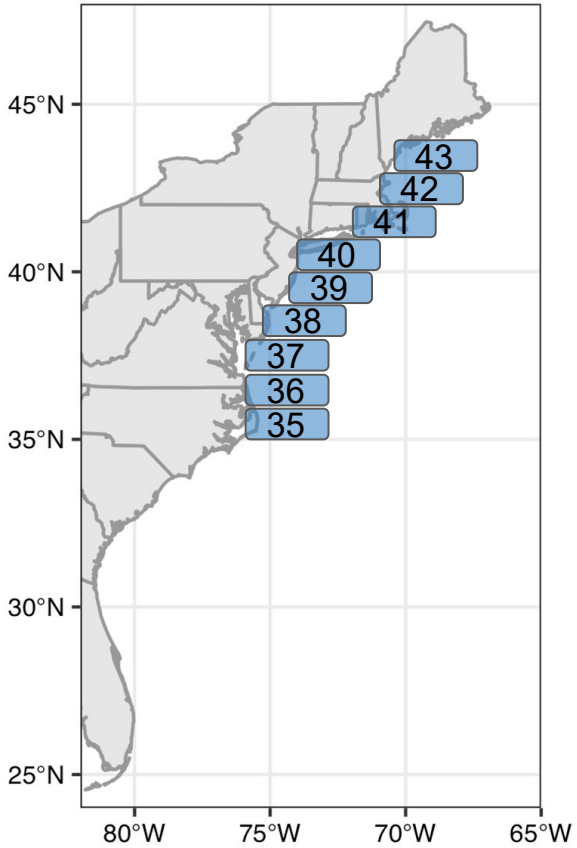
Summary of approach

Fit to data from bottom trawl survey, 1972-2006



Summary of approach

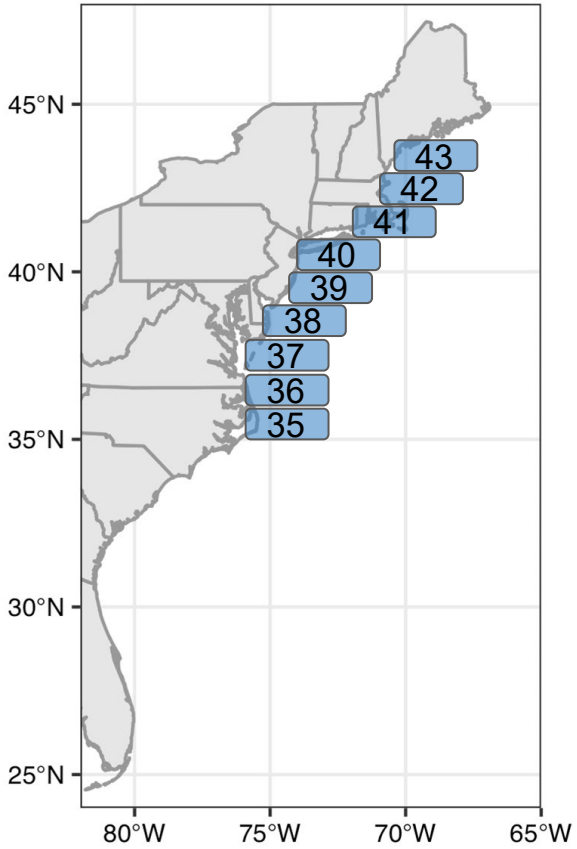
Fit to data from bottom trawl survey, 1972-2006



Test the forecast 2007-2016

Summary of approach

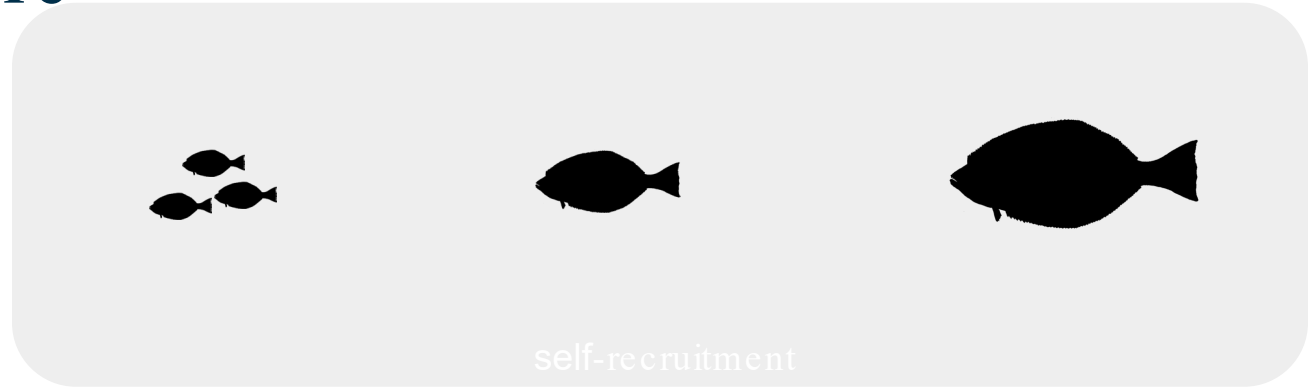
Fit to data from bottom trawl survey, 1972-2006



