# Phenological variation in forage fishes and trophic consequences for top predators in the Gulf of Maine



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USGS science for a changing world
NECASC Northeast Climate Adaptation Science Center
UMASS AMHERST
Anderson Cabot Center for Ocean Life at the New England Aquarium
PURDUE UNIVERSITY
Oregon State University
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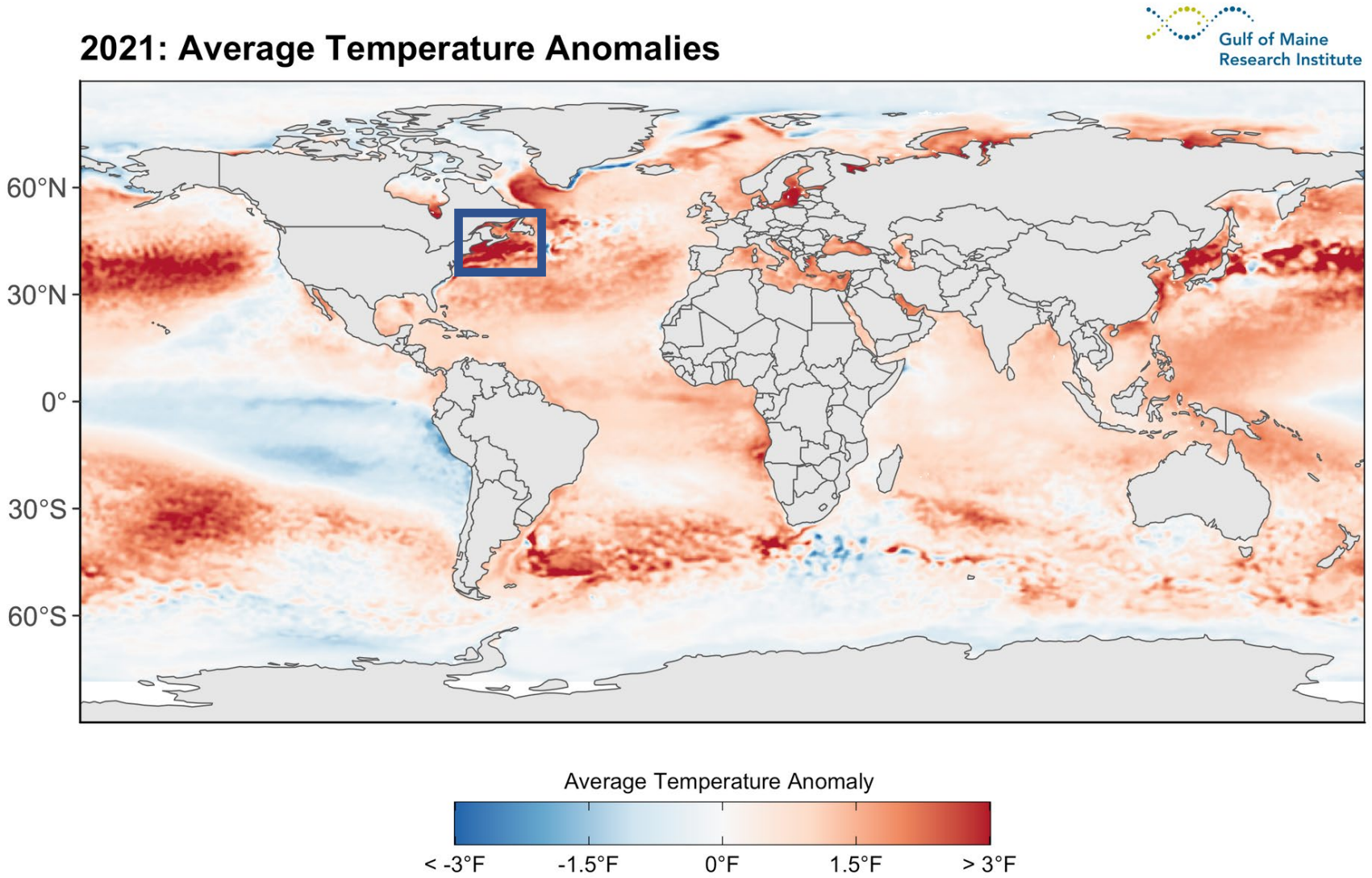
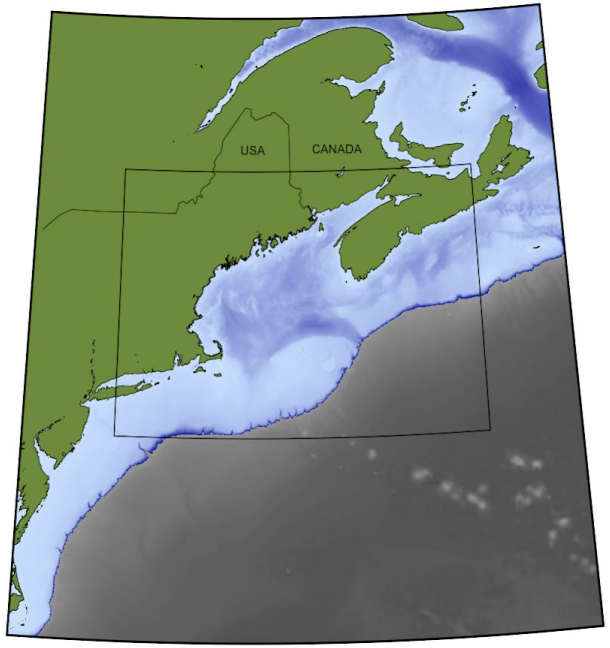
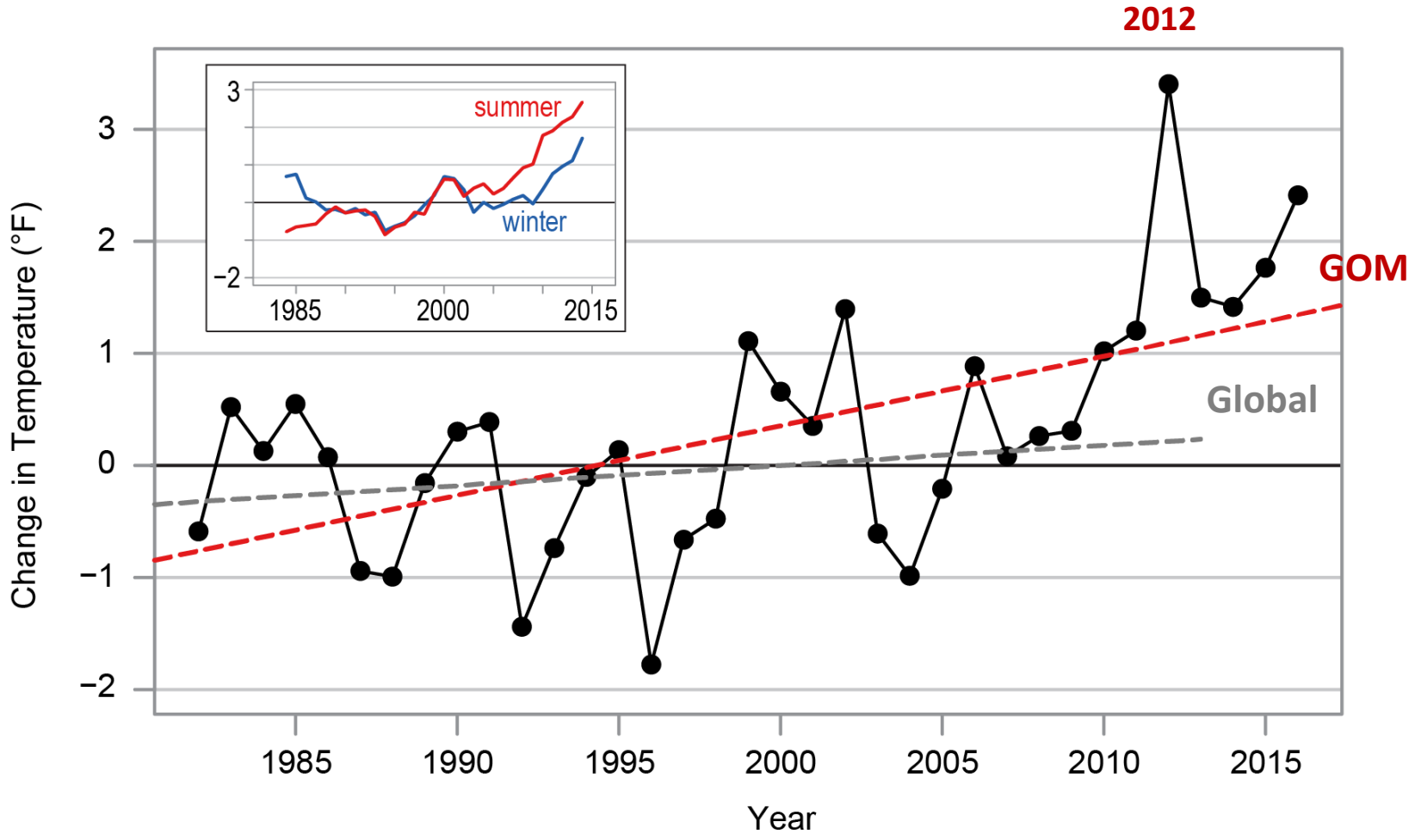
# The Gulf of Maine – a hotspot of warming






