FISH EARLY LIFE STAGES, BIOPHYSICAL MODELING, & CLIMATE VARIABILITY

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Vancouver, BC, CA

Research goal

- Understand the fundamental biological-physical mechanisms controlling fisheries

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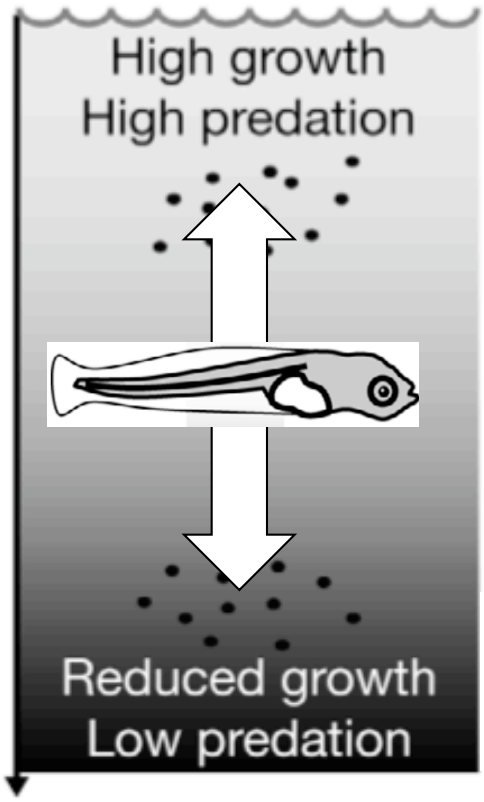
  - For many populations, recruitment determined in the early life stages (c.f. Hjort 1914)
  - Study the processes involved

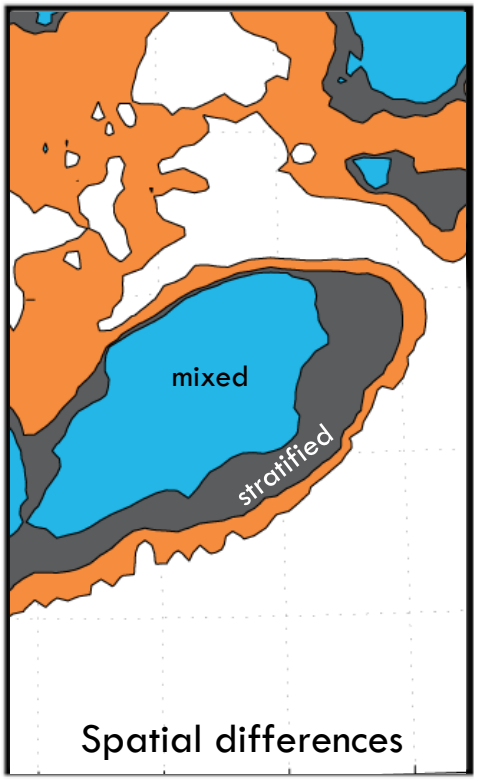
Early life stage processes

1-D



1-D

3-D

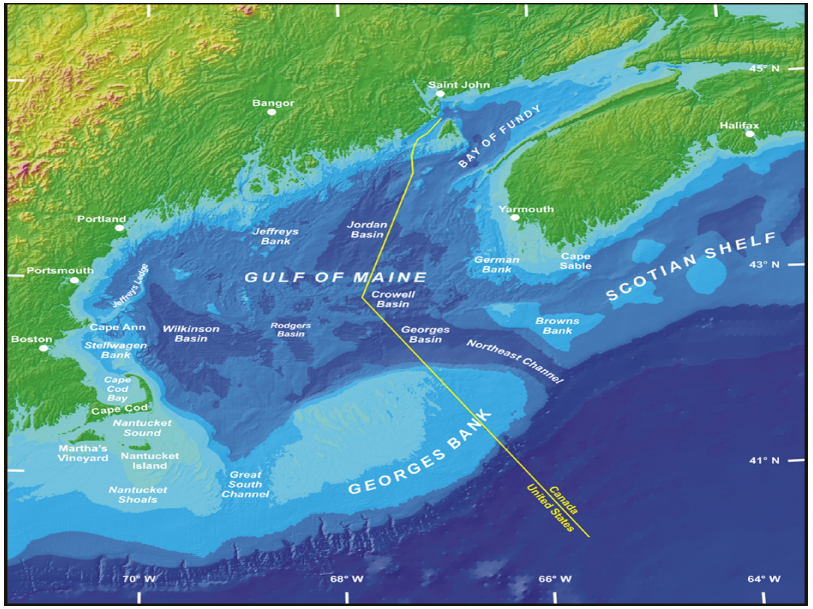


Adapted from Fiksen et al. 2007

Examples

Haddock

- Georges Bank
- Demersal gadid
- Coastal, shallow shelf
- Well-mixed and stratified regions



Pollock

- Eastern Bering Sea
- Demersal gadid
- Coastal, shallow shelf
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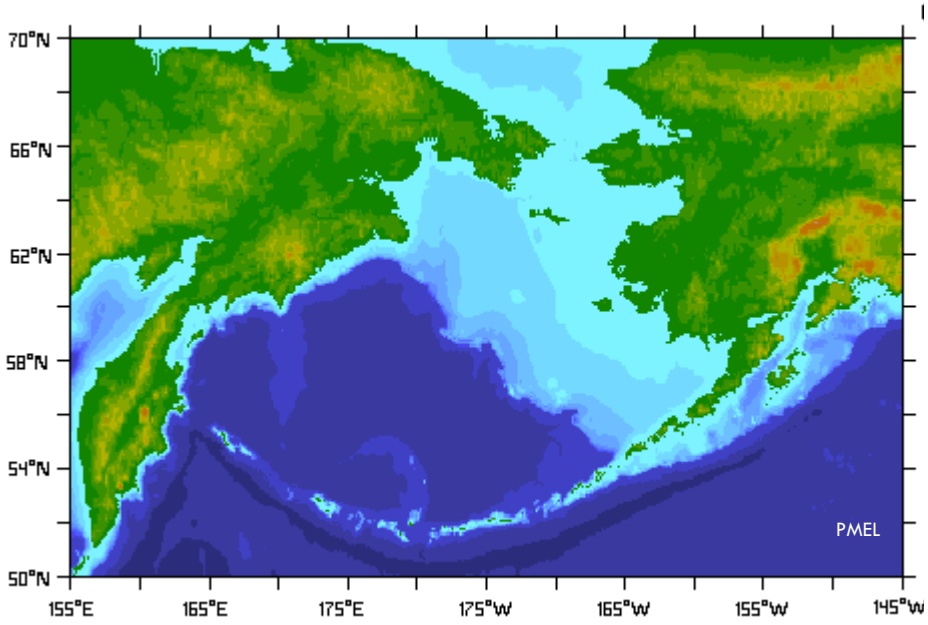
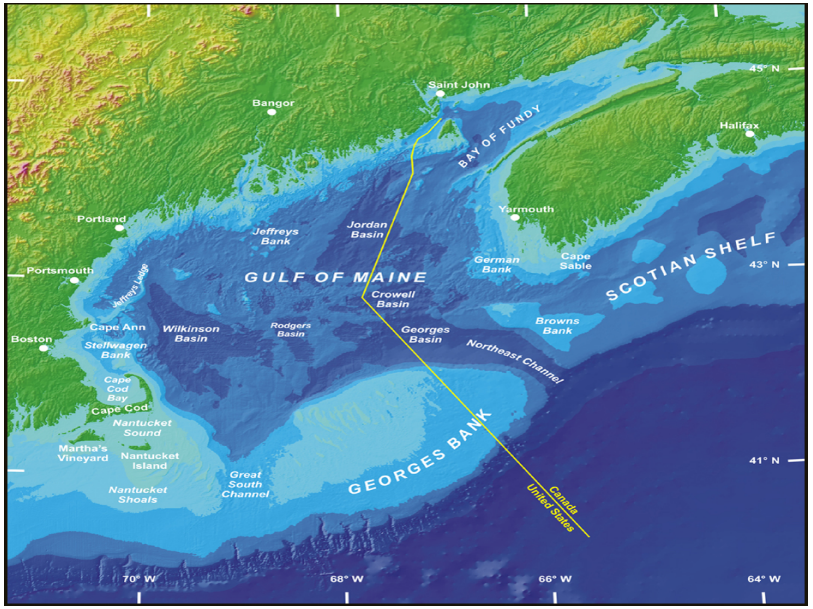


Example 1: Sources of mortality

Haddock

- Georges Bank
- Demersal gadid
- Coastal, shallow shelf
- Well-mixed and stratified regions

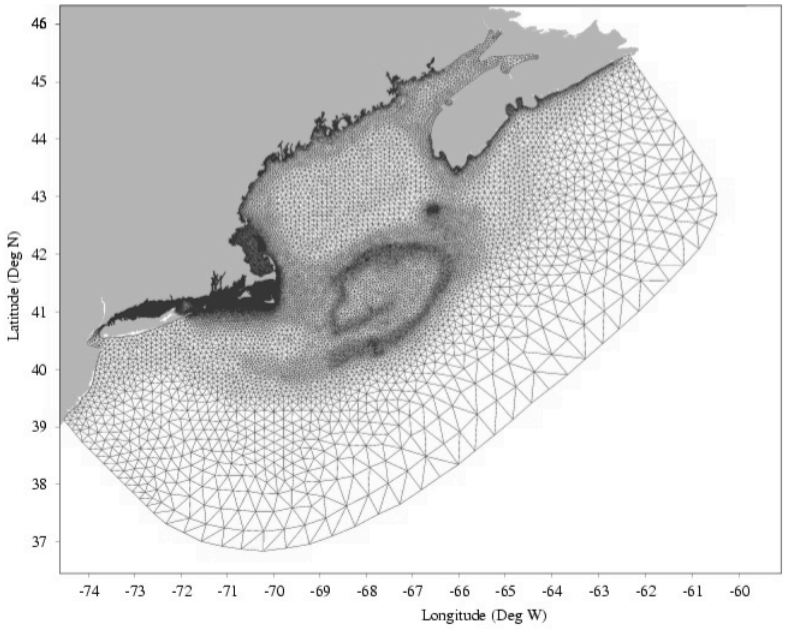


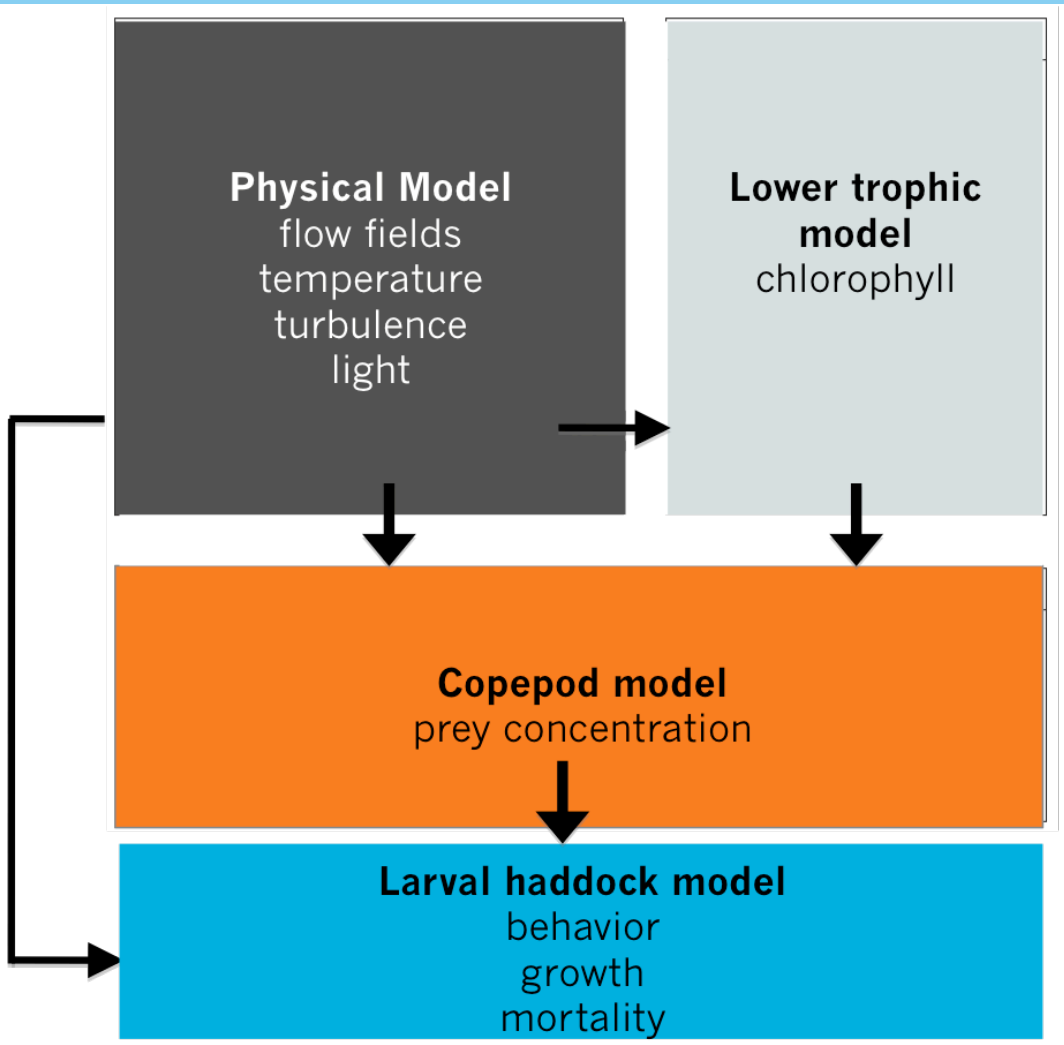
Objectives

- Explore how transport through a 3-D environment influences larval haddock survival

- Compare two disparate GLOBEC years
  - 1995
    - low recruitment
    - more winds
    - low prey
    - food-limited growth
  - 1998
    - high recruitment
    - less winds
    - high prey
    - high egg and larval survival

