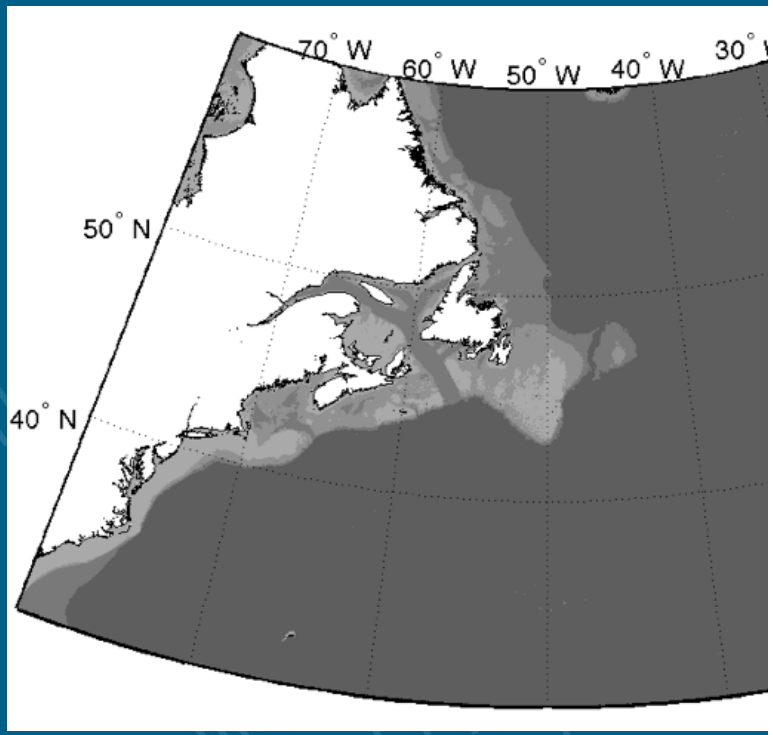
# Response of North Atlantic Ecosystems to Climate Change

*Andrew J. Pershing*

Gulf of Maine Research Institute
Science. Education. Community.

# Outline

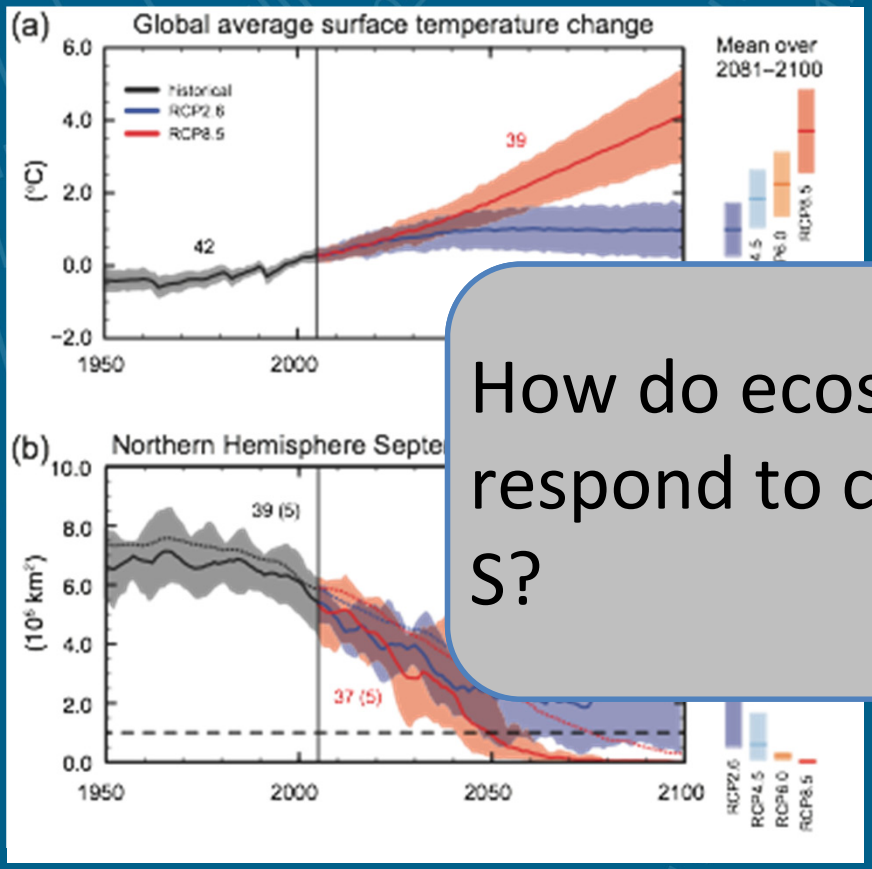
- Change in the North Atlantic
- Plankton community assemblages
- Physical drivers
- Implications
- Warming & fisheries



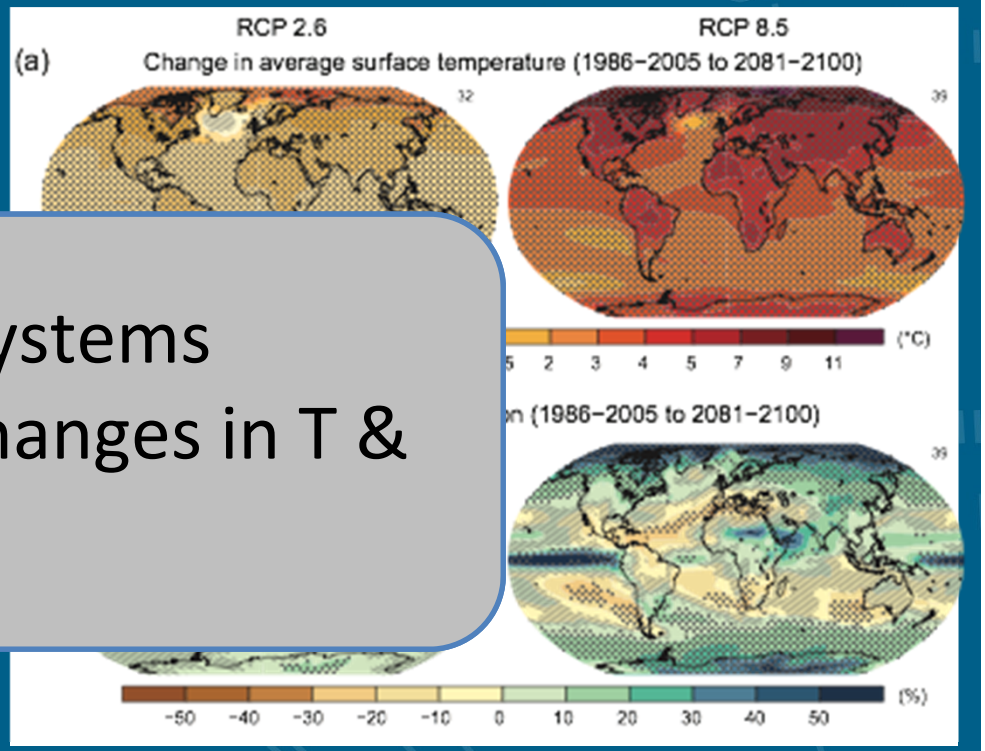


- Acknowledgements
  - collaborators:
    - Chuck Greene, Nick Record
    - Kathy Mills, Karen Stamieszkin
  - funding:
    - NSF CAMEO
    - NSF Coastal SEES
  - data: NMFS, SAHFOS, BIO

# Climate Projections




How do ecosystems respond to changes in T & S?




- North Atlantic will get warmer and fresher

# Plankton Patterns: CPR

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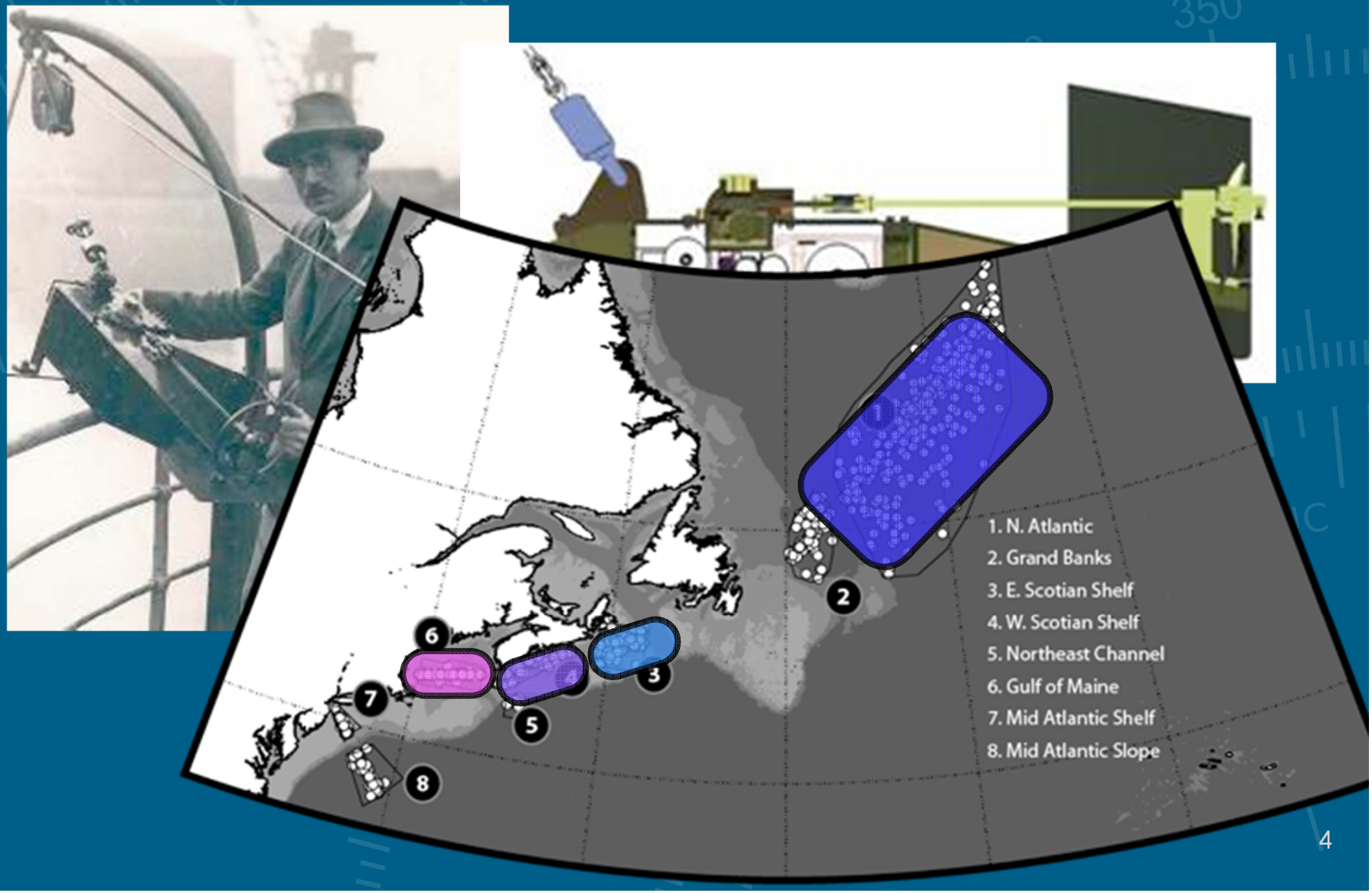
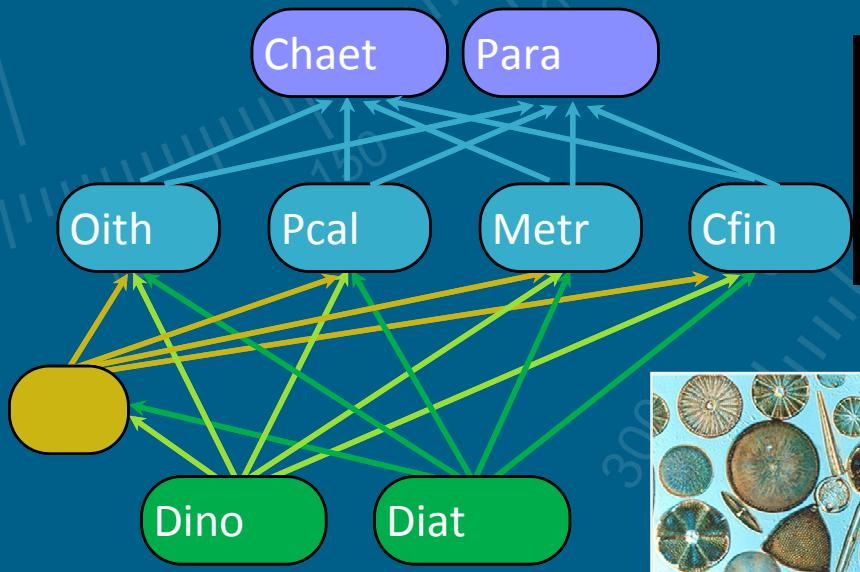
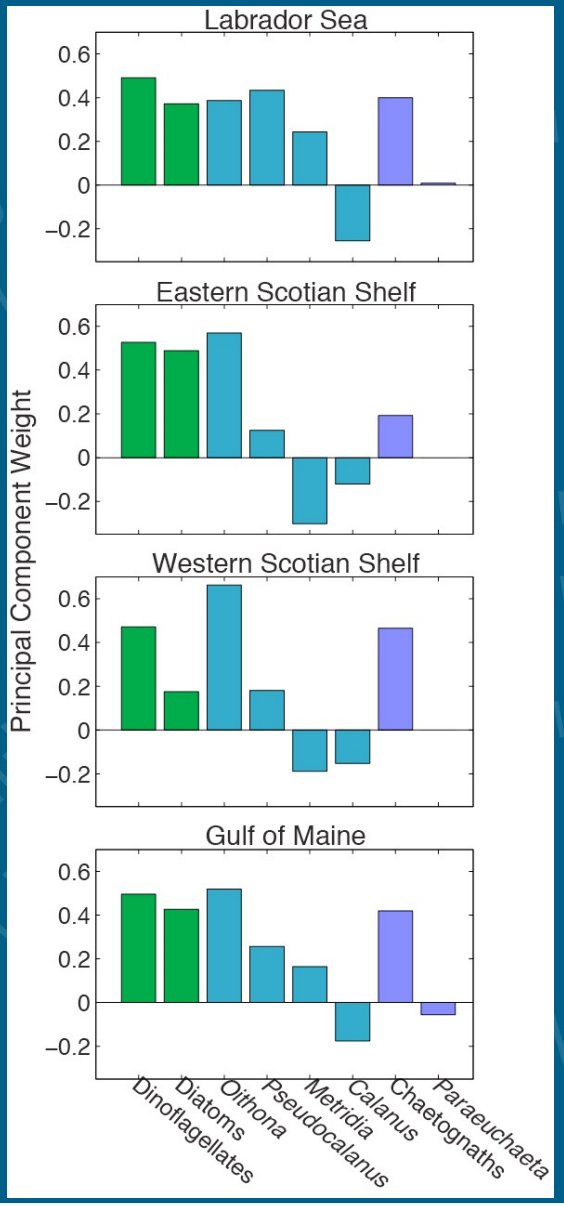


