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Temporal Variability in Organic Carbon Fixation and Fate in the CCZ

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Carbon Fixation and Fate

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- Abyssal sediments sequester ~50 Tg C y^{-1}
- Exported organic matter feeds benthic ecosystems
- Spatial, seasonal and interannual variability are present in surface ocean primary productivity
- Comprehensive data sets are rare, so direct coupling from the surface ocean through the water column to sediment and benthic communities is understudied

Research Questions

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- To what extent do primary productivity vary seasonally and interannually?
- To what extent are surface productivity and export / sinking flux at different depths coupled?
- Are temporal variations in productivity and sinking flux reflected in sediment organic carbon concentration and composition?
- How does the abundance of different benthic communities respond to organic carbon supply?

Methods

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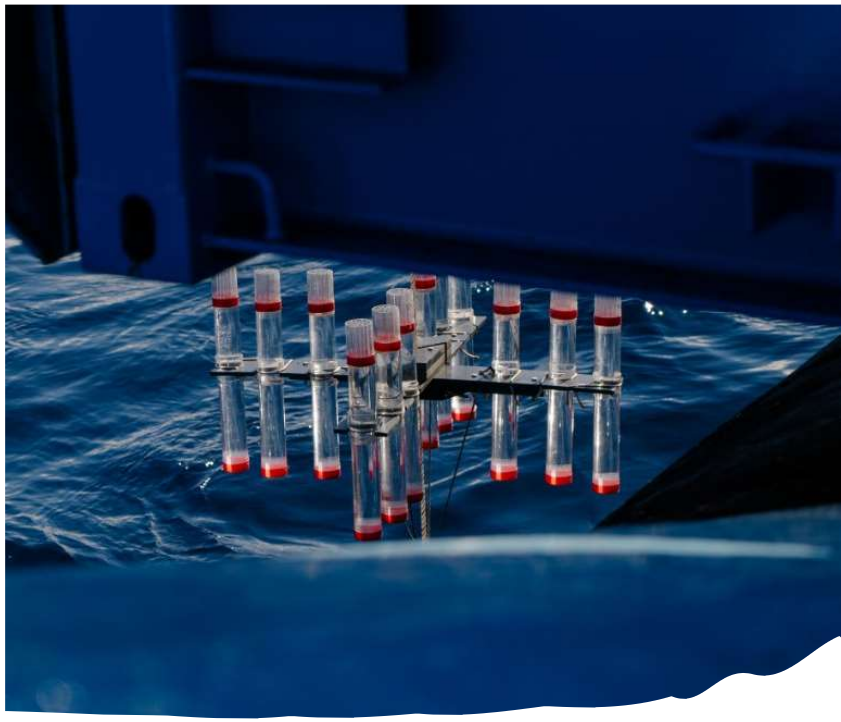
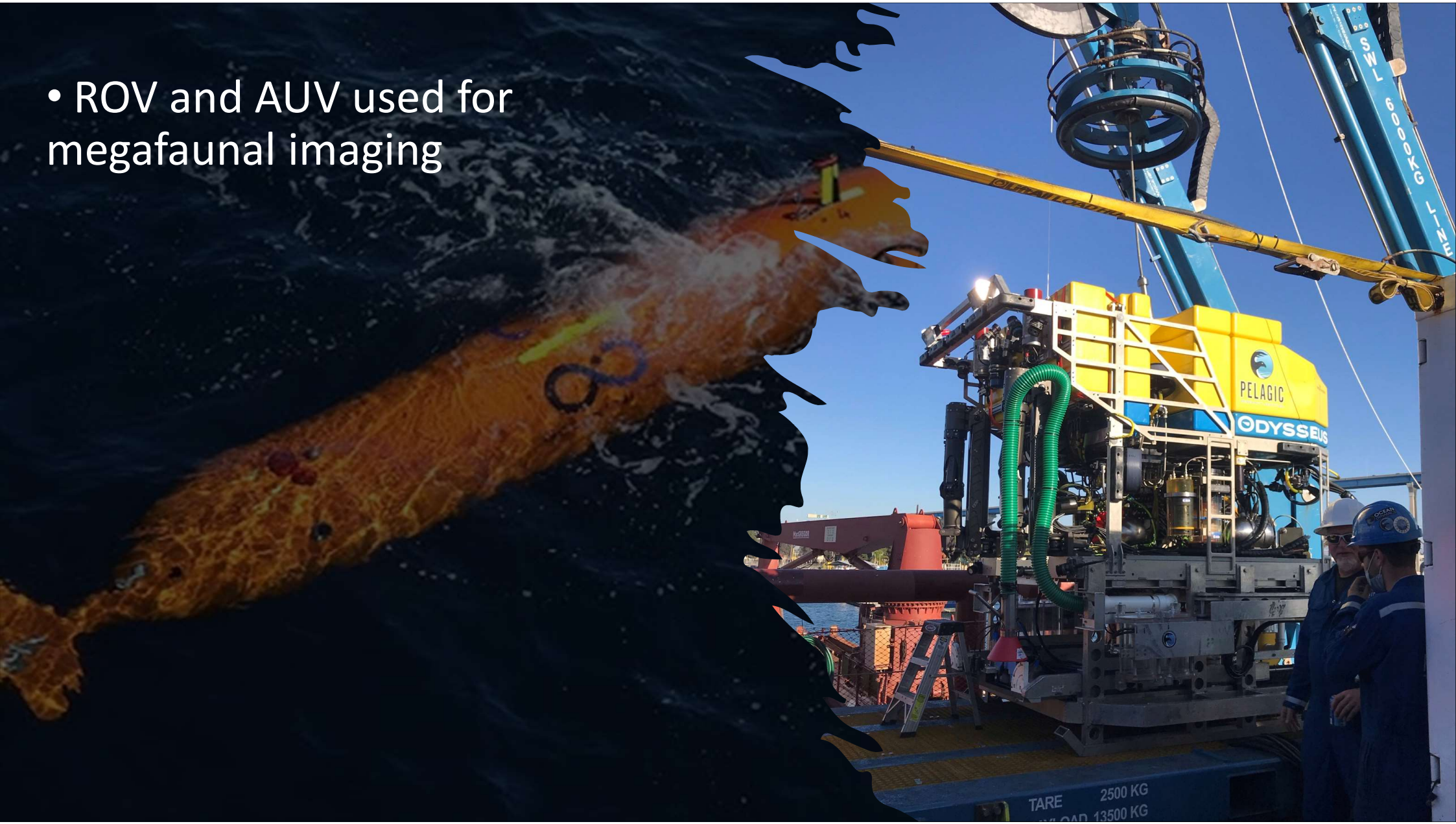
Method	Spring 2020	Fall 2020	Spring 2021	Fall 2021	Winter 2021	Fall 2022
Surface productivity (satellite)		X	X	X		X
Surface productivity (oxygen production)			X	X		
Shallow sinking flux			X	X		
Mid-water traps (2000 m and 500 m above bottom)						
Sediment composition (TOC, chl-a, lipids, $\delta^{13}C$)		X	X			X
Megafauna	X				X	X
Macrofauna		X	X			X
Meiofauna (metazoan)		X	X			X
Foraminifera		X	X			X
Sediment community DIC production		X	X			



