

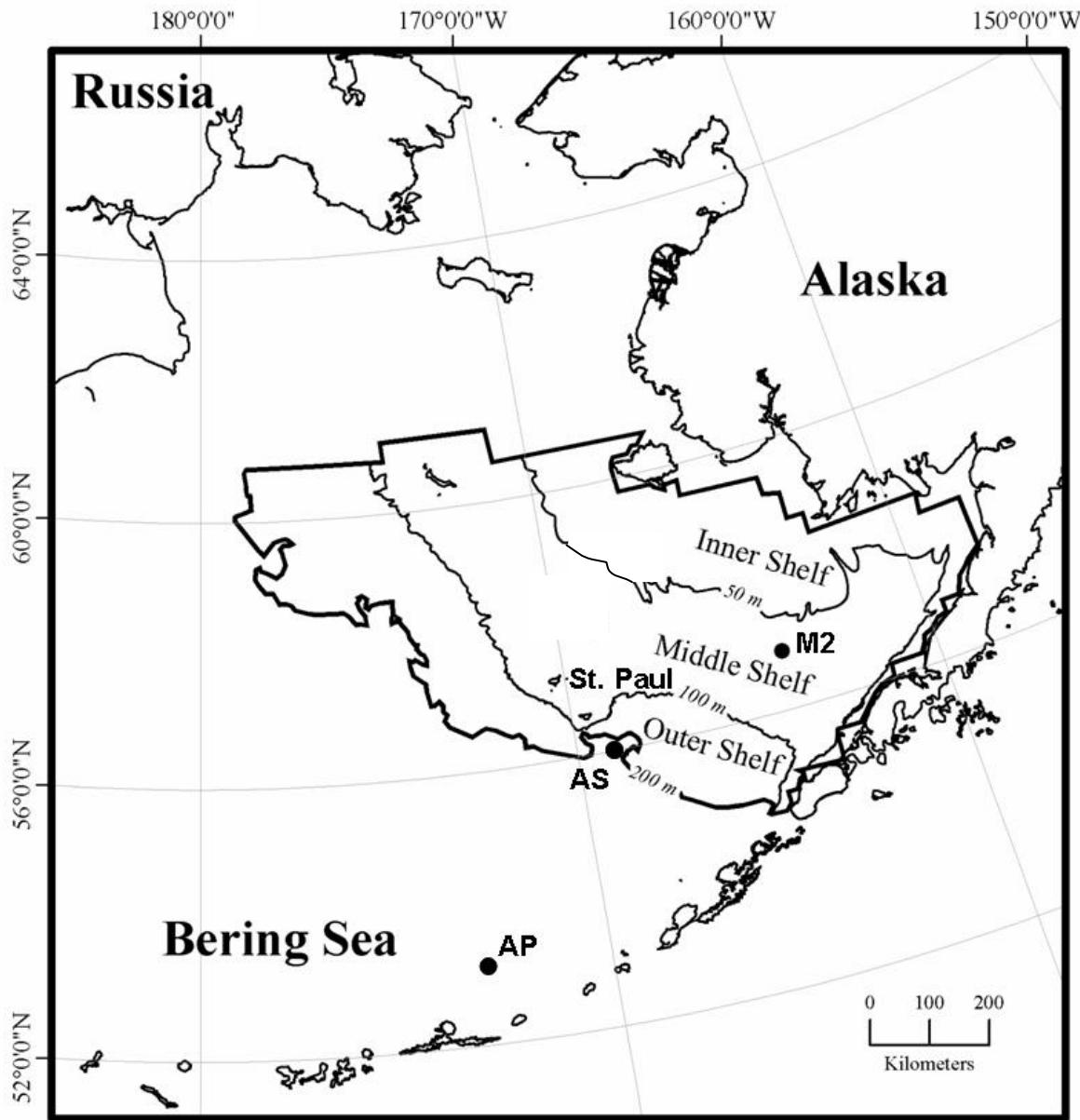
From physics to fish: Climate effects on Bering Sea food webs and fisheries

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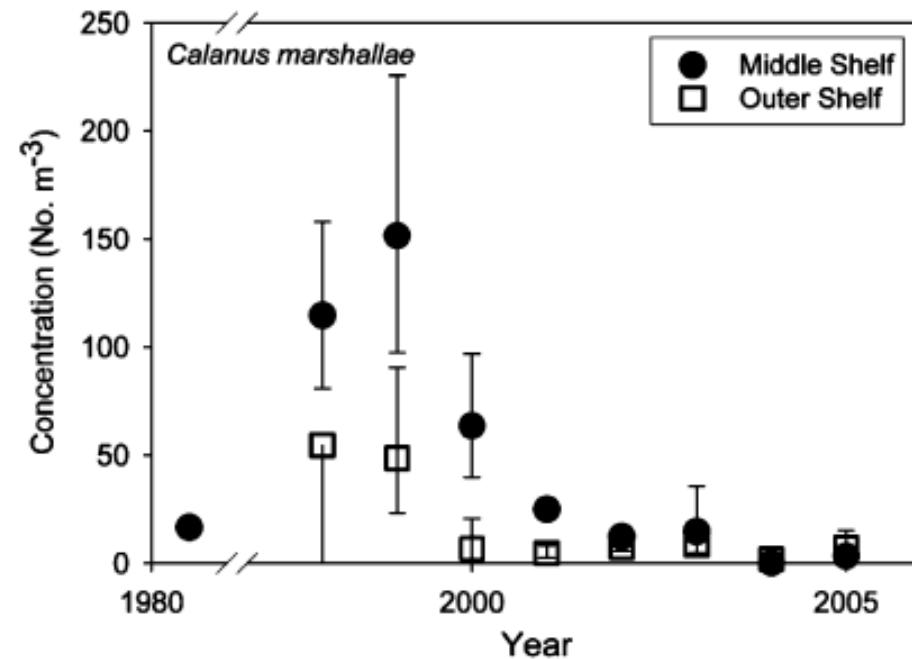
Study region



Motivation

- Very low abundances of large zooplankton (*Calanus marshallae*, euphausiids) on shelf in recent years.

Mean density of *Calanus marshallae*



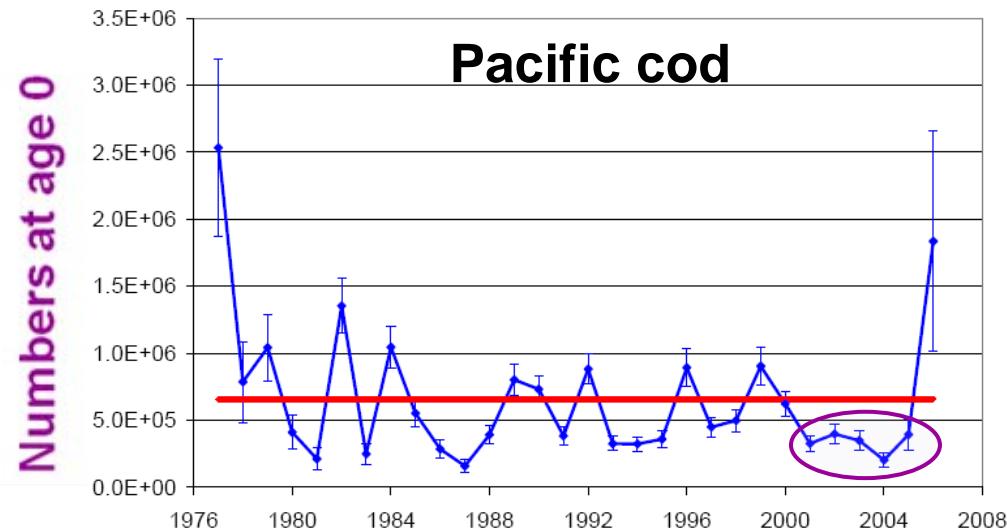
Source: Hunt et al. 2008.

Based on data from:

Jeff Napp, AFSC, NOAA

Motivation

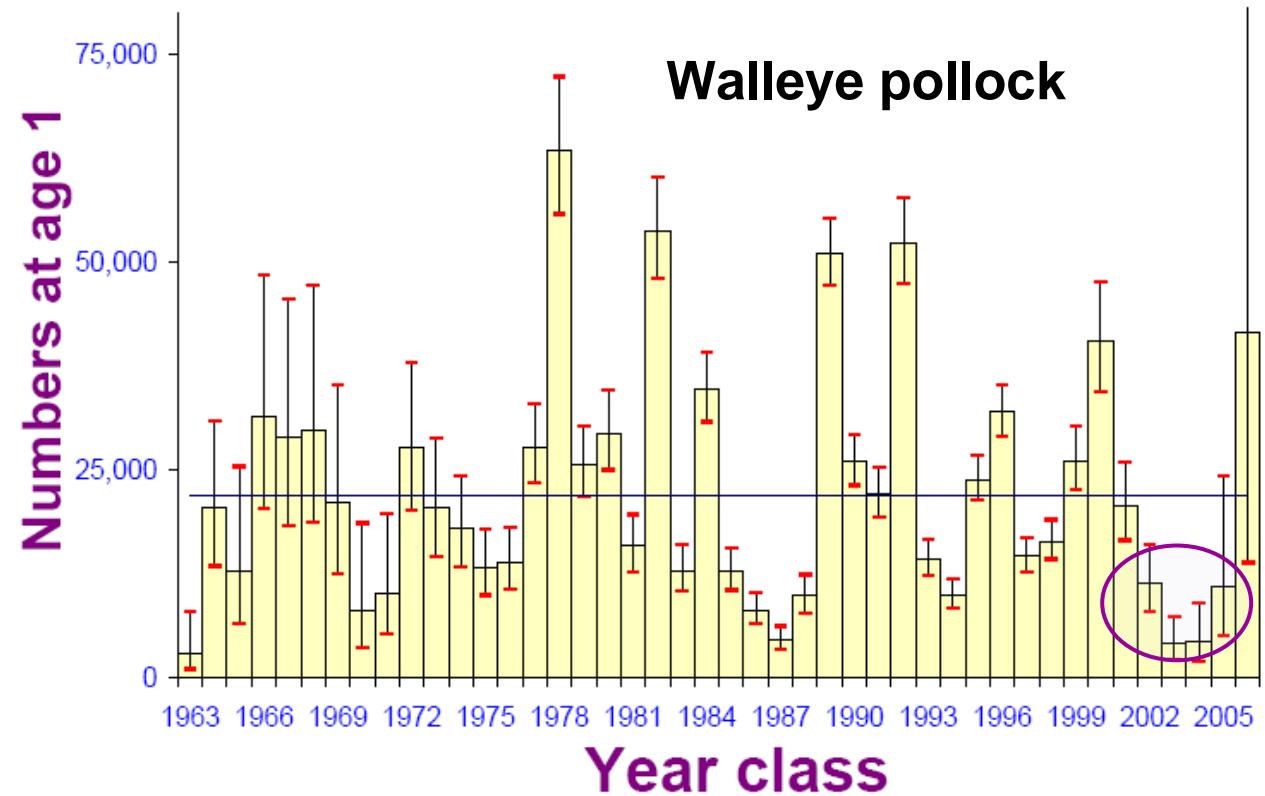
- Unusual series of poor recruitments in Pacific cod and walleye pollock



