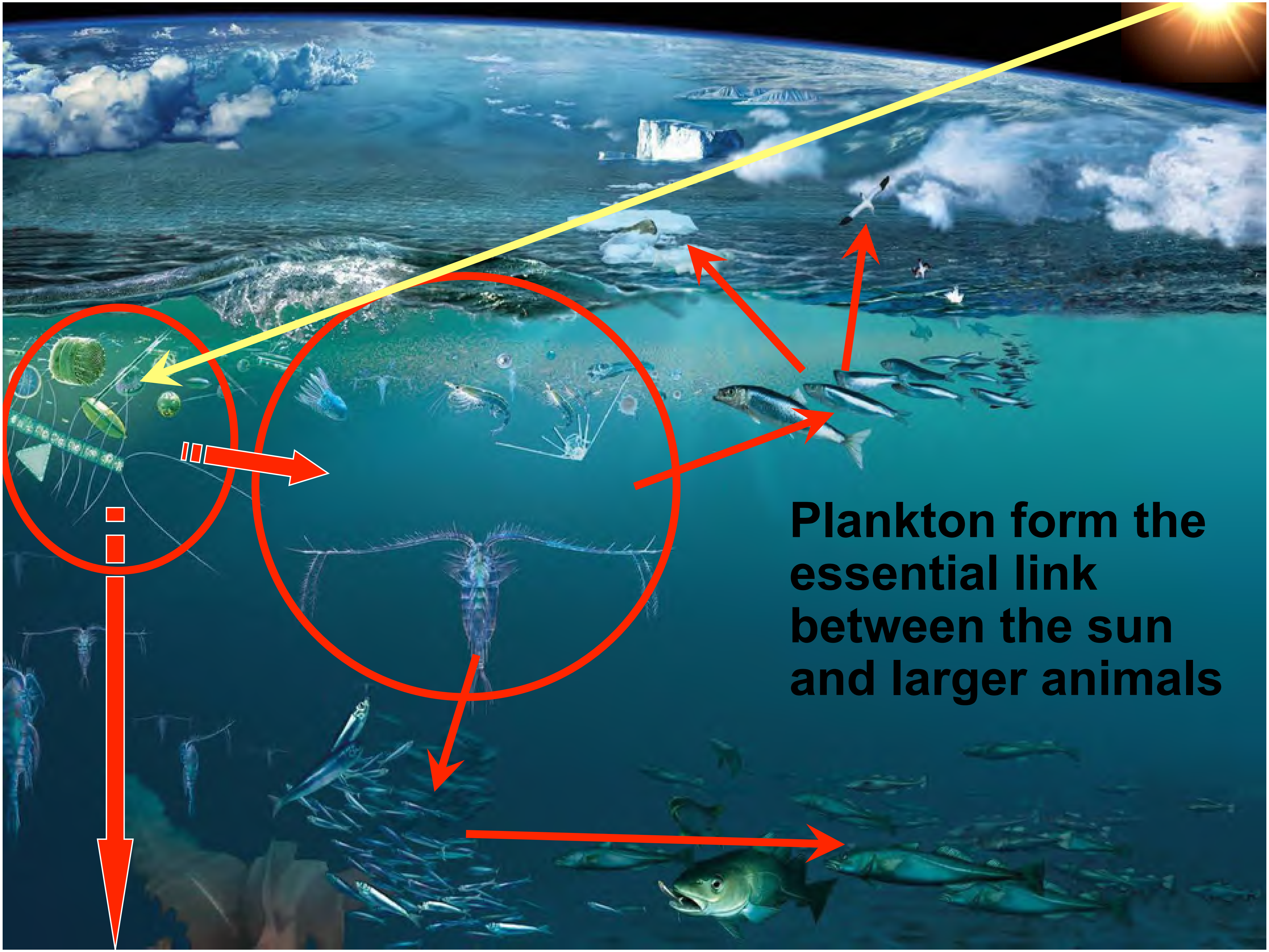
Twenty Years of Observations Along the Gulf of Alaska's Seward Line: Impact of Continued Warm Conditions

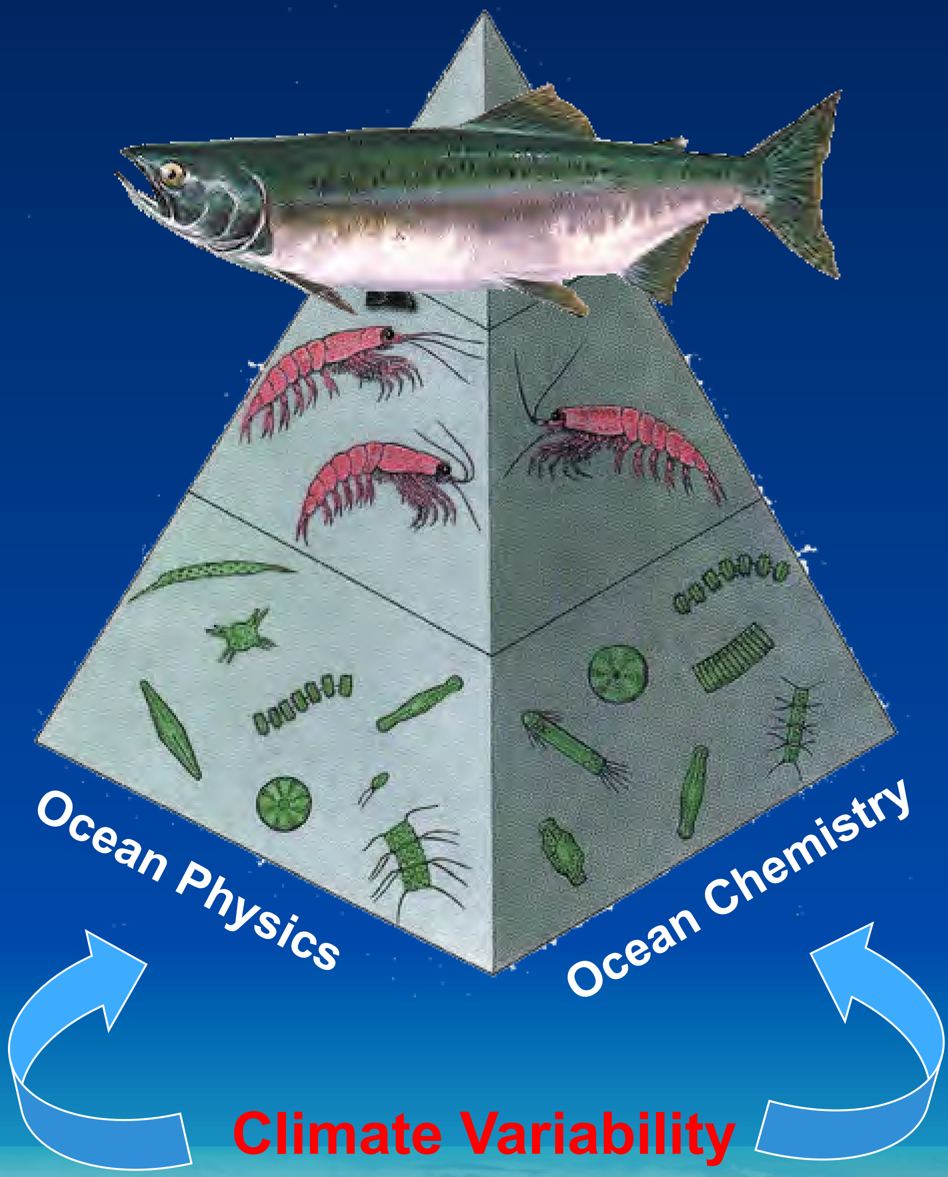
Russ Hopcroft, Ken Coyle, Seth Danielson, Suzanne Strom


Plankton form the essential link between the sun and larger animals

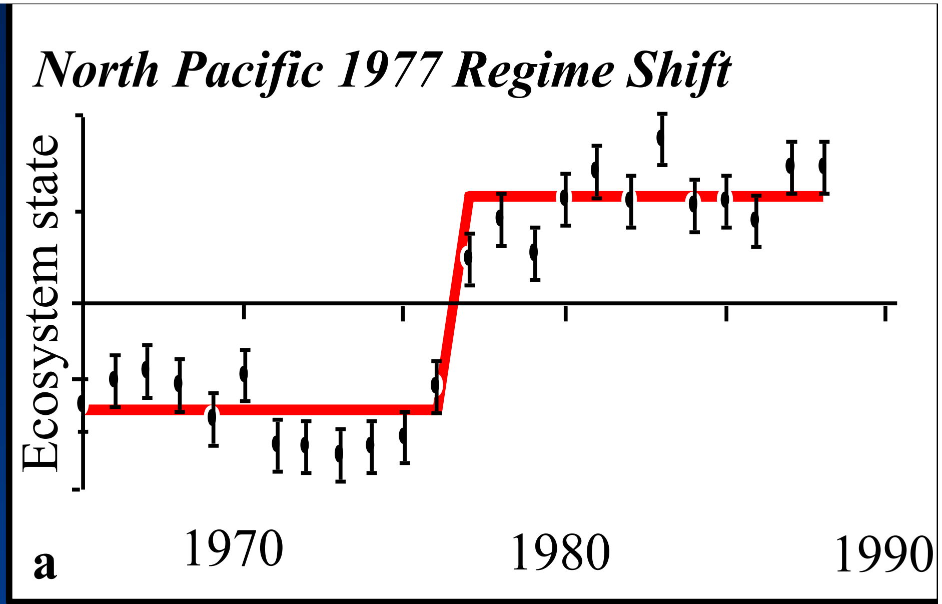

No Plankton
= no fish to
harvest

Food Pyramid

- Climate variability alters marine groups through changes in ocean physics and chemistry that cascade through the food web
- To understand AND predict a harvested species, we need routine observations of the complete food web



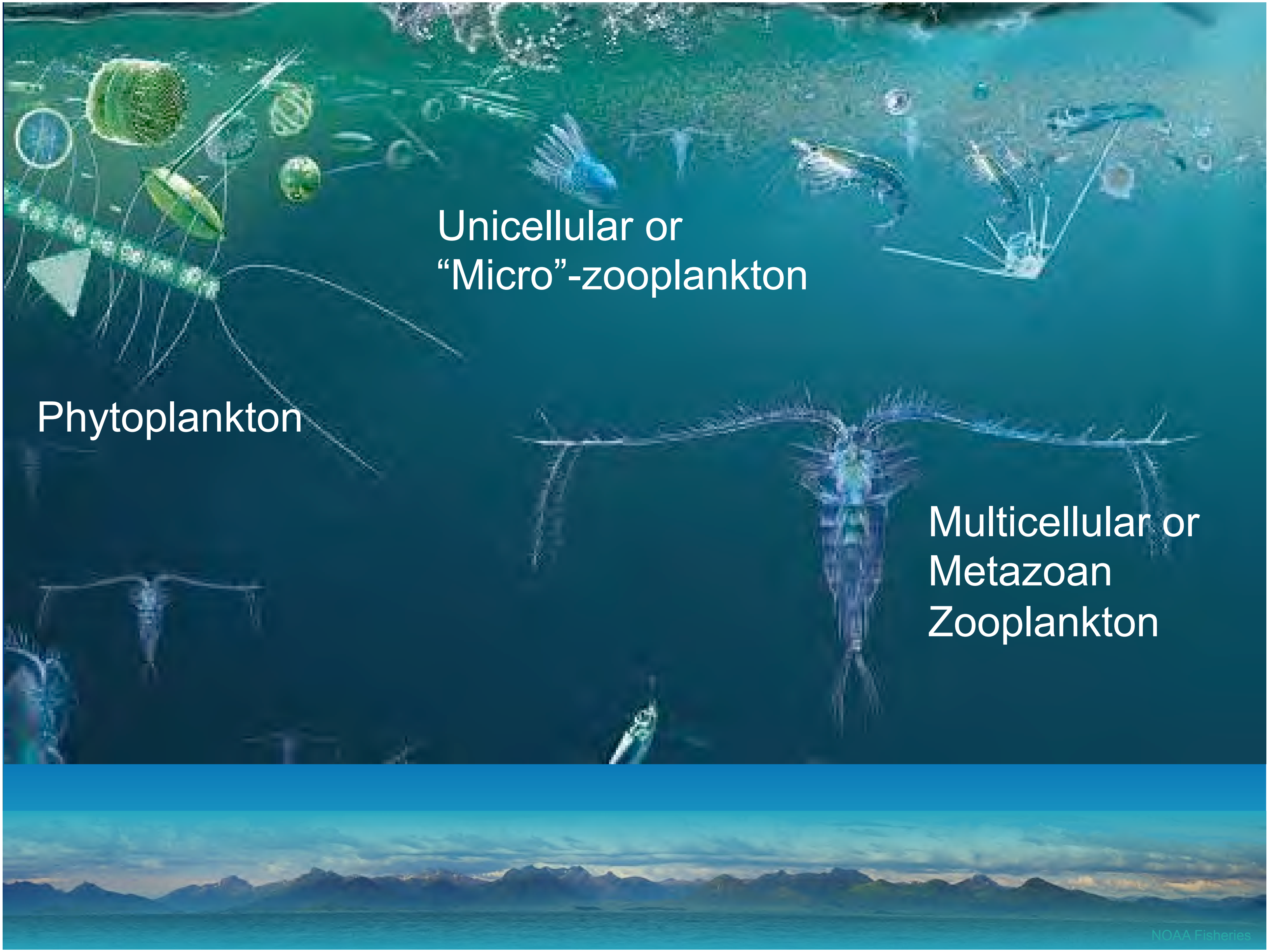
Climate: Why care?



