Marine Heatwaves and Pyrosome Blooms: Are these the New Normal for the California Current?

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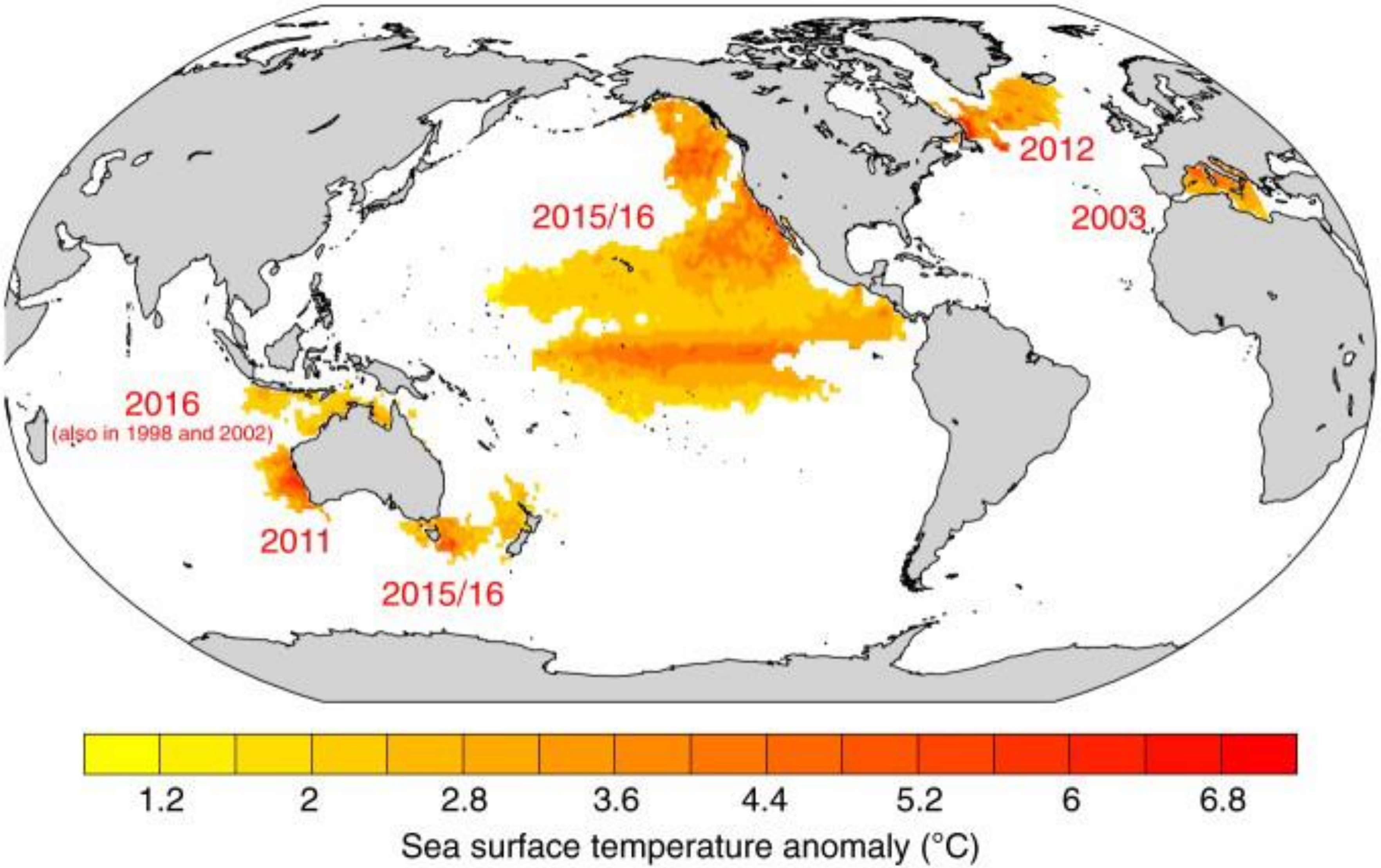
Recent Marine Heat Waves



Froelicher and Laufkoetter (2018) Nature Comm.

North Pacific Surface Temperature Anomalies

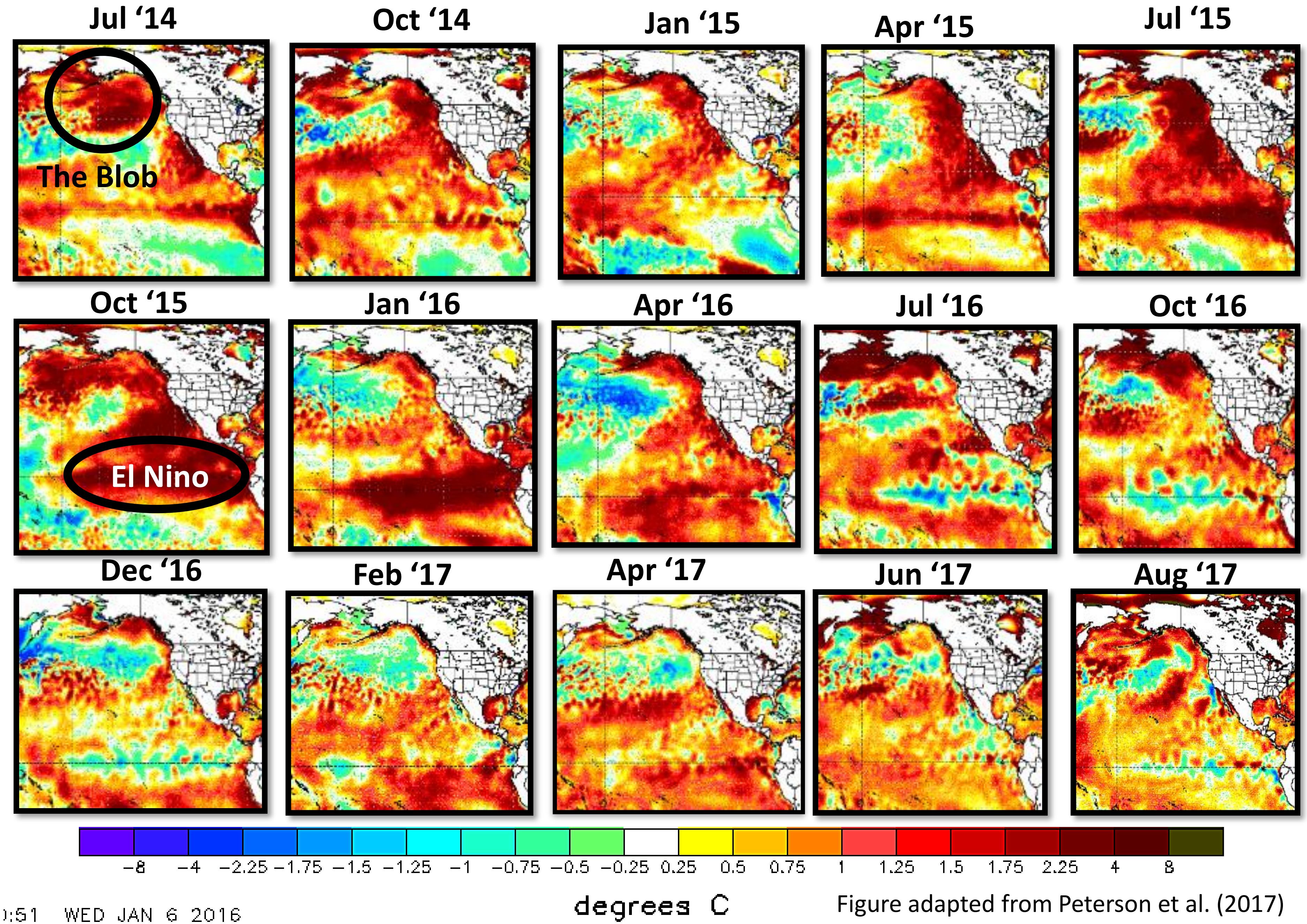
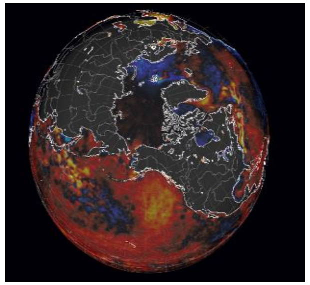
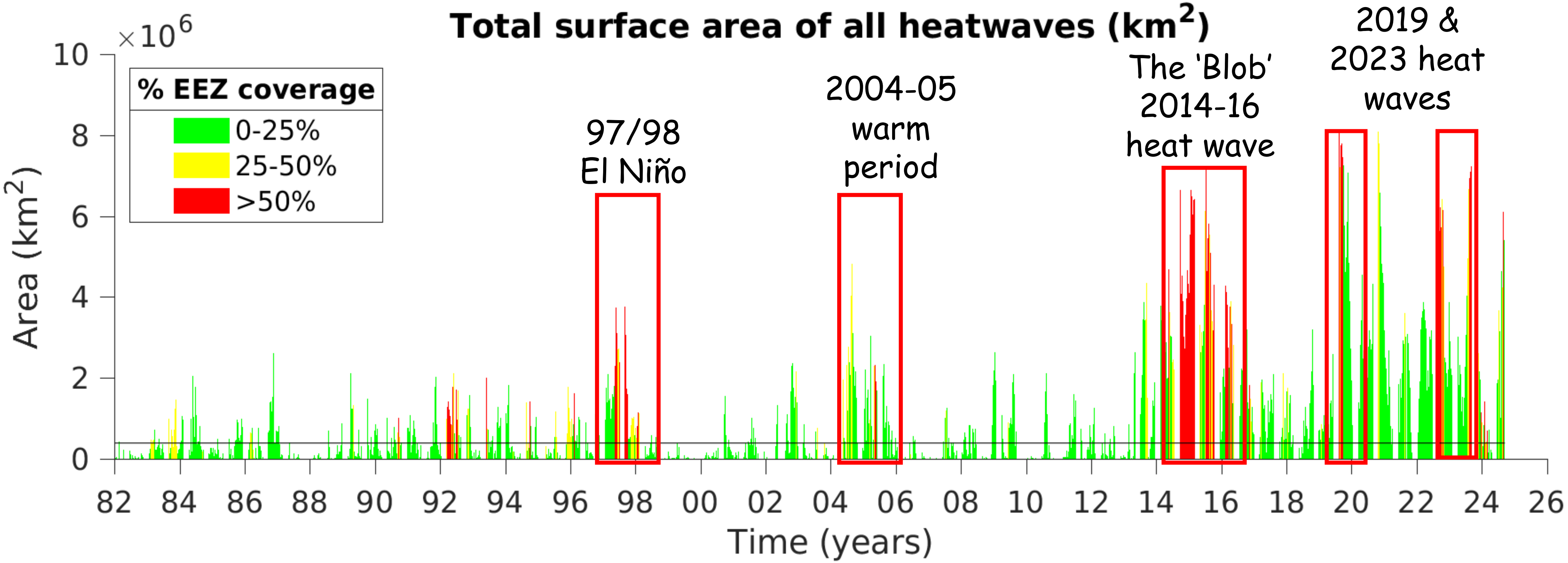


