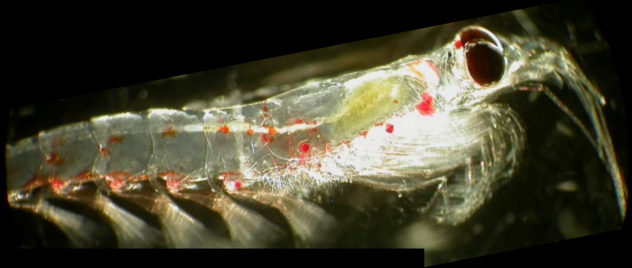
Population dynamics of the euphausiids *Euphausia pacifica, Thysanoessa spinifera, and T. inspinata* off of Newport, Oregon, USA

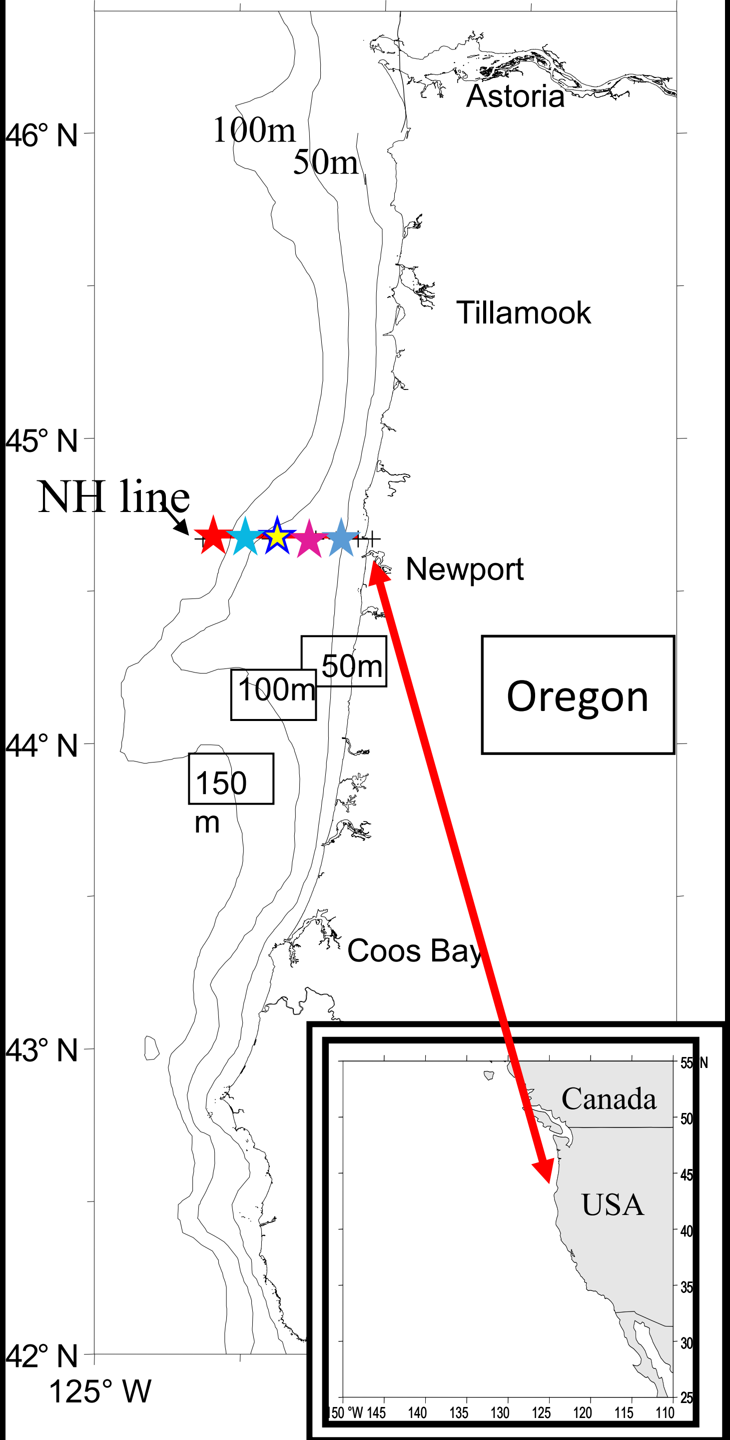


Euphausia pacifica

Thysanoessa spinifera

Thysanoessa inspinata

C. Tracy Shaw, Jennifer L. Fisher, and William T. Peterson



Newport Line (NH) Time Series

- Night bongo net samples for adult euphausiids from 2001- present
- Stations: distances offshore & depths
  - NH05 – 8 km, depth 60m
  - NH10 – 16 km, depth 80m
  - NH15 – 25 km, depth 90m
  - NH20 – 32 km, depth 140m
  - NH25 – 40 km, depth 296m
- Data for this presentation:
  - 2001-2016, stations NH05-25
- All euphausiids identified and measured by me ☺

Meet the krill of the Oregon coast

Euphausia pacifica

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

Thysanoessa spinifera

- Found across the shelf, less abundant during warm ocean conditions
- Spawn before & during upwelling, no intense spawning season
- Prefer cooler ocean conditions

Thysanoessa inspinata

- Low abundance, found across the shelf, mainly offshore (140-296m)
- Abundance too low to determine timing of spawning
- Present during cool & warm ocean conditions

What we know for sure about euphausiids

1) Their distribution is notoriously patchy
2) They are highly variable ☺

I think the warmer water makes a nice change

You're crazy! Cold water is the best!

Environmental Conditions

Cold water on shelf
Long upwelling season

Late upwelling
Short upwelling season

El Nino winter 2009-10

Late upwelling
Short upwelling season

Warm Blob

Warm Blob

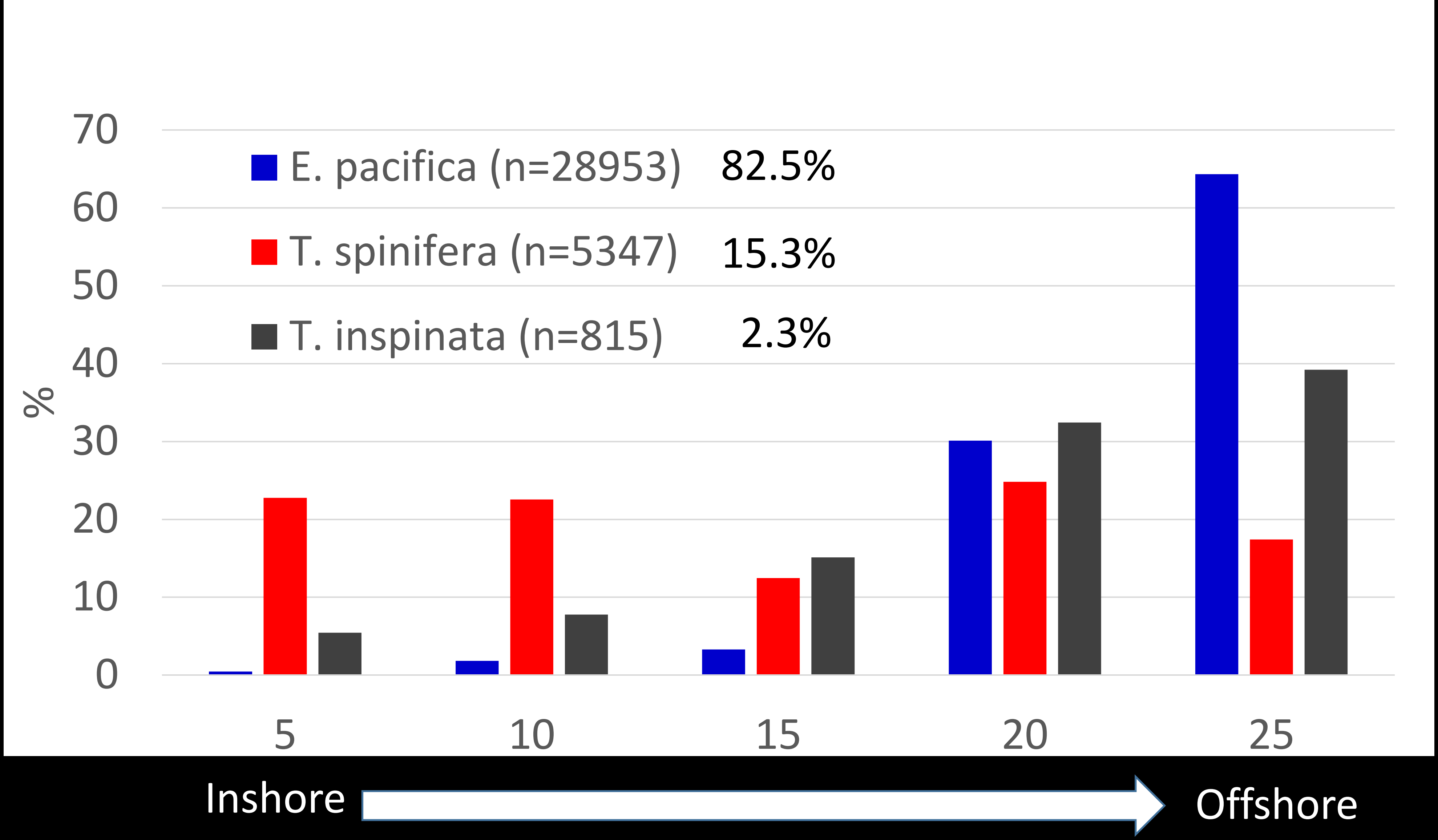
Warm Blob

Year	Spring transition (ST)	Fall transition (FT)	Upwelling (months)	PDO phase	Unusual Conditions
2001	1-May	7-Oct	5.3	Cool	
2002	17-Apr	4-Nov	6.7	Cool	cold water on shelf
2003	20-Apr	26-Sep	5.3	Warm	
2004	21-Apr	21-Aug	4.1	Warm	
2005	22-May	29-Sep	4.3	Warm	late onset of upwelling
2006	20-Apr	31-Oct	6.5	Warm	
2007	27-Apr	28-Sep	5.1	Cool	
2008	29-Apr	15-Sep	4.6	Cool	
2009	14-May	11-Oct	5.0	Cool	El Niño - winter 2009-2010
2010	10-Jun	14-Sep	3.2	Cool	late upwelling, strong La Niña
2011	16-Apr	11-Sep	4.9	Cool	
2012	4-May	7-Oct	5.2	Cool	
2013	7-Apr	22-Aug	4.6	Cool	
2014	10-May	20-Sep	4.4	Warm	Blob arrives on 14-Sept
2015	11-Apr	1-Oct	5.8	Warm	Warm Blob
2016	27-Mar	29-Sep	6.2	Warm	Warm Blob

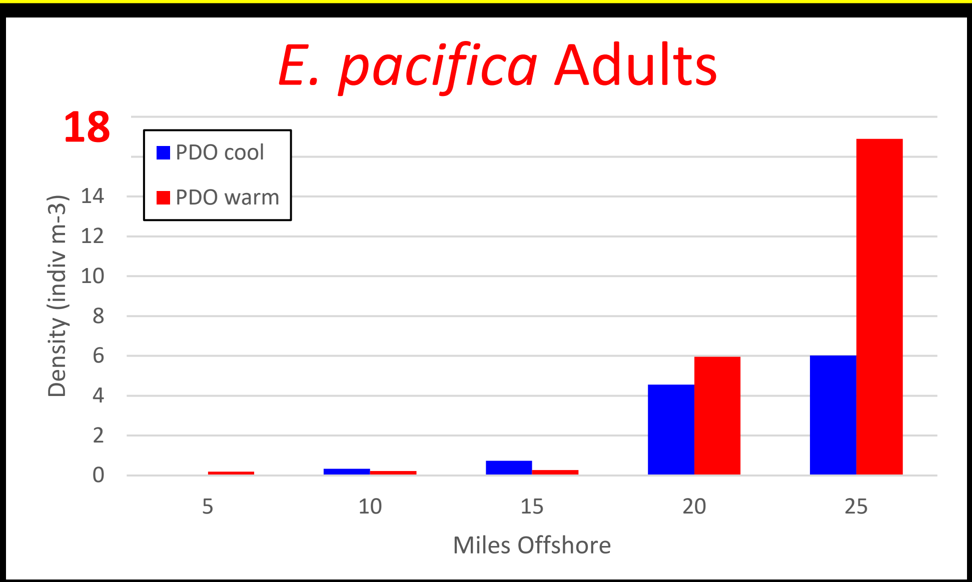
Physical Transition dates: http://damp.coas.oregonstate.edu/windstress/allyears.html

