Exploration of ecosystem factors responsible for coherent recruitment patterns of Pacific cod and walleye pollock in the eastern Bering Sea

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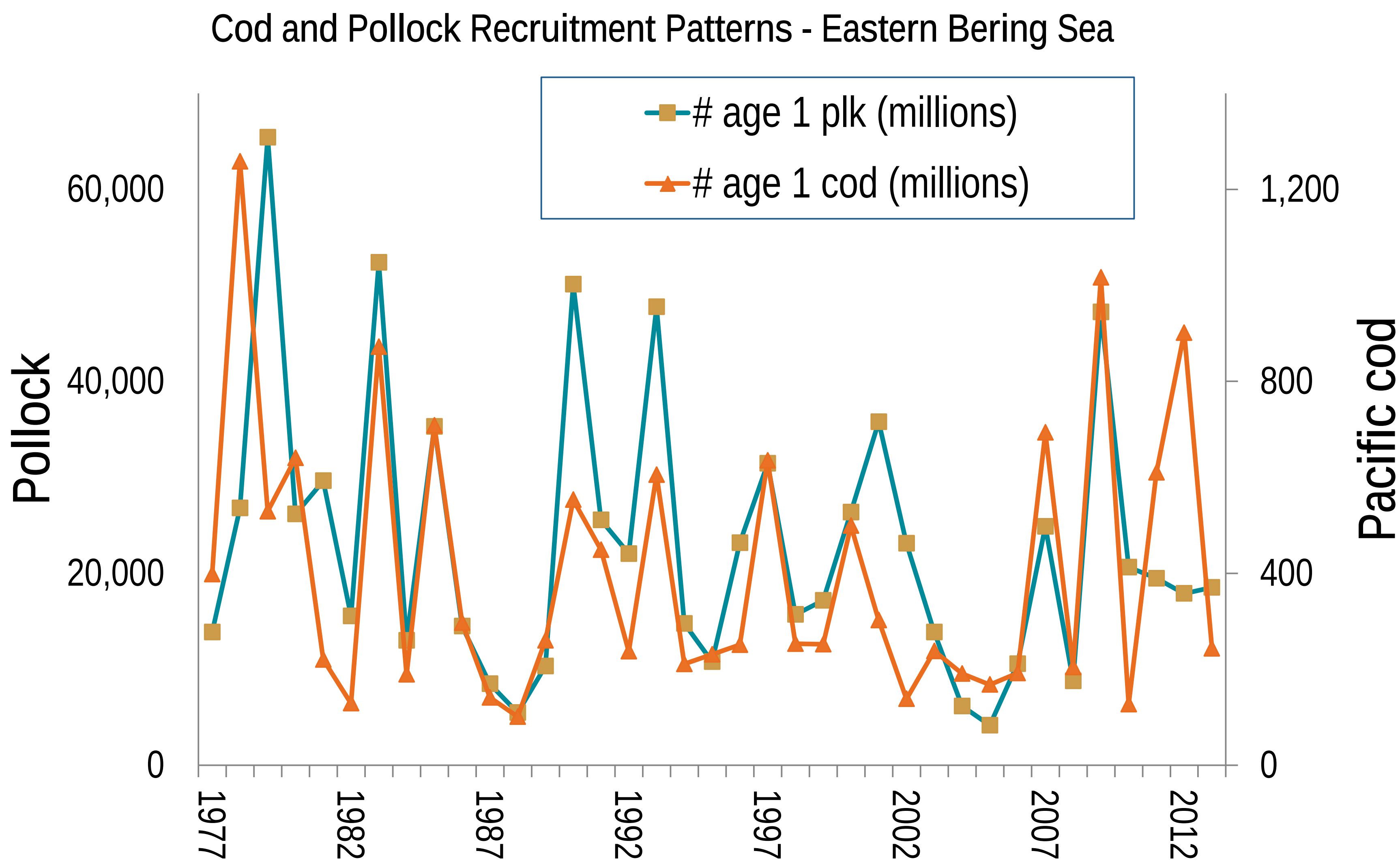
Motivation: Are the same factors responsible?



Overview

- Review life history patterns
  - Spawning distribution and timing
  - Early life history characteristics

- Recruitment hypotheses and evidence

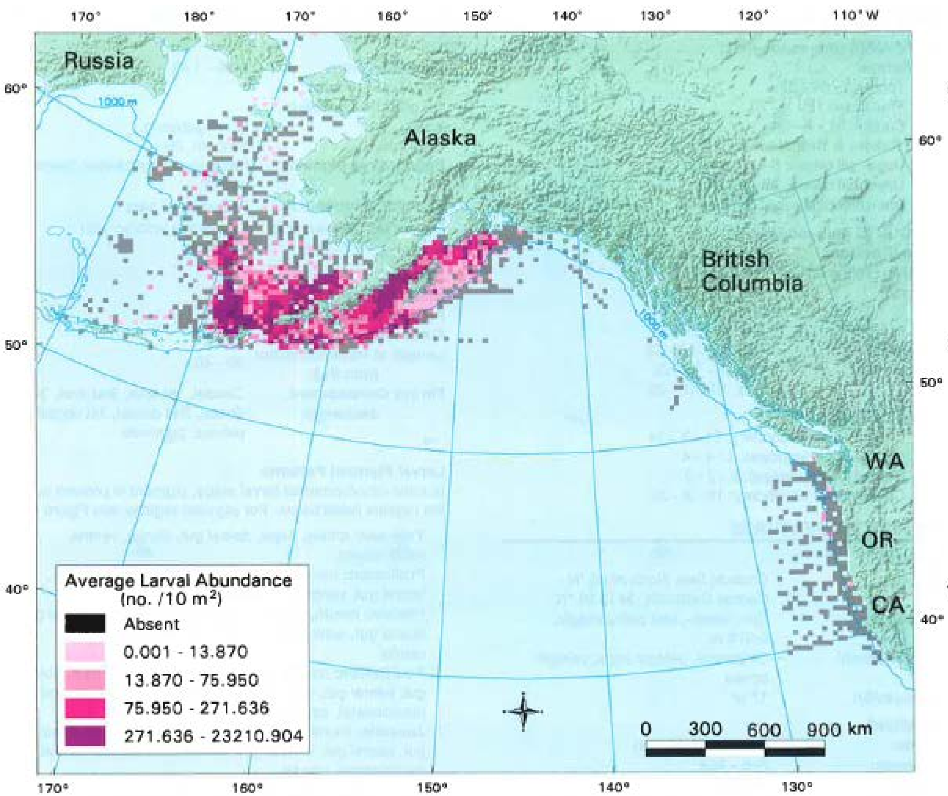
- Implications for Research and Management

