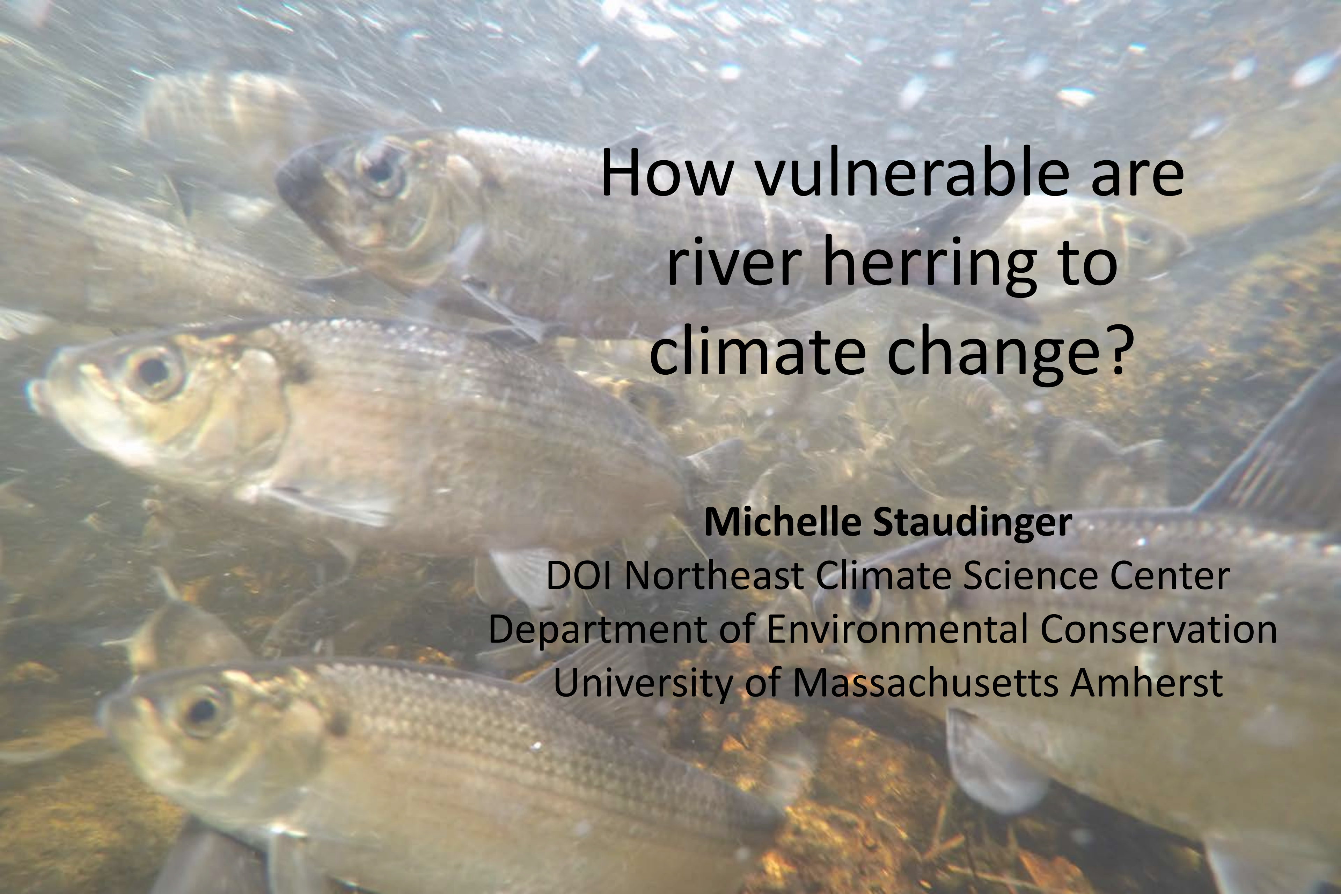

How vulnerable are river herring to climate change?

Michelle Staudinger
DOI Northeast Climate Science Center
Department of Environmental Conservation
University of Massachusetts Amherst

DOI Northeast Climate Science Center Consortium

University of Massachusetts Amherst

Richard Palmer (Lead PI)
Ray Bradley (PI)
Curt Griffin (PI)
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Columbia University

Radley Horton (Lead PI)

Marine Biological Laboratory

Linda Deegan (Lead PI)

University of Minnesota

Anthony D'Amato (Lead PI)

College of Menominee Nation

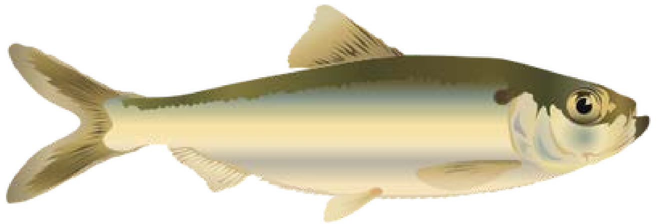
Chris Caldwell (Lead PI)

University of Missouri Columbia

Frank Thompson III (Lead PI)

University of Wisconsin-Madison

Ken Potter (Lead PI)



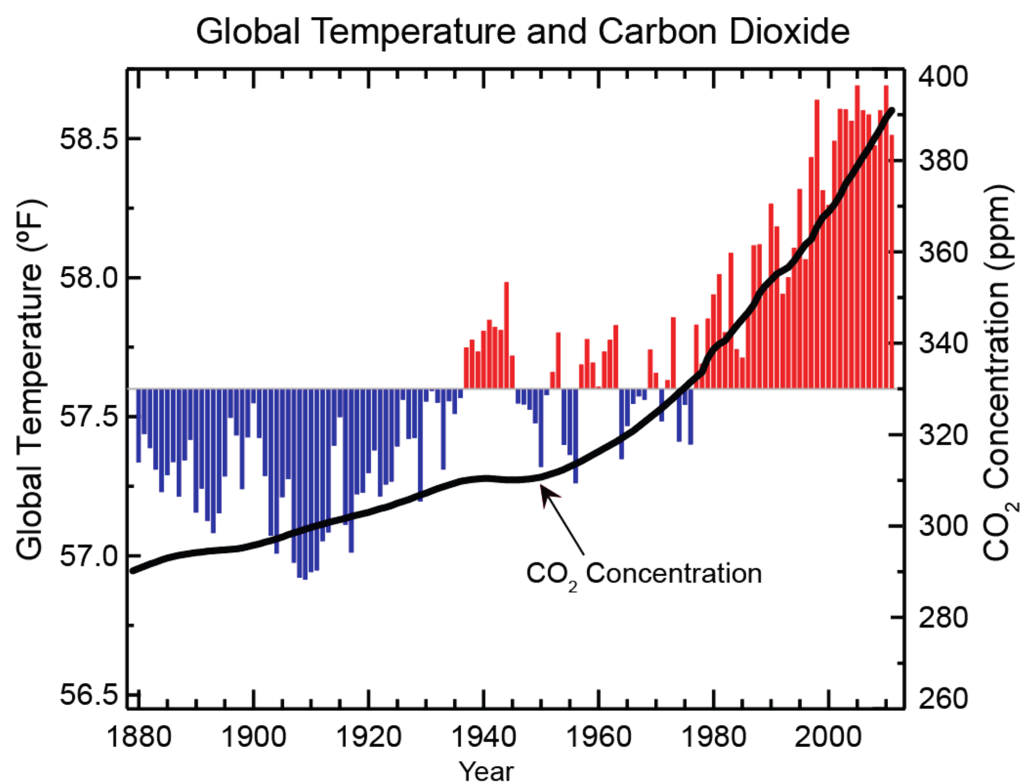
Outline

1. Regional climate impacts on coastal ecosystems
2. Vulnerability to climate change
3. Ecological responses to climate impacts
4. Climate change adaptation approaches and tools

Observed climate change in the Northeast

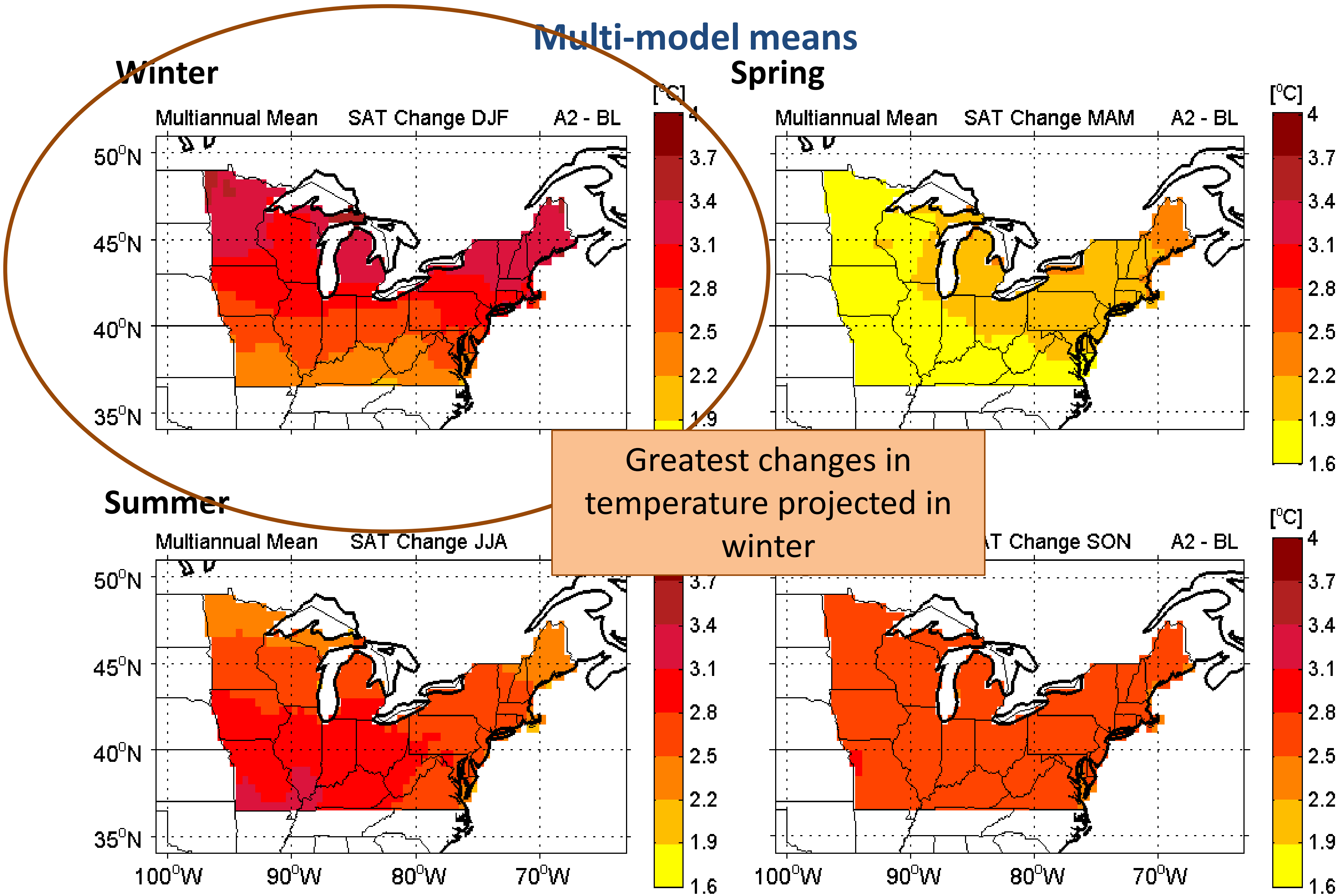
- Since 1970, annual average temperature has increased by 2°F; winter temperatures ~4°F
- More extreme heat days > 100°F
- Annual precipitation totals have gone up ~5" over the last century
- Less snow, more rain
- Changes in hydrological flows
- Regional SLR of ~ 1 foot

  since 1900



US GCRP (2009)

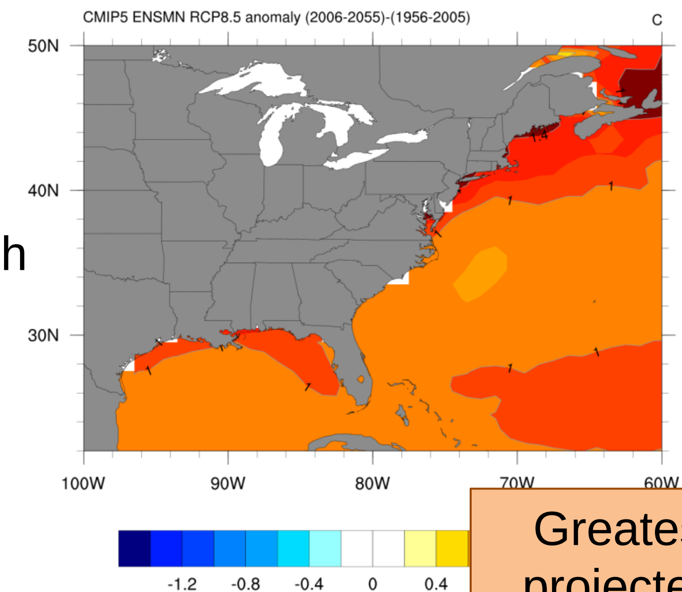
Projected seasonal air temperatures



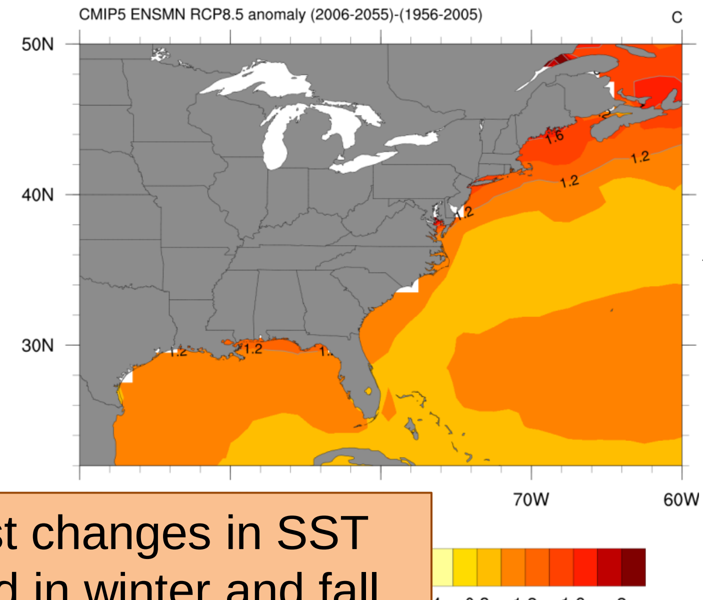
Downscaled projections – Dr. Ray Bradley, UMass Amherst

