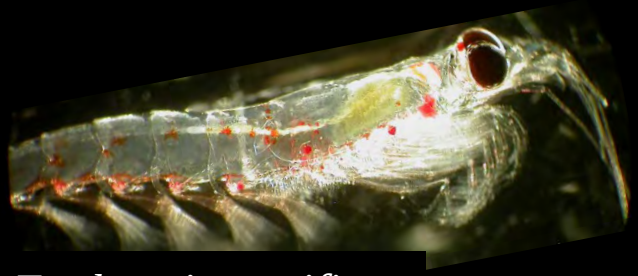
Euphausiid responses to recent warming events in the coastal upwelling zone off the Oregon Coast, USA



Euphausia pacifica

Thysanoessa spinifera

C. Tracy Shaw and William T. Peterson

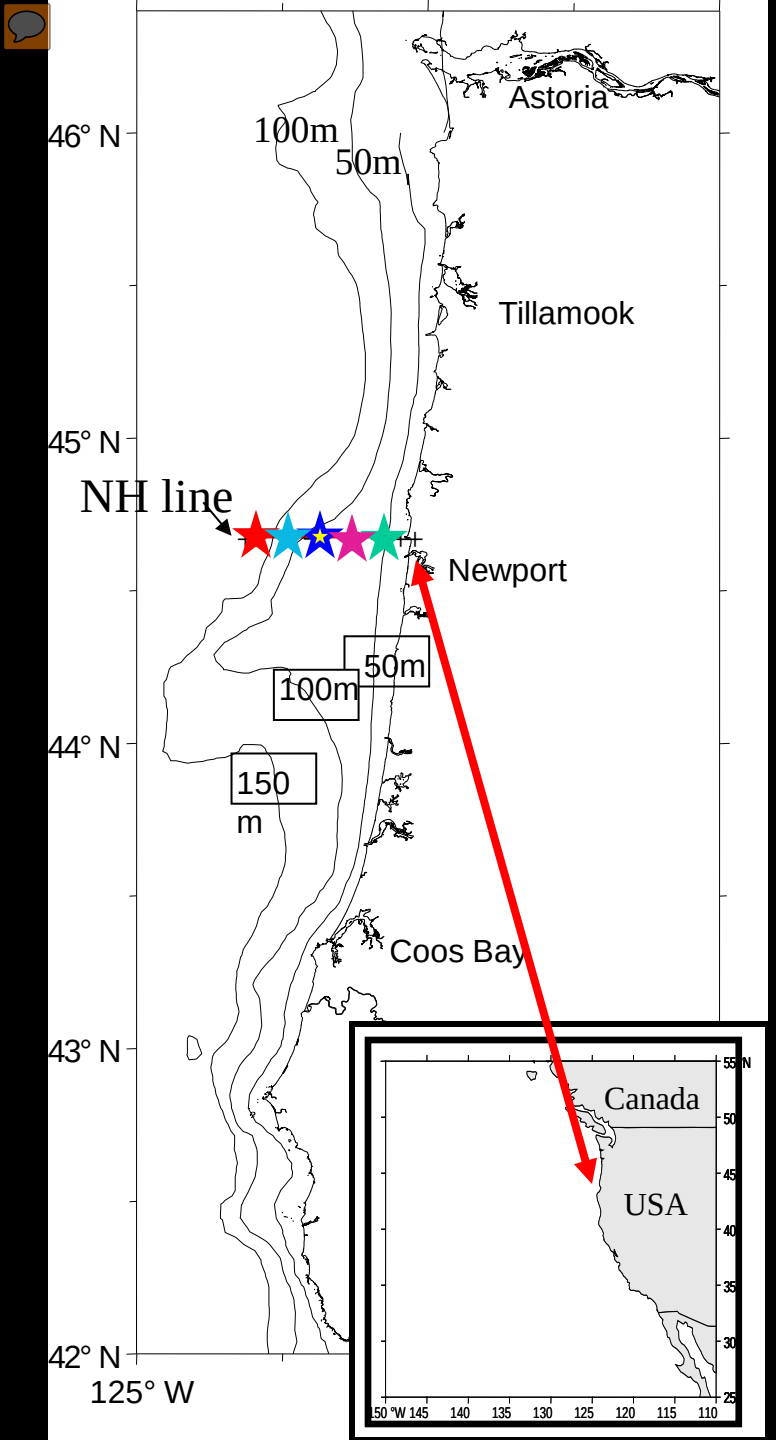
Target Species

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



Time series off Newport, OR (NH line)

- Sampled twice per month 1996-2013; ~monthly 2014-present
- Night bongo net samples for adult euphausiids from 2001- present (16 years so far)
- Data for this presentation:
  - 1998-1999, 2001-2015
- Station distance offshore & depth
  - 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
- ☺

