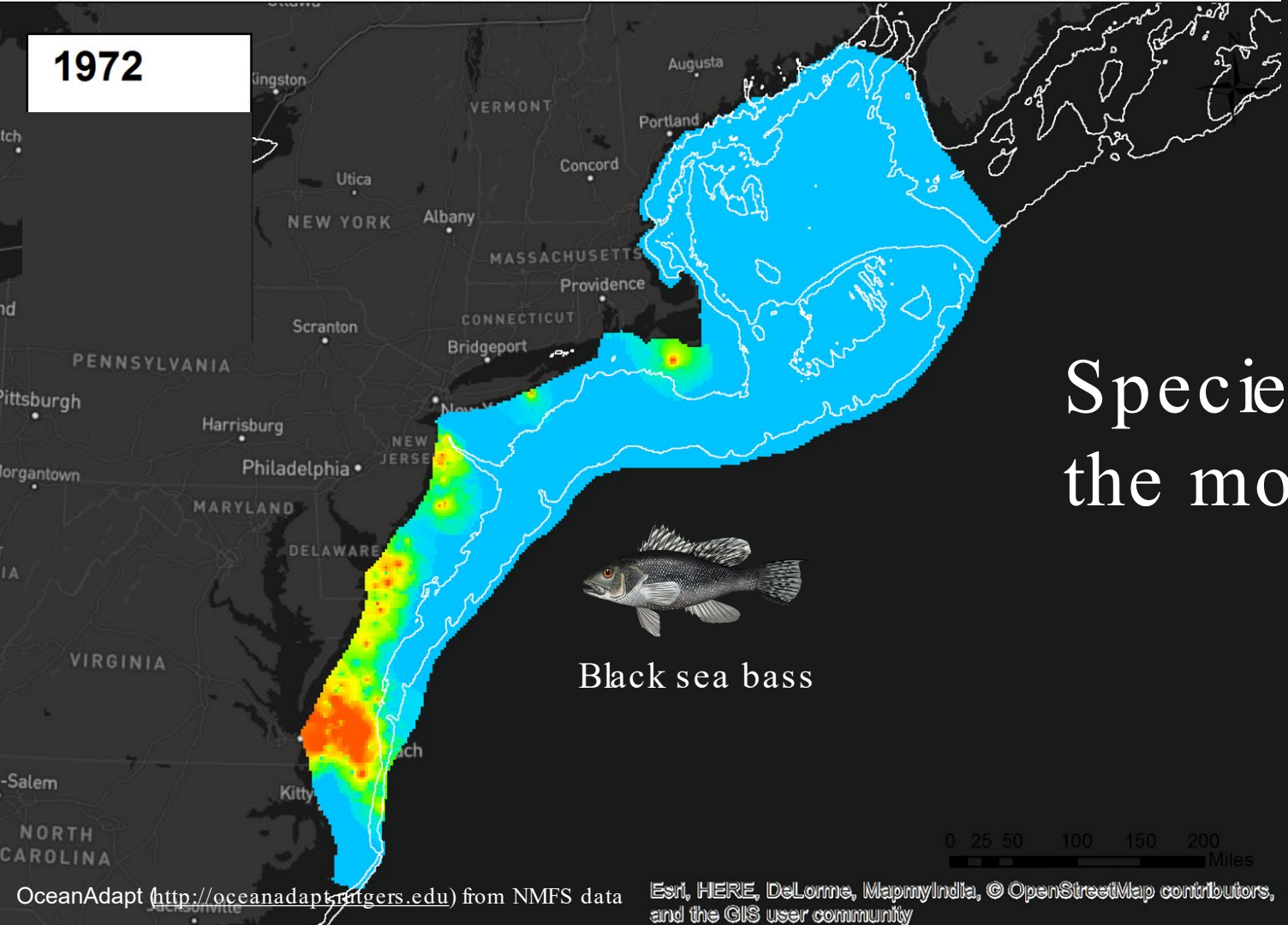
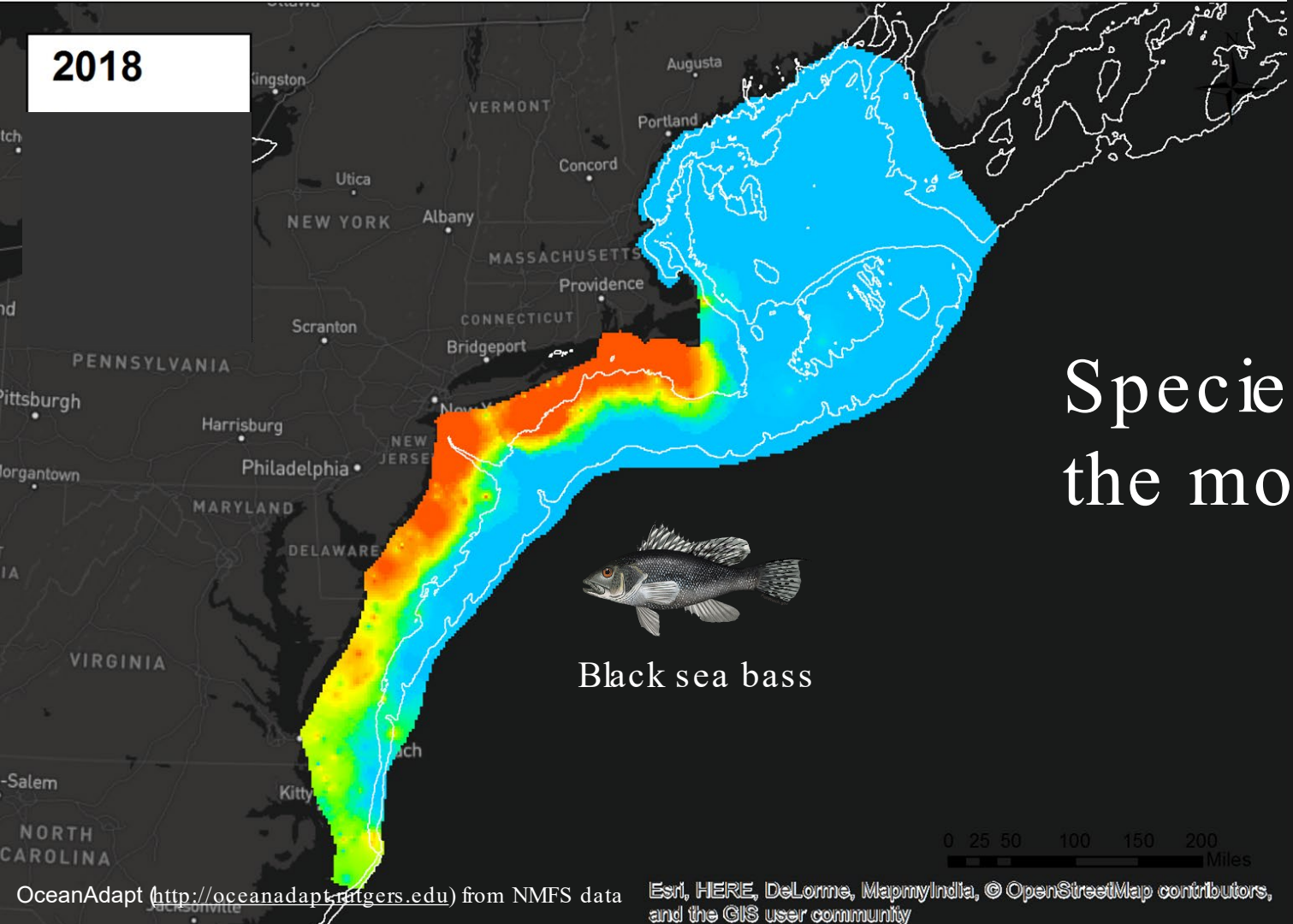
Short-term forecasts of species distributions for fisheries management