Floating sediment trap array deployment

McLane *in situ* pumps for particle collection

- ROV and AUV used for megafaunal imaging



Macrofauna collected from box cores

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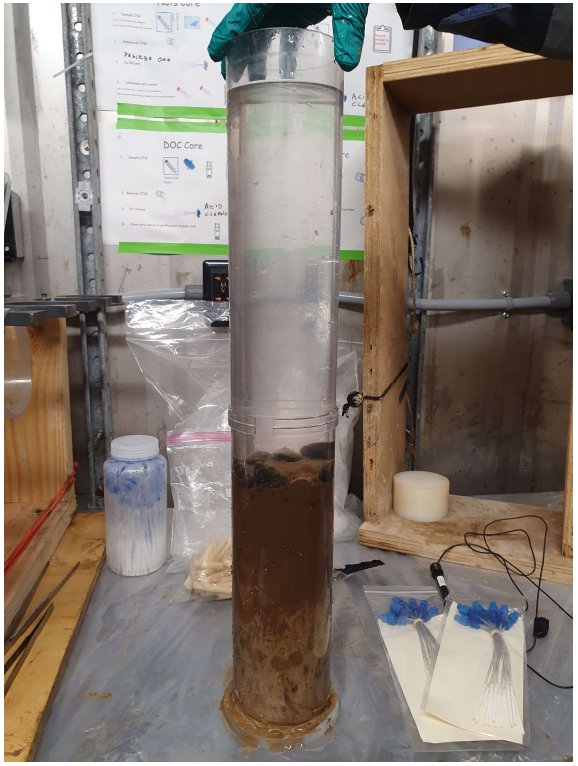
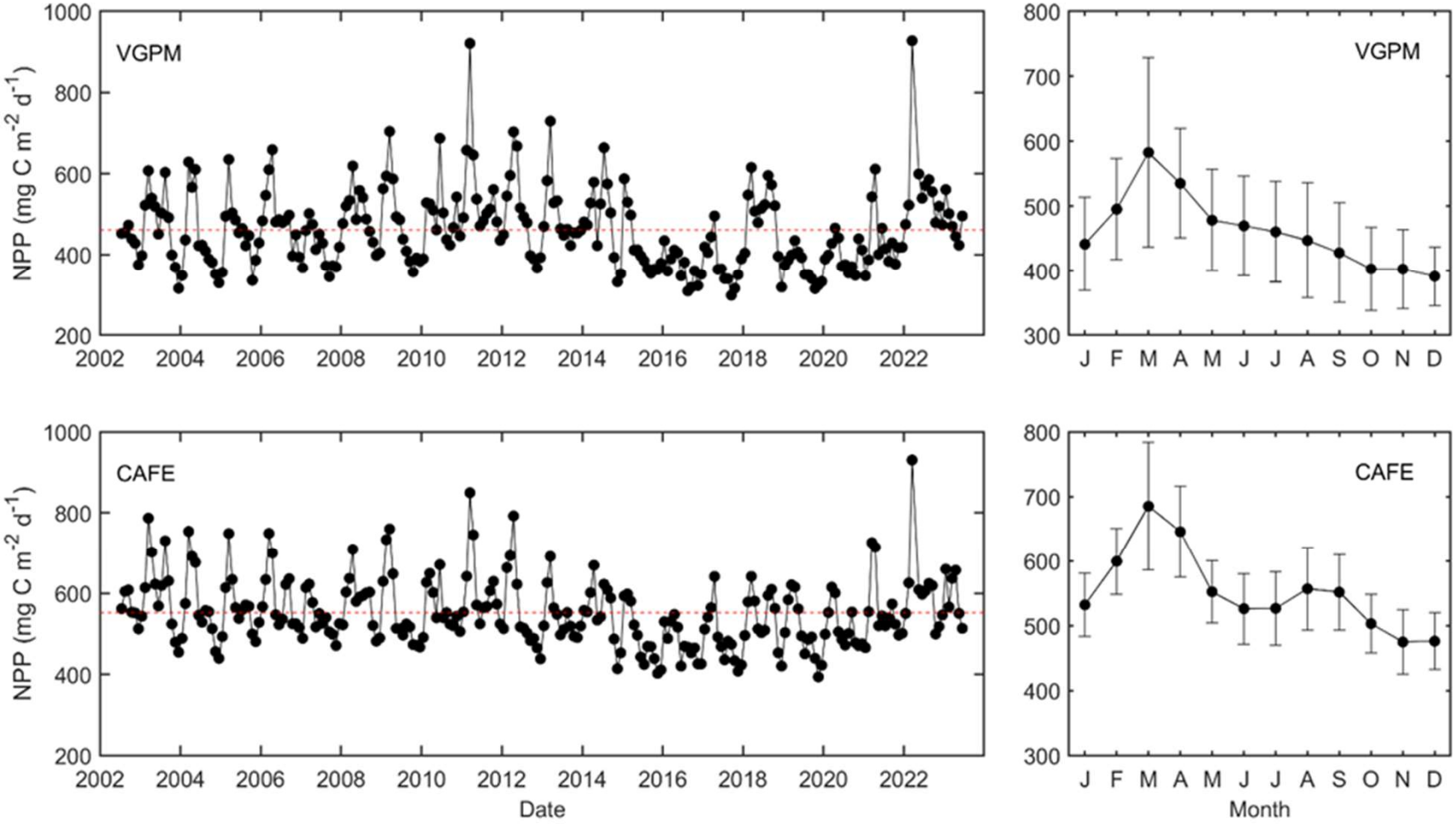


Photo credit: The Metals Company

Meiofauna, foraminifera and sediment collected from megacores

Primary Productivity



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Primary Productivity - Seasonality