# Why study phenology in the Gulf of Maine?

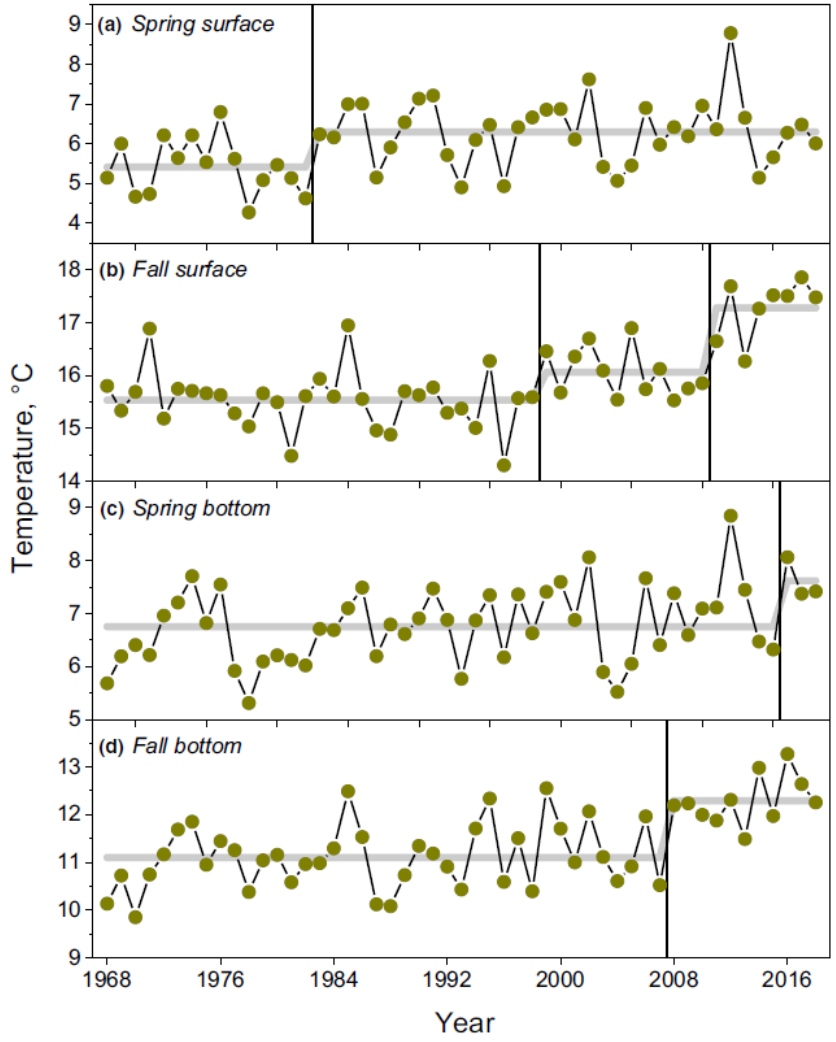
- Highly seasonal system
- Seasonal foraging and breeding/spawning area




*Dupigny-Giroux et al. 2018. NCA4, NE Chapter.*

# Seasons change…but not like before

## Seasonal thermal regime shifts




*Friedland et al. 2020*

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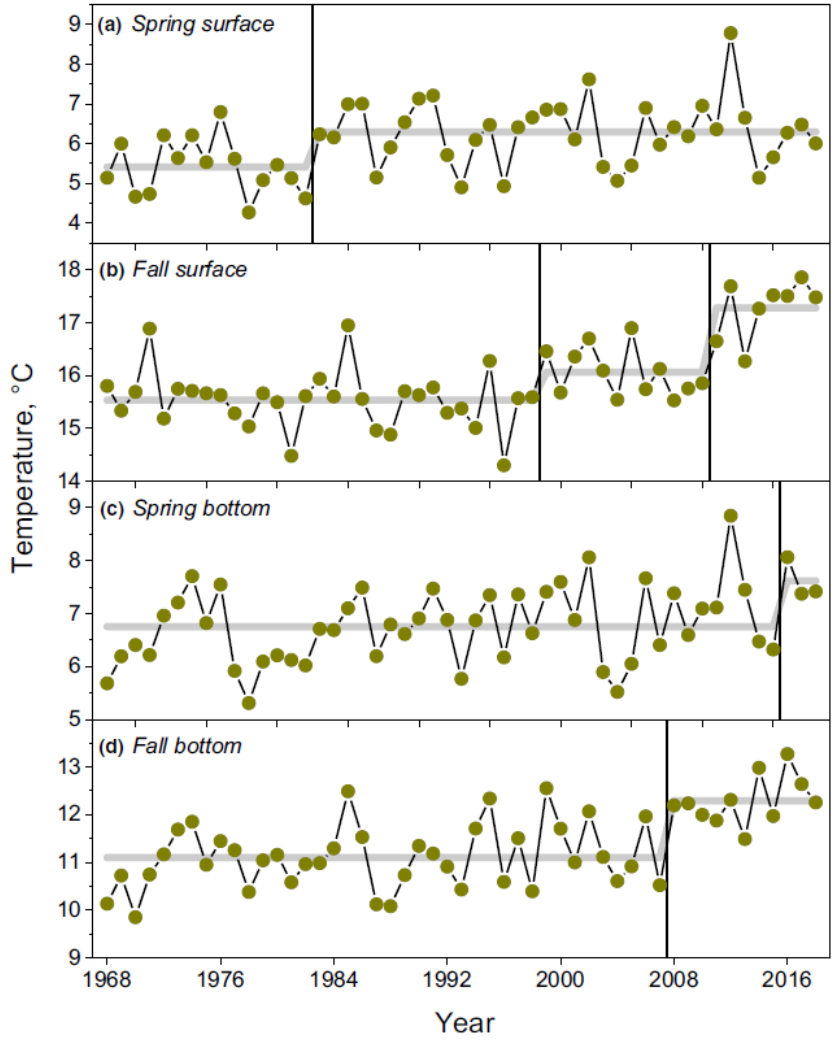
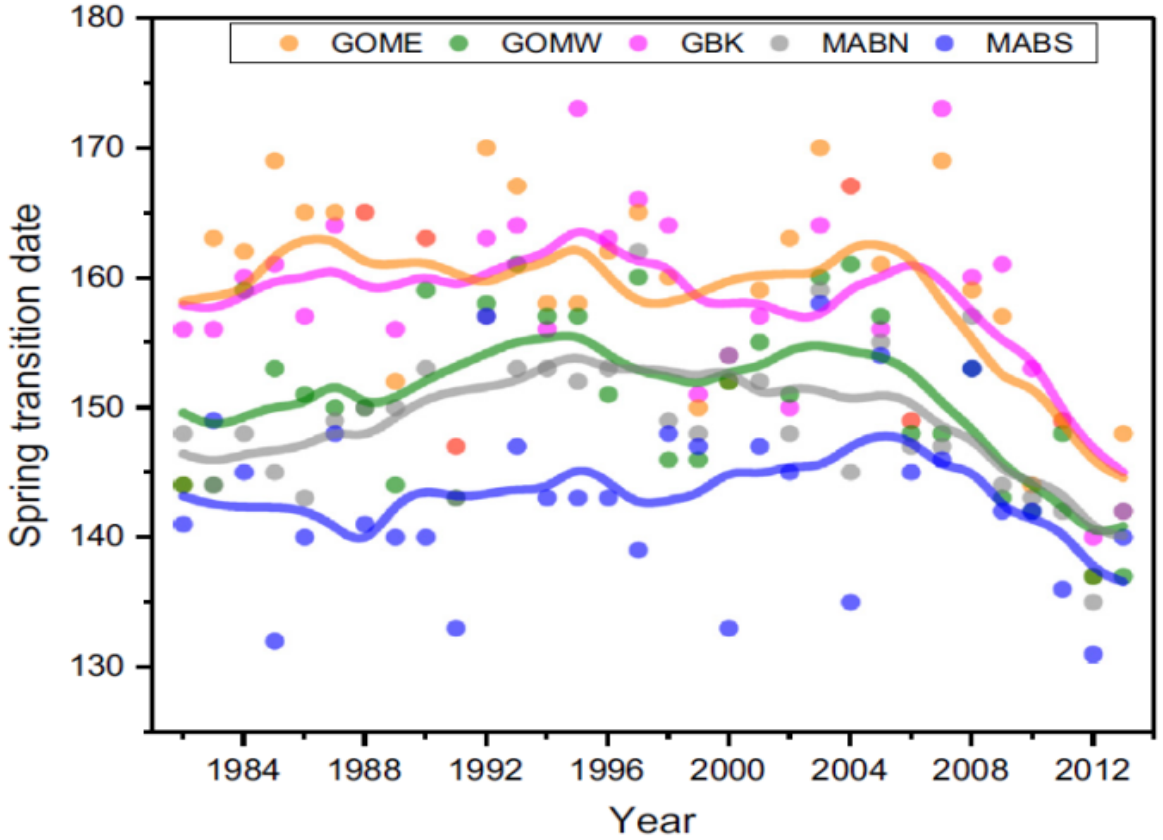
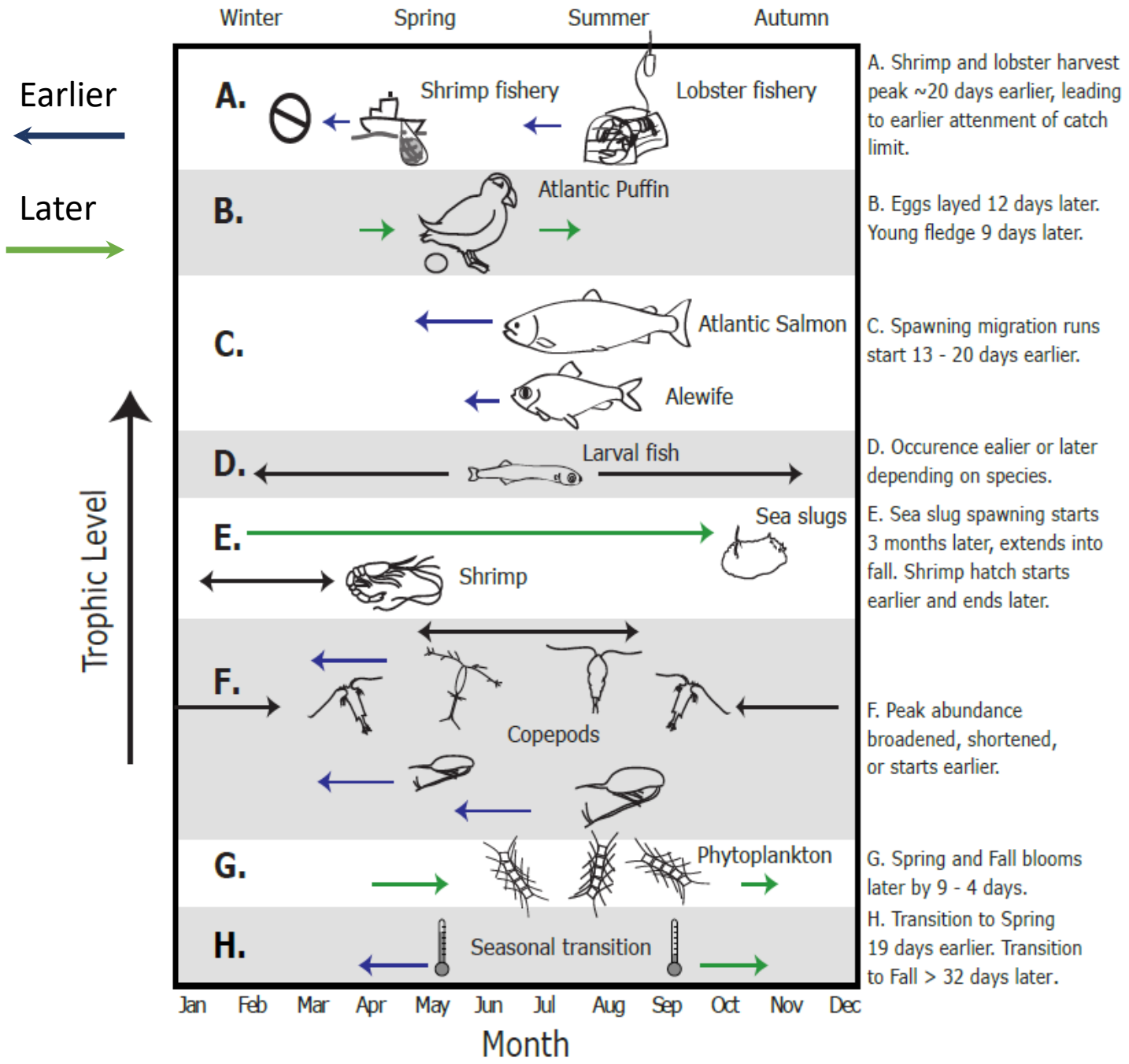



