Zooplankton Ecological Baselines in the Eastern Tropical Pacific Amidst Deep-sea Mining Risks

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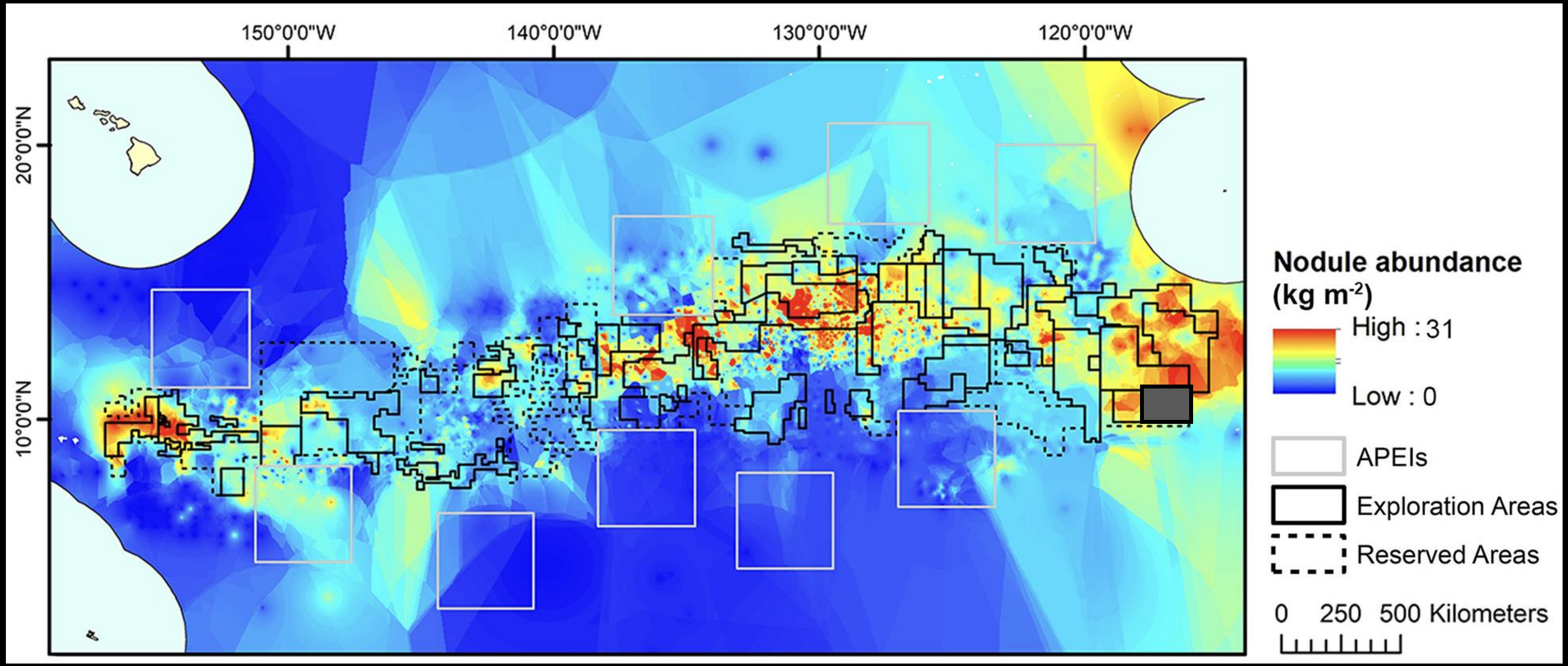
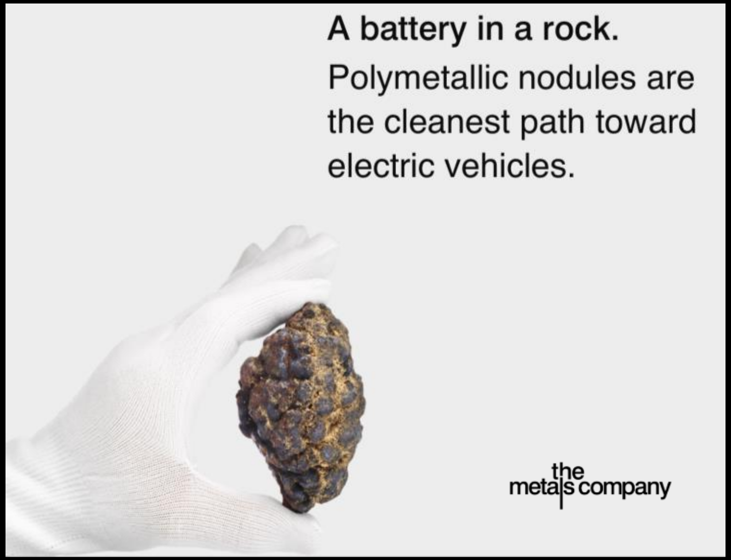
Mining the deep sea for metals

Clarion Clipperton Zone is the mining target



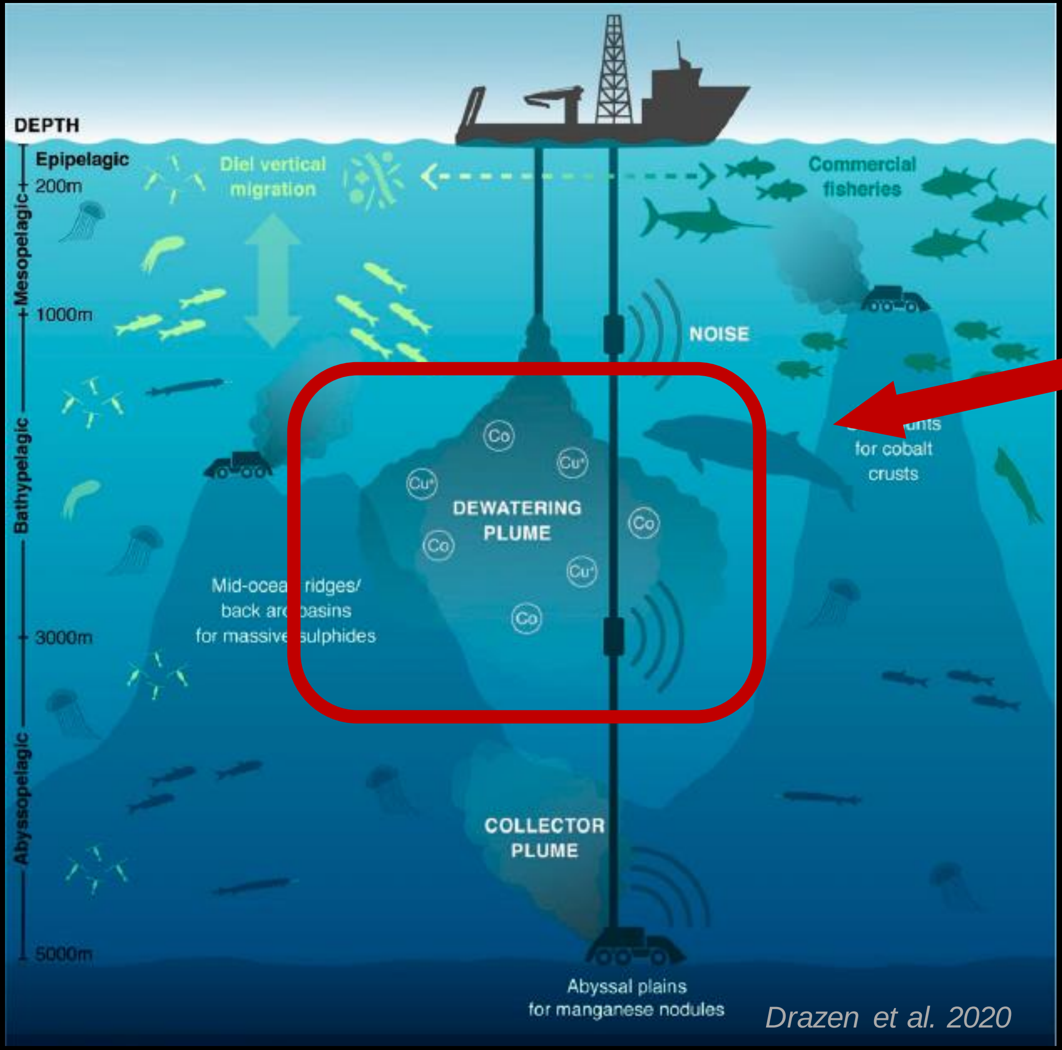
Modeled nodule abundance based on 61,583 data stations - McQuaid et al. 2020



- Manganese nodules contain cobalt, nickel, copper and manganese – all essential for battery production

Mining impacts in midwater?

