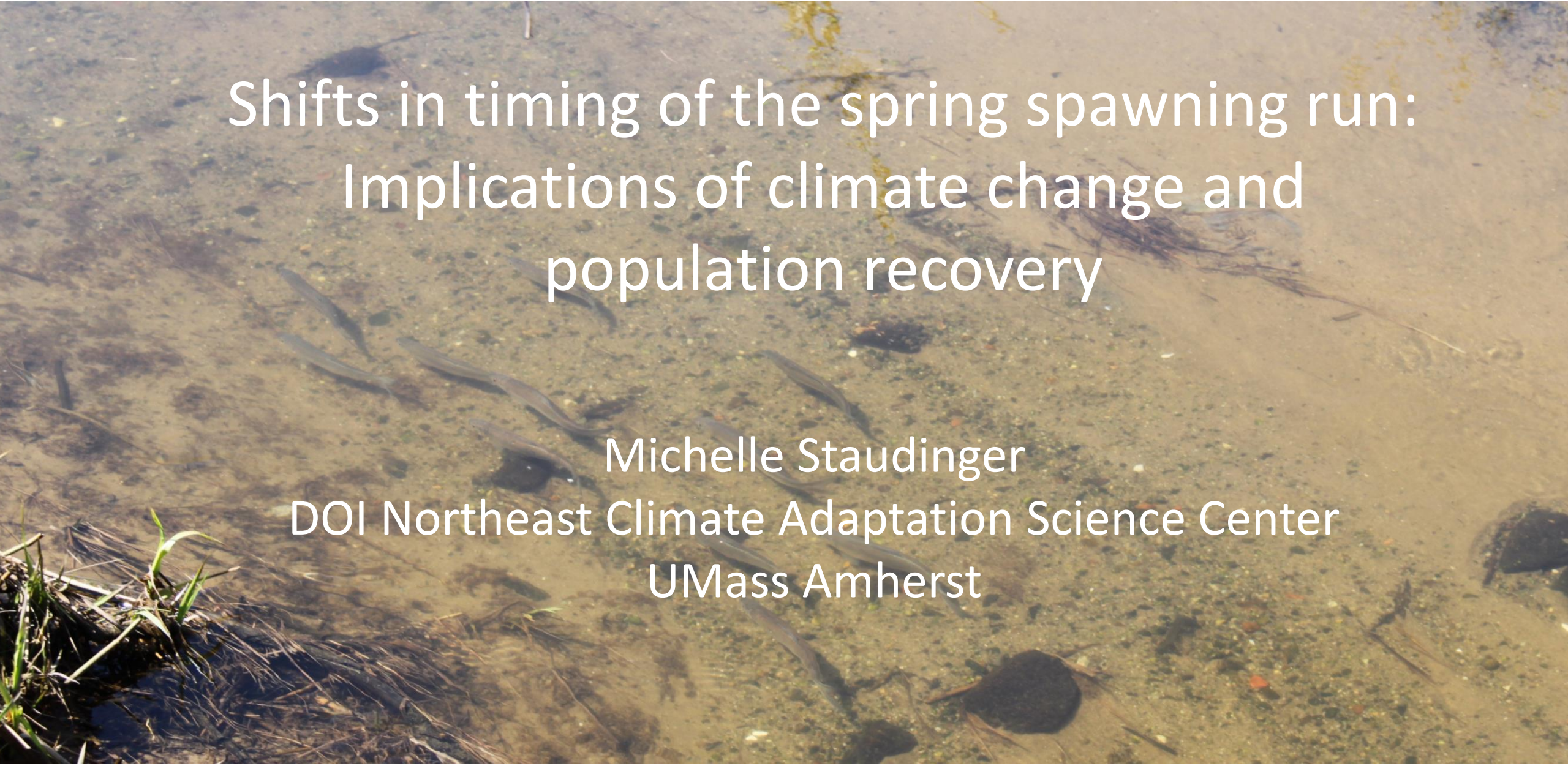


Shifts in timing of the spring spawning run: Implications of climate change and population recovery

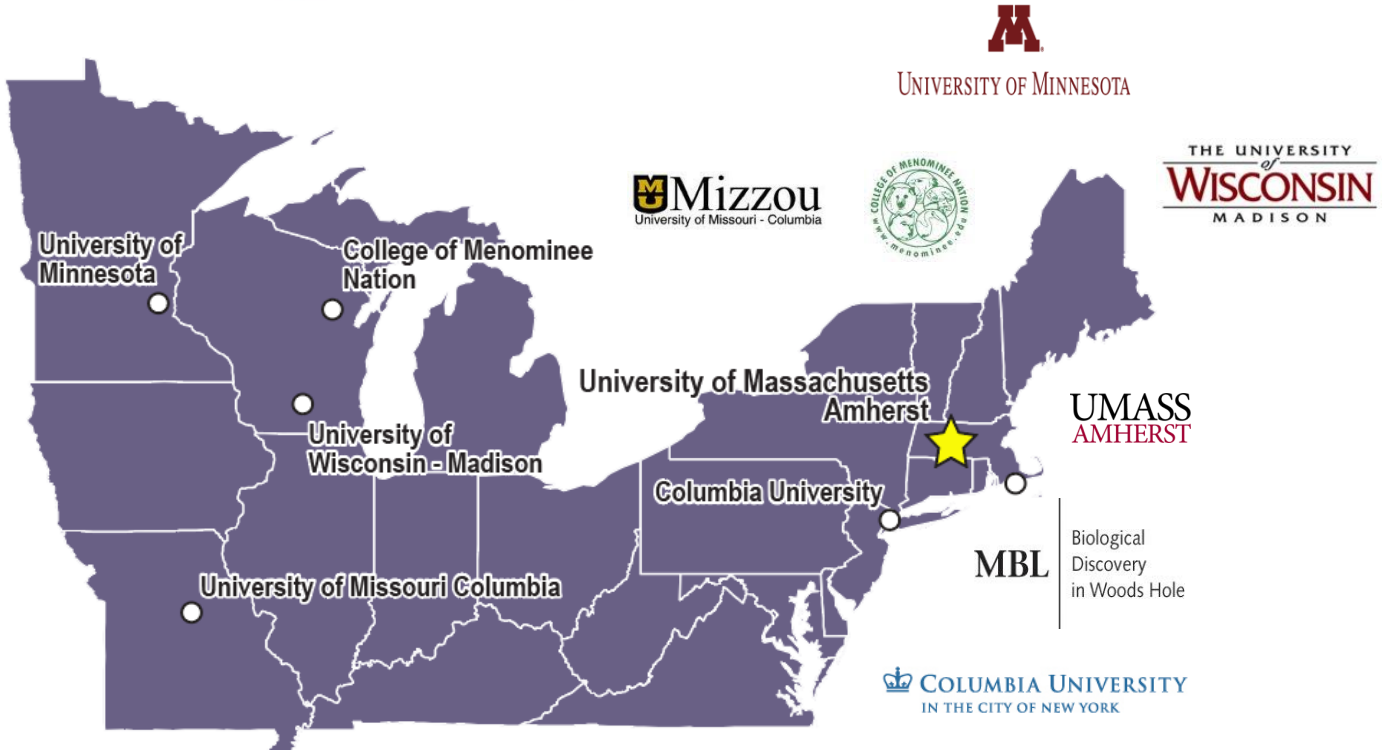
Michelle Staudinger
DOI Northeast Climate Adaptation Science Center
UMass Amherst

USGS science for a changing world

NE CASC Northeast Climate Adaptation Science Center

UMASS AMHERST

NE CASC
Northeast Climate Adaptation Science Center



Our Mission: *Provide scientific information and tools to anticipate, monitor, and adapt natural and cultural resources to climate change in the Northeast region*

NE CASC Science Themes

1. Climate projections & assessments
2. Land-use & land-cover
3. Freshwater resources & ecosystems
4. Atlantic & Great Lakes coastal/nearshore environments
5. Ecosystem vulnerability & species response
6. Cultural resources
7. Decision frameworks for evaluating risk and managing natural resources

USGS science for a changing world

UMASS AMHERST

Phenology - *Timing* of critical, re-occurring, life events

- Life history events are species-specific, occurring at a particular **time** of year and at a specific **location**

How do you know when the seasons change?

A significant obstacle with marine organisms

"Managing fisheries is hard: it's like managing a forest, in which the trees are invisible and keep moving around"

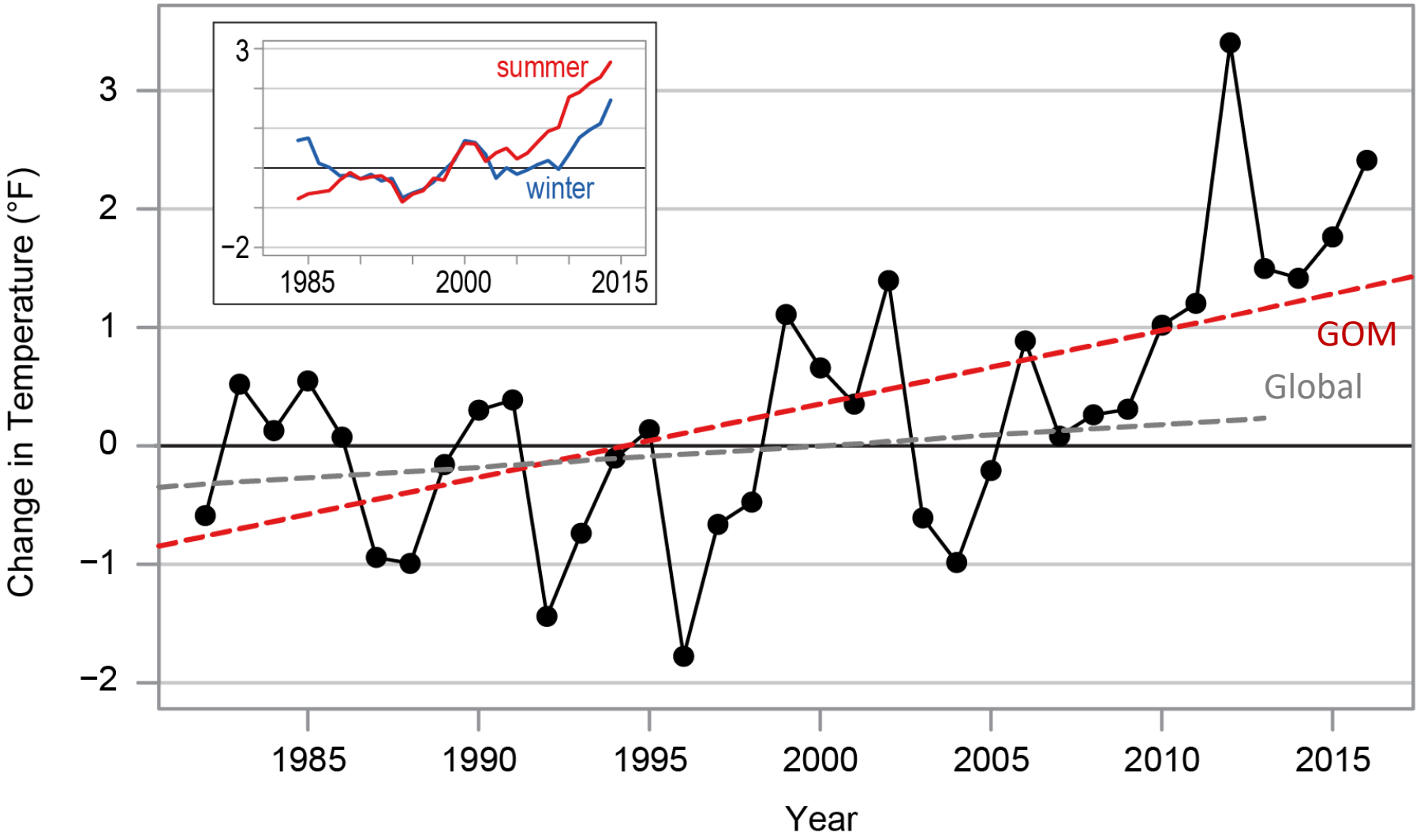
http://www.treefish.com/

John Shepherd

University of Southampton

Lecture at Princeton University, ca 1978

Why study phenology in the Gulf of Maine?