3D Coupled Models

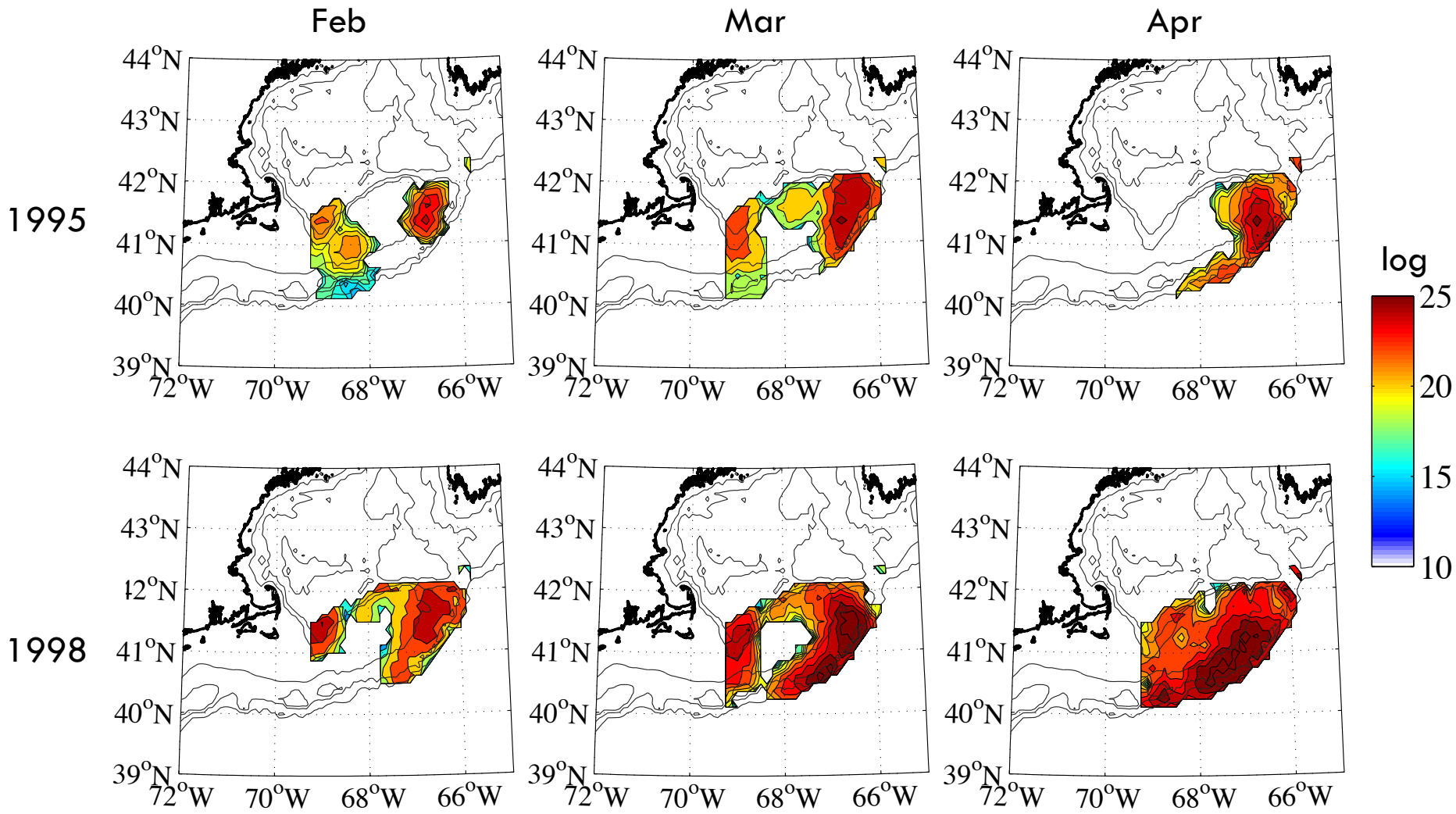




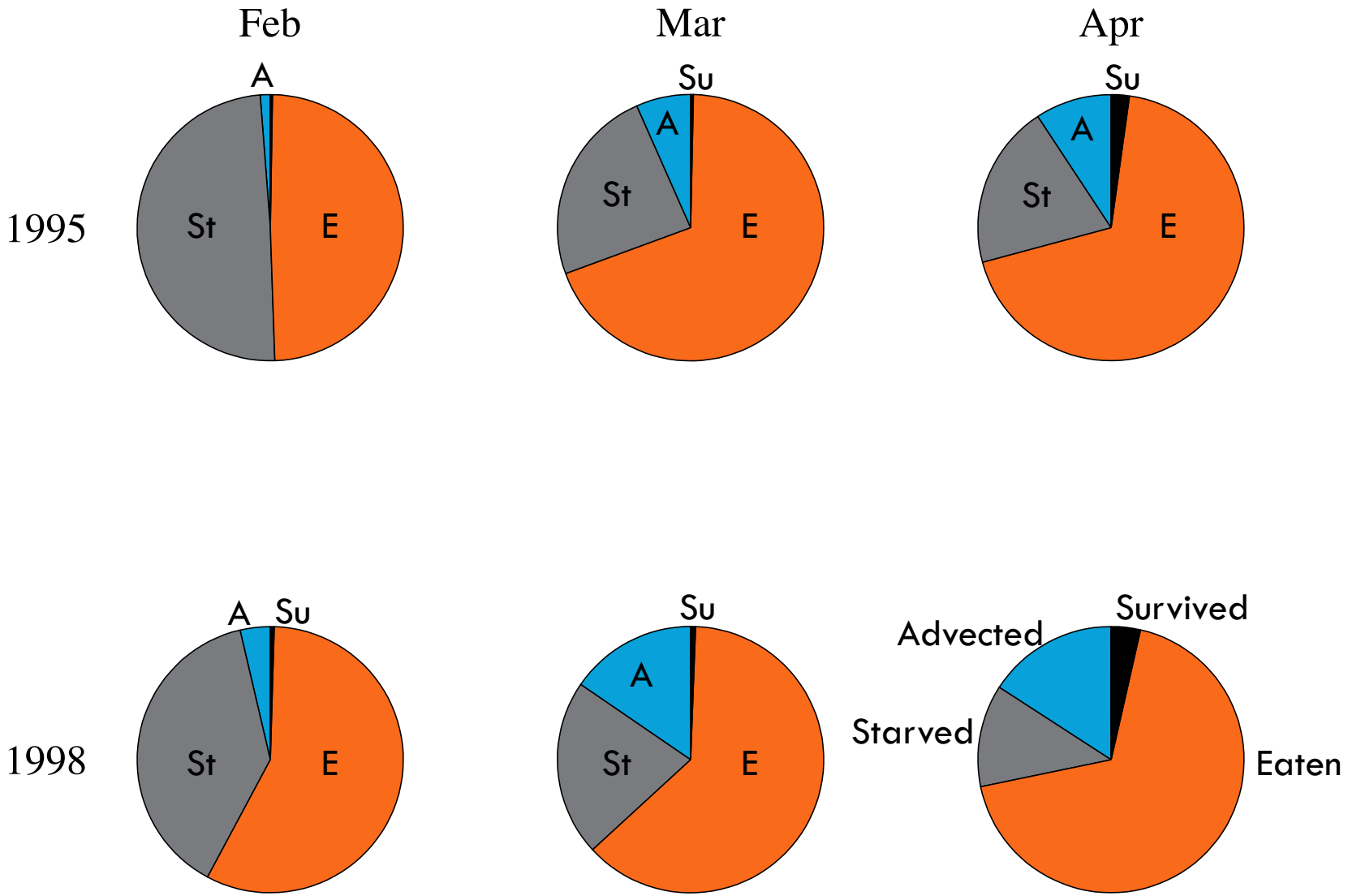
Reference Case

- Passive larvae
- Size- and light-dependent predation rate
  - Constant horizontally and temporally
- Year-specific
  - Hatch locations and numbers
  - Prey concentrations (2-3x higher in 1998)
  - Temperatures
  - Currents

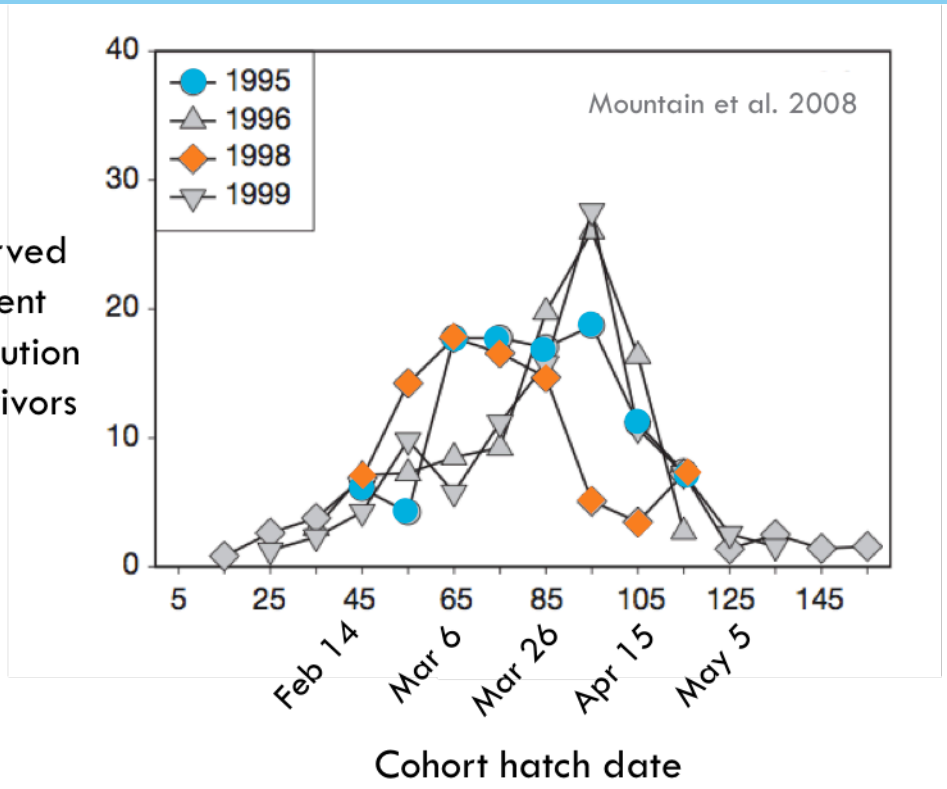
Hatch Distribution



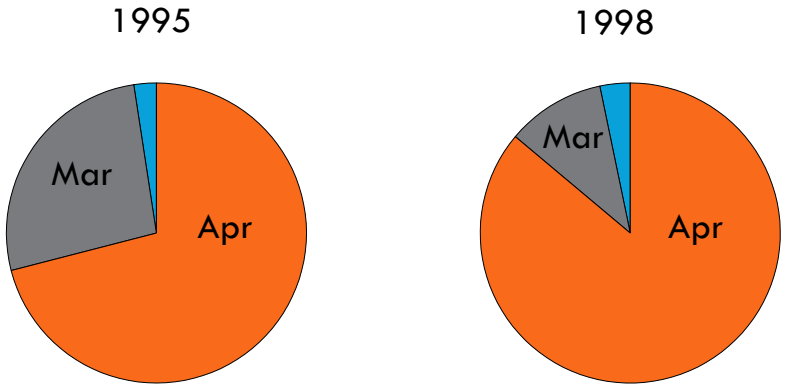
Fate of Individuals



Comparison to Observations



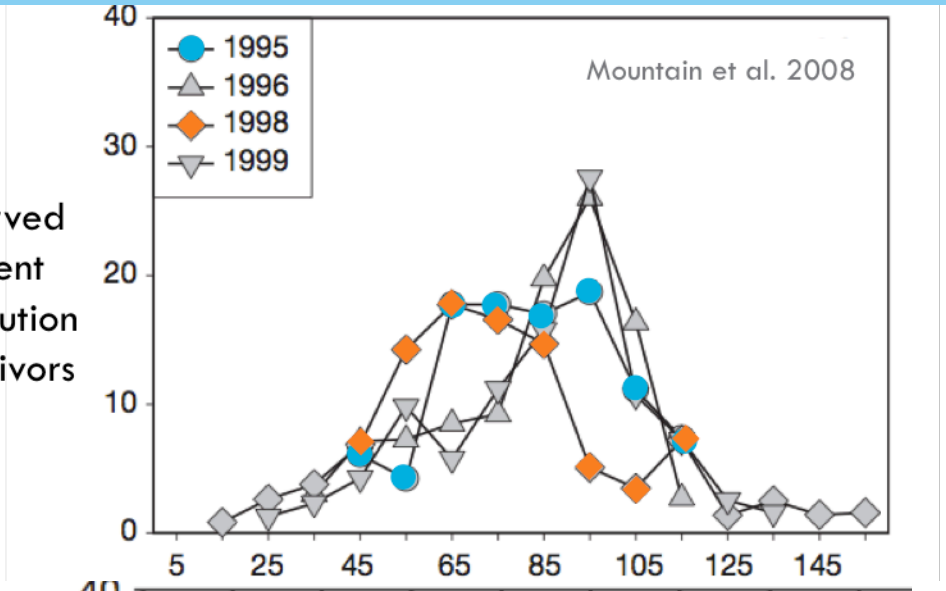
Modeled percent contribution to survivors



