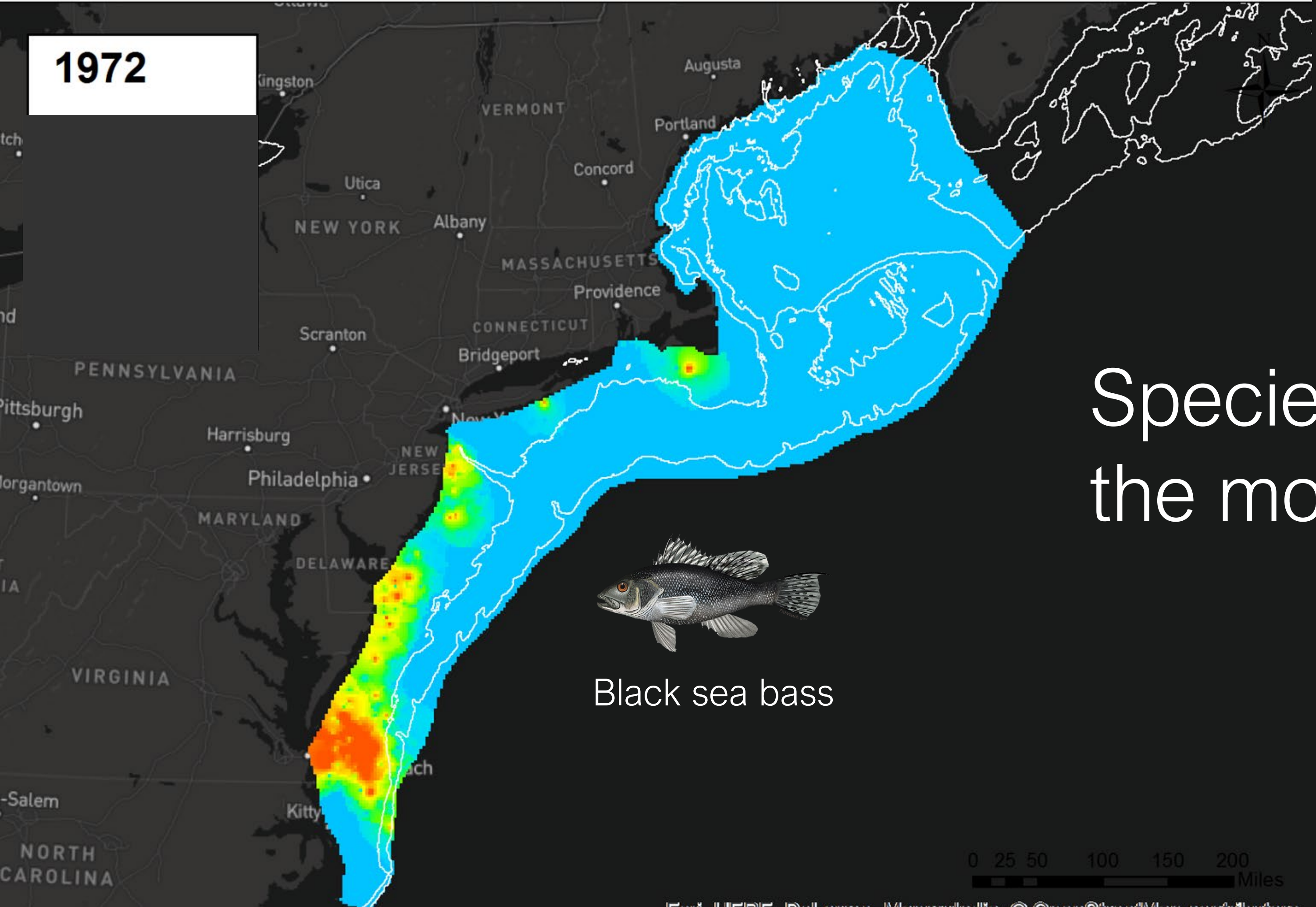
Short-term forecasts of species distributions for fisheries management

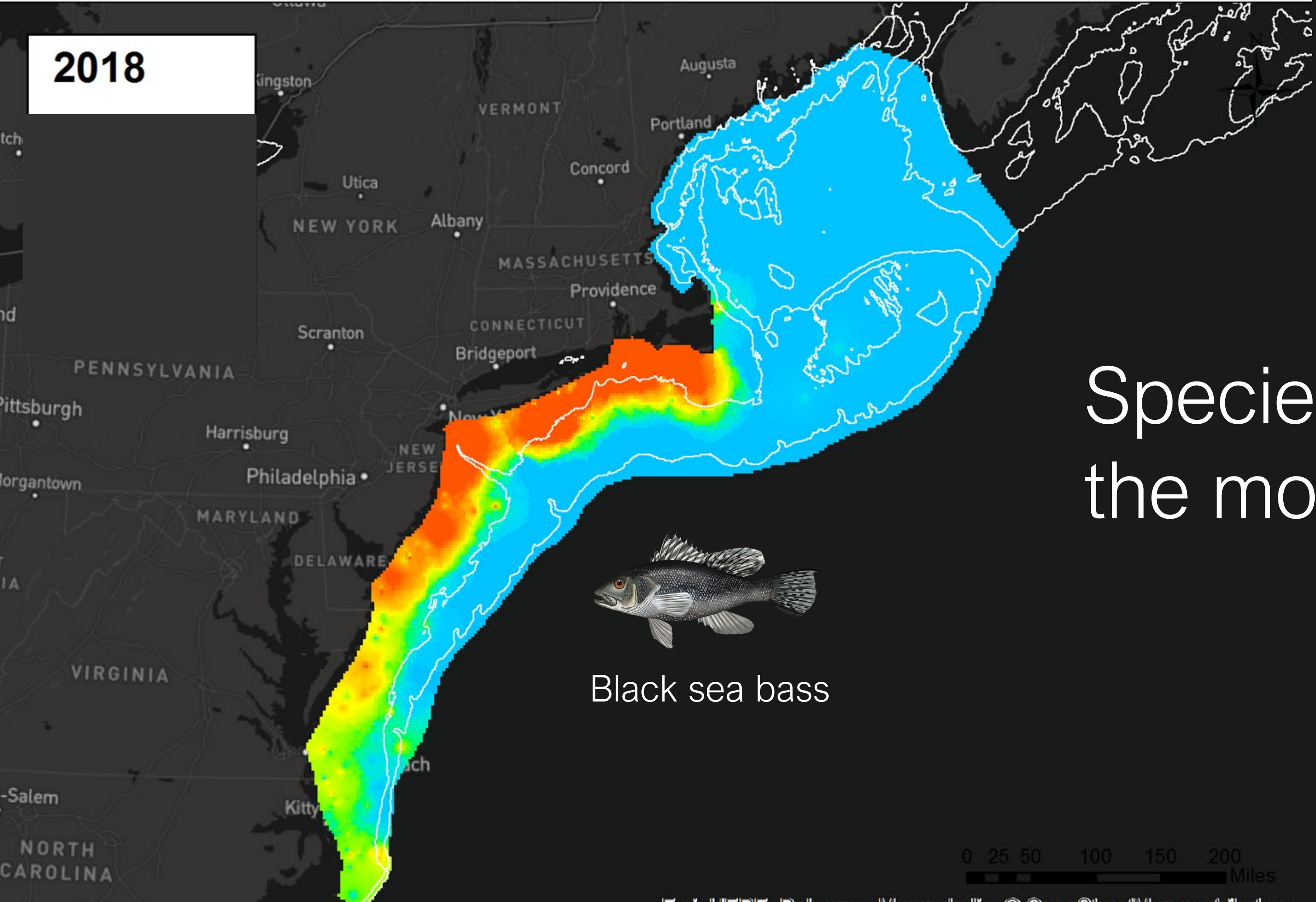
Dennis Stallings

Malin Pinsky, Rutgers University
Alexa Fredston, Rutgers University
Brandon Muffley, Mid-Atlantic Fishery Management Council

Species are on the move



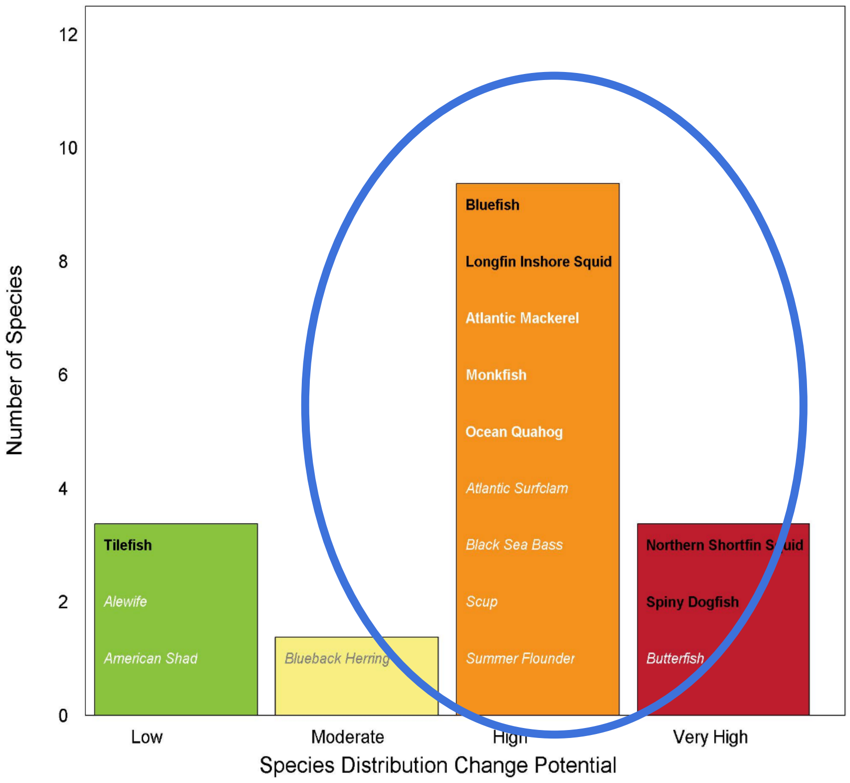
OceanAdapt (http://oceanadapt.rutgers.edu) from NMFS data



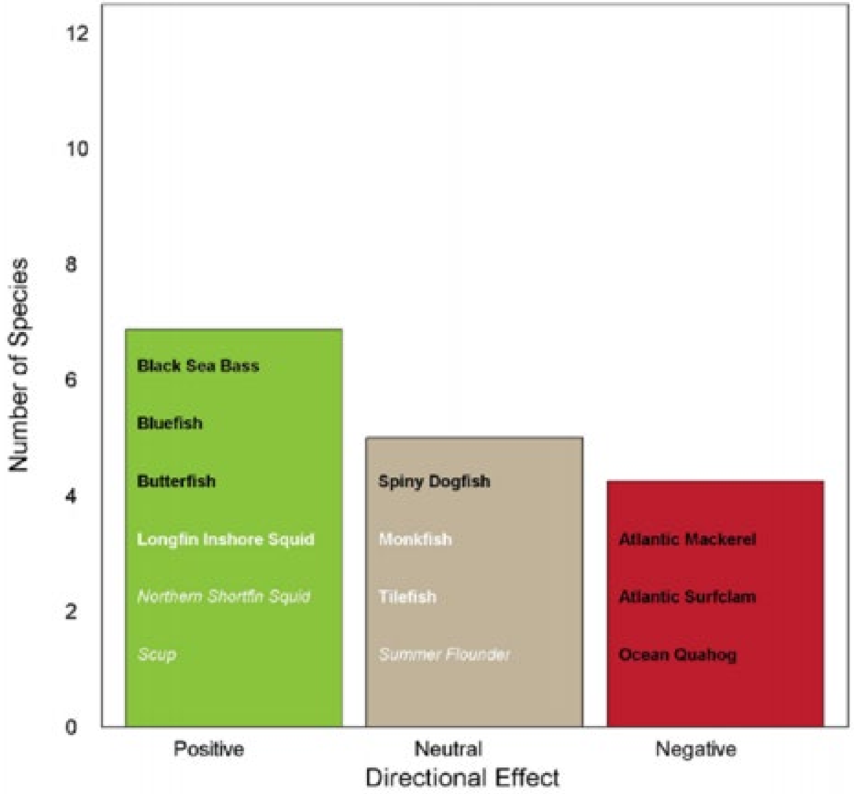
OceanAdapt (http://oceanadapt.rutgers.edu) from NMFS data

Species are on the move

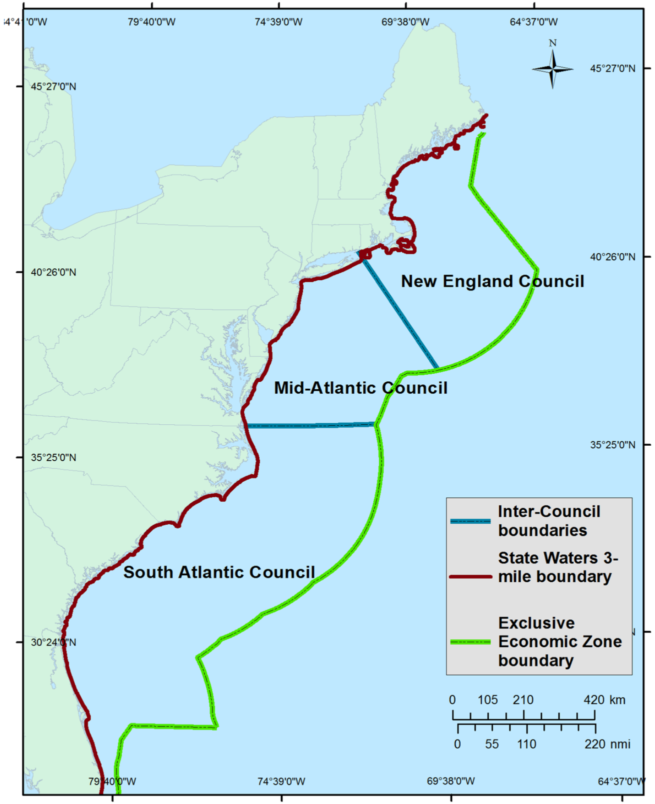
Potential change in species distribution



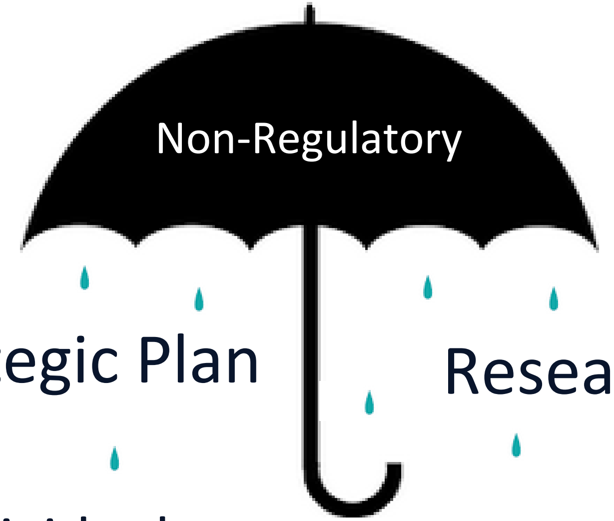
Directional effect of climate change



Governance Issues



EAFM Guidance Document

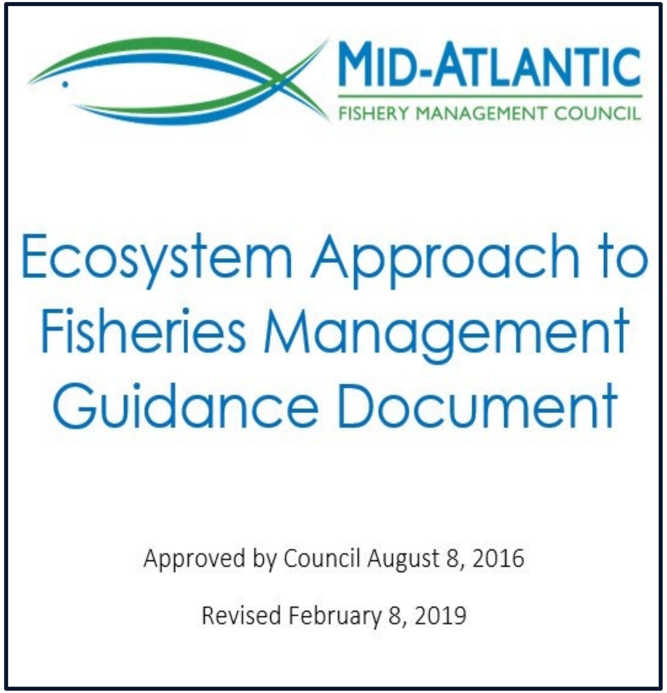


Strategic Plan

Research Plan

Individual FMPs Activities

Other Council Activities


MID-ATLANTIC
FISHERY MANAGEMENT COUNCIL

Ecosystem Approach to Fisheries Management Guidance Document

Approved by Council August 8, 2016

Revised February 8, 2019

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 consider distribution change in a more tactical way
    - Focus on Mid At species, but interest in South At changes – e.g. blueline tilefish

Potential Council Application of Research

- Continued development and implementation of EAFM guidance document
  - EAFM Risk Assessment

Risk Assessment Update 2020

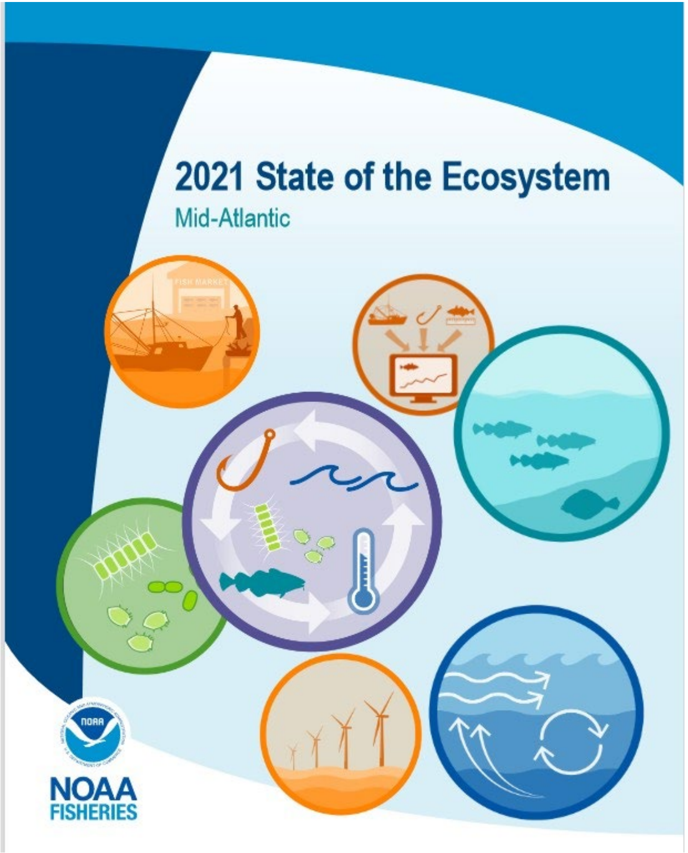
Table 4: Species level risk analysis results; l=low risk (green), lm= low-moderate risk (yellow), mh=moderate to high risk (orange), h=high risk (red)

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 Applications of Research (cont.)



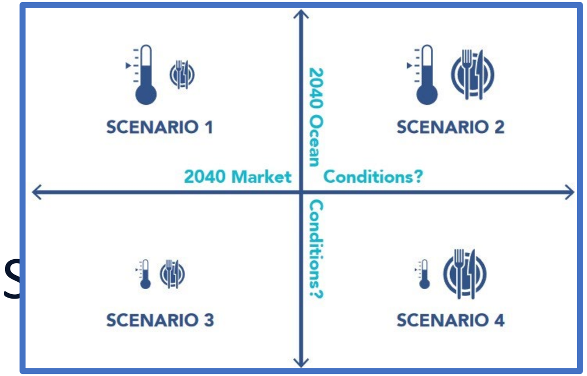
Less Uncertainty → More Uncertainty

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.

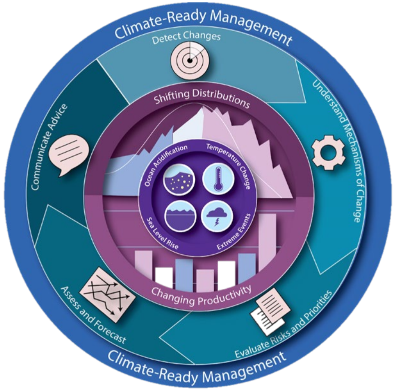
From MAFMC Scientific and Statistical Committee OFL CV Guidance Document 2020 – https://www.mafmc.org/ssc

Potential Applications (cont.)