# Plankton Patterns: PCA

- Mode 1: Similar structure
  - phytoplankton + small copepods + chaetognaths
  - vs. *Calanus finmarchicus*

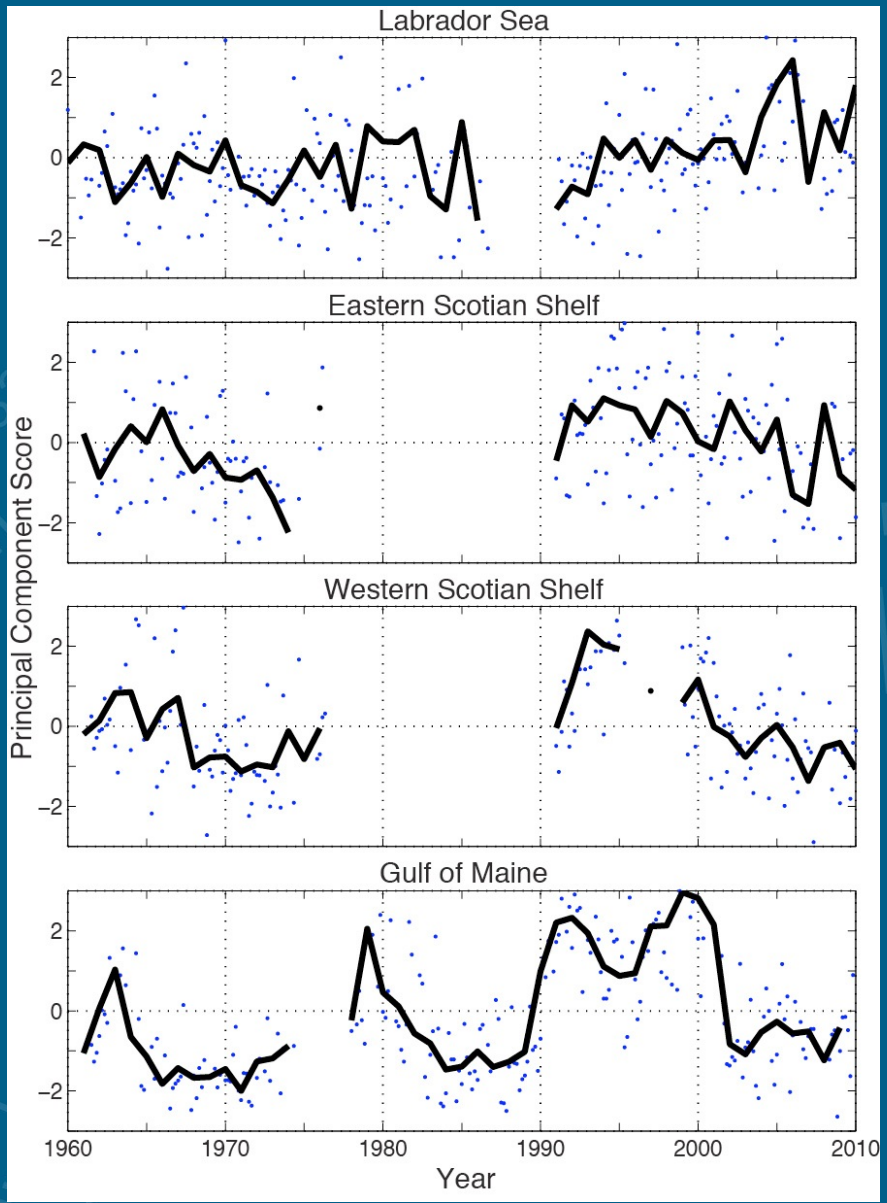






# Plankton Patterns: PCA

- Labrador Sea
  - trend since 1990
- ESS
  - 1980s black hole
  - 1960s slightly lower
- WSS
  - 1980s black hole
  - high 90s, lower 2000s
- Gulf of Maine
  - regime shift-like pattern
  - similarities with WSS



# Salinity Changes

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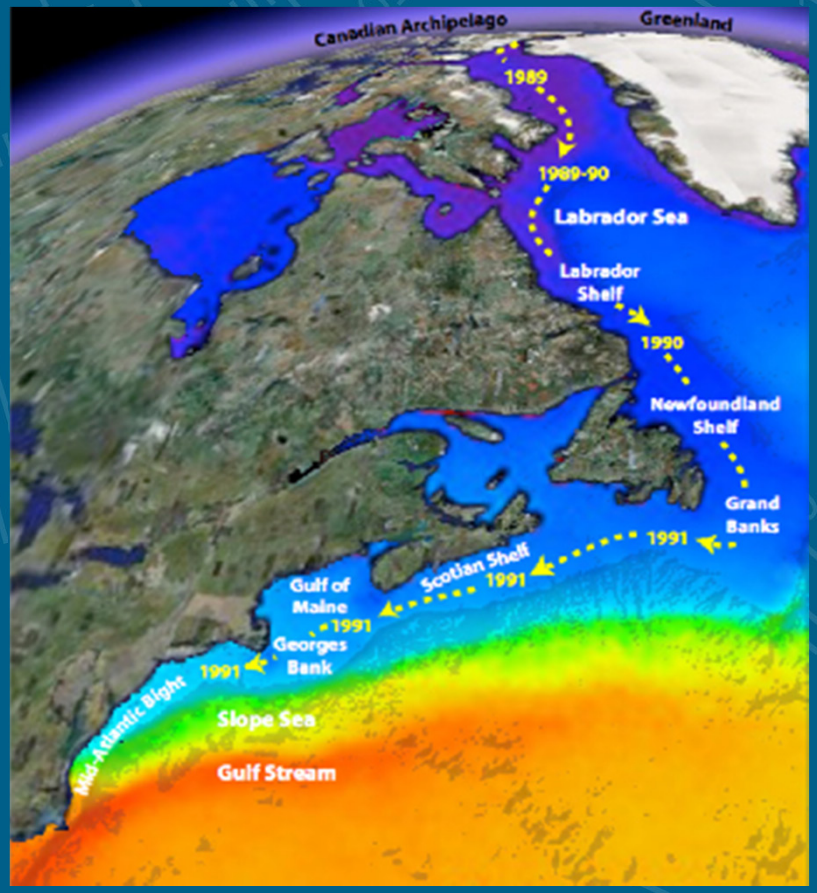
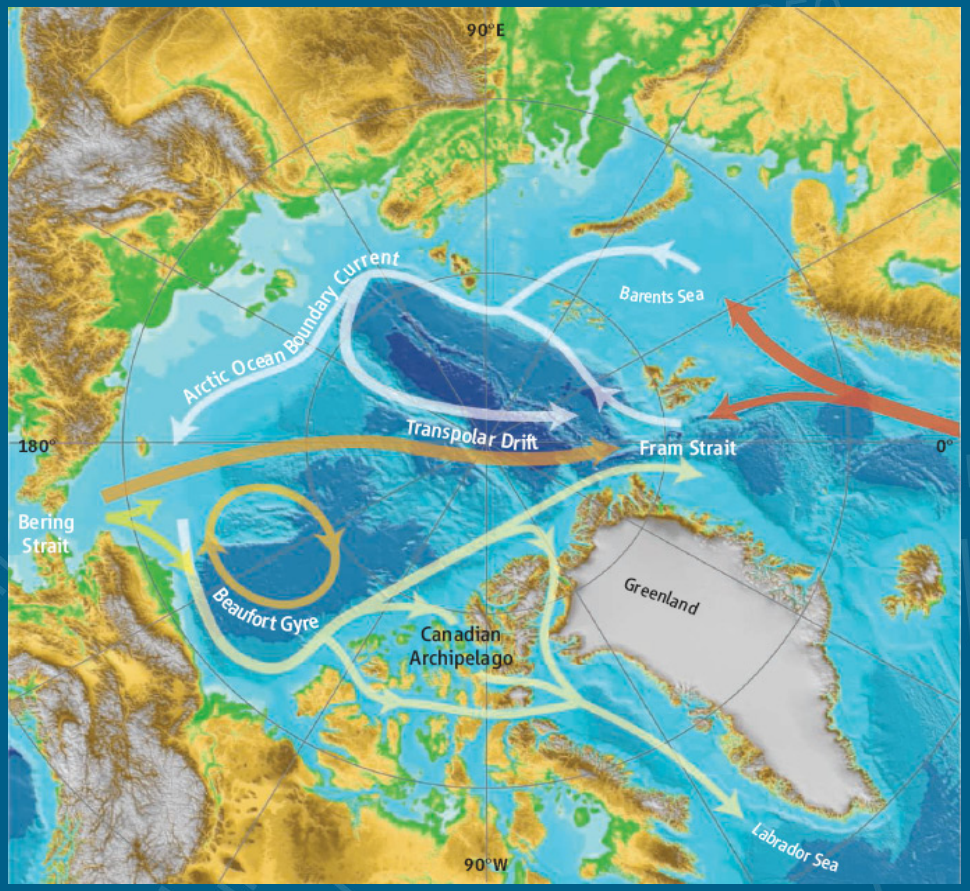
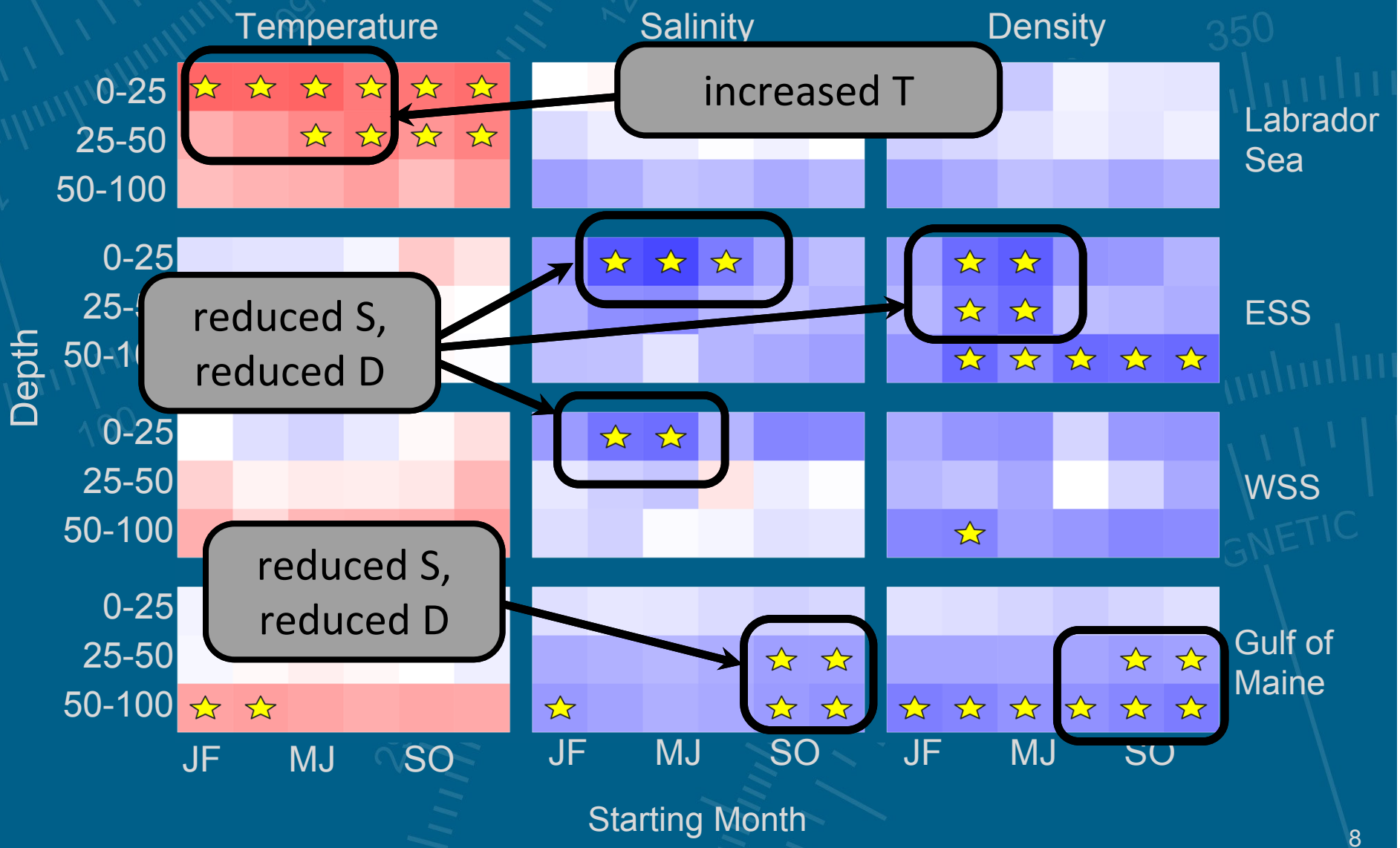