Figure adapted from Peterson et al. (2017)

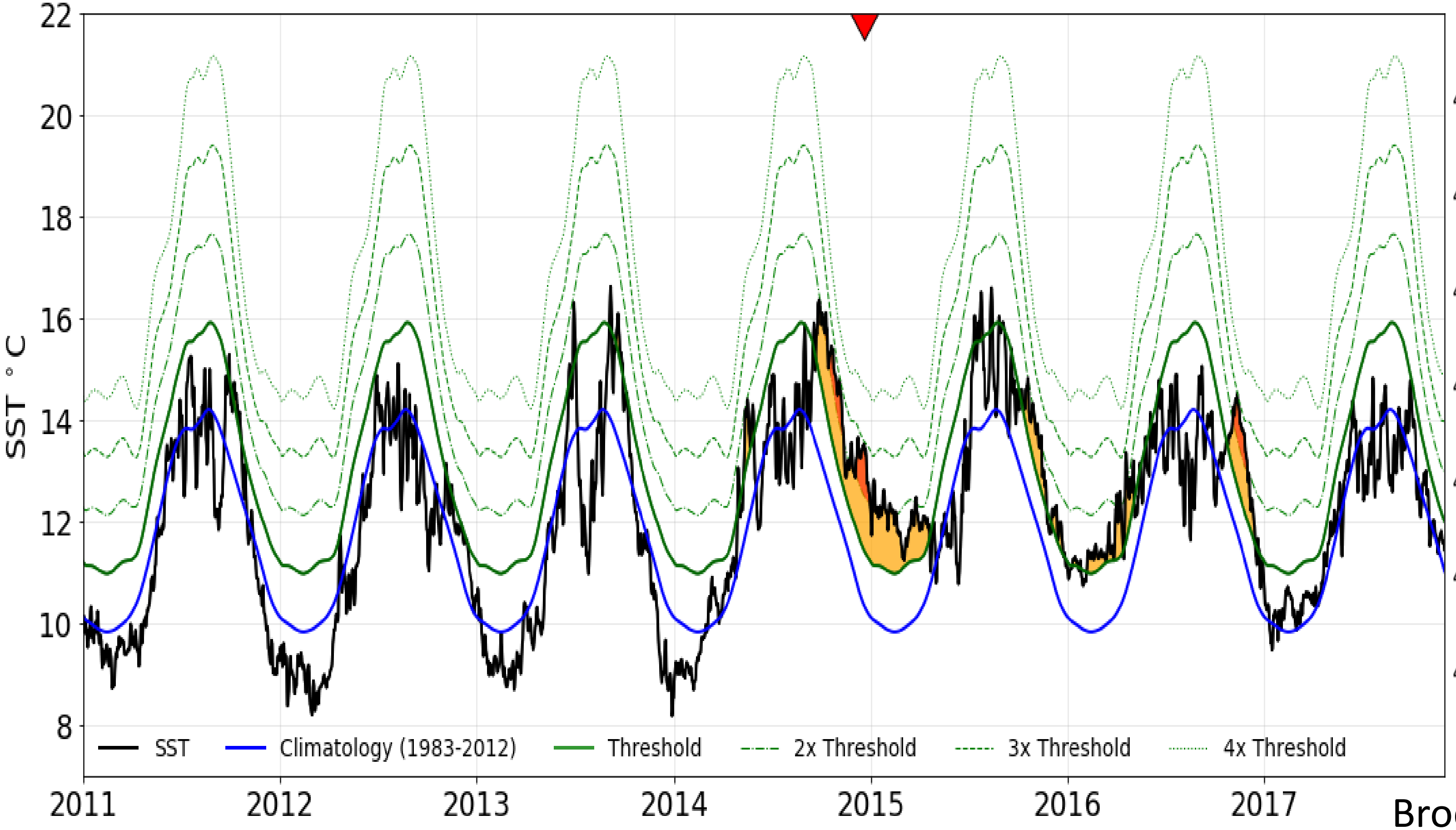


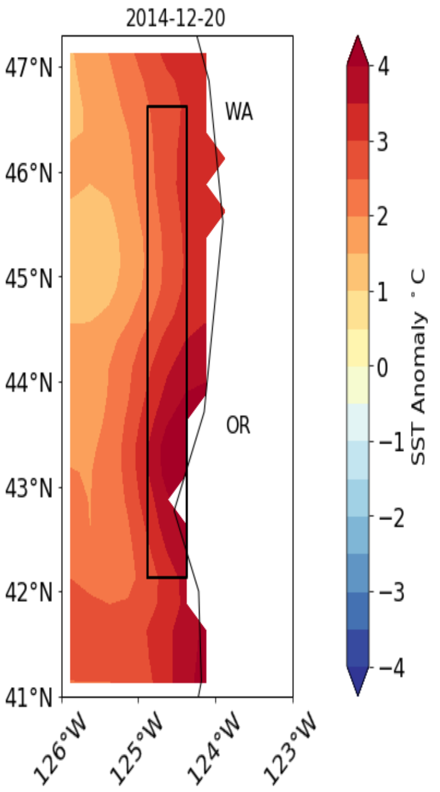
Area of NE Pacific Marine Heatwaves



https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-projects-blobtracker

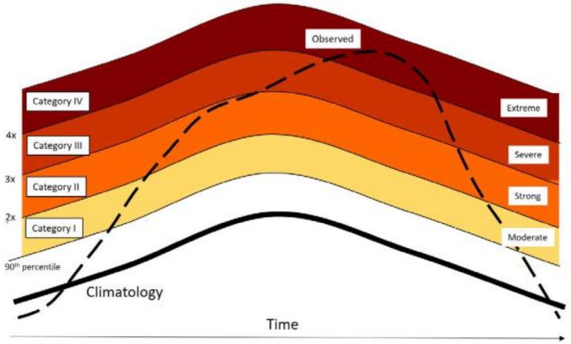
Sea Surface Temperature Anomalies in the Northern California Current





Brodeur et al. (2019) Front. Mar. Sci.

Classified as a Severe Marine Heat Wave with a duration of 711 days in the Central North Pacific (Hobday et al. 2018)



Ecosystem Changes associated with 2015/16 MHW

- Dramatic decrease in overall productivity but increase in Harmful Algal Blooms leading to shellfish poisoning along the West Coast
- Occurrence of many tropical and offshore zooplankton and anomalous higher trophic level taxa and decreases in normal taxa
- Changes in reproduction (phenology) and growth of marine fishes
- Unusual mortality events in marine mammals and birds and changes in distribution
- Major changes in gelatinous zooplankton with decrease in normal medusae but an unprecedented bloom of pyrosomes in the North Pacific

Great Pyrosome Bloom in the North Pacific Ocean

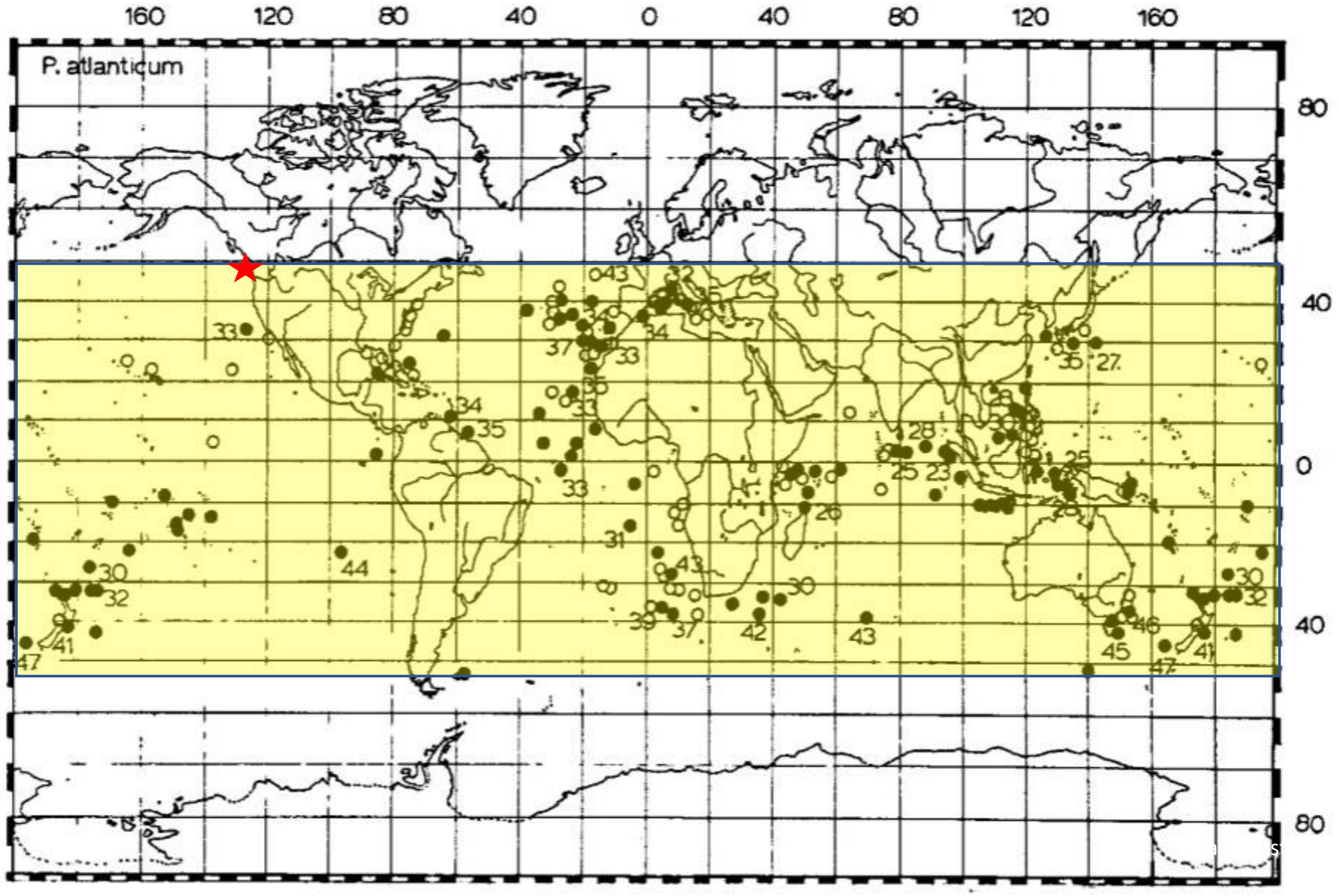
Photos from Brodeur et al. (2018), Sutherland et al. (2018)