Walleye pollock and Pacific cod life history

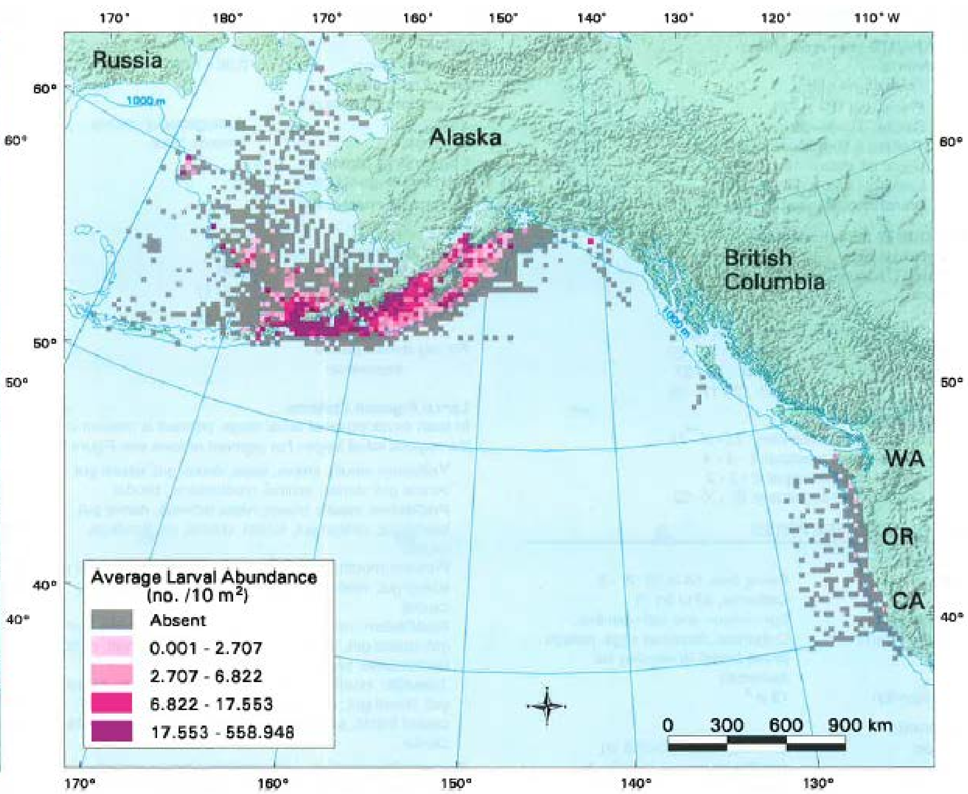
Life history character	Walleye pollock	Pacific cod
Average spawning date	Mid-late winter	Mid-March
Age at 50% maturity	~3.5 yrs	4.9 yrs
Egg type	Pelagic	Demersal
Hatch date	Mid-April	Mid-April
Habitat preferences age 0 fish	Initially surface, then diel migrations with increasing size, widespread on shelf	Initially surface, then diel migrations with increasing size, S middle shelf, temperature dependent vertical behavior
Age 0 prey	Zooplankton(smaller) – varies with cold/warm years	Zooplankton (smaller)-varies with cold/warm years. More diverse in cold years and more pollock consumed in warm years
Age 1+ prey	Zooplankton, becoming more piscivorous with age	Increasingly benthic with increasing age, fish and crustaceans as adults

Spawning Locations and Larval Distribution

Walleye pollock



Pacific cod



Matarese et al. 2012

Life History Evidence of coherence

In eastern Bering Sea

- Similar spawning and larval distribution patterns, age 0 feeding and behavior
- Thus, it is likely that the same mechanisms operate during the first year of life to control survival

The Search for Understanding – Early Days

“WARM IS GOOD”

1980’s - 2000

Francis and Bailey 1983:

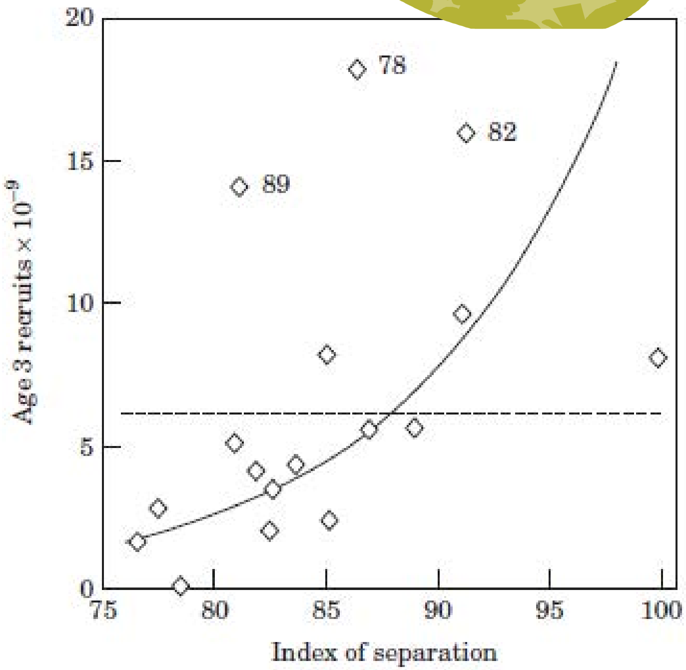
- Location of spawning and vertical stratification in fall of warm years produces large year-classes

