The effects of the recent anomalous warming on zooplankton in the Northeast Pacific, from Continuous Plankton Recorder sampling.

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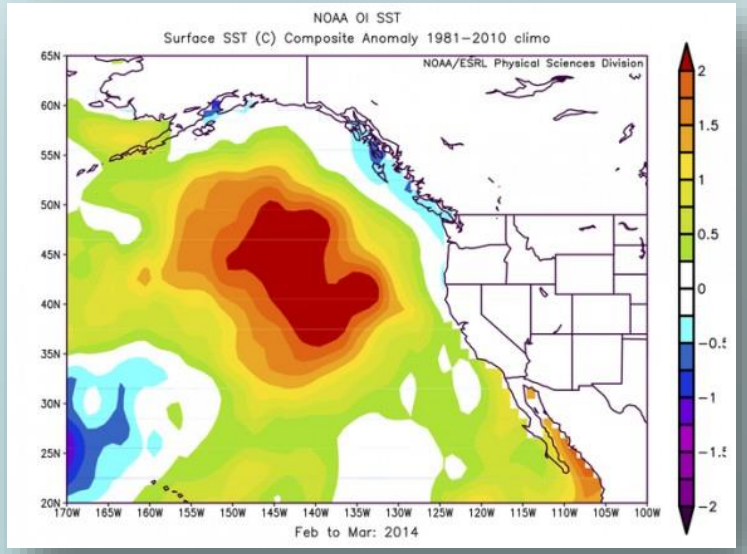
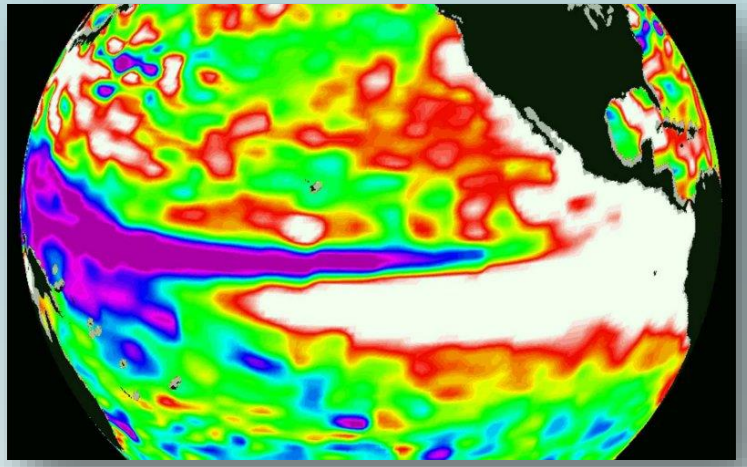
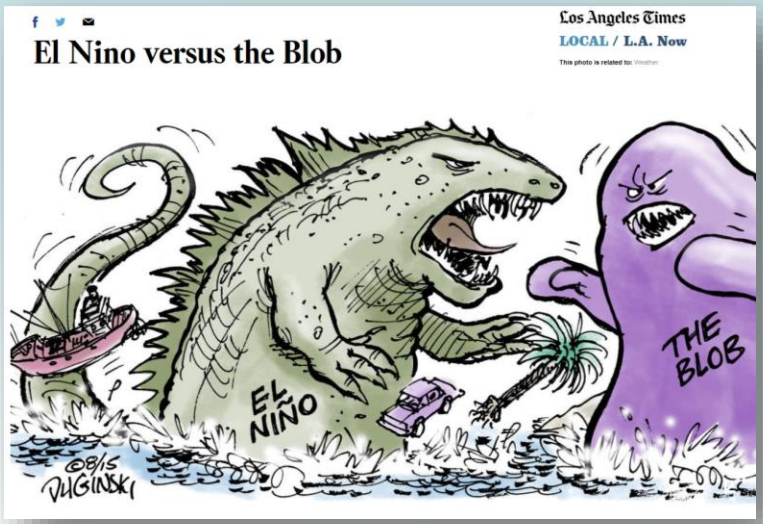
Warmth appeared suddenly late in 2013 as an offshore pool of anomalously warm water, nicknamed “The Blob”. Evident throughout 2014 but moved shorewards.

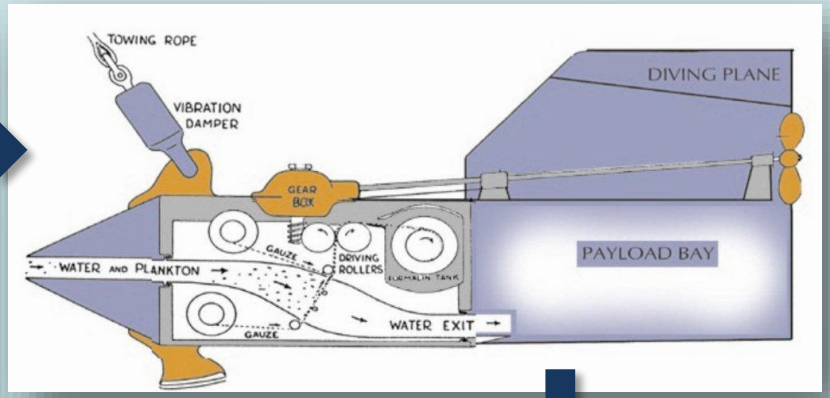


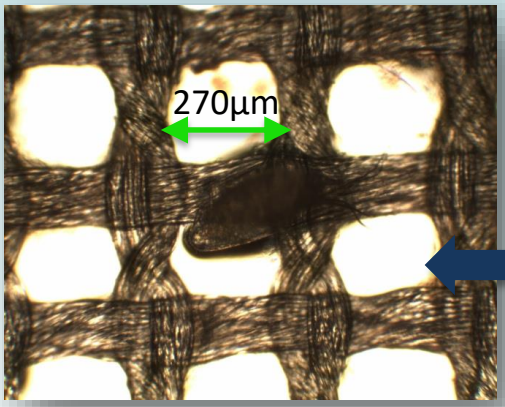
Then in 2015, a large (Godzilla) El Niño developed, persisting through the winter.





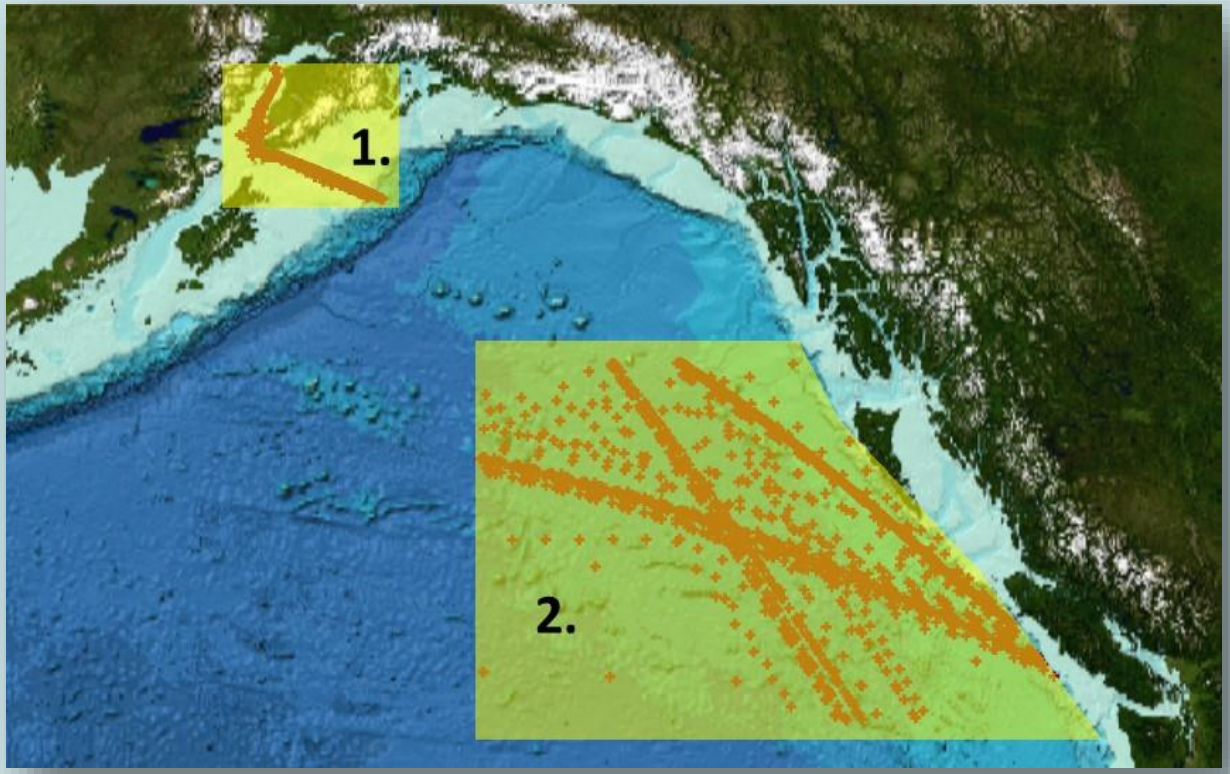
Data used here are from the Continuous Plankton Recorder Survey:

