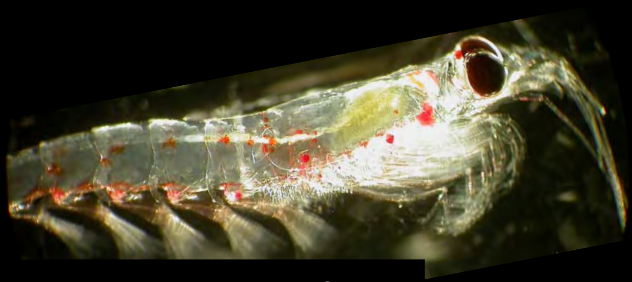
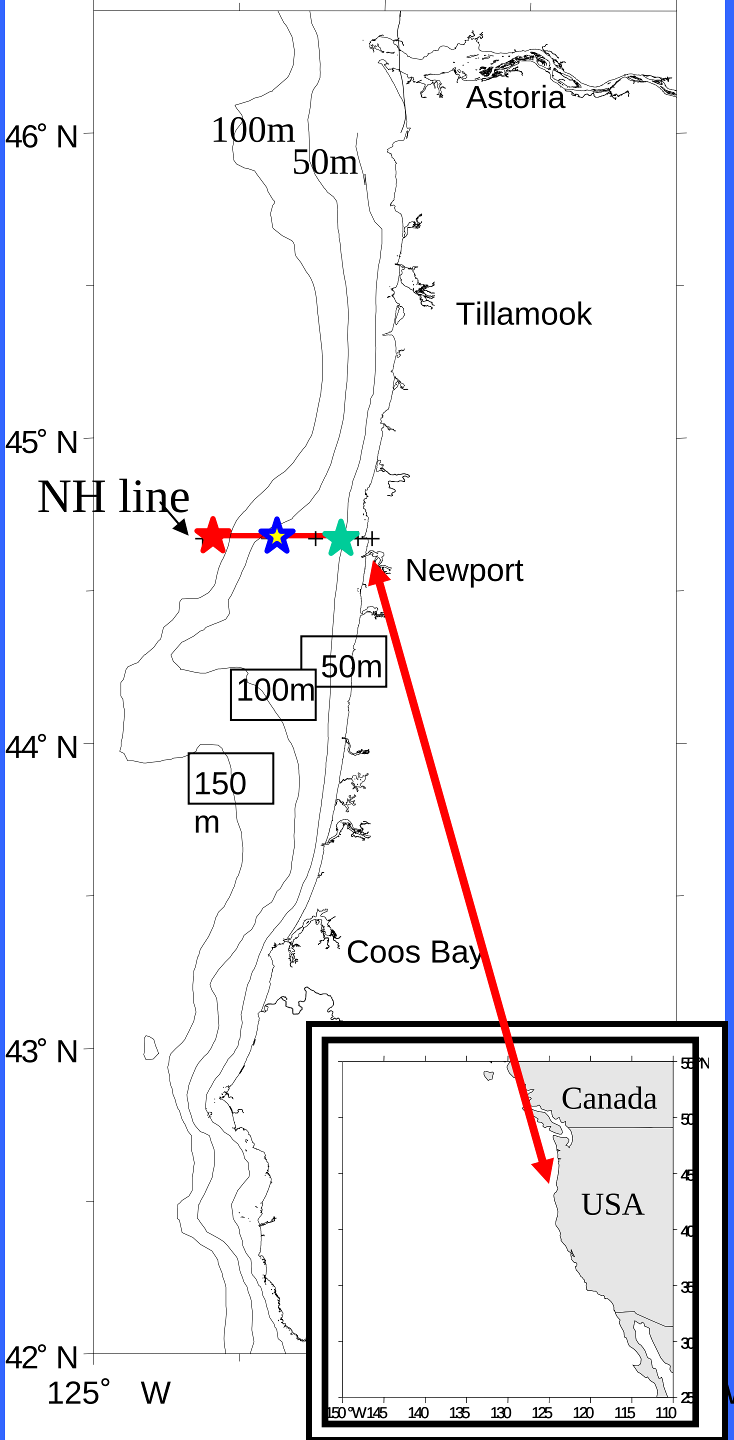
# Possible effects of climate variability on the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* off Newport, OR, USA



*Euphausia pacifica*

*Thysanoessa spinifera*

C. Tracy Shaw, Leah R. Feinberg, and William T. Peterson




# Time series off Newport, OR (NH line)

- Sampled twice per month starting in 1996
- Adult euphausiids sampled with night bongo tows from 2001-present (11 years so far)
- Environmental conditions
  - warm & cold PDO phases
  - timing of spring and fall transition dates
  - duration of upwelling
  - 2002 – anomalously cold due to intrusion of subarctic water