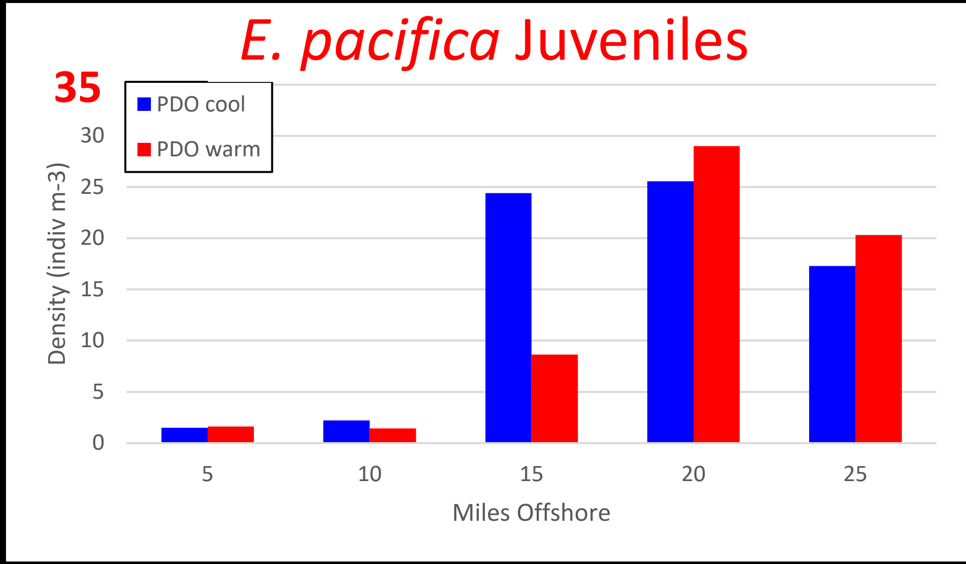
Cross-shelf density 2001-2016

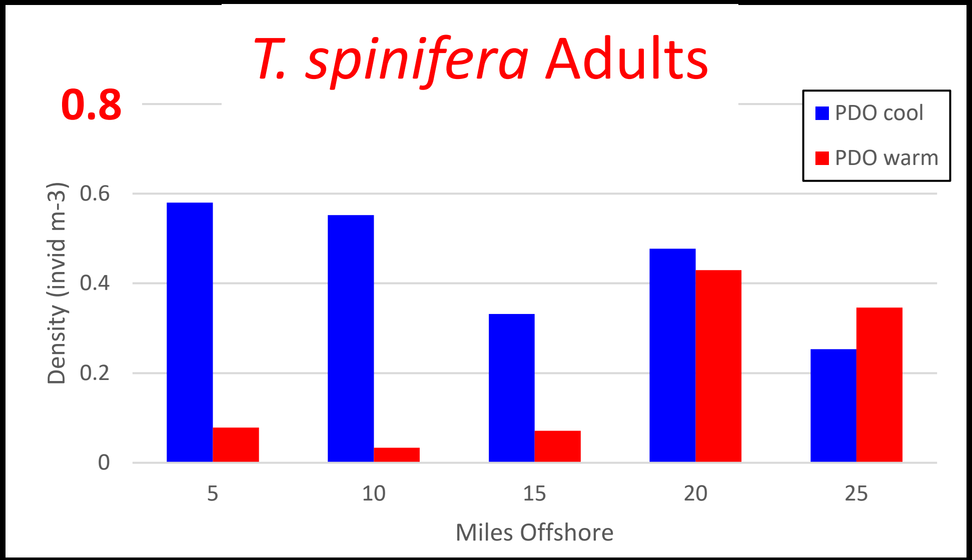
(all species combined – Ep and Ts adults, Ti all)