Pyrosoma atlanticum

Image from Perissinotto et al. (2007)

This colonial species is the dominant pyrosome in the world's oceans and is typically found in tropical and sub-tropical open ocean waters

P. atlanticum has been historically observed in tropical oceanic waters (between 50ºN and 50ºS).



van Soest (1981)

Pyrosoma atlanticum

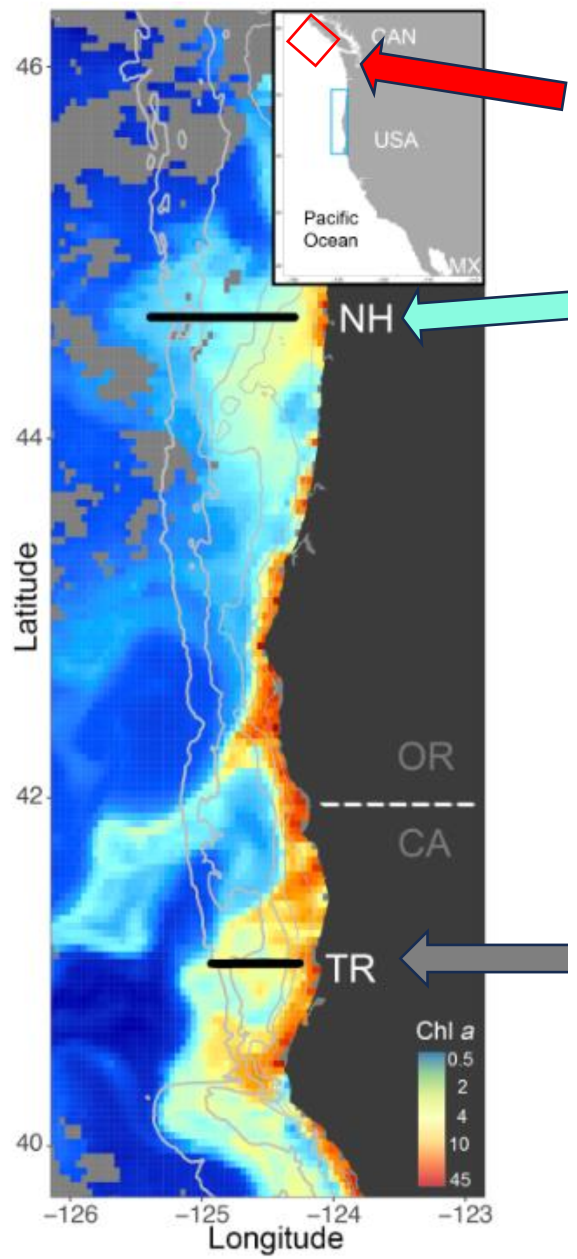
Image from Perissinotto et al. (2007)

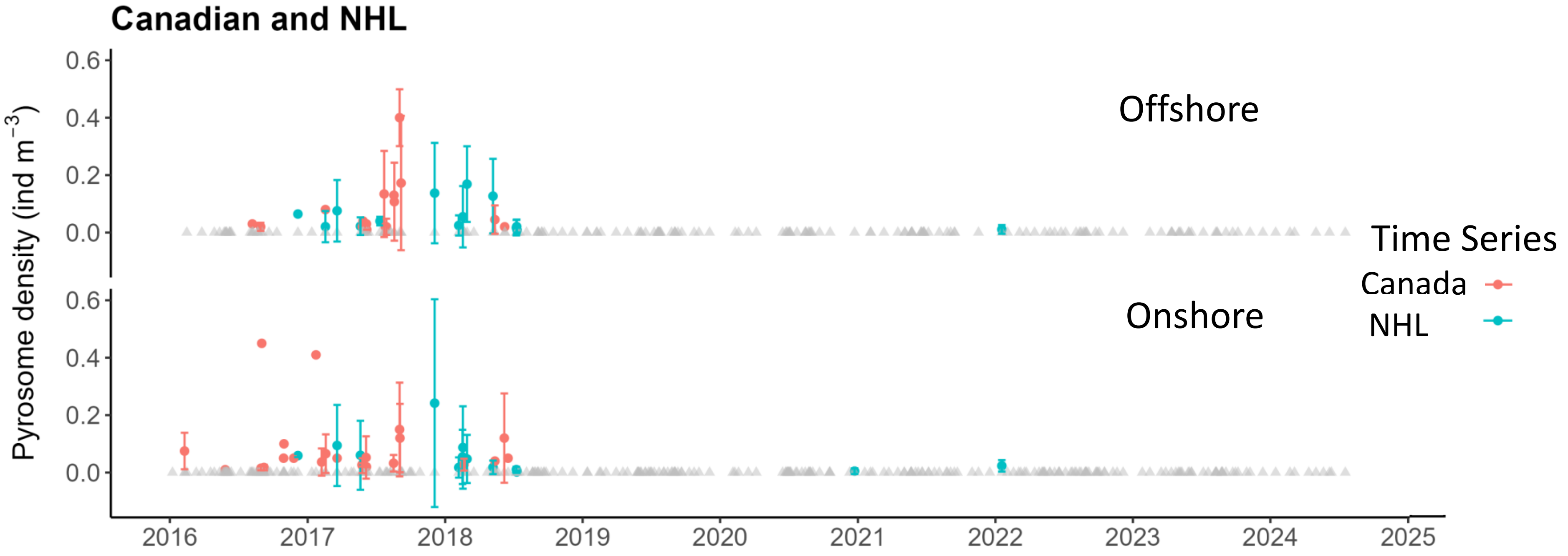
This colonial species is the dominant pyrosome in the world's oceans and is typically found in tropical and sub-tropical open ocean waters

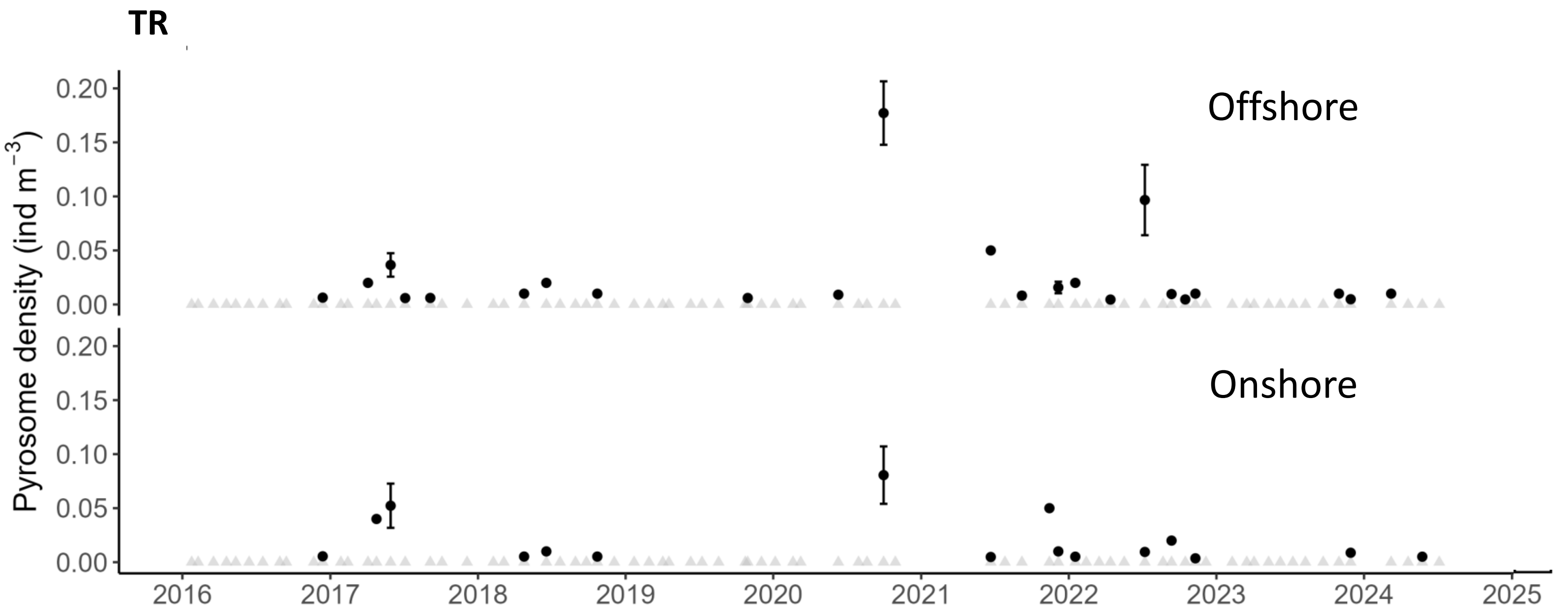
NOAA NWFSC

Pyrosomes are known to feed on planktonic microorganisms (e.g., picoplankton) and can consume a substantial proportion of the standing stocks of these plankton (Schram et al. 2021 MEPS, O'Loughlin et al. 2012 PiO)