# Target Species

*Euphausia pacifica*

- Generally found at and beyond the shelf break (>200 m depth)
- Intense period of spawning during summer upwelling season
- Present in cool & warm ocean conditions

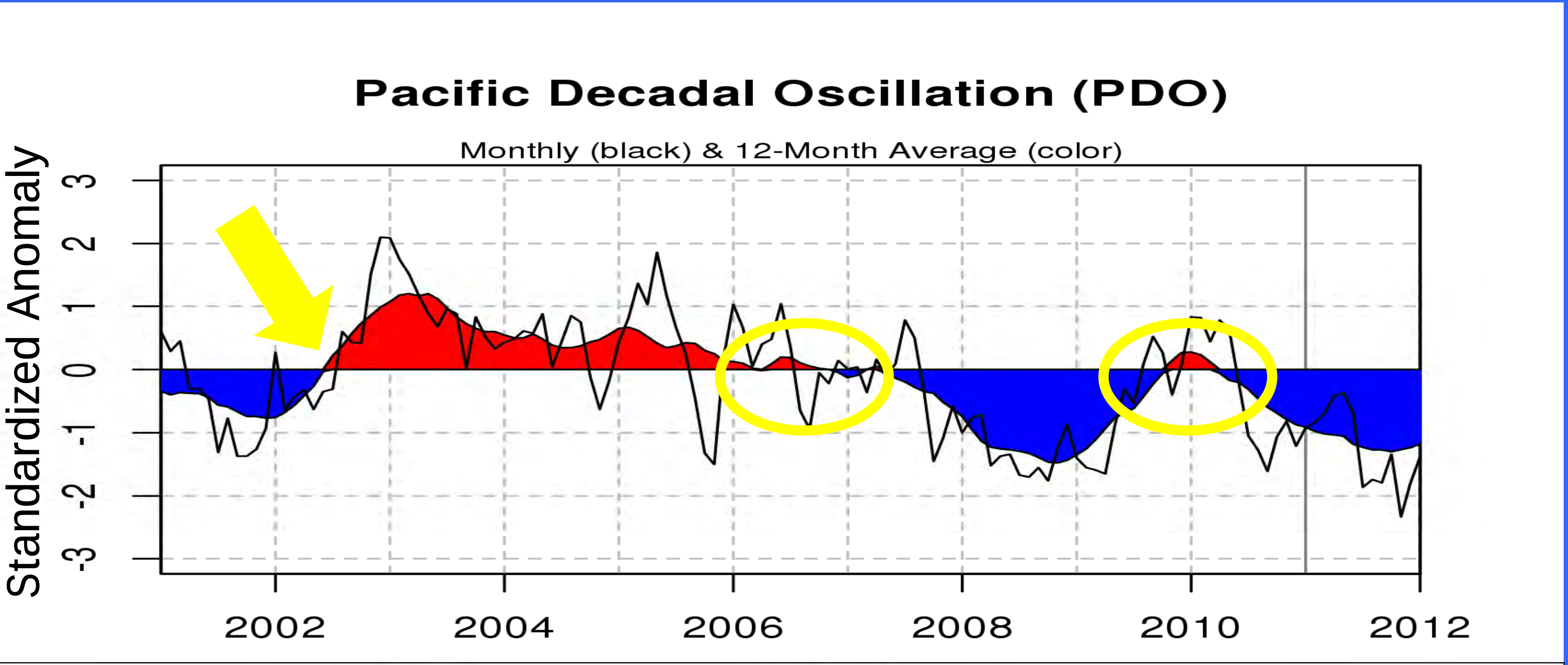
*Thysanoessa spinifera*

- Generally found on the shelf (<200 m depth)
- Spawn before & during upwelling, no intense period
- Prefer cooler ocean conditions

