Response of North Atlantic Ecosystems to Climate Change

Andrew J. Pershing
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
How do ecosystems respond to changes in T & S?

- North Atlantic will get warmer and fresher
Plankton Patterns: CPR
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

Correlation between plankton & hydrography

- Labrador Sea
- ESS
- WSS
- Gulf of Maine

Temperature
- increased T
- reduced S, reduced D

Salinity
- reduced S, reduced D

Density
- reduced S, reduced D

Depth
- 0-25
- 25-50
- 50-100

Starting Month
- JF
- MJ
- SO
Correlation between plankton & hydrography

Communities respond to same forcing (stratification) in a similar way
What drives the response?

Labrador Sea

Reduced light limitation

Reduced Calanus, reduced grazing
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?

Labrador Sea

- Reduced light limitation
- Reduced *Calanus*, reduced grazing

Gulf of Maine

- Chaetognaths create positive feedback loop

- 06°
Summary

Cold, Salty, Mixed
- Sm Cop.
- Chaet.
- Calanus
- Phyto

Warm, Fresh, Stratified
- Sm Cop.
- Chaet.
- Calanus
- Phyto

Global average surface temperature change

(a) Historical vs. future scenarios (RCPs 2.6 and 8.5)
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 Biology 19:3046-3061
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.*
The 2012 Ocean Heat Wave

• 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

- Valued over $429M
- Second most valuable species fished in US
- Accounts for over 75% of Maine’s landed value
Phenology in 2012

![Graph showing temperature changes over different months, comparing 2012 and 1982-2011 data.](image)
Lobster Landings

![Graph showing lobster landings over months from January to November. The graph compares landings for 2012 and 1982-2011.](image)

- **Y-axis**: Landings (millions lbs)
- **X-axis**: Month (Jan. to Nov.)

- **2012** line
- **1982-2011** line

The graph indicates a peak in lobster landings in July and a decline by November.
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

Lobster Landings Phenology vs. Temperature

Change in Start of Lobster Season (days)

April Temperature Anomaly (°C)

\[ D = -9.4 \, T + 1.5 \]

\[ r^2 = 0.61, \, p < 0.01 \]
### 2014 Lobster Forecasts

#### Predicted Start Date

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**Legend:**
- **Early**
- **Late**
# 2014 Lobster Forecasts

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**Legend:**
- Early
- Late

*Gulf of Maine Research Institute*
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

Seascape Modeling
www.seascapemodeling.org