C. H. Greene, A. J. Pershing, Science 315, 1084 (2007).

# Correlation between plankton & hydrography



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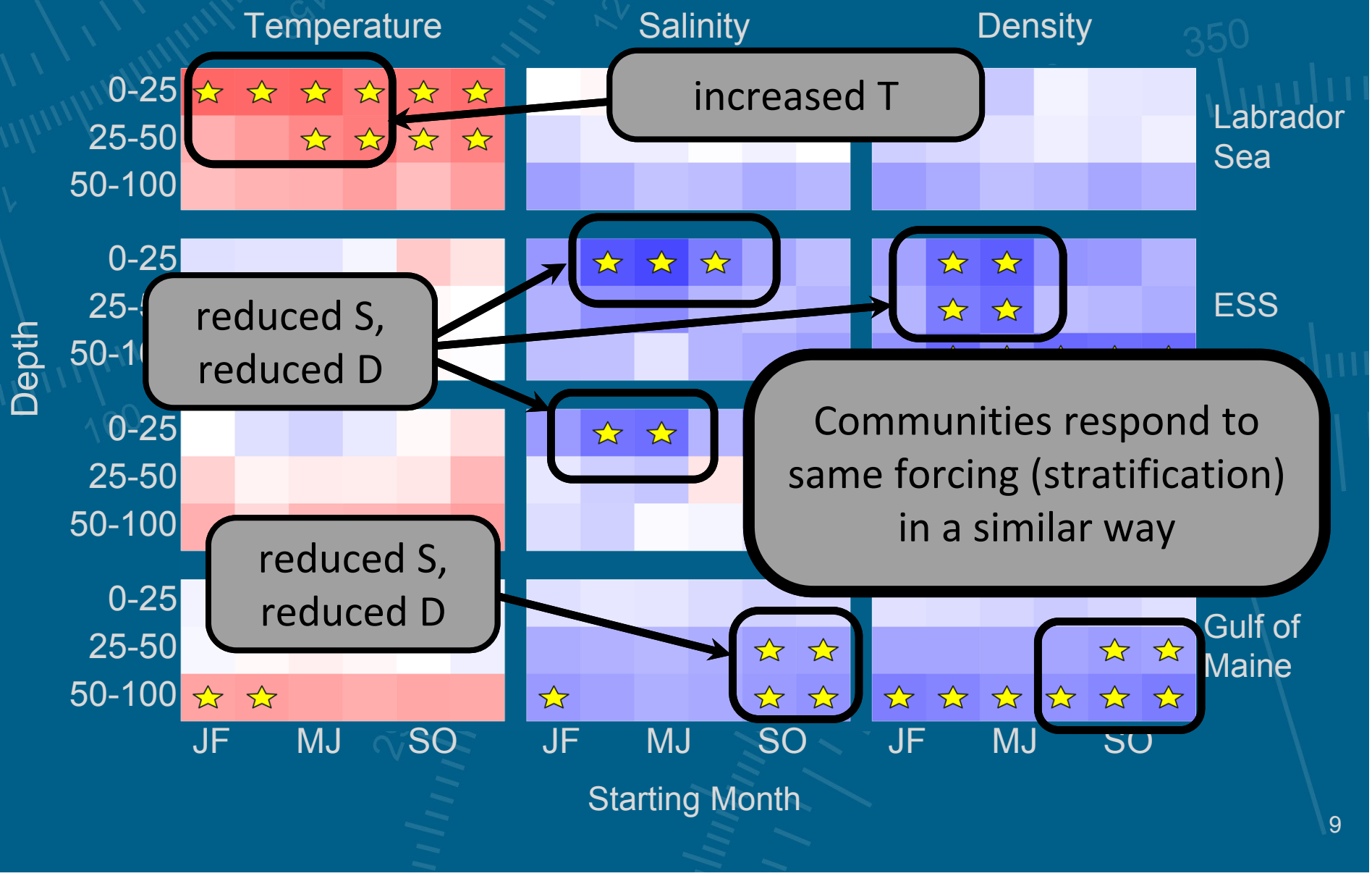

# What drives the response?

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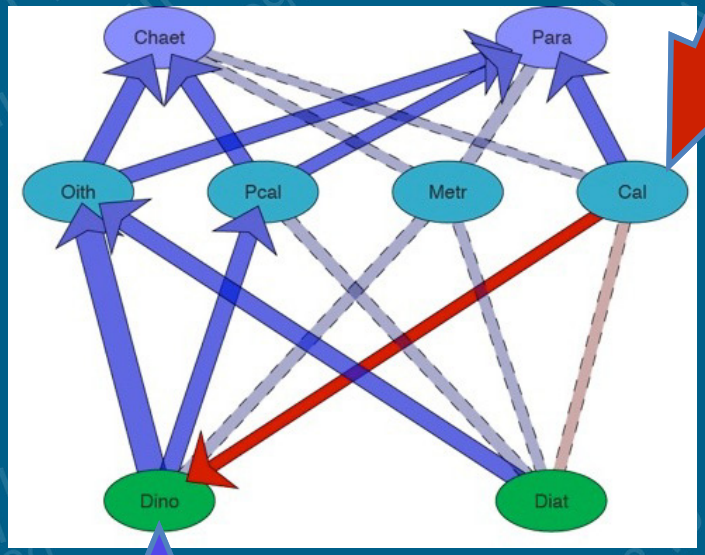
Labrador Sea




-90

Reduced *Calanus*, reduced grazing

Reduced light limitation

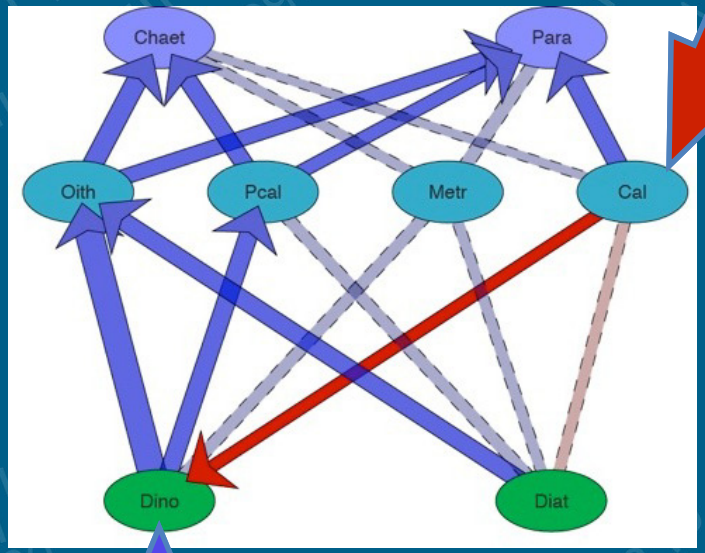
# Possible Mechanisms

- Forcing likely affects both *Calanus* and phytoplankton
- Phytoplankton
  - more stratification --> reduced light limitation
  - dinoflagellates esp. are associated with high stratification
- *Calanus*
  - habitat suitability?
    - *Calanus* prefers oceanic conditions (cold, salty, mixed)

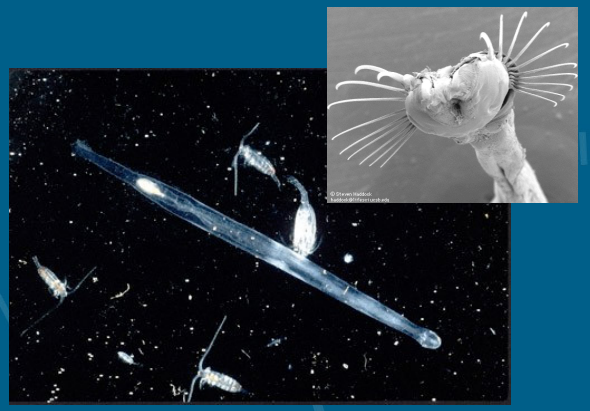
# What drives the response?

