A satellite image of the Northeast United States coastline, showing the Atlantic Ocean, the Gulf of Maine, and the New England coast. The land is brown and green, and the water is dark blue. White clouds are visible over the ocean and land.

## Other Perspectives from the Northeast United States

Kevin Friedland  
National Marine Fisheries Service  
Narragansett, Rhode Island

Acknowledgements: Doug Lipton, Geret DePiper, James Weinberg, Jamie Scott, Janet Nye, Jason Link, John Manderson, Jon Hare, Malin Pinsky, Mike Alexander, Mike Fogarty, Olaf Jensen, Rich Seagraves, Ryan Morse, Sarah Gaichas, Terra Lederhouse, William Overholtz



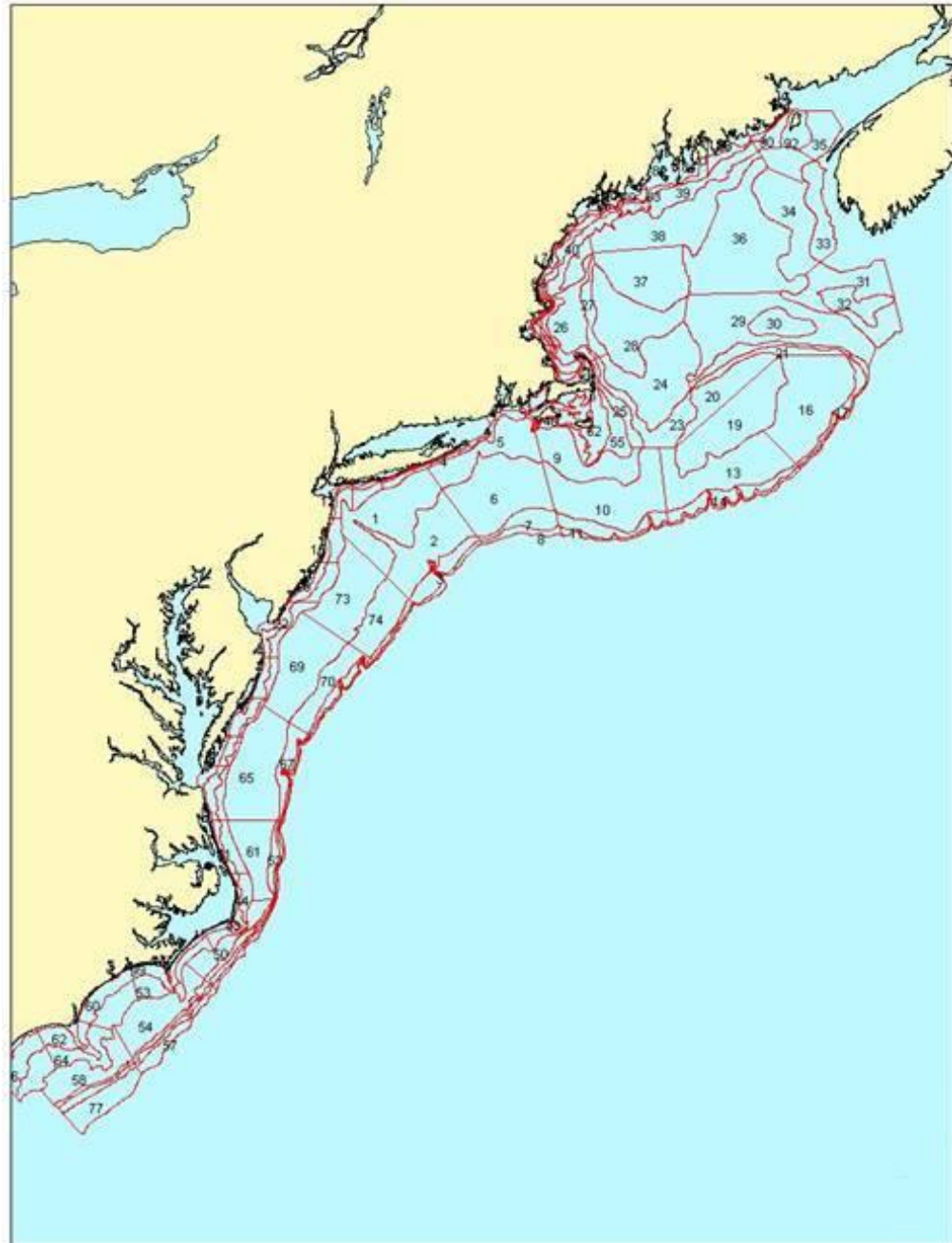
## Northeast Environmental Monitoring





## NEFSC Ecosystem Monitoring and Observing Program Elements

- Satellite Oceanography
- In Situ Instrumentation
- Standardized Surveys
  - Trawl & Acoustics & Video
  - Plankton
  - Shellfish Dredge
  - Air Craft
- Ships of Opportunity
- Observer Program
- Cooperative Industry Research
- Fishery Reporting System