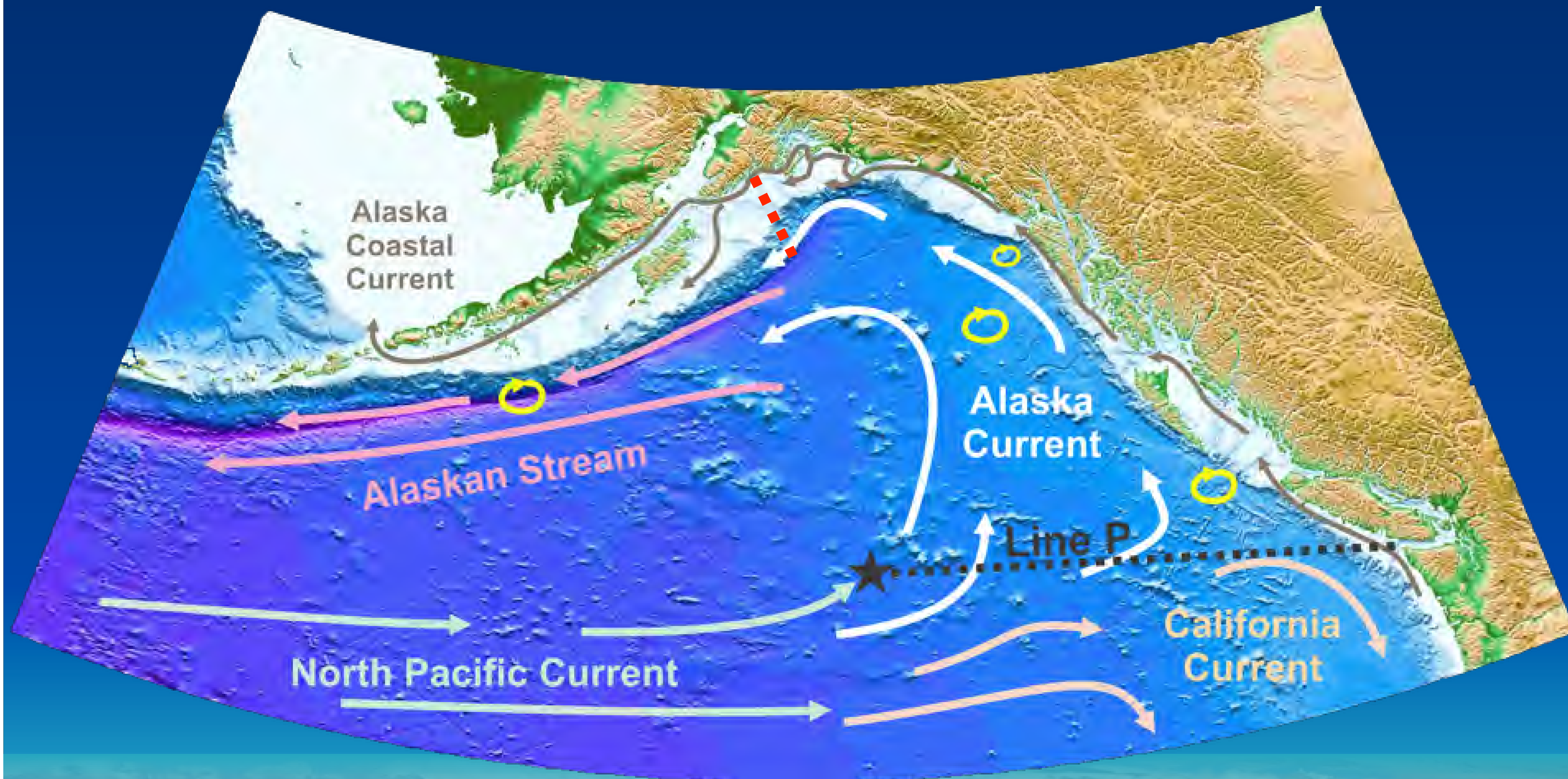
Late 1960's

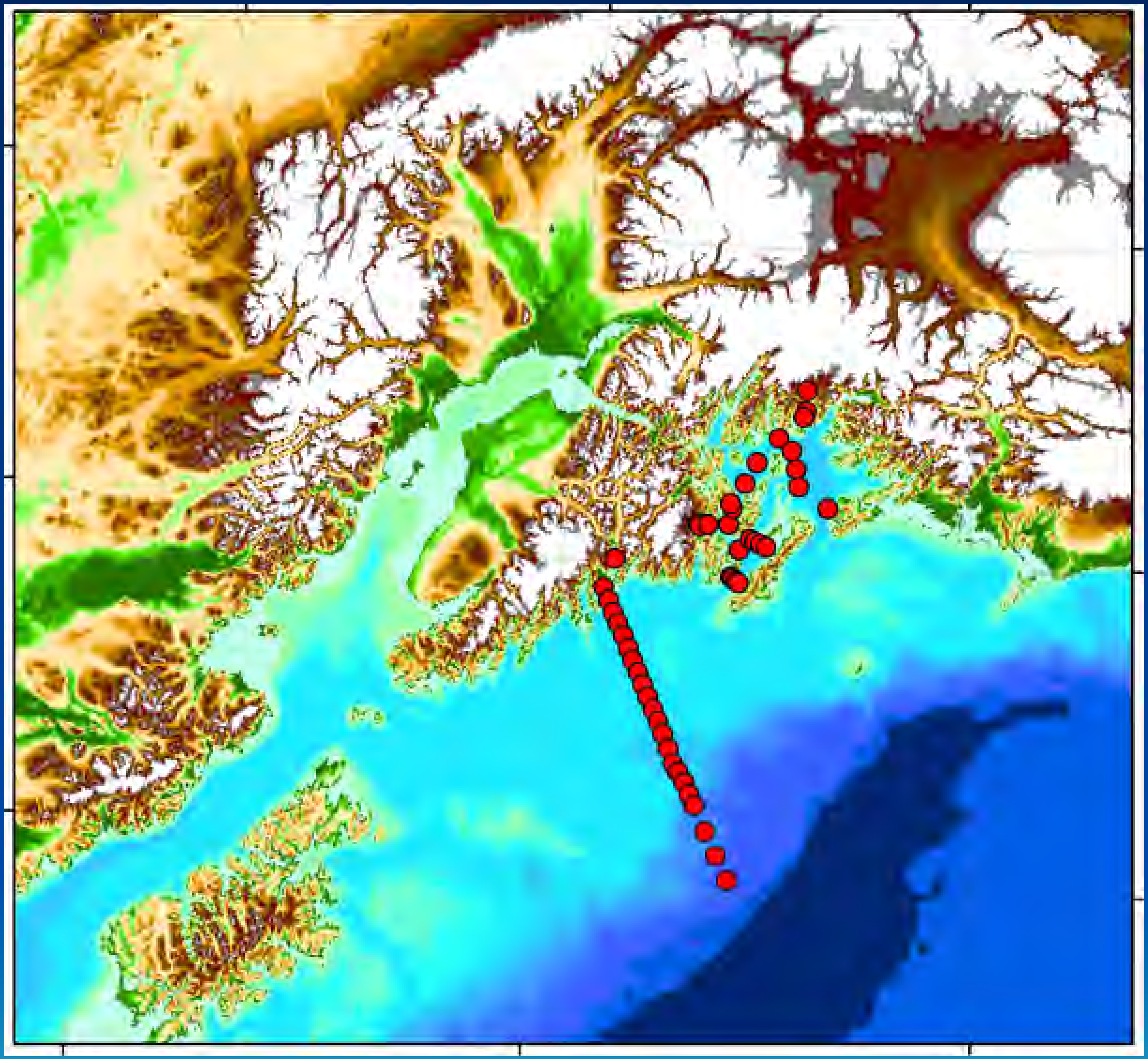
Early 1980's

Changes catches in a small mesh bottom trawl in Pavlof Bay, Alaska, through the regime shift of the mid-1970s.


Unicellular or
“Micro”-zooplankton
Phytoplankton
Multicellular or
Metazoan
Zooplankton
NOAA Fisheries

The sub-arctic Gulf of Alaska

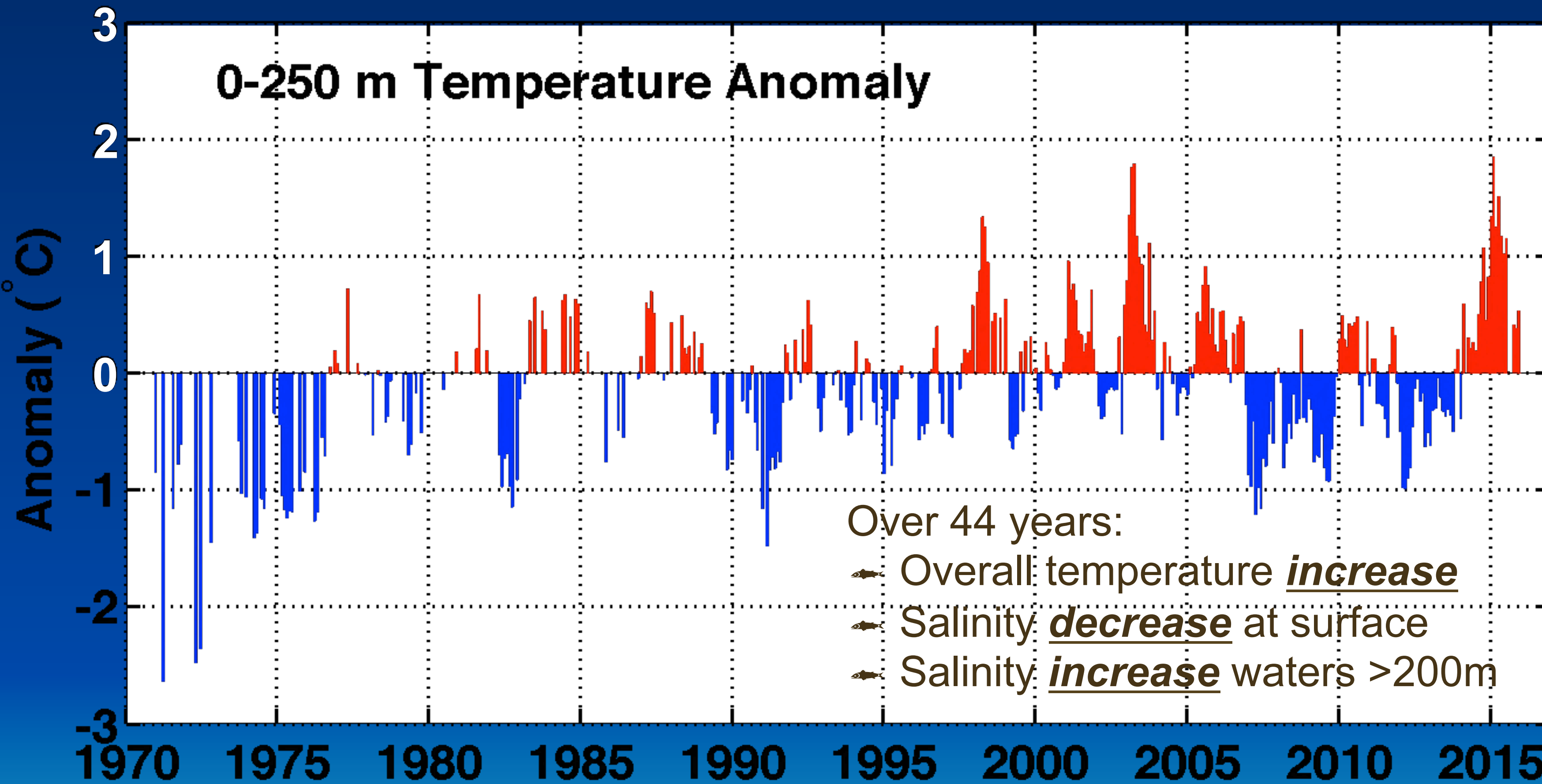




Seward Line

- Physical data over ~5 decades
- Biological data over 20 years
- GLOBEC 1997-2004 > **NPRB** > Consortium 2010
- Sample early May & mid September
- 2011 expansion to eastern PWS

GAK1: Coastal Gulf of Alaska



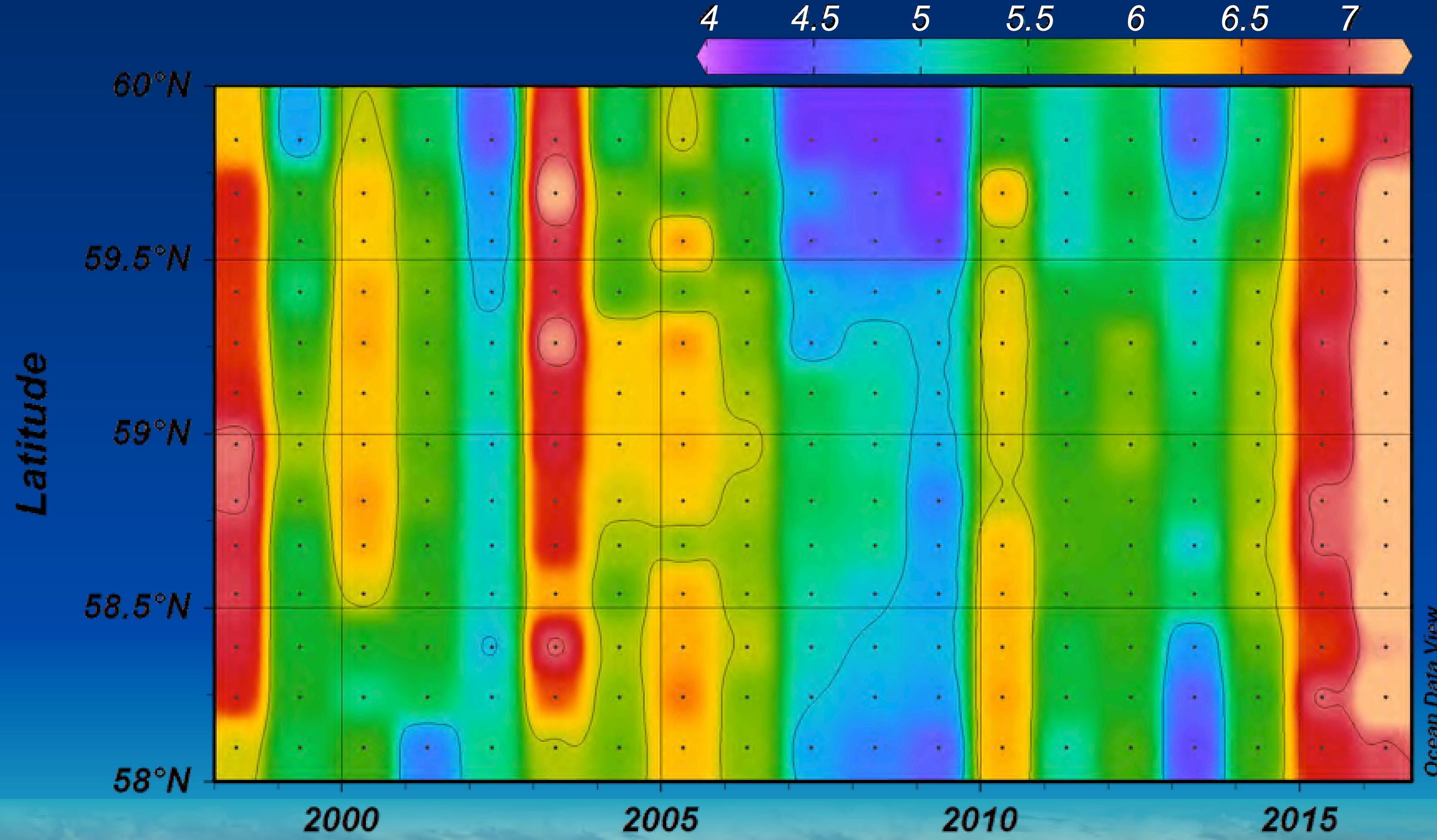
Over 44 years:

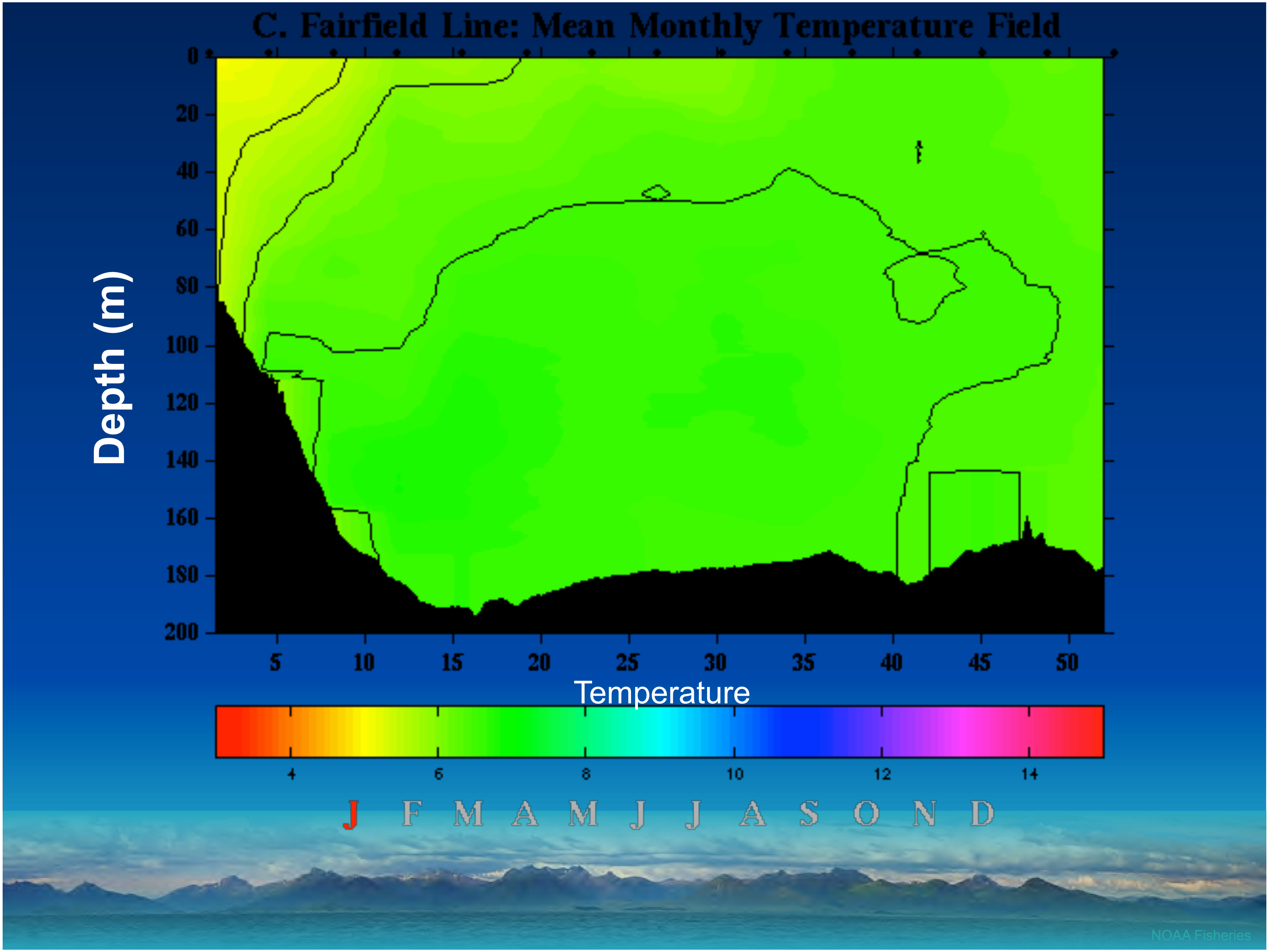
- Overall temperature ***increase***
- Salinity ***decrease*** at surface
- Salinity ***increase*** waters >200m