Plankton Sampling

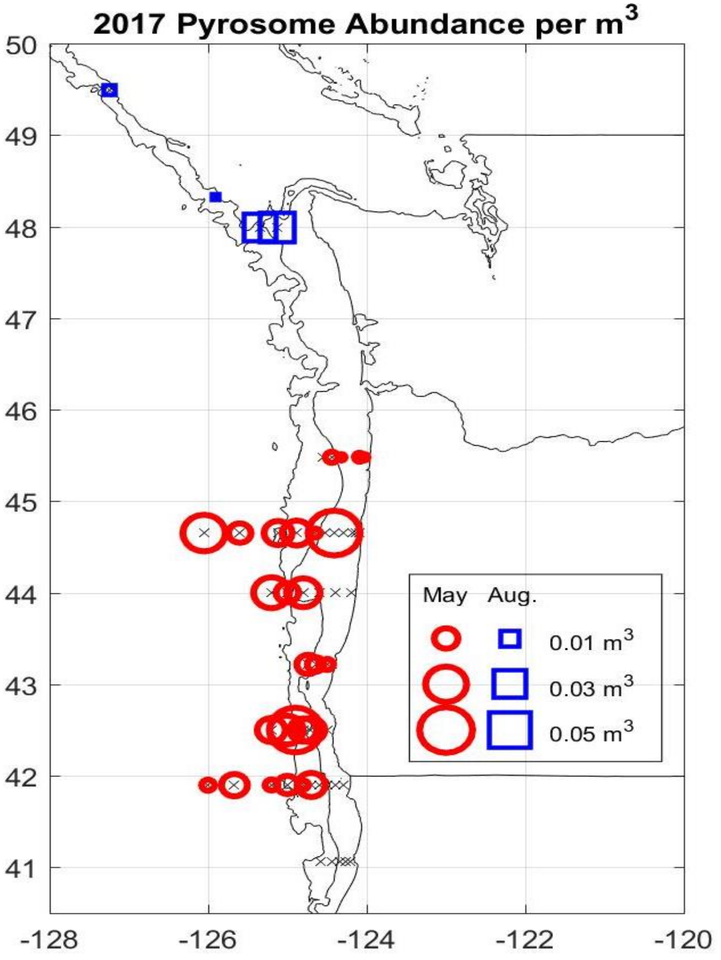


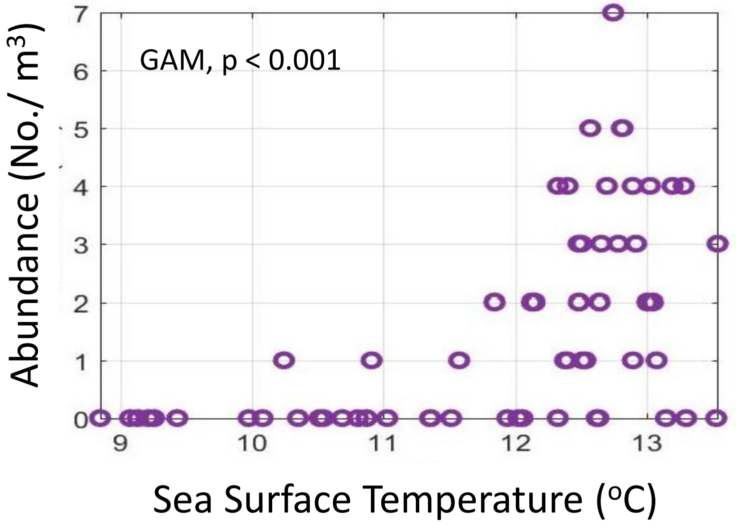


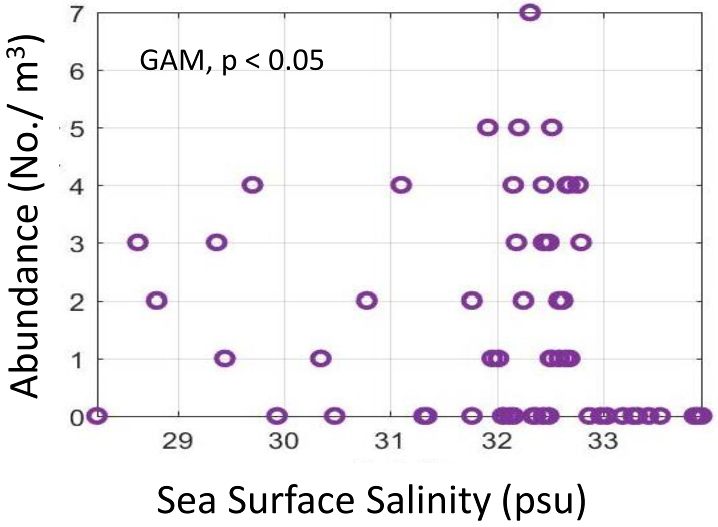


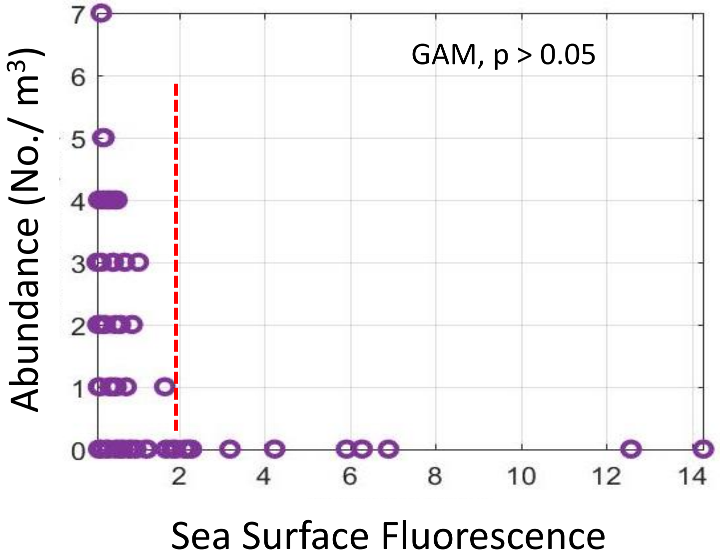
Abundance and environmental variables May and August 2017

Pyrosome densities in oblique bongo tows down to 100 m





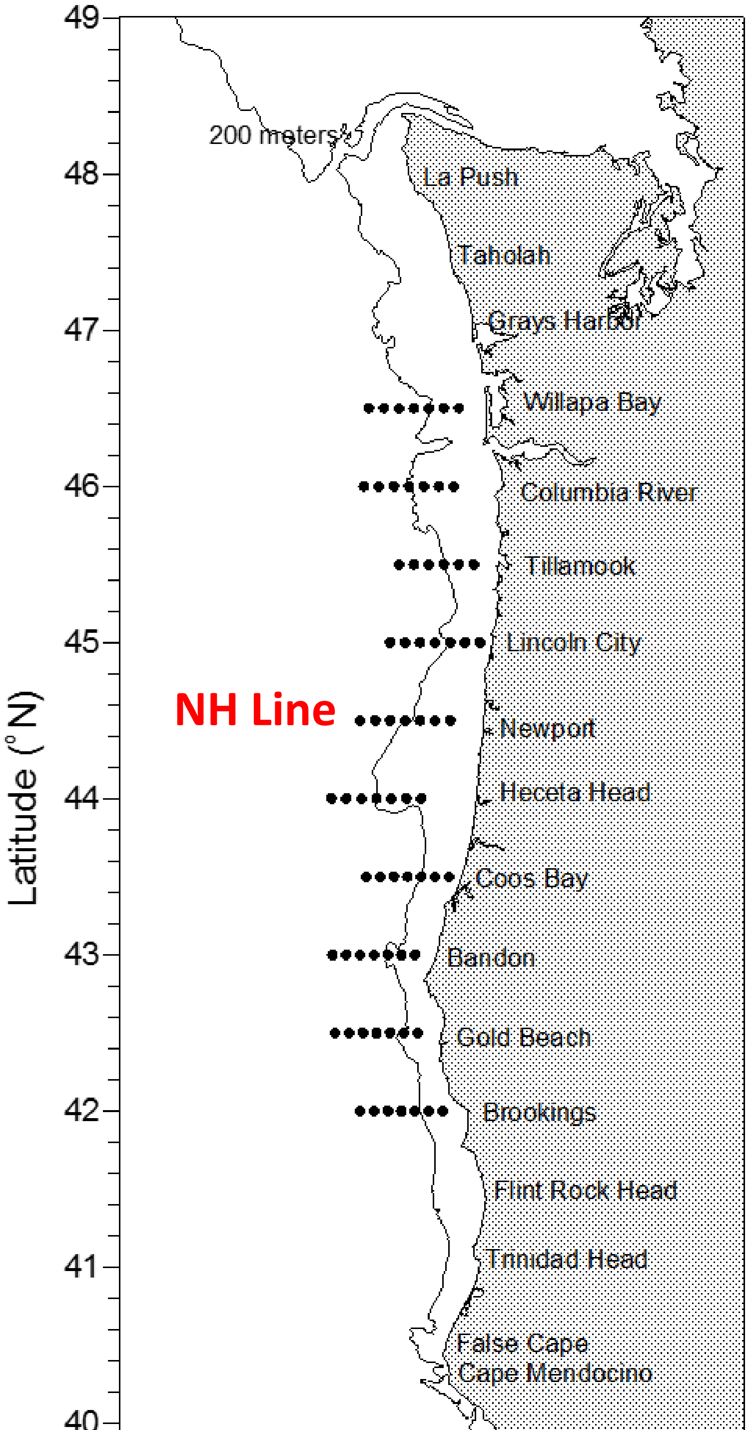


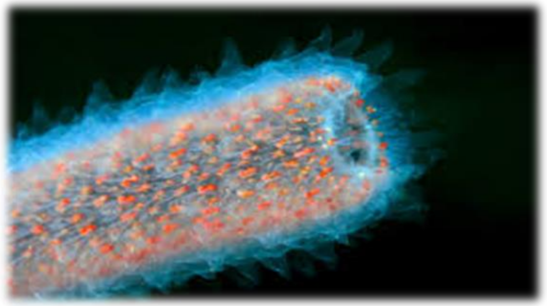


Pyrosomes were concentrated in warmer surface temperatures, moderate salinities and low fluorescence areas (e.g., offshore oceanic waters)