El Niño

Cold water on shelf

Late upwelling

Summer cool until Blob arrived

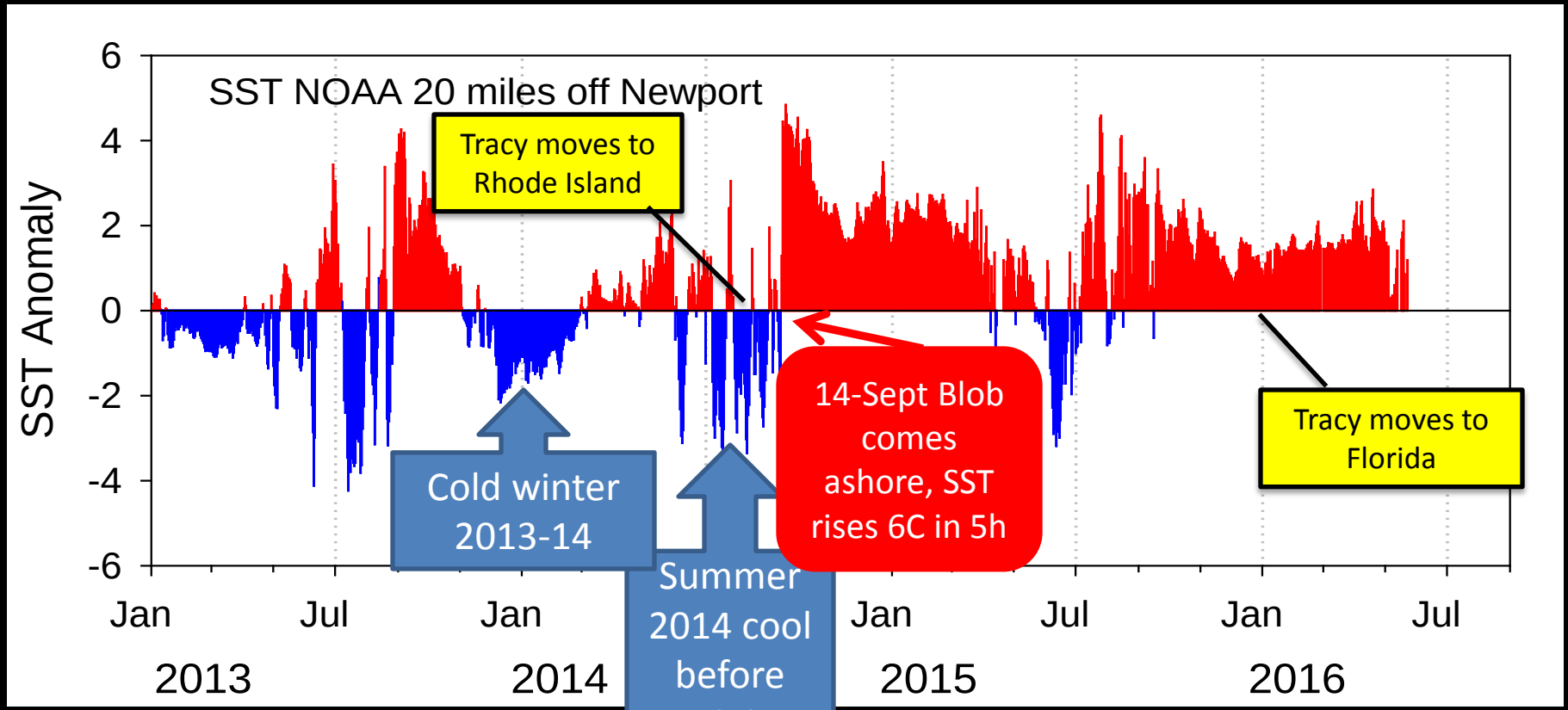
blob

Year	Spring transition (ST)	Fall transition (FT)	Upwelling (months)	Cold water copepods (months)	PDO phase
1998	El Niño				Warm
2001	1-May	7-Oct	5.3	7.7	Cool
2002	17-Apr	4-Nov	6.7	6.6	Cool
2003	20-Apr	26-Sep	5.3	4	Warm
2004	21-Apr	21-Aug	4.1	5.2	Warm
2005	22-May	29-Sep	4.3	1.1	Warm
2006	20-Apr	31-Oct	6.5	4.1	Warm
2007	27-Apr	28-Sep	5.1	9.5	Cool
2008	29-Apr	15-Sep	4.6	7.9	Cool
2009	14-May	11-Oct	5.0	9	Cool
2010	10-Jun	14-Sep	3.2	5.3	Cool
2011	16-Apr	11-Sep	4.9	6.3	Cool
2012	4-May	7-Oct	5.2	5.8	Cool
2013	7-Apr	22-Aug	4.6	5.9	Cool
2014	10-May	20-Sep	4.4	3.5	Warm
2015	11-Apr	1-Oct	5.8	NA	Warm

No biological transition

(www.damp.coas.oregonstate.edu/windstress/allyears.html)

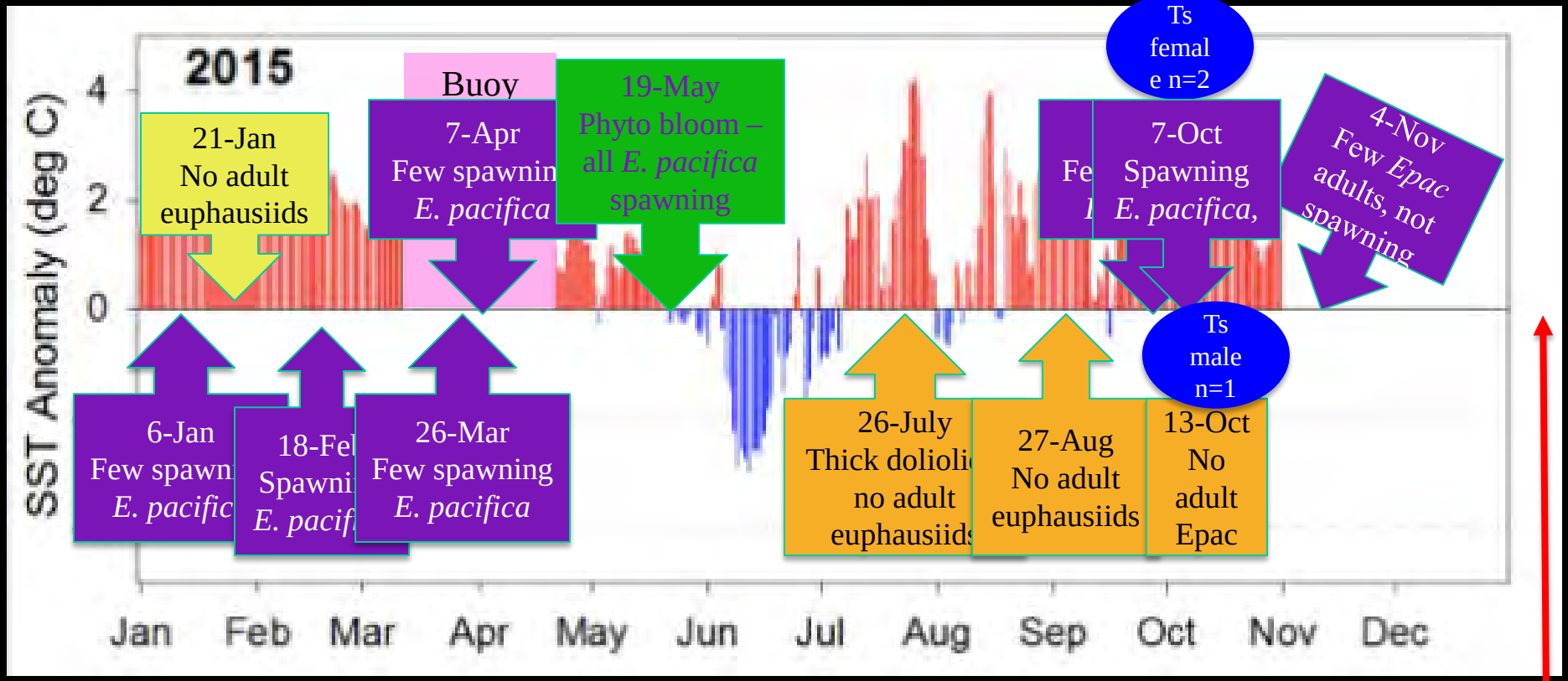
Daily SST Anomalies off Newport, OR Jan 2013-May 2016



How would the warm Blob affect euphausiids?

- Will there be any around?
- Rare or new species?
- Spawning?
- Change in length?
- Changes in density & biomass?
- Changes in cross-shelf distribution?