Sea surface temperatures

Jan - March

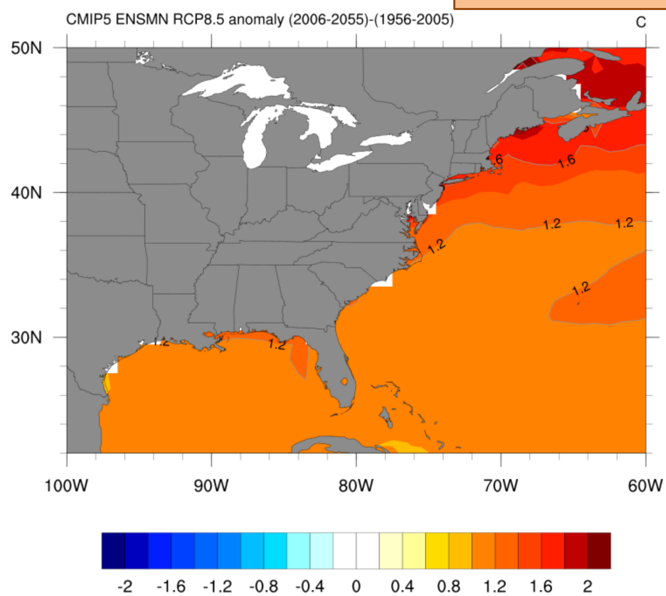


April - June

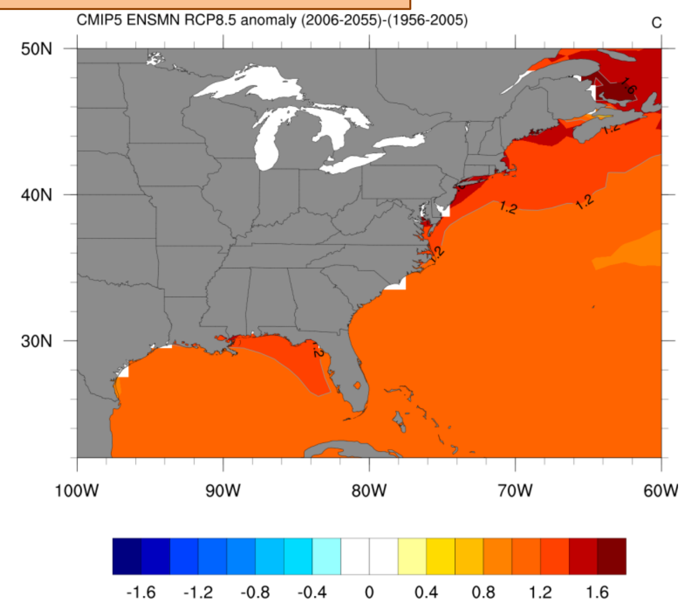


Greatest changes in SST projected in winter and fall

July – Sept



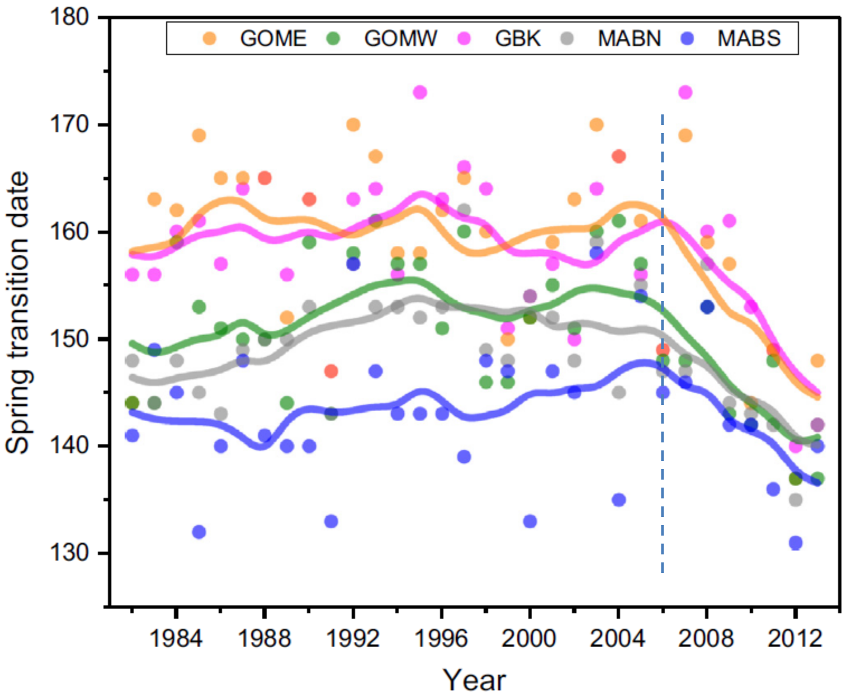
Oct - Dec



Data courtesy of NOAA's Climate Change Web Portal

Changes in the timing of seasons

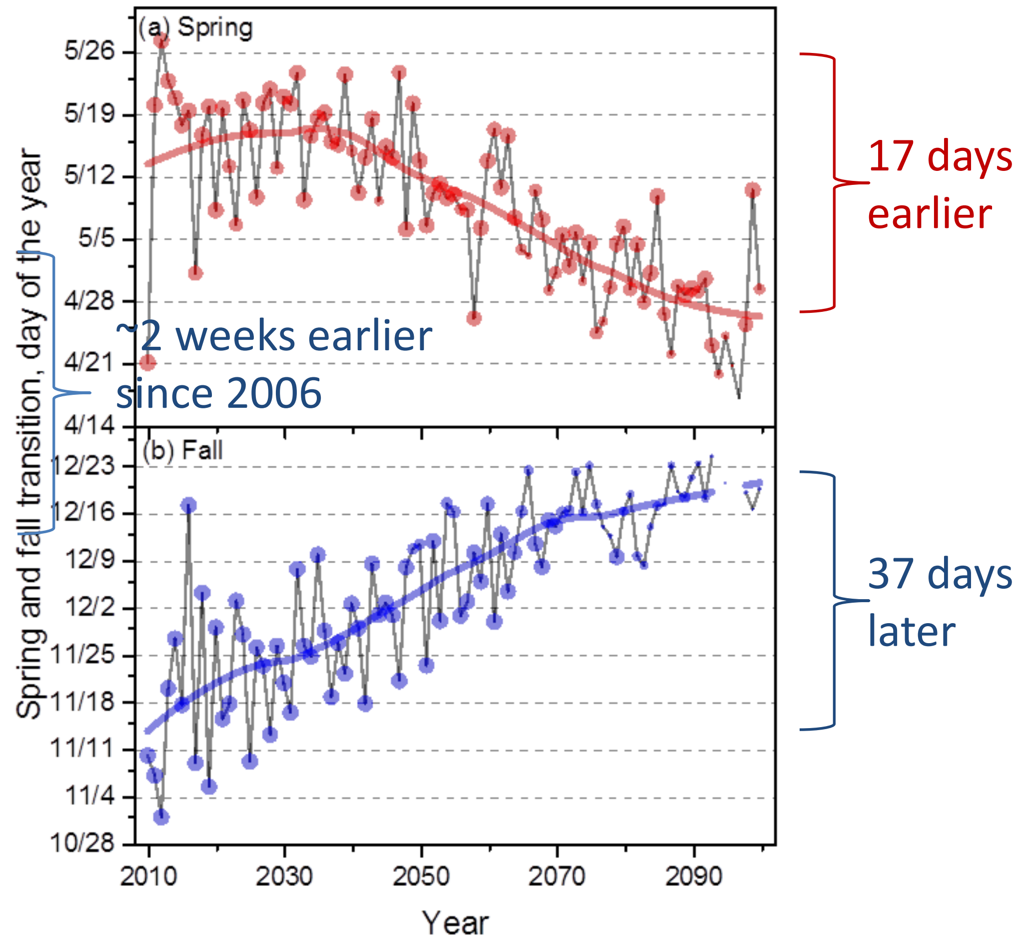
Spring transition dates



GoM (east & west); Georges Bank; Mid-Atlantic Bight (north & south)

Friedland et al. 2015. CSR

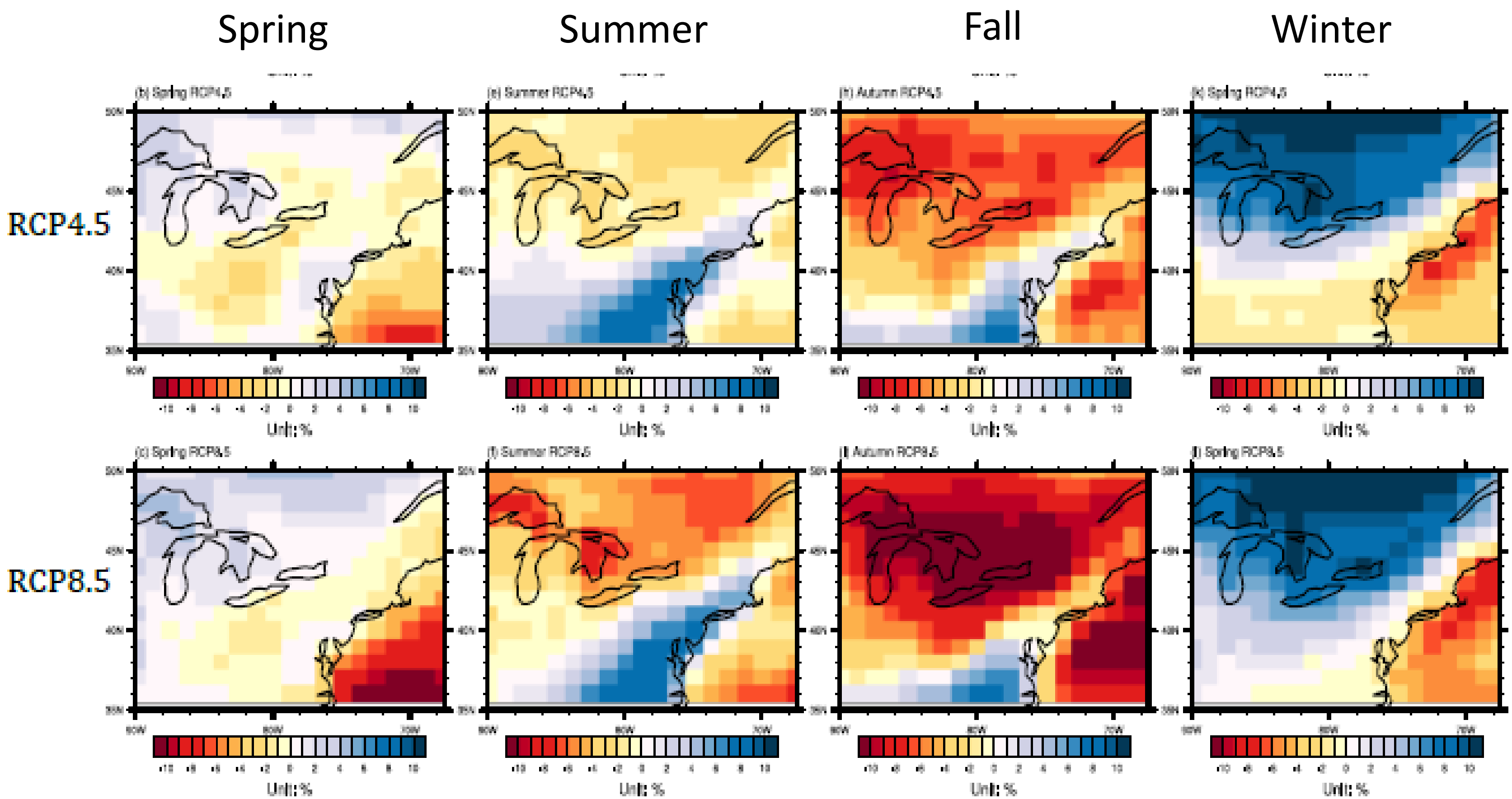
NE Shelf Large Marine Ecosystem



Friedland, unpublished data

Seasonal updates available at: http://www.nefsc.noaa.gov/ecosys/current-conditions/

Projected seasonal precipitation



- Annual precipitation is increasing, particularly in winter (Projections for 2050-2100)
- Precipitation events expected to be less frequent
- More heavy rainfall events
- Increased risk of both flooding and drought

Ning et al. 2015

Spatial distributions of extreme precipitation events

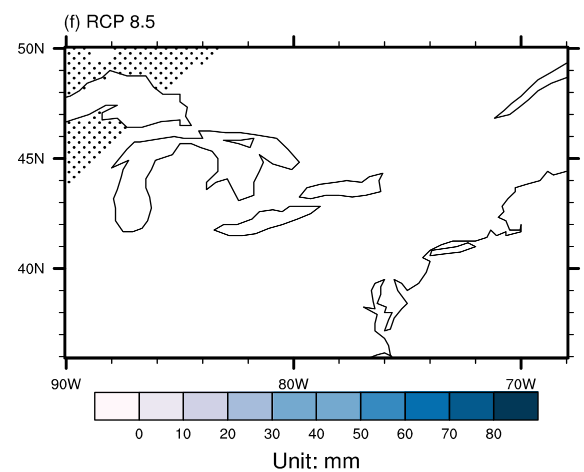
Days

Magnitude (mm)

RCP 4.5

Projections for 2050-2100
Extreme = days with > 10 mm (~0.4 inch)