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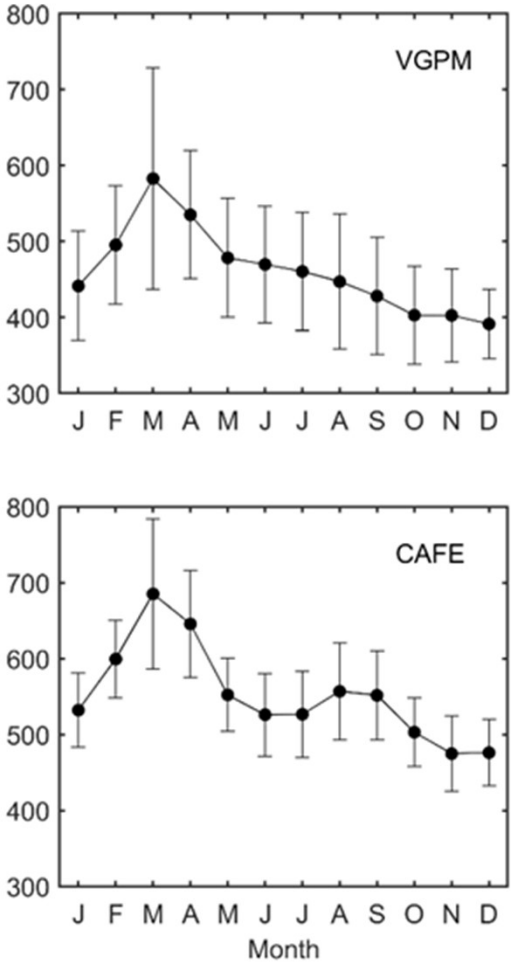
- Primary productivity maximal during spring (February – April)
- Fall peak sometimes present (August – September)

Season	Measured Primary Productivity mmol O_2 m^{-2} d^{-1}
Spring 2021	2.39 ± 0.08
Fall 2021	1.46 ± 0.21



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Export and Sinking Flux

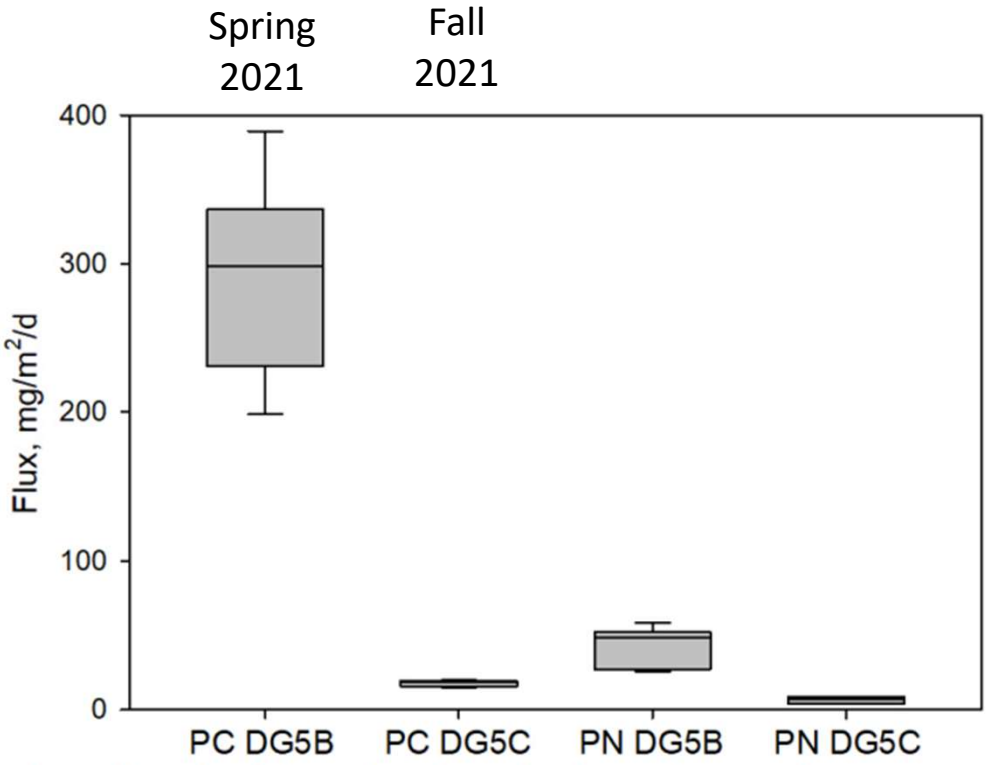

Figure 3. Comparison of flux of particulate carbon (PC) and particulate nitrogen (PN) at the CTA site between DG5B and DG5C. The flux of PC and PN were significantly higher during DG5B.