Quinn and Niebauer 1995:

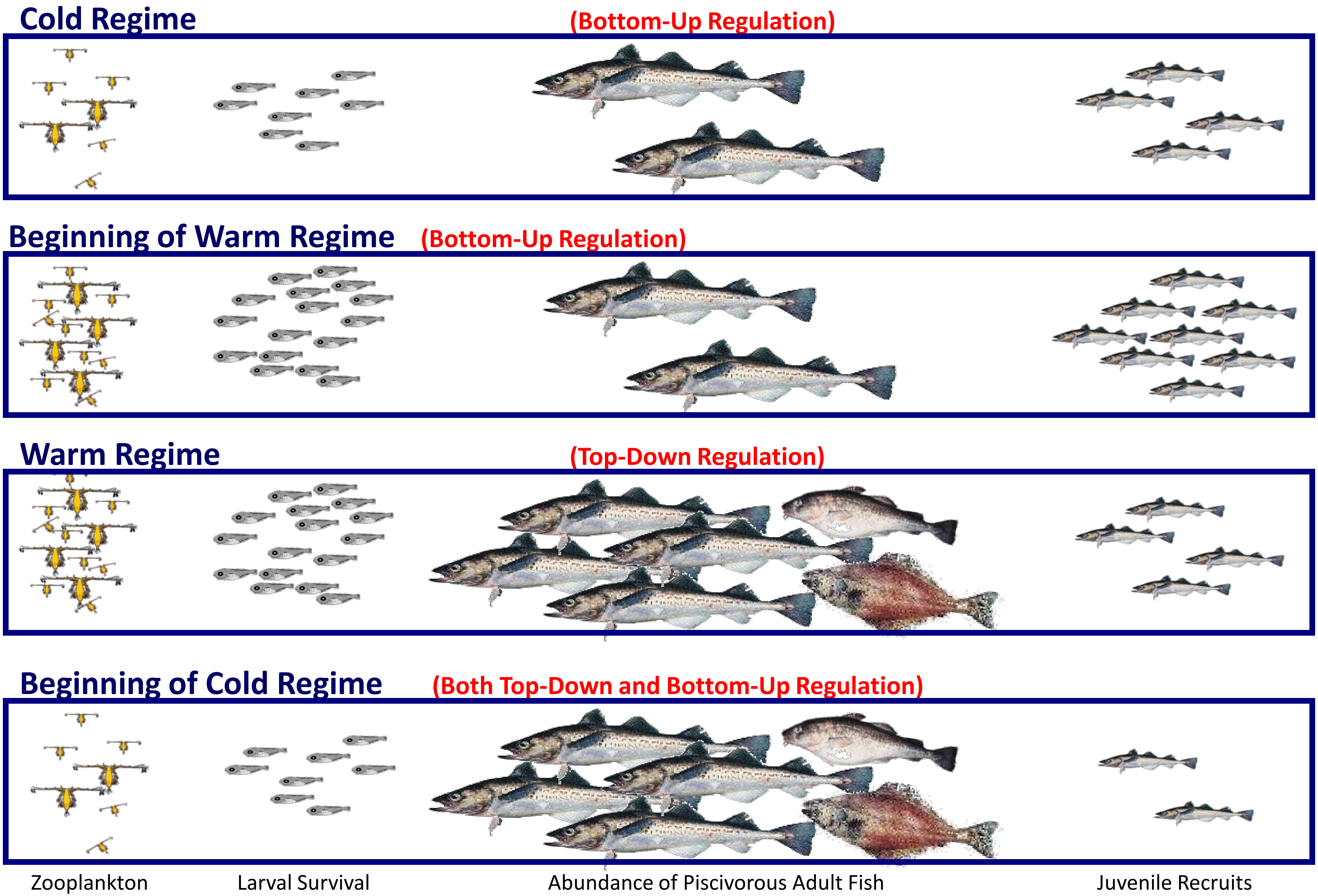
- High recruitment coincides with above normal air and bottom temperatures and reduced ice cover

Wespestad et al. 2000:

- Cannibalism is a major determinant of recruitment and depends on separation between adults and juveniles in warm years when juveniles are transported away from adults from spring



Oscillating Control Hypothesis *(Hunt et al. 2002)*



The Search for Understanding- More recent

“WARM IS BAD”

2000 - present

Mueter et al 2006:

- Timing of spring bloom and dome shaped relationship of summer wind mixing influencing feeding conditions in early juvenile stage are important

Mueter et al 2009:

- Post-regime shift (1977) negative correlation between SST at the larval and juvenile stages and pollock and cod recruitment