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



Species are on the move

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

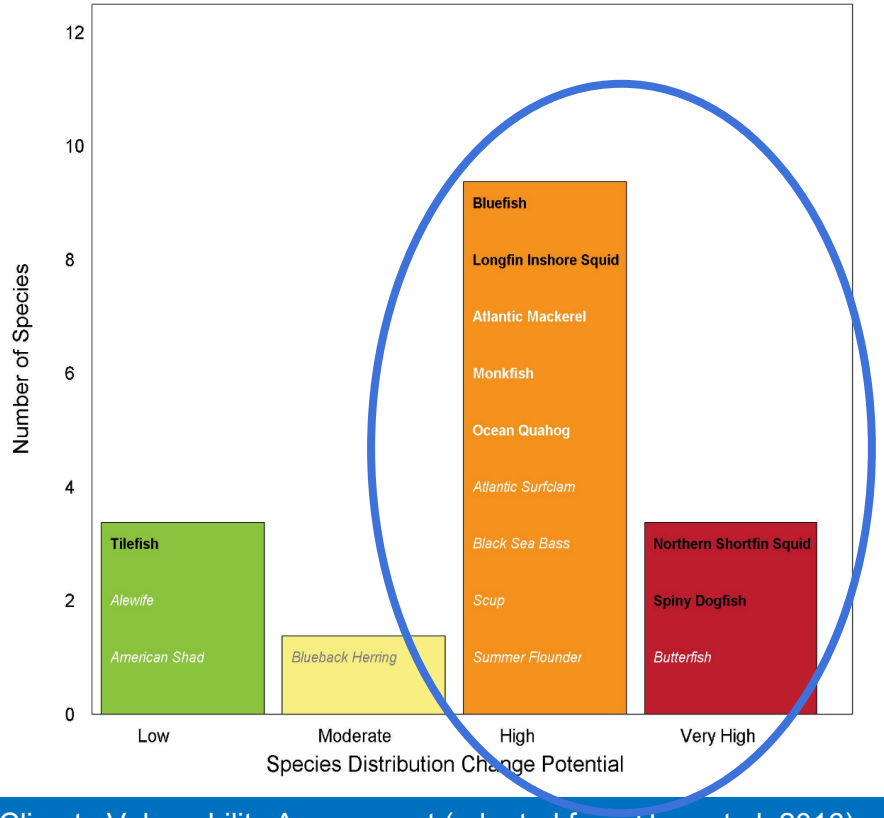


Species are on the move

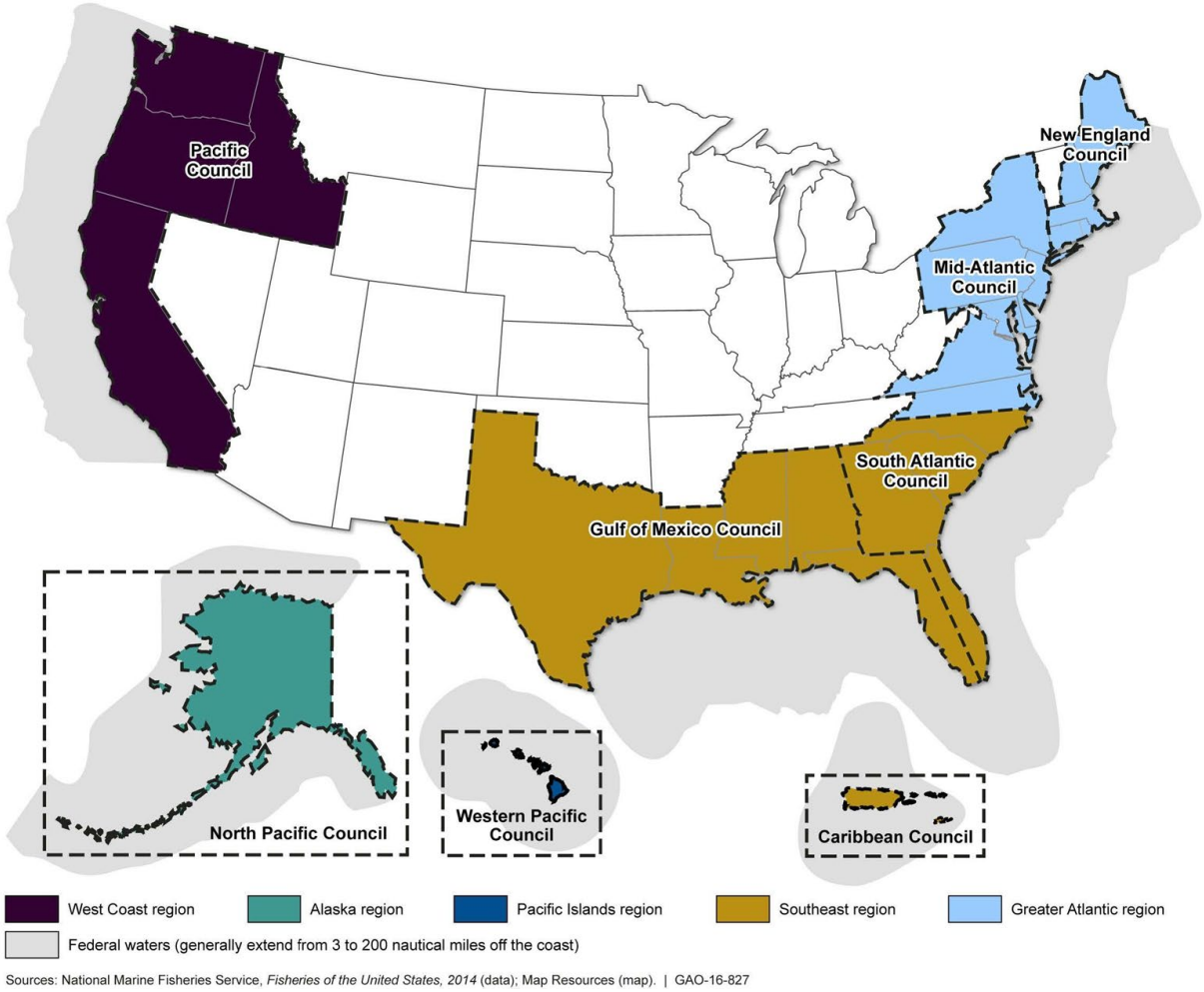
Black sea bass

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

Potential change in species distribution

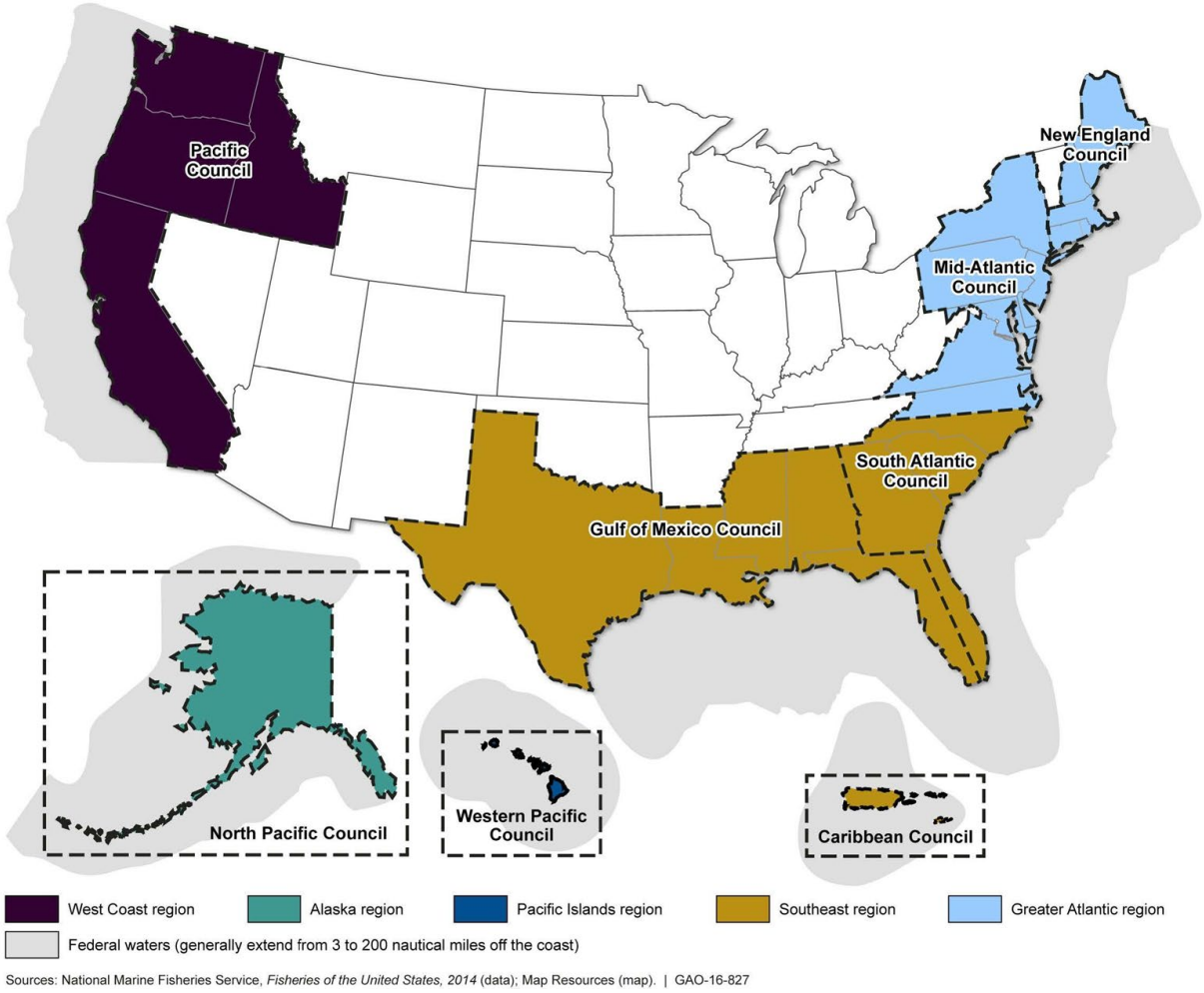


Fisheries management requires knowing where fish are



Fisheries management requires knowing where fish are

- Stock definitions



Fisheries management requires knowing where fish are

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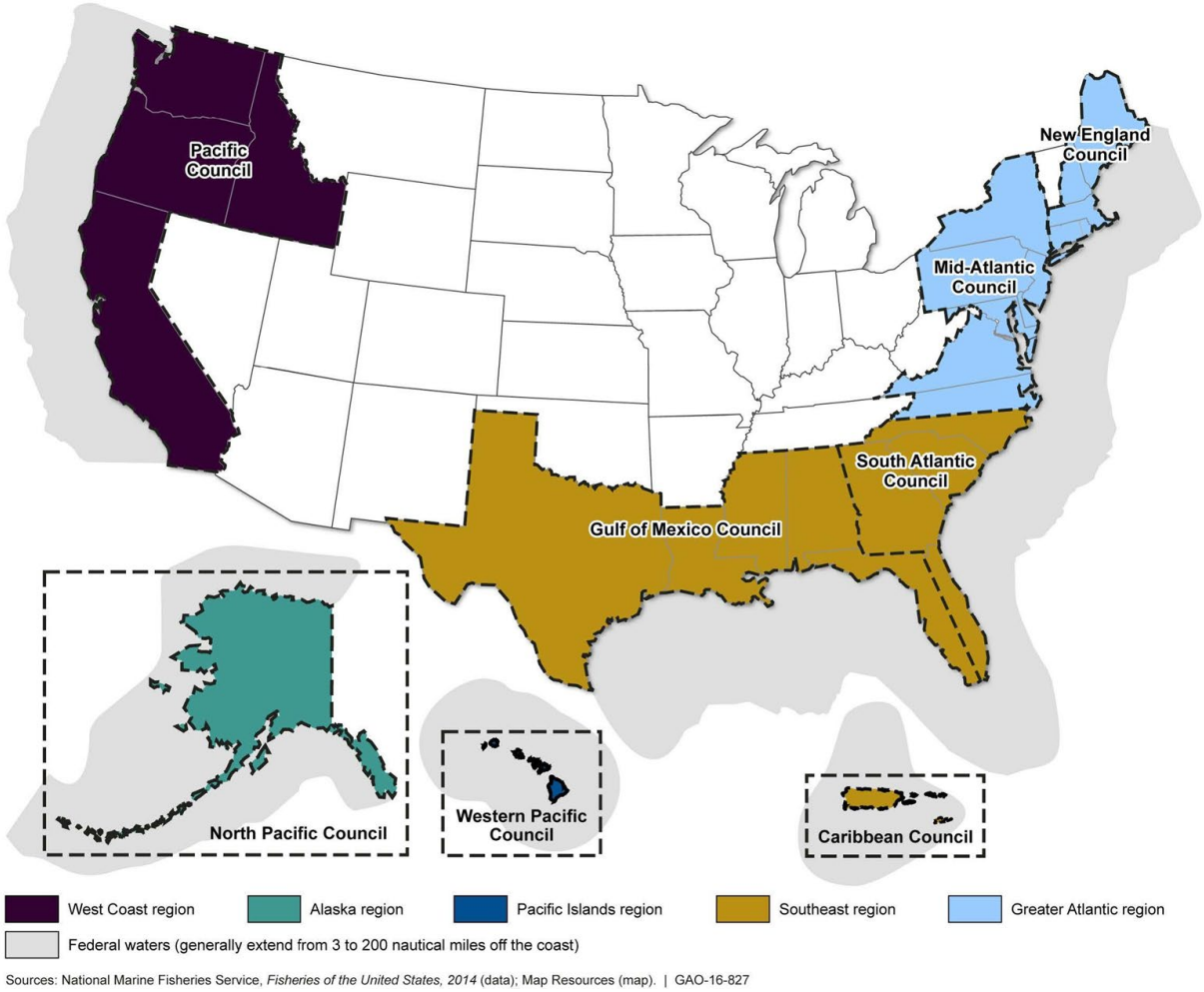
- Stakeholder representation



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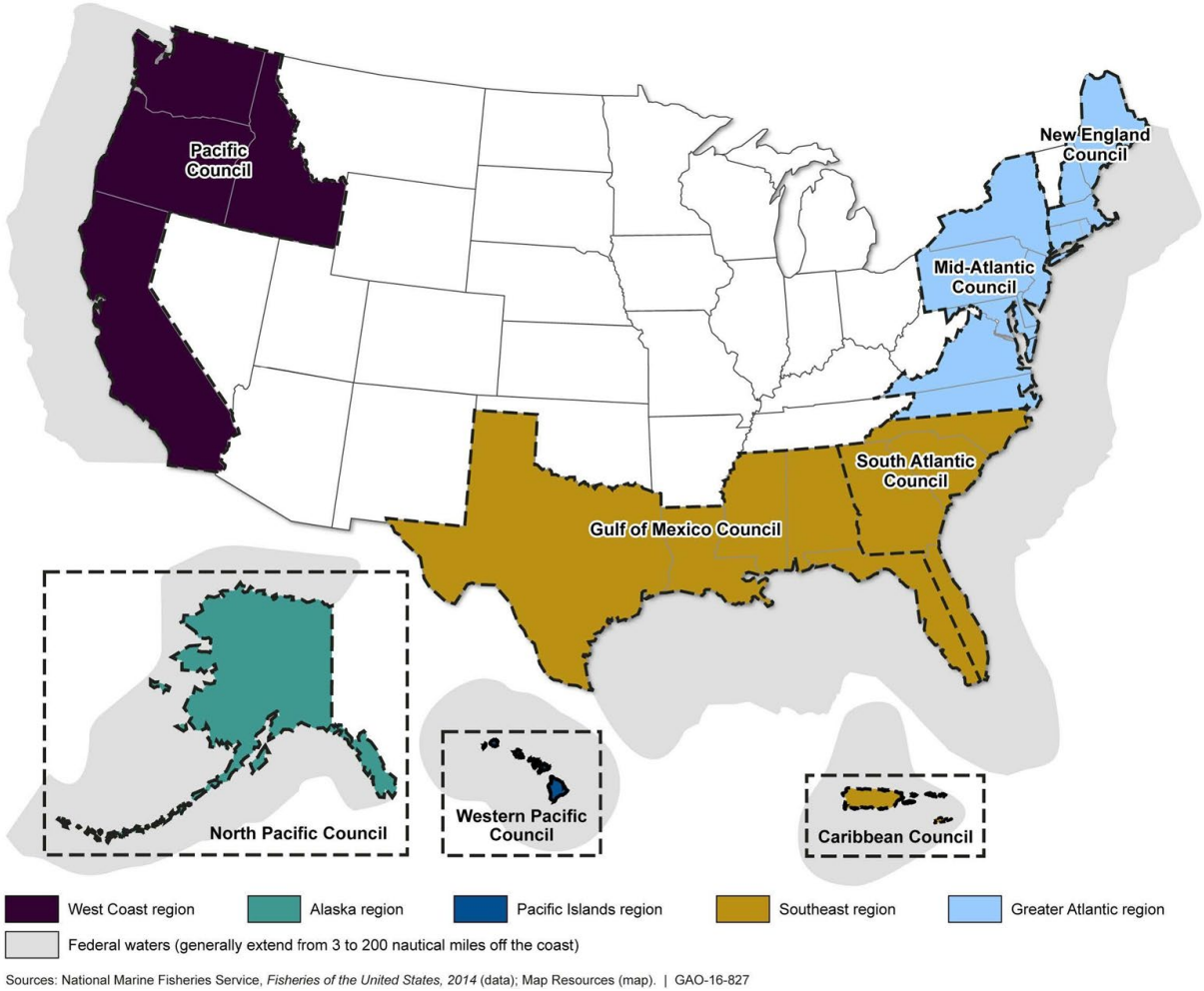

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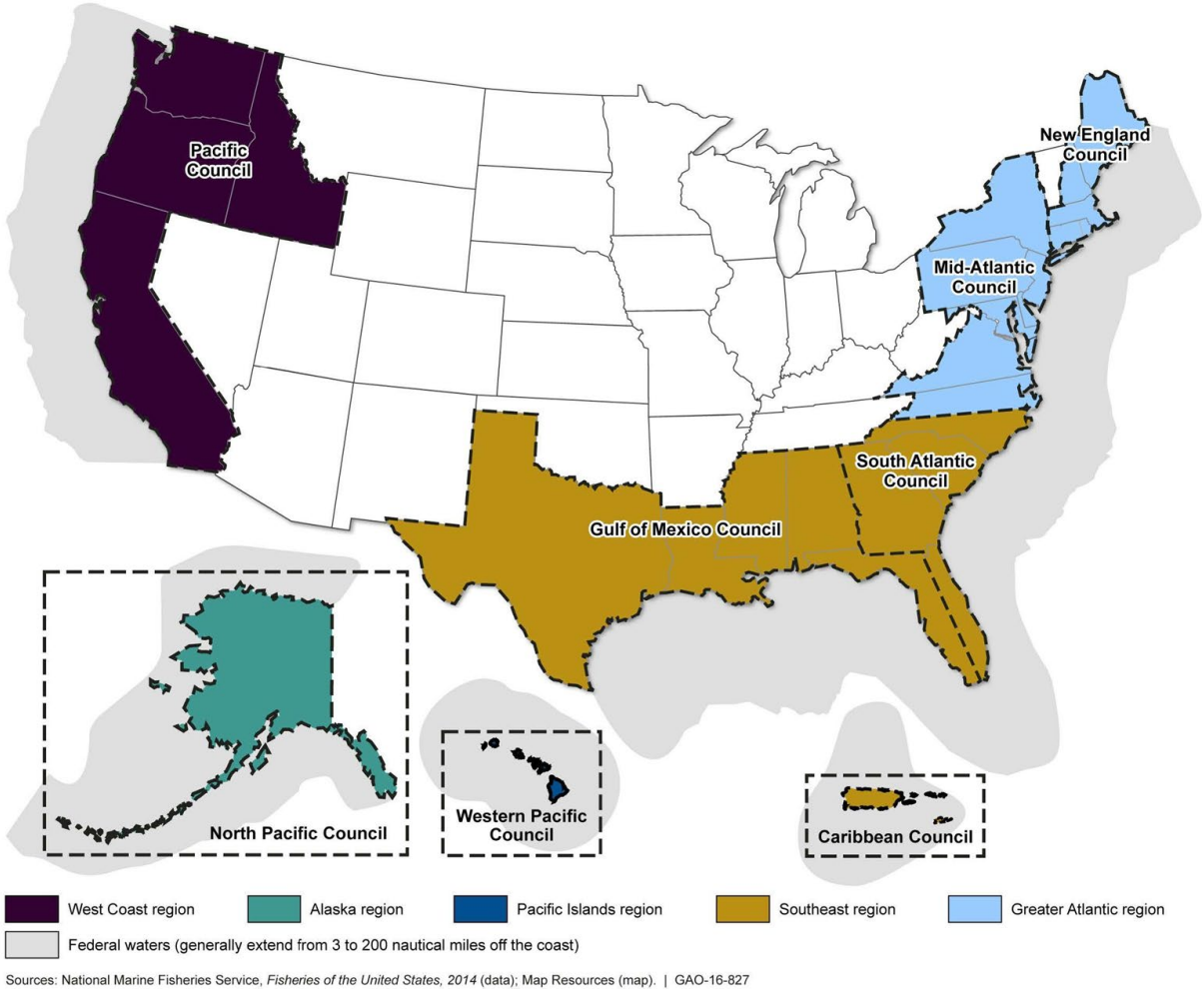

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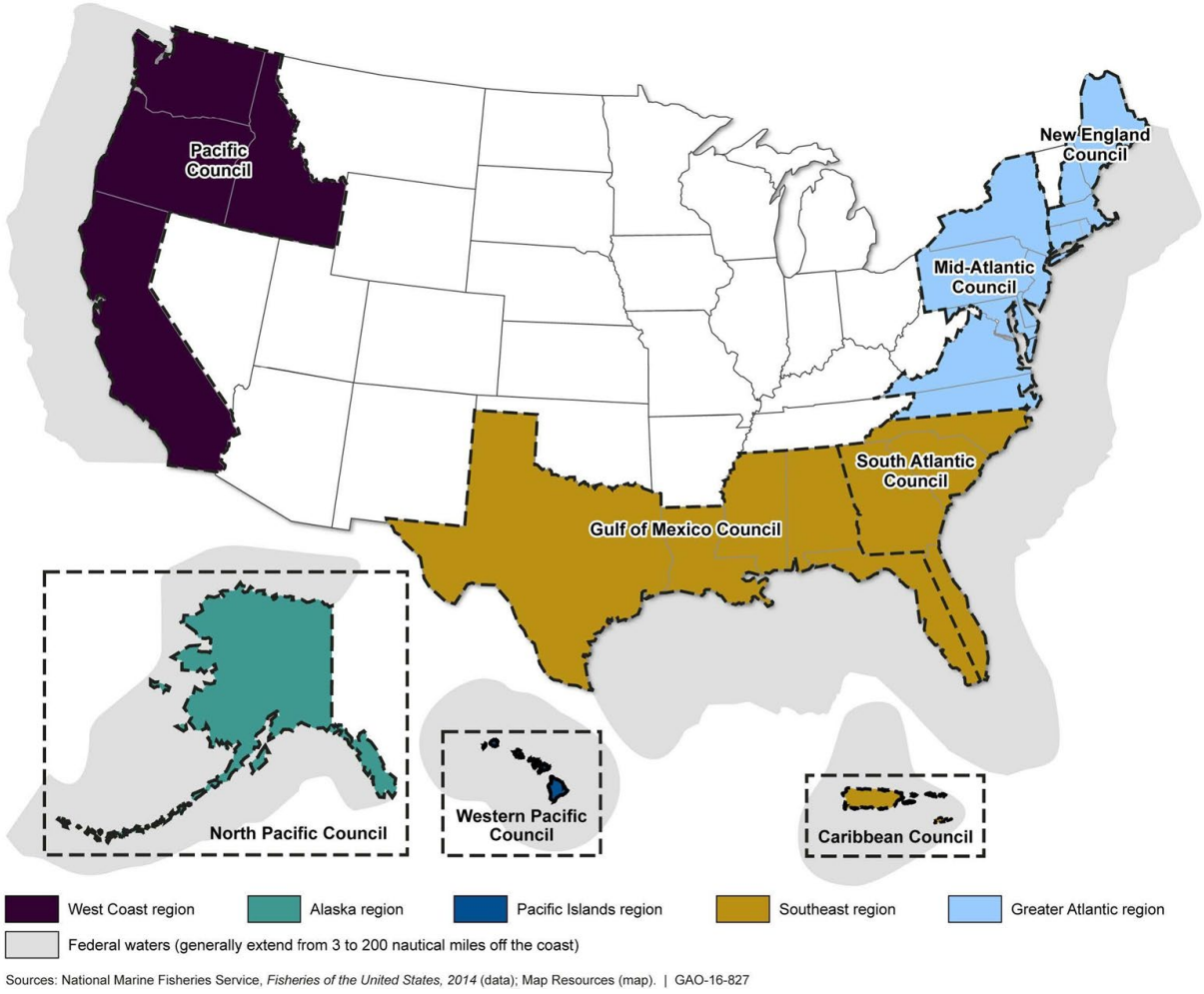