RCP 8.5



Ning et al. 2015

Observed hydrological shifts

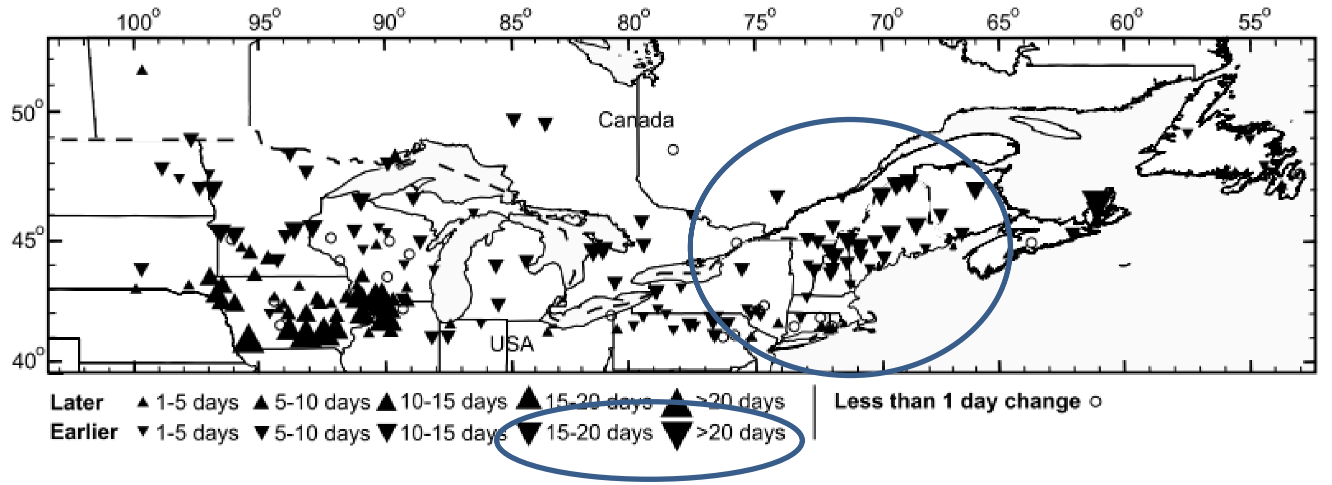
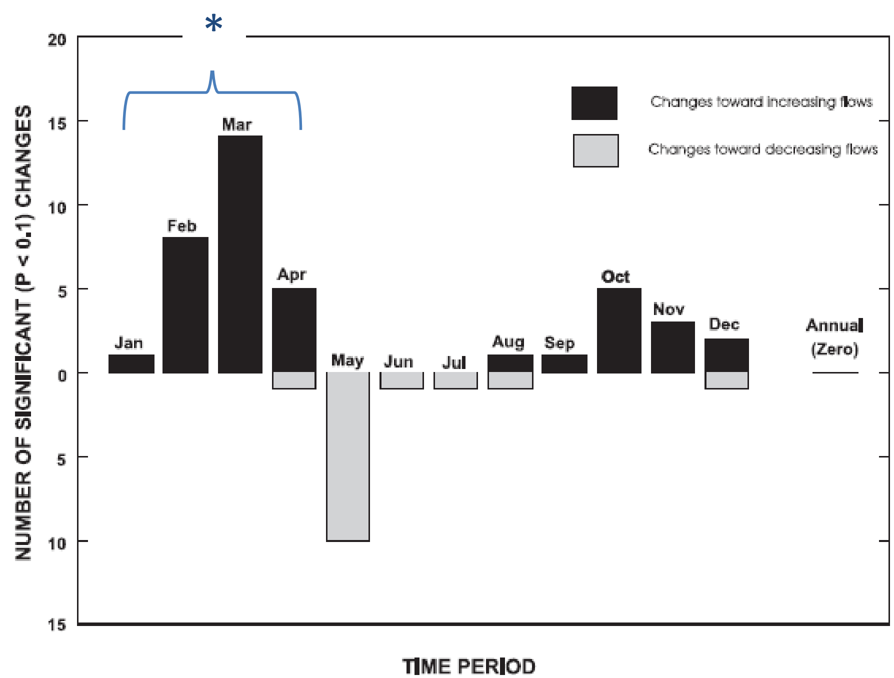


Figure 2. Magnitude and direction of changes in winter-spring center of volume dates, 1953–2002.

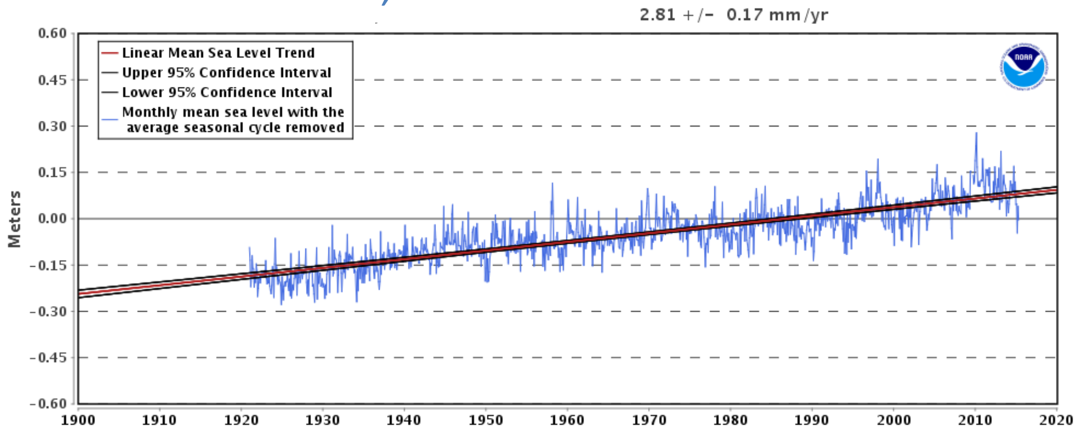
- Peak spring flows have ↑ significantly in volume and shifted earlier by 5 - 15 days (1900 - 2000)

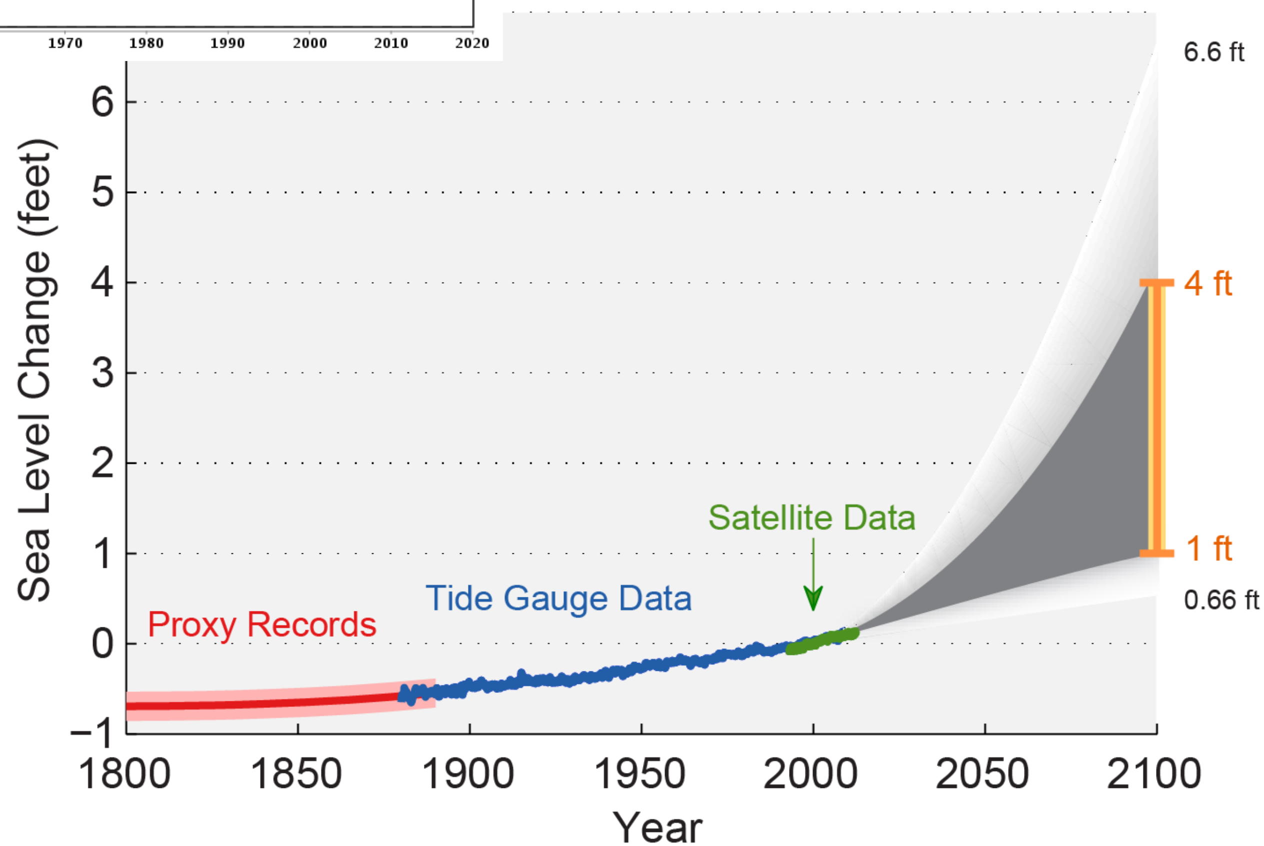


Hodgkins & Dudley 2005; 2006

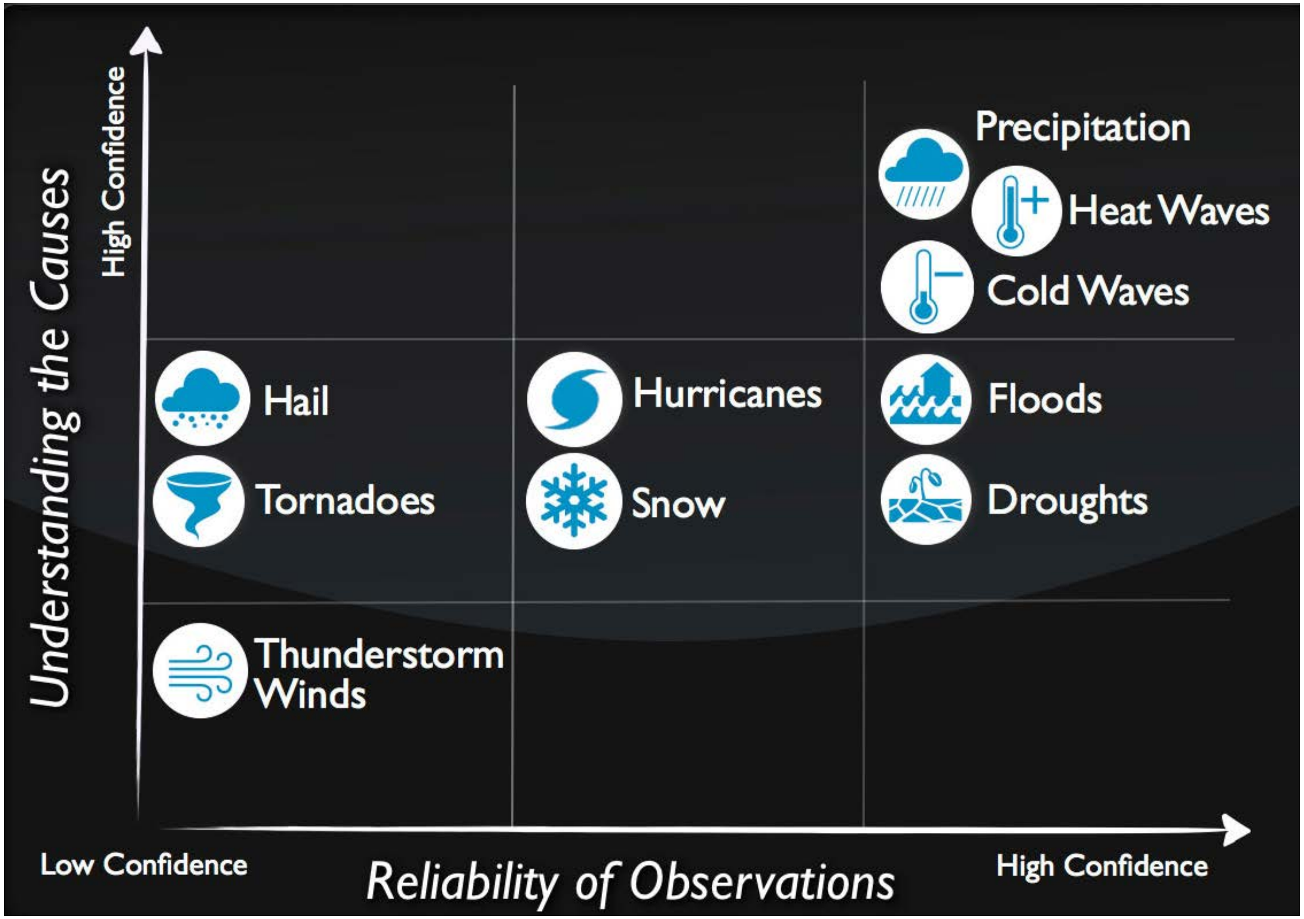
Sea level rise

Boston, MA





Extreme precipitation and storm events



Peterson et al. 2013

Hurricane Irene
August 28, 2011

❖ New paper shows extreme cold winters fueled by jet stream and climate change (*Overland et al. 2016 Nature Climate Change*)

Climate Change Vulnerability Assessments

- Tools used as an initial step in adaptation planning
- *Identify* species and habitats at greatest risk
- Provide index of *relative* vulnerabilities
- Identify key attributes that explain *why* species/habitats are vulnerable
- *Inform* conservation strategies designed to reduce those vulnerabilities