Interaction of sediment plumes and oxygen minimum zones



Drazen et al. 2020

Animal distribution and behavior
Feeding ecology
Buoyancy
Clogging of respiratory/feeding structures
Release of metals, pollutants
Biogeochemical cycling and export

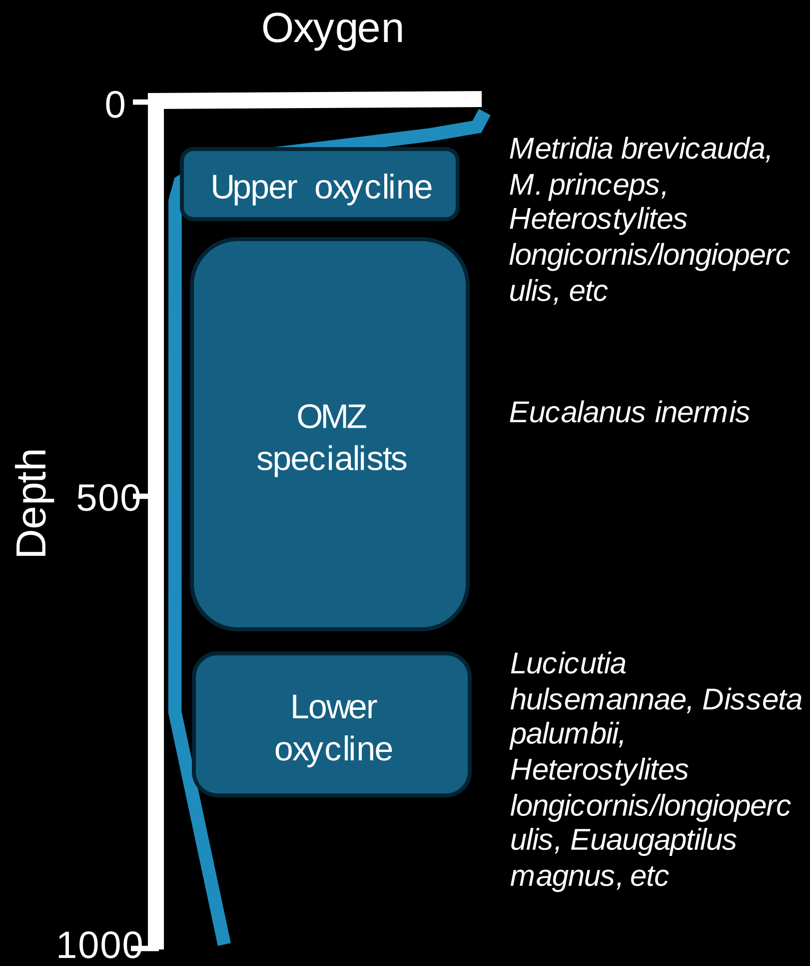
** Drazen et al., 2020; van der Grient & Drazen 2022; Stenvers et al. 2023*

Zooplankton ecology in the ETP

Life is structured around oxygen gradients

- Biomass and community composition is structured by oxygen gradients
  - Biomass peaks in the upper well-oxygenated layer and in the lower oxycline (LO)
  - Specialization of species to distinct oxygen habitats

- Epipelagic zooplankton biomass changes seasonally, and is correlated with chlorophyll, primary production, phosphate, and thermocline depth



**Wishner et al. 1995, Saltman & Wishner 1997a, b, Wishner et al. 2013, 2018, & 2020; Fernández-Álamo & Färber-Lorda 2006*

Establishing ecological baselines prior to impact:

- Characterize the abundance, biomass, diversity and composition of the zooplankton community from the sea surface to the seafloor
- Characterize spatial and temporal variability in these assemblages

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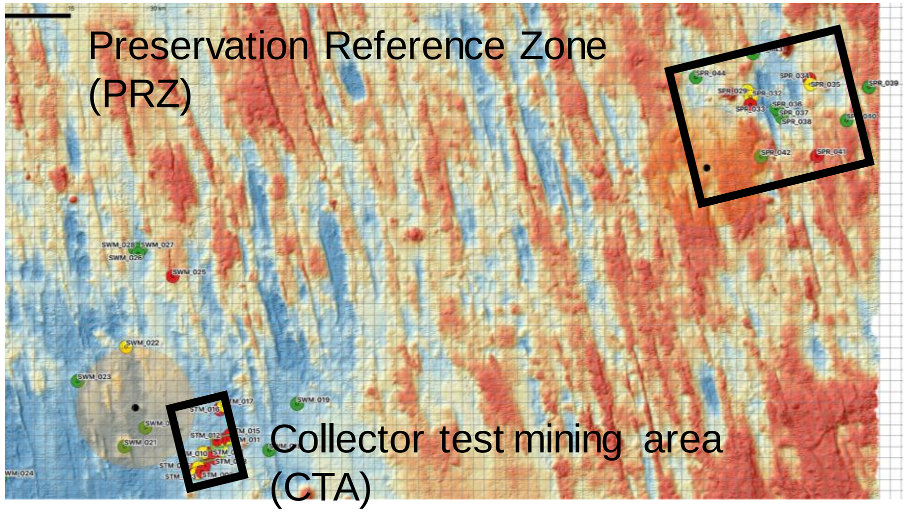
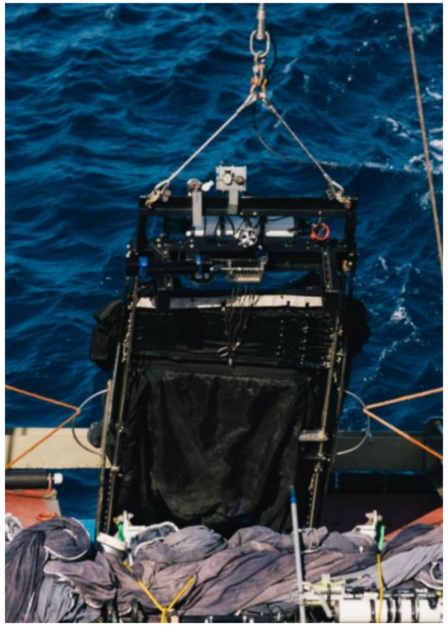
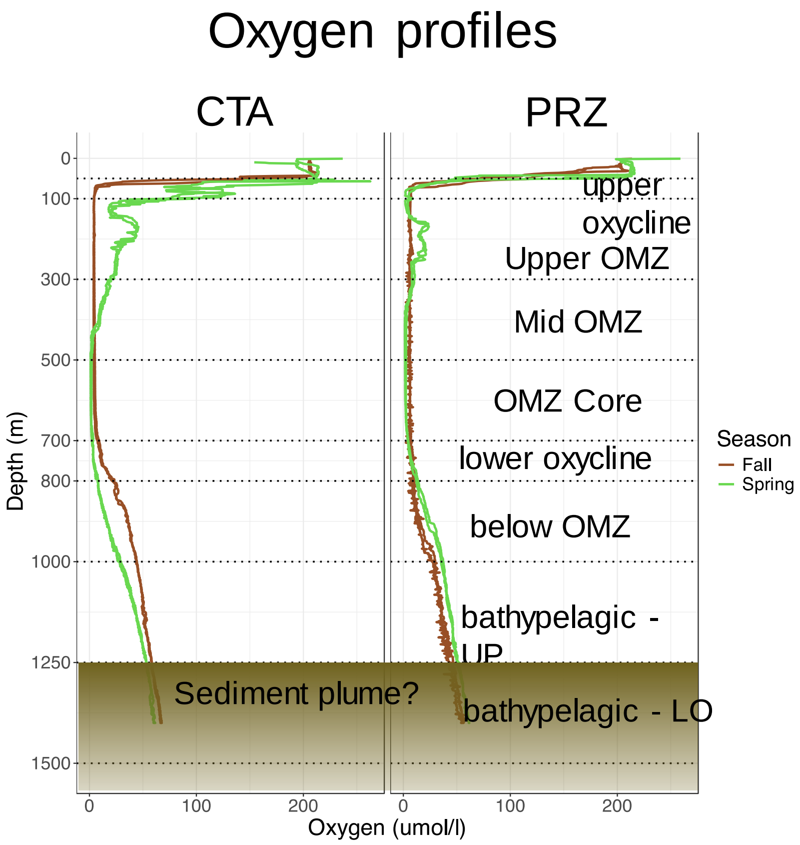
- Characterize spatial and **temporal variability** in these assemblages

Study site, sampling, and analyses

Depth-stratified sampling around the OMZ







24 Depth-stratified MOCNESS tows

Sampling 0-1500m, 9 Nets

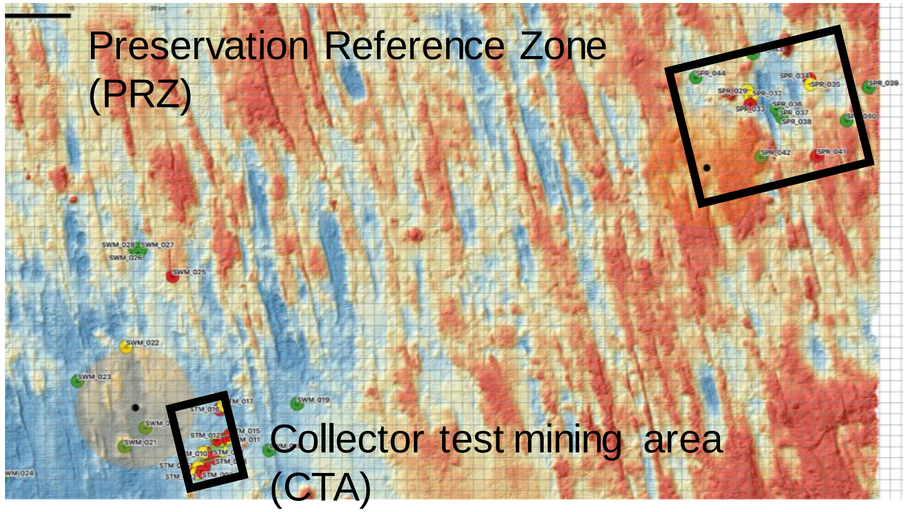
2 cruises - Spring & Fall 2021

12 tows, 6 each at CTA and PRZ

CTD Sensors onboard

Study site, sampling, and analyses

Depth-stratified sampling around the OMZ



24 Depth-stratified MOCNESS tows
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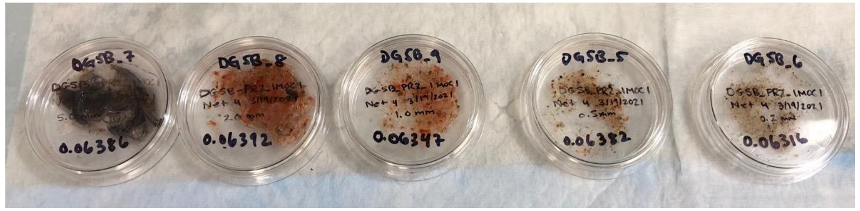
Biomass
Wet/dry weight biomass, 5 size fractions, each net