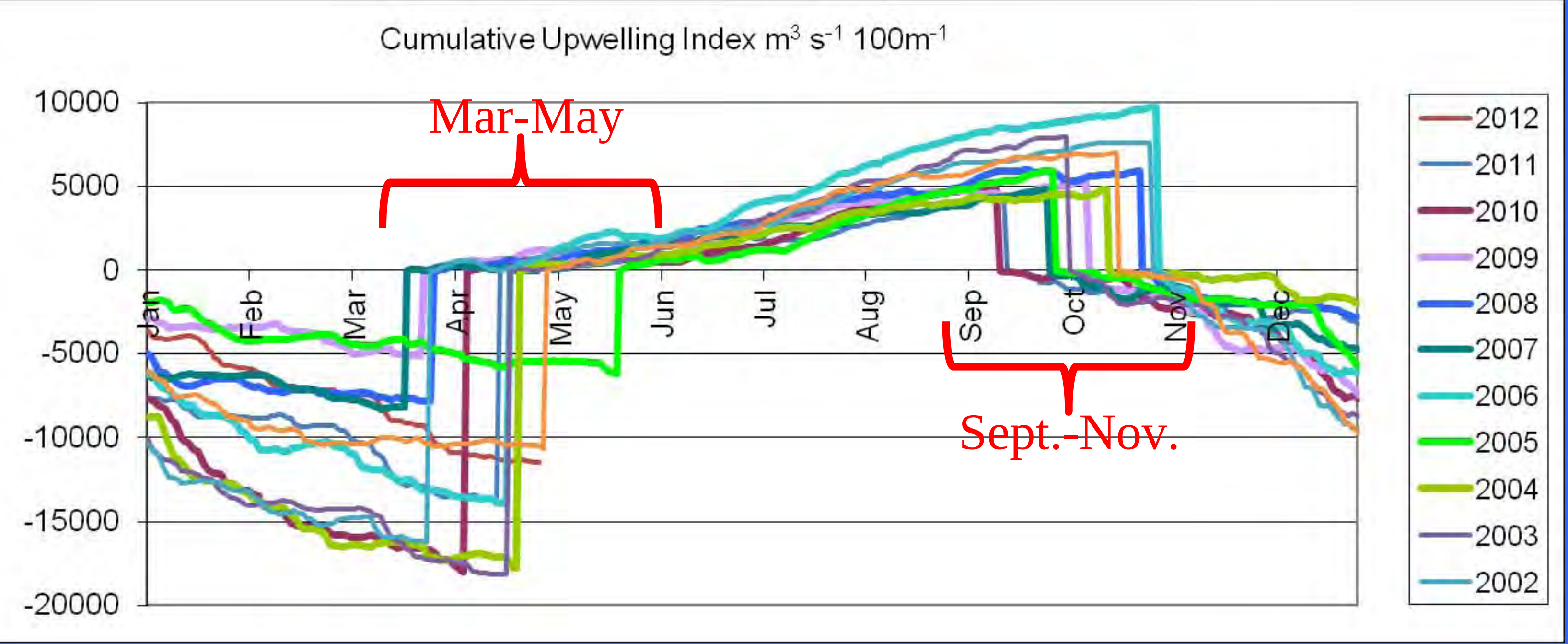
# The Question

Based on their responses to short-term environmental variability, how might krill respond to effects of climate change?

PDO


Pacific Decadal Oscillation (PDO)
Monthly (black) & 12-Month Average (color)
Standardized Anomaly
3
2
1
0
-1
-2
-3
2002
2004
2006
2008
2010
2012