- Council Actions
  - Dynamic allocation strategies
- Stock Assessments and projections
  - Ecosystem TORs and ESP for assessments
- East Coast Climate Change and Distribution S
  Shift Scenario Planning Project



- Marine Spatial Planning/Coordination
  - Offshore wind and aquaculture development
- NOAA Fisheries Climate Ready Fisheries Management
- 7th National Science Coordination Subcommittee
  - Workshop Themes: Ecosystem indicators in assessments
    - Fishing level advice for stocks experiencing distribution change



Engagement with Council's EOP Committee and AP

Held a kick-off webinar in December 2019 to introduce research and get initial feedback on project goals and species considered

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?

Focal Species

Summer Flounder, Illex Squid, Spiny Dogfish, Gray Triggerfish

Considerations: relevant to Council management, range of life history types, current/future shifts likely, data availability

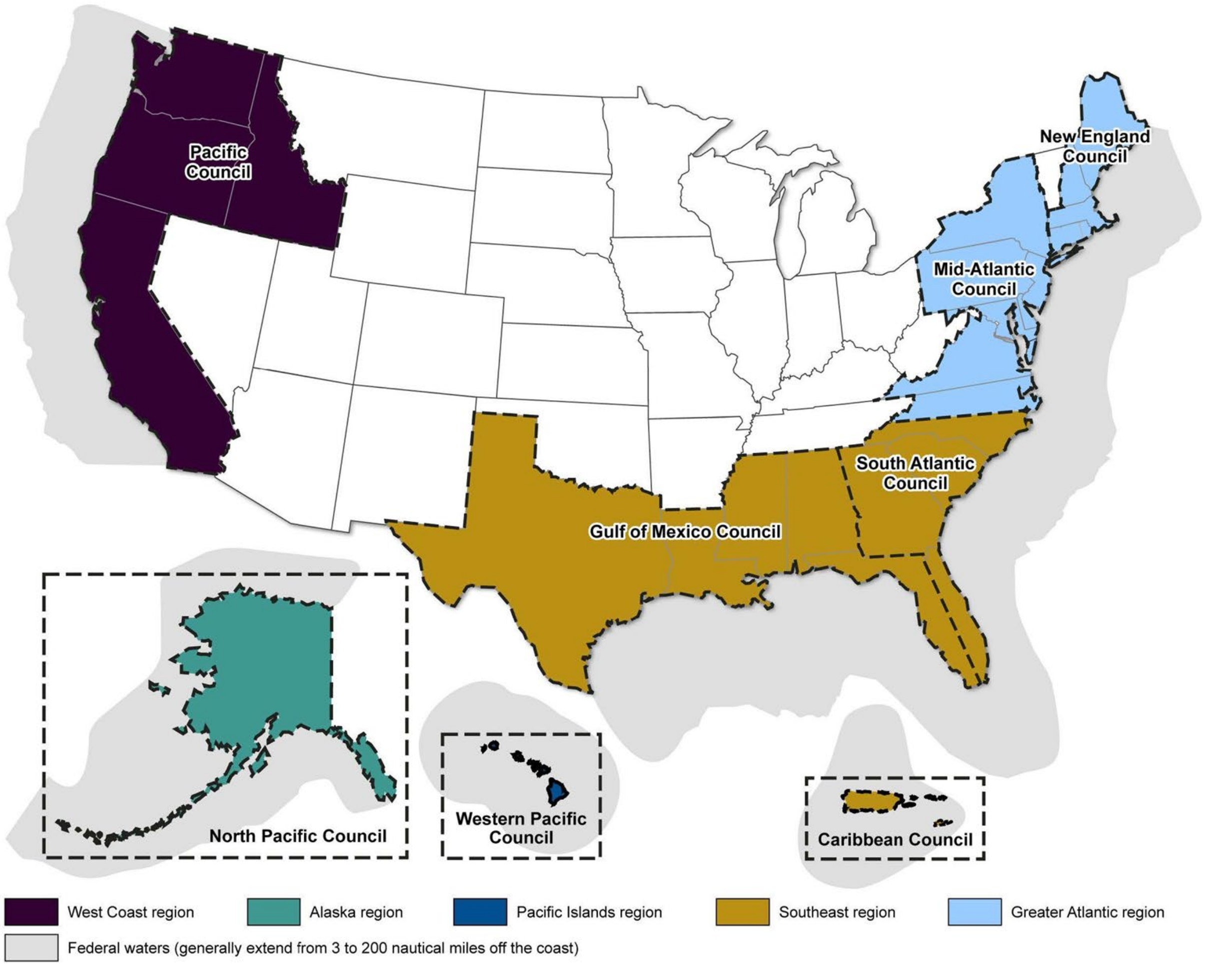
Questions/topics for group to be thinking about

- What types model outputs and information would be most useful - in both content and format?
- How/where could this type of information be applied in our science and management processes and decisions?
- What might be missing or what other considerations should the team be thinking about?
- Do the initial outputs for summer flounder make sense? What does/doesn’t?

Further shifts by 2100

Morley *et al.* 2018 PLOS ONE

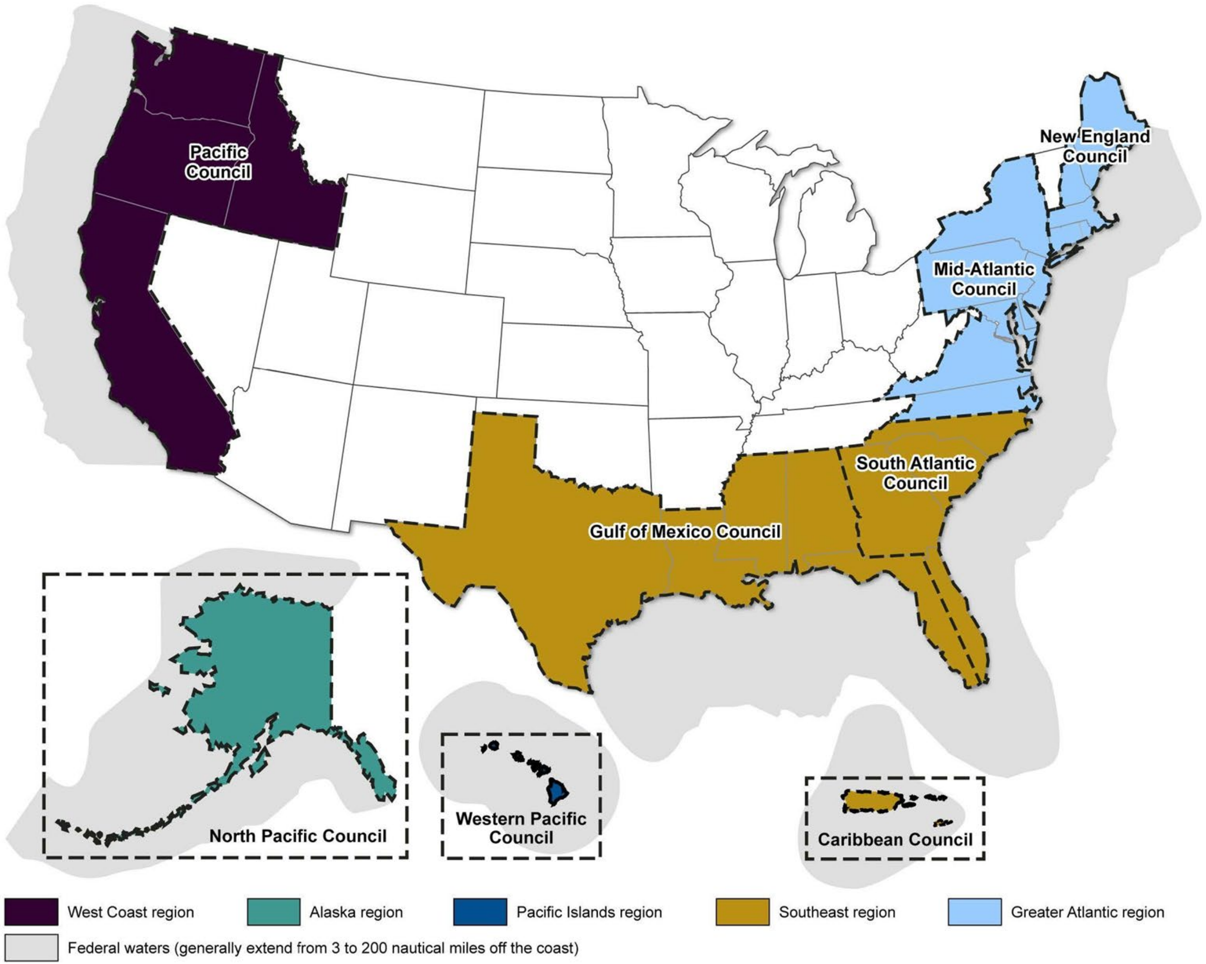
Fisheries management requires knowing where fish are



Sources: National Marine Fisheries Service, *Fisheries of the United States, 2014* (data); Map Resources (map). | GAO-16-827

Fisheries management requires knowing where fish are

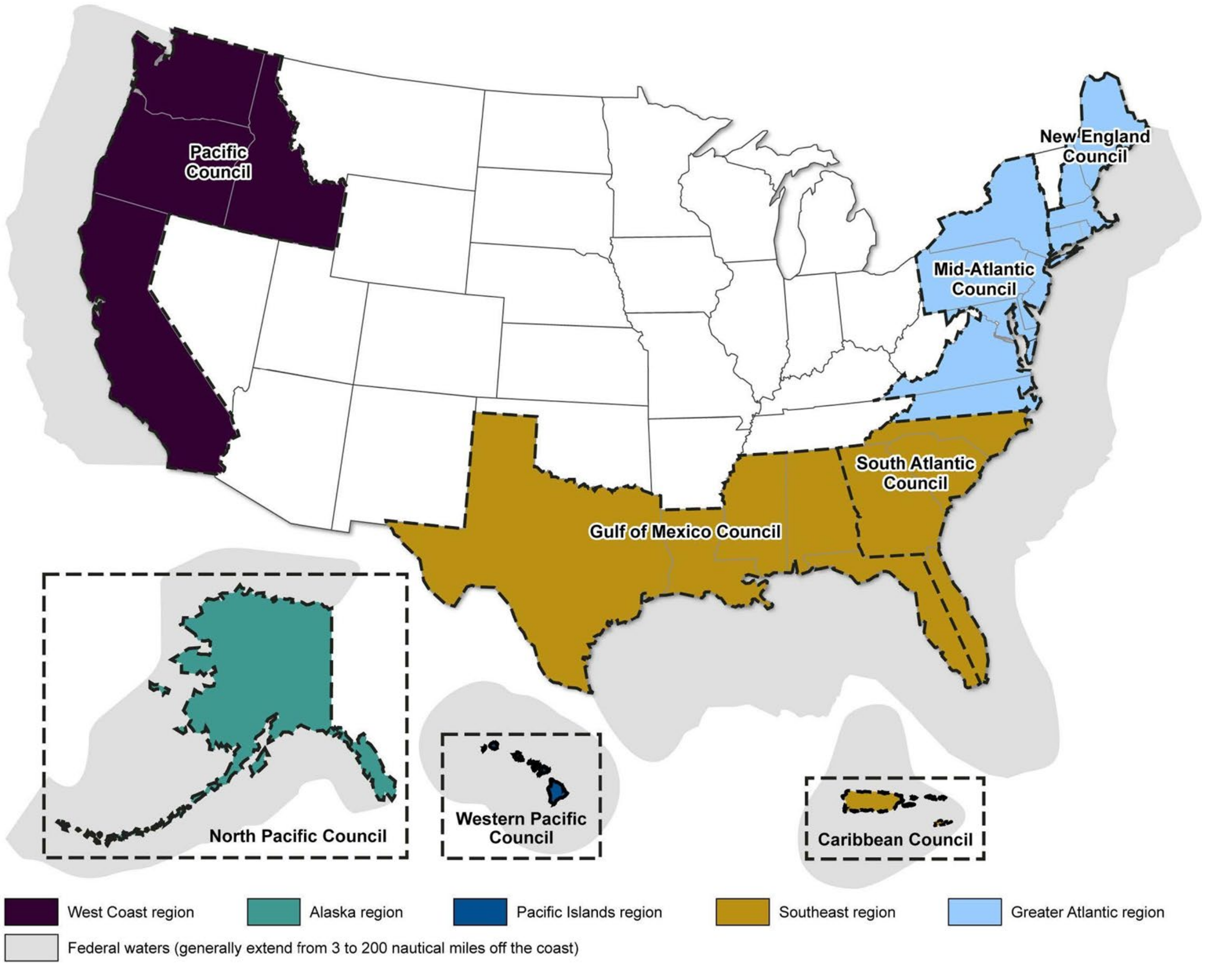
- Stock definitions



Sources: National Marine Fisheries Service, *Fisheries of the United States, 2014* (data); Map Resources (map). | GAO-16-827

Fisheries management requires knowing where fish are

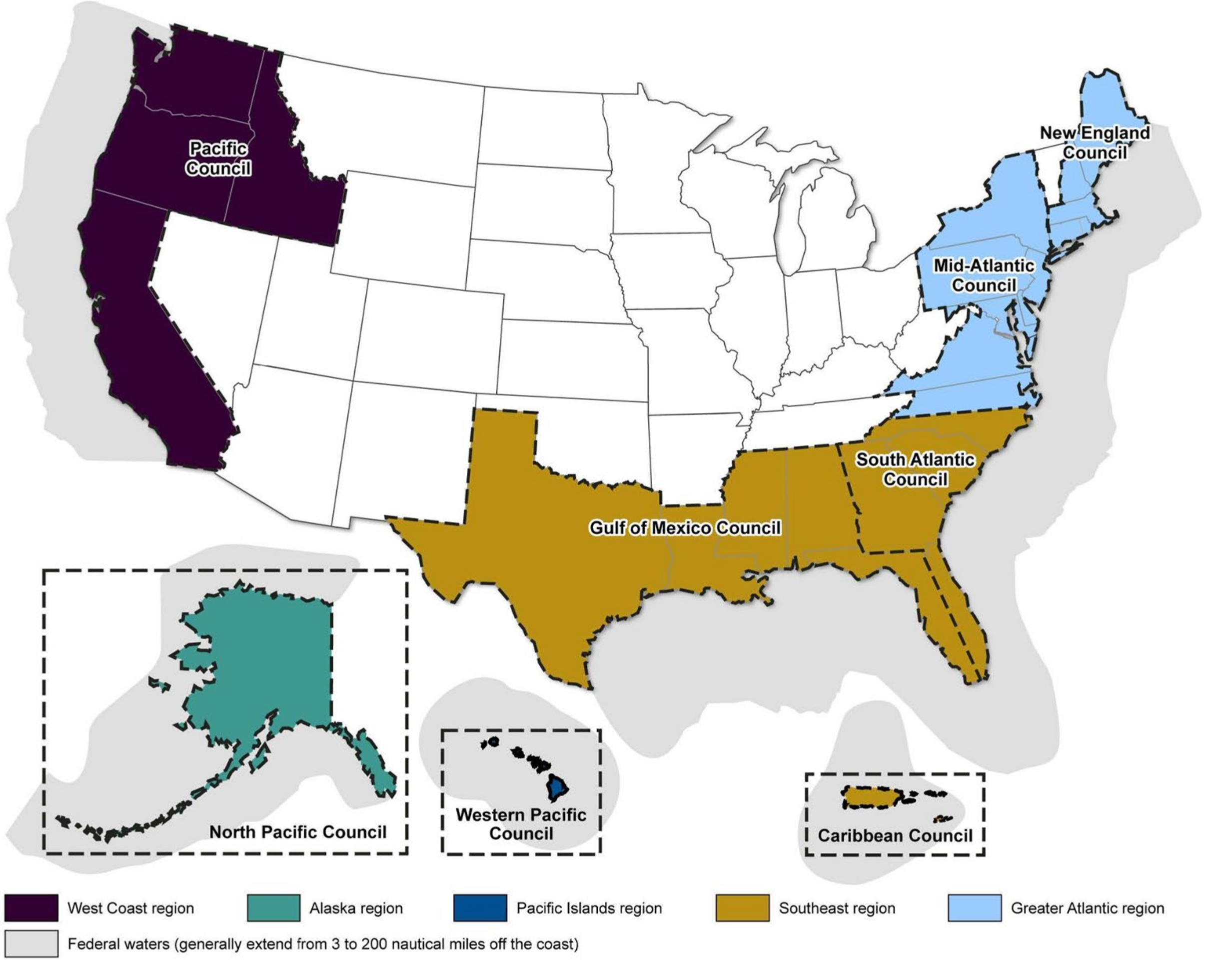
- Stock definitions
- Stakeholder representation



Sources: National Marine Fisheries Service, *Fisheries of the United States, 2014* (data); Map Resources (map). | GAO-16-827

Fisheries management requires knowing where fish are

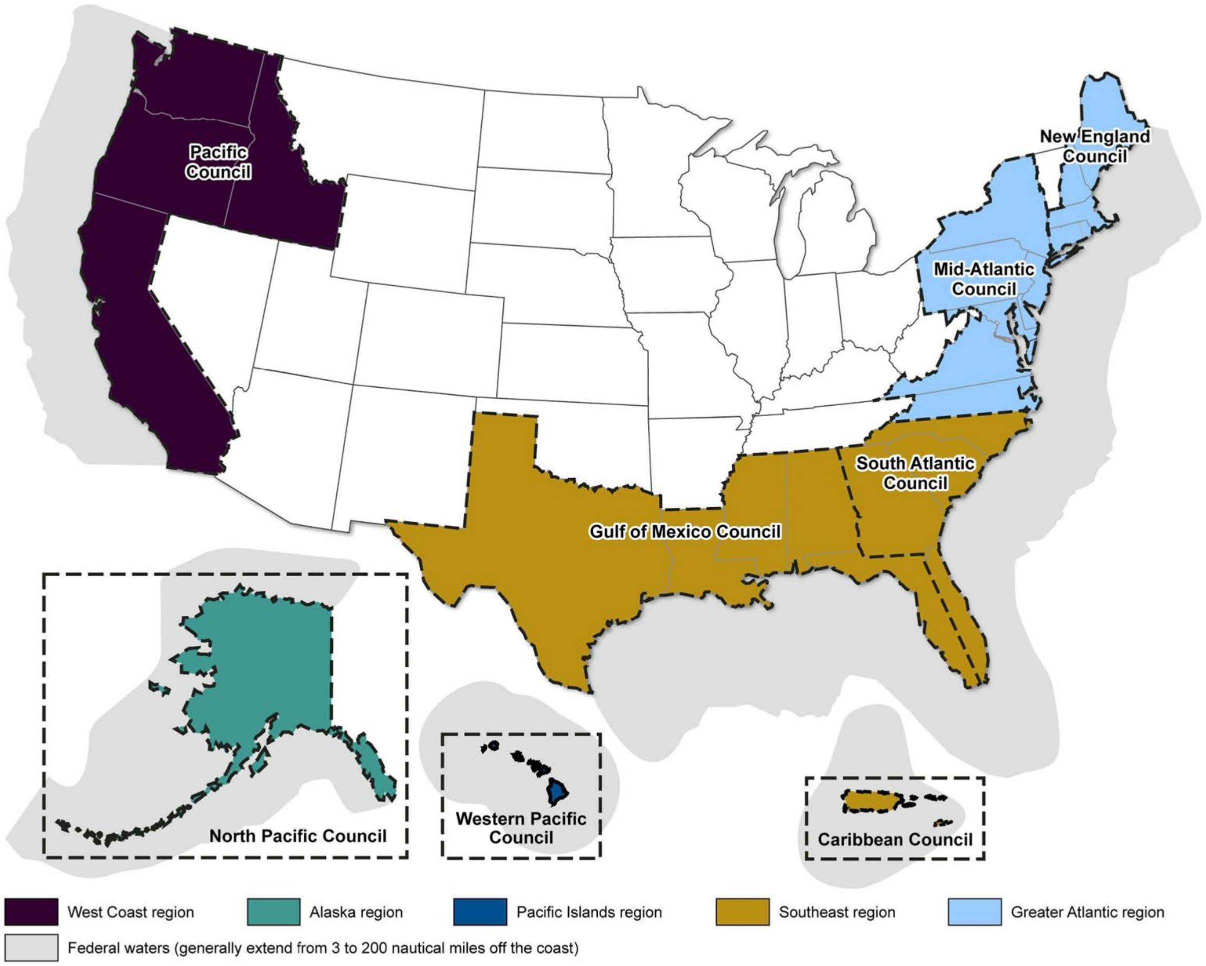
- Stock definitions
- Stakeholder representation
- Spatial management



Sources: National Marine Fisheries Service, *Fisheries of the United States, 2014* (data); Map Resources (map). | GAO-16-827