Fisheries management requires knowing where fish are

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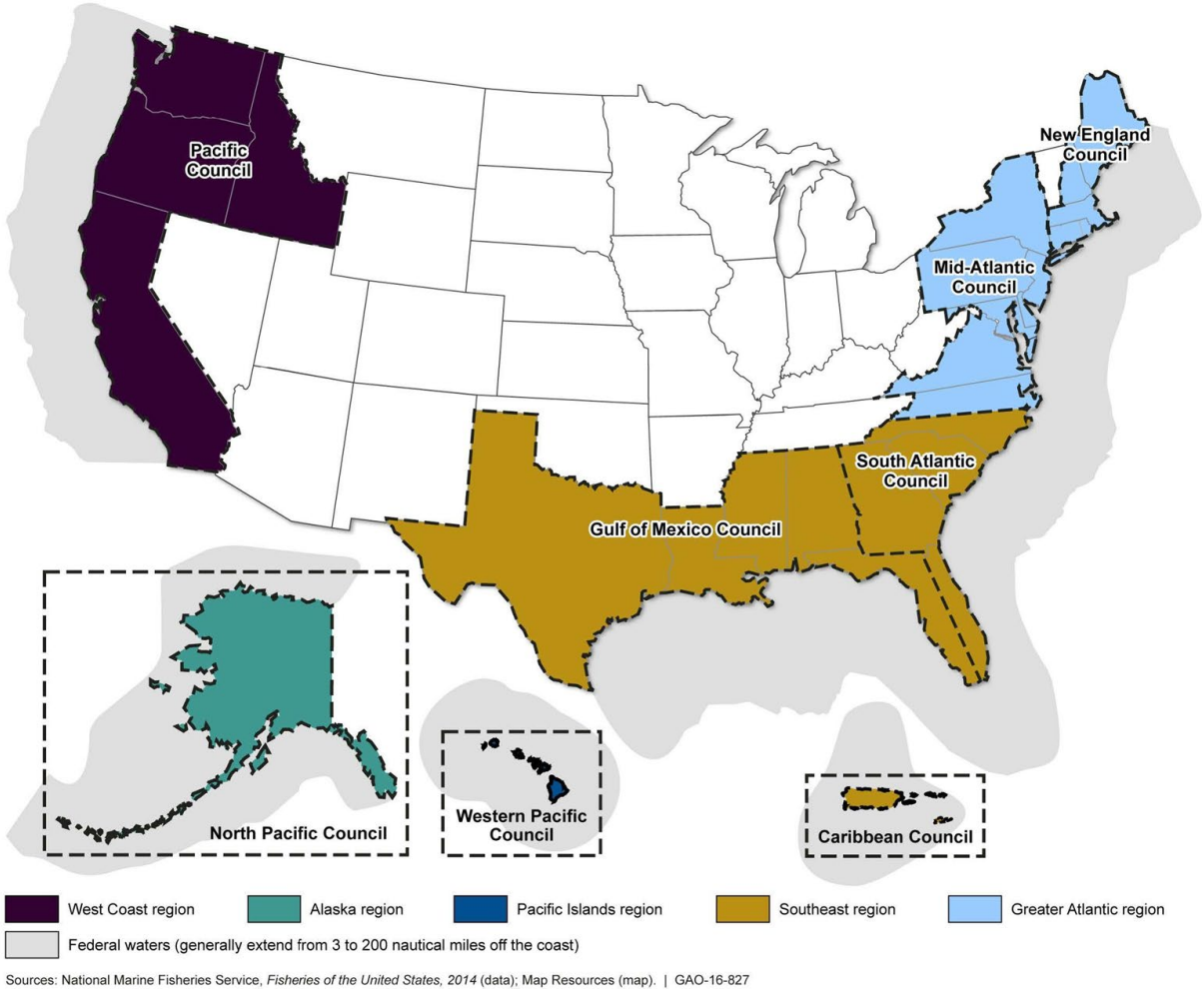
- Incidental catch
- New fishery species
- Allocations



Research questions

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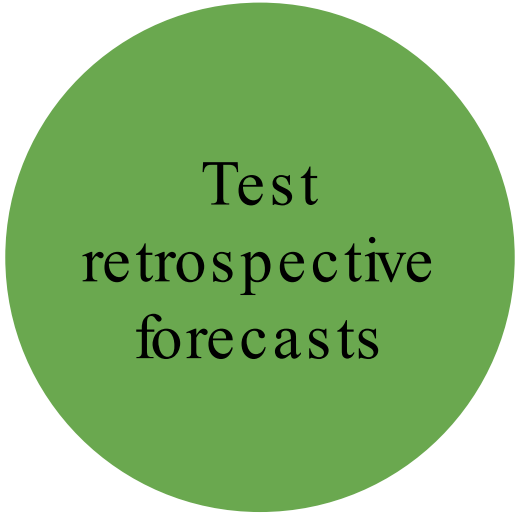
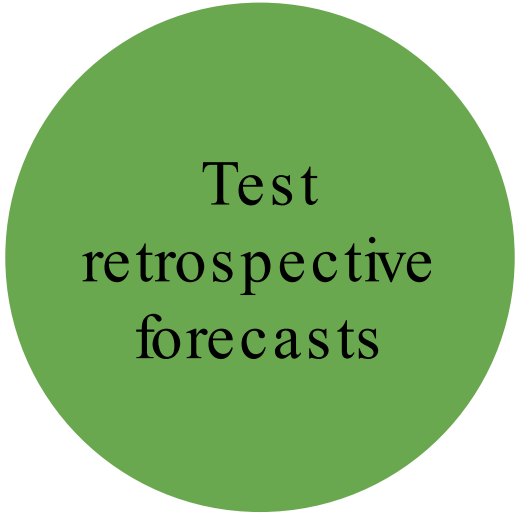
Goals



Goals

True forecasts will require forecast oceanographic conditions



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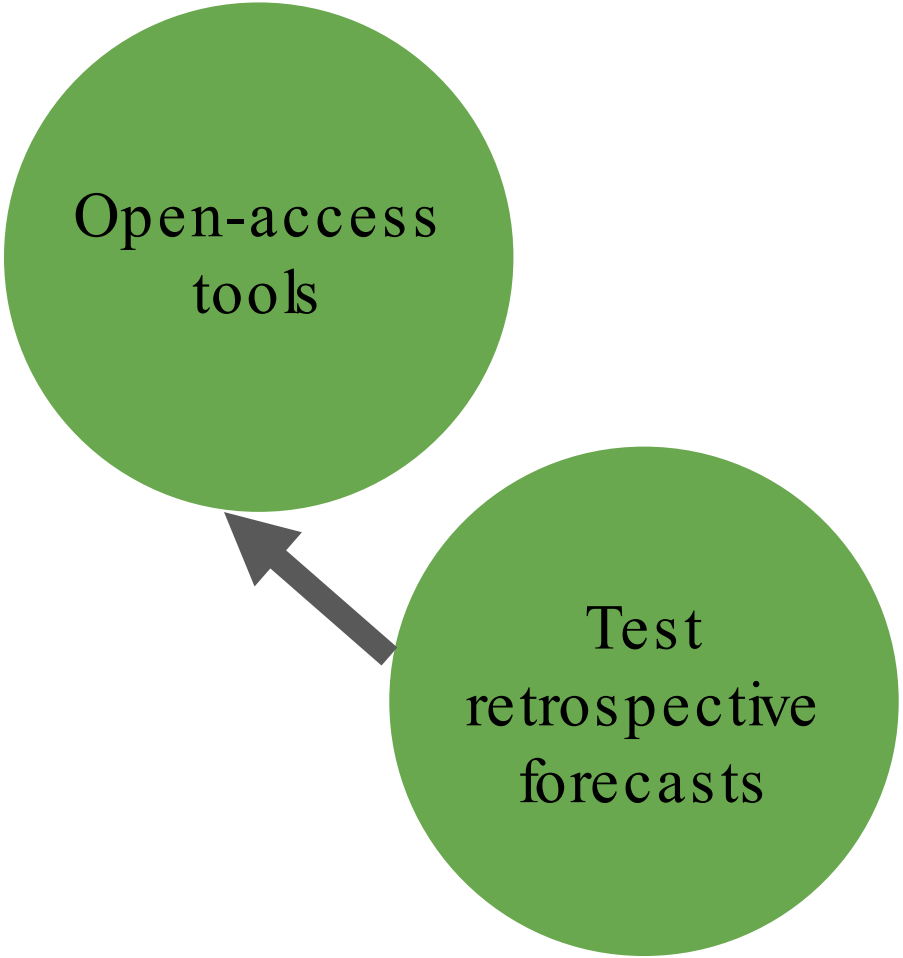

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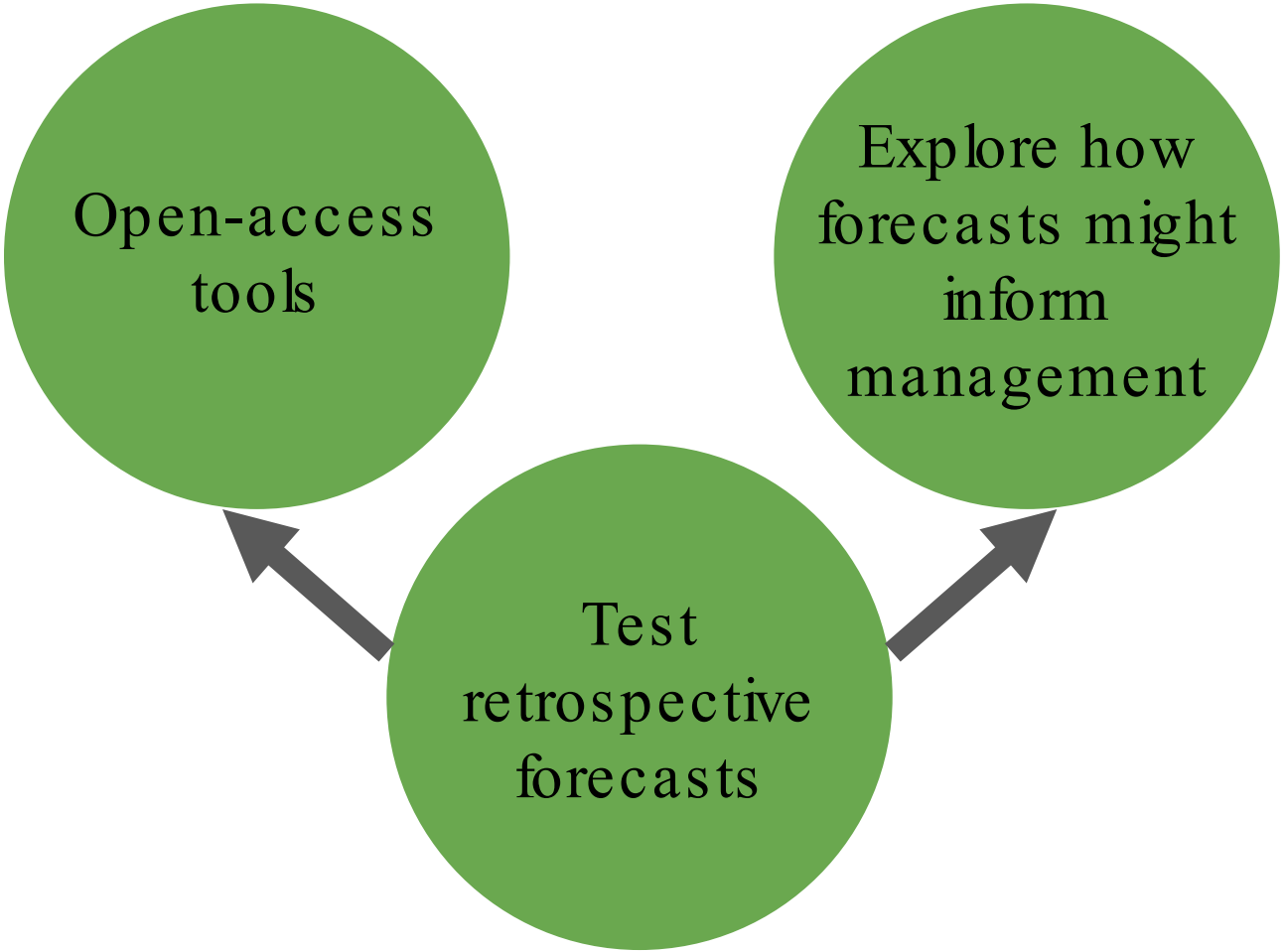
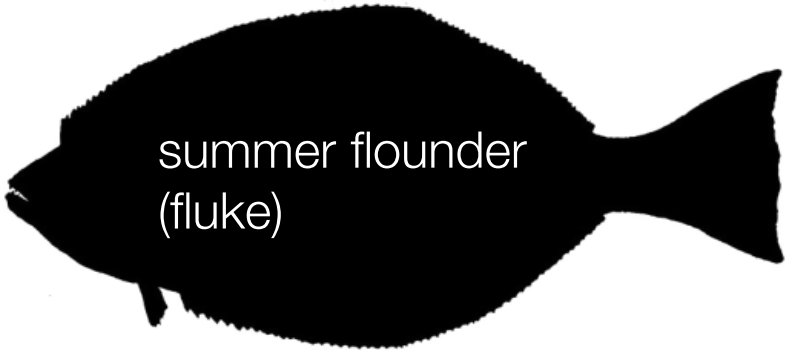
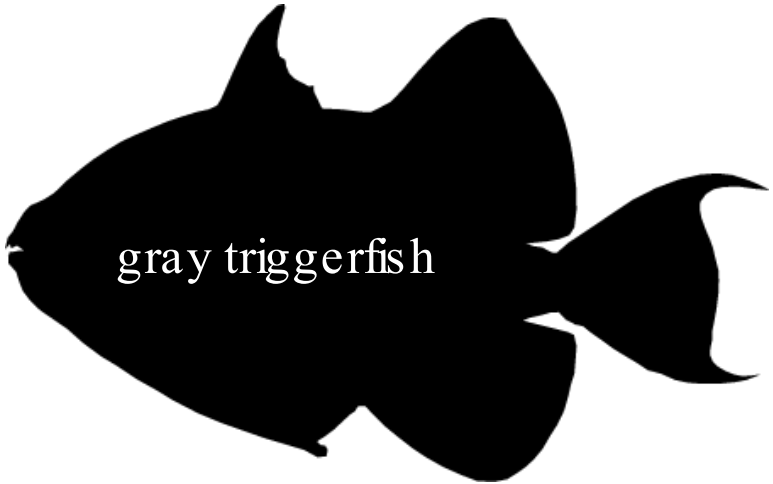
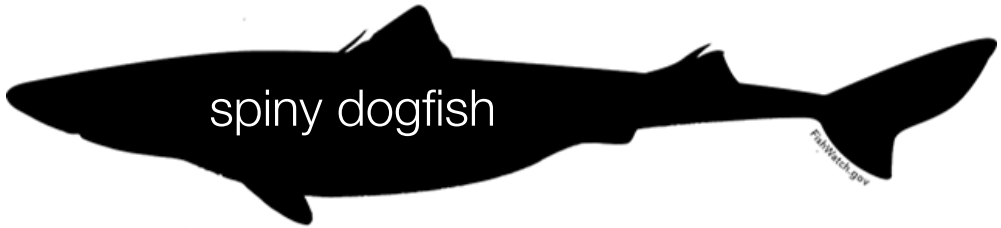