*Friedland et al. 2020*

## Spring onset




*Friedland et al. 2015*




# Evidence for shifts across the GOM ecosystem

- Few studies overall (N=20)
- Most evidence for base trophic levels
- High variability suggests potential for mismatches

*Staudinger et al., 2019. Fisheries Oceanography*

# Focal small pelagic (forage) fish in the GOM

**River herring**

- Alewife (*Alosa pseudoharengus)* blueback herring *(A. aestivalis)*
- Highly migratory, anadromous
- Moratorium on fishing
- Bycatch in At. Herring fishery
- Limited inshore data

**Sand lances**

- American *(Ammodytes americanus*) Northern (*A. dubius)*
- Inshore, offshore
- Unmanaged forage fish
- Catchability issues in trawls

**Atlantic herring**

- *Clupea harengus*
- Commercial fishery
- Inter-guild competition, anti-cycle w/sand lance
- Limited inshore data

# Co-produced research questions

- **Have there been changes alewife spawning migration phenology?**
  - Time-of-year (TOYs) restrictions on watershed development, water withdrawals, irrigation
  - Seasonal fishing restrictions

- **Are nesting seabirds becoming temporally mismatched with their prey?**
  - Local availability / depletion
  - Effects on fitness, survival and population dynamics

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- **Is whale (foraging) habitat use of Cape Cod Bay changing?**
  - Seasonal closed areas
  - Fishing / entanglements with fixed gear
  - Shipping traffic

# Data collection and analyses

**To track phenology** – need to know not just that species was there, but when it was there

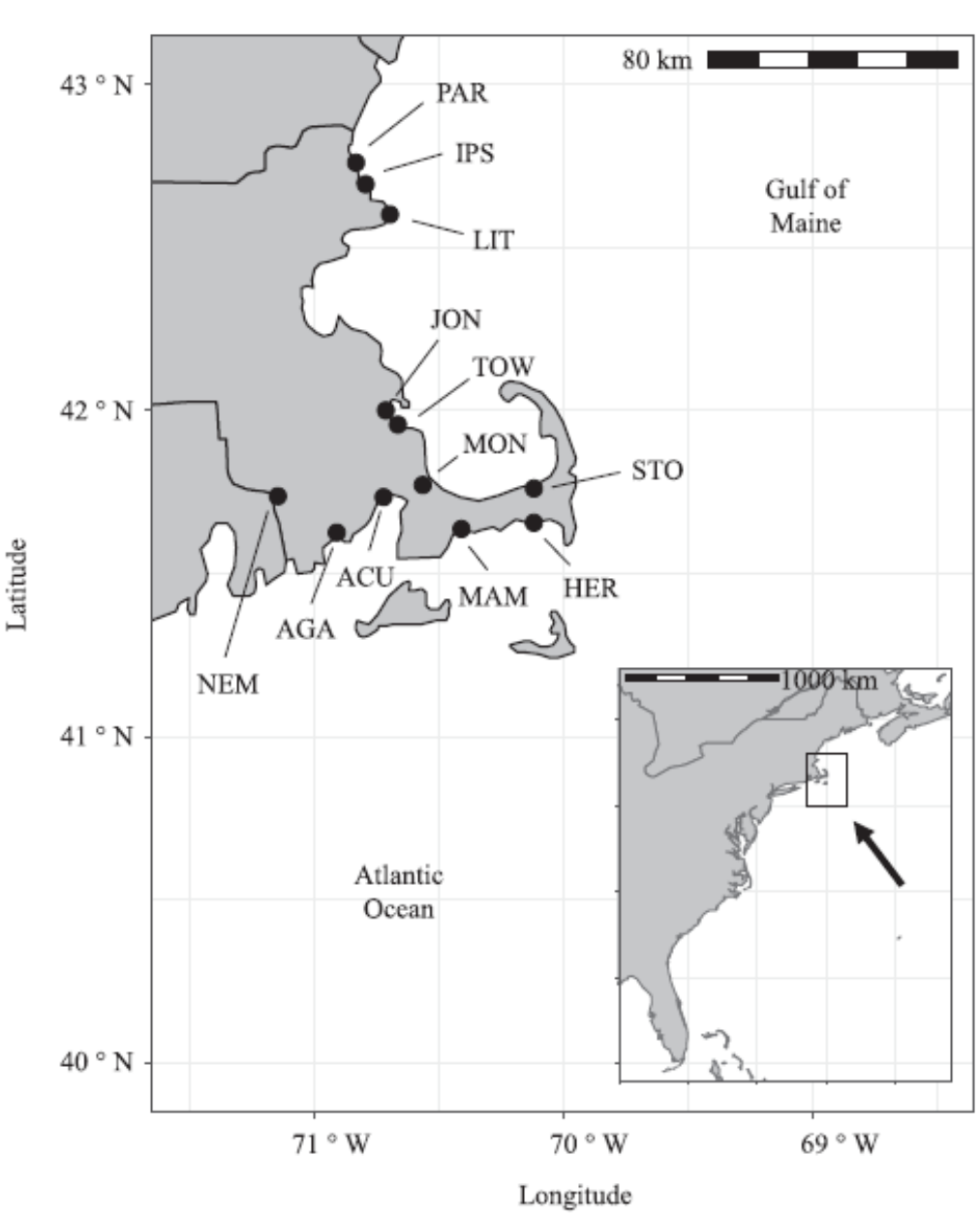
**Non-traditional data sources**

- Citizen science networks for river herring
- Using predators as biological samplers

**High maintenance  data**

- Compile
- Digitize
- Standardize

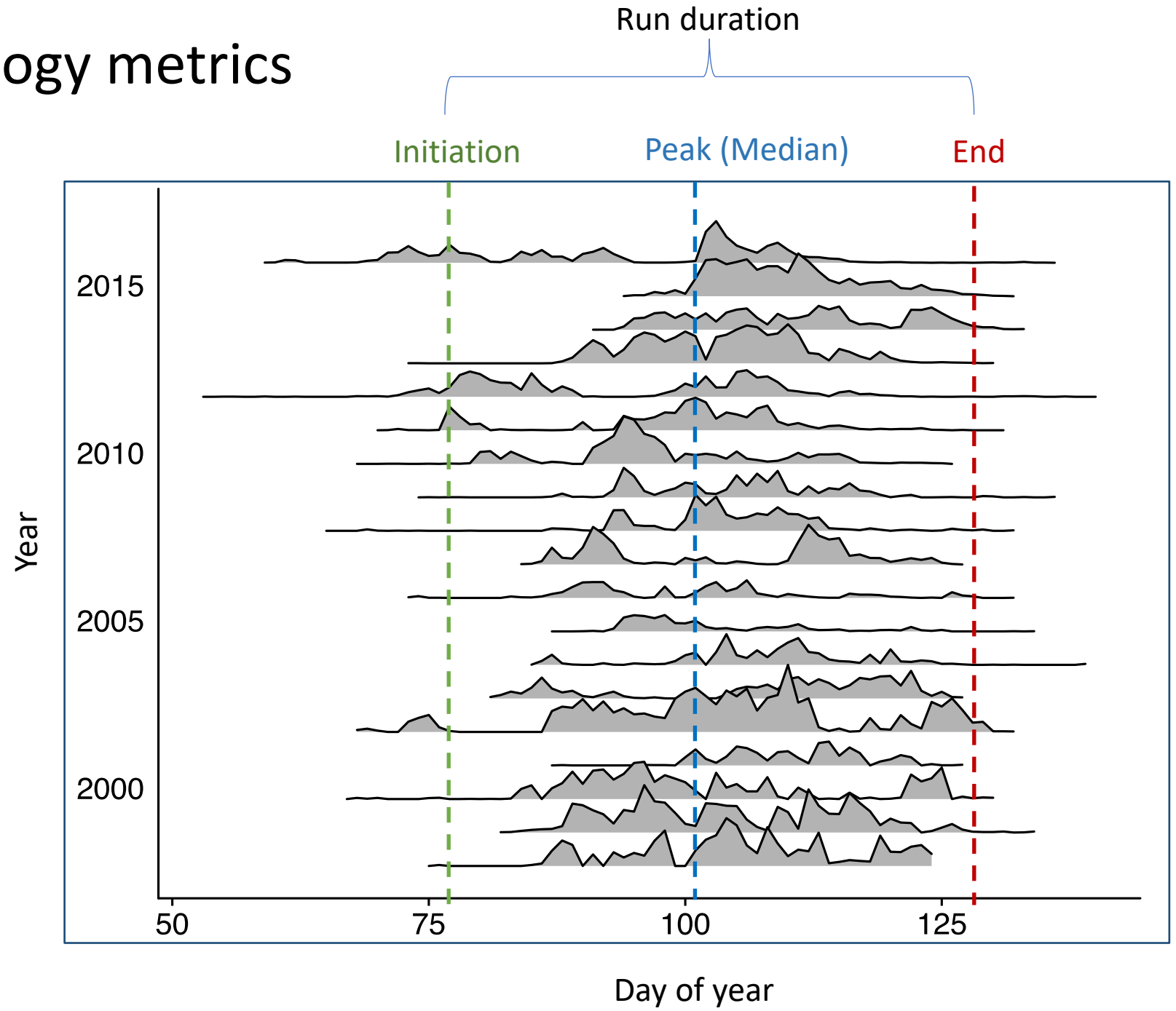
# Monitoring river herring with citizen science networks