Gulf of Maine Research Institute

## Labrador Sea



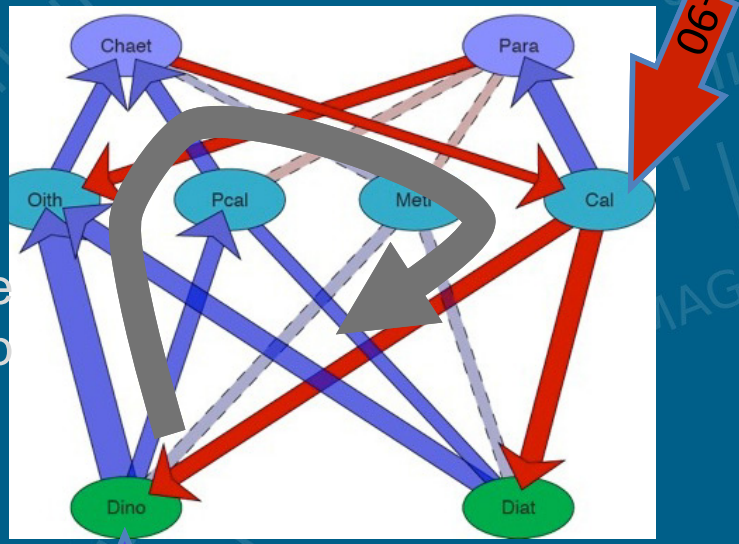

Reduced *Calanus*, reduced grazing



Reduced light limitation

Chaetognaths create positive feedback loop

## Gulf of Maine



# Summary

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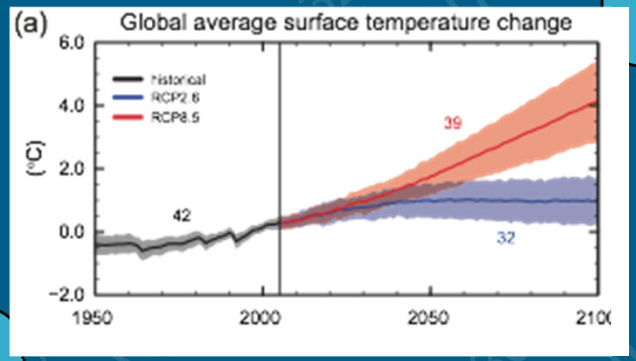
Warm, Fresh, Stratified

Chaet.

Sm Cop.

Calanus

Phyto




Cold, Salty, Mixed

Chaet.

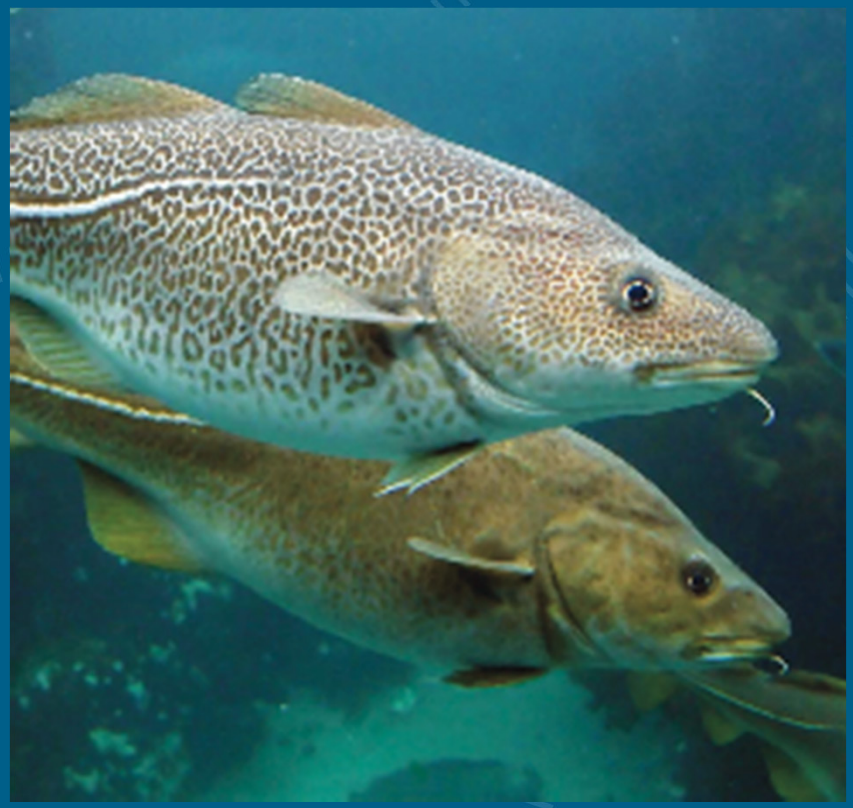
Sm Cop.

Calanus

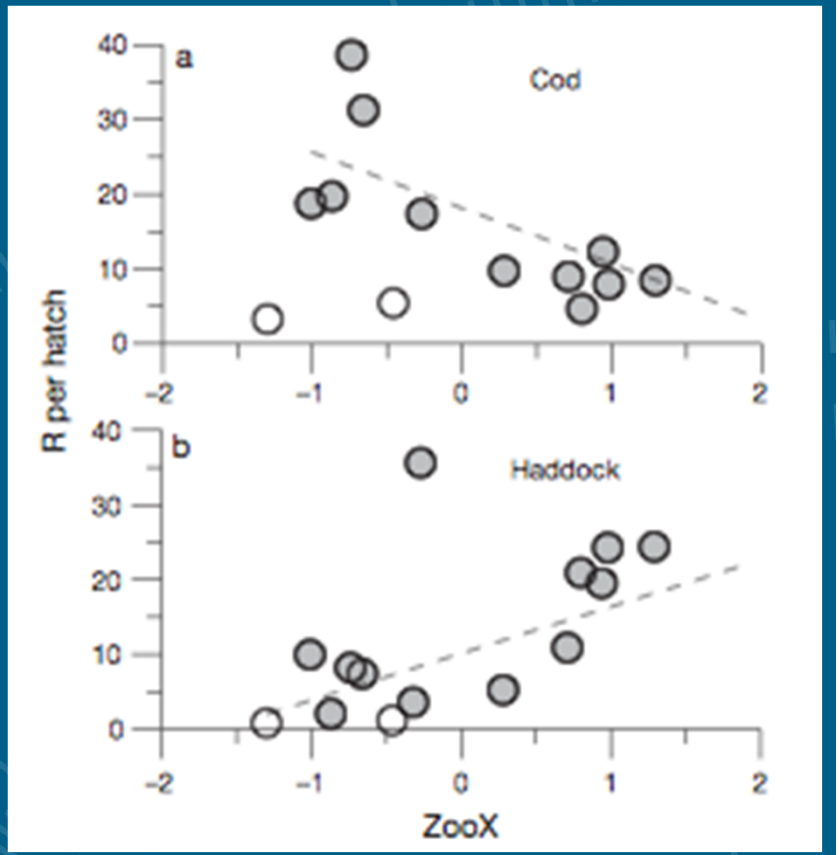
Phyto

# Implications

- Small copepods favor haddock over cod



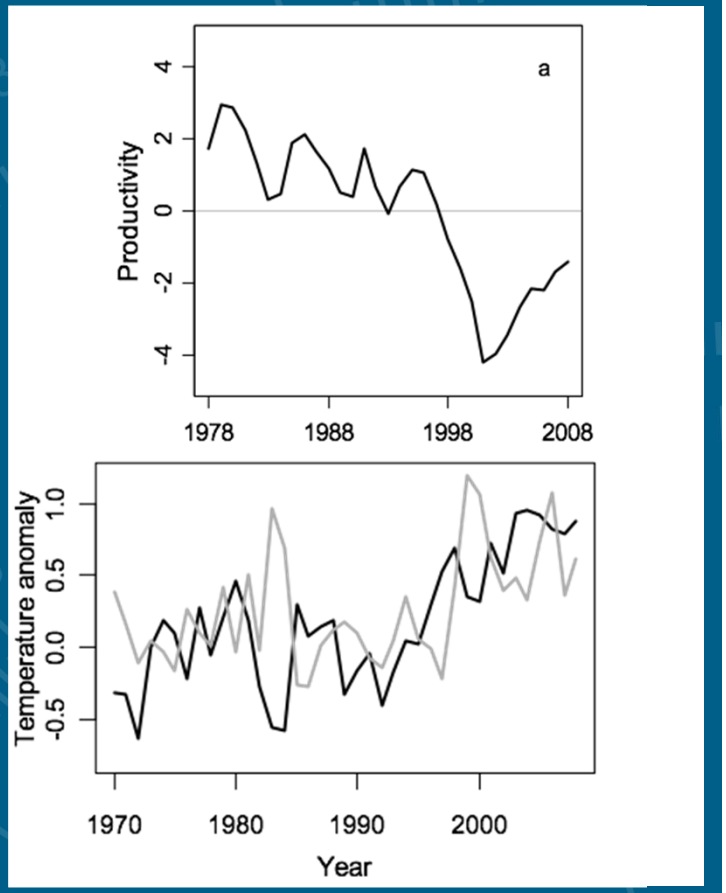
Cod & haddock year 1 survival vs. zooplankton




From Mountain &Kane (2010) MEPS 398:81-91

# Implications

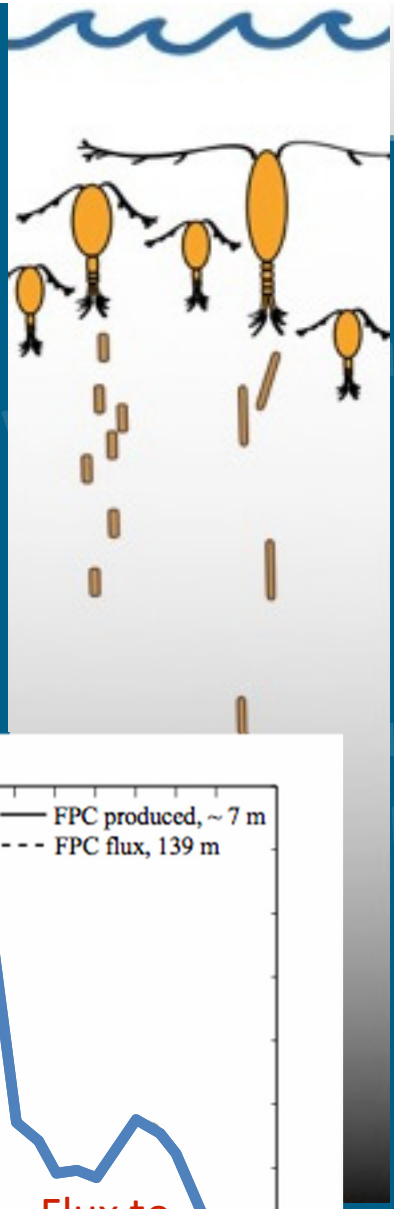
- Small copepods favor haddock over cod
- Decline of Atlantic salmon linked to Labrador Sea T and plankton

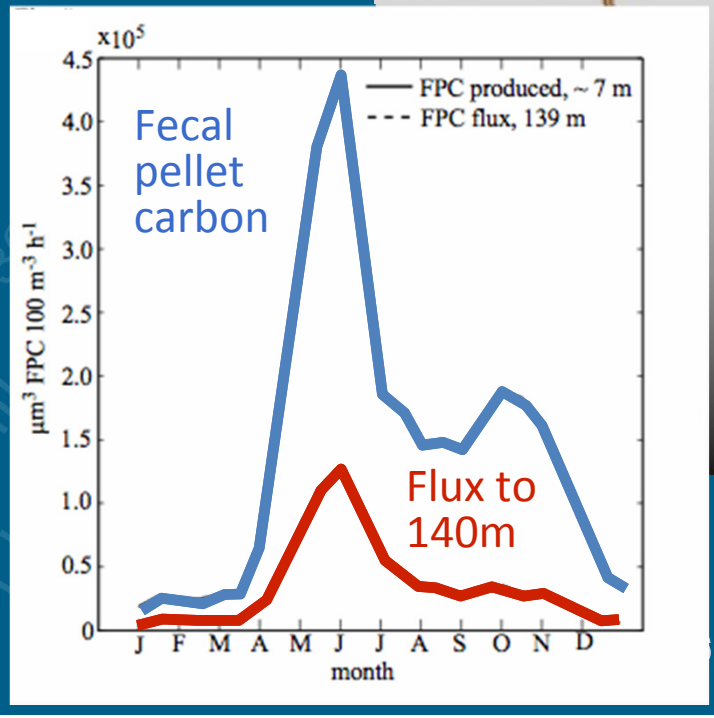



K.E. Mills et al. (2013) Global Change Biology19:3046-3061

# Implications

- Small copepods favor haddock over cod
- Decline of Atlantic salmon linked to Labrador Sea T and plankton
- Reduced *Calanus*, reduced carbon export
  - favor pelagic over demersal fish
  - impact on N. Atlantic carbon sink?