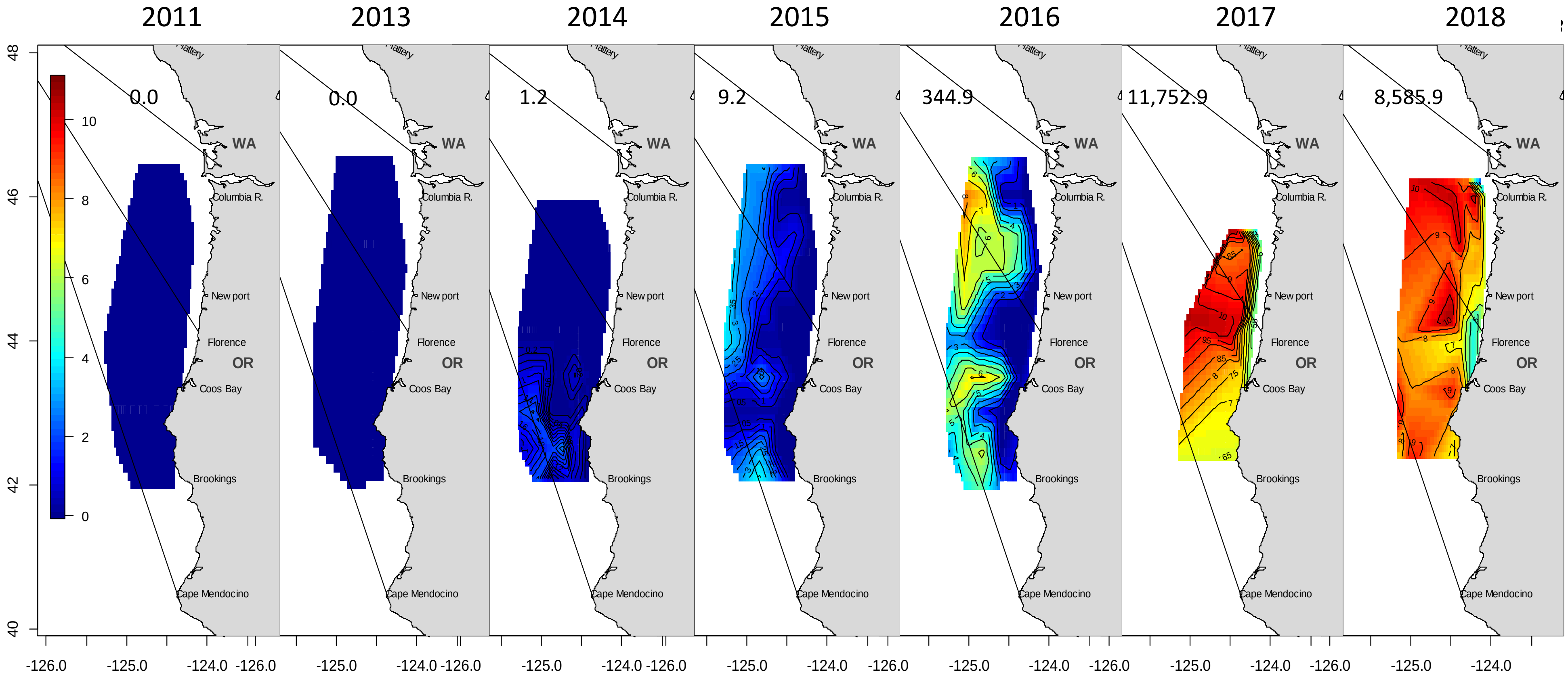
Prerecruit survey and ecosystem assessment project

Sampling: May-June (2011, 2013-2019); night trawls at 30 m depth, plankton, CTD, acoustic and seabird and mammal surveys





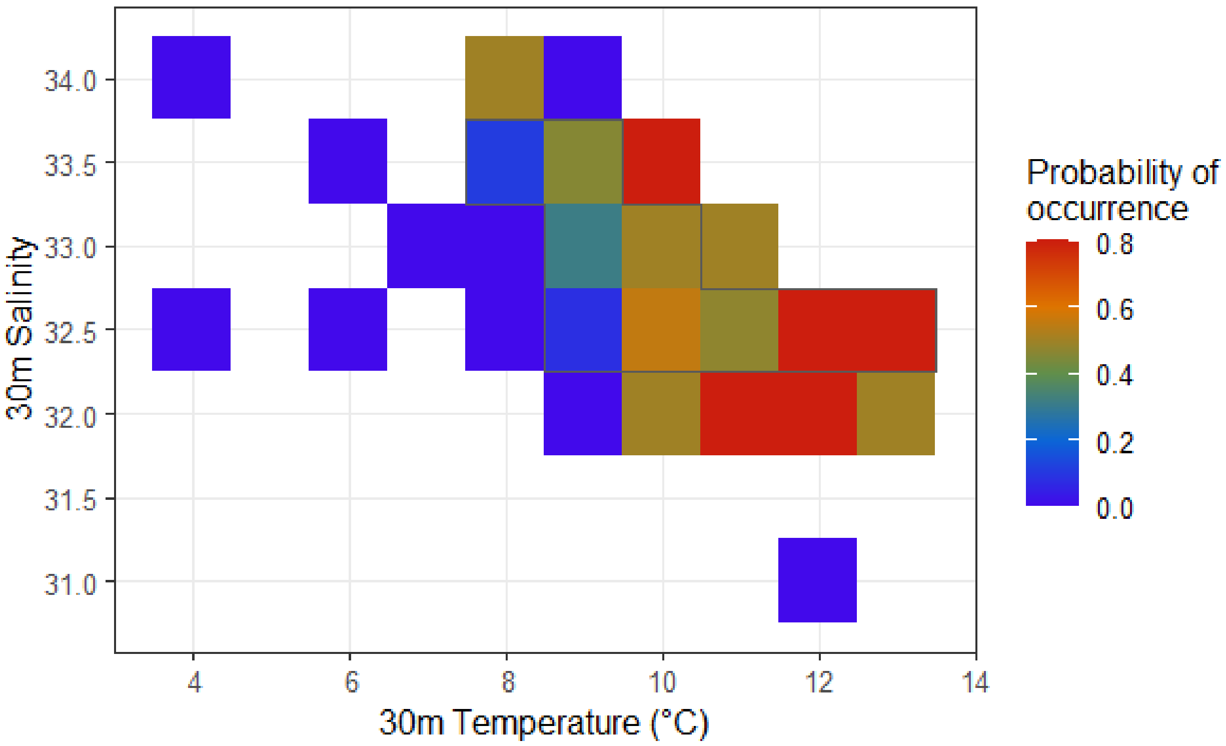
Pyrosome Catch in Pelagic Trawls $n(\log_e+1)$

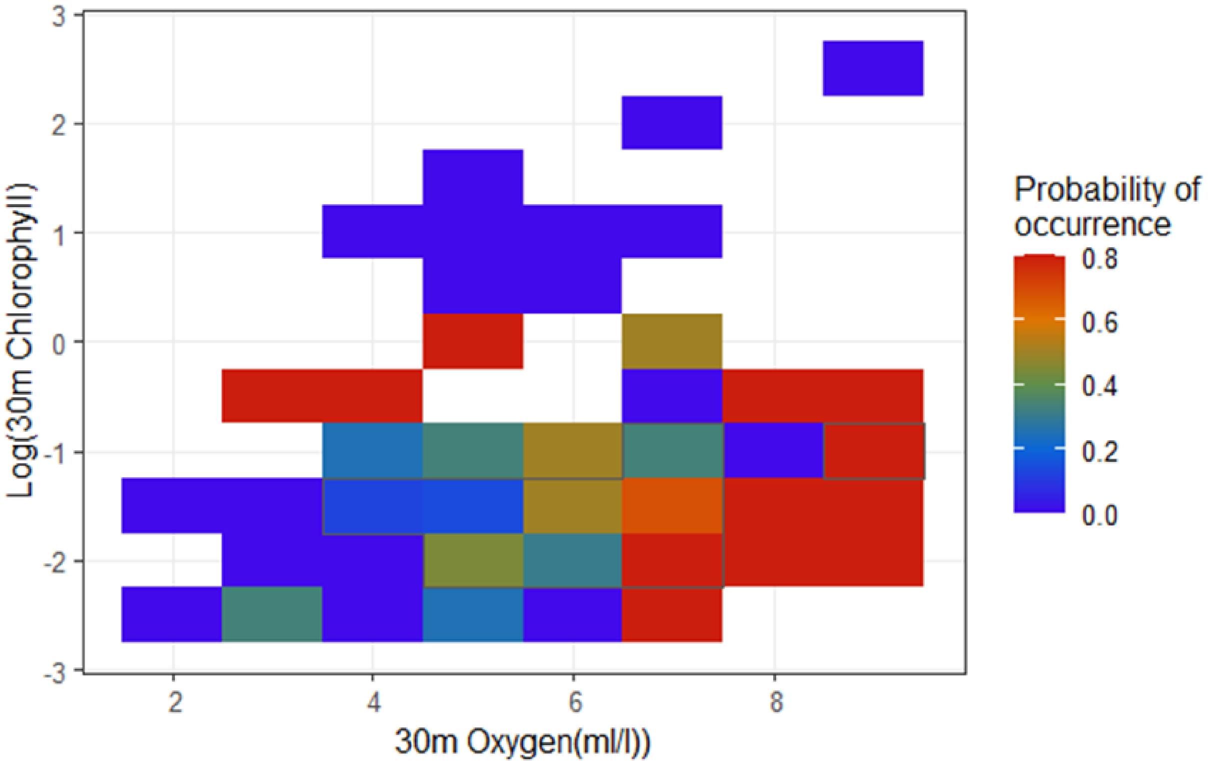


Scale bar = log (abundance)
Number = Geometric mean abundance

Brodeur et al. (2019) Frontiers in Marine Science

Relationship to Environmental Variables for Prerecruit Cruises





Pyrosome occurrences were highest at high temperatures and oxygen, intermediate salinities, and low Chlorophyll values

Where do all these pyrosomes end up?

- Biomass >200,000 kg/km^3 off Oregon and Washington Coasts (Brodeur et al. 2018) or 5 $ind./m^3$ off Oregon (Schram et al. 2020)
- Caloric content around 4.96 kJ/g dry mass for *Pyrosoma atlanticum* (Doyle et al. 2007) which is higher than many other invertebrates, but well below the range of forage fishes (7-21 kJ/g dry mass)
- Vast majority of this biomass either sinks to the bottom to enter detrital pool or is consumed by predators in the water column or on the bottom

Carbon Inputs to Benthic and Neritic Ecosystems

Agate Beach, Newport, OR

ODFW ROV Photo from Sutherland et al. (2018)

ROV *Hercules*, Quinault Canyon

Vertebrate predators on pyrosomes

NWFSC FRAM

Sablefish stomach off Washington

Also seen in diets of juvenile and adult salmon, halibut, tuna, many rockfish and other groundfishes.