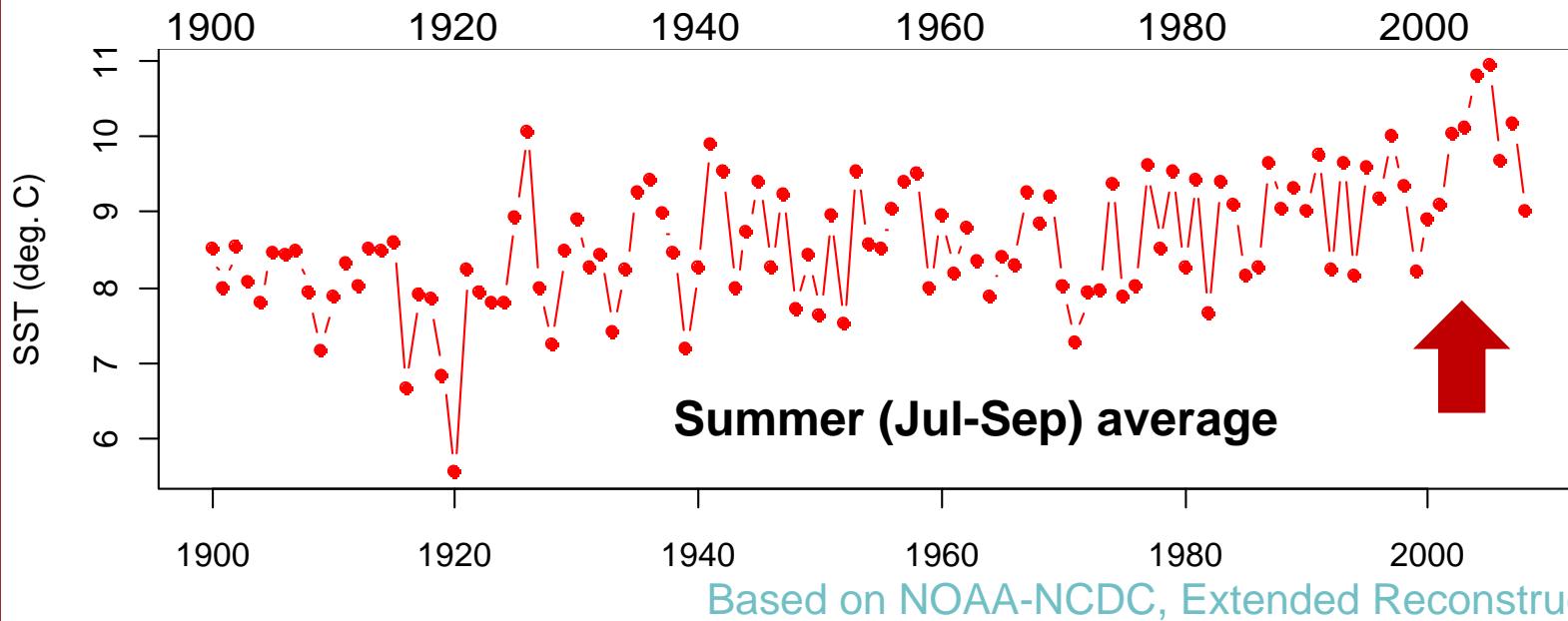
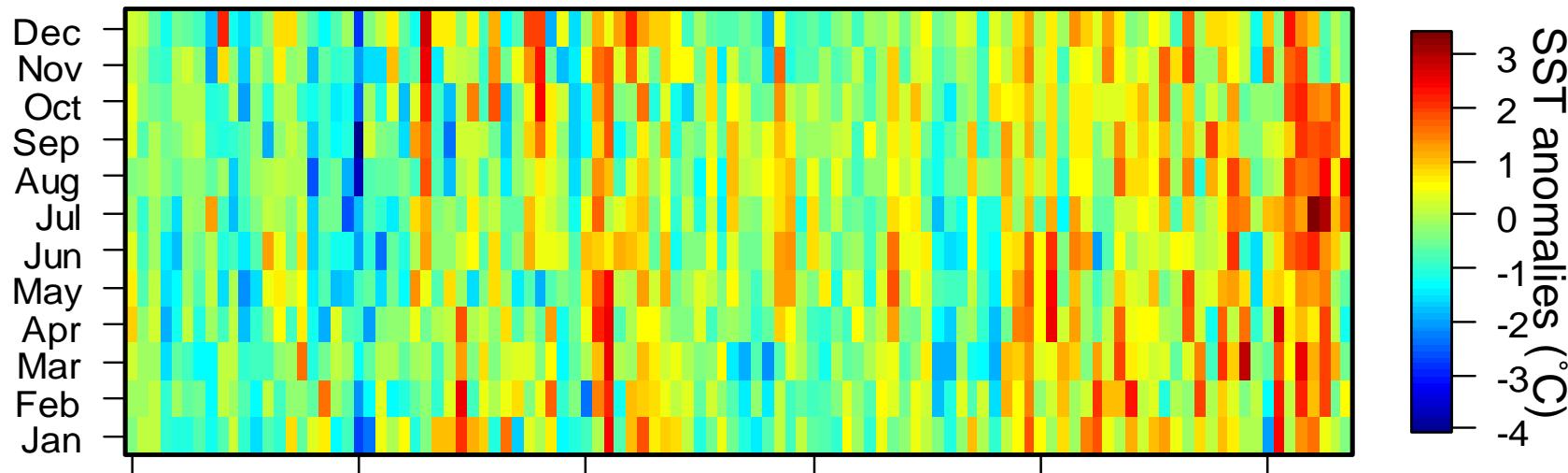
Sources

Pacific cod:
Thompson et al.
2007

Walleye pollock:
Ianelli et al 2007



Eastern Bering Sea SST anomalies and summer SST trend



Hypothesis

Strong, thermally induced stratification on the middle shelf during warm years (e.g. 2004)

- reduced mixing of nutrients into surface waters
- lower summer production
- warm, nutrient-poor conditions resulted in a shift from large zooplankton species to small, warm water species of zooplankton
- poor feeding conditions for larval & juvenile fishes
 - poor year classes

Has stratification increased beyond the
optimal stability window (Gargett 1997)?

Approach

- Compare oceanographic conditions and species responses at various trophic levels on the middle shelf of the EBS between a cold (**1999**) and a warm (**2004**) year
- Examine longer-term trends and relationship to provide context and test elements of the hypothesis

Why 1999 / 2004?

- Good contrast in oceanographic conditions
- Data availability



Ice conditions / cold pool

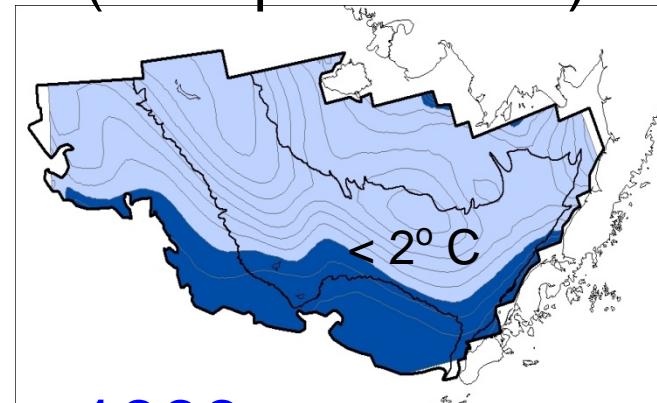
1999

- Extensive ice
- Late ice retreat (M2)
(~ May 5)

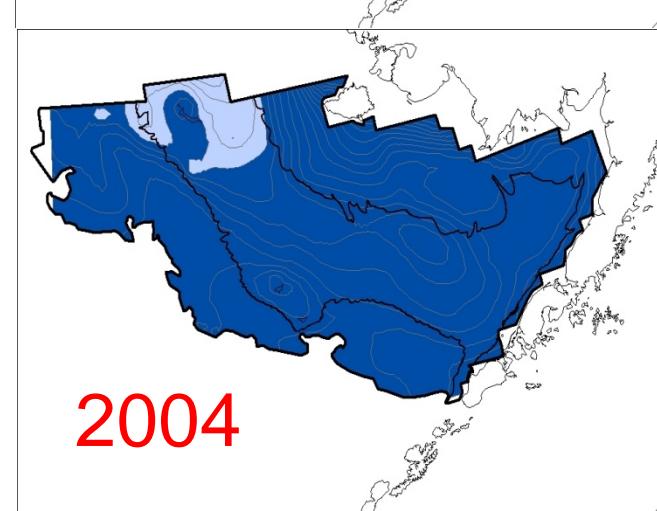
2004

- Little ice
- Early retreat
(~ April 7)

Summer bottom temp.
(Cold pool extent)