- Hotspot of warming
- Highly seasonal system
- Seasonal foraging and breeding/spawning area

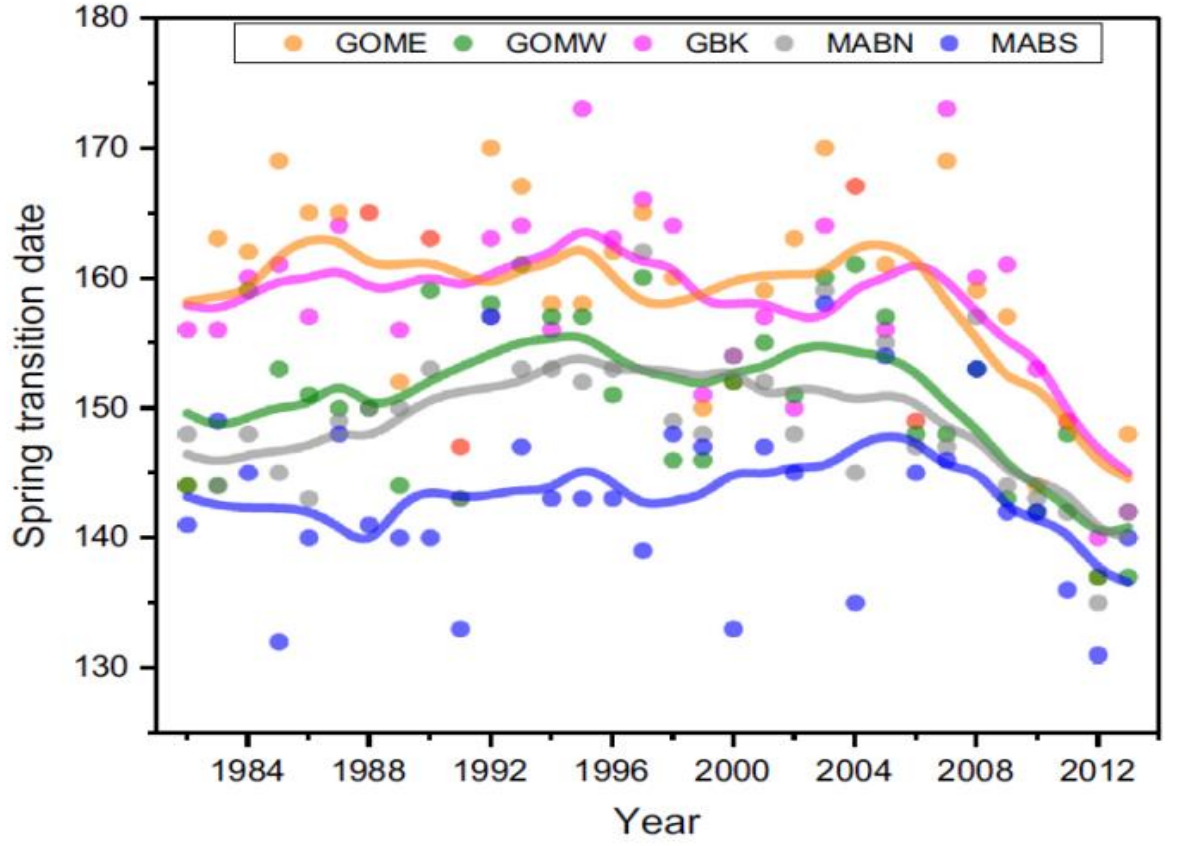
Figure from Dupigny-Giroux et al. 2018. NCA4, NE chapter.

Seasons change…but not like before

- Earlier onset of spring (~1 d/yr)
- Earlier summer (~1 d/yr)
- Later fall transition →

- ↑ summer duration (>2 d/yr)
- ↓ winter duration

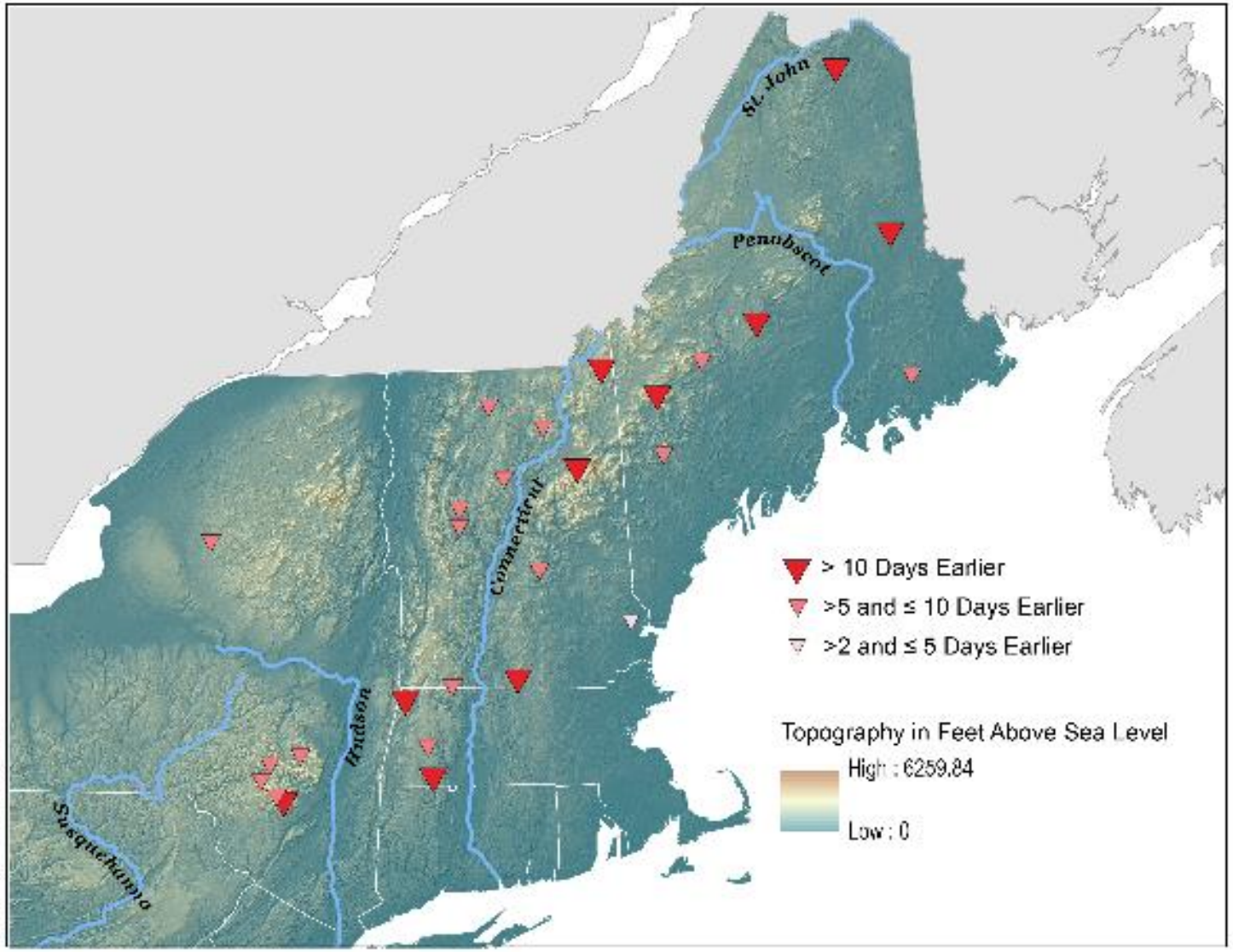
Spring onset



~2 weeks earlier since 2006

Friedland et al. 2015; Thomas et al. 2017

Changes in hydrology

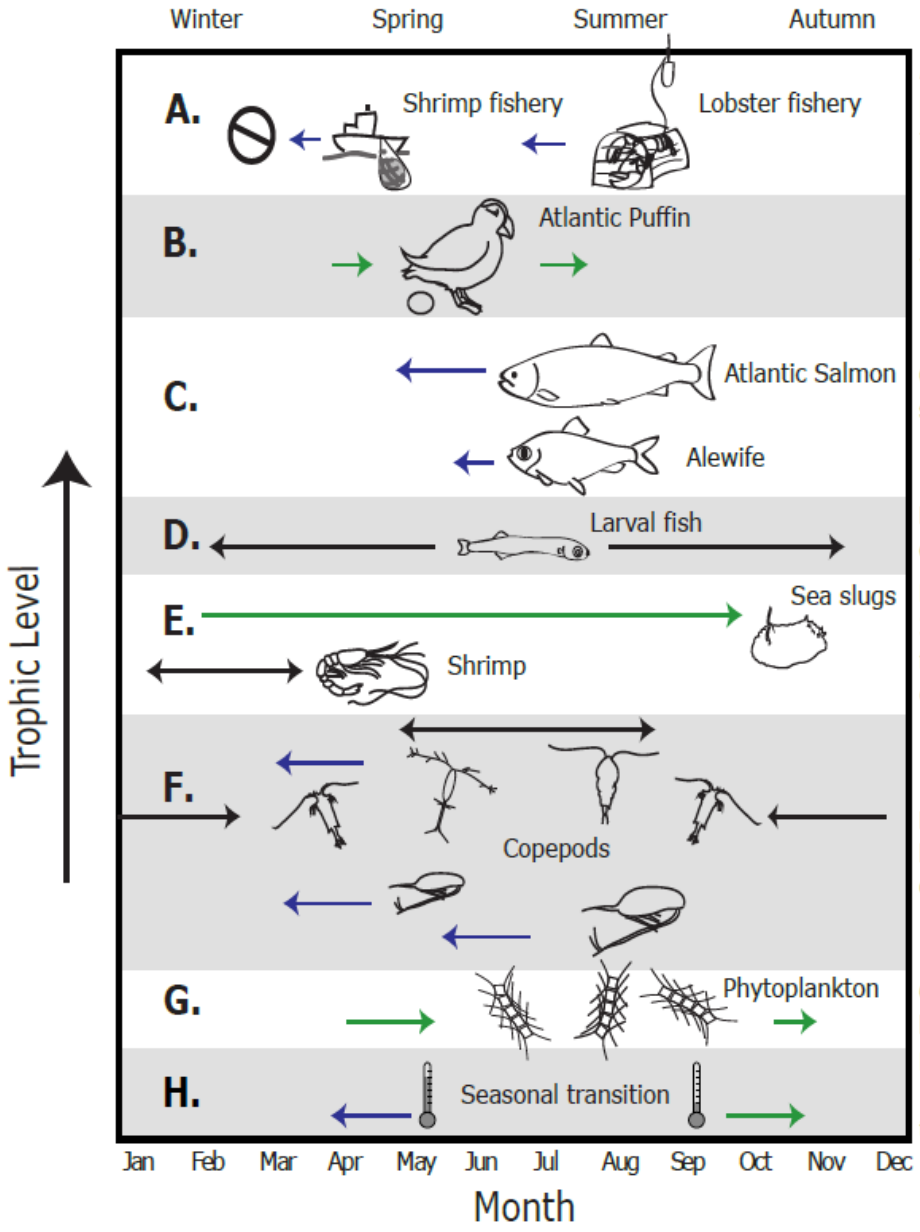


Adapted from Dudley et al. 2017. Journal of Hydrology; Dupigny-Giroux et al. 2018. NCA4, NE chapter.

Evidence for regional shifts in phenology

Earlier

Later



A. Shrimp and lobster harvest peak ~20 days earlier, leading to earlier attenment of catch limit.

B. Eggs layed 12 days later. Young fledge 9 days later.

C. Spawning migration runs start 13 - 20 days earlier.

D. Occurence ealier or later depending on species.

E. Sea slug spawning starts 3 months later, extends into fall. Shrimp hatch starts earlier and ends later.

F. Peak abundance broadened, shortened, or starts earlier.

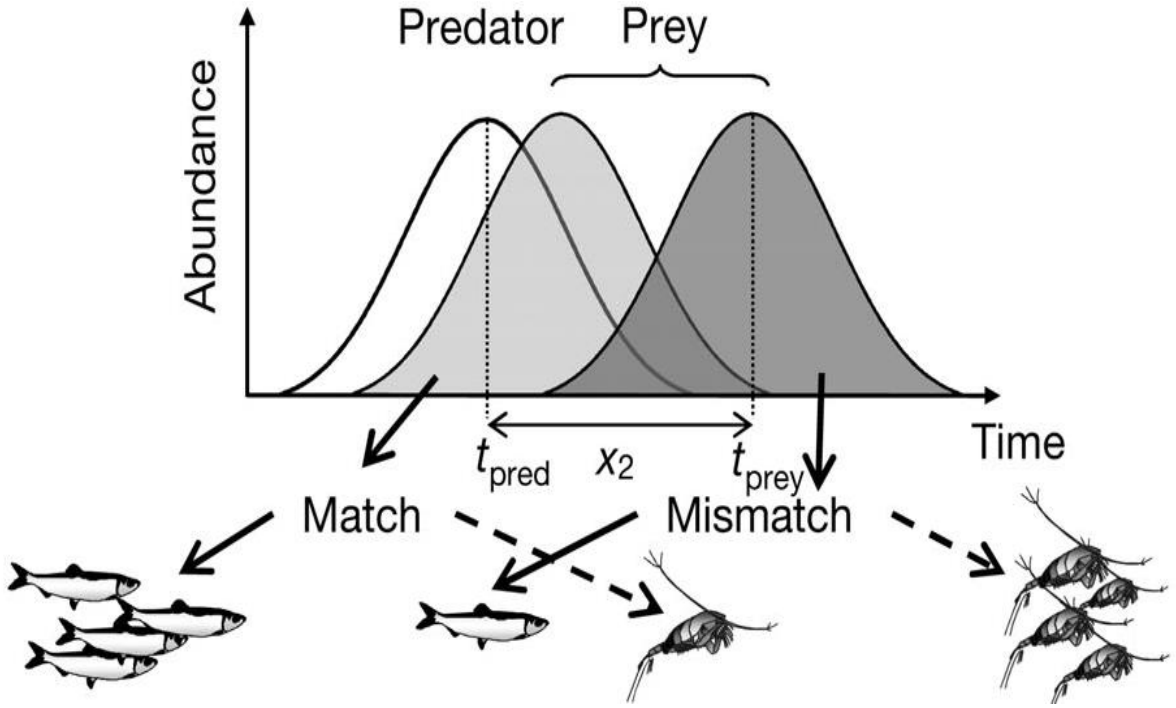
G. Spring and Fall blooms later by 9 - 4 days.

H. Transition to Spring 19 days earlier. Transition to Fall > 32 days later.

Staudinger et al., 2019. Fisheries Oceanography

Ecological implications of shifting phenology

Match – mismatch theory (Cushing 1969, 1990)



Durant et al., 2013. MEPS

What do phenological shifts tell us about climate adaptation?