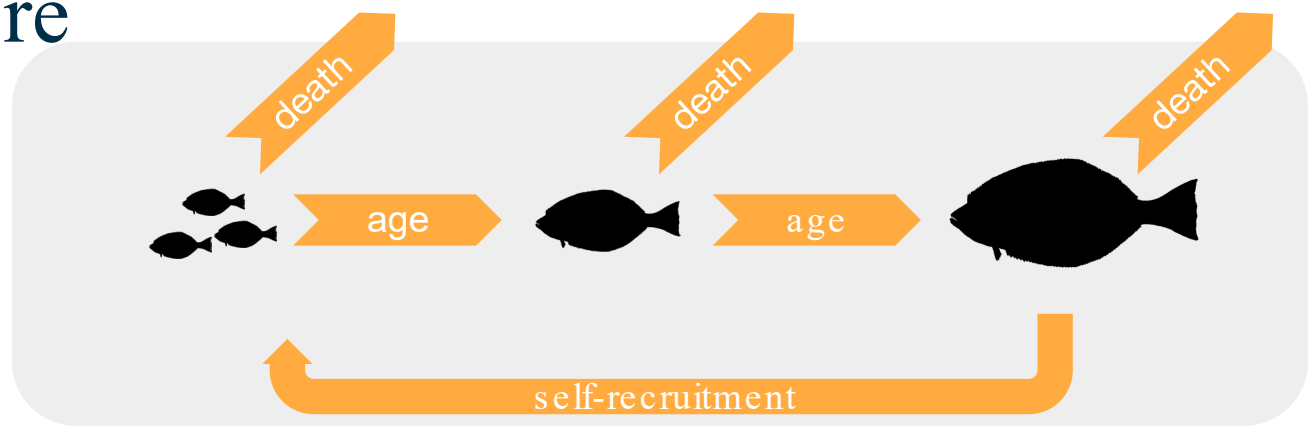
Test the forecast 2007-2016

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

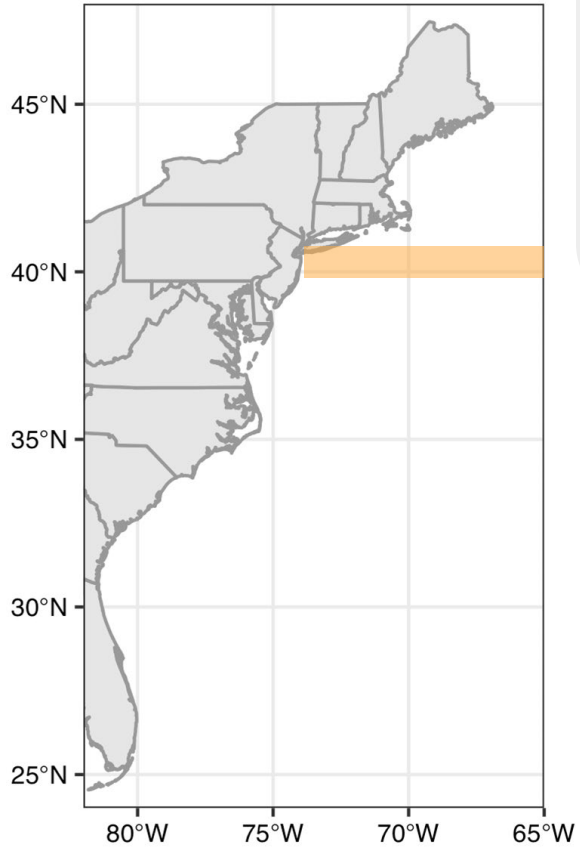
Model structure

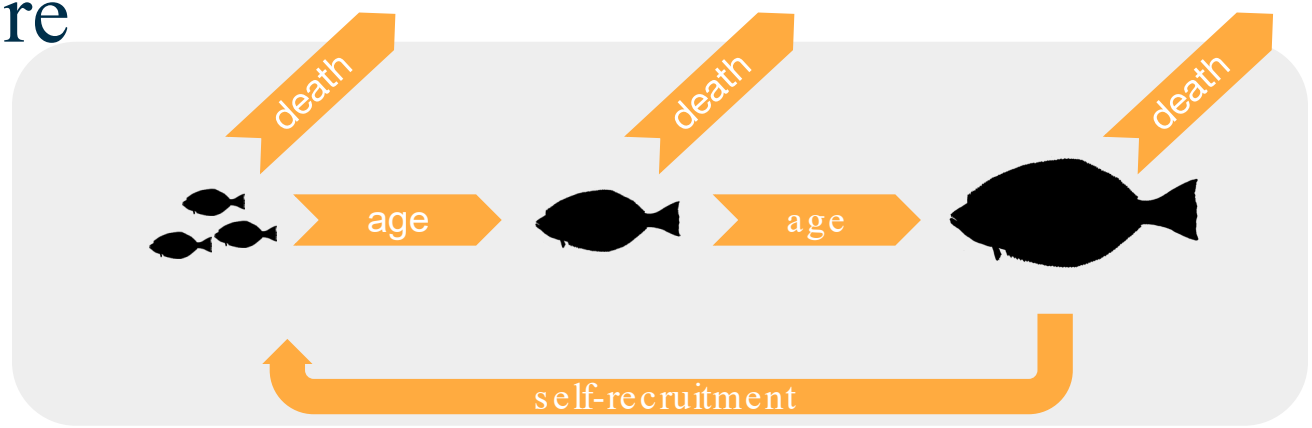


Model structure

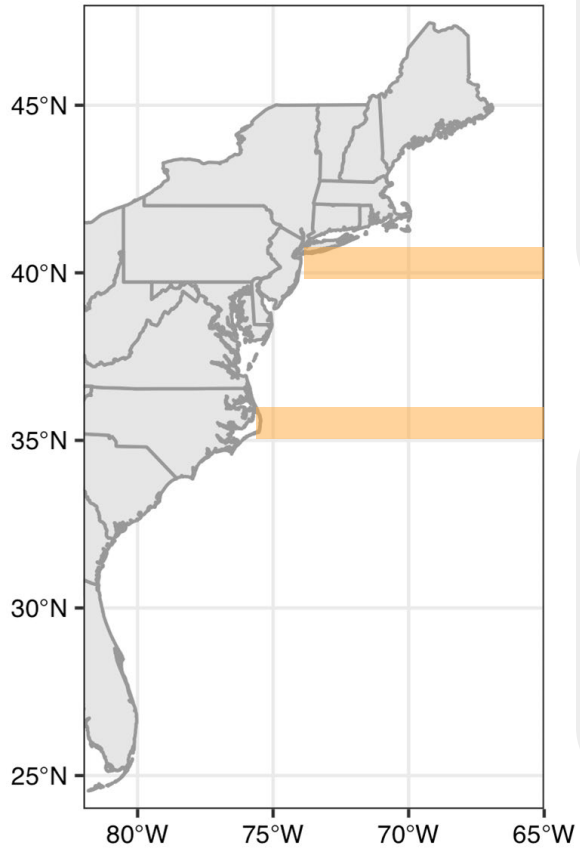


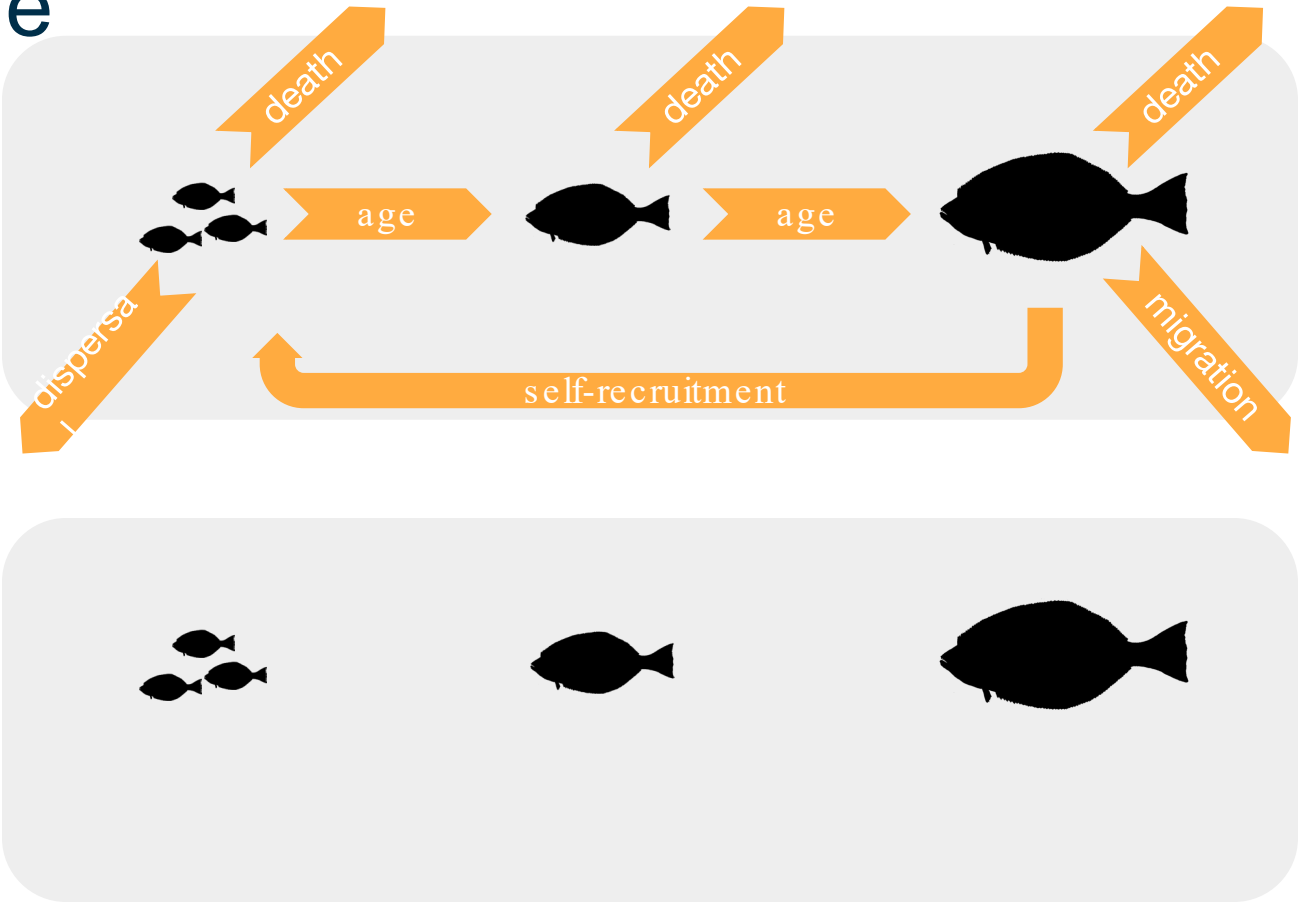
Model structure



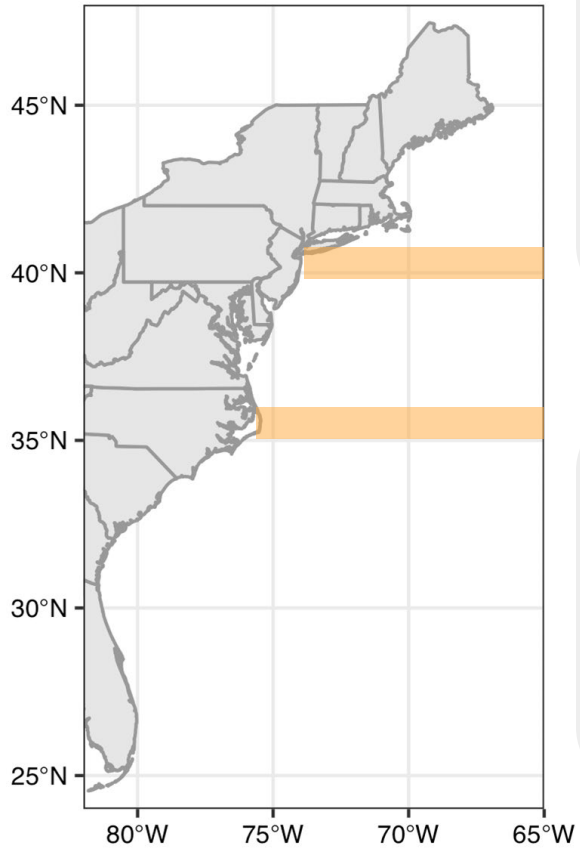


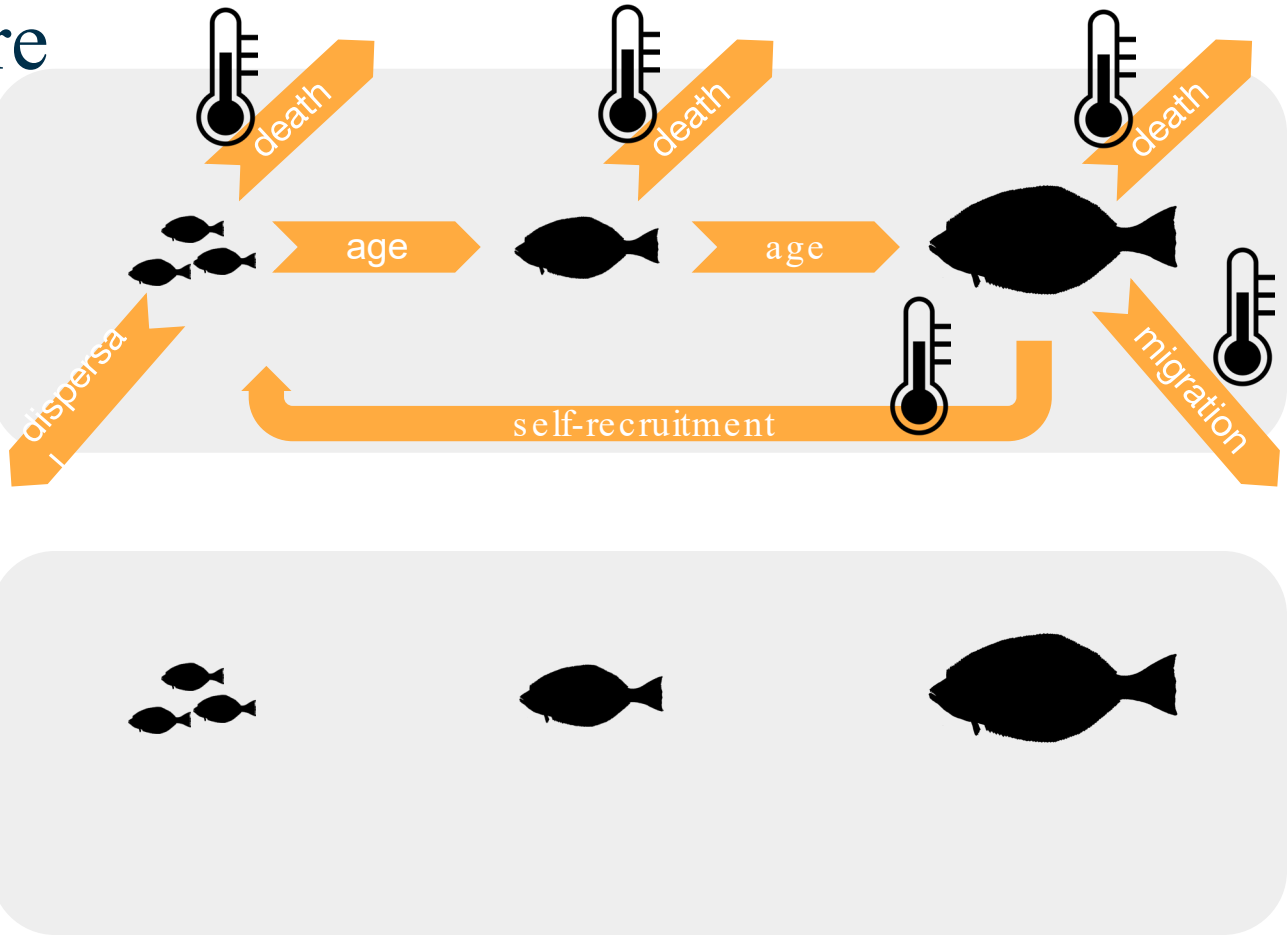
Model structure





Model structure





Model implementation for summer flounder

Stochastic recruitment

yes/no

Temperature affects…