Fisheries management requires knowing where fish are

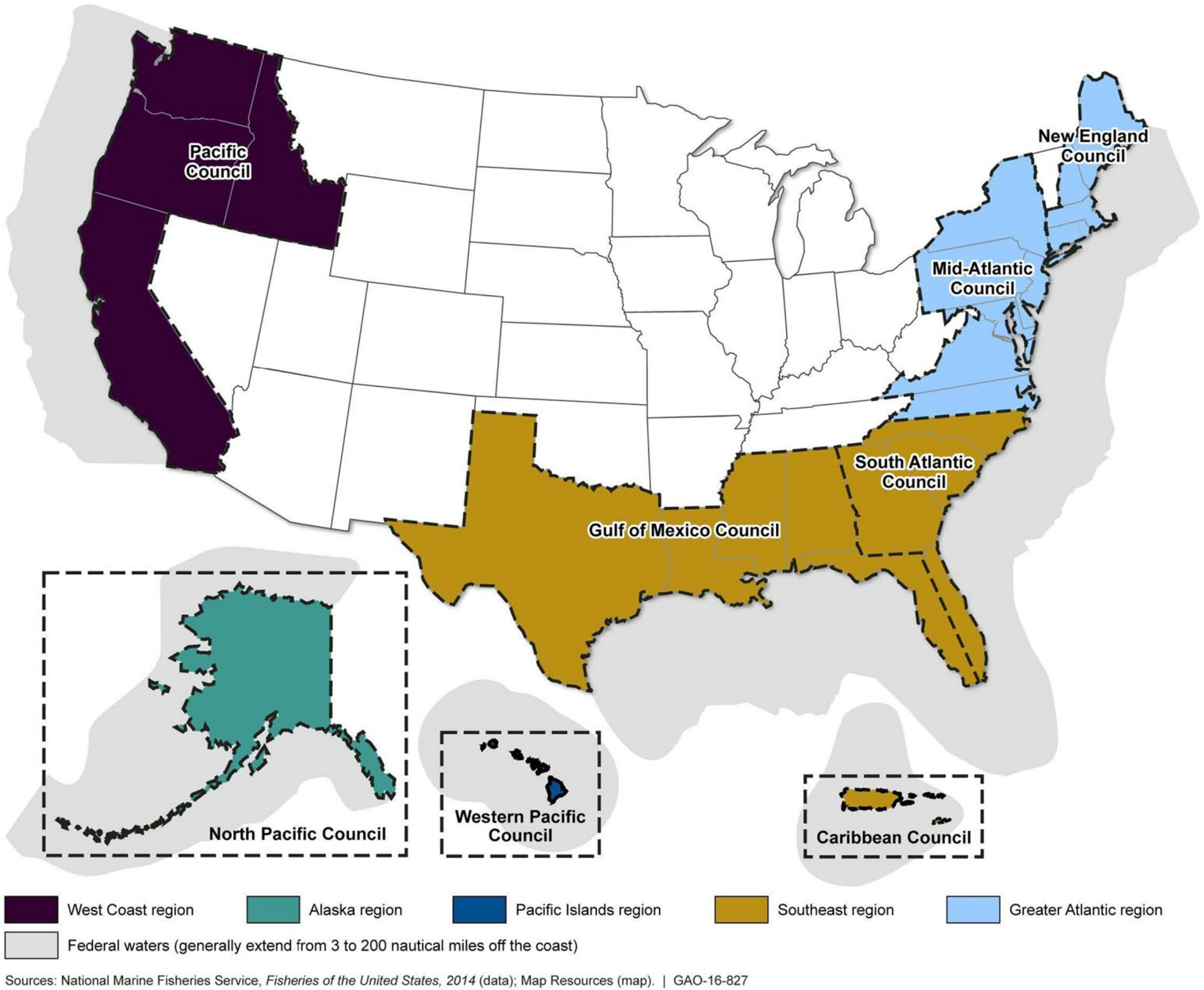
- Stock definitions
- Stakeholder representation
- Spatial management
- Incidental catch



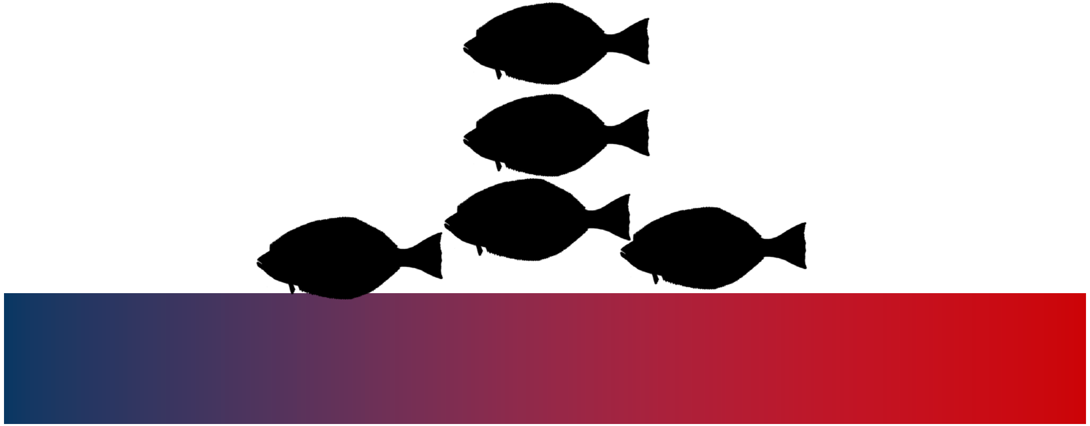
Sources: National Marine Fisheries Service, *Fisheries of the United States, 2014* (data); Map Resources (map). | GAO-16-827

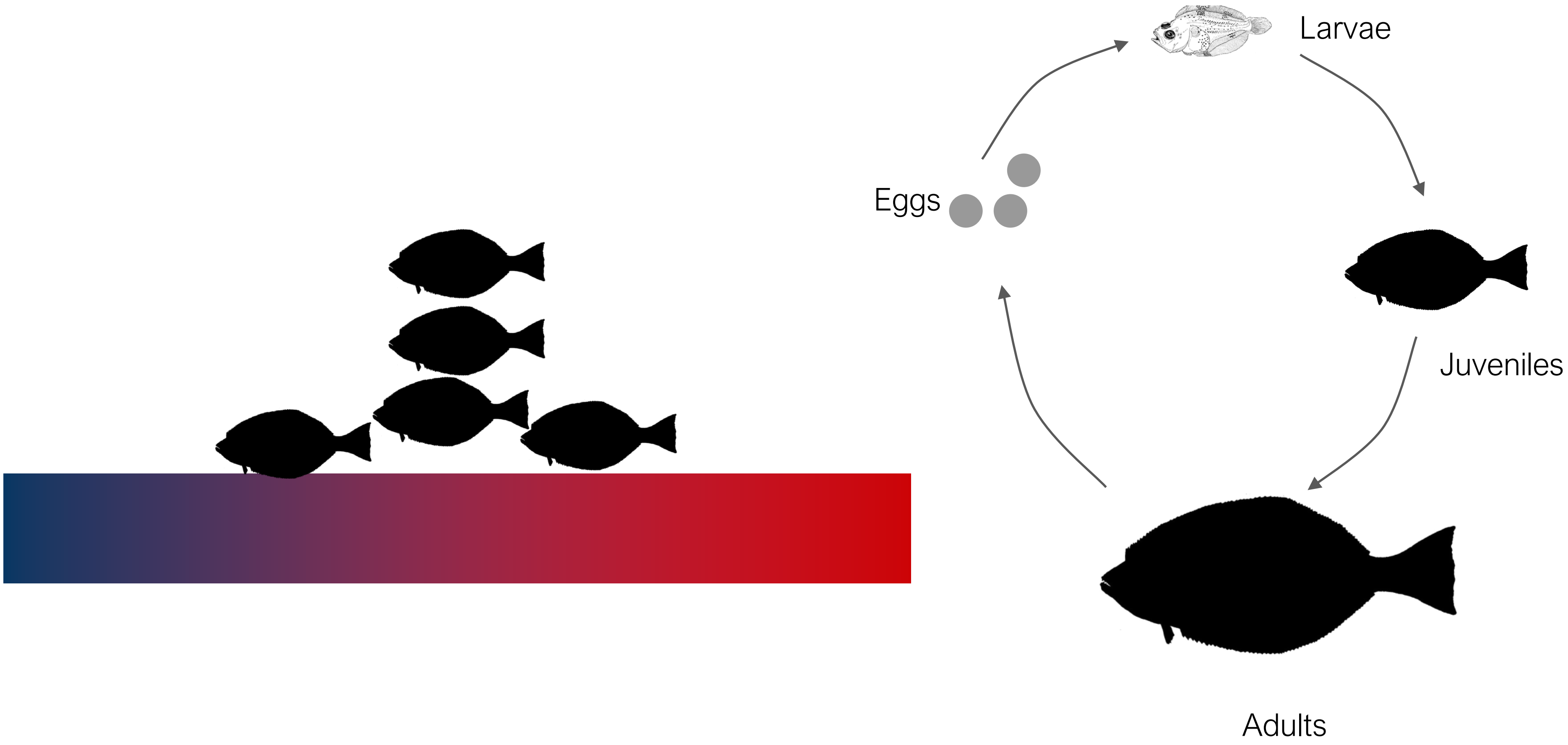
Fisheries management requires knowing where fish are

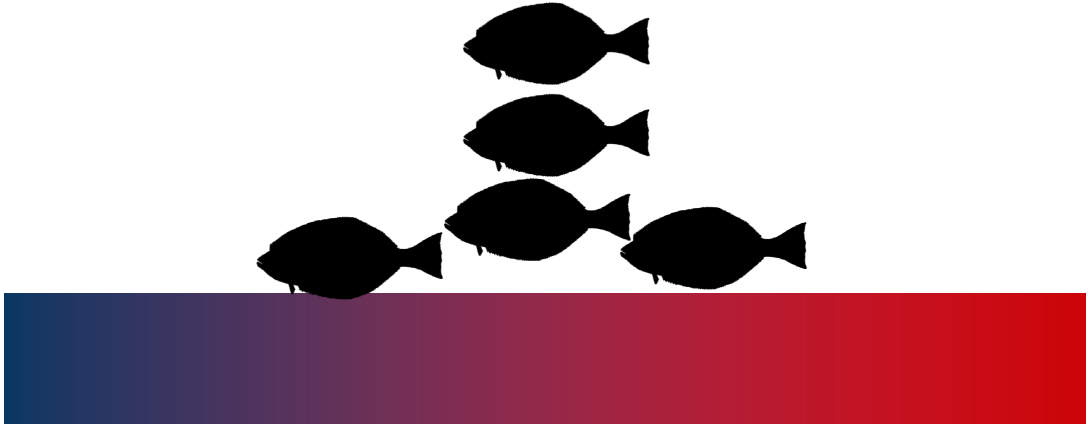
- Stock definitions
- Stakeholder representation
- Spatial management
- Incidental catch
- Allocations

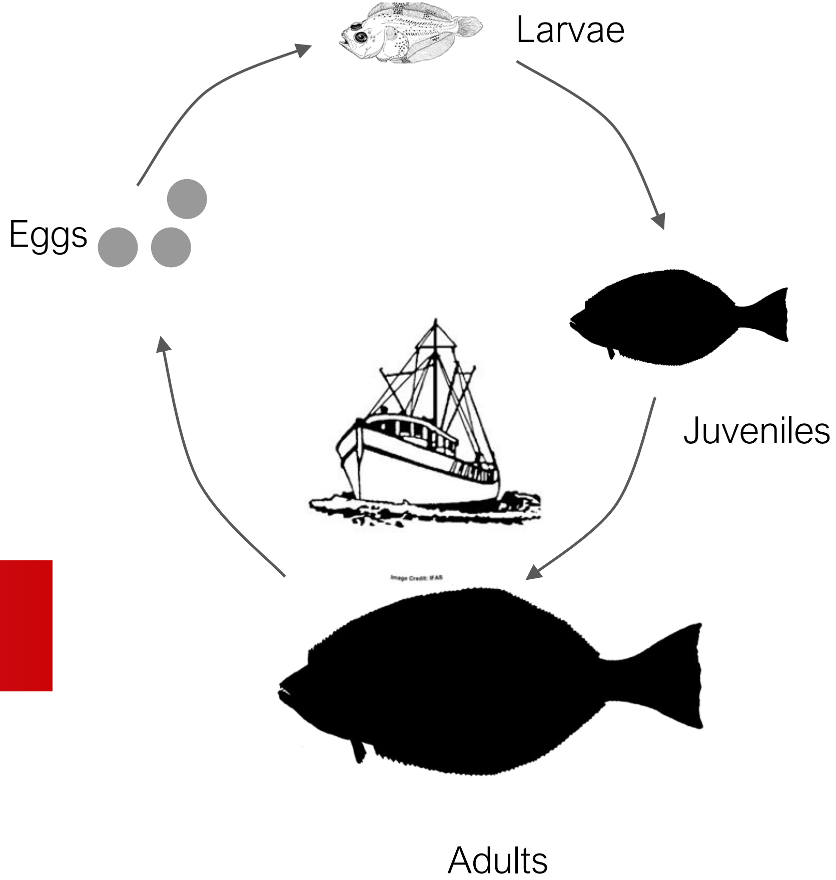


Mismatch in timescales




Larvae
Eggs
Juveniles
Adults

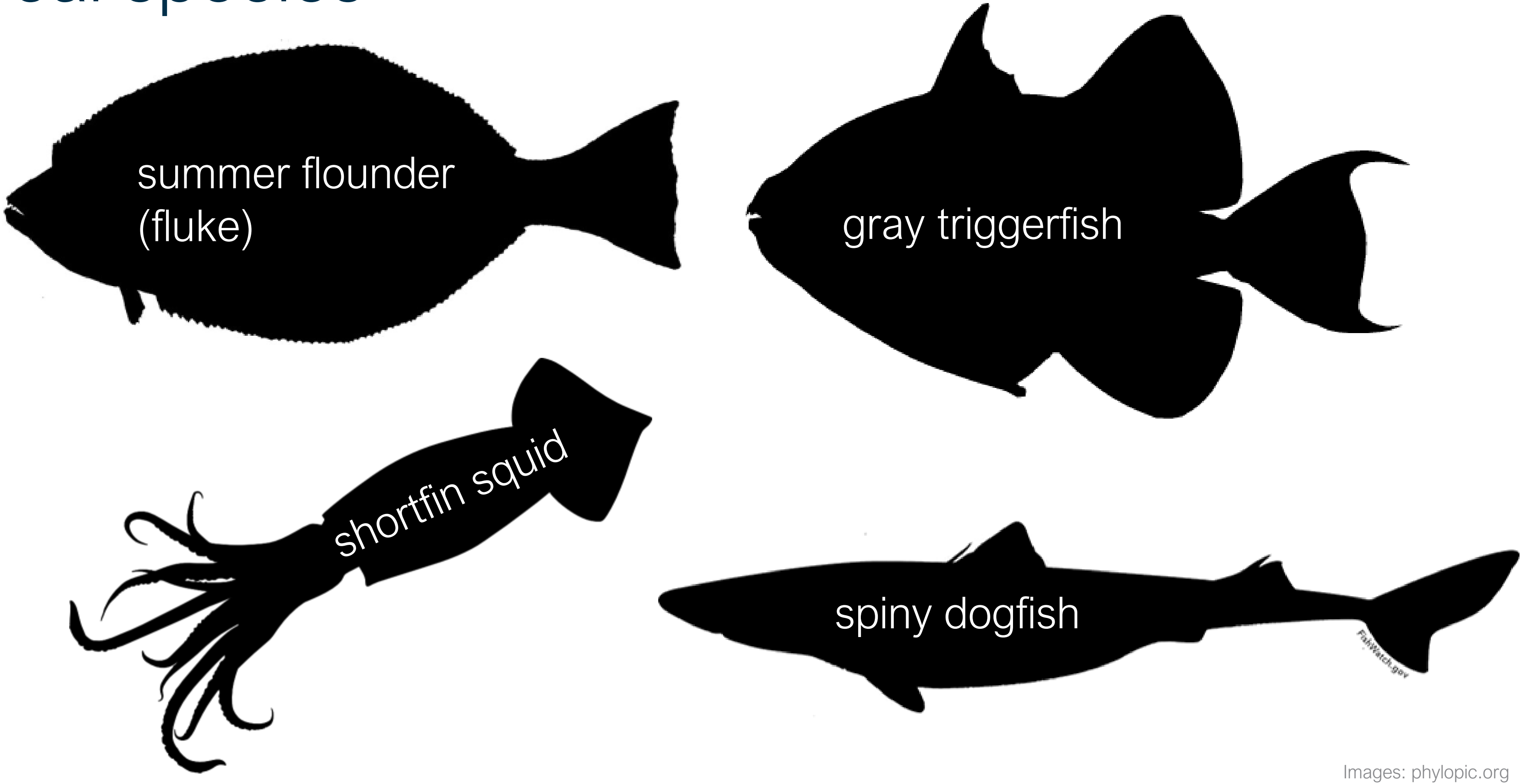




Fisheries Bulletin of the United States

Develop and test
dynamic range models
for near-term forecasts

Focal species



Images: phylopic.org
FishWatch.gov

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)?