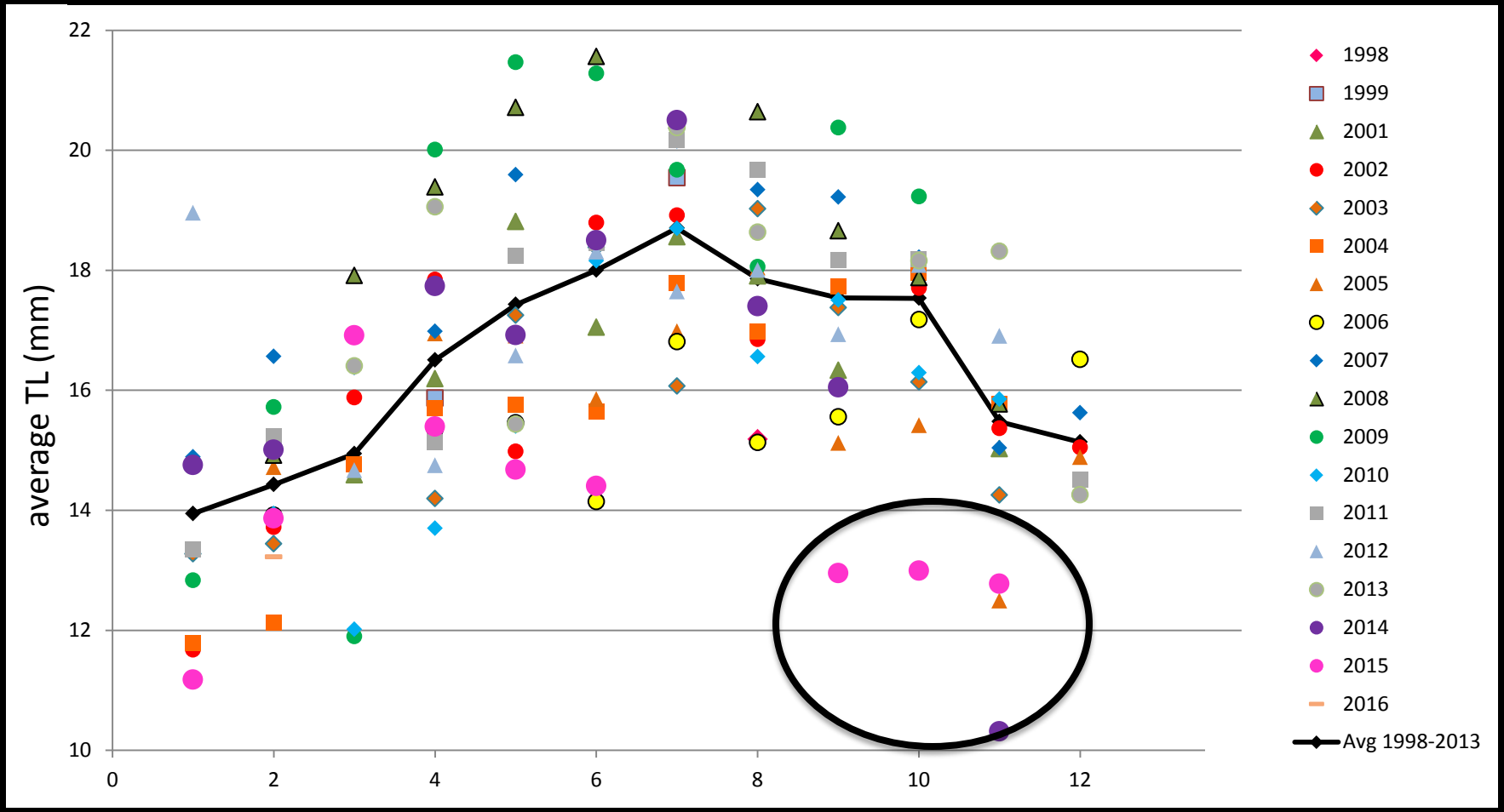
2015 SST & Krill Data Overview



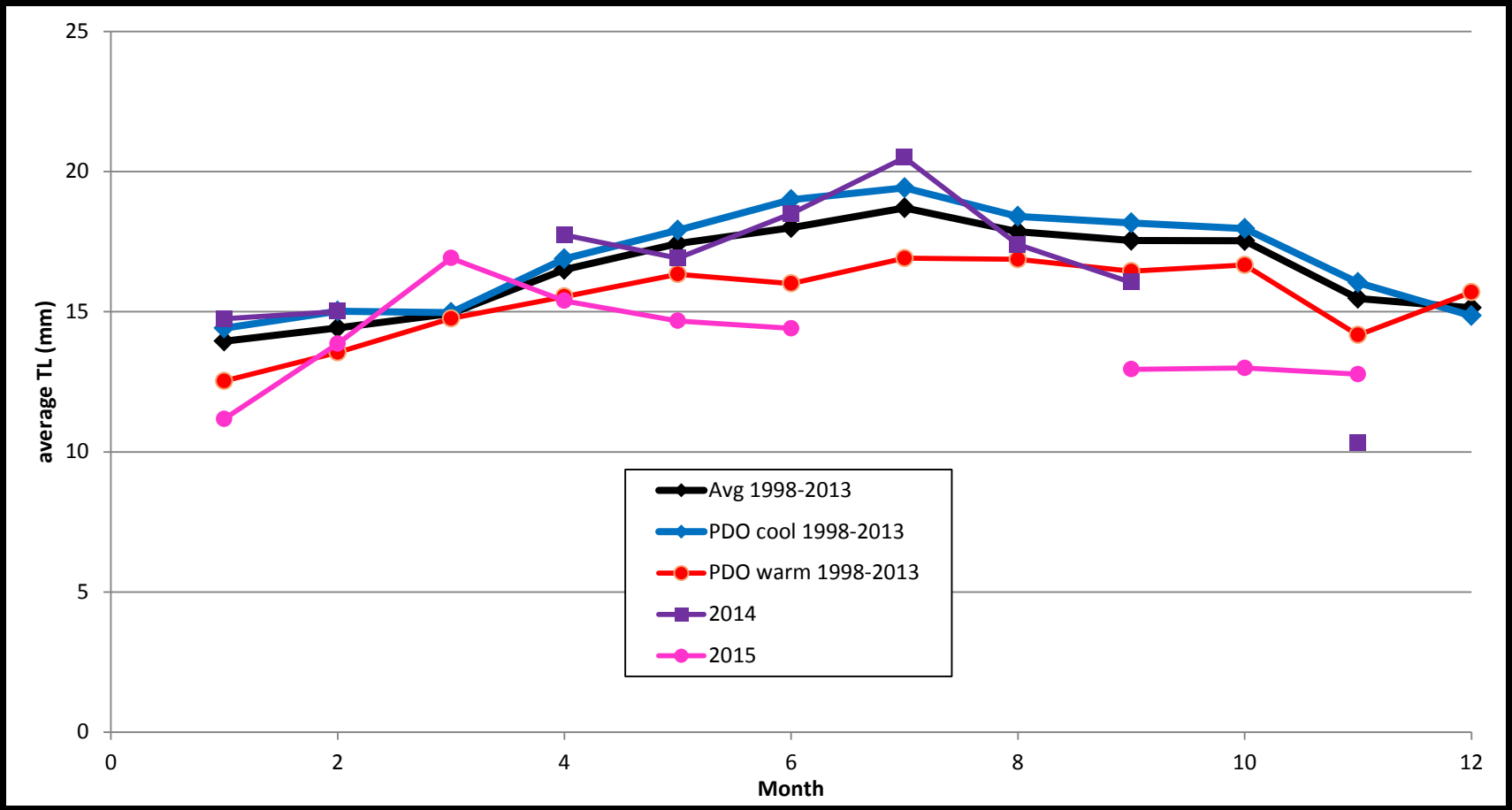
16-Feb-2016 Wide size range of adult Epac – all spawning, no T. spinifera