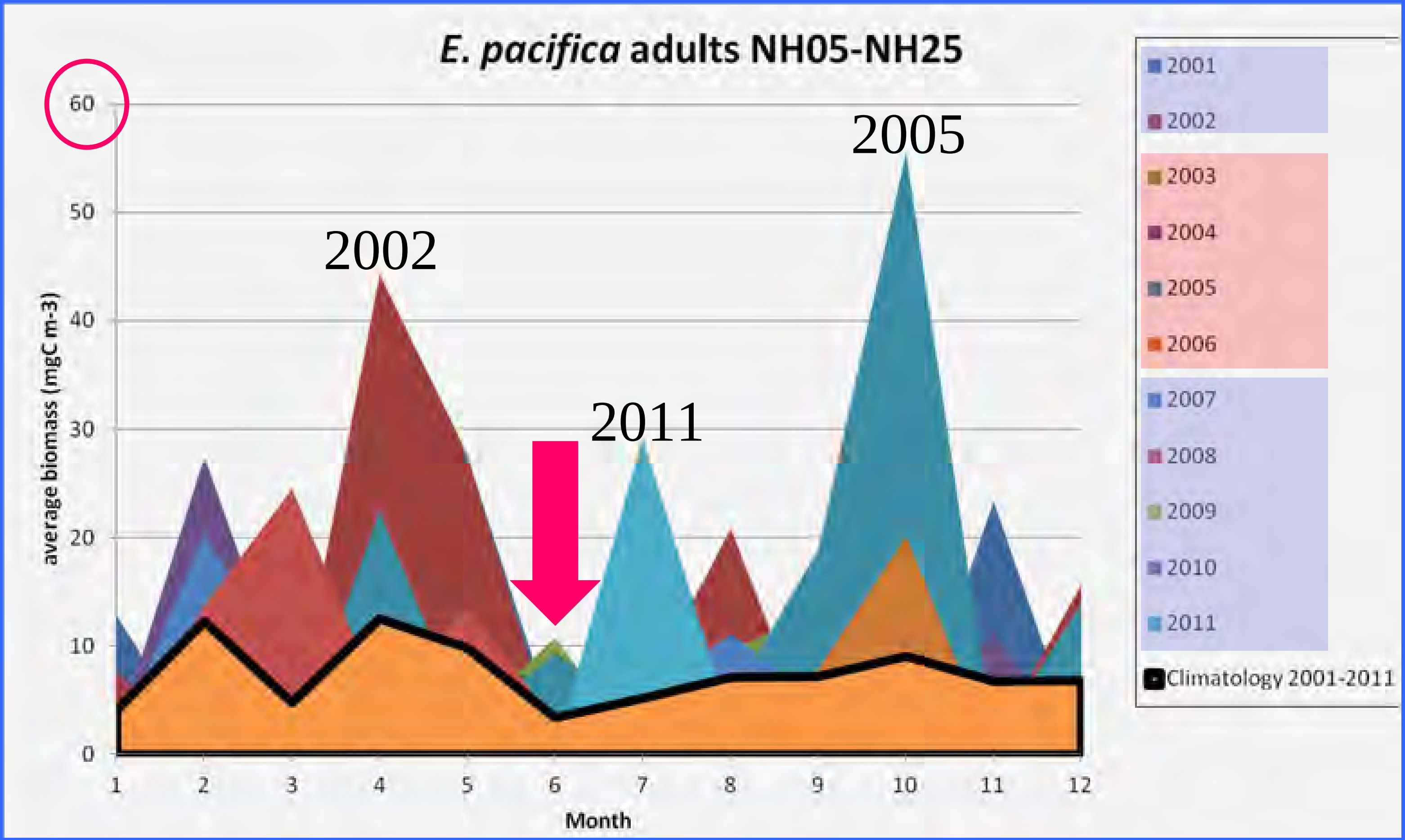
CUI


Cumulative Upwelling Index m3 s-1 100m-1
Mar-May
Sept.-Nov.
10000
5000
0
-5000
-10000
-15000
-20000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2012
2011
2010
2009
2008
2007
2006
2005
2004
2003
2002