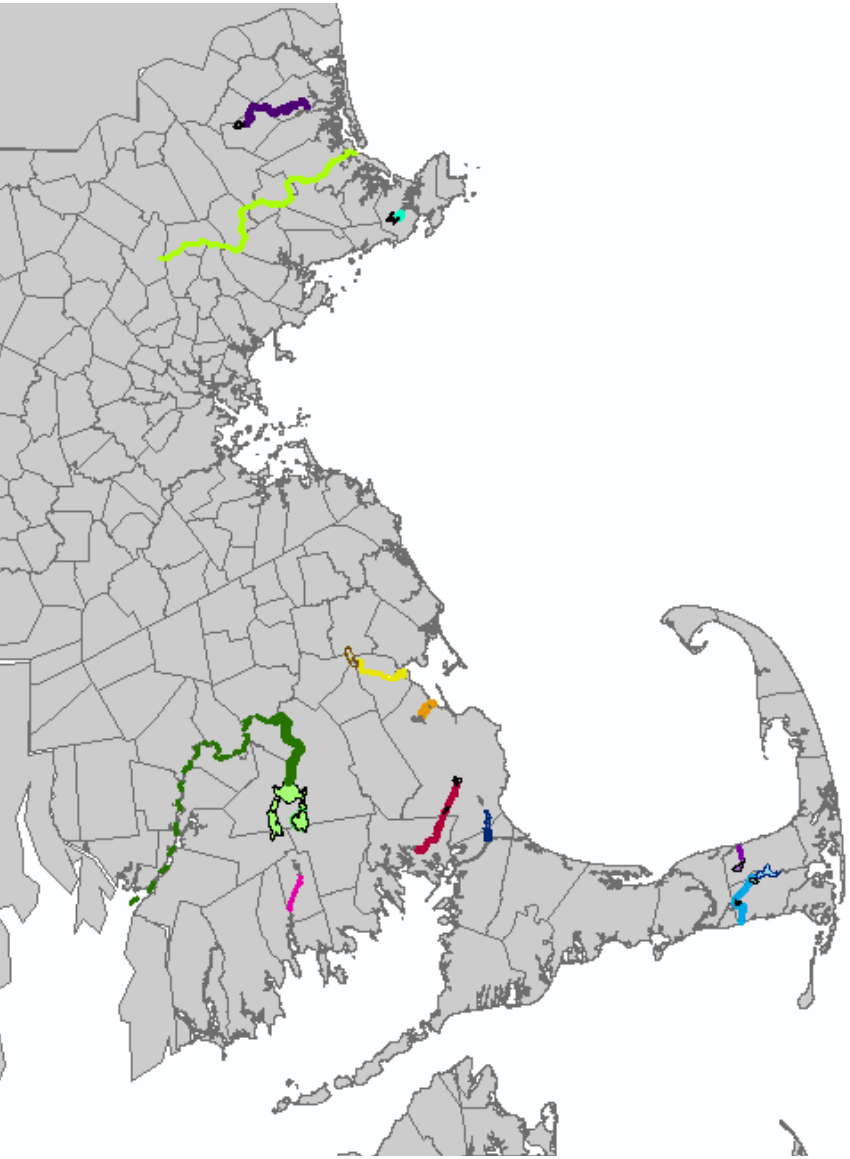

- Daily counts and temps
- 12 coastal streams
- 1990 – 2017

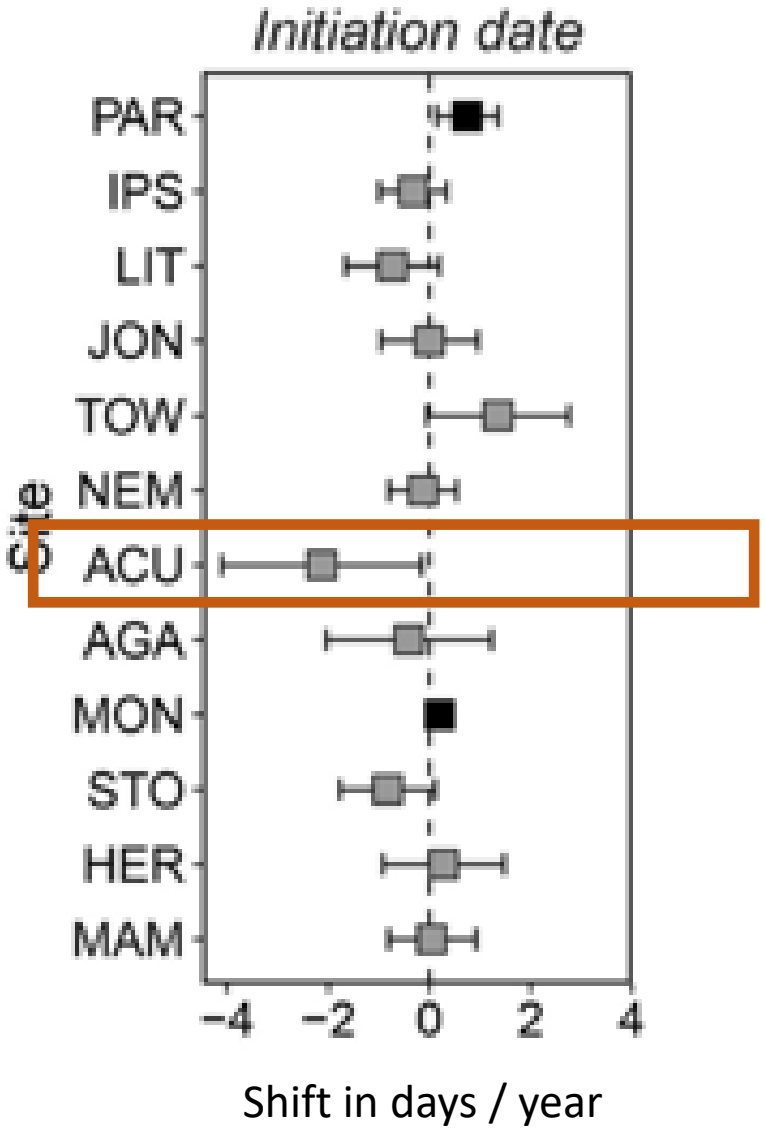
*Legett et al. 2021. TAFS; Dalton et al. 2022. Marine & Coastal Fisheries.*

# Phenology metrics



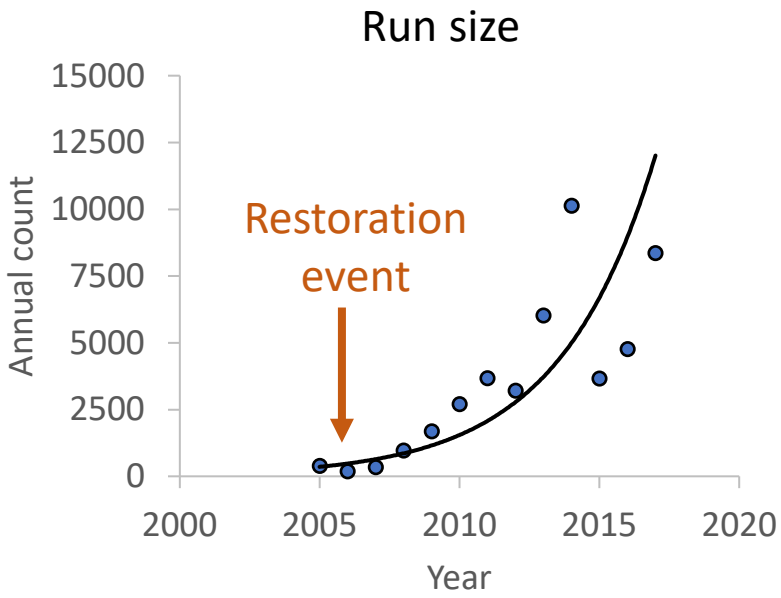
# Shifts in spawning migration phenology varies spatially