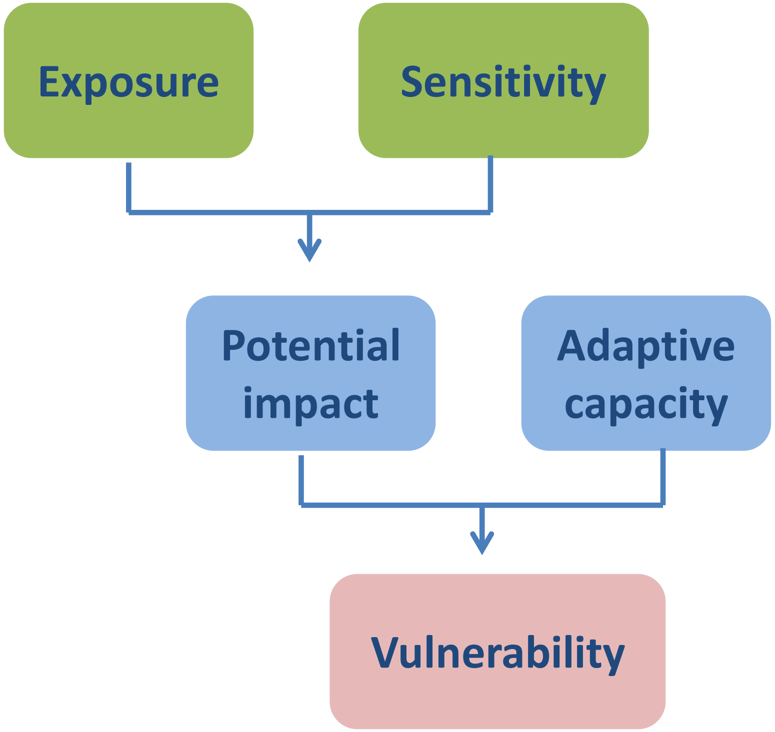
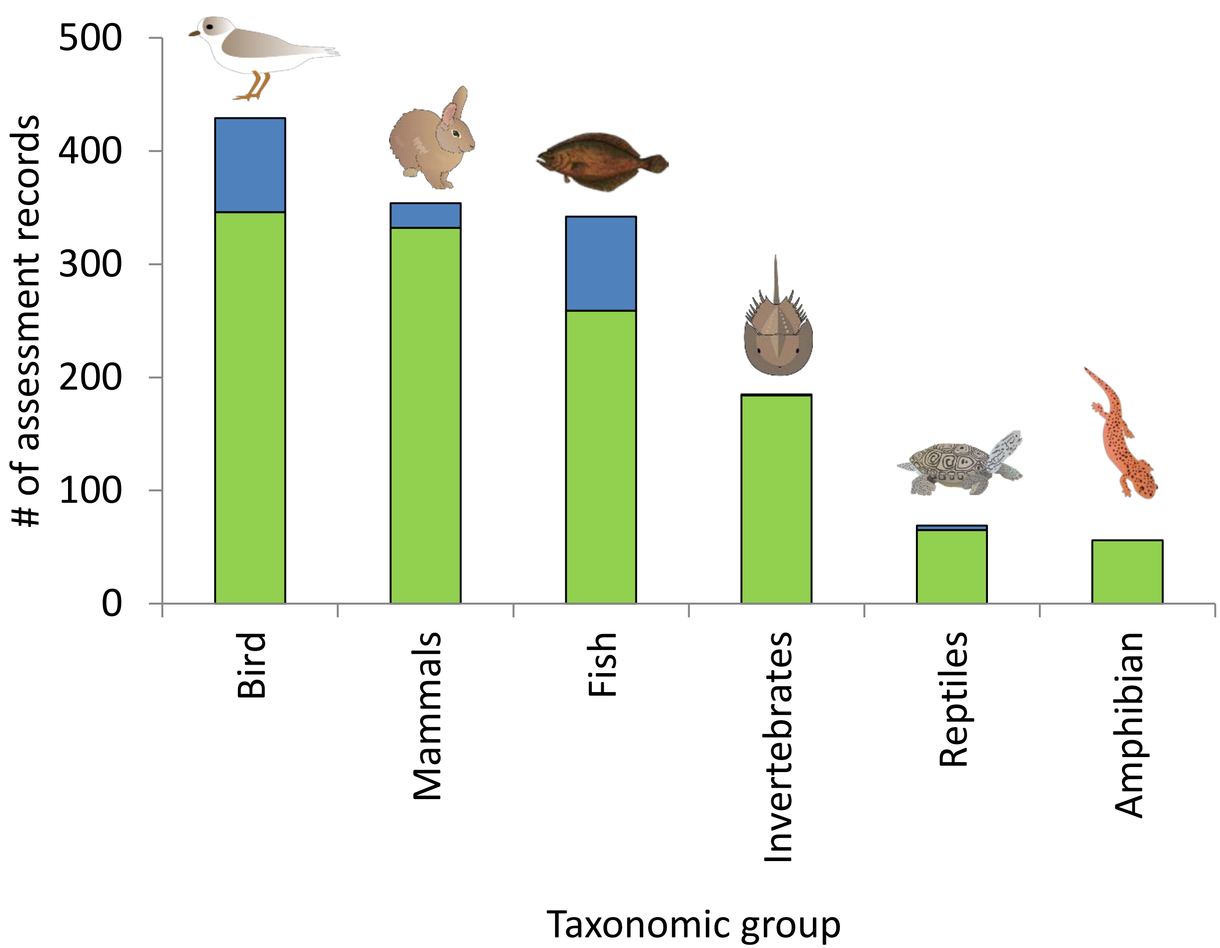


Figure adapted from Glick et al. 2011

Regional synthesis of CCVAs



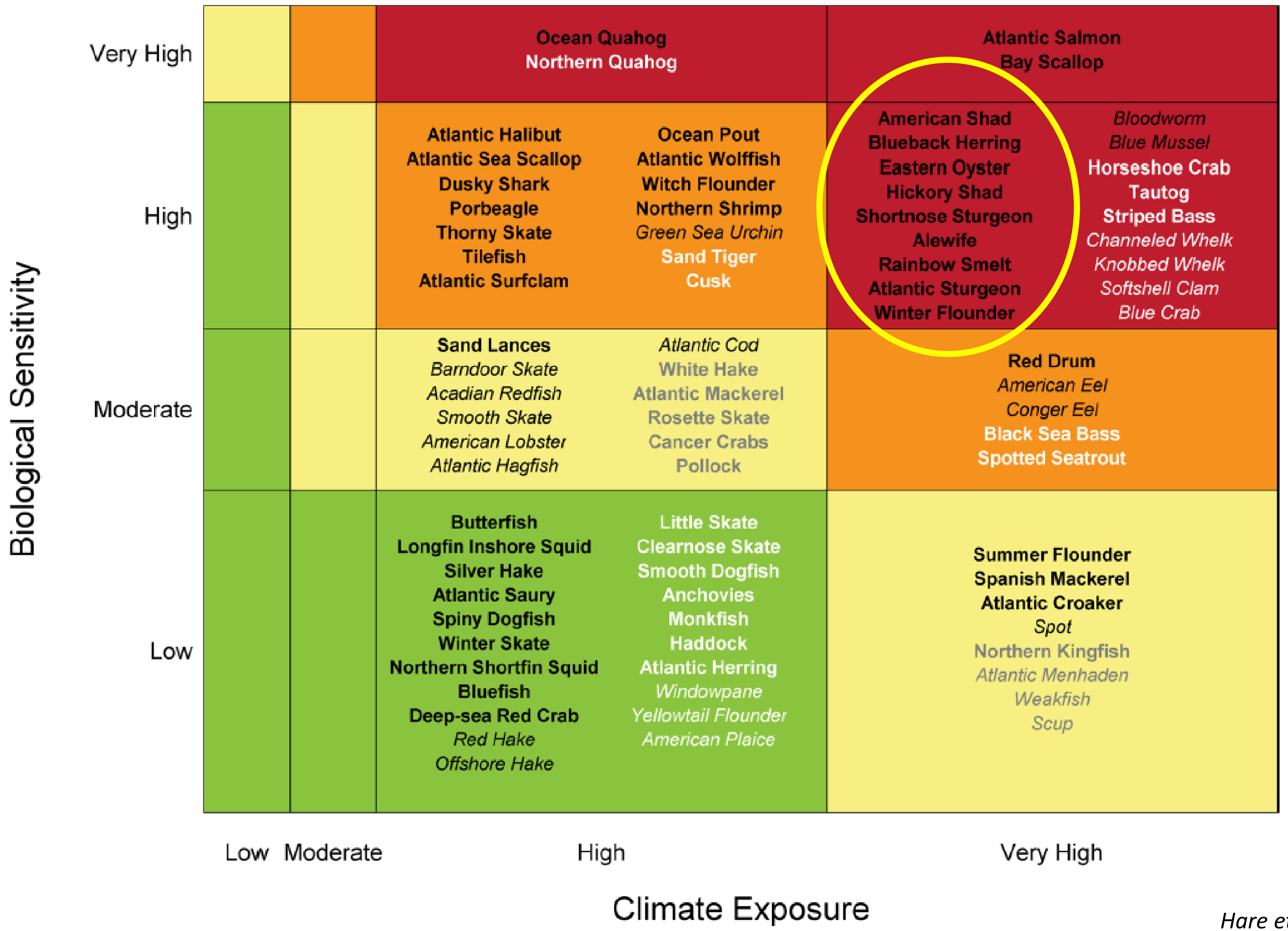
14 studies across Northeast & Mid-west U.S.

Coastal & marine (N = 193; 13%)

Terrestrial & freshwater aquatic (N = 1,242; 87%)

Staudinger et al. 2015

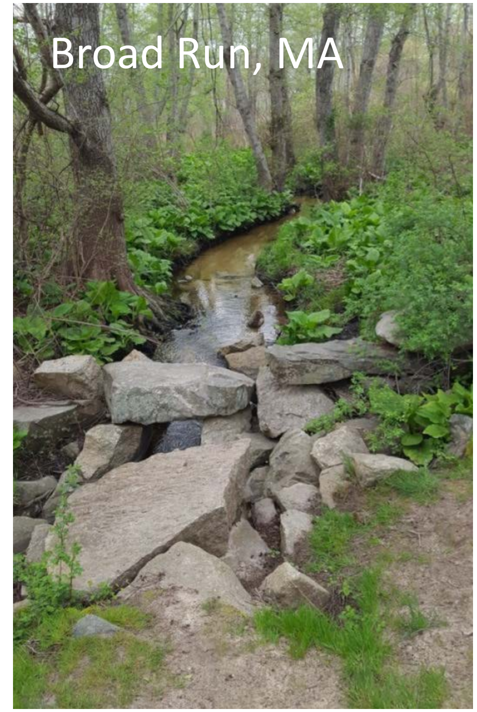
Relative climate vulnerability



Hare et al. 2016

Attributes contributing to climate vulnerability

Ranking: Highly Vulnerable
Confidence: High
Climate scenario: RCP 8.5
Time period: 2005-2055



Factors contributing to river herring's vulnerability to climate change:

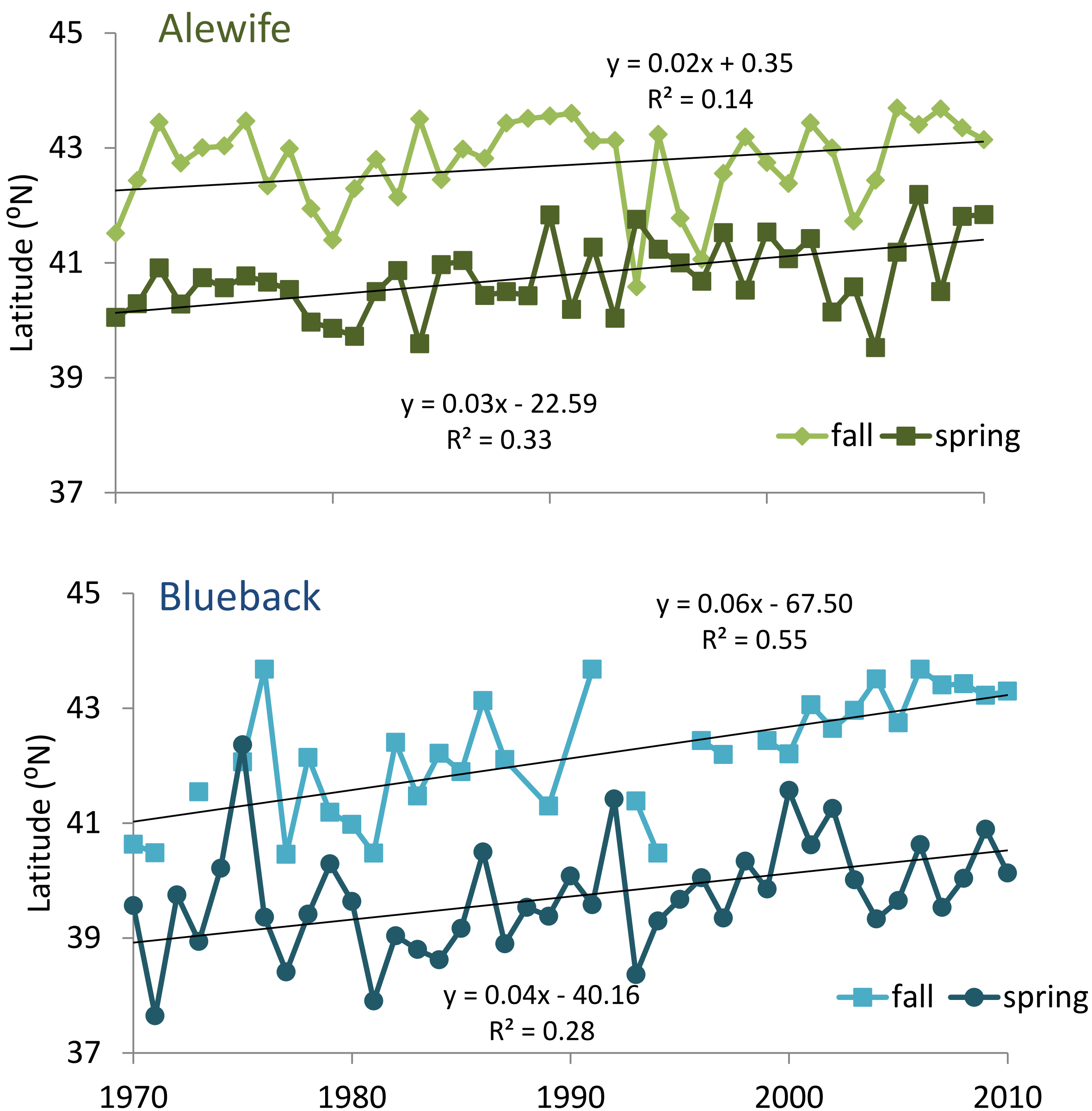
- Increasing SST
- Ocean acidification
- Increasing air T

Exposure

- Spawning cycle
- Early life history requirements
- Complexity in reproduction
- Dispersal and early life history

Sensitivity

Ecological responses to climate impacts



Geographic range shifts (1968-2007)