K. Stamieszkin, *in prep.*

# Mode

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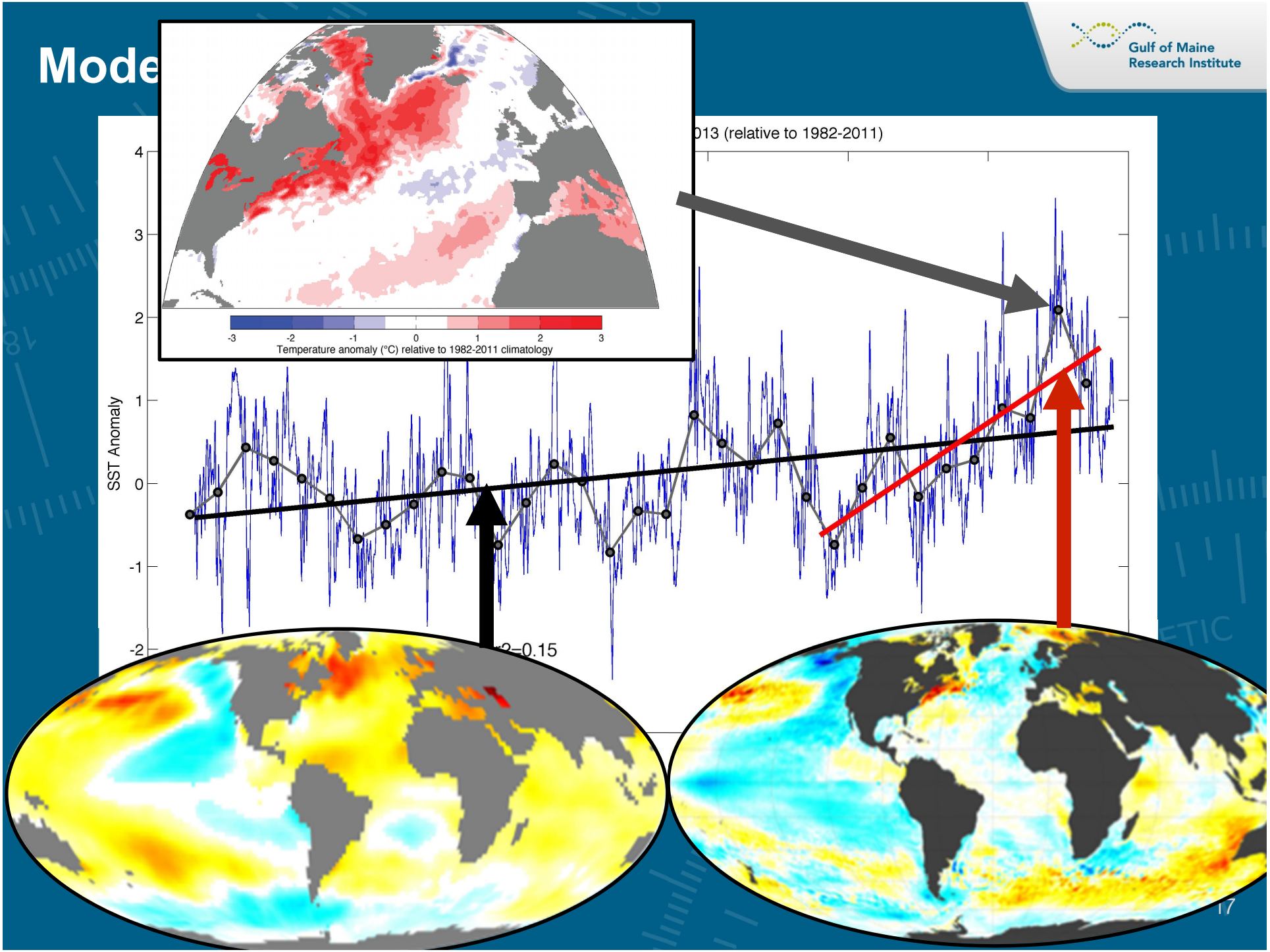

# The 2012 Ocean Heat Wave

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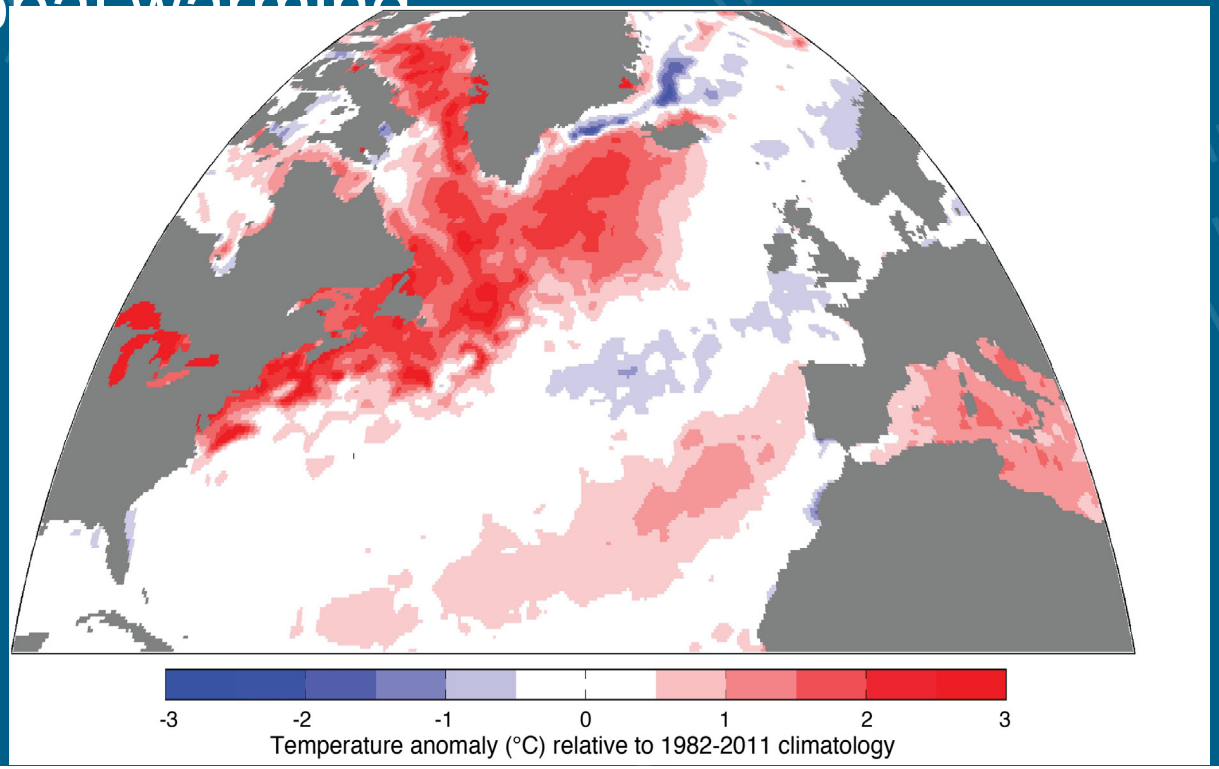
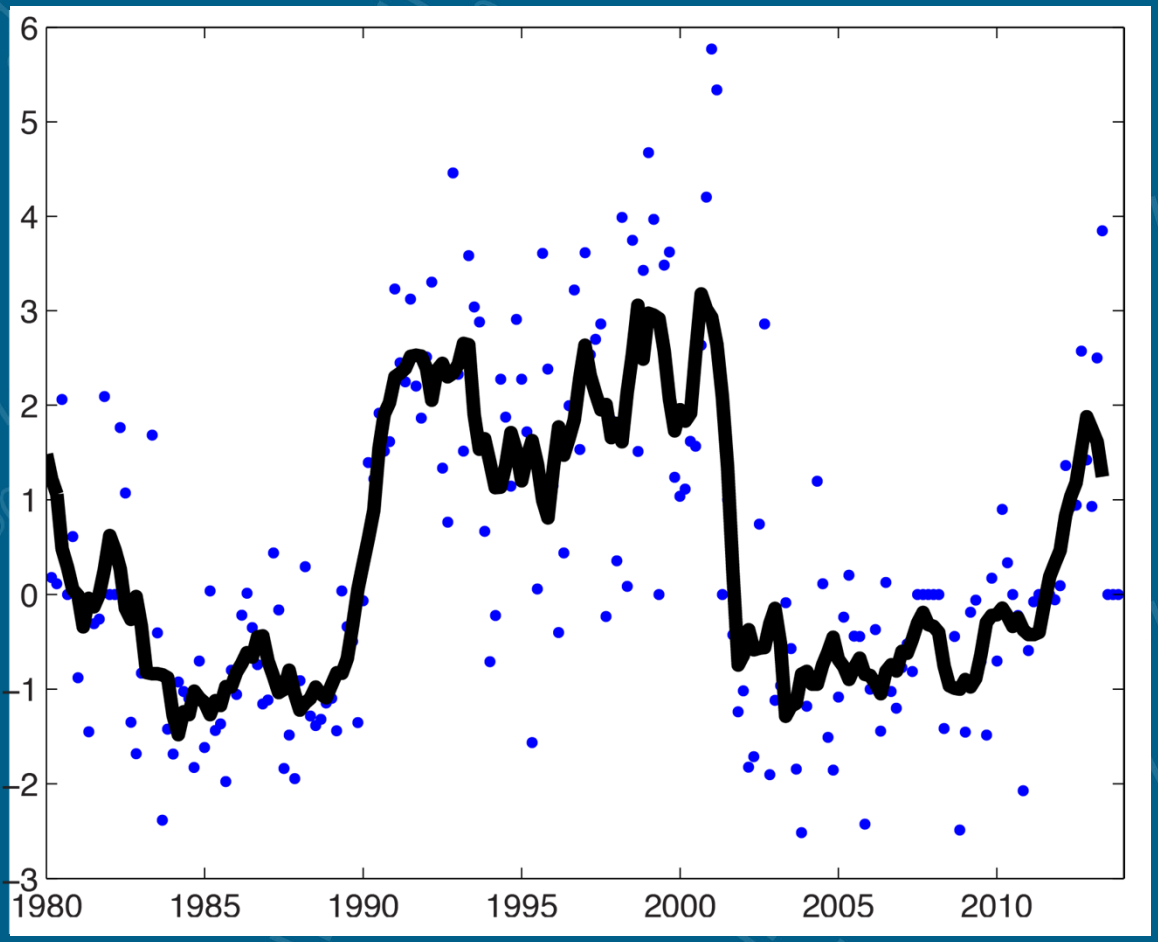
- Causes
  - abnormally mild fall & winter (jet stream)
  - part of trend in the Gulf of Maine
  - part of trend in the North Atlantic (AMO)
  - global warming