(SST anomaly graph from NOAA/NWFSC website)

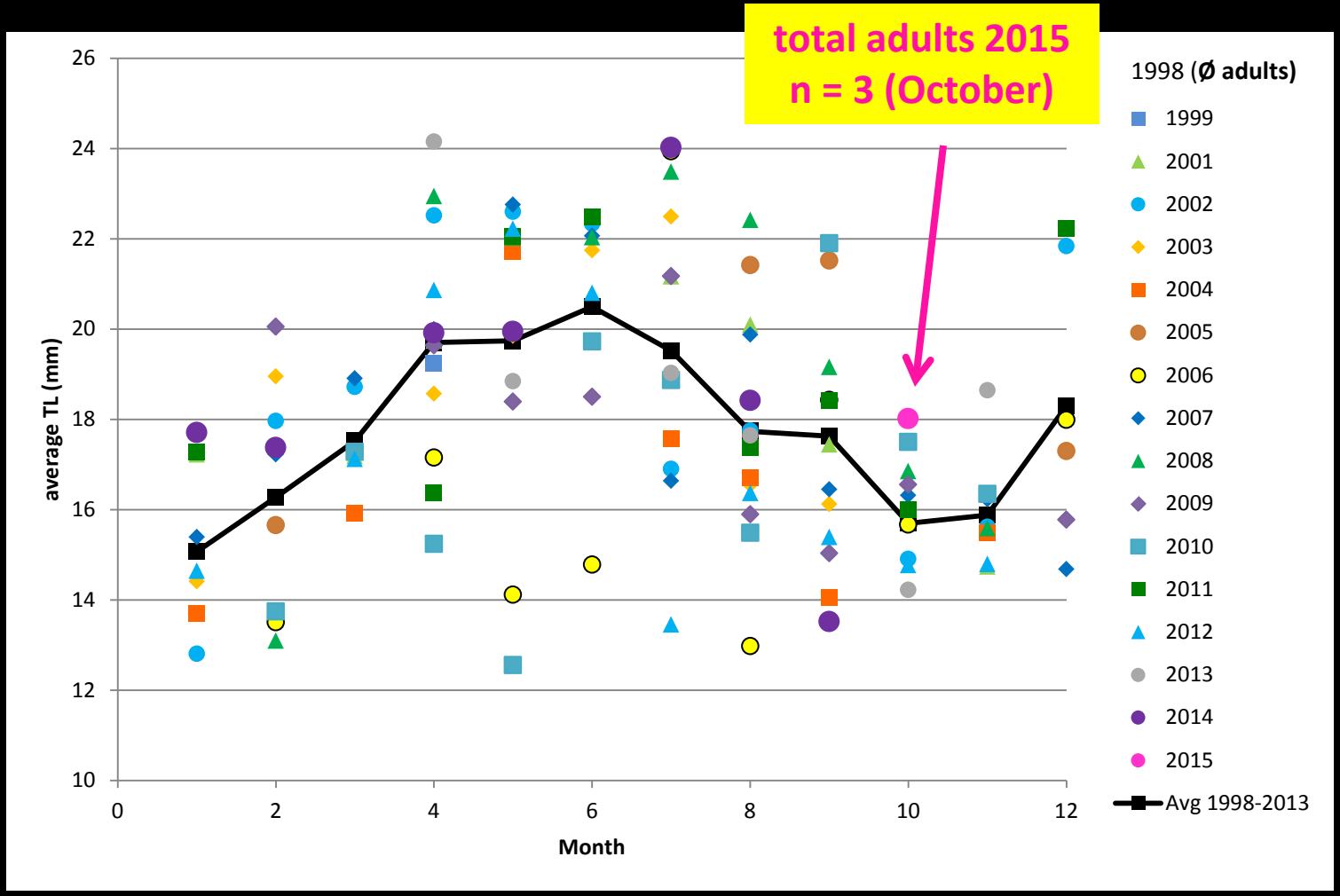
E. pacifica adults



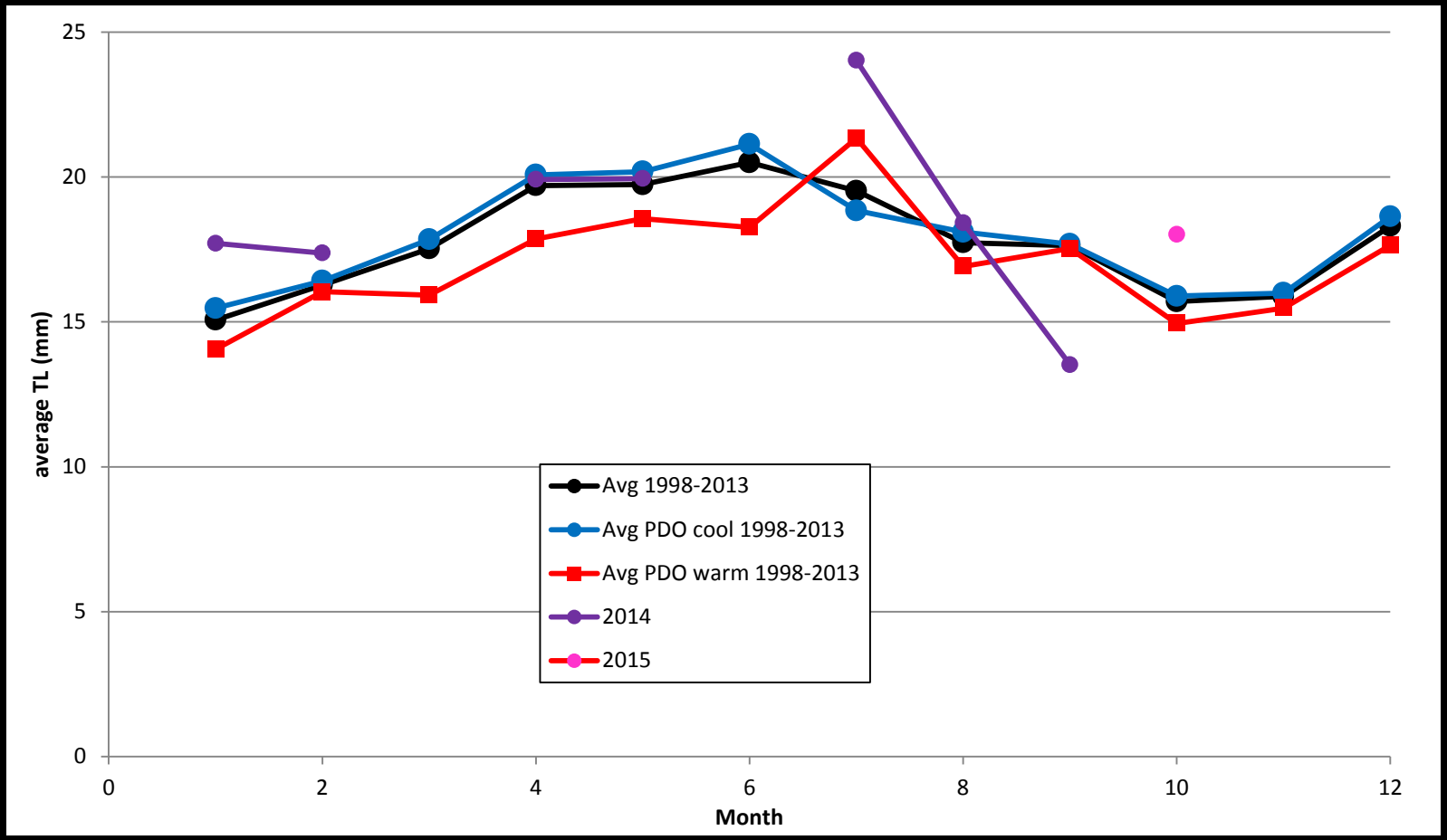
E. pacifica adults



T. spinifera adults

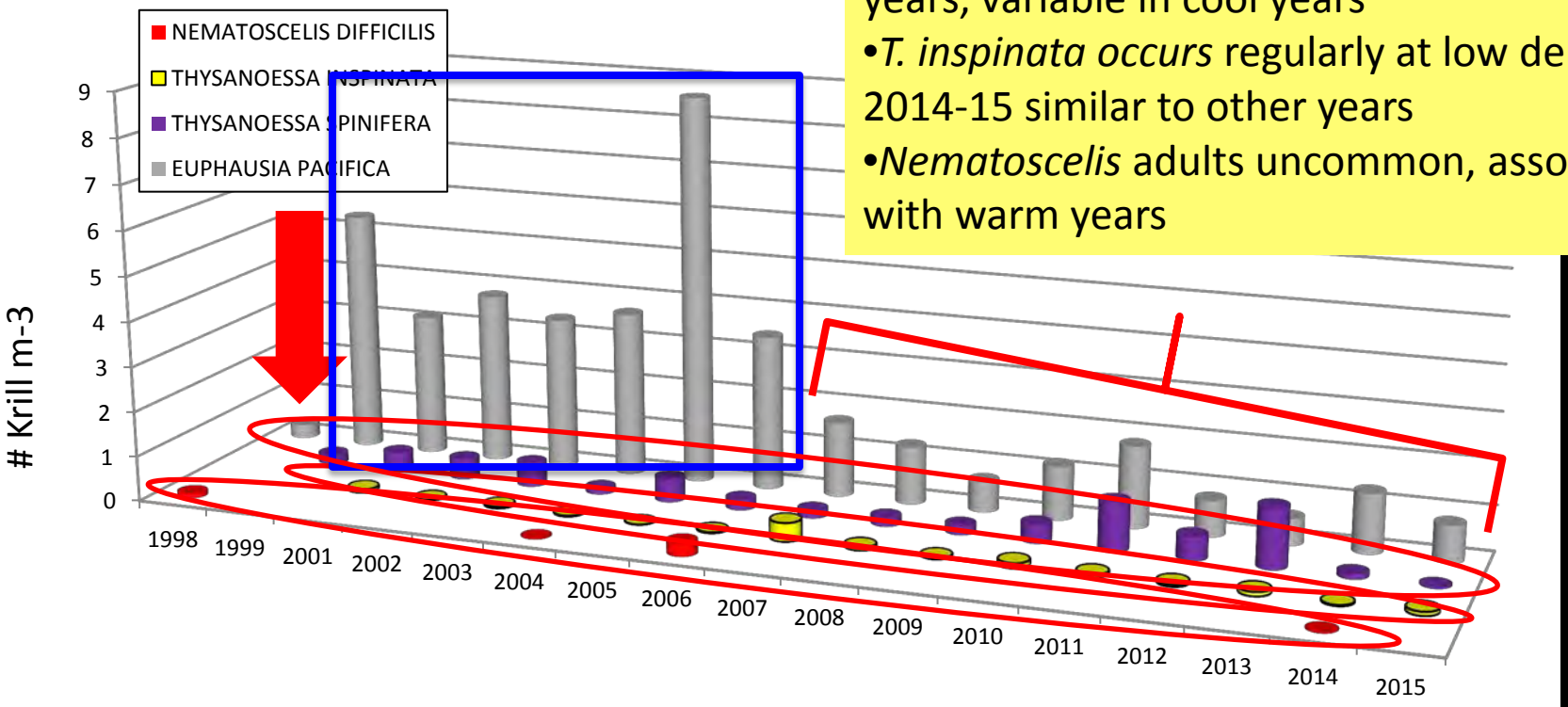


T. spinifera adults



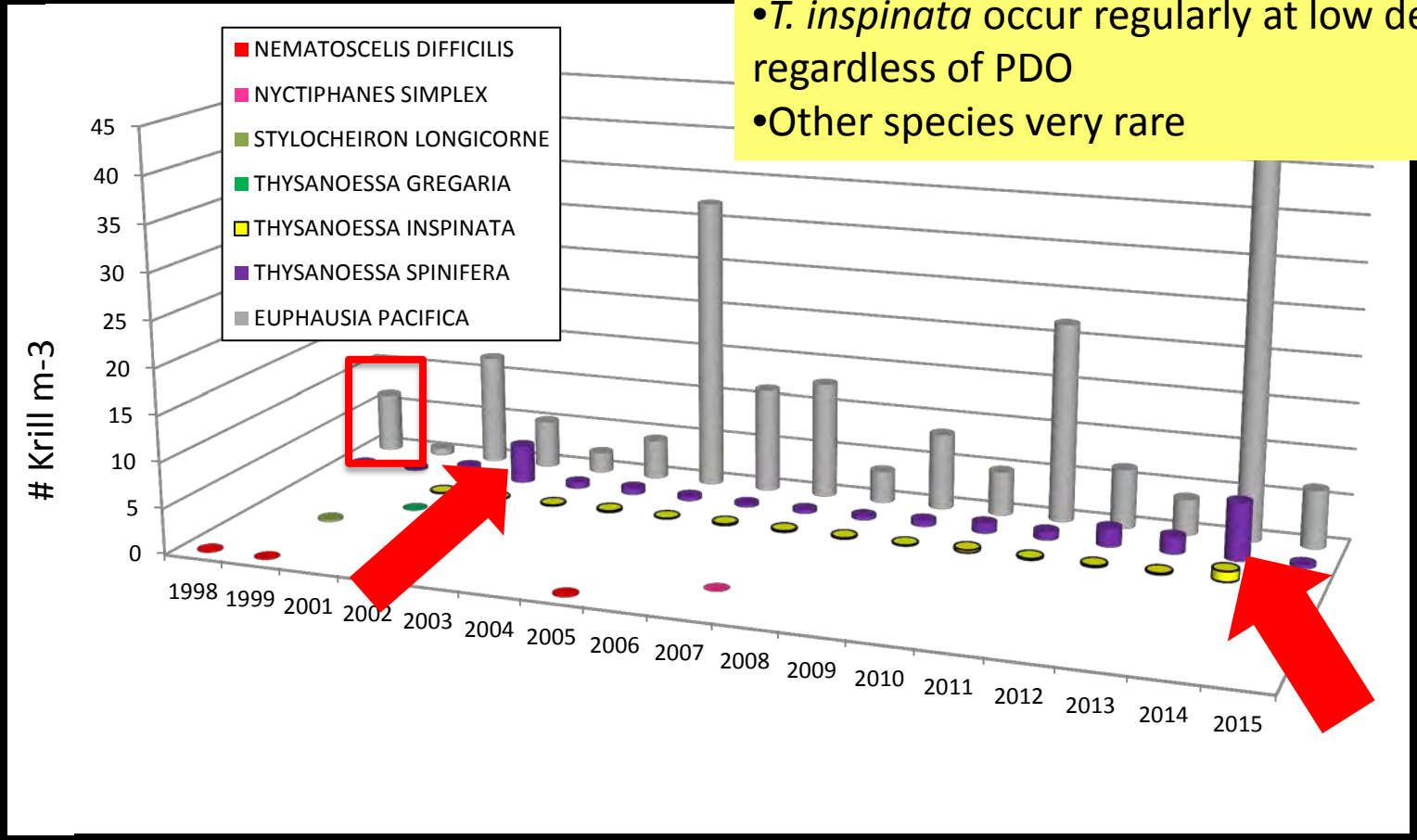
Adult Densities

- *E. pacifica* density very low 1998 (El Niño)
- *E. pacifica* densities high 1999-2006, lower 2007-present
- *T. spinifera* densities low during warm PDO years, variable in cool years
- *T. inspinata occurs* regularly at low densities; 2014-15 similar to other years
- *Nematoscelis* adults uncommon, associated with warm years