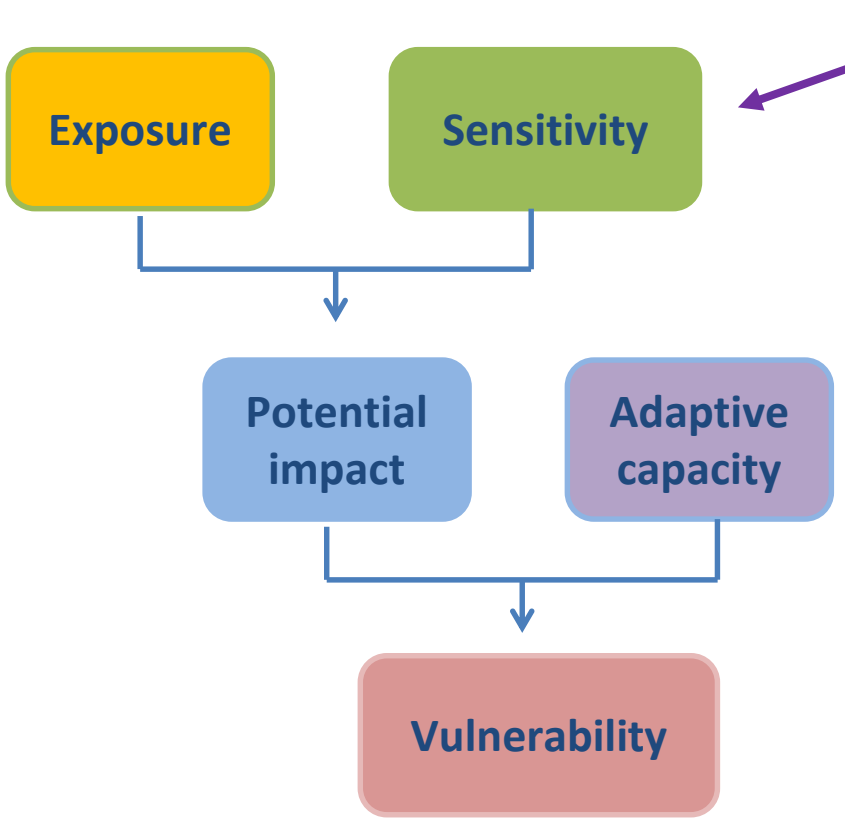


Figure adapted from Glick et al. 2011

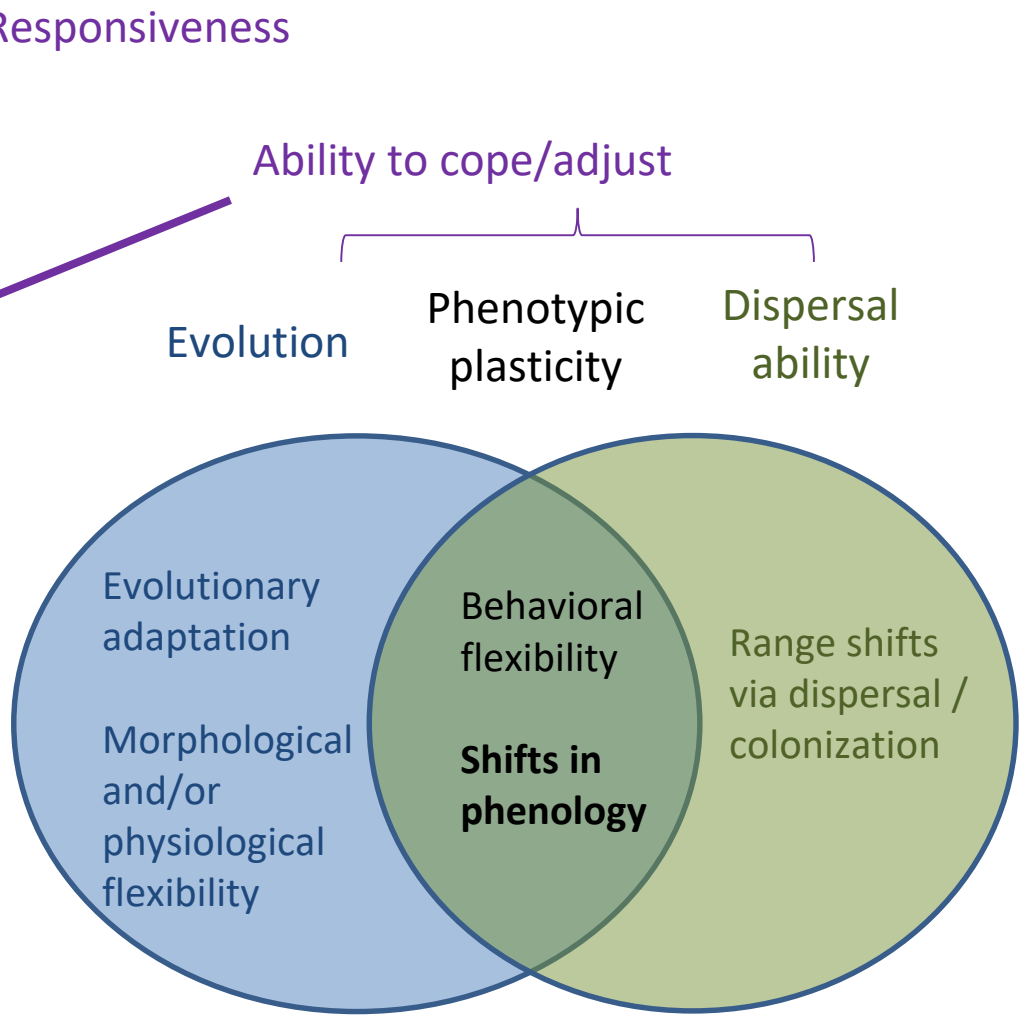


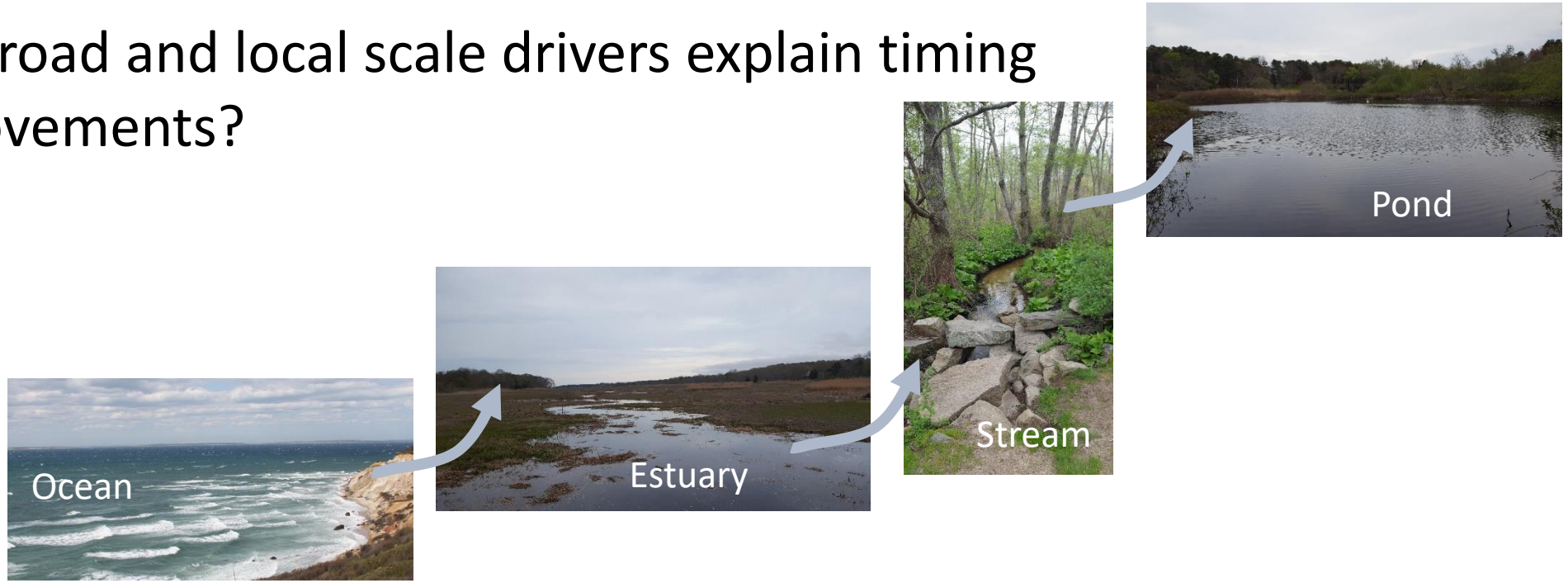
Figure adapted from Beever et al. 2016

Project objectives

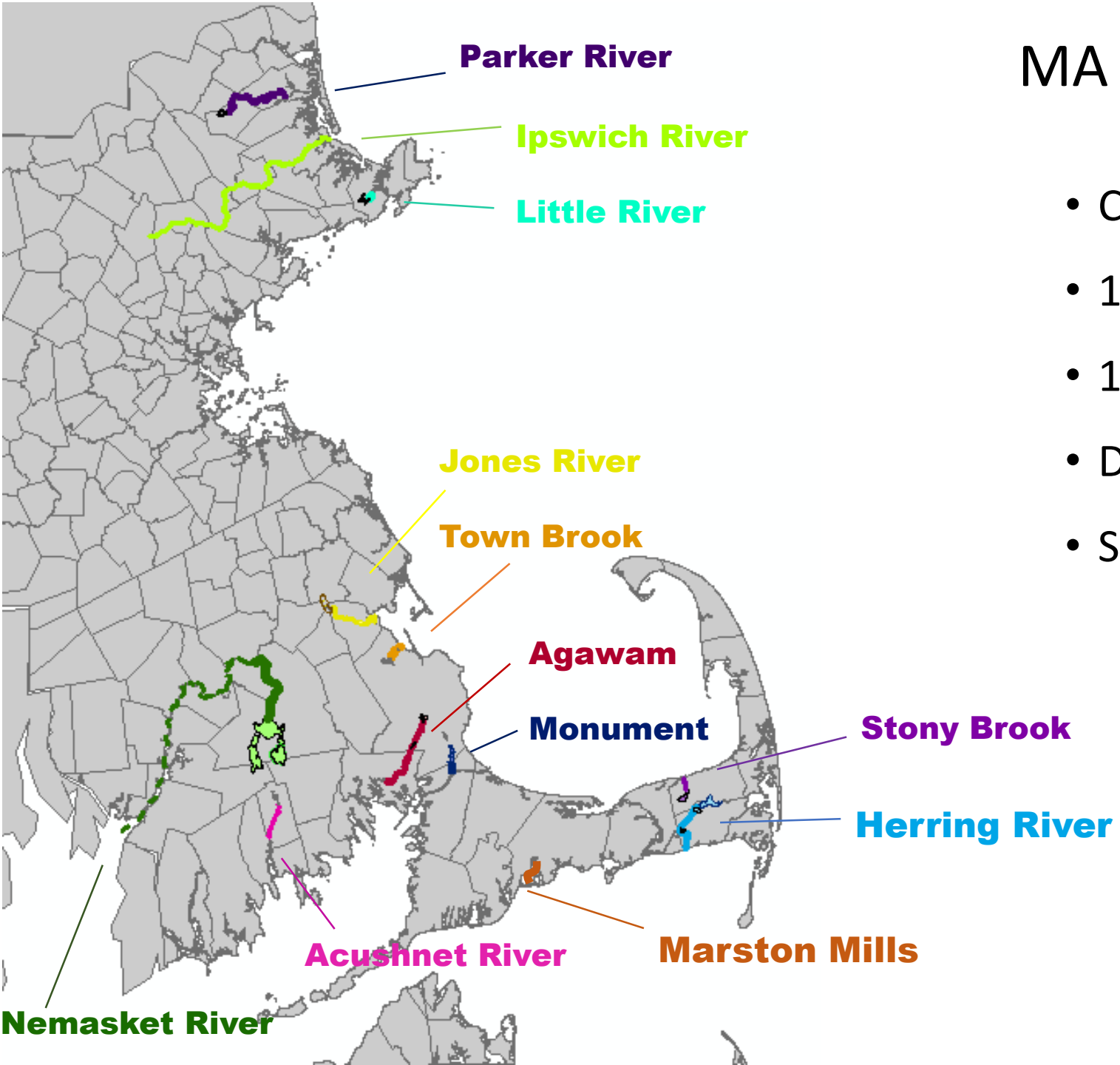
1) Has the timing of the adult alewife spawning migration shifted?

2) How do responses vary across sites?

3) What broad and local scale drivers explain timing and movements?



