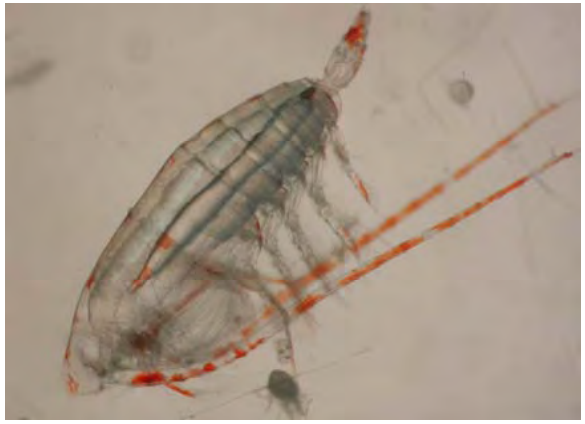
Calanus marshallae: life history, seasonal cycle of abundance and egg production rates in shelf waters off Newport OR

Bill Peterson, Cheryl Morgan and Jay Peterson
NOAA/Fisheries and CIMRS
Hatfield Marine Science Center, Oregon State University, Newport Oregon

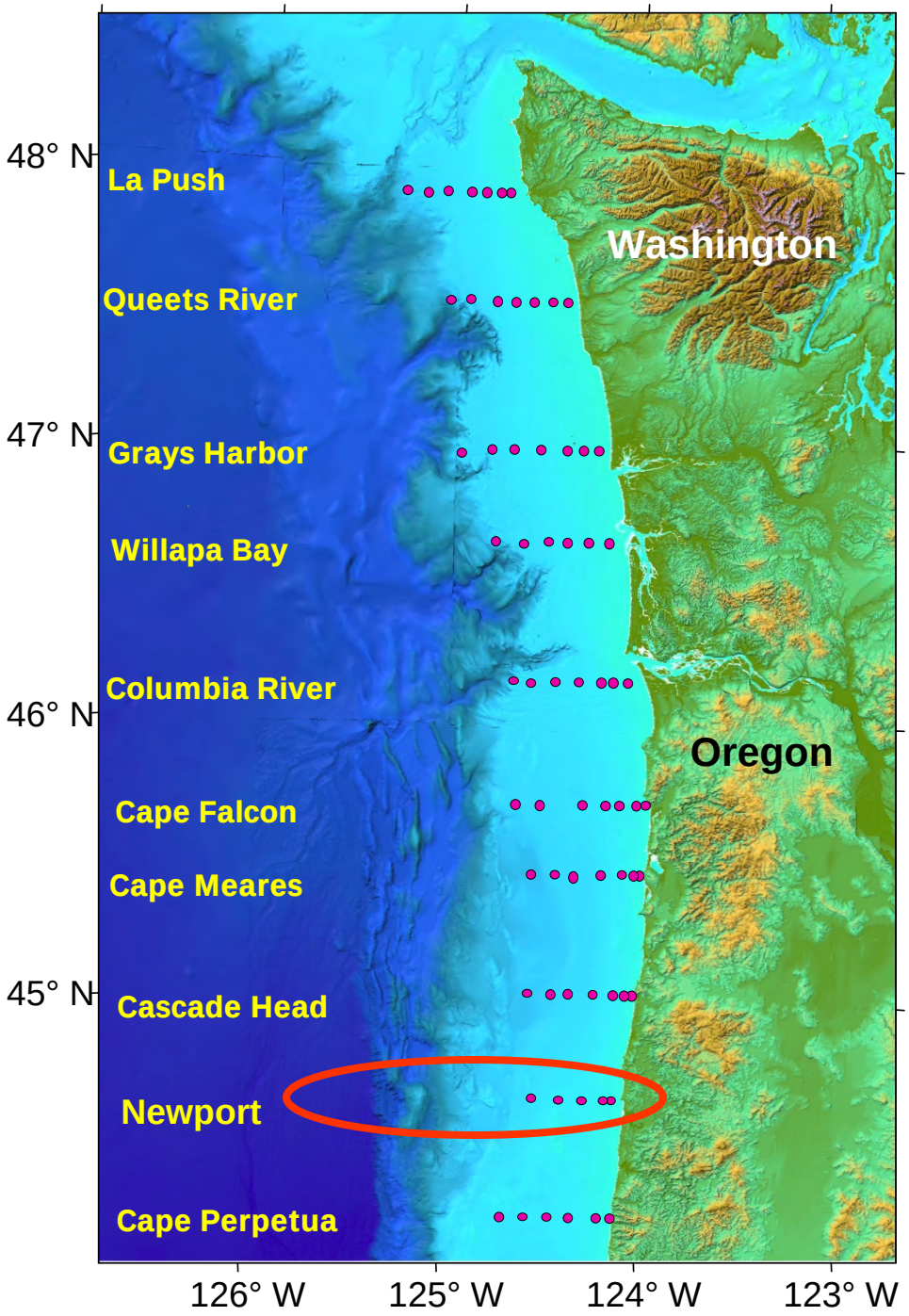


Topics

- Background info on local oceanography
- Abundance and egg production rates
- Species Pairs (*Calanus marshallae* and *C. pacificus*
- Climate Change

Methods

- Sample every two weeks, since 1996 along the Newport Hydrographic Line.
- CTD, nutrients, chl-a, zooplankton by vertical tow with ½ m 202 μm mesh net and 50 cm 333 μm bongo nets
- Incubate females for egg production measurements