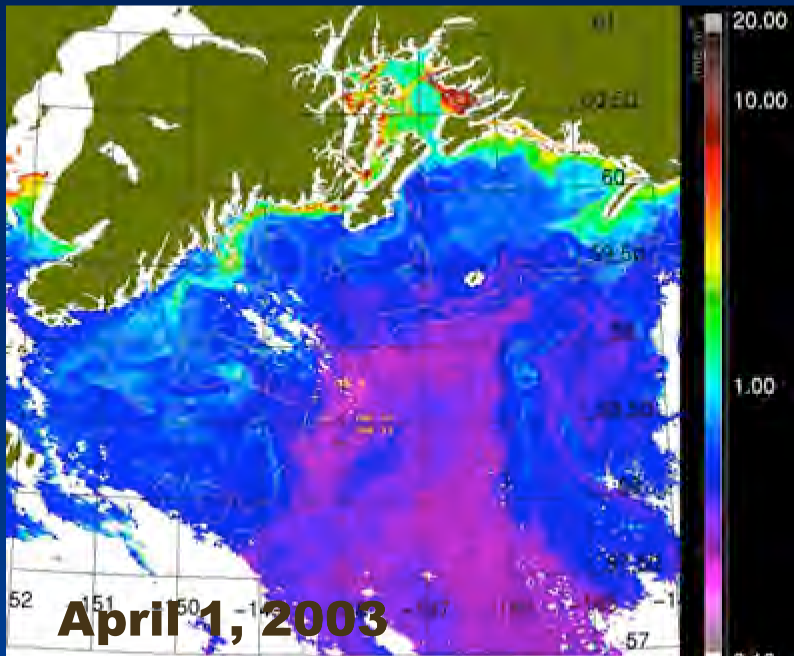
SL Observations

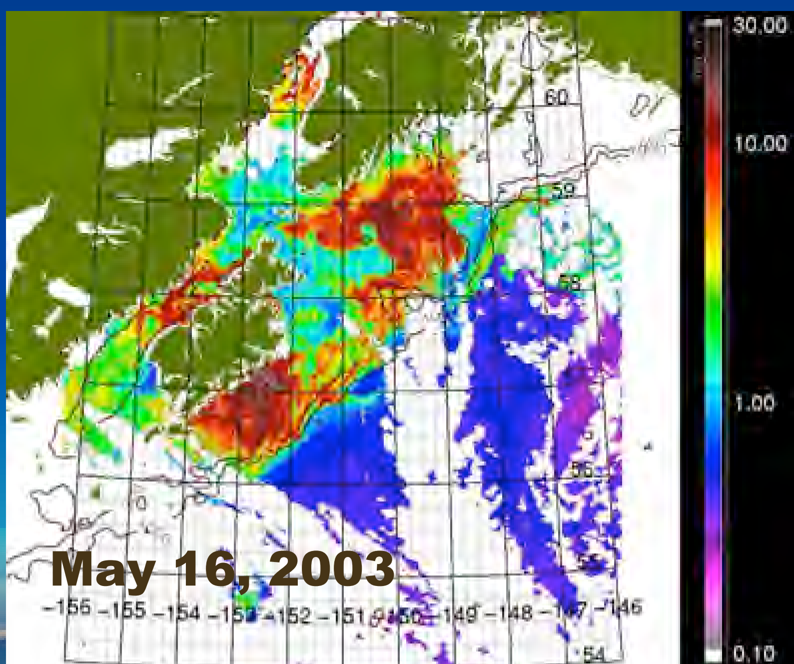
- Physics (T, S, Optical properties)
- Chemistry
  - Macronutrients (nitrate, phosphate, silicate)
  - Carbon (Ocean acidification)
  - Iron (Gulf of Alaska Project)
- Chlorophyll (+Primary production)
- Phyto/Microzooplankon
- **Metazooplankton (3 mesh sizes)**
- Seabirds/Marine Mammal observer

Seward Line: May 0-100m Temperature

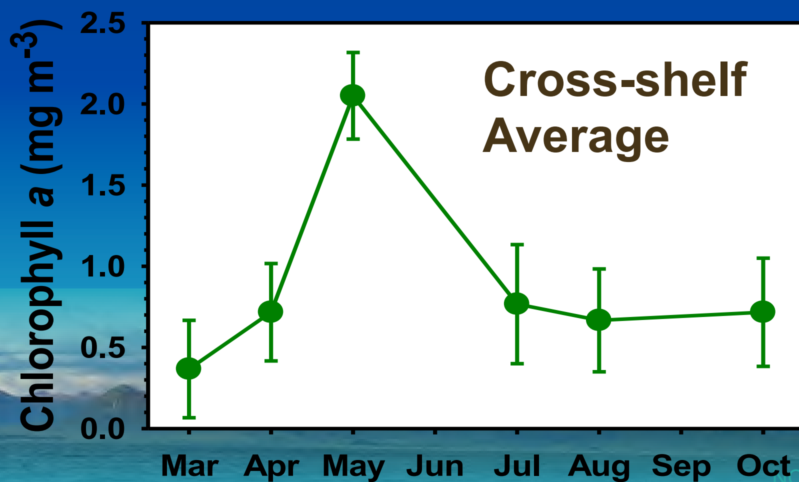


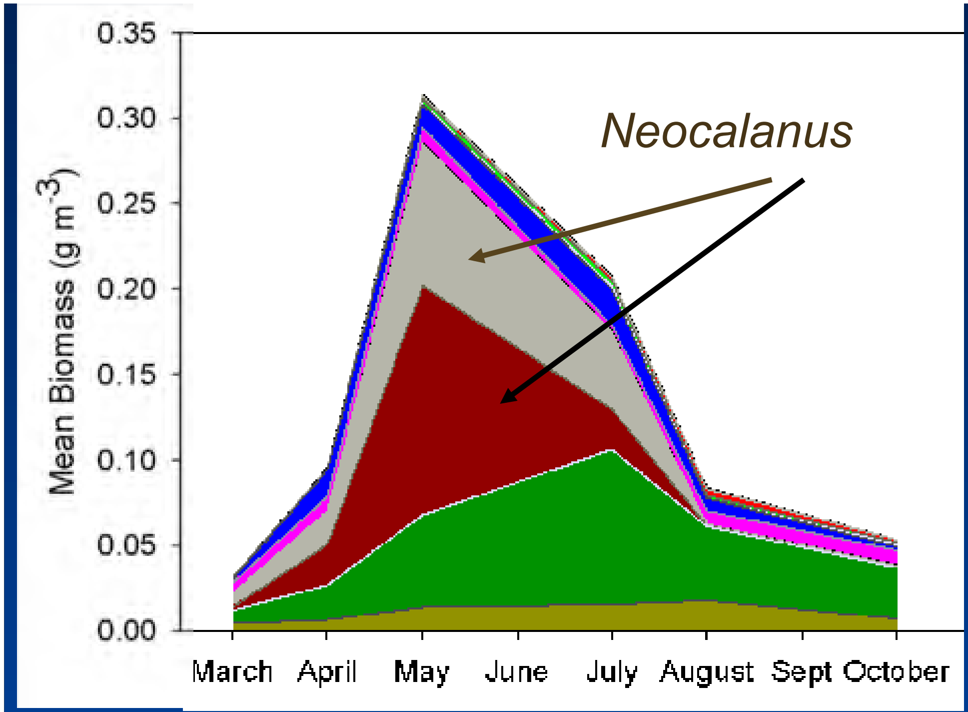

C. Fairfield Line: Mean Monthly Temperature Field
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
5
10
15
20
25
30
35
40
45
50
Temperature
4
6
8
10
12
14
J F M A M J J A S O N D
NOAA Fisheries





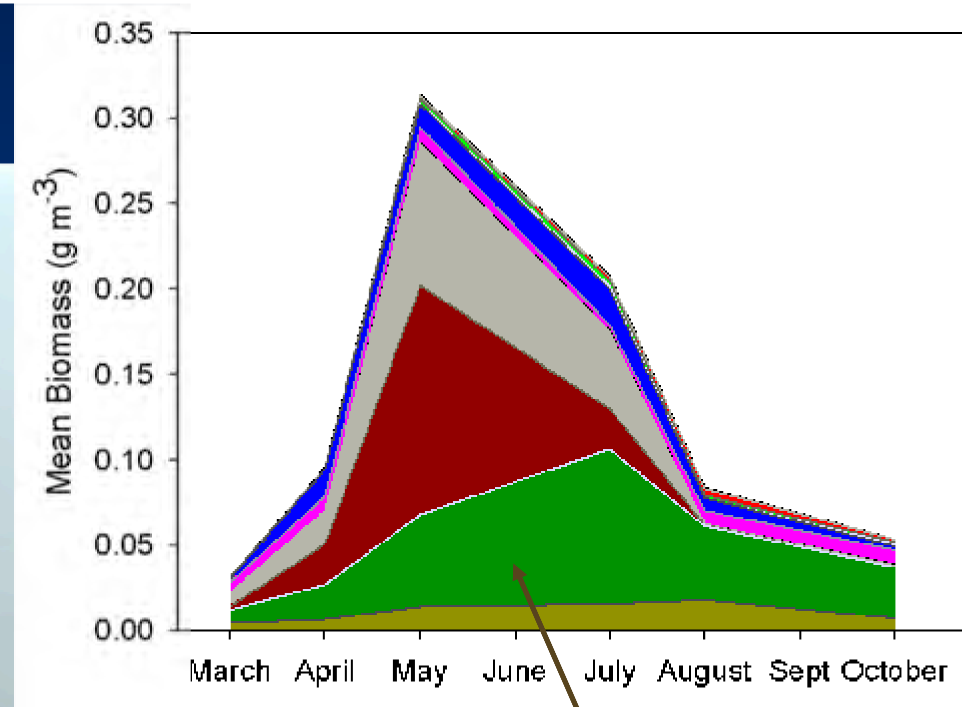
- In spring, returning light favors algal growth, but mixing limits how much time they spend in good light
- Mixing can be stopped by the sun warming surface waters or fresher water floating on top of saltier water
- Primary production starts in PWS and on the inner shelf (weeks) earlier than the mid- and outer shelf due to different stratifying mechanisms





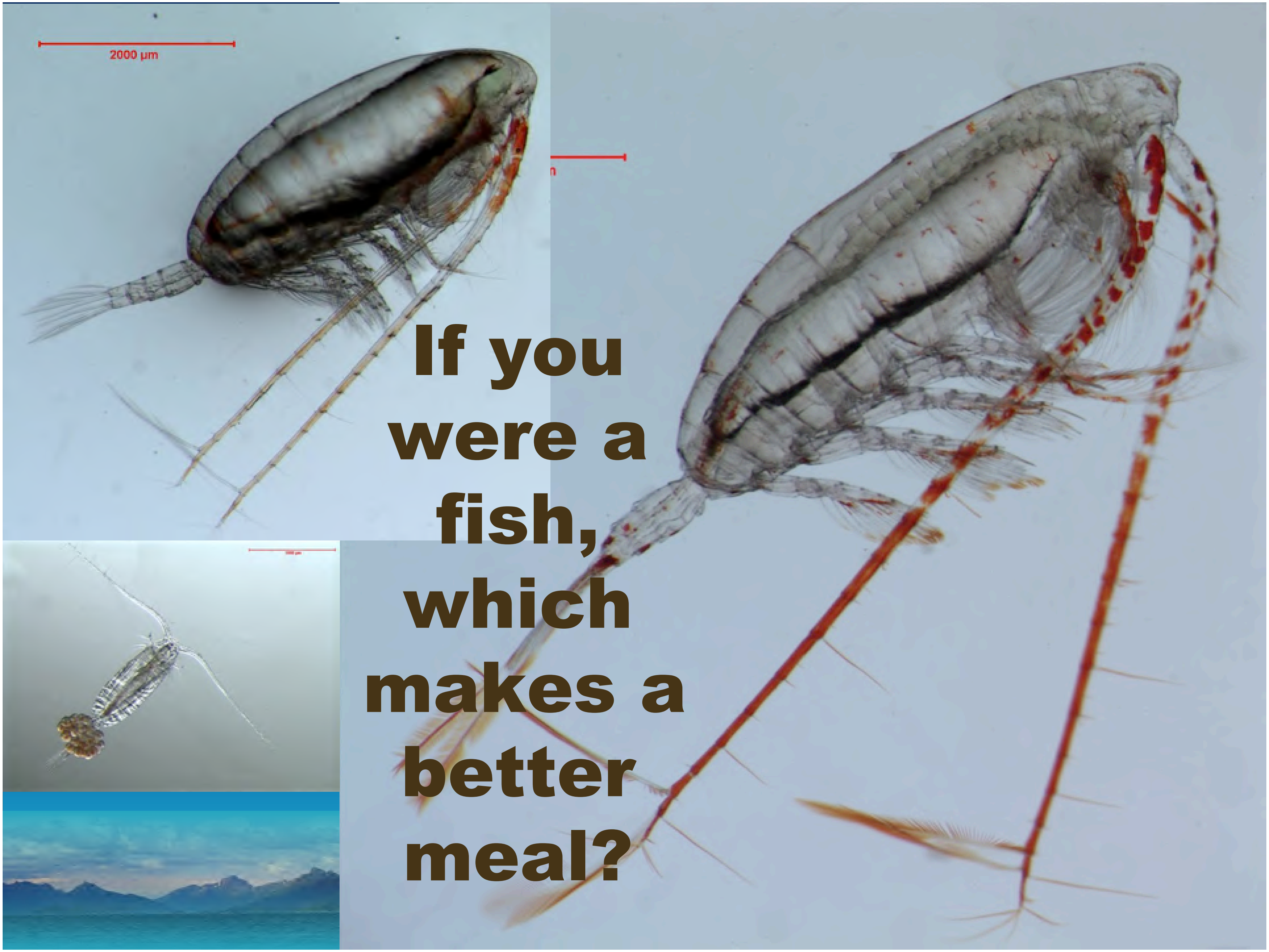
The success of the zooplankton that dominate the spring is related to their unique adaptations to the production cycles of the Gulf

Three *Neocalanus* copepods species dominate the ecosystem during spring



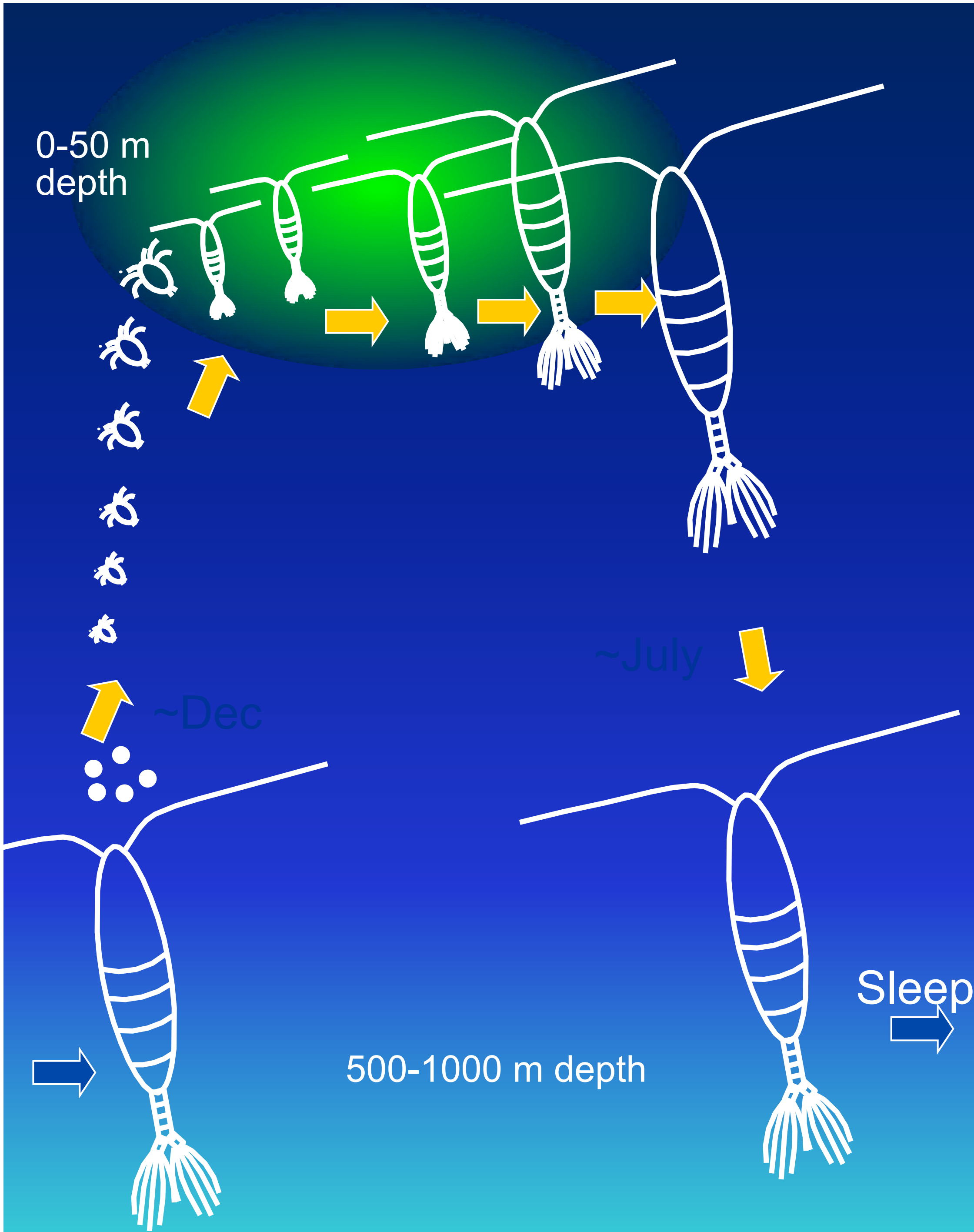
Sometime in June/July, *Neocalanus* complete their feeding stages and begin descending to depth to sleep.