DNA Metabarcoding
2 markers: mitochondrial COI, nuclear 18S V1-V2 *
28,731,977 total reads, all samples
35,786 average reads / sample COI; 44,371 average reads/sample 18S
Qiime2 with DADA2, & R decontam removal of contaminants

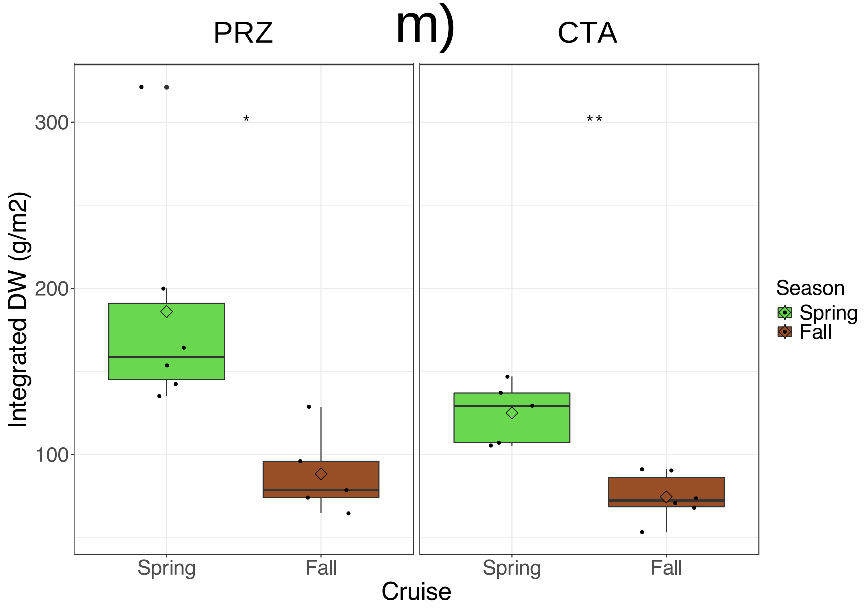
ZooScan image-based analyses
In progress

* universal primers; *Leray et al. 2013, Geller et al. 2013, Fonseca et al. 2010*

Zooplankton biomass is higher in spring

Coupled with higher primary production and particle export

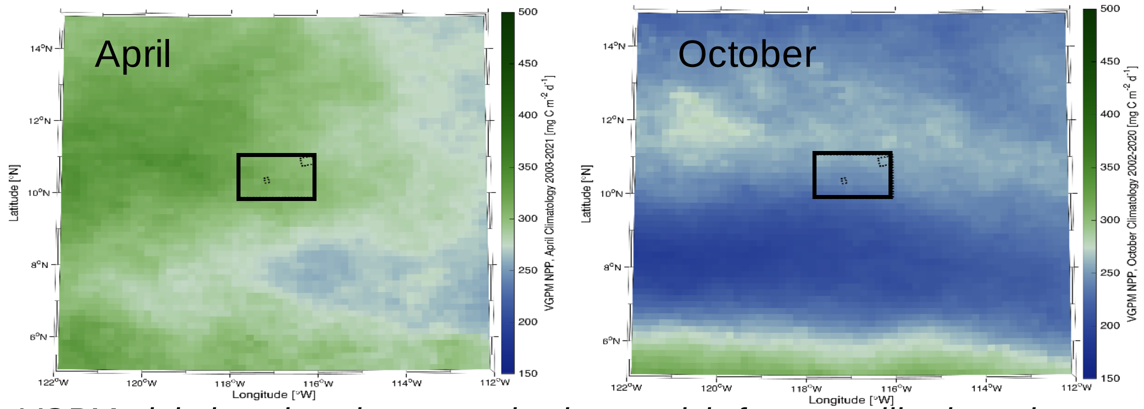
Integrated biomass (0-1500 m)



Higher biomass in spring (158±60 g/m^2) than fall (81±20 g/m^2)

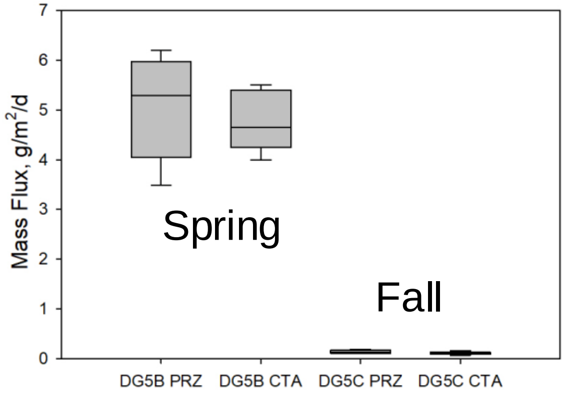
0 '****' 0.0001 '***' 0.001 '**'0.01 '*' 0.05 'ns' 1.0