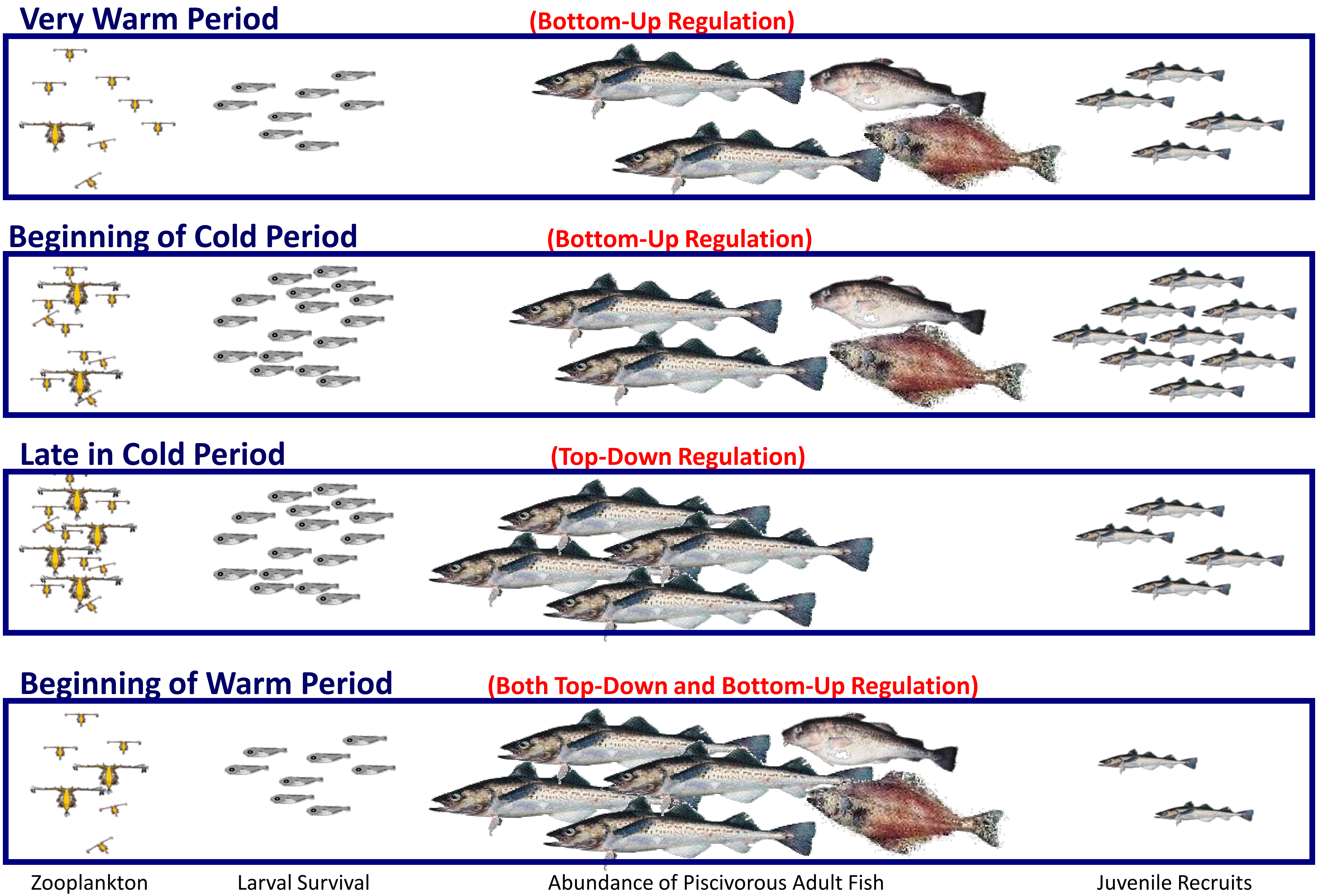
Mueter et al. 2011, Hunt et al. 2011, Heintz et al 2013:

- Warm spring enhances larval survival but high temperature in late summer and fall result in poor feeding condition and overwinter survival

Coyle et al. 2011, Heintz et al. 2013, Stachura et al 2014:

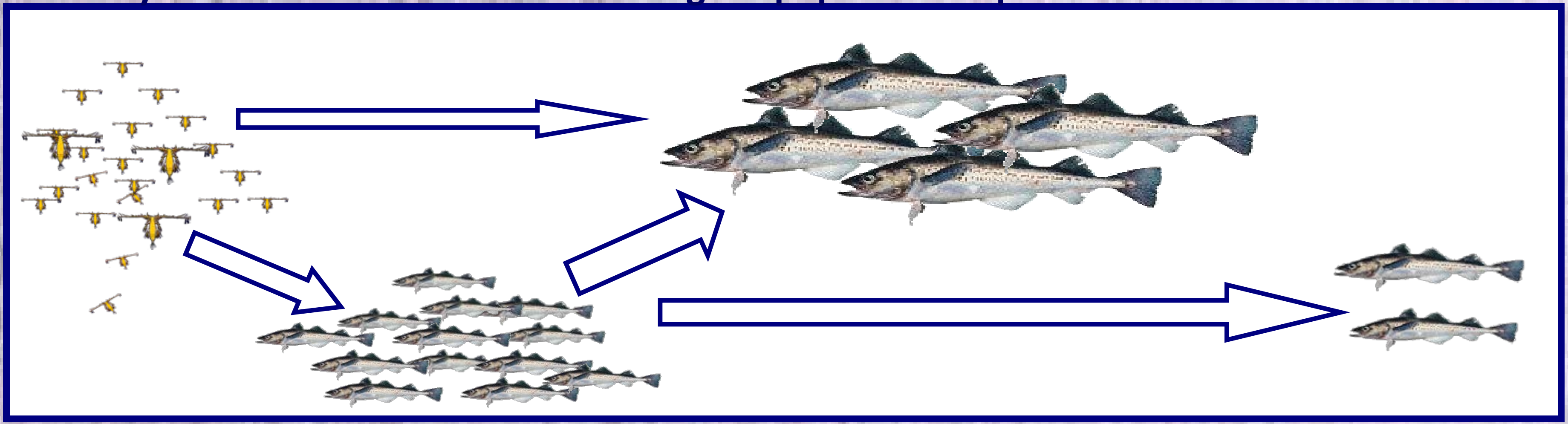
- Late ice retreat produces more lipid rich large zooplankton that results in better age 0 cod and pollock condition in fall, enhancing overwinter survival