# Ocean Conditions

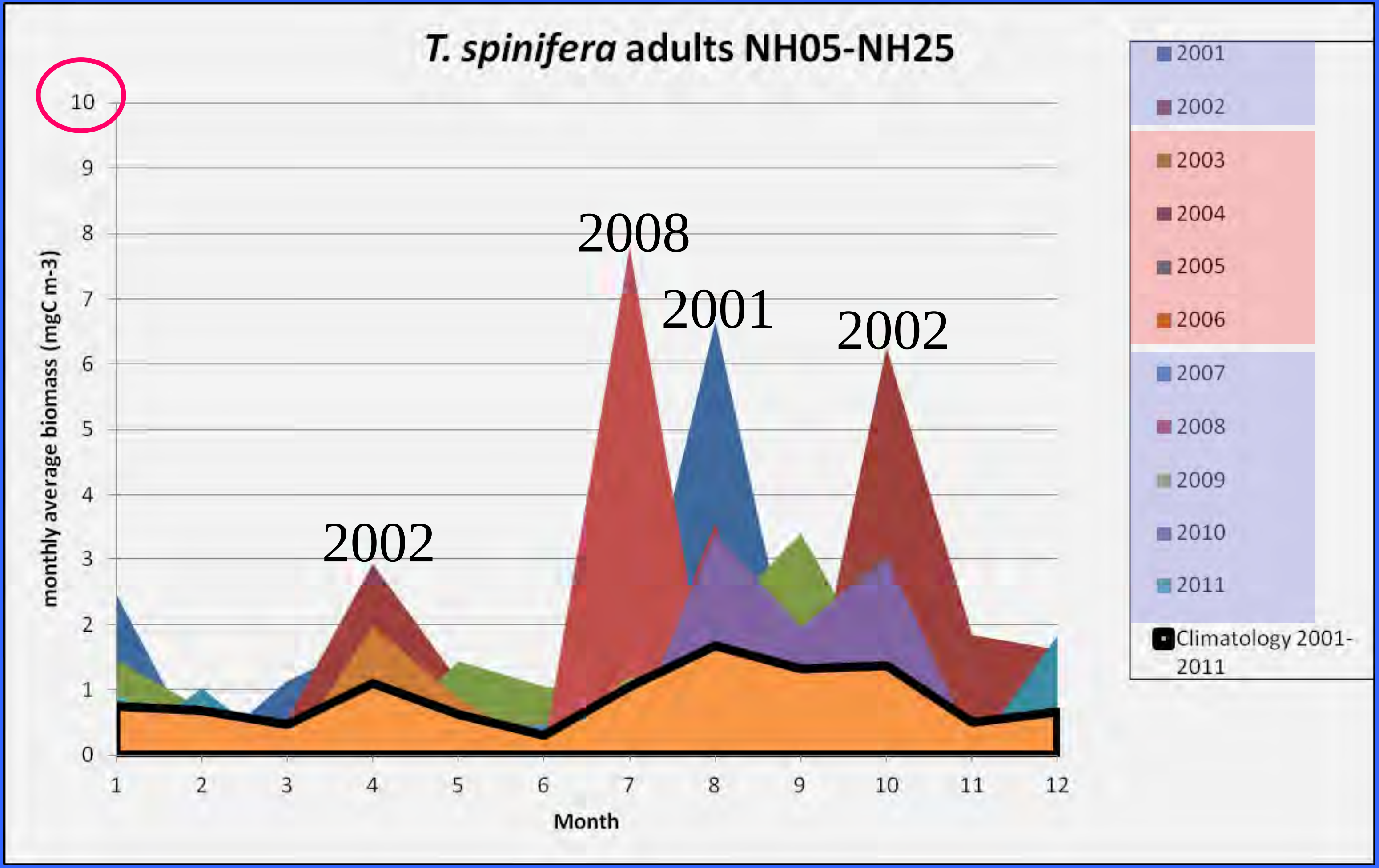
| Year | Spring transition (ST) | Fall transition (FT) | Duration of upwelling (mo) | Ocean temp. (PDO phase) |
|---|---|---|---|---|
| 2001 | 2-Mar | 12-Nov | 8.5 | Cool |
| 2002 | 21-Mar | 6-Nov | 7.7 | Cool |
| 2003 | 22-Apr | 15-Oct | 5.9 | Warm |
| 2004 | 20-Apr | 7-Nov | 6.7 | Warm |
| 2005 | 25-May | 29-Sep | 4.2 | Warm |
| 2006 | 22-Apr | 31-Oct | 6.4 | Warm |
| 2007 | 15-Mar | 27-Sep | 6.5 | Cool |
| 2008 | 30-Mar | 24-Oct | 6.9 | Cool |
| 2009 | 8-Mar | 6-Oct | 7.1 | Cool |
| 2010 | 9-Apr | 13-Oct | 6.2 | Cool |
| 2011 | 31-Mar | 16-Sept | 5.6 | Cool |

# Biomass – *E. pacifica* adults




- Climatology ~10 mgC $m^{-3}$ carbon year-round
- High interannual variability
- Lowest biomass consistently in June
- Always present in all years, high biomass can occur in both cool and warm years