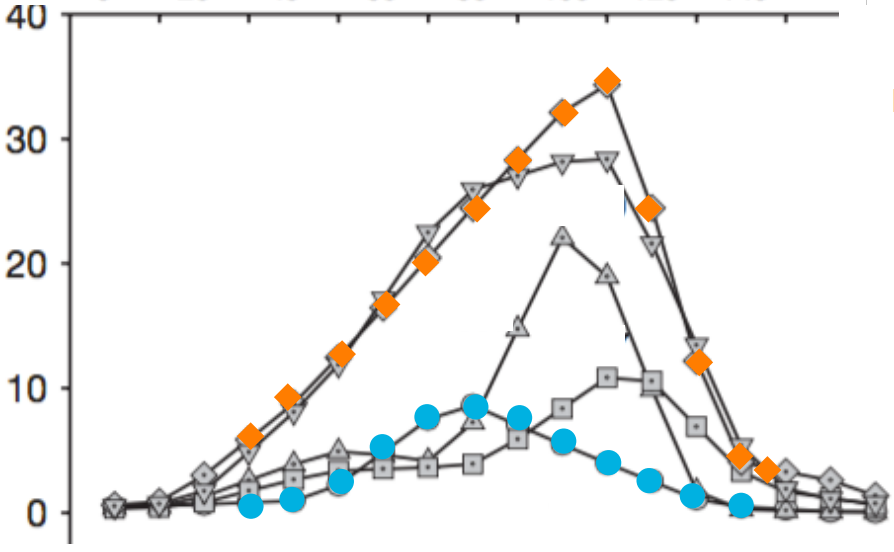
- Hatch date survival pattern
  - Observations: March
  - Model: April

Comparison to Observations

Observed percent contribution to survivors

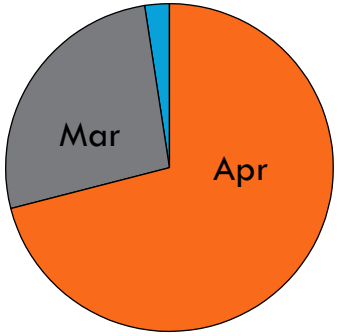
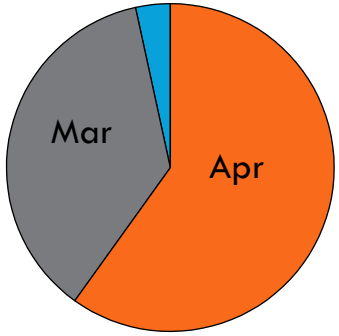
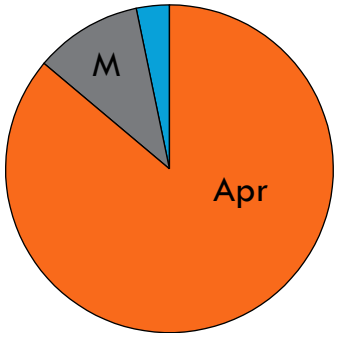
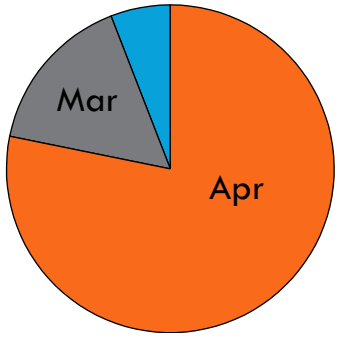


Eggs Hatched (# 10 m^{-2} d^{-1})

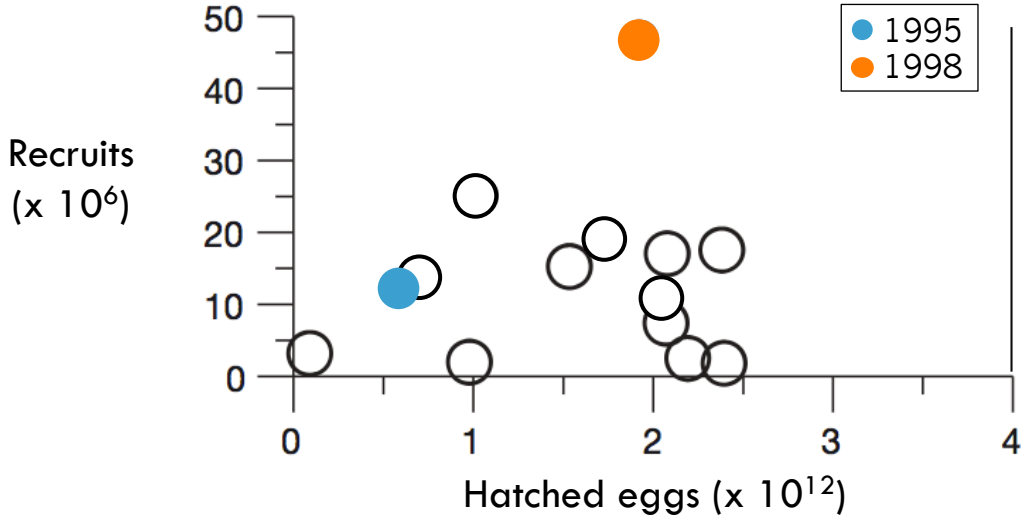


- Hypothesis that predation increases seasonally

Hypothesis Testing

	Constant predation	Temperature-dependent predation
1995		
1998		

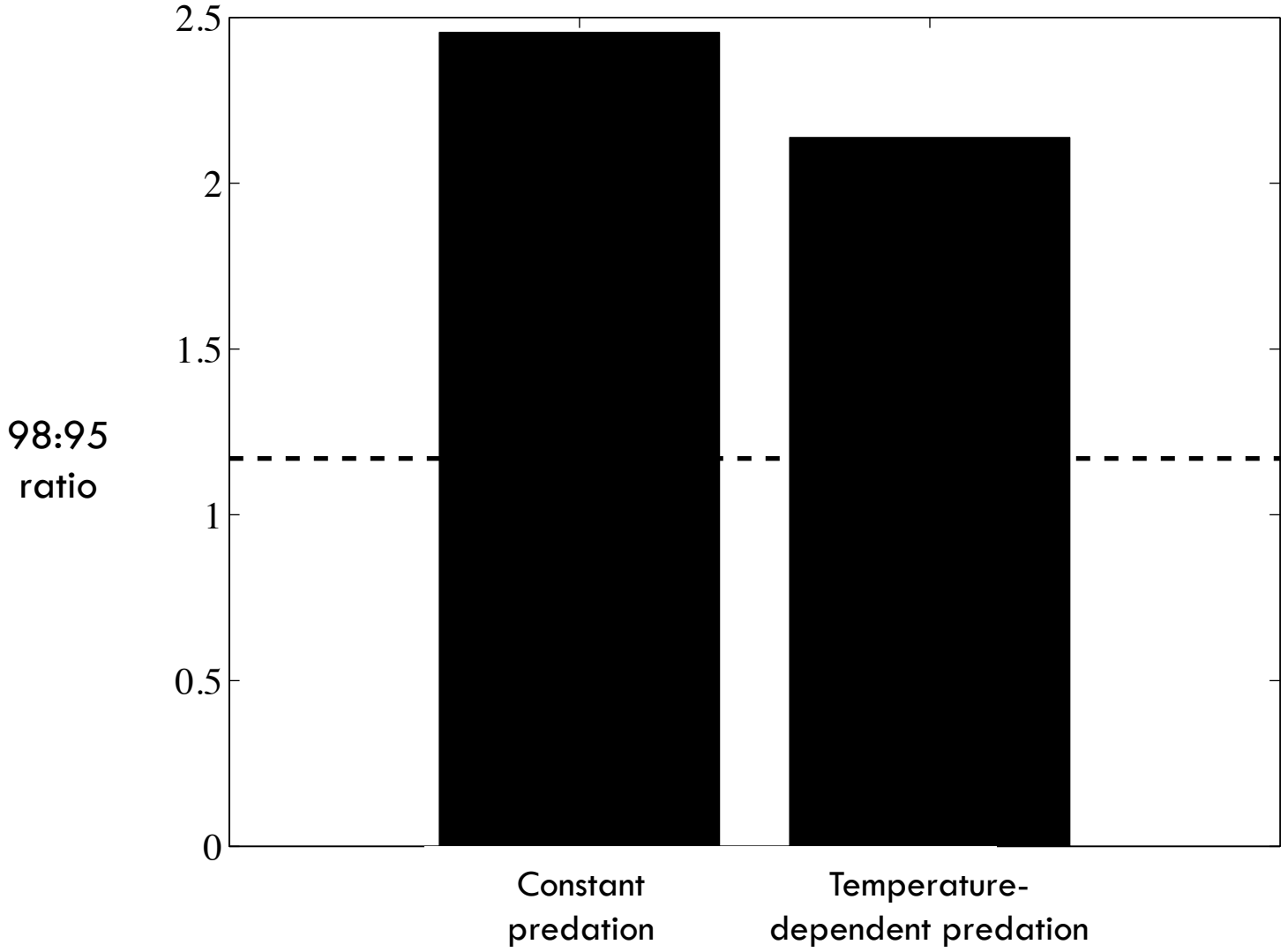
Observed recruits per hatched egg



	Observed Recruits:Hatch
1995	20.9 x10^{-6}
1998	24.4 x10^{-6}
98:95	1.17

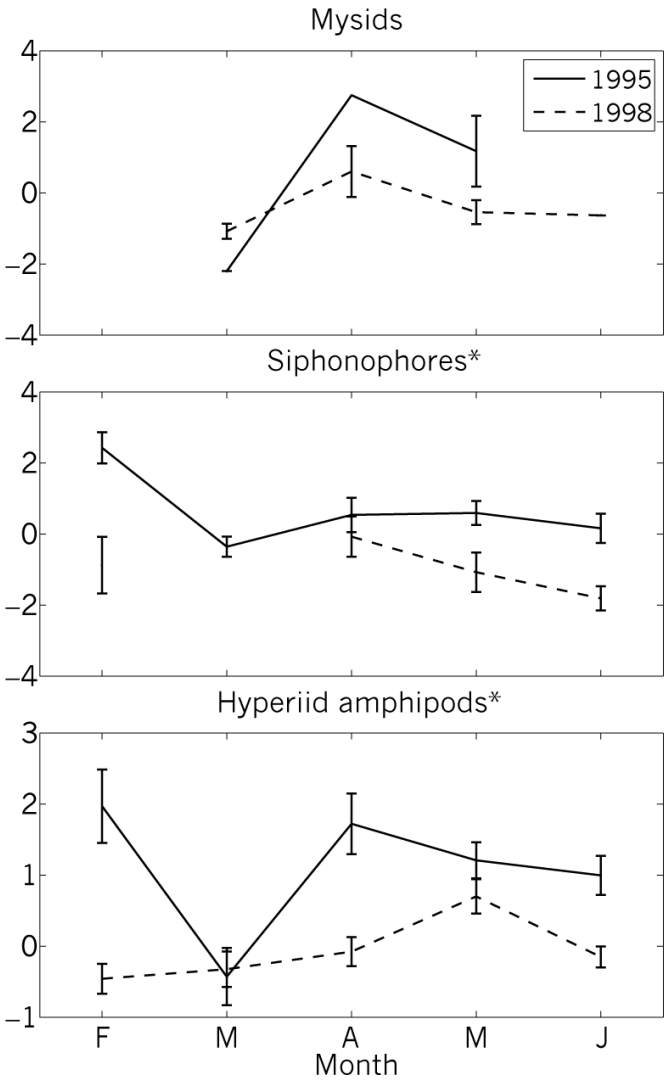
Mountain & Kane 2010

Modeled survival per hatched egg



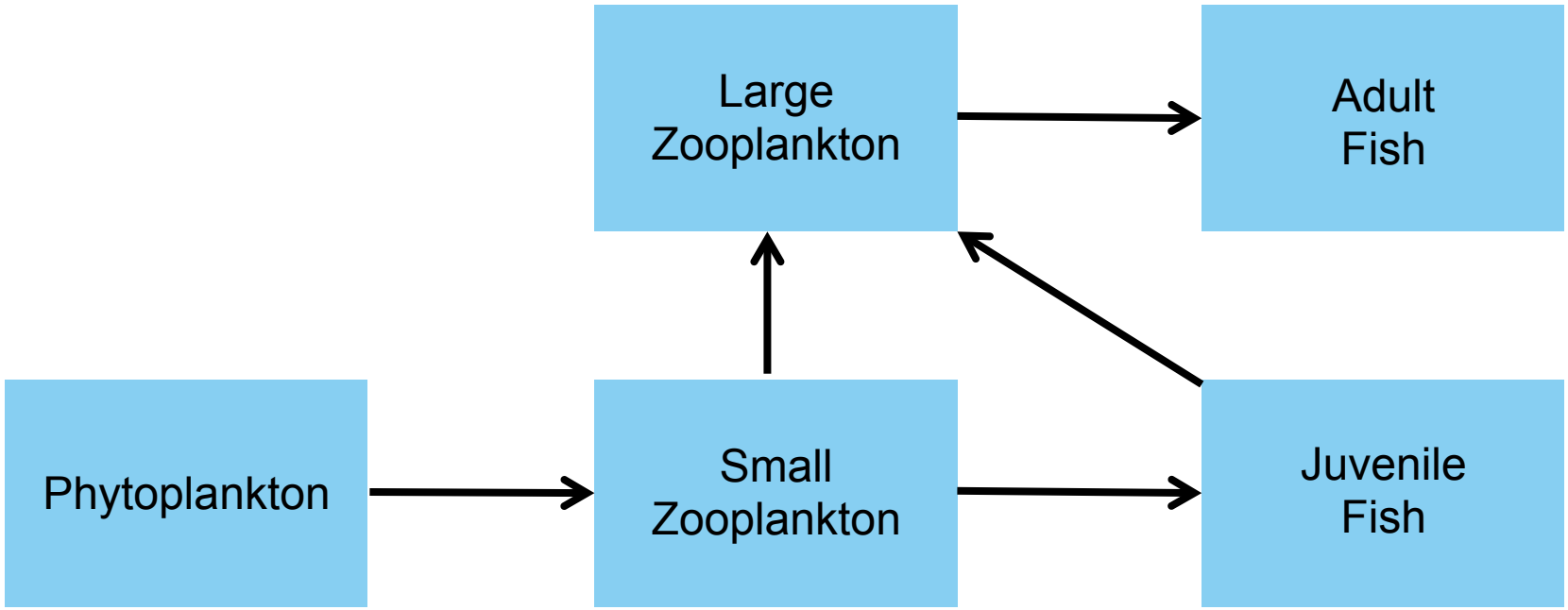
Potential Predators

Mean log abundance (m^{-3})