Oscillating Control Hypothesis *(Revised ex Hunt et al. 2002)*

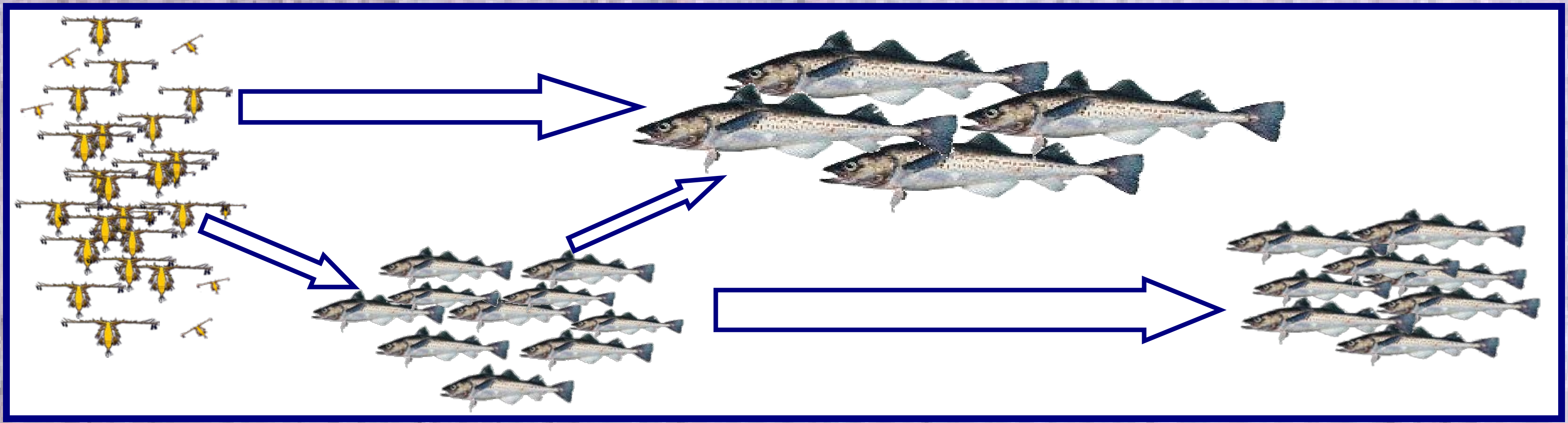


Impacts of Availability of Large Zooplankton

Warm year with late bloom and few large copepods or euphausiids

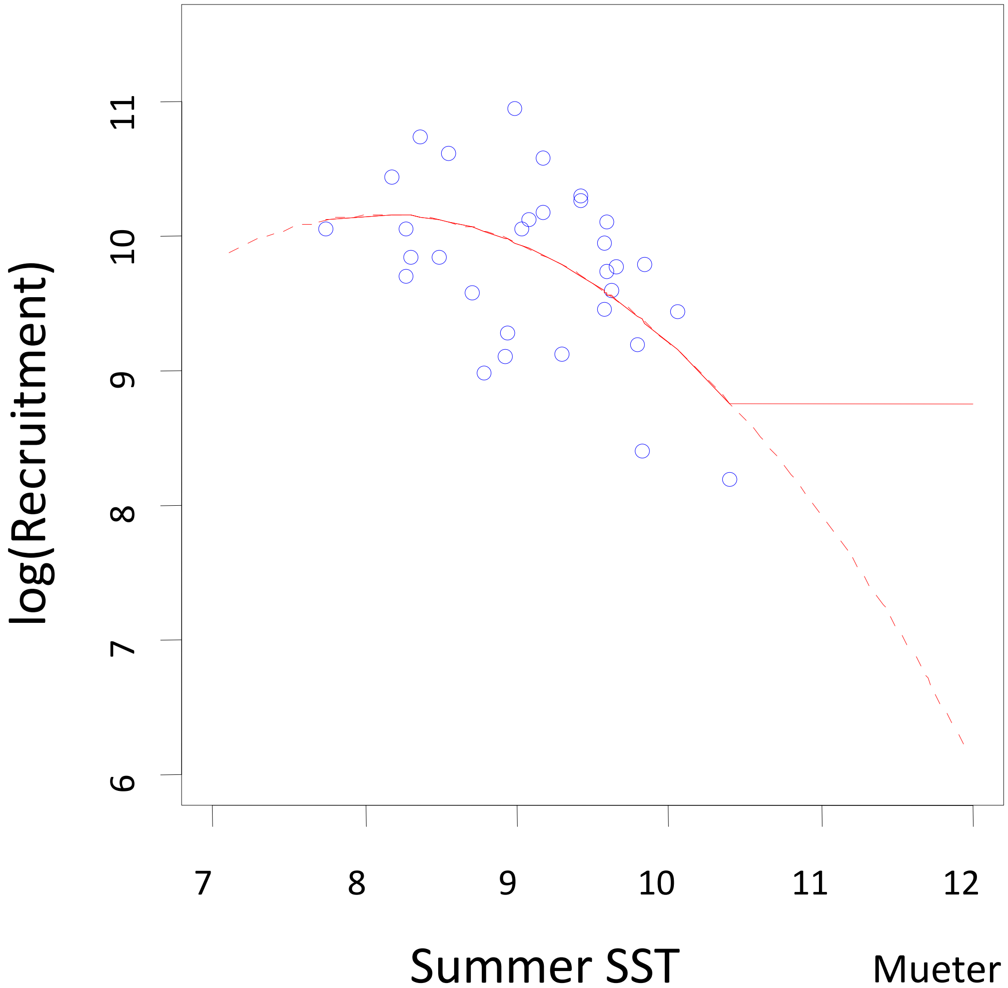


Cold year with early bloom and abundant large copepods and euphausiids



Mesozooplankton **Age-0s** **Year 2 and older** **Age-1s**

Too warm, too cold or just right?



Mueter et al. 2011

What about transport?