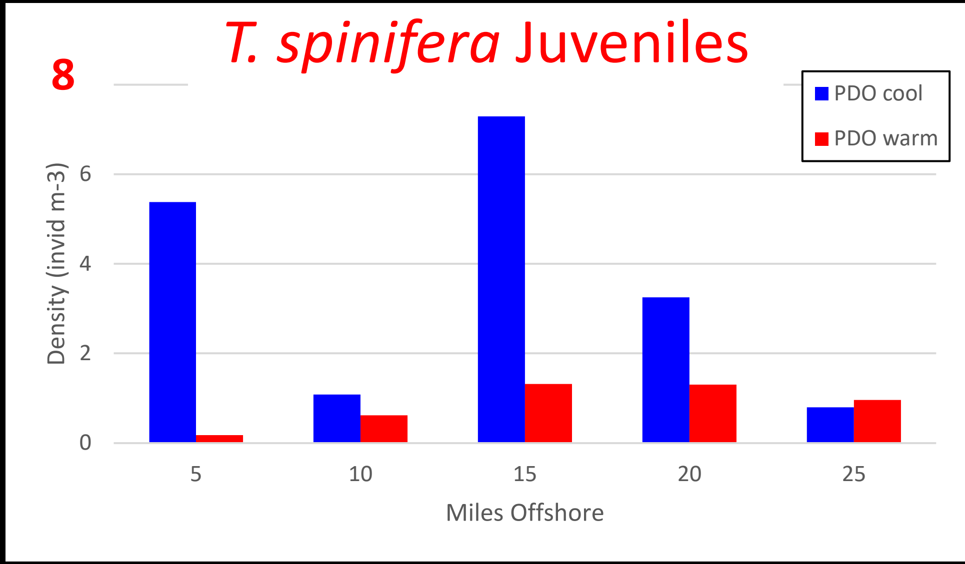


Cross-shelf Density

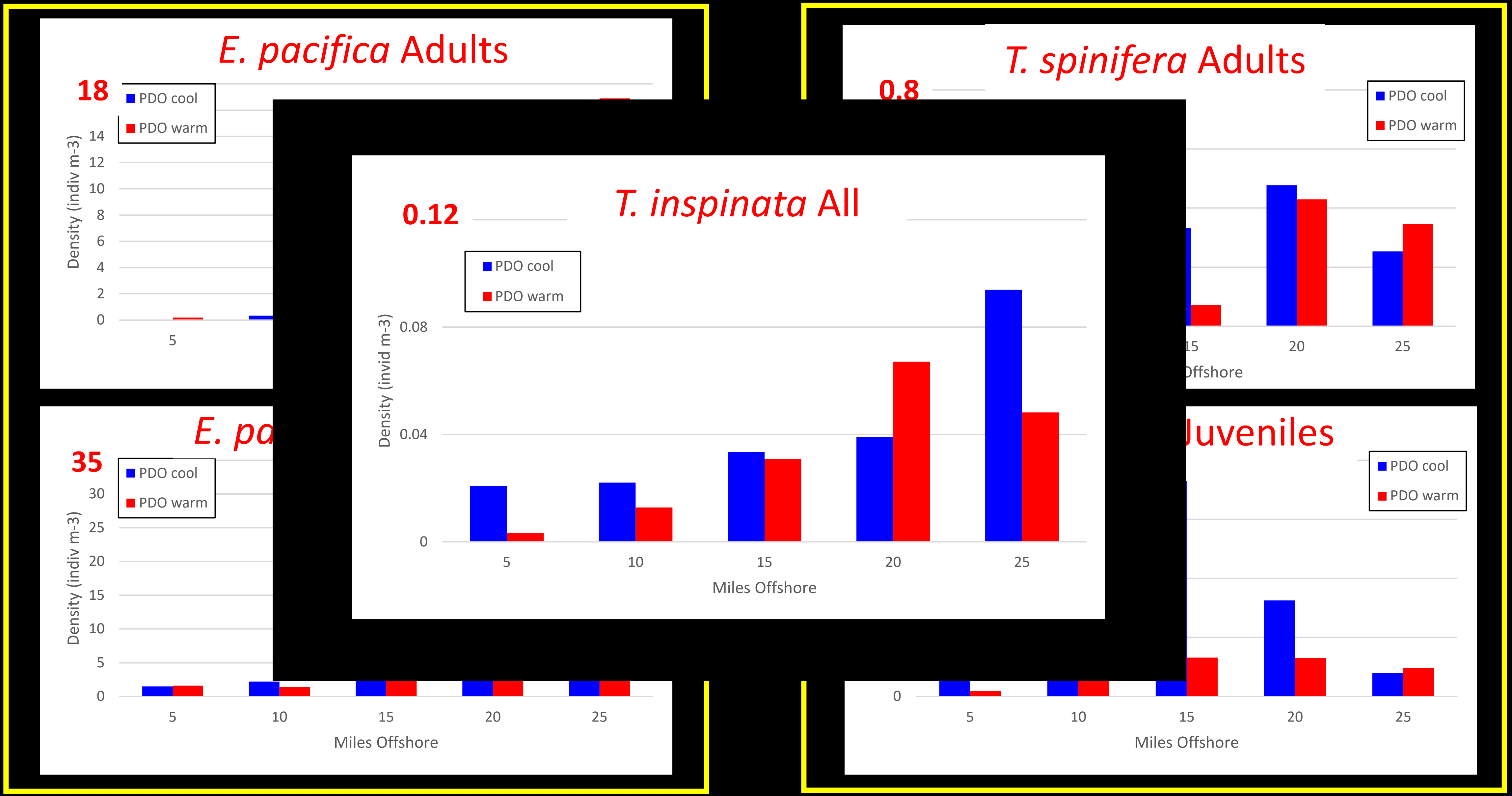




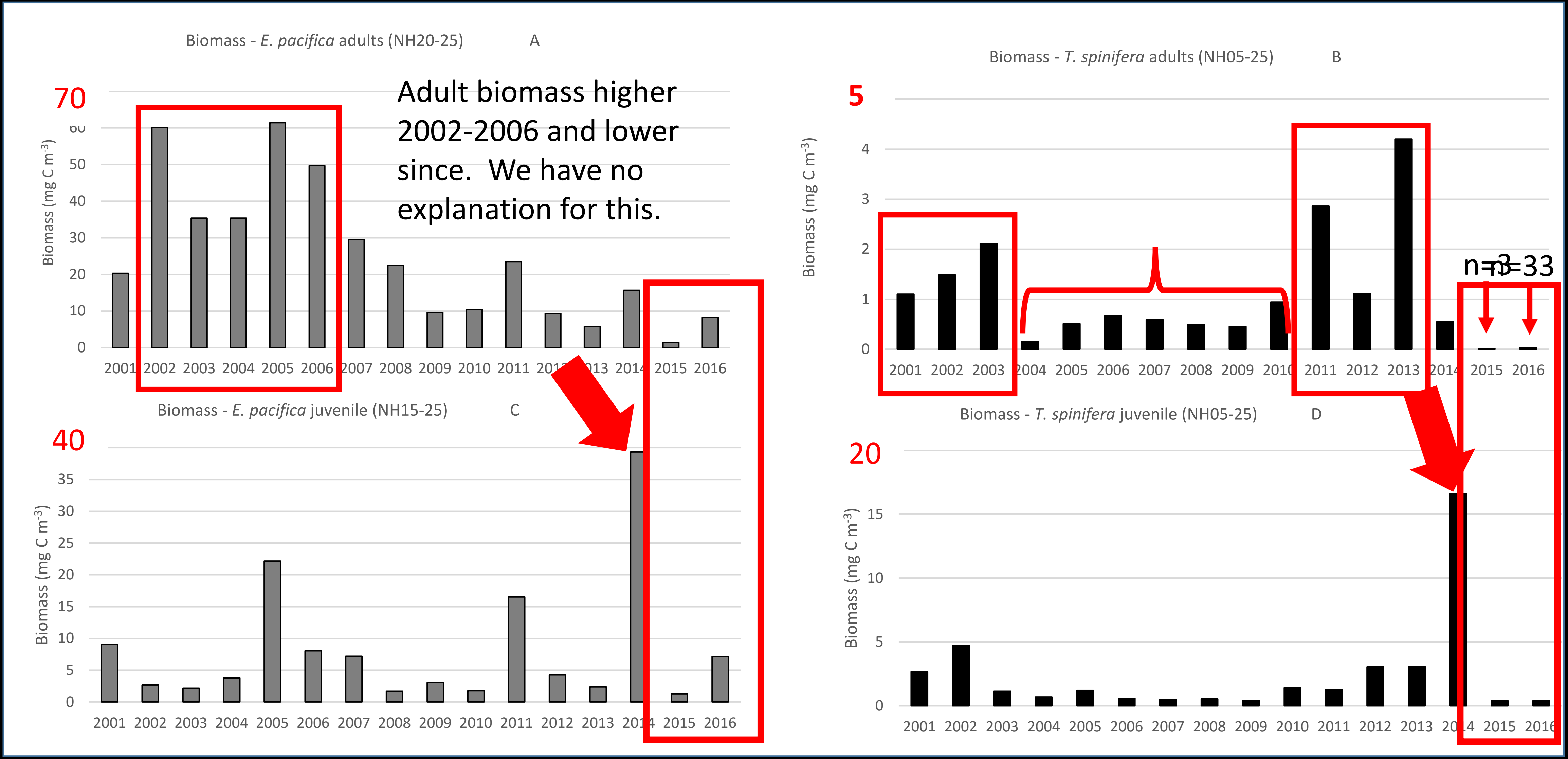




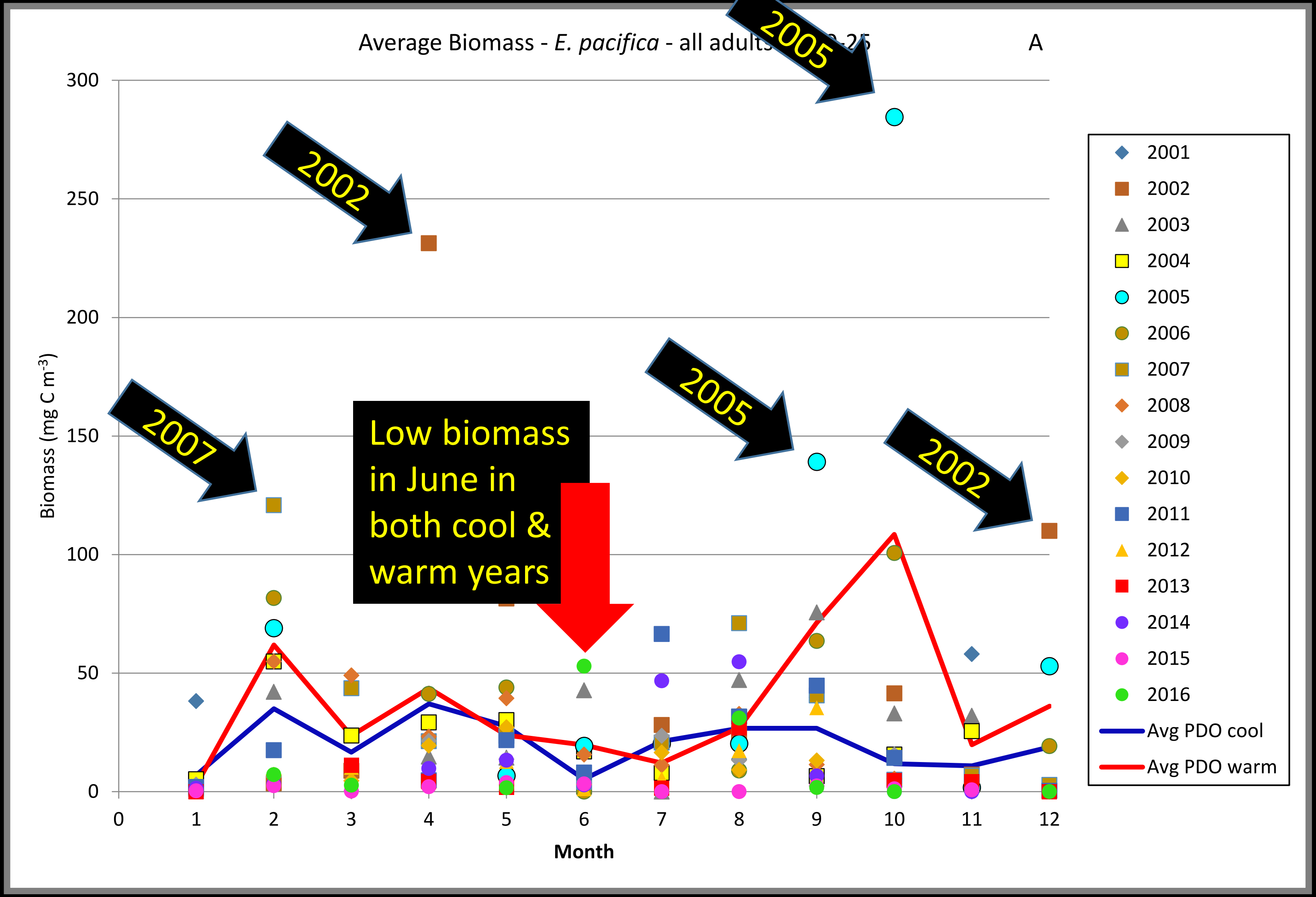
Cross-shelf Density



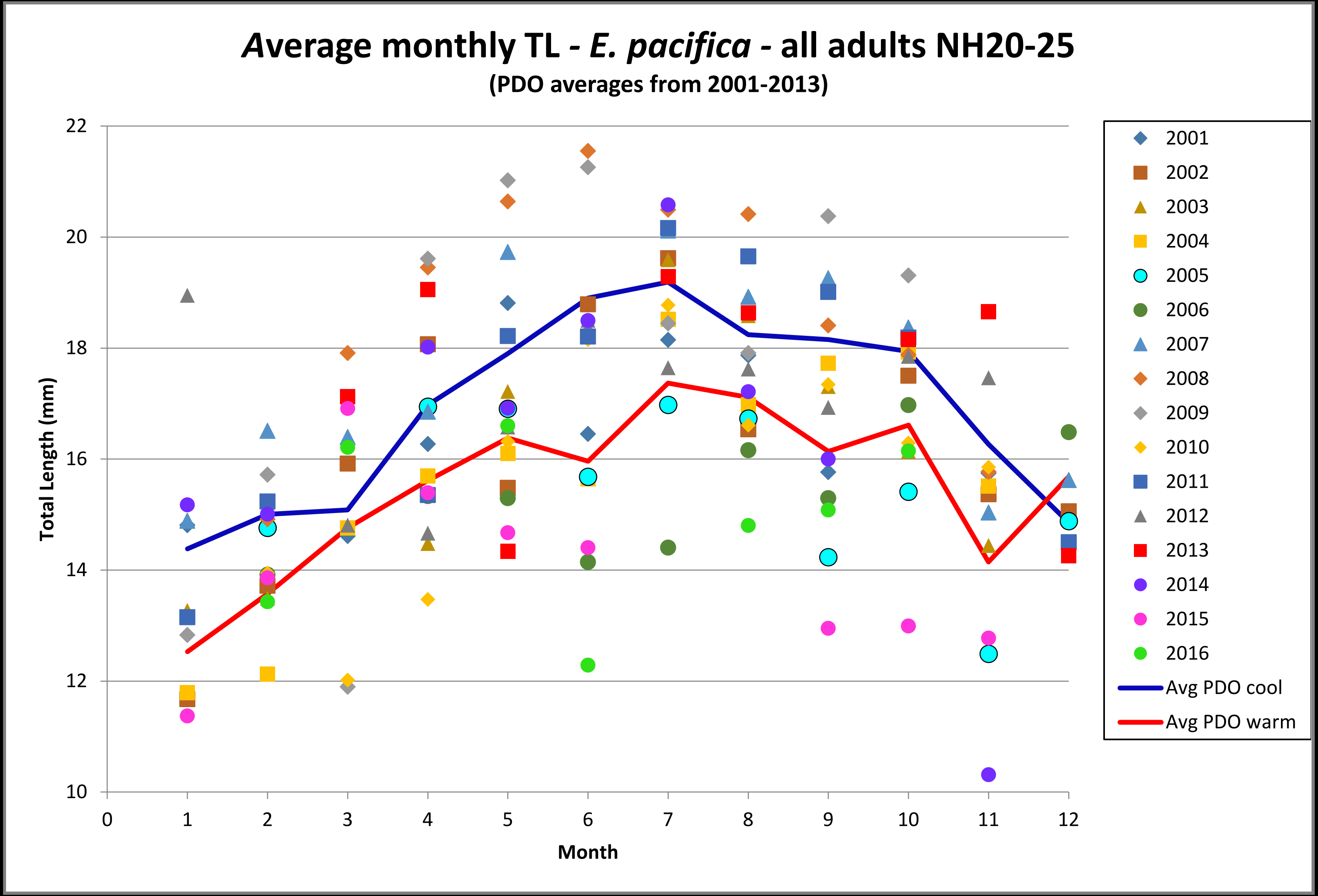
Biomass – Adults & Juveniles



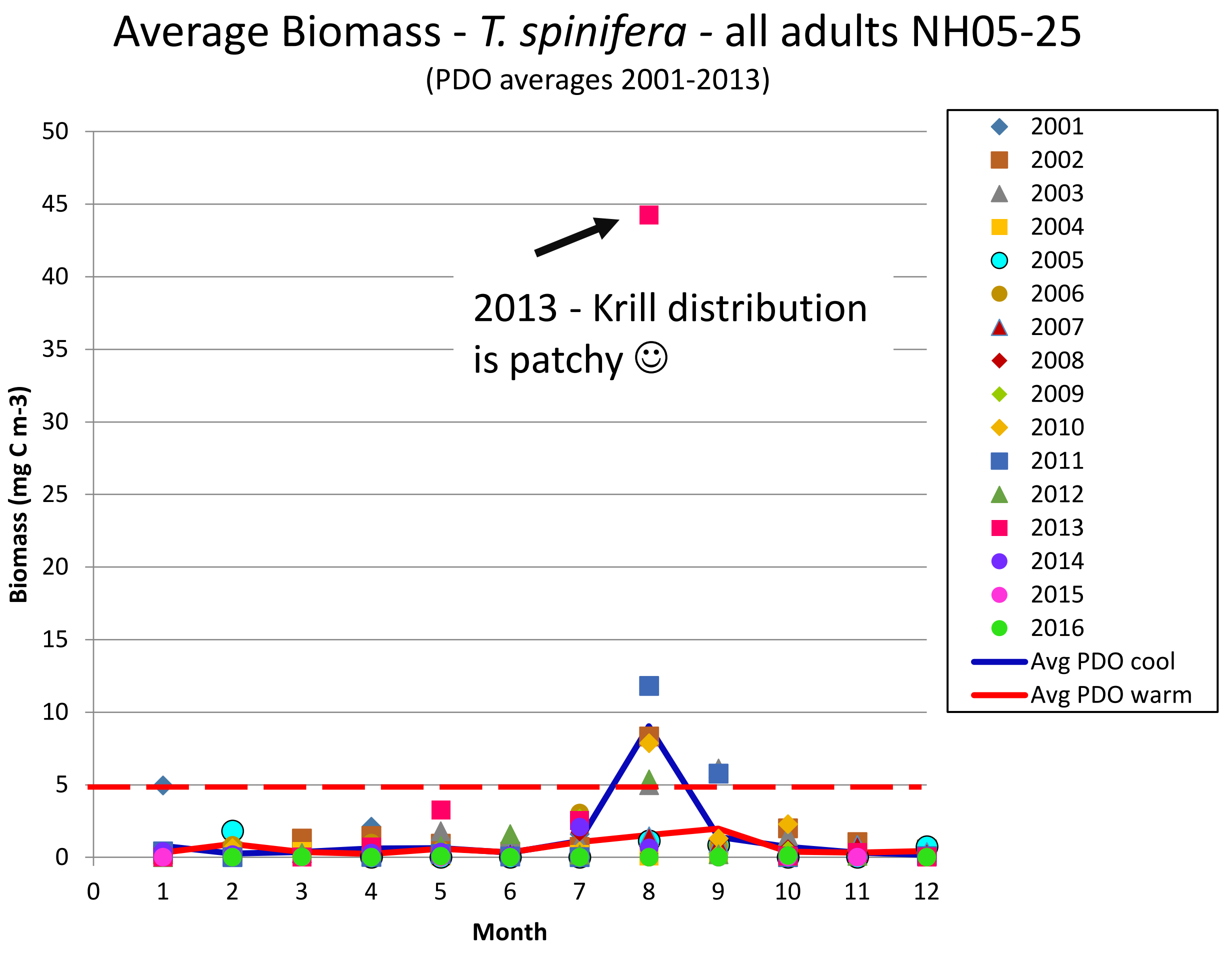