Small multi-generation surface-dwelling species such as *Pseudocalanus* then dominate for the remainder of year

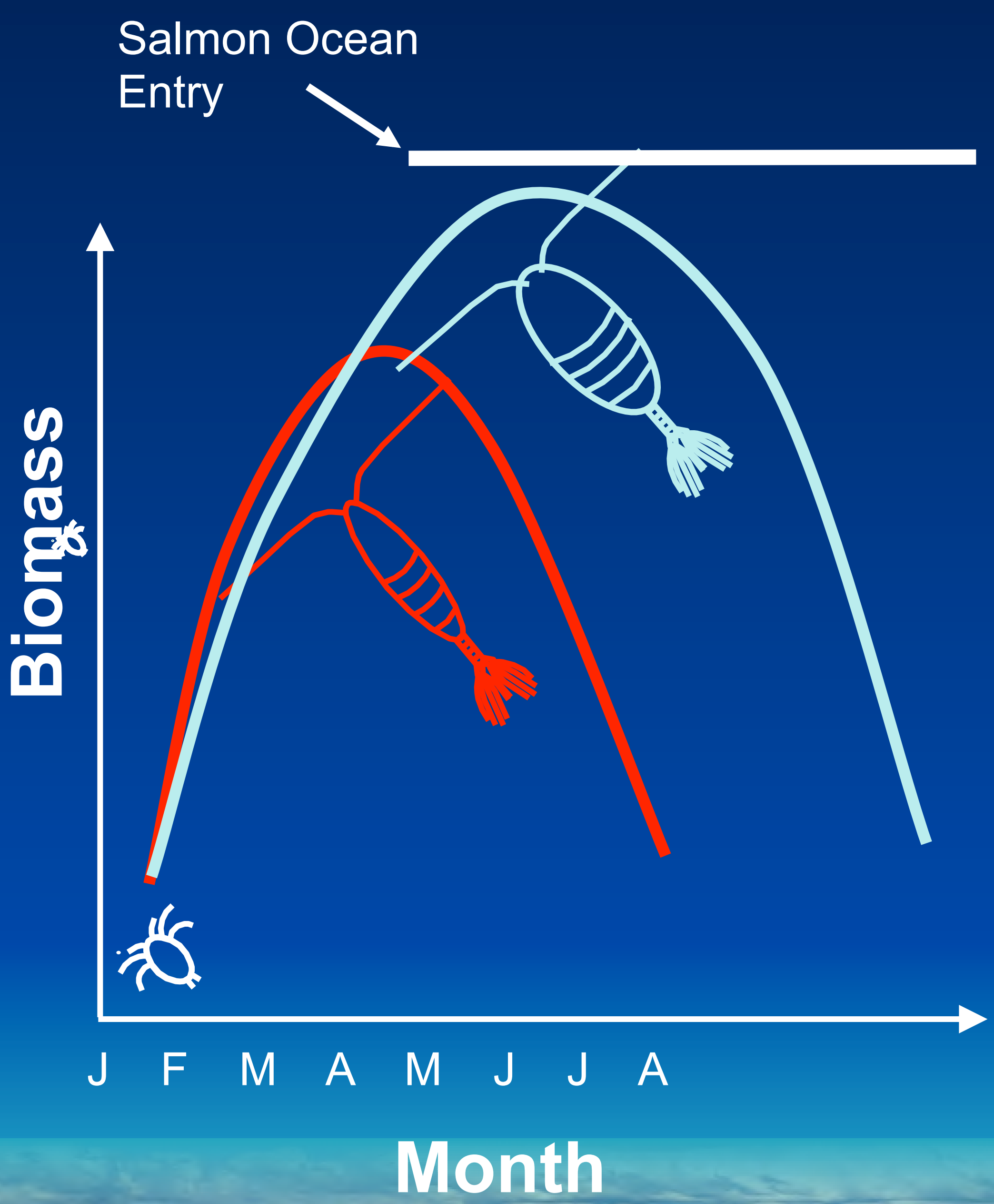


If you were a fish, which makes a better meal?

Neocalanus



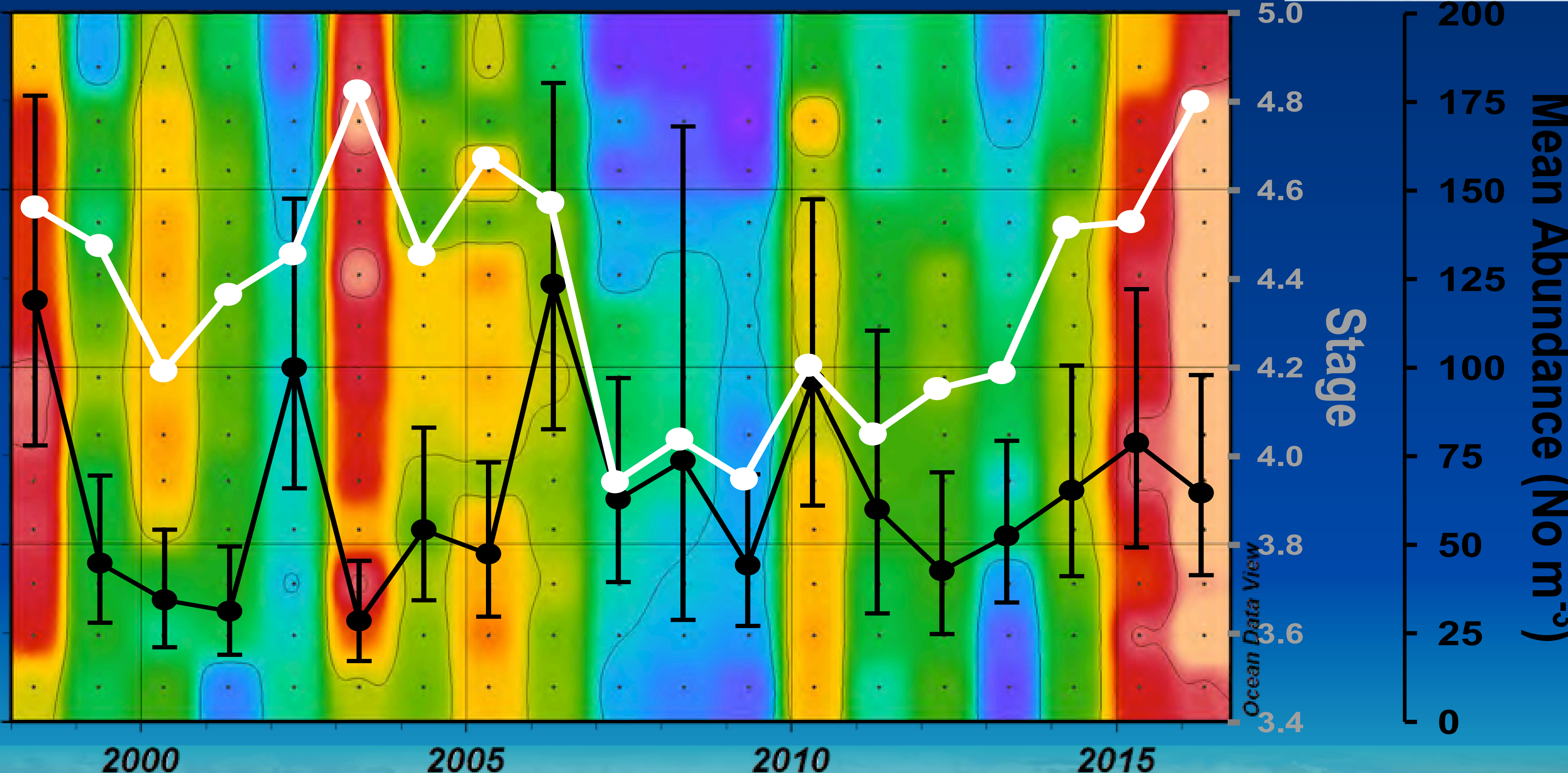
- Spawns Dec-Feb deep in the ocean (queued by day length)
- Young grow, while swimming to surface in “anticipation” of spring bloom – great flexibility in hitting the timing of the spring bloom
- Abundance of *Neocalanus* in a given year has little to do that year’s temperature
- Length of time feeding at surface until going deep is determined largely by temperature and food, that together influence lipid accumulation



Initial Paradigm

- In a warm year, spring bloom is earlier (and often smaller) – *Neocalanus* growth phase is completed earlier….
- In a cold year, bloom is later, larger and longer – *Neocalanus* success is greater, growth is completed later….
- Cold years have better & longer overlap of *Neocalanus* with juvenile salmon and other fishes

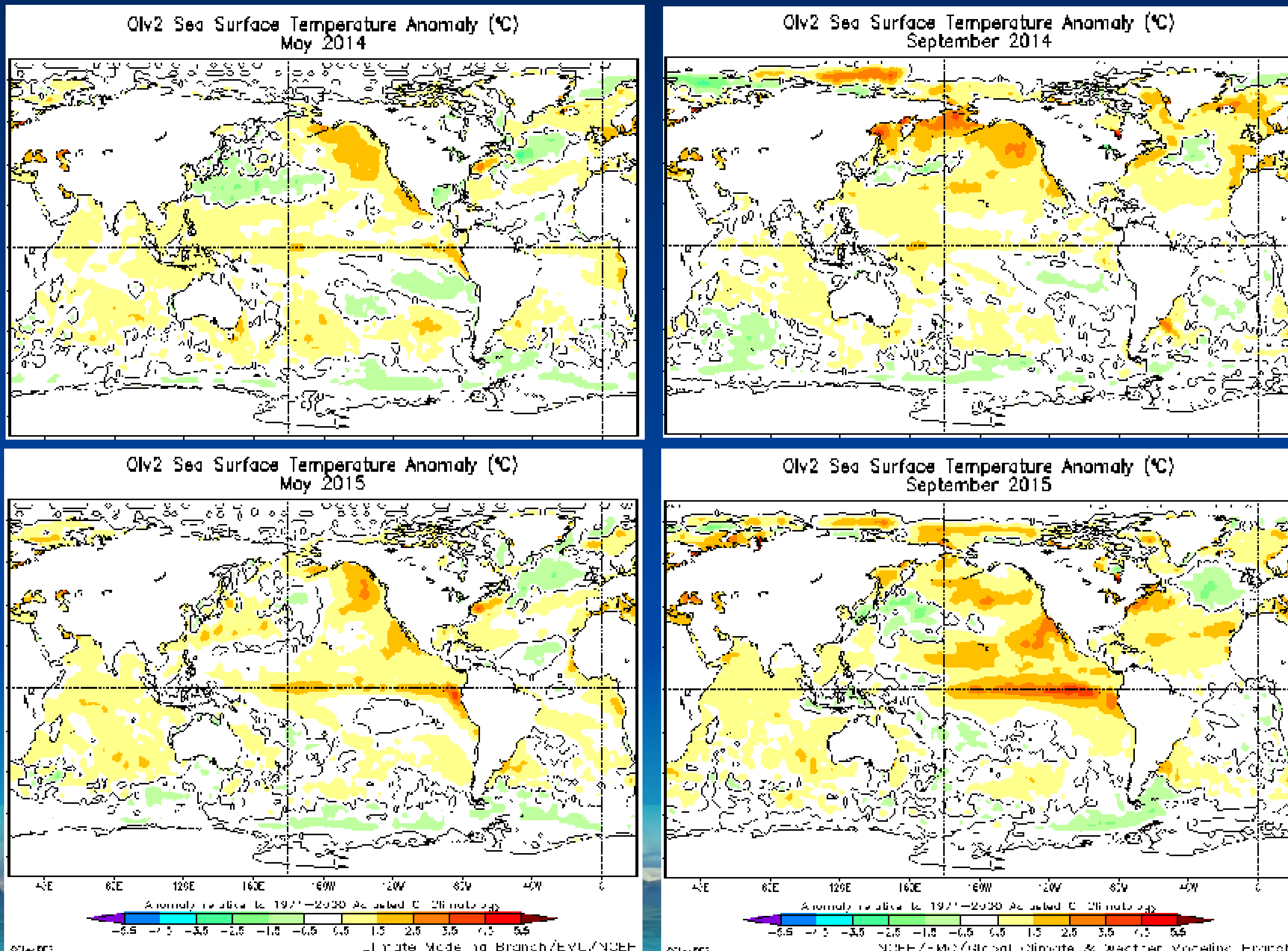
Seward Line temperature & *Neocalanus*



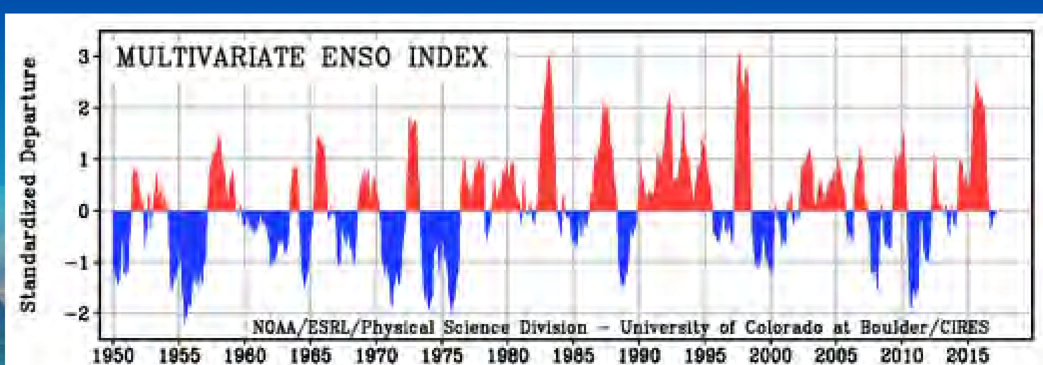
NOAA Fisheries

What does a warming ocean do to the Gulf of Alaska?