Haddock Perspectives

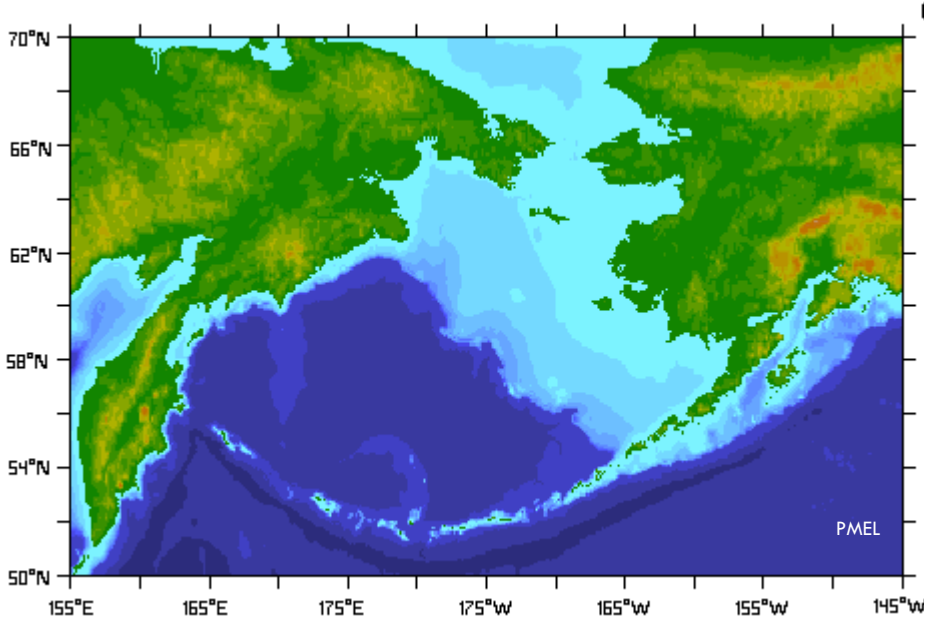
Haddock Perspectives



Example 2: Spawning and Dispersal

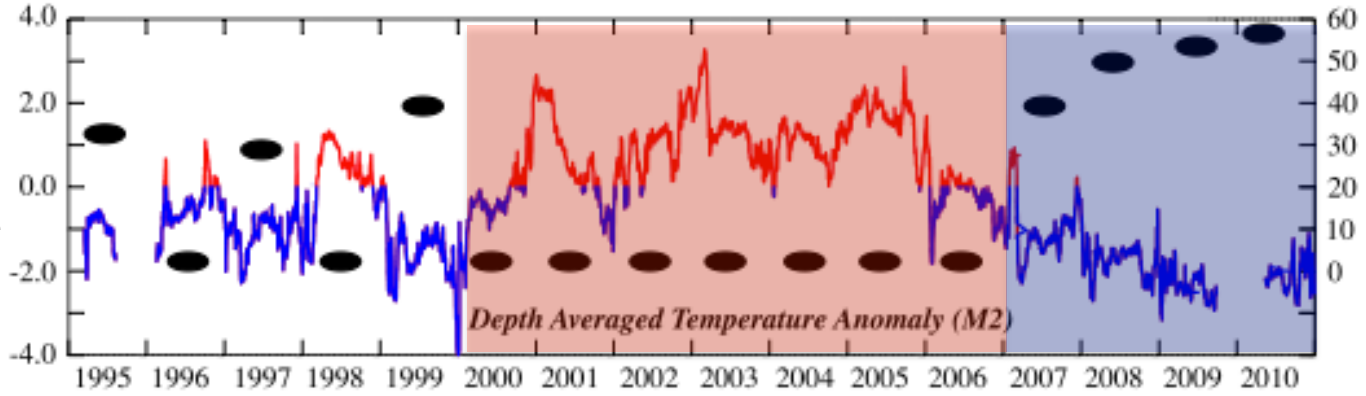
Pollock

- Eastern Bering Sea
- Demersal gadid
- Coastal, shallow shelf
- Well-mixed and stratified regions



Sea Ice and water temperature

Depth-averaged temperature



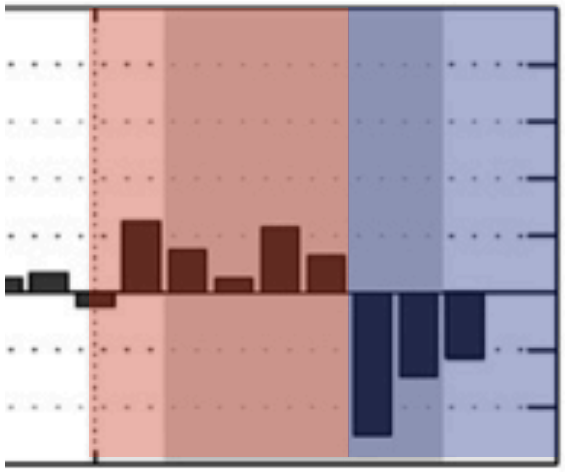
Percent ice cover

Year

Stabeno et al. 2012

Winds and currents

Oct-May wind direction anomaly = Winter cross-shelf Ekman transport

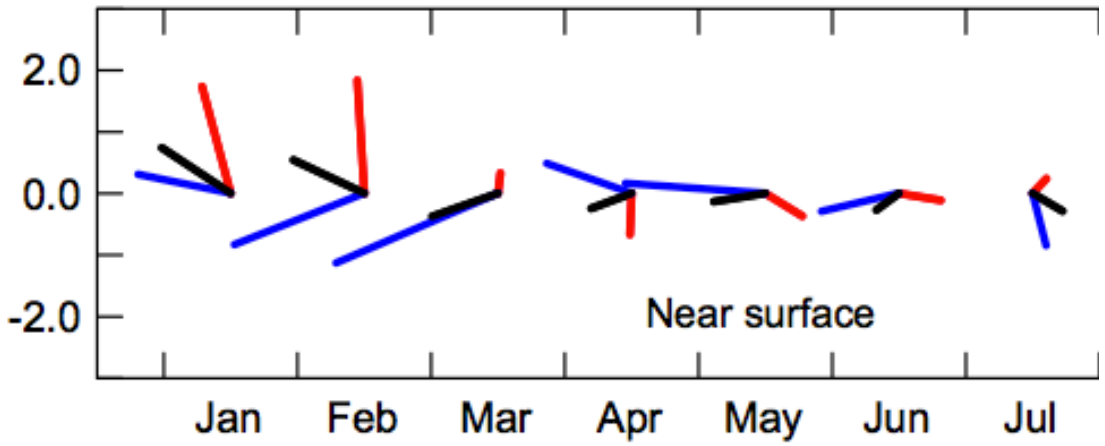


positive = on-shelf

negative = off-shelf

Danielson et al. 2011

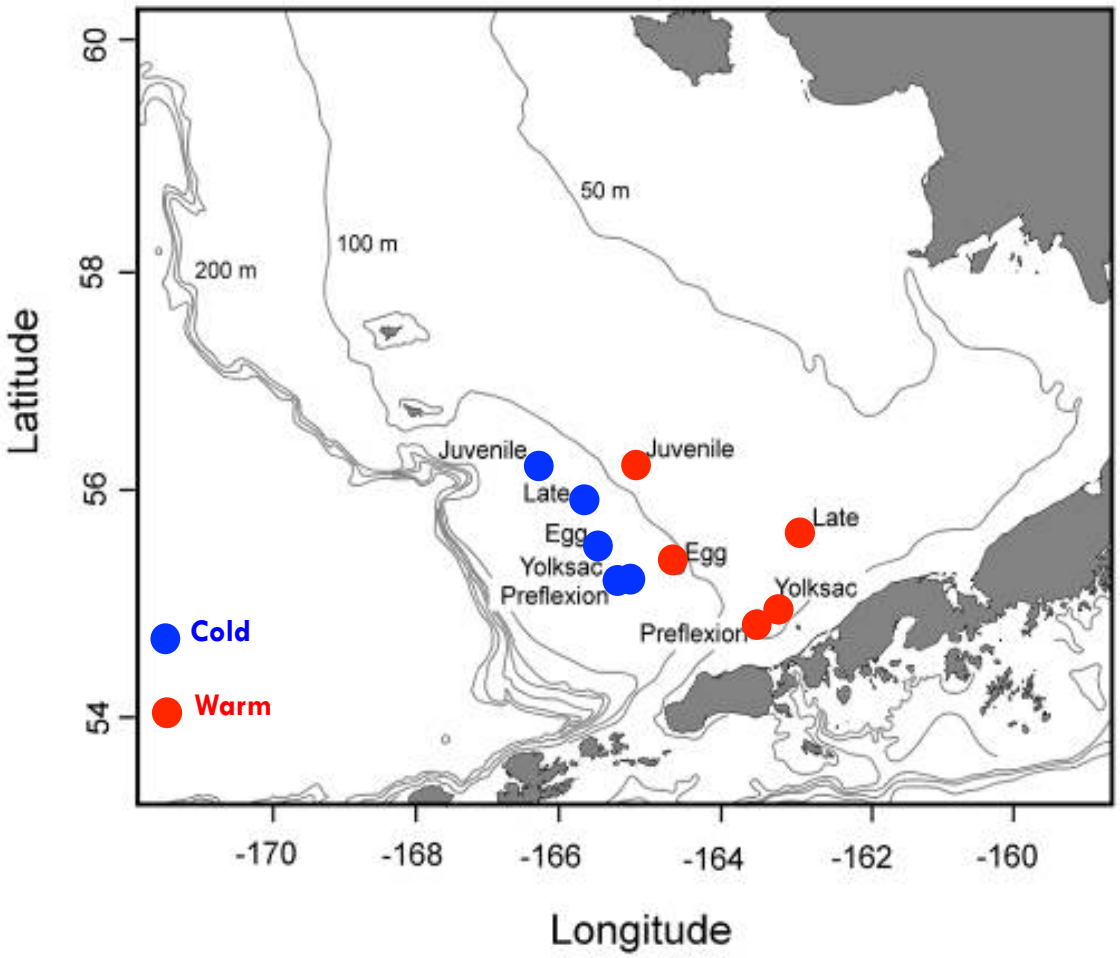
Monthly averaged currents at M2



Stabeno et al. 2012

Pollock ELS Distribution

More on-shelf in warm years



Smart et al. 2012

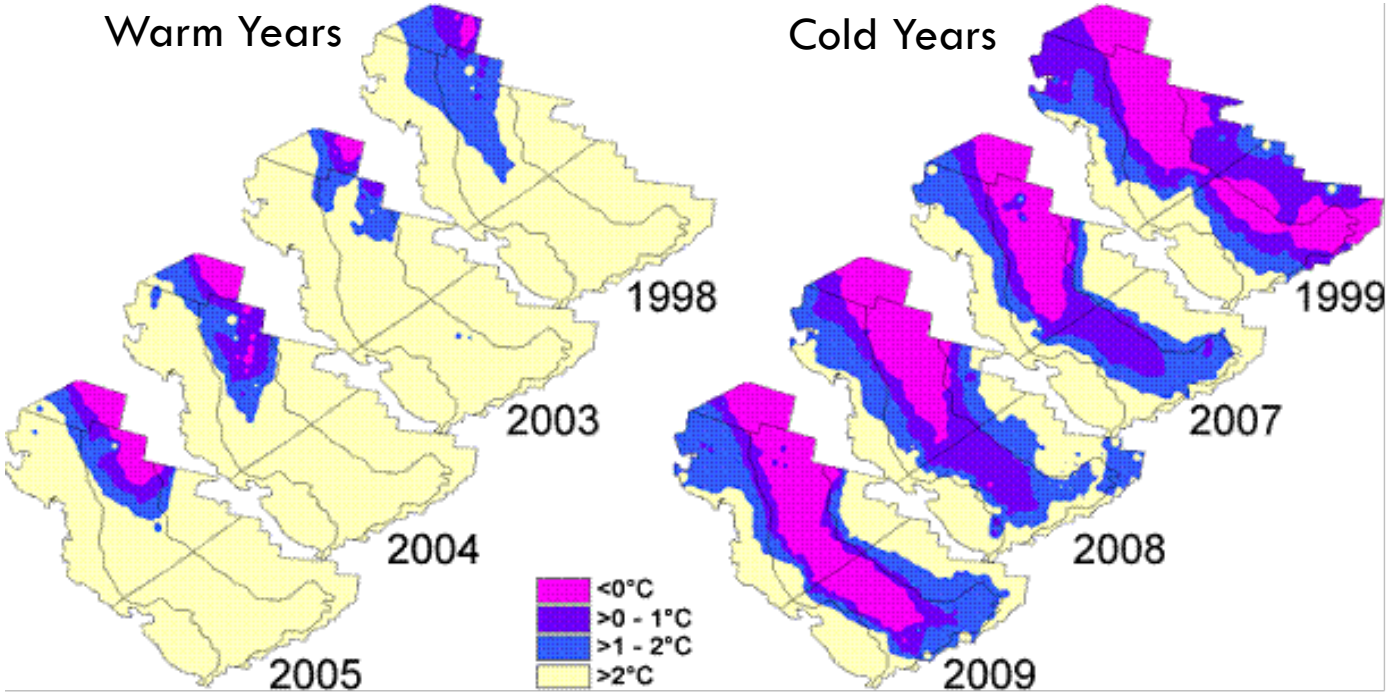
Pollock Objectives

- Does interannual climate variability result in different distributions of pollock early life stages?