Open-access tools
Explore how forecasts might inform management
Test retrospective forecasts

Focal species





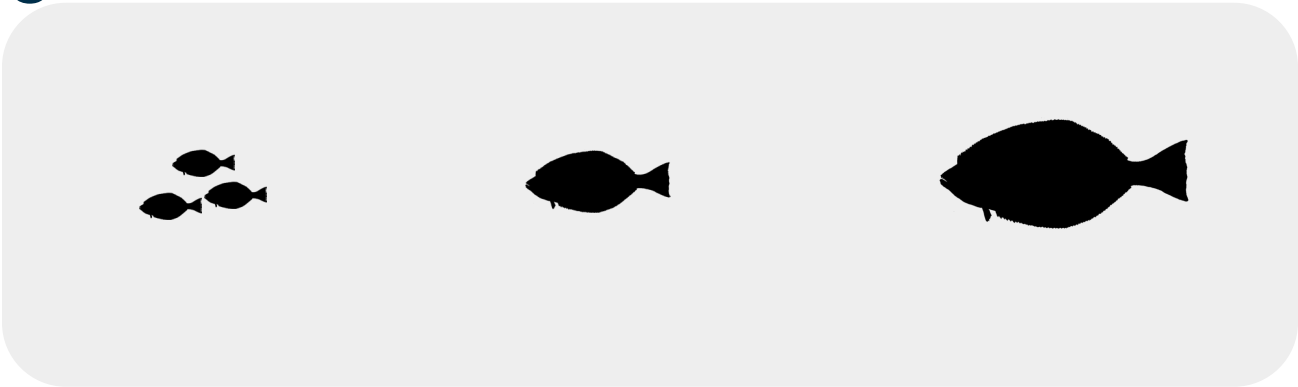


Images: phylopic.org
FishWatch.gov

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

Model structure



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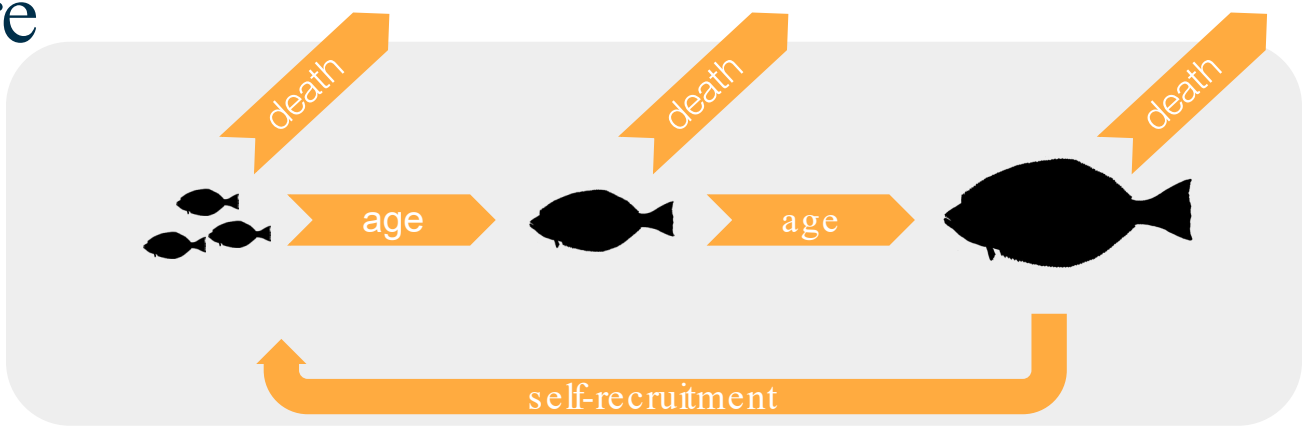

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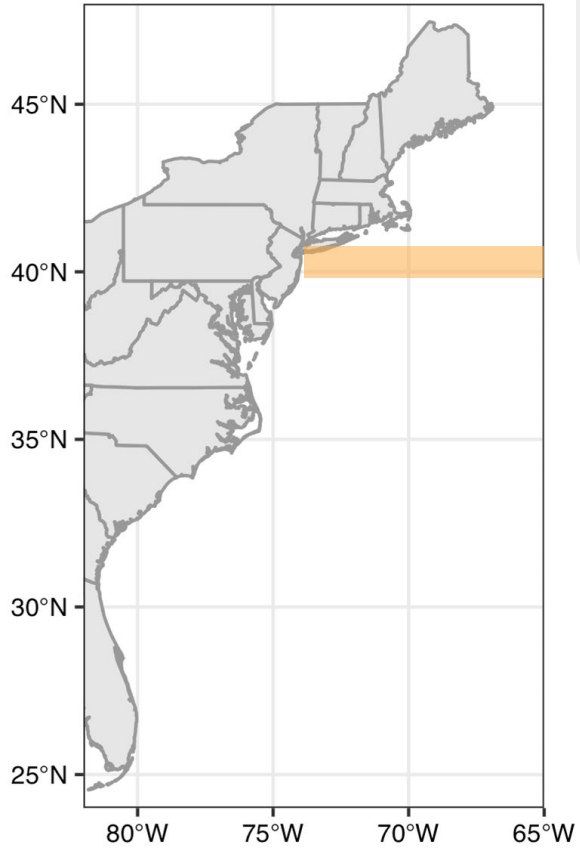

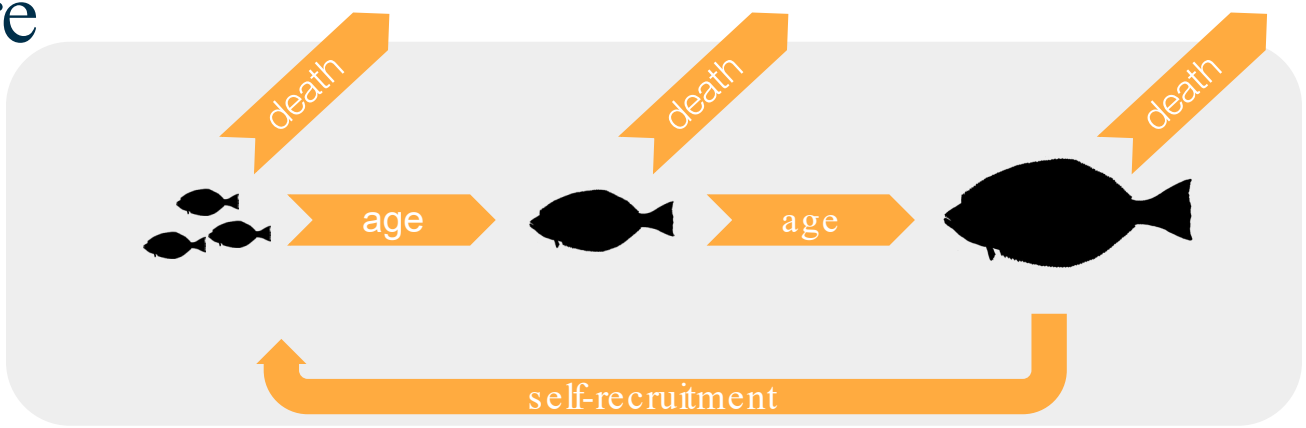

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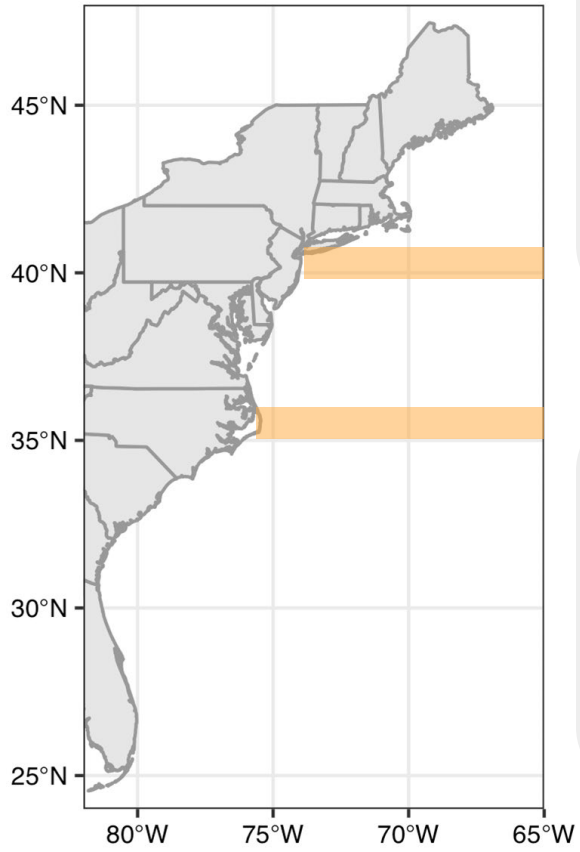