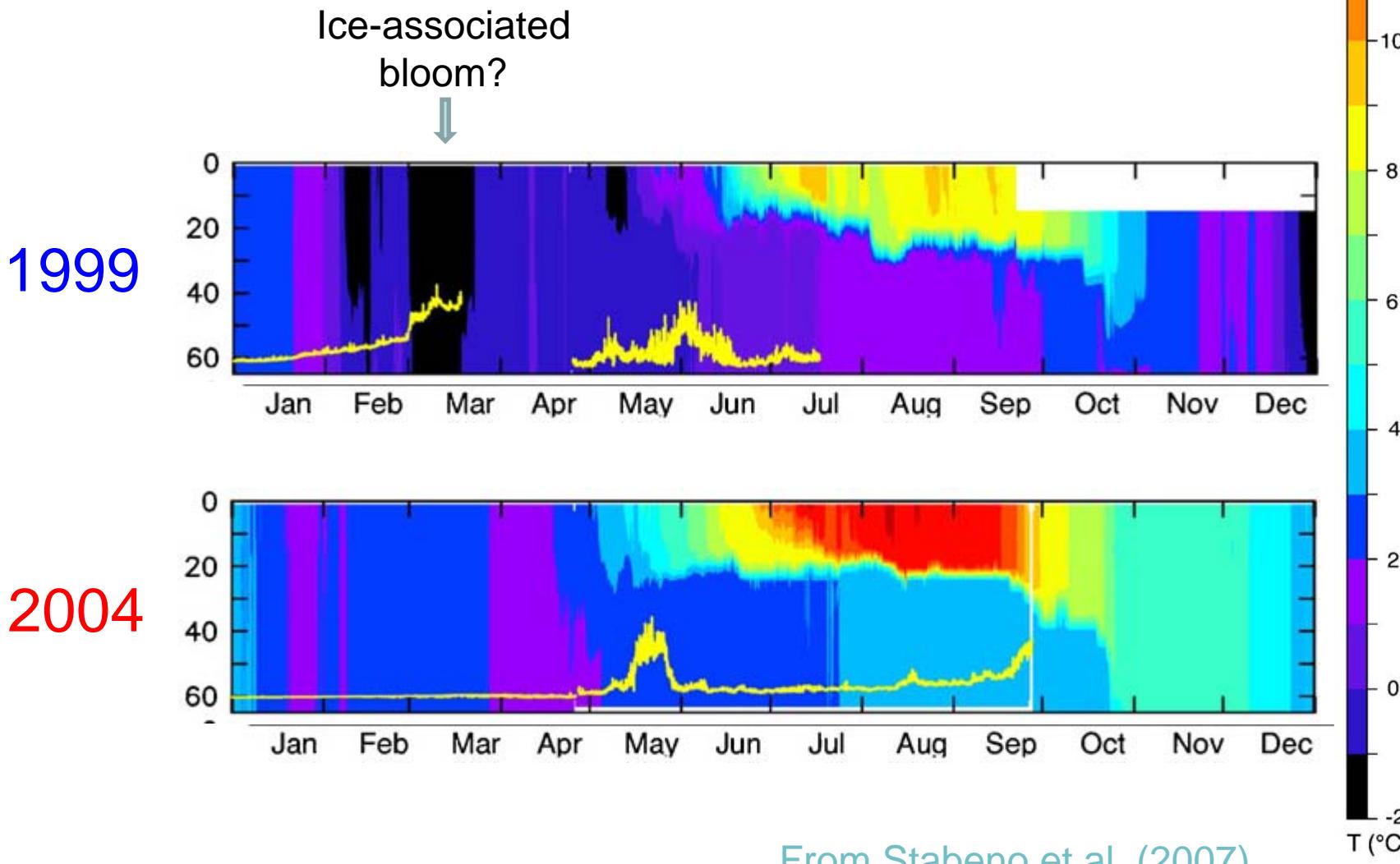


1999



2004

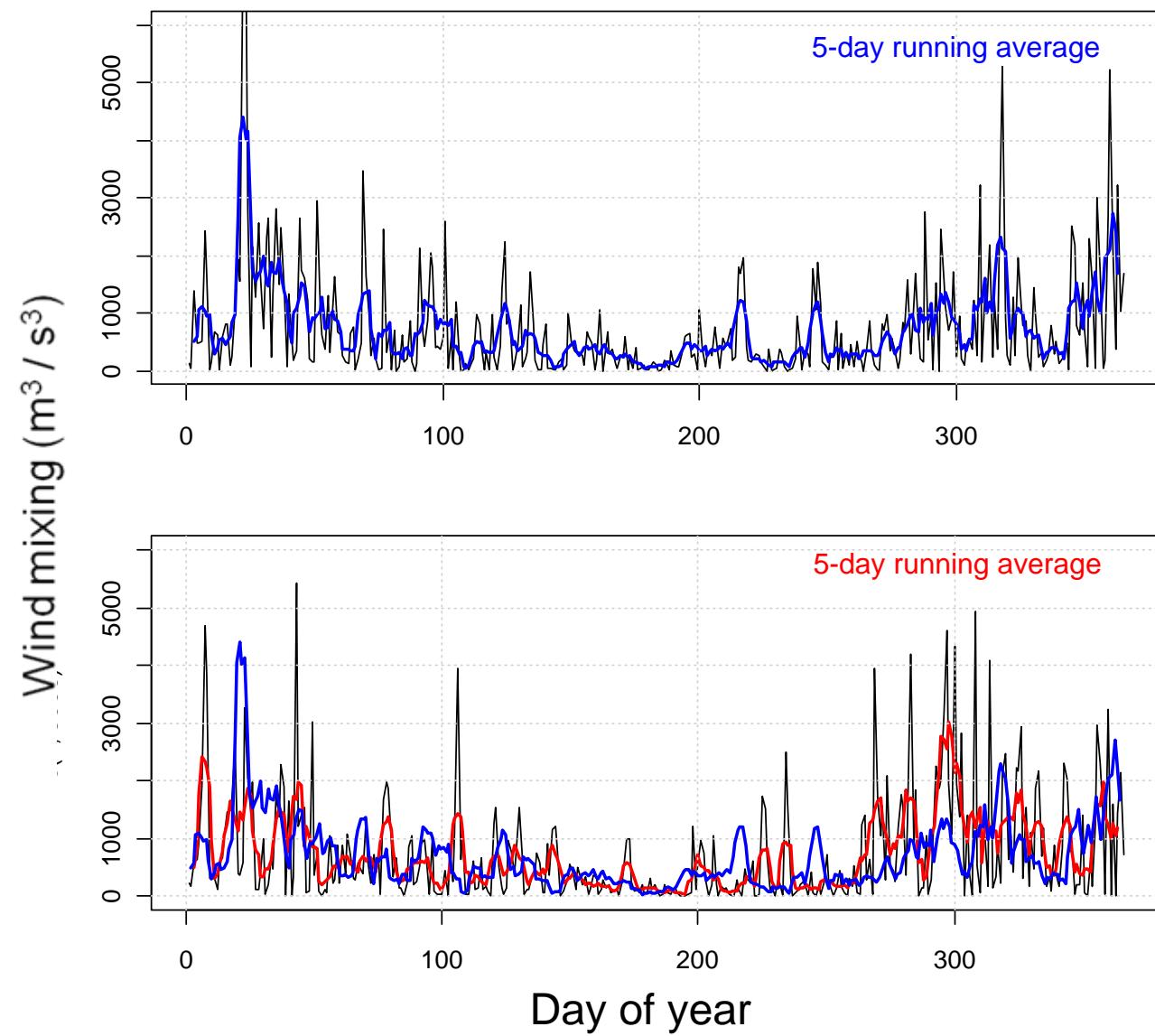
Temperature profiles on middle shelf (Mooring 2)



1999

2004

Daily winds based on
NCEP/NCAR reanalysis
NOAA Climate Data Center



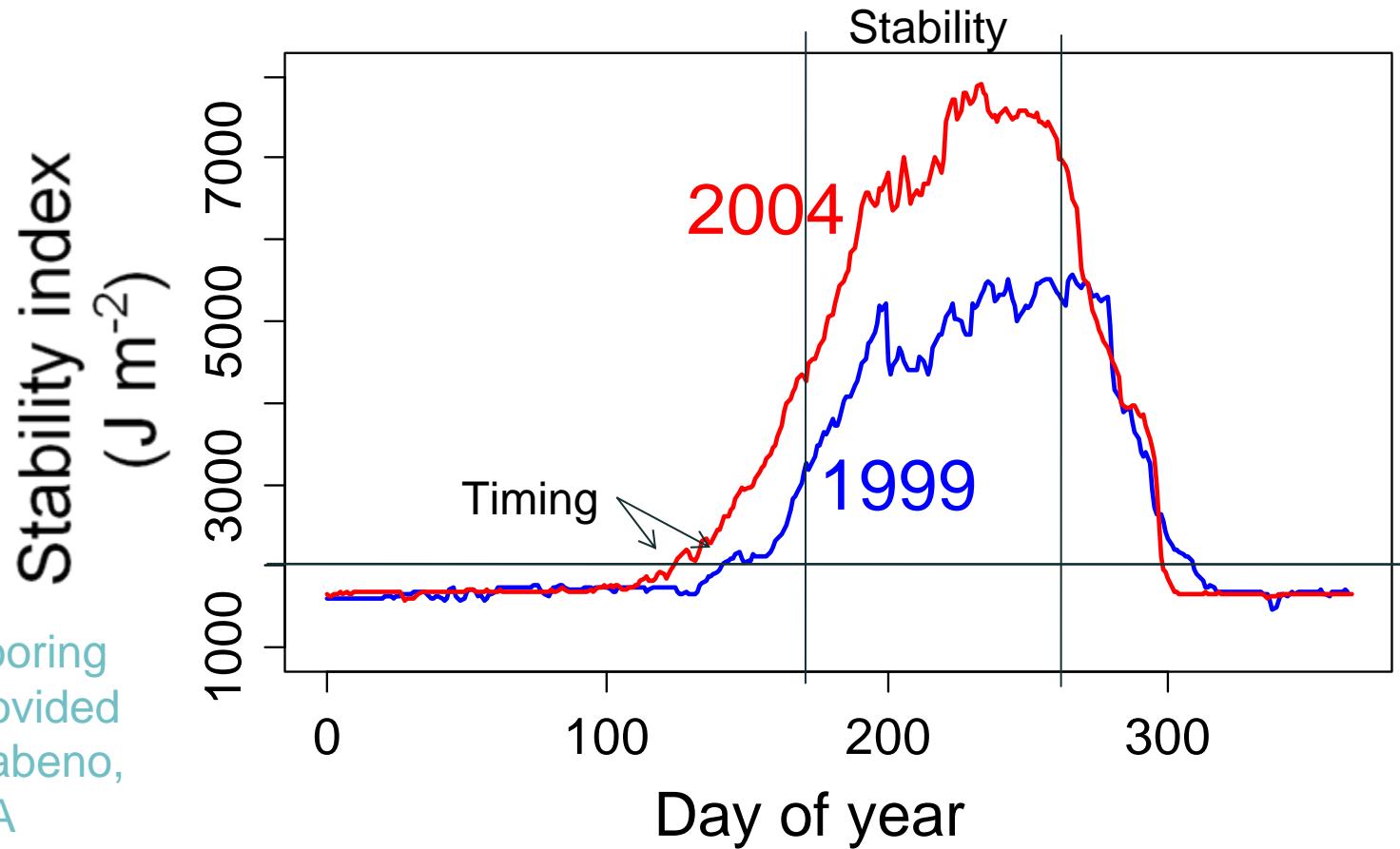
Hypothesis (part 1):

- Stratification stronger in 2004
- Stratification generally stronger in warm years

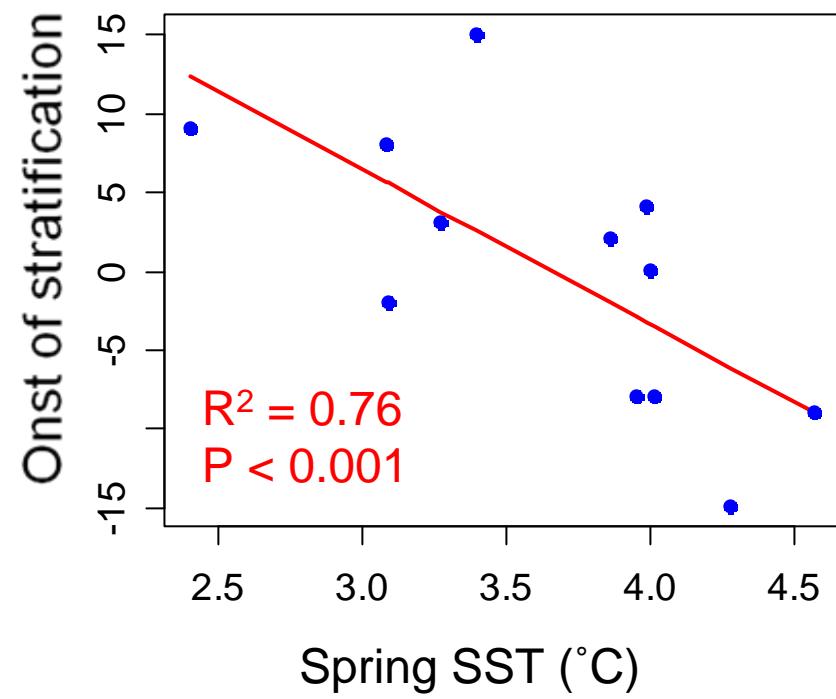
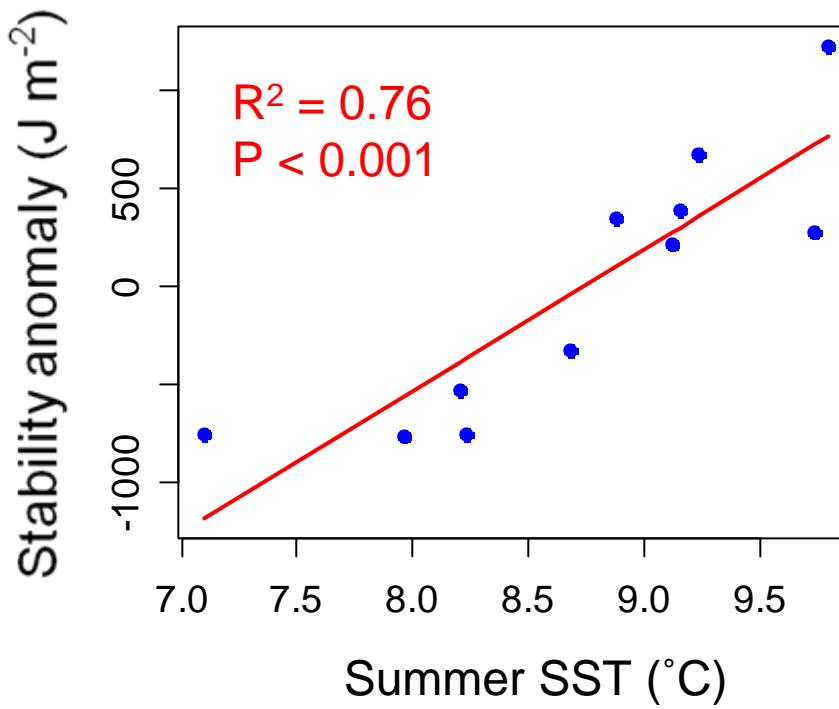


Daily index of water column stability

- Index (location M2) based on Simpson et al. (1977): Reflects energy required for mixing
- Stronger & earlier stratification in 2004



Interannual variability in strength and timing of stratification



Hypothesis (part 2):