Statistically significant

Non-significant



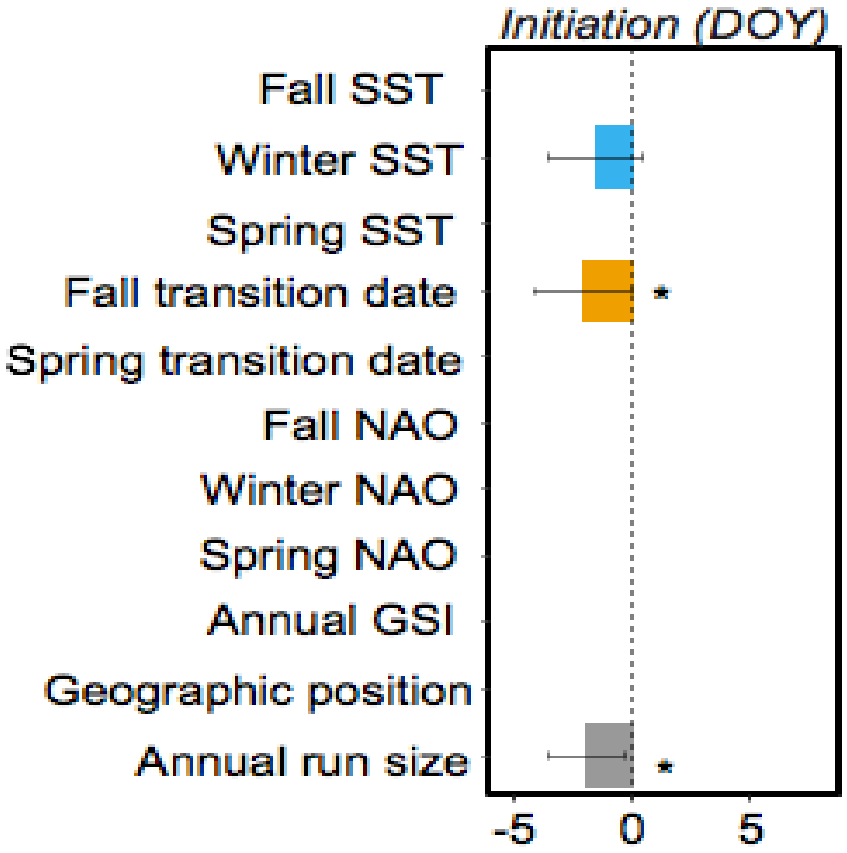

*Dalton et al. 2022. Marine & Coastal Fisheries*

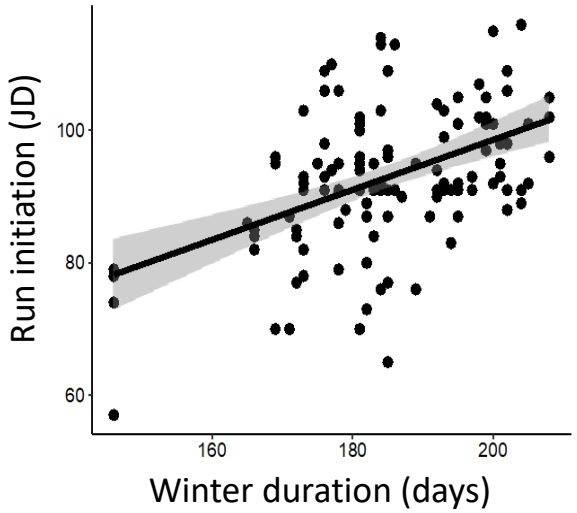
# Regional environmental and ecological drivers of movements

- Warmer winter minimum temps
- Shorter winters (FTD)

≈ Winter severity

- Annual run size



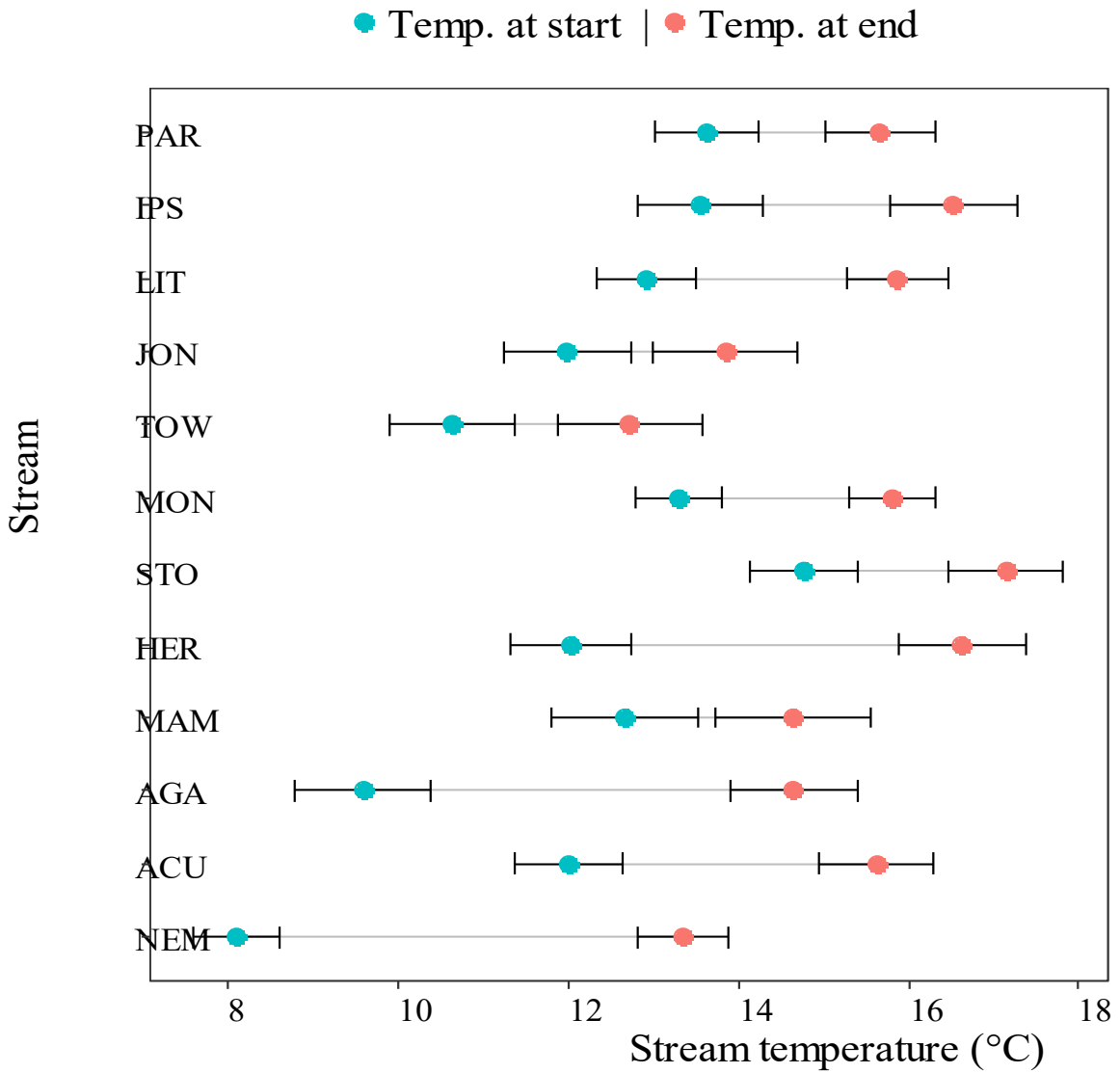





Full-average model coefficients ± S.E.
from linear mixed-effects regressions

*Dalton et al. 2022. Marine & Coastal Fisheries*

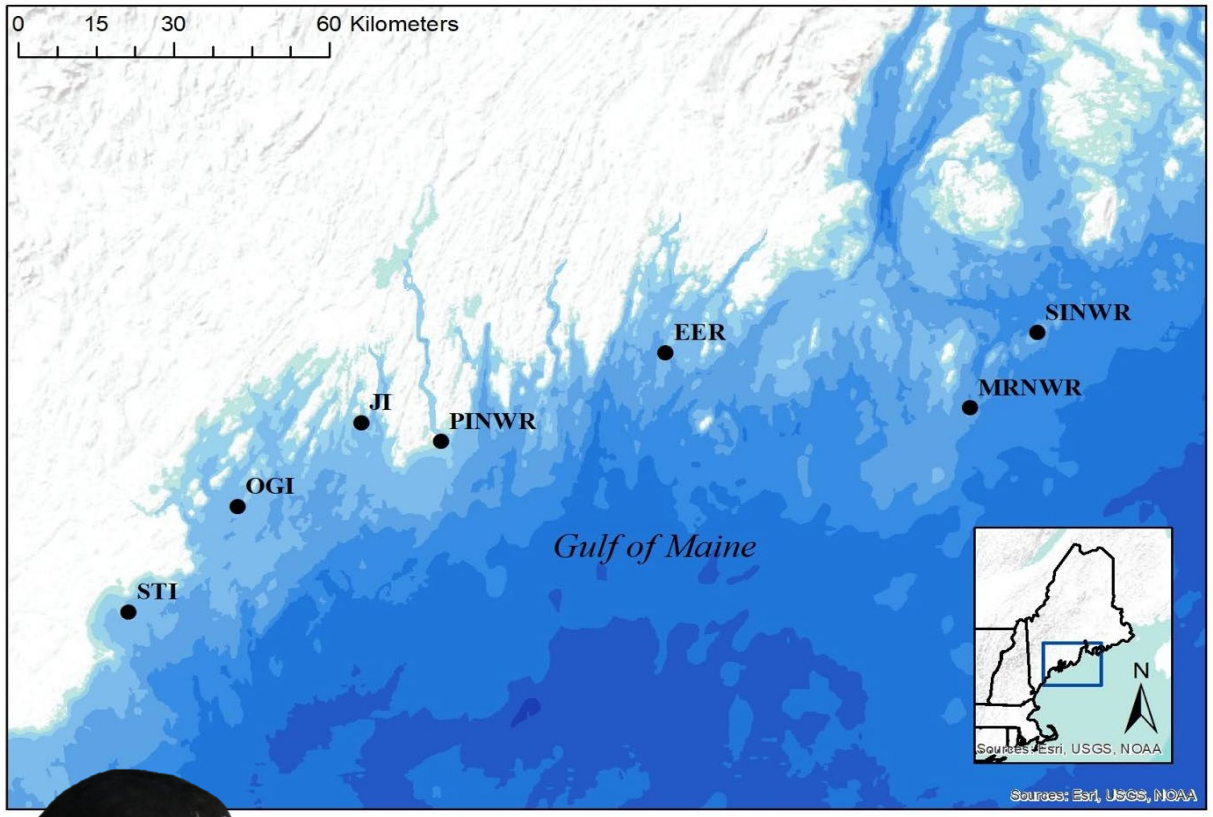
# Runs that started later were shorter in duration