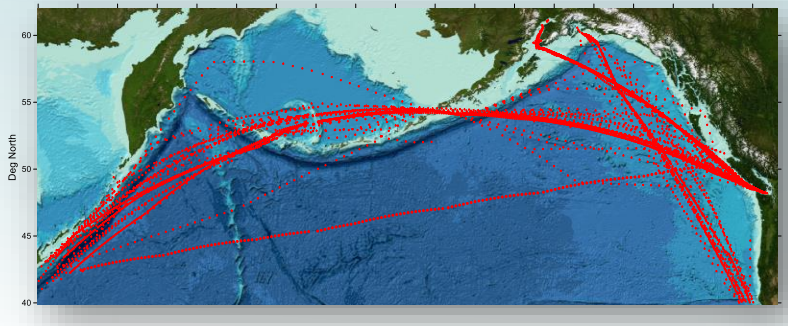




Regions covered in this study

1. The Alaskan Shelf
- Sampled typically Apr-Sept, 5-6x p.a.
- 2004-2015
- Transect has good spatial consistency





2. Oceanic NE Pacific
- Sampled typically Apr-Sept, 8-9x p.a.
- 2000-2015
- Two transects, one close to shelf/slope since 2004, one much more variable and runs west across gyre.

The lower trophic level data consist of:

180+ Phytoplankton Taxa

- Larger diatoms, hard-shelled dinoflagellates ☺

- Small, single cells 😐
  - *Naked flagellates* ☹

200+ Zooplankton Taxa

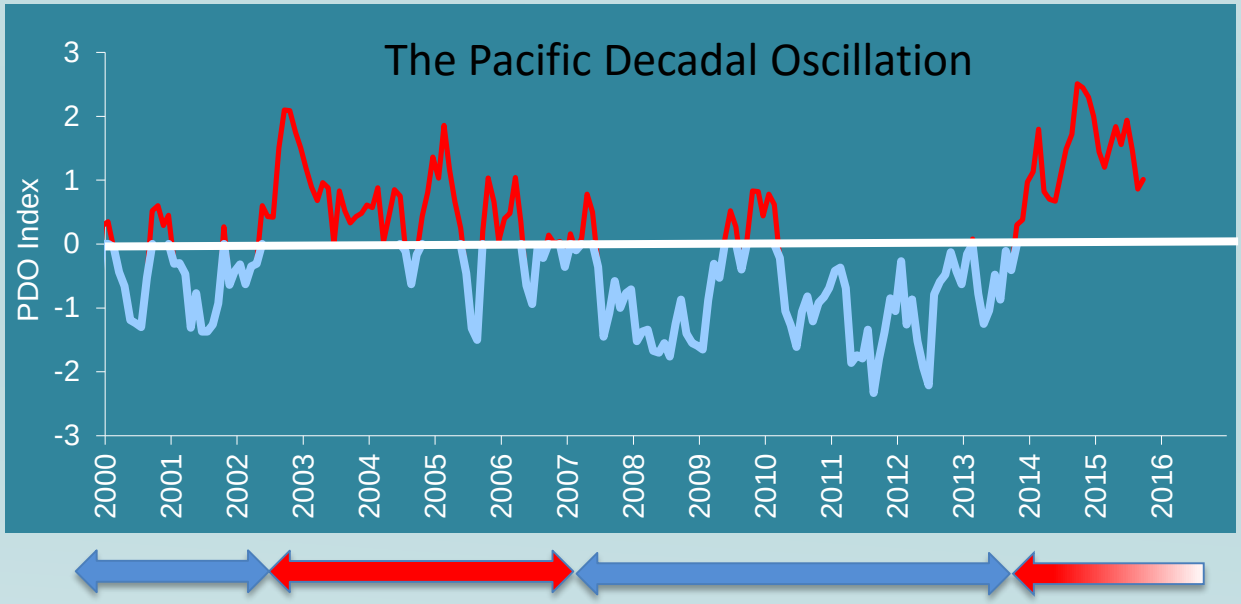
- Crustacean plankton ☺
- Organisms 200µm-1cm ☺

- Organisms < 200µm, > 1cm or fragile 😐
  - *Gelatinous plankton* ☹

Additional caveats:

- Sampling covers ~April to September
- Surface ~0-15m mixed sample
- Data > June 2015 are provisional

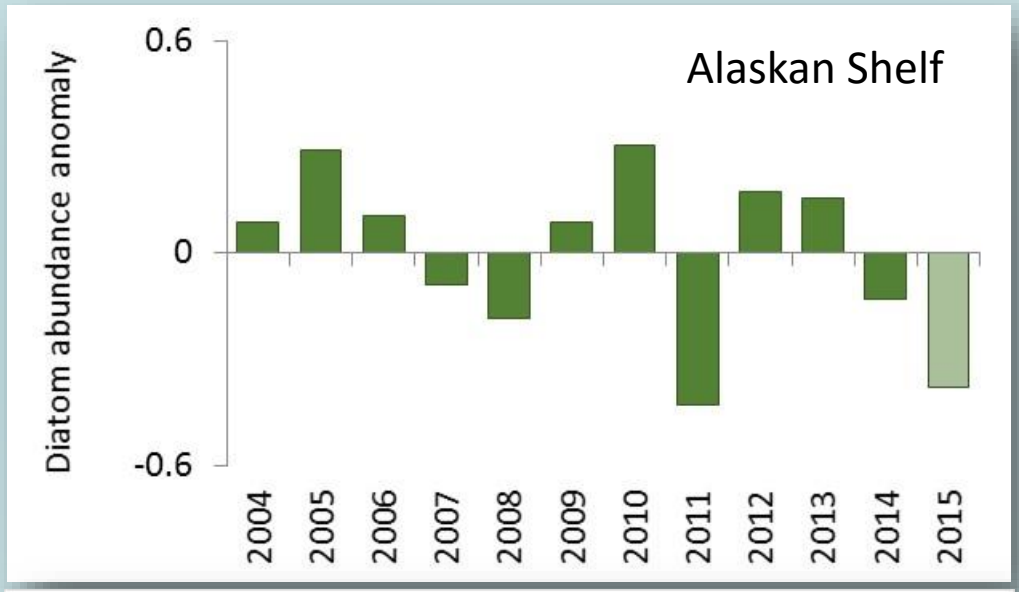
During the length of the CPR time series, the ocean has alternated between PDO+ve, warm (top) to PDO-ve and cool (bottom). Recently, conditions have been unusually warm and PDO+ve, influenced by the Blob and El Niño.