Net Primary Production



VGPM global-scale primary production model, from satellite-based ocean color

Particle Flux

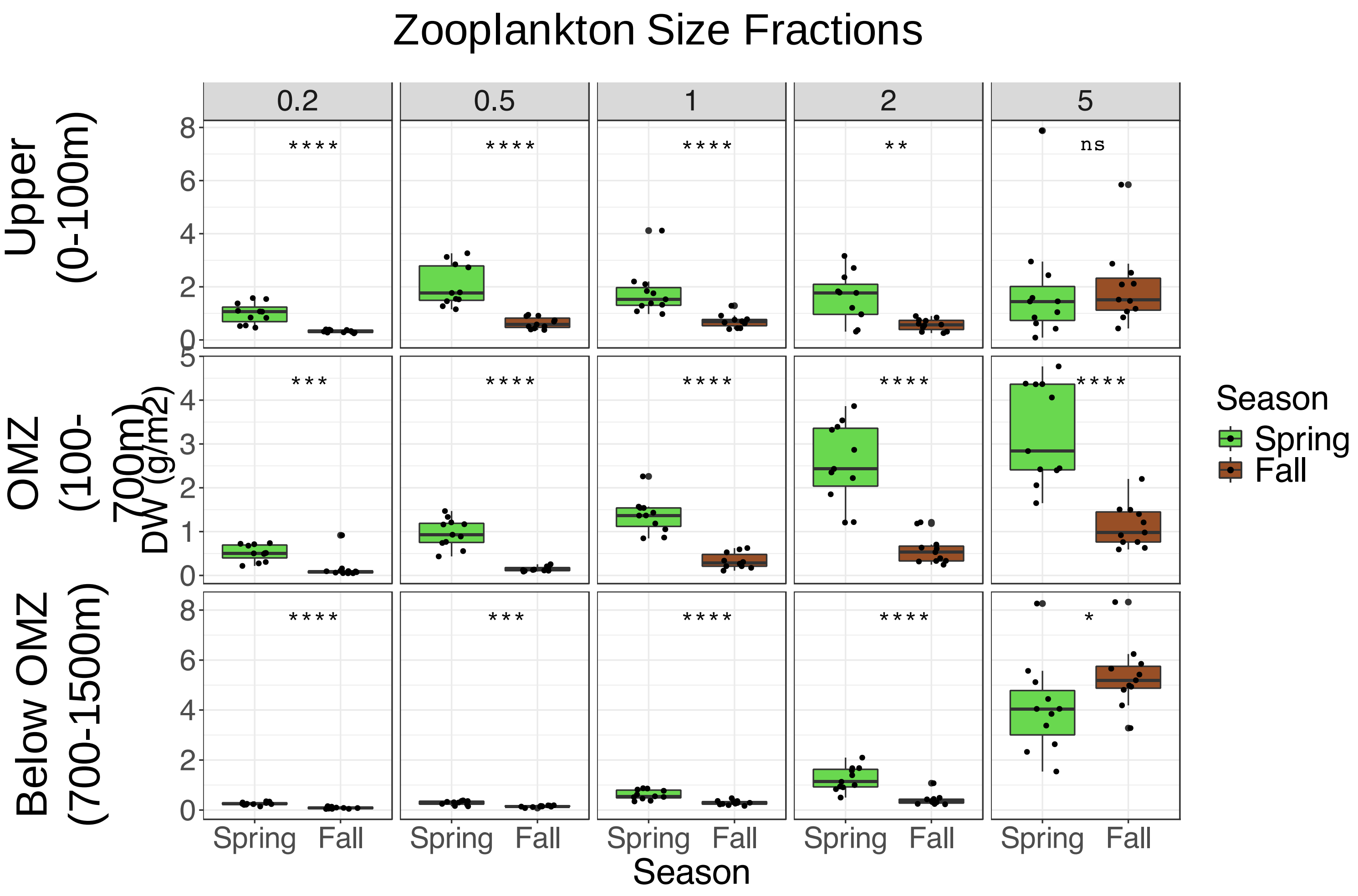


Particle Interceptor Traps (PIT) deployed between 65 and 90m

Data: A. White, S. Ferron, B. Popp

Zooplankton biomass is higher in spring

Seasonality is particularly pronounced within the OMZ



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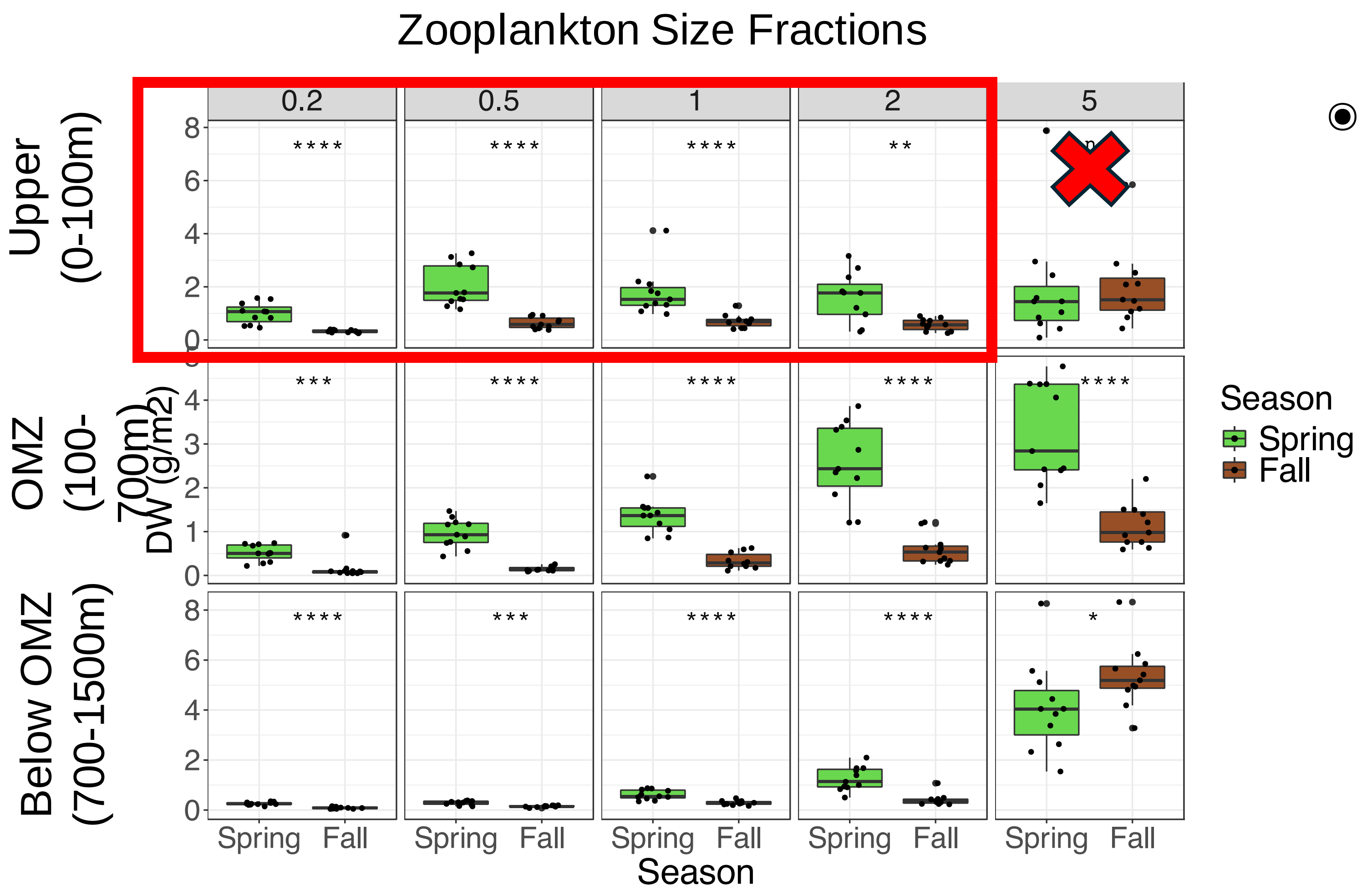

- Upper 100m: strong seasonality in all size classes, except >5.0 mm

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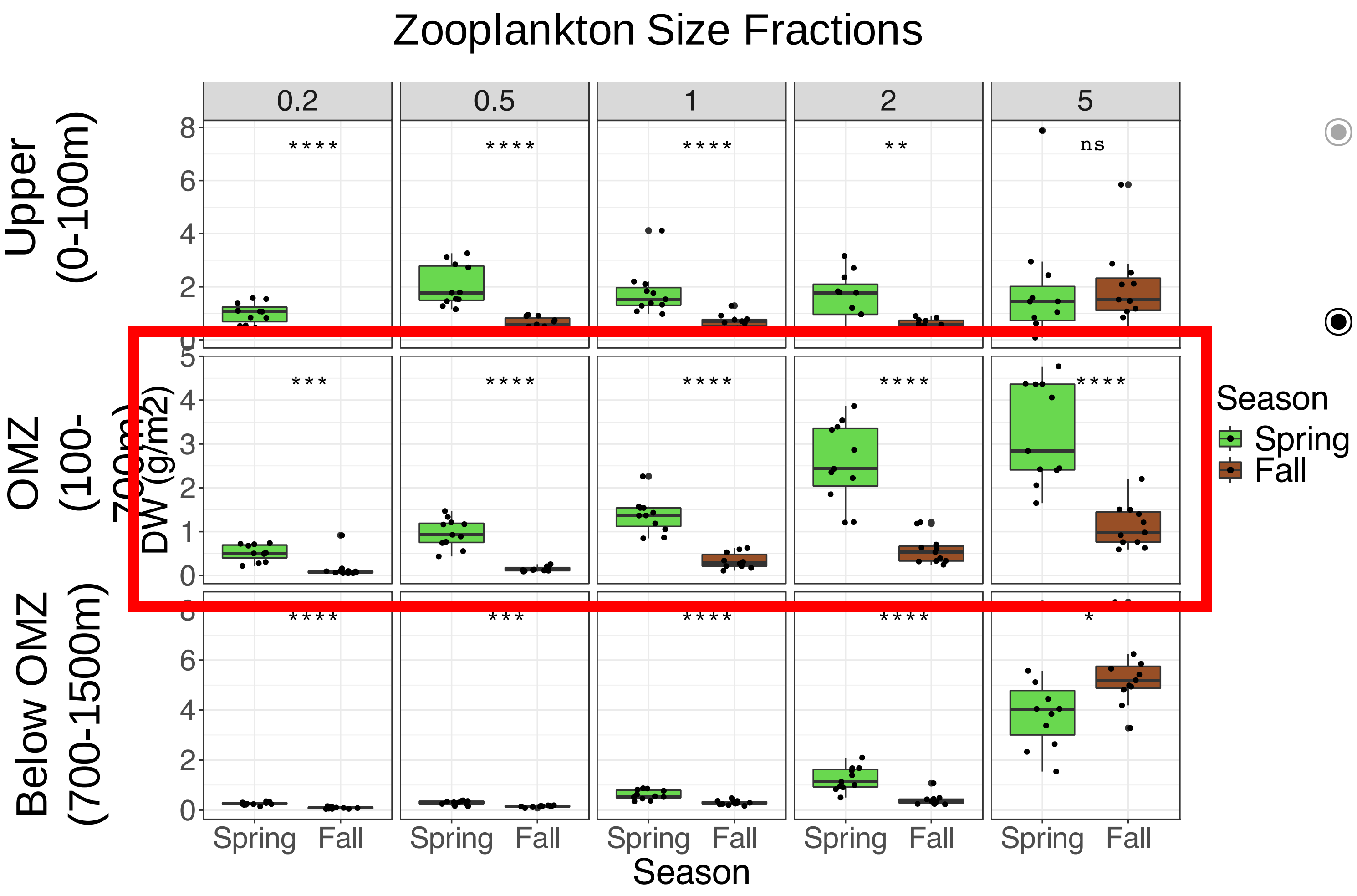

- Upper 100m: strong seasonality in all size classes, except >5.0 mm
- OMZ: Strong seasonality in all size classes

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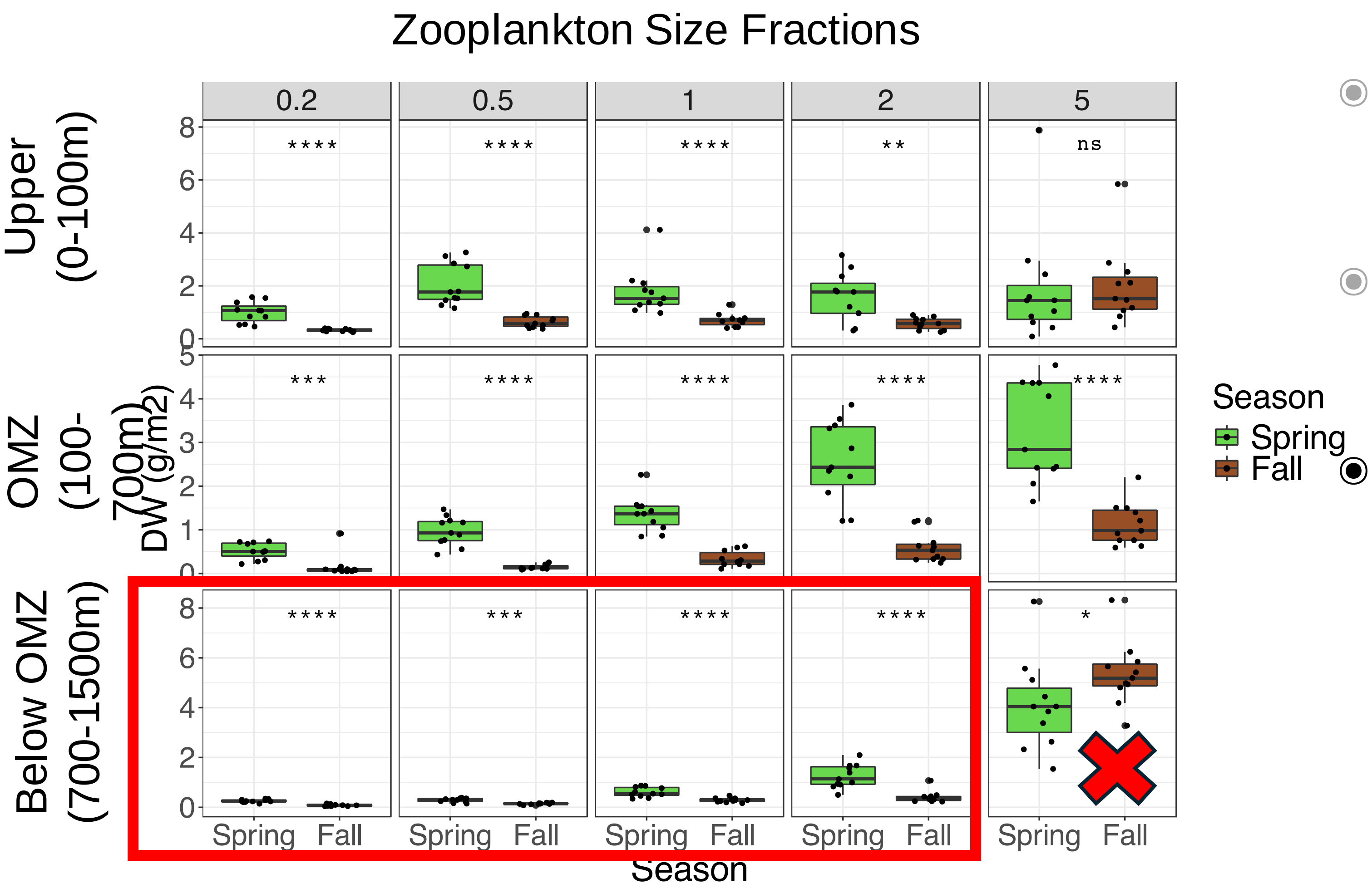
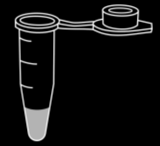