- Narrow range of temperatures
- Increase risk of thermal squeeze
- Approaching historical thermal thresholds (~20°C)

*Legett et al. 2021. TAFS.*

# Seabird-forage fish predator-prey mismatches

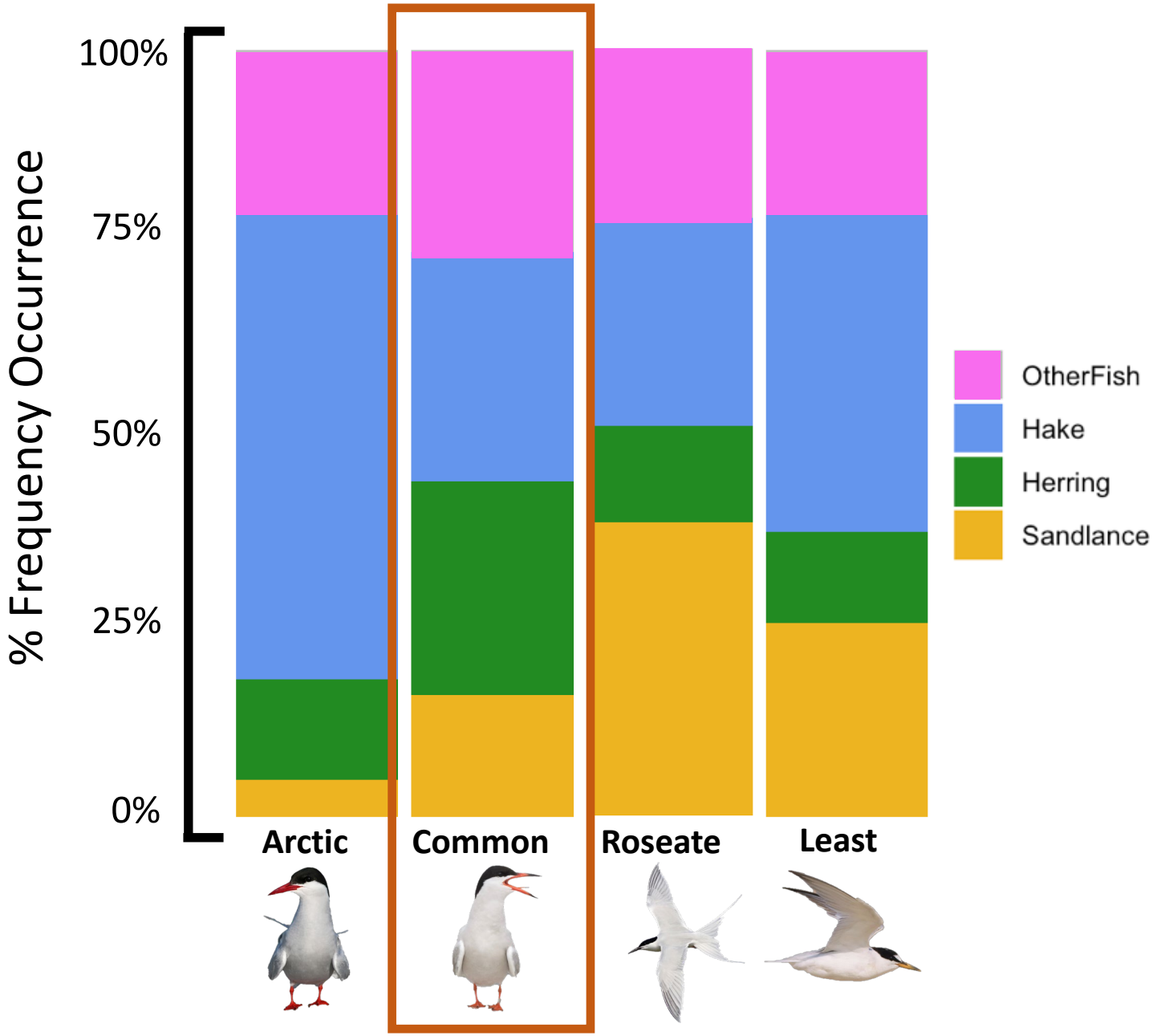



- Forage fish occurrence in diets
- 7 nesting islands, Maine Coastal Islands NWR
- 1988 - 2018

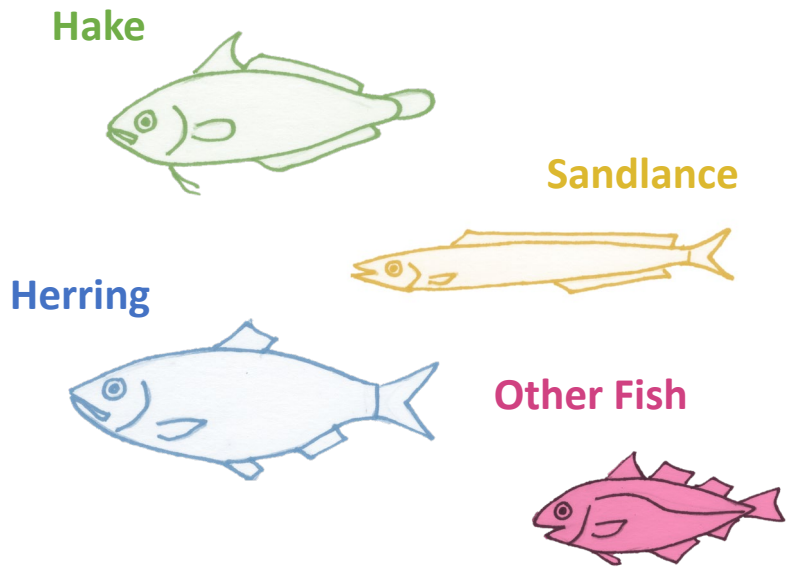
U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

