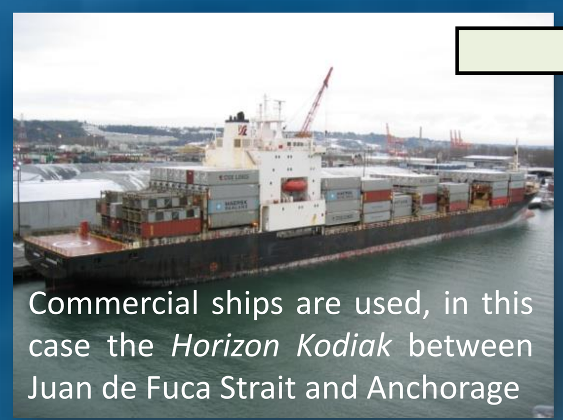
The effects of the anomalous warming on lower trophic levels in the NE Pacific, from Continuous Plankton Recorder sampling.

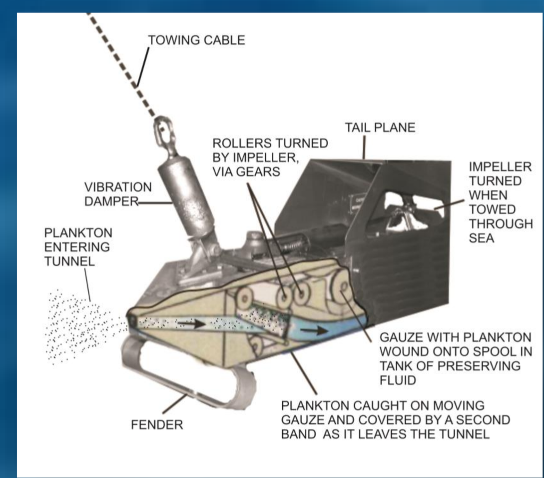
Sonia Batten soba@sahfos.ac.uk

Background. The Continuous Plankton Recorder Survey is a ship-of-opportunity program that has been sampling lower trophic levels in the eastern North Pacific since 2000. Two transects, sampled several times a year, originate in the Strait of Juan de Fuca and cross the Gulf of Alaska, sampling plankton from the surface layer. During this 15 year time series the region has experienced cool and warm phases. Here we assess response of the plankton, as sampled by the CPR, to the recent, unusual warming .


Commercial ships are used, in this case the *Horizon Kodiak* between Juan de Fuca Strait and Anchorage