recruitment

dispersal

mortality

nothing

Known f over time

yes/no

Fit to length data

yes/no

Stock-recruit relationship

yes/no

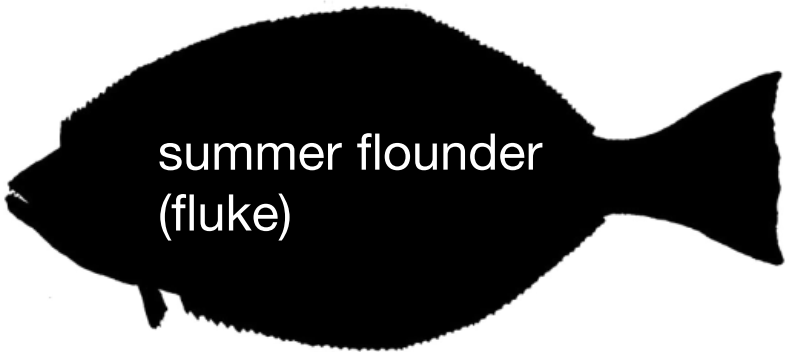
64 candidate models

Candidate model for summer flounder

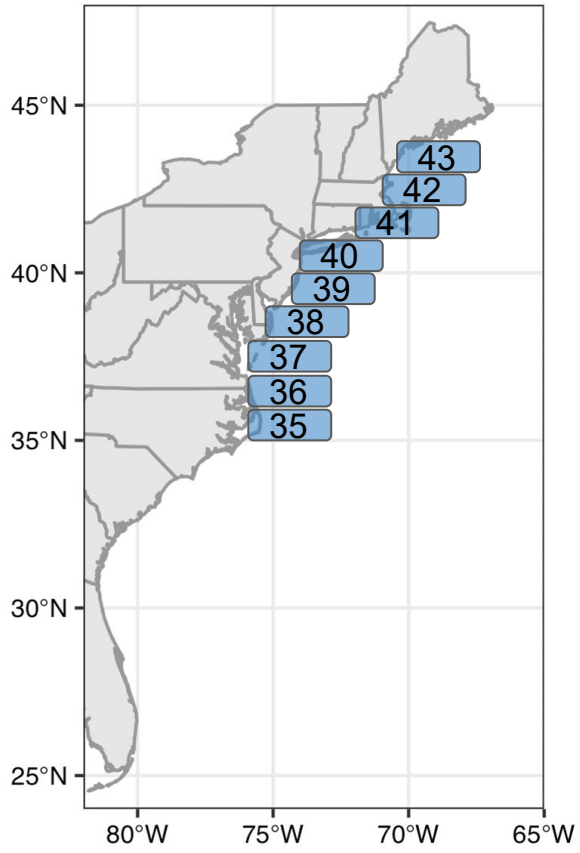
Model structure decision	Yes	No
Fishing values from stock assessment inform mortality rate		✓
Stochastic recruitment process	✓	
Length data informs age structure		✓
Stock-recruit relationship		✓
Temperature affects recruitment		✓
Temperature affects mortality		✓
Temperature affects migration	✓	