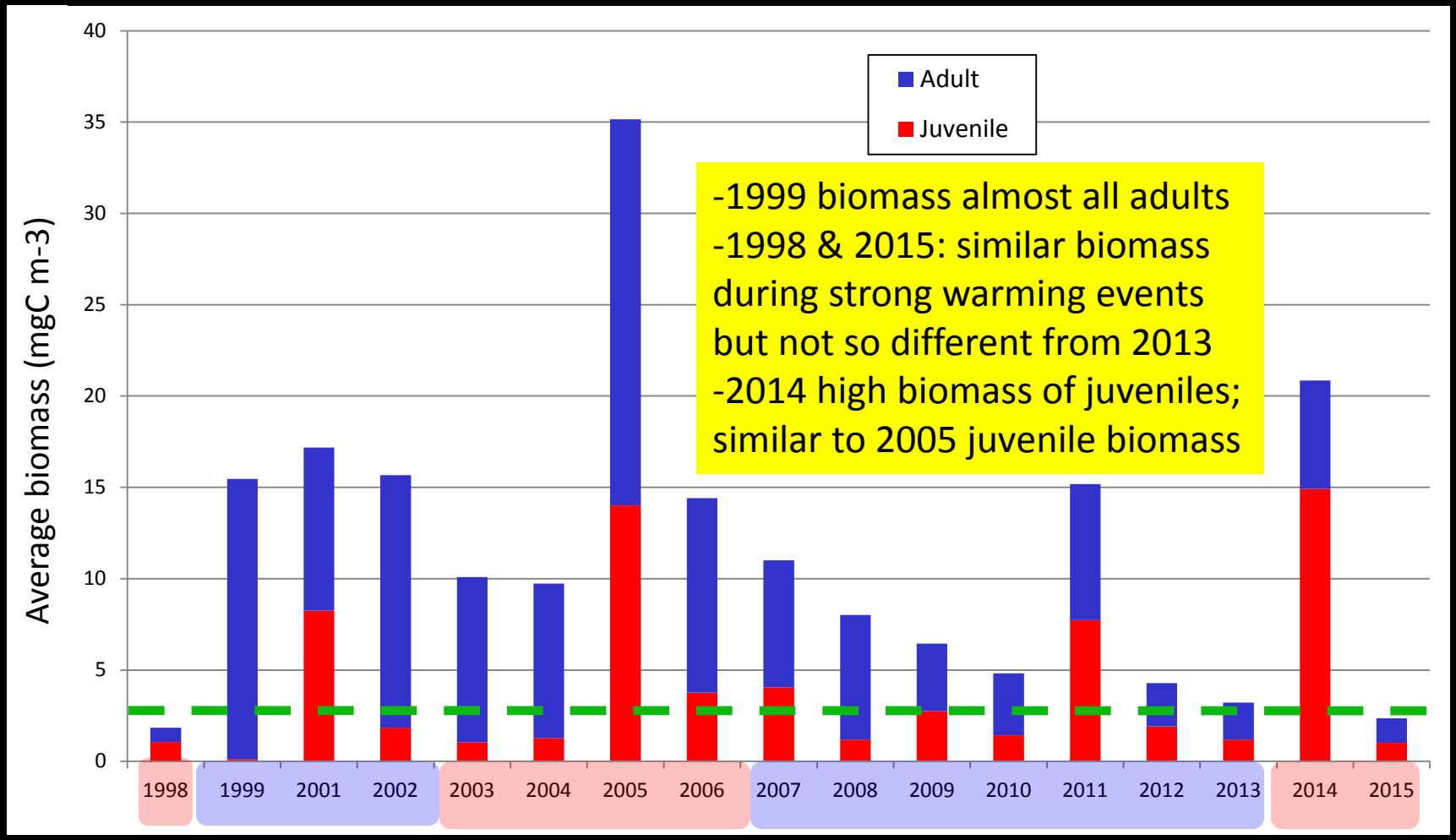


Juvenile Densities

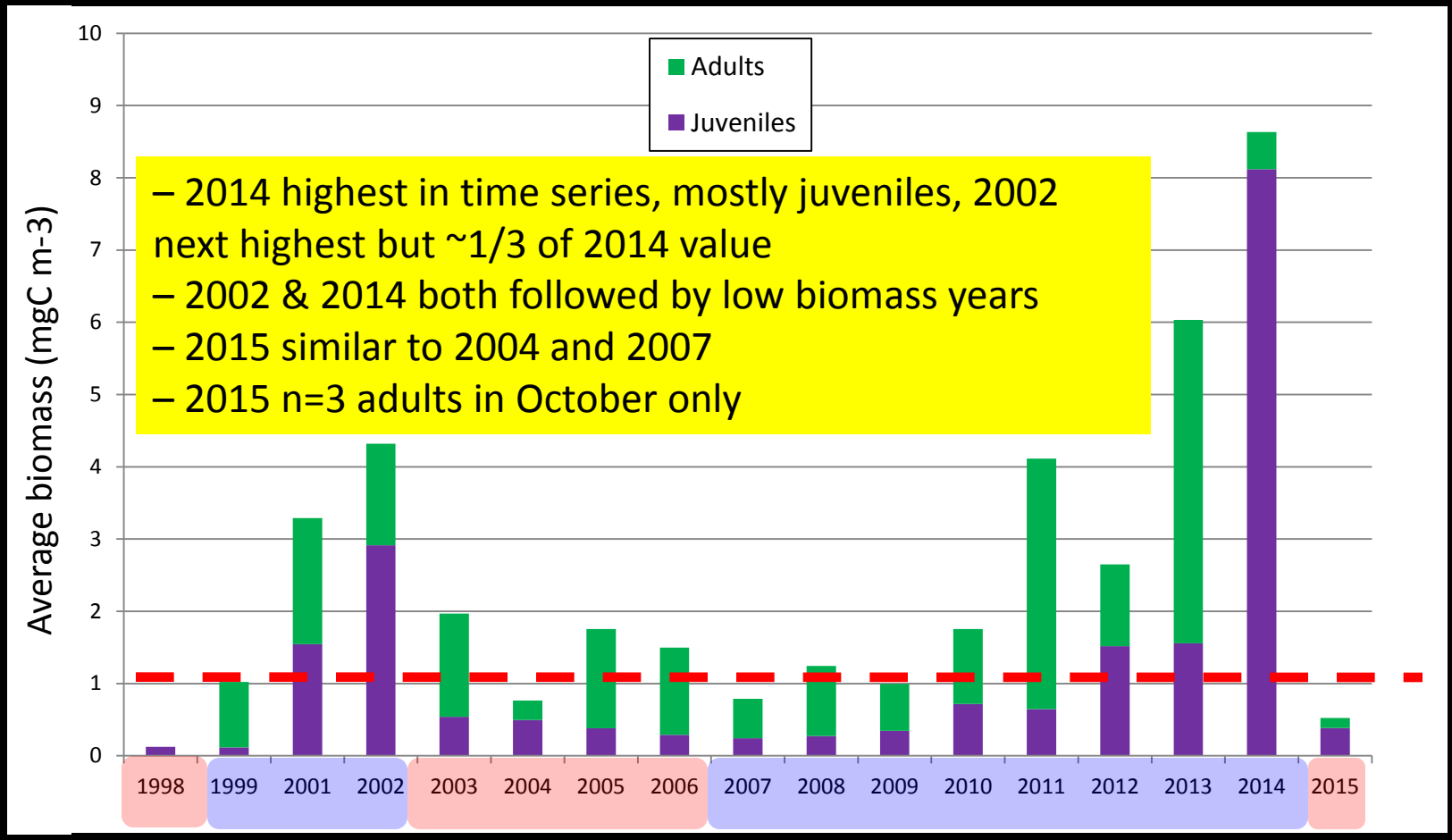
- *E. pacifica* density highly variable; density during 1998 El Niño not unusually low
- *E. pacifica* densities highest 2006, 2012, 2014
- *T. spinifera* densities generally low regardless of PDO; highest 2002 and 2014
- *T. inspinata* occur regularly at low densities regardless of PDO
- Other species very rare