- What are the dominant physical mechanisms responsible for the different distributions?
  - Wind effects on transport
  - Temperature/ice effects on spawning location
  - Temperature/ice effects on spawning time

Pollock Spawning

Adults avoid cold water → Change in spawning areas

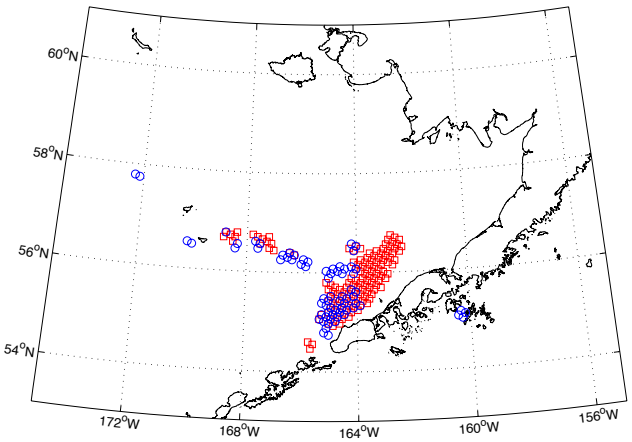


Stabeno et al. 2012

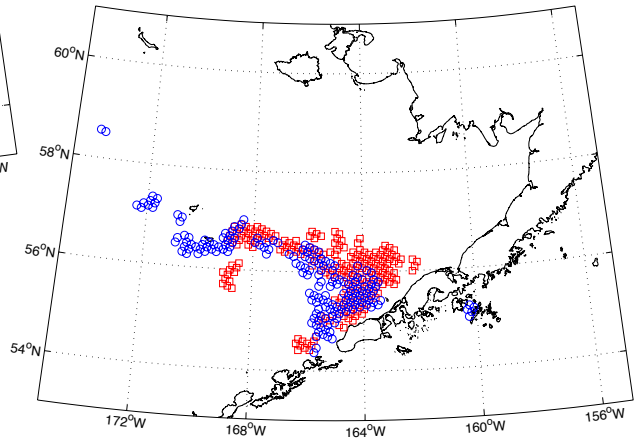
Pollock Spawning

More on-shelf in warm years

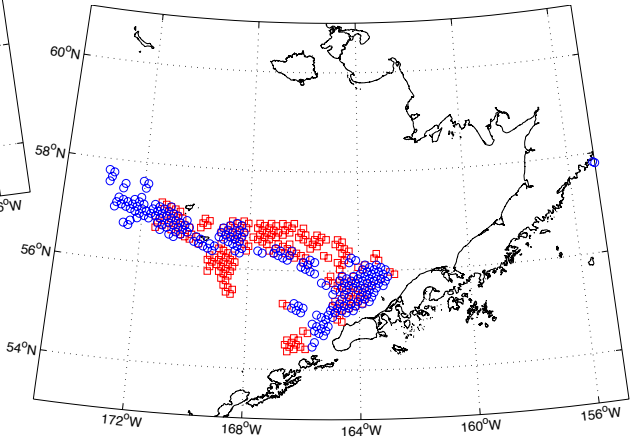
Jan wks 3-4



Feb wks 1-2

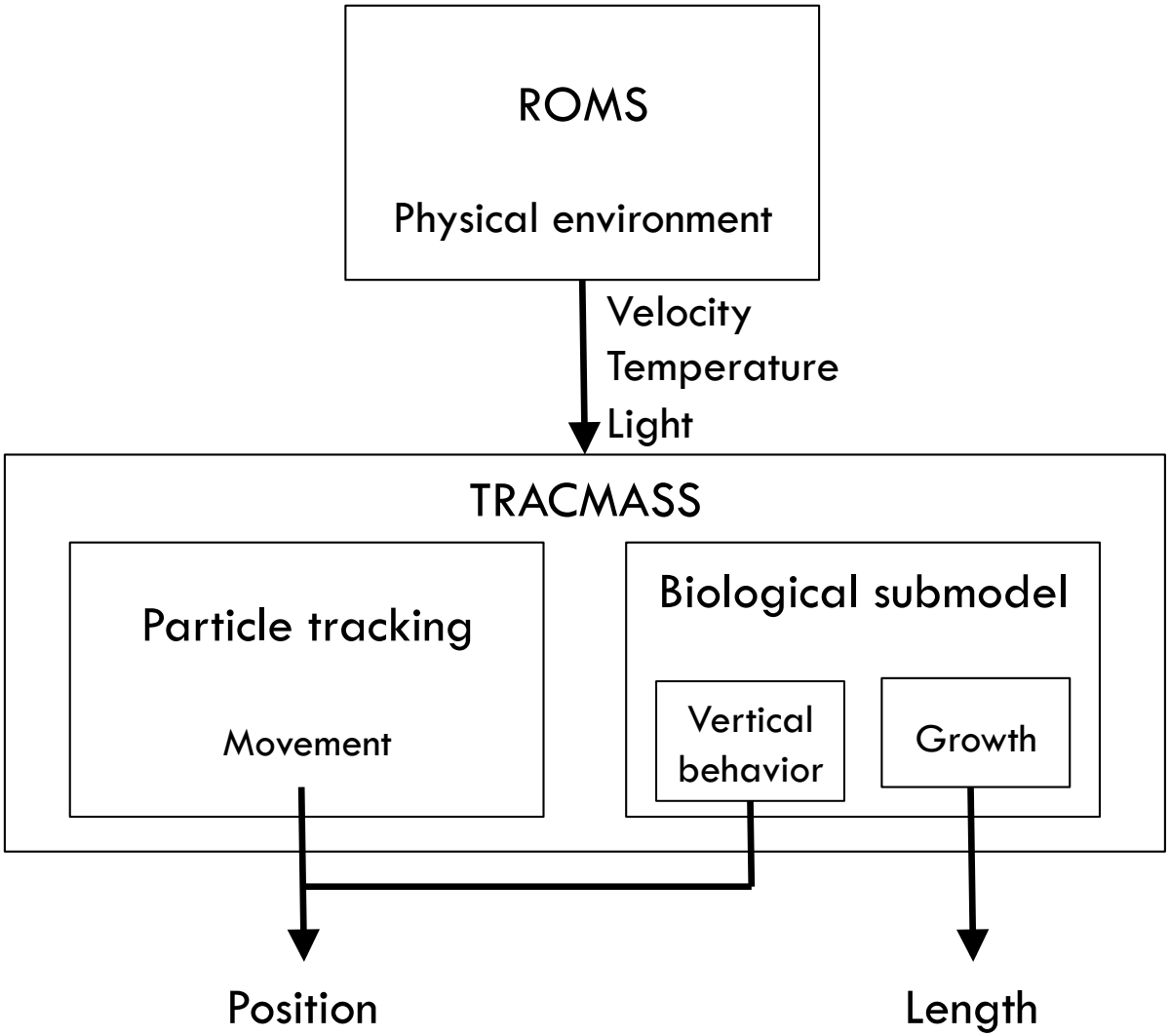


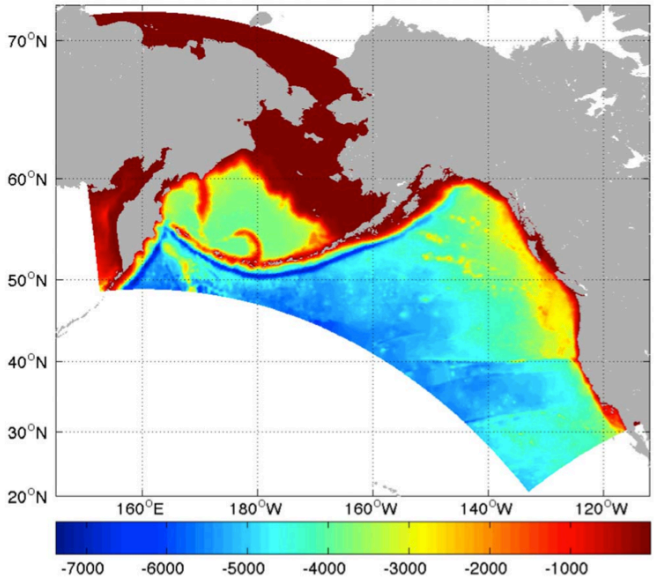
Feb wks 3-4



S. Barbeaux unpublished data

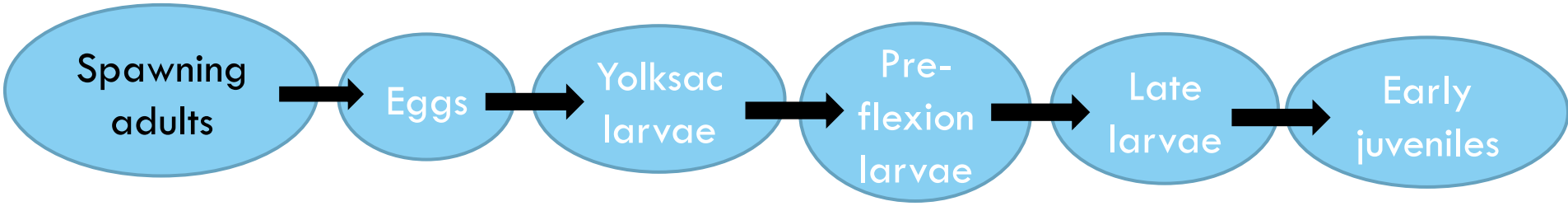
3D Coupled Models





NEP-6 domain with bathymetry (m)

Pollock Biological Model



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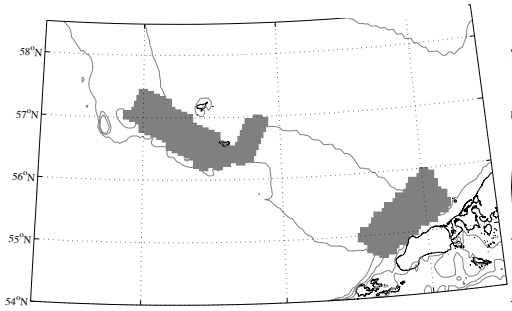
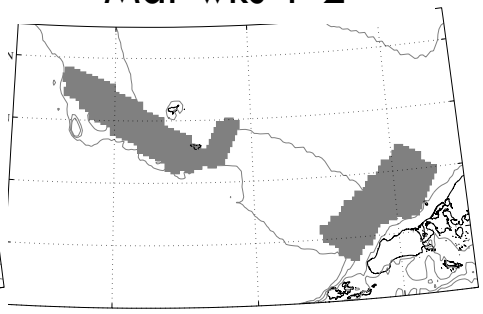
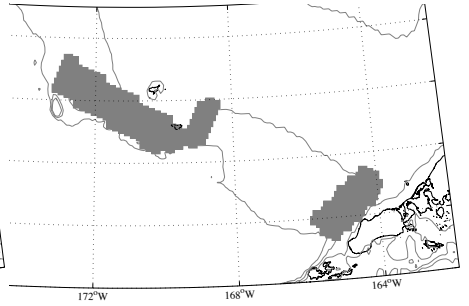


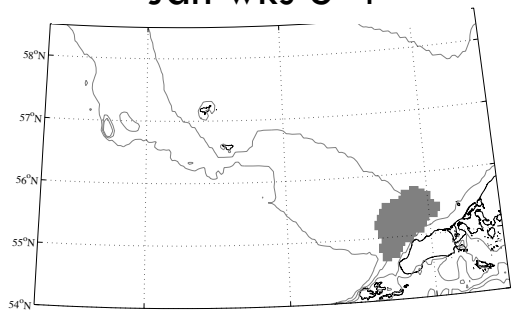
Mar wks 1-2



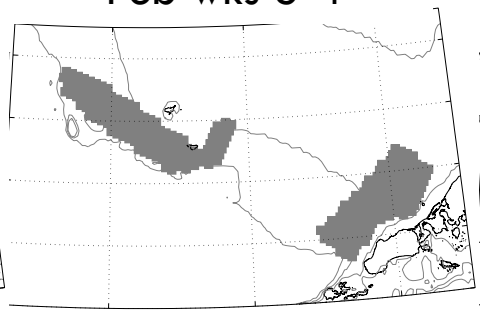
Apr wks 1-2



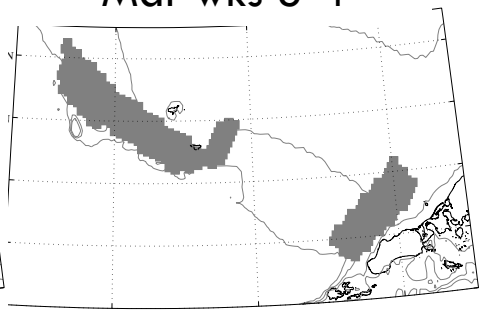
Jan wks 3-4



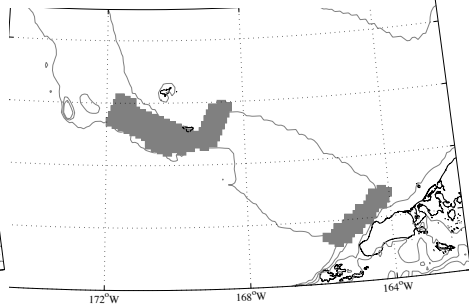
Feb wks 3-4



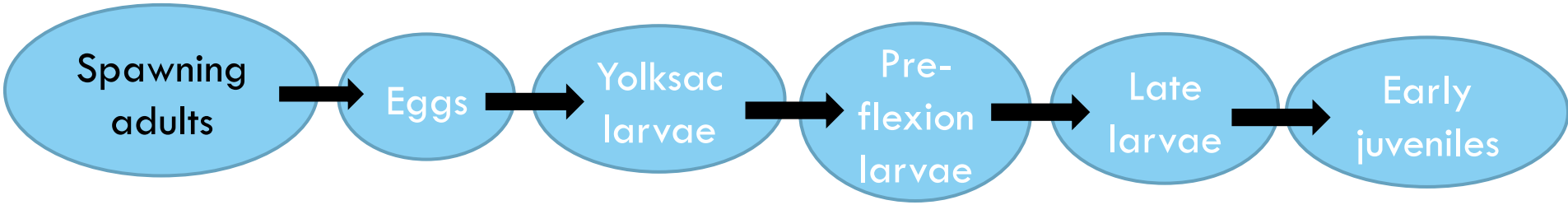
Mar wks 3-4



Apr wks 3-4



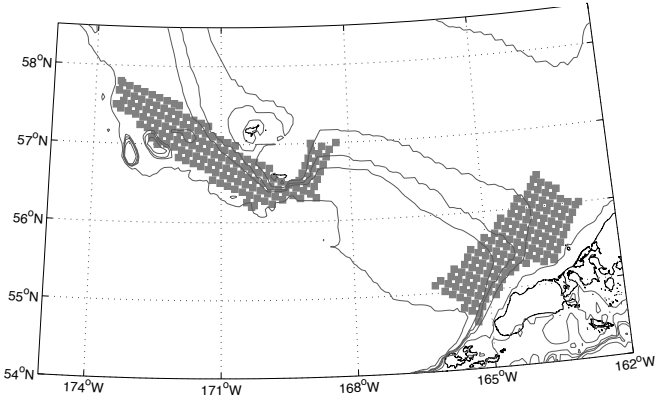
Pollock Biological Model



(e.g. Mar wks 1-2)