- Upper 100m: strong seasonality in all size classes, except >5.0 mm
- OMZ: Strong seasonality in all size classes
- Below the OMZ: significant but weak seasonality in all size classes, except >5.0 mm

0 ‘****’ 0.0001 ‘***’ 0.001 ‘**’0.01 ‘*’ 0.05 ‘ns’ 1.0

Community is highly structured

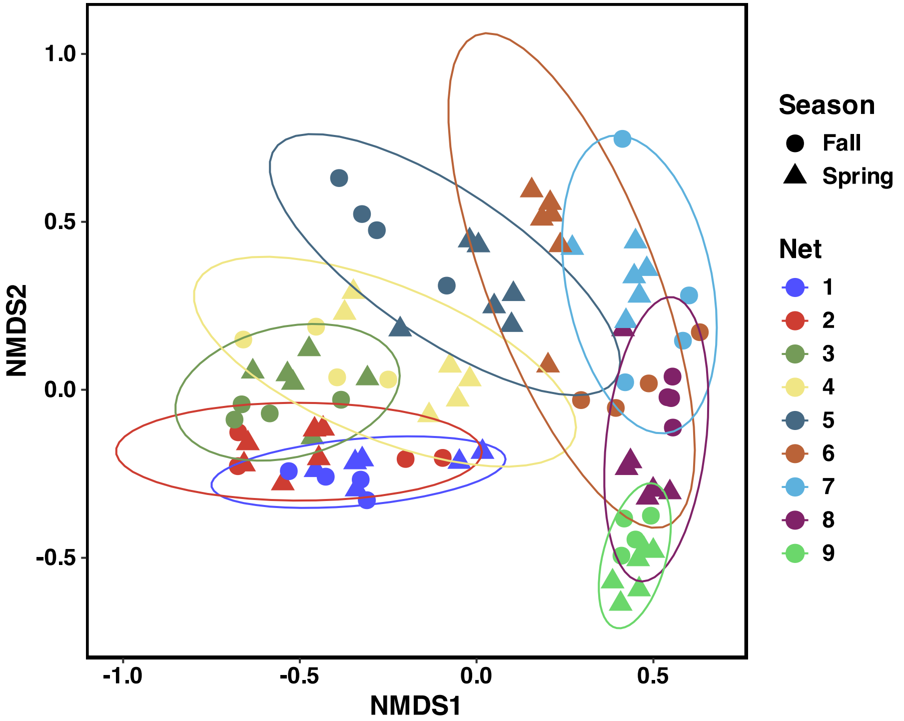
Metabarcoding



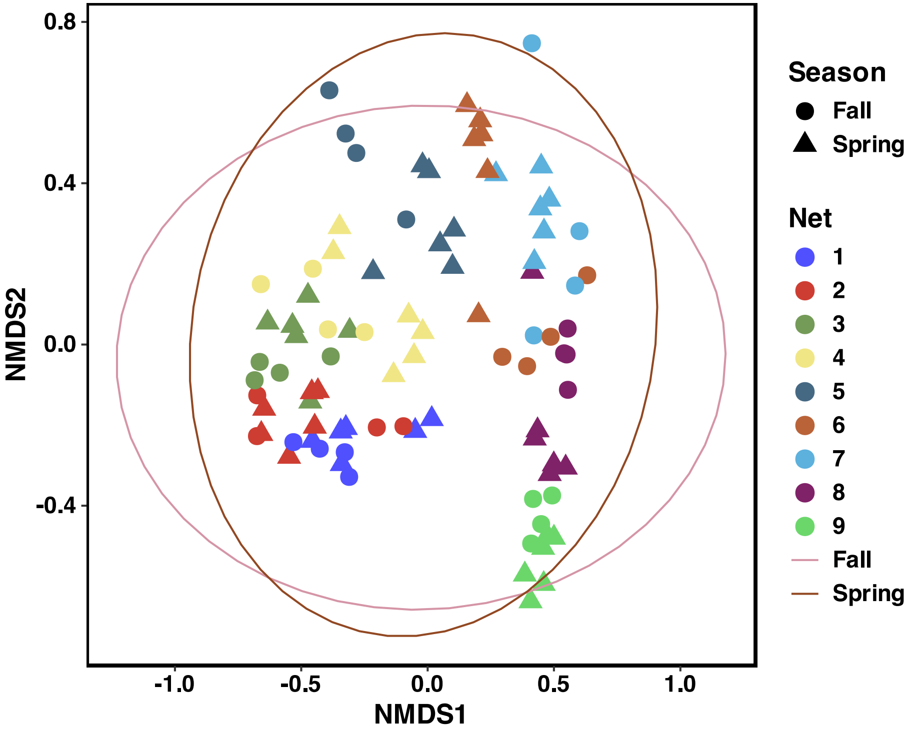
Both depth and season are important

Site CTA
Nuclear 18S
Bray-Curtis
dissimilarity

Depth strata



Season

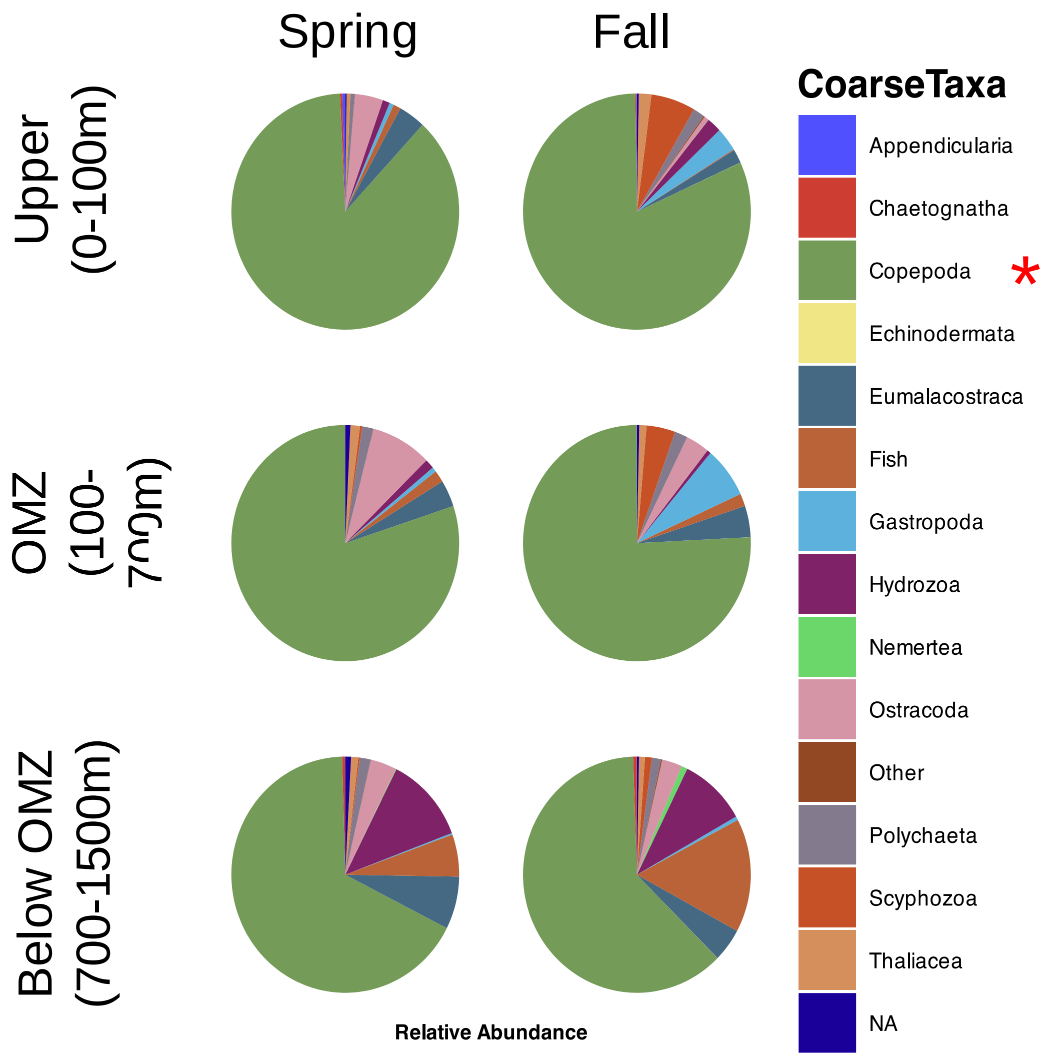


18S: PERMANOVA, $p<0.05$ for Net + Season; Net $R^2 = 0.20$, Cruise $R^2 = 0.04$

COI: PERMANOVA: $p<0.05$ for Net + Season, Net $R^2 = 0.11$, Cruise $R^2 = 0.05$

How does community change seasonally?