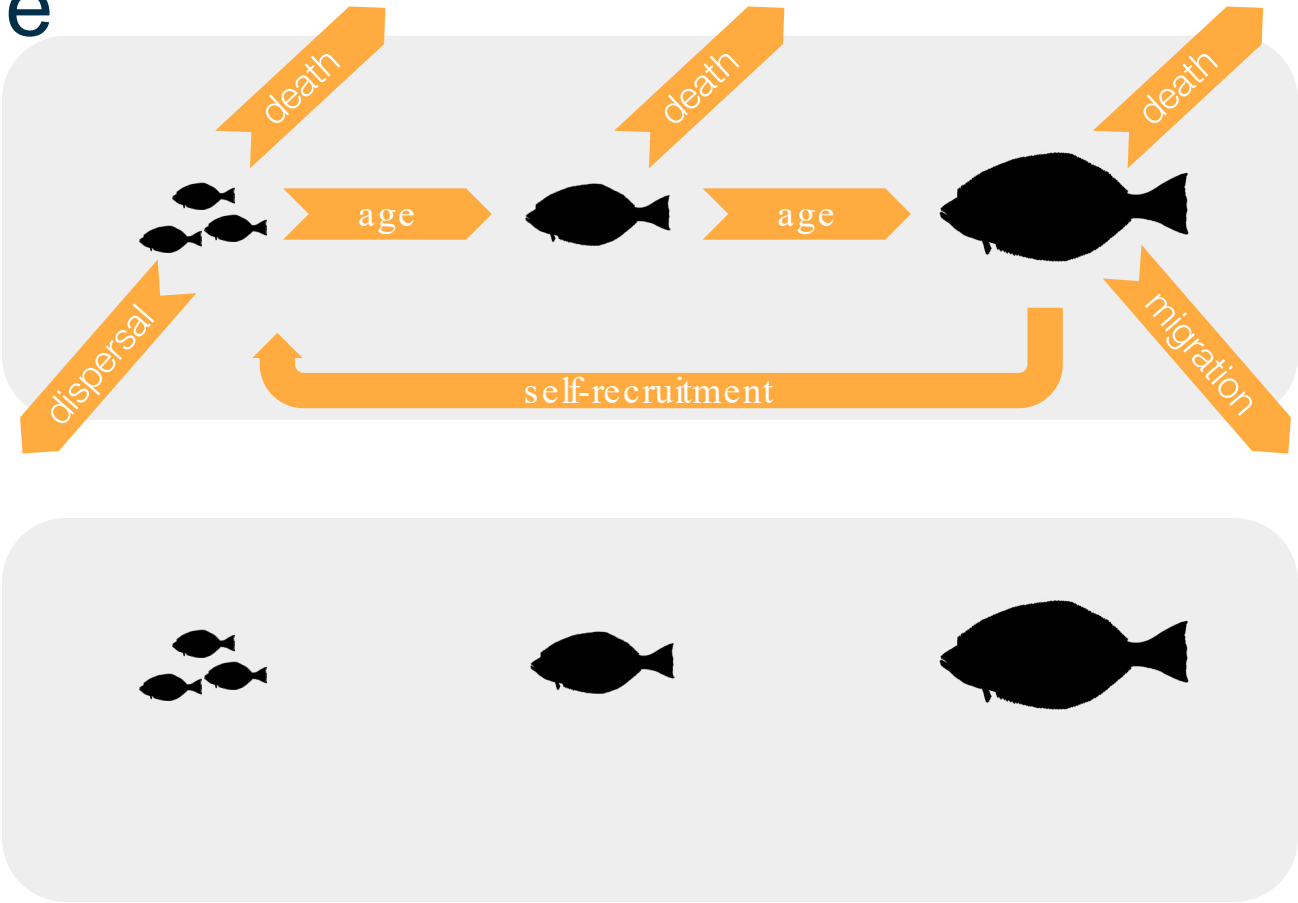

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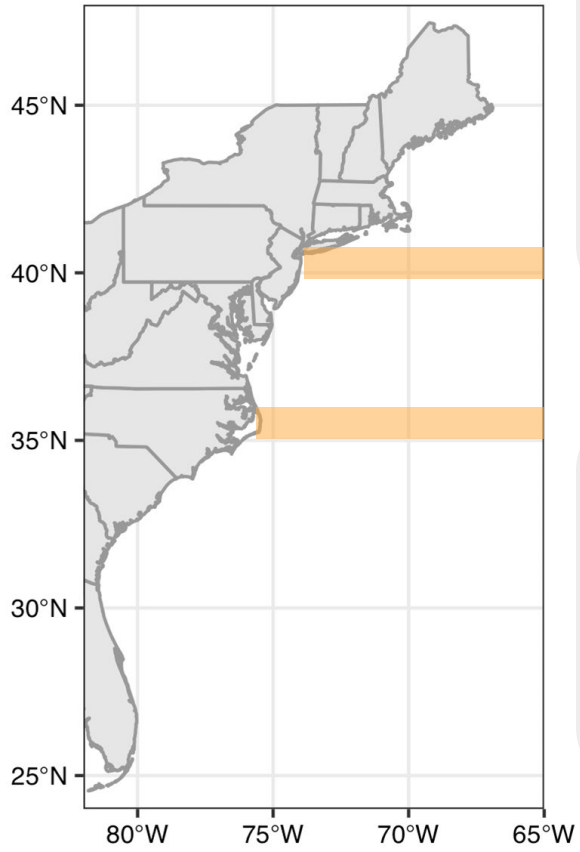
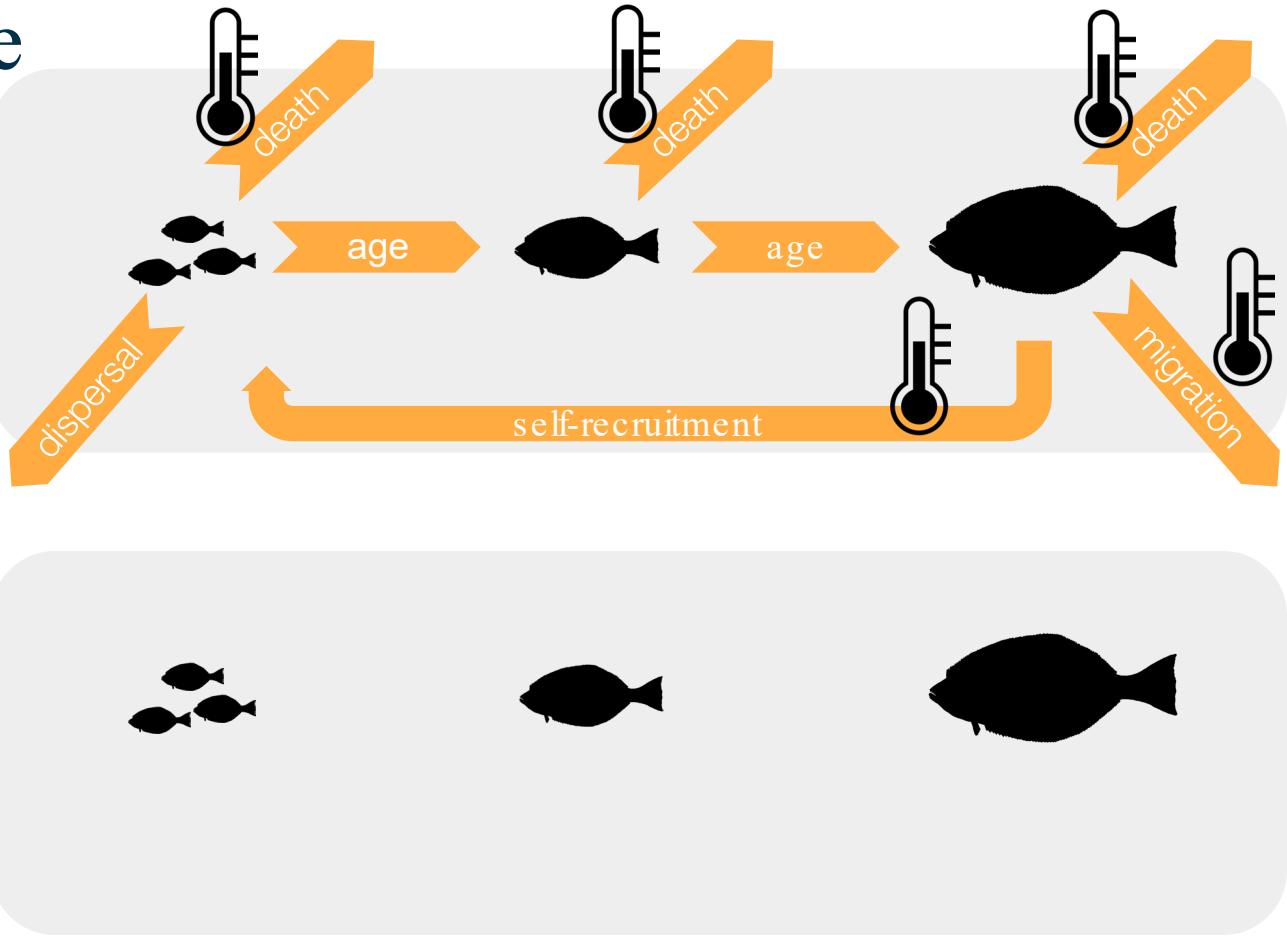
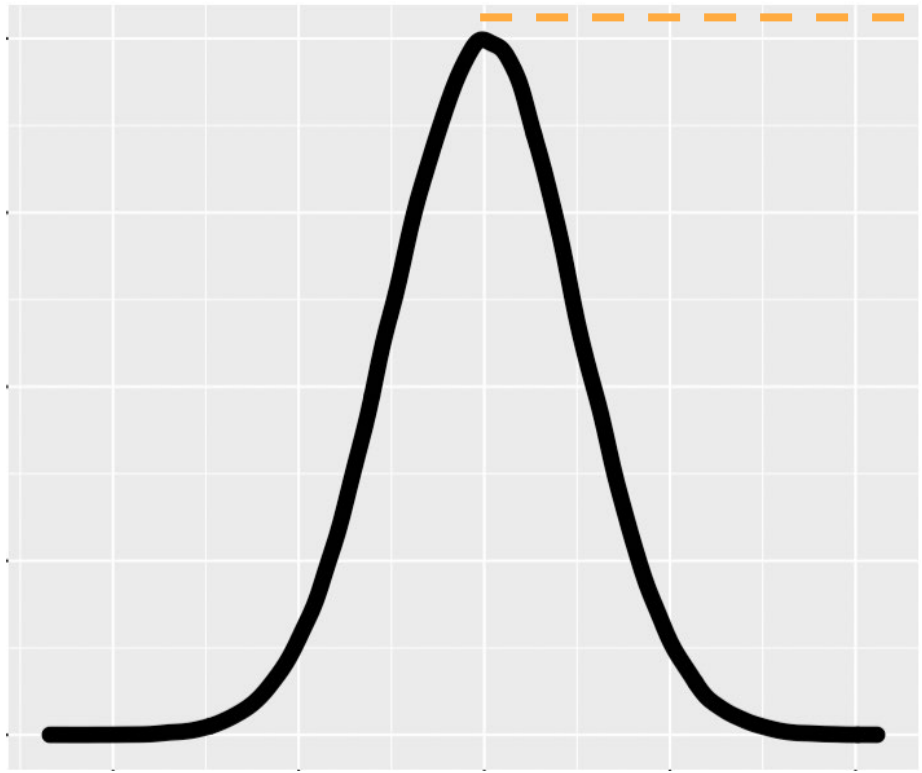




Temperature dependence

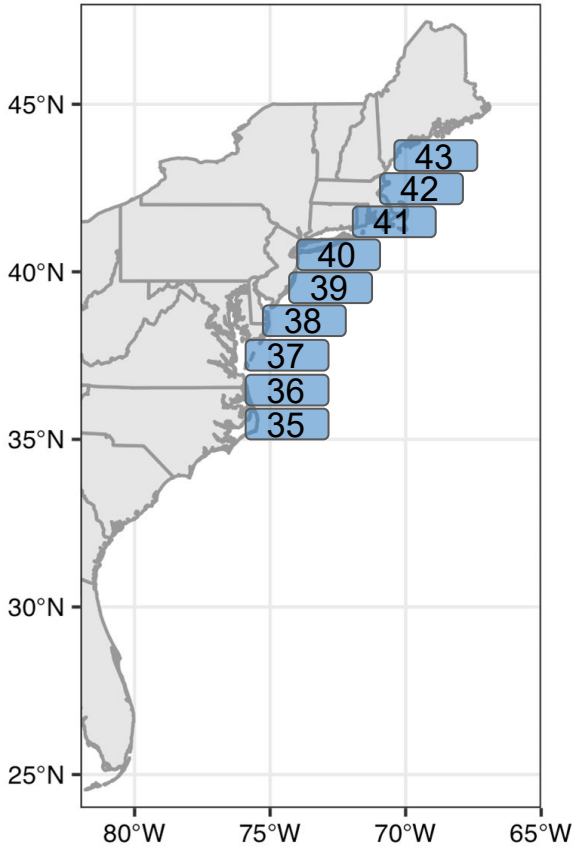


Temperature

Temperature at which
recruitment is maximized
mortality is minimized
movement is maximized

Summary of approach

Fit to data from bottom trawl survey, 1972-2006



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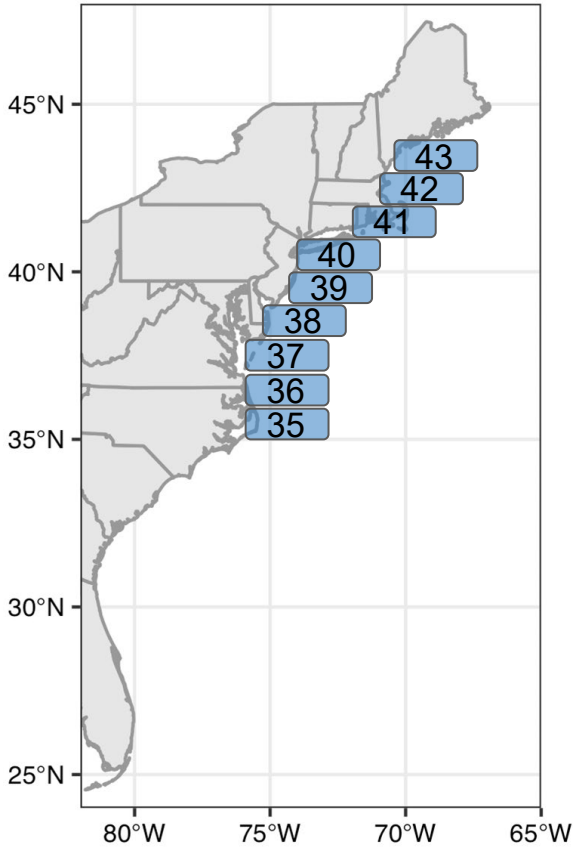

Test the forecast 2007-2016

Summary of approach

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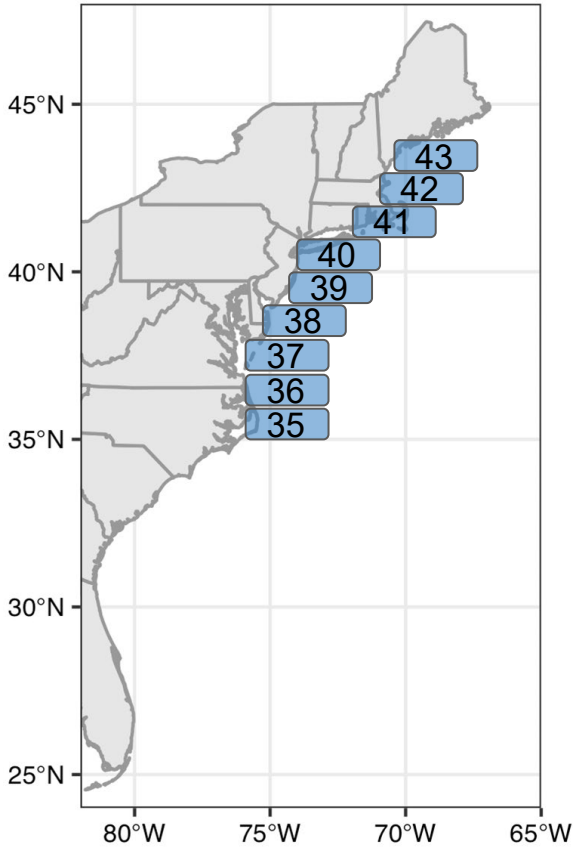
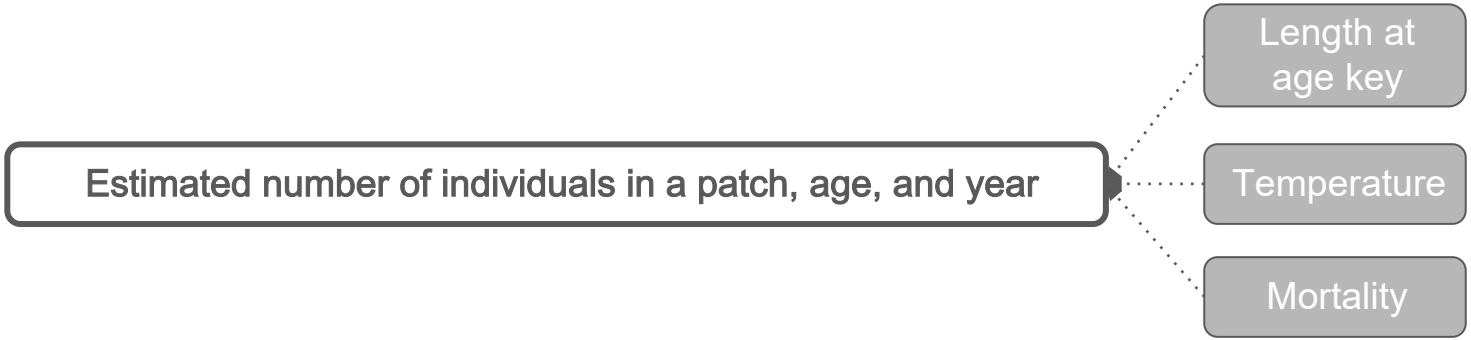


Test the forecast 2007-2016

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

Bayesian network (DAG); T → movement



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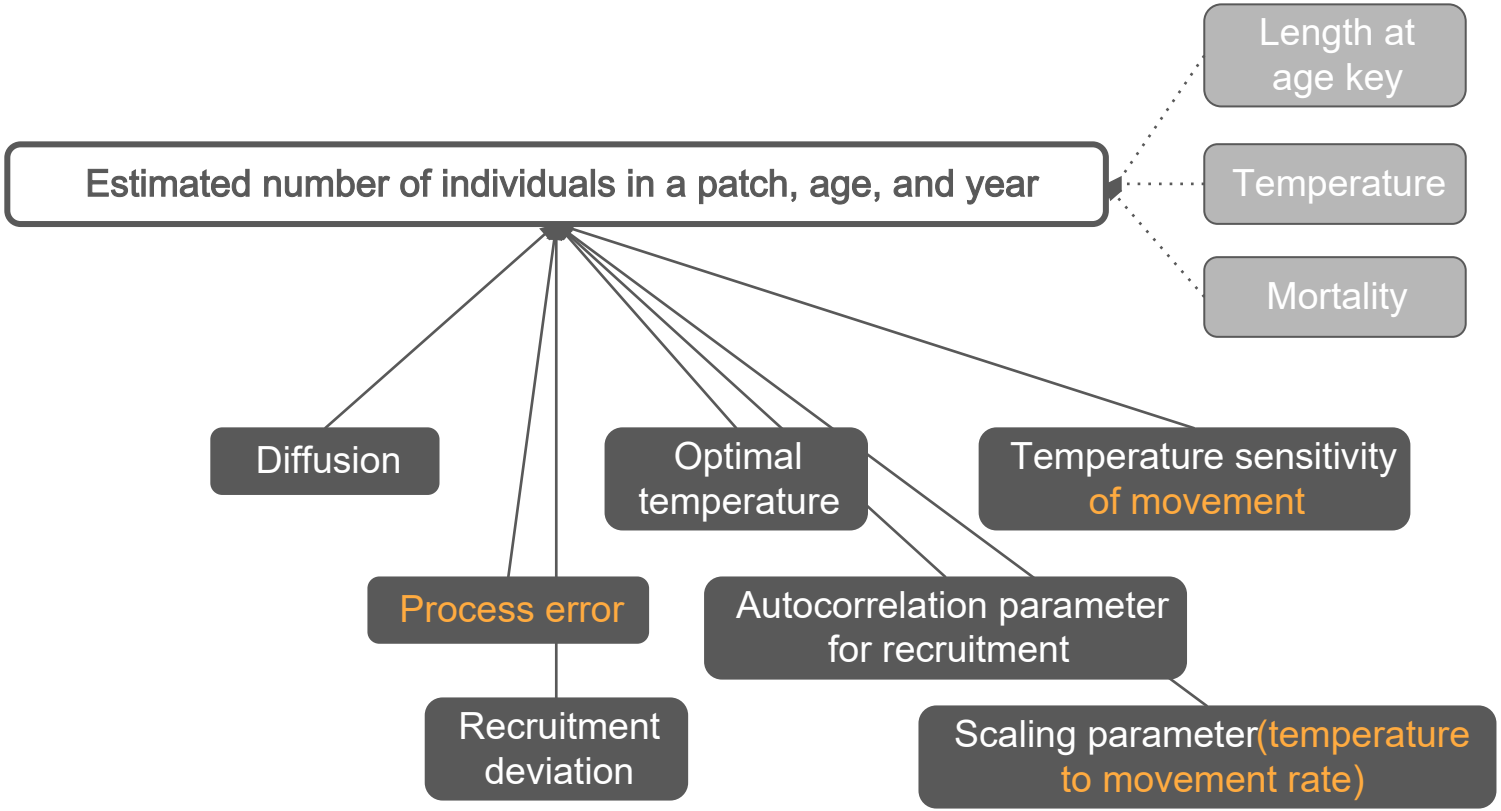