Seasonal Biomass - *E. pacifica* Adults

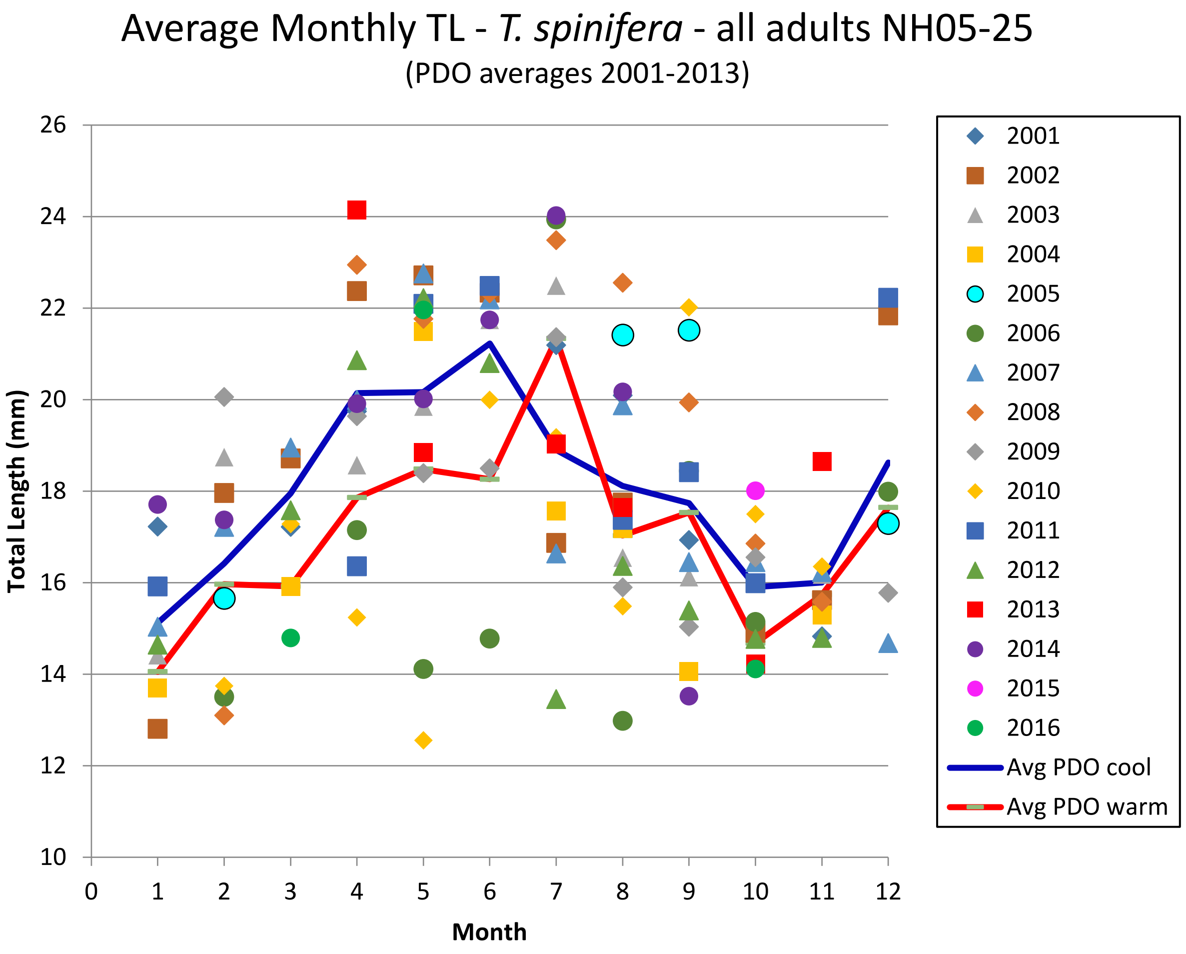


Seasonal Lengths - *E. pacifica* Adults

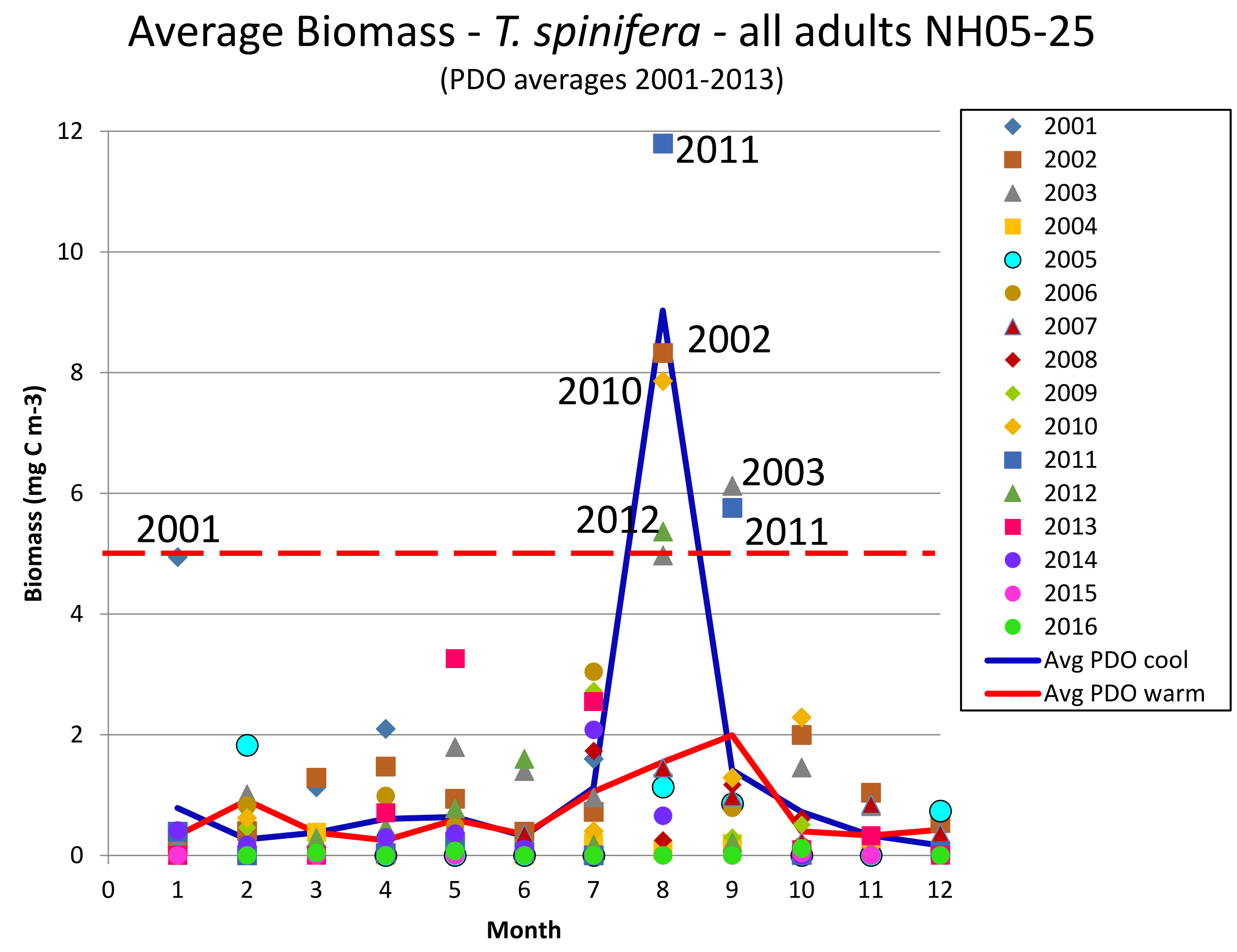


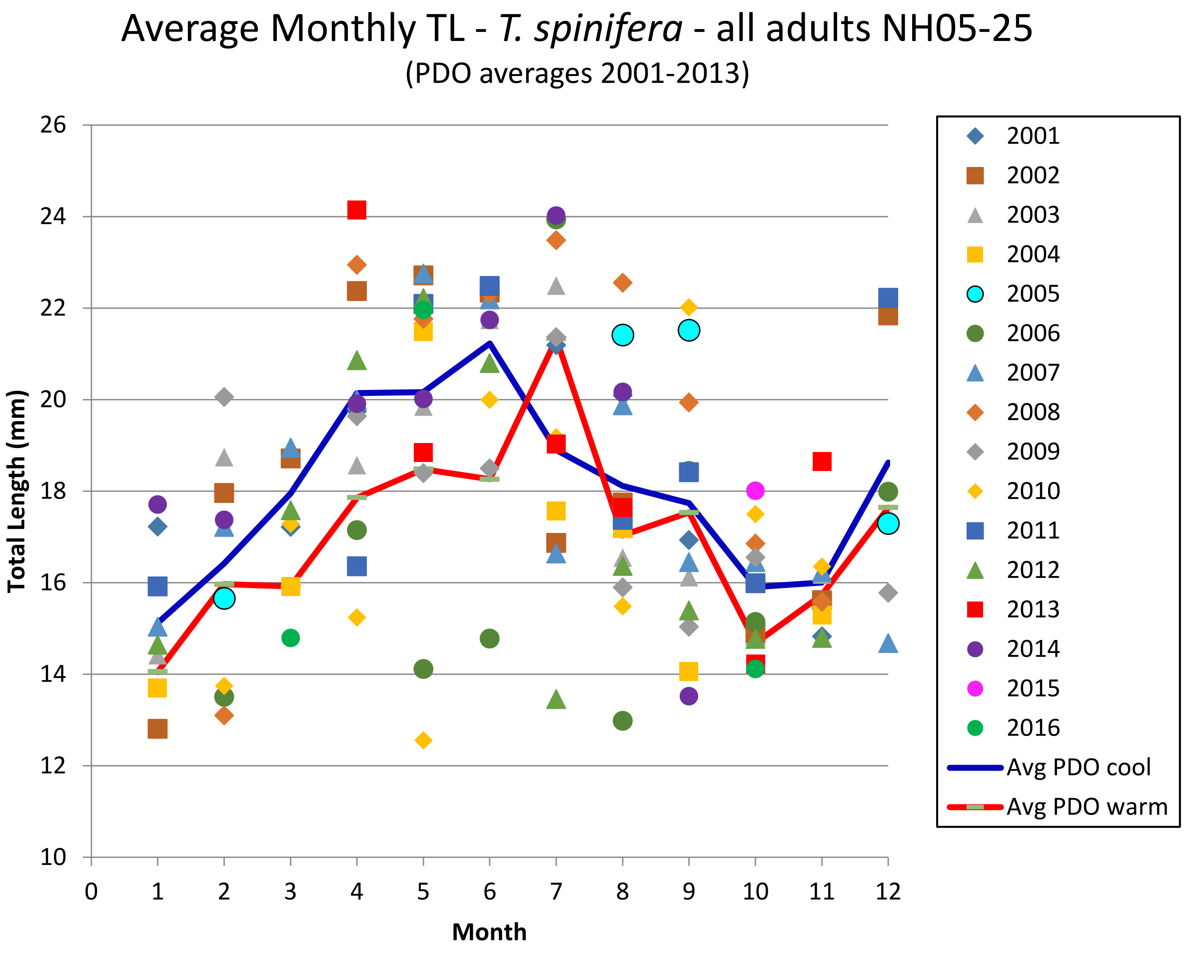
T. spinifera Adults



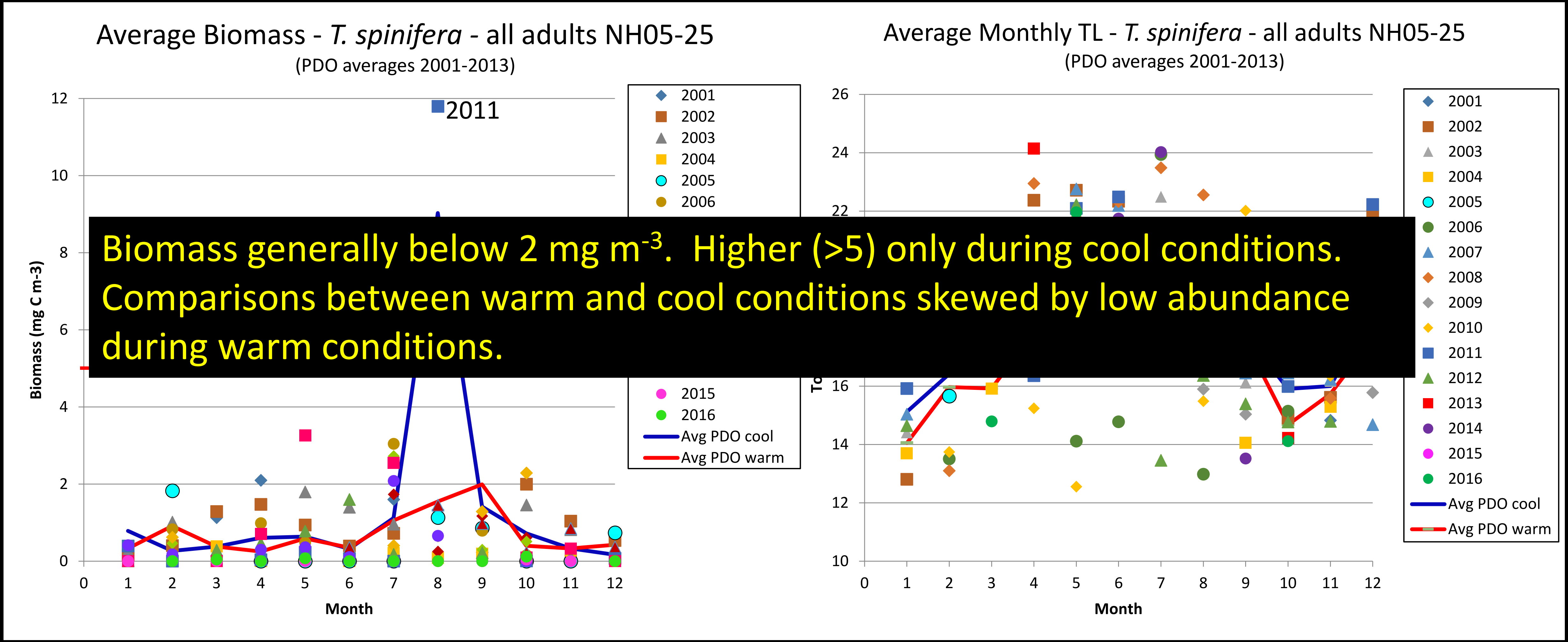


T. spinifera Adults