- Stronger stratification reduces mixing of nutrients into surface layer



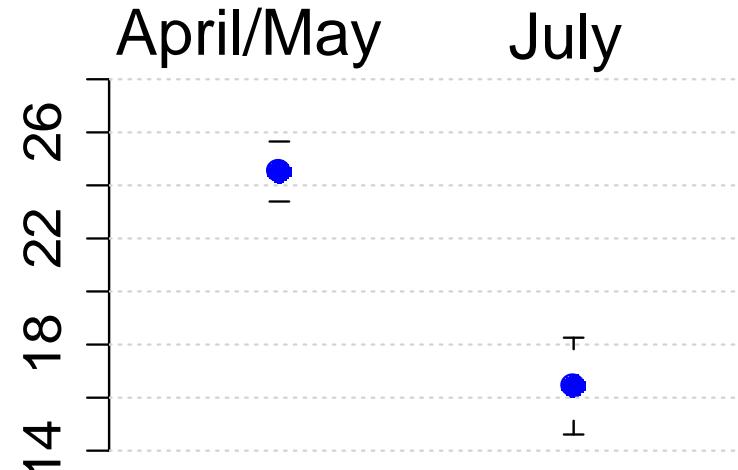


Estimated nitrate concentrations below 70 m (middle & outer shelf)

1999

2004

Mean nitrate concentration (μM)

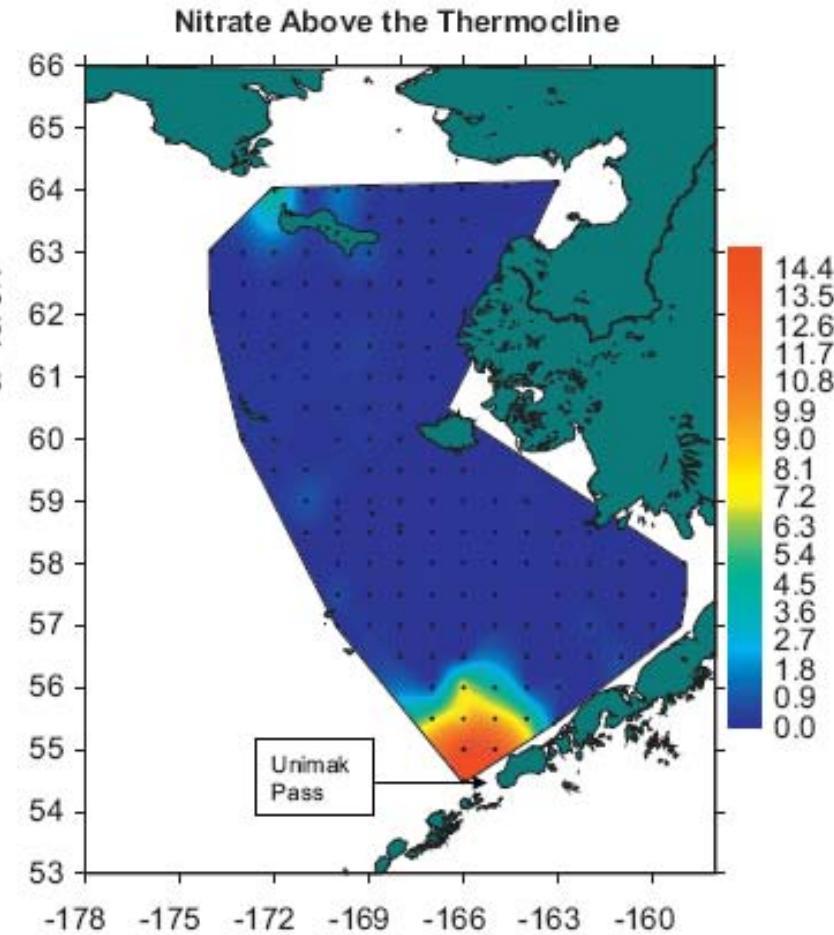
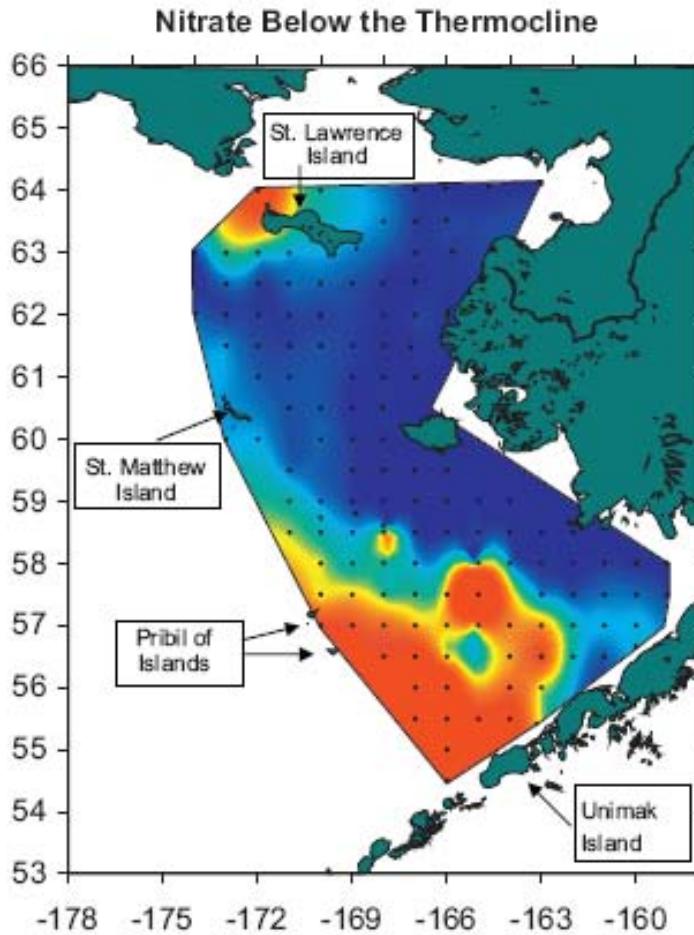


Data sources:

Terry Whittlesey, UAF

Calvin Mordy, PMEL, NOAA

Nitrate above and below the thermocline in Aug/Sep 2004



From Coyle et al (2008); data from BASIS



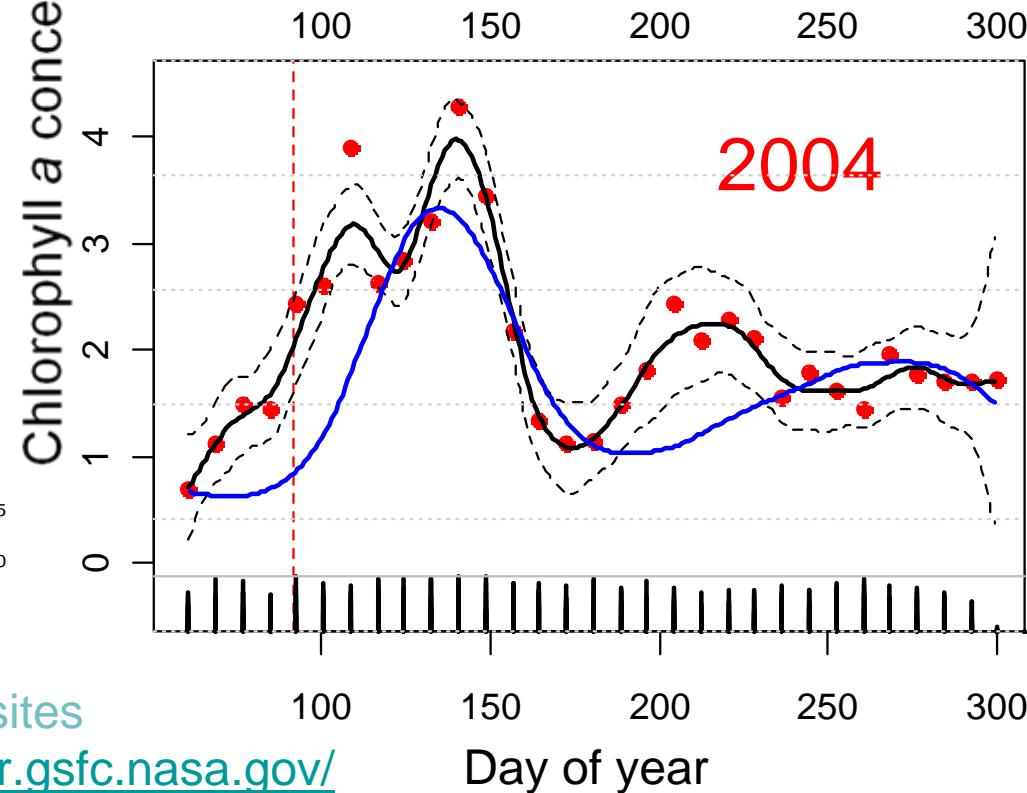
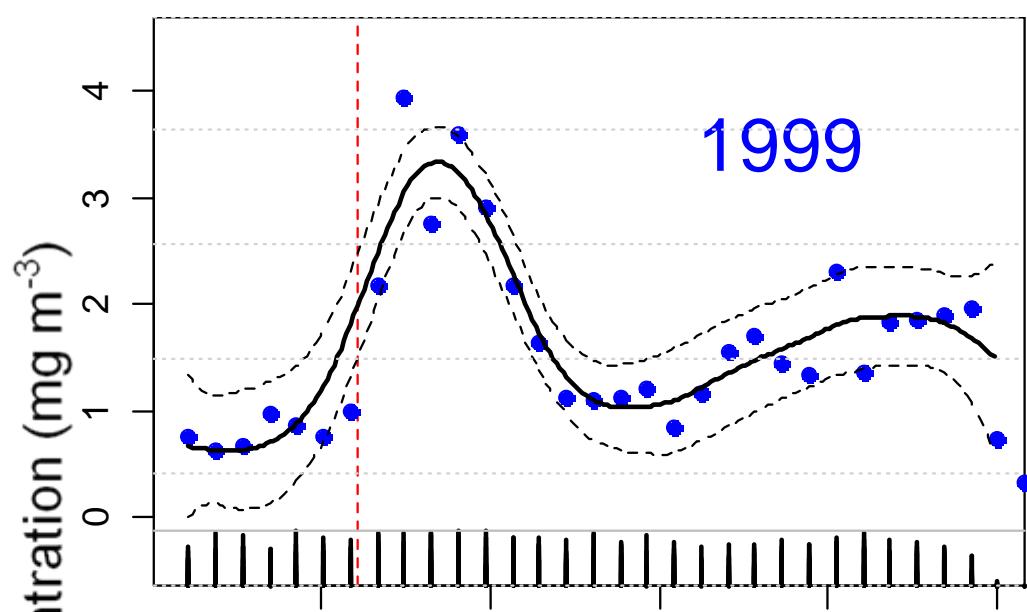
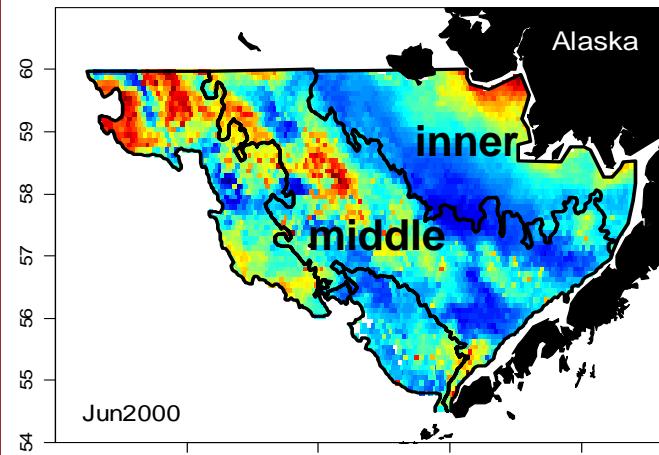
Hypothesis (part 3):

- Summer production lower in 2004
- Summer production generally lower in warmer years





Seasonal trends in surface Chl. a (middle shelf)