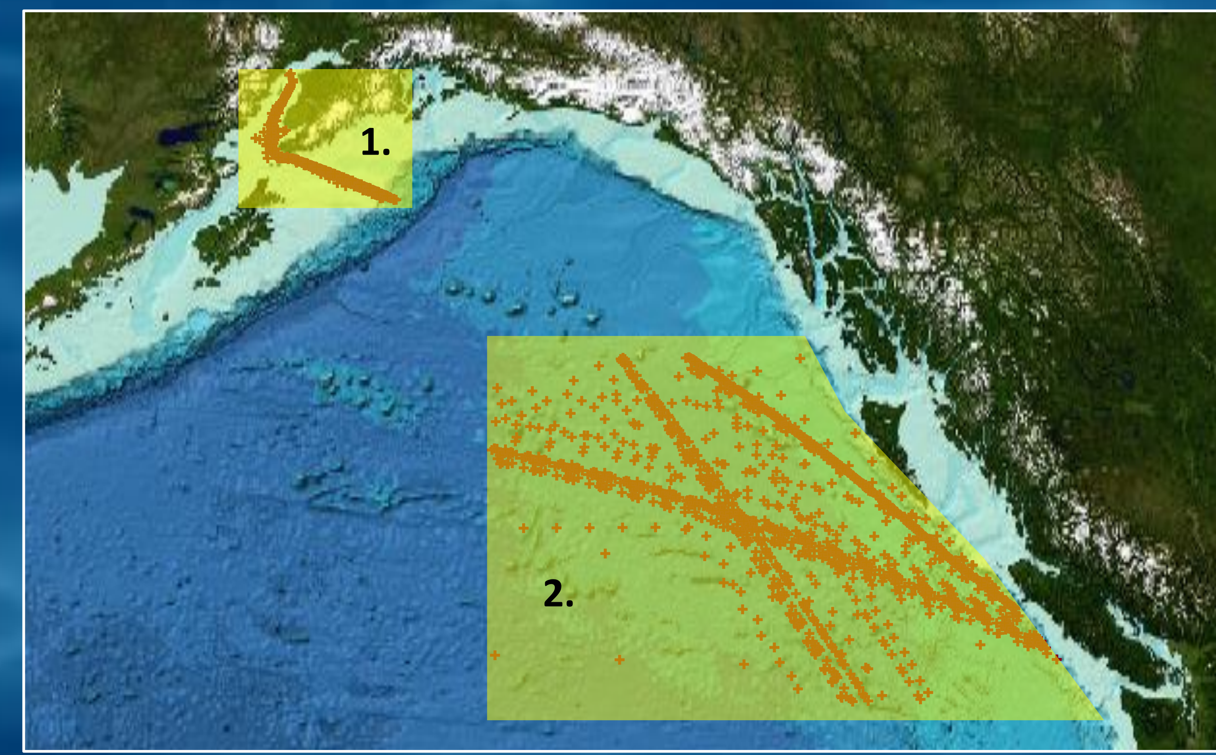

The CPR is towed behind the ship at about 7m depth

The outer CPR body holds an internal cassette filled with filtering mesh that can be towed for up to 500 nautical miles




Back in the lab the filtering mesh is cut into samples representing 18 km (10 nm) of the transect.


Microscopes are used to count and identify the zooplankton and phytoplankton on the samples



Map showing the location of the two regions focused on in this study: 1. the Alaskan Shelf and 2. The oceanic NE Pacific. CPR samples collected and analysed within each region are shown in red.

Phytoplankton.

The CPR samples larger diatoms and hard-shelled dinoflagellates. Fig. 1 below shows the relationship (2000-2013) between diatom abundances and the Pacific Decadal Oscillation (PDO, an index of ocean climate) and the results for 2014 and 2015.

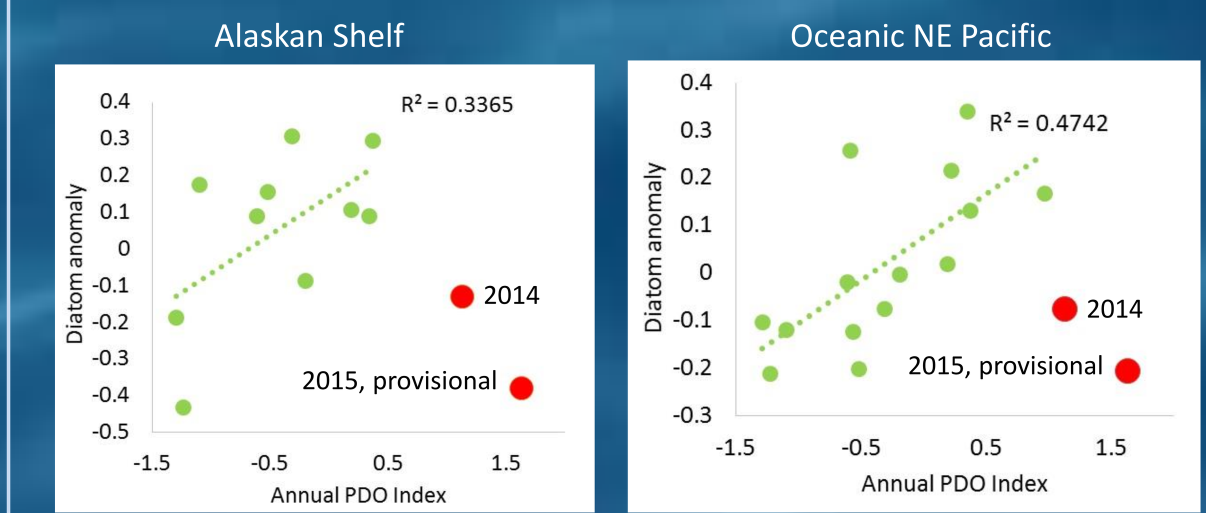


Fig.1. The relationship between annual anomalies of diatom abundance and the annual mean PDO for each region