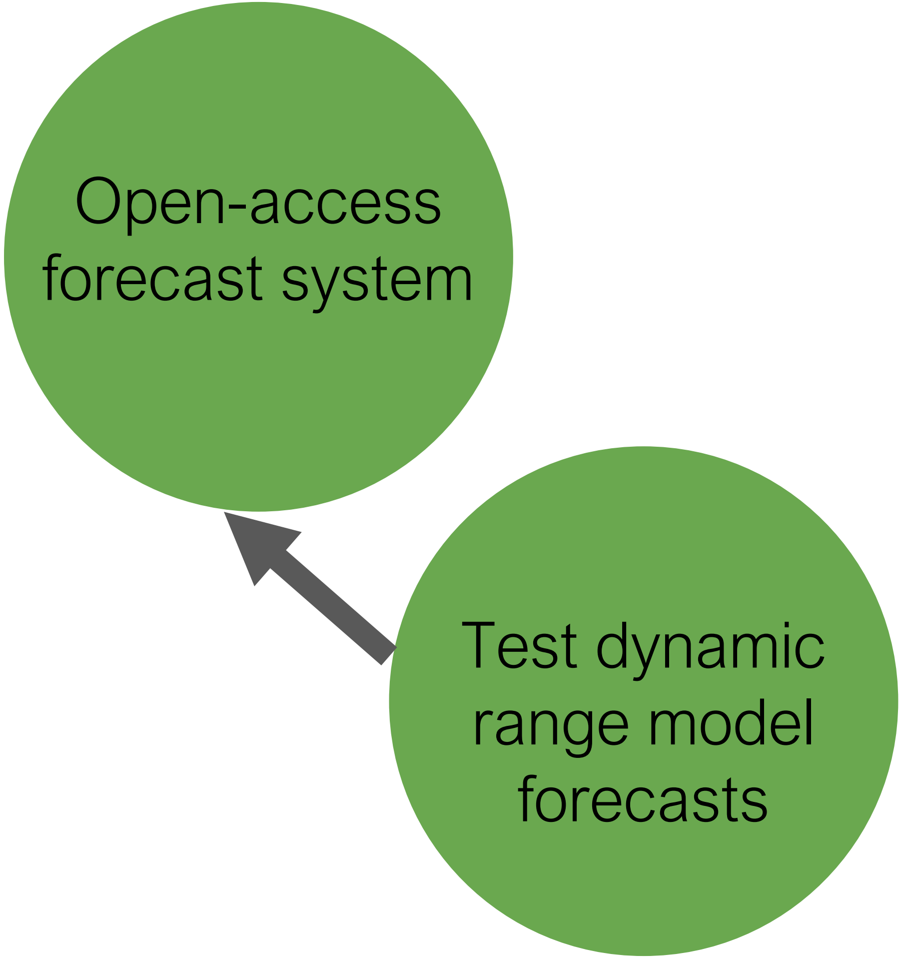
Research questions

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

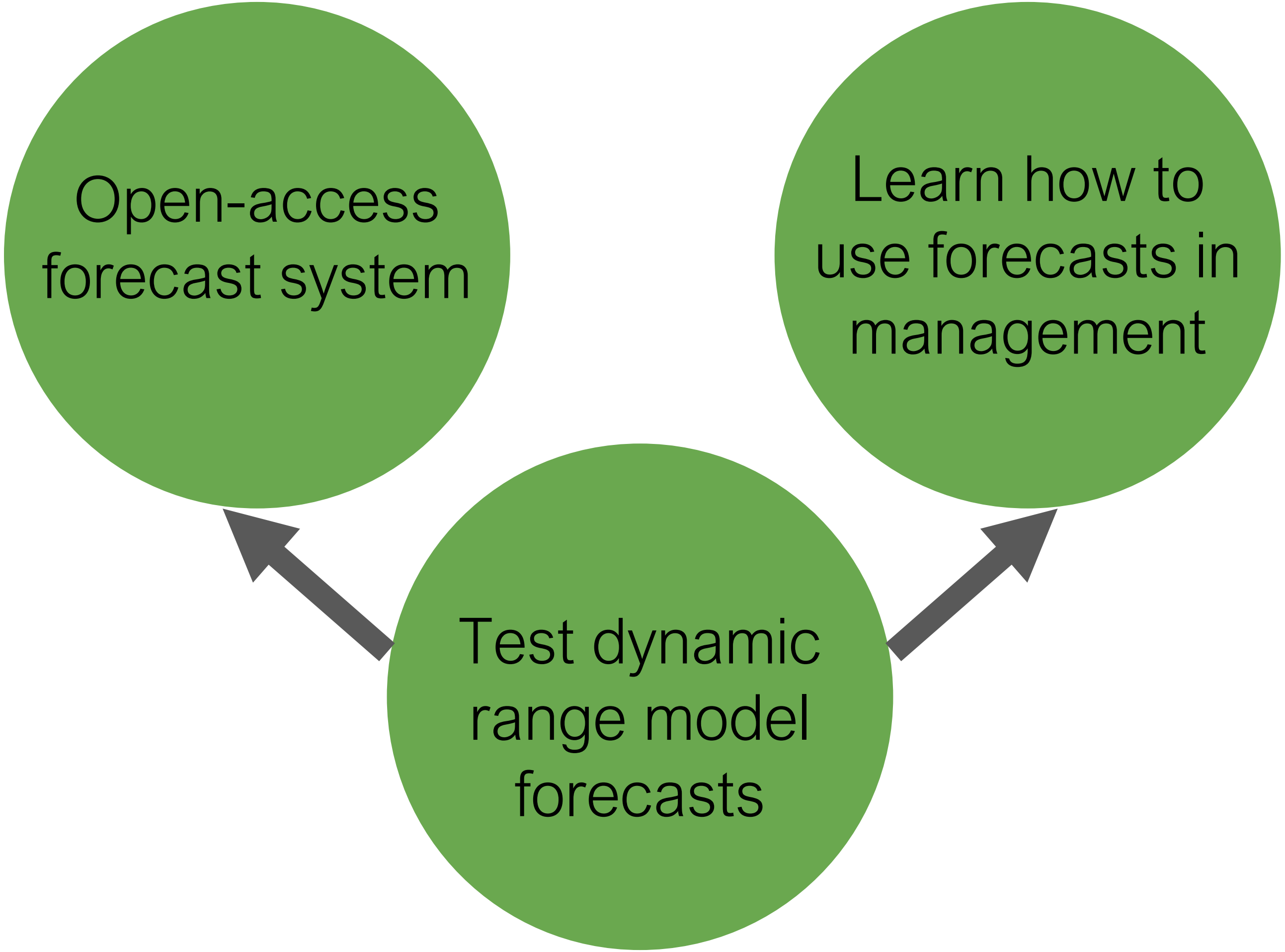
Test dynamic range model forecasts

Goals

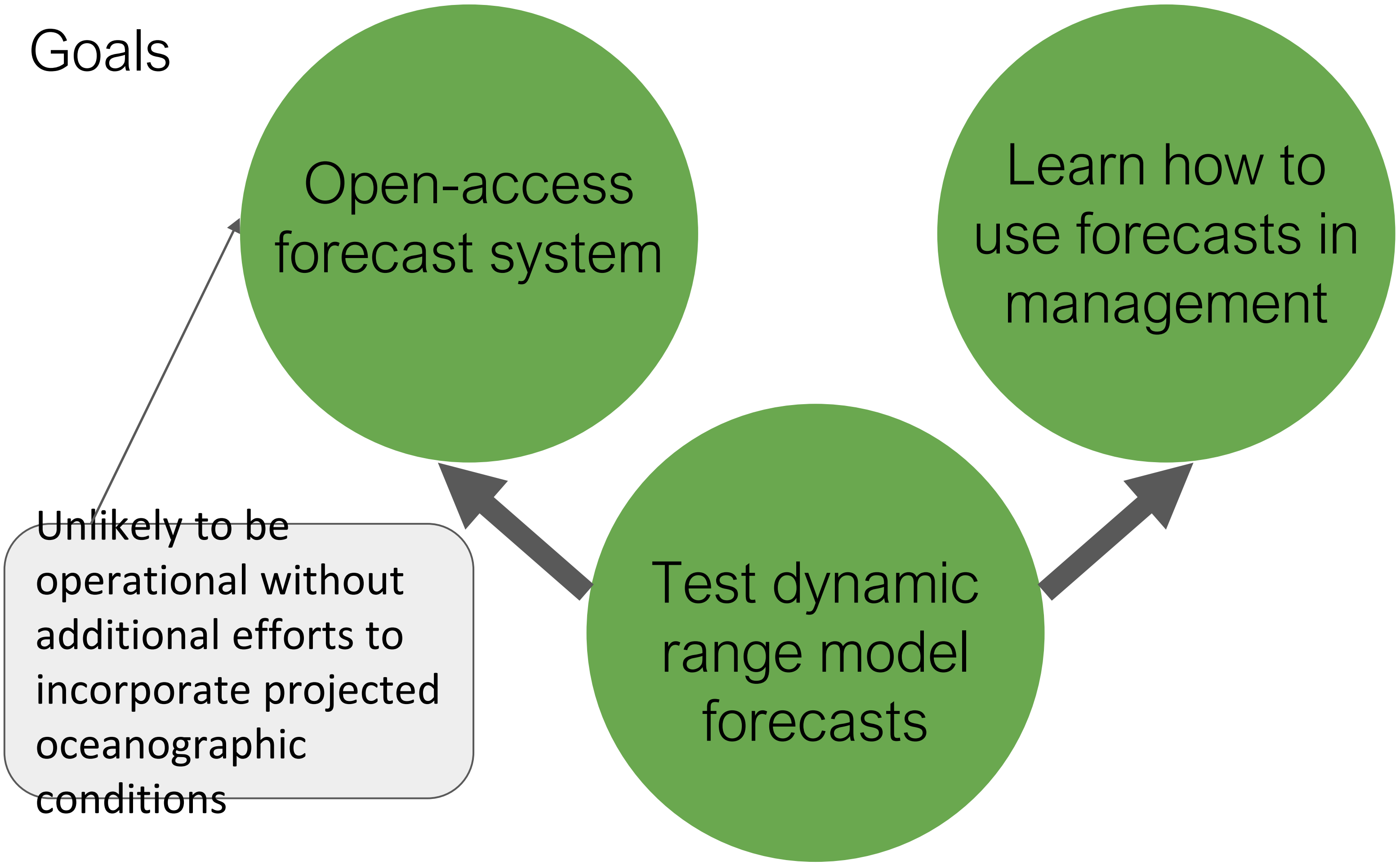


Open-access forecast system
Test dynamic range model forecasts

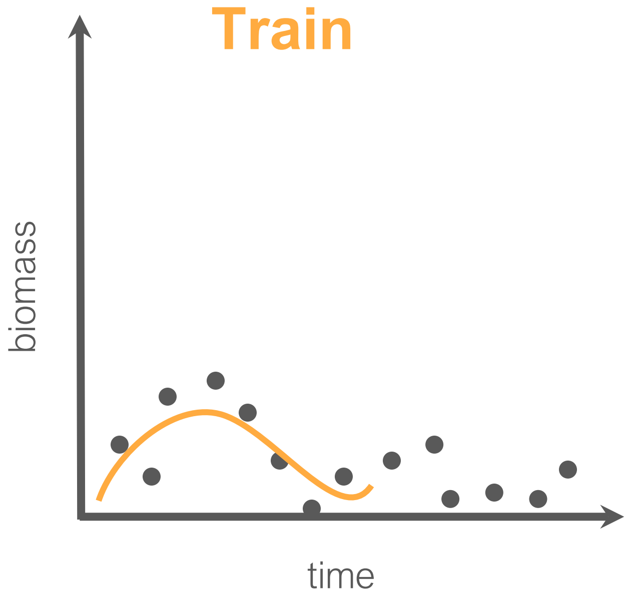
Goals


Open-access forecast system
Learn how to use forecasts in management
Test dynamic range model forecasts

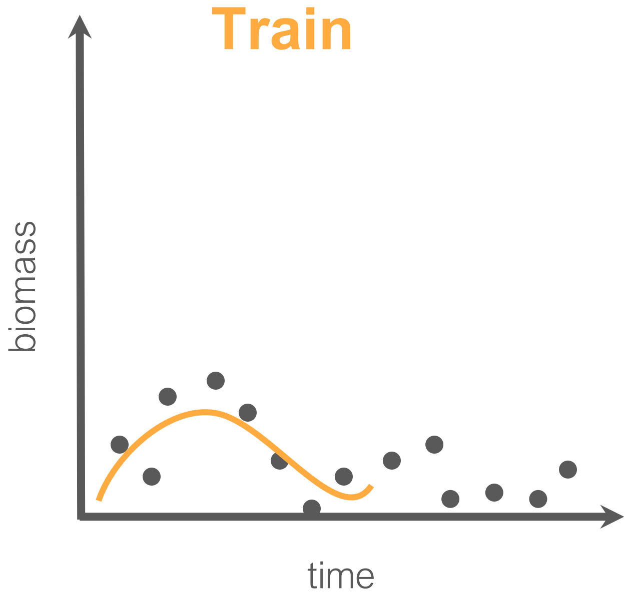
Goals

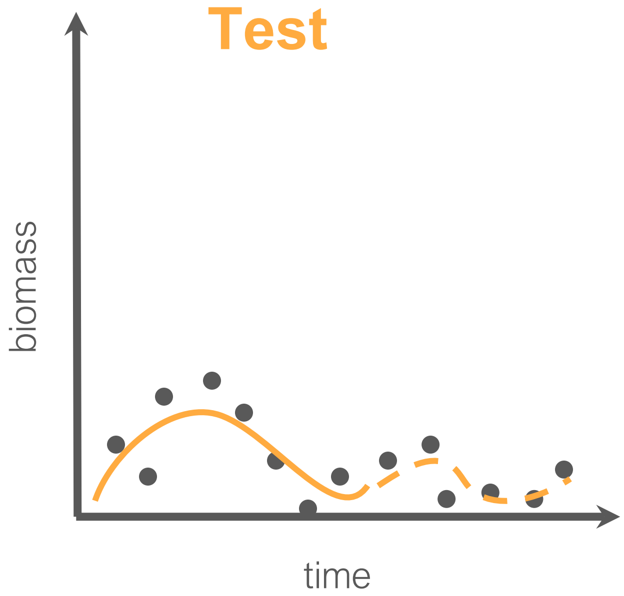

Open-access forecast system
Learn how to use forecasts in management
Test dynamic range model forecasts
Unlikely to be operational without additional efforts to incorporate projected oceanographic conditions