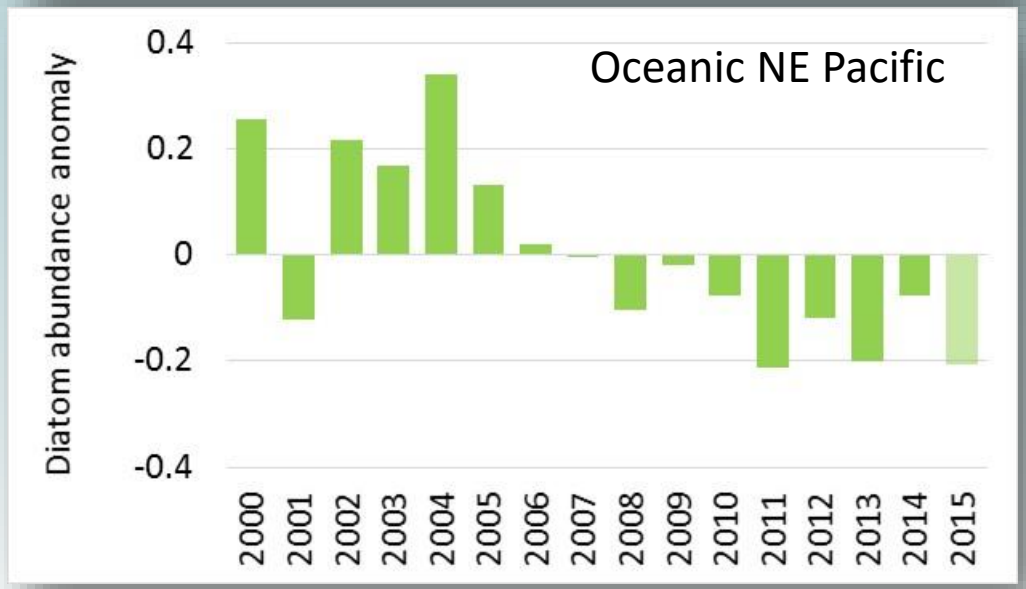


We can test whether the recent responses by plankton to the warmth fit with what we expect from past observations.

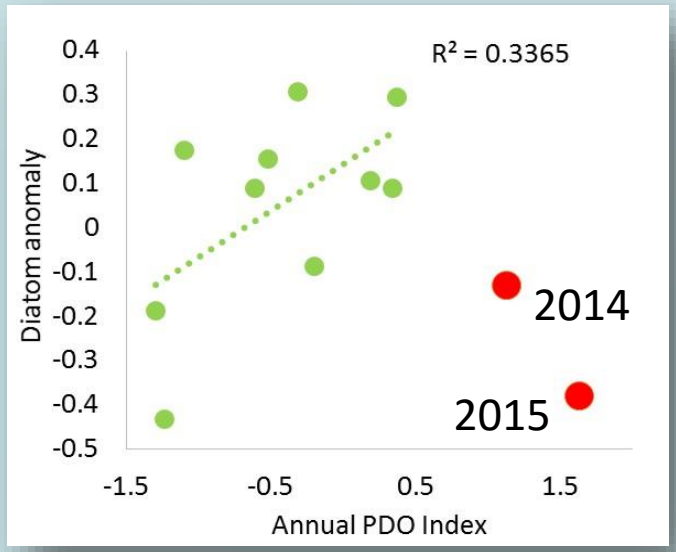
Phytoplankton

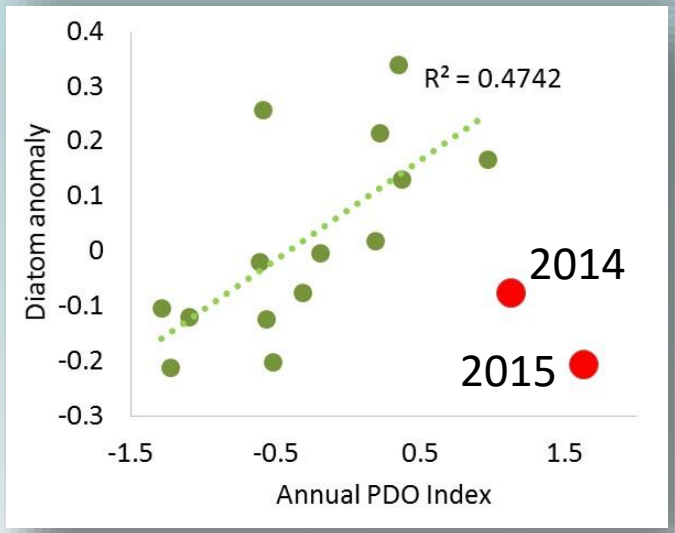
Mean annual relative abundance of large diatoms:





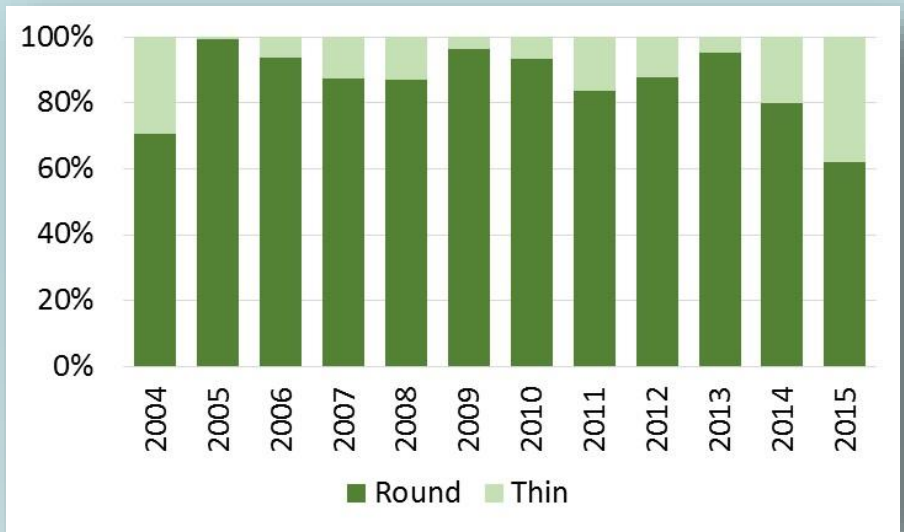
Relationship with the PDO:



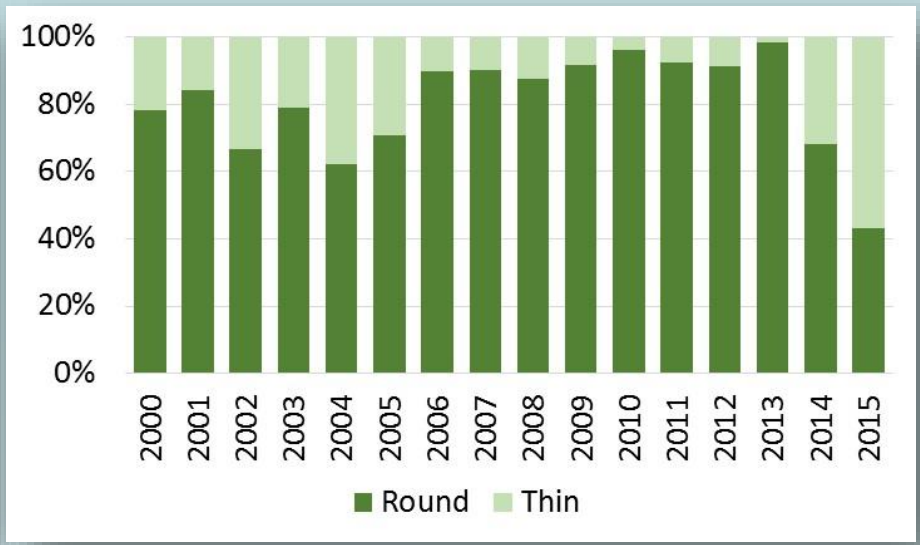


Diatom Composition

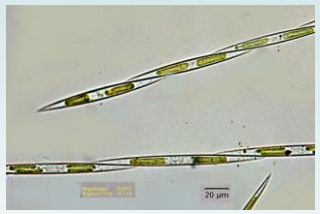
The proportion of the spring community comprising the different cell shapes; round centric types or long, thin pennate types:



Alaskan Shelf



Oceanic NE Pacific



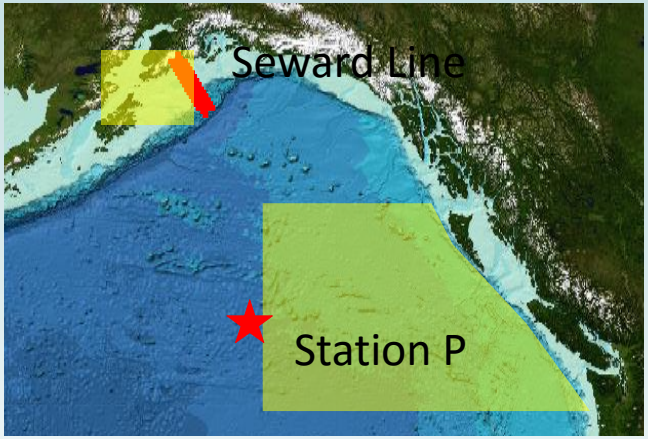
e.g. *Guinardia* and *Pseudonitzschia*

Chaetoceros and *Neodenticula*

So,

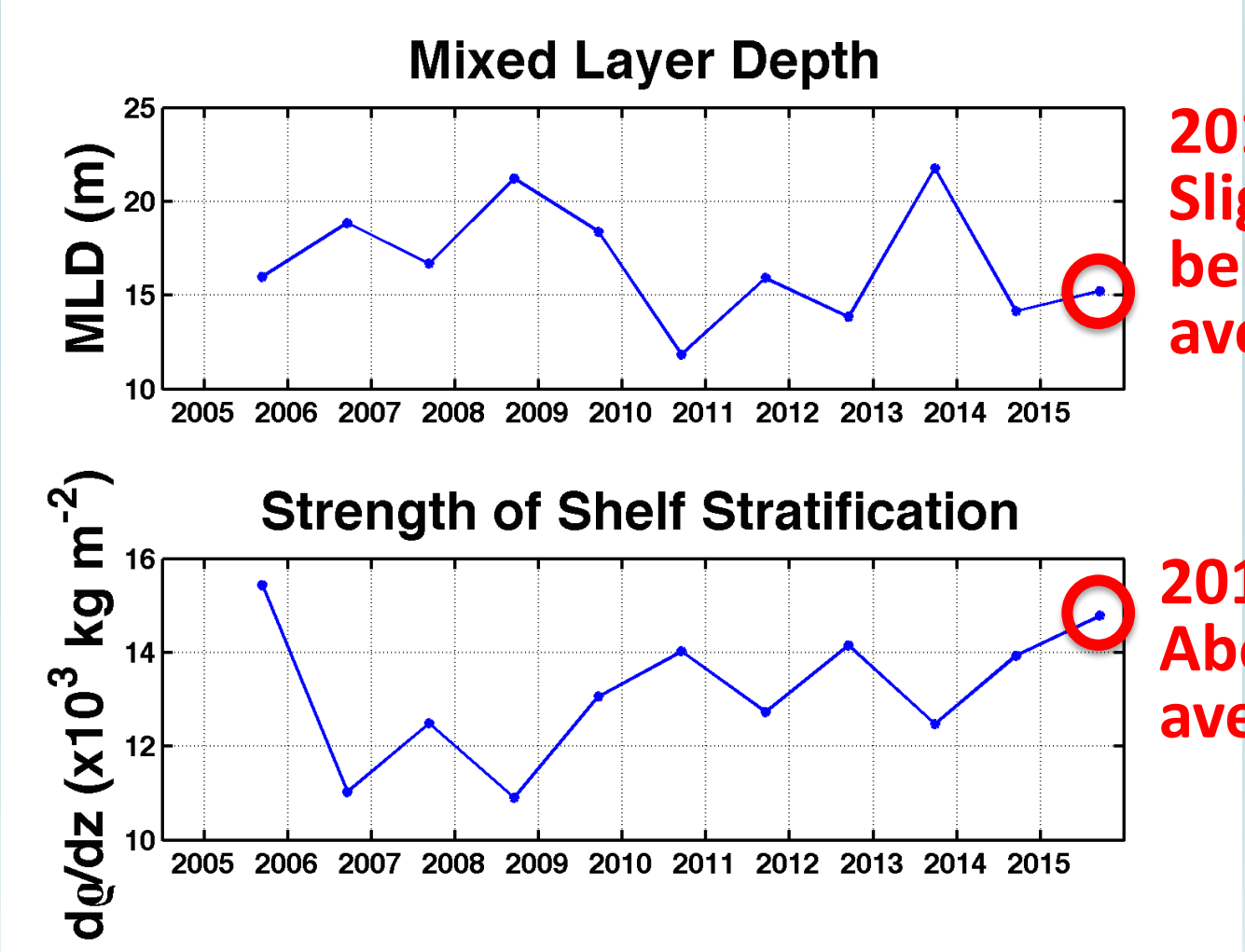
- Large diatoms were unexpectedly low in abundance in spring 2014 and 2015.
- Of the cells that were present, relatively more than usual were of the long, thin type (>50% in offshore).
- These cells have a high Surface Area : Volume, making them more efficient at taking up nutrients.
- If nutrients are scarce these cell types are favoured.

- What can we say about changes in water column conditions?