# Model Validation

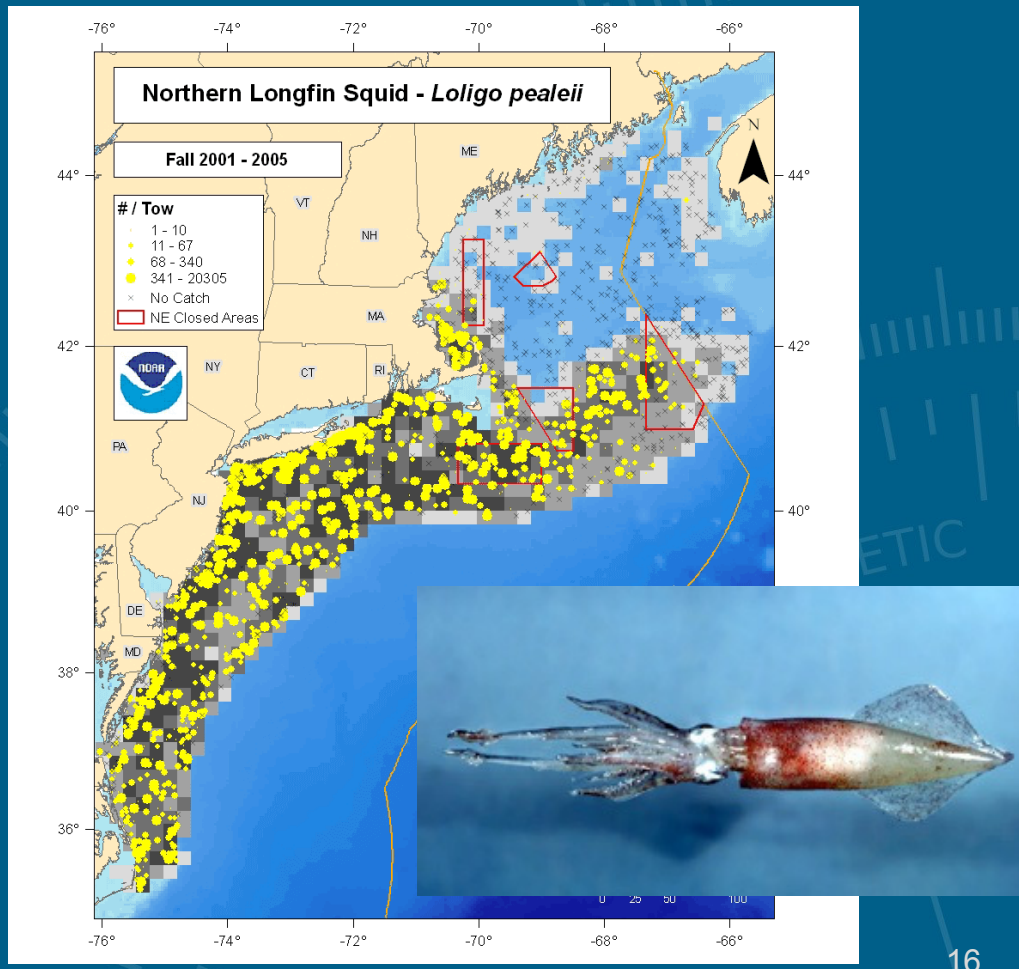
## Gulf of Maine PC 1




- Warming produced expected response in plankton community

# Impacts of 2012

- Mid-Atlantic species moved into the Gulf of Maine



# Maine lobster fishery

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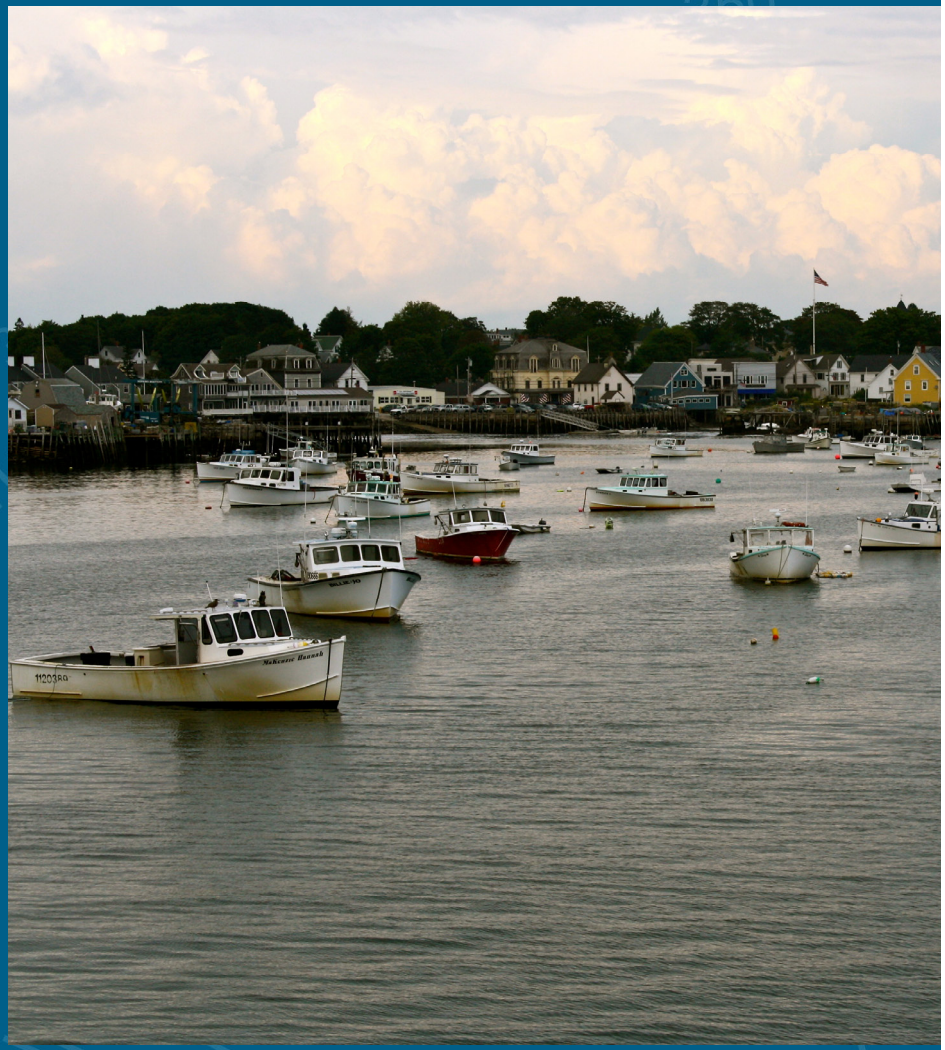
- Valued over $429M
- Second most valuable species fished in US
- Accounts for over 75% of Maine's landed value



# Phenology in 2012

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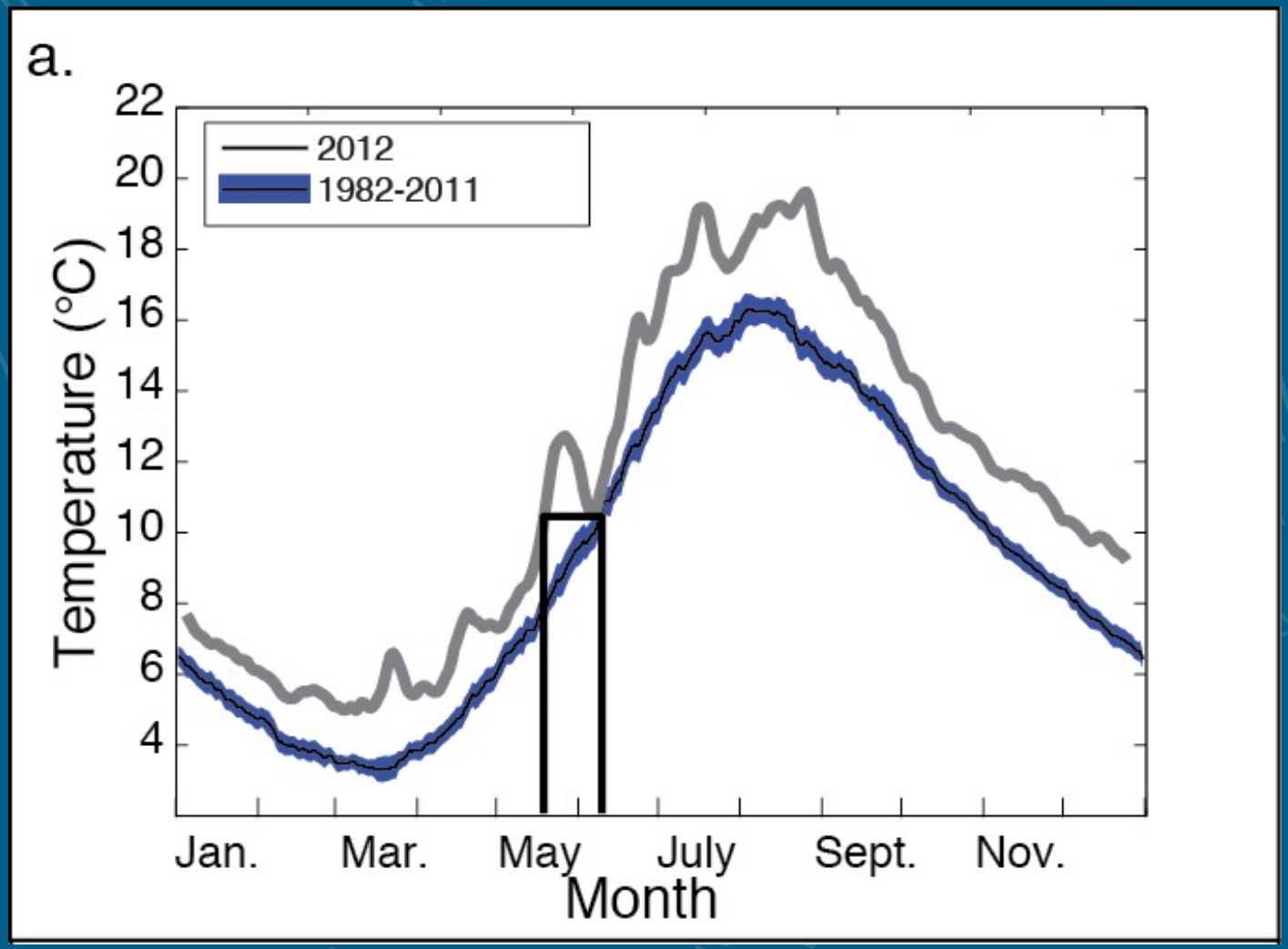

# Lobster Landings

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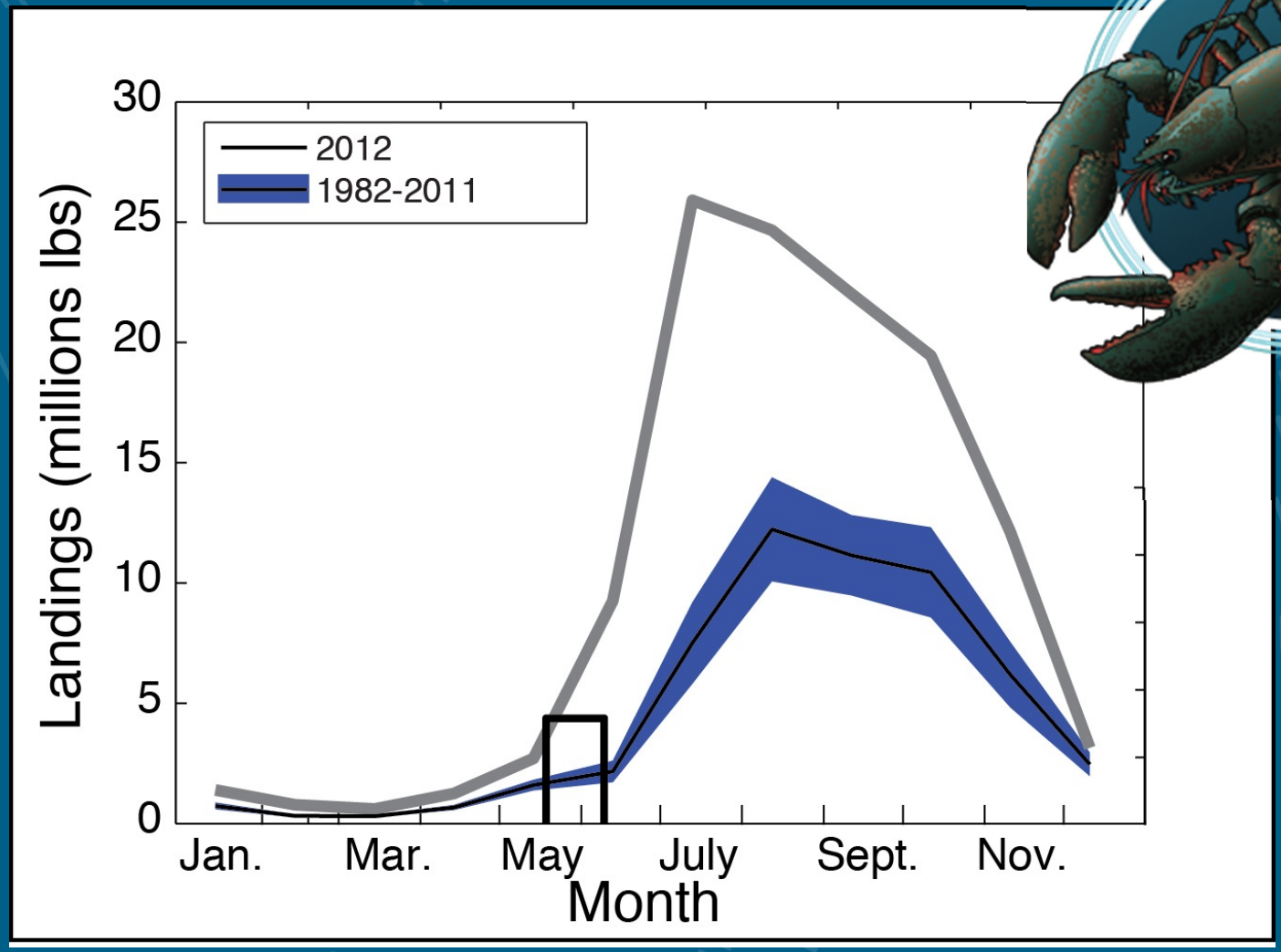