MA Alewife Spawning Runs



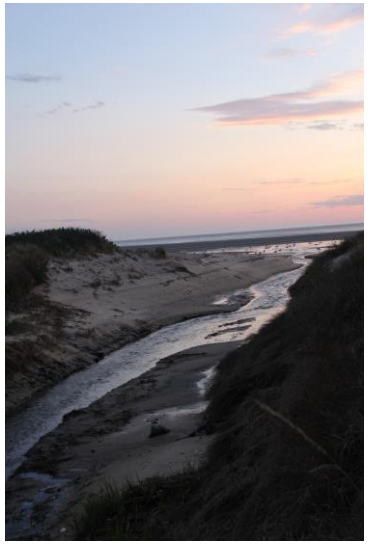
- Collaboration with MA DMF
- 12 locations
- 1990 – 2017
- Daily fish counts
- Stream temperature


Stony Brook, MA

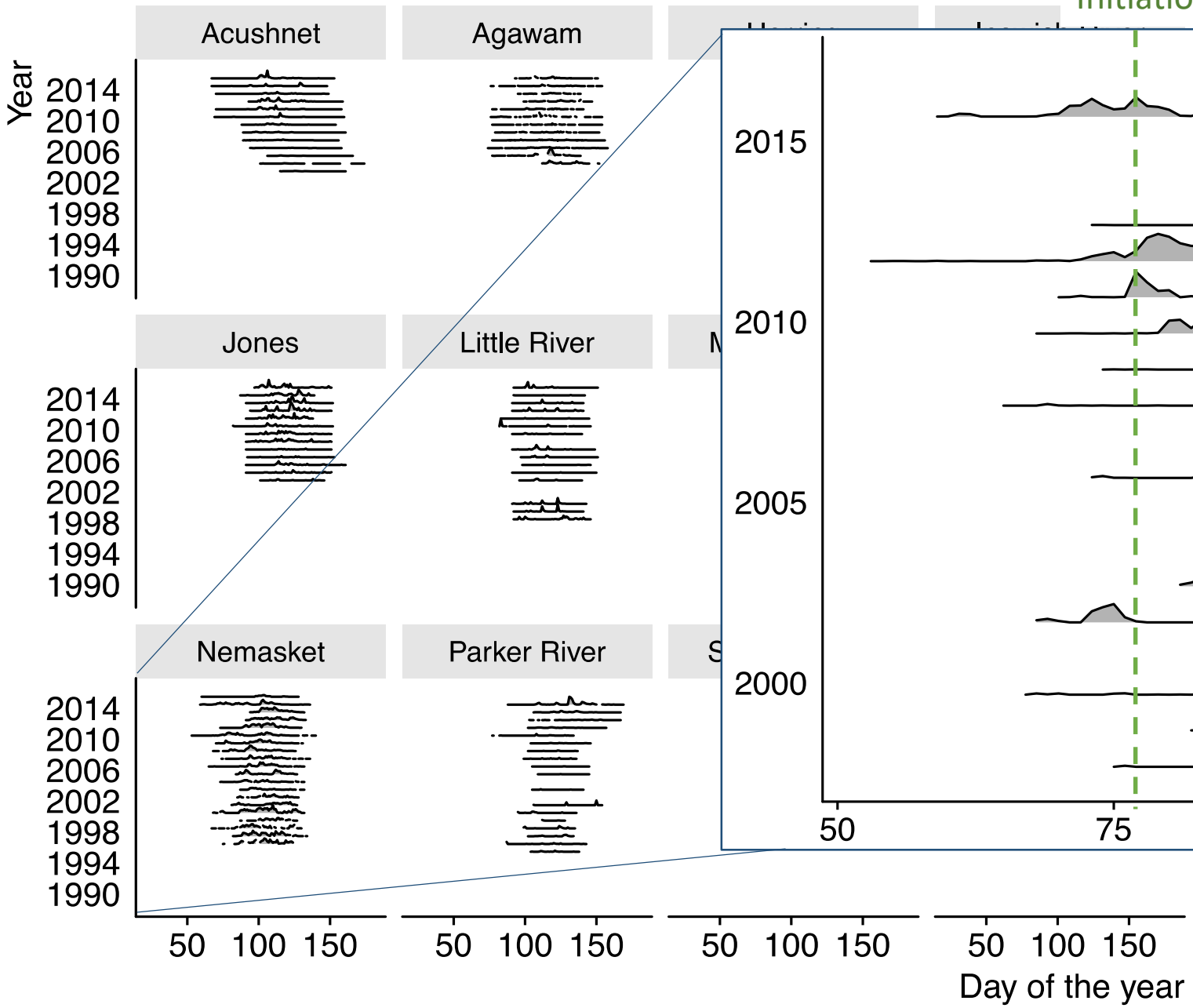
Monitoring for climate change

- Long-term datasets are critical!!!

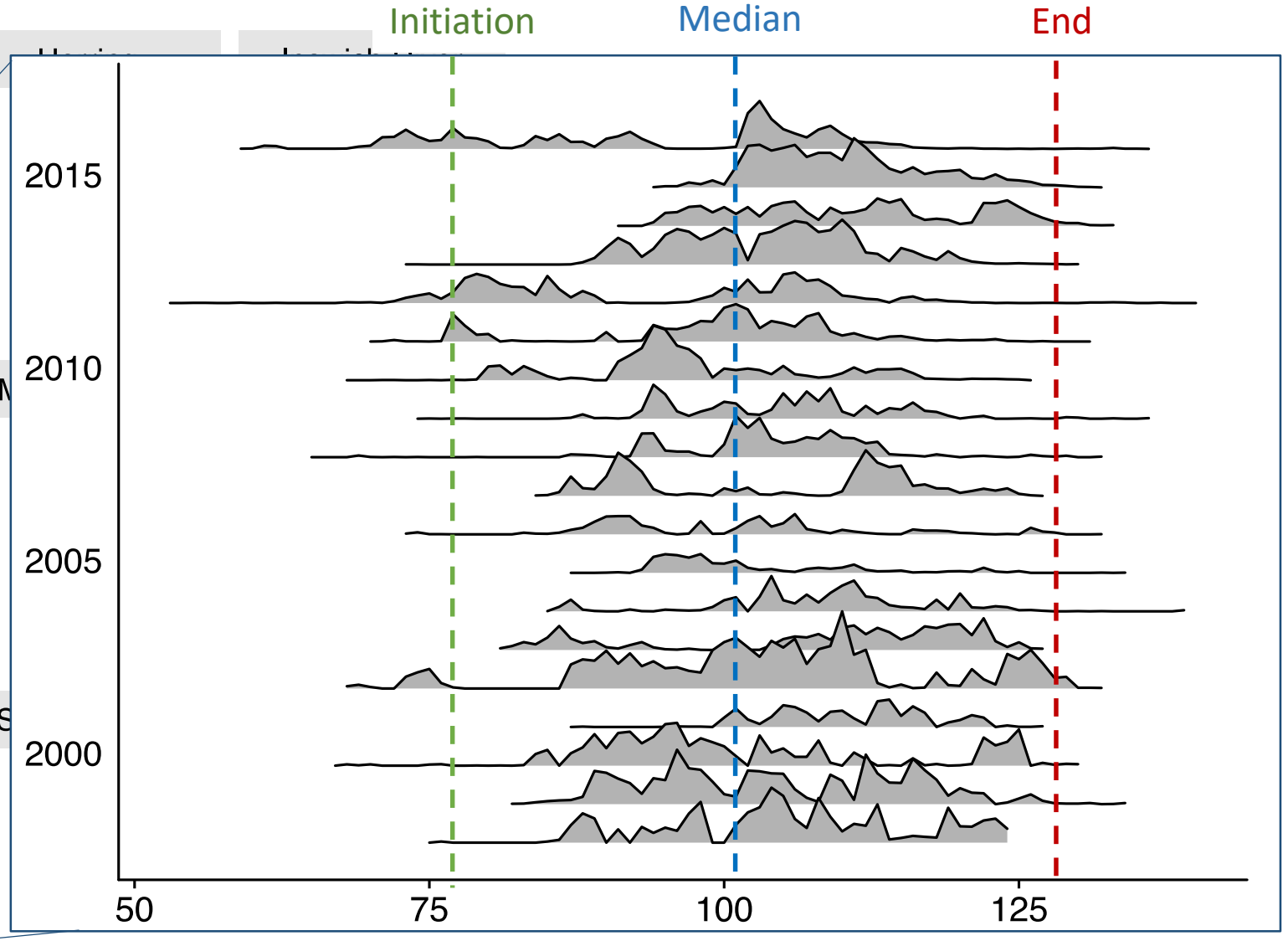
- River herring monitoring in MA is ideal for phenology studies
  - High temporal frequency
  - Broad range of sites
  - Paired biological-environmental data



Annual Counts

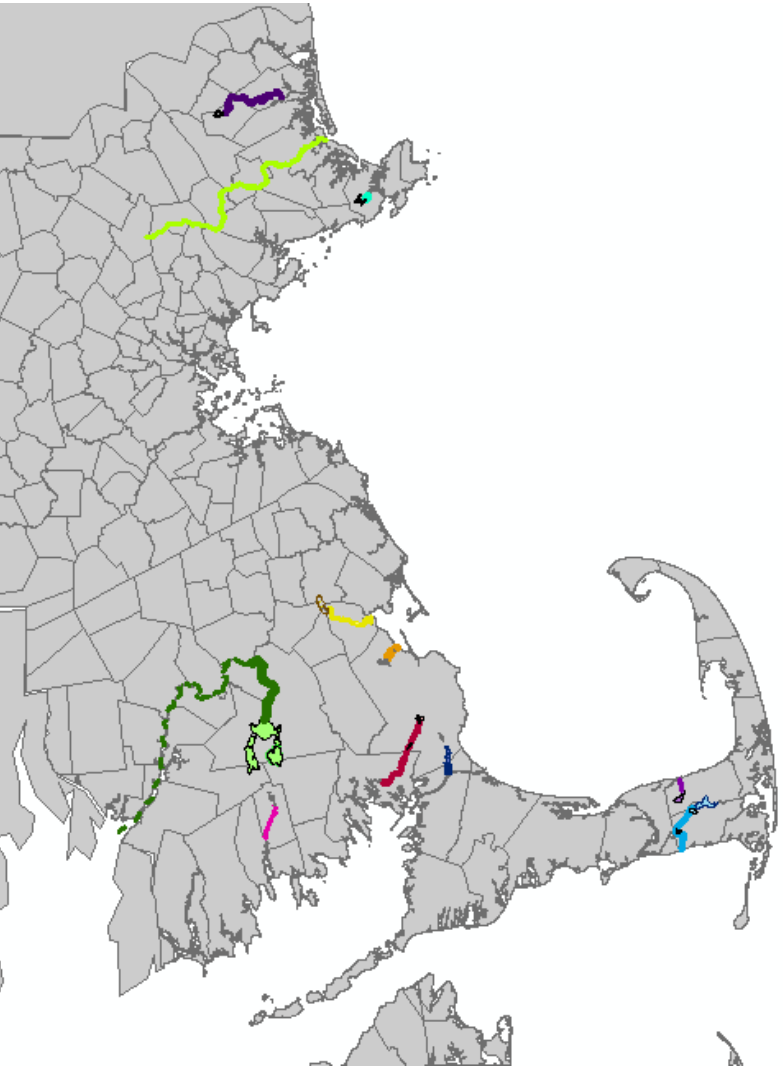


Nemasket River

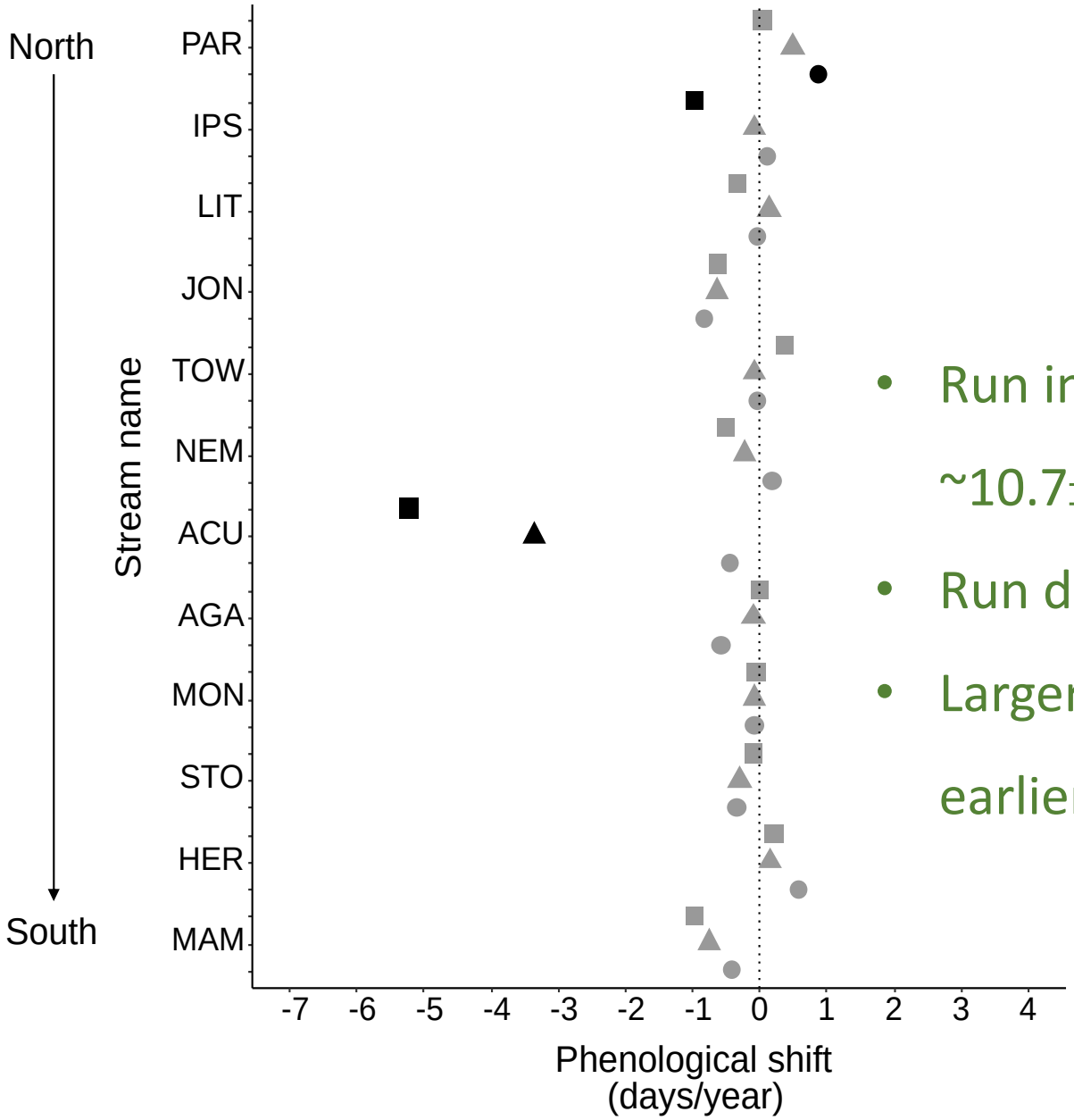


Data: MA DMF

Shifts in migration timing varies by site and metric



Dalton et al. In review.