In both regions diatom abundance was low in 2014 and even lower in 2015, when the positive PDO/warm conditions would have predicted high numbers. Furthermore, the spring composition of the diatoms was biased towards long, thin cell types rather than the round chain forming centric types (fig. 2).

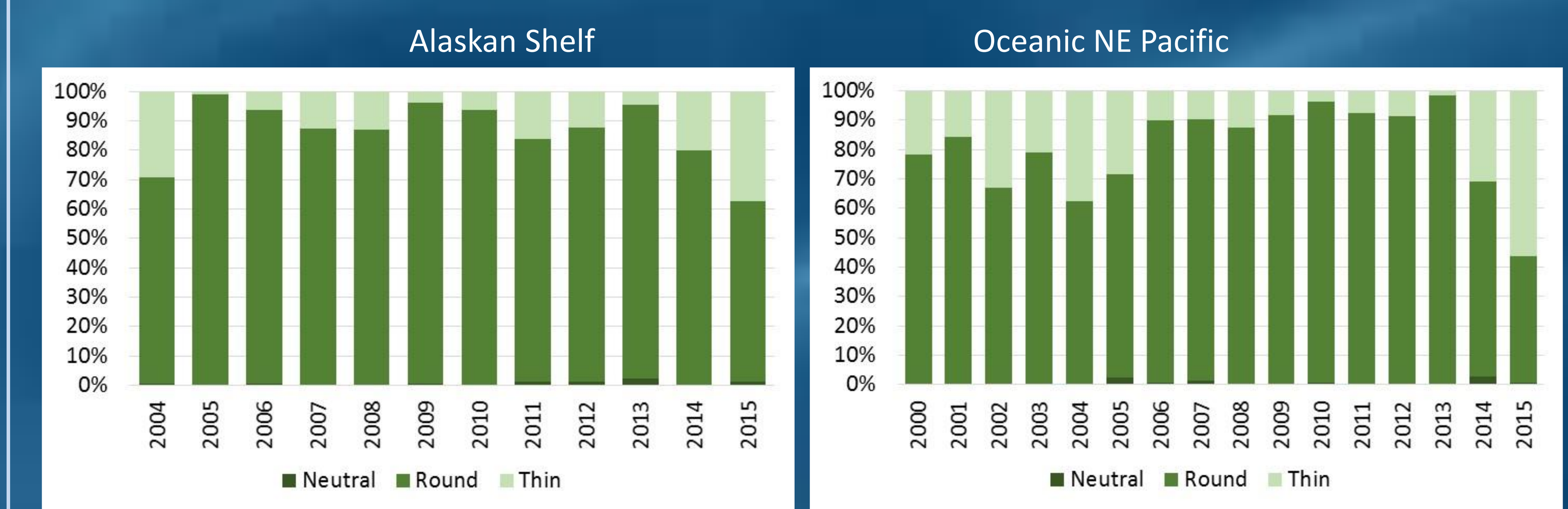
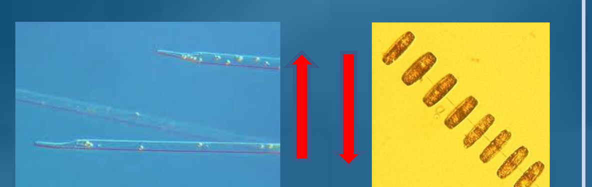


Fig.2. The contribution of the different diatom cell types to the diatom communities in spring of each year (Mar-Jun) in each region.