- Seasonality was reflected in shallow traps – so primary productivity is coupled to shallow sinking flux

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Primary Productivity - Interannual

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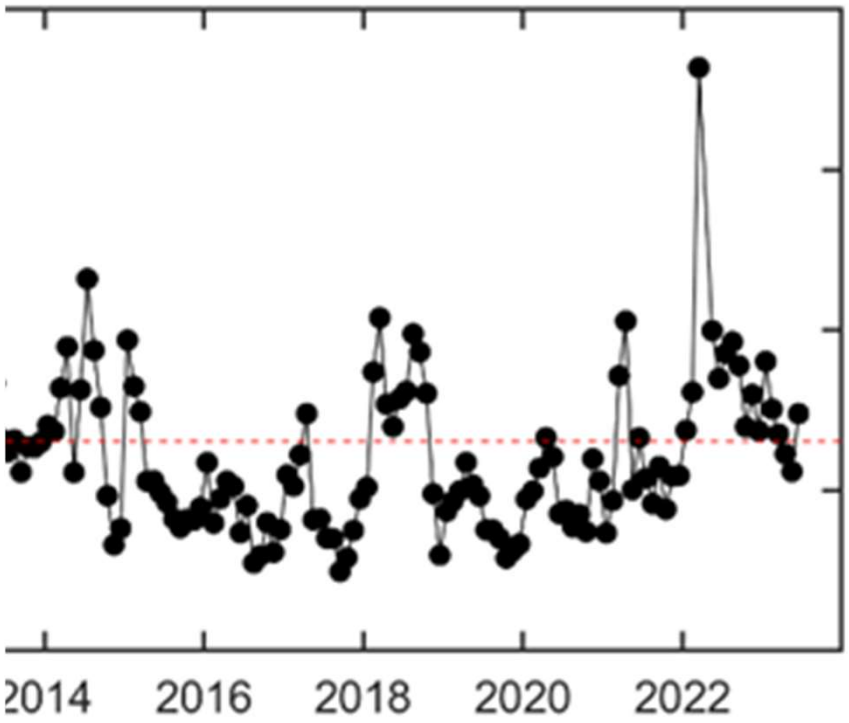

- Comparatively low productivity from 2016 - 2020
- Spring bloom in 2021 was a return to ‘average’ conditions, and was higher than that in 2020
- Both years within the range of inter-annual variability since 2002
- Spring peak in 2022 was the highest since 2002

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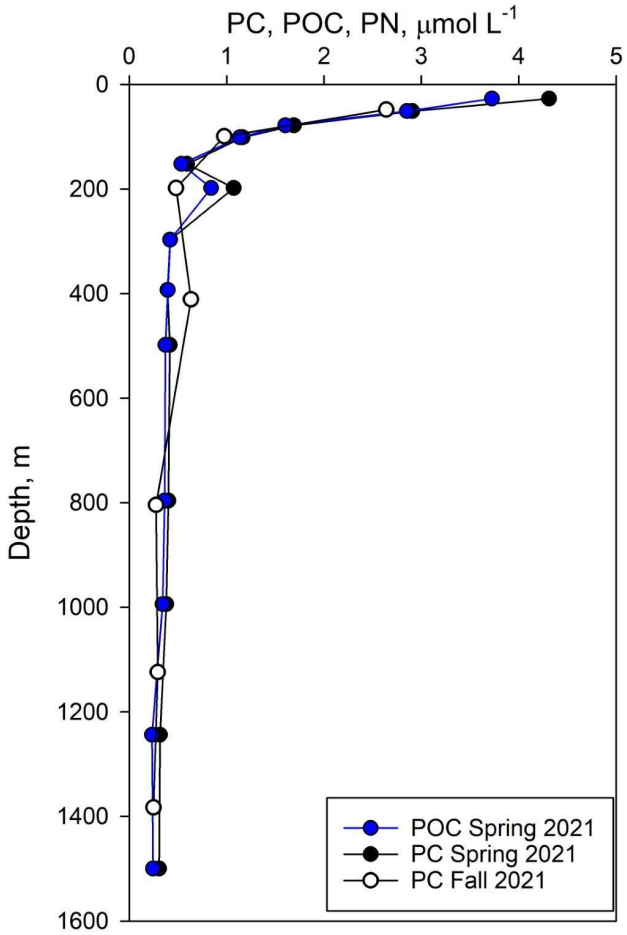