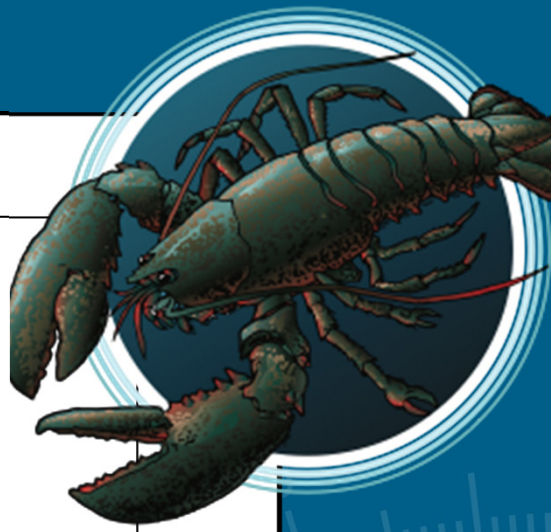

# 2012 Lobster Price Collapse

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BDN MAINE

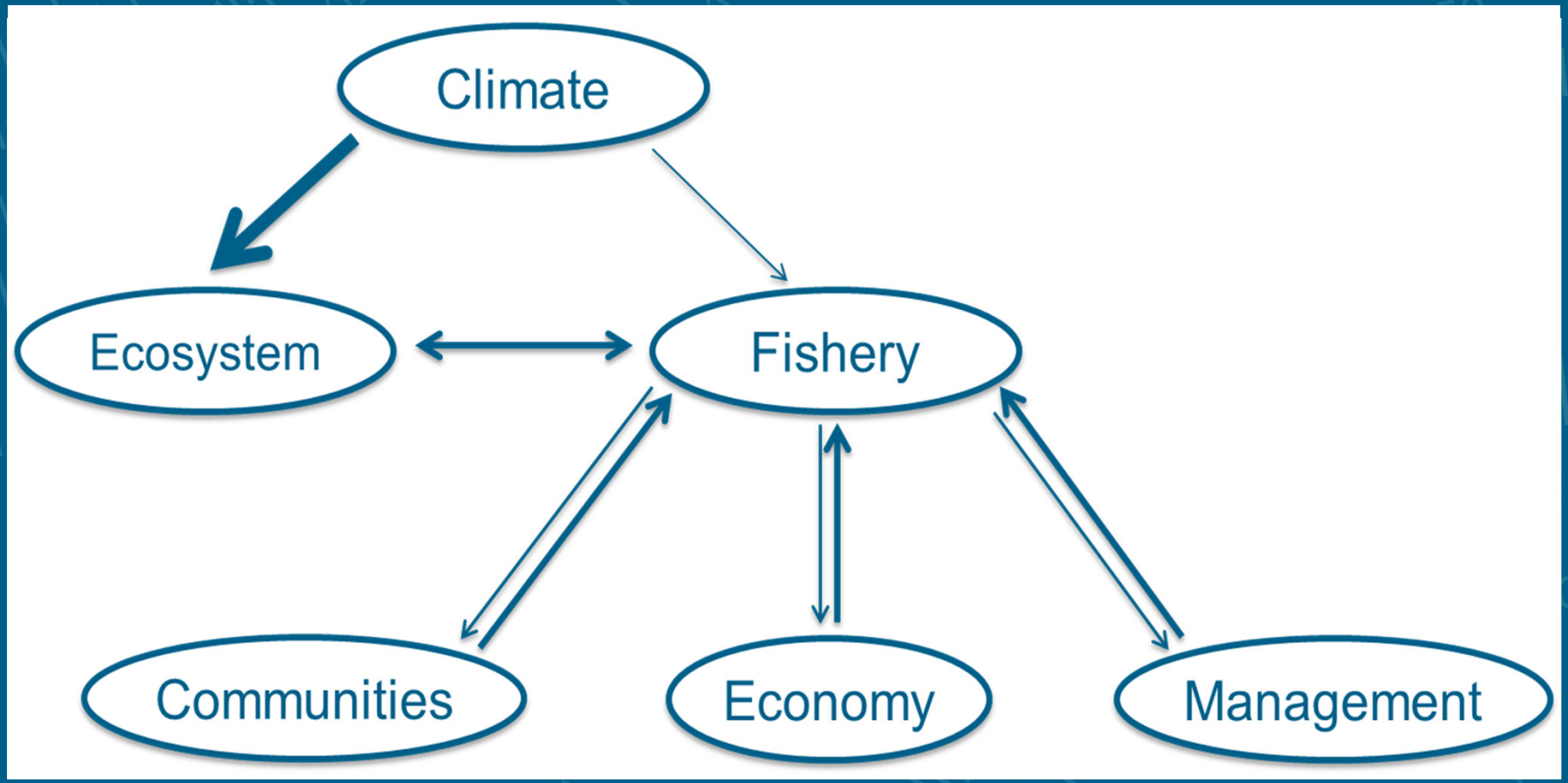
**Maine lobstermen reeling from low prices, seeking cooperation from dealers**

"We can't say we're striking or anything; that's against the law. I'm just taking a few days off and enjoying the sun."