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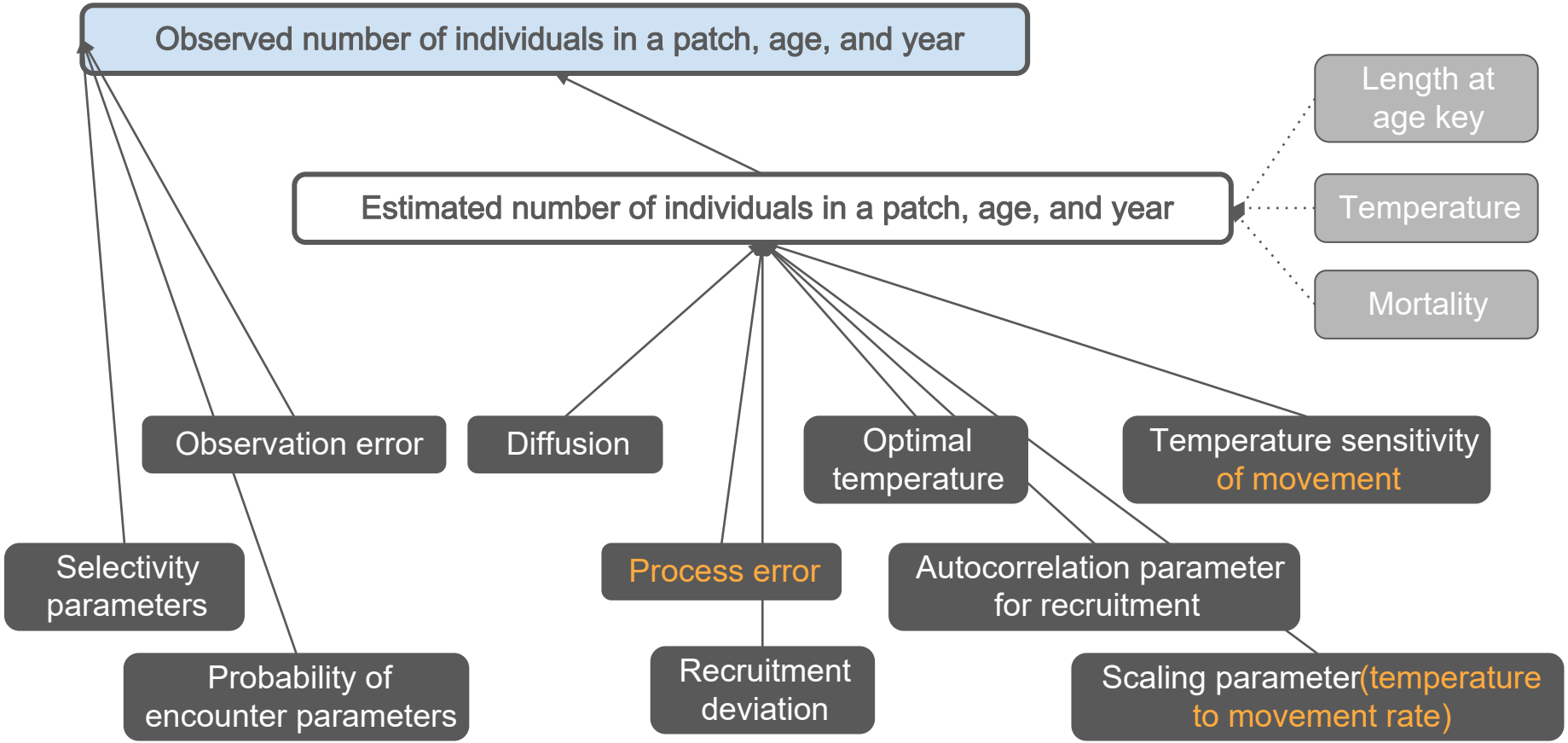
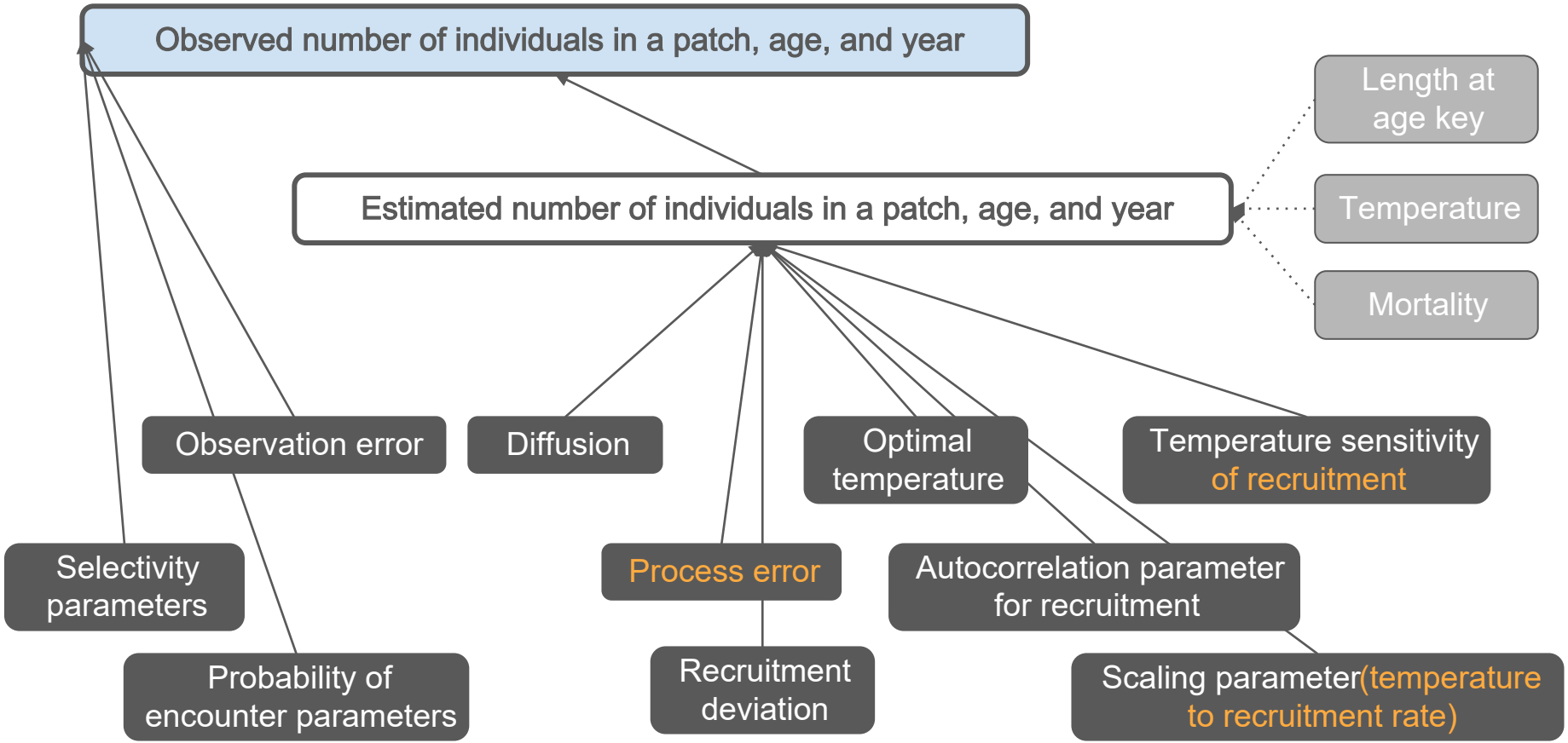
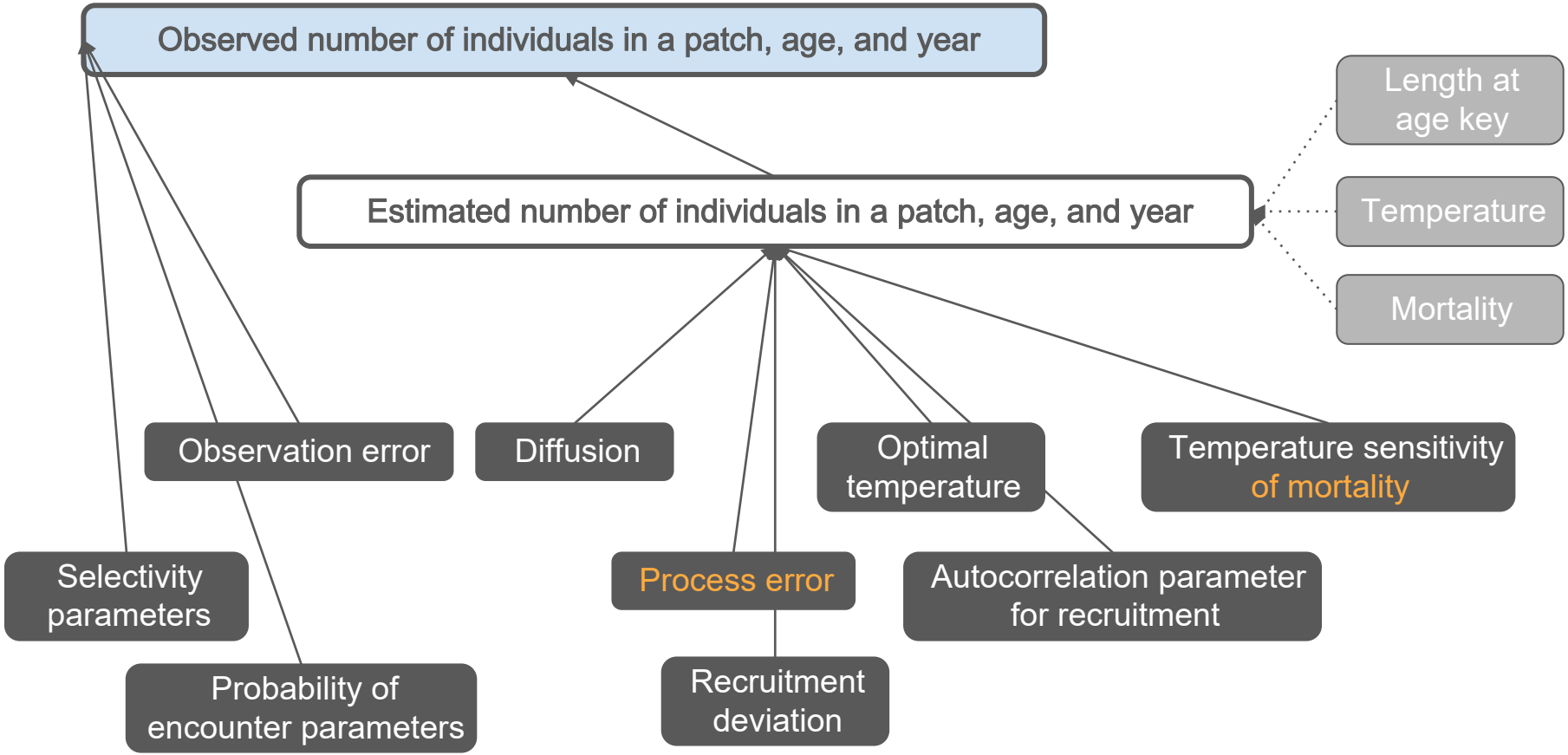


Bayesian network (DAG); T → recruitment



Bayesian network (DAG); T → mortality



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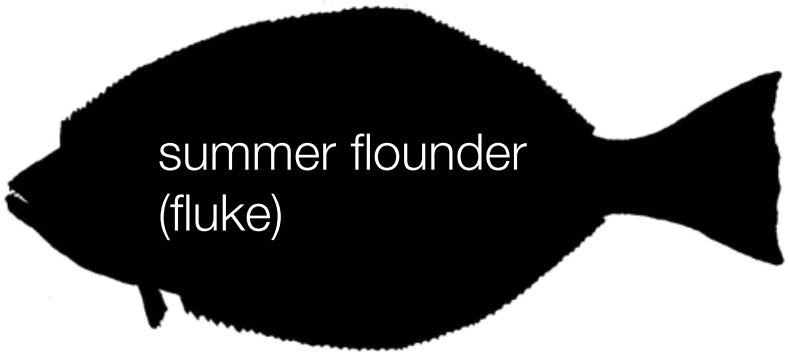
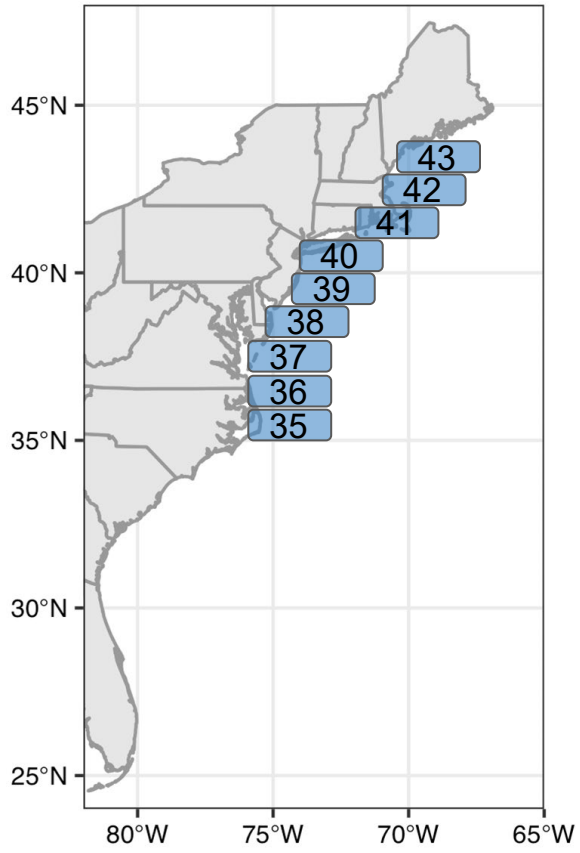
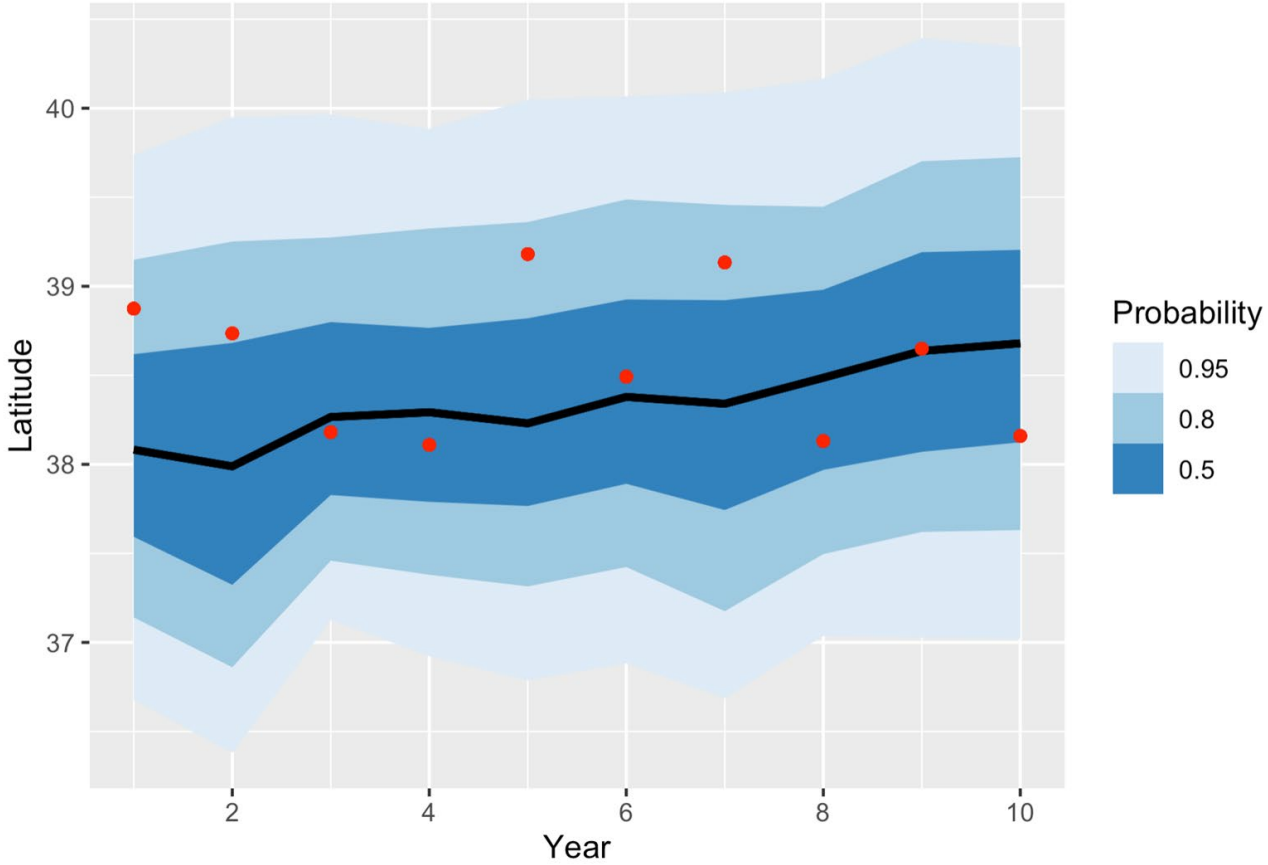
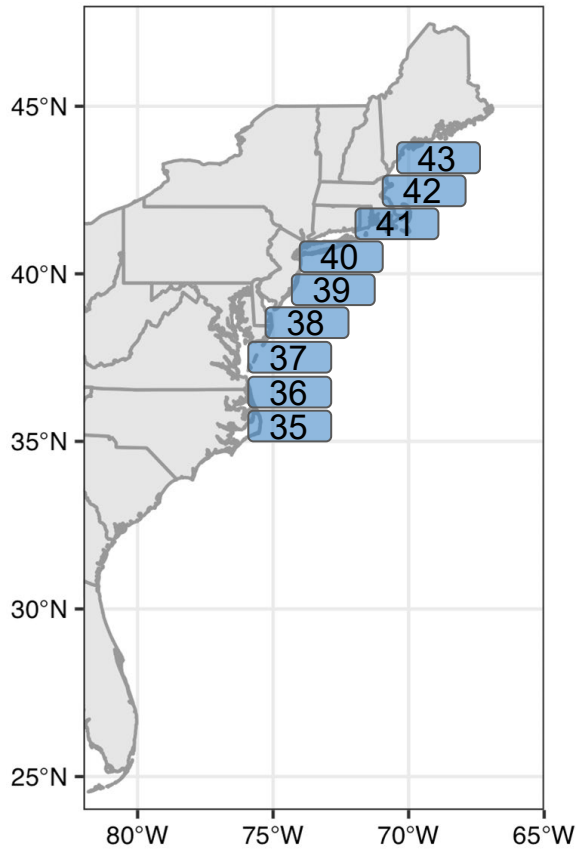