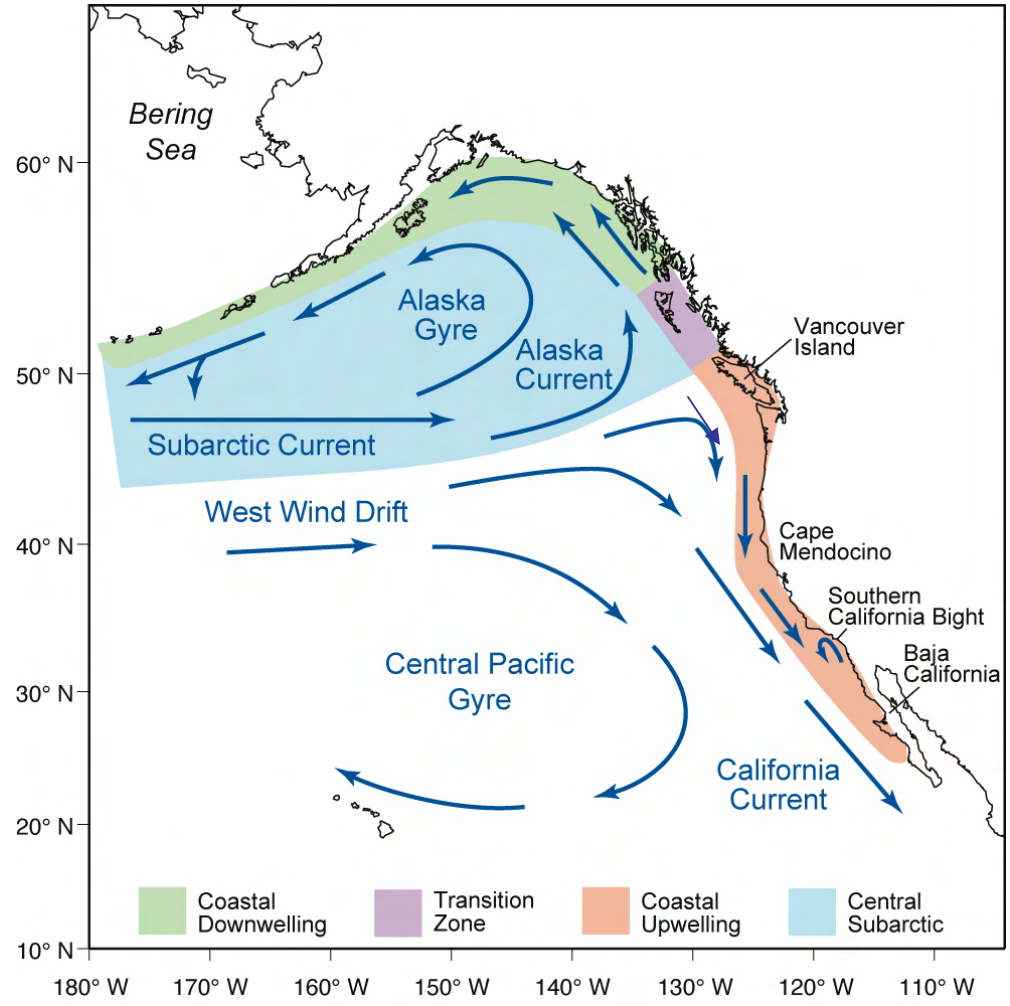


Observations: Newport Line

- Sampled biweekly since 1996 (15th year) using research vessels of 36-53 feet.

- Sample to 25 miles from shore and to 65 miles when we can get a large ship.

- Historical data: hydrography, 1960s; plankton, 1969-1973; 1983, 1990-1992



Circulation off the Pacific Northwest

Subarctic Current brings cold water and northern species to the N. California Current;

The West Wind Drift brings subtropical water and subtropical species to the N. California Current

Therefore, ecosystem structure is affected by the source waters which feed the California Current.

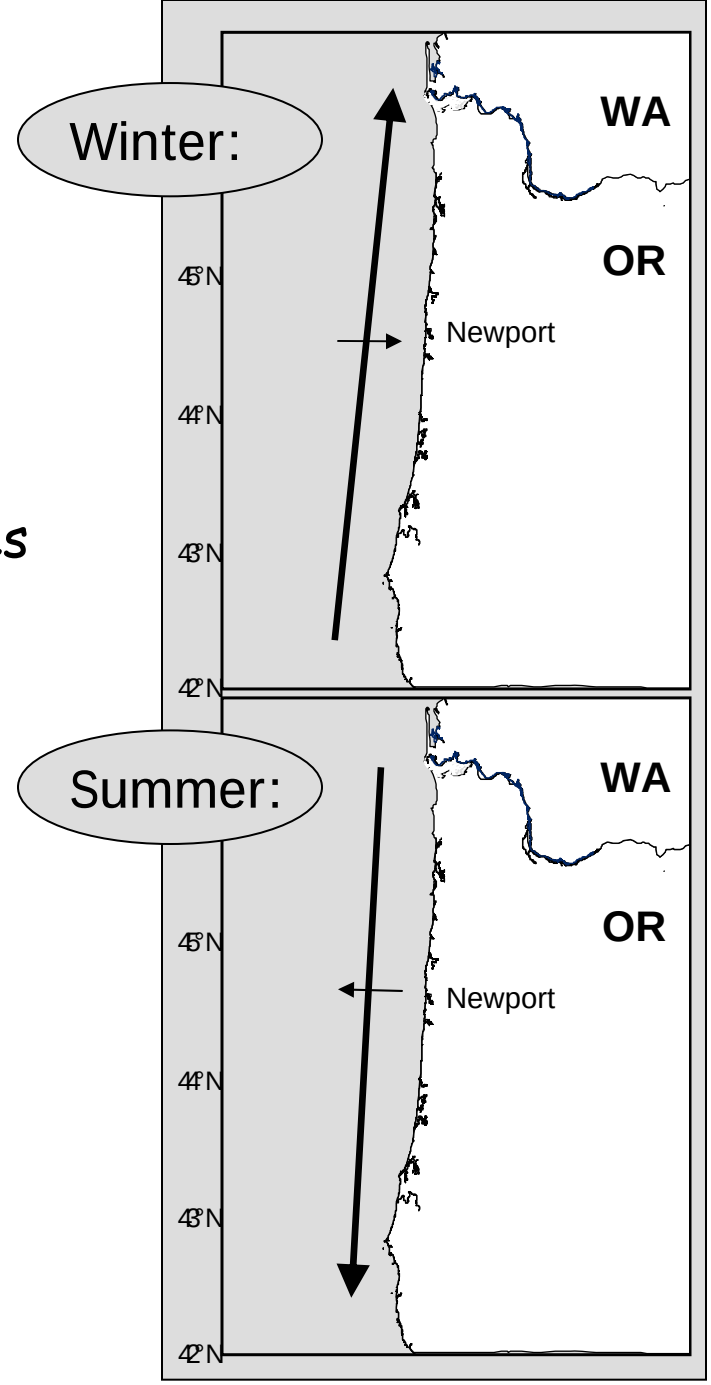
Winds and current structure off coastal Oregon:

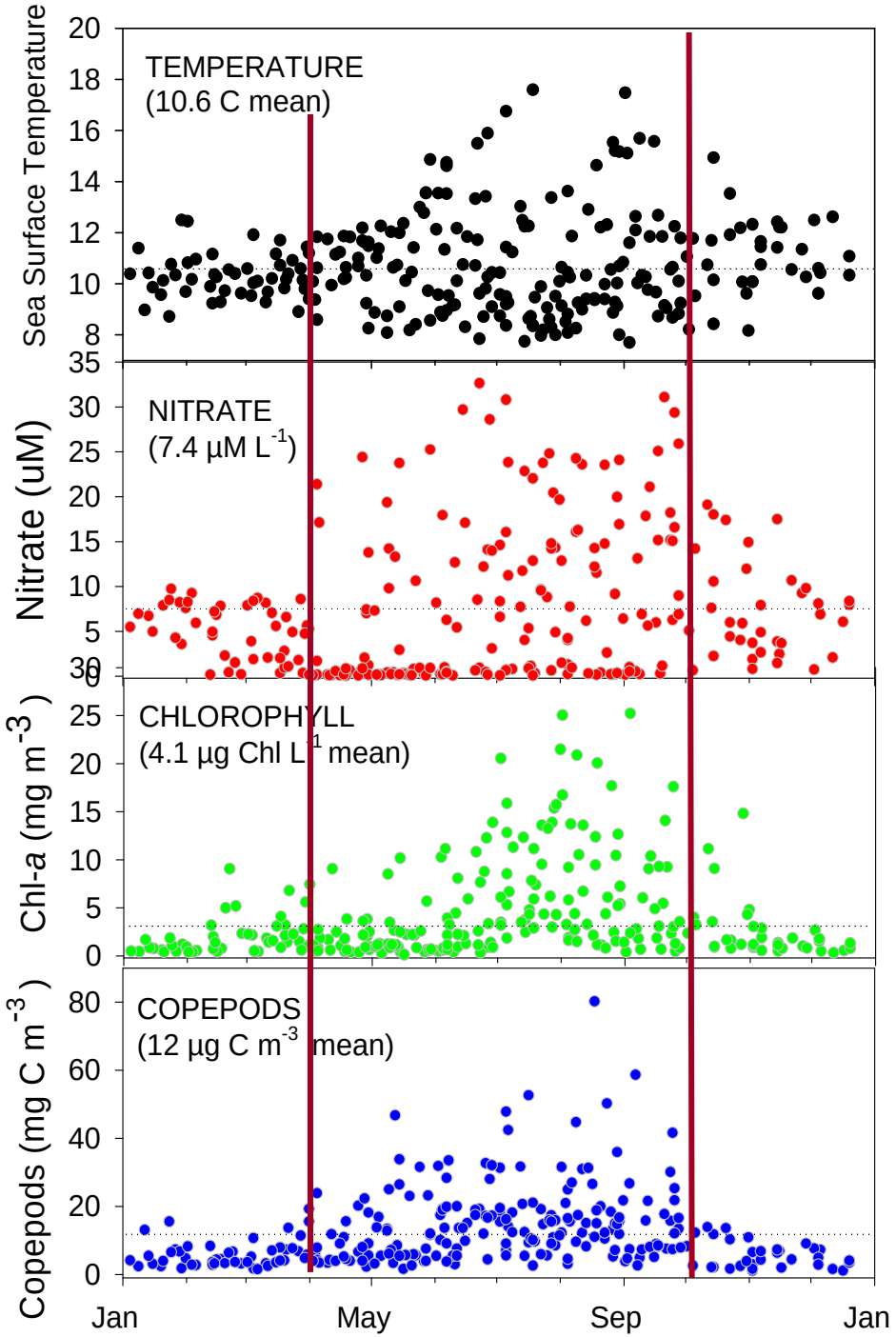
- Winter:
  - Winds from the South
  - Downwelling
  - Poleward-flowing Davidson Current
  - Subtropical and southern plankton species transported northward & onshore
  -

- **Spring Transition in April/May**

- Summer:
  - Strong winds from the North
  - Coastal upwelling
  - Equatorward alongshore transport
  - Boreal/northern species transported southward

- **Fall Transition in October**





Seasonal Cycles and seasonal variability

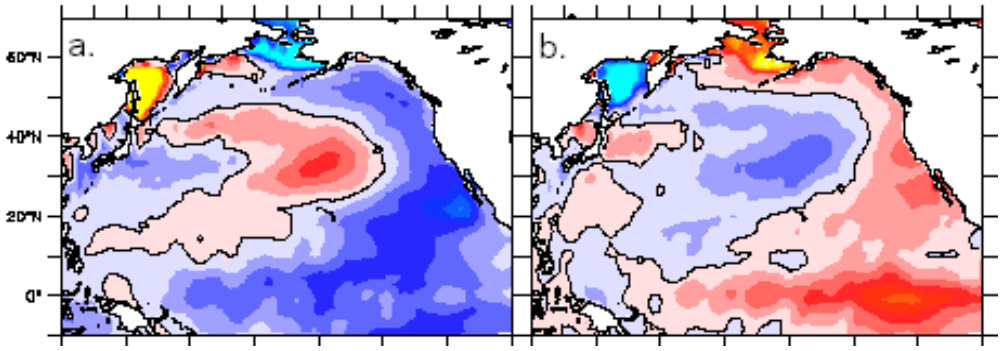
- When viewed as a climatology, one can clearly see the two seasons (winter and summer)
- Climatological "summer" begins in April; climatological winter begins in October

Decadal Variability: PDO & SST

The PDO has two phases, resulting from the direction from which winds blow in winter.

The SST anomaly patterns shown on the right results from basin scale winds: W'ly and NW'ly [negative phase] and SW'ly [positive phase]

Westerlies dominated during winter 07-08; SW'ly winter 09-10.