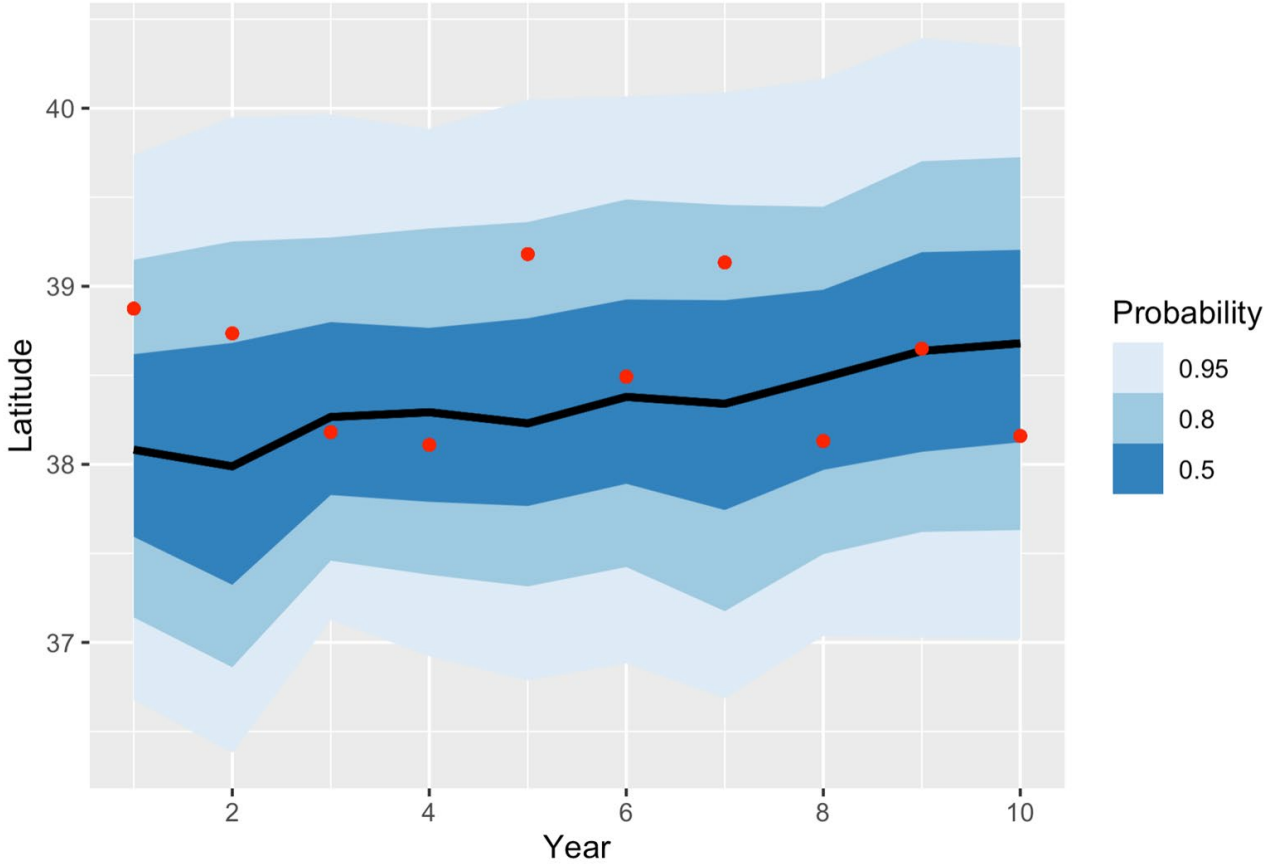
Research questions

1. Can dynamic range models **forecast** changes in species distributions?

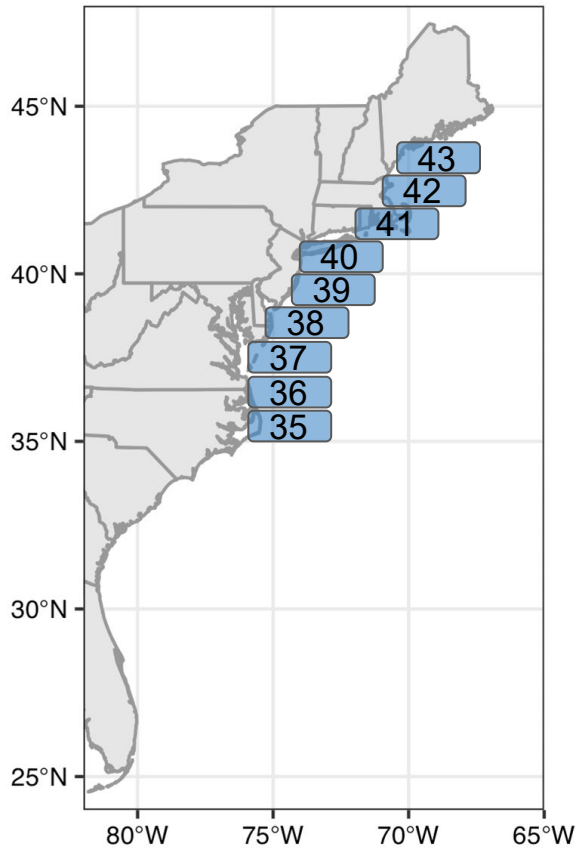


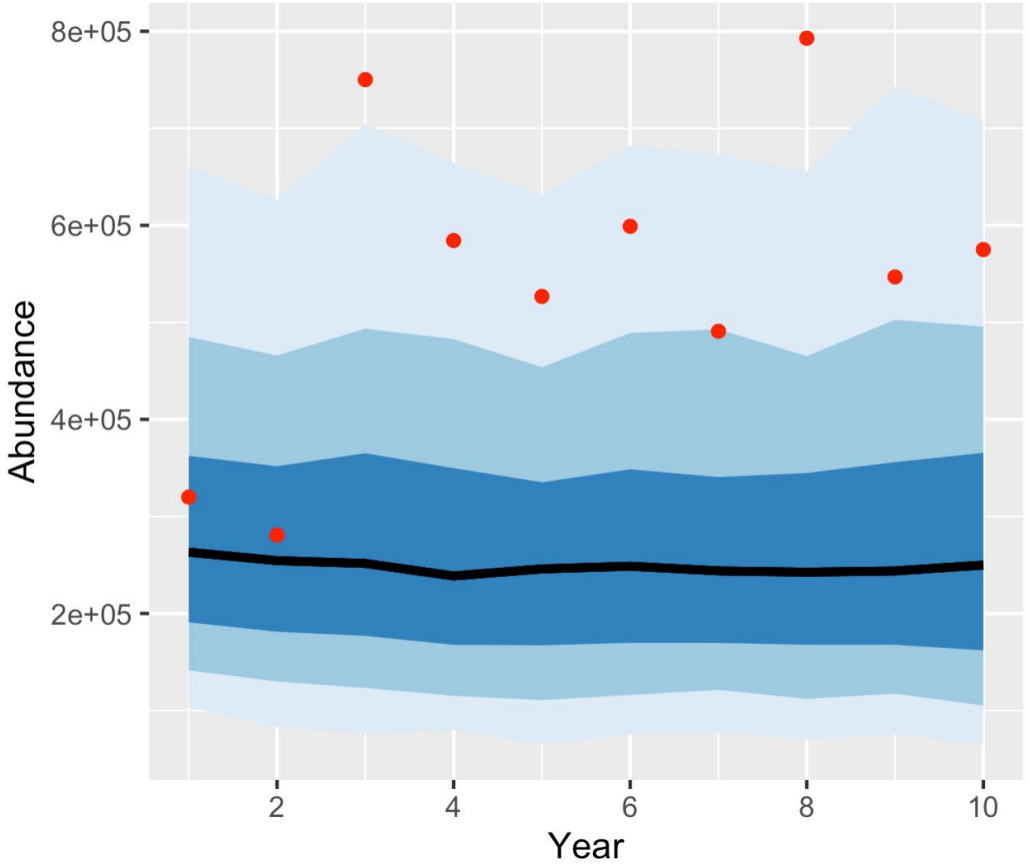
Forecast vs. reality: centroid position