## Food Habits Data

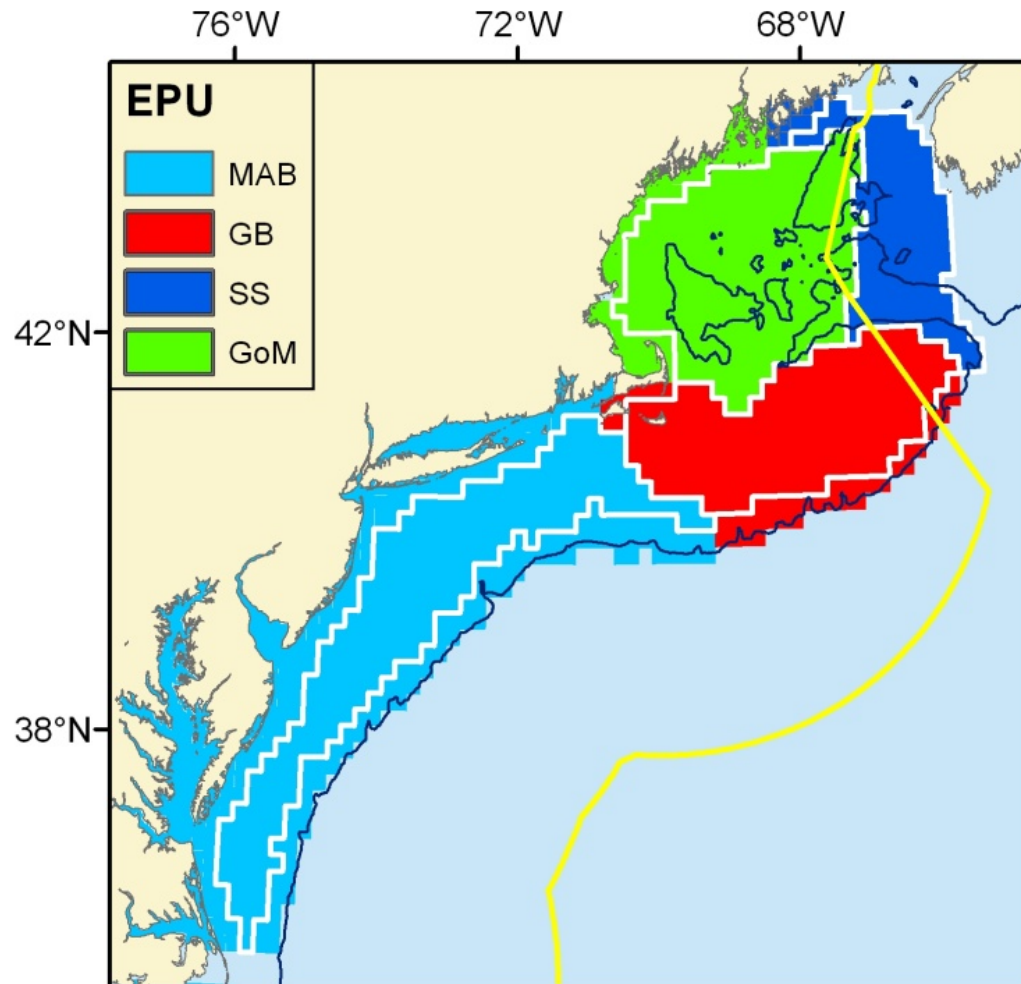
Over 100 distinct species of predators

Over 1,200 distinct prey taxa

Over 500,000 stomach examined



# Northeast Shelf Ecosystem



# Recent Changes of Northeast Shelf Ecosystem

Temperature

Salinity

Precipitation

Ocean Acidification

Currents

Winds

Sea-level

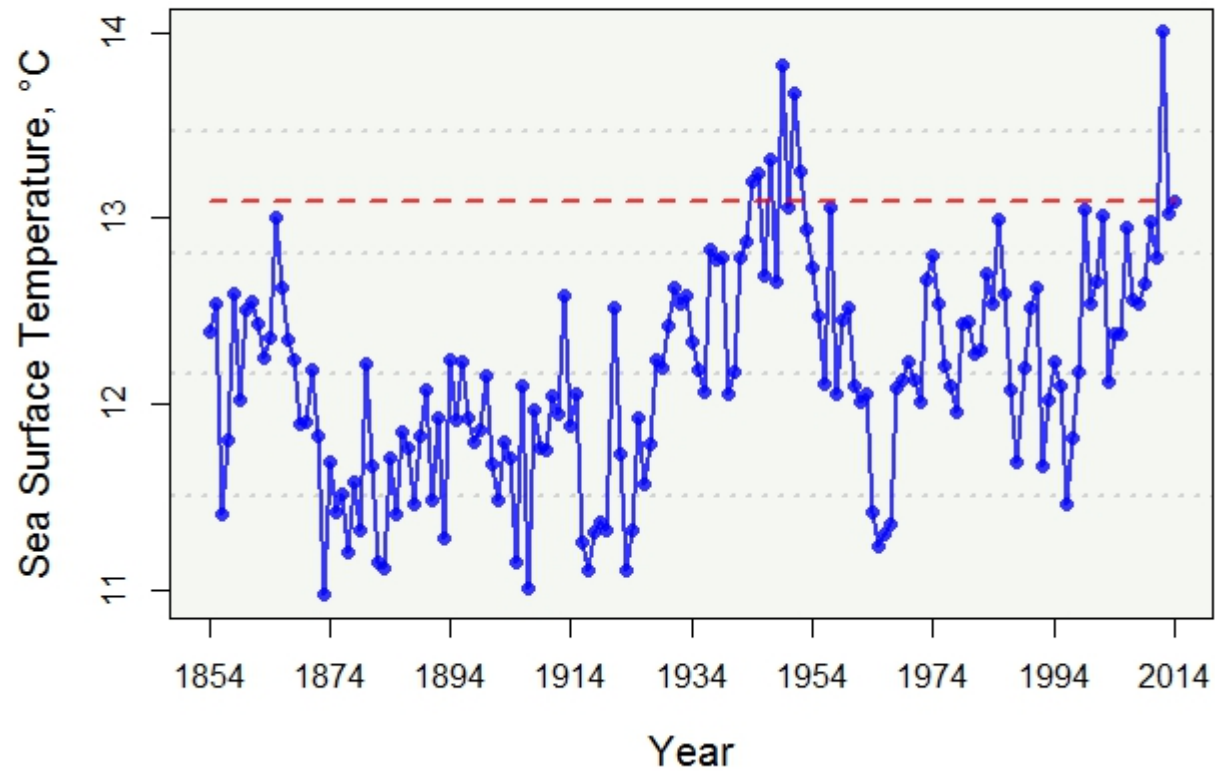
Primary production

Secondary production

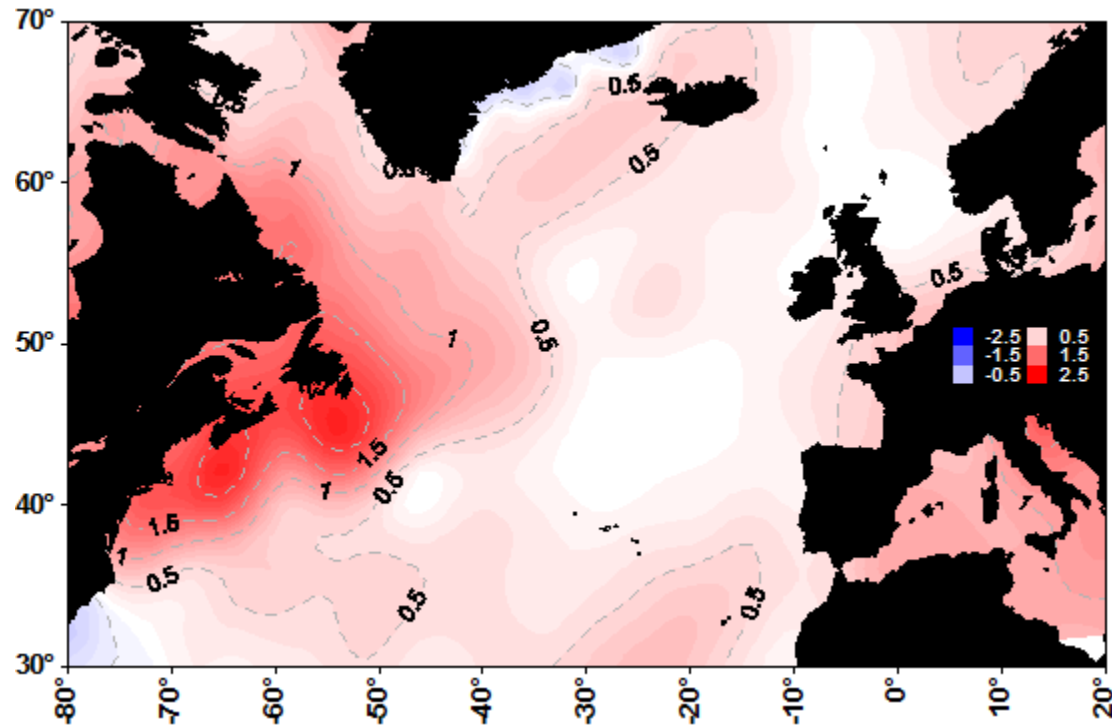
Distribution



## Long-term Sea Surface Temperature

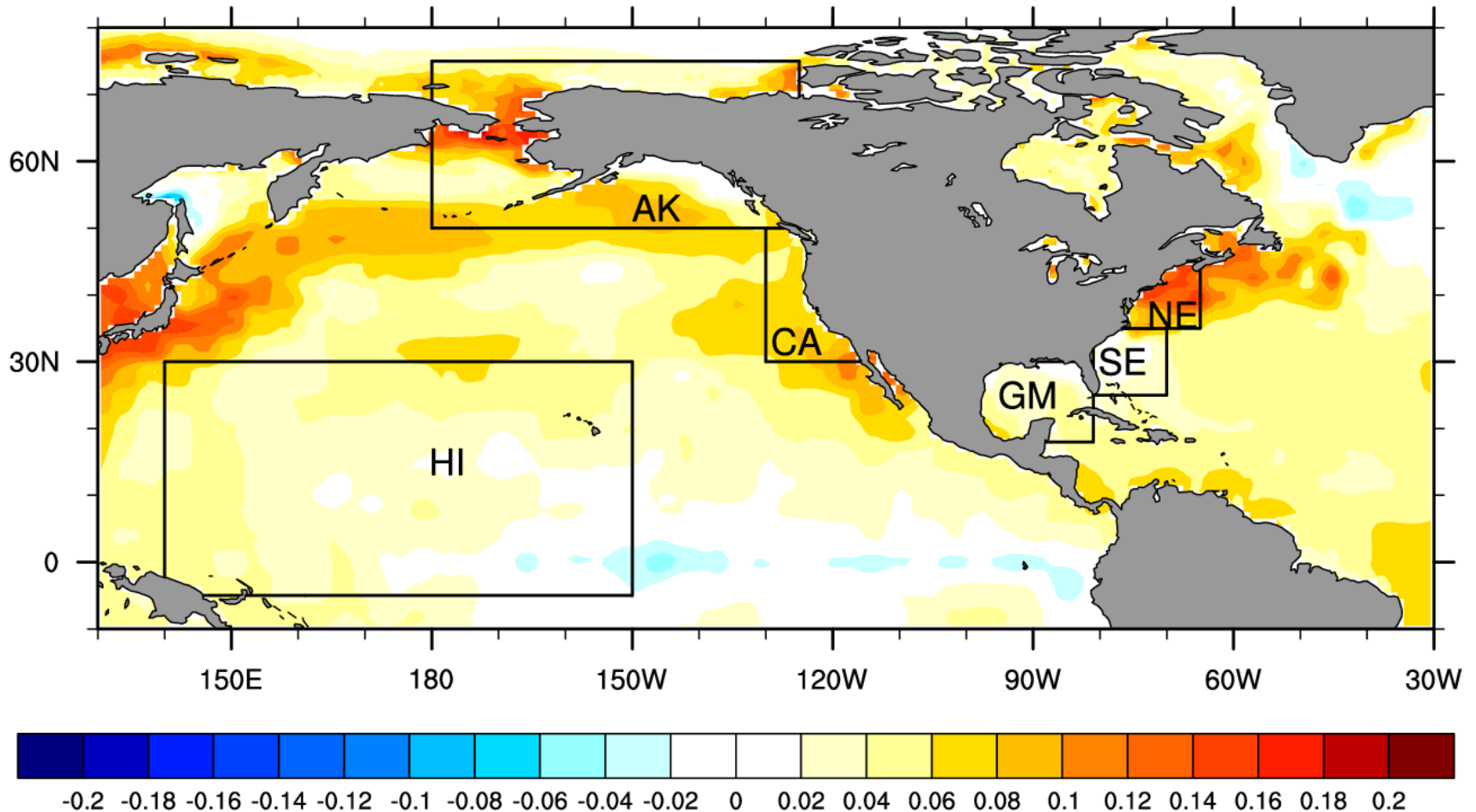


## Northeast Shelf 2012 SST in Context to the North Atlantic



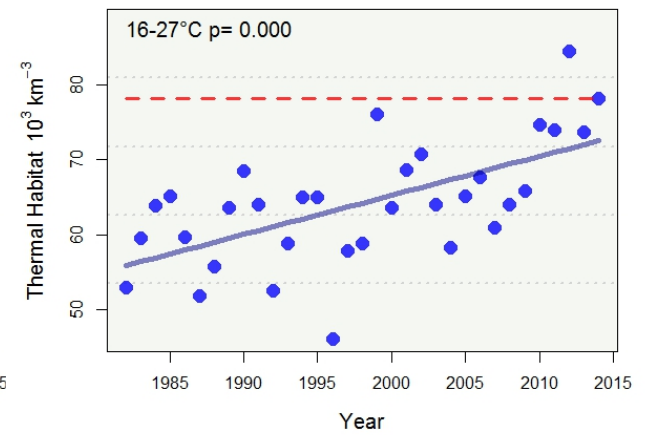
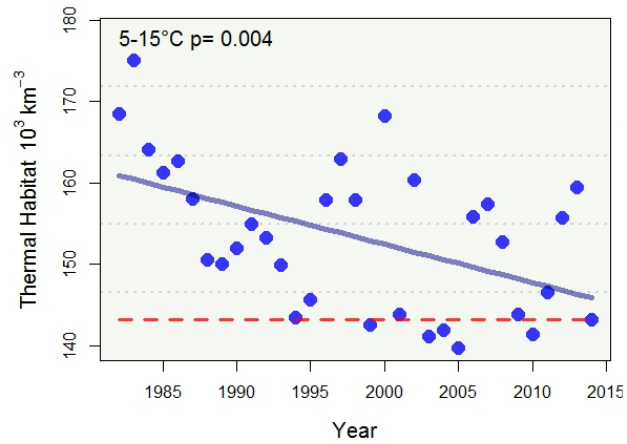
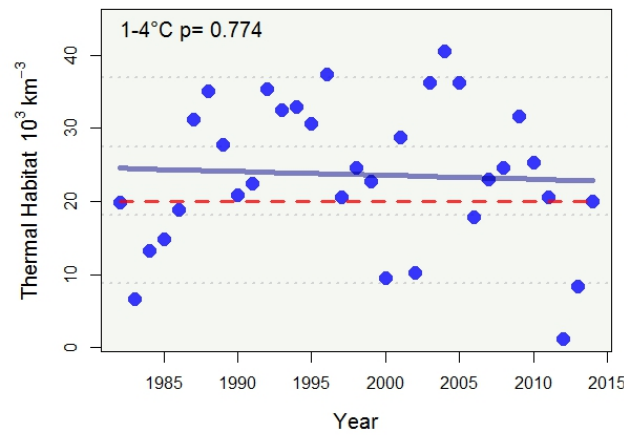
# Warming of Northeast Shelf and US LMEs

Hadley SST Trend 1900-2011 ( $^{\circ}\text{C}/\text{decade}$ )