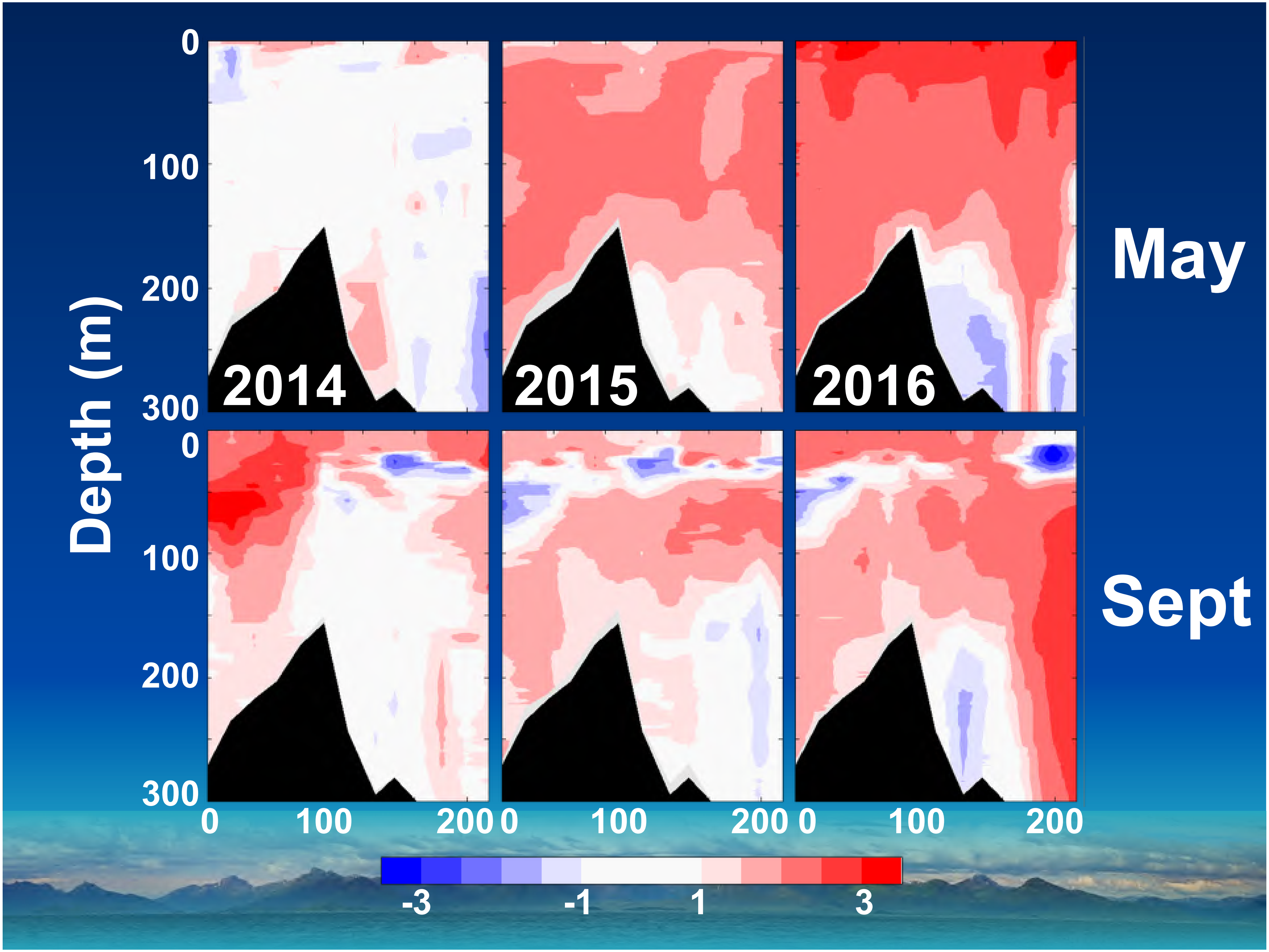
Recent warmings: The Blob

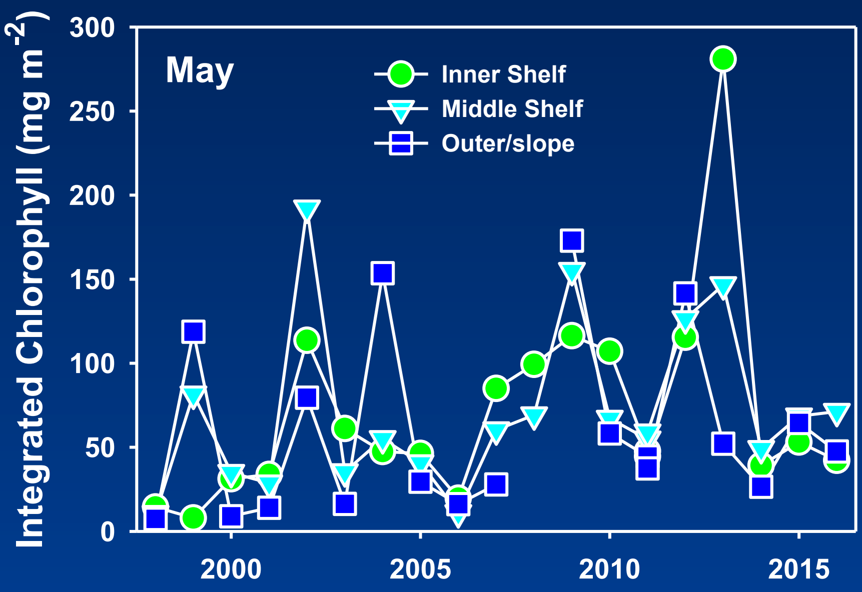


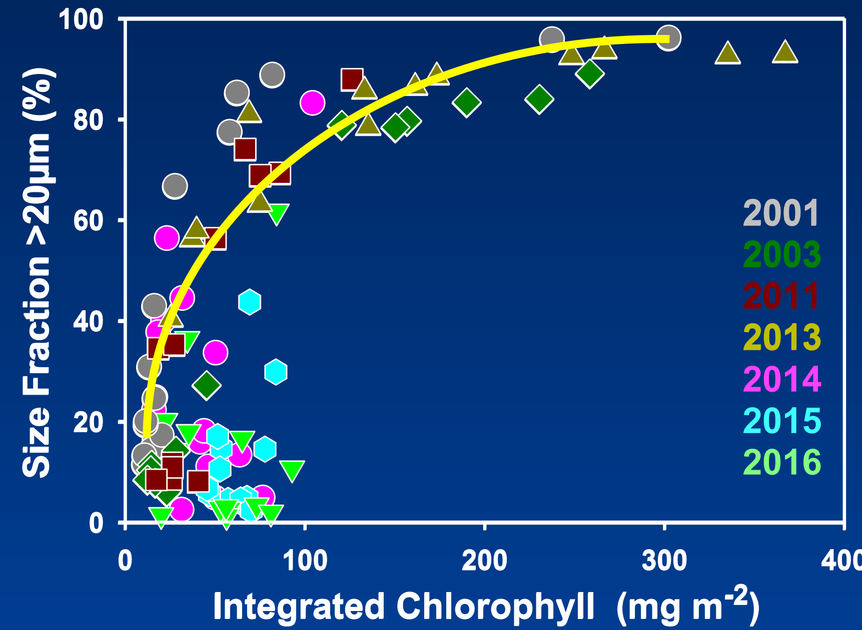
Fisheries

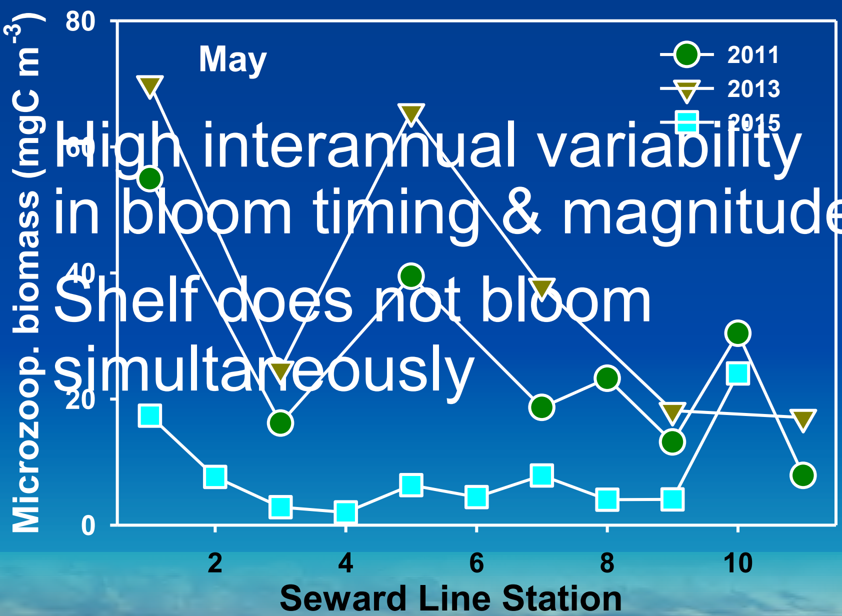


We just exited one of the top 3 El Nino's of the last 65 years


Depth (m)
0
100
200
300
2014
2015
2016
May
Sept
-3
-1
1
3



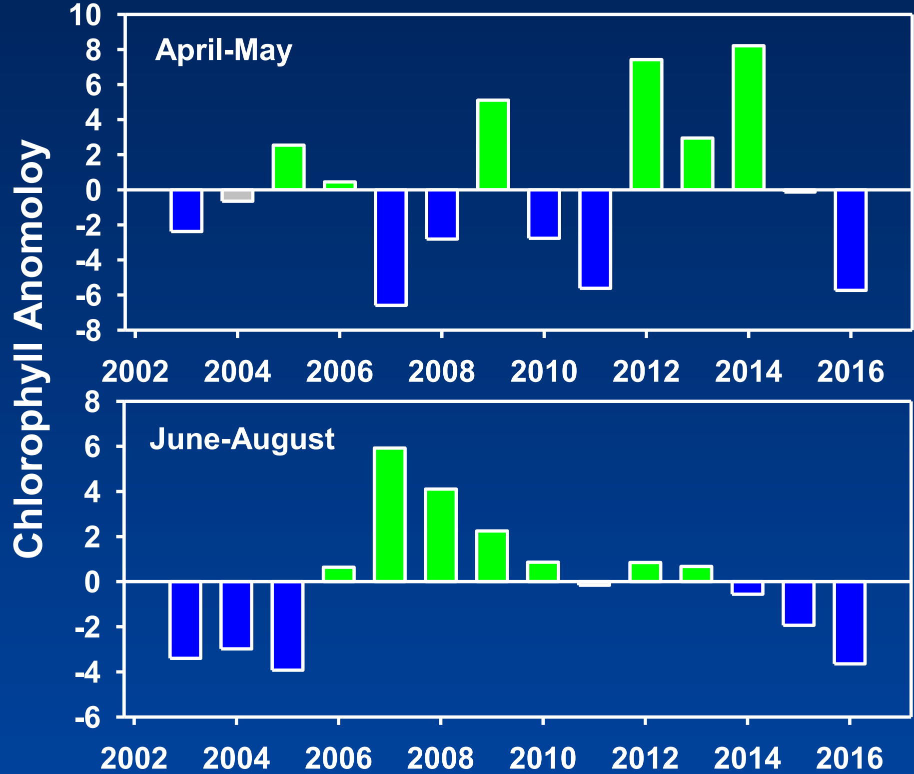




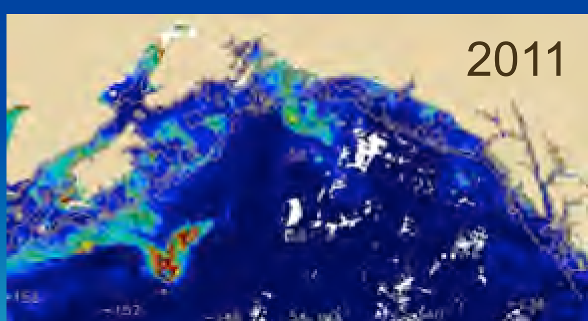
- High interannual variability in bloom timing & magnitude
- Shelf does not bloom simultaneously

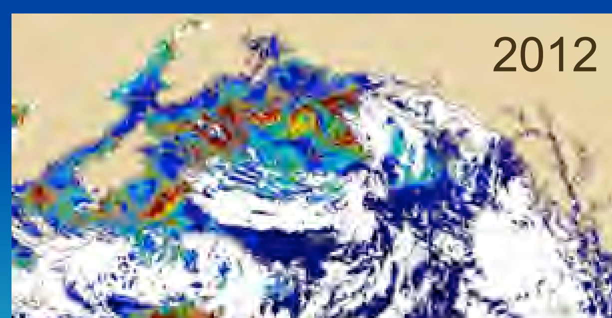
- Normally as chloro increases, %large cells does too
- During “blob” years, increase is modest, but cells stay small
- Microzooplankton biomass is low during blob, mostly small

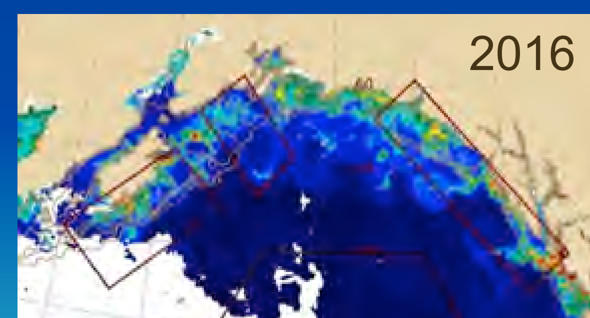
NOAA Fisheries

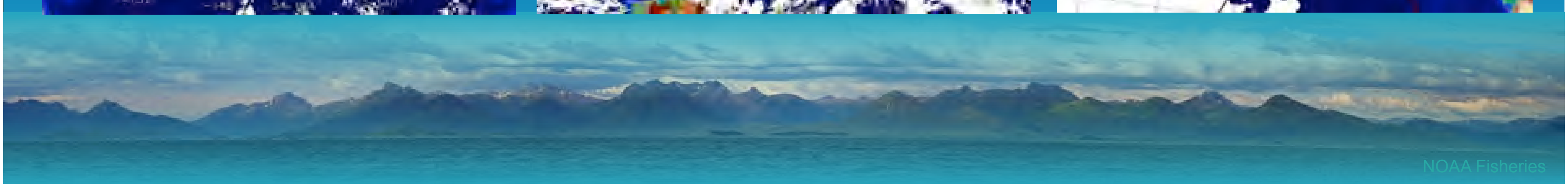


MODIS Aqua ocean color shows blob resulted in reduced summer chlorophyll, with 2016 being low in **both** spring & summer (like 2003 El Niño)

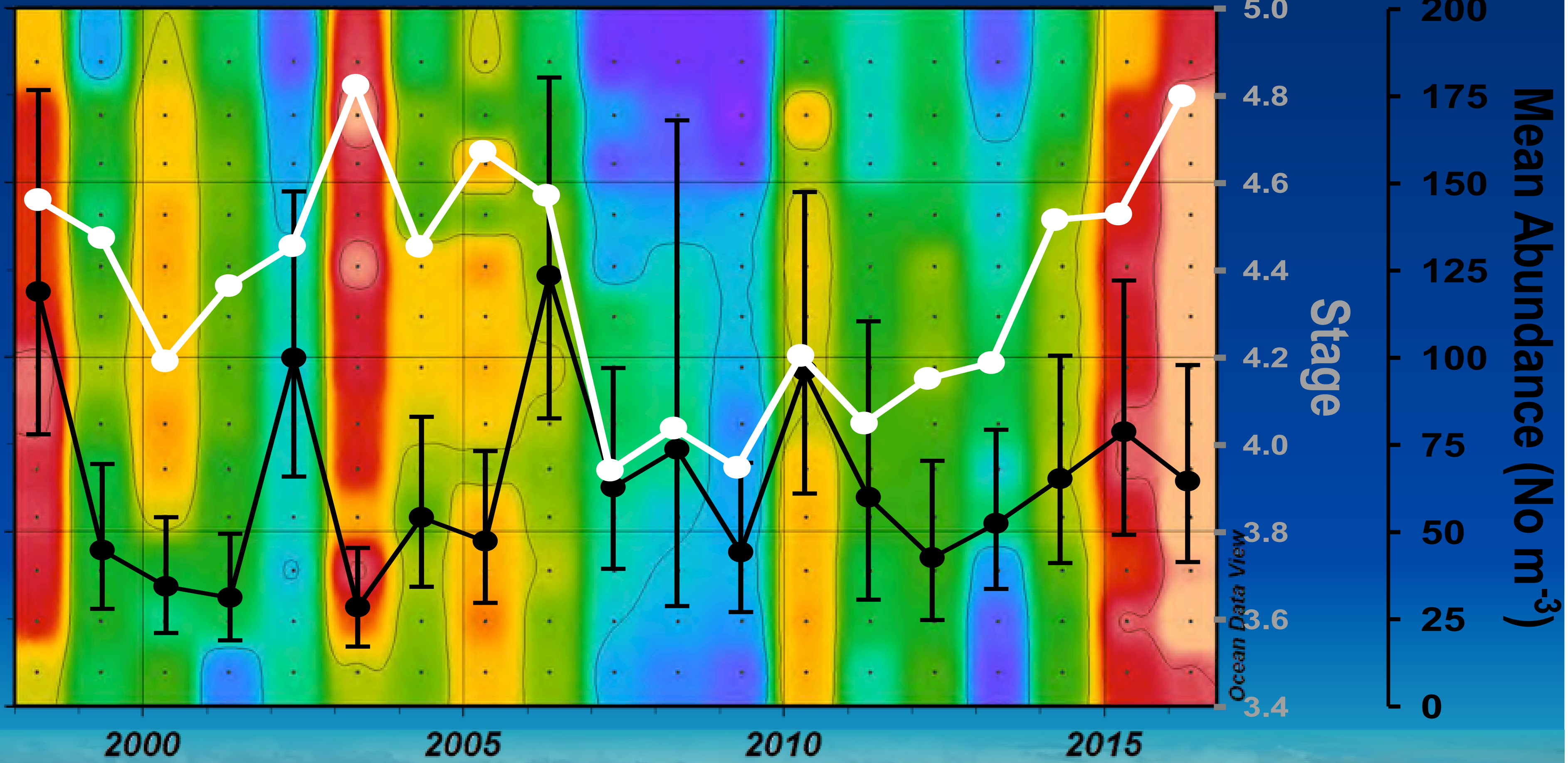








Neocalanus development is faster in warm years, but metabolic costs are higher AND food was limited in 2016