With a high Surface Area:Volume the long thin cells are favoured by low nutrient conditions. Spring 2015 had the highest recorded proportion of this cell type in both regions, and in fact their numbers exceeded 50% of the community in the offshore, for the first time.



Zooplankton.

The CPR samples crustacean zooplankton well, fragile forms less well. Fig. 3 shows the seasonal abundance of small copepods (< 2mm) on the Alaskan shelf. These were abundant in 2014/15 and made up a record proportion of the zooplankton community in spring.

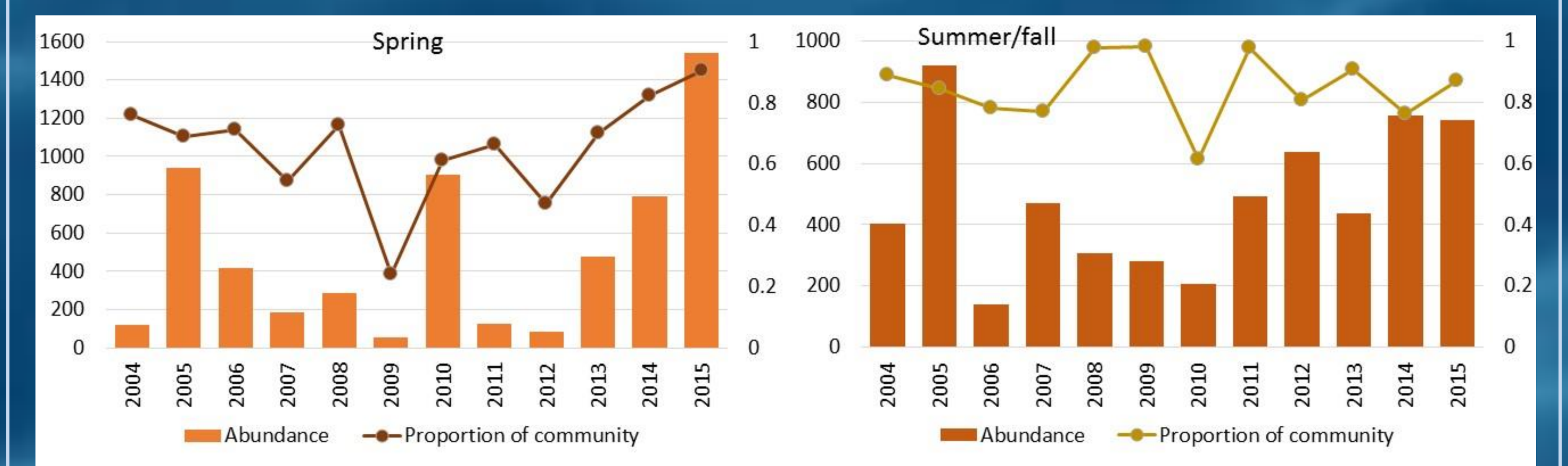


Fig.3. The abundance (bars) and contribution (lines) of small copepods on the Alaskan Shelf. Spring = Mar-Jun, Summer/fall = Jul-Oct.

In contrast, large copepods (> 2mm) are more important in the offshore, especially in spring. They typically make up between 20-40% of the numbers but dominate the biomass. Fig 4. shows that their numbers were relatively low in spring 2014/15 (though not exceptional) and they made up a small proportion of the summer community. This would be expected in warm conditions when their seasonal timing would be shifted earlier, out of summer.