End of summer conditions, 2005 to 2015 from Seward Line data

Courtesy of Seth Danielson

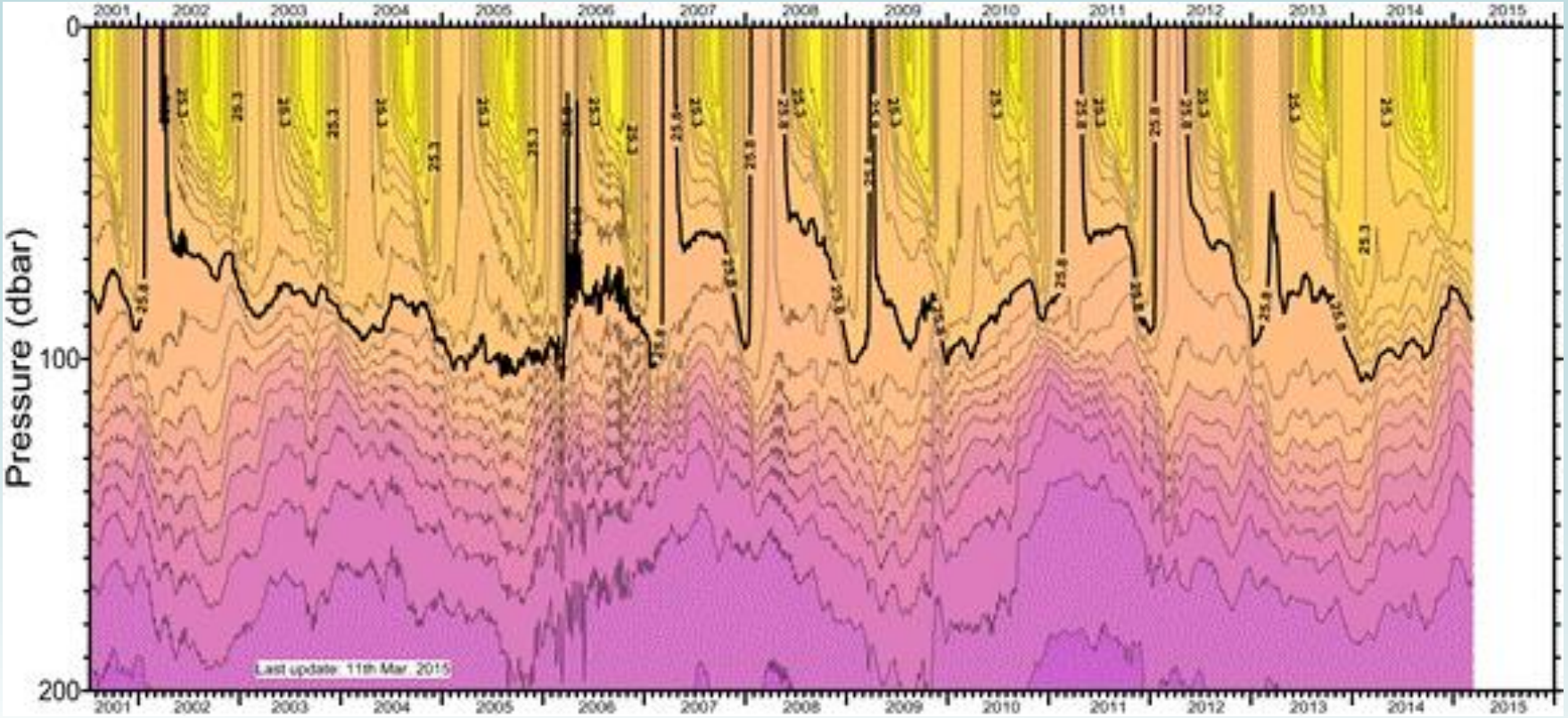


Shallow MLD and strong stratification would reduce nutrient availability…….

Ocean Station P:

"Nutrient renewal from vertical transport was restricted in winters 2013/14 and 2014/15 due to increased stratification." (Howard Freeland, DFO State of the Pacific Ocean report 2015)

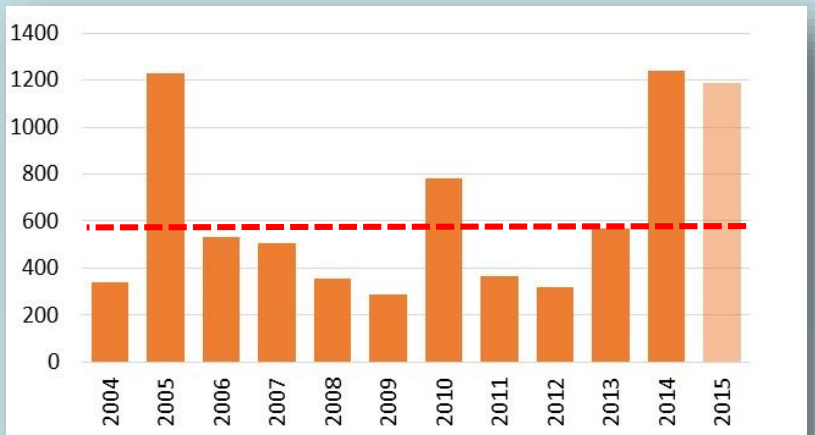
Freeland: Figure 6-5. Density (σt) versus depth at Ocean Station Papa at 5-day intervals from 2001 to the present, interpolated from Argo observations. The bold line represents the 25.8 σt surface.

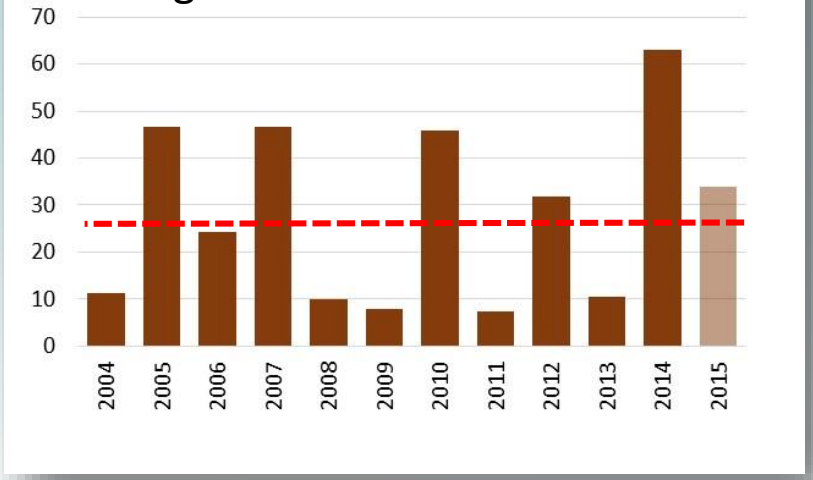


Zooplankton

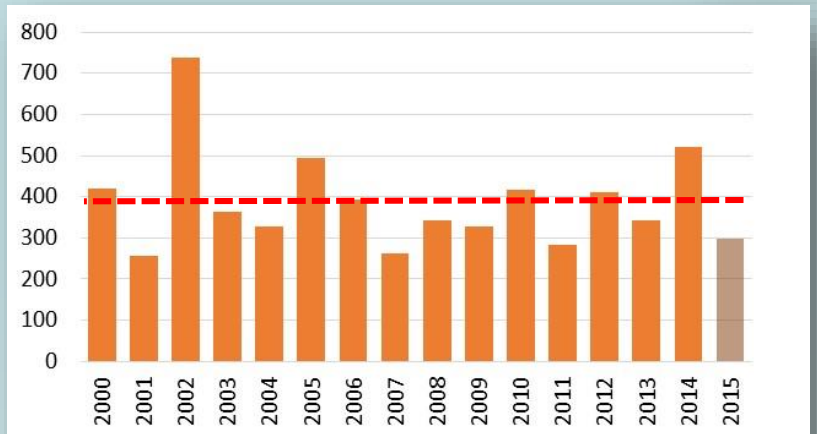
Graphs show mean number of organisms per sample (top) and estimated biomass (mg dry weight, bottom) with 2000/04-2014 mean in red:

Alaskan Shelf

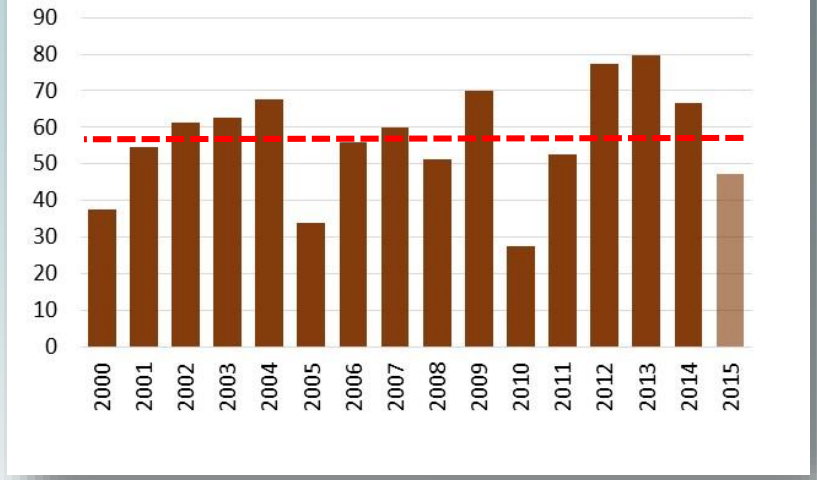




Oceanic NE Pacific

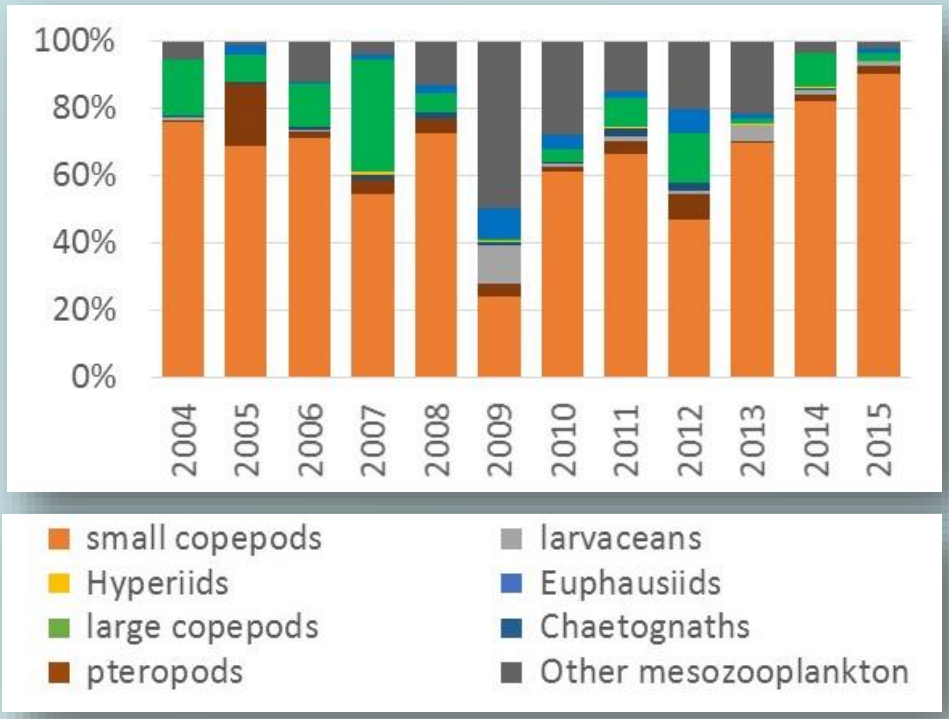


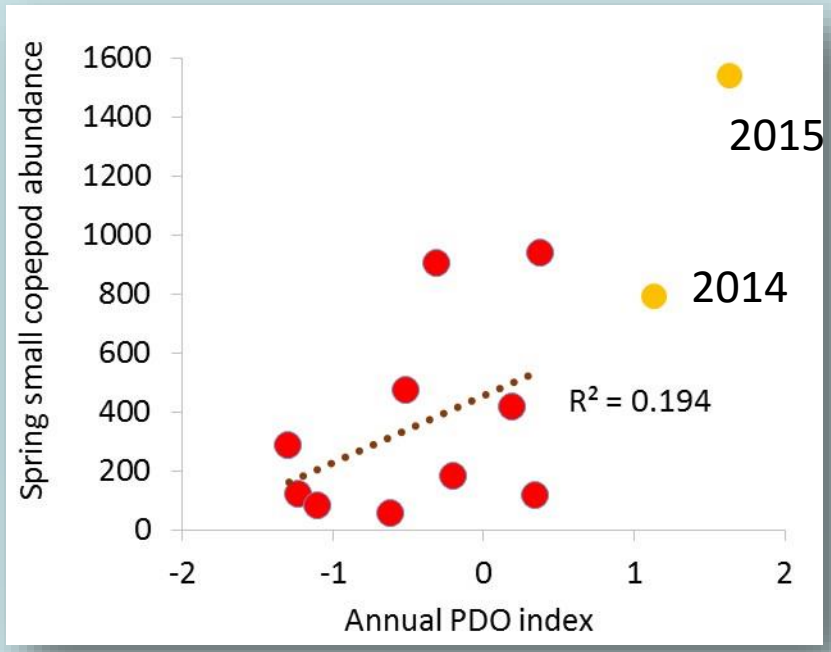
Strong +ve correlation between abundance and PDO on the shelf, but weak offshore



Zooplankton composition – spring, broad groups

Alaskan Shelf

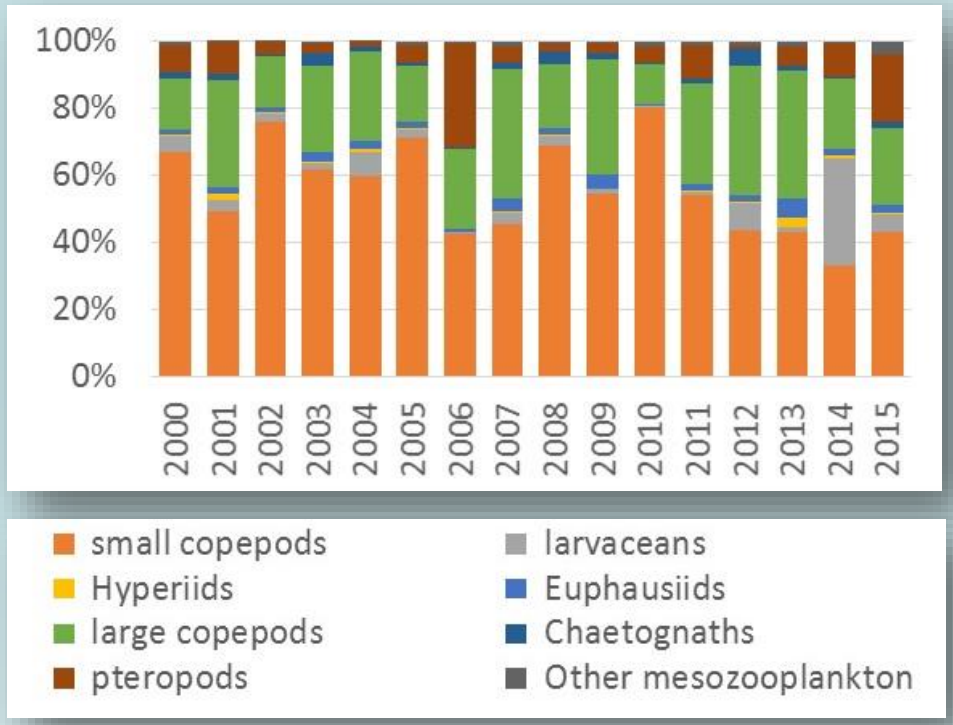


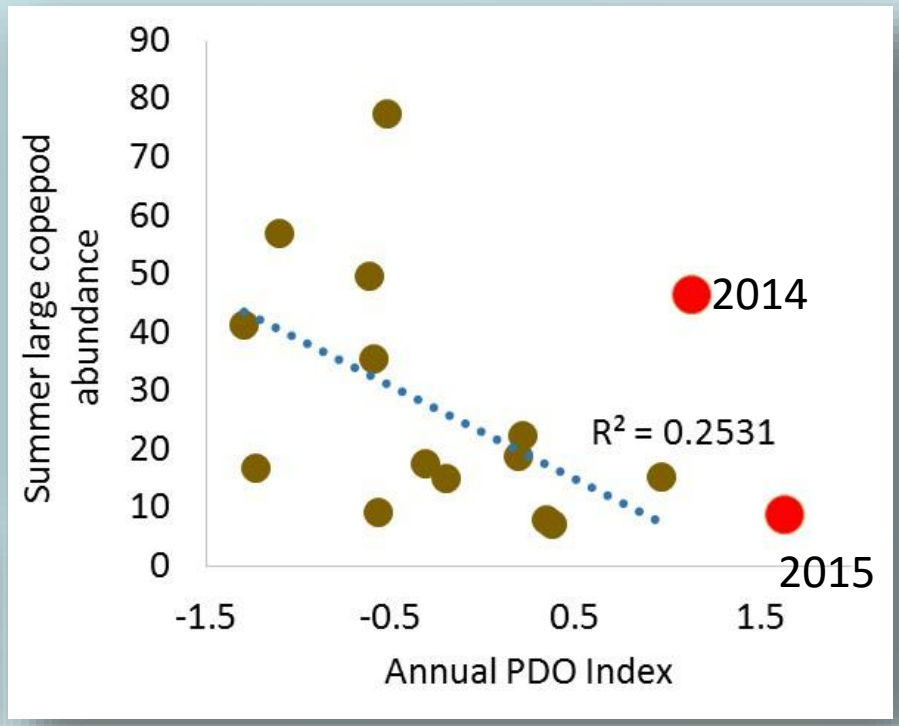


- Small copepods dominate community in most springs.
- 2014/15 values are very high (over 90% of the community)
- Relationship between PDO and abundance for whole time series is highly significant (r^2=0.56, p<0.01)