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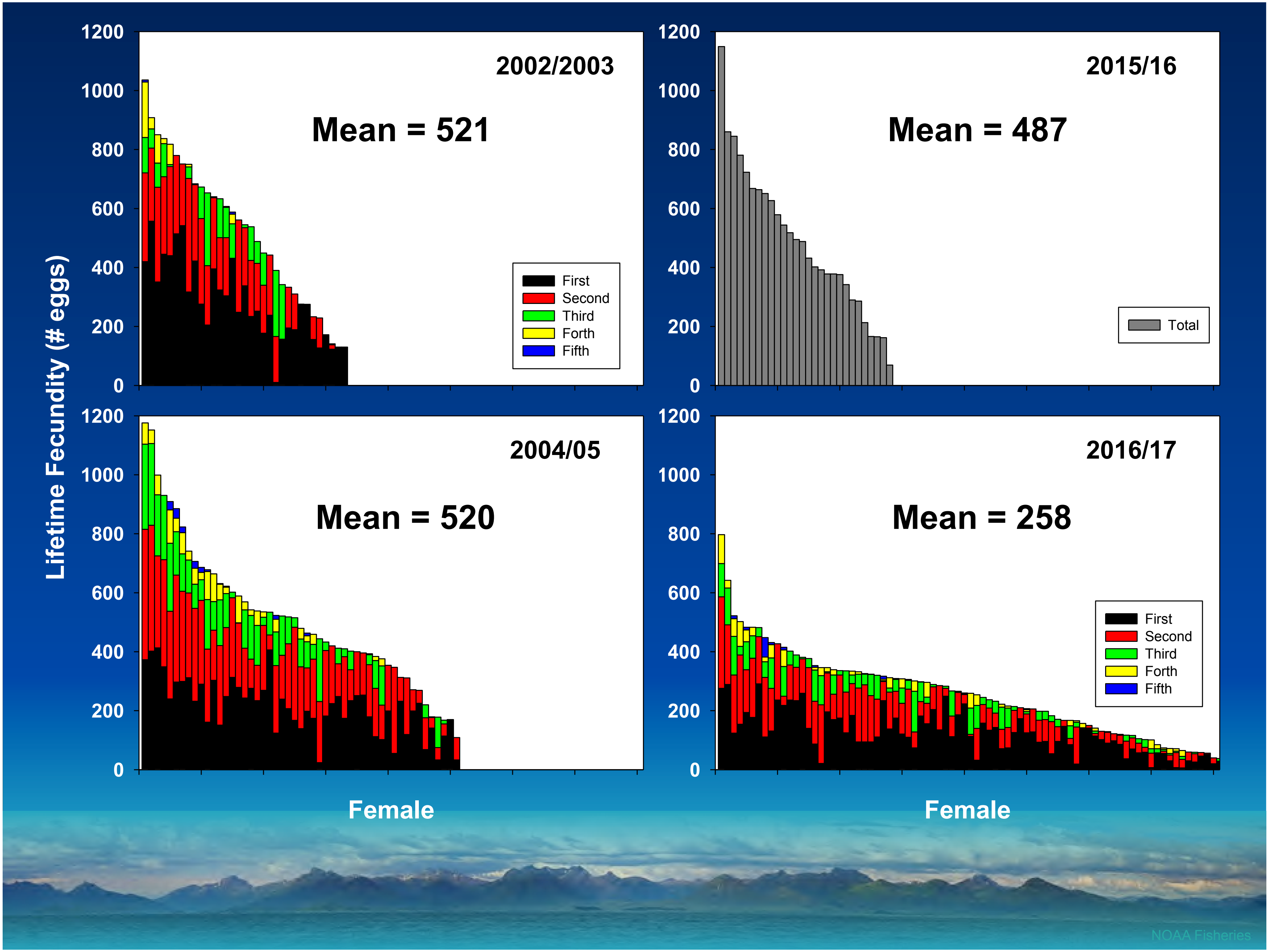
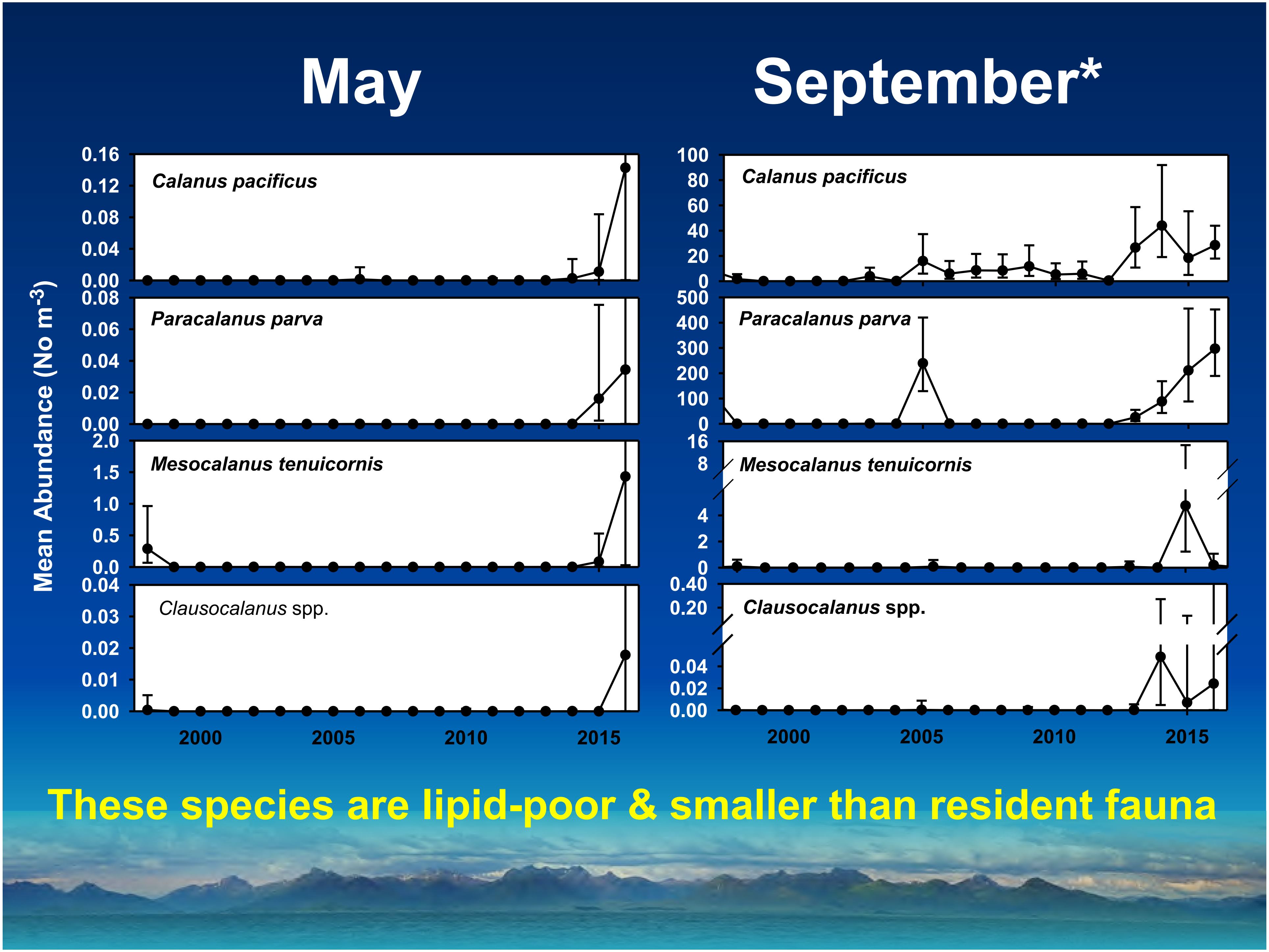
Typical fall lipids

2016 fall lipids

Low chlorophyll AND microzoop spring & summer 2016

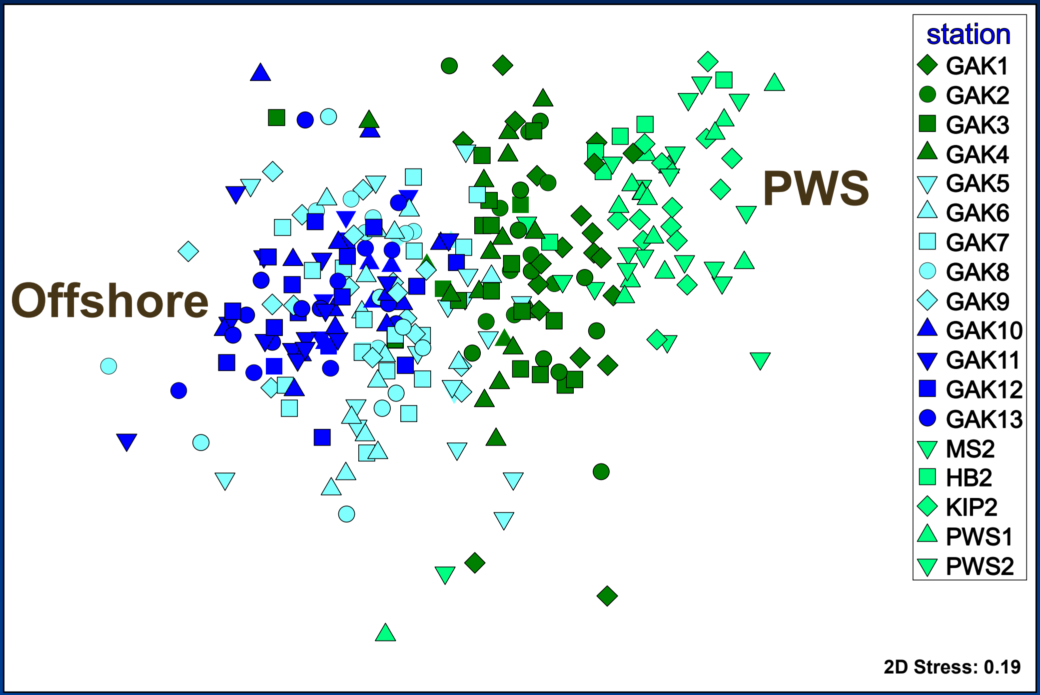

Lifetime Fecundity (# eggs)
2002/2003
Mean = 521
First
Second
Third
Forth
Fifth
2015/16
Mean = 487
Total
2004/05
Mean = 520
2016/17
Mean = 258
First
Second
Third
Forth
Fifth
Female
Female
0
200
400
600
800
1000
1200
NOAA Fisheries

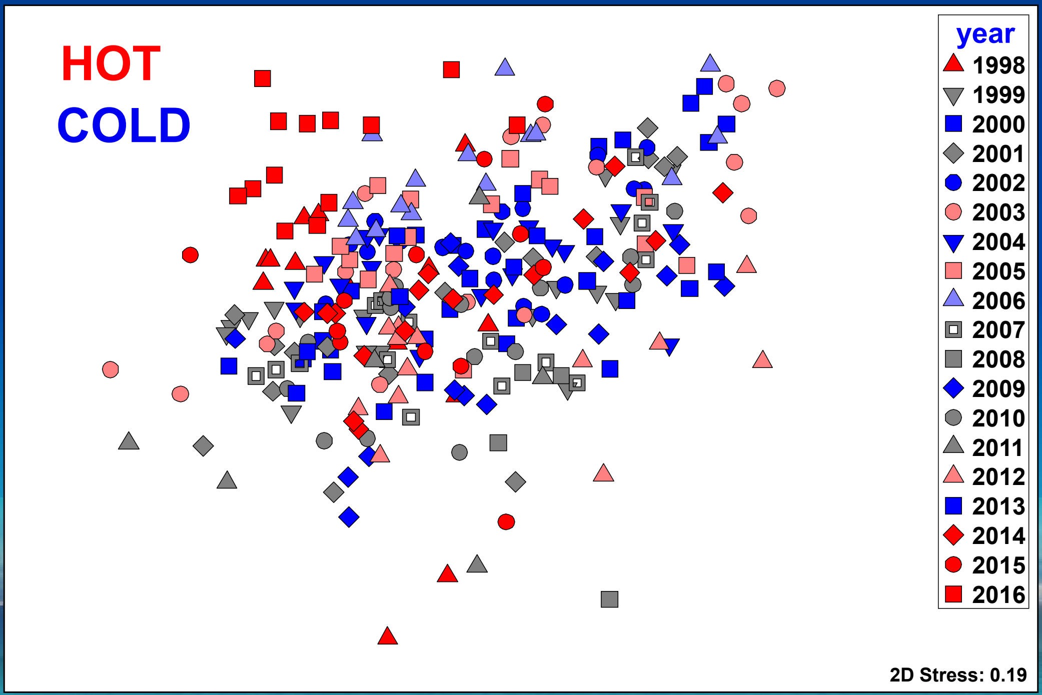

May
September*
Calanus pacificus
Paracalanus parva
Mesocalanus tenuicornis
Clausocalanus spp.
Mean Abundance (No m-3)
0.16
0.12
0.08
0.04
0.00
0.08
0.06
0.04
0.02
0.00
2.0
1.5
1.0
0.5
0.0
0.04
0.03
0.02
0.01
0.00
100
80
60
40
20
0
500
400
300
200
100
0
16
8
4
2
0
0.40
0.20
0.04
0.02
0.00
2000
2005
2010
2015
These species are lipid-poor & smaller than resident fauna

Caution: Multivariate Analysis

- To explore pattern, we can determine how **similar** the community in each of our samples is to **every other** sample (Bray-Curtis similarity)
- This method accounts for both abundance and contribution of each species and places the data into a multi-dimensional space (where # of dimensions = # species)
- We can then determine how "close" each sample is to every other sample, and start grouping them based on their similarity
- This is presented either as a tree of progressive joining, or by reducing to strongest 2-3 dimensions

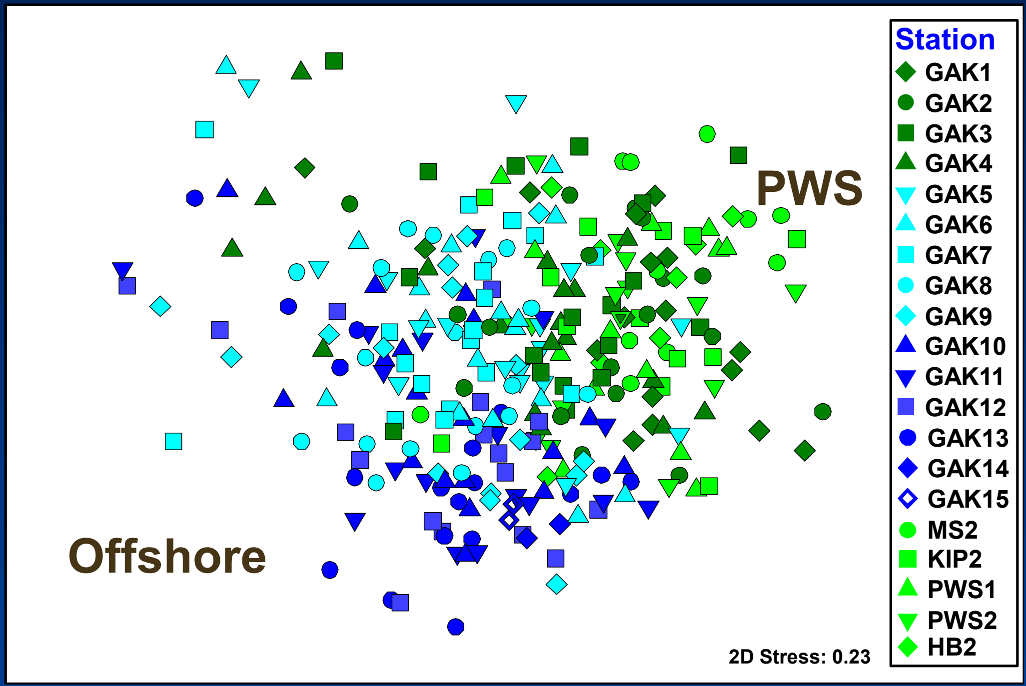
NOAA Fisheries



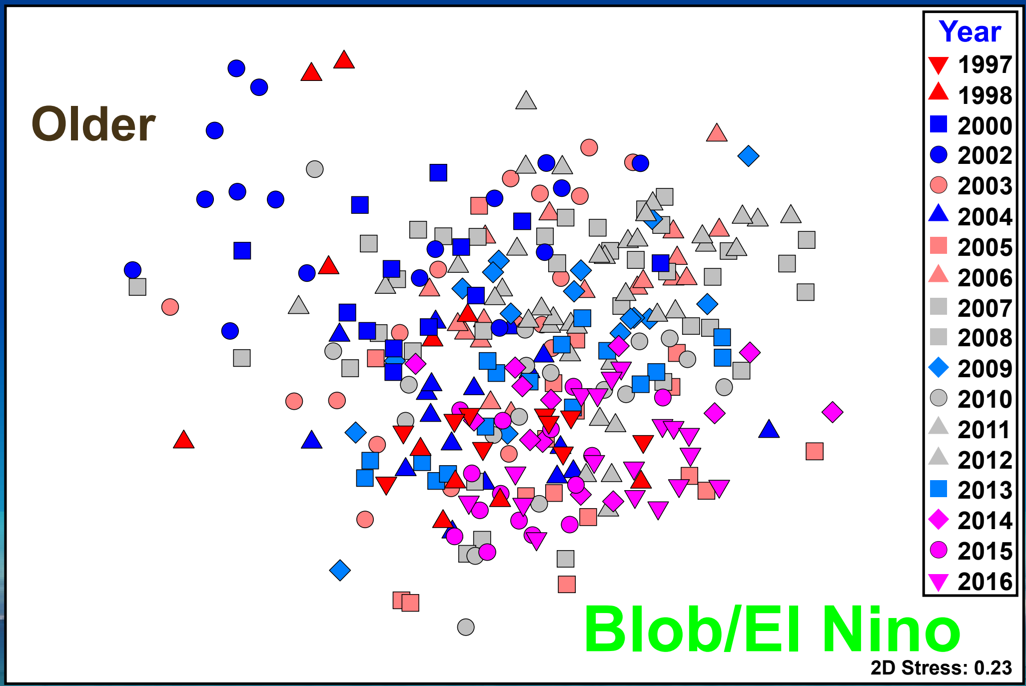


Spring Communities are driven primarily by cross-shelf habitat gradients

Spring Community structures are NOT directly driven by 'simple' hot or cold year relationships



Fall Communities also show a strong cross-shelf gradient



While Fall Community structures are NOT directly driven by hot or cold, recent years are displaced suggesting overall community shifts are underway