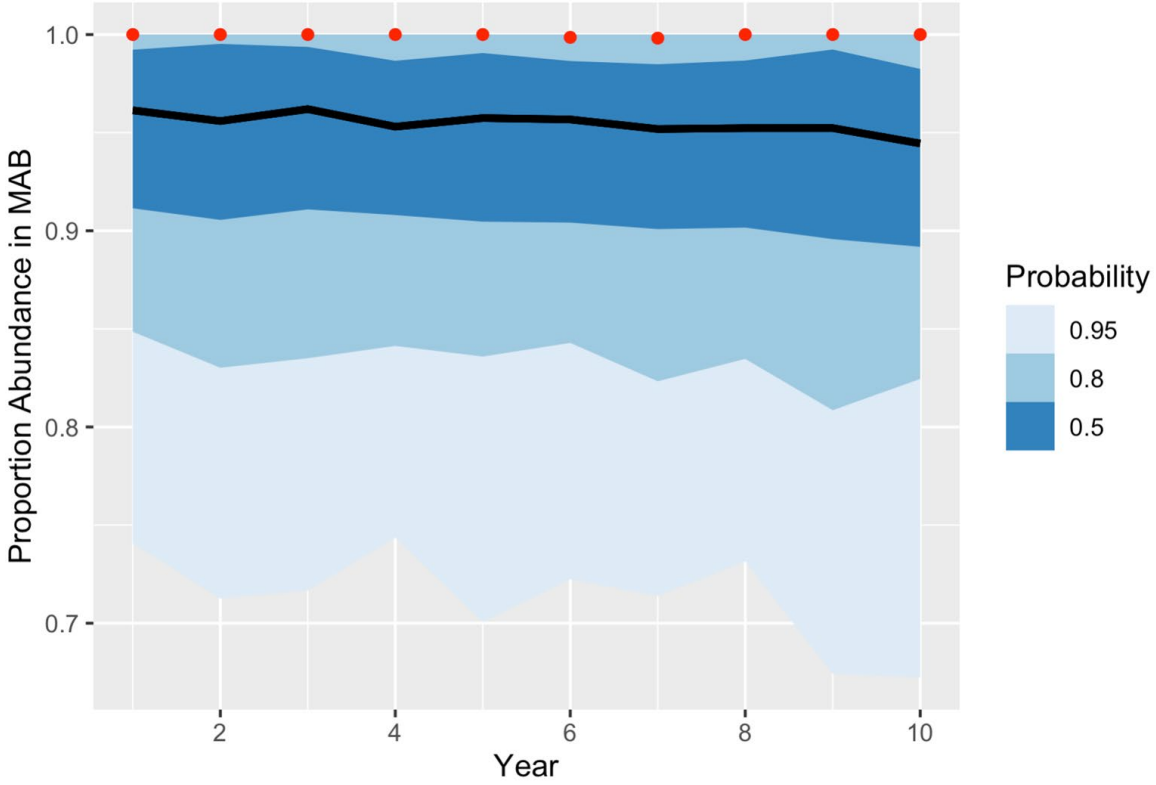


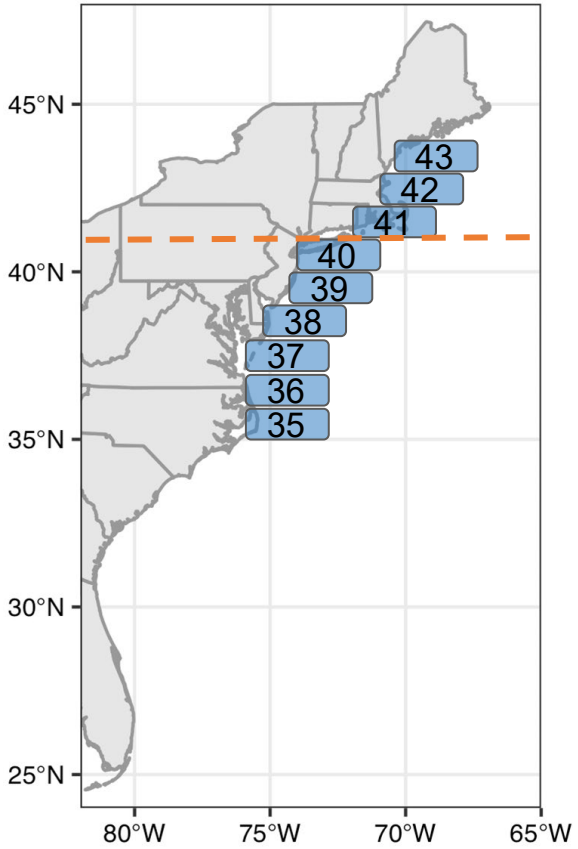
Forecast vs. reality: overall abundance



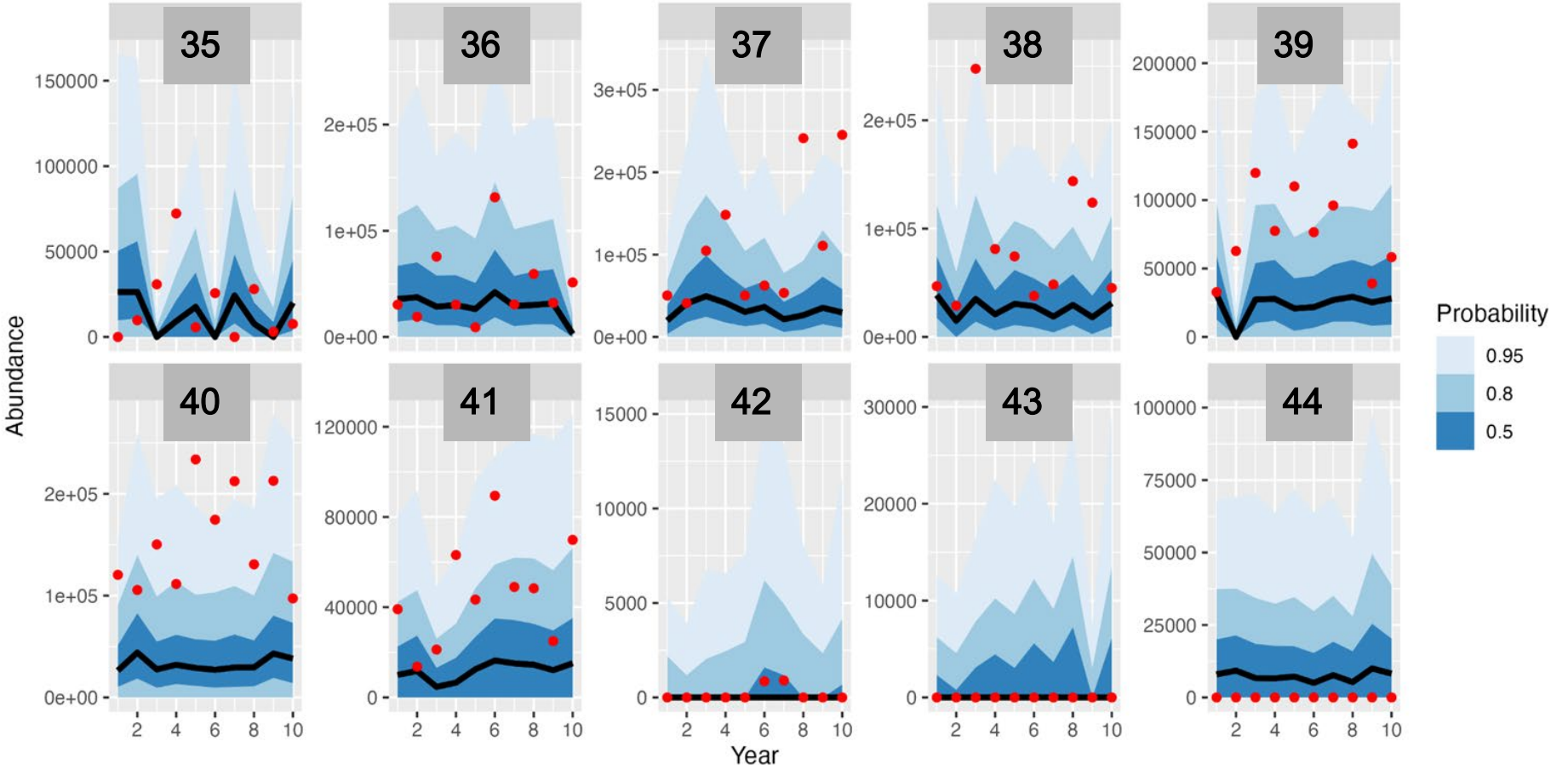


Forecast vs. reality: Mid-Atlantic Bight vs Gulf of Maine / Georges Bank