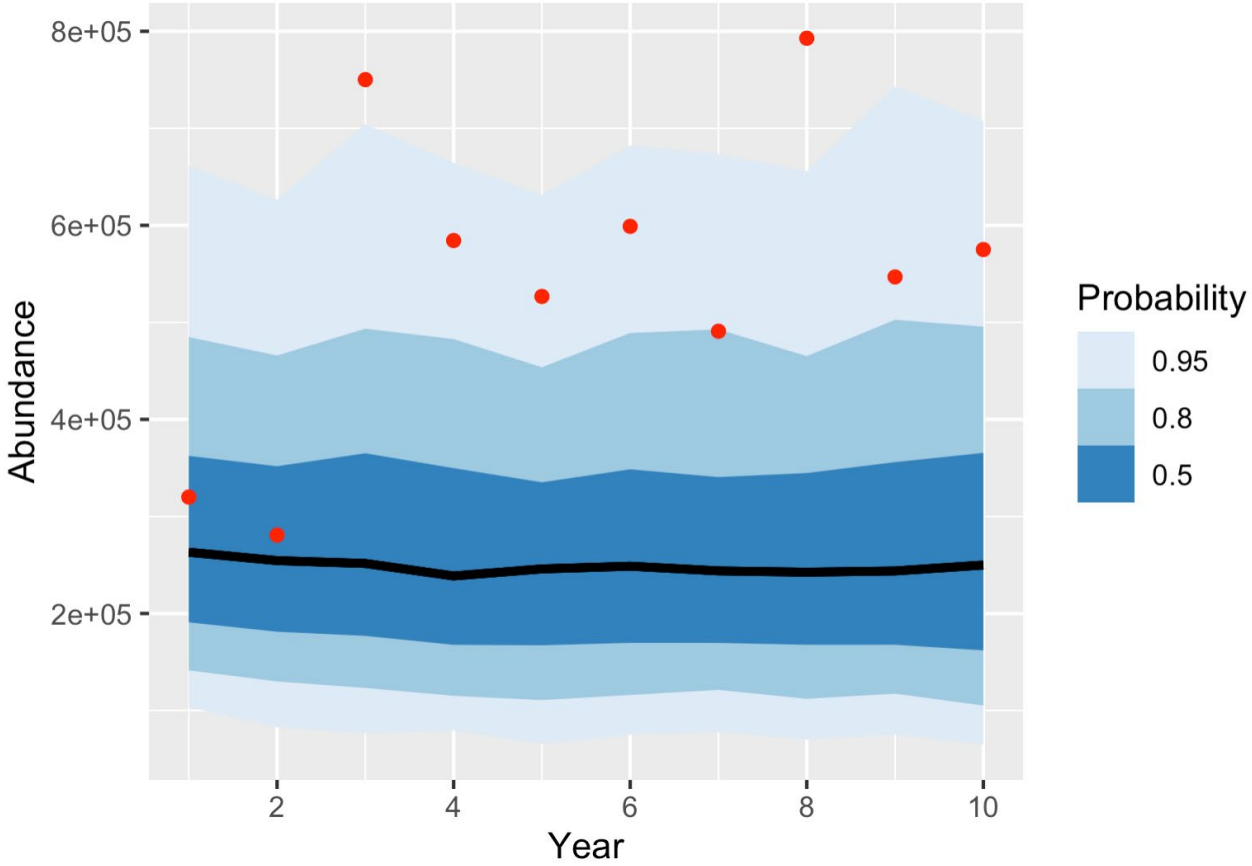
Forecast vs. reality: centroid position



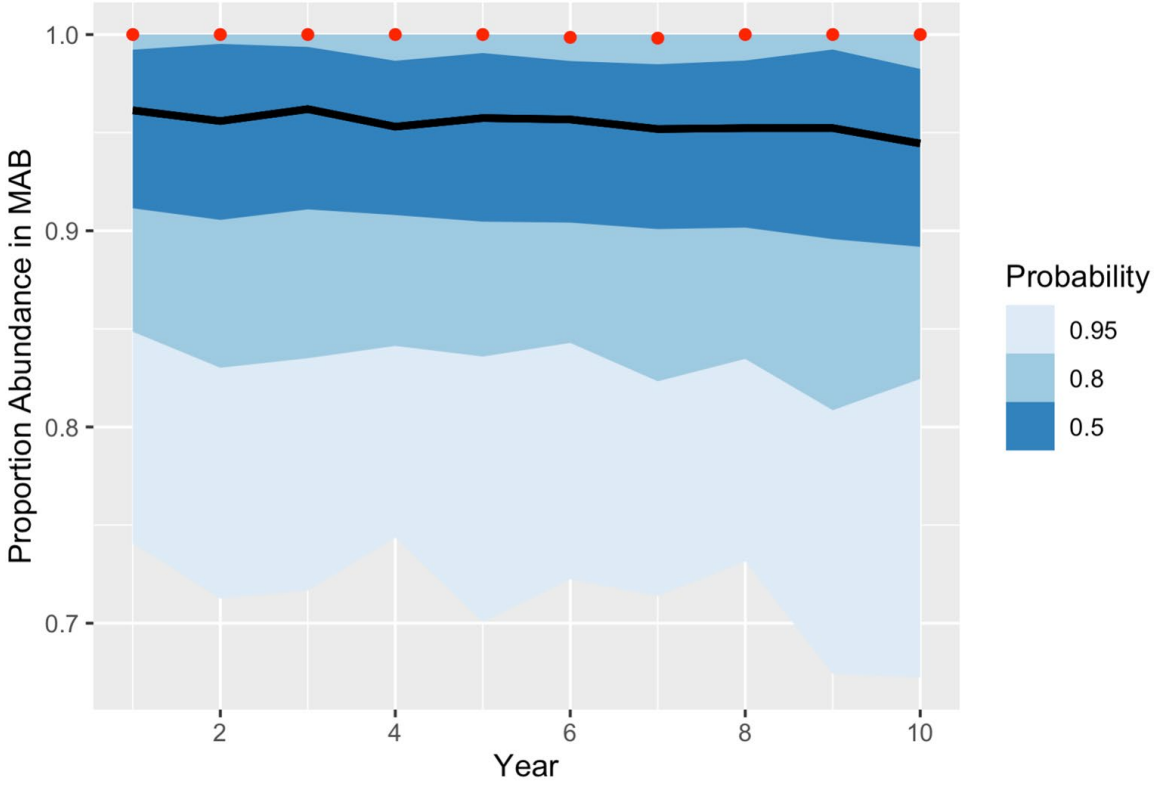


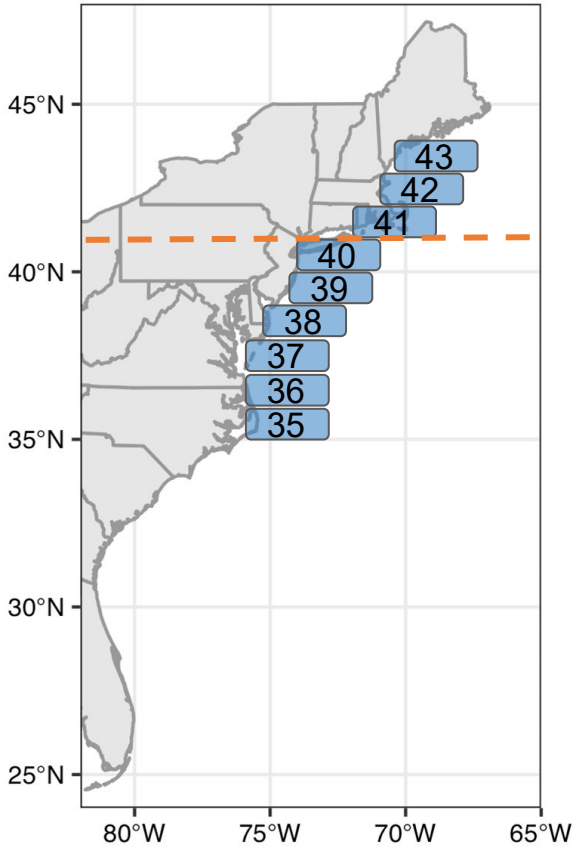
Forecast vs. reality: overall abundance



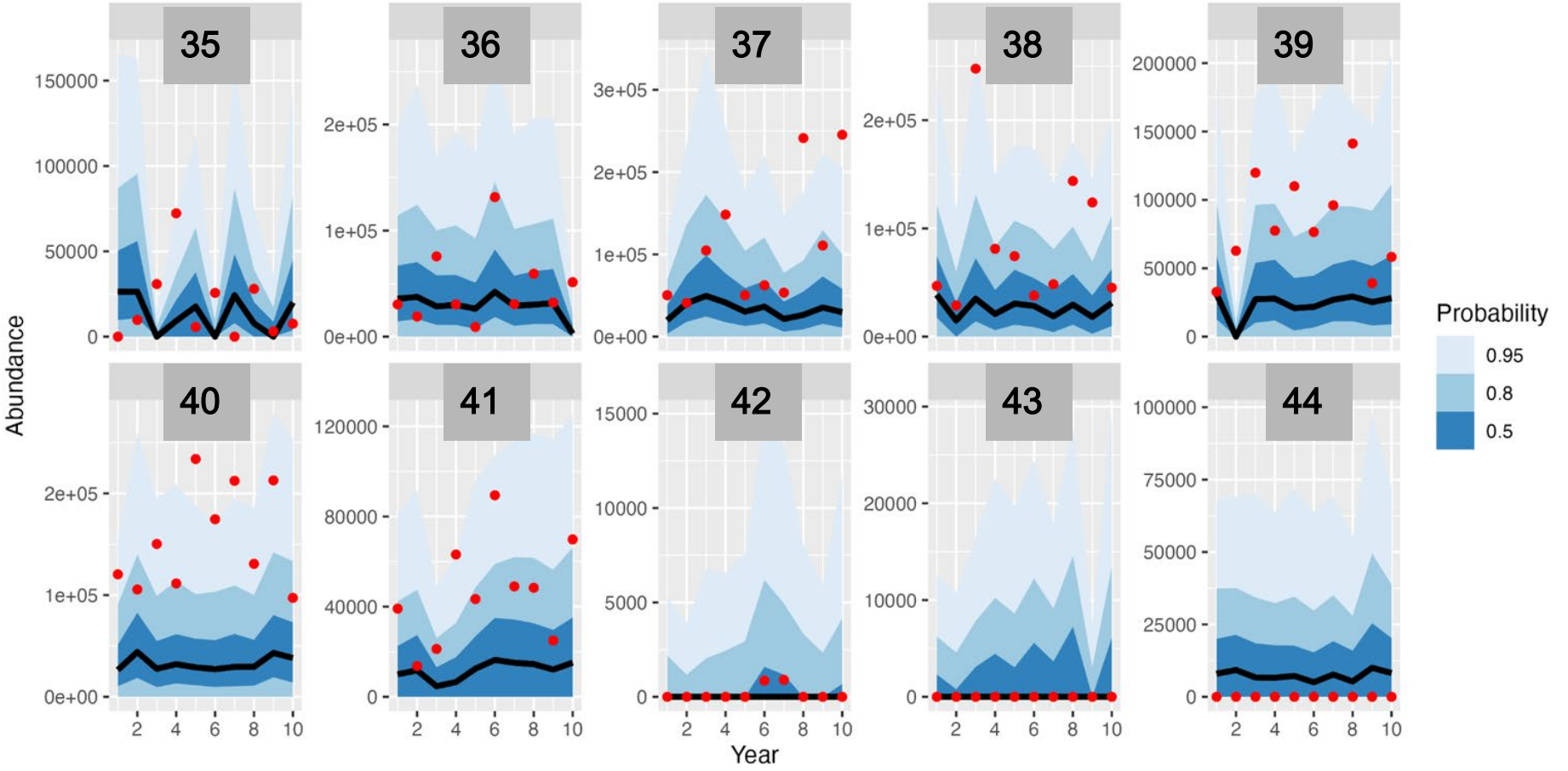


Forecast vs. reality: Mid-Atlantic Bight vs Gulf of Maine / Georges Bank

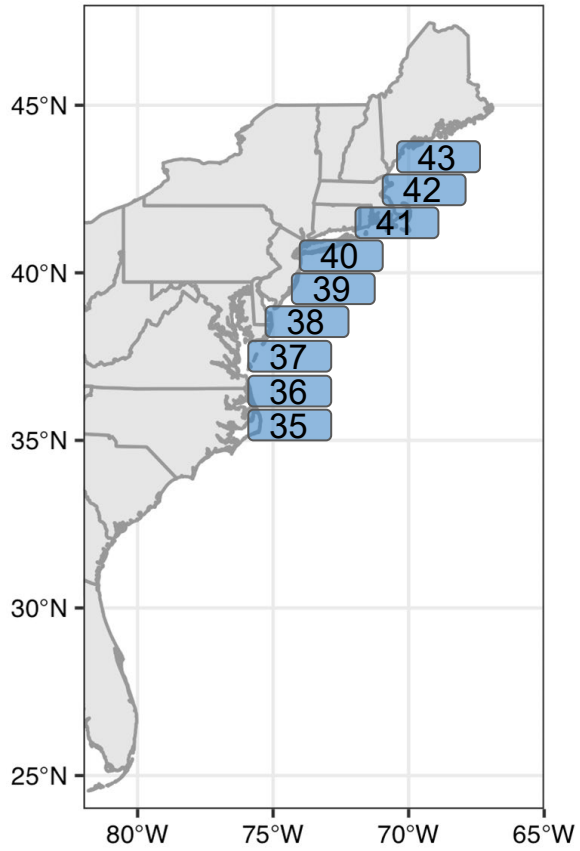


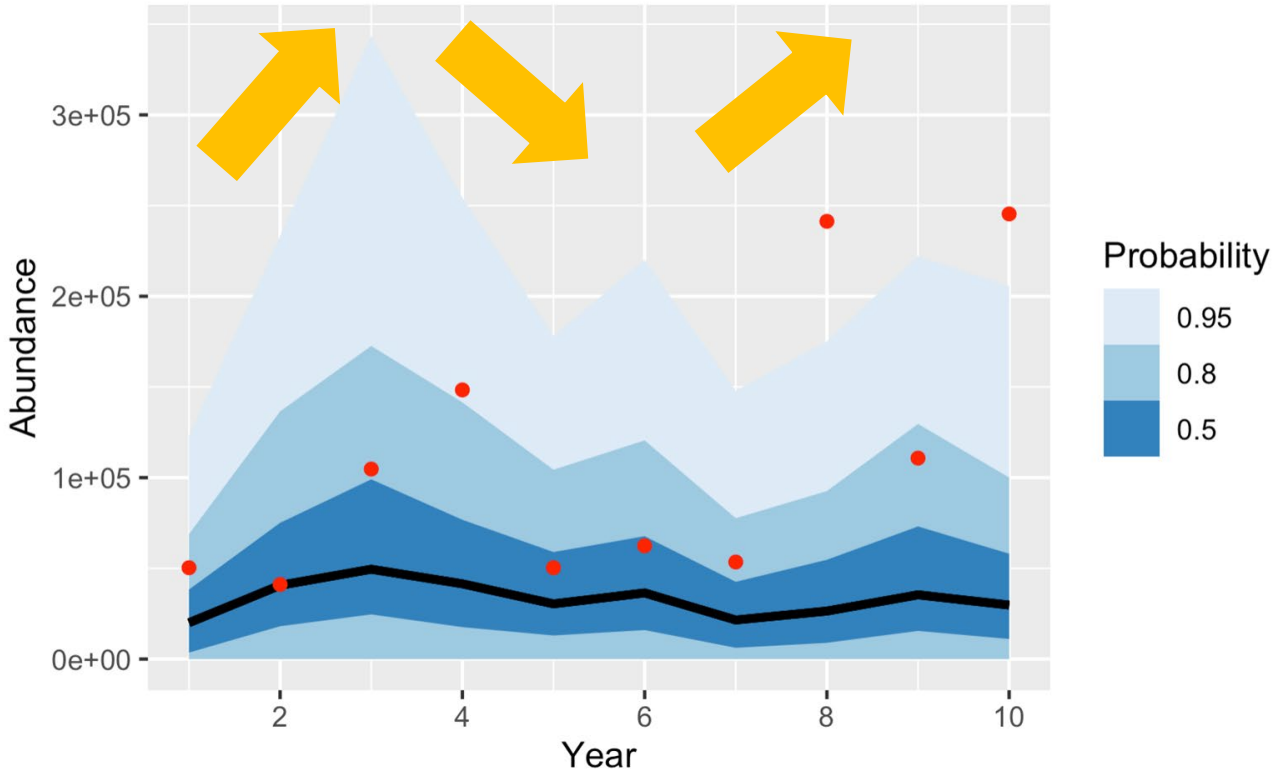


Forecast vs. reality: abundance by patch

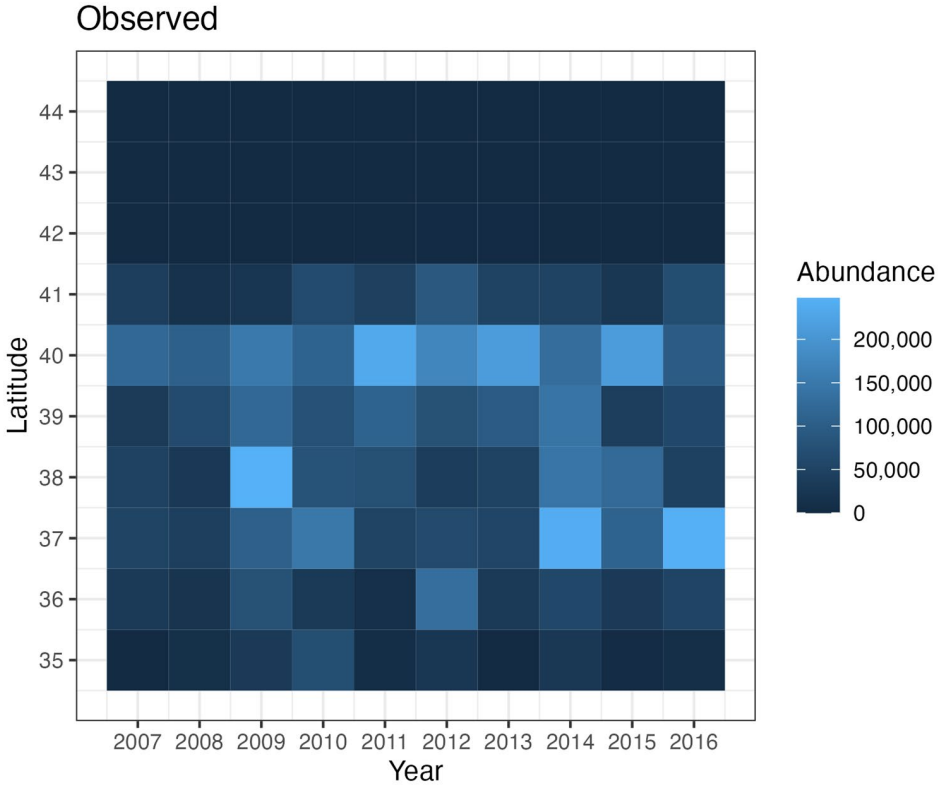


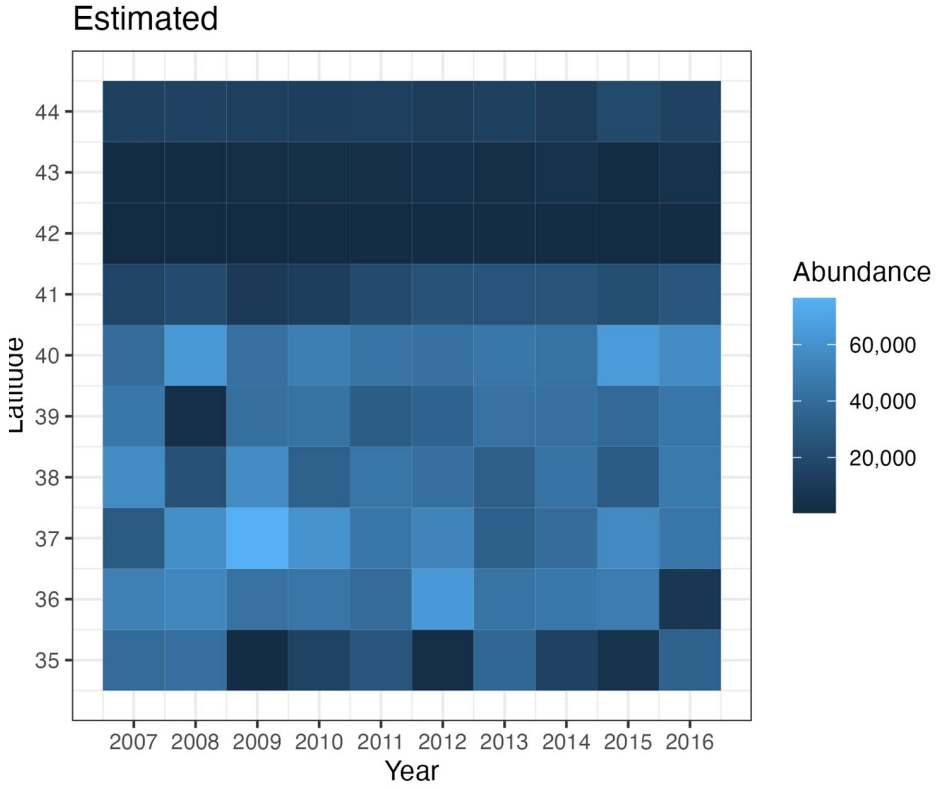
Forecast vs. reality: 37-38 N





Forecast vs. reality: best estimates





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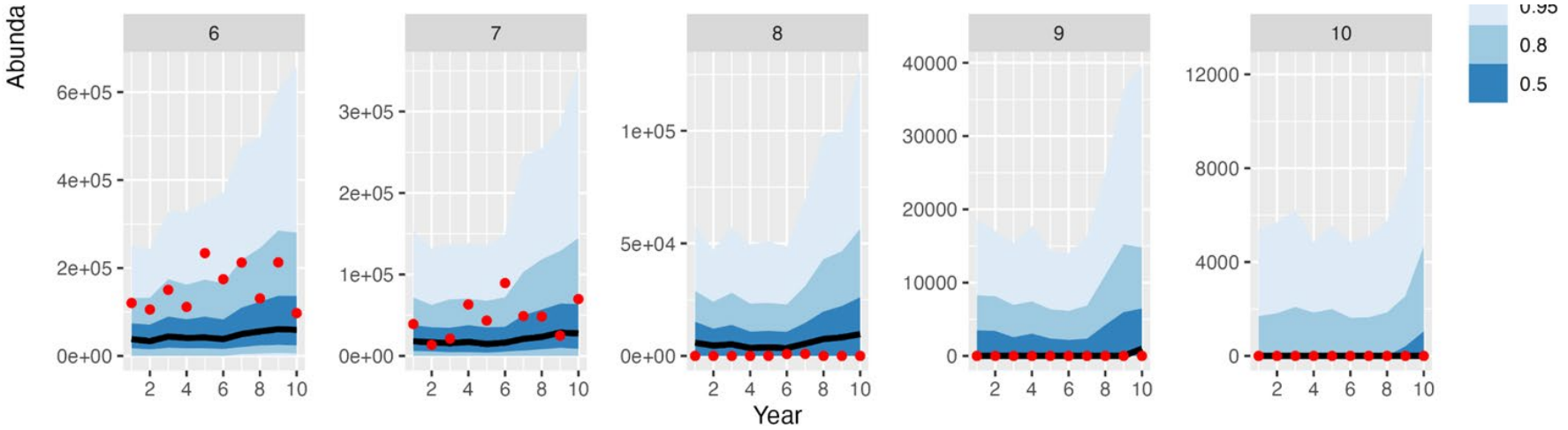

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3. Does information on **fishing** pressure improve forecasts of species distributions?

Yes!

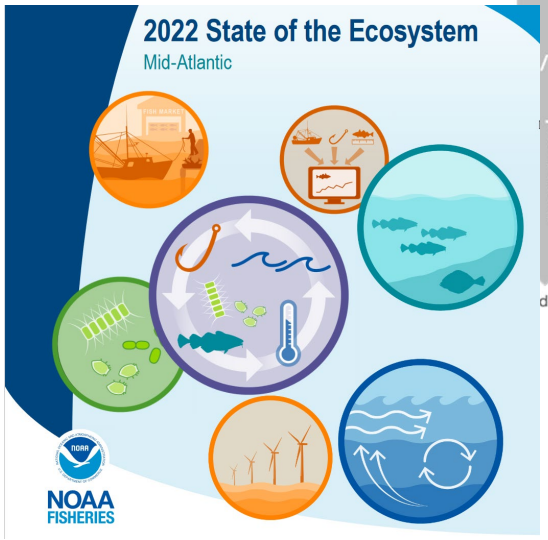
Updates and next steps

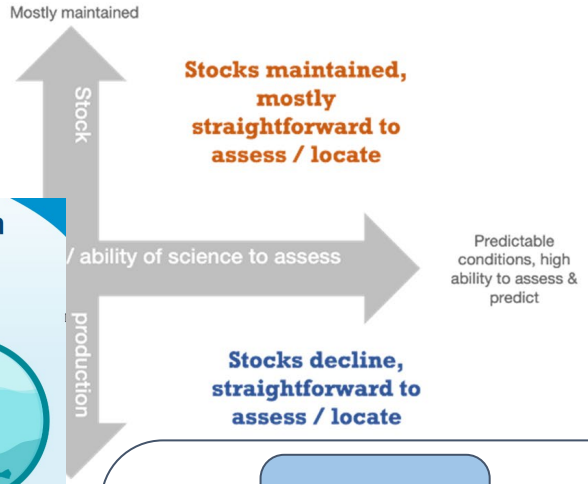
1. All model features are programmed
   Not shown: options to fit to length data or add a stock-recruit relationship
2. Summer flounder models are running on supercomputers at Rutgers this month
3. Ran traditional SDMs for comparison
4. Next up: formally evaluate and compare models
5. Other three species 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. Are there other data streams or parameter estimates you suggest we use, recognizing the generality / specificity trade-off?

Potential Project Application(s)



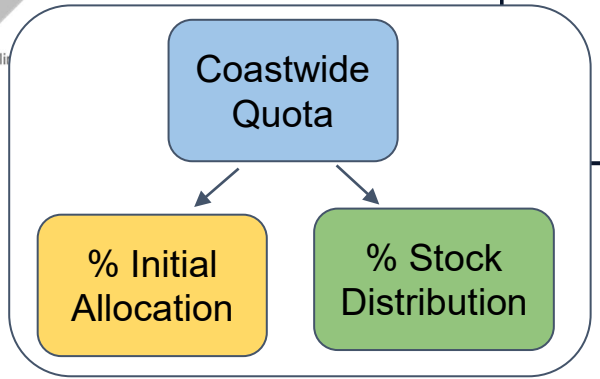


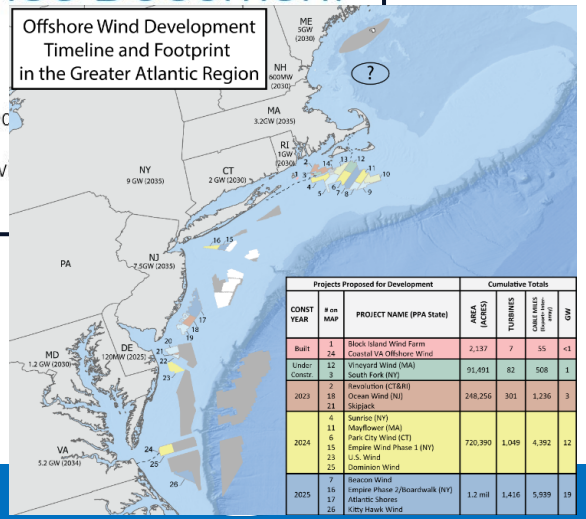
MID-ATLANTIC
FISHERY MANAGEMENT COUNCIL

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

Examples of Potential Science Applications

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

- SOE risks to meeting management objectives