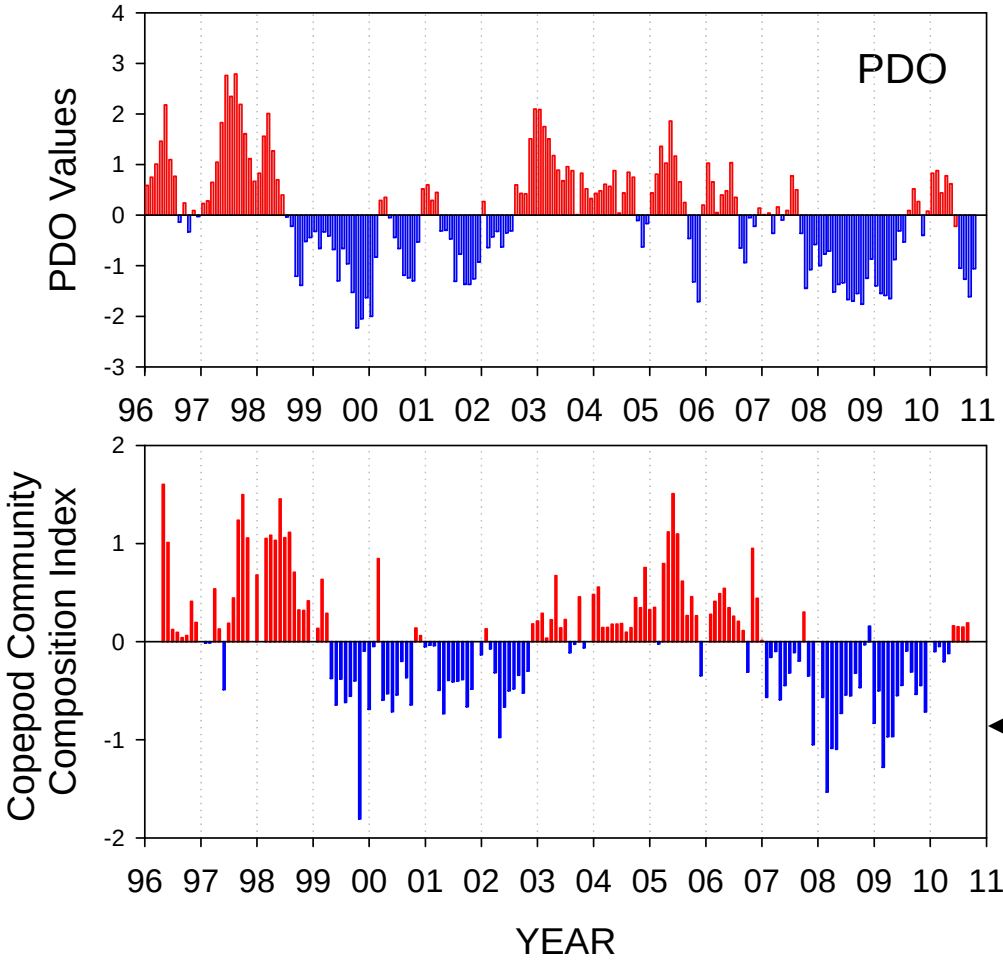
Blue is anomalously cold
Red is anomalously warm

EOF Analysis produces a "score" which describes the SST pattern across the entire North Pacific

PDO and zooplankton: copepod community composition

The sign of the PDO is associated with advection of either warm or cold water to the coast.

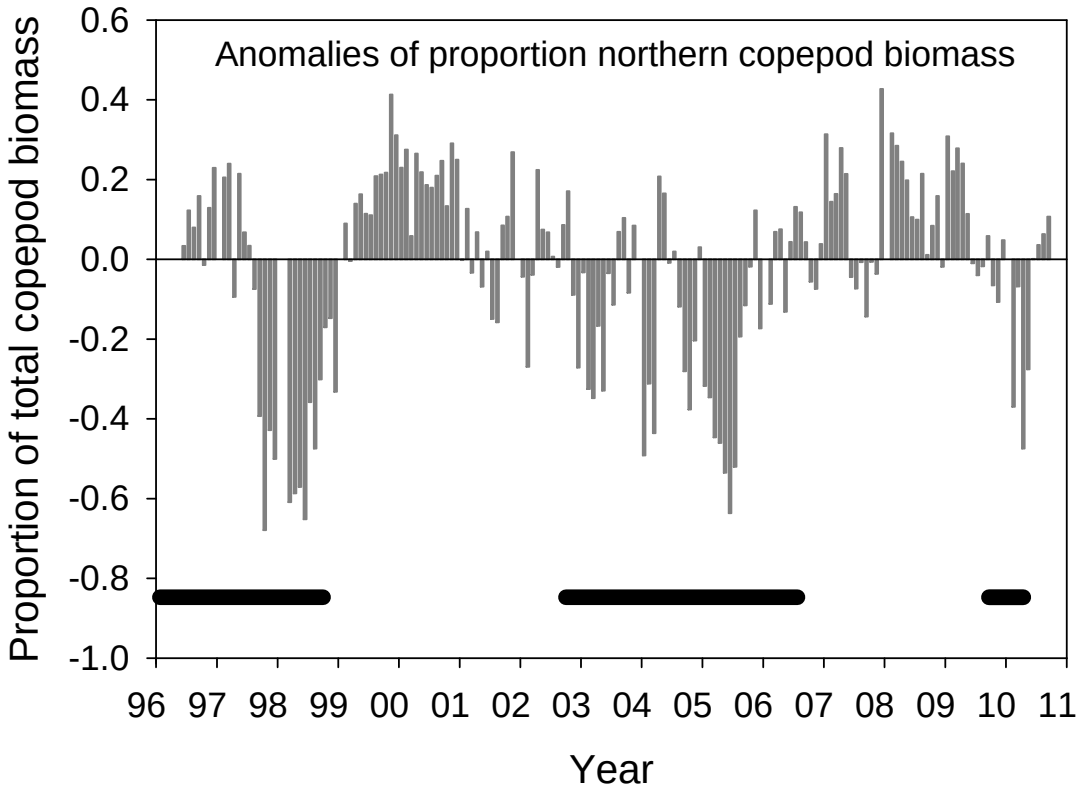
As a consequence you get "warm" and "cold" water zooplankton communities in coastal waters in association with positive (warm phase) or negative (cool phase) of the PDO.