Work plan

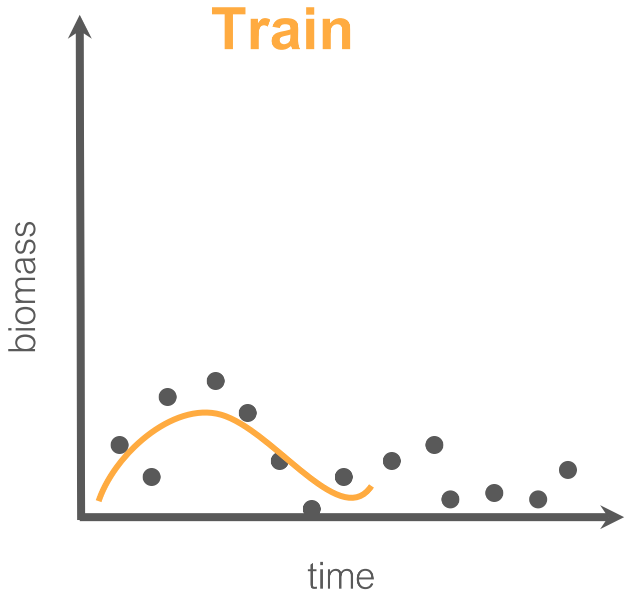


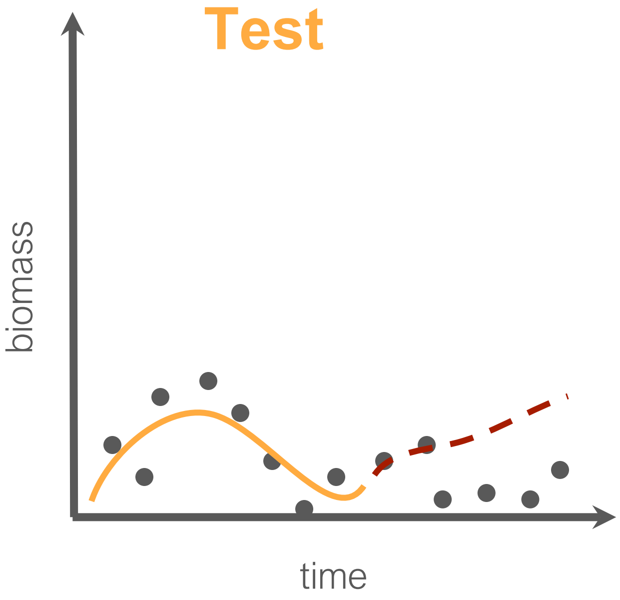
Work plan



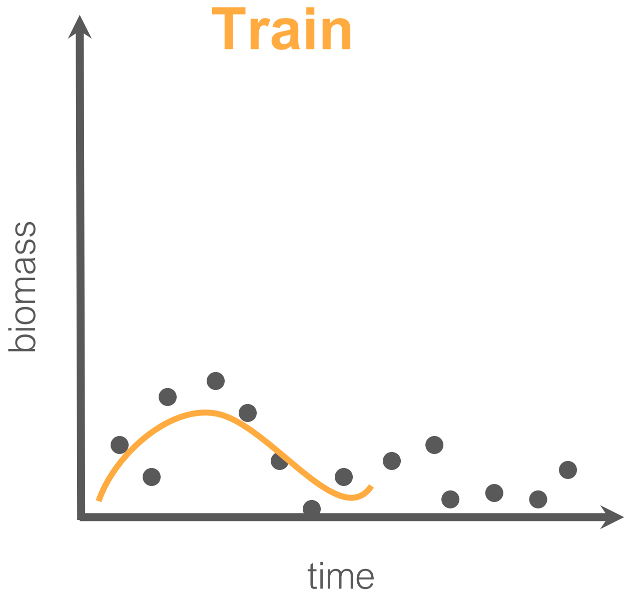


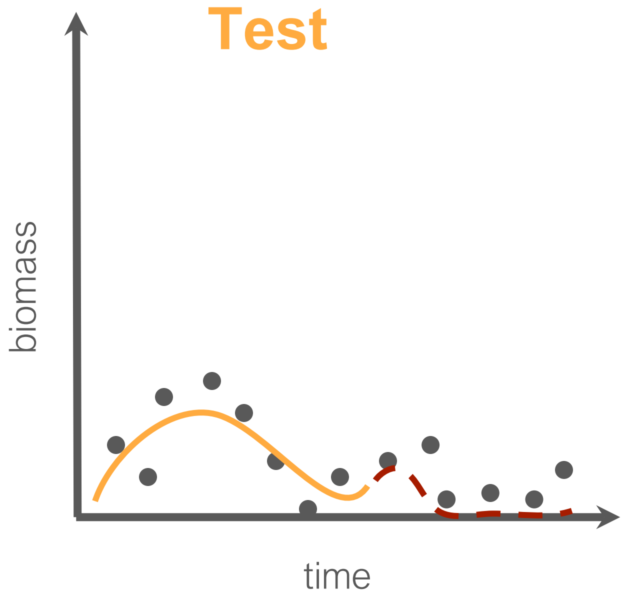
Work plan



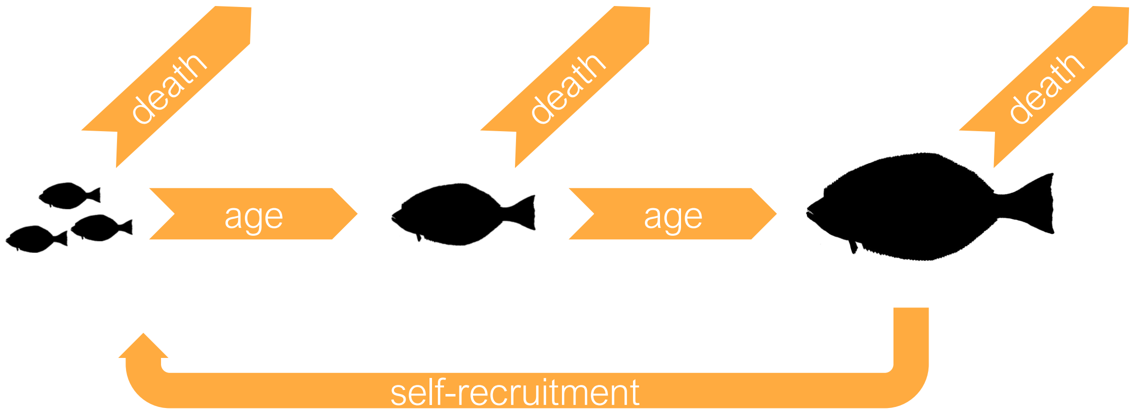


Work plan

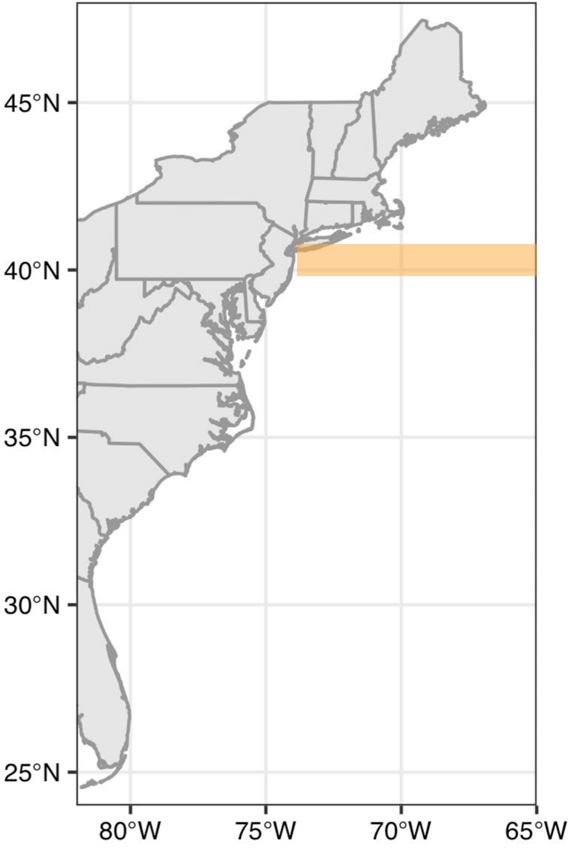


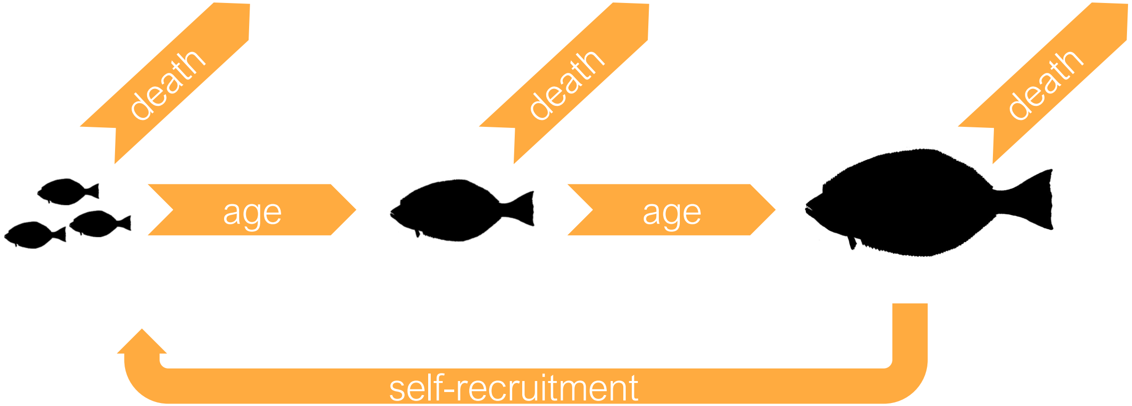


Model structure

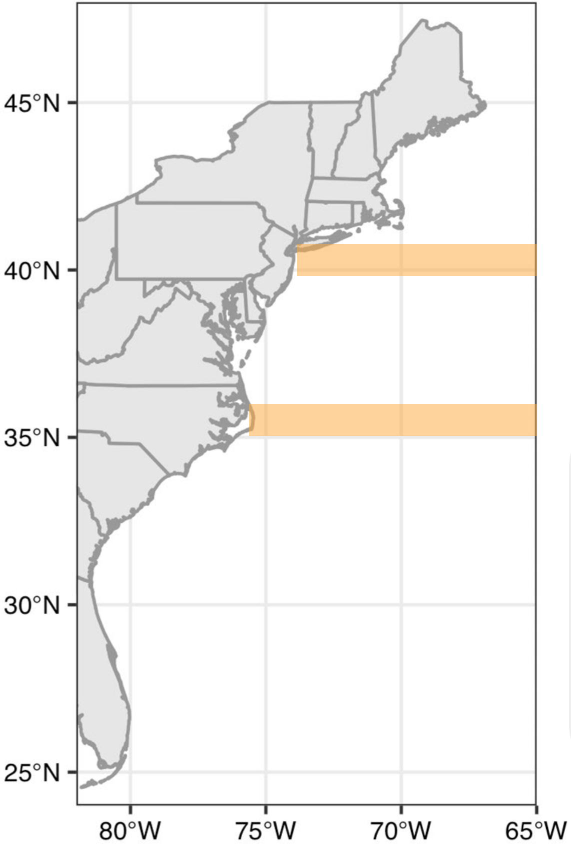


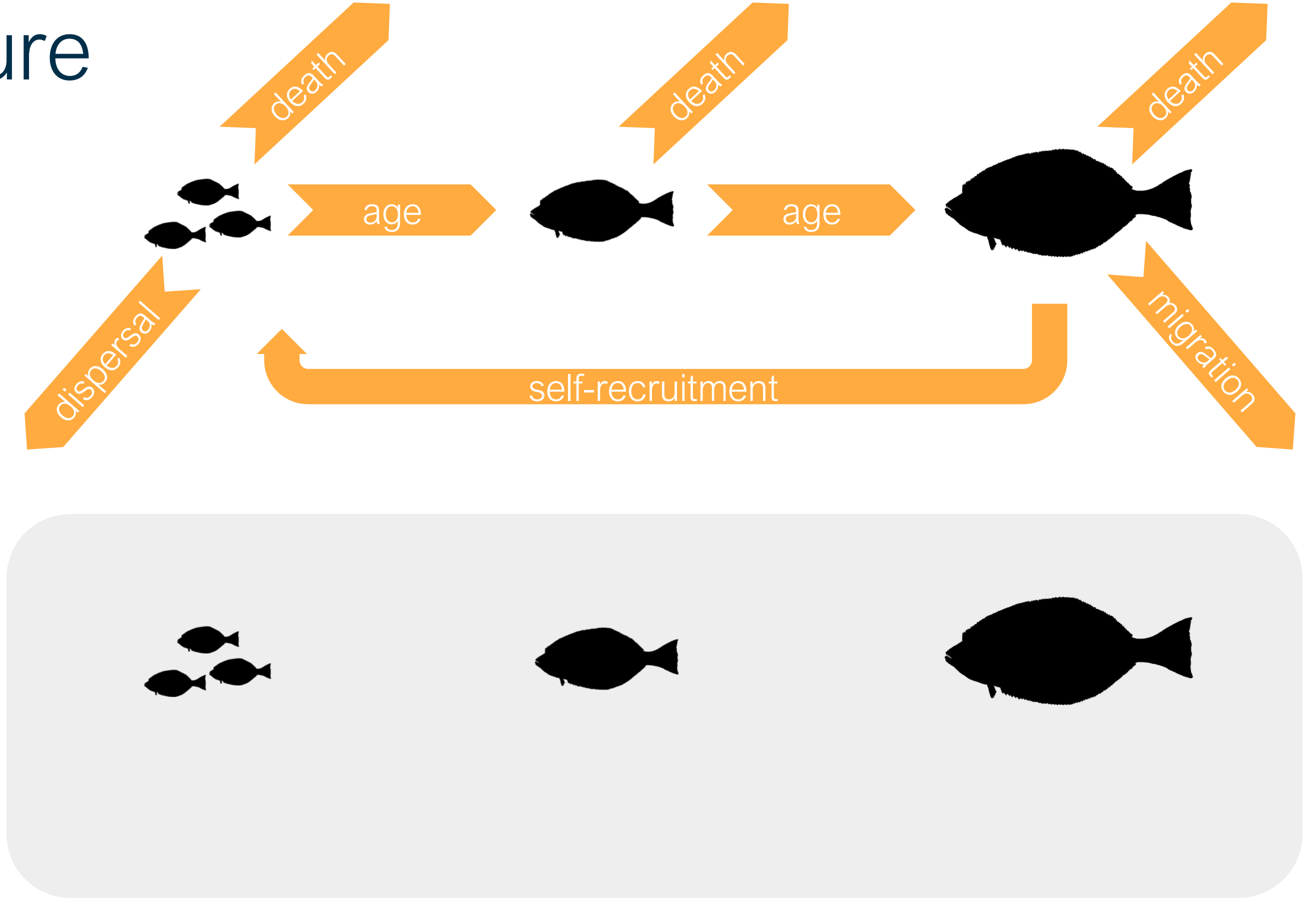
Model structure



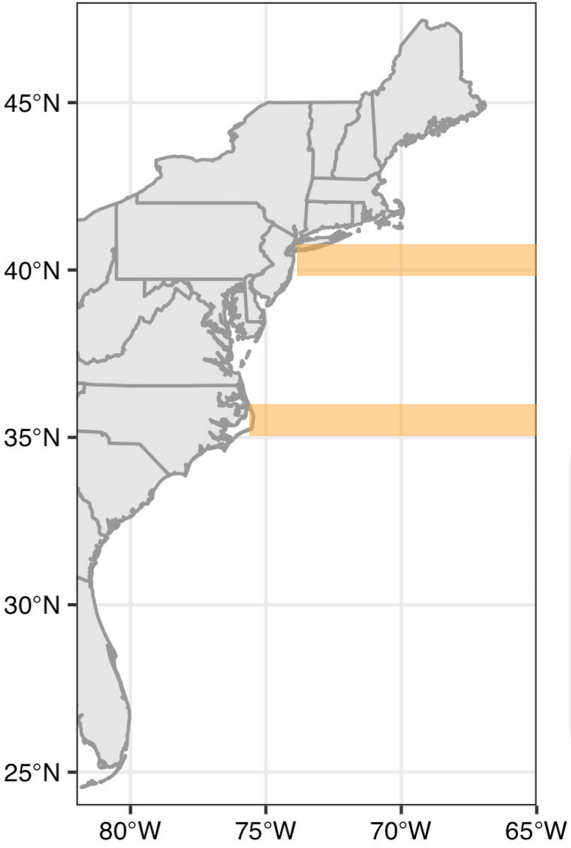


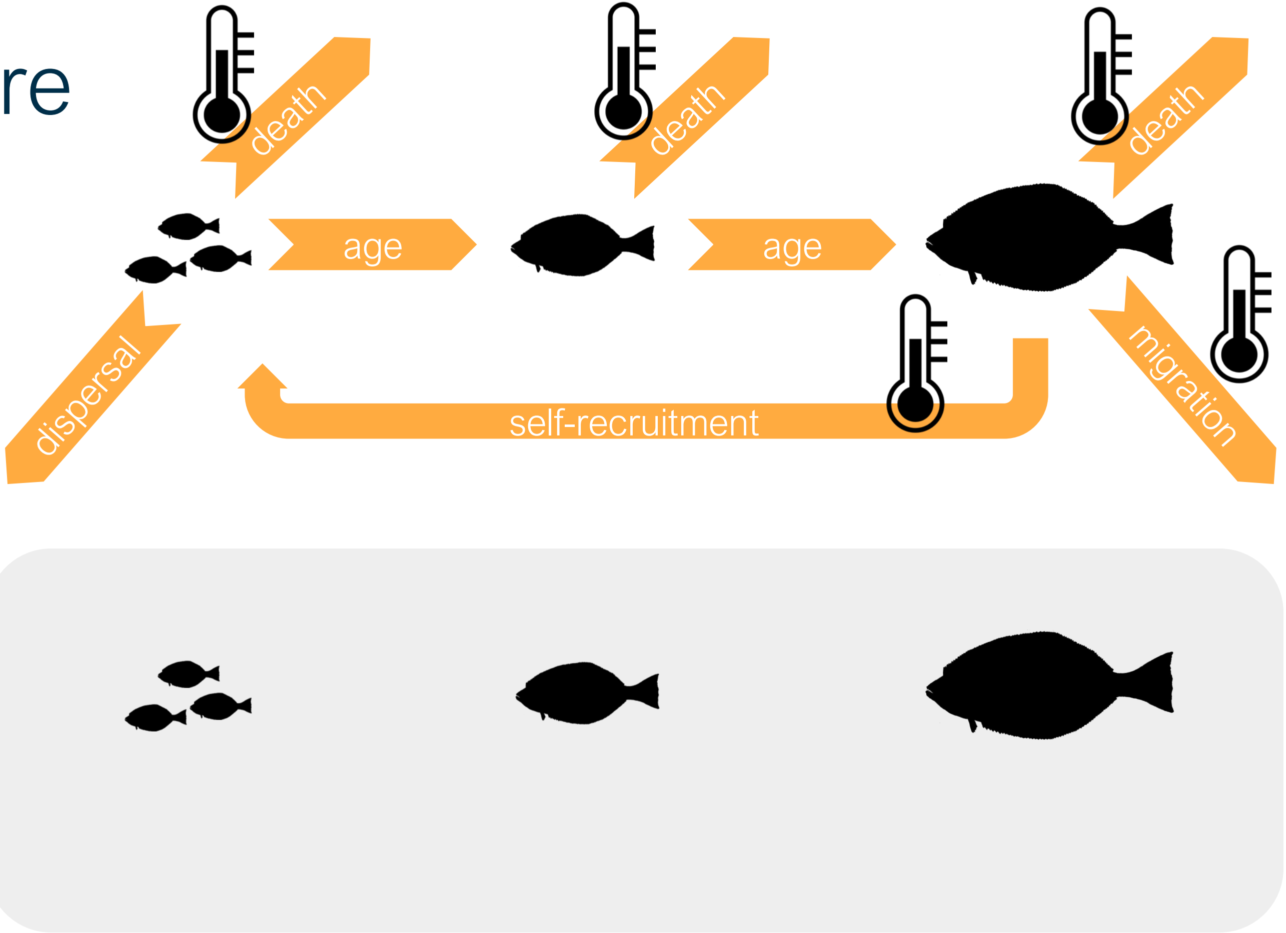
Model structure



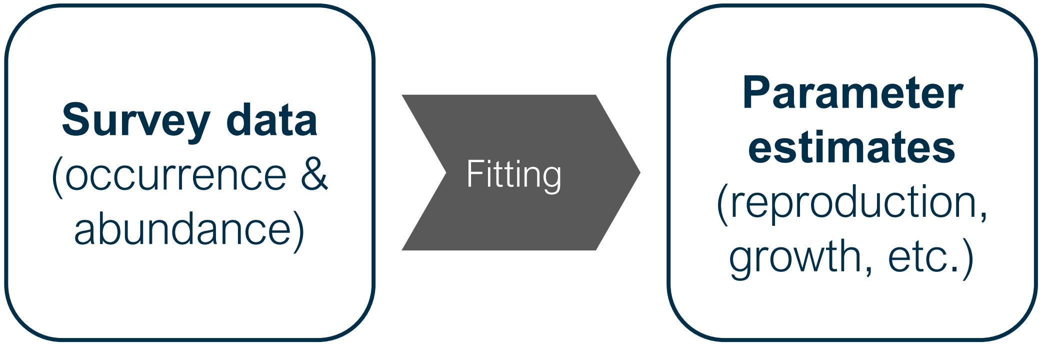


Model structure



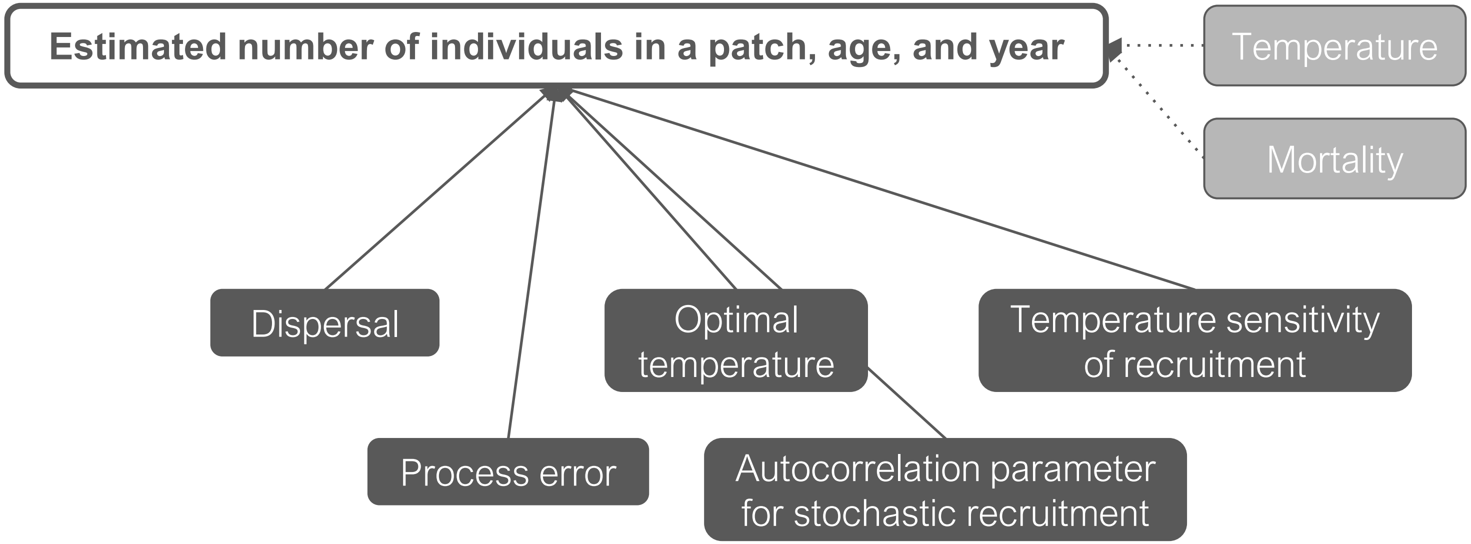


Model overview

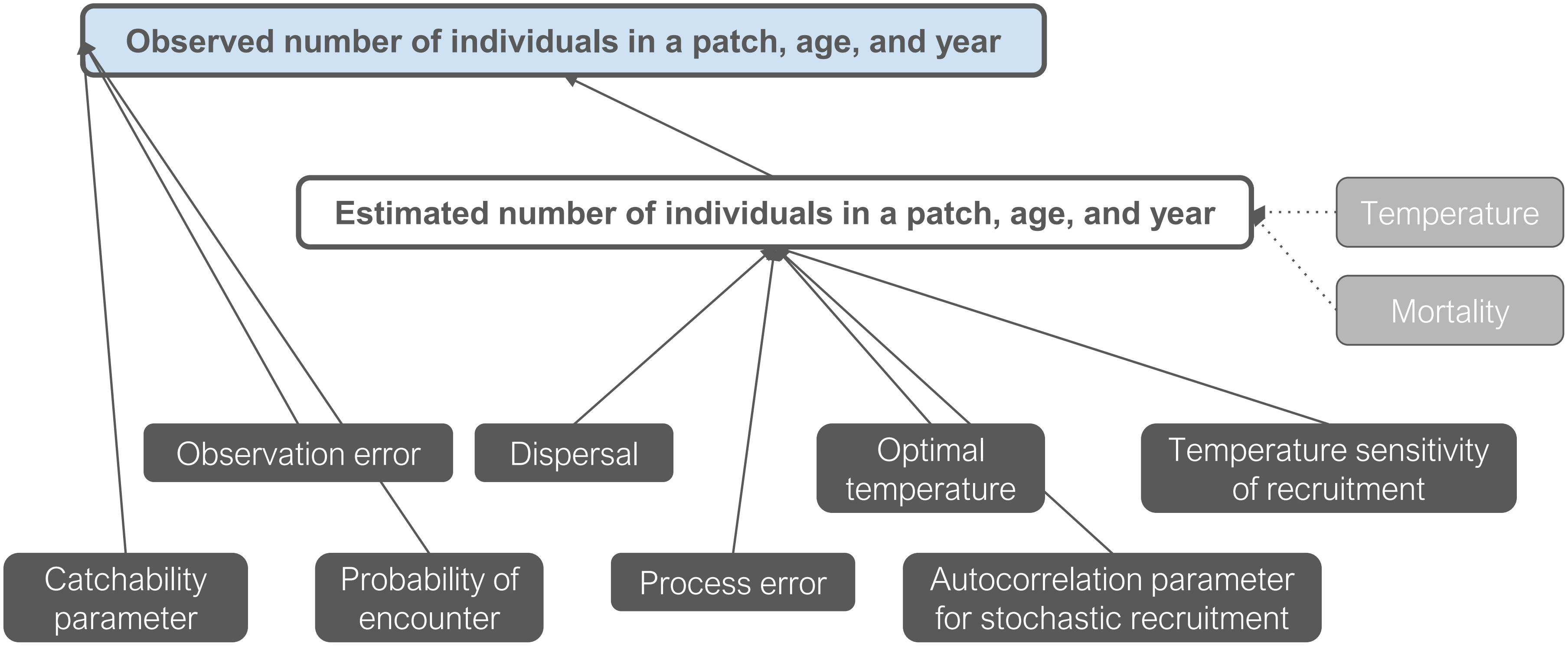


Bayesian network diagram

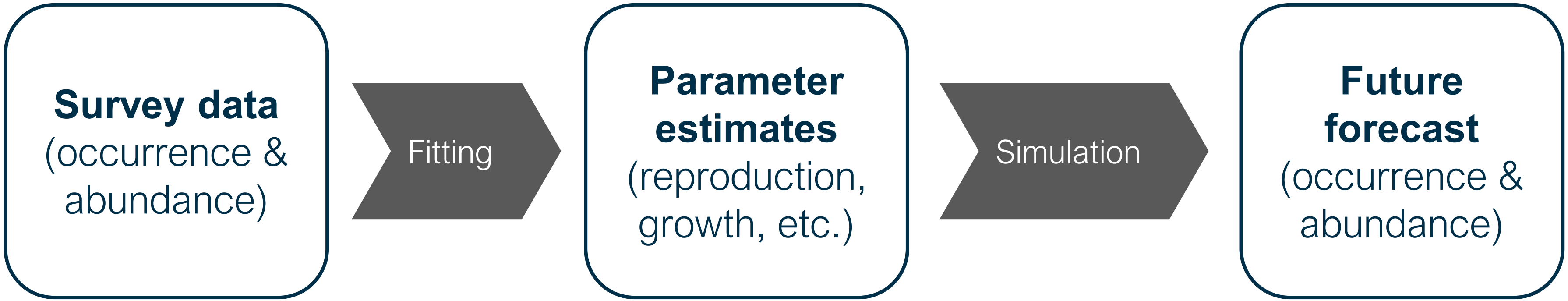
(for a model where temperature affects recruitment)



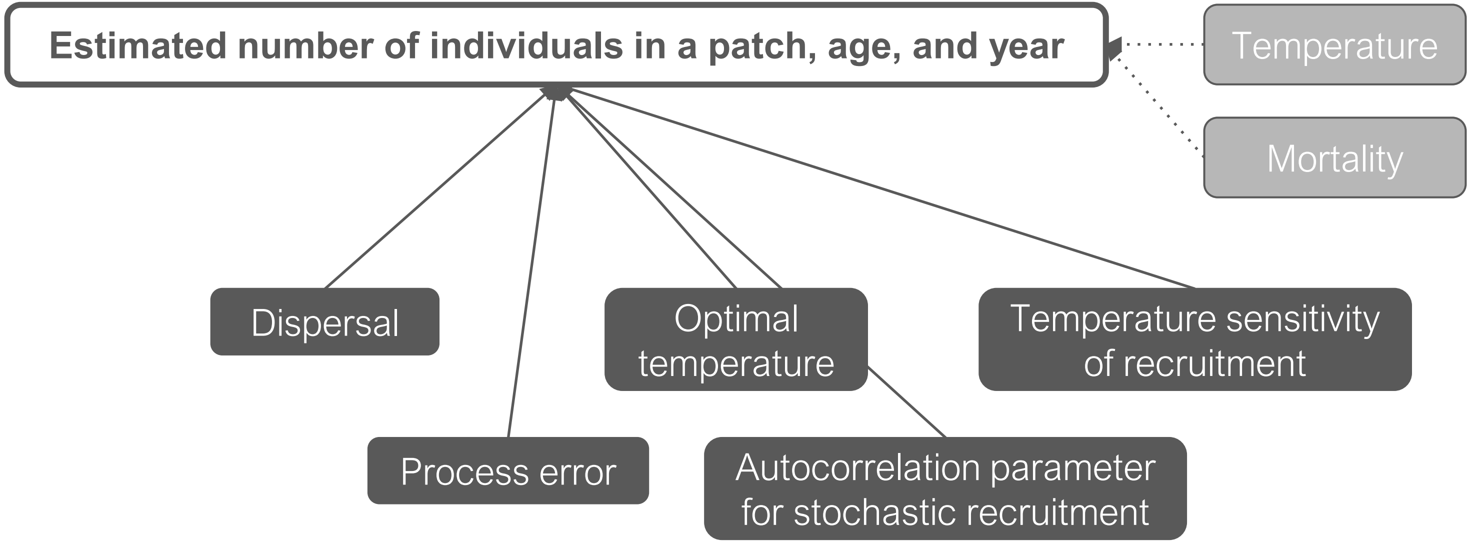
Bayesian network diagram



Model overview

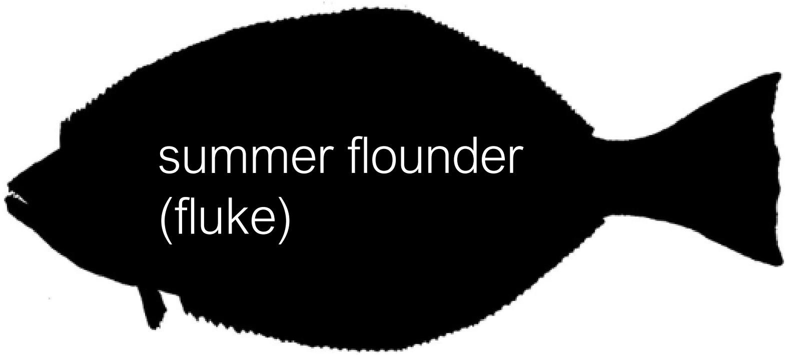


Bayesian network diagram
(for a model where temperature affects recruitment)