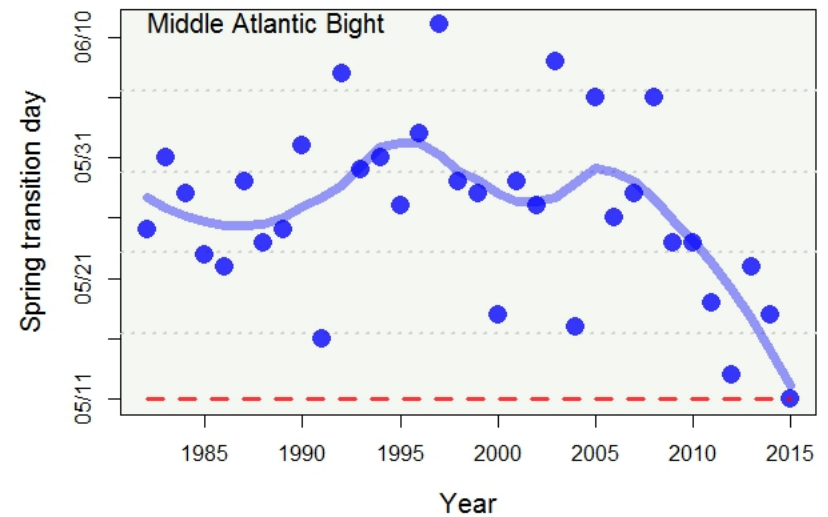
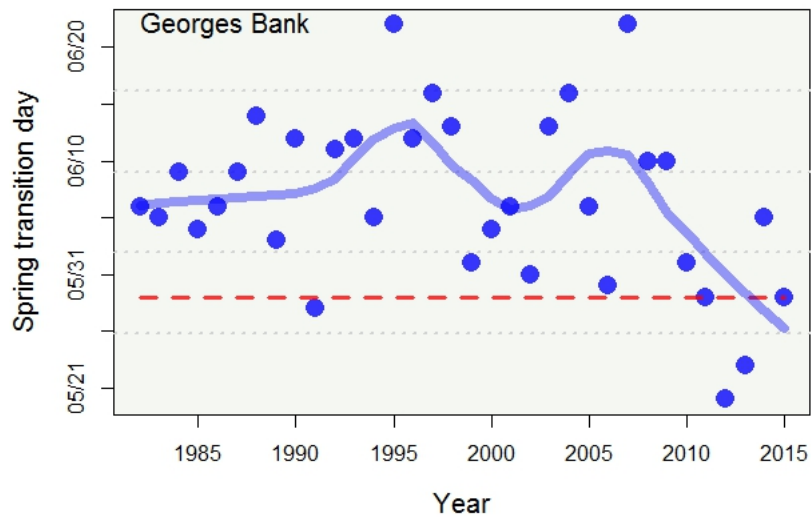
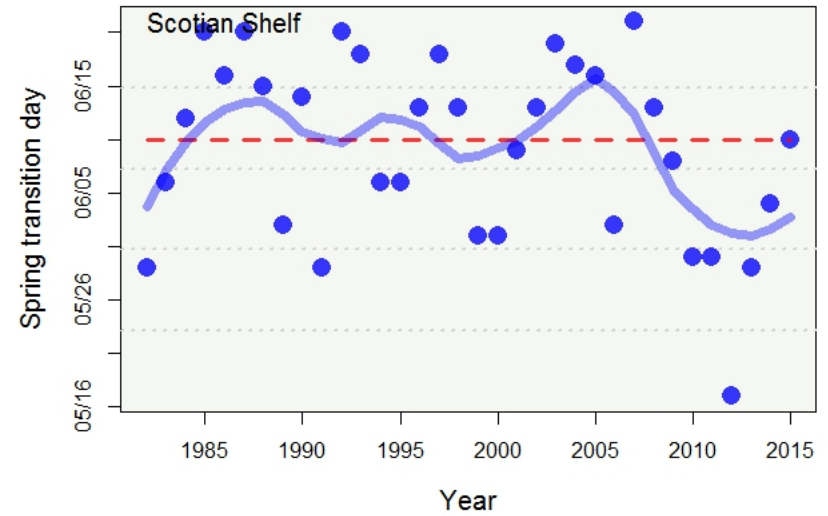
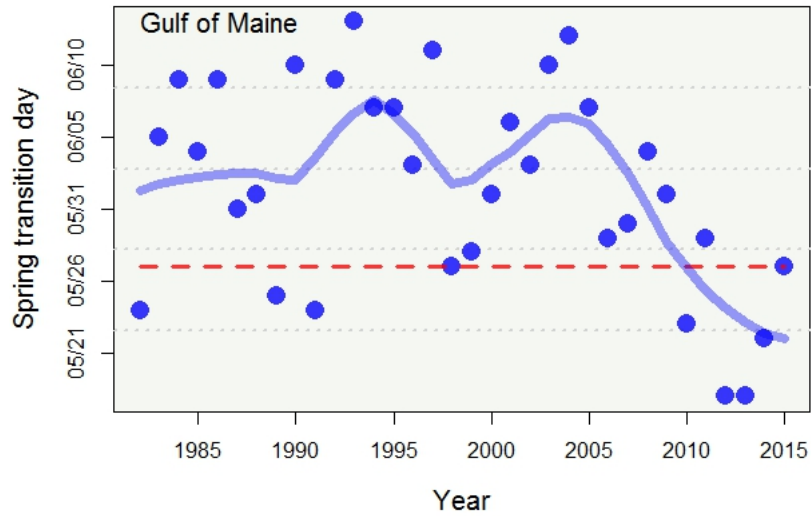




# Northeast Shelf Thermal Habitat

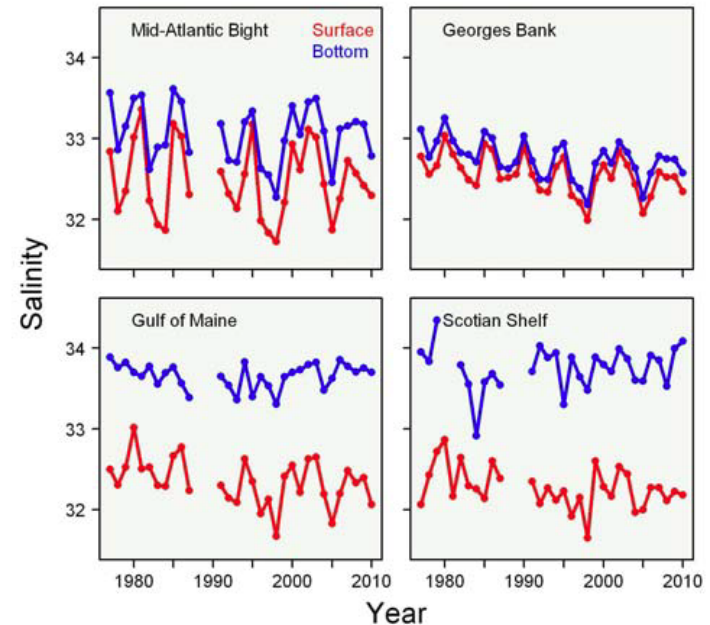
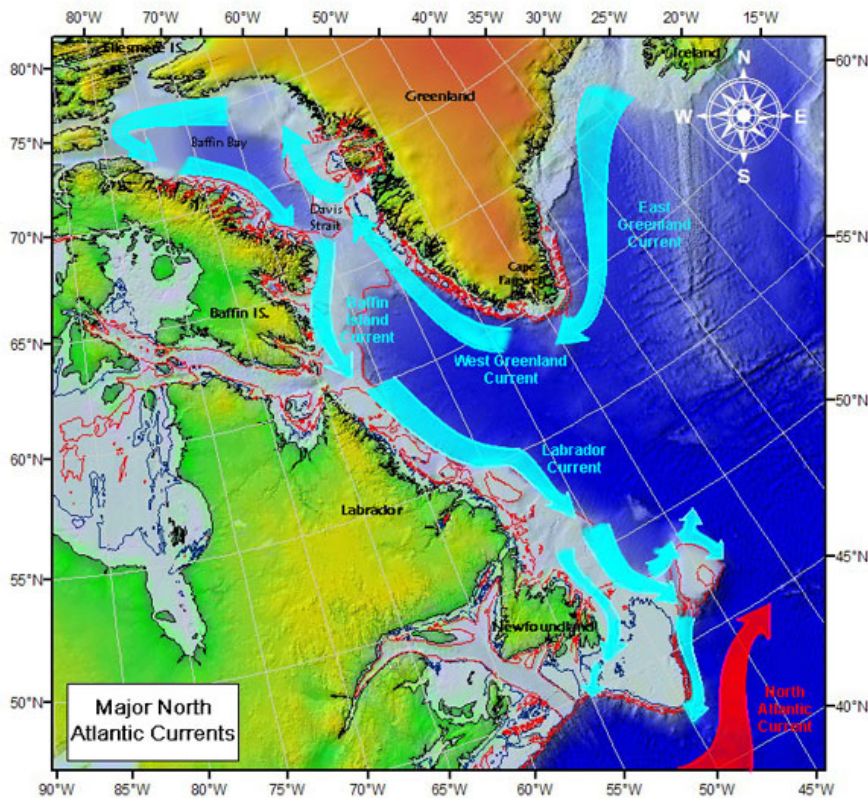


# Spring Thermal Transitions



# Northeast Shelf Salinity

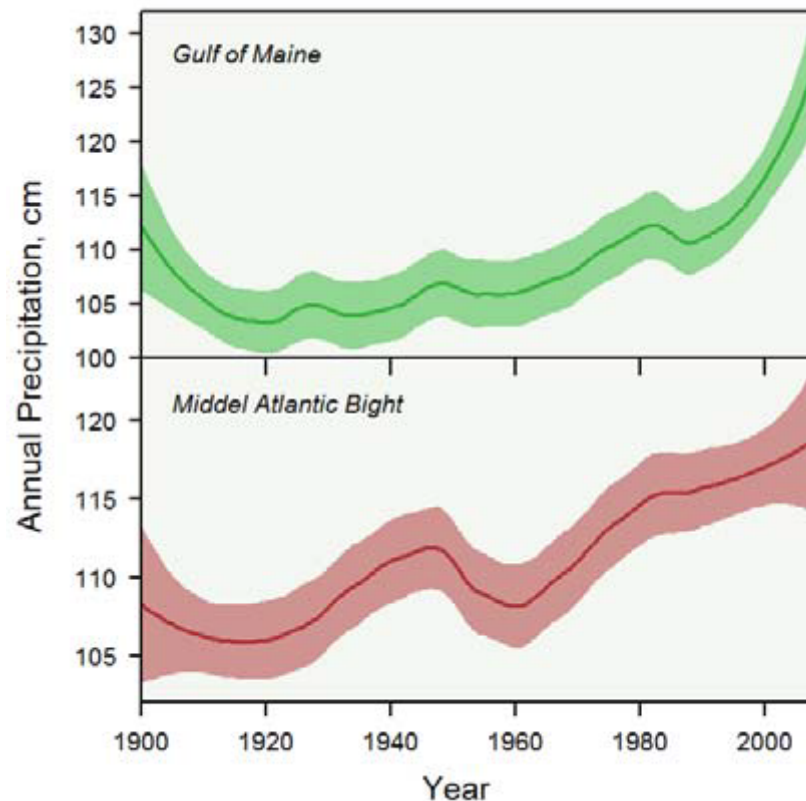
Evidence of variability and change that is linked to freshwater input from the Arctic.