Alewife

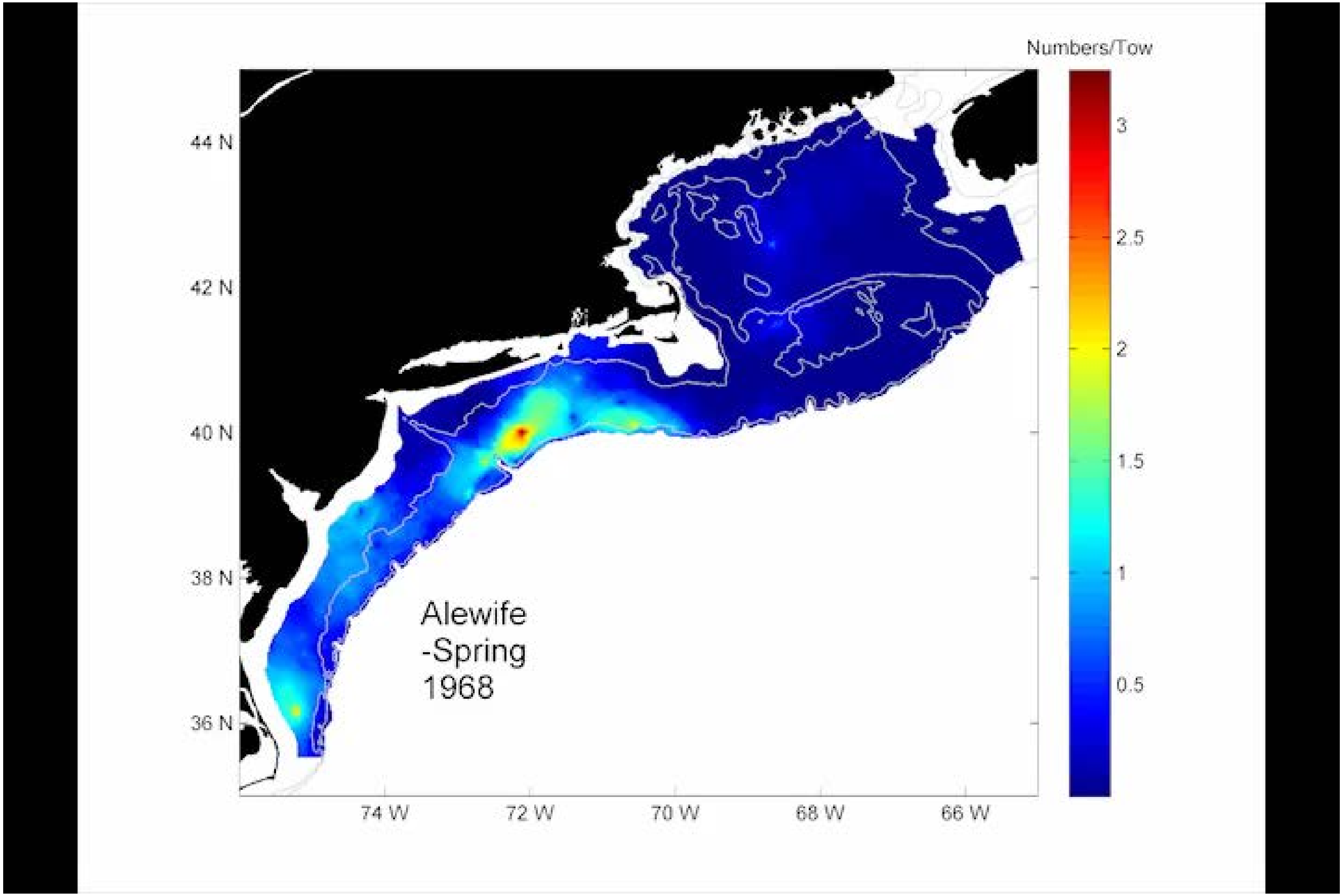
- Poleward Shift: 5.47 km/yr
- Mean depth change: 1.15 m/yr

Nye et al. 2009

❖ Alewife exhibited one of the greatest latitudinal shifts out of 36 stocks

Pinsky et al. 2013. Science, Data downloaded from Ocean Adapt

Ecological responses to climate impacts



Pinsky et al. 2013. Science, Video file courtesy NOAA

Ecological responses to climate impacts

Shifts and increased variability in phenology :

- Migration
- Breeding
- Early life history
- Food habits
- Species interactions
- Fitness

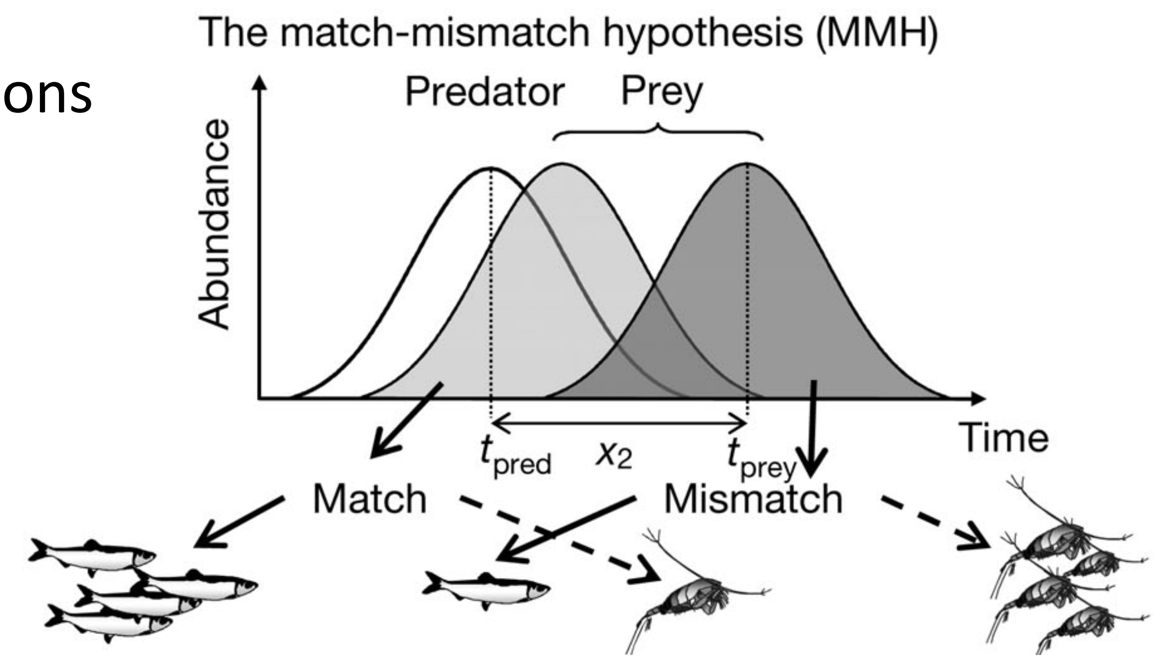


Figure from Durant et al., 2013. MEPS

Ecological and management implications of climate change induced shifts in phenology of coastal fish and wildlife species in the Northeast U.S.

Project Objectives:

- Synthesize alewife spawning migration timing data, potential environmental drivers, climate and other stressors
- Evaluate influence of climate and environmental variables on alewife migration timing
- Determine relationship between habitat quality/extent/connectivity and spawning run strength