Phenology metric

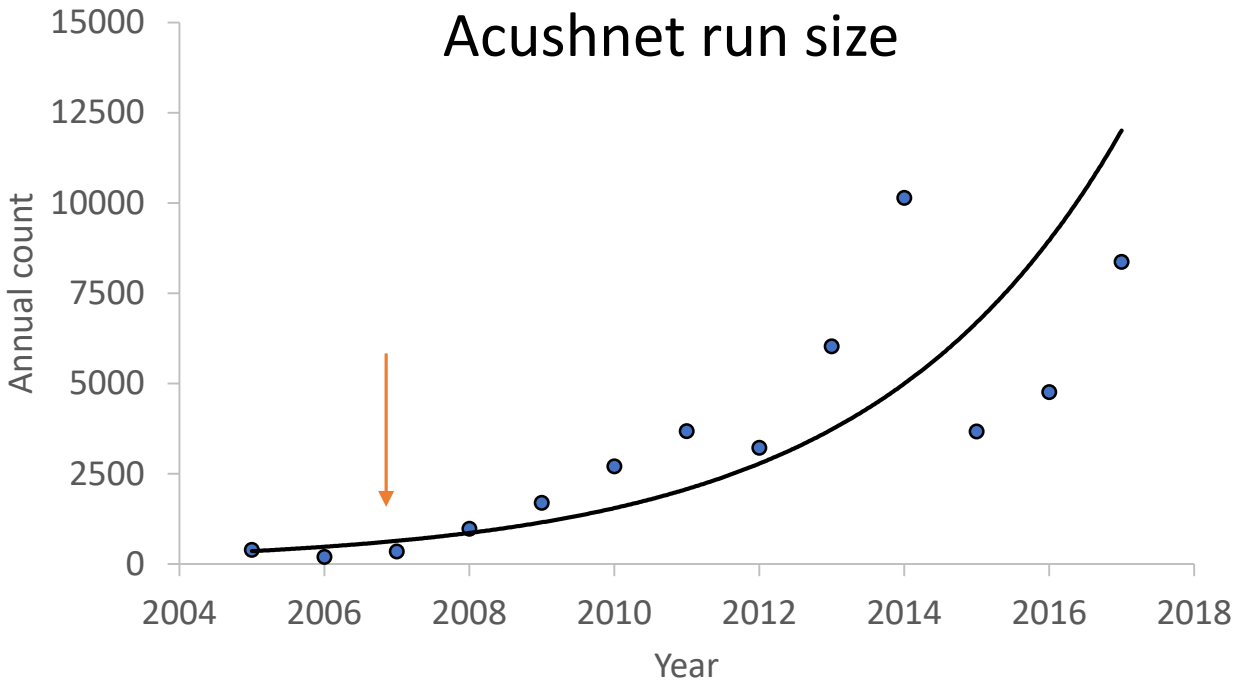
- Initiation
- Median
- End

Significance

- $p > 0.05$
- $p \leq 0.05$

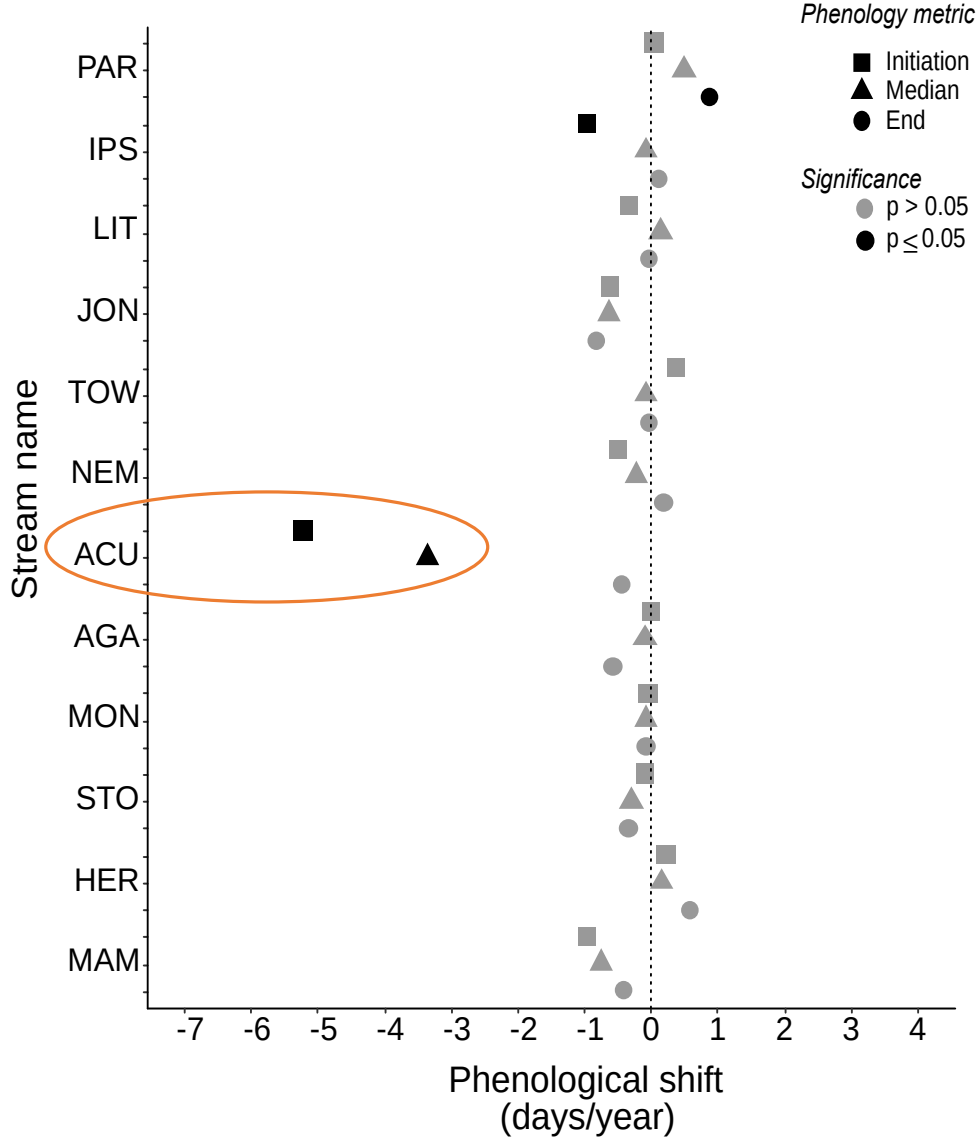
- Run initiation advanced ~10.7±4 days since 1990
- Run duration lengthened
- Larger runs exhibited earlier migration

Restoration effected phenology



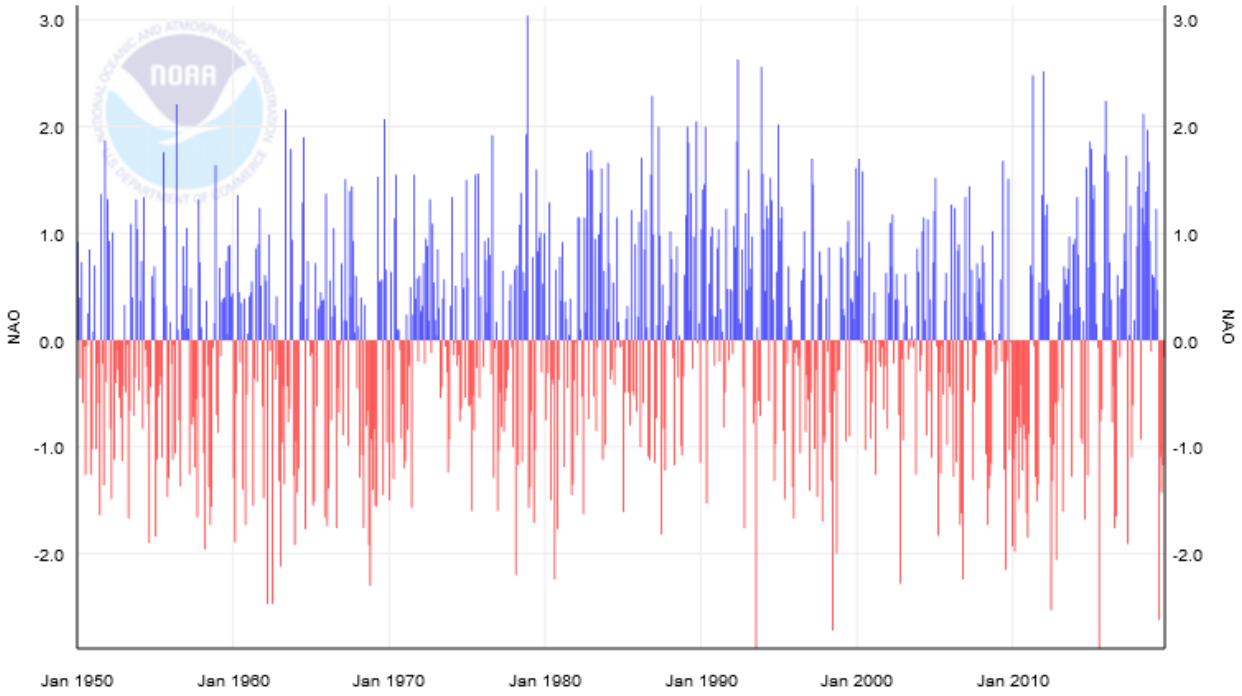
Acushnet Sawmill dam & fishway (2006)

Acushnet Sawmill fishway (2008)



What **broad** scale drivers best predict movements?

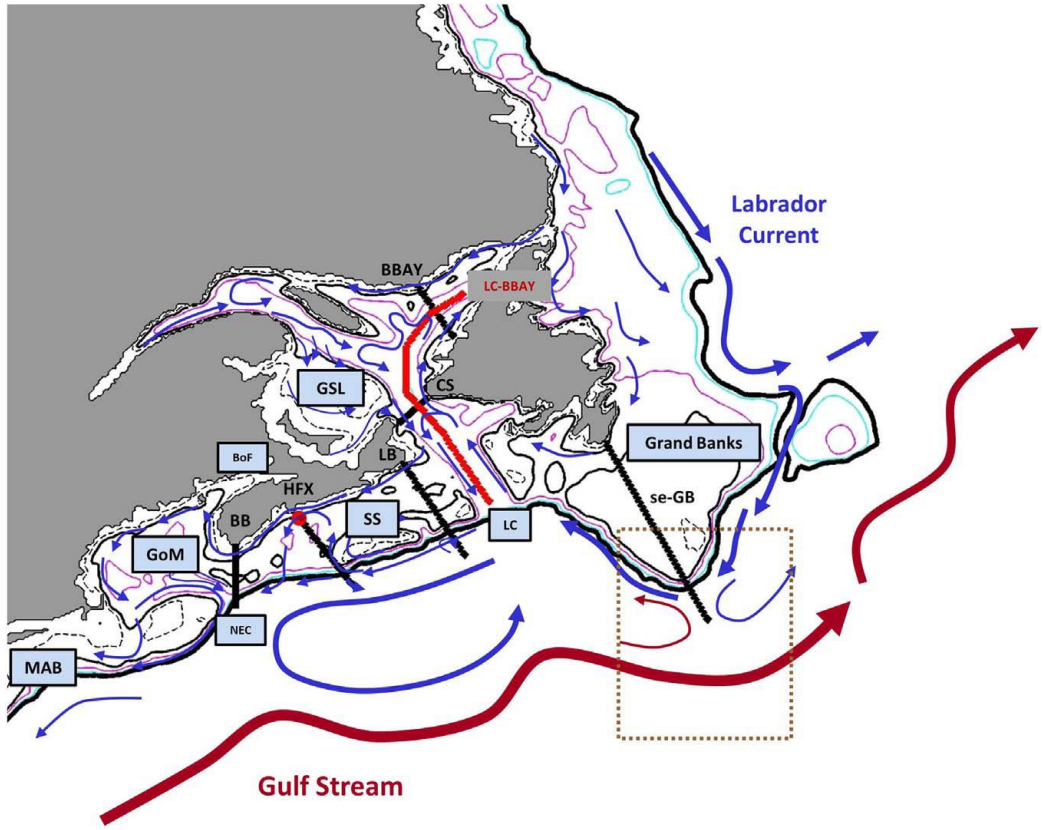
North Atlantic Oscillation (NAO)