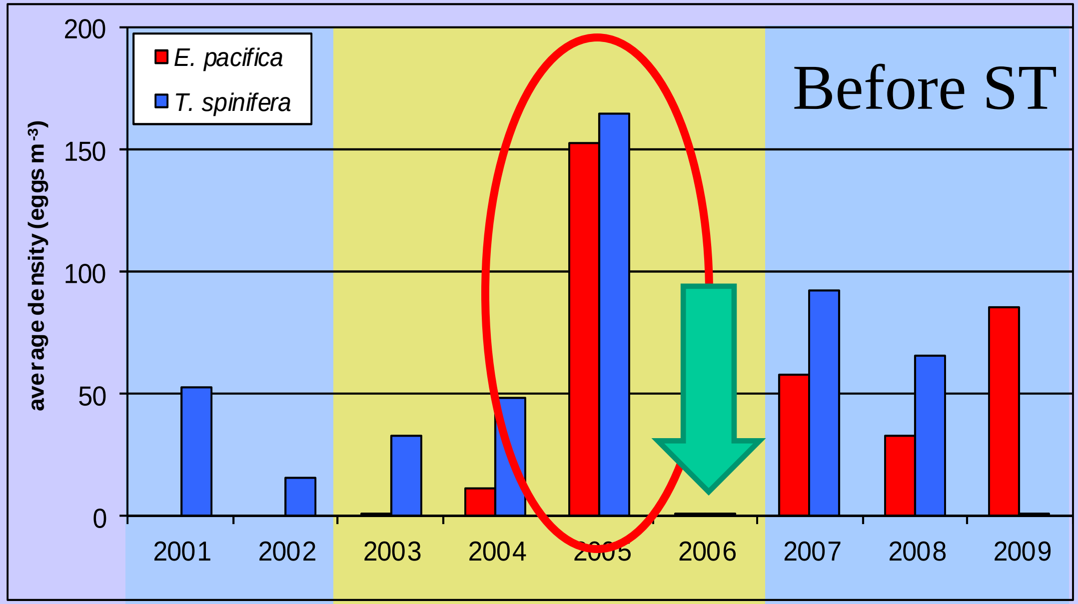
# Biomass – *T. spinifera* adults

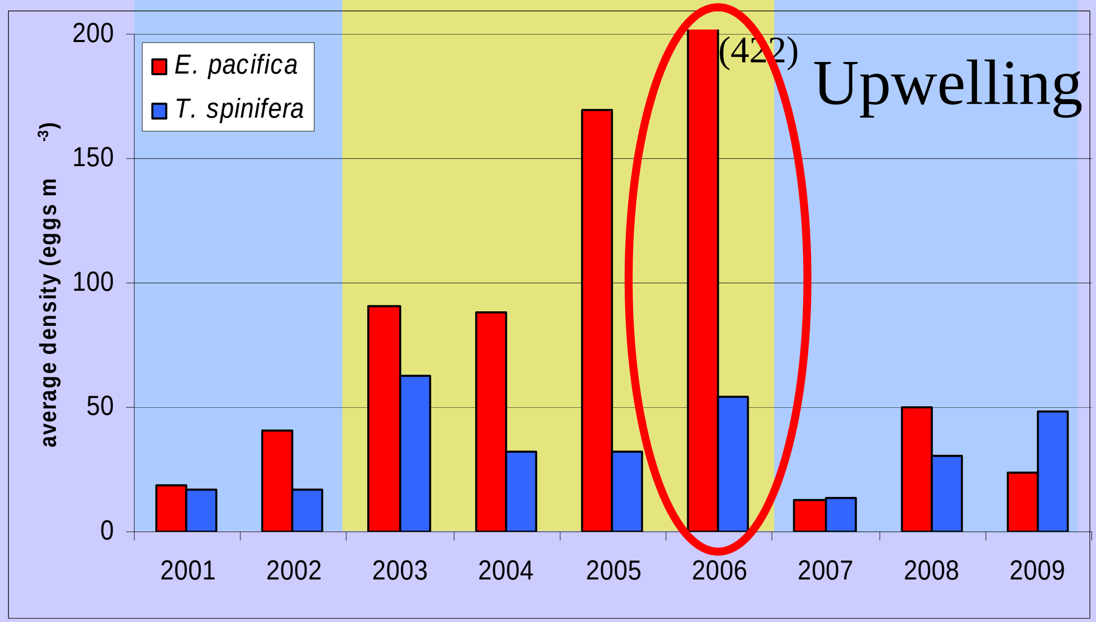



- Climatology ~1 mgC m$^{-3}$ year-round
- High interannual variability
- Higher biomass values occur in cold years
- Rare in warm years