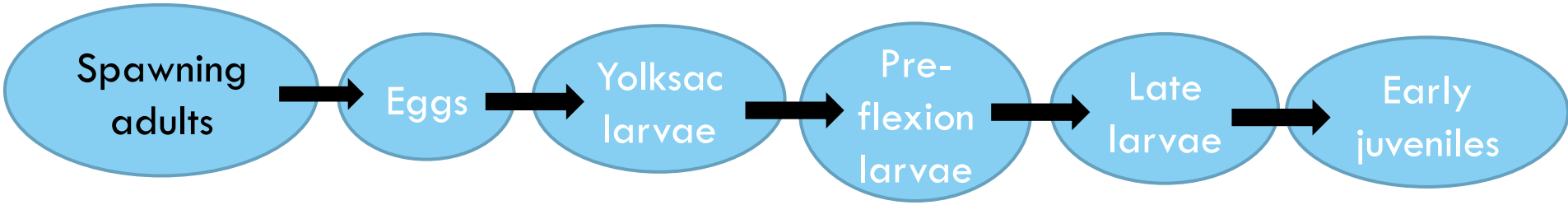
Transport test

Control



Same spawning locations in warm and cold years

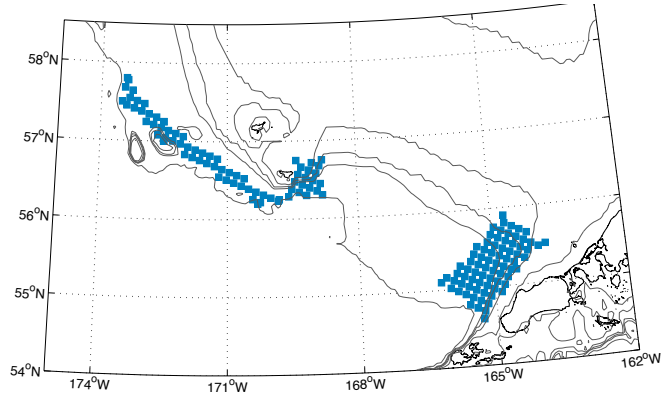
Pollock Biological Model



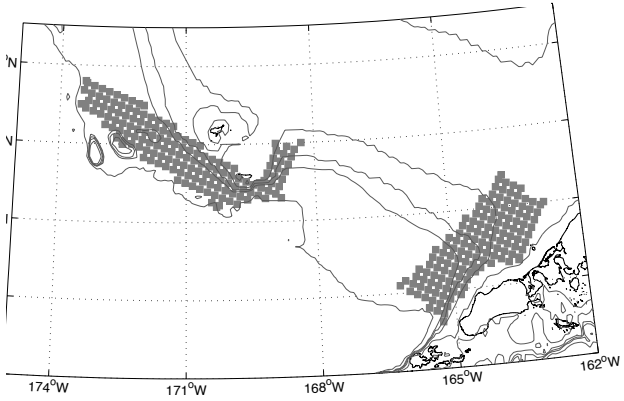
(e.g. Mar wks 1-2)

Spawning location test

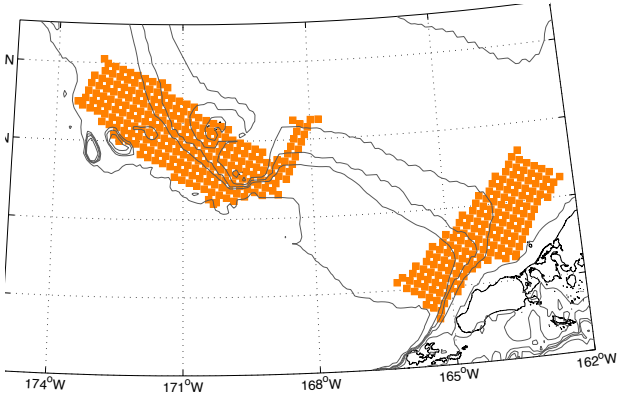
Cold



Control



Warm

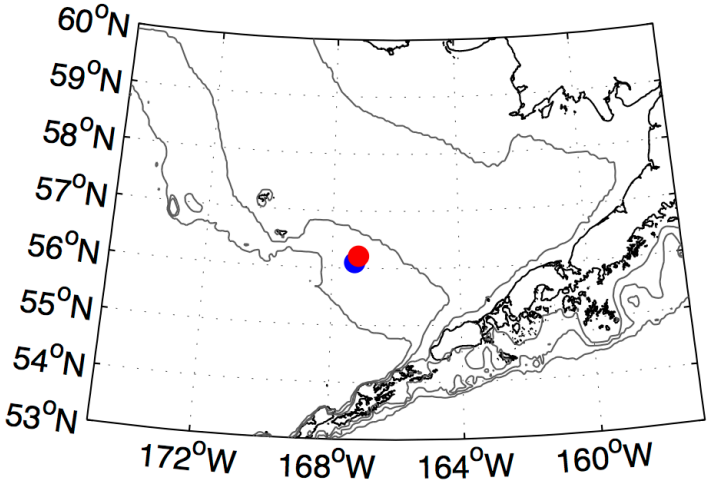


Contracted off-shelf

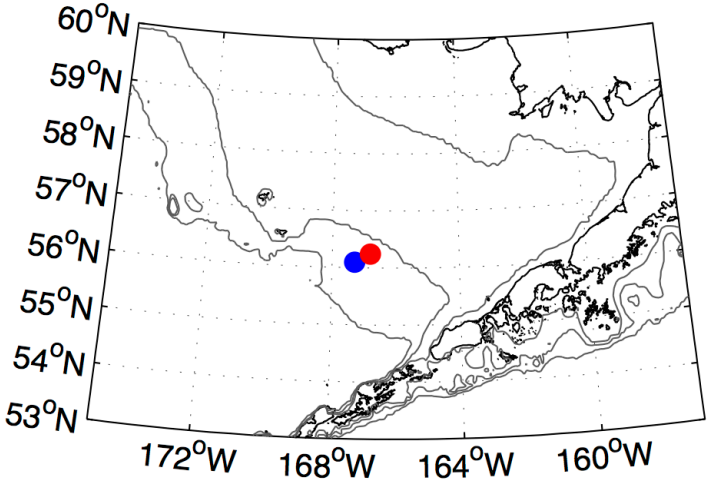
Expanded on-shelf

Modeled Late Stage Larvae

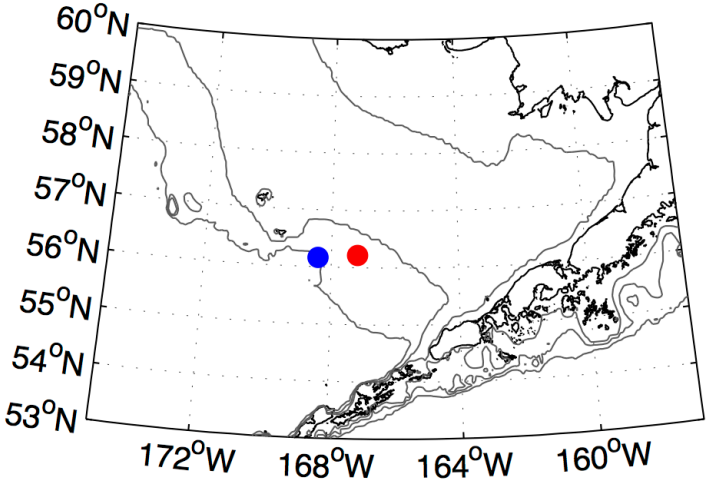
Transport Only



Expanded on-shelf



Contracted off-shelf



cold

warm

Pollock Model Results

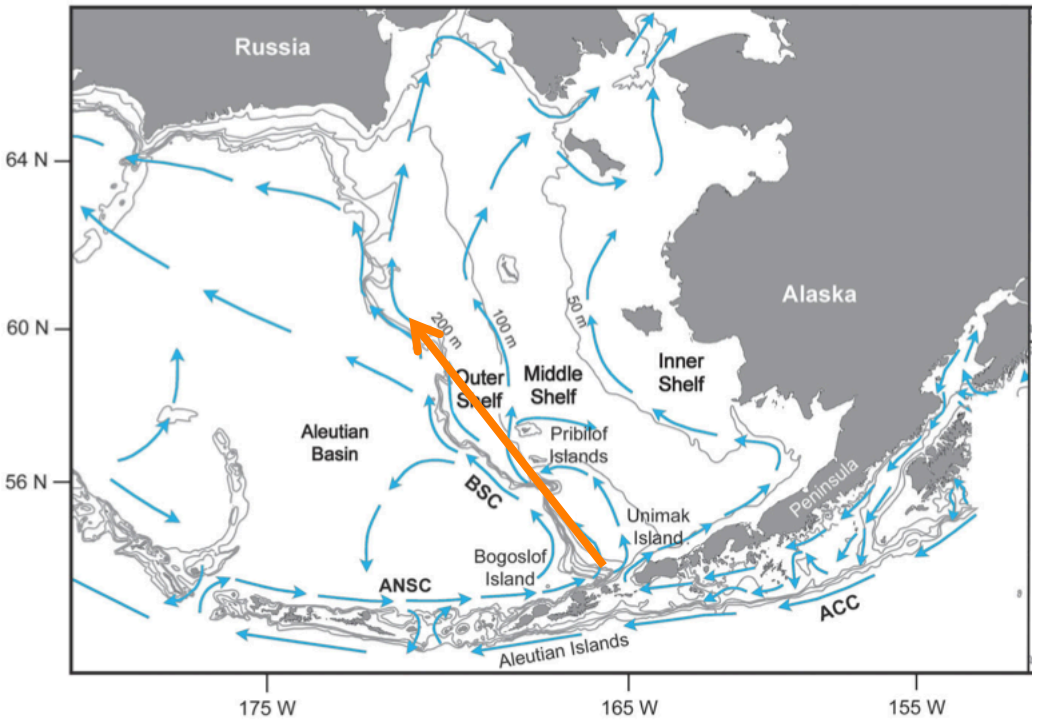
- Does interannual climate variability result in different distributions of pollock early life stages?
  - Yes

Pollock Model Results

- What are the dominant physical mechanisms responsible?
  - Spawning Location > Transport
    - Contraction > Expansion

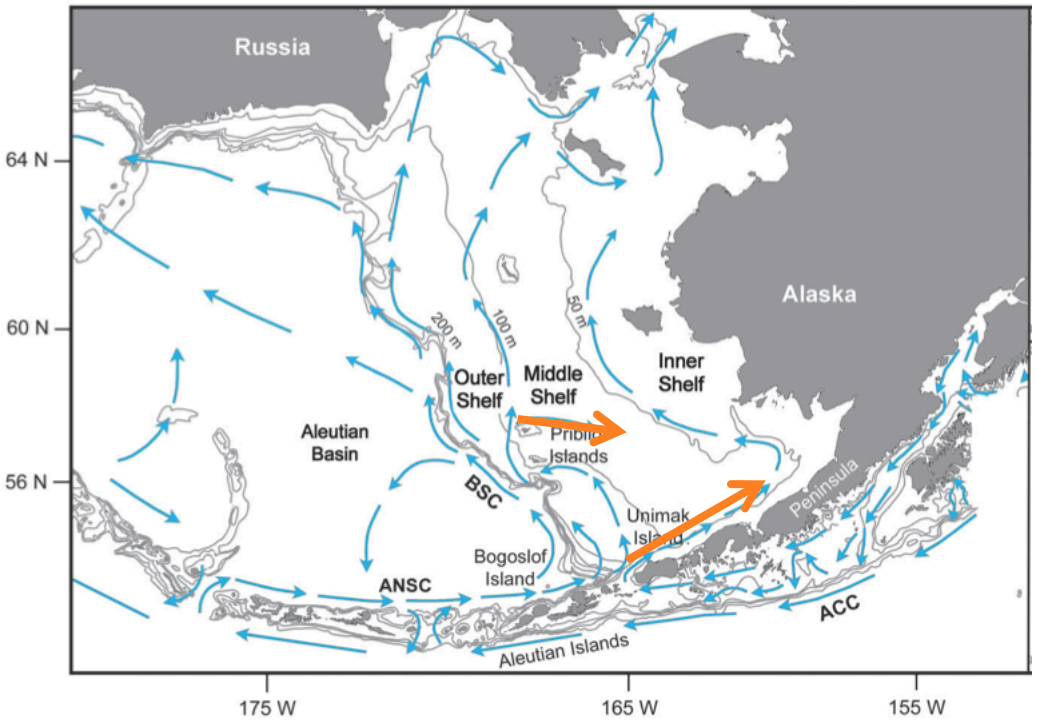
Pollock Model Conclusions

- Why?
- Related to location of currents
  - Outer shelf currents more along-shelf