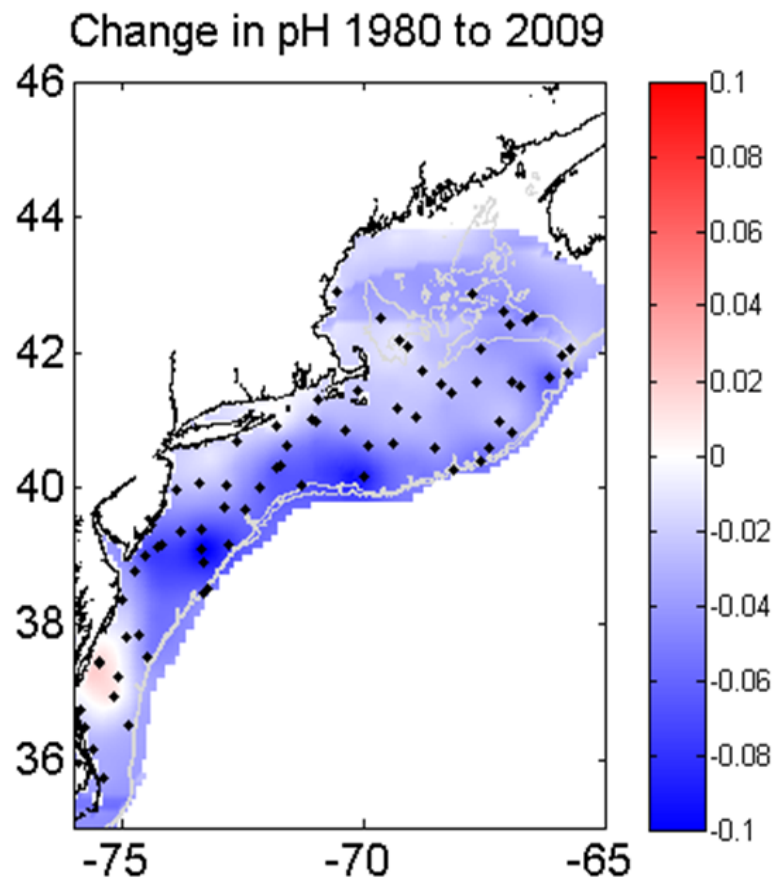
# Northeast United States Precipitation

Annual precipitation related to the Gulf of Maine and Middle Atlantic Bight.



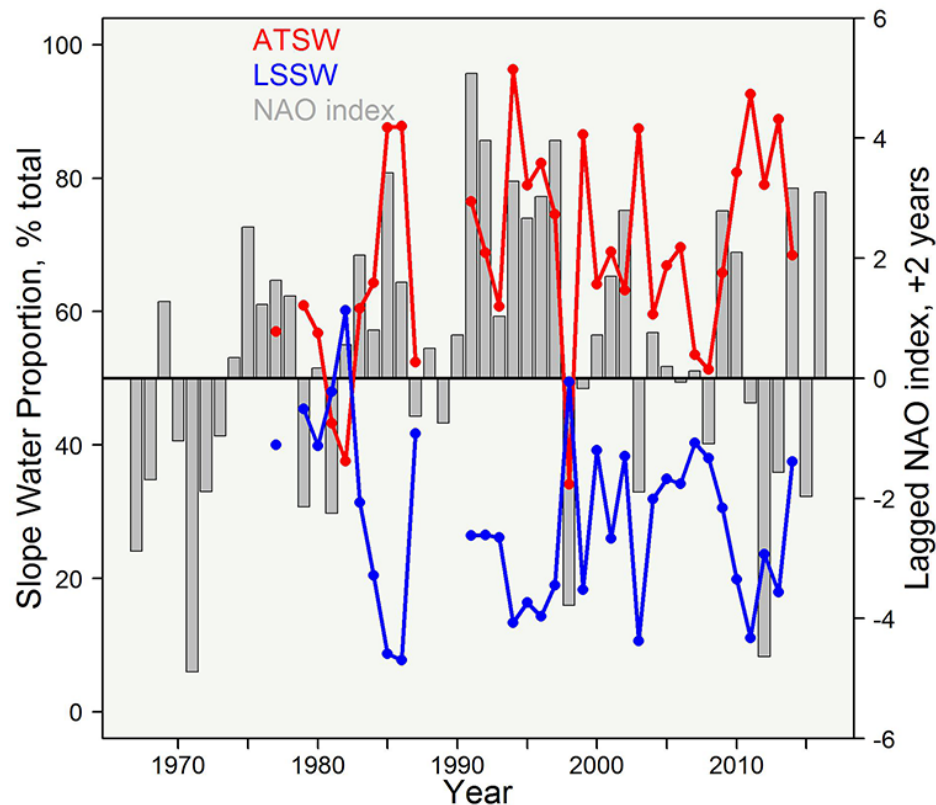
# Northeast Shelf Ocean Acidification

Historical data collected as part of the NEFSC's MARMAP program from 1976-1983 were compared to recent data collected as part of joint NOAA-NASA partnership aboard the ECOMON survey cruises in 2010 and 2011.



# Northeast Shelf Currents

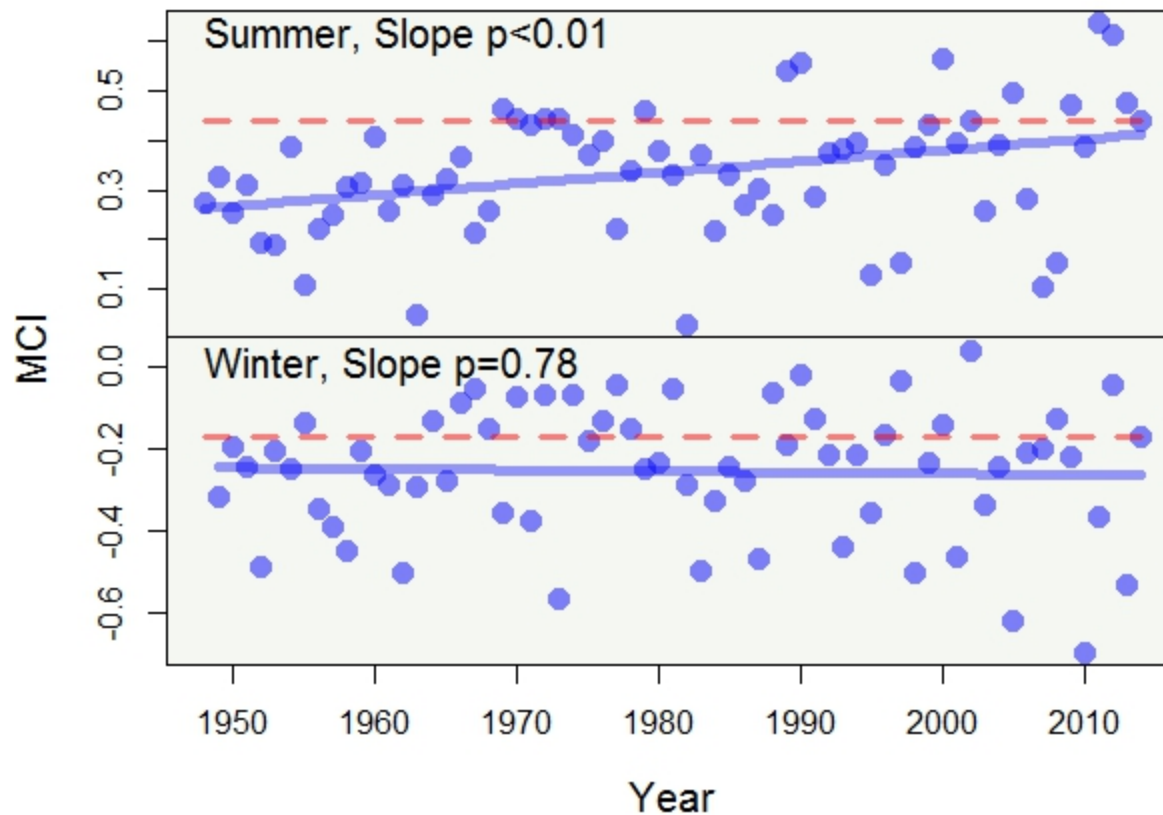
Relative proportion of water mass derived from Labrador Subarctic Slope Water (LSSW, blue) and Atlantic Temperate Slope Water (ATSW, red) in the deep northeast Channel of the Gulf of Maine. The wintertime North Atlantic Oscillation index is also shown, shifted forward in time by two years (gray bars).





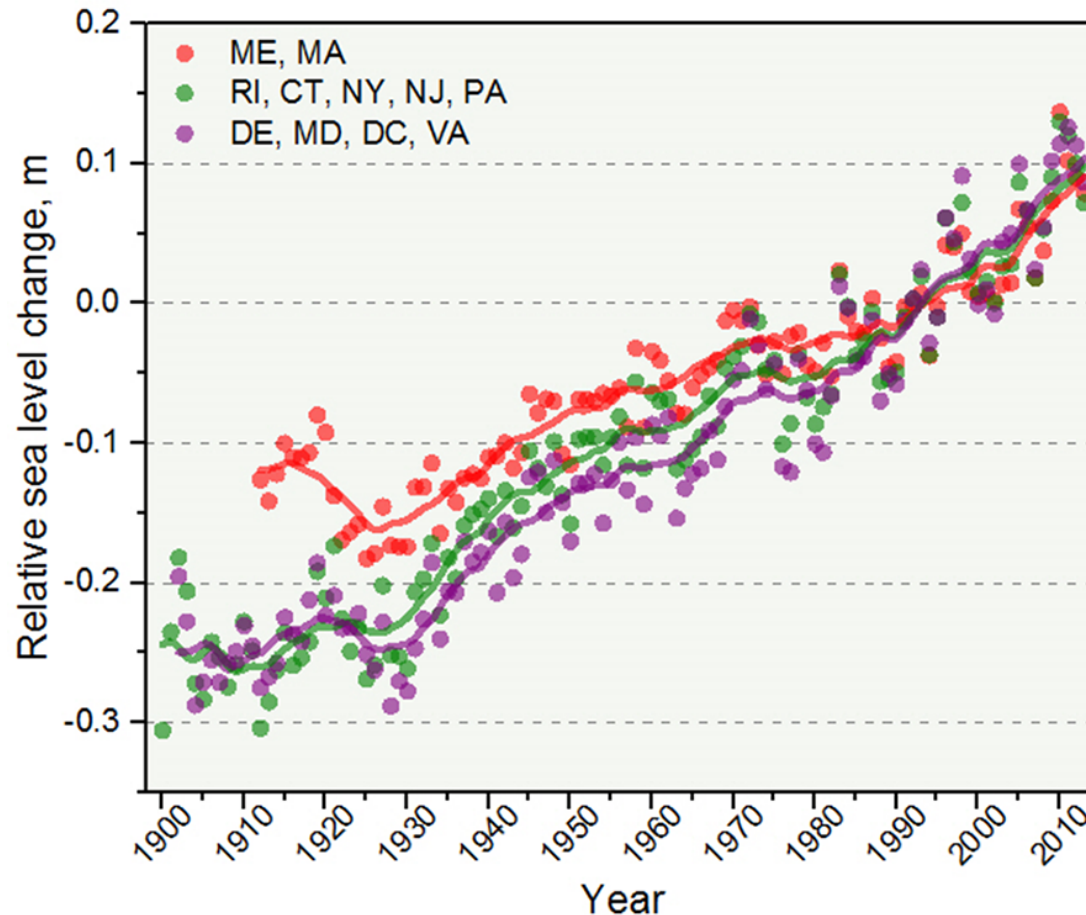
## Northeast Shelf Wind Direction

Meridional circulation index (MCI) for the Northeast Shelf. The change in summer MCI is associated with a decrease in summer wind speeds, mainly due to slower west to east movement.