+ phase ≈ warmer ocean surface conditions and wetter conditions

- phase ≈ colder ocean surface conditions and drier conditions

Gulf Stream Position



Northern position ≈ warmer conditions

Southern position ≈ cooler conditions

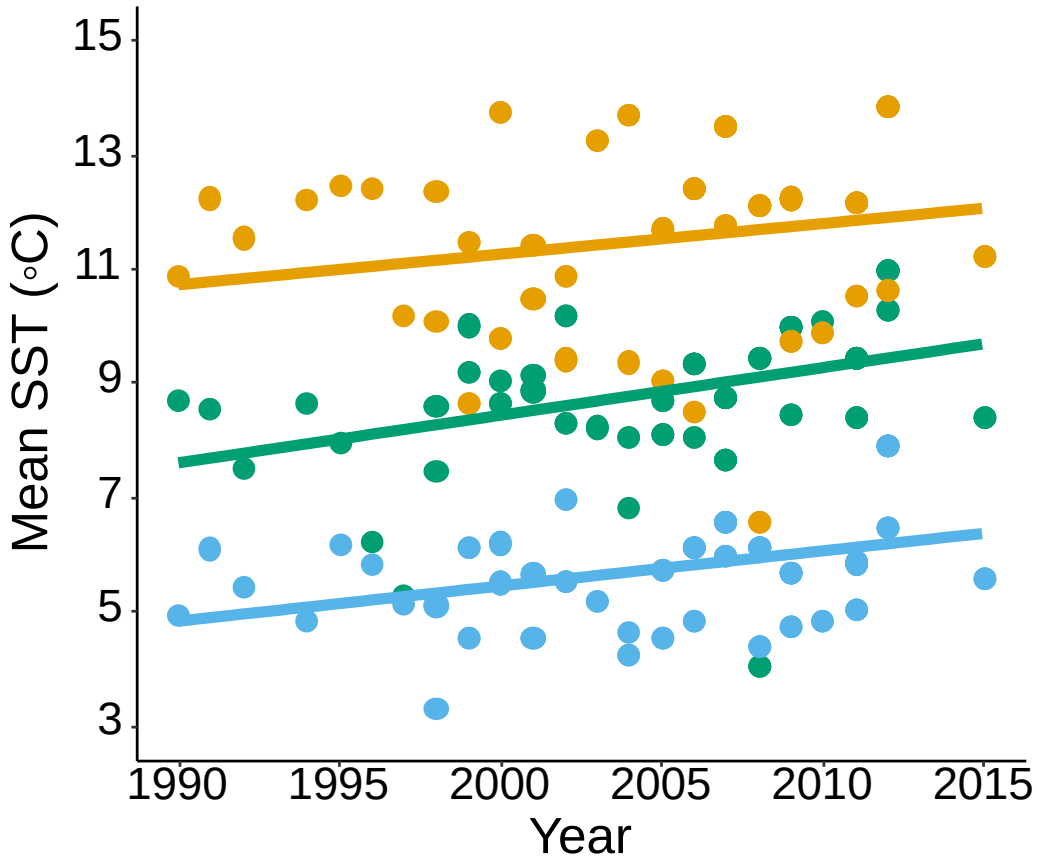
Broad scale drivers

Fall: Oct - Dec

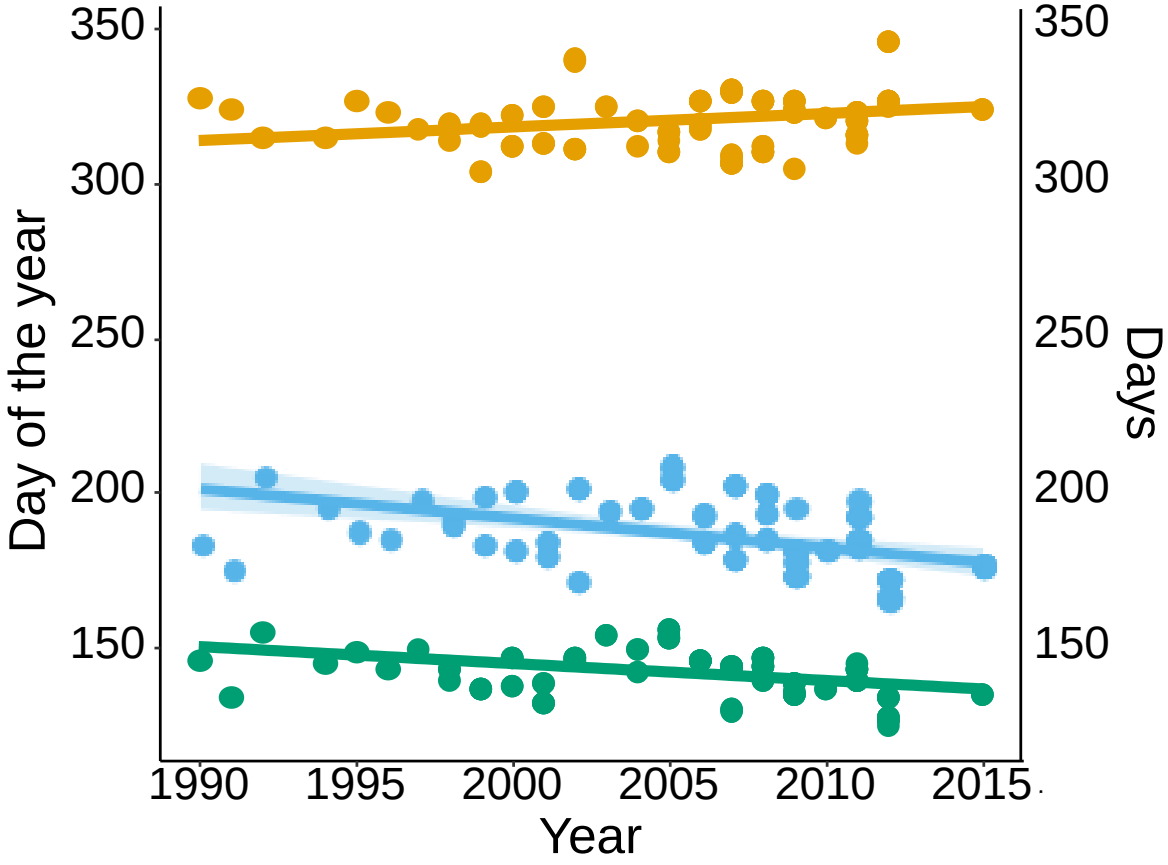
Winter: Jan - Mar

Spring: Apr - Jun

Sea Surface Temp



Seasonal transition dates



Temperature data from GOM and Nantucket Ocean buoys

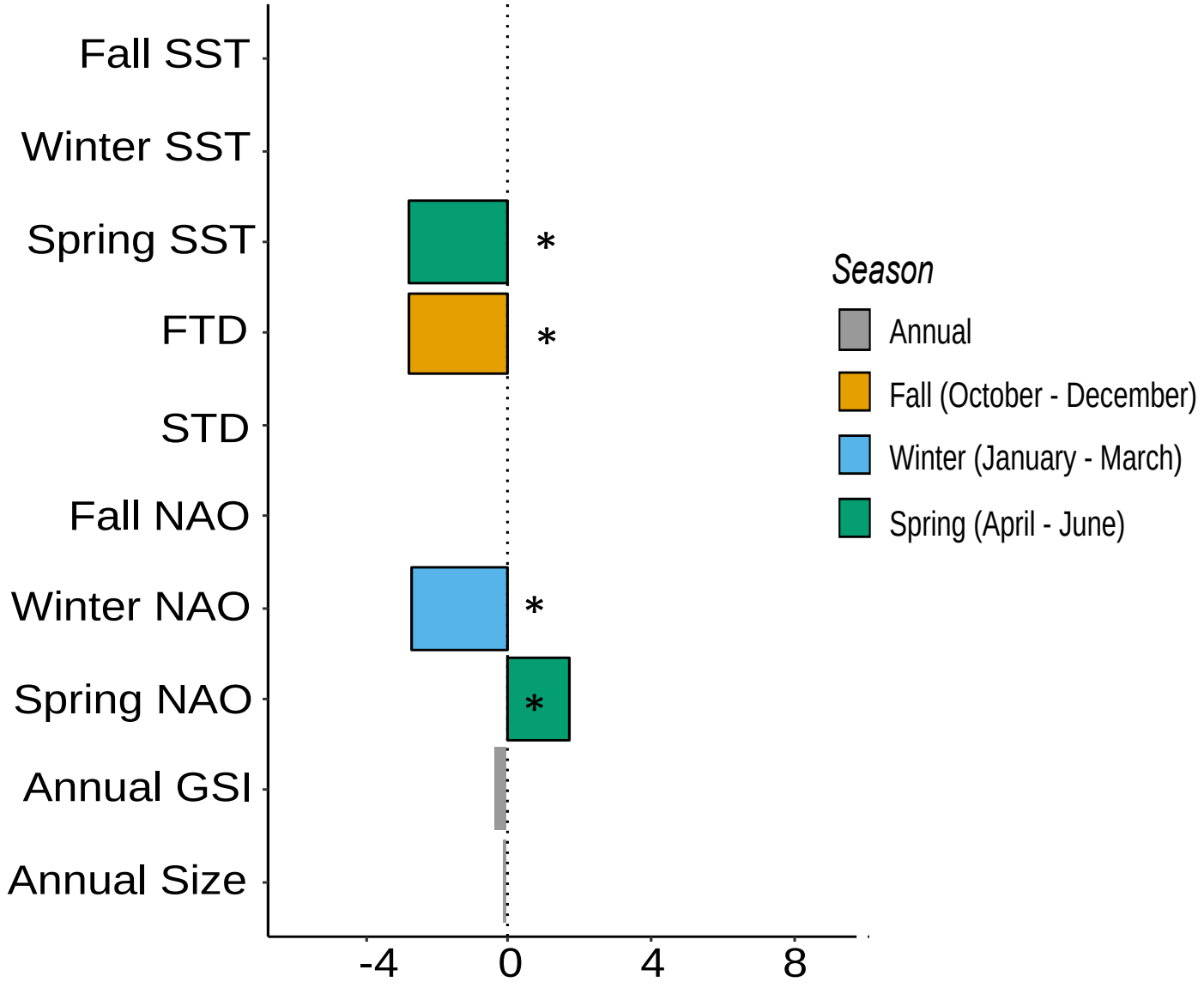
Seasonal transition data from Friedland et al., 2015

A combination of spring and winter drivers predict run initiation

- Warmer spring Tmin
- Shorter winters (FTD)
- + phase winter NAO

  (warmer wetter conditions)

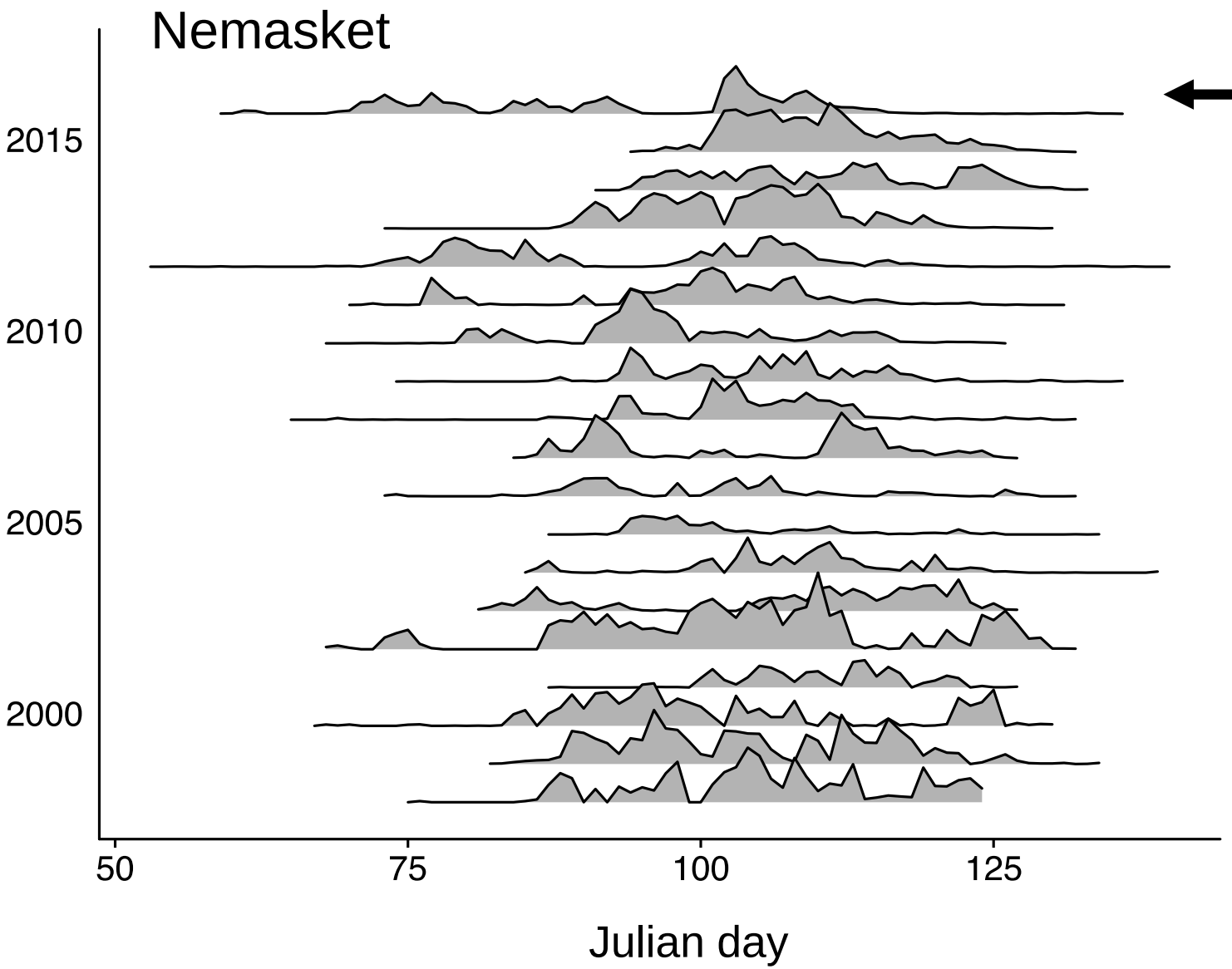
≈ Winter severity



Full-average model coefficients ± S.E.