Associated with hypotheses involving top down regulation and remain part of recent studies' mechanisms, e.g.:

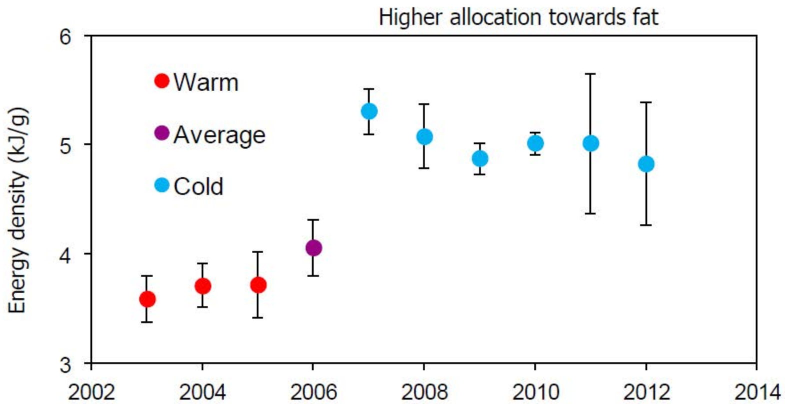
- Strong northward advection separate juvenile pollock from adults (Mueter et al. 2006)
- Northeasterly cross-shelf winds during winter of spawning reduces cannibalism (Stachura et al. 2014)

Other studies focus primarily on the bottom-up aspects involving the prey base and juvenile condition

Recent pollock research

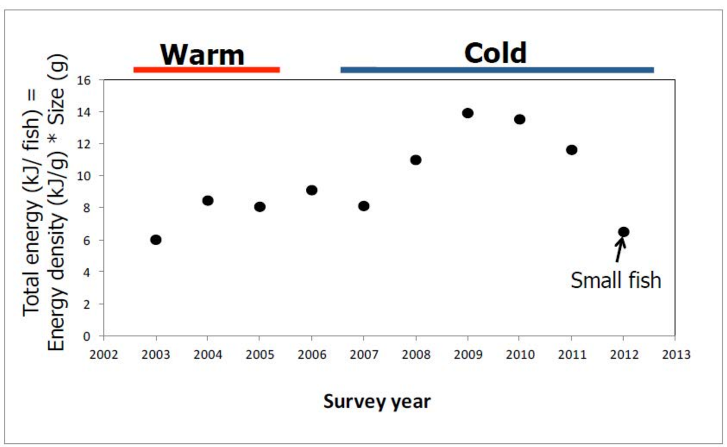
Colder late summers at age 0 are favorable for age 0 pollock overwinter survival Heintz et al 2010

Climate & age-0 pollock condition

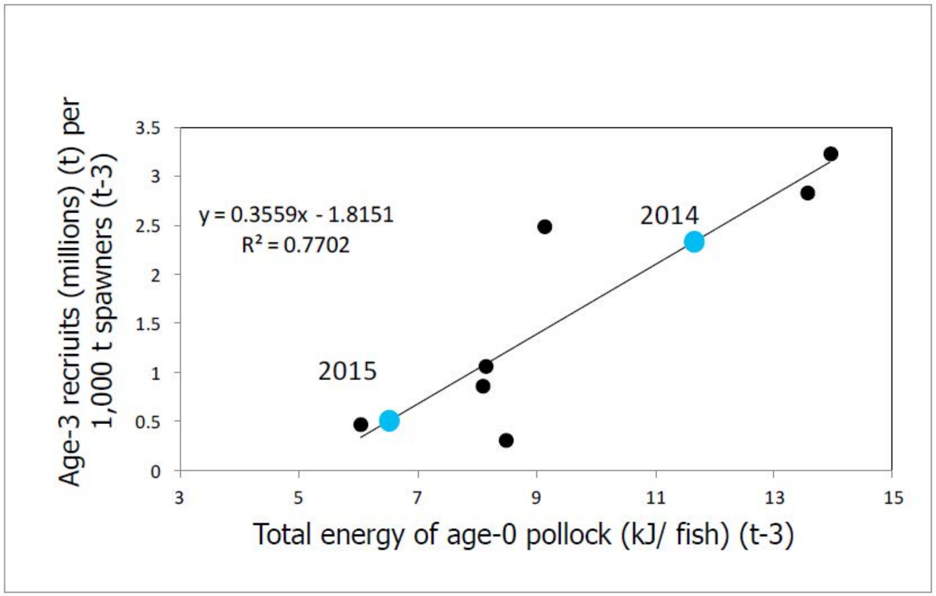


Total energy of age-0 pollock

15
NOAA Fisheries



Total energy & survival



Courtesy: Heintz

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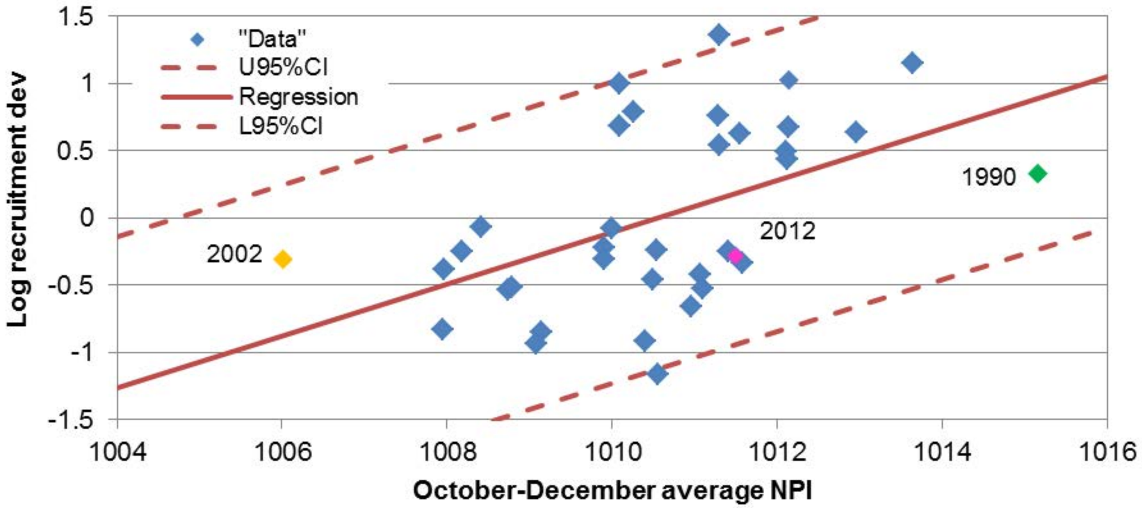
NOAA Fi

This relationship predicts that number of age 3 recruits in 2014 will be large but small in 2015

Yet another mechanism?