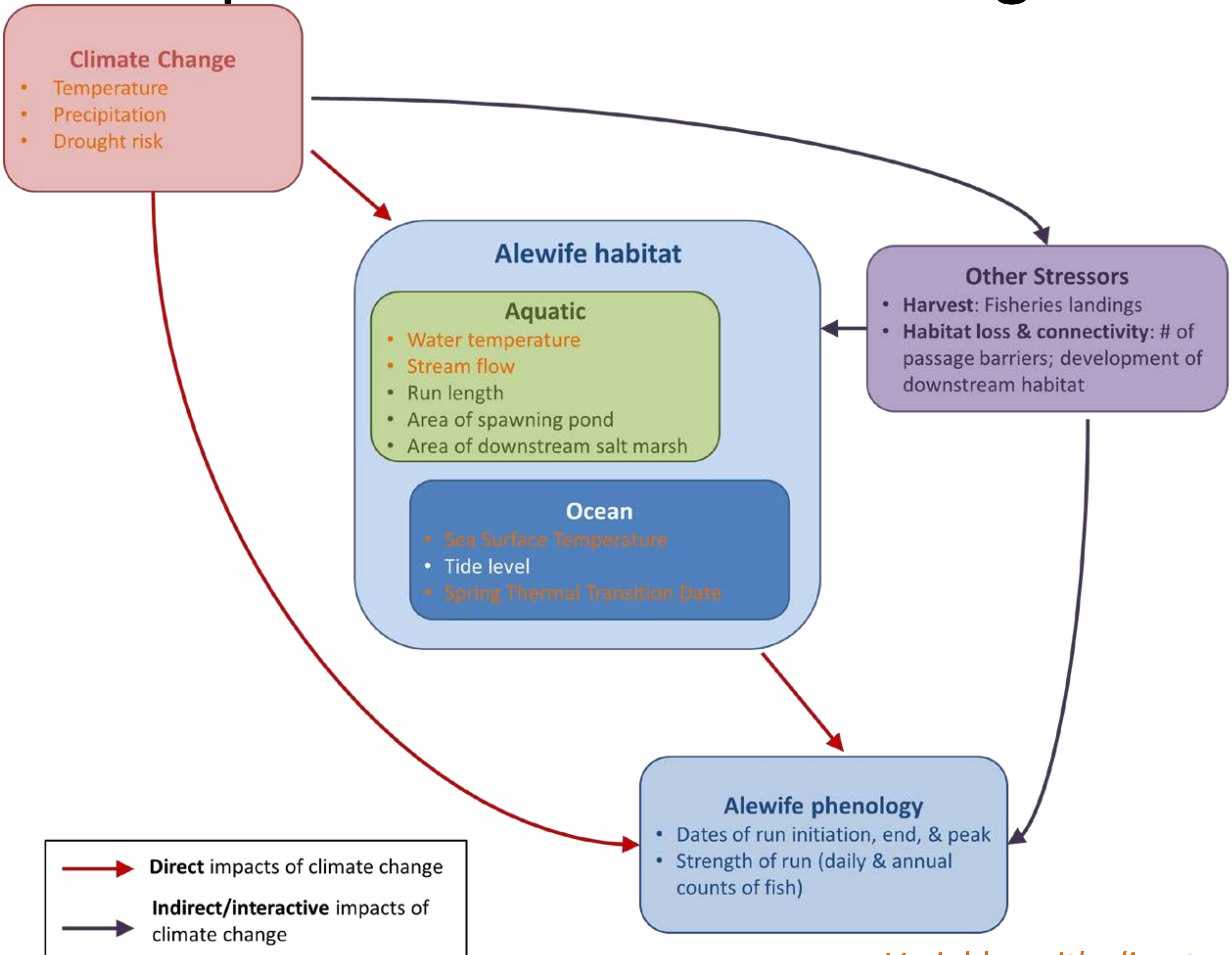
UMASS AMHERST

NECSC Northeast Climate Science Center

USGS science for a changing world

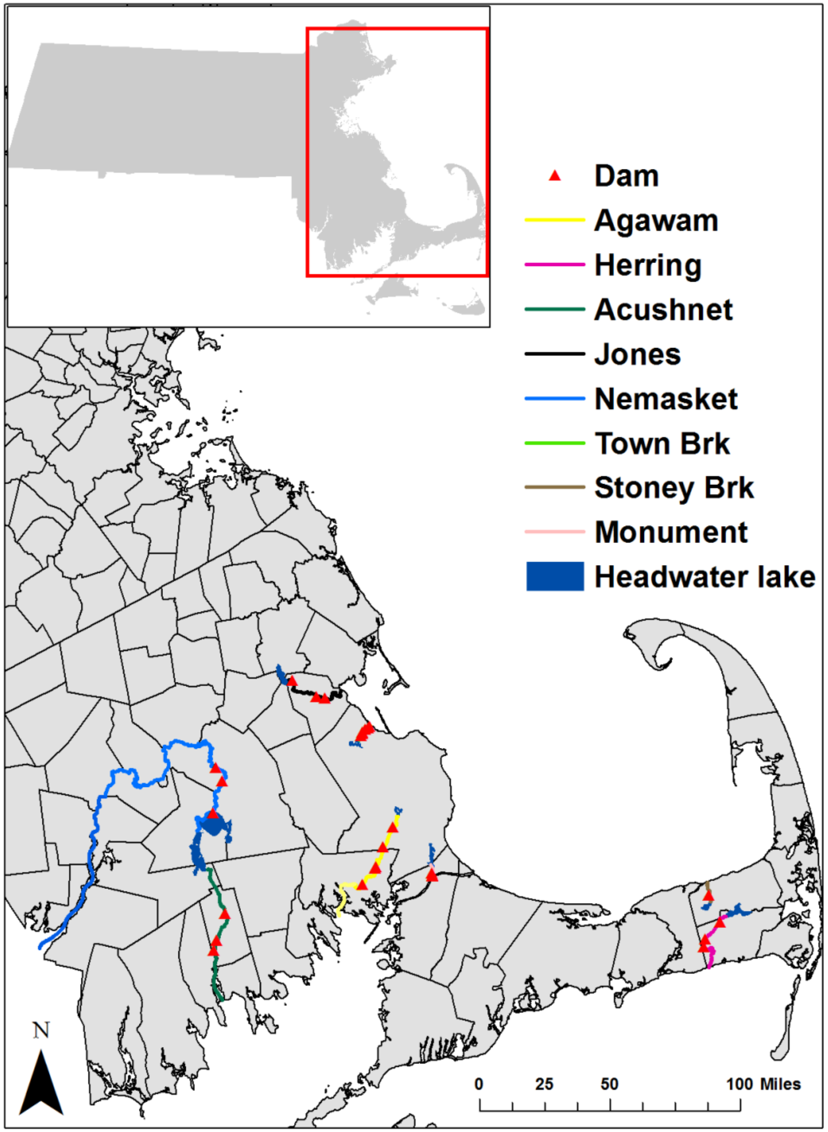
Image: M. Devine

Conceptual model of modeling activities



Variables with climate projections

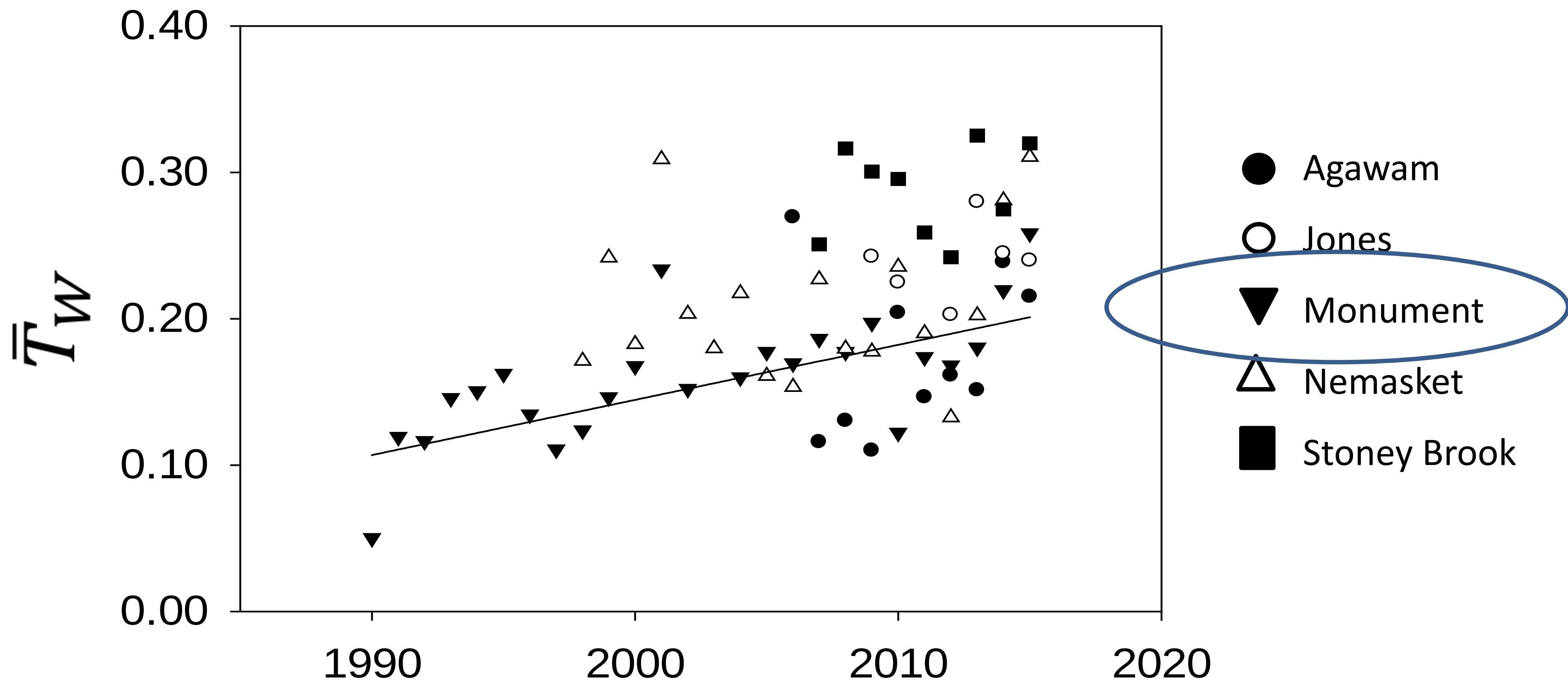
Changes in alewife spawning run timing



Location	Range of Years	Mean day of year		Direction of change	
		Run initiation	Run peak	Run initiation	Run peak
Acushnet	2005-2015	98	120	↓	↓
Agawam	2006-2015	88	117	—	↓
Herring	2009-2015	97	122	↓	↑
Jones	2005-2015	101	120	—	↓
Monument	1990-2015	100	123	↓	↓
Nemasket	1998-2015	81	105	—	—
Stoney Brook	2007-2015	105	125	↓	↑
Town Brook	2010-2015	98	120	↑	↑

↑ later ↓ earlier — no change

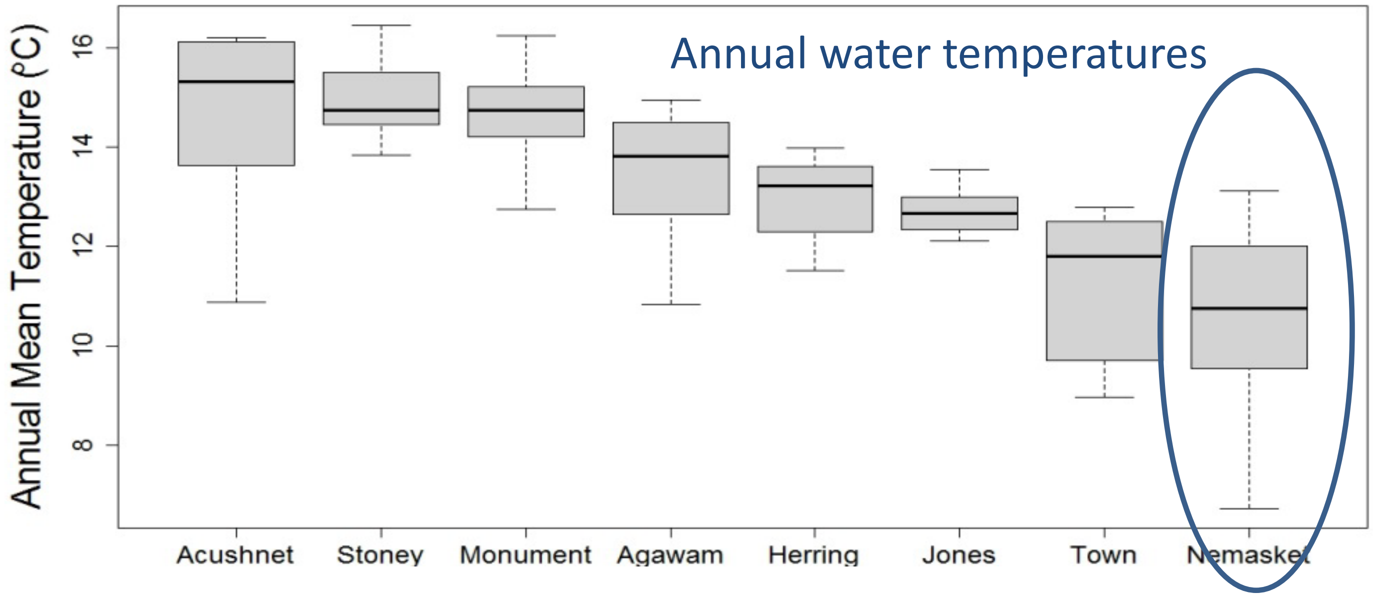
Weighted mean migration temperatures

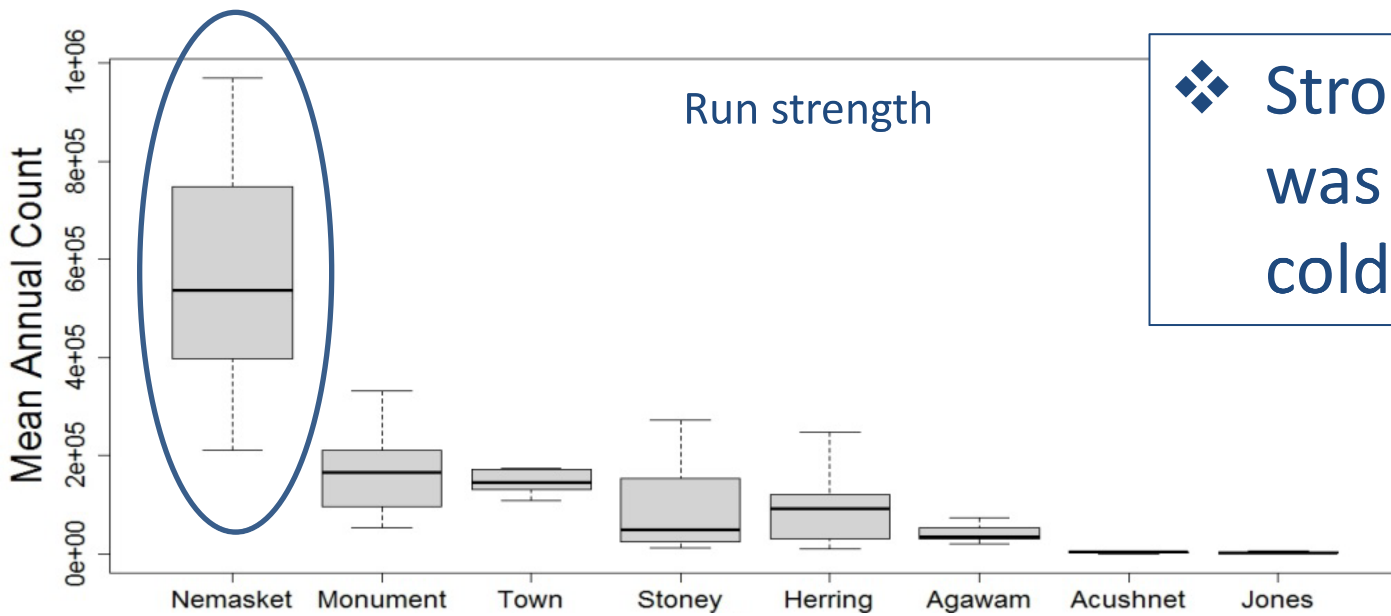


$$\bar{T}_W = \frac{\text{daily \# of fish x daily temp}}{\text{Annual total \# of fish}}$$

Estimates the temperature that best characterizes each population (Quinn & Adams 1996; Ellis & Vokoun 2009)

Annual temperatures and counts





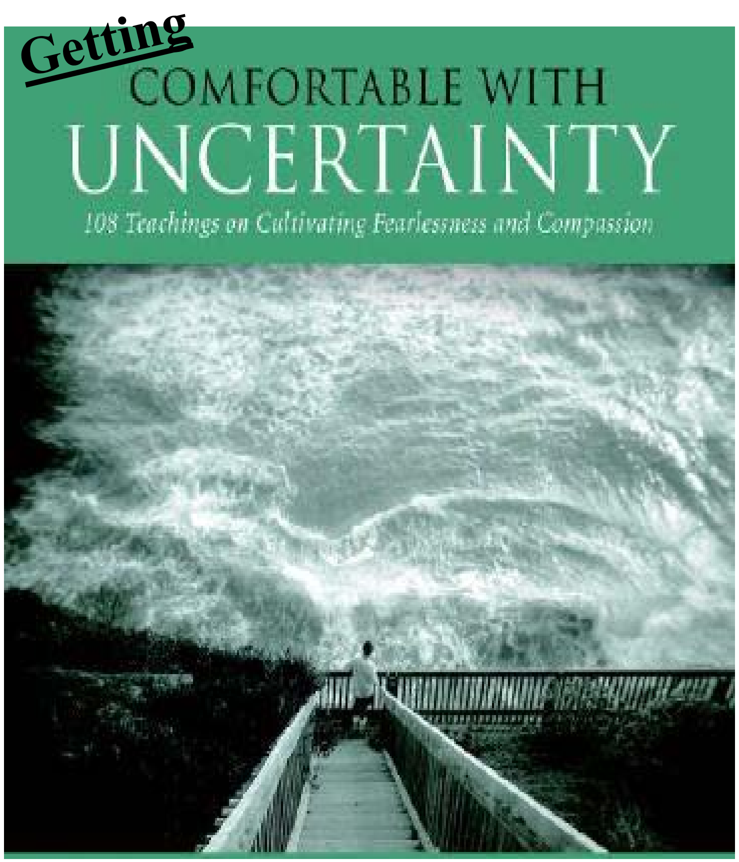
- Strongest run was in the coldest river

Next steps

- Evaluate drivers of migration patterns – temperature or flow?
- Synthesize data from additional sites in MA and New England
- Evaluate influence of climate from other stressors

Managing for change

- “Stationarity is dead”
- Consideration of uncertain future projections as well as historic conditions
- Emphasis on landscape-scale conservation, connectivity among protected habitats, and ecological functioning



Massachussetts Wildlife
CLIMATE ACTION TOOL

Select your topic of interest to learn how climate change is affecting your community's fish, wildlife, and other natural resources. Use the tool to explore and plan climate change adaptation actions.

I'm interested in…

- LEARNING ABOUT CLIMATE CHANGE
- FISH & WILDLIFE
- FOREST RESOURCES
- WETLAND & AQUATIC RESOURCES
- PROTECTING LAND
- MANAGING MY LAND
- ROADS & OTHER INFRASTRUCTURE
- IMPROVING POLICY, LAWS & REGULATIONS
- LAND USE PLANNING
- STARTING WITH TOWN OR WATERSHED

Massachusetts Wildlife Climate Action Tool

Inspiring local action to protect the Commonwealth's natural resources in a changing climate

A Cooperative Project Involving:

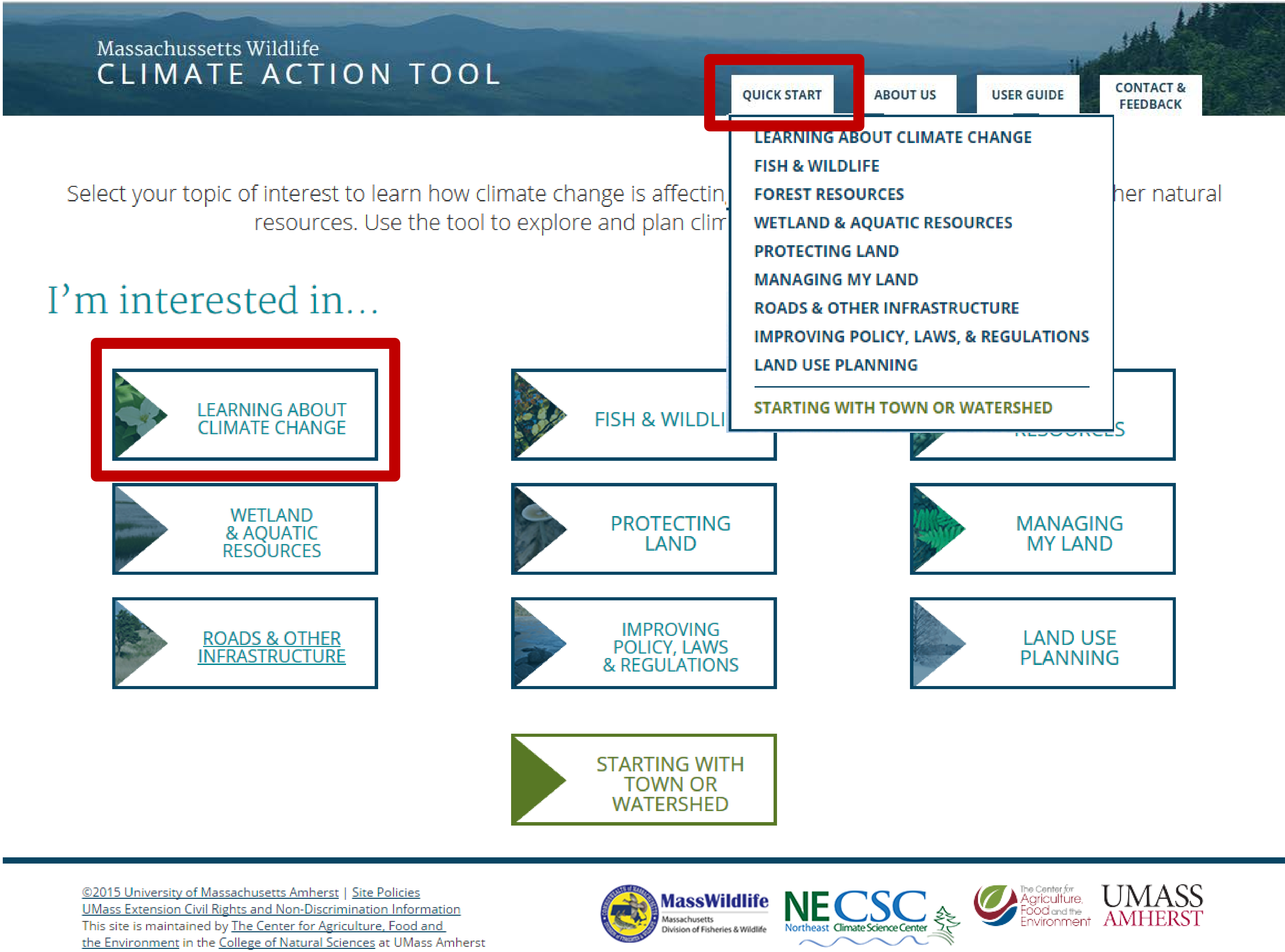
- MA Division of Fisheries and Wildlife
- UMass Amherst Center for Agriculture, Food and the Environment
- MA USGS Cooperative Fish and Wildlife Research Unit
- DOI Northeast Climate Science Center

Objective: Make science accessible for people active at the local and regional levels by providing -

- Information about climate change impacts
- Vulnerabilities of various fish, wildlife, and habitats
- Actions that can be taken to maintain ecosystem health and productivity in the face of climate change

Target Audiences:

- Local conservation organizations (land trusts, watershed associations)
- Municipal government (conservation commissions, open space committees, departments of public works)
- Regional planning authorities (RPAs)
- Landowners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ABOUT US
USER GUIDE
CONTACT & FEEDBACK
LEARNING ABOUT CLIMATE CHANGE
FISH & WILDLIFE
FOREST RESOURCES
WETLAND & AQUATIC RESOURCES
PROTECTING LAND
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Learning about Climate Change

Overall Trends in Climate Change | Uncertainty | Emission and Climate Scenarios | Climate Models | Interpreting Outputs | Projections Used | Other Resources | References

Overall Trends in Climate Change

The climate is changing rapidly in Massachusetts in ways that have already impacted fish, wildlife, and their habitats. These impacts will continue as climate change increases over the coming decades.

Warming is occurring in all seasons, with the greatest changes in winter, at higher latitudes, and potentially at higher elevations. Seasonal warming is extending the growing season, particularly with more frost free days occurring earlier in spring. Precipitation amounts are increasing, especially in winter. Warmer winters are also resulting in more precipitation falling as rain instead of snow, leading to reduced snowpacks - though stronger blizzards may lead to locally higher snowpacks in Massachusetts and New England. In the summer, heavier downpours combined with longer dry streaks are expected, increasing the risk of both droughts and floods. Sea level is also rising at a rapid rate along the Massachusetts coastline, leading to coastal flooding, which is compounded by increasingly intense coastal storms, such as hurricanes.

- Temperature changes
- Precipitation changes
- Changes in hydrology
- Changes in winter
- Sea level rise
- Storms and floods
- Change in timing of seasons

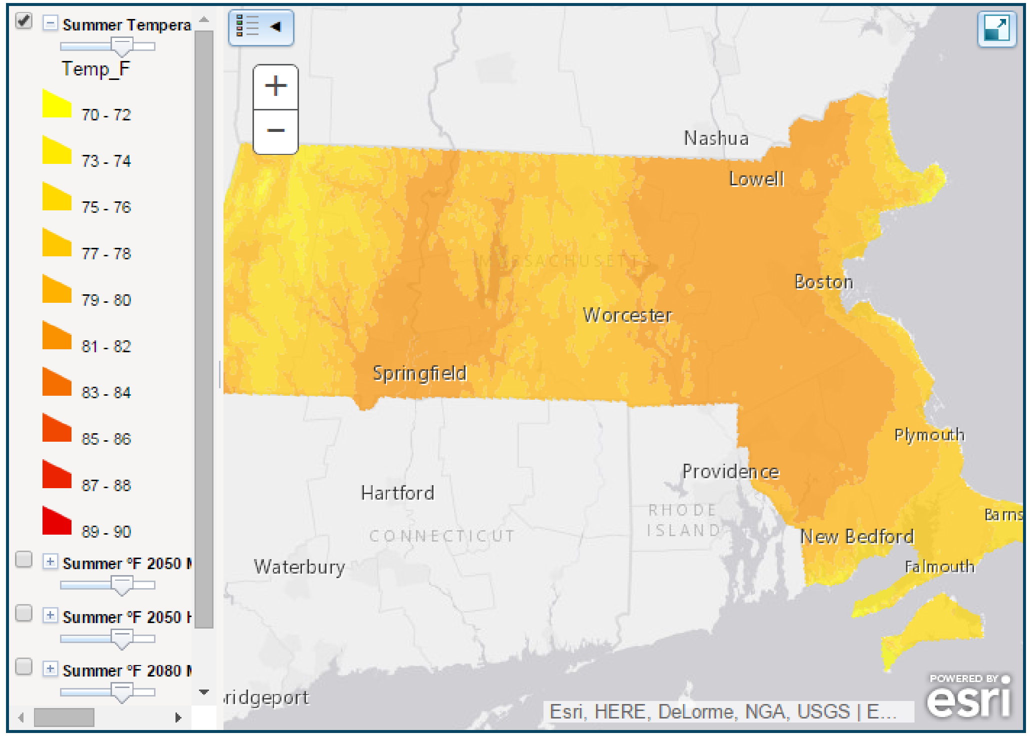
Climate changes over the past century can be explained through a combination of human and natural factors with the majority explained by

Stressors

Temperature changes

Annual and Seasonal Temperature Changes

The Earth's climate is warming. Global average annual temperatures have increased by 1.5° F since 1895, and the vast majority of this increase has occurred since 1980. The Northeast United States has experienced an increase in annual temperatures of 1.6°F over the last century. Warming has been occurring during all seasons, but has been greatest during winter (0.24°F/decade). Warming is also greatest at higher latitudes, elevations, and inland from the Atlantic coast.



Climate projections displayed in this map represent the average of the maximum air temperature (degrees F) for June, July, and August for the years 2010-2080...
Read More

Future climate projections consistently show continued warming over the 21st century across Massachusetts and the entire New England region. All climate models agree that the warming trend will continue over the coming decades with high emission scenarios giving the greatest warming. However, for a given emissions scenario, the exact magnitude of warming varies slightly depending on the models used and their structure. Massachusetts is projected to see average temperature increases that exceed the global average, with potential warming of around 5°F annually by mid-century under a high emissions scenario. Model projections of future seasonal changes generally suggest winter will continue to show the greatest amounts of warming with increases up to 5°F by mid-century.

Extreme Temperature Events

Extreme temperatures in the form of heatwaves may become more frequent, more intense, and last longer. Extreme high temperature events are on the rise globally. Warmer night-time temperatures are driving this overall trend with fewer cold nights and more warm nights. However,

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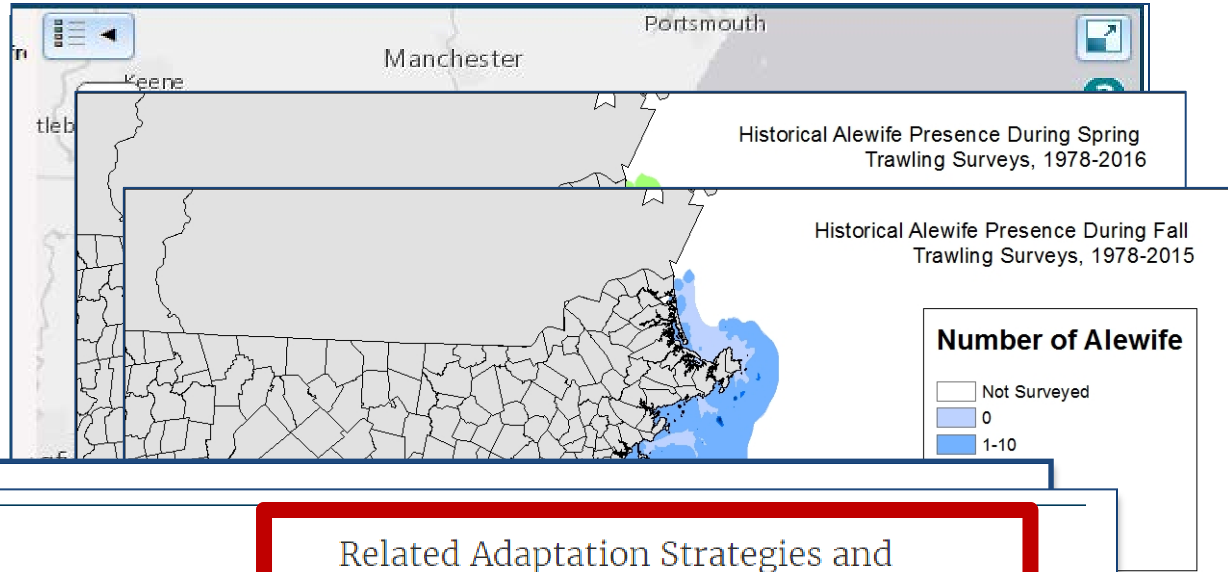
Alewife

Photo credit: Leanda Fontaine, MassWildlife



Related Habitats (broad)

Coastal

Lakes and ponds

Rivers and streams

Related Habitats (detailed)

Coastal: Estuaries & embayments

Lakes and ponds: Small lakes and ponds

Rivers and streams: Large and great rivers

Rivers and streams: Rivers

Related Species Groups

Fish

Fish: Diadromous Fish

Wetland and Aquatic Species

Related Adaptation Strategies and Actions

Maintain habitat connectivity: Assessment of road-stream crossings

Maintain habitat connectivity: Retrofit or replace culverts

Protect land: Protect land in perpetuity

Protect land: Strategic land protection

Restore habitat connectivity: Remove obsolete dams

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Adaptation Strategies and Actions

Maintain habitat connectivity:
- Retrofit or replace culverts
- Assessment of road-stream crossings

Restore habitat connectivity & corridors:
- Removal of dams and other barriers

Aquatic & terrestrial

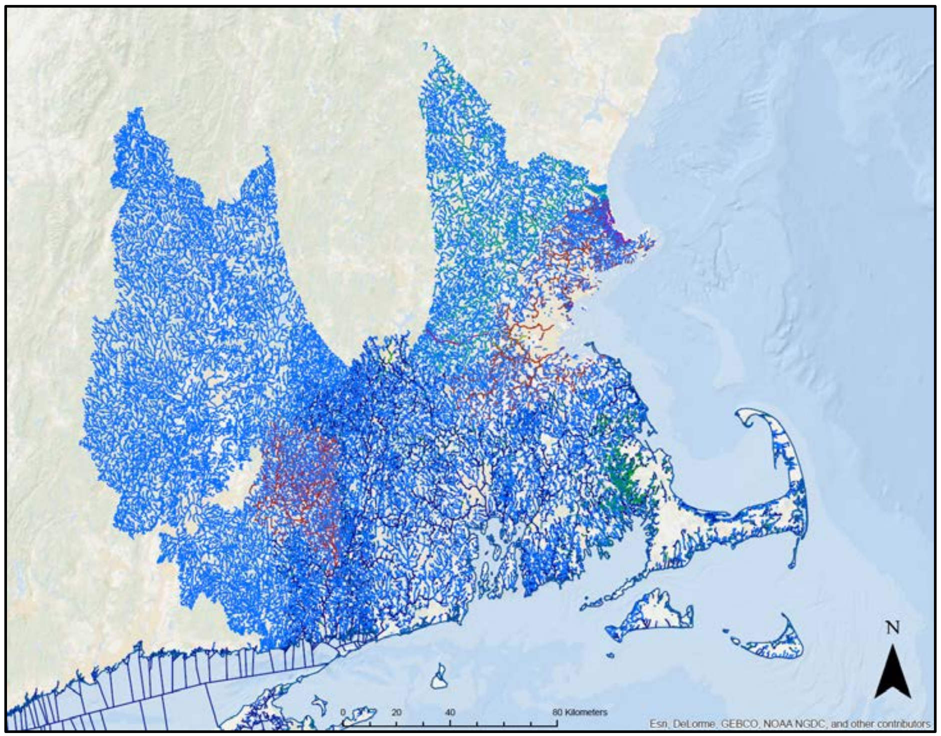
Restore natural coastal buffers:
- Native vegetation buffers and plantings