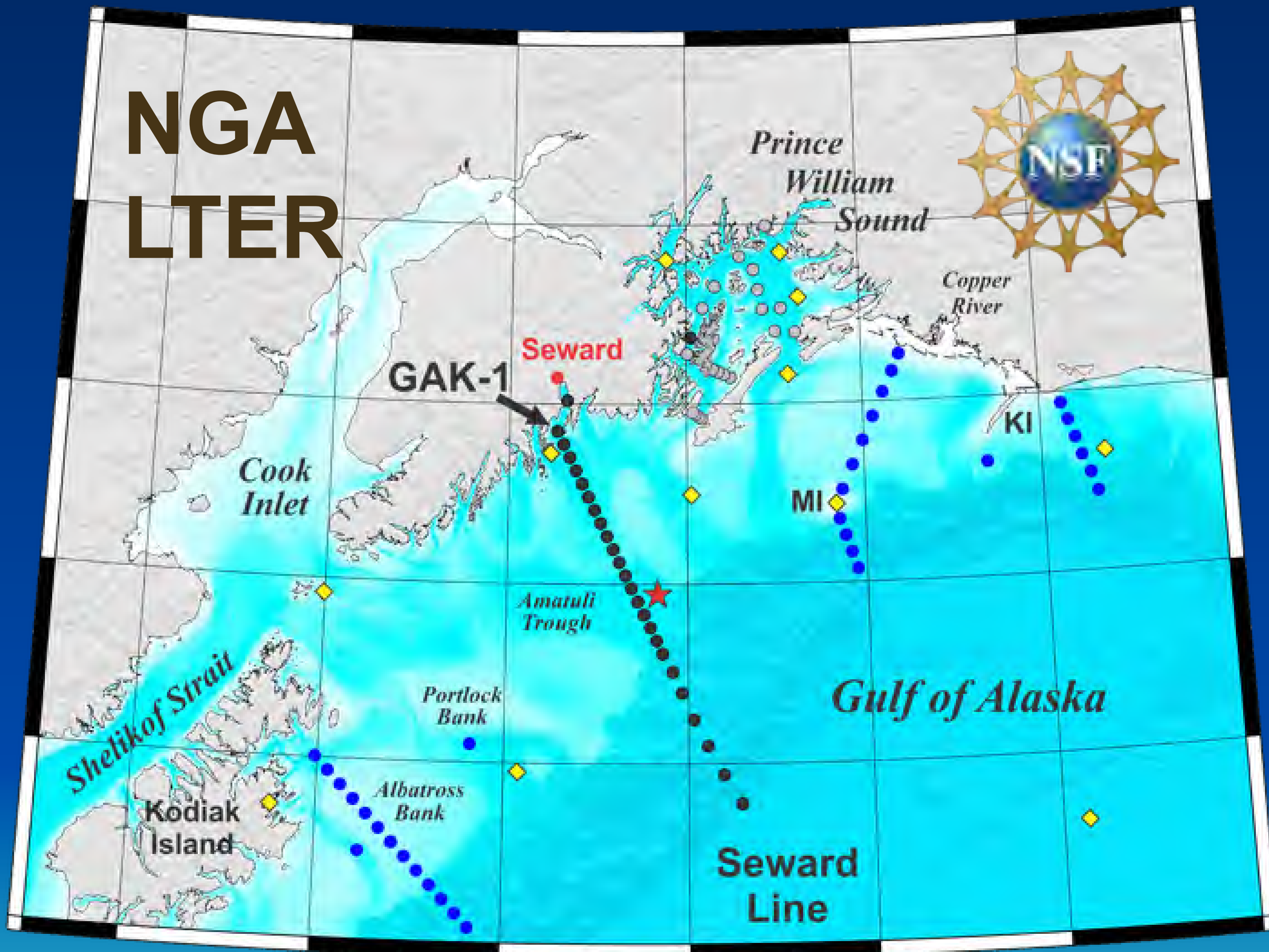
Recent Unusual Plankton Community Events

- Warm water copepods are increasing year-round over the past decade in PWS
- 2011 – Salp blooms
- 2014-2016 – increase frequency/duration of PSP
- 2016 – Doliolid blooms
    - Pseudo-Thecosome pteropods
    - Heteropods (sea elephants) SE Alaska
- 2017 – Pyrosome blooms off Sitka

Summary

- Recent warm year has disrupted spring bloom
- Spring *Neocalanus* communities are resilient to temperature variability and spring bloom timing
- However, extreme high temperatures and low food can impact reproductive output
- Spring communities do not show systematic temperature relationships (as yet)
- Extreme temperature events in recent years are manifested as a displacement in fall community structure, driven by smaller lipid-poor warm-water species
- These shifts will be amplified in future years

The Future



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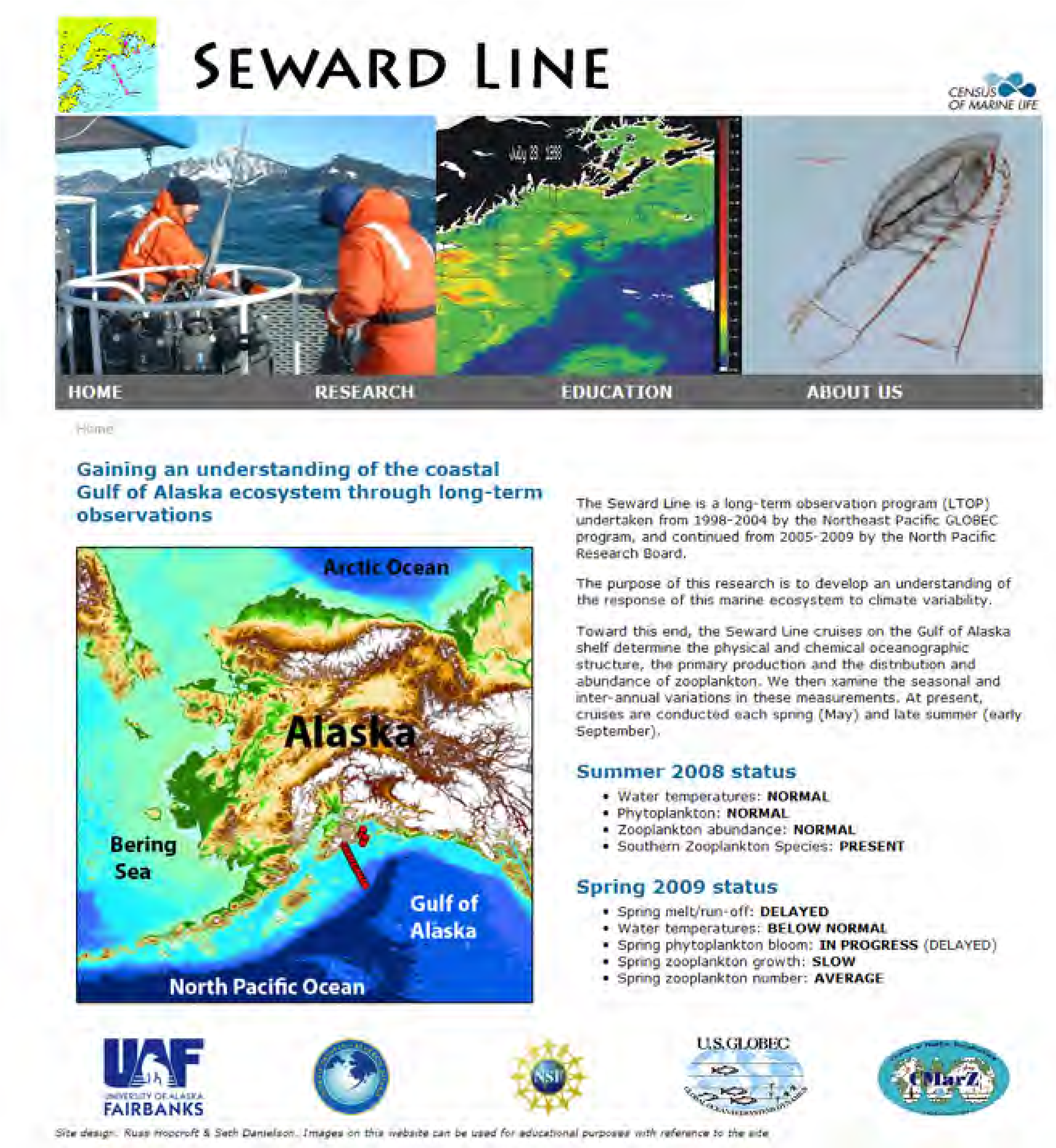
Enhancements

- Longer cruises (2.5-3 wks) – one UNOLS annually
- Expanded domain
- Process studies targetting productive “features”
- Summer cruise (late June/July)
- Mid-shelf heavily-instrumented mooring
- Particle flux / Sedimentation
- *Jellyfish trawl*
- Modelling
- Outreach



Seward Line Website

Contains:

- time-series results
- individual cruises
- information on key species
- content still growing

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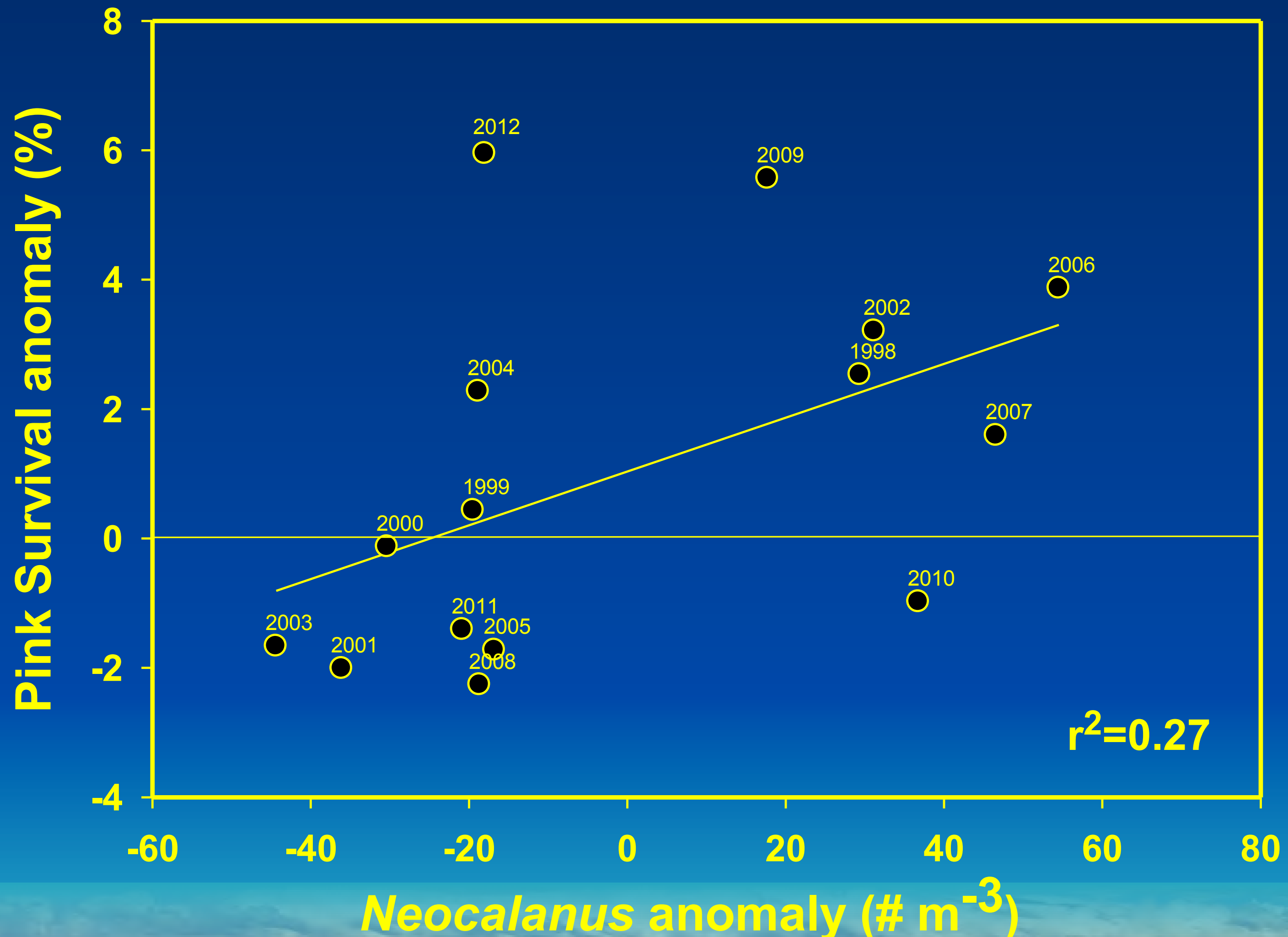
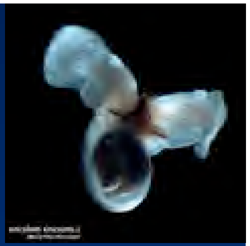
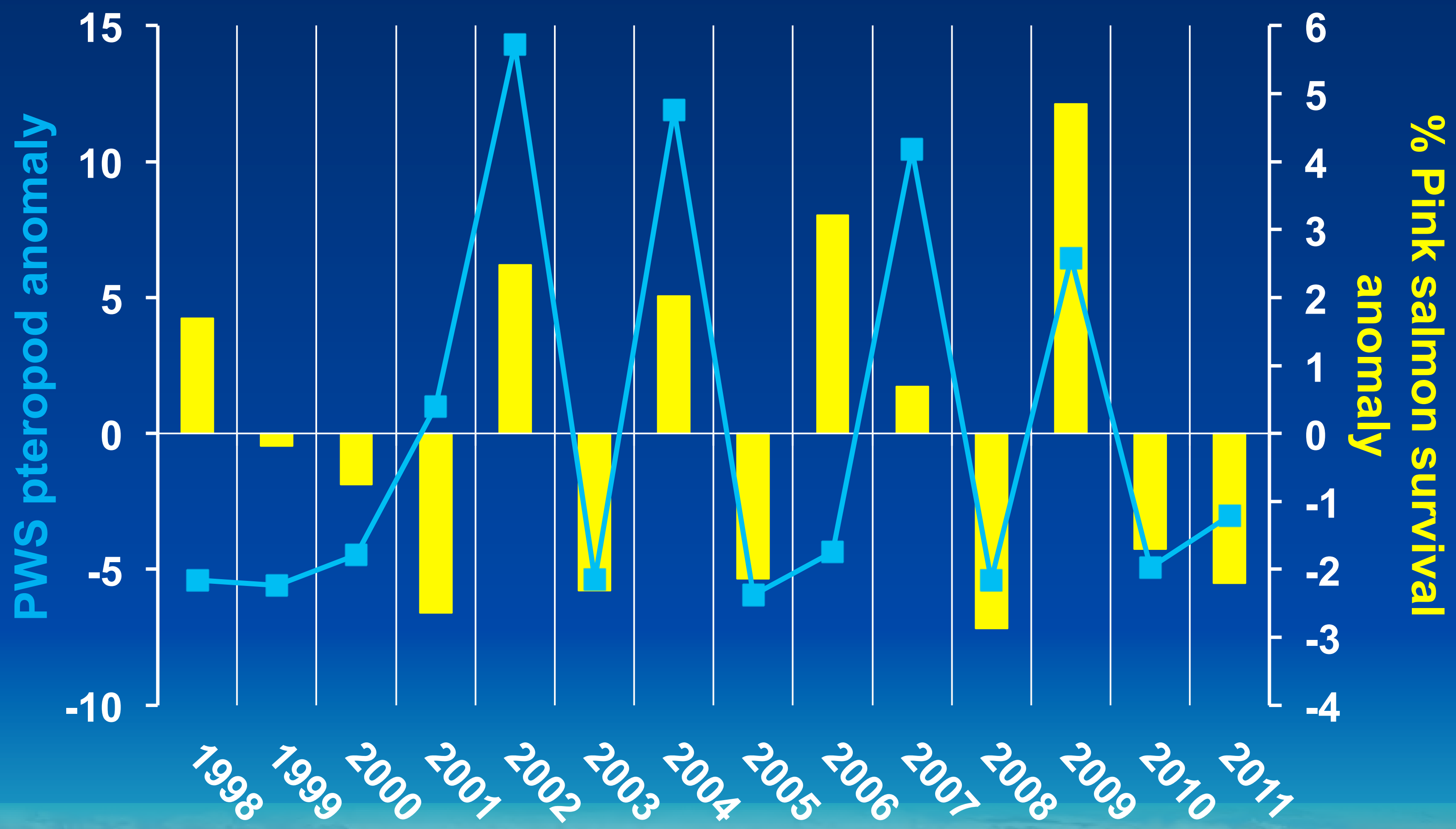
Although temperature drives rates of *Neocalanus* development, it does not explain their overall success on the shelf, however…