Site PRZ
Nuclear 18S



* Copepoda make up 50-85% of the community

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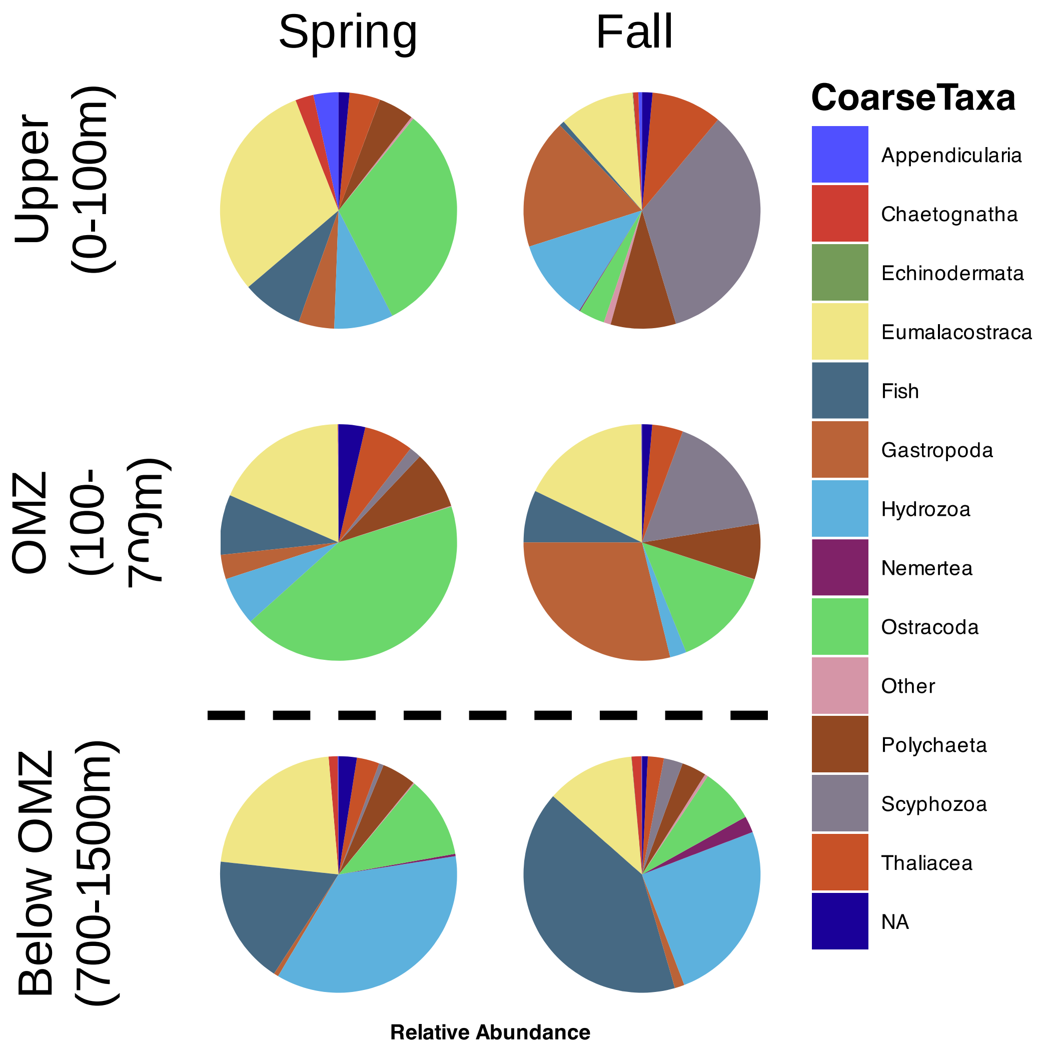


Spring

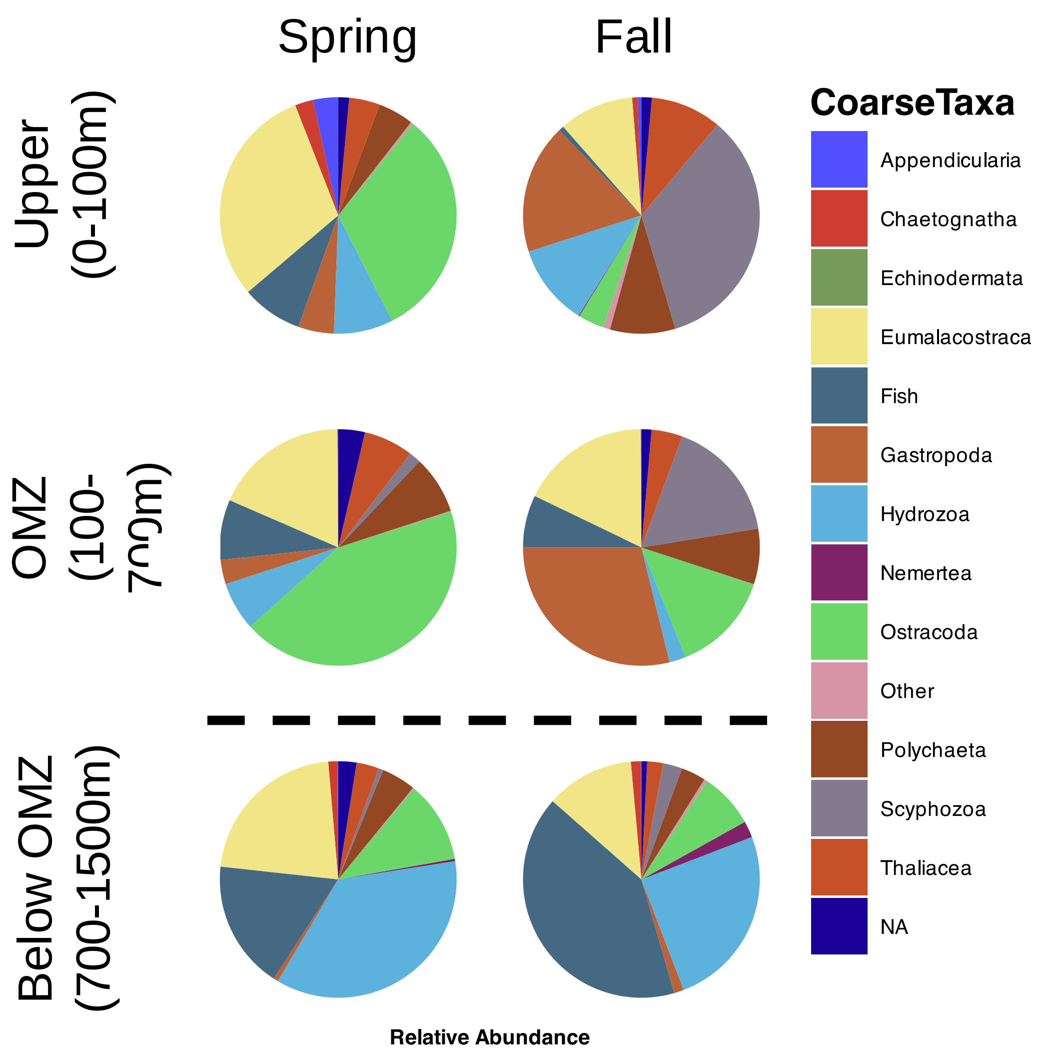
Ostracods

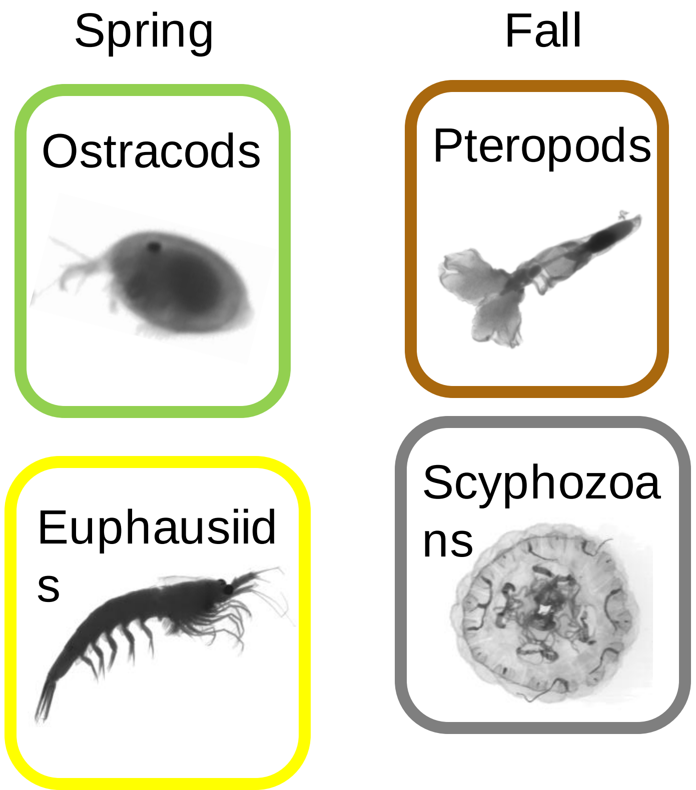
Euphausiids

Site PRZ
Nuclear 18S

Metabarcoding

How does community change seasonally?





Site PRZ
Nuclear 18S

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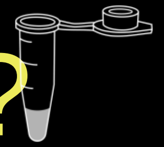

How does community change seasonally?