Zooplankton composition – spring, broad groups

Oceanic NE Pacific

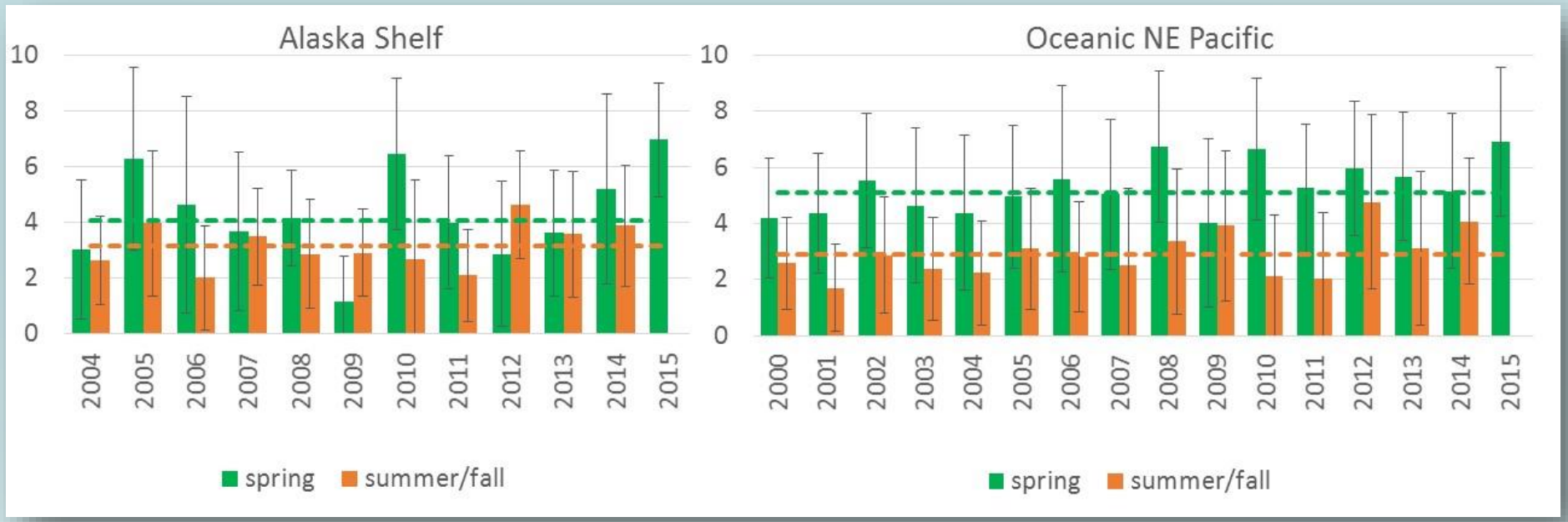




- Open ocean, large copepods more important in spring, they drive the biomass.
- Tend to be less abundant in spring in warm/PDO +ve years (though n.s.) and significantly less abundant in summers of warm years ($p<0.05$) as timing shifted earlier.

Copepod taxonomic richness:

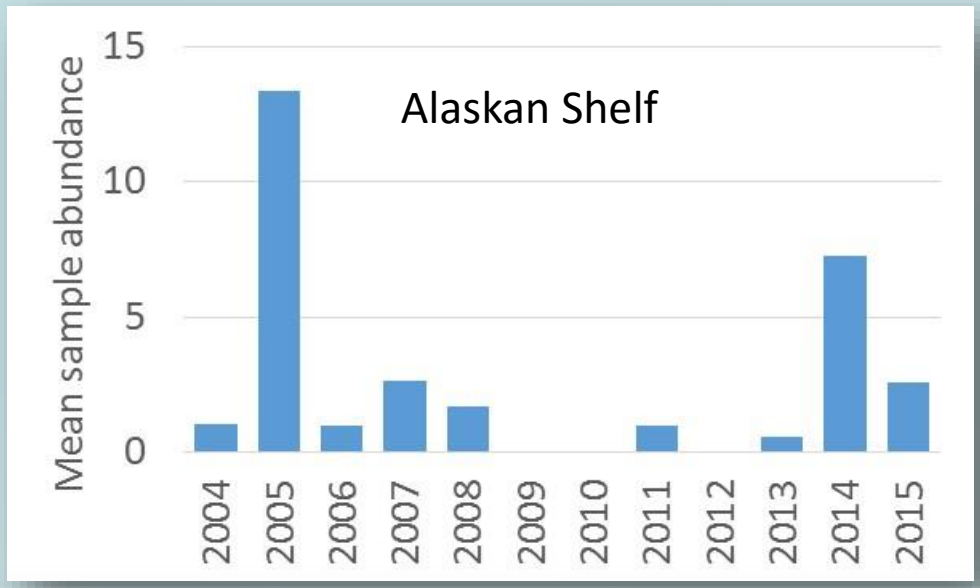
Mean number of copepod taxa per sample (bars), against long term mean (dashed lines)