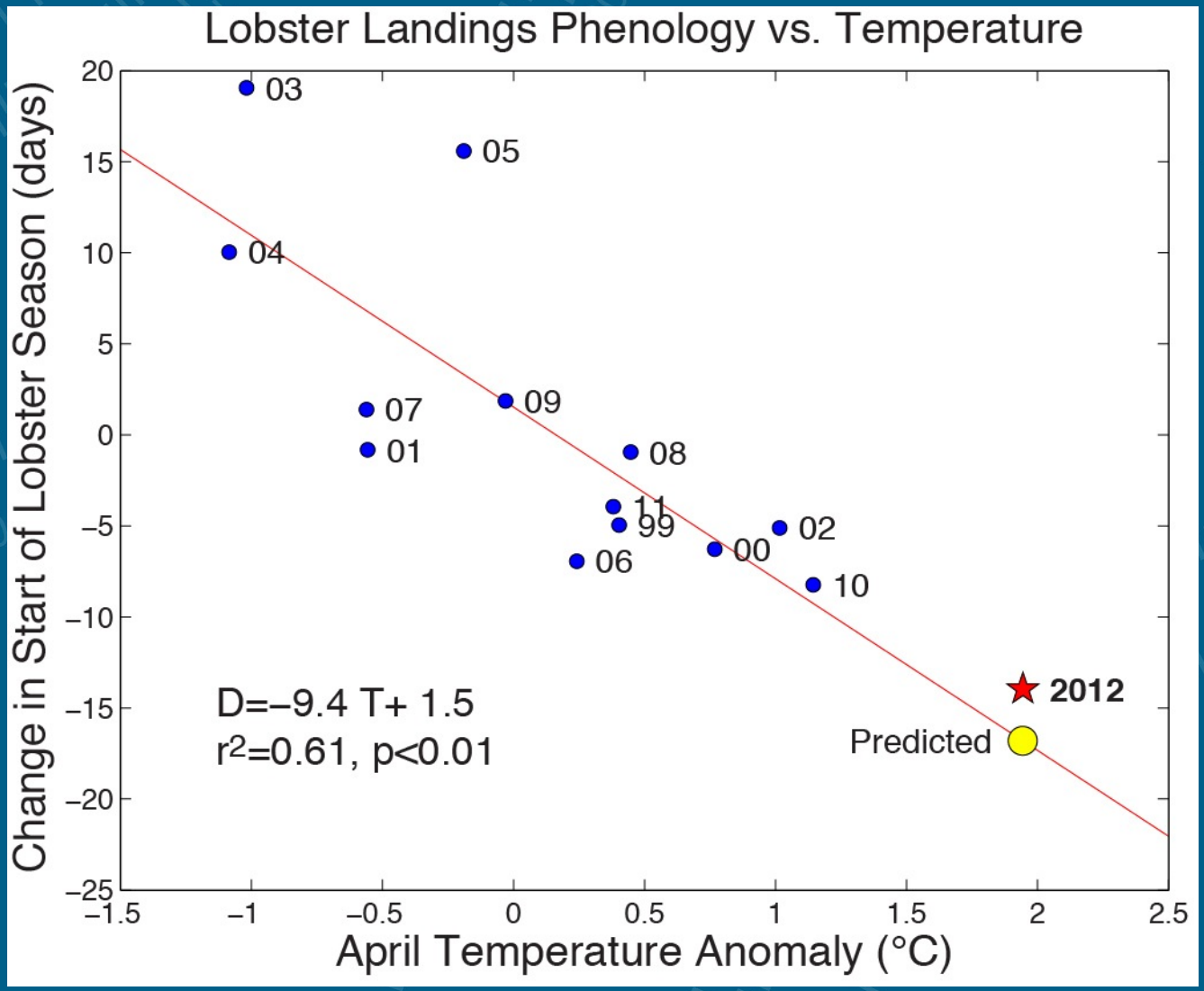
- Richard Alley

**Protests over Maine lobster continue in New Brunswick**

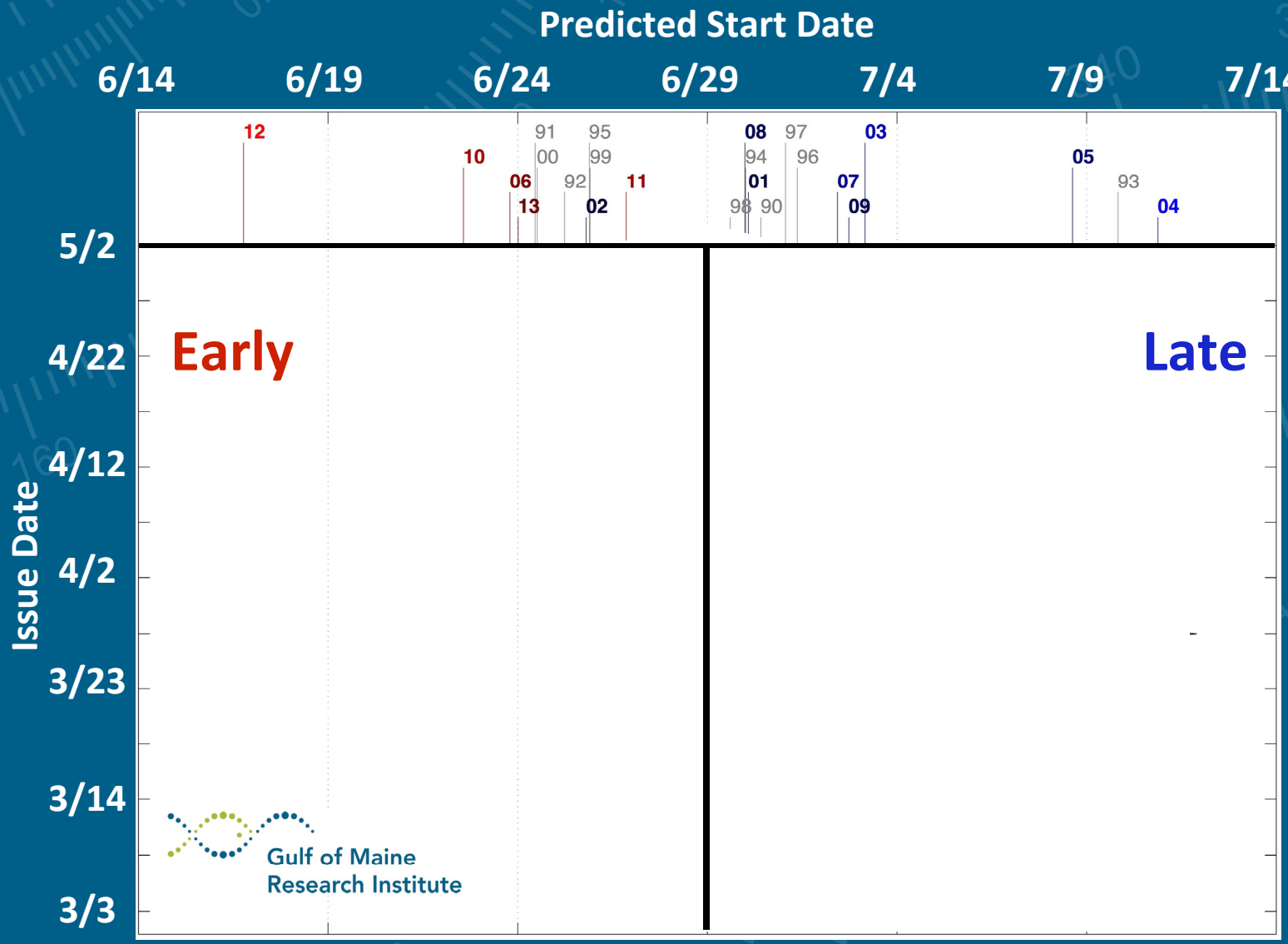
# 2012 heat wave:
# From physics to fisheries



# Prediction 1: Lobsters



# 2014 Lobster Forecasts



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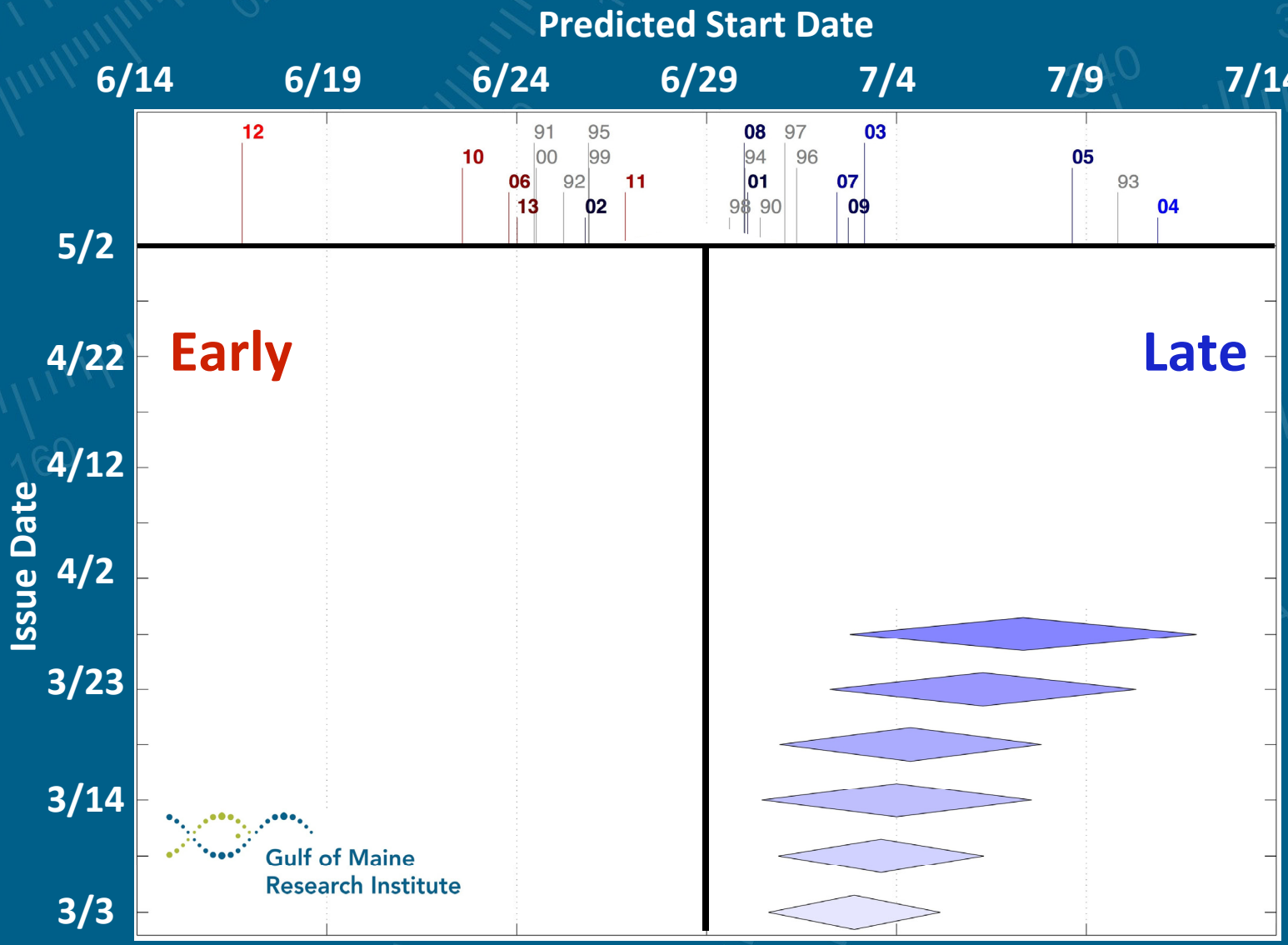

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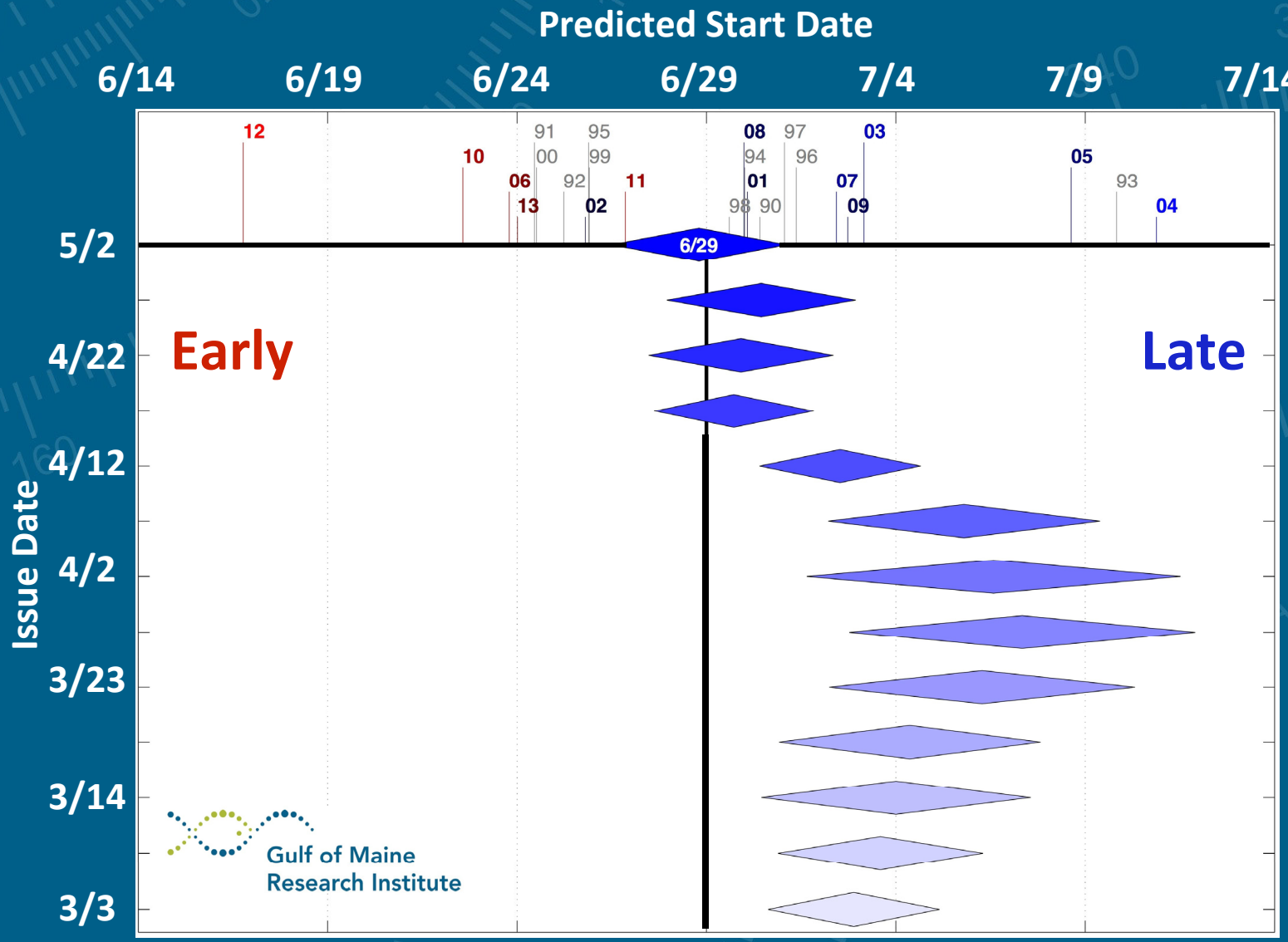
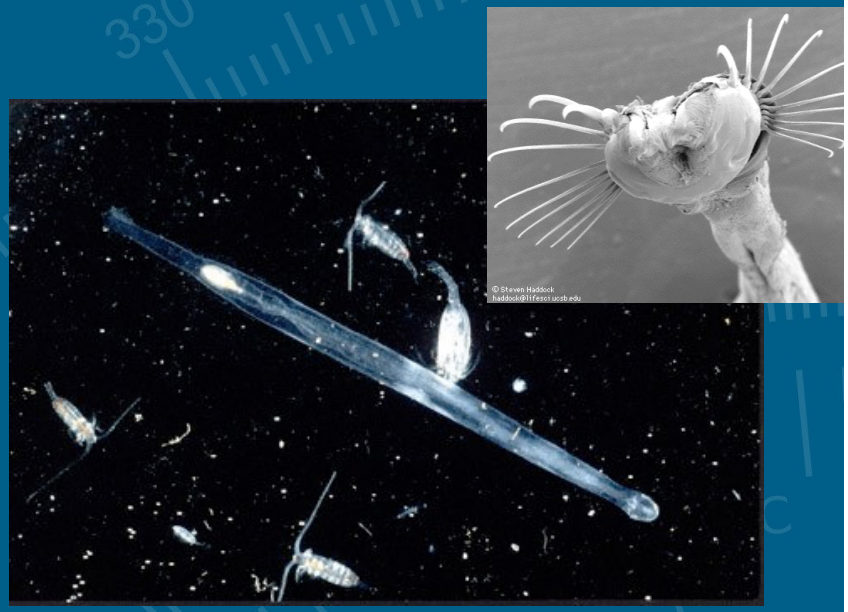


# Conclusions

- Widespread ecosystem change in NW Atlantic
  - different forcings, same response:
  - increased P, small copepods, decreased *Calanus*

- Changes explained by physics
  - P, *Calanus*, or both?
  - Chaetognaths as keystone predator?

- Future ecosystem changes
  - N. Atlantic is getting warmer and fresher




images: Jean-François St-Pierre at http://www.marinespecies.org/photogallery.php?album=689&pic=40863, and Stephen Haddock at http://papillondaniel.free.fr/science.html