# Northeast United States Sea Level

Data from gauging stations set relative to the most recent mean sea level established by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS)



## Detection of Blooms - STARS Algorithm

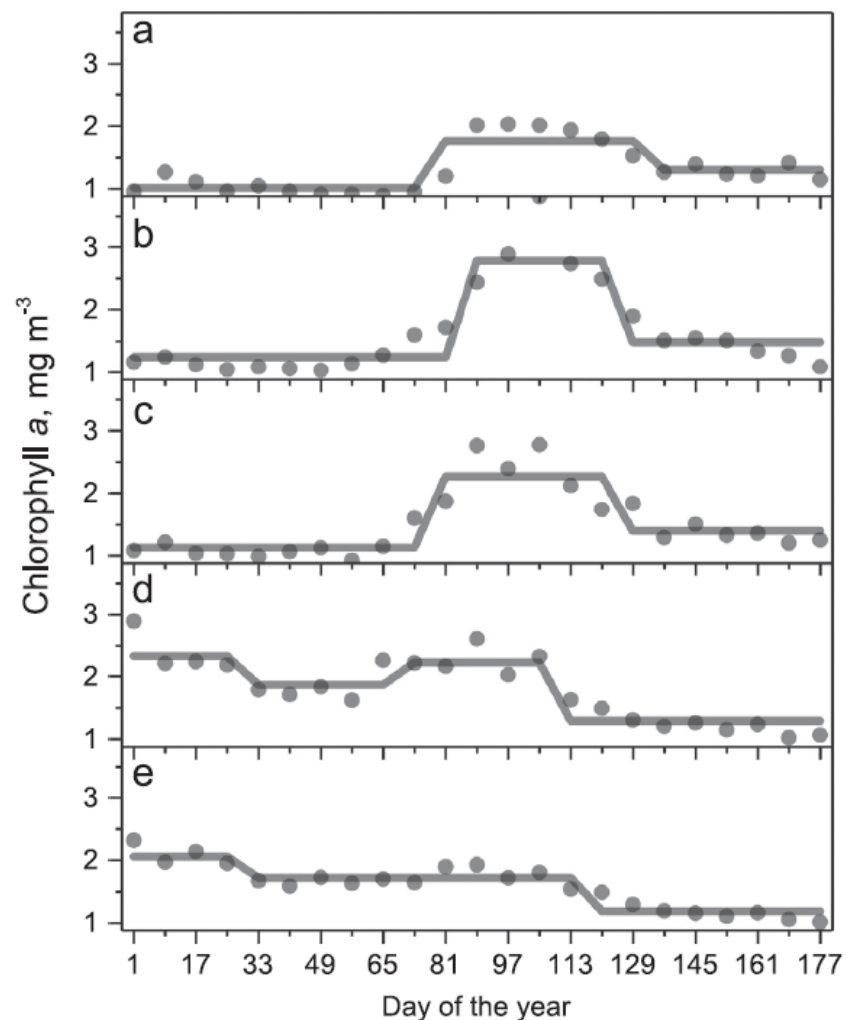
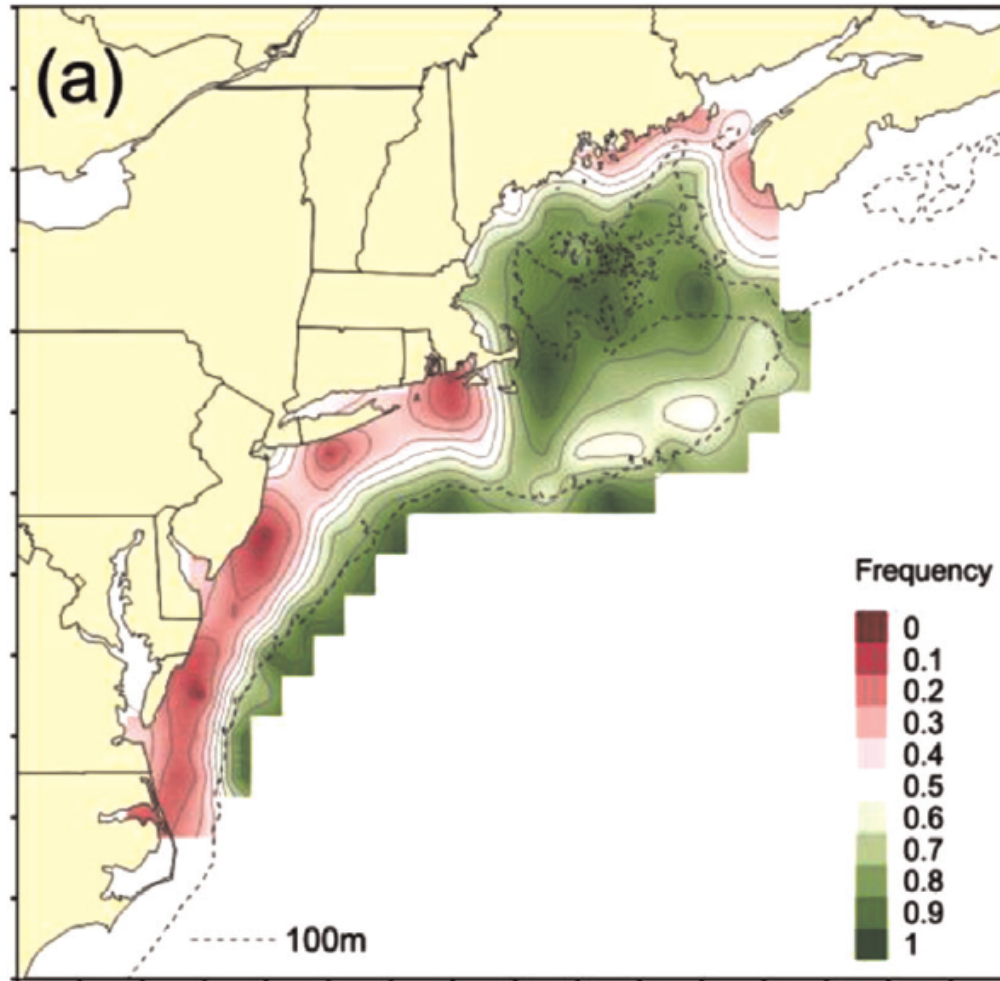
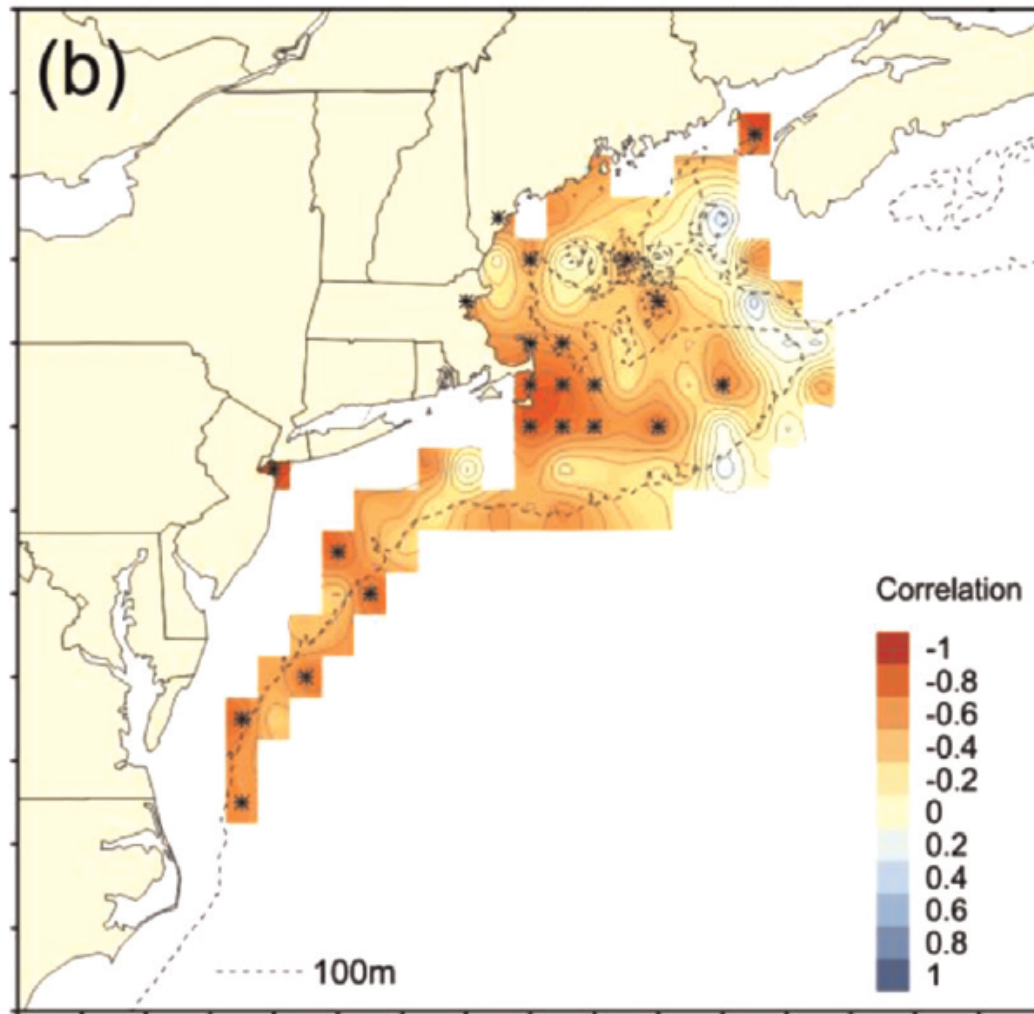


Fig. 2. Points depict smoothed (3-point moving averages) of time series (1998–2013) mean *chlorophyll-a* concentrations for the first half of the year by production unit. Lines are STARS algorithm fit for each production unit. (a) Gulf of Maine East, (b) Gulf of Maine West, (c) Georges Bank, (d) Middle Atlantic Bight North and (e) Middle Atlantic Bight South.