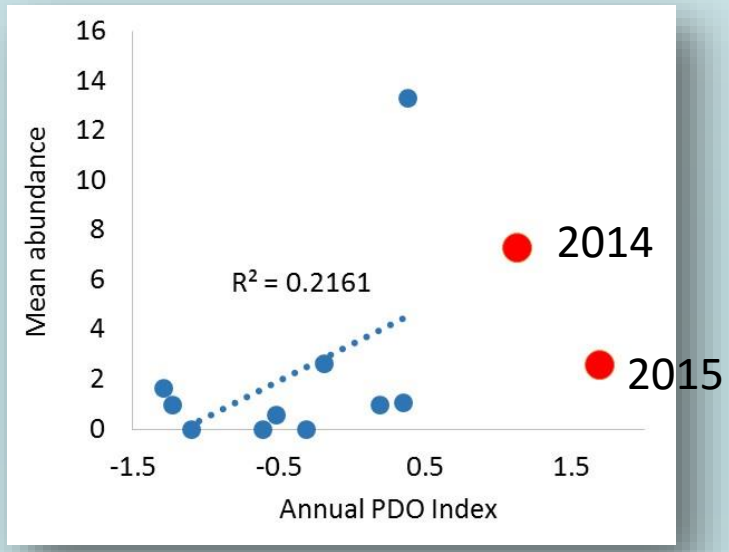


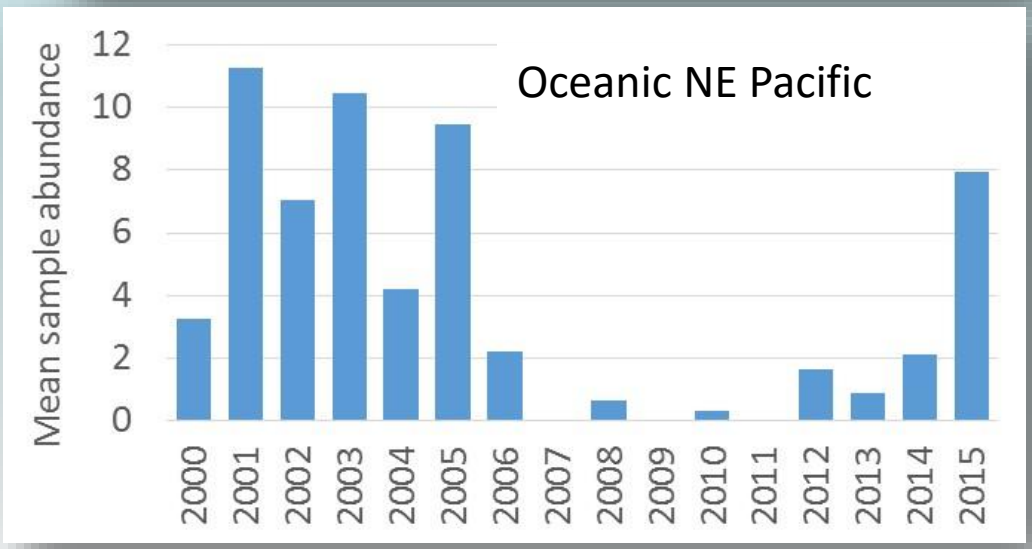
- Highest mean number of taxa in spring 2015 (relatively high in 2014, at or above mean)
- Number of taxa NOT related to PDO (except perhaps Ak Shelf in spring)

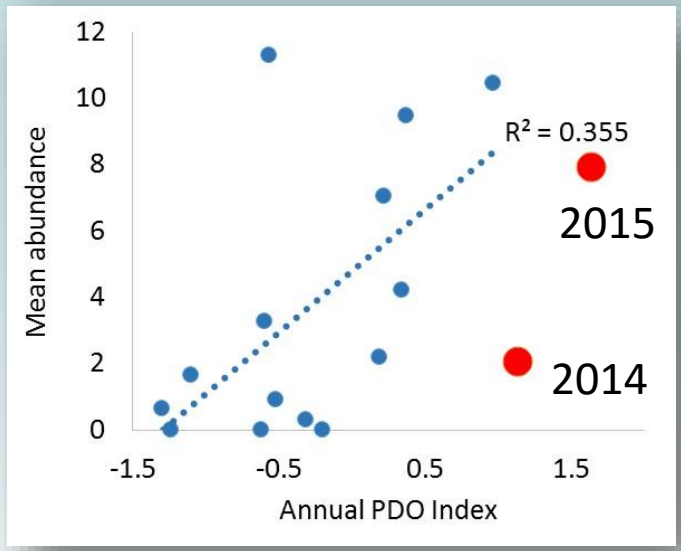
Warm water indicators:

The mean abundance of a group of small copepods that are usually found further south e.g. *M. tenuicornis, Clausocalanus* spp.:



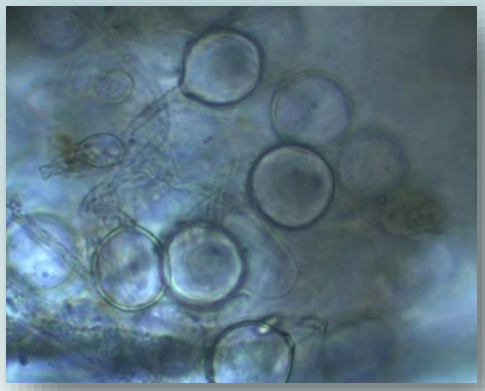


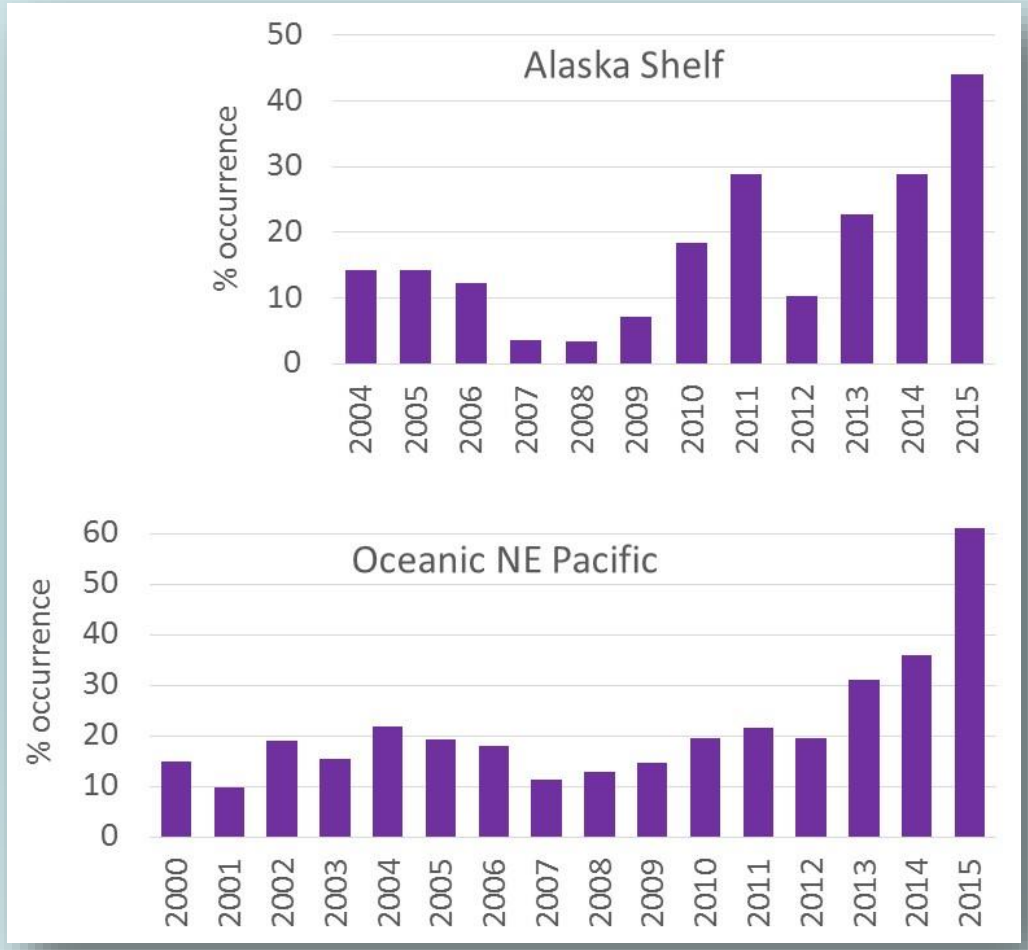




Jellyfish

Jellyfish cannot be counted from CPR samples, but their presence in the samples is noted using the occurrence of nematocysts.





Proportion of samples containing jellyfish has increased in recent years.

So, the base of the food chain was "different" during the Blob influenced years, with many similarities between shelf/open ocean:

- Large diatoms were low in number and long thin types made up more of the community.
  - This is consistent with lower nutrients brought about by increased stratification, less mixing.
    - Is there a nutritional impact on grazers?
- Small copepods were high in number on the Alaskan Shelf especially in 2015. Earlier increase in numbers likely because of warmth. Large copepods less abundant, also earlier.
  - Small copepods not so high in lipids as large copepods
  - More work for the same amount of calories for predators.
  - We don't measure productivity, however we see average-high zooplankton and low diatoms – grazing pressure, or, perhaps ciliates eaten instead?
- Higher copepod taxanomic richness in 2015 – consequences?
- Jellyfish look to be more abundant
  - More competition for other predators?

Acknowledgements

•Officers, crew and shipping companies that voluntarily tow the CPR (Horizon/Matson/Seaboard/Austral-Asia Lines)

•Kinnetic Labs in Anchorage for local servicing, Doug in BC, and all those who spend time at the microscope in SAHFOS

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