Audubon

# Terns are highly specialized predators

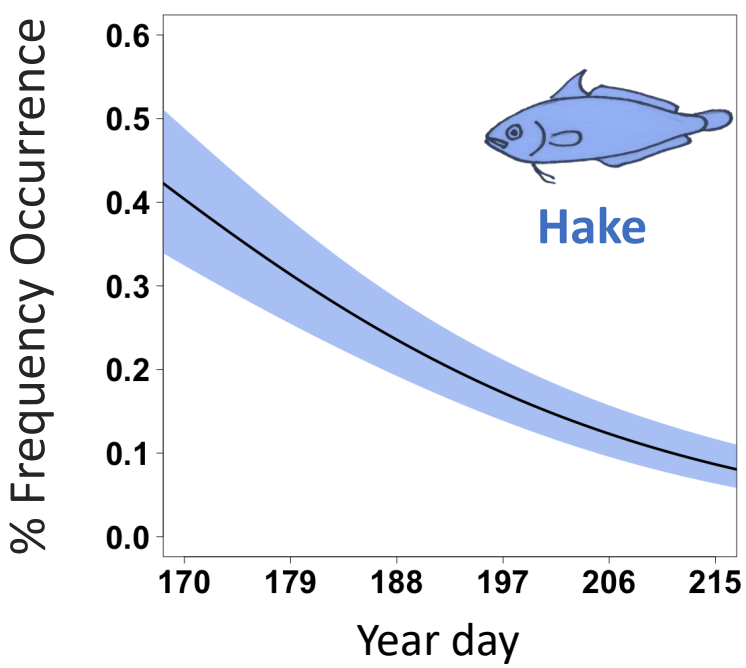


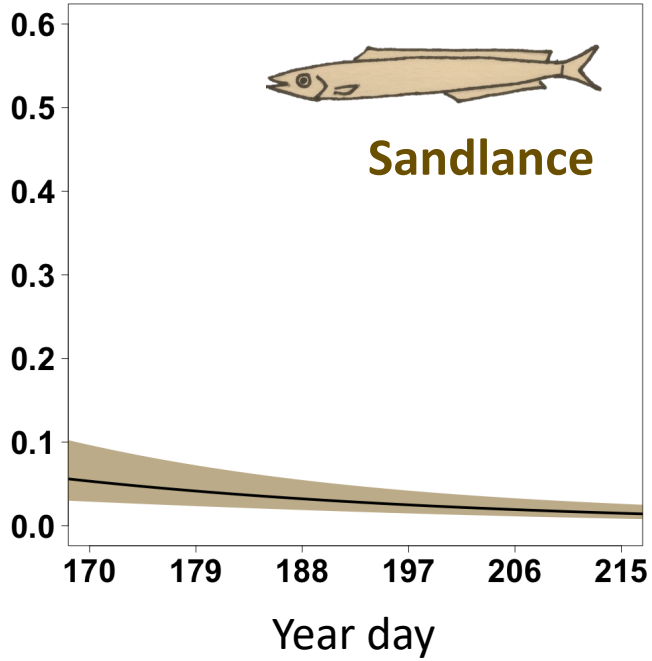

- btw 1988 - 2018 > 70% of fish in chick diets contain only 3 prey groups

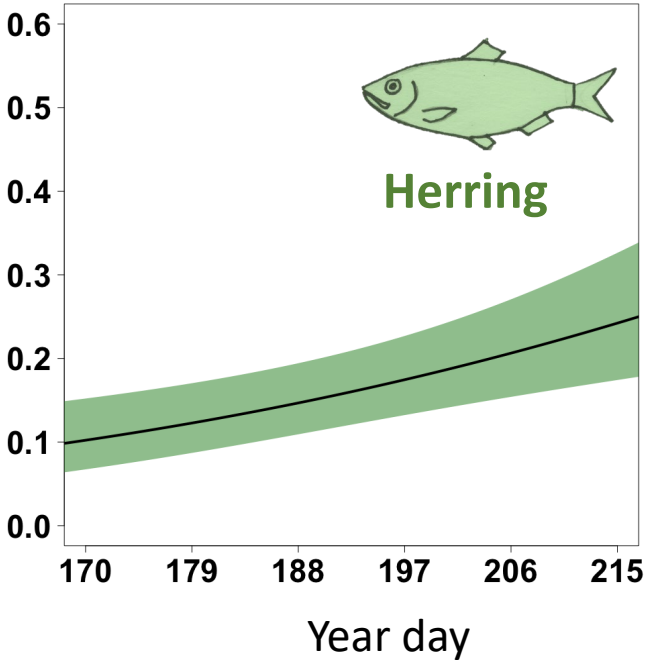



*Yakola et al. 2022. Waterbirds.*

# Seasonal dietary phenology



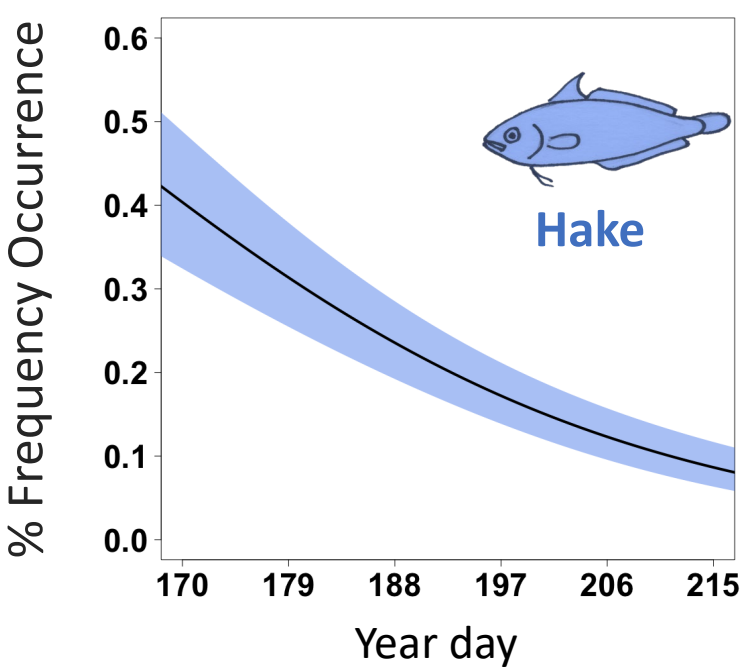

June 15th

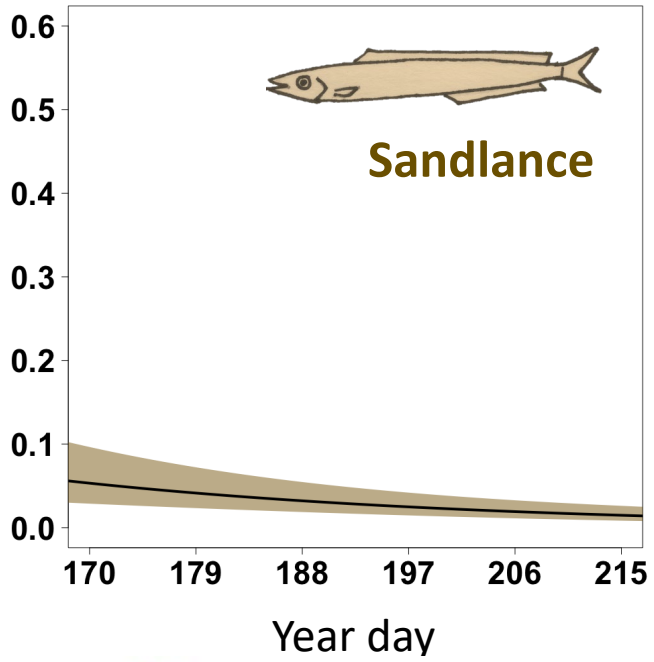
July 10th

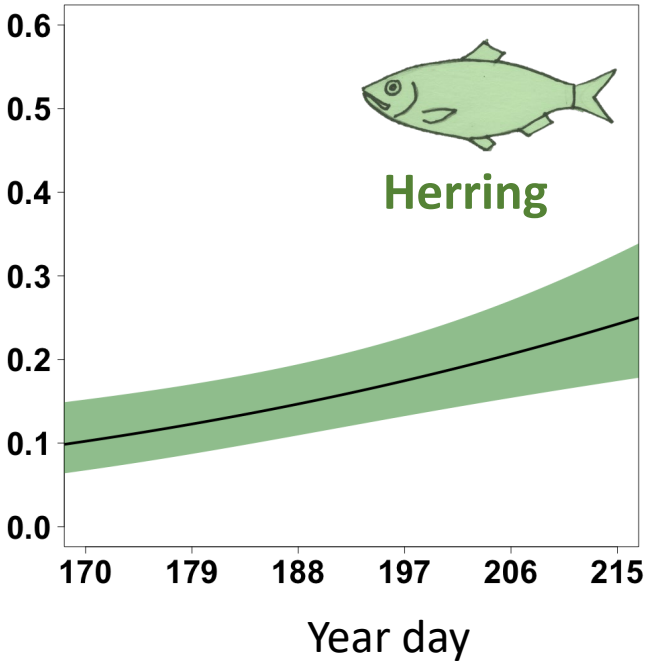
Aug 3rd

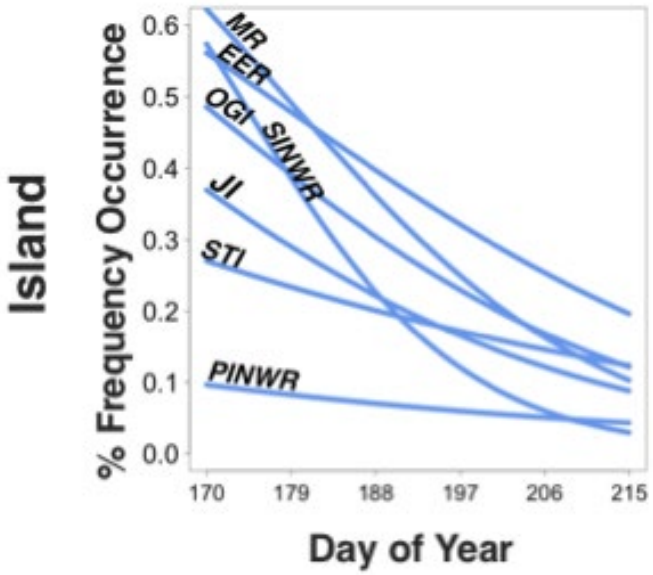
*Yakola et al. In preparation for PLoS One.*

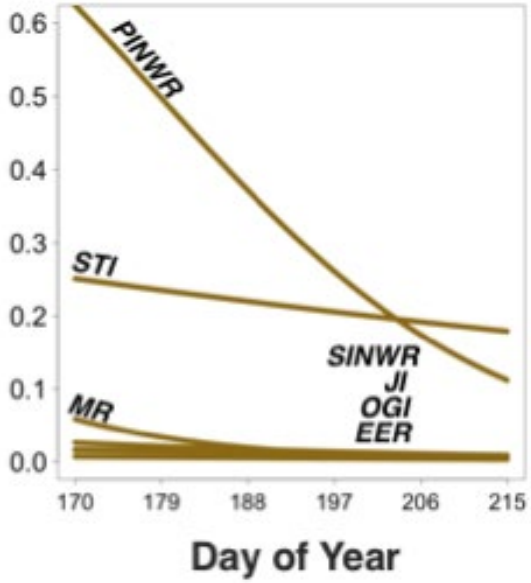
# Location matters!