## Spring Bloom Frequency

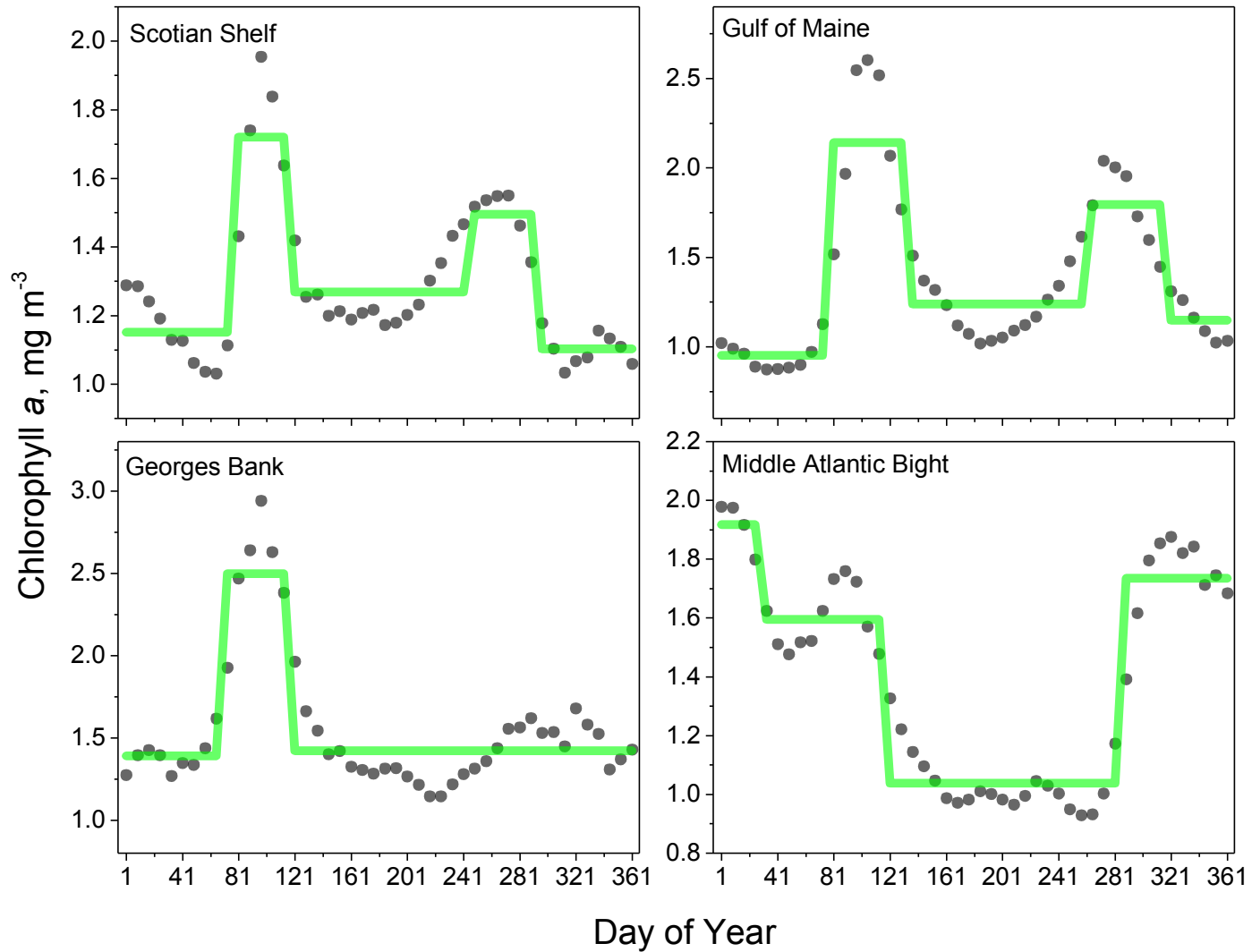


## Bloom Start and Duration

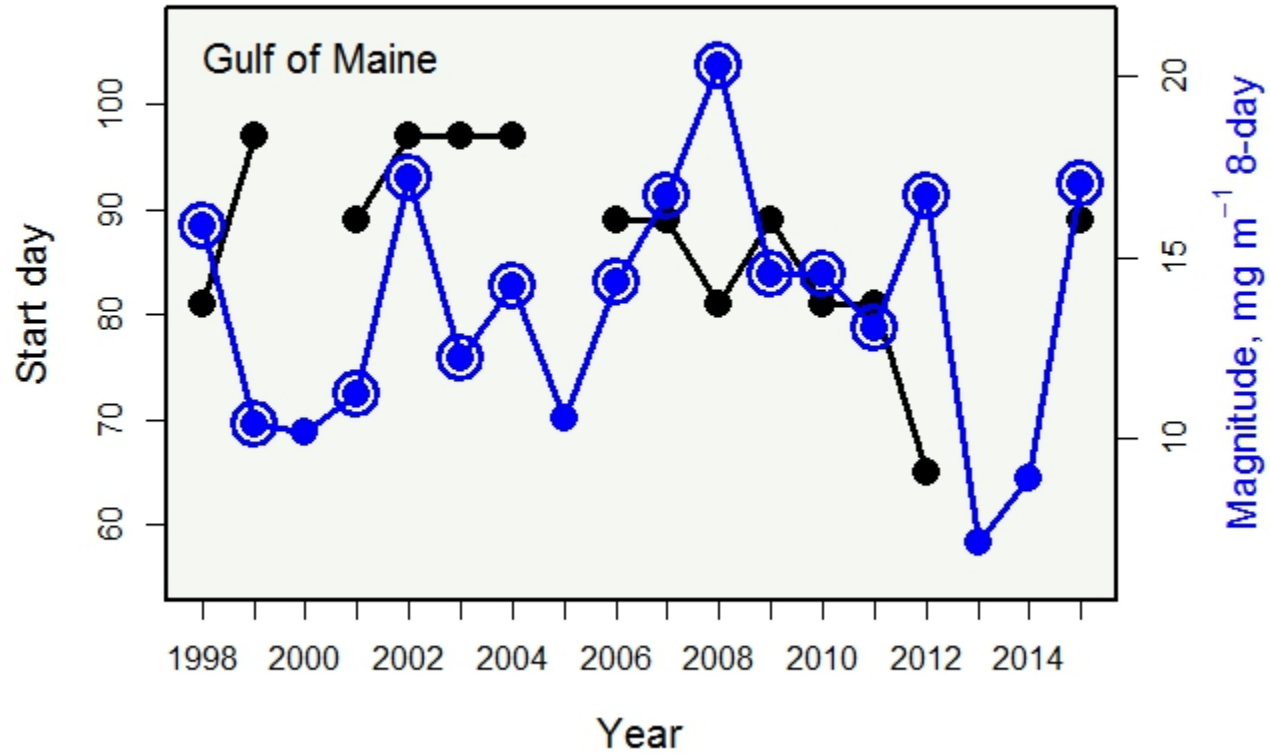




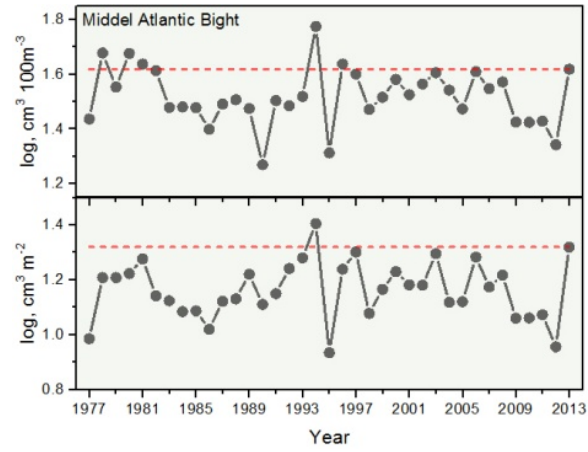
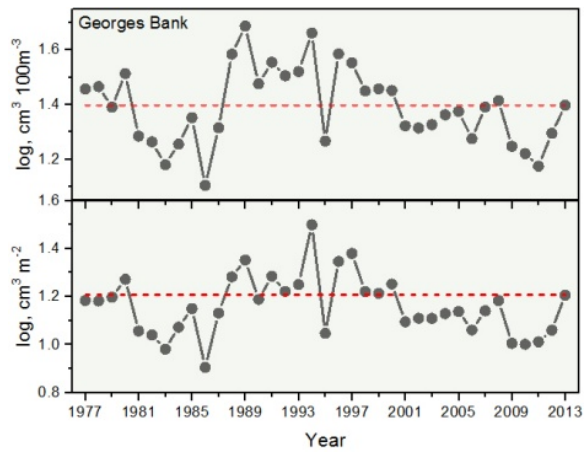
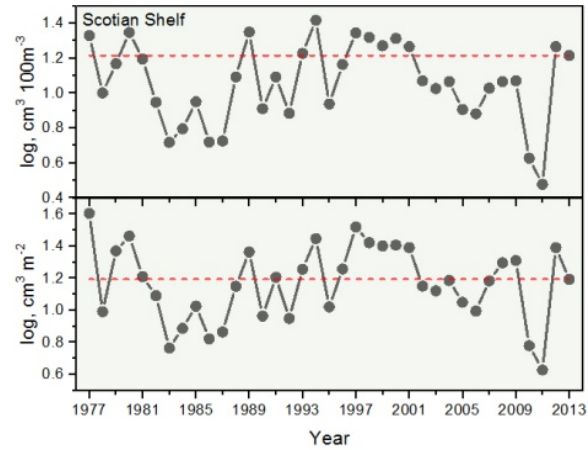
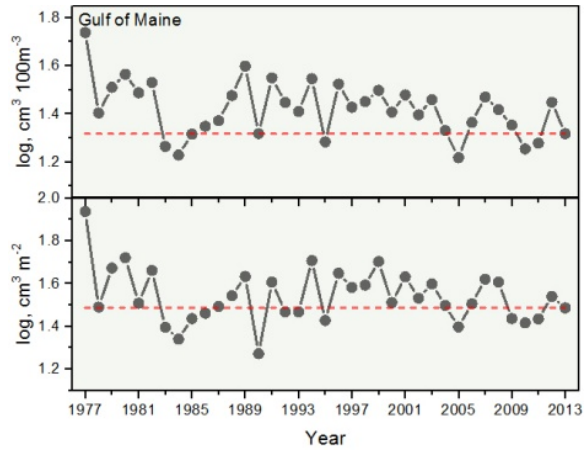
# Climatological bloom patterns