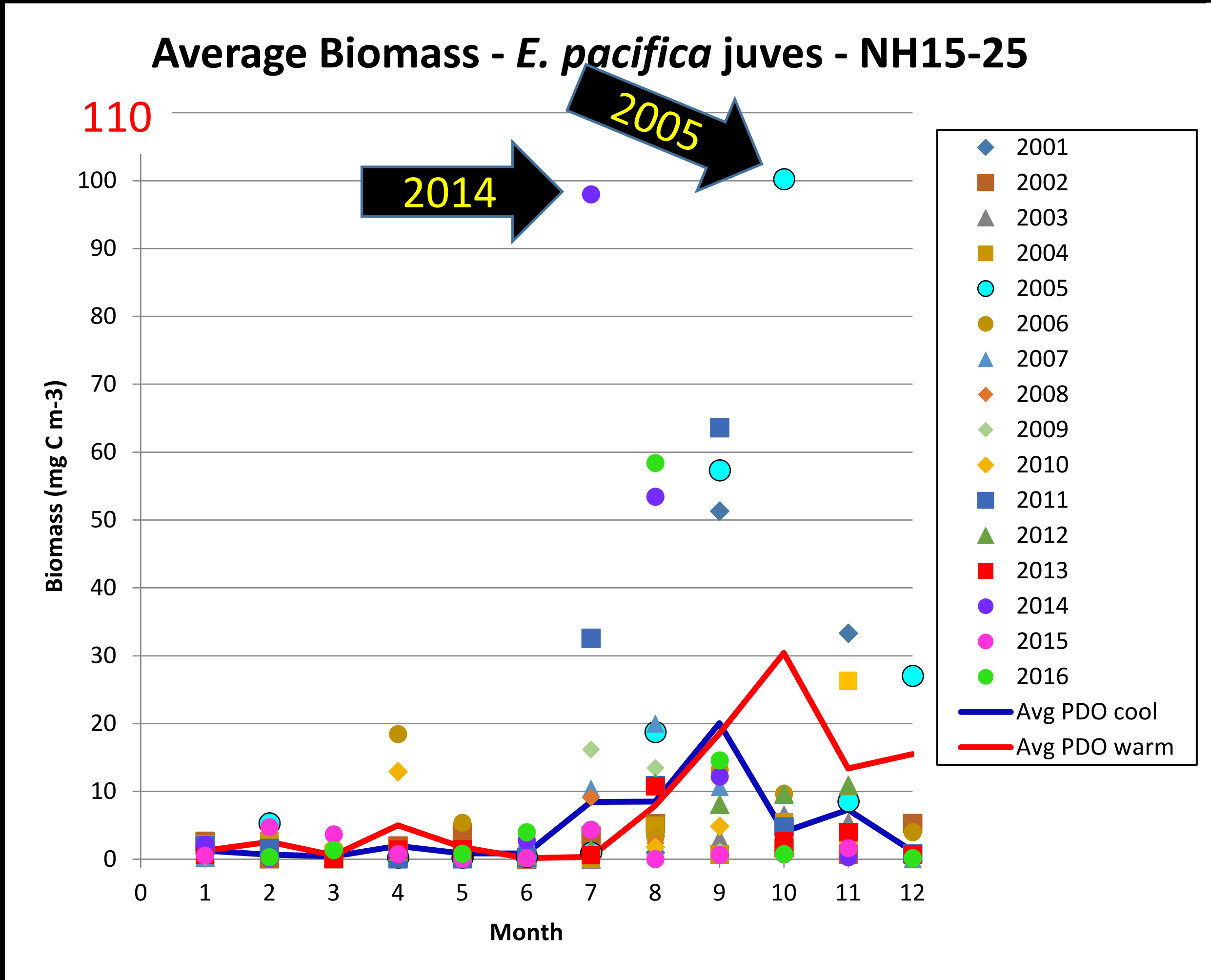


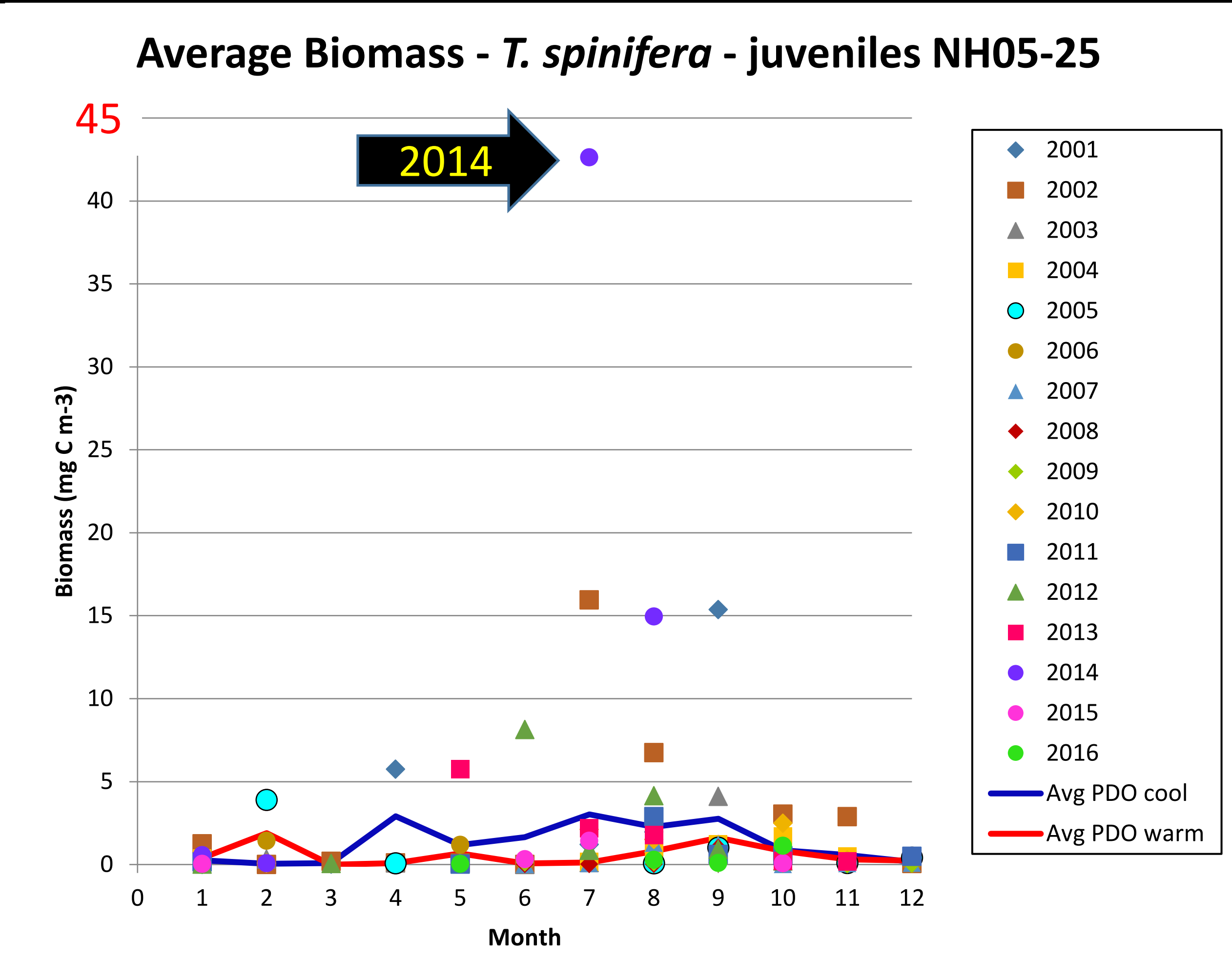
T. spinifera Adults



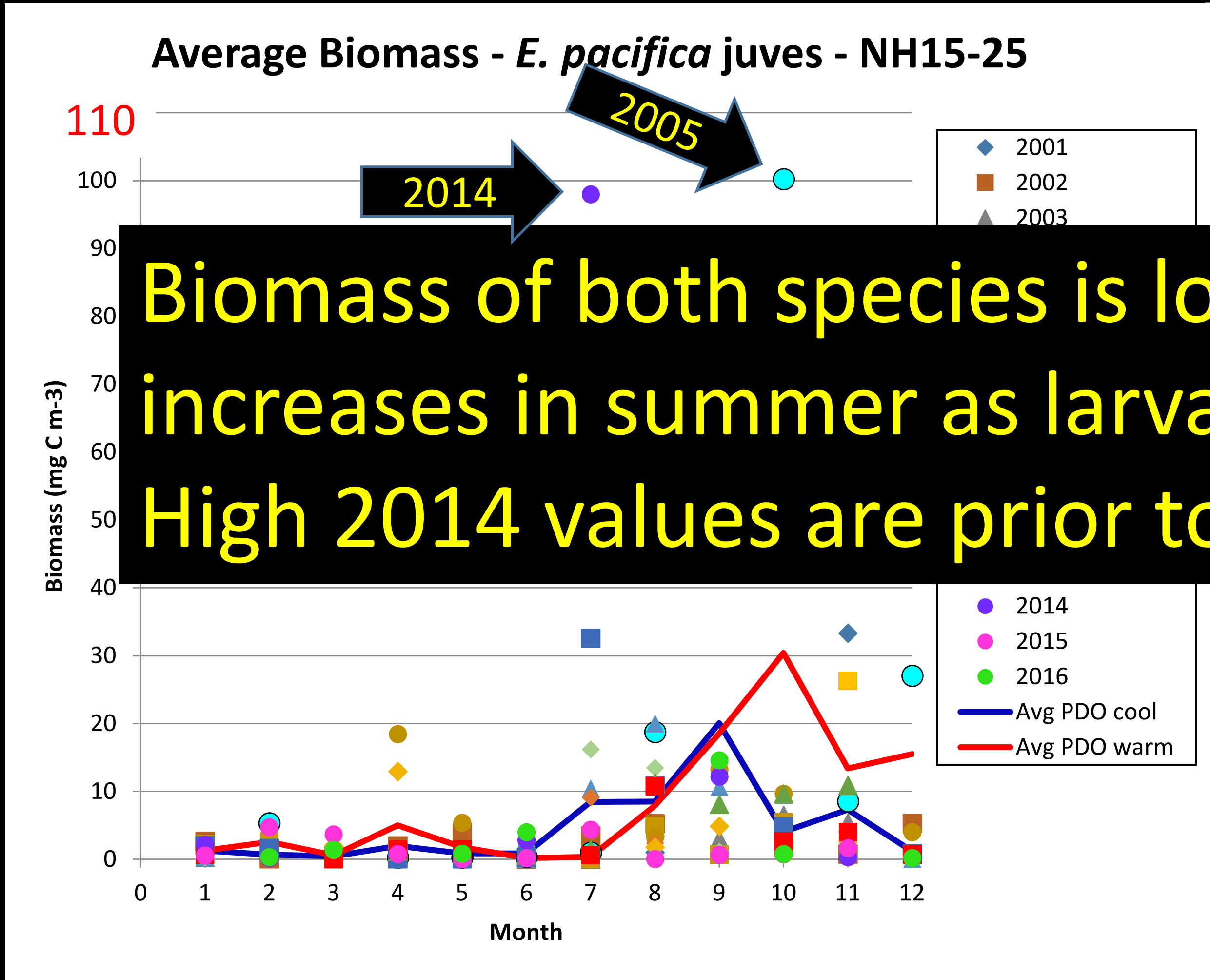
Biomass generally below 2 mg m^{-3}. Higher (>5) only during cool conditions. Comparisons between warm and cool conditions skewed by low abundance during warm conditions.