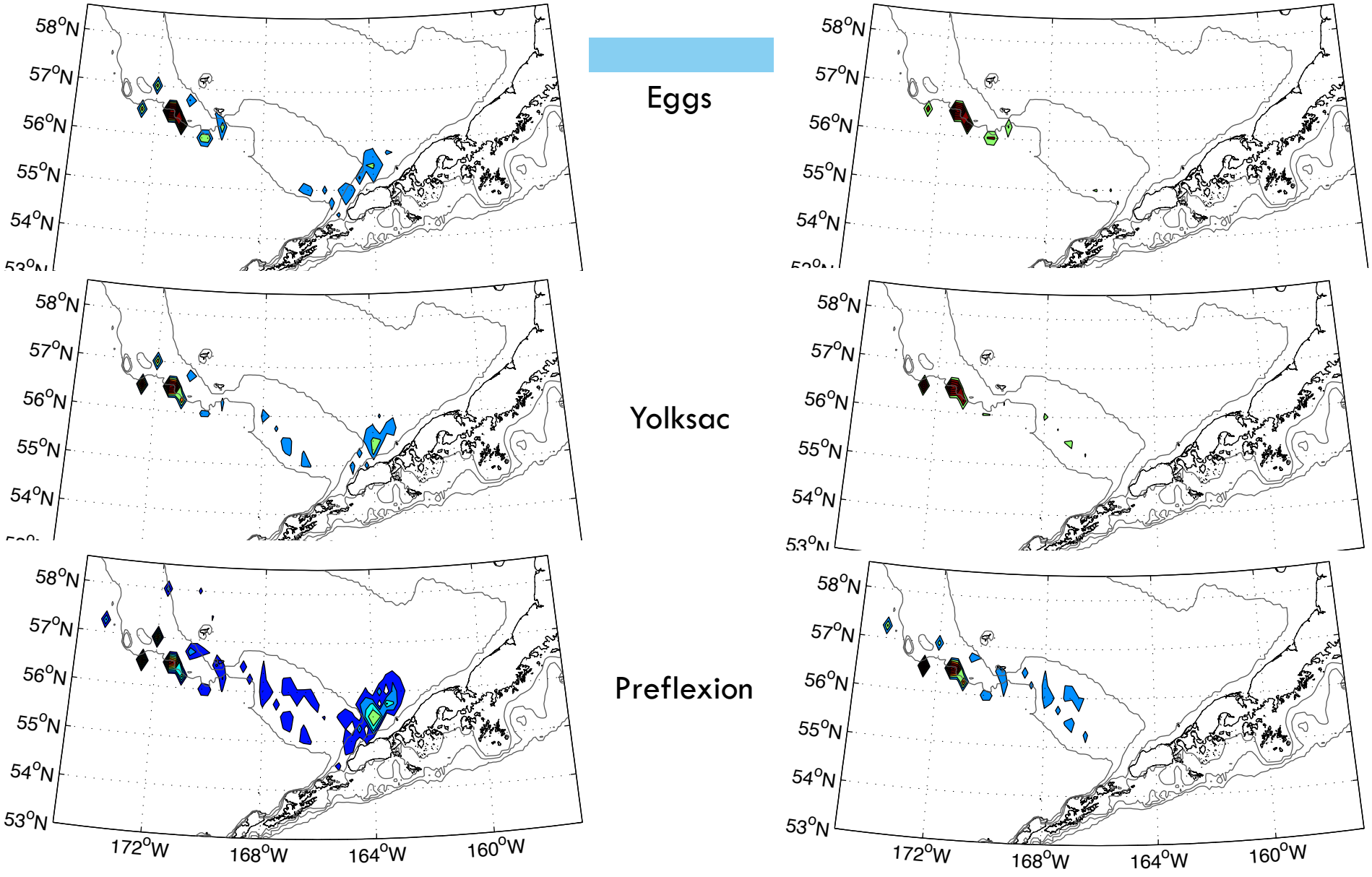


Pollock Model Conclusions

- Why?
- Related to location of currents
  - Middle shelf currents more across-shelf



Transport only vs. Contracted



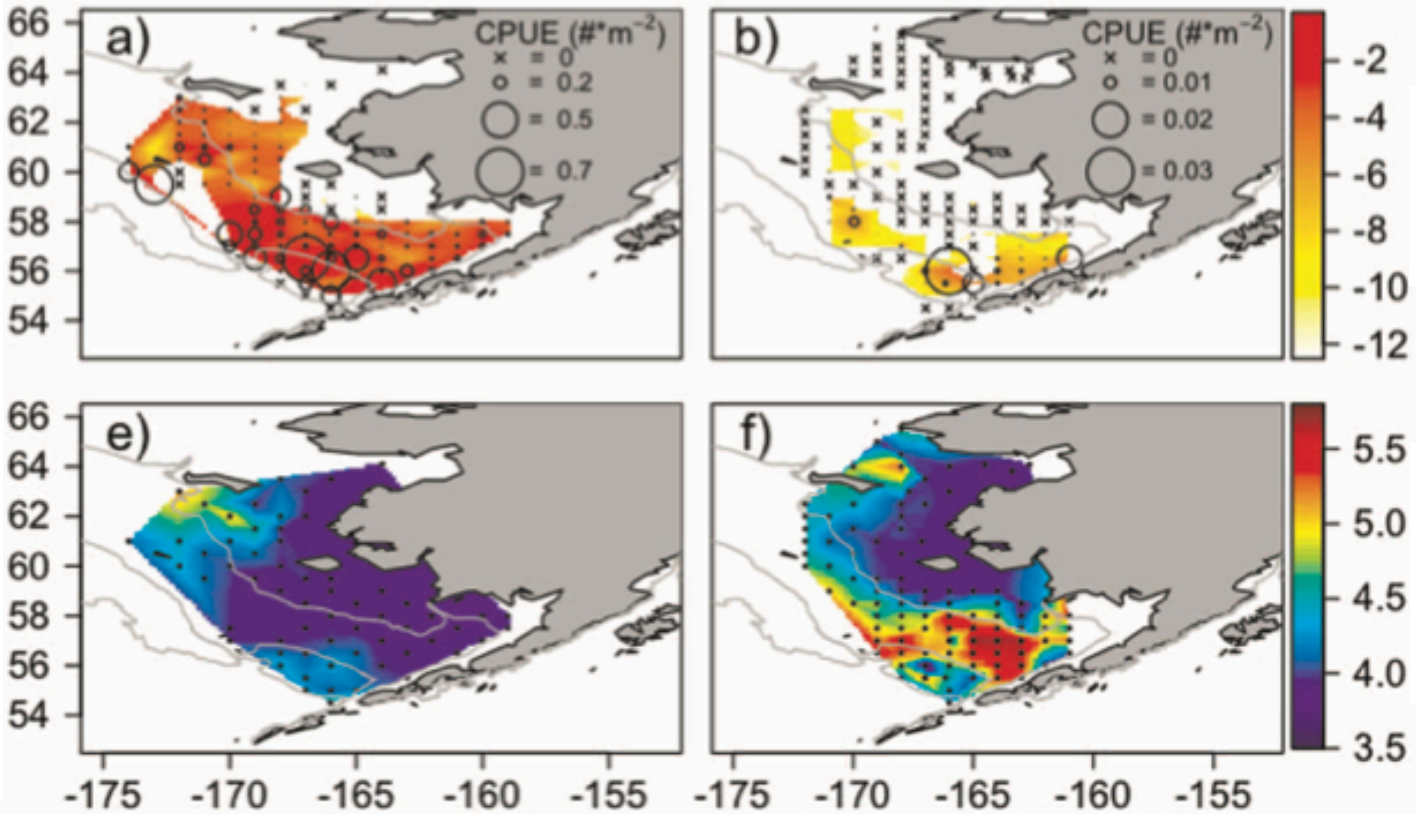
Juvenile Pollock Observations

Warm

2005

Cold

2010



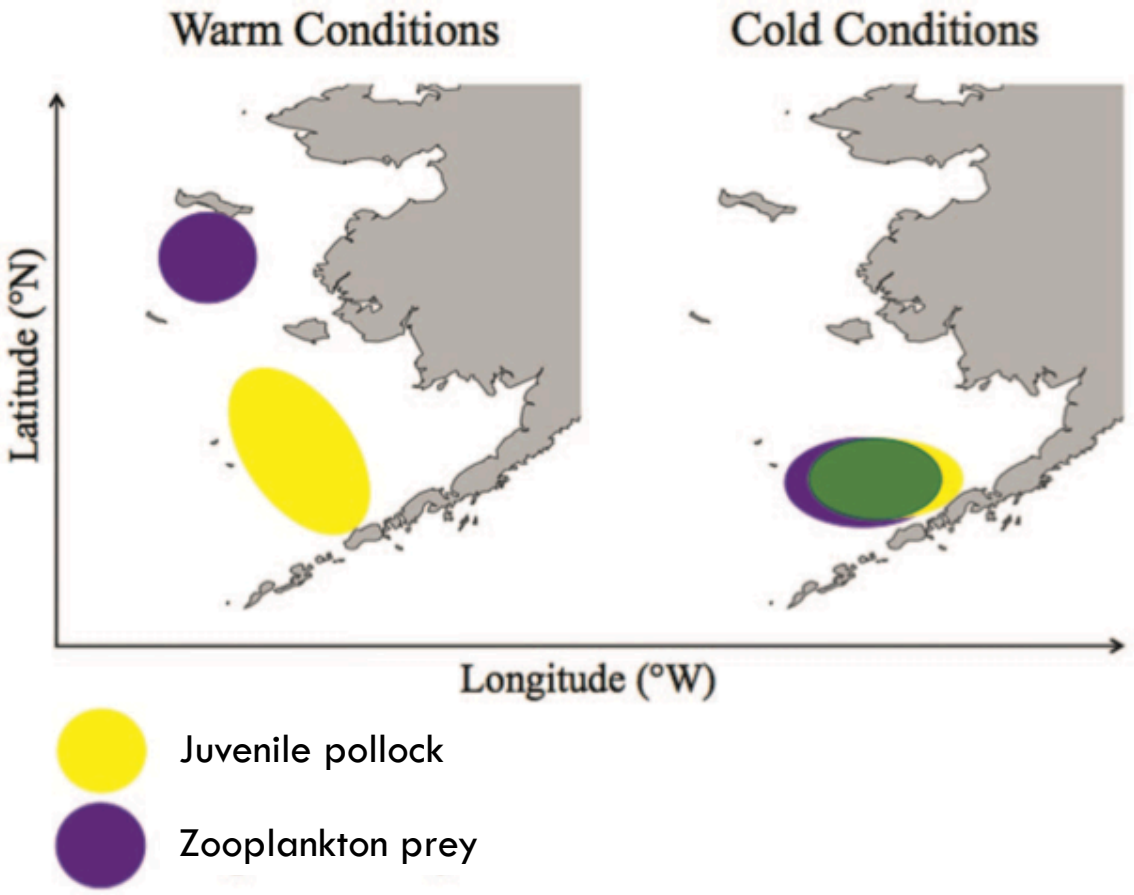
Juvenile pollock log CPUE (# m^{-2})