Site PRZ
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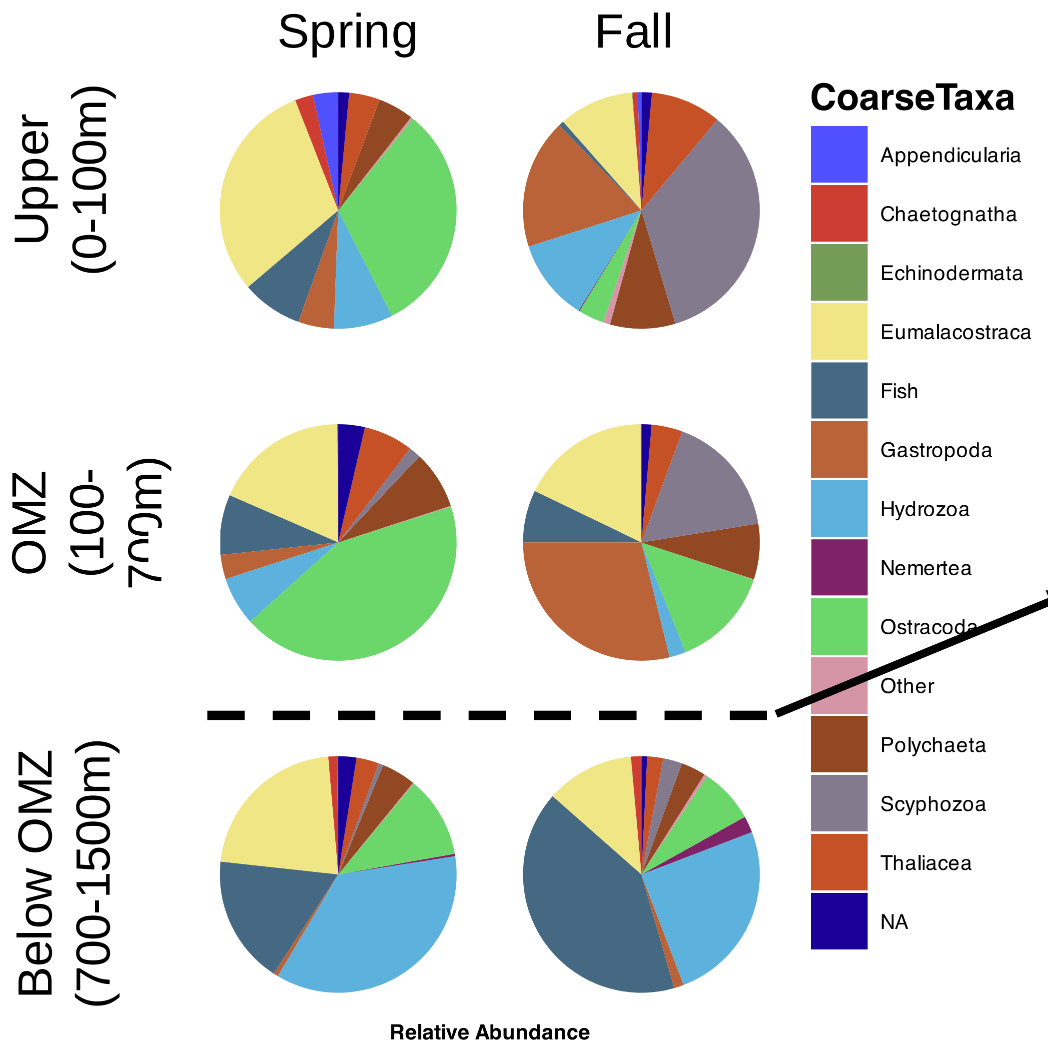


Community transition below the OMZ
Siphonophores, Fishes make up 55-65% of the community