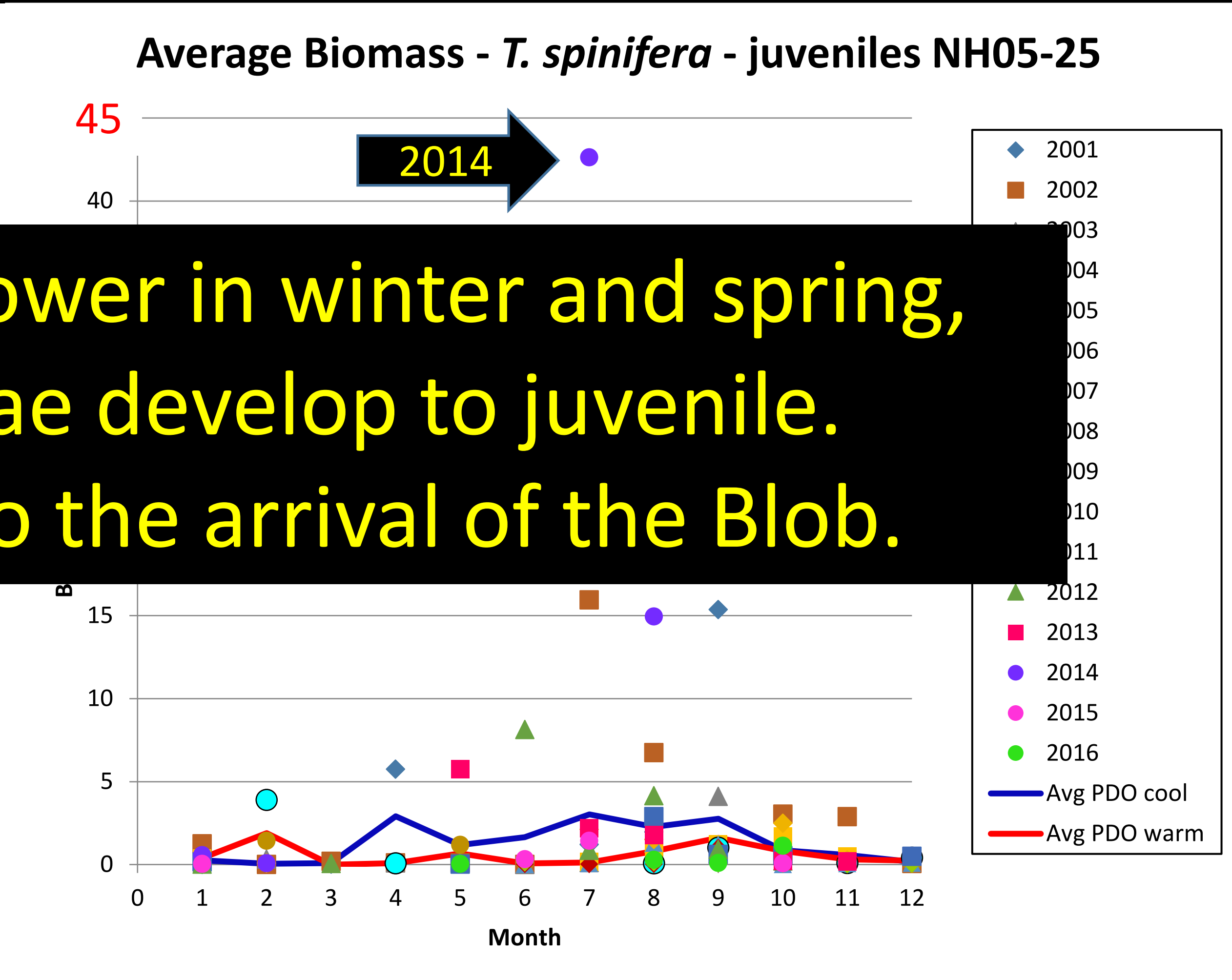
Juveniles *E. pacifica* & *T. spinifera*





Juveniles *E. pacifica* & *T. spinifera*

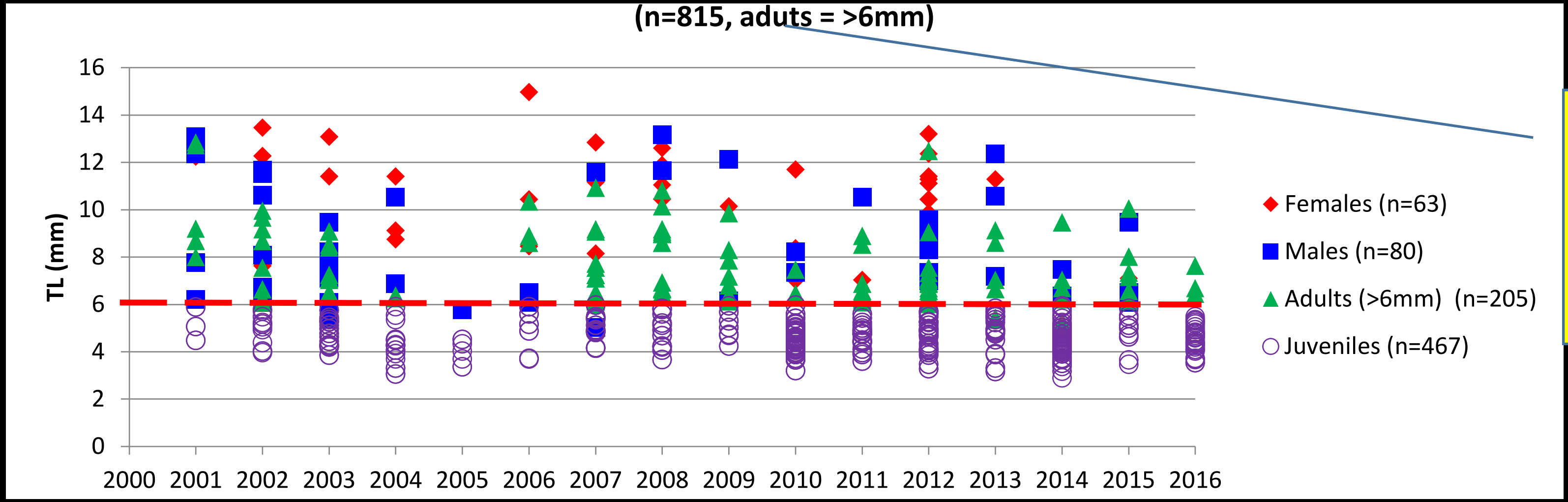




Biomass of both species is lower in winter and spring, increases in summer as larvae develop to juvenile. High 2014 values are prior to the arrival of the Blob.