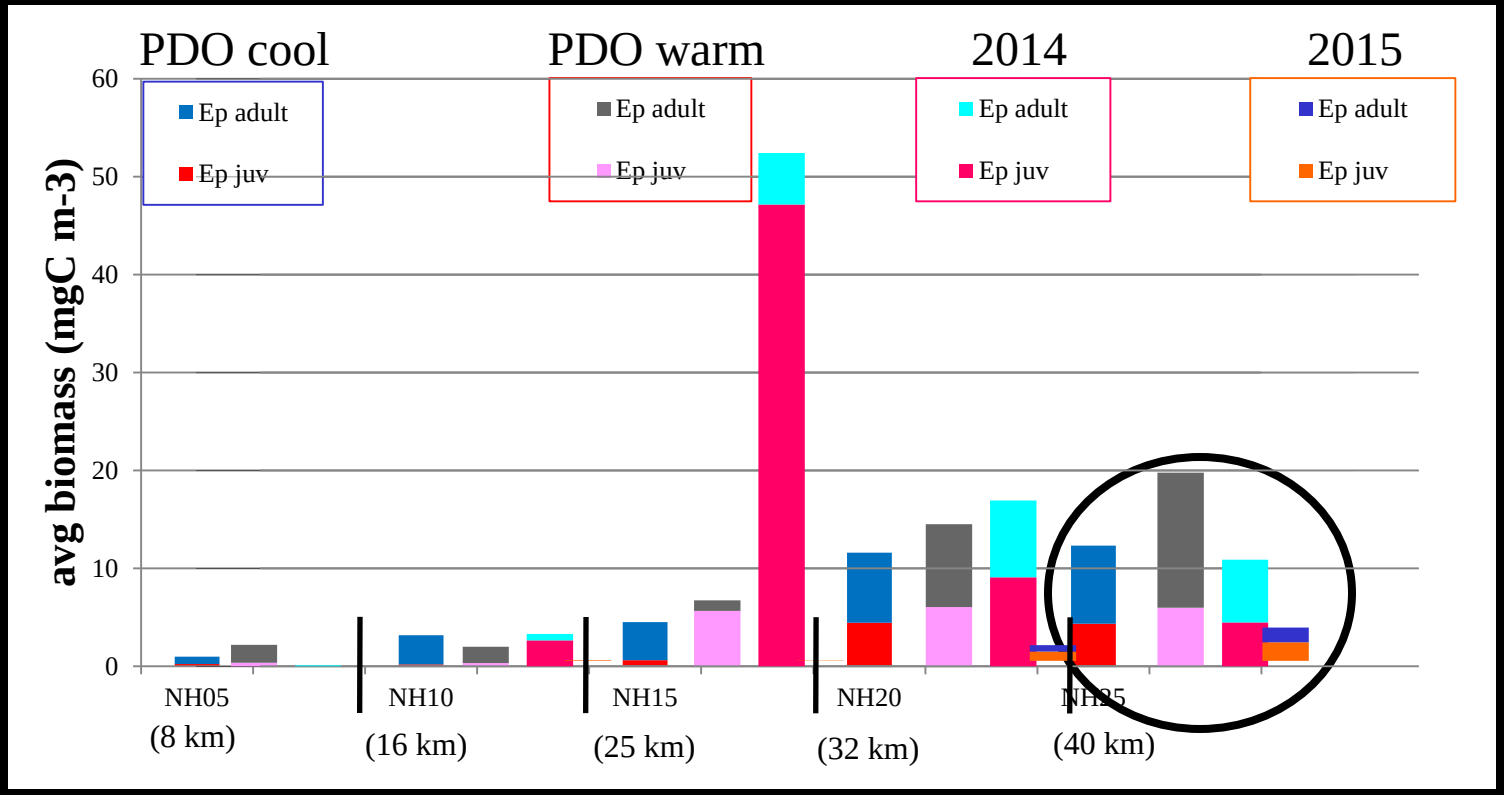
E. pacifica biomass



T. spinifera biomass



E. pacifica cross-shelf biomass cool vs. warm PDO + 2014 & 2015

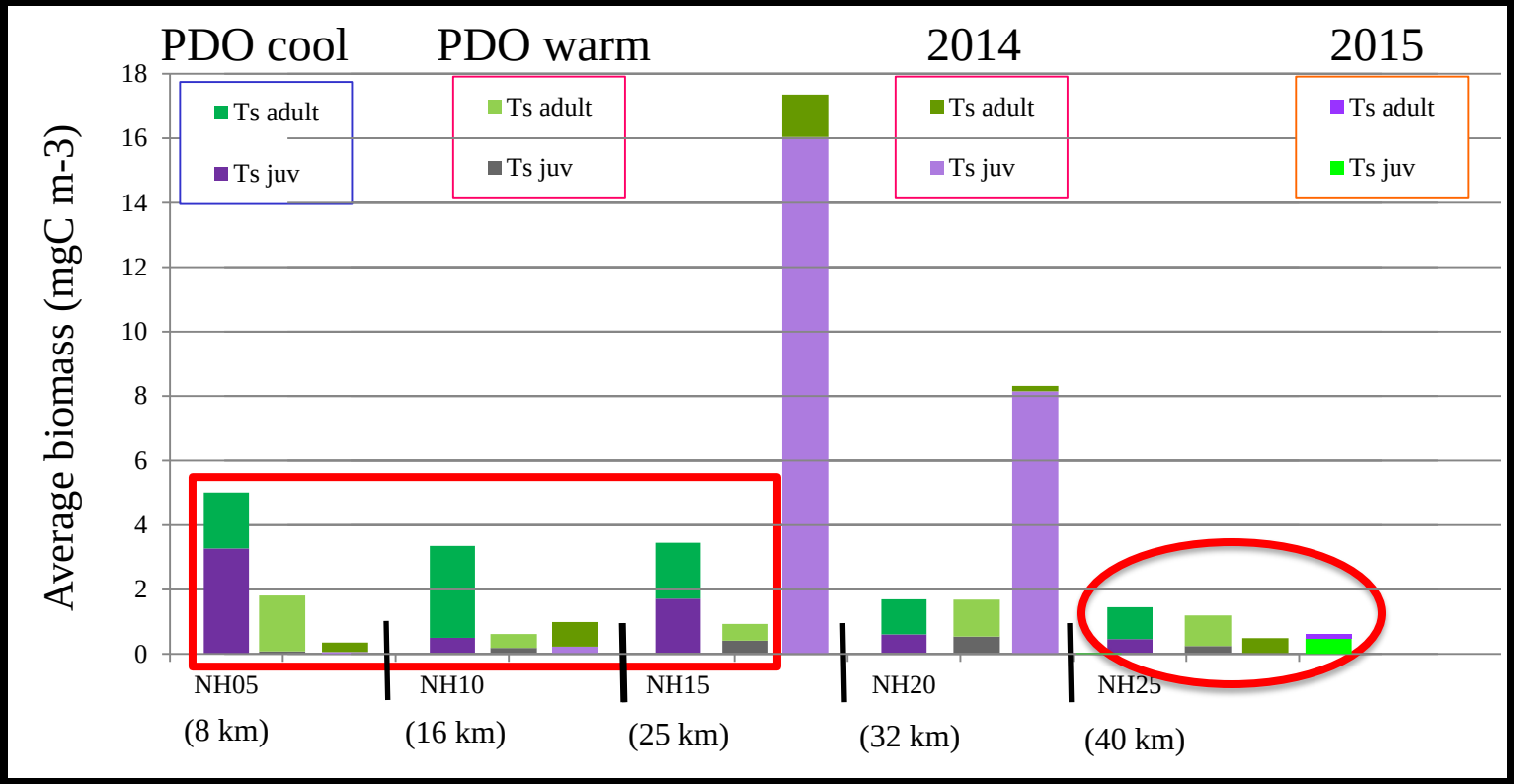


Cross-shelf pattern for 2001-2013 similar for cool & warm PDO

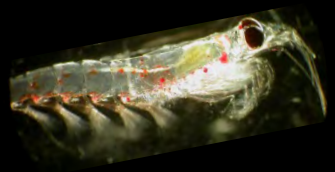
2014 – high biomass mid-shelf, mostly juveniles

Higher offshore biomass with warm PDO suggest *E. pacifica* might like a little warming but low 2015 biomass suggests they would **NOT** like a lot of warming

T. spinifera cross-shelf biomass cool vs. warm PDO + 2014 & 2015



- Biomass offshore essentially the same for cool and warm PDO
  - Very low 2014 (all adults) and 2015 (mostly juveniles, n=3 adults)
- 2014 mid-shelf biomass unprecedently high; almost all juveniles
- Biomass inshore higher during cool conditions (max of 5 mgC m^{-3} = 5 large adults)

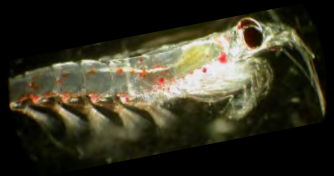


Warm Blob Results

- *Euphausia pacifica*
  - Present?
  - Spawning?
  - Smaller lengths?
  - Lower density?
  - Lower biomass?
  - Cross-shelf?
    - No *E. pacifica* biomass inshore, offshore biomass much lower than other years

Yes

- *Thysanoessa spinifera*
  - Total adults 2015 n=3 in October, some juveniles present in summer & fall
  - Cross-shelf
    - No biomass inshore where it is usually highest; offshore biomass low and mostly juveniles
- Rare or new species of euphausiids? No



Effects of Warming

- 2014 cold prior to arrival of Blob, warm after – euphausiids responded rapidly to temperature change
  - Lengths decline for both species in 2014 after Blob arrives