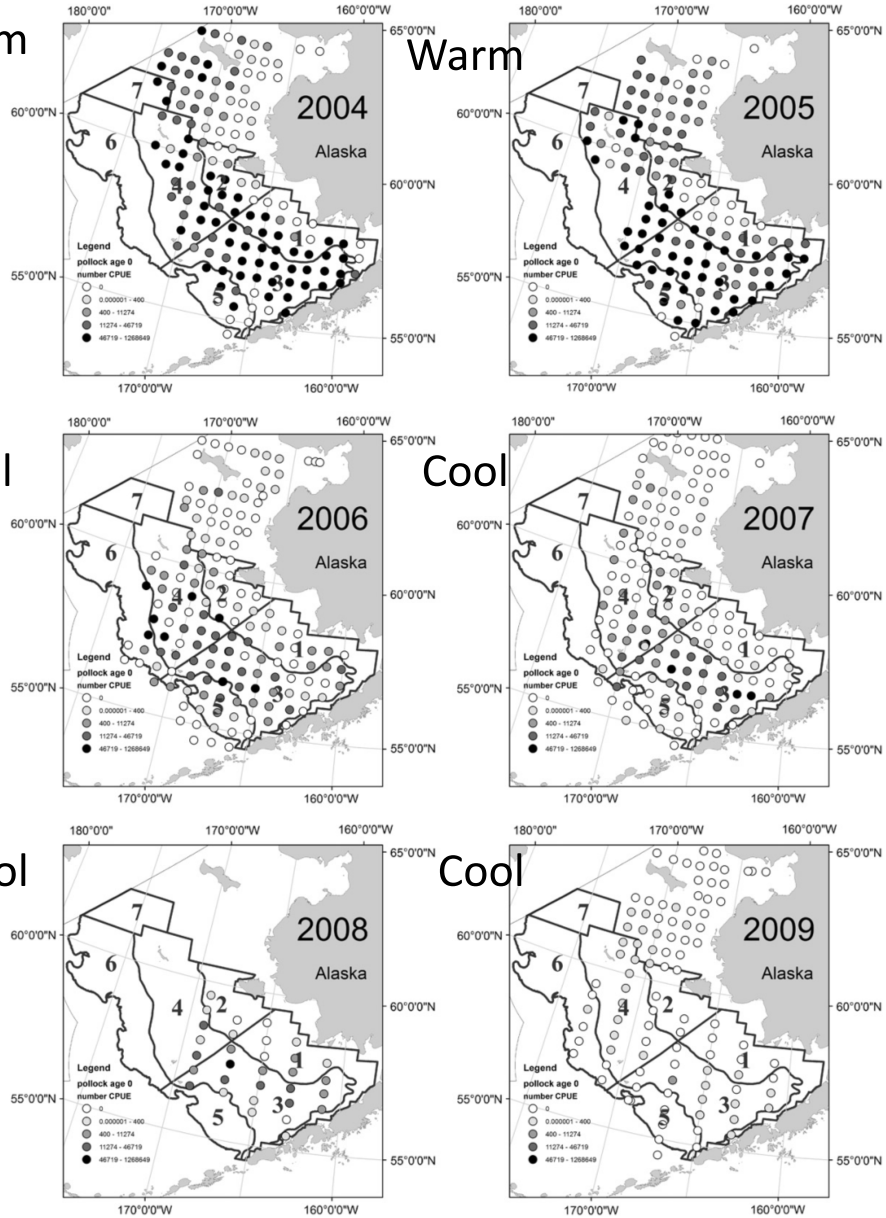
High pressure in the fall/winter of the first year of life is good for survival. Mechanism? Note: NPI leads SST changes by 1-2 mos.

Relationship between age-0 Pacific cod recruitment deviations and the October-December North Pacific Index (NPI) in the first year of life. Source: Thompson, G. 2013 BS Cod stock assessment Fig 2.15 http://www.afsc.noaa.gov/REFM/Docs/2013/EBSpcod.pdf

2013 Oct-Dec NPI is 4^{th} largest in the time series – This implies that 2013 YC of cod will be above average.

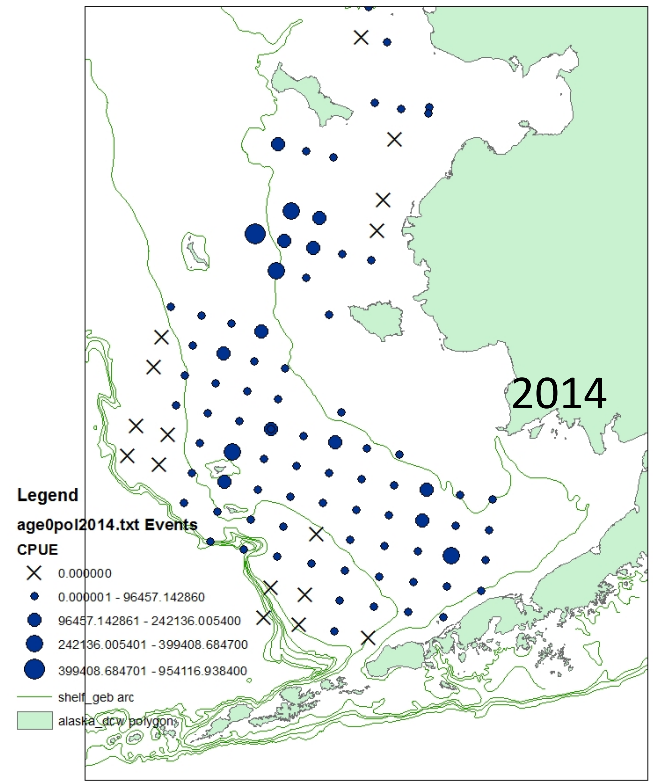
Age 0 Pollock Distribution

Warm | Warm
Cool | Cool
Cool | Cool



Hollowed et al. 2012

Warm



Preliminary- Source: Farley

How should we interpret the evidence?