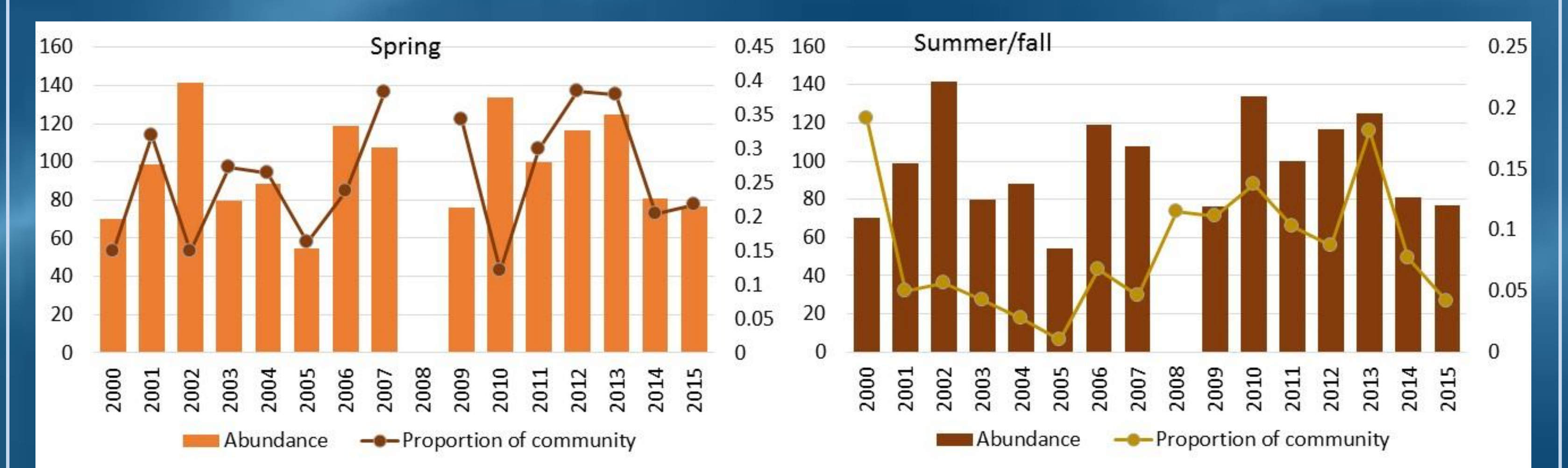


Fig.4. The abundance (bars) and contribution (lines) of large copepods in the Oceanic region. Spring = Mar-Jun, Summer/fall = Jul-Oct.

Zooplankton cont.

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

Fig. 5 shows jellyfish presence in each region.

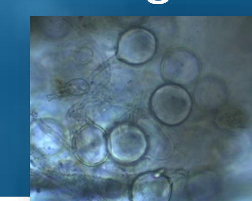


Fig.5. The % of samples containing jellyfish in each region, in each year

Both regions showed a small increase in the warm years of the mid-2000s but recent increases are much larger. 2015 data are based on only April to June data so far, but its almost certain that this year will have by far the highest occurrence for both time series. More than half of the oceanic samples had jellyfish present in 2015, for the first time.

Summary

Alaska Shelf	Oceanic NE Pacific
Diatoms were low in spring 2014 and exceptionally low in spring 2015 – not predicted by the previous relationship between diatoms and PDO/Temp.	Diatoms were low in both years, not predicted by the previous relationship between diatoms and PDO/Temp.
Long, thin diatom cell types were more abundant than usual. Favored by low nutrients.	Long, thin diatom cell types were more abundant than usual and in fact comprised more than 50% of the diatom community for the first time. Favored by low nutrients.
Zooplankton were generally abundant, predominantly small copepods (lower biomass).	Zooplankton slightly above average in numbers. Large copepods low in summer 2015, as predicted by shift in seasonal timing to earlier.
Warm water copepods (data not shown) were more common in 2014/15 than in recent years, but not as abundant as in 2005. Community composition not dramatically changed.	Warm water copepods more common in 2014/15 than in recent years (data not shown), but not as abundant as the mid-2000s. Would have expected higher numbers from PDO relationship alone. Community composition not as dramatically changed as might be expected – because of the Blob source?
Jellyfish likely more abundant in 2014 and even more so in 2015	Jellyfish likely more abundant in 2014 and even more so in 2015 where more than 50% of samples had jellyfish present.

Acknowledgements
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