ODFW

Deacon Rockfish stomach off Oregon

Jesse Huggins, Cascadia Research

Fin whale stomach off Washington

Fish Predators on Pyrosomes

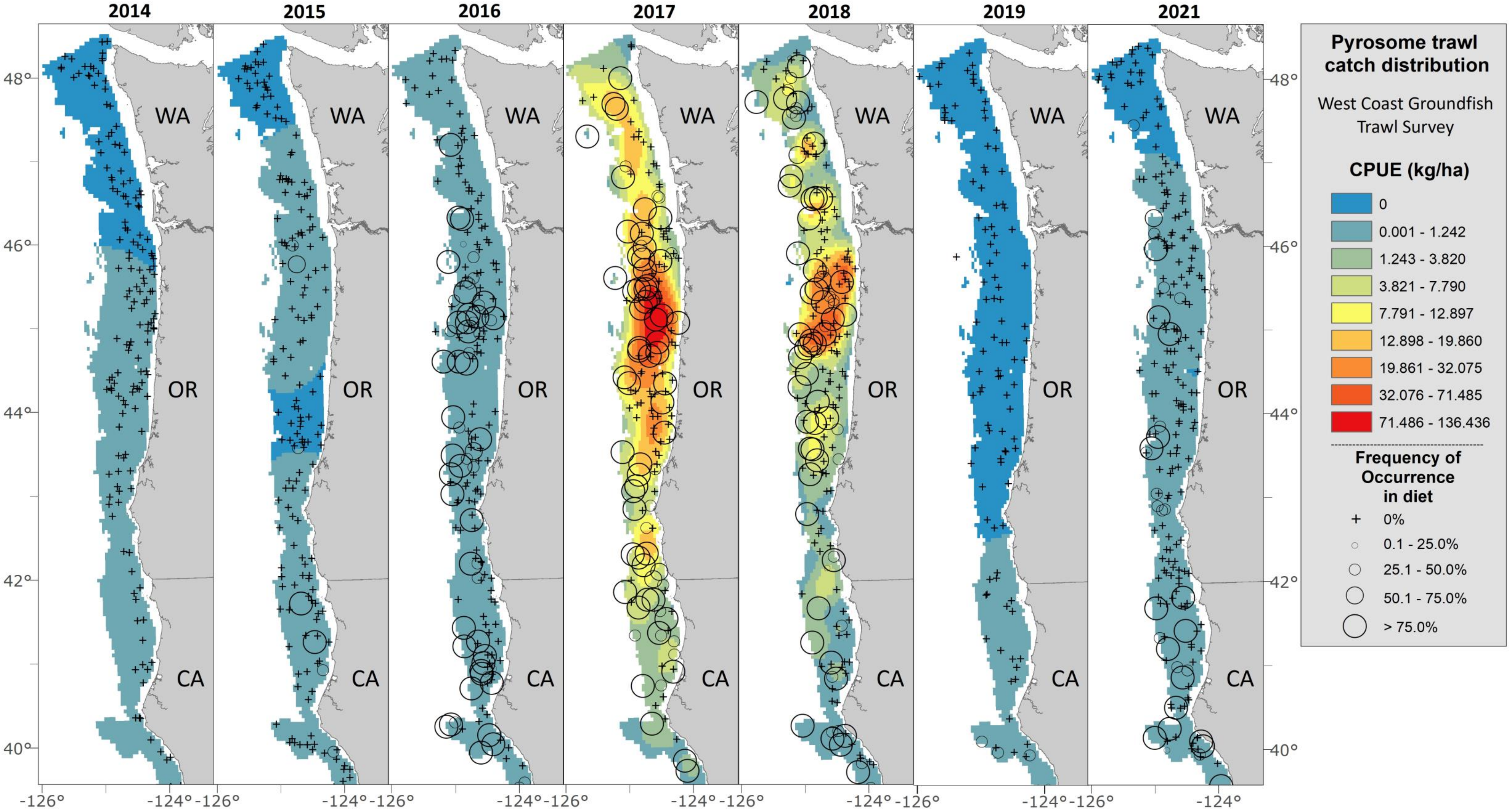
Over 7000 stomachs in 22 species examined.

Common Name	Stomachs with food	Years Observed	Percent of Diet By Weight (%)	Frequency of Occurrence (%)
Sablefish	1426	2015-2021	14.3	28.6
Pacific sanddab	411	2017-2018	7.4	10.2
Longspine thornyhead	133	2020-2021	17.9	7.5
Shortspine thornyhead	190	2020-2021	0.9	2.1
Lingcod	734	2021	0.2	0.1
Canary rockfish	177	2018	2.3	0.7
Yellowtail rockfish	221	2017-2018	0.2	1.1
Blackgill rockfish	135	2017-2021	7.1	14.8
Rougheye rockfish	153	2017	1.1	0.8

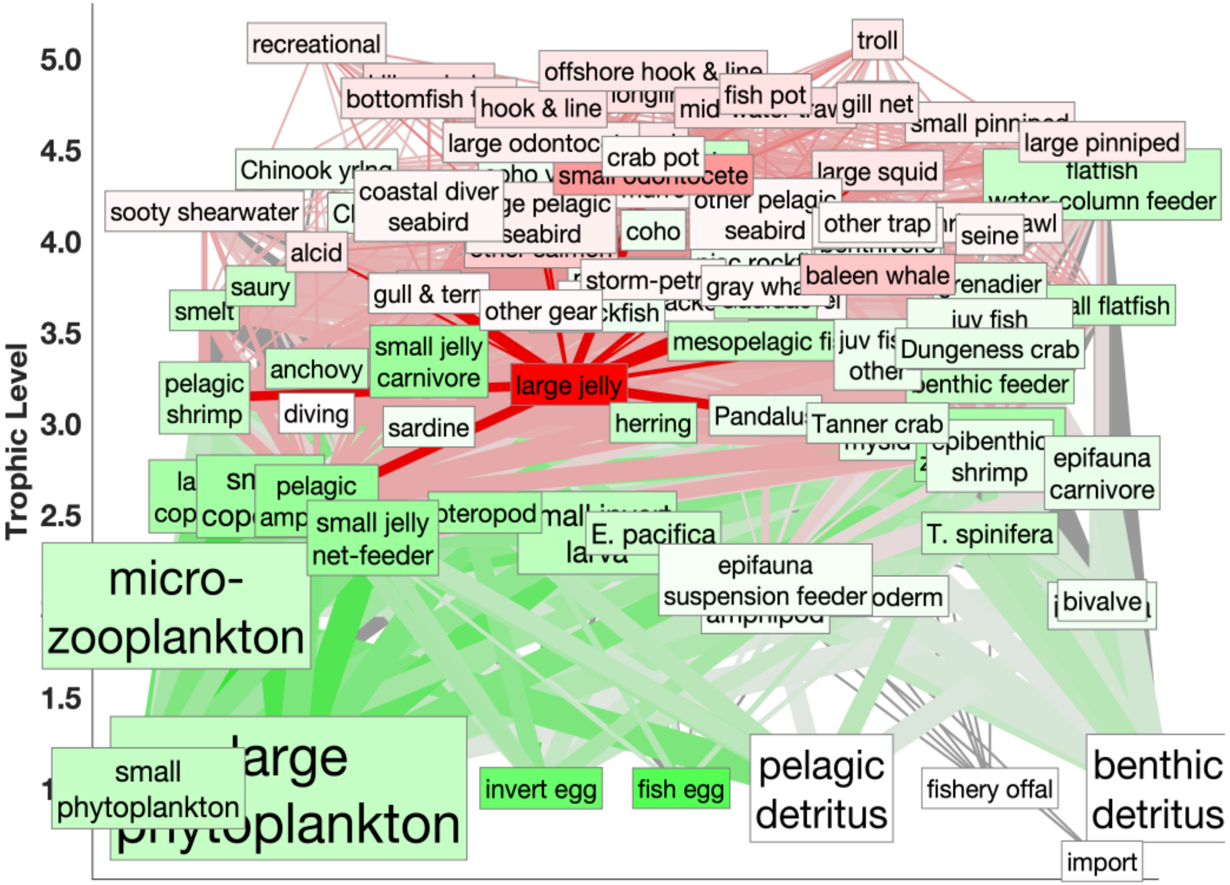
Data from Doug Draper and John Buchanan (NOAA)