- Fall conditions for YOY important for pollock and cod survival
  - Colder late summer and higher energy density is better (Heintz et al 2011 and Farley et al 2014)

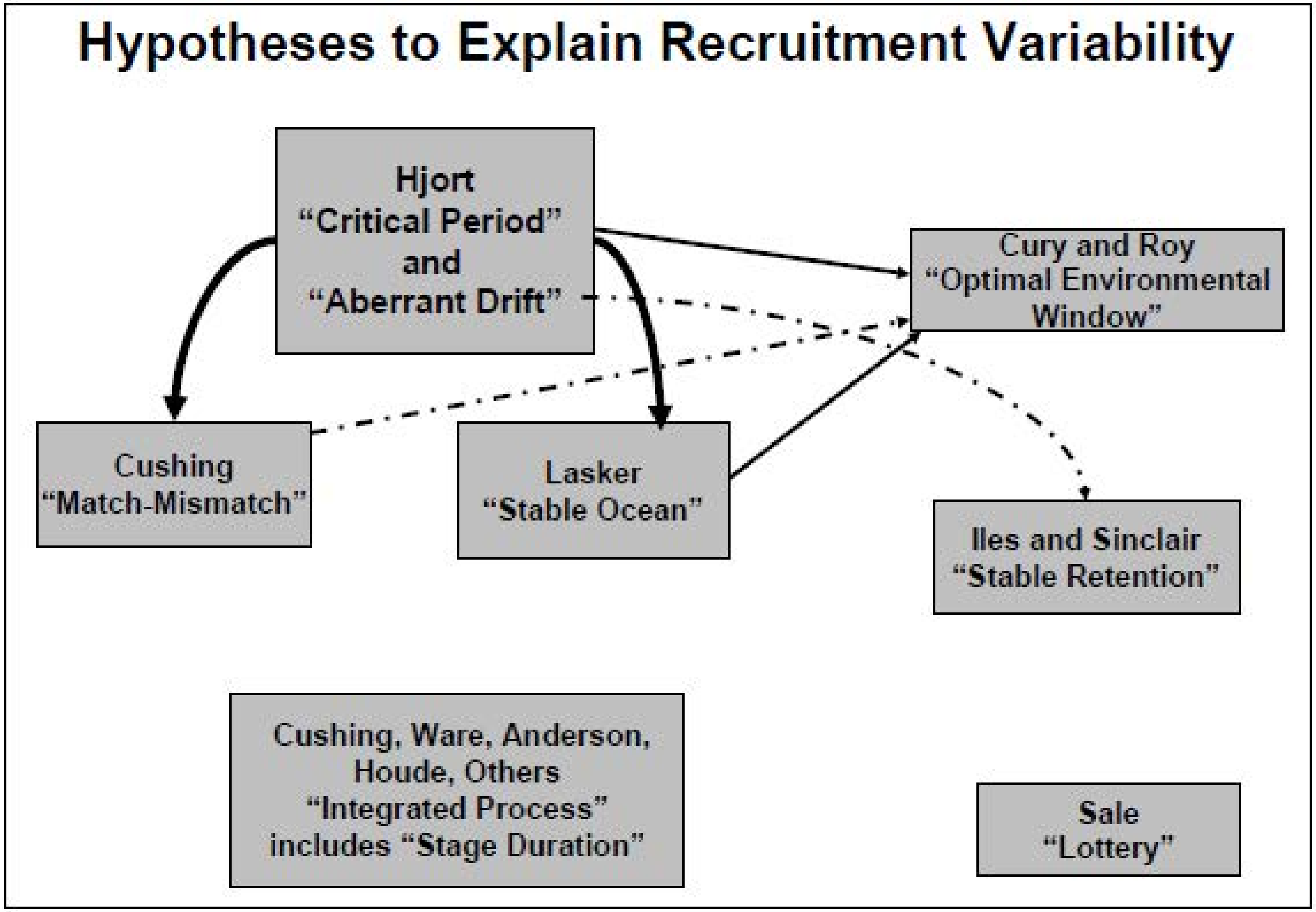
- Oct-Dec NPI in birth year correlated with Pacific cod recruitment (Thompson et al. 2013) (leads SST by 1-2 mos) – Is the type of winter or following spring that YOY/age 1 experience important?

- Spring temperature conditions may affect age 1 pollock survival (Yasumiishi 2014)

Recruitment Hypotheses

"Recruitment variability can result from numerous processes operating on different time and space scales and represents and integrated process acting throughout the pre-recruit life."

"The stage at which recruitment is fixed can vary from year to year."



From: Houde, E.D. 2008 Emerging from Hjort's Shadow. J. Northw. Atl. Fish. Sci., 41:53-70.

Conclusions for Scientists

- Environmental linkage to recruitment mechanism is important
- Multiple switches likely involved
  - Various combinations and strengths over time
- “Warm” versus “cold” relative
  - Optimal ranges useful
- Don’t ignore past studies and variables

Conclusions for Management

- Recruitment predictions are uncertain – management frameworks should be designed to be robust to this
- Funding of process oriented research is critical to improving recruitment prediction
  - Overwinter studies?
- Developing forecasting capability for environmental variables linked to recruitment is an important goal

Questions?