Restoring affected estuaries:
- Reduce nutrient and sediment pollution runoff

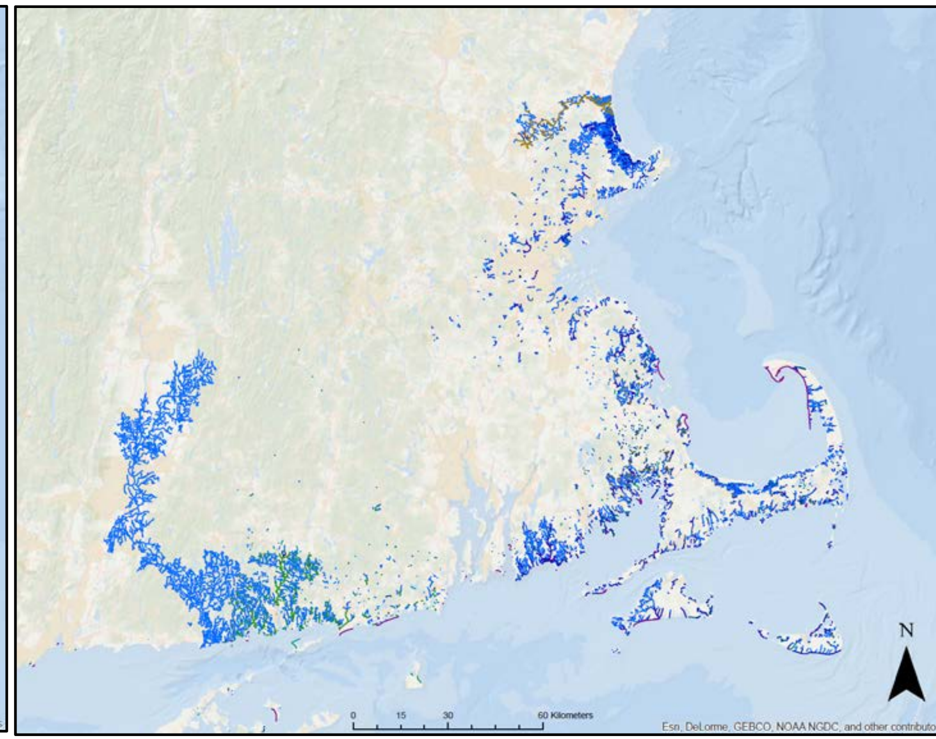
Coastal & marine

Available river herring spawning habitat

1600



1900



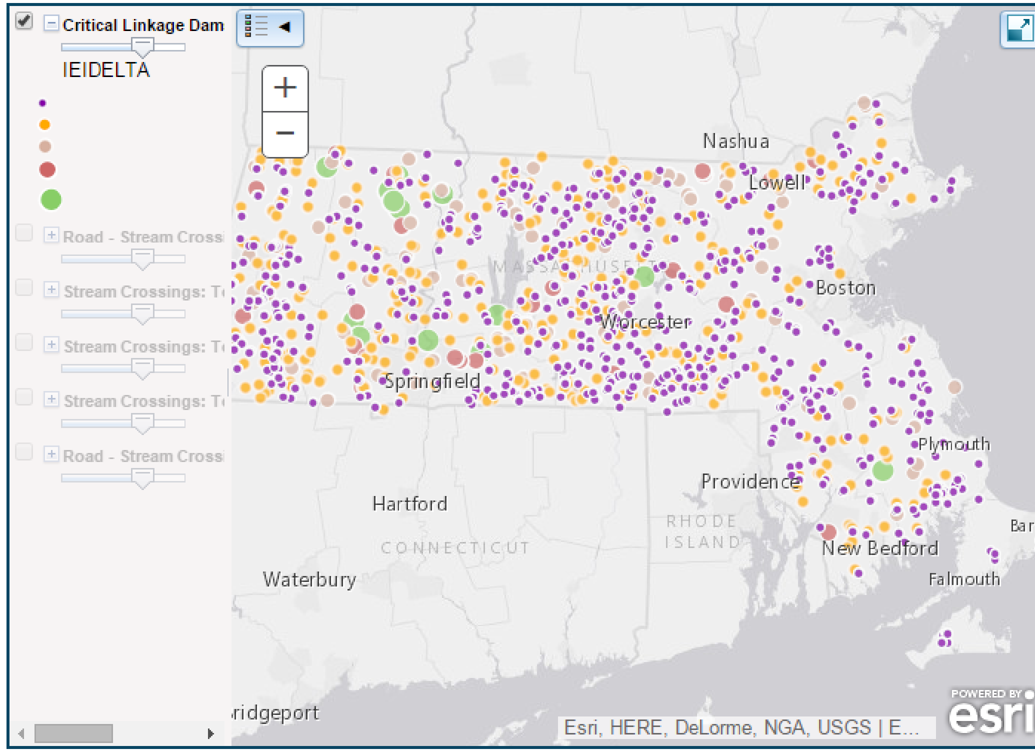
- Mean lake and stream habitat remaining in 5 New England watersheds by 1900 was 14.7% and 16.6%, respectively

Figures from S. Mattocks MS Thesis

Stressors

Aquatic connectivity loss (roads and dams)

Fish and wildlife need to move in order to feed, reproduce, avoid predators, respond to changing habitat conditions and maintain health local and regional populations. Species that inhabit wetlands and aquatic ecosystems often rely on an interconnected network of streams and rivers as pathways for movement. Fully aquatic species (fish, mussels, crayfish) travel through the water while semi-aquatic wildlife (turtles, salamanders, beaver, mink, otter) move along streams utilizing both water and adjacent upland or wetland habitats.



The first data layer is the results of a Critical Linkages analysis of dams based on the ecological restoration potential of dam removal; larger circles represent greater restoration potential.... **Read More**

Downstream movements are not generally difficult for these species, unless they have to pass over a dam or through a hydroelectric turbine. In fact, much downstream movement occurs involuntarily during flood events.
Upstream movements are much more difficult as aquatic organisms must make headway against the current and contend with shallow riffles, natural waterfalls and cascades, and a variety of human created obstacles such as dams and road-stream crossings (bridges and culverts). Yet, without upstream movements that counter the inevitable downward shift in organisms headwater streams would be depopulated of fish and wildlife.

Rivers and streams are long, linear ecosystems that stretch out across the landscape. As such they are highly vulnerable to fragmentation due to barriers such as dams, channelized and buried stream segments, and the numerous intersections of roads and streams. Under normal conditions, this fragmentation is a serious conservation challenge. Given the stresses anticipated with climate change – increased water

Most culverts under roads were designed to pass water, not fish or wildlife. Thus, many culverts represent significant barriers to the passage of aquatic organisms as well as some semi-aquatic wildlife, such as turtles. Photo credit: Scott Jackson.

Resources

North Atlantic Aquatic Connectivity Collaborative (NAACC)
Critical Linkages Phase I
MA Division of Ecological Restoration - Aquatic Ecosystem Restoration

Related Adaptation Strategies and Actions

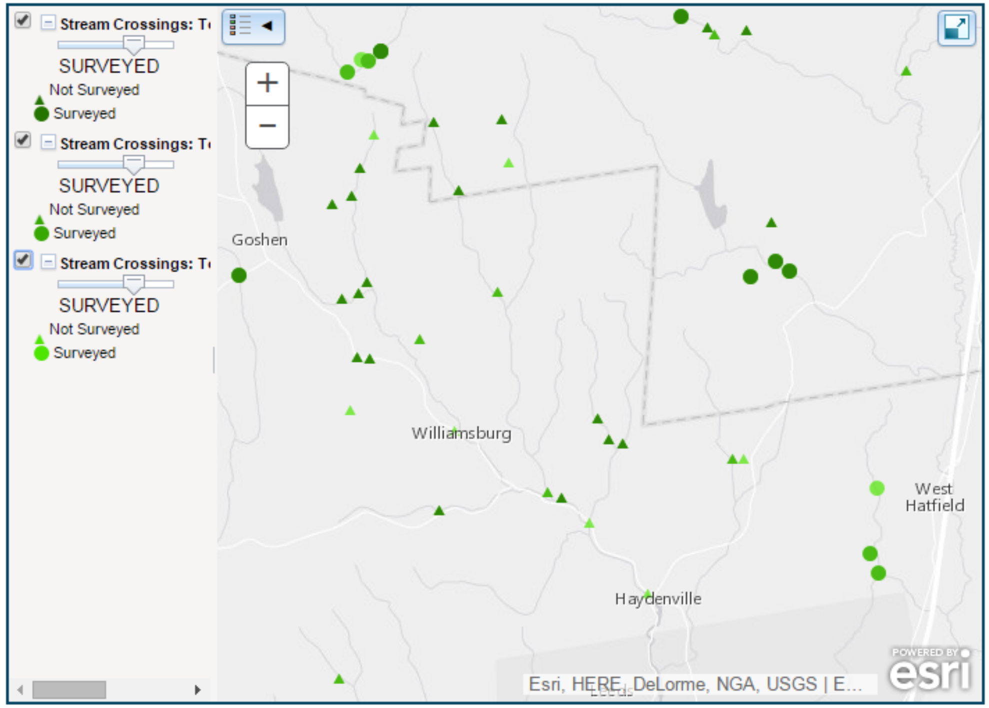
Land protection: Strategic land protection
Maintain habitat connectivity: Assessment of road-stream crossings
Maintain habitat connectivity: Modify stream crossings to allow wildlife passage
Maintain habitat connectivity: Retrofit or replace culverts
Restore habitat connectivity: Remove obsolete dams

Adaptation Strategies and Actions

Maintain habitat connectivity: Retrofit or replace culverts

Adaptation type:
Removal of dams and other barriers to aquatic connectivity
Roadway infrastructure, crossings, and dams

Strategy:
Restore and maintain terrestrial and aquatic connectivity sufficient to maintain healthy ecosystems and wildlife populations



Priority crossings for possible culvert replacement or retrofit are represented by green dots and triangles. If these are not visible, use the plus sign to zoom in. You can layer in locations for...
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Animal movements (of individuals or their offspring) across the landscape are important for maintaining health wildlife populations. Climate change is likely to result in changes to habitat conditions (temperature, rainfall, vegetation) that will require adjustments in the areas occupied by many species. Restoring and maintaining landscape connectivity sufficient to allow wildlife populations to adjust their distribution over time is a critically important strategy for adapting to climate change.

Action

Replace or retrofit deficient culverts at strategic locations

It has been recognized that dams are significant barriers to upstream movement of fish and other aquatic organisms. Road-stream crossings, especially culverts, can also constitute barriers to aquatic organism passage. Although the impacts of dams may be more severe, road-stream projects. Tim Chorey has extensive experience with culvert replacement, Stream Simulation design, and construction. He is available to provide technical assistance and can be reached at: email: timothy.chorey at state.ma.us or phone: (617) 626-1541.

Before

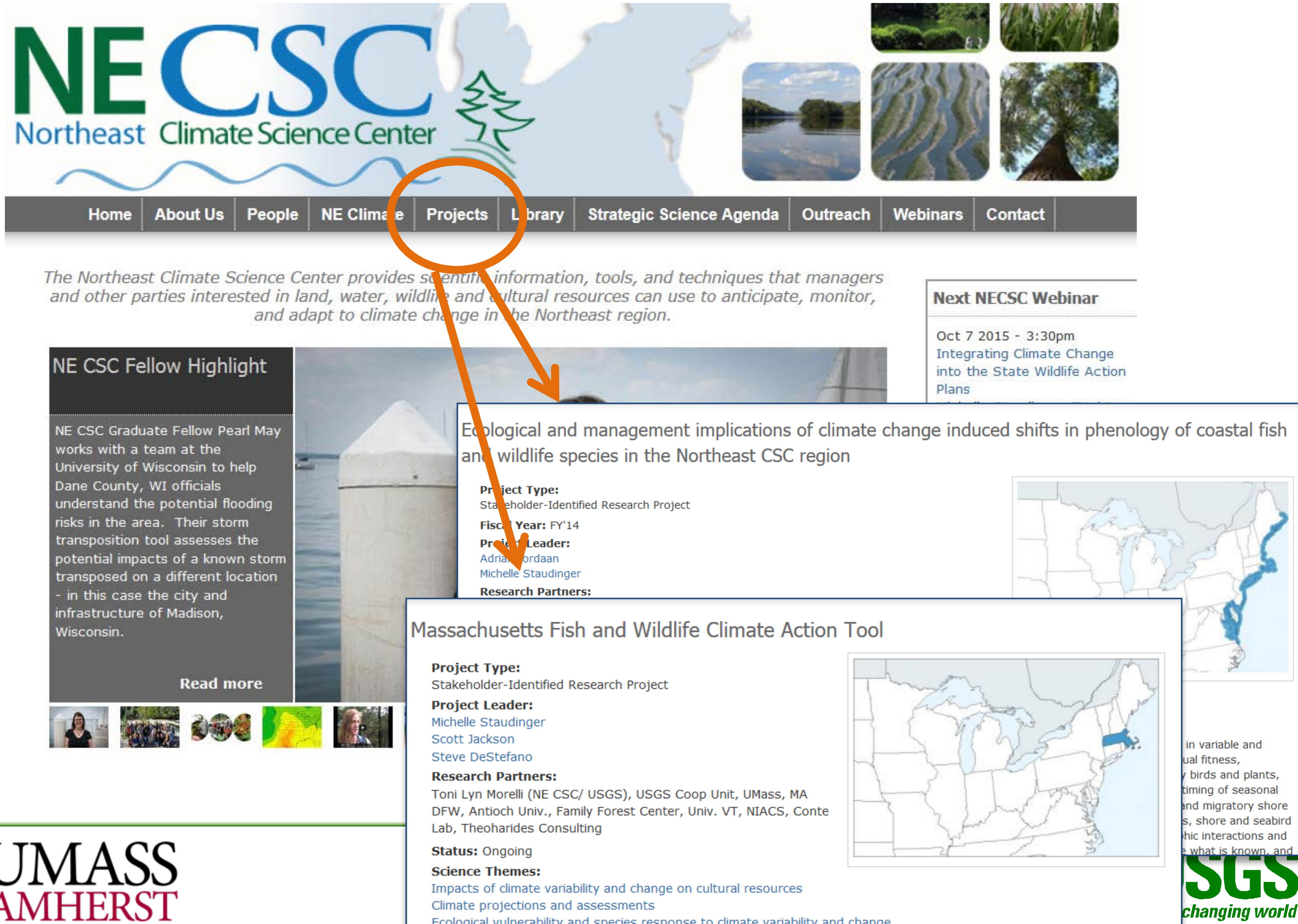
After

Mitchell Brook in Whately, MA, before and after culvert replacement. The PVC piping in the photos are antennae to monitor the passage of fish through the crossing. Researchers report that not only are more brook trout moving from the West Brook up into Mitchell Brook but dace are now being found in the stream for the first time. Photo credits: Scott Jackson.

Resources

USFS Stream Simulation Manual
Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams
Massachusetts Stream Crossings Handbook
Massachusetts Stream Crossings Poster
Massachusetts River and Stream Crossing Standards
Culvert Replacement Examples

More information available at http://necsc.umass.edu/



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