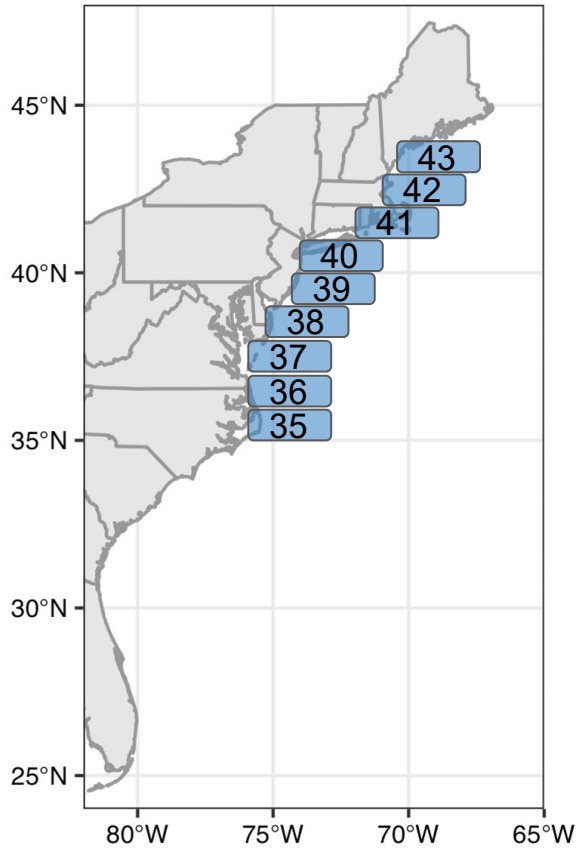


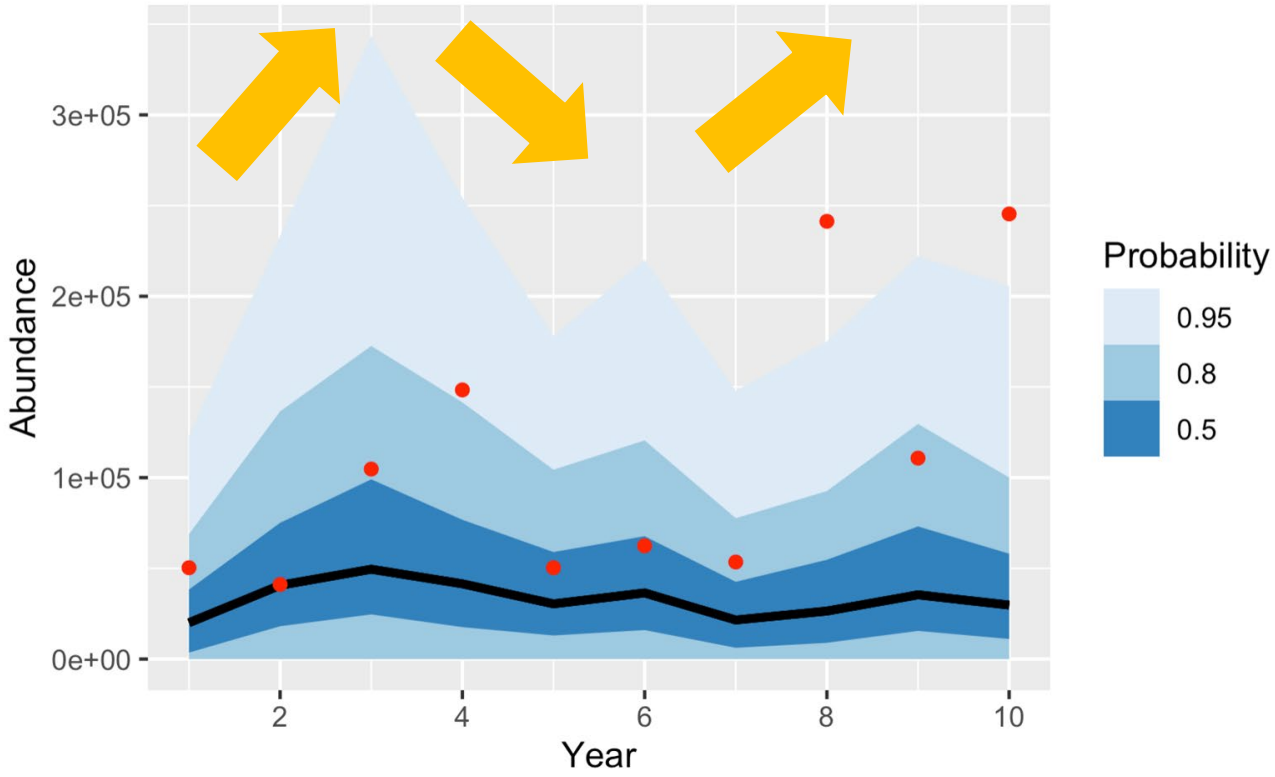


Forecast vs. reality: abundance by patch

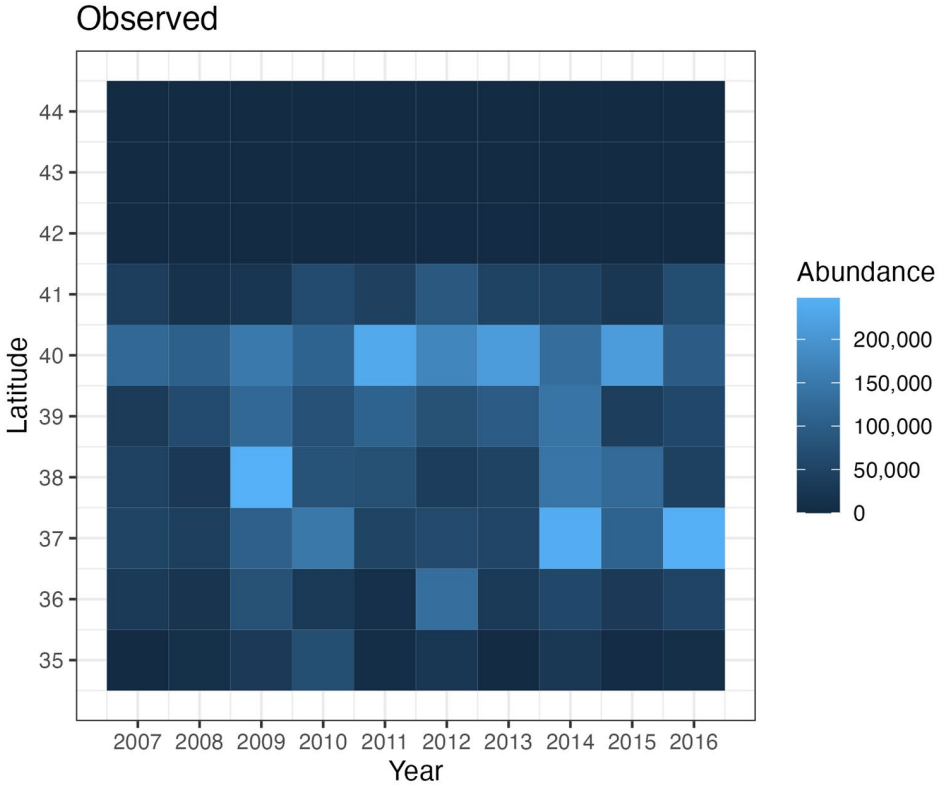


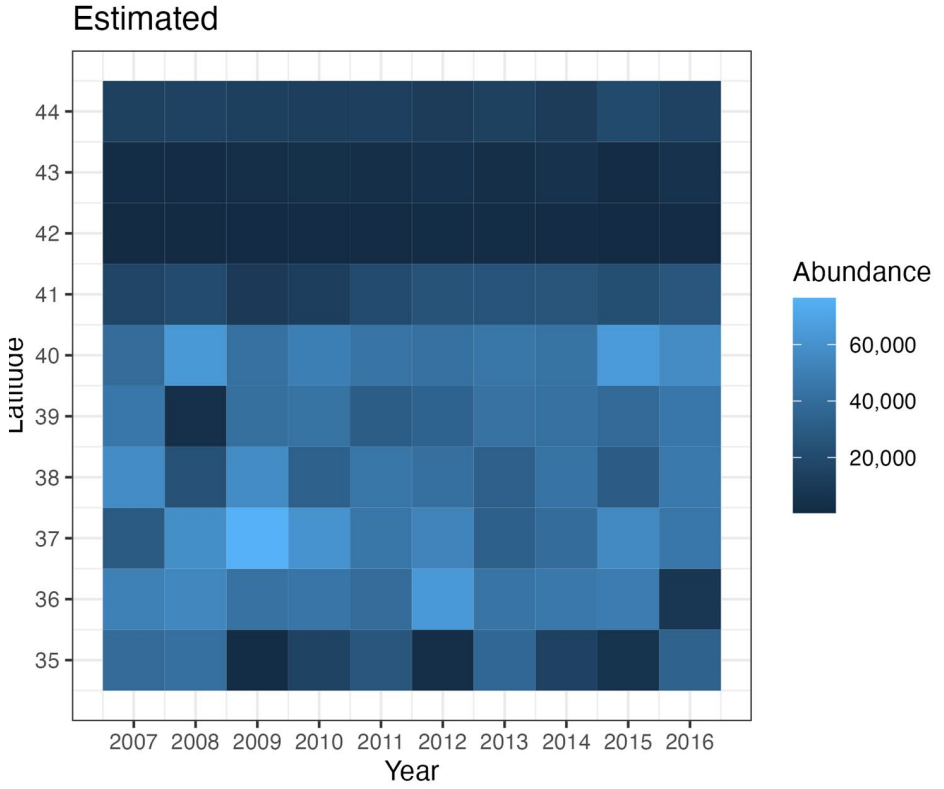
Forecast vs. reality: 37-38 N