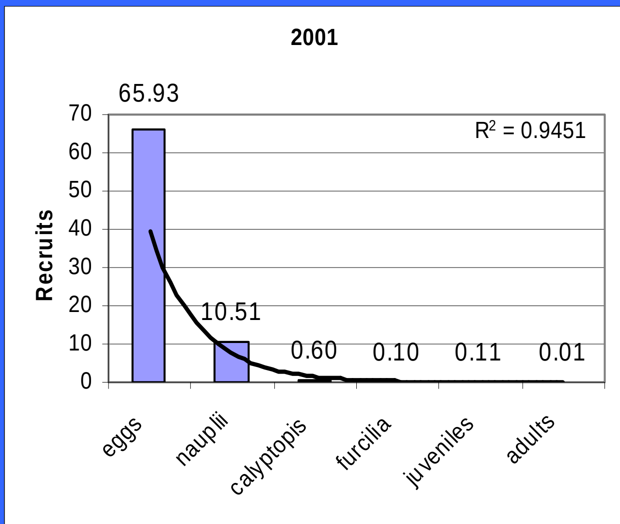
# Egg Densities

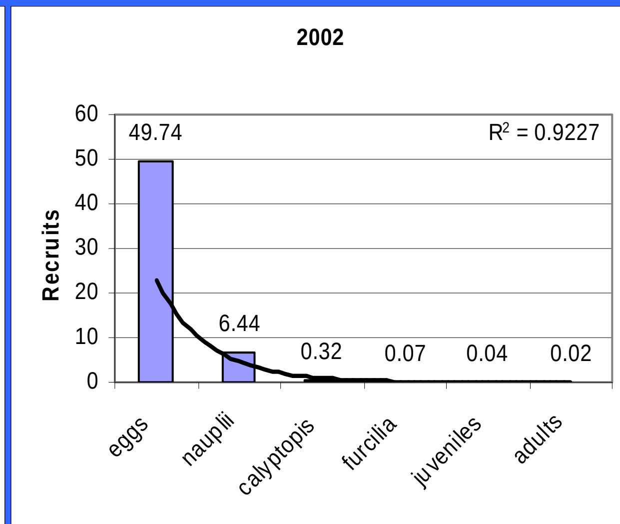
- Before spring transition:
  - Generally more Ts eggs than Ep eggs
  - 2005 high spawning effort by both spp.
  - 2006 no effort at all
- Upwelling:
  - 2006 huge spawning effort by Ep & fairly high for Ts also
  - Ep eggs higher 2003-2006 (warm)
  - Ts eggs always present, generally less abundant than Ep eggs

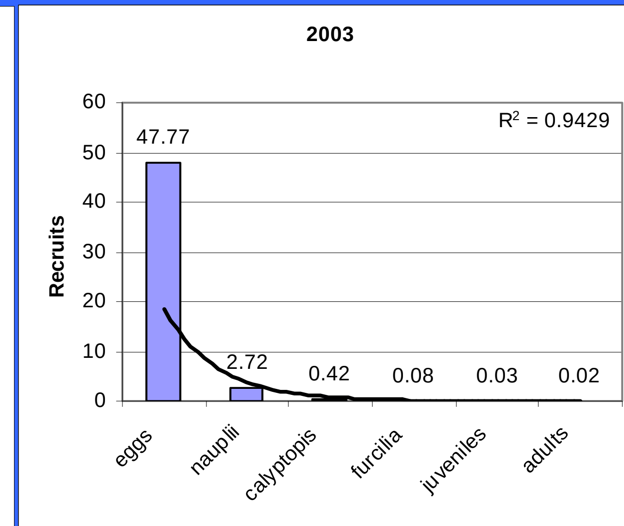


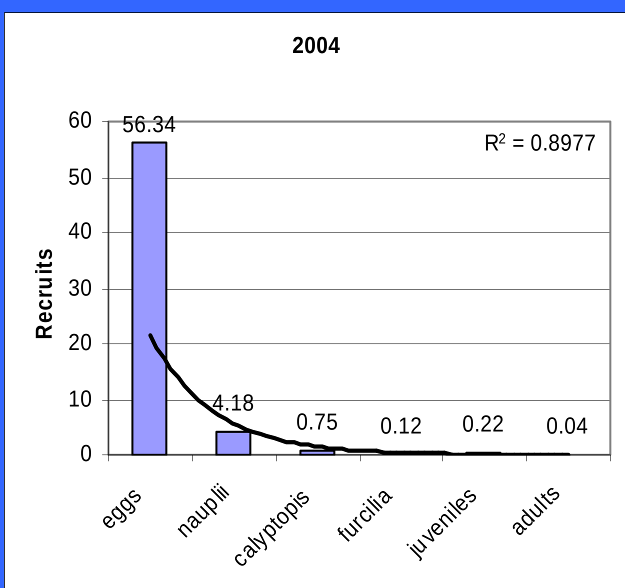



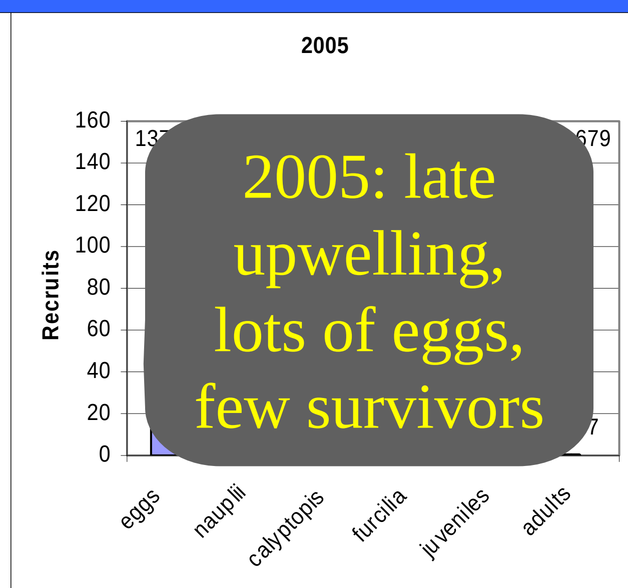
# Survivorship Curves – *E. pacifica*




Annual averages divided by stage duration. (Feinberg et al. 2006)

Similar survivorship cool (2001-2002) and warm (2003-2004) years with 6+ mo. of upwelling. More eggs in warm years, so some warming could have a positive effect.