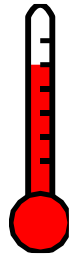
Dalton et al. In review.

What **local** scale drivers best predict movements?



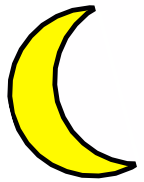
What factors are driving daily movements?

Daily fish counts



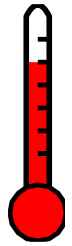
Stream temperature

Stream flow

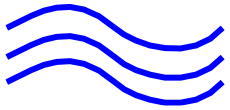


Lunar cycle

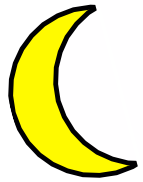
Stream temperature often drives fish movements



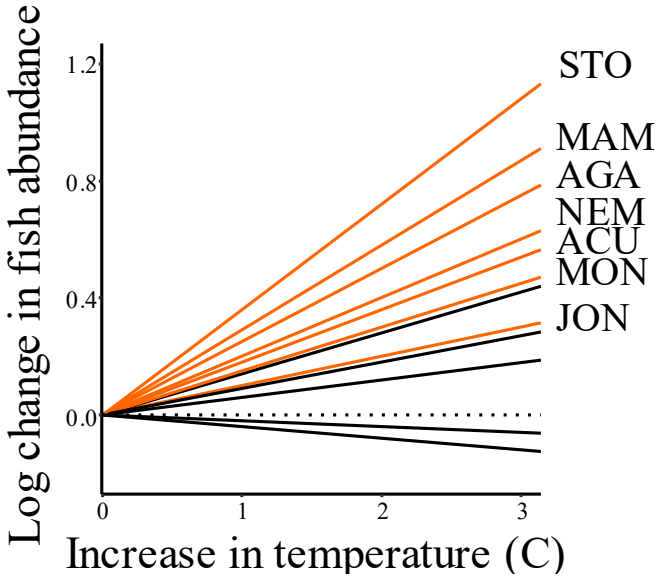
Acushnet, Agawam, Jones, Marston Mills, Monument, Nemasket, Stony Brook

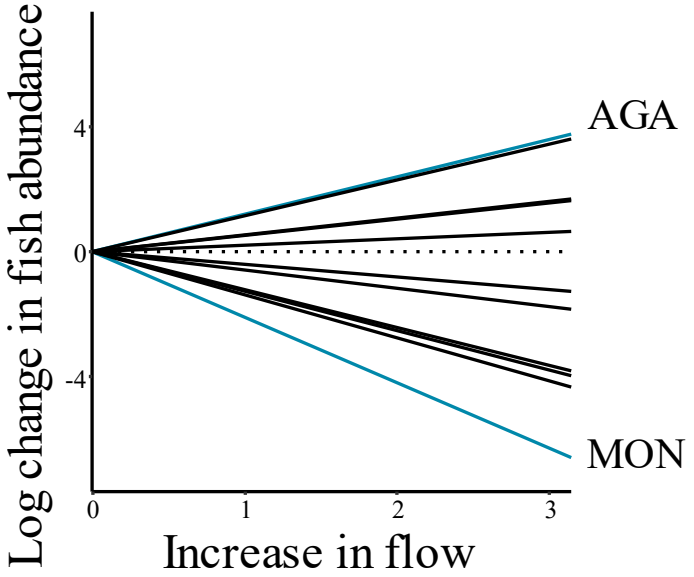


Agawam, Monument

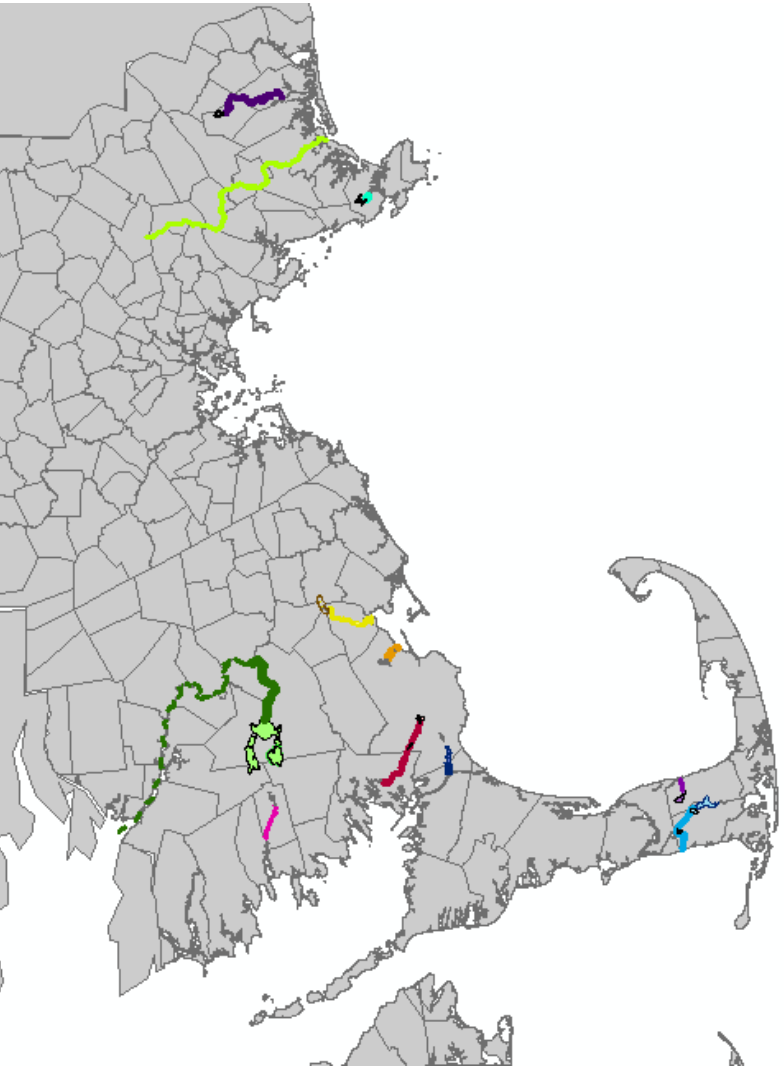


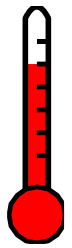
Marstons Mills

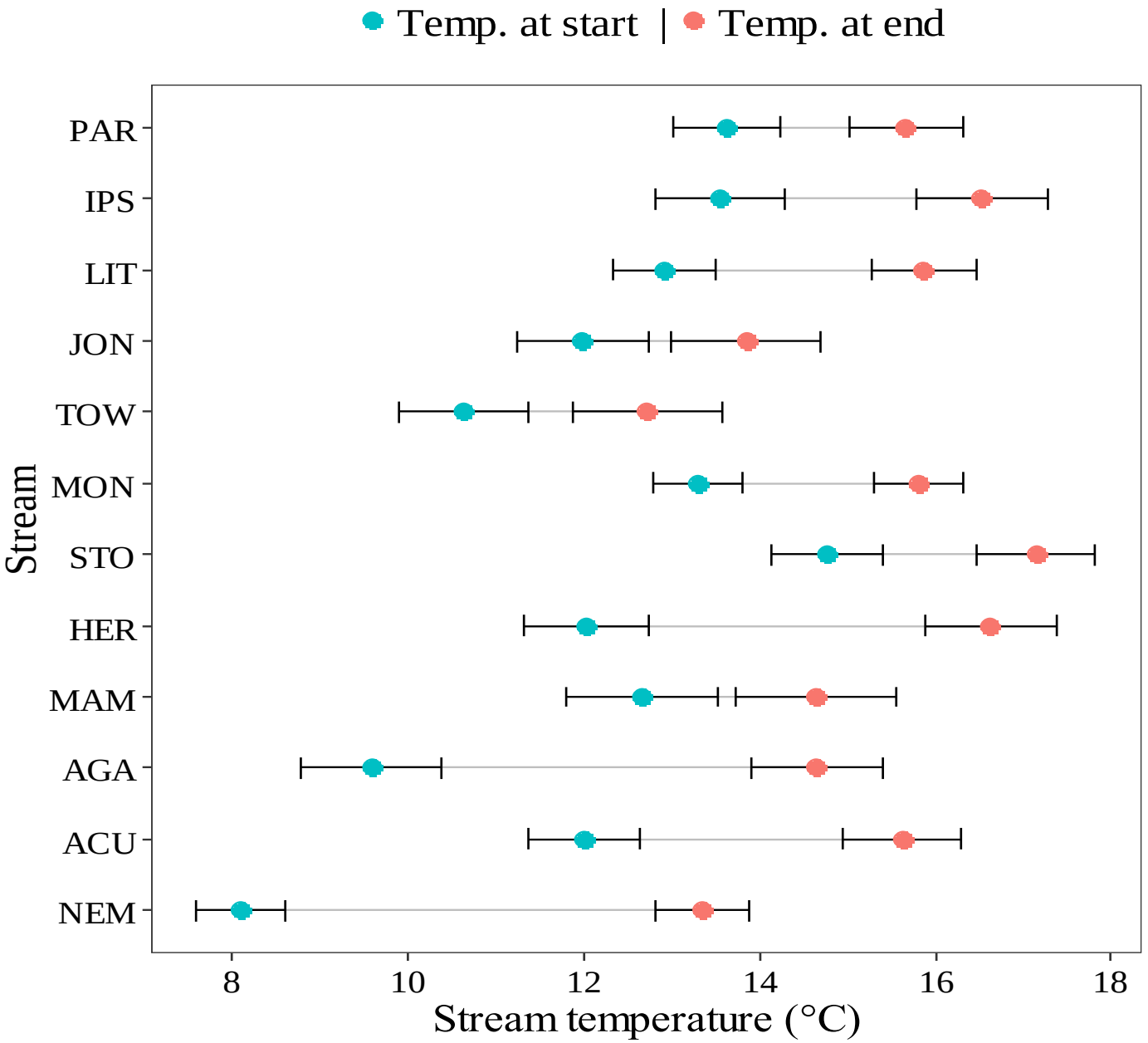


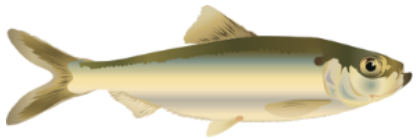


Stream temperatures vary across sites









Key take aways

1) Has migration timing shifted? → Yes, but not uniformly

2) How do responses vary across sites? → A lot
   - Run initiation showed strongest shift
   - Run duration increased due to no change in end dates

3) What broad and local scale drivers explain timing and movements?
   - Winter severity
   - Stream temperature
   - Population run size

Management Implications

- Understanding shifts in phenology is complex
- Drivers and responses vary widely
- Restoration effects phenology
- Variation may be a good or bad thing – is it resilience or asynchrony?

❖ Site-specific management

❖ Understanding where, ***when***, and how much species are responding to changes influences efficacy of management tools

Acknowledgements

Team river herring

Rebecca Dalton

Henry Legett

John Sheppard (MA DMF)