Groundfish Predation on Pyrosomes by Year – All Predators Combined

0214 **2015** **2016** **2017** **2018** **2019** **2021**

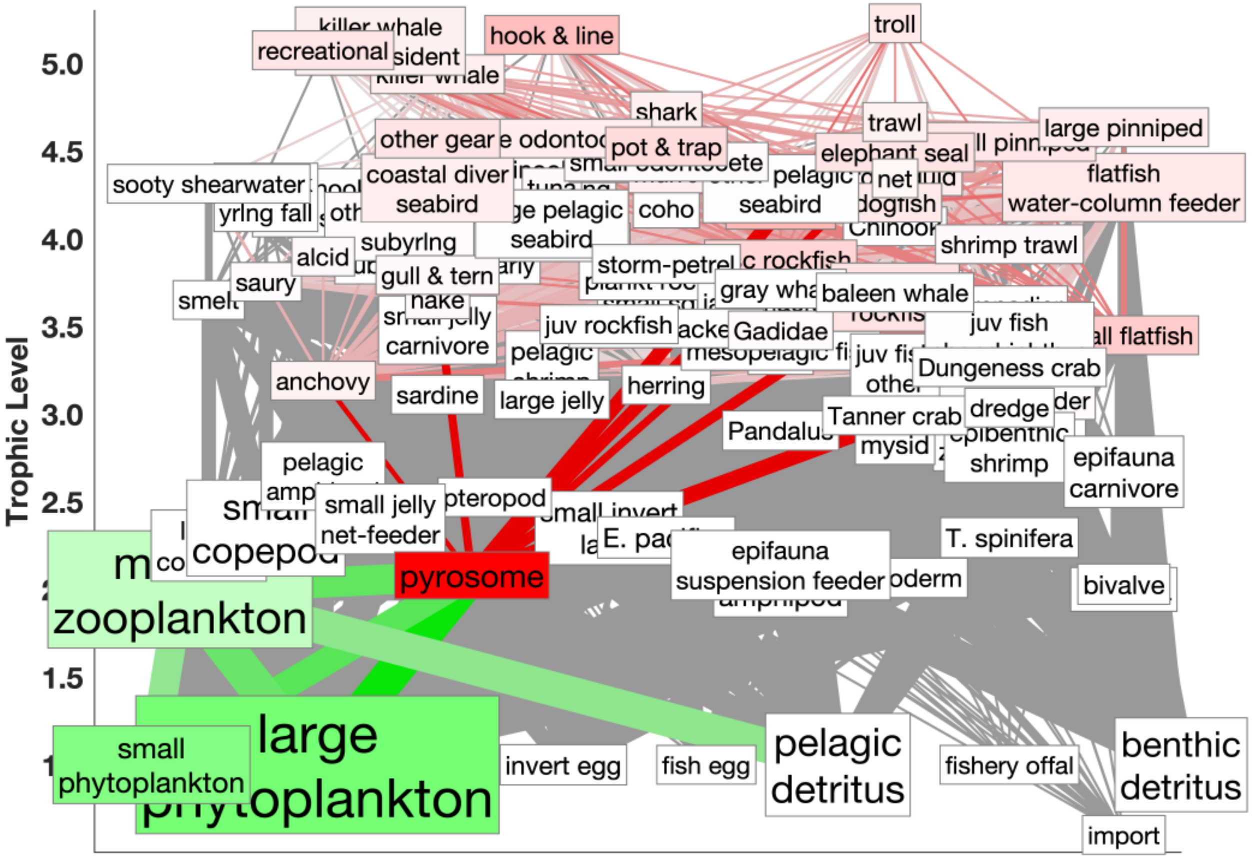


Pre-MHW Food Web Centered on Large Medusae



Ruzicka et al. (2012) Prog. Oceanog.

Post-MHW Food Web Centered on Pyrosomes

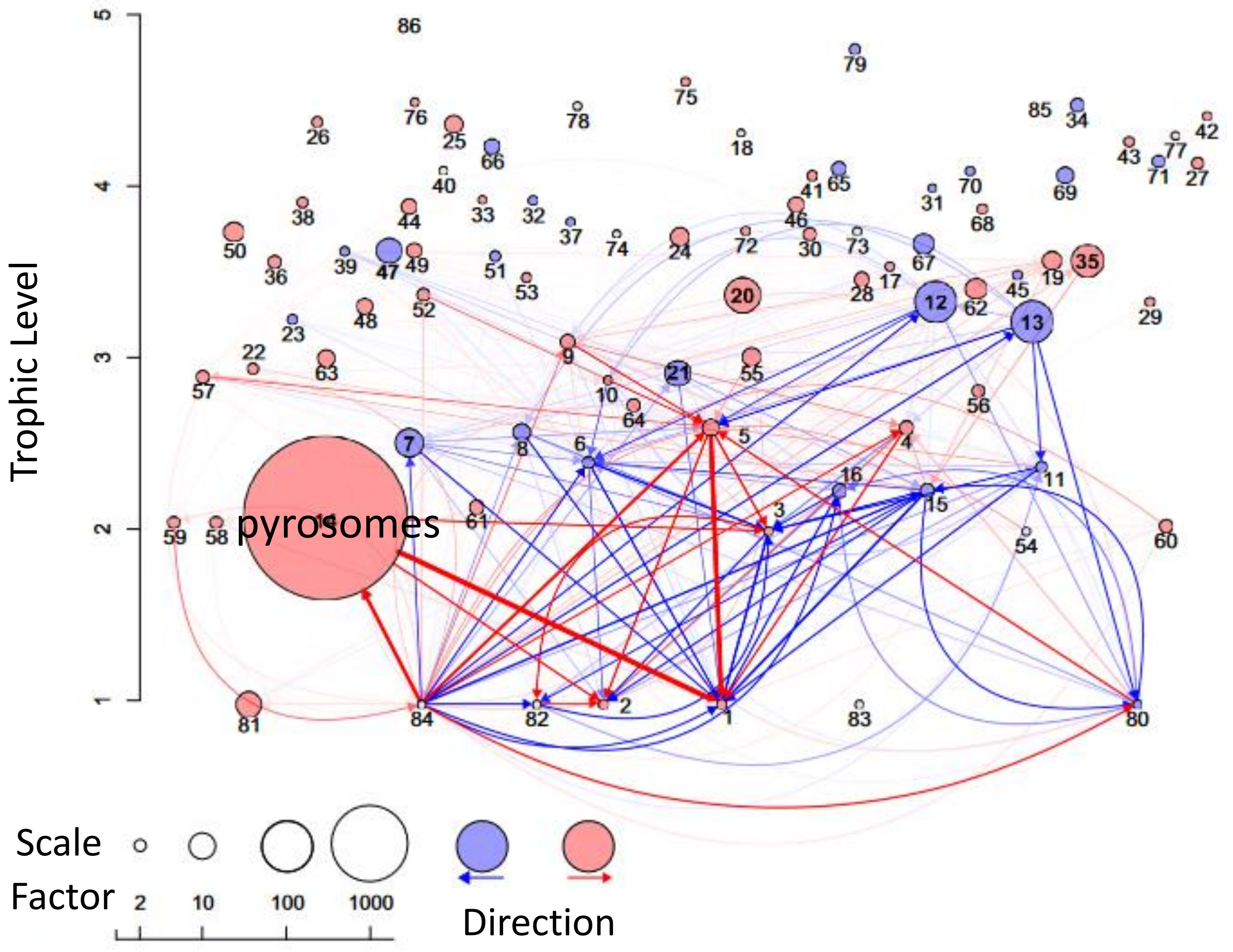


Ruzicka (unpub.)

End-to-end Ecosystem Model for the Northern California Current

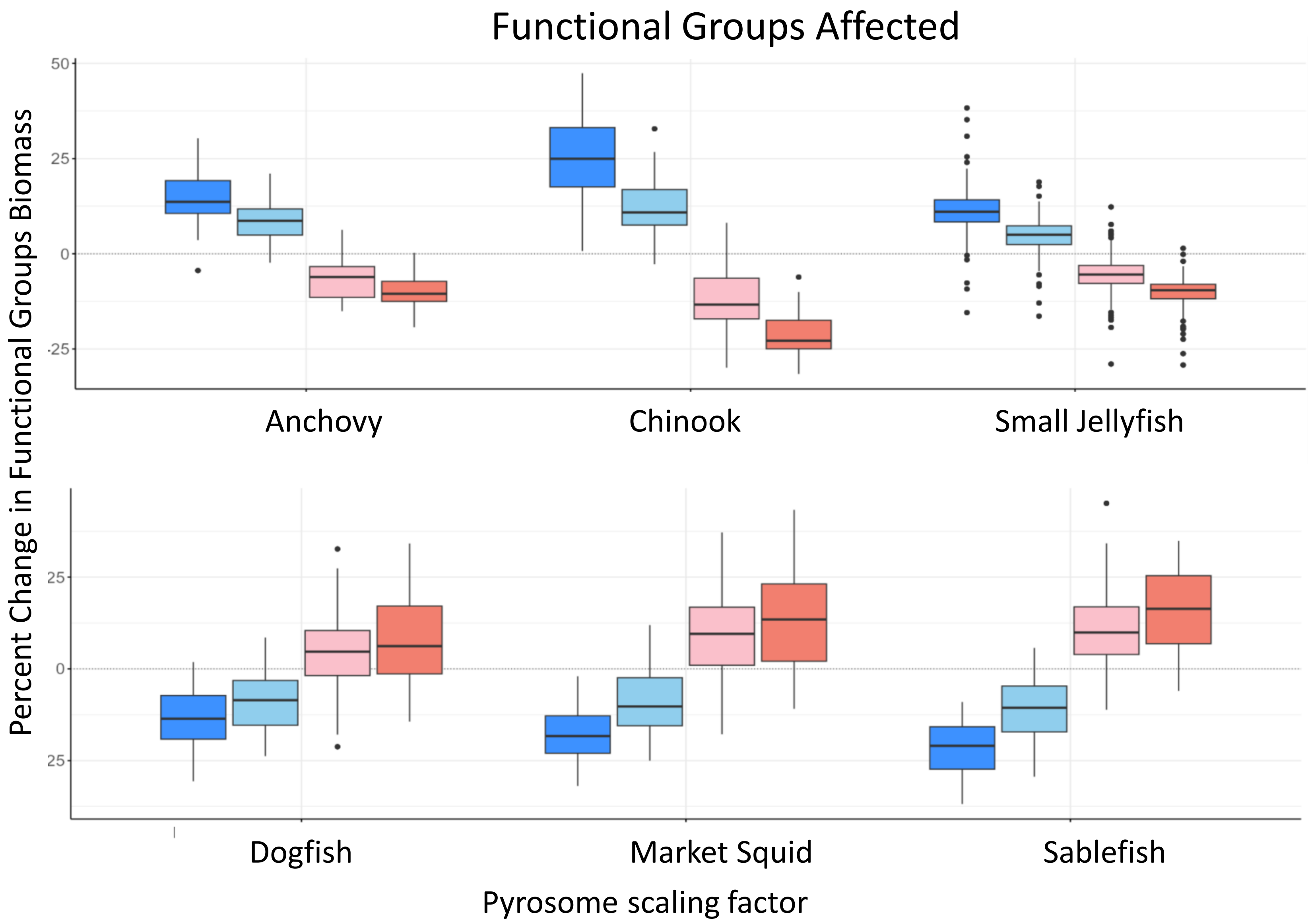
Red circles and lines indicate increased biomass and flows during the MHW

Blue circles and lines indicate decreased biomass and flows during the MHW



Gomes et al. (2024) Nat. Comm.