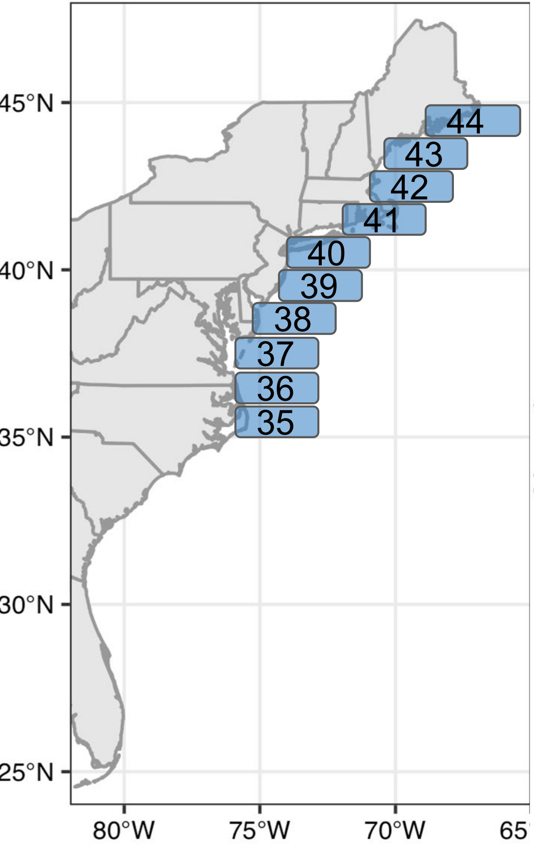


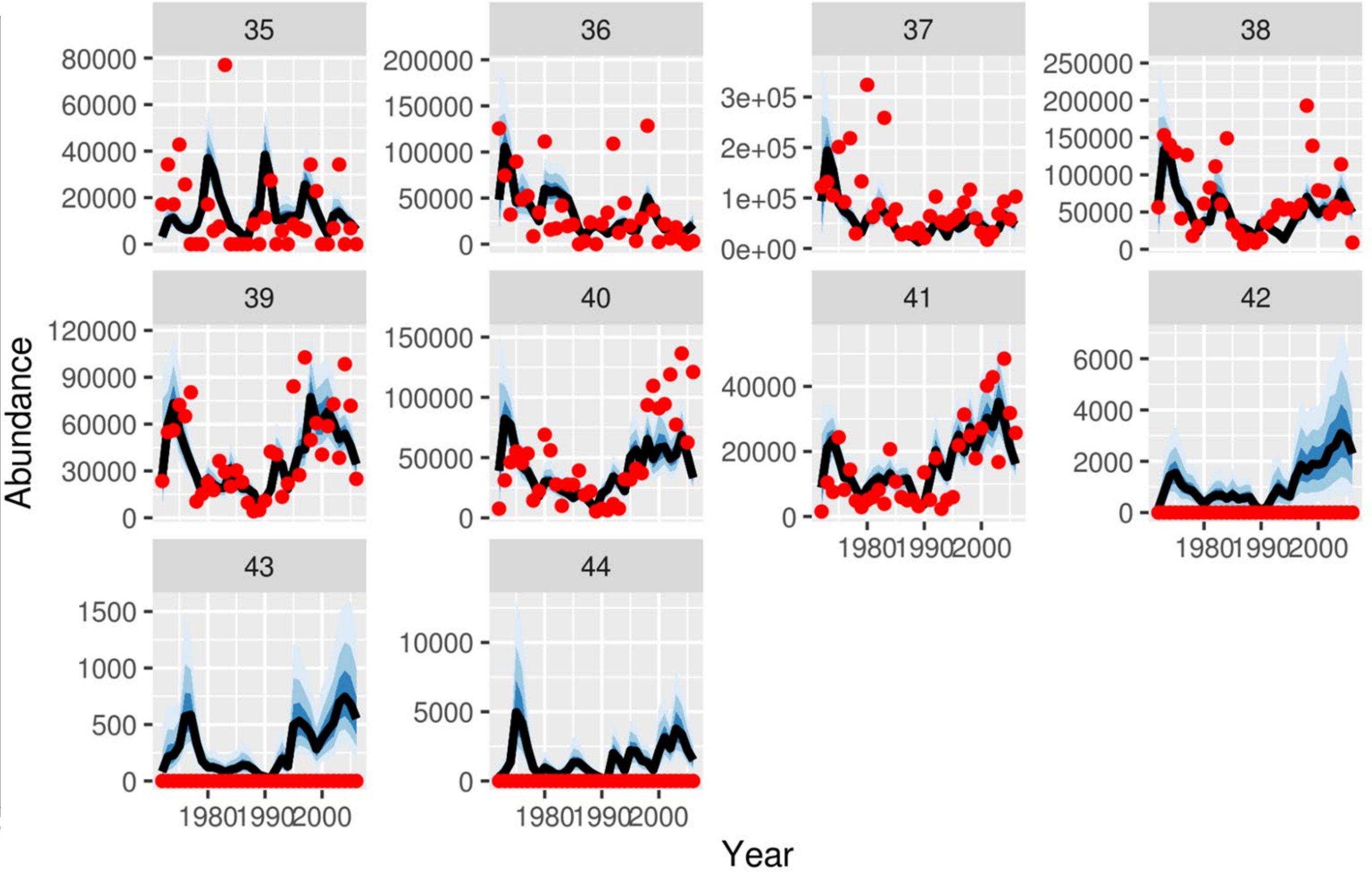
Research questions

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

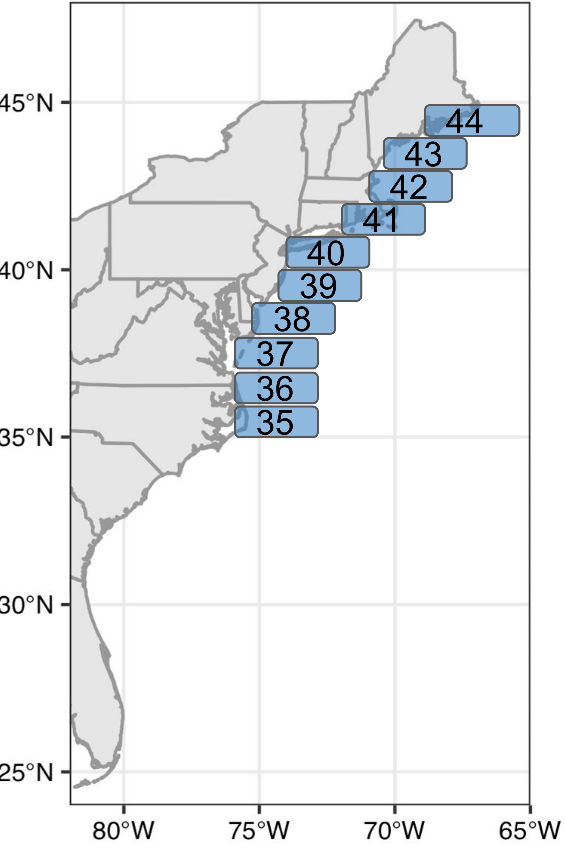


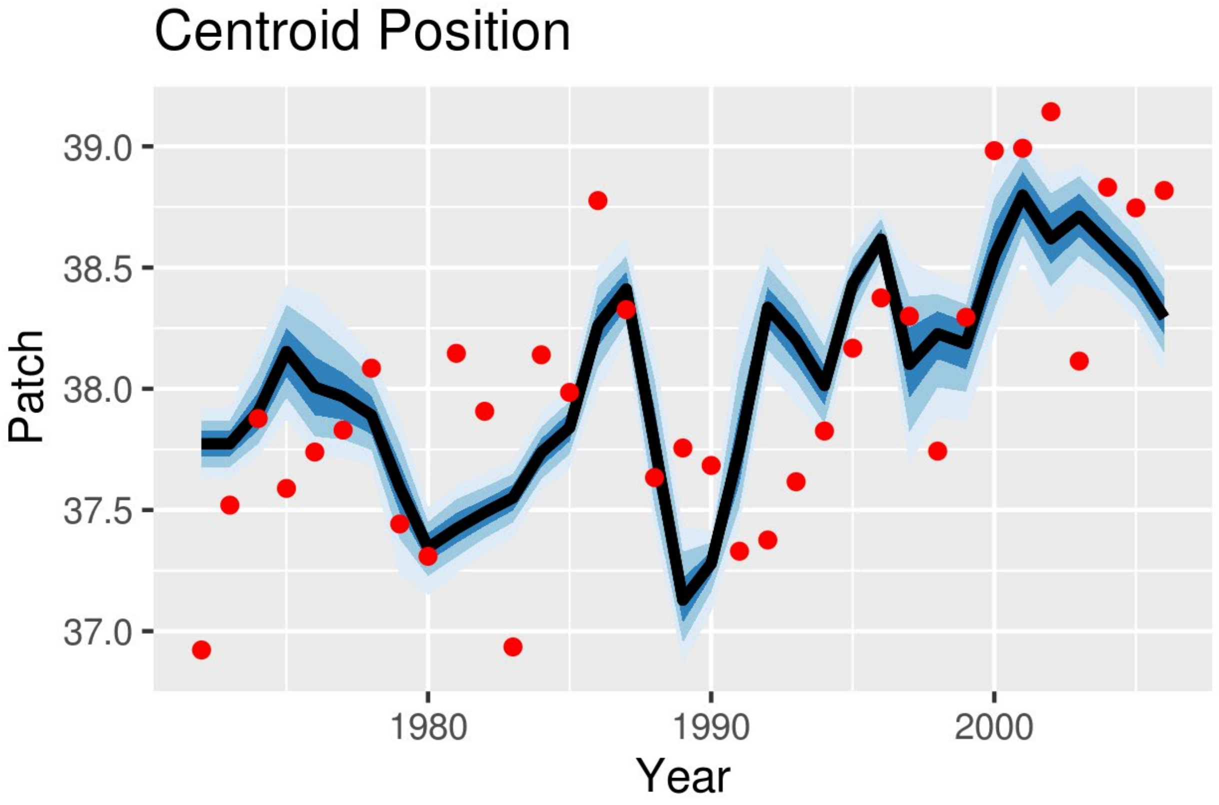
Model fit to summer flounder training data



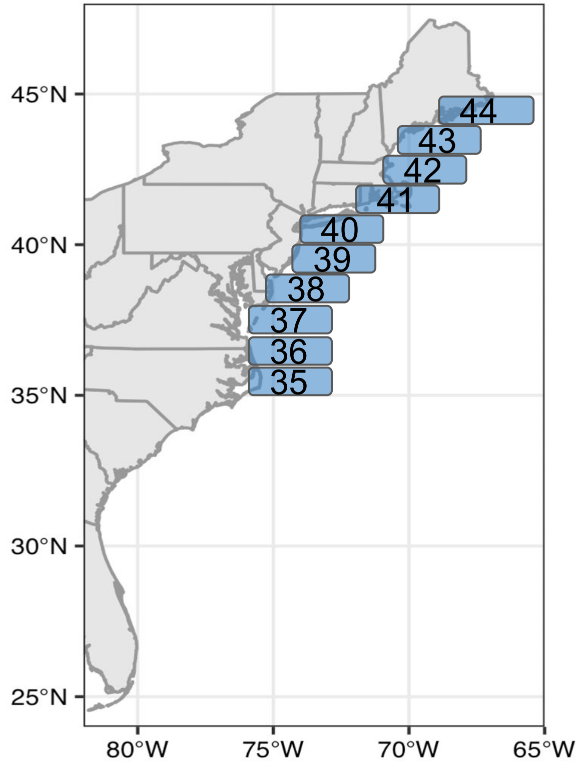


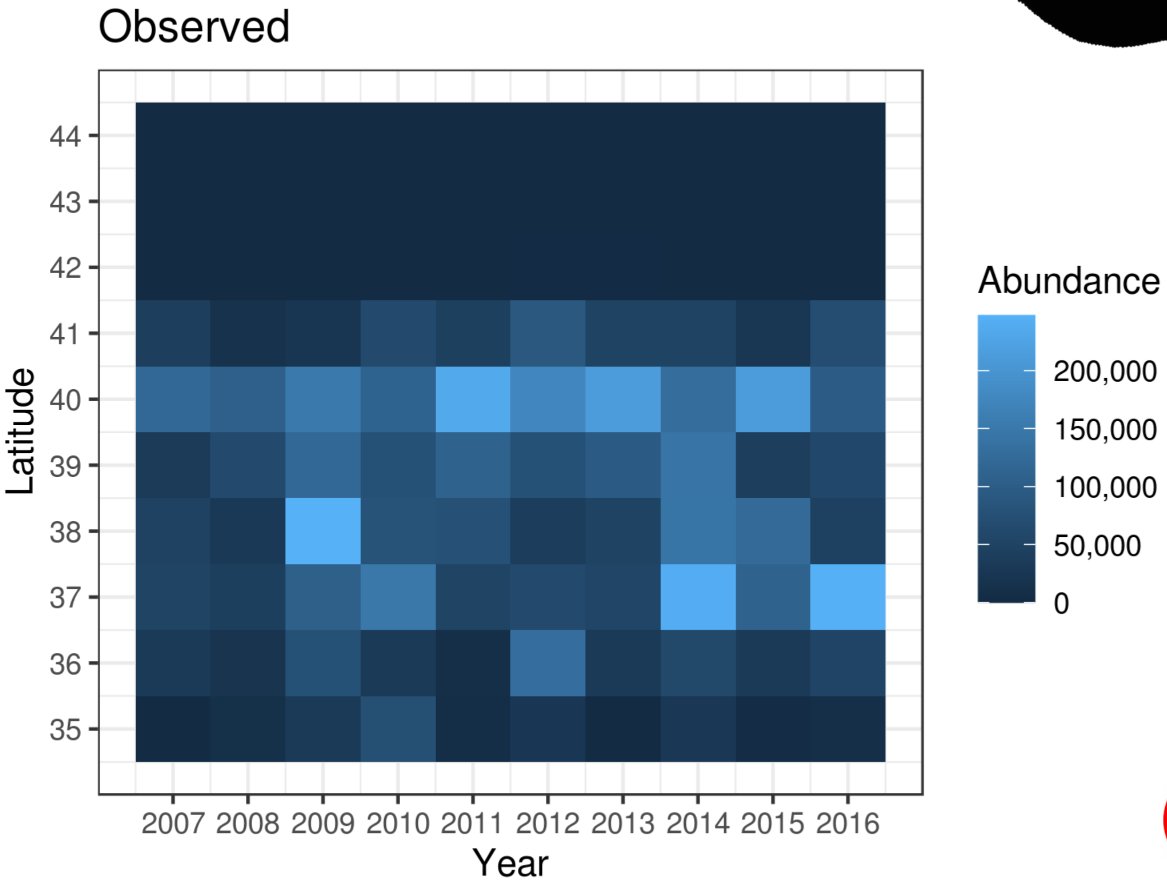
Model fit to summer flounder training data