  - 2015 - *E. pacifica* lengths far below warm PDO average, *T. spinifera* essentially absent
  - High biomass of juveniles of both species in summer 2014 suggest lots of spawning before the Blob arrived. Low biomass in 2015 may reflect low survivorship of those juveniles.
  - Spawning success may decrease during warm conditions due to fewer adults, lack of phytoplankton blooms, increases in gelatinous zooplankton
  - Both euphausiid species have a lifespan of about two years. Warm conditions lasting two or more years in a row could result in reduced euphausiid abundance (migration and reduced reproduction).
  - Reduced euphausiid abundance may impact higher trophic levels, including commercial fish and seabirds
- How would we interpret these data if we didn't have this long-term time series data set for context?

Euphausiid Live Work Protocol

Protocols for Measuring
Molting Rate a[illegible]d
Egg Production o[illegible]
Live Euphausiids

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

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Celebrating over a decade on the PICES website! (posted 2005)

- Everything you always wanted to know about working with live euphausiids!

Available on the PICES website! (www.pices.int) under the "Projects" heading

Acknowledgements

- Research vessels: *Elakha, Wecoma, Atlantis, Frosti, Miller Freeman, McArthur II, New Horizon, Shimada*

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- My boss at the University of South Florida (Dr. Brad Seibel) for sending me to this meeting to talk about data that has nothing to do with my current job

- My former boss (Bill Peterson) just for being Bill