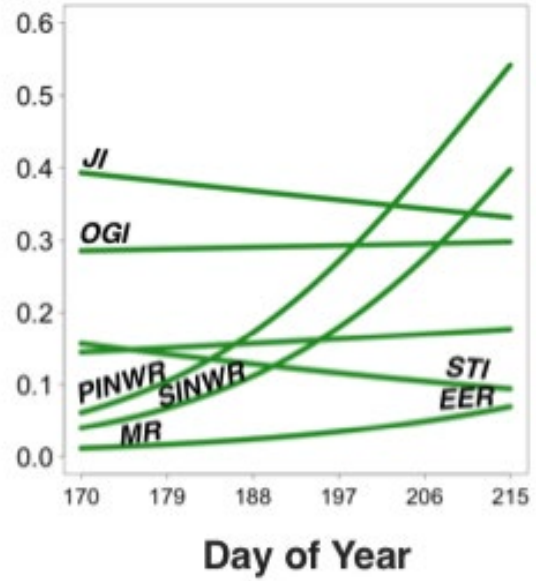


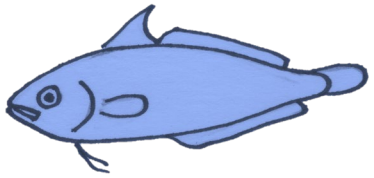



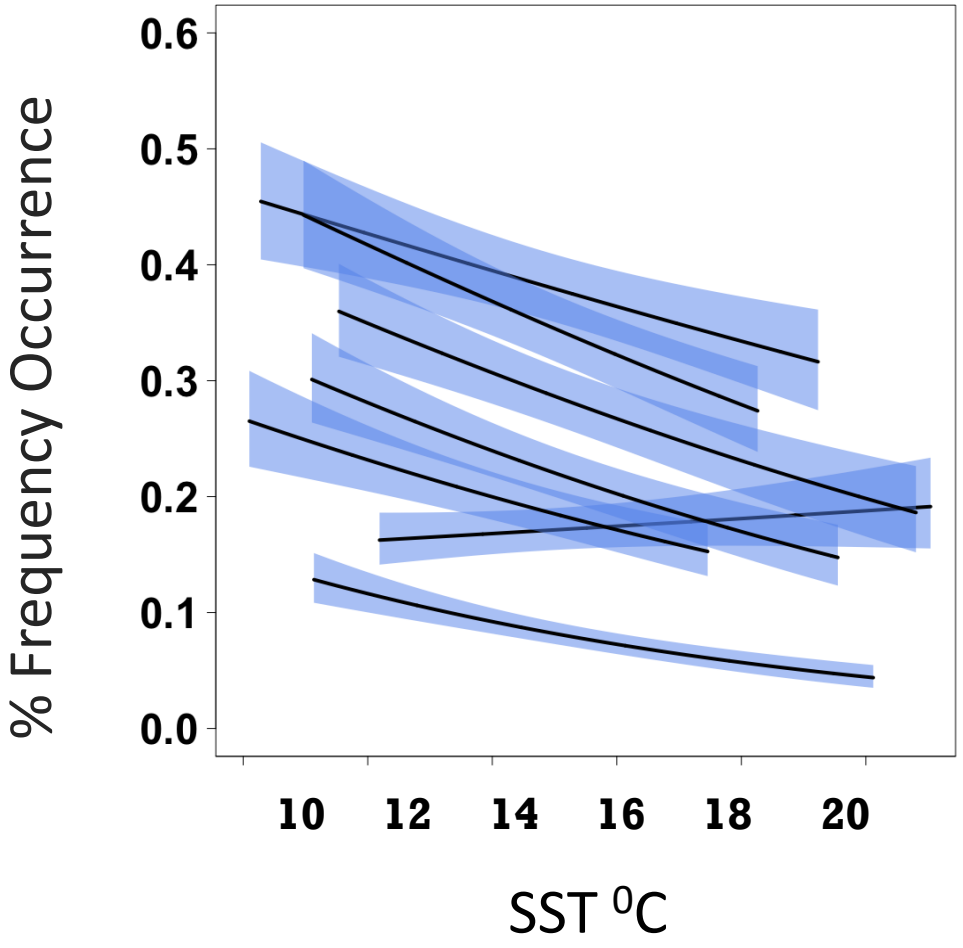



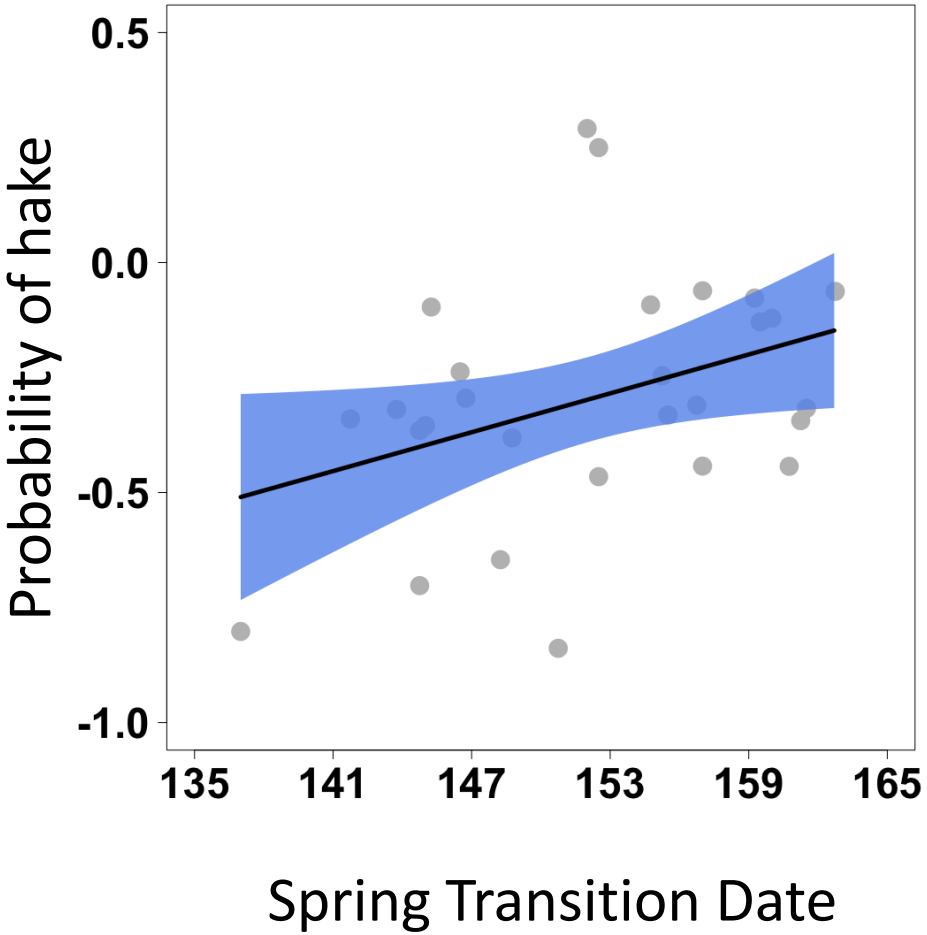



# Hake show sensitivity to multiple warming signals



**Hake**

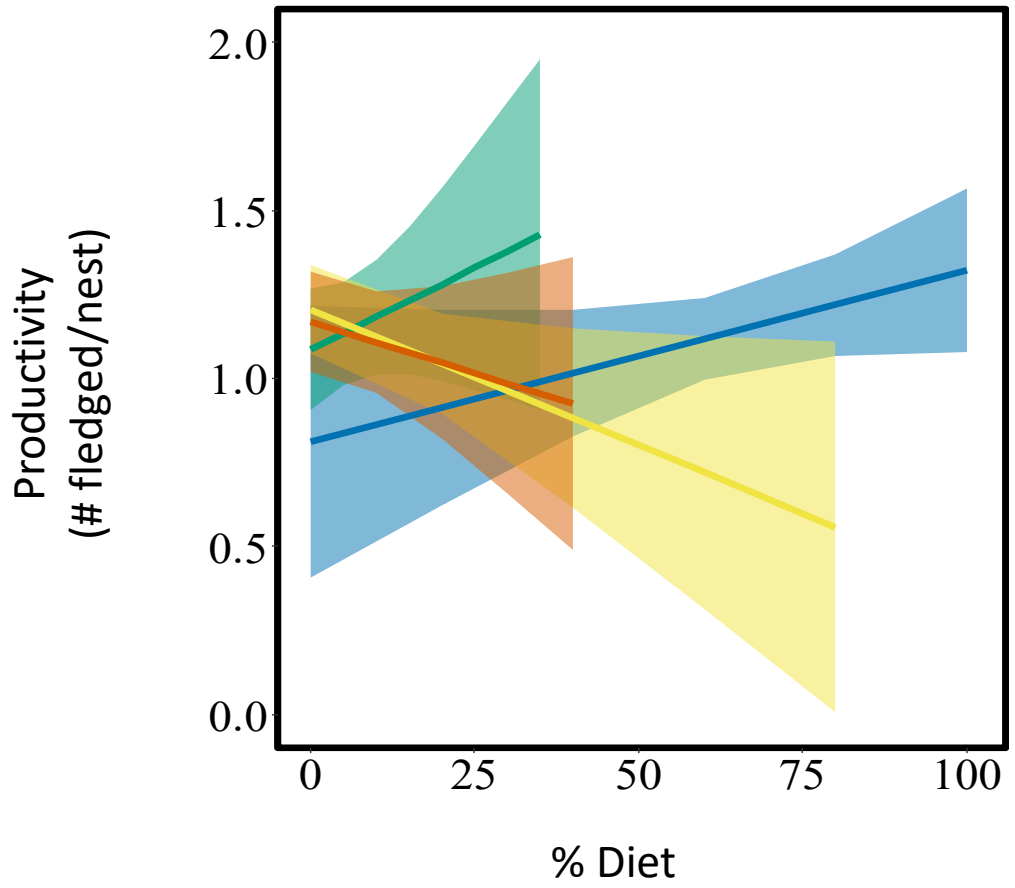



*Yakola et al. In preparation for PLoS One.*

# Preferred prey positively influences tern productivity

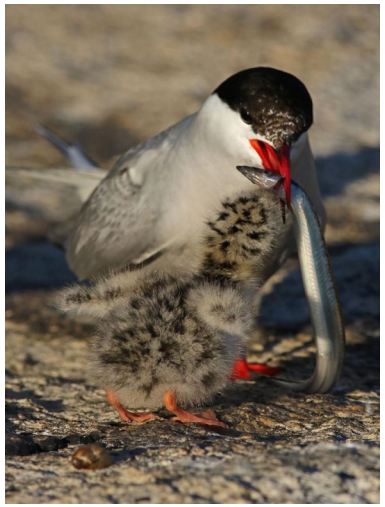
Common terns




*Legett et al. in preparation for Animal Ecology.*

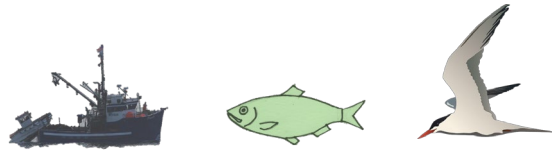
# Conclusions

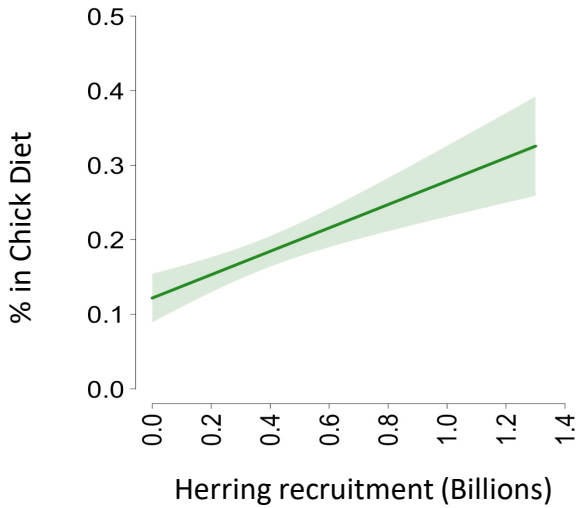
- New insights gained from non-traditional sources
  - Citizen science networks
  - Predators as biological samplers



- Responses are non-uniform in magnitude and directionality across:
  - Regional and local scales
  - Species and populations
  - Environmental drivers

- Ecological and anthropogenic factors confound climate responses:
  - Population size
    - Restoration
    - Fishing






*NOAA 65th Regional Stock Assessment (1986-2017)*

# THANK YOU!!!

*Learn more at:*

necasc.umass.edu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