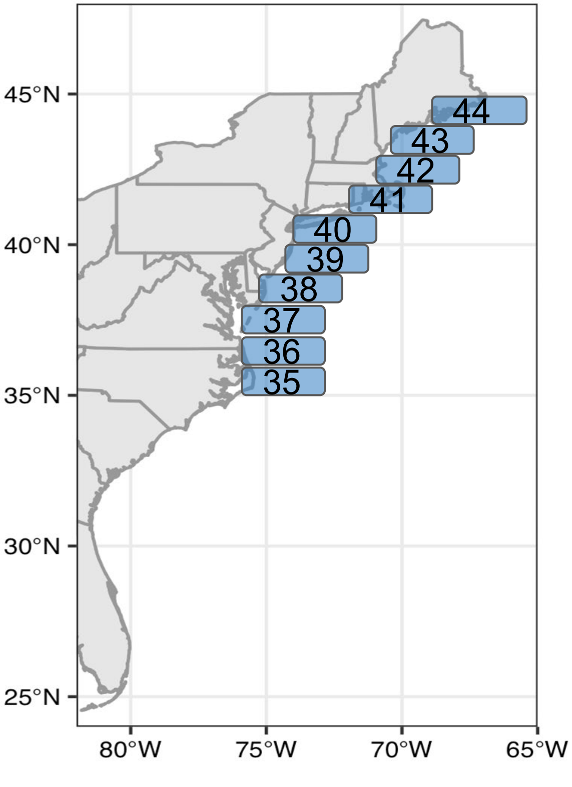


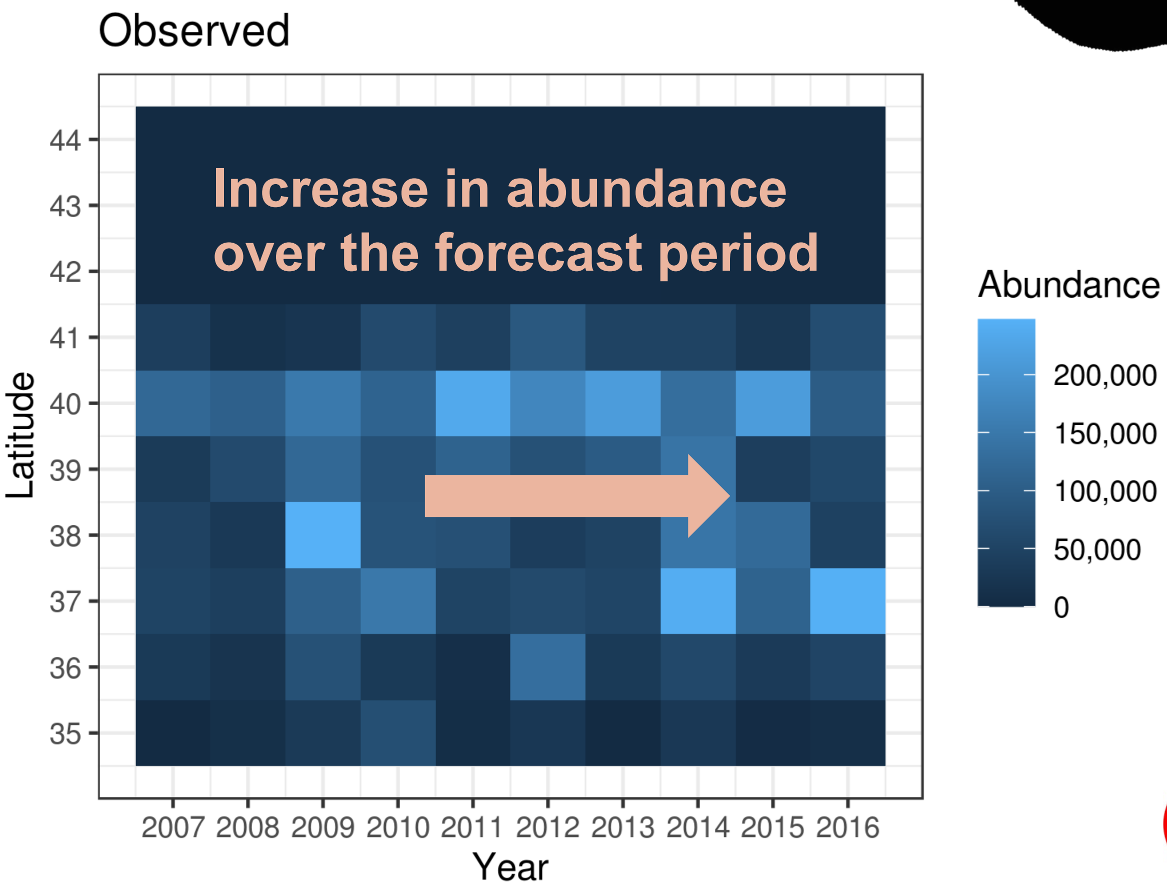
Summer flounder testing data



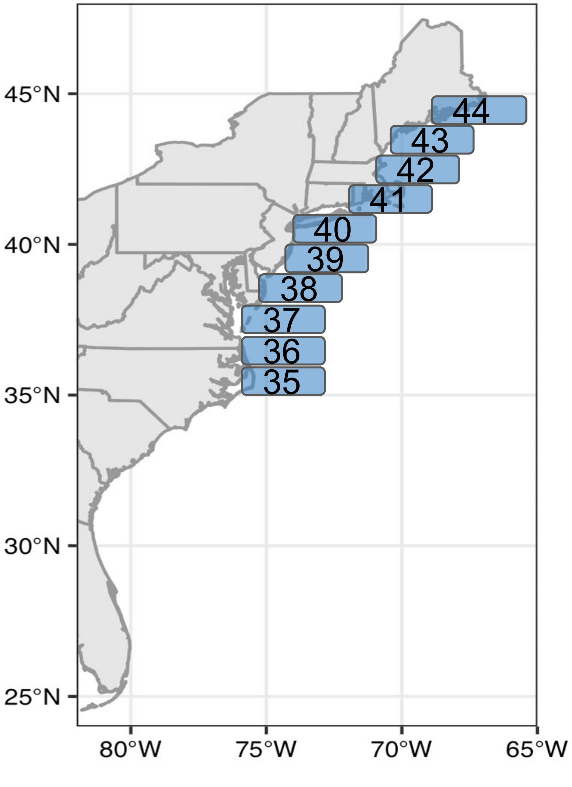


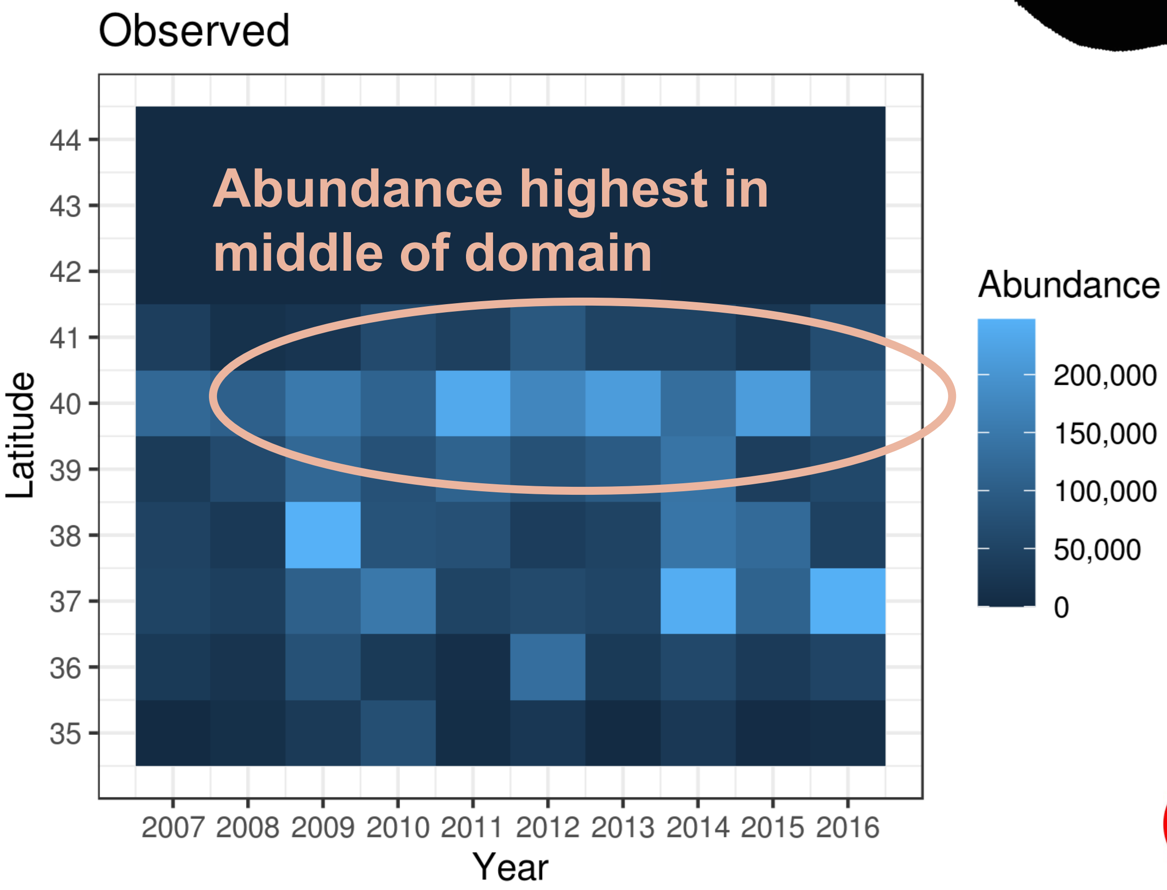
Summer flounder testing data



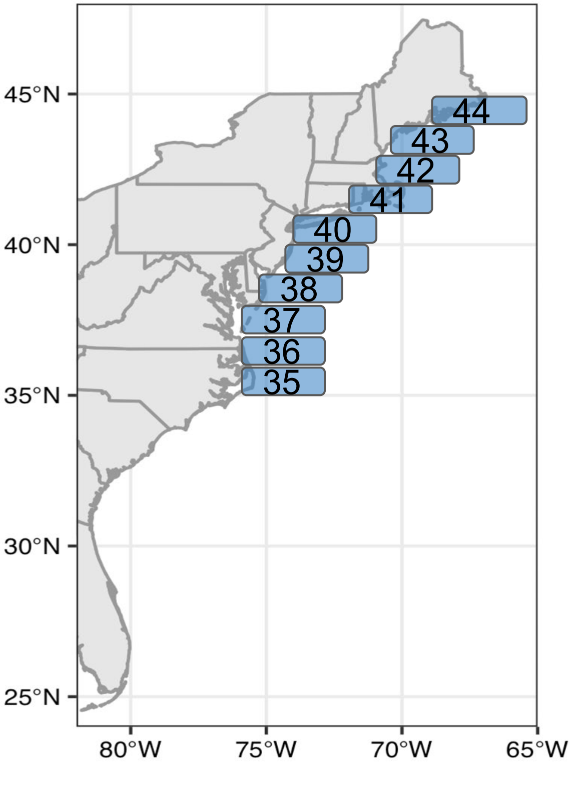


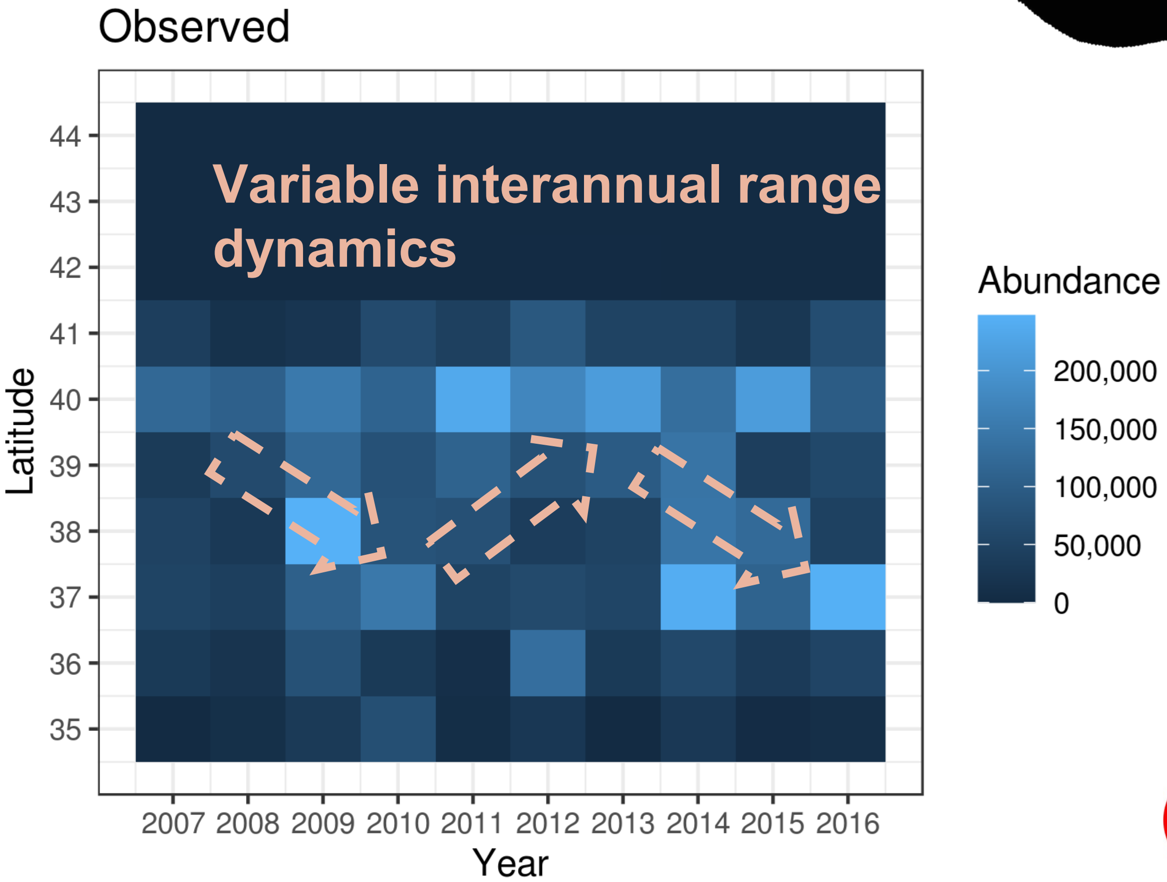
Summer flounder testing data



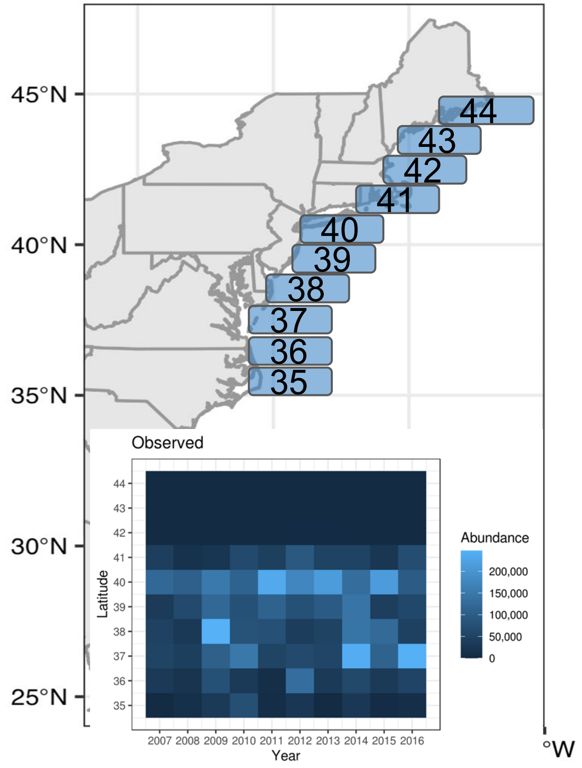


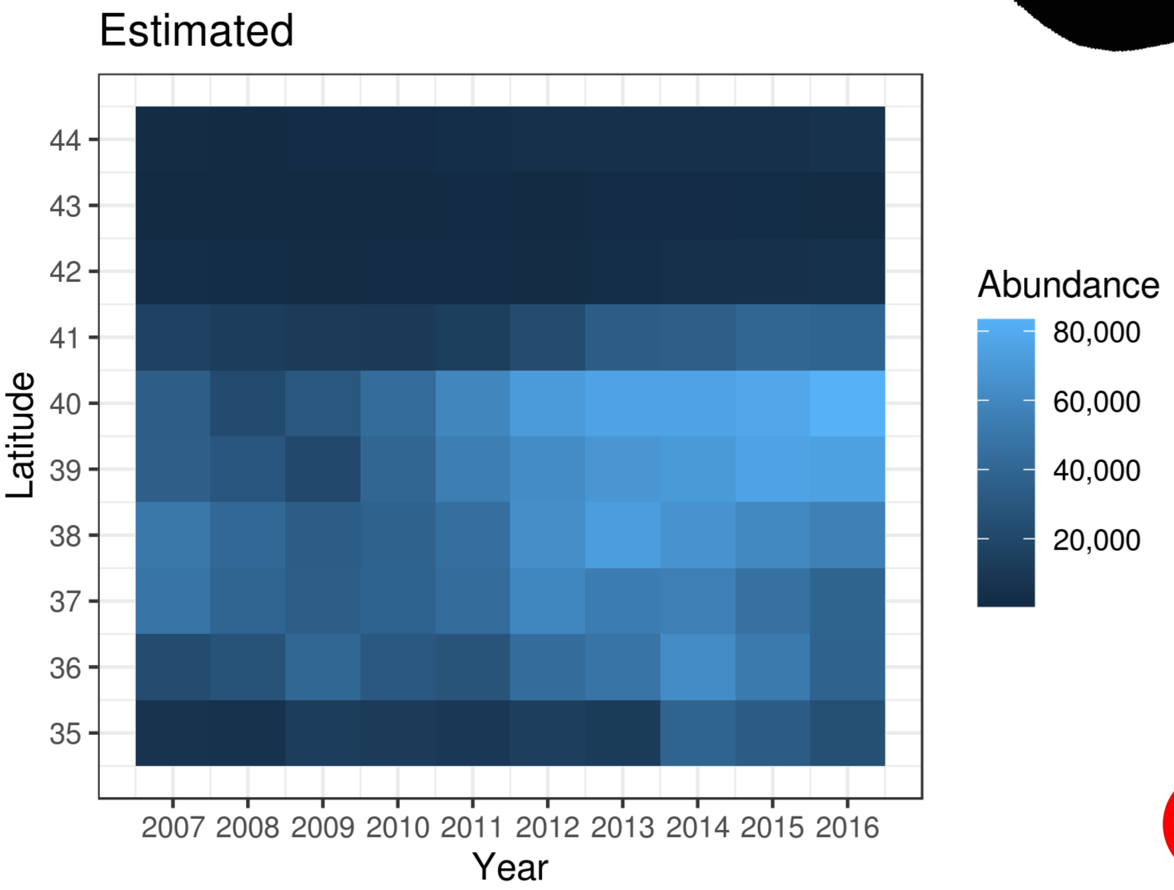
Summer flounder testing data



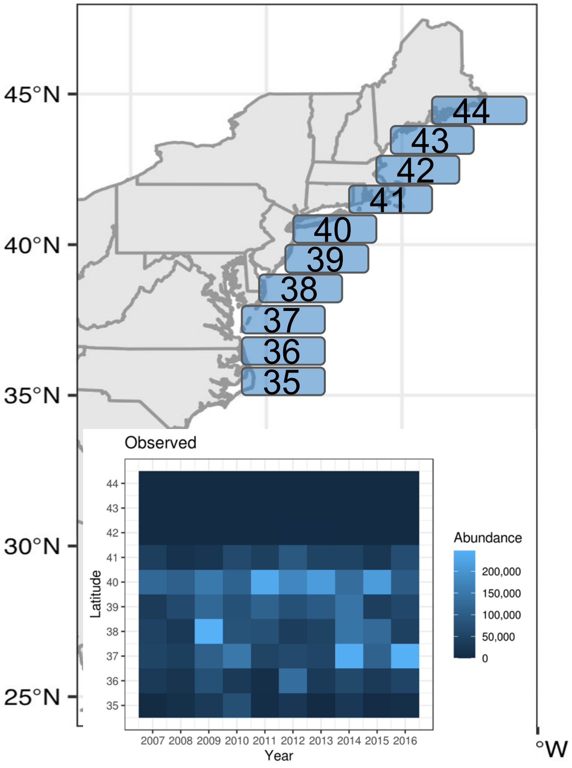


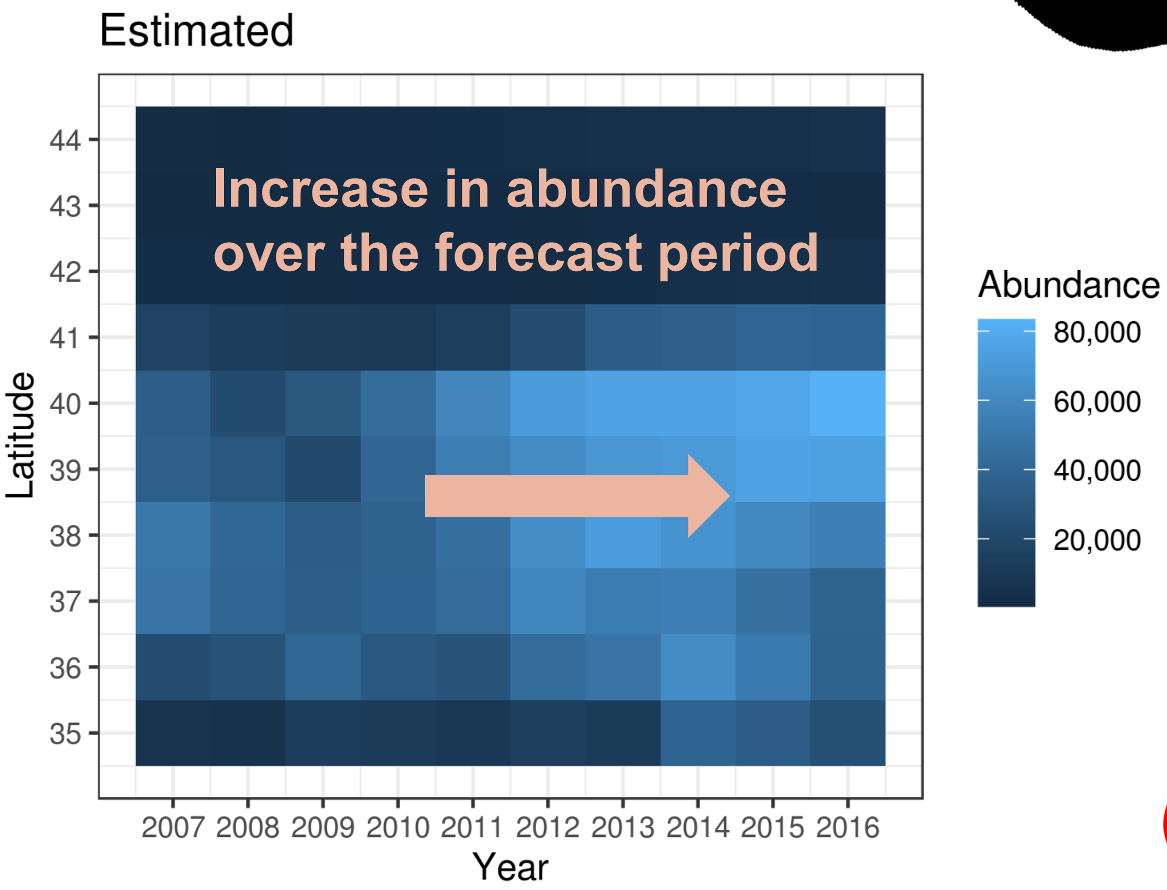
Summer flounder forecast abundance



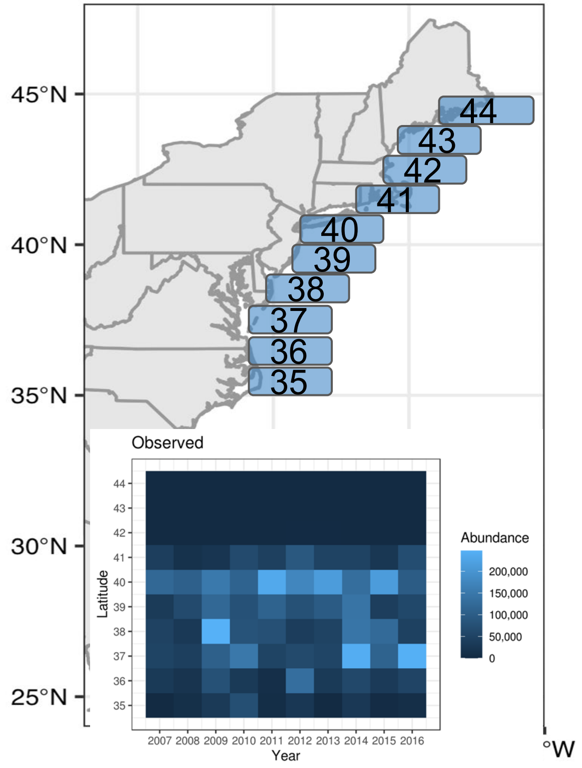


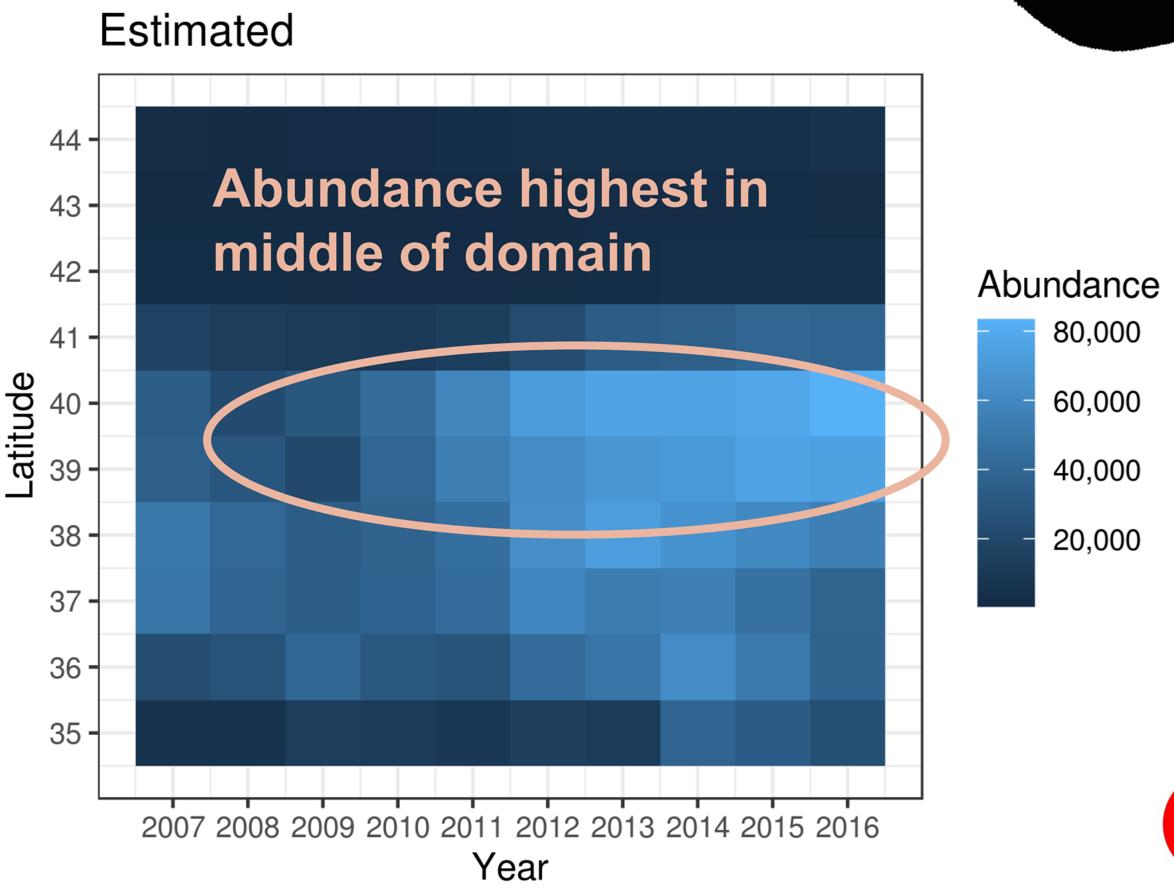
Summer flounder forecast abundance



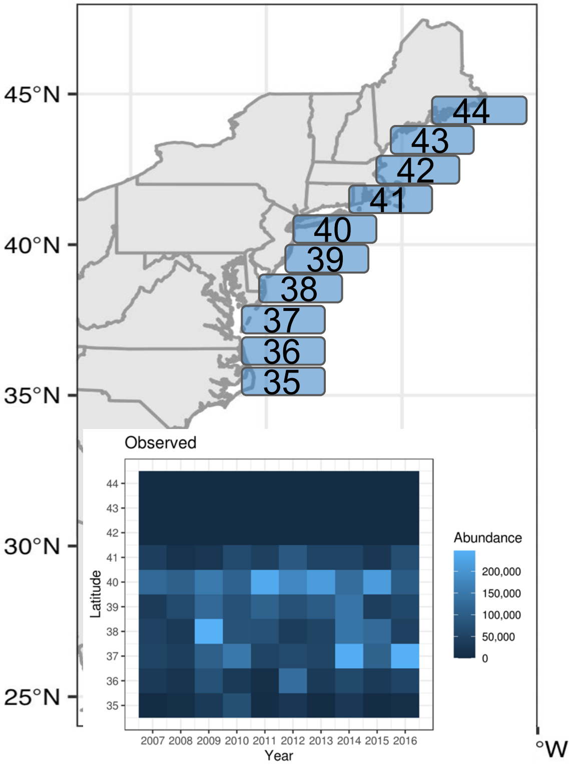


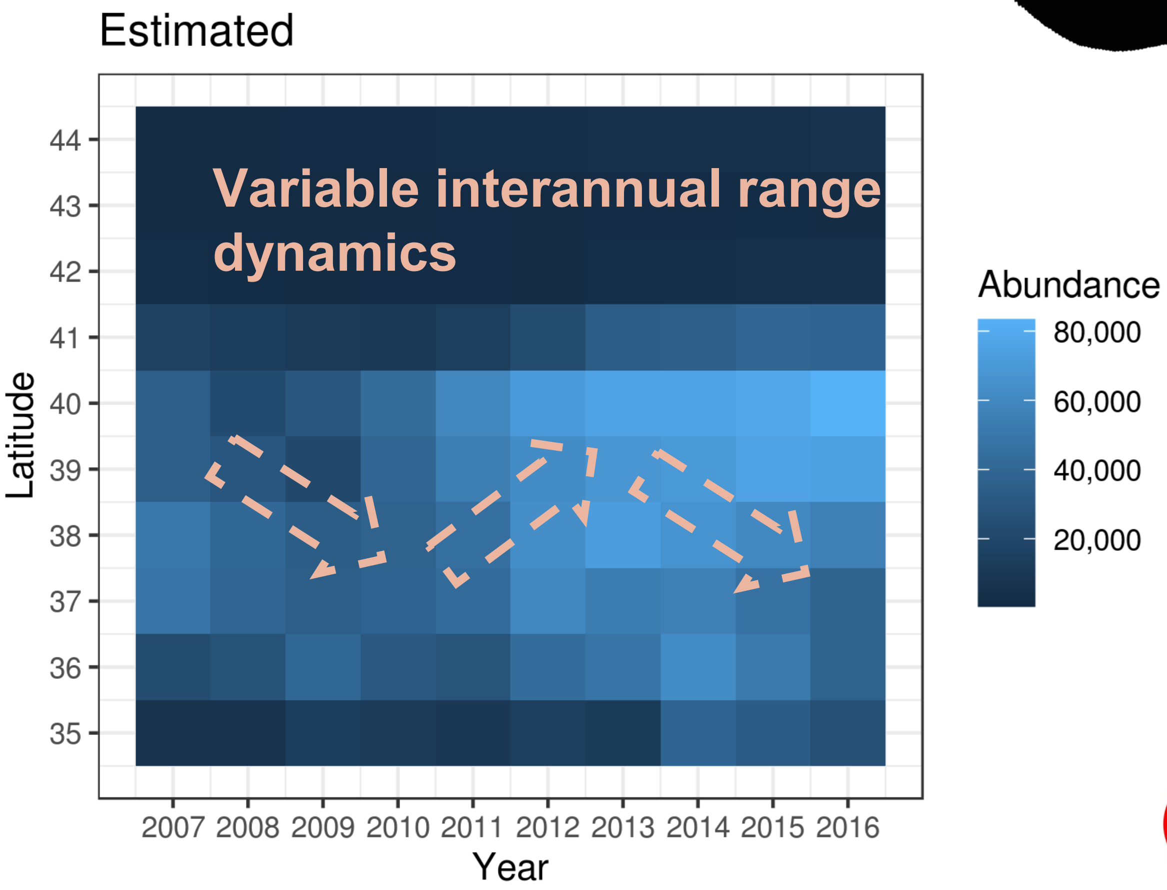
Summer flounder forecast abundance





Summer flounder forecast abundance

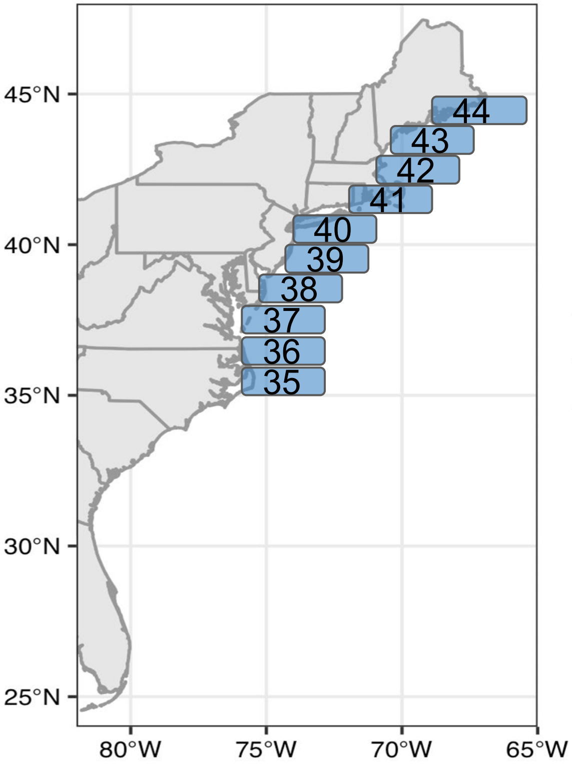


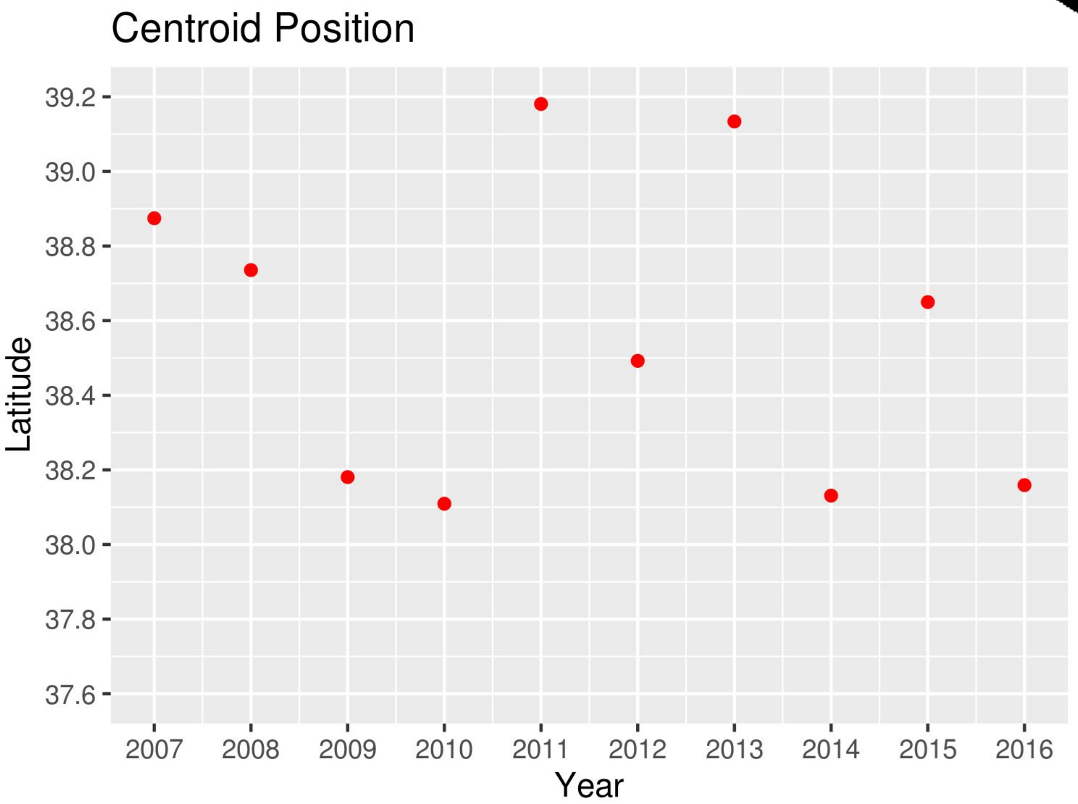


Research questions

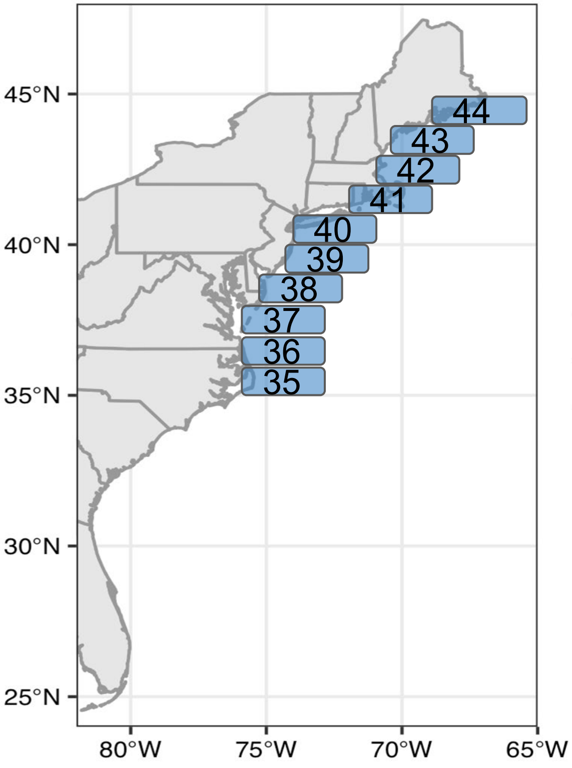
1. Can dynamic range models forecast changes in species distributions?