  - Linking ecosystem indicators to distribution changes

Examples of Potential Science Applications

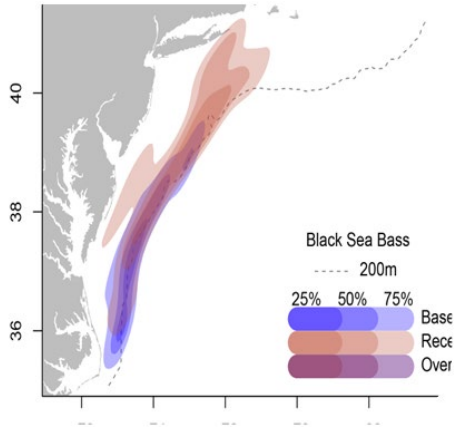
- Inform research priority projects
  - SSC priority area - *Climate change impacts on stock productivity and distribution shifts*
- Stock assessment information
  - Ecosystem TORs and Ecosystem and Socio-Economic Profiles for assessments
  - Stock projection considerations

MID-ATLANTIC FISHERY MANAGEMENT COUNCIL

Mid-Atlantic Fishery Management Council

Comprehensive Five Year (2020–2024) Research Priorities

Approved December 2019



Examples of Potential Council Application

- Continued development and implementation of EAFM guidance document

  - Comprehensive review this year
  - Connection/link with Ecosystem Work Group

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)

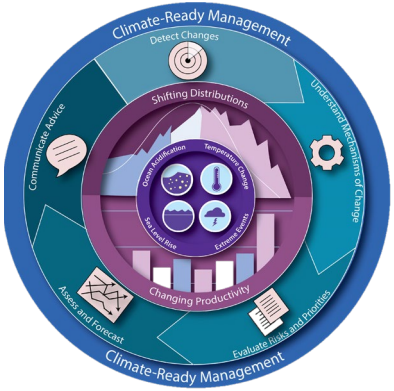
Species	Assess	Fstatus	Bstatus	FW1Pred	FW1Prey	FW2Prey	Climate	DistShift	EstHabitat
Ocean Quahog	l	l	l	l	l	l	l	lm	l
Surfclam	l	l	l	l	l	l	mh	mh	l
Summer flounder	l	l	lm	l	l	l	lm	mh	h
Scup	l	l	l	l	l	l	lm	mh	h
Black sea bass	l	l	l	l	l	l	mh	mh	h
Atl. mackerel	l	h	h	l	l	l	lm	mh	l
Butterfish	l	l	l	l	l	l	l	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



Research Application Questions for SSC

1. Comment on potential applicability of short-term forecasts of species distribution for stock assessment, science, and management purposes of Mid-Atlantic species. Consider potential implications for the SSC's OFL CV approach

1. Provide any research recommendations and inclusion of relevant data for future model development that could facilitate their consideration of factors influencing determination of ABCs.

Feedback from the SSC and EOP Committee/AP (2/23 meeting) will be provided to the Council for consideration at April Council meeting