Another example: Sea butterflies





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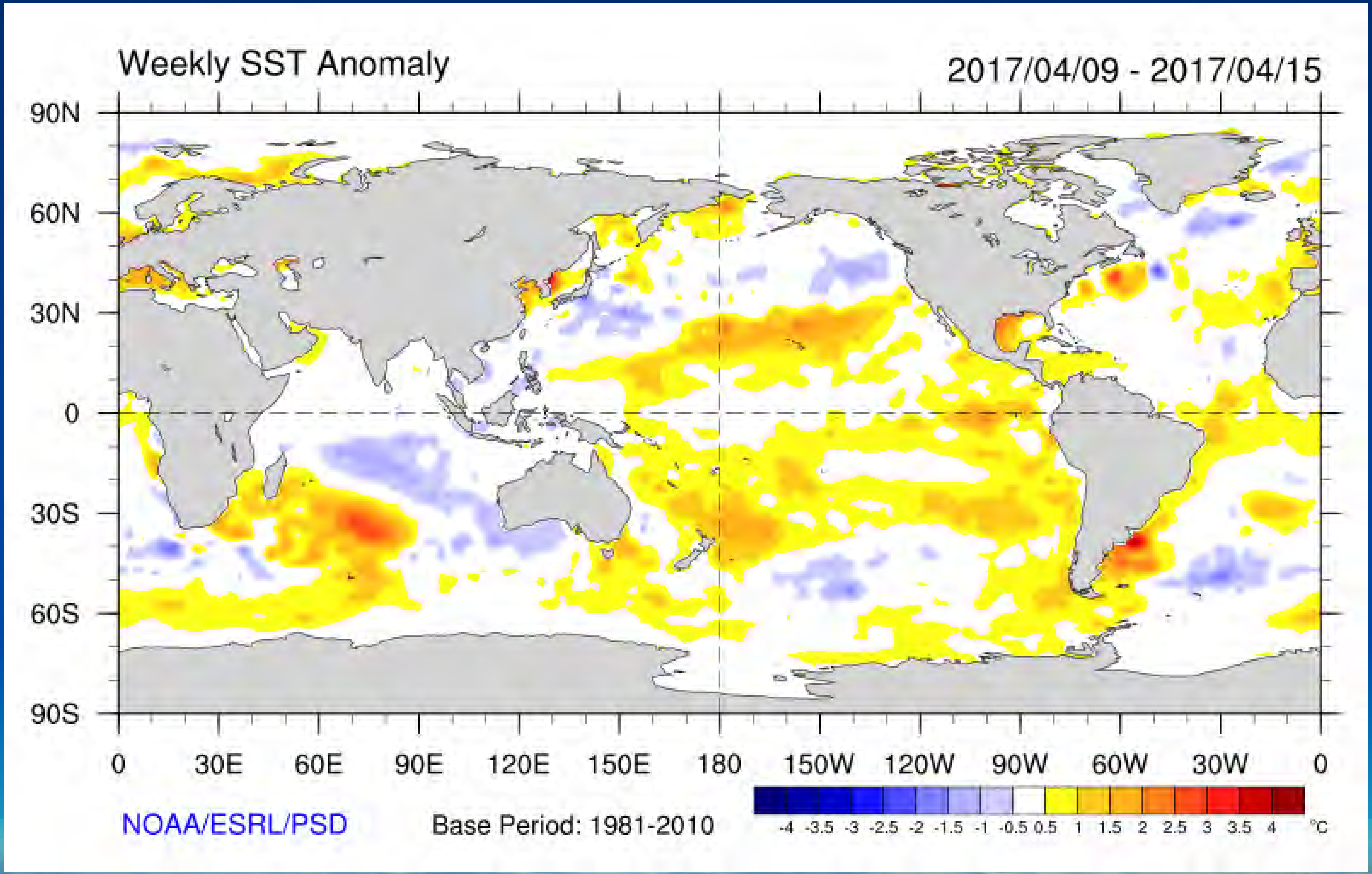
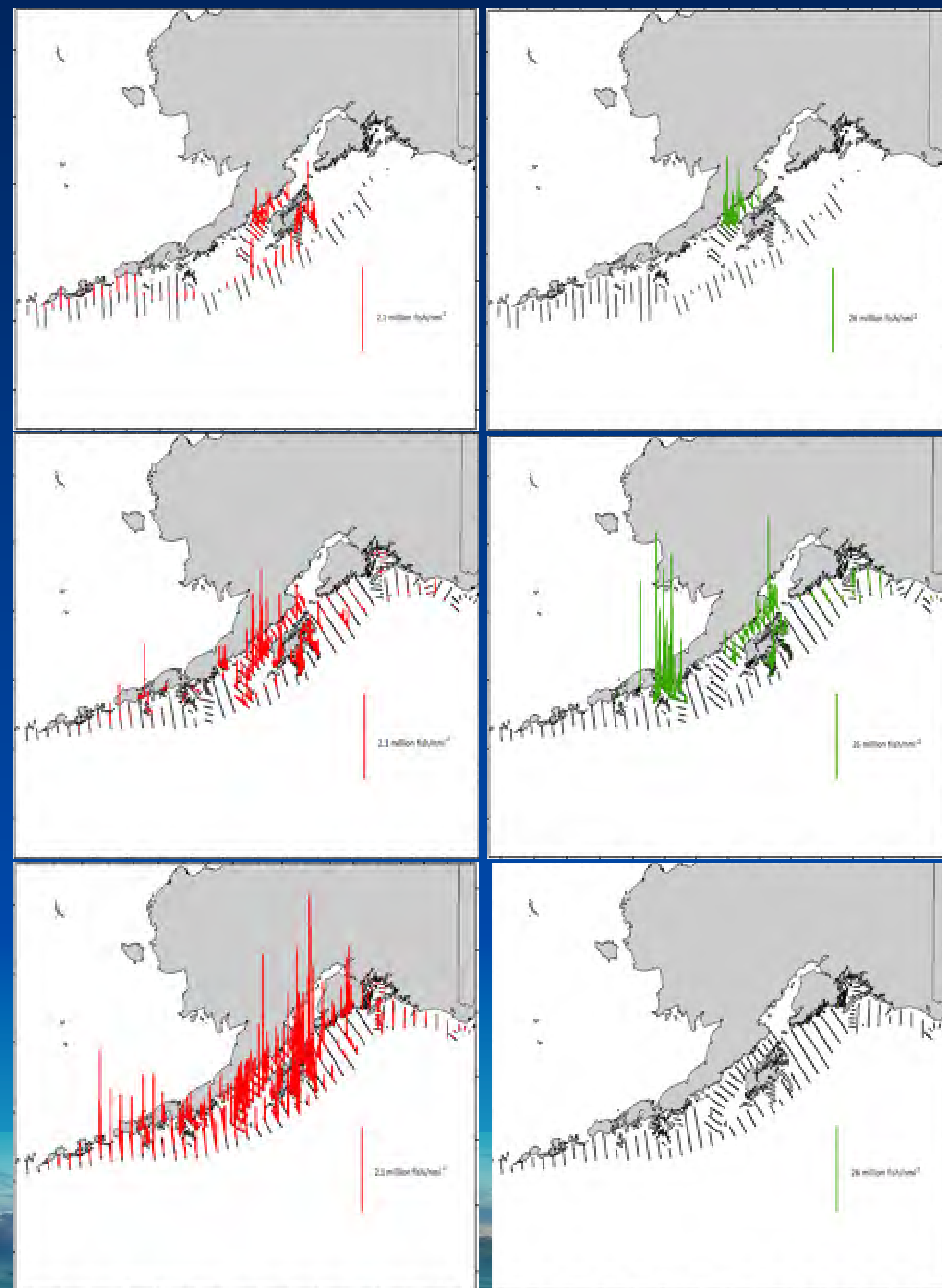
The blob is dead?



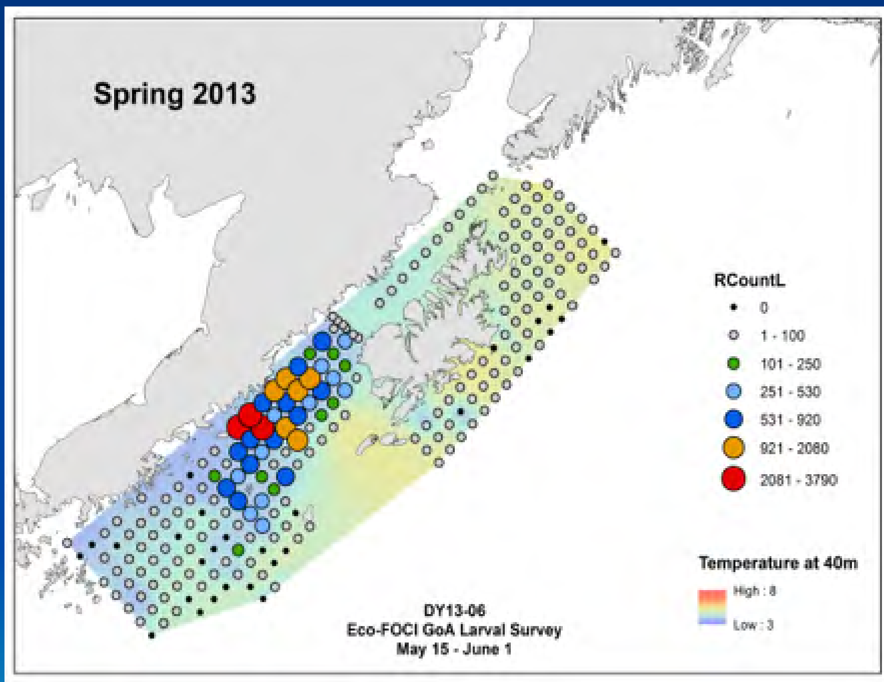
Preliminary Observations of the Impact of Anomalous Ocean Conditions on the Distribution of Marine fish in the Gulf of Alaska and California Current
Hollowed et al.

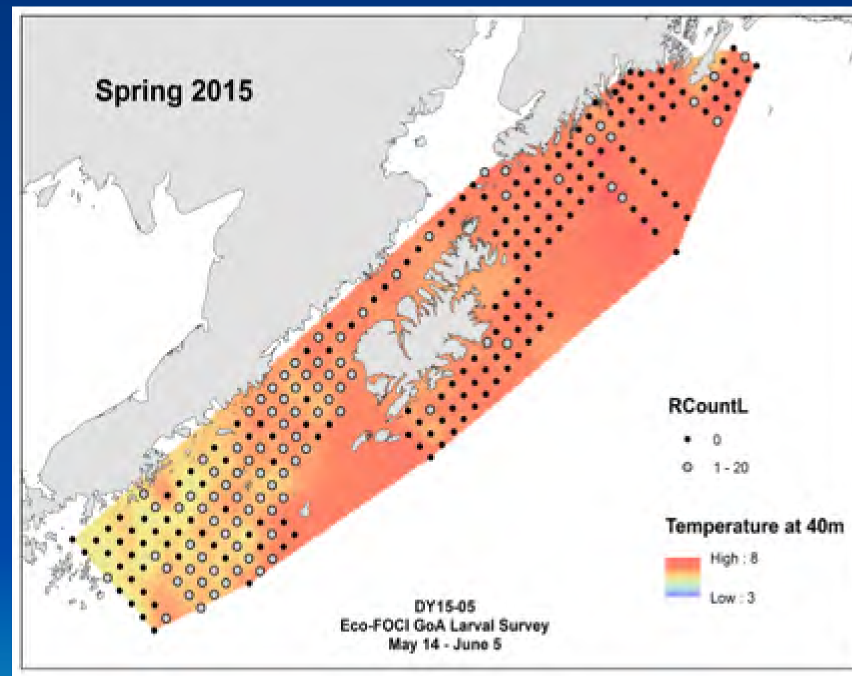


Maps of age 2+ (red) and age 1 (green) pollock density from the 2005 (top), 2013 (middle) and 2015 (bottom) acoustic surveys in the GOA.

Too hot for Pollack larvae in 2015?

Annette Dougherty, EcoFOCI Program

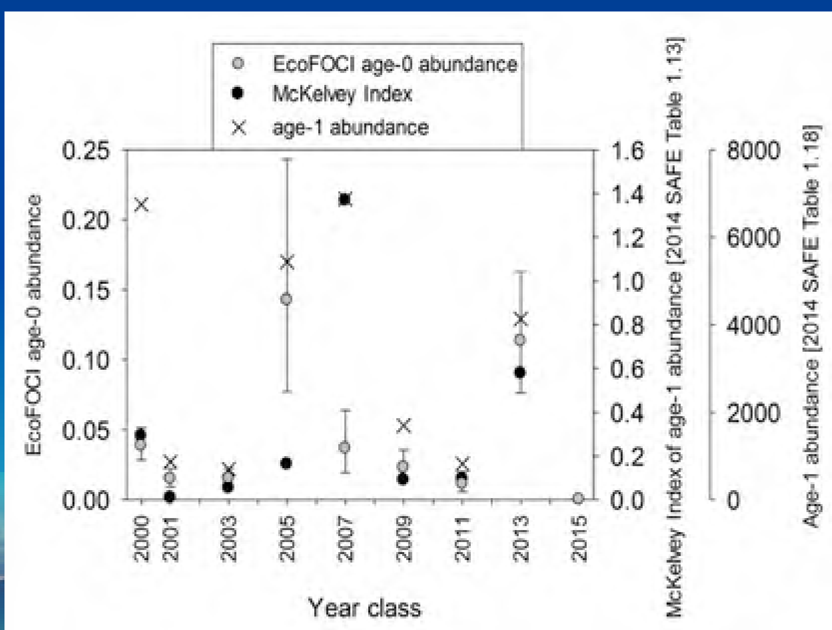


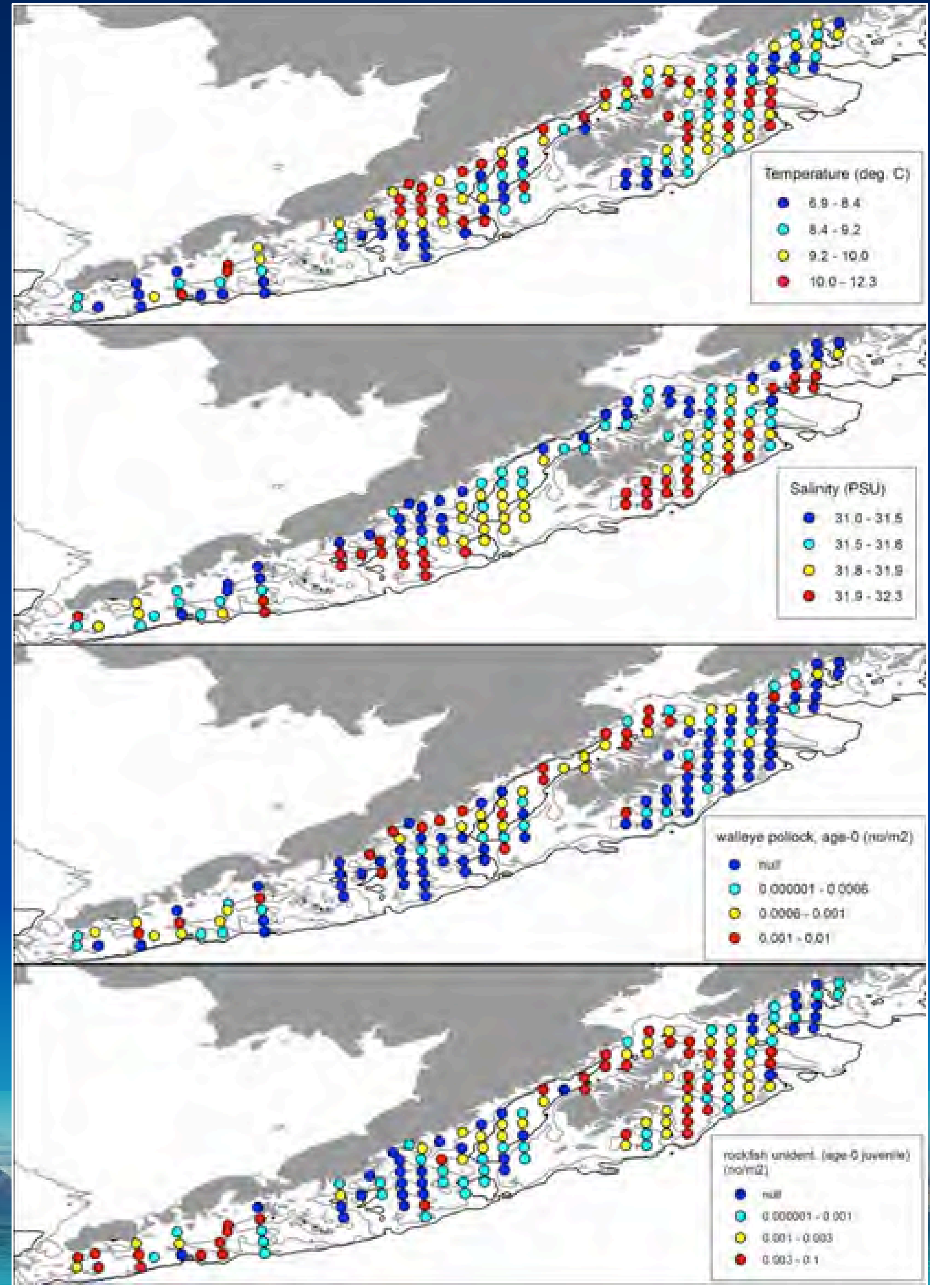


NOAA Fisheries

Age-0 pollock, late summer

M. Wilson, S. Porter, & W. Strasburger, Eco-FOCI






2000 µm
Thysanoessa inermis
Hopcroft/UAf/NOAA/CoML
5000 µm