Based on 8-day SeaWiFS composites

Data from NASA: <http://oceancolor.gsfc.nasa.gov/>

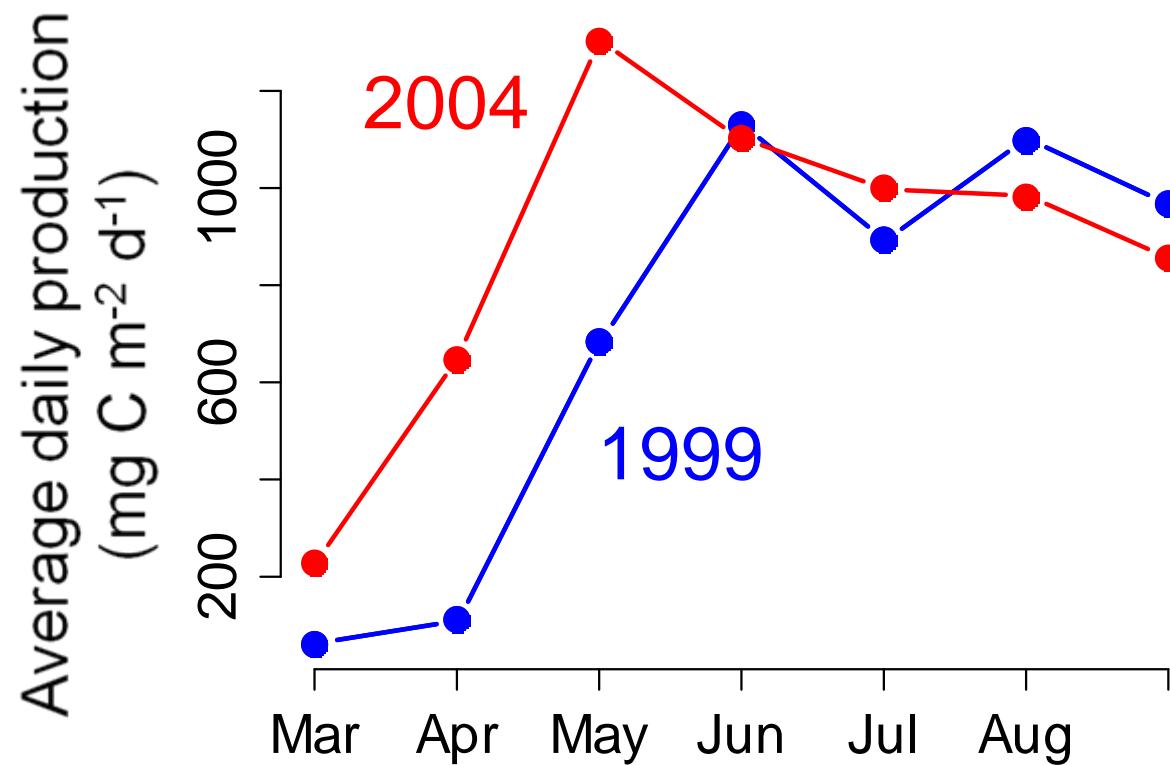
Day of year

Estimated net primary production by month (Mar-Sep)

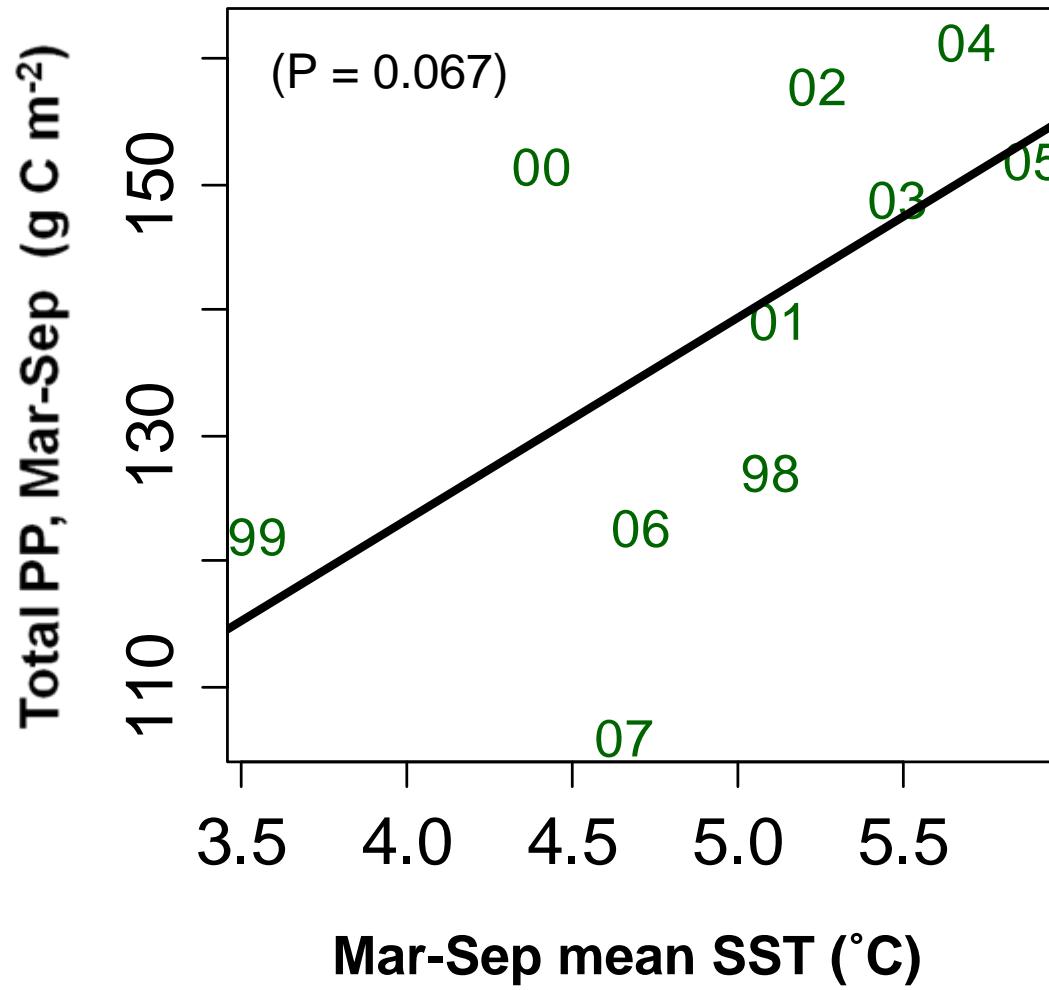
From Carbon-based
production model
(CbPM)
Behrenfeld et al (2005)

Available at:

<http://web.science.oregonstate.edu/ocean.productivity/>



Spring/summer net primary production (CbPM) and SST



Hypothesis (part 4):

- Low abundances/biomass of large zooplankton in 2004





Zooplankton

1999

- Average year for abundance of large zooplankton: *Calanus marshallae*, *Thysanoessa* spp., *Sagitta elegans*
- Few small zooplankton

2004

- Almost complete absence of large zooplankton
- High abundance of small zooplankton
- High abundance of hydromedusae

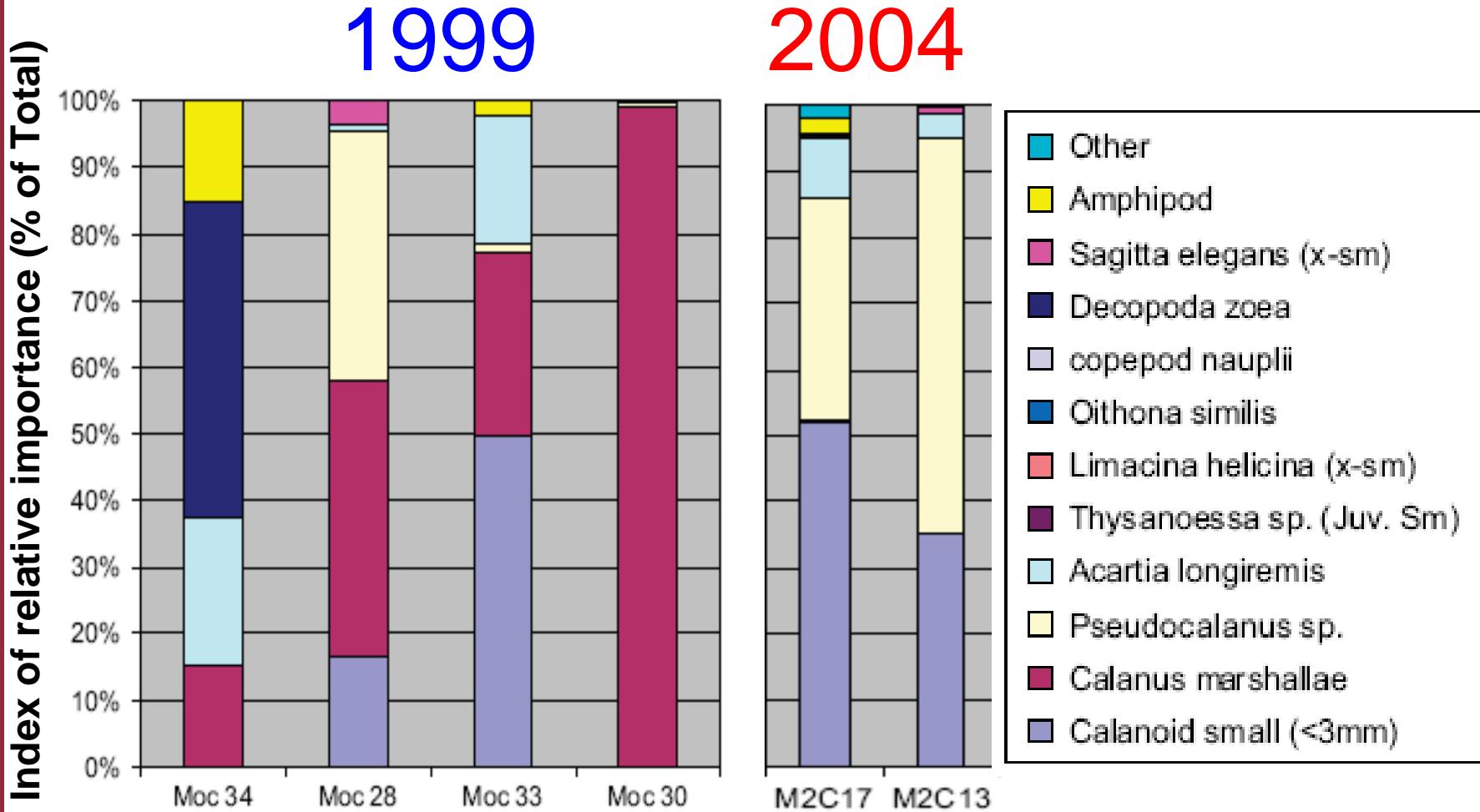
Hypothesis (part 5)