TL of all *T. inspinata* 2001-2016

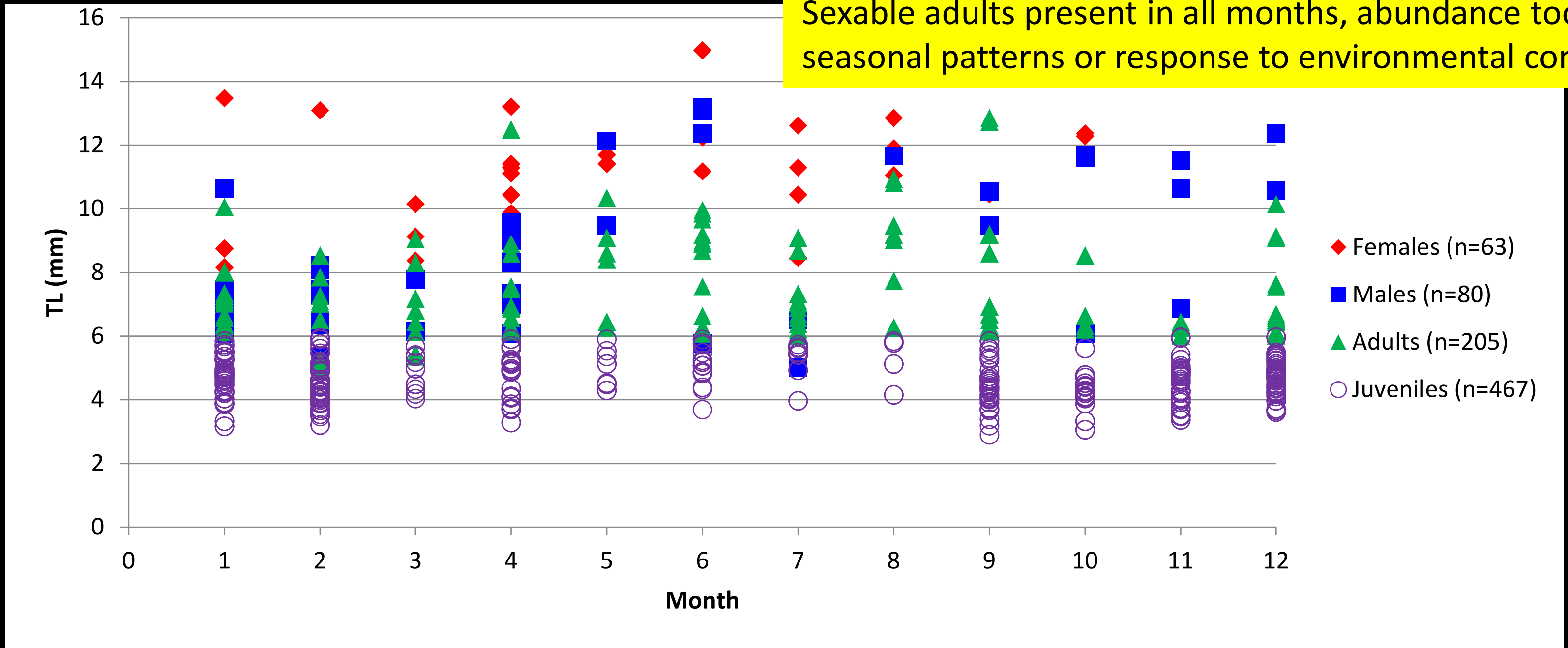
By Year

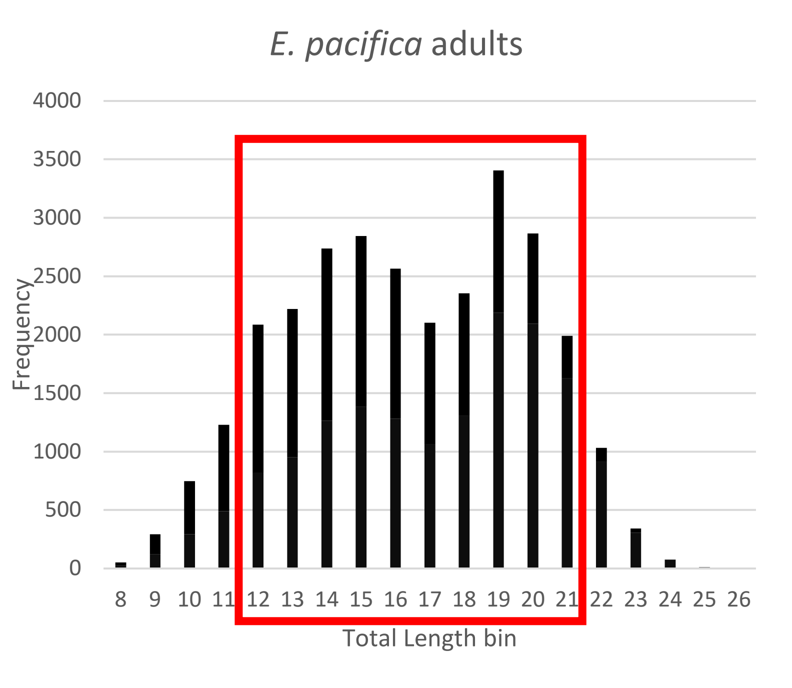


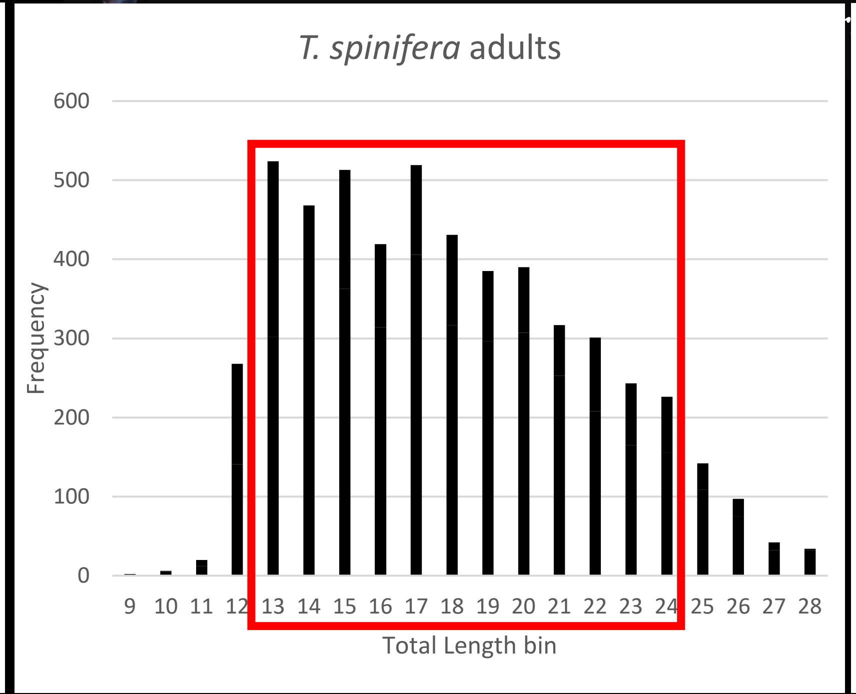
Cutoff of 6mm based on TL of smallest sexable adults

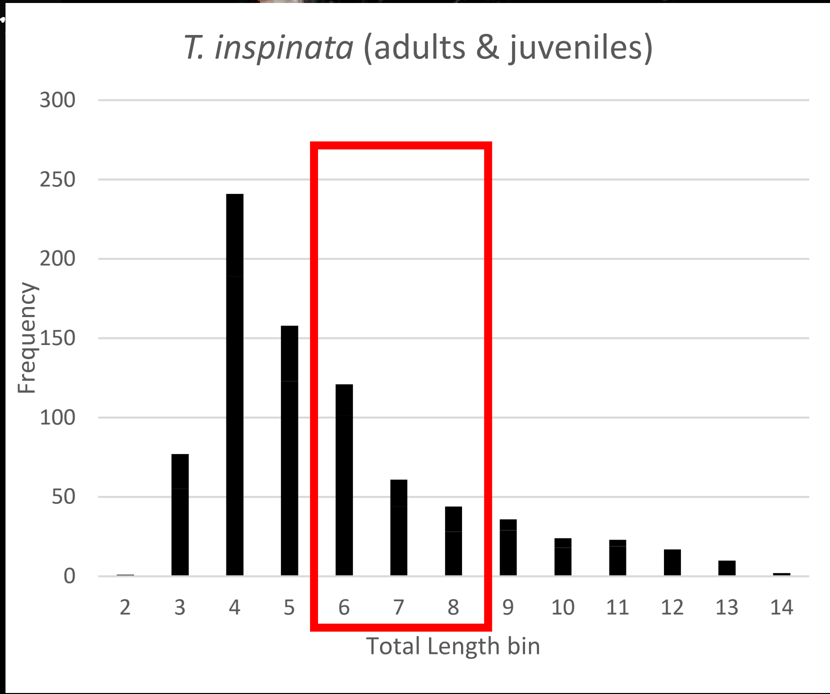
By Month

Sexable adults present in all months, abundance too low to determine seasonal patterns or response to environmental conditions







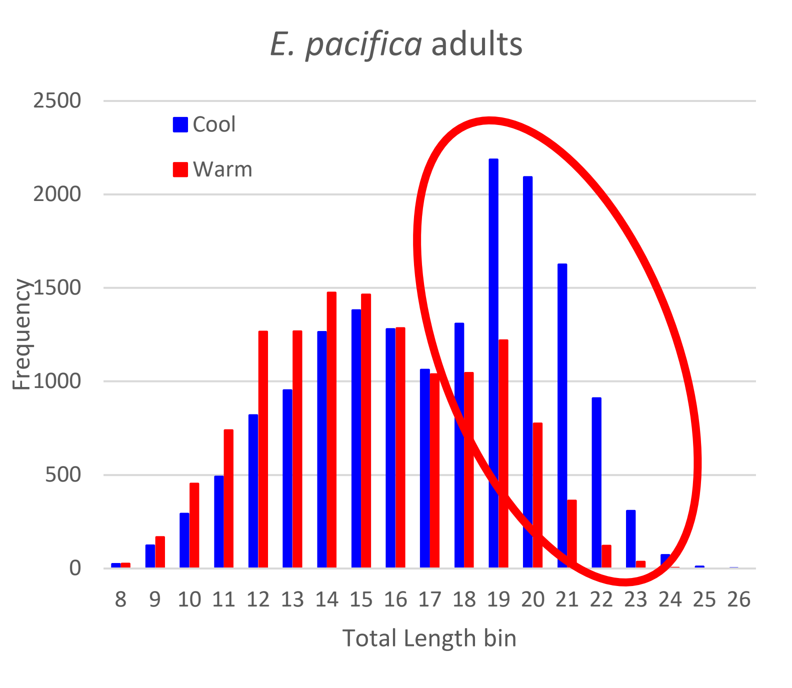


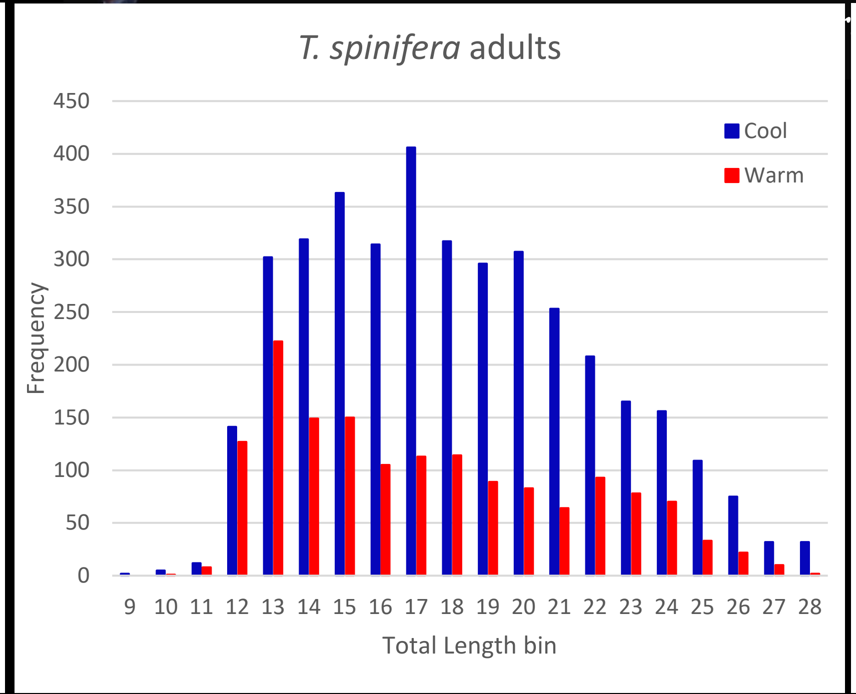
- Adult size range 8-26mm
- Most adults 14-21mm

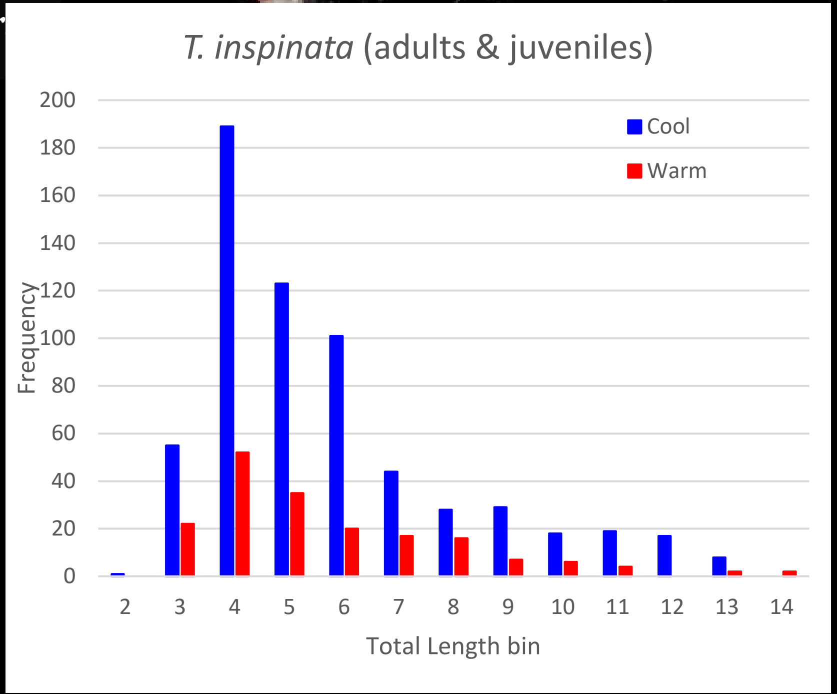
- Adult size range 9-29mm
- Most adults 13-24mm

- Adult size range 6-15mm
- Most adults 6-8mm

Total Lengths 2001-2016







- More adults >18mm during cool PDO
- Similar size range even though adults are rare in warm conditions
- Similar size range, more abundant in cool conditions

Total Length 2001-2016 and PDO

Results

	E. pacifica	*T. spinifera*	*T. inspinata*
ABUNDANCE	most abundant species, consistently present in cool & warm conditions	less abundant during warm conditions	low abundance but consistently present in cool & warm conditions
DISTRIBUTION	rare inshore in cool and warm conditions	rare inshore in warm conditions but still present offshore	increases inshore to offshore, more abundant in cool conditions
BIOMASS	high 2002-2006 - mysterious lowest in June –mysterious	higher biomass always in cool conditions	NA
LENGTH	17-22mm, >18mm more abundant in cool conditions, females larger Jan-Sept	13-24mm, females always larger than males	6mm cutoff between juvenile and adult

Future krill population dynamics?

Gaze into my "krill-stal" ball…

Strong Upwelling?

Cool PDO?

Persistent warming?

Change in prey field?

Smaller adults?

Early Upwelling?

Reduced spawning population?

Late Upwelling?

Warm PDO?

Weak Upwelling?

Lots of jellies?

That's terrible… yet funny ☺

There are many variables that affect krill population dynamics

Future krill population dynamics?

I like a long upwelling season!

Strong Upwelling?

Cool PDO?

Persistent warming?

Change in prey field?

Smaller adults?

Early Upwelling?

Reduced spawning population?

Late Upwelling?

Warm PDO?

Weak Upwelling?

Lots of jellies?

I like cold water!

Can variables we measure from land tell us what is happening with the krill at sea?

“Green lights” for euphausiids?

Year	Spring transition (ST)	Upwelling (months)	PDO phase	*E. pacifica* adult biomass	*T. spinifera* adult biomass	*E. pacifica* adult avg TL	*T. spinifera* adult avg TL
2001	1-May	5.3	Cool	22.75	0.99	16.30	19.34
2002	17-Apr	6.7	Cool	52.56	1.43	16.29	18.53
2003	20-Apr	5.3	Warm	35.50	2.11	15.71	17.16
2004	21-Apr	4.1	Warm	24.03	0.15	15.56	16.24
2005	22-May	4.3	Warm	61.45	0.51	15.93	16.69
2006	20-Apr	6.5	Warm	50.54	0.67	15.99	18.98
2007	27-Apr	5.1	Cool	29.82	0.59	18.28	18.29
2008	29-Apr	4.6	Cool	23.53	0.49	19.47	20.52
2009	14-May	5.0	Cool	9.97	0.45	18.91	18.62
2010	10-Jun	3.2	Cool	10.44	0.94	16.85	17.87
2011	16-Apr	4.9	Cool	23.53	2.86	18.31	17.85
2012	4-May	5.2	Cool	9.30	1.11	16.27	18.65
2013	7-Apr	4.6	Cool	5.66	4.20	18.05	18.63
2014	10-May	4.4	Warm	16.87	0.57	18.07	20.27
2015	11-Apr	5.8	Warm	1.47	0.004	14.14	18.01
2016	27-Mar	6.2	Warm	8.53	0.03	14.78	17.33

Cold water on shelf
Long upwelling season

Late upwelling
Short upwelling season

El Nino winter 2009-10

Late upwelling
Short upwelling season

Warm Blob

Warm Blob

Warm Blob

High Ep biomass in response to late upwelling

Late ST and short upwelling season

Pre-Blob values

n=3 animals

Physical Transition dates: http://damp.coas.oregonstate.edu/windstress/allyears.html

"Green lights" for euphausiids?