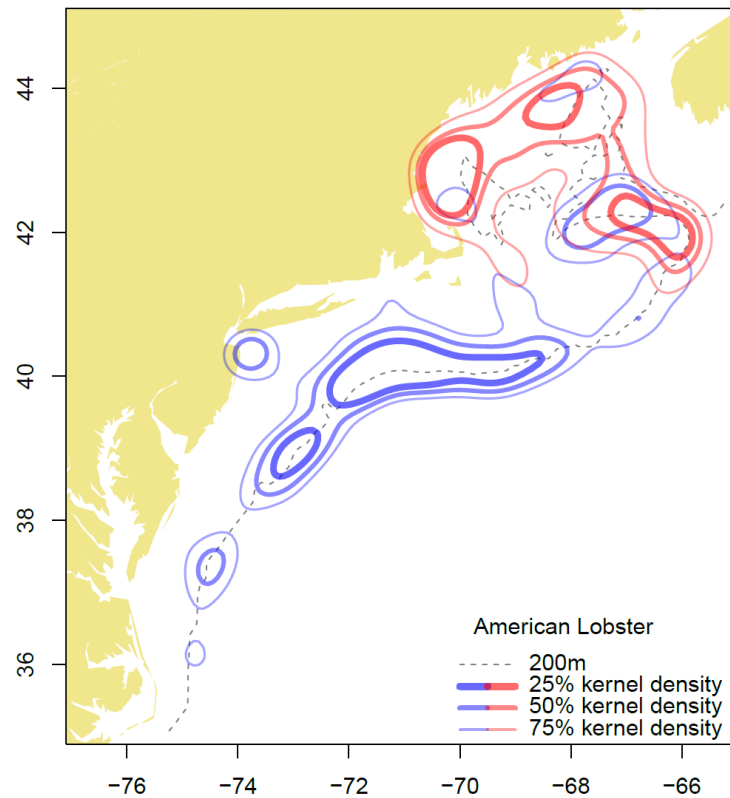
## Gulf of Maine Bloom Time Series



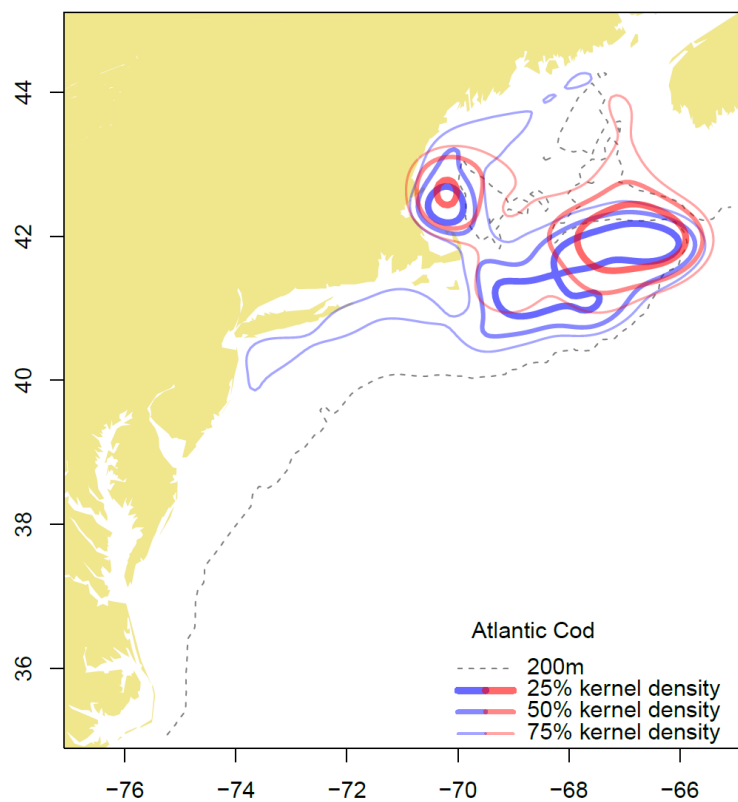
# Zooplankton Production



# American Lobster



# Atlantic Cod





What's at risk?



# Risk Assessment – Northeast Fisheries Climate Vulnerability Assessment

79 Species were considered by an expert panel

Exposure, how much climate related change a stock is likely to experience

Sensitivity, biological attributes believed to be indicative of the stock's response to climate change

Exposure to climate change is high to very high

Sensitivity higher for diadromous and shellfish; lower for groundfish and pelagics

		Vulnerability			
Sensitivity	Very High			1 Shellfish	1 Shellfish 1 Diadromous
	High			5 Shellfish 6 Groundfish 4 Elasmobranchs	8 Shellfish 7 Diadromous 3 Coastal
	Medium			5 Groundfish 3 Elasmobranchs 2 Shellfish 1 Pelagic	2 Diadromous 3 Coastal
	Low			8 Groundfish 5 Elasmobranchs 5 Pelagics 1 Shellfish	8 Coastal
		Low	Medium	High	Very High
		Exposure			

## Application of the Vulnerability Assessment

Management: Decisions regarding catch levels and rebuilding plans for vulnerable species could be revisited. The information can be used in Environmental Impact Statements, Biological Opinions, and Listing Decisions (has already been used in Dusky Shark listing decision).  
Reevaluate spatial management and assessment for vulnerable species.

Reduce climate vulnerability: Work to improve population status of vulnerable species by reduce other stressors (e.g., dams for anadromous species), work to include climate factors into assessments.

Research Priorities: Examine effect of temperature and ocean acidification on resources, develop down-scaled climate models or higher-resolution climate models, evaluate consistency between expert opinion assessments.

## Climate impacts on management



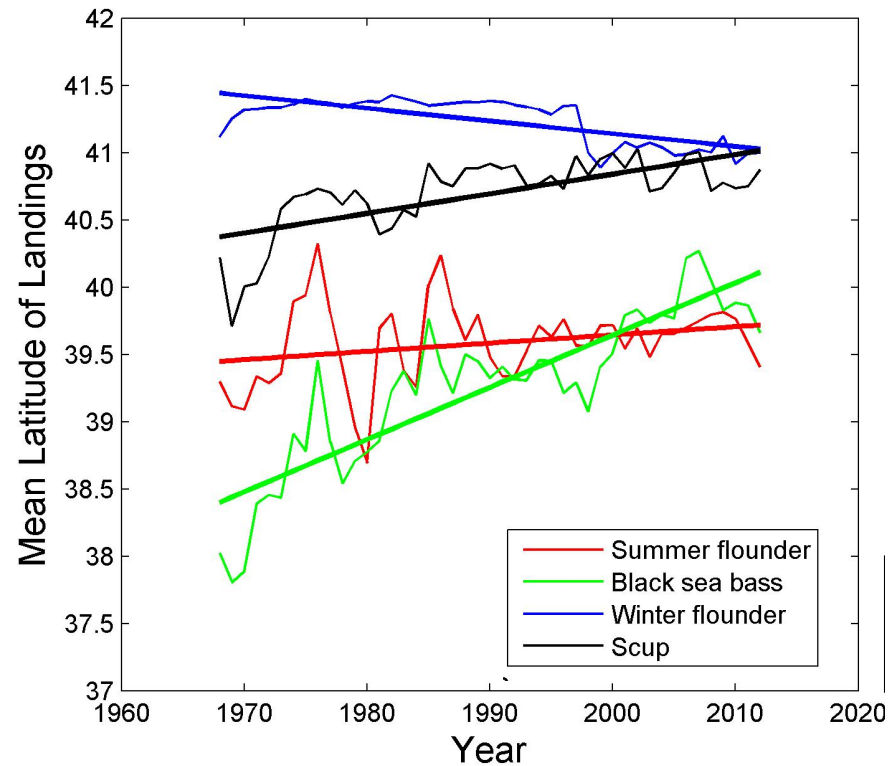
# Effects of Climate on Social and Economic Assessments

Fisheries are changing as fish and shellfish respond to climate change

Distribution of landings is changing

Species landed are changing

Example: Blueline Tilefish action to prevent the unmanaged expansion of this data-poor fishery.





The importance of partnerships to  
address climate impacts.



# Research Partnerships

## Academic:

Cooperative Institute for the North Atlantic Region (CINAR)

<http://www.cinar.org/home>

Gulf of Maine Research Institute (GMRI) <http://www.gmri.org/>

## IOOS:

Northeastern Regional Association of Coastal Ocean Observing Systems  
(NERACOOS) <http://www.neracoos.org/>

Mid-Atlantic Regional Association Coastal Ocean Observing System  
(MARACOOS) <http://maracoos.org/>

## Federal:

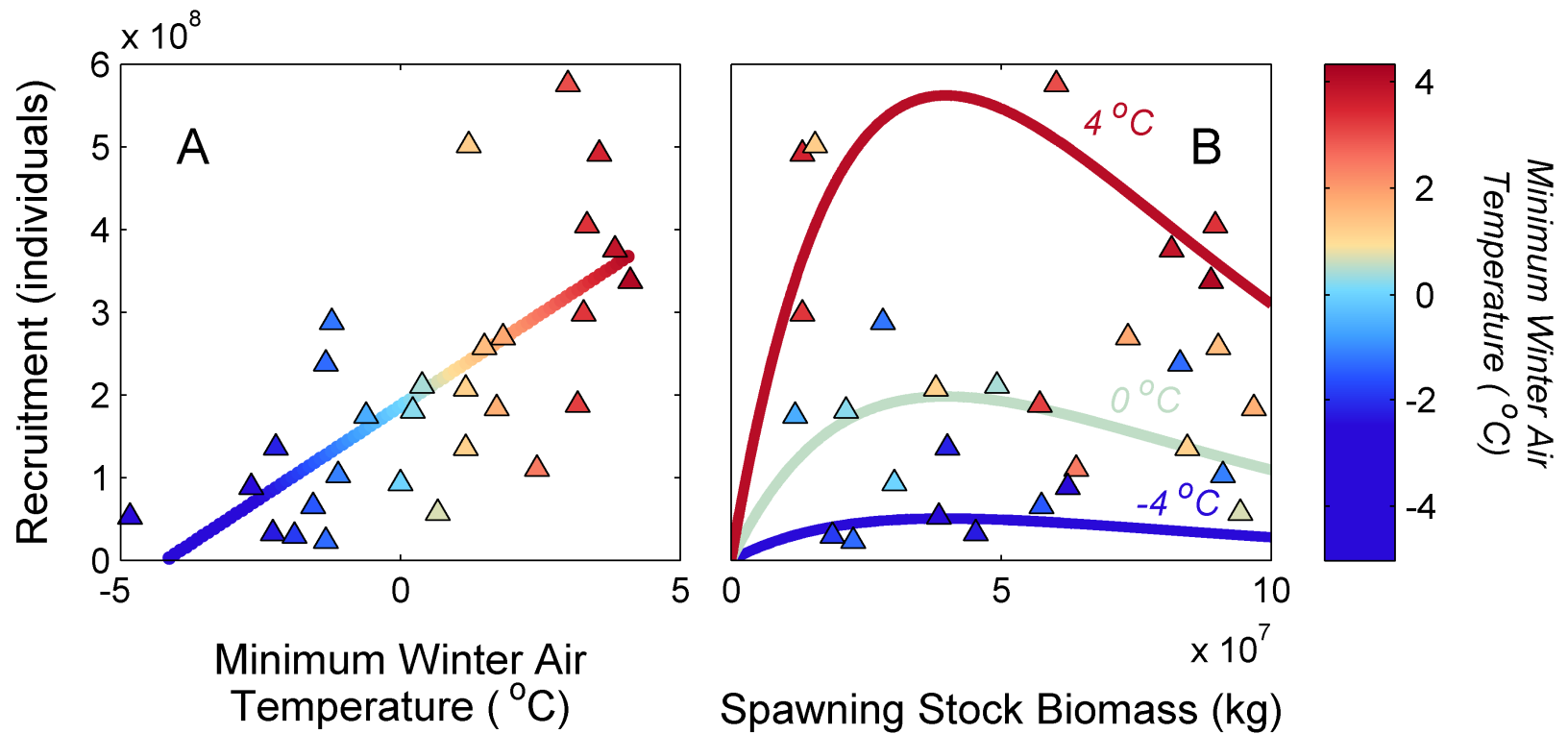
Geophysical Fluid Dynamics Laboratory (GFDL) <http://www.gfdl.noaa.gov/>