Forecast vs. reality: best estimates



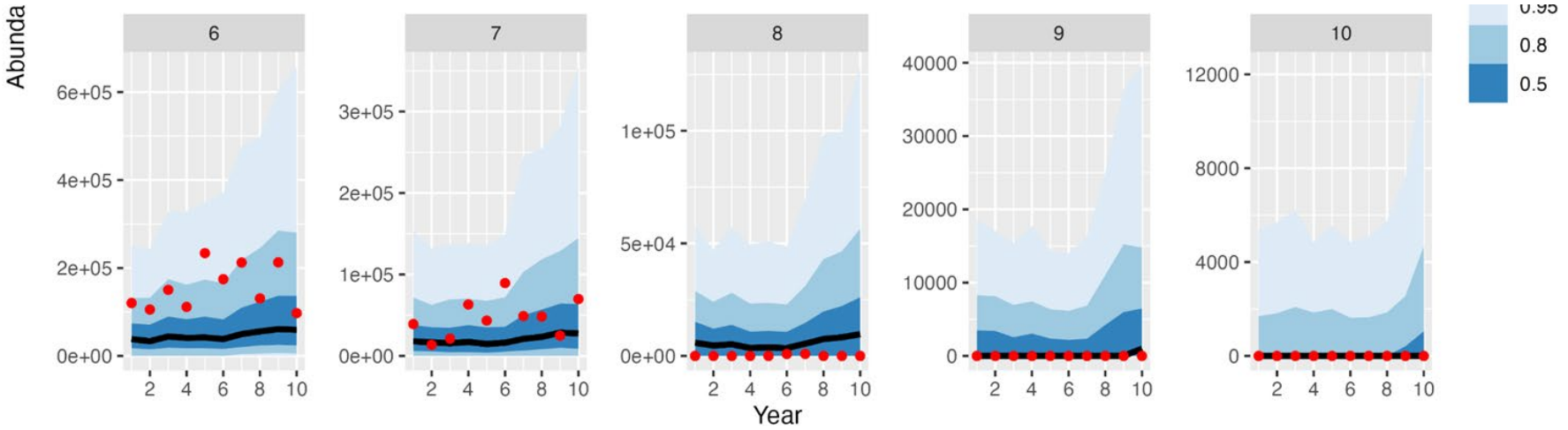


Research questions

1. Can dynamic range models forecast changes in species distributions?
2. At what **time-scales** do forecasts have skill (1-10 years)?