2. At what **time-scales** do forecasts have skill (1- 10 years)?

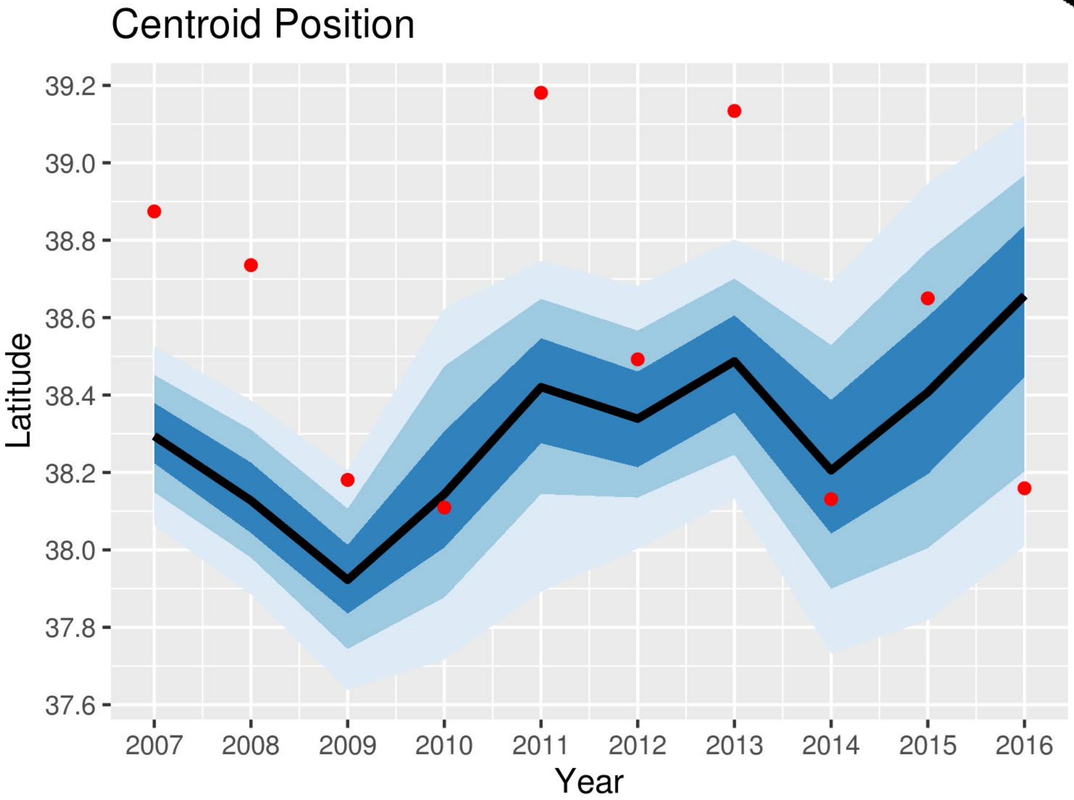
Summer flounder centroid — data





Summer flounder centroid — forecast





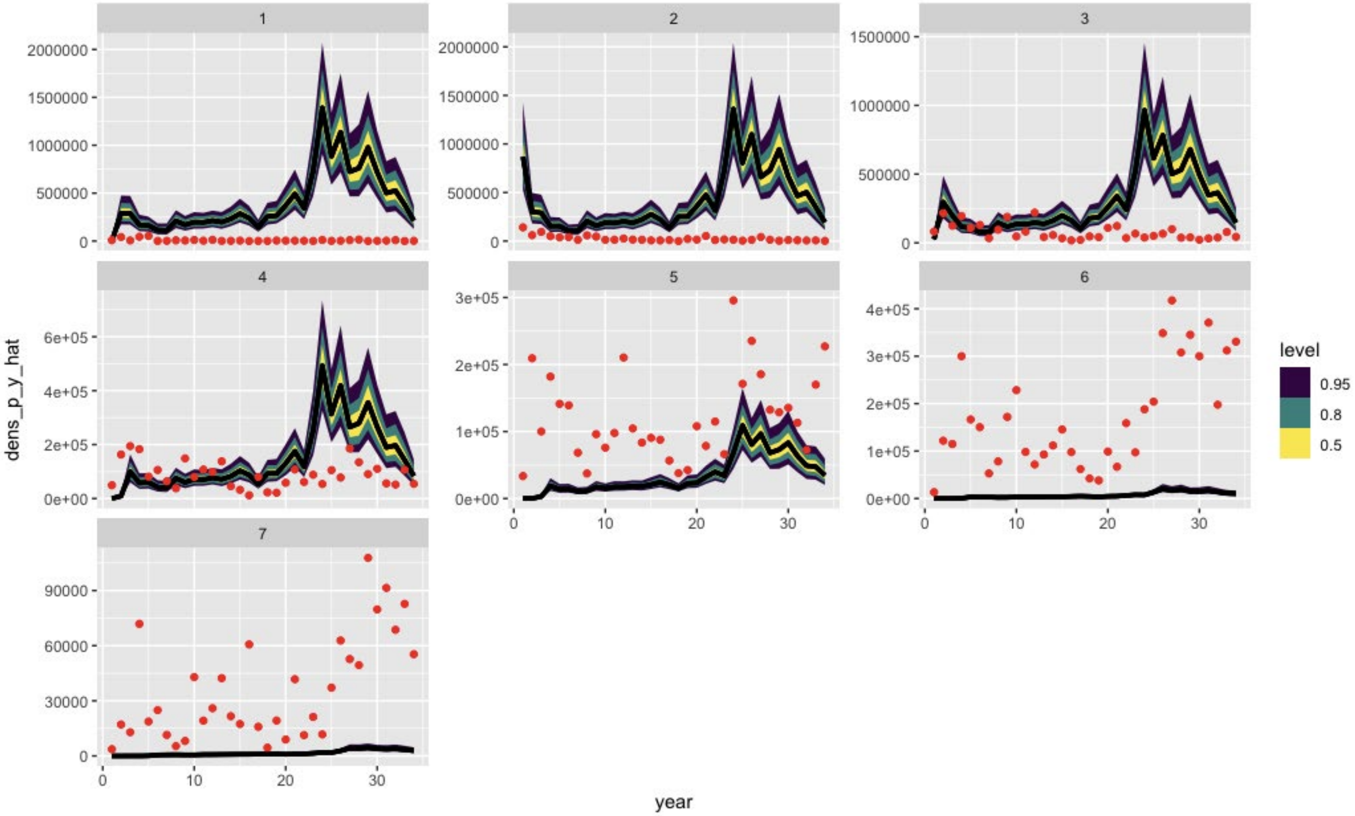
Research questions

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?

Best candidate model for summer flounder

Model structure decision	**Yes**	**No**
Use fishing to inform mortality rate	✔	
Incorporate age structure into process model	✔	
Fit to length data to inform age structure		✔
Use stock-recruit relationship (instead of stochastic recruitment)		✔
Adults disperse among patches	✔	
Temperature affects recruitment	✔	
Temperature affects mortality		✔
Temperature affects migration *still under development		

Most models fail model fitting checks



Next steps

1. Repeat for shortfin squid, spiny dogfish, and gray triggerfish, developing additional model functionality along the way
2. “Compete” the best model(s) against traditional species distribution modeling methods
3. Formalize forecast evaluation
4. Package and share model code