Fish

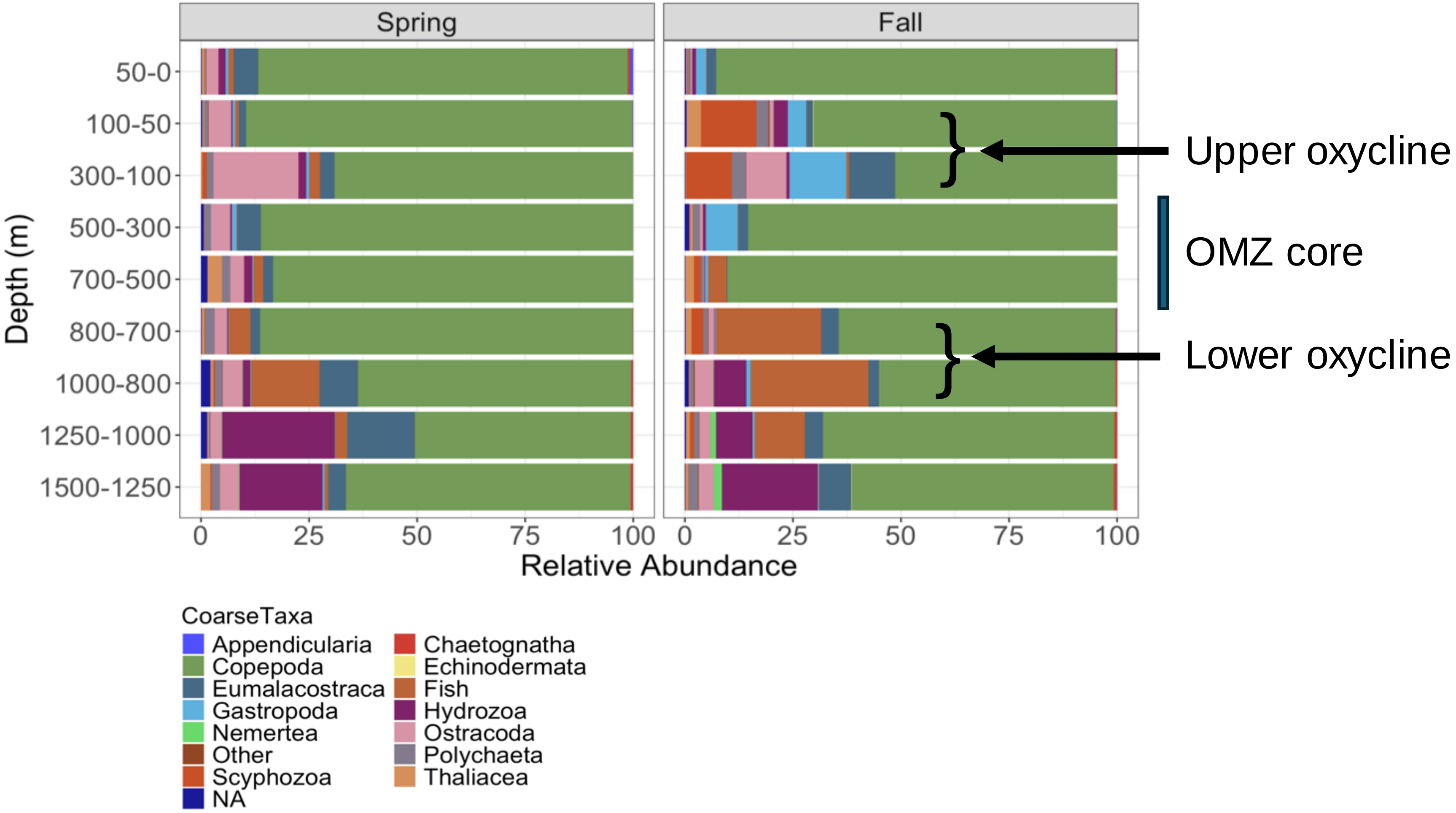
Siphonophores

Upper OMZ is seasonally dynamic

Life structured around oxygen gradients

Metabarcoding

Site PRZ
Nuclear 18S



Upper OMZ is seasonally dynamic

Life structured around oxygen gradients

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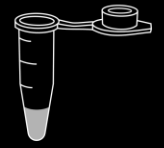
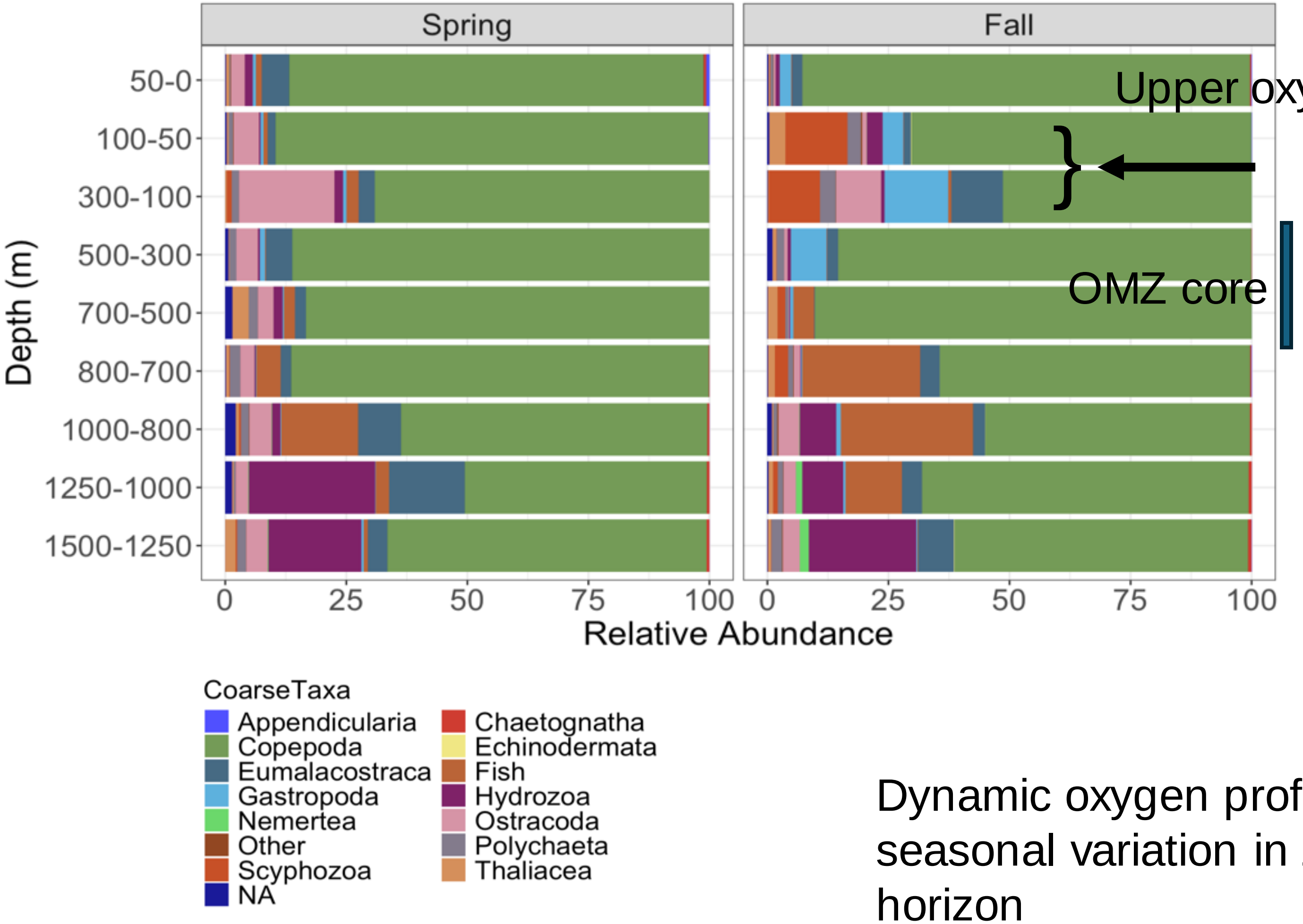
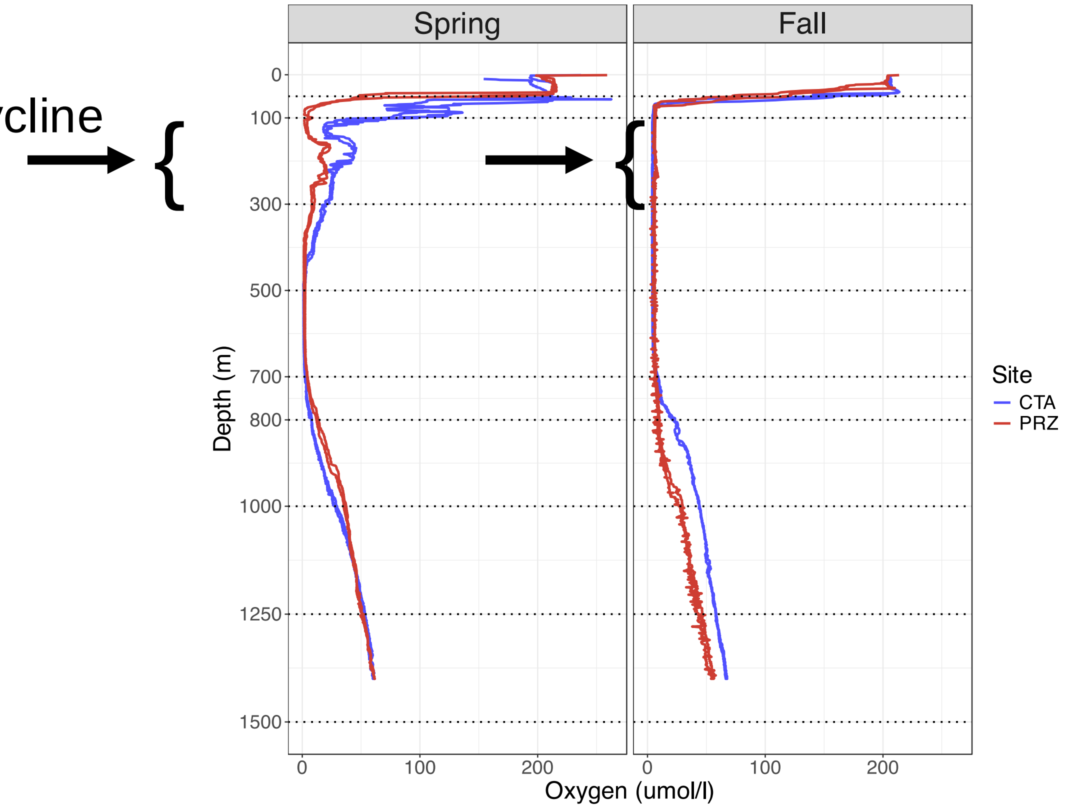


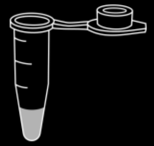




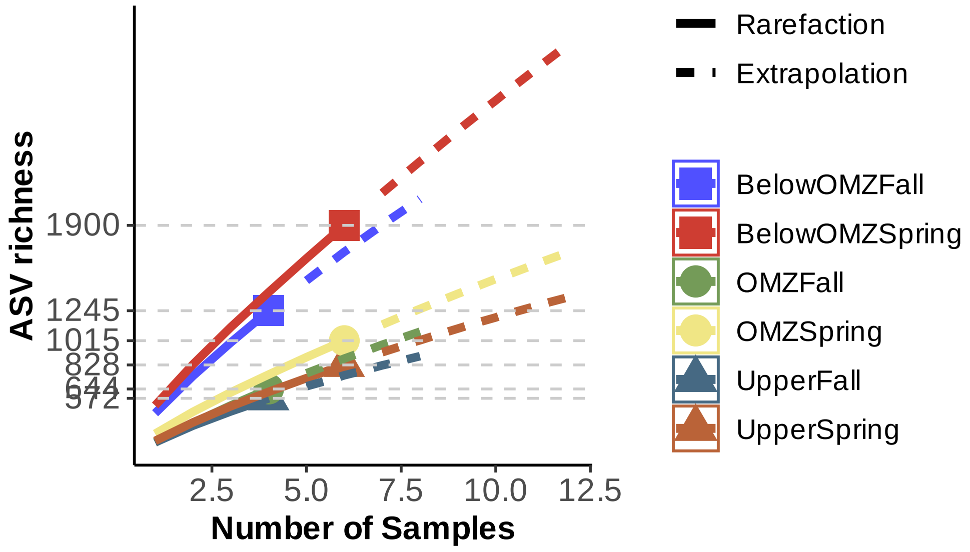
Dynamic oxygen profiles at 100-300m in the upper OMZ likely drive seasonal variation in zooplankton community structure in this depth horizon

Diversity is relatively constant across season

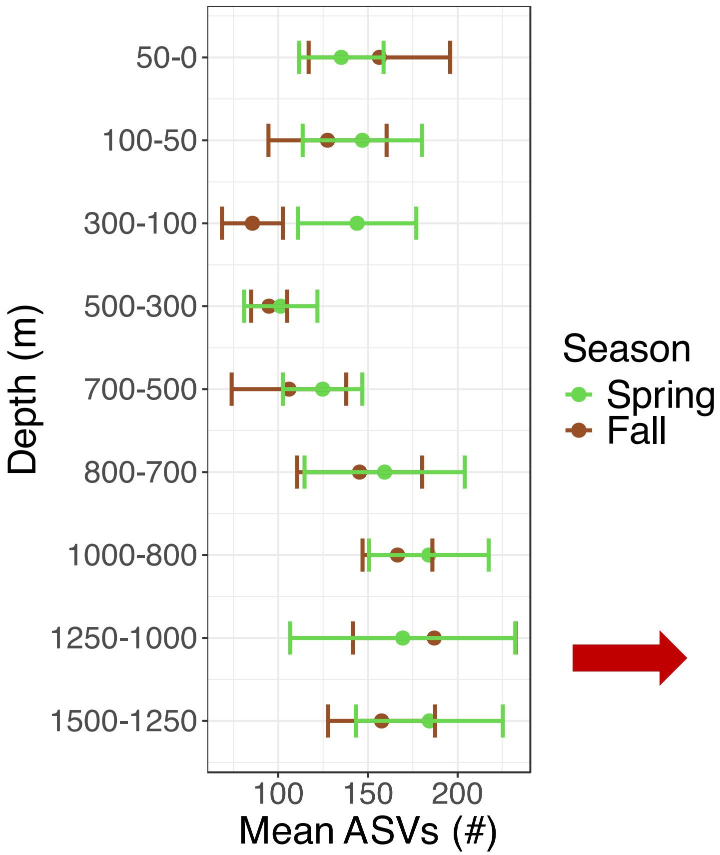
BUT highest richness is found in the deep mesopelagic and bathypelagic



Nuclear 18S
Chao2 estimated richness



Sample coverage: 48-61%, 18S



Richness highest below the OMZ, in regions of the water column targeted for sediment release

Conclusions & Synthesis

Establishing ecological baselines prior to mining impact

- Seasonal forcing in the upper ocean drives zooplankton biomass response across the epi-, meso- and upper bathypelagic, with attenuation of the signal with depth.
- Community is primarily structured by depth, but also varies across season, with a shift from crustaceans (spring) to pteropods and gelatinous plankton (fall) in the upper ocean.
- Upper OMZ a particularly dynamic region of the water column

Implications for mining regulation

- Adequate characterization of natural variability prior to anthropogenic impacts is required. Urgently need longer time series and greater spatial resolution
- Deep pelagic ocean holds the highest biodiversity and is not an attractive target location for sediment plume release

Acknowledgements

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