Year	Spring transition	Upwelling (months)	PDO phase	*E. pacifica* adult	*T. spinifera* adult	*E. pacifica* adult avg TL	*T. spinifera* adult avg TL
2011	16-Apr	4.9	Cool	23.53	2.86	18.31	17.85
2012	4-May	5.2	Cool	9.30	1.11	16.27	18.65
2013	7-Apr	4.6	Cool	5.66	4.20	18.05	18.63
2014	10-May	4.4	Warm	16.87	0.57	18.07	20.27
2015	11-Apr	5.8	Warm	1.47	0.004	14.14	18.01
2016	27-Mar	6.2	Warm	8.53	0.03	14.78	17.33

Spring transition, length of upwelling season, and PDO phase can provide a general idea about some aspects of euphausiid population dynamics (e.g. timing of *E. pacifica* spawning, *T. spinifera* nearshore abundance) but the details are more complicated.

Krill are highly variable – but so is their environment ☺

ass in
upwelling

Warm Blob

Warm Blob

Warm Blob

Pre-Blob values

n=3 animals

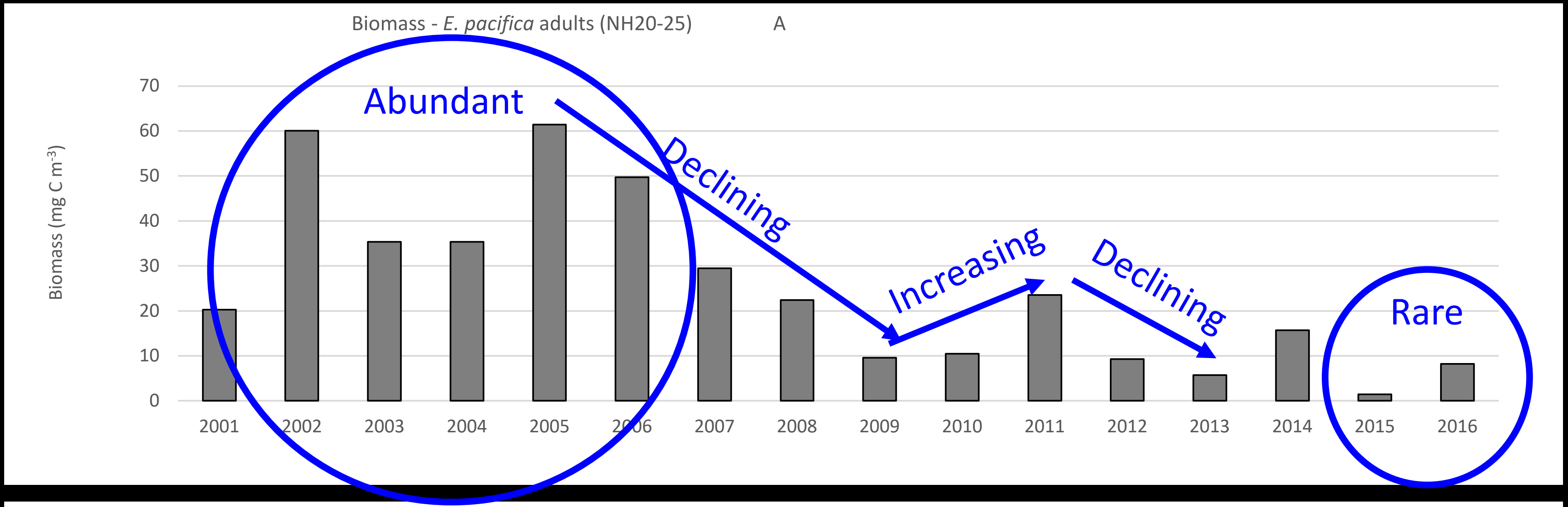
Physical Transition dates: http://damp.coas.oregonstate.edu/windstress/allyears.html

Implications

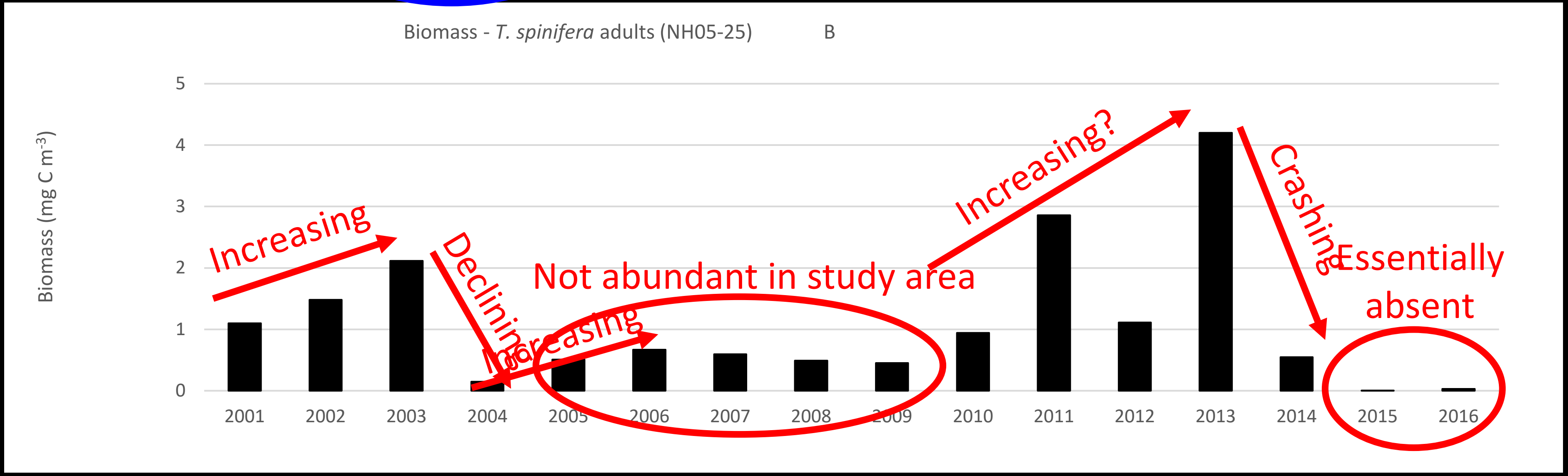
- Euphausiid species respond differently to environmental conditions (highly variable ☺)
  - Try to incorporate species-specific krill data into models
- Effects of longer periods of warm conditions?
  - *E. pacifica* and *T. spinifera* both have a lifespan of about two years
  - *E. pacifica* consistently present regardless of environmental conditions
  - Warm conditions lasting two or more years in a row could result in reduced *T. spinifera* abundance (migration and reduced reproduction)
- *T. inspinata* are larger and more abundant in the western Pacific. An increase in their abundance and/or size in the Oregon Coast region could indicate a change in the environment.
- How would our interpretation of these data differ without this long-term time series for context?

What if we had only had subsets of these 16 years?

E. pacifica adult biomass 2001-2016



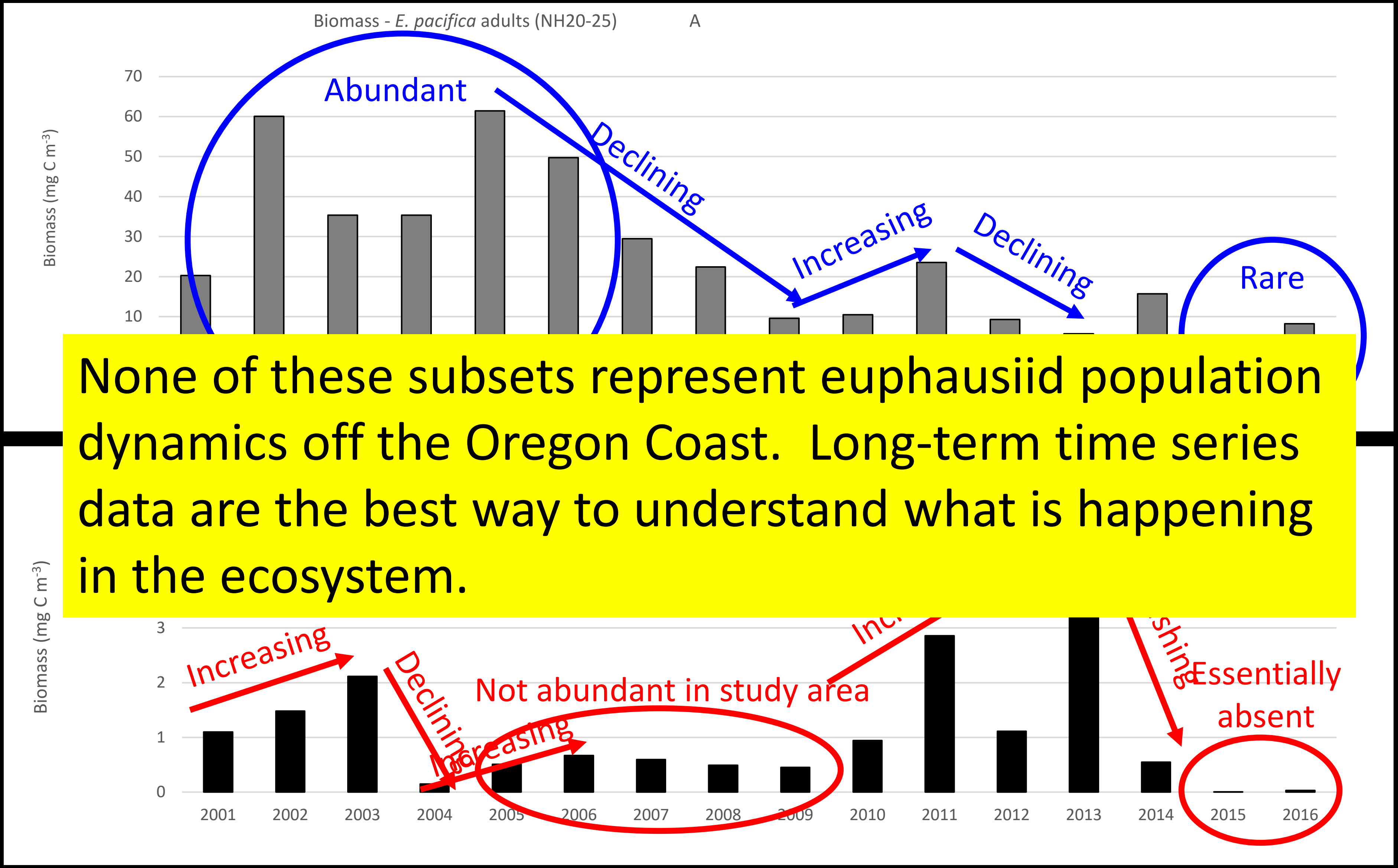
T. spinifera adult biomass 2001-2016



What if we had only had subsets of these 16 years?

E. pacifica adult biomass 2001-2016

T. spinifera adult biomass 2001-2016



None of these subsets represent euphausiid population dynamics off the Oregon Coast. Long-term time series data are the best way to understand what is happening in the ecosystem.

Acknowledgements

- Research vessels: *Elakha, Wecoma, Atlantis, Miller Freeman, Frosti, McArthur II, New Horizon, Shimada*
- Funding sources: NOAA/NWFSC, ONR/NOPP, NSF/CoOP/COAST, NOAA-GLOBEC, NSF/CoOP/RISE, NOAA-SAIP

Contents of this presentation, plus more that I didn't have time to cover, will be published in the upcoming special issue of Progress in Oceanography in honor of Bill Peterson

U.S. GLOBEC

GLOBAL OCEAN ECOSYSTEMS DYNAMICS

UNIVERSITY OF SOUTH FLORIDA

College of MARINE SCIENCE

Euphausiid Live Work Protocol

Protocols for Measuring
Molting R ate and
Egg Produc n of
Live Euphaus

On PICES
website since
2005!

Courtesy of the Peterson Lab at Hatfield Marine Sci ce
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)
-Programs and Projects
  -Projects
    -Projects Completed