- Shift in zooplankton community affects diet and condition of pollock



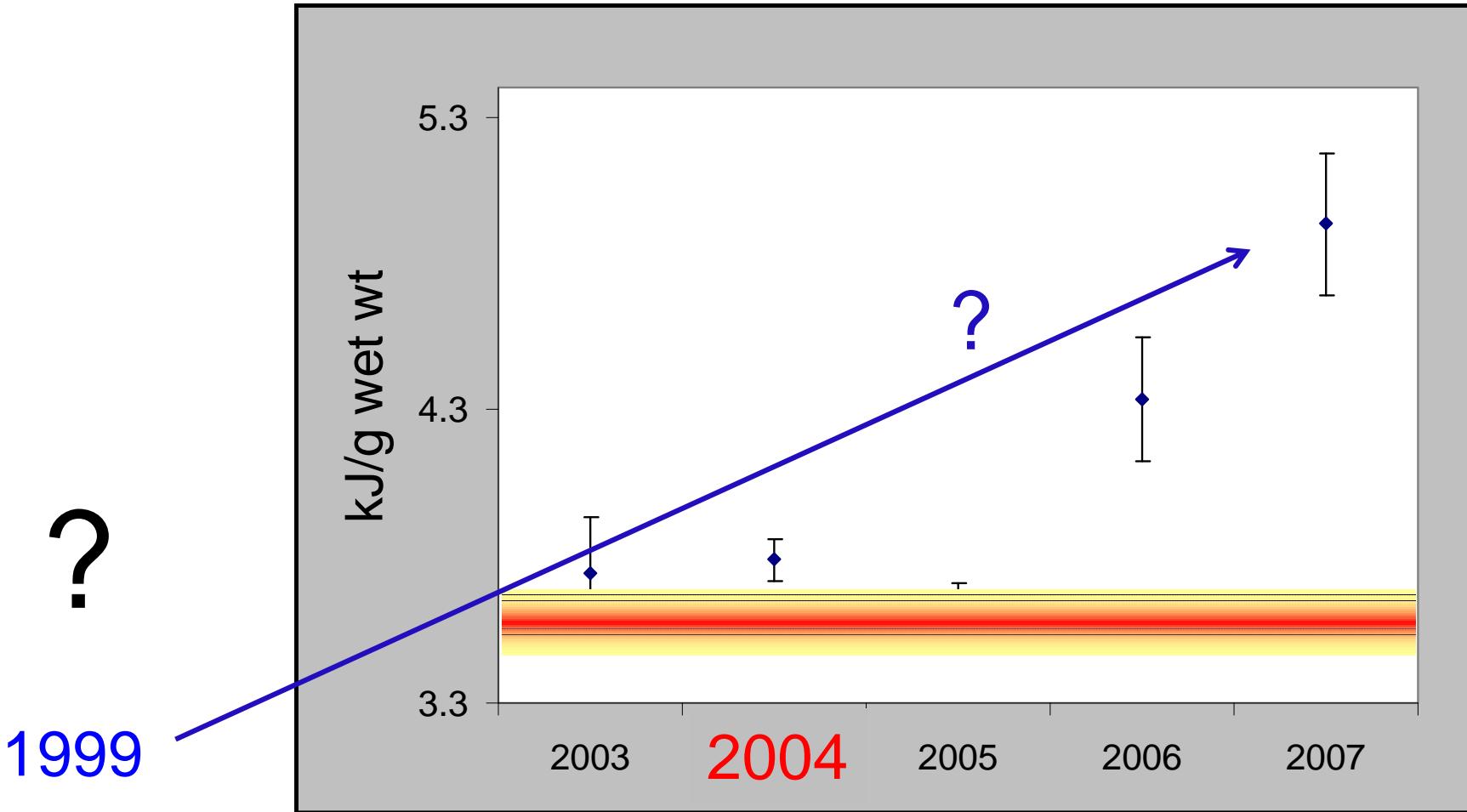


Diet of age-0 walleye pollock (Middle shelf, Eastern Bering Sea)



From Coyle et al. (2008)

Condition of age-0 walleye pollock (energy density in September)



Courtesy of Ron Heintz, TSMRI, AFSC, NOAA



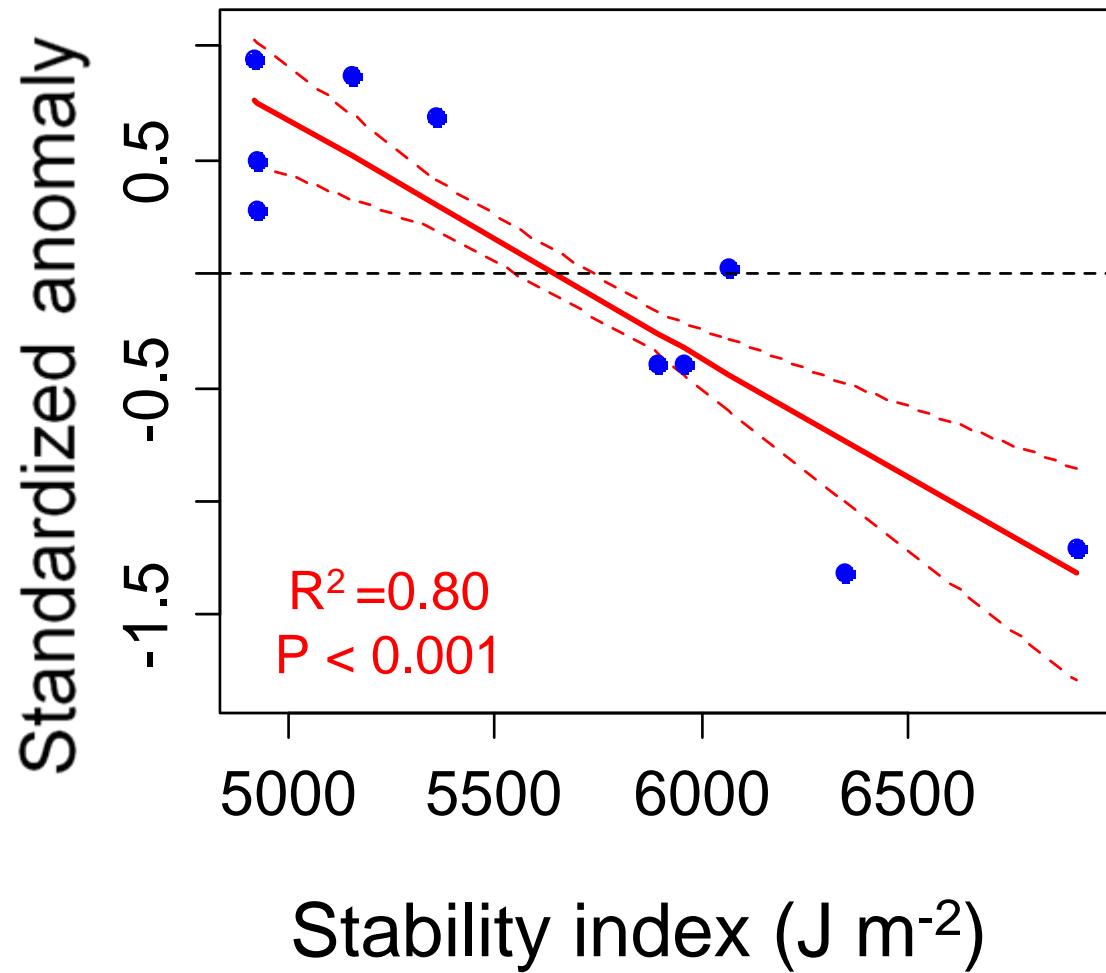


Hypothesis (part 6)

- Feeding conditions affect the survival of pollock
 - Age-0 pollock in 2004 had low energy reserves, suggesting low winter survival
 - Estimated survival rate (stock assessment model) much lower for 2004 year class than for 1999 year class
 - Survival rates from 1998-2006 decreased strongly with stability (stability may reflect feeding conditions?)

Pollock survival anomaly and stability (M2)

- High stability associated with low pollock survival

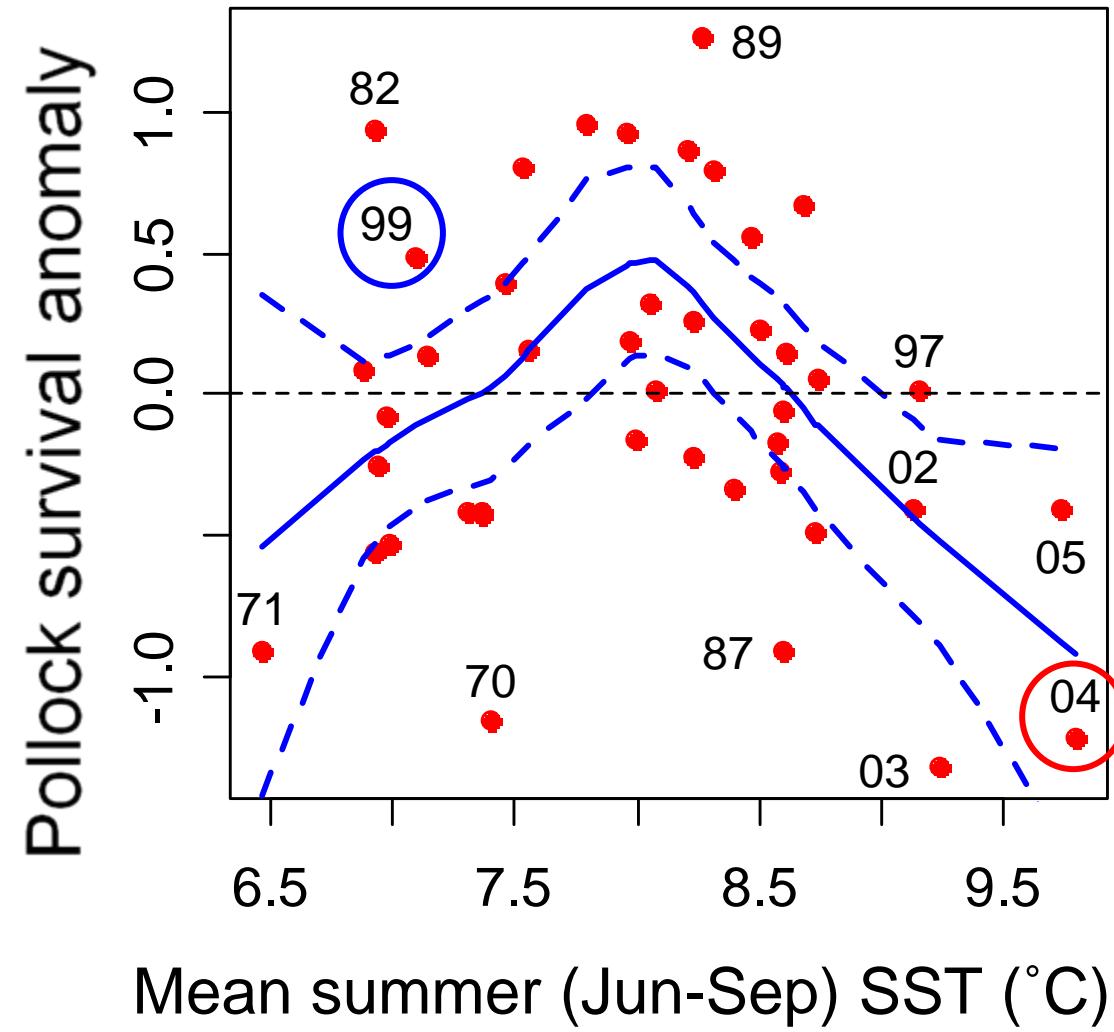


Optimum stability window?