Adrian Jordaan

Chris Sutherland

Kevin Friedland

Jack Finn

Amanda Davis

NSF

MarineFisheries
Commonwealth of Massachusetts

NE CASC
Northeast Climate Adaptation Science Center

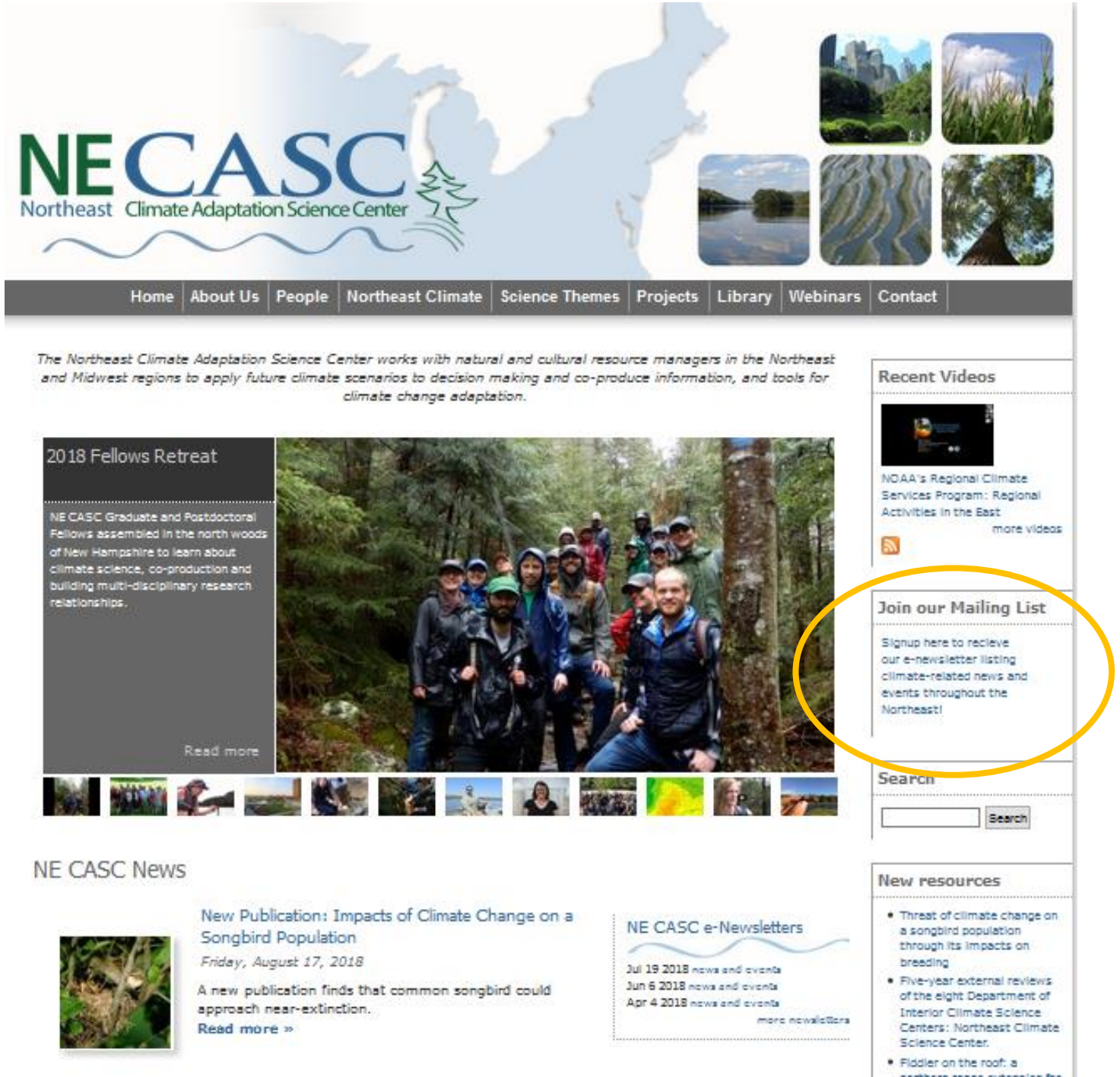
USGS
science for a changing world

UMASS
AMHERST

THANKS!

Sign up for our newsletter at

necsc.umass.edu



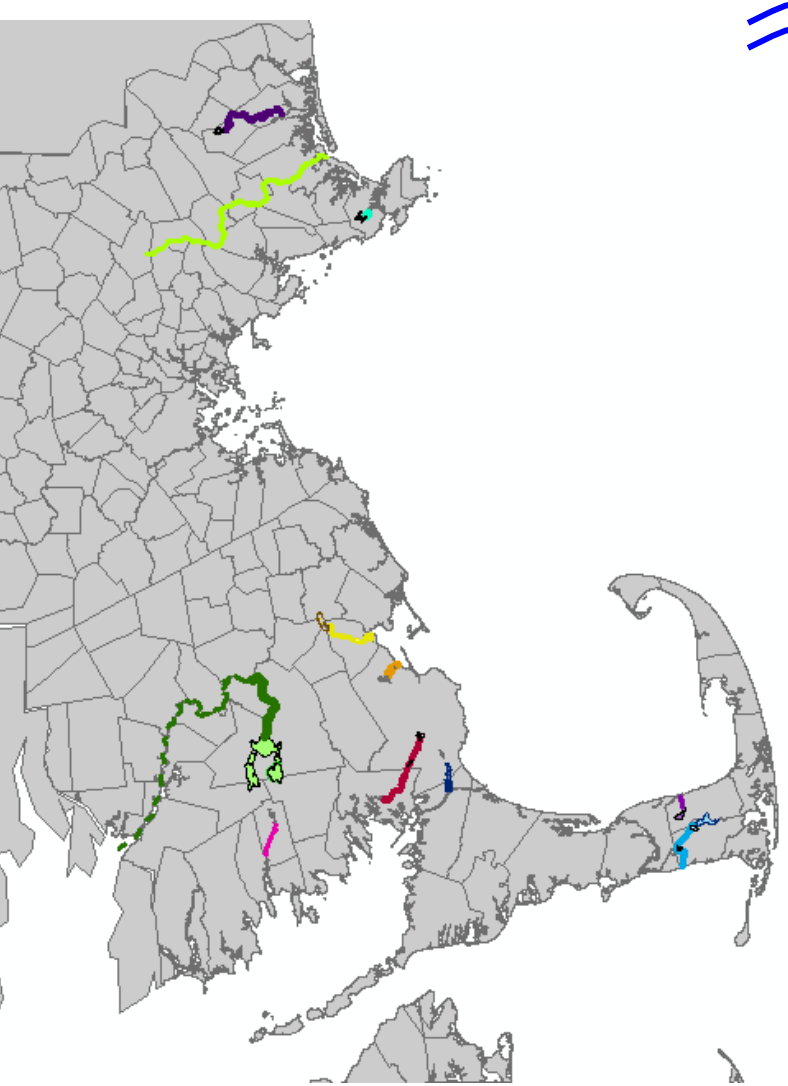
How do we help species adapt?

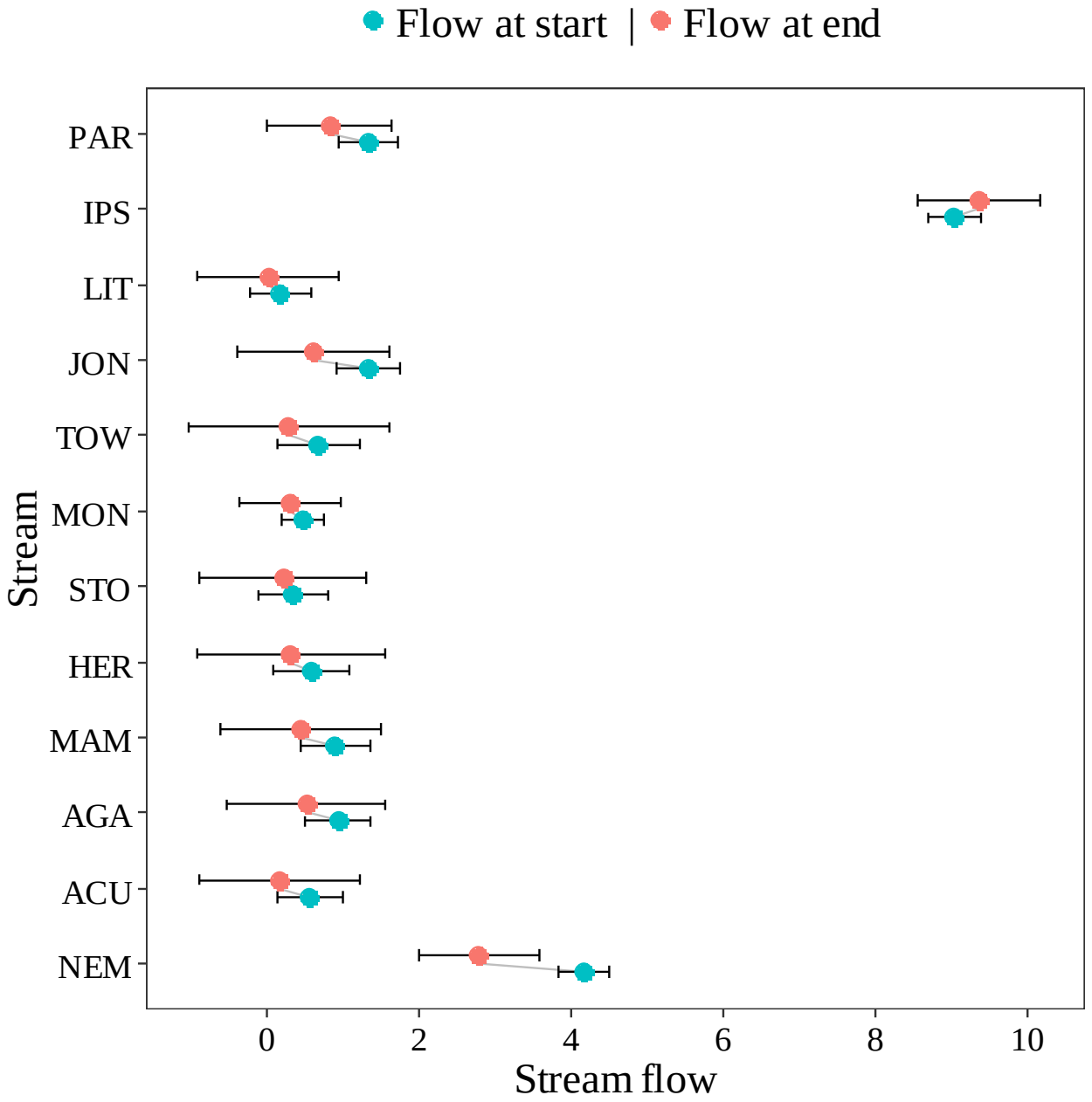
- Increase understanding of *impacts* and *responses*
- Conserve and manage to support and protect healthy populations and *ecosystem functioning*
- Support *adaptive management* through integrated observation, monitoring, and use of *decision support tools*
- Reduce *non-climate stressors*
- *Enhance capacity* for effective management

NATIONAL *fish, wildlife & plants*
CLIMATE ADAPTATION STRATEGY

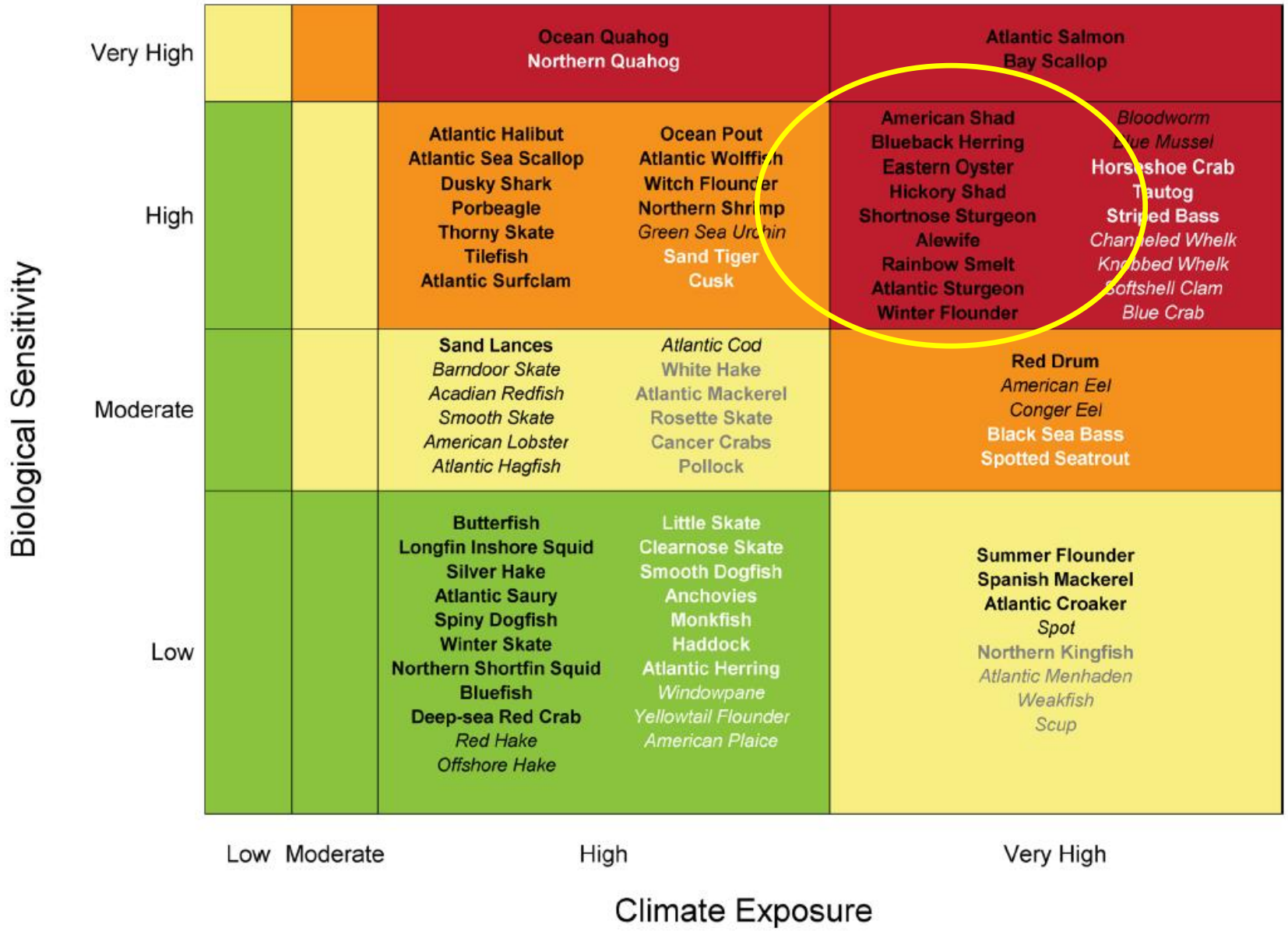
Adapted from the 7 goals of the NFWPCAP (2012)

Stream flow varies across sites





Climate Vulnerability



- ↑ Temperatures
- Ocean acidification
- Complex early life cycle
- Complex spawning and reproduction

Hare et al. 2016