Warm water community

Cold water community

Percent of copepod biomass composed of "northern-cold water" species



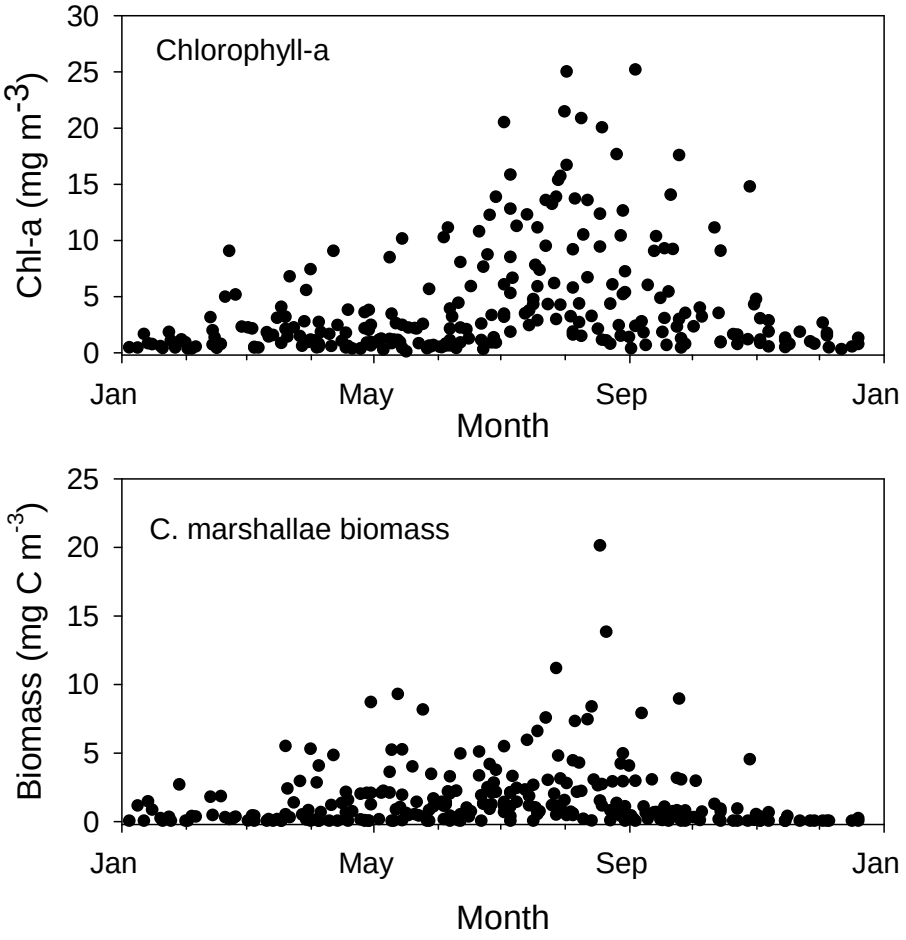
- Black bars indicate periods of positive PDO
- Positive PDO => warm water species
- Negative PDO => cold water species

Cold water species: *Pseudocalanus mimus*, *Calanus marshallae* and *Acartia longiremis*

Life History of *C. marshallae* in a nutshell

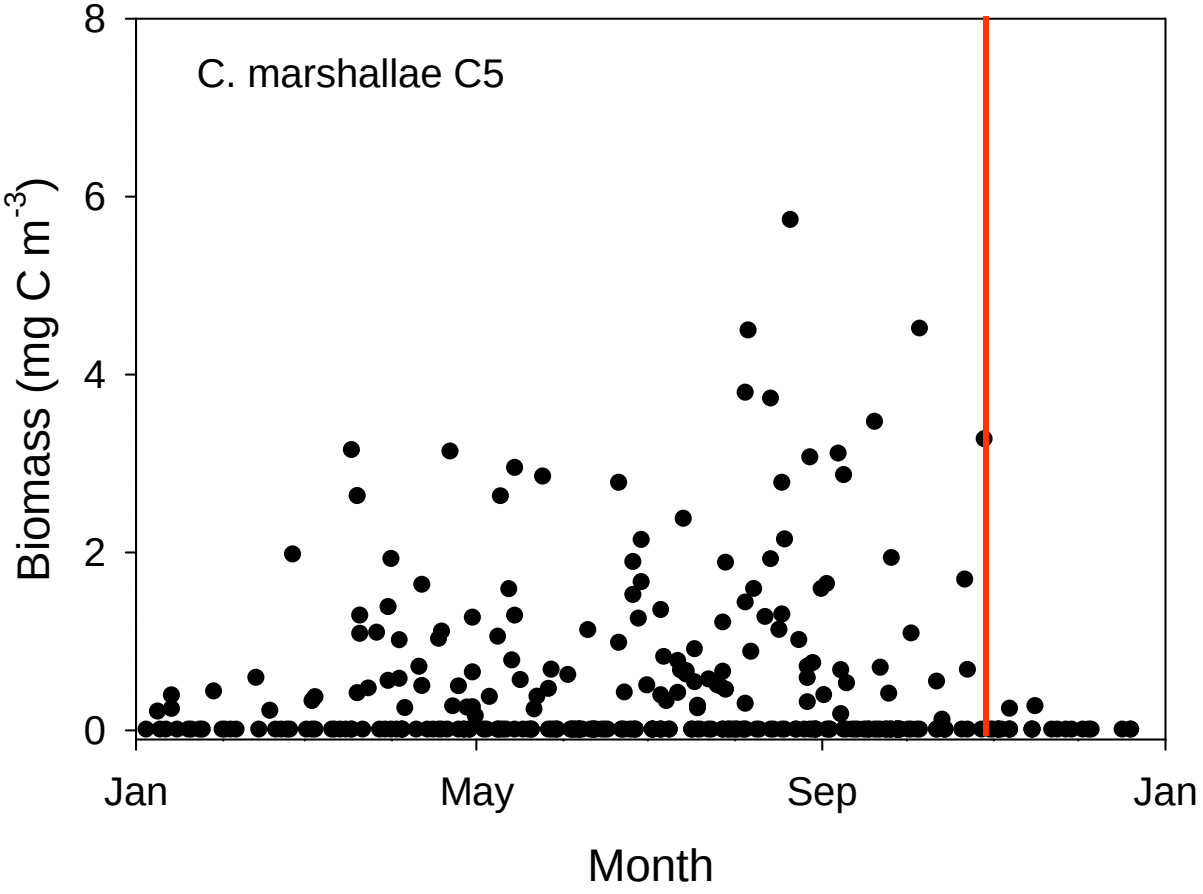
- *Calanus marshallae* are related to *C. finmarchicus*, *C. glacialis* and *C. chilensis* (but not related to *C. helgolandicus, C. pacificus, C. australis)*
- Diapause when conditions are unfavorable
- In the northern California Current, they are present in the upper water column from January through September or October. The awakening time seems to be fixed; the sleeping time is variable and may be related to the length of the upwelling season
- Produce 5-6 generations per year
- Important food resource due to their high lipid content
- They are iteroparous, producing a batch of up to 50-60 eggs every day if food is not limiting. When they first wake up in January-early February they use stored lipids as an energy reserve.
- A winter bloom often occurs in February/March which leads to increased in egg production rates.
- Development time from egg to adult is ~ 50 days.
- Female age likely on the order of a few days; egg mortality very high (see Peterson 1980).