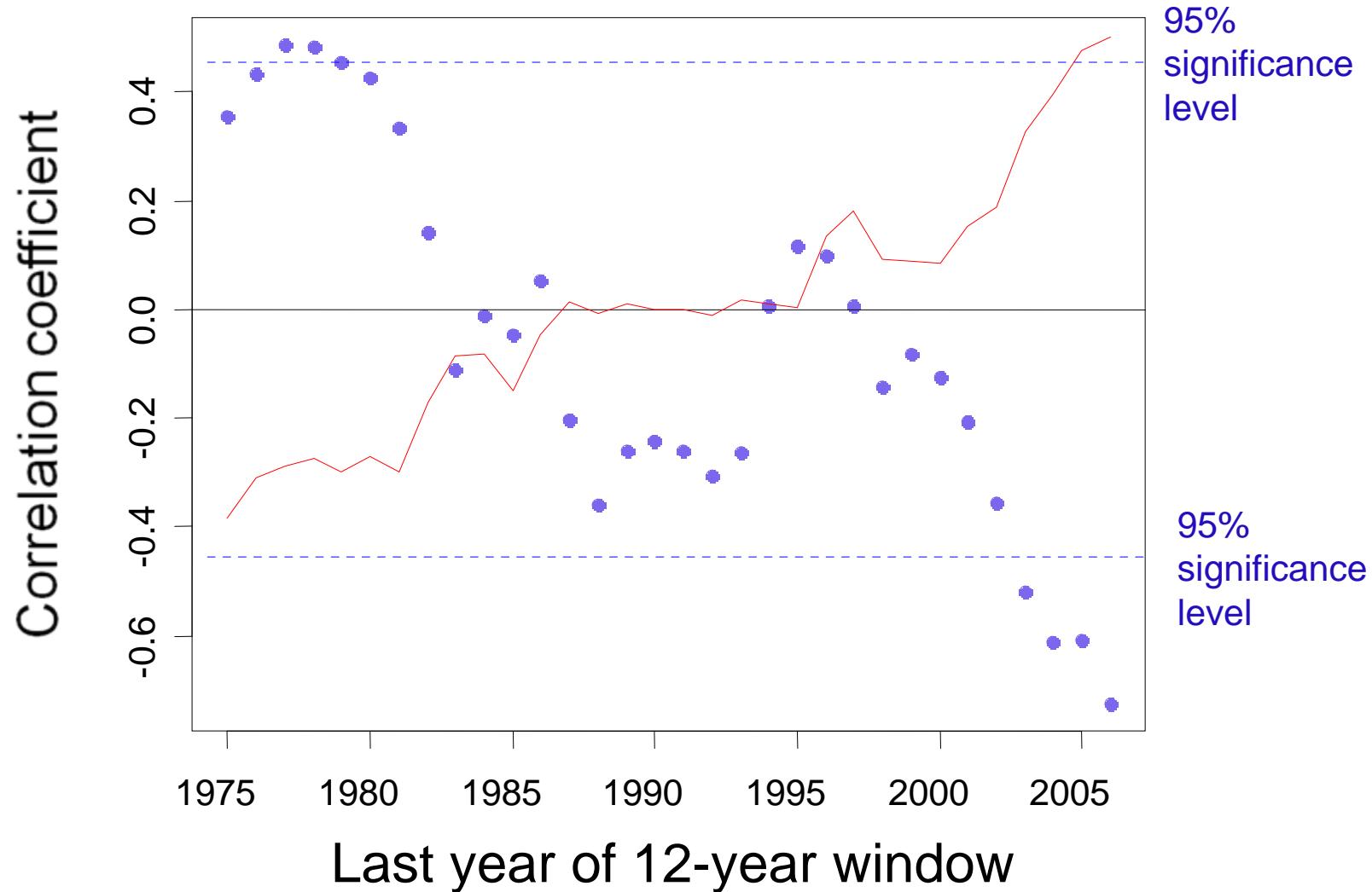
- Assumes dome-shaped relationship between stability and, for example, survival of pollock!
- Use SST as proxy for stability?

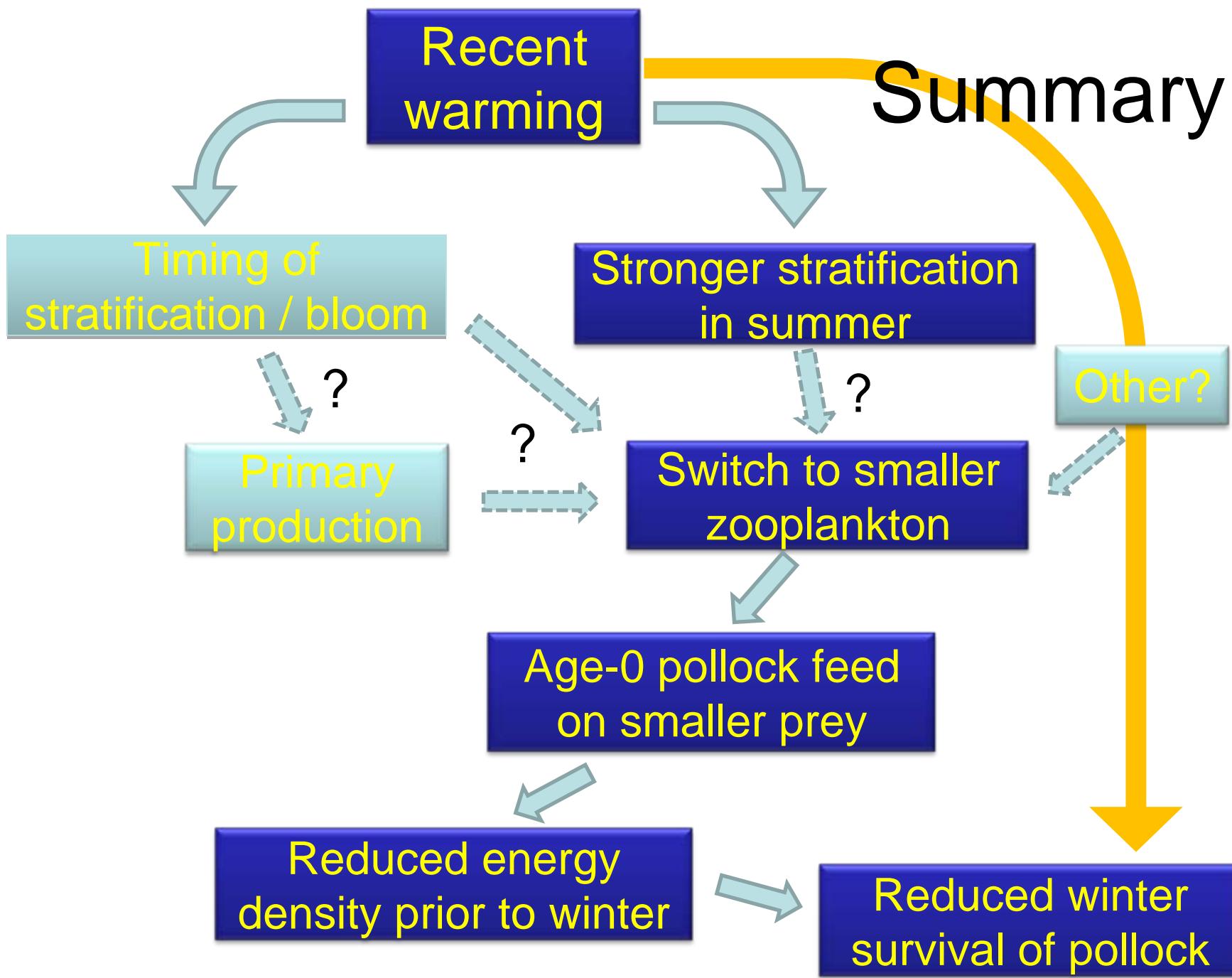
Pollock survival anomaly and SST

- Highest pollock survival at intermediate summer SST
- Generally low survival $> 9^{\circ}\text{C}$



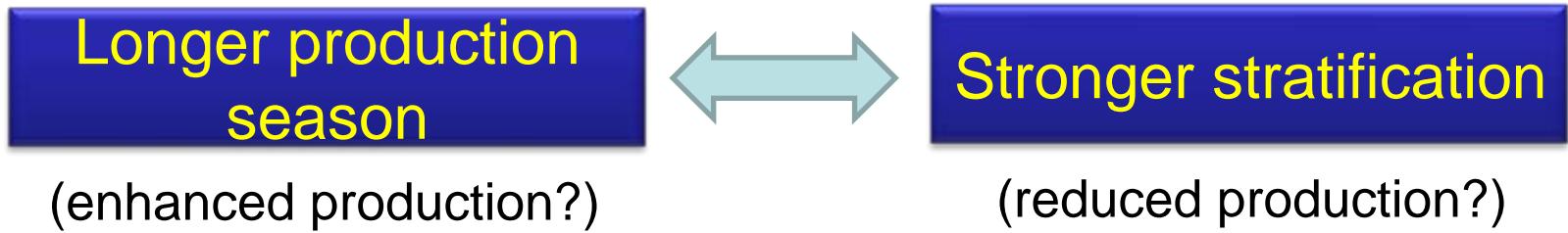
Changing correlations over time (pollock survival vs. SST)





Uncertainties

- Response of net primary production to warming



- Role of timing of bloom on phytoplankton and zooplankton species composition

Match / mismatch?

Conclusions

- We have “seen the future” (2001-05) and walleye pollock in the eastern Bering Sea may decline under continued warming
 - More warm periods similar to 2001-05 are likely.
 - Similar responses can be expected.
- There are likely to be winners IF primary production remains stable or increases, but we don’t know who
- Forecasting effects of warming
 - Current models do not capture stratification / timing of bloom very well, hence are unlikely to capture switches in species/size composition or changes at higher TL
 - Simple relationships between recruitment of important species and, for example, SST, combined with plausible mechanisms, remain important to identify likely responses of fish to warming

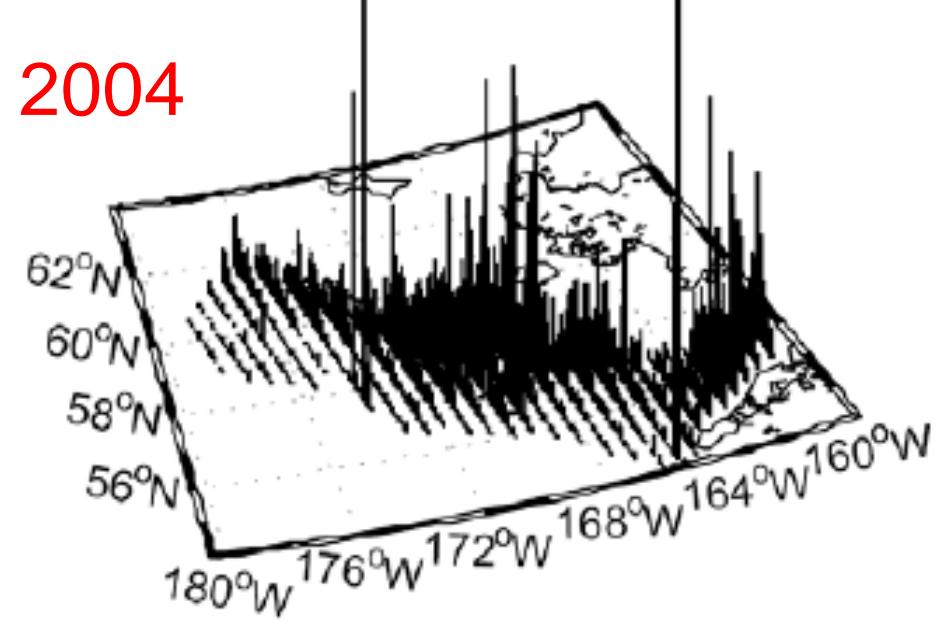
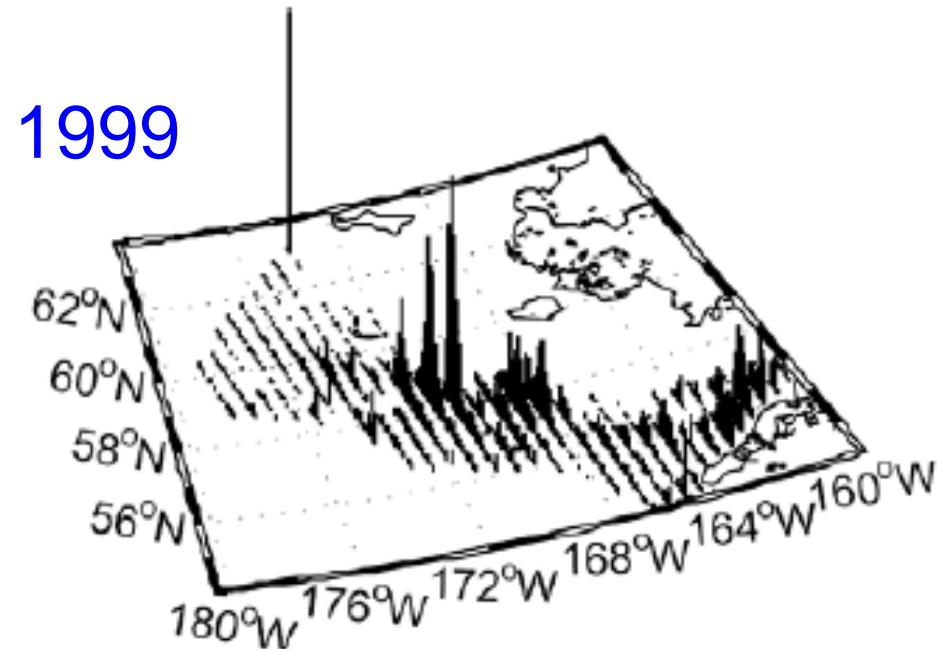




<http://bsierp.nprb.org>

BEST-BSIERP Ecosystem
Partnership

“Other” backscatter (non-pollock, non-euphausiid)

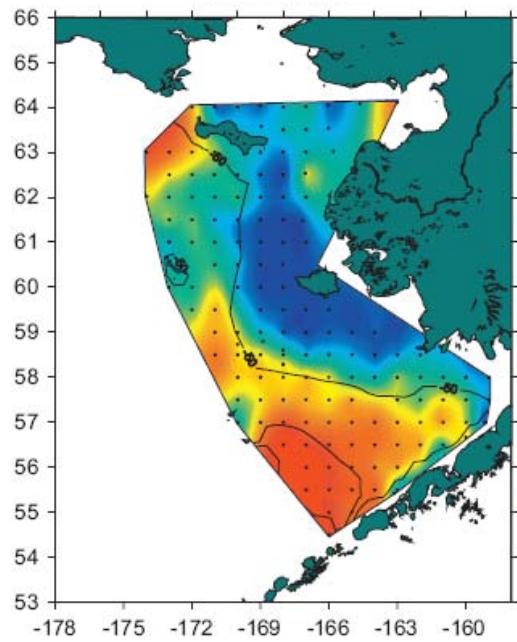


Ianelli et al (2007), Patrick Ressler (AFSC, Seattle, pers. comm.)