- Majority of OC degradation occurs just below the photic zone

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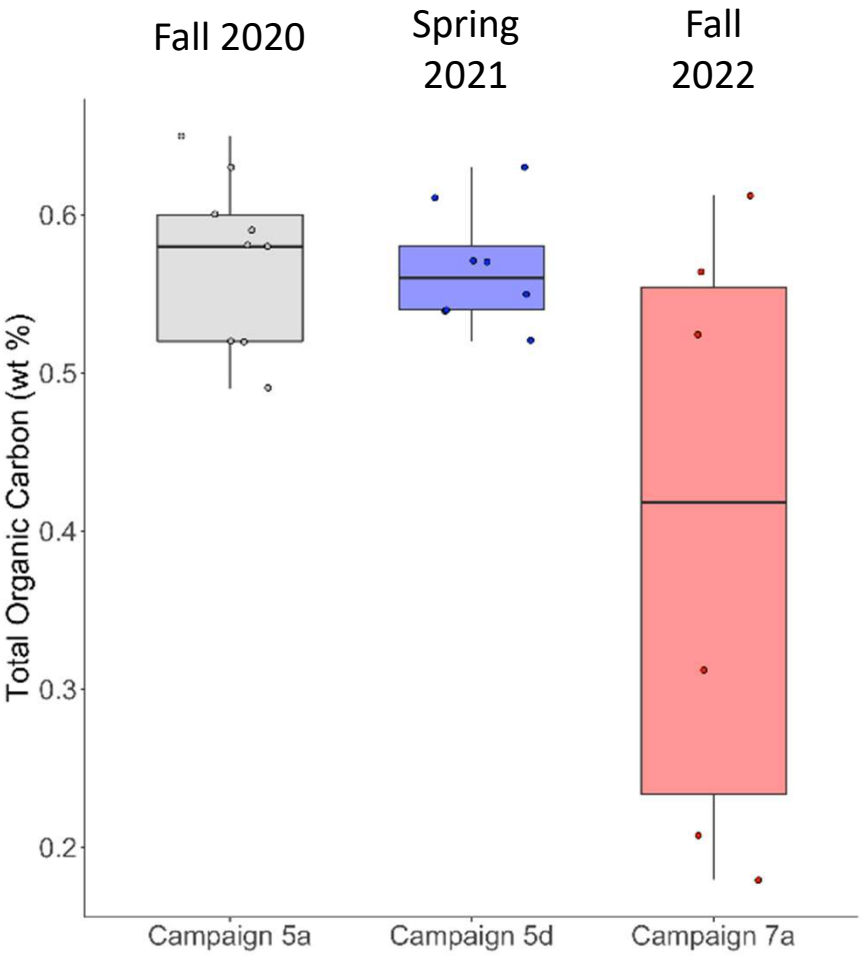
Sedimentary Carbon



- Seasonal variability not present
- Interannual variability is present
- Sedimentary TOC not fully coupled to surface productivity and export flux

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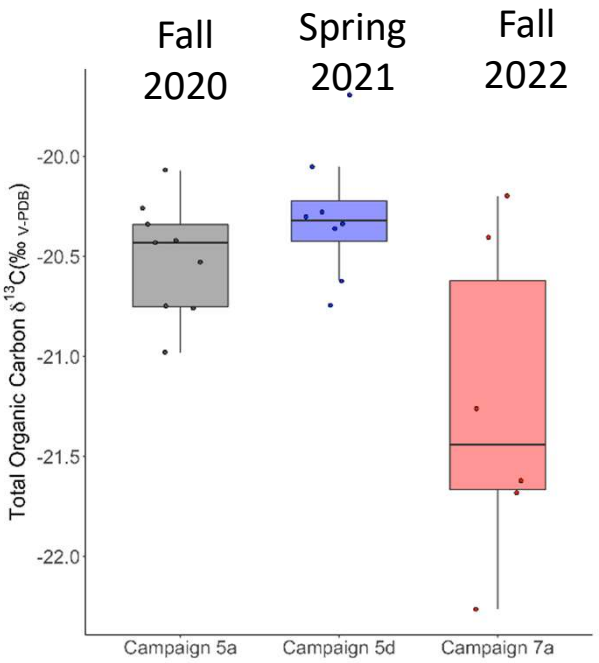