# Relationship between spring transition and *E. pacifica* spawning

Spring transition → ~4 months → Peak in euphausiid egg density → ~2 months → Juveniles

- Consistent pattern regardless of environmental conditions
- *E. pacifica* spawning behavior is highly dependent on upwelling and the associated phytoplankton blooms
- Changes in upwelling off the Oregon coast are likely to affect *E. pacifica* spawning behavior

# Summary of Environmental Responses

- *E. pacifica* **Mainly influenced by: upwelling**
  - Biomass similar among cool and warm years
  - Spawning closely tied to timing of spring transition and upwelling
  - Late spring transition + short upwelling season = low overwinter survivorship of juveniles
- *T. spinifera* **Mainly influenced by: PDO**
  - Biomass generally low, higher values only in cool years
  - Spawn before & during upwelling, no peak period
  - 2002: Found far offshore in relation to cold conditions

# Species-specific impacts

*Euphausia pacifica*

Spawn in response to upwelling & subsequent phyto bloom

Delayed upwelling = delayed spawning & possible reduced survivorship & recruitment

Lifespan ~2 years.  Two or more years of low recruitment could mean a substantial decline in abundance

Reduced Ep = reduced food supply for some seabirds and commercially important fish

*Thysanoessa spinifera*

Rare or absent during warmer years

Consistently warmer water = change in distribution, further north or offshore to cooler water

Reduced numbers = fewer krill spawning on shelf and possibility of  lower recruitment

Important food source for some nesting seabirds since usually found closer to shore. Longer foraging trips = reduced fledging success.

# Bering Sea – sea ice dependent


- Oceanic
- Mainly carnivorous
- Spawning – not well known in Bering Sea, April-May in other areas

- Outer shelf & Shelf break
- Omnivorous
- Store energy over the winter to fuel reproduction in early spring
- Short spawning season

- Shelf
- Mainly herbivorous
- Spawn later in spring based on ambient food supply
- Prolonged spawning season (depending on available food)

Change their distribution in relation to temperature (Pinchuk & Coyle 2008)

# Things we wish we knew...

- How quickly can krill adapt to increasing temperatures?
- Are there multi-year effects? How might a longer series of warm or cold years affect krill that live for 2+ years?
- How will changes in ocean conditions affect availability and abundance of preferred food sources?
  - What are the preferred prey items for these species?
  - How well might krill adapt to a different prey field?
- Mortality rates? How can we tell if the rates change in relation to environmental conditions if we don't know what they are now?
- Will increased numbers of jellyfish eat all the krill eggs?
- Given that different species of krill in the same ecosystem respond differently to changes in the environment, how feasible is it to incorporate species-specific krill responses into models?

# Acknowledgements


- Research vessels: *R/V Sacajawea, R/V Elakha, R/V Wecoma, R/V Atlantis, R/V Frosti, R/V Miller Freeman, R/V McArthur II, R/V New Horizon, FSV Bell M. Shimada*

- Funding sources: NOAA/NWFSC, ONR/NOPP, NSF/CoOP/COAST, NOAA-GLOBEC, NSF/CoOP/RISE, NOAA-SAIP

Thanks for help with experiments: Julie Keister, Mitch Vance, Jaime Gómez-Gutiérrez, Rian Hooff, Jesse Lamb, Jennifer Menkel, Jay Peterson.


# Euphausiid Live Work Protocol

Protocols for Measuring Molting Rate and Egg Production of Live Euphausiids

Courtesy of the Peterson Lab at Hatfield Marine Science Center, Newport, Oregon, USA

Tracy Shaw
2030 S. Marine Science Dr.
Newport, OR 97365
tracy.shaw@noaa.gov

Leah Feinberg
2030 S. Marine Science Dr.
Newport, OR 97365
leah.feinberg@noaa.gov

Bill Peterson
2030 S. Marine Science Dr.
Newport, OR 97365
bill.peterson@noaa.gov

- Everything you always wanted to know about working with live euphausiids!
- Available on the PICES website! (www.pices.int) under the “Projects” heading