Seasonal Cycle: (climatology of 15 years of data)

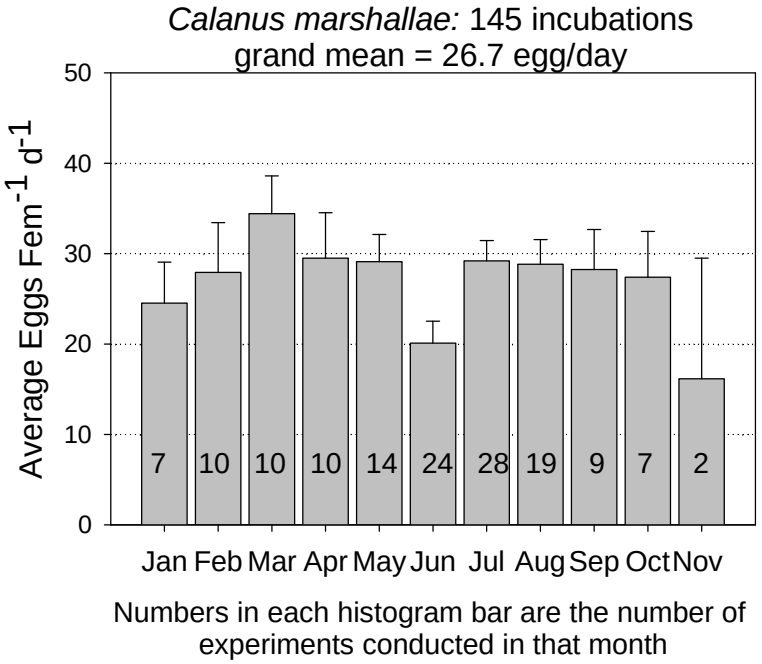


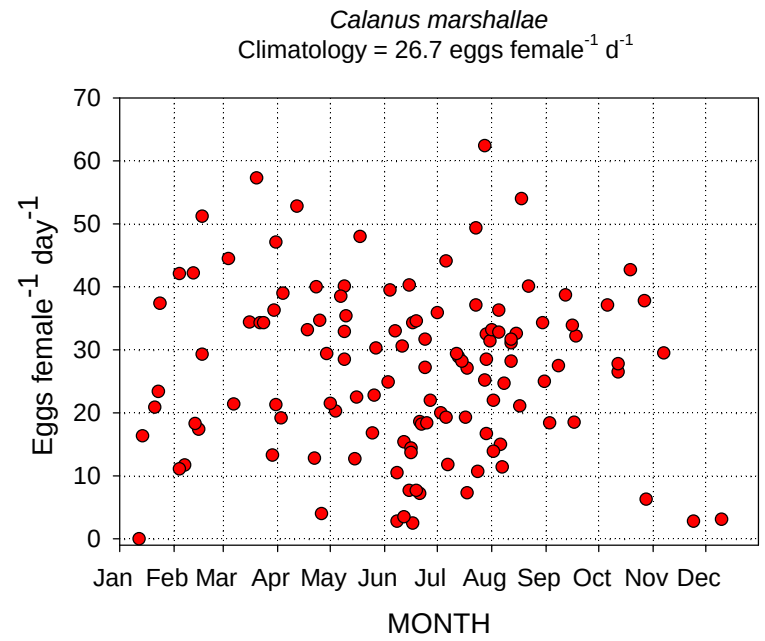
- *Calanus marshallae* wake up in January
- Produce five or six generations per year based on 9 month residence in the photic zone and a 45-50 day generation time
- Apart from a few sampling dates, peak abundances can extend from April-September