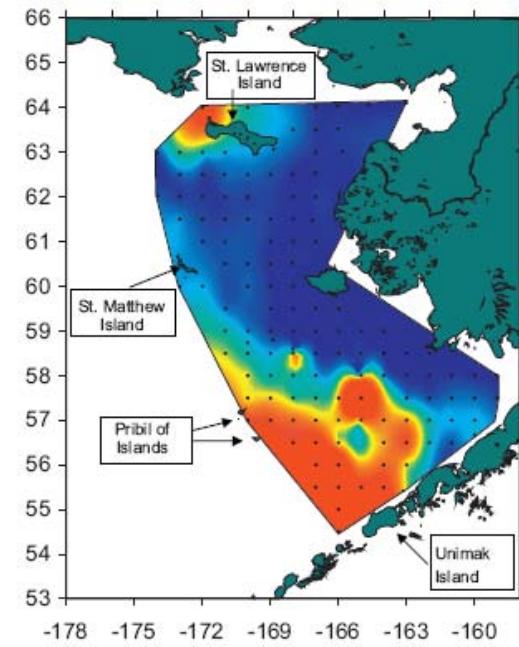


Spatial patterns in stability, nitrate & *Calanus marshallae* (Aug/Sep 2004)

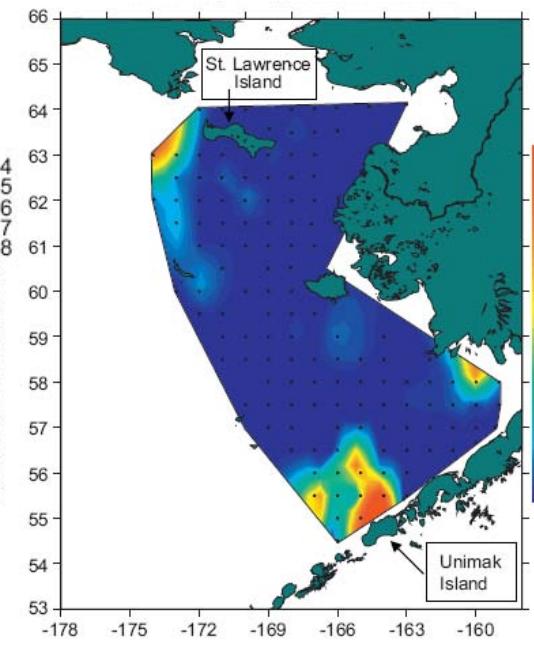
Stability parameter



Nitrate below thermocline

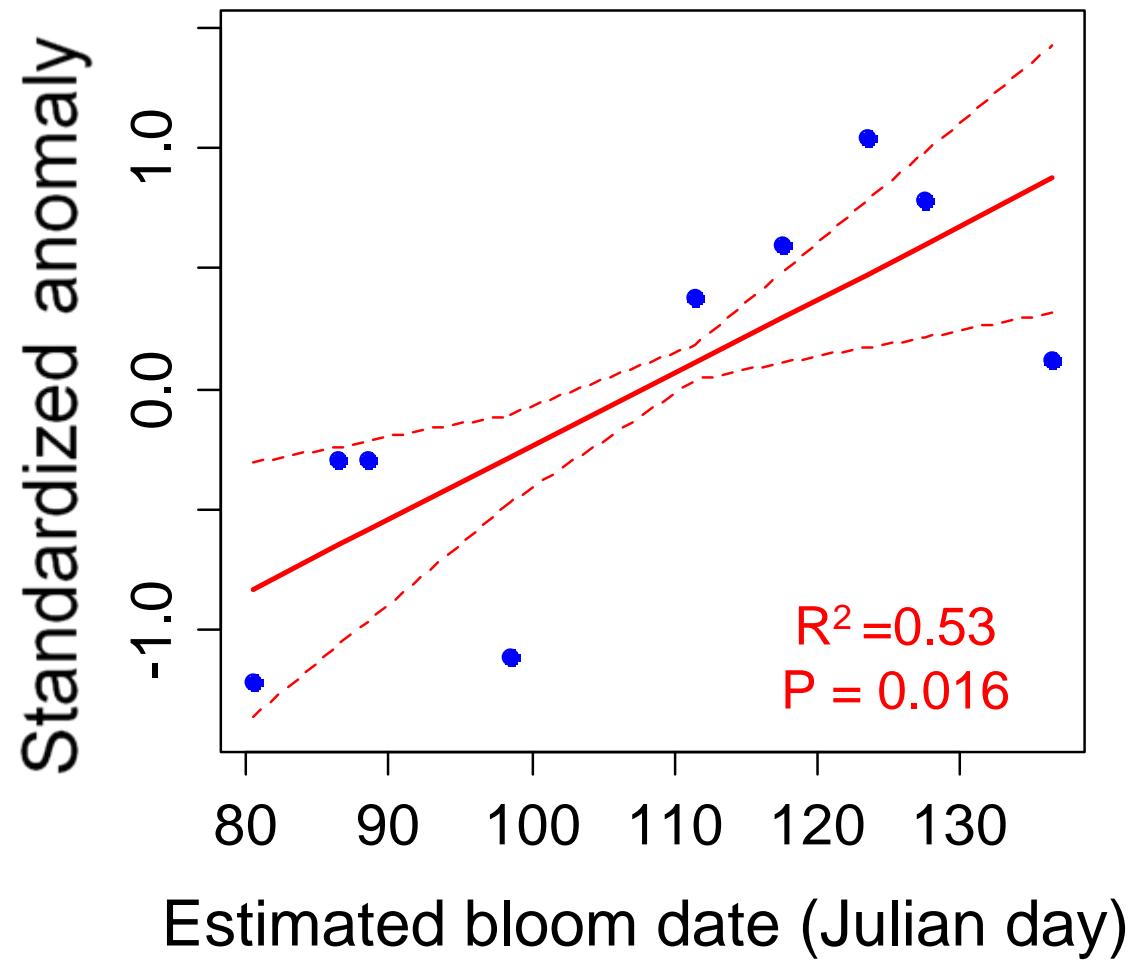


Abundance (no m⁻³) of *Calanus marshallae*

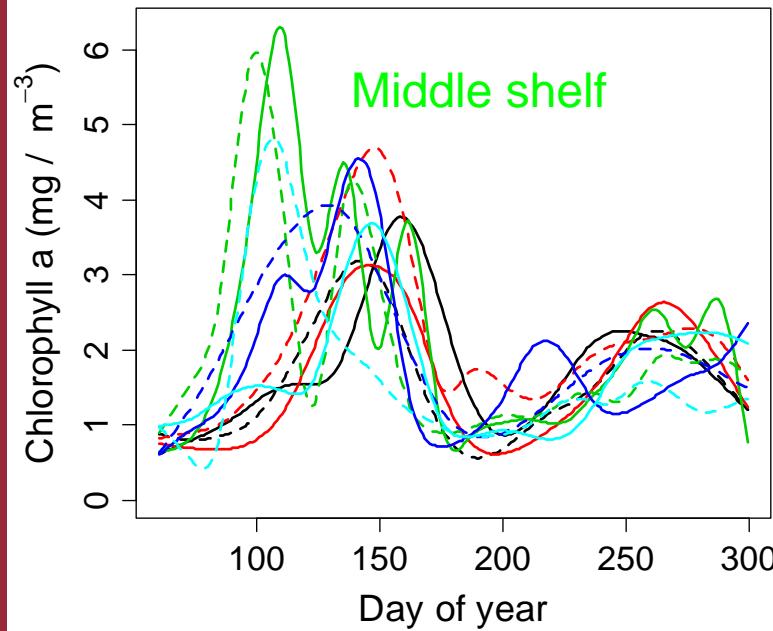


Pollock survival anomaly and bloom timing (middle shelf)

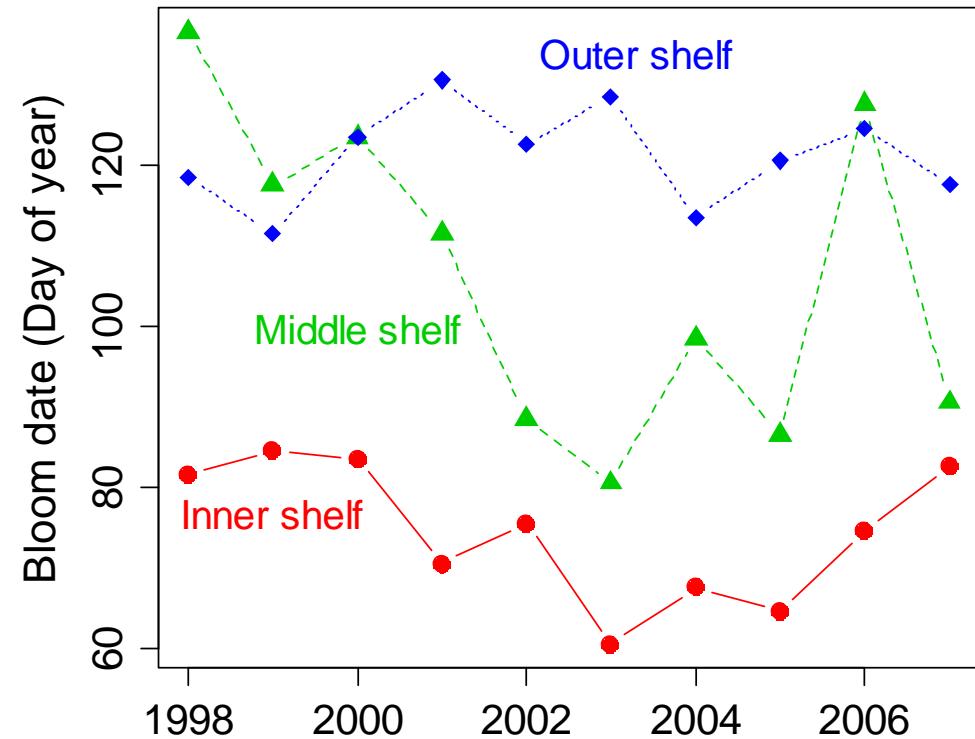
- Early bloom on middle shelf is associated with poor pollock survival



Interannual variability in Chl. a and bloom timing



Interannual variability in bloom timing
(first day where Chl. a > 2)



Primary production and SST