Comparative effects of scaling pyrosomes on various functional groups



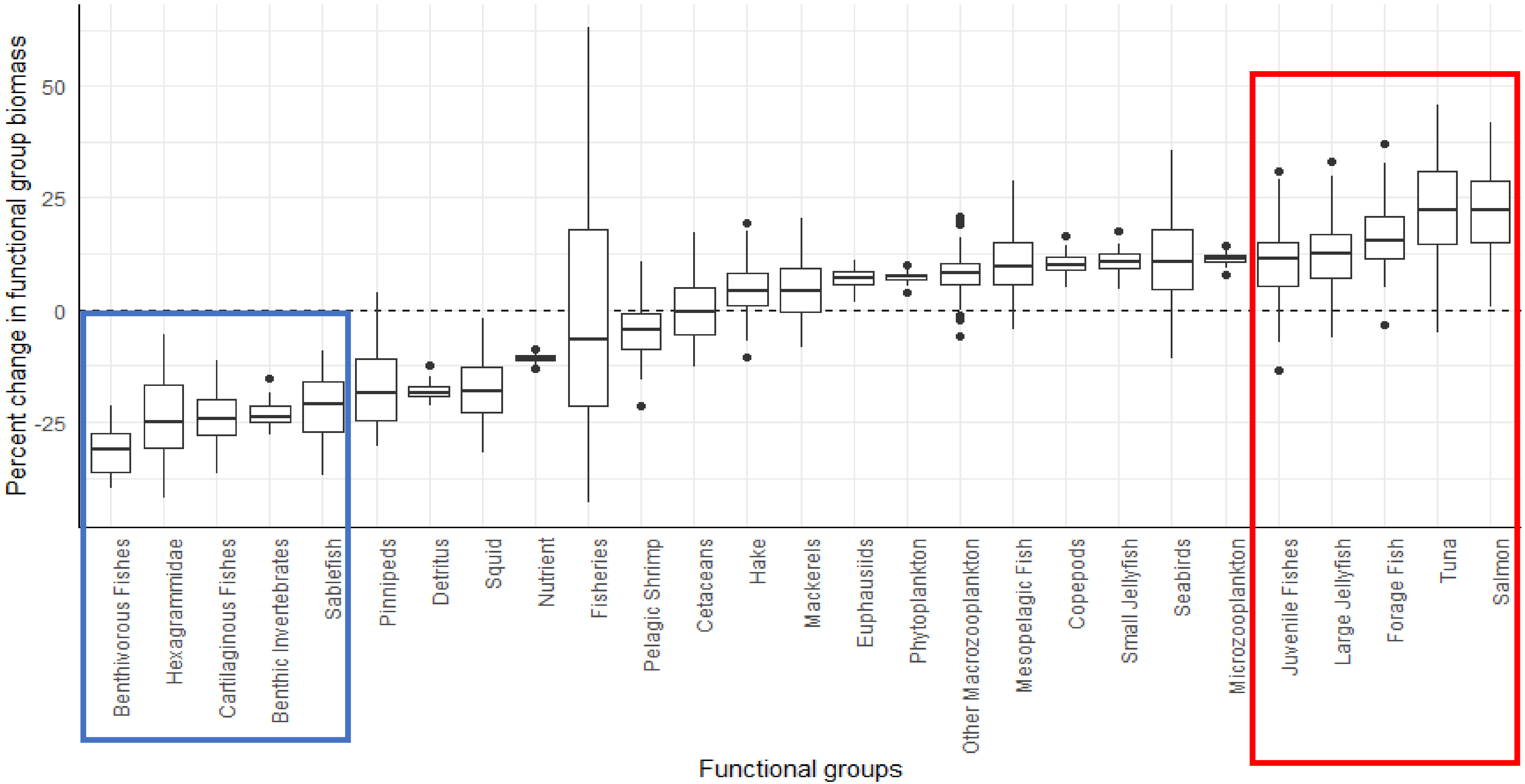
Scaling factor = 0 means pyrosomes are reduced by 100%

Scaling factor = 0.5 means pyrosomes are reduced by 50%

Scaling factor = 1.5 means pyrosomes are increased by 50%

Scaling factor of 2 means pyrosomes are increased by 100%.

Comparative effects of removing pyrosomes on various functional groups



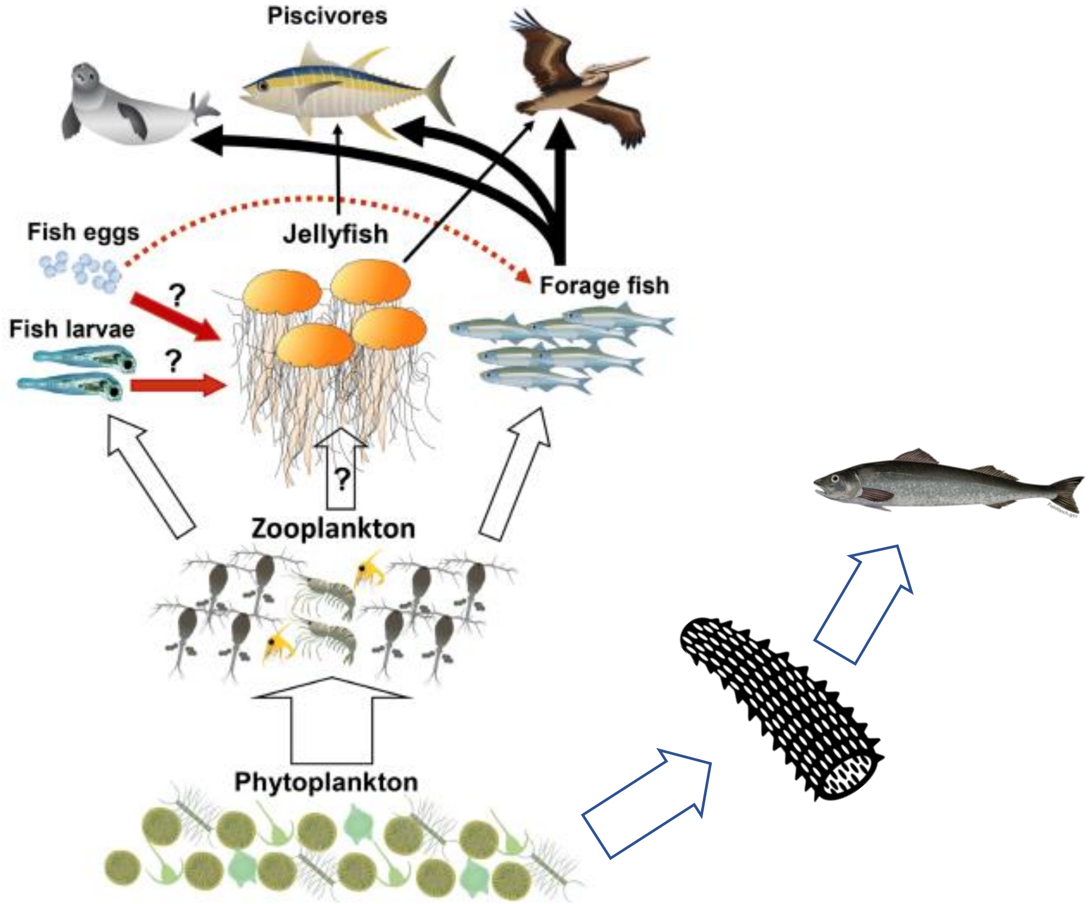
boxplots show the median (center line) and first and third quartiles (lower and upper hinges) of 50 simulations

Brodeur et al. (MS)

Conclusions

Pyrosomes were found in warmer, less productive waters in the NCC which may be similar to tropical pelagic habitat where they are typically found

Pyrosomes consume small plankton and are fed upon by some fish and other top predators. May benefit the demersal food web more than pelagic food web.

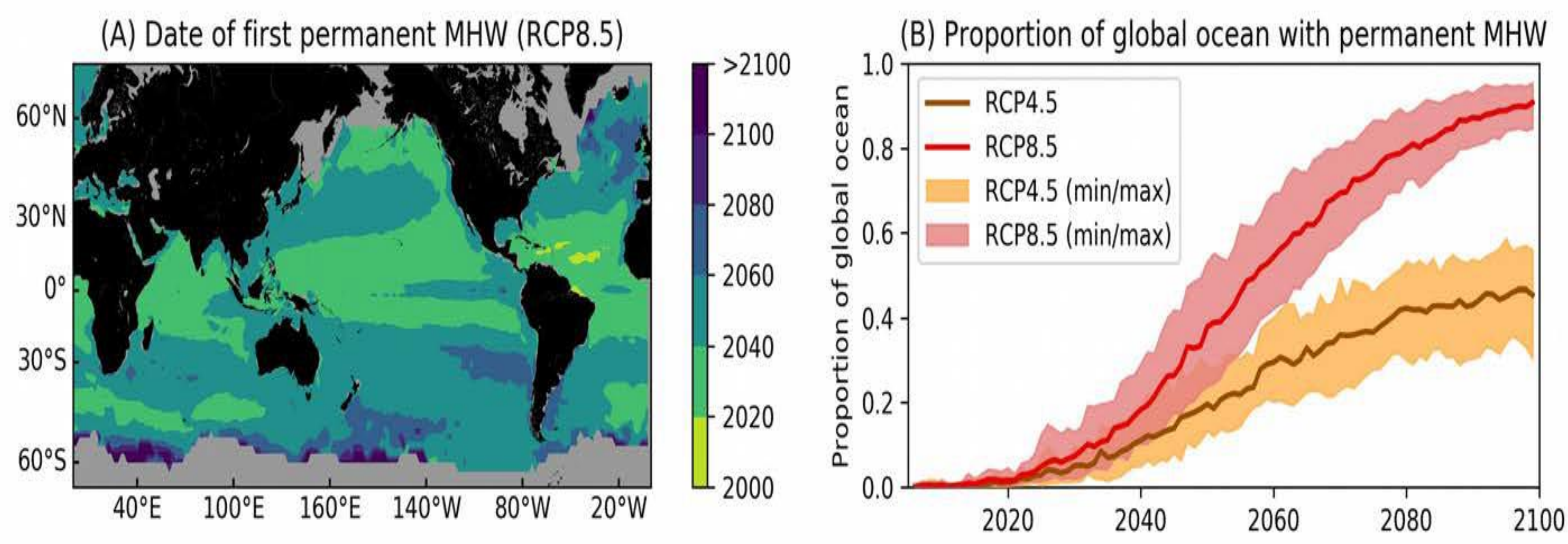


Are pyrosomes going to be permanent residents in the California Current?

North Pacific Permanent Heat Wave by the 2040s

Definition: *"Permanent MHW" = Full year (365 days) of MHW state*

- **Permanent MHW** first reached in tropics by 2040, later at higher latitudes *(both RCP4.5 and RCP8.5)*
- **Proportion** of globe in Permanent MHW state **varies greatly by emissions scenario**



Oliver et al. (2019) Front. Mar. Sci.

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