Research questions

1. Can dynamic range models forecast changes in species distributions?
2. At what **time-scales** do forecasts have skill (1-10 years)?



Research questions

1. Can dynamic range models forecast changes in species distributions?
2. At what time-scales do forecasts have skill (1- 10 years)?
3. Does information on **fishing** pressure improve forecasts of species distributions?

Research questions

1. Can dynamic range models forecast changes in species distributions?
2. At what time-scales do forecasts have skill (1- 10 years)?
3. Does information on **fishing** pressure improve forecasts of species distributions?

Yes!

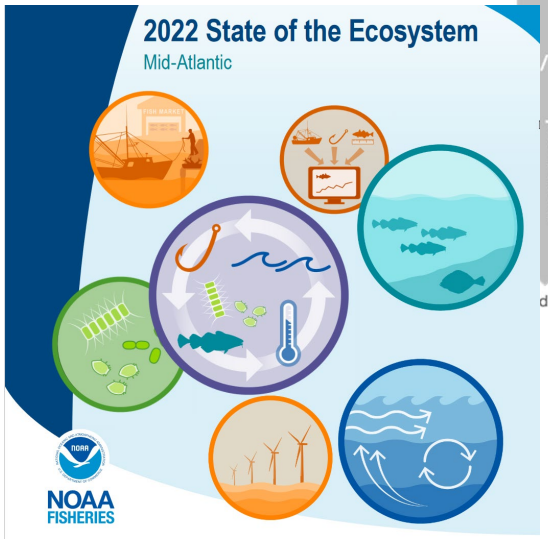
Updates and next steps

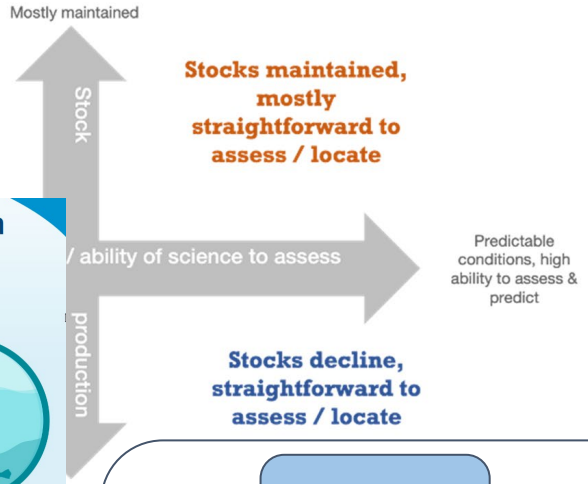
1. All model features are programmed
2. Summer flounder 64 models are running on supercomputers at Rutgers this month
3. Ran traditional SDMs for comparison
4. Next up: formally evaluate and compare models
5. Other three species are in the works

Our questions for you

1. If this was a future forecast, what would you do with it?
2. What types of information (for example, biomass in/out of Mid-Atlantic Bight) would be most useful?
3. How does quantifying uncertainty inform your interpretation of the model results?

Potential Project Application(s)



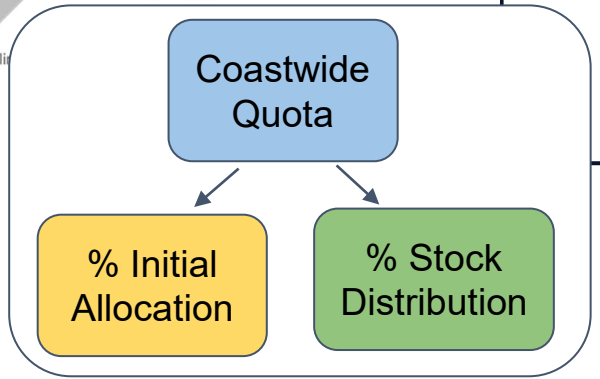


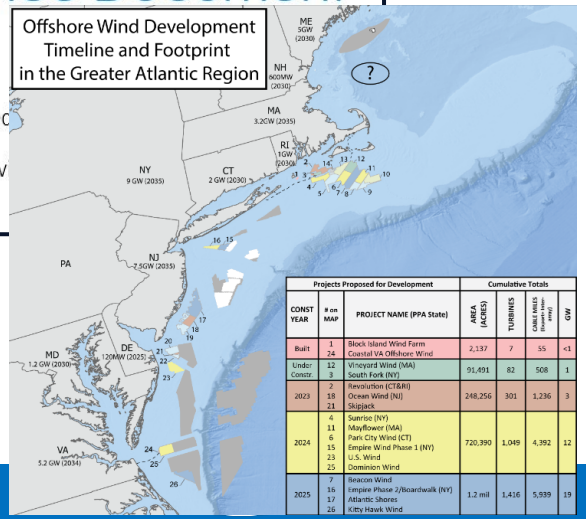
MID-ATLANTIC
FISHERY MANAGEMENT COUNCIL

Ecosystem Approach to Fisheries Management Guidance Document

Approved

Rev





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

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 potnetailly consider distribution change in a more tactical way
  - Focus on Mid At. species, but interest in possible South At. changes

Examples of Potential Council Application

- Continued development and implementation of EAFM guidance document

  - EAFM Risk Assessment
  - Comprehensive review this year

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)

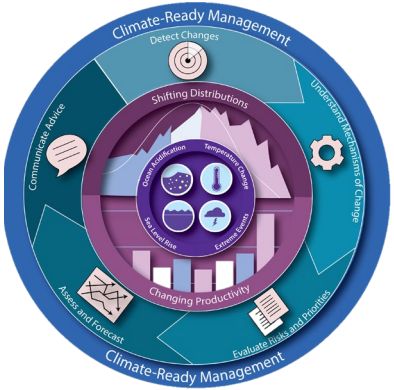
Species	Assess	Fstatus	Bstatus	FW1Pred	FW1Prey	FW2Prey	Climate	DistShift	EstHabitat
Ocean Quahog	l	l	l	l	l	l	h	mh	l
Surfclam	l	l	l	l	l	l	mh	mh	l
Summer flounder	l	l	lm	l	l	l	lm	mh	h
Scup	l	l	l	l	l	l	lm	mh	h
Black sea bass	l	l	l	l	l	l	mh	mh	h
Atl. mackerel	l	h	h	l	l	l	lm	mh	l
Butterfish	l	l	l	l	l	l	l	h	l
Longfin squid	lm	lm	lm	l	l	lm	l	mh	l
Shortfin squid	lm	lm	lm	l	l	lm	l	h	l
Golden tilefish	l	l	lm	l	l	l	mh	l	l
Blueline tilefish	h	h	mh	l	l	l	mh	l	l
Bluefish	l	l	h	l	l	l	l	mh	h
Spiny dogfish	lm	l	lm	l	l	l	l	h	l
Monkfish	h	lm	lm	l	l	l	l	mh	l
Unmanaged forage	na	na	na	l	lm	lm	na	na	na
Deepsea corals	na	na	na	l	l	l	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
  - MSE to evaluate summit outcomes
  - Adaptive governance/management
- Marine Spatial Planning/Coordination
  - Offshore wind and aquaculture development
- NOAA Fisheries Climate Ready Fisheries Management



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 2020
https://www.mafmc.org/ssc

Research Application Questions

- If provided species-specific short term forecasts, how would you use that information?
- What time-scale(s) are most informative/relevant?
- Where/what types of Council actions, priorities, and/or projects would this type of information be informative or most appropriate?
- 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.)

Feedback from the EOP Committee/AP and SSC will be provided to the Council for consideration at April Council meeting