Calanus marshallae C5 climatology



- First appearance 8 Jan
- Last appearance 28 October

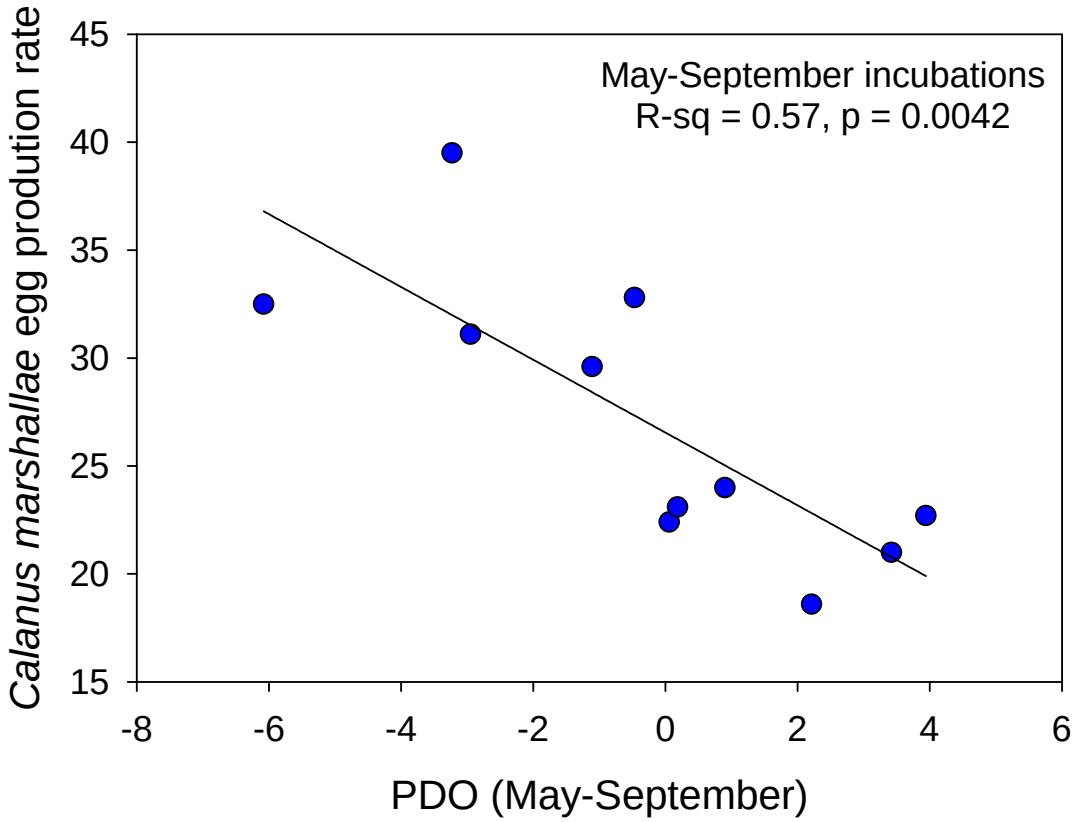




Egg Production

- Earliest date that egg production was observed was 10 January (2011)
- Rates similar month to month
- Latest date that egg production was measured was 10 Dec (2007), but usually after mid-October, few females are found and EPR's are very low as shown on the left.

PDO and EPR
Calanus marshallae



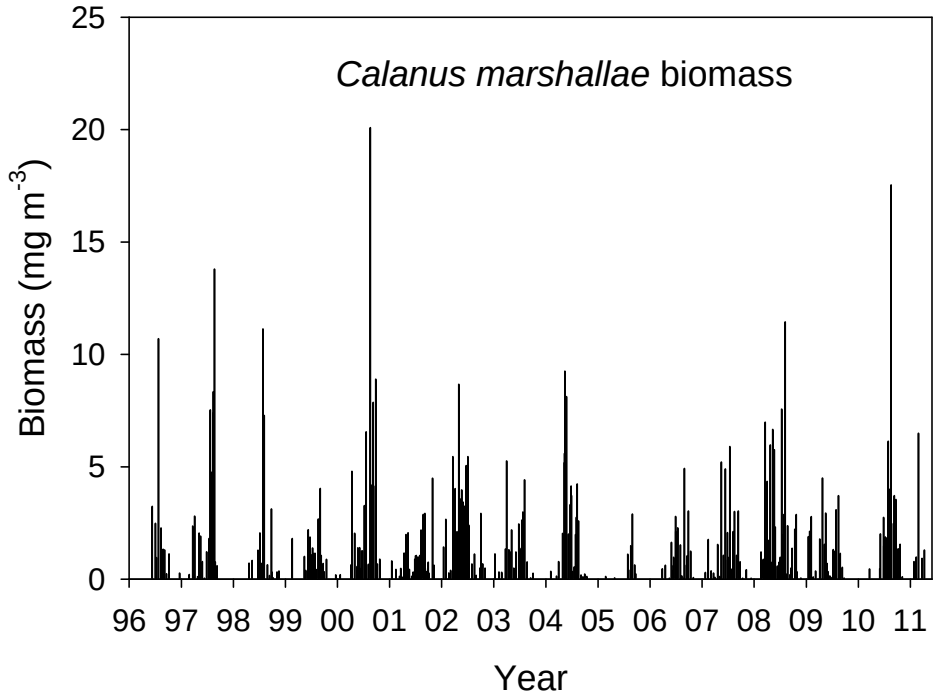
- Uncanny though it may seem, egg production is correlated with the PDO – the more negative the PDO, the greater the egg production rate.
- Why? Source waters; temperature; phytoplankton?

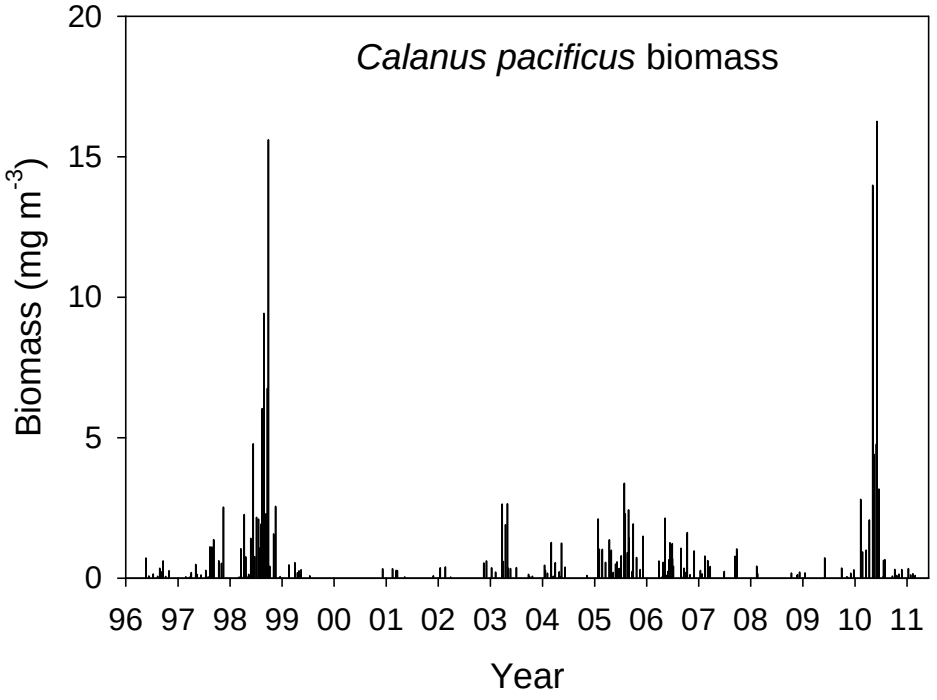
Species pairs: *marshallae* and *pacificus*

- *Calanus pacificus* common in southern California Current (replaces marshallae) and is common offshore of Oregon

	annual average biomass (mg C m^{-3})		
	marsh	pac	ratio
– NH 05 (62 m shelf)	1.71	0.51	3.2
– NH 25 (300 m slope)	0.81	0.18	4.5
– NH 65 (4,000 m)	0.03	0.17	0.2

- *C. pacificus* appears in coastal waters of the northern California Current every winter and throughout the year during El Niño events and when PDO is positive. Particularly abundant during certain El Niño events but uncertain why.