Earth System Research Laboratory (ESRL) <http://www.esrl.noaa.gov/>

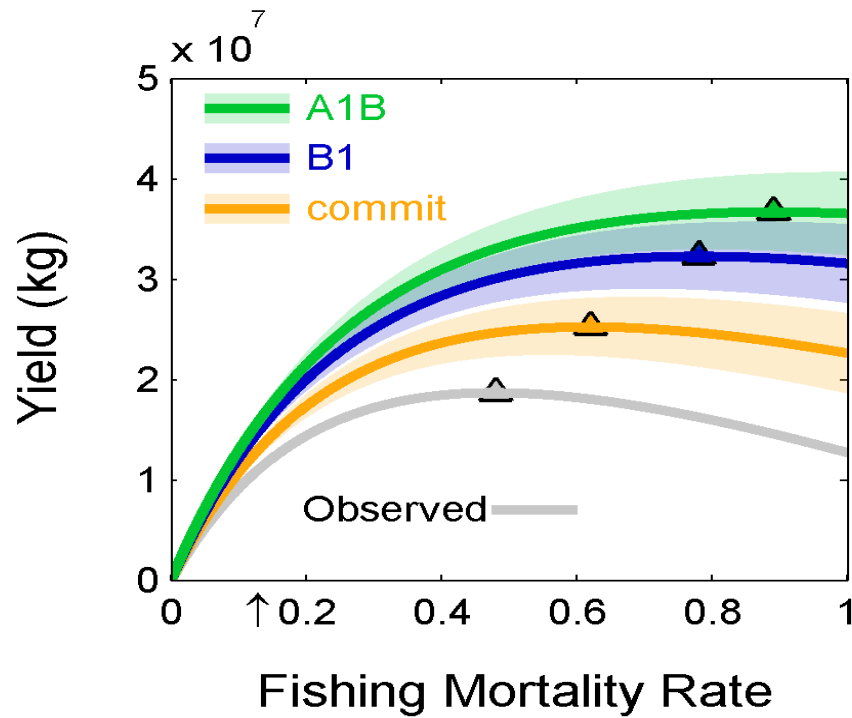
Mechanistic understanding of  
climate impacts



# Atlantic Croaker Recruitment



## Projected Yield of Croaker





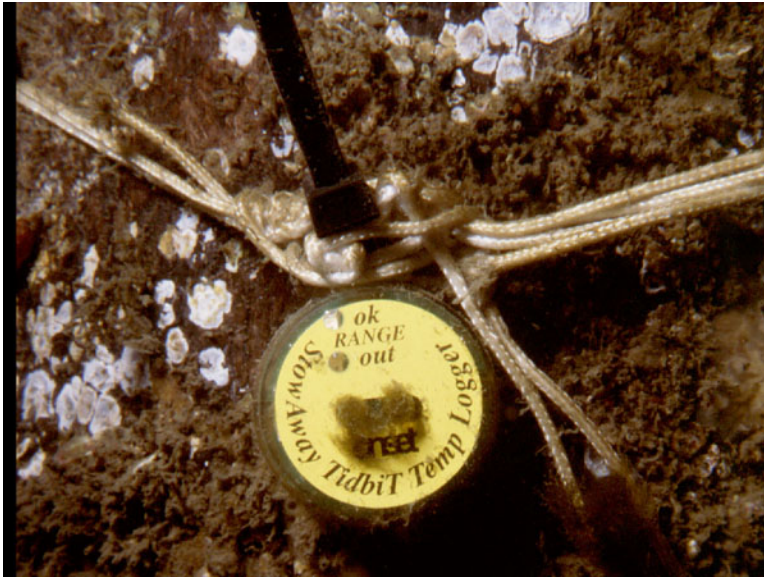
## Ways Forward



# Citizen and Fishermen and School Science

## Environmental Monitors on Lobster Traps (eMOLT)

<http://www.nefsc.noaa.gov/epd/ocean/MainPage/emolt.html>

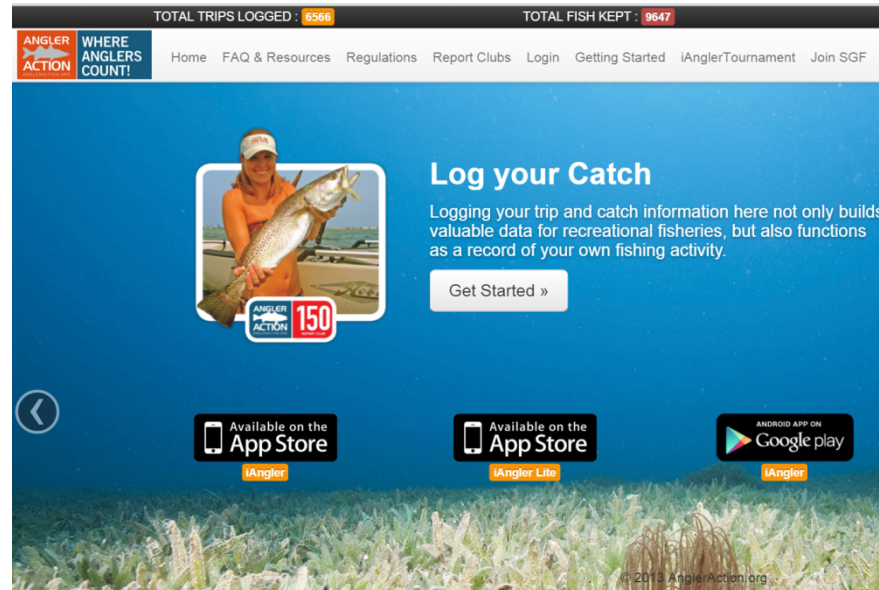


# Recreational Fishermen Science

<http://www.chesapeakecatch.org/angleraction/affiliation/page/chesapeakecatch>



<http://www.snookfoundation.org/membership.html>



# Tools for Tracking Climate, Distribution, Productivity, Interactions, and Impacts

NEFSC Ecosystem Considerations

<http://www.nefsc.noaa.gov/ecosys/>

NEFSC Climate Change Webpage

<http://www.nefsc.noaa.gov/ecosys/climate-change/>

NOAA ESRL Climate Change Portal

<http://www.esrl.noaa.gov/psd/ipcc/>

Rutgers University OceanAdapt Webpage

<http://oceanadapt.rutgers.edu/>

MAFMC Annual Ecosystem Report

<http://www.mafmc.org/eafm/>

NEFMC Ecosystem Management Webpage

<http://www.nefmc.org/committees/ecosystem-based-fisheries-management>

# Incorporating Climate Factors into Assessments

Stock Identification

Emerging Fisheries

Changes in Reference Points

Impacts on Data (e.g., butterflyfish availability)

Rebuilding Plans



“Would you please elaborate on ‘then something bad happened’?”



# How might Council Risk Policy adjust to climate change?

For stocks that are impacted by climate change, current buffers may not be adequate

Adjustment of risk level within existing OFL/ABC framework

Reevaluation of stock definitions

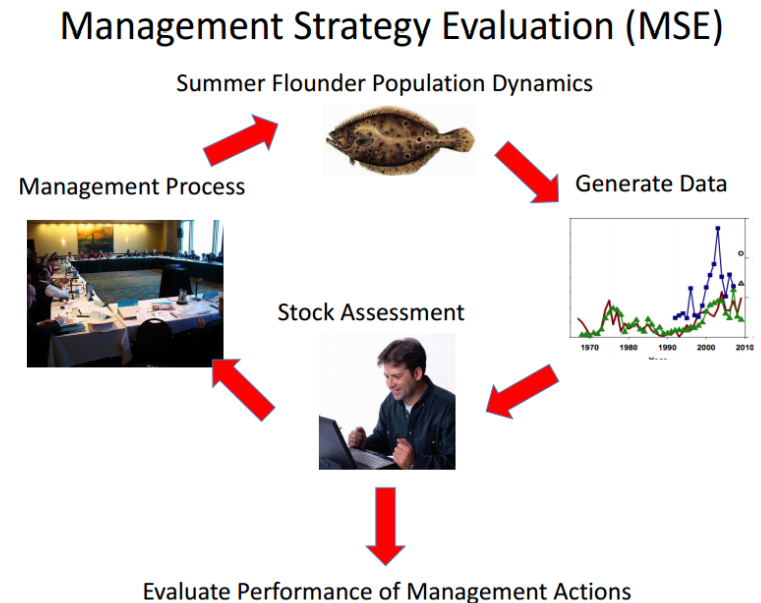


# Management Strategy Evaluation

Assess the consequences of a range of management strategies and examine tradeoffs in performance across a range of management objectives.

Concept can also be used to evaluate surveys (Observing System Simulation Experiments) and assessment models

Need to develop a regional capacity to support development and implementation





## Parting Thoughts, in the Form of a Question

Do we need a new research framework to understand recruitment?

How do we determine if a species/stock cannot be rebuilt?

How do we deal with such a species/stock?

Is there utility for long-term, climate forced fisheries forecasts?



Questions?