Mean zooplankton energy density

Siddon et al. 2013

Juvenile Pollock Distribution

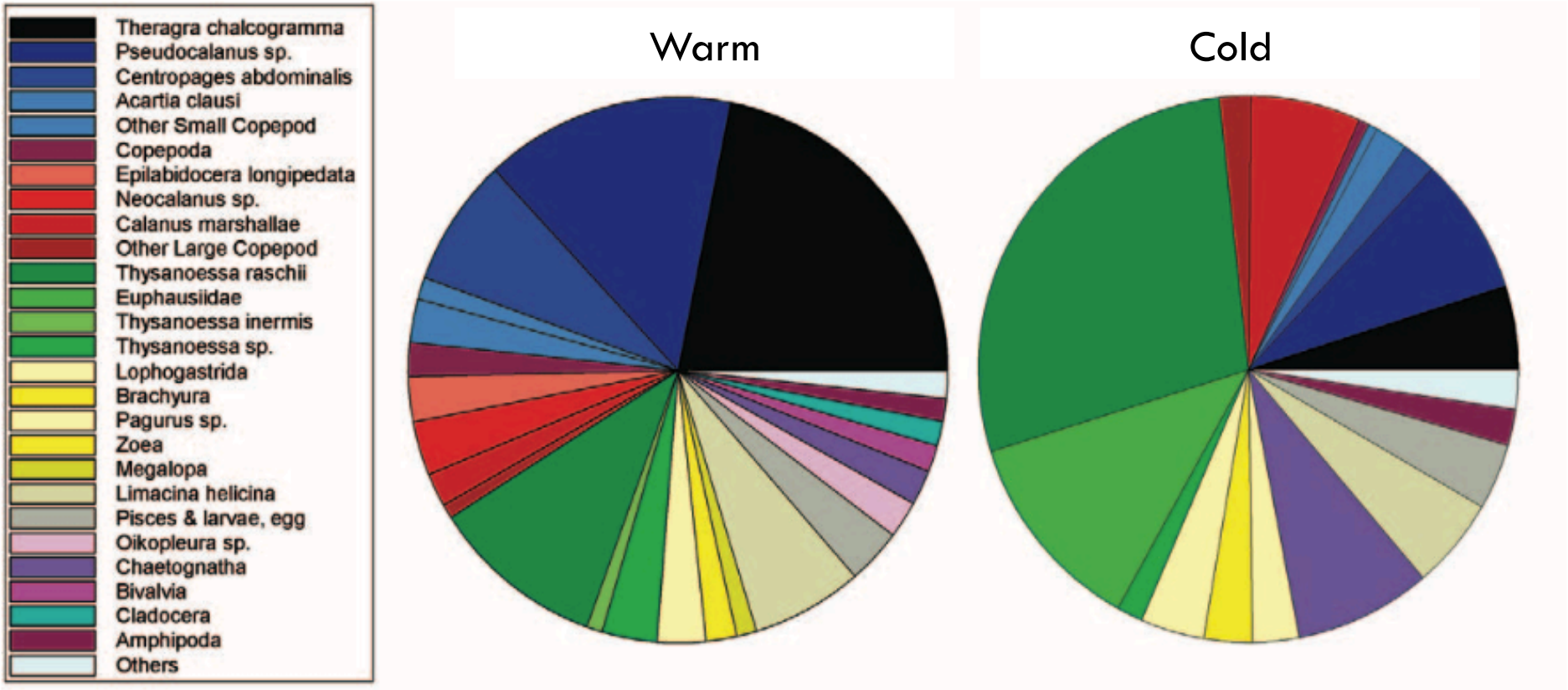
Less overlap with big, energy-rich prey



Siddon et al. 2013

Juvenile Pollock Diet

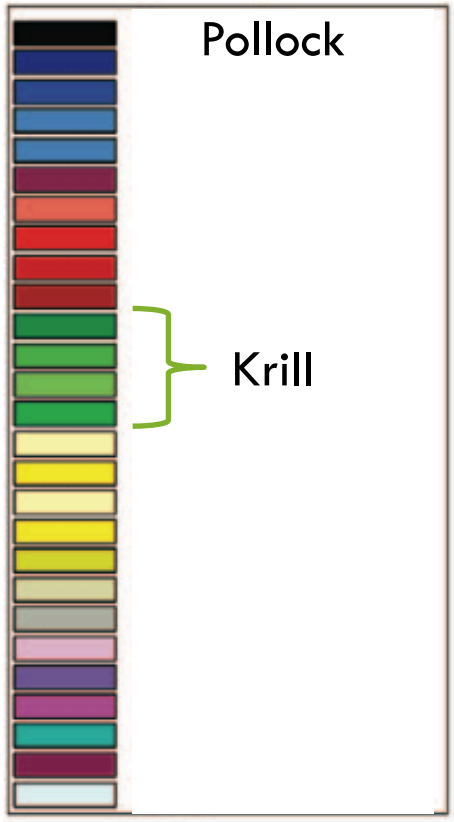
Pollock eat more pollock

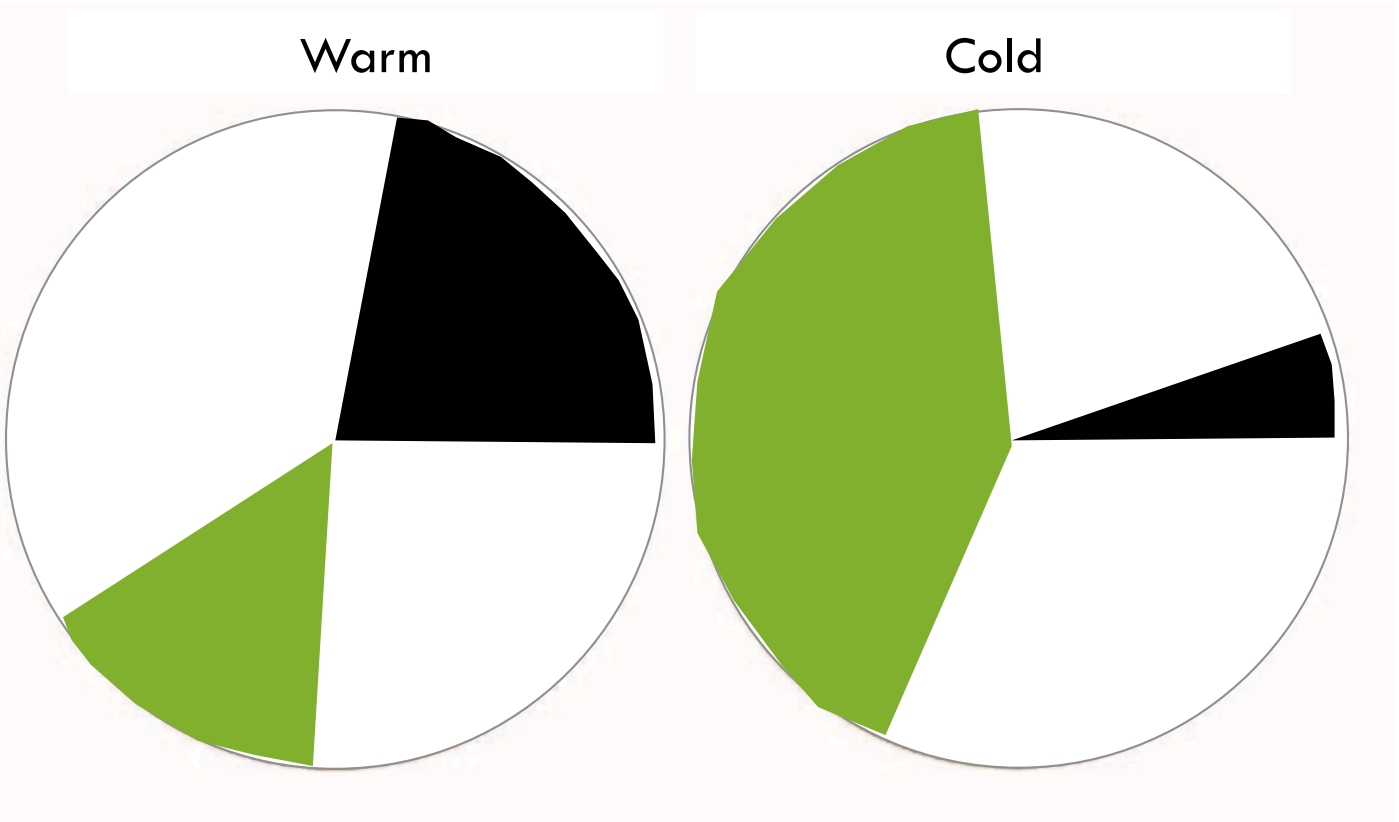


Moss et al. 2009

Juvenile Pollock Diet

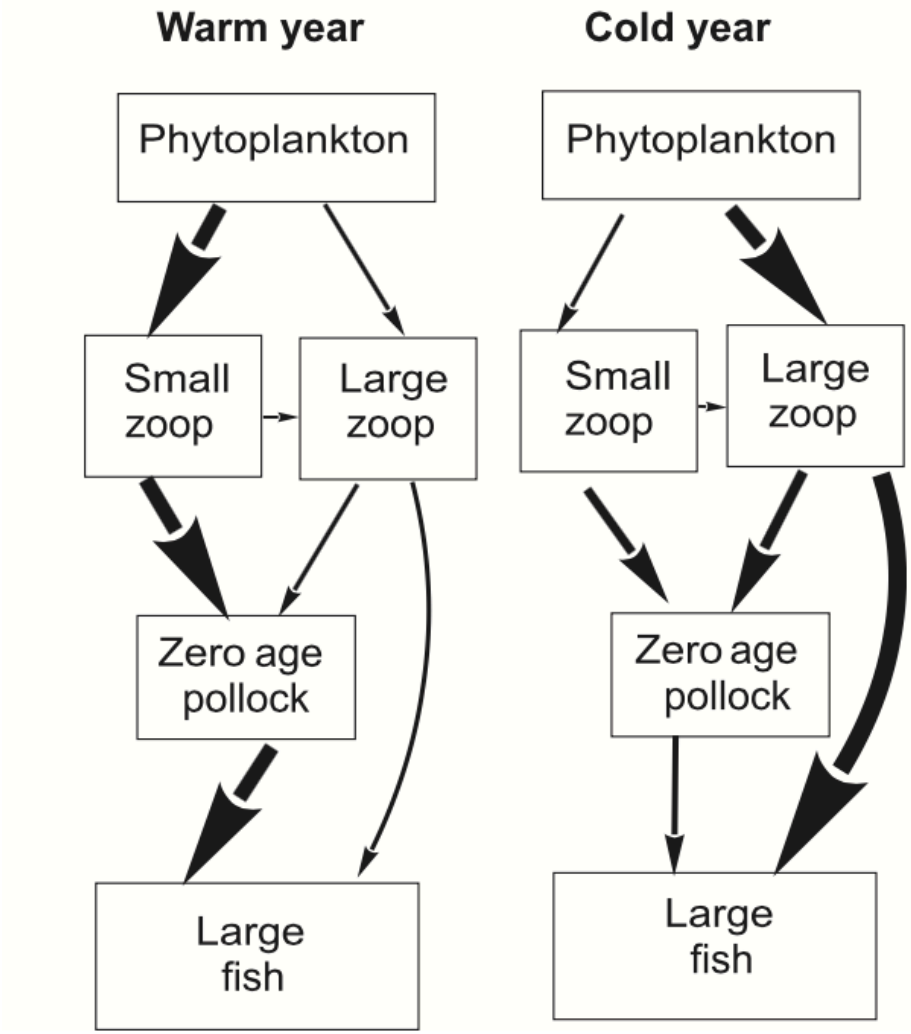
Pollock eat more pollock





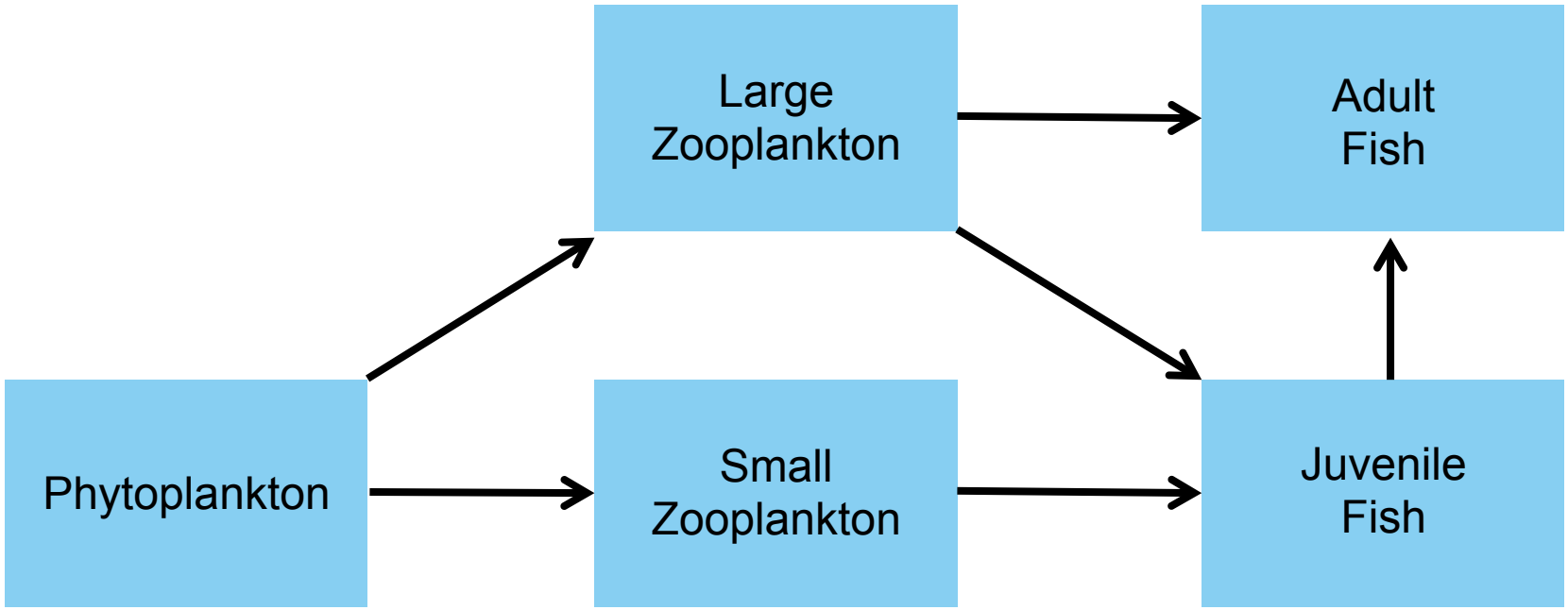
Moss et al. 2009

Juvenile Pollock Dynamics

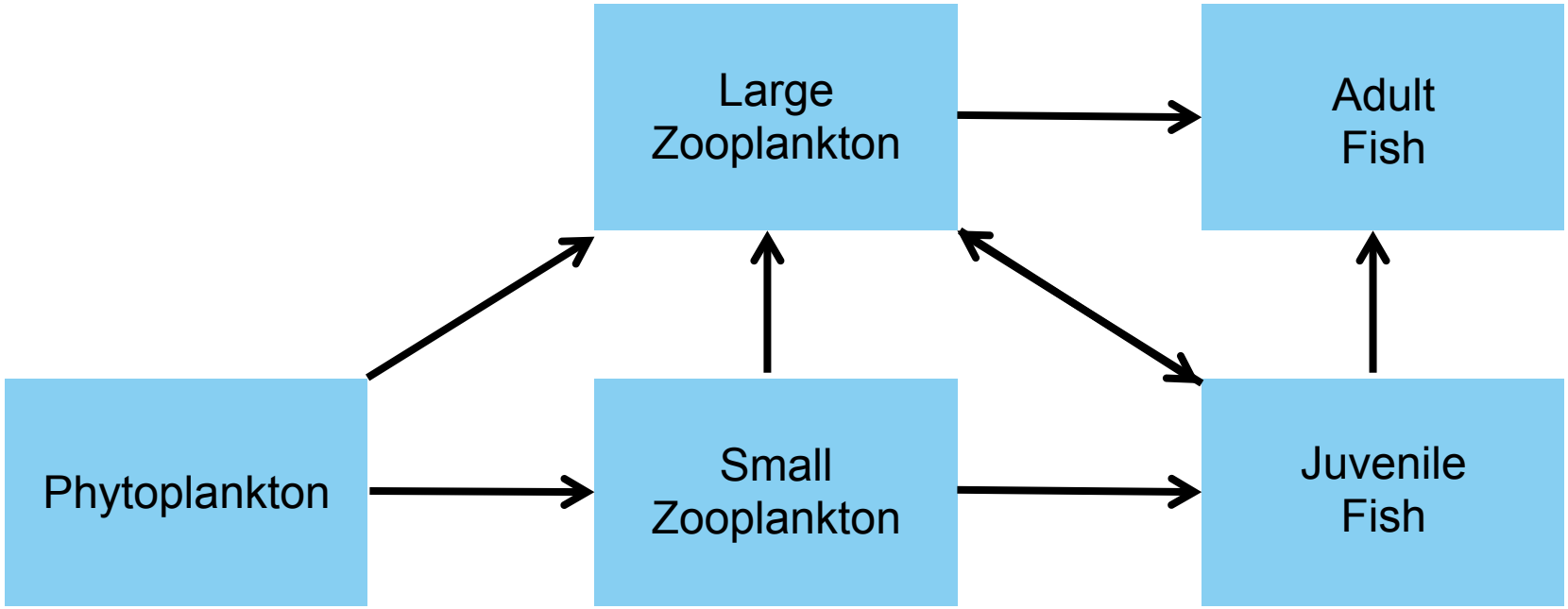


Coyle et al. 2011

Pollock Perspectives



Nereus Ideas



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