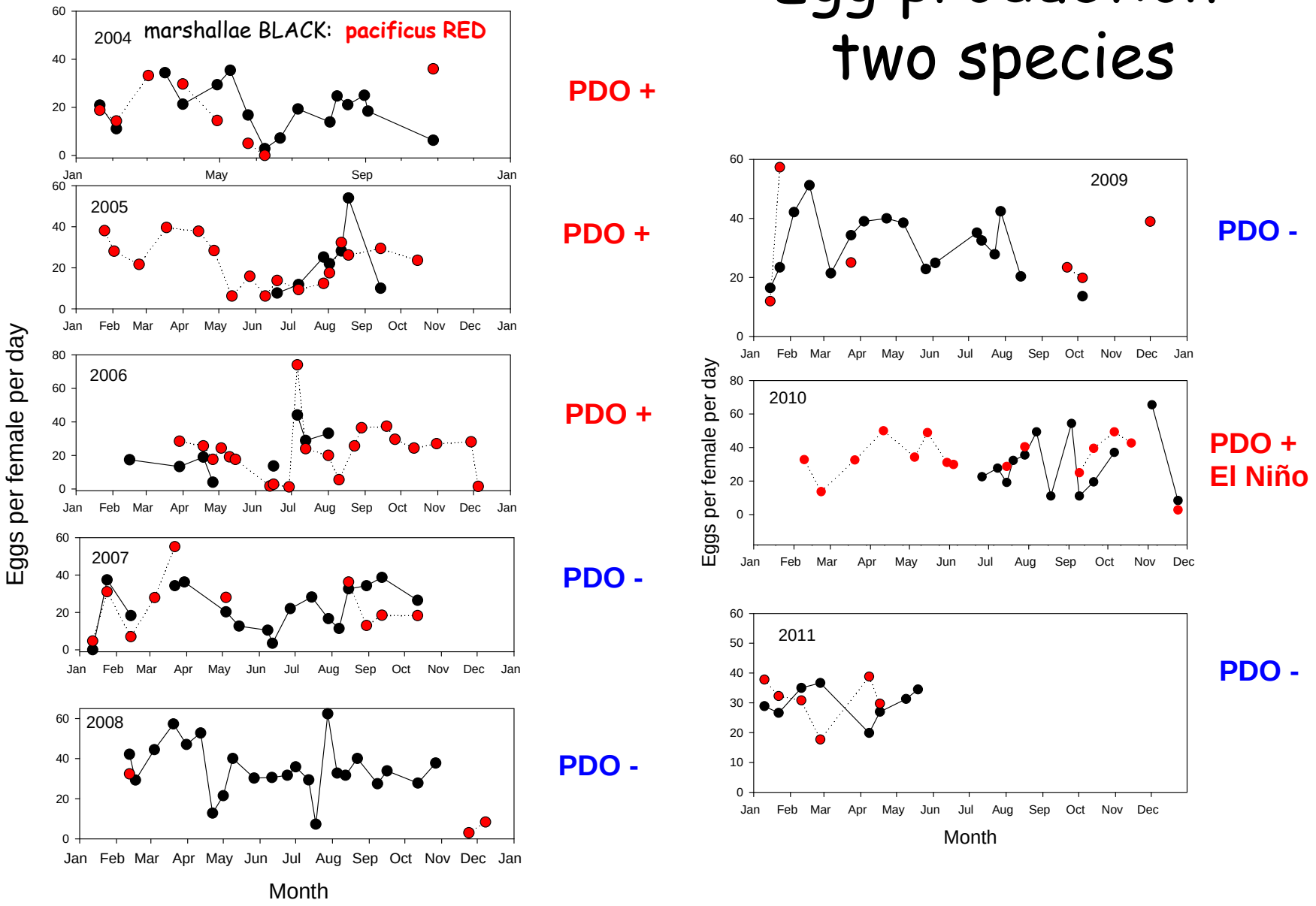




A Tale of Two *Calanus* at NH 05

- Note: *C. pacificus* mostly only found during years of positive PDO and during El Niño events
- Present during all winters regardless of phase of the PDO

Egg production: two species



Species pairs and climate change

- Positive PDO, if a common feature in the future, may lead to a subtropical community of copepods. Replacements may be as follows:

  Calanus marshallae = *C. pacificus*
  Pseudocalanus mimus = *Paracalanus parvus*
  Acartia longiremis = *Acartia tonsa*

- If true, this will change the bioenergetics and lipid content of the food chain since warm-water species don't store lipids. Knowing that salmon are rich in omega-3 fatty acids and need a "lipid-rich food chain", and knowing that warm water conditions now result in poor salmon returns, one has to wonder about the future of salmon in a warmer northern California Current that will likely be dominated by a sub-tropical food chain.

Unresolved questions

- Why don't *C. pacificus* , *Paracalanus* and *A. tonsa* persist in the upwelling zone year around?
  - Water temperature (too cold in summer)?
  - Or is it the retention problem?
  - Or long diatom chains that cannot be consumed easily?

  What is it about positive PDO that seems to favor the subtropical copepods – temperature, phytoplankton, transport, upwelling?

Issues related to climate change

- Will coastal upwelling become weaker, stronger or stay the same?
- Will warming of the ocean lead to greater stratification thus reducing the effectiveness of coastal upwelling?
- Will the Pacific "Decadal" Oscillation return to "Decadal"?
- Will the central North Pacific Gyre expand northward and make the waters off Oregon more subtropical?
- Alternatively, will expansion of the gyre make coastal upwelling more productive?
- Of concern in coastal upwelling systems is the trend toward decreased oxygen concentration and of decreased pH in waters which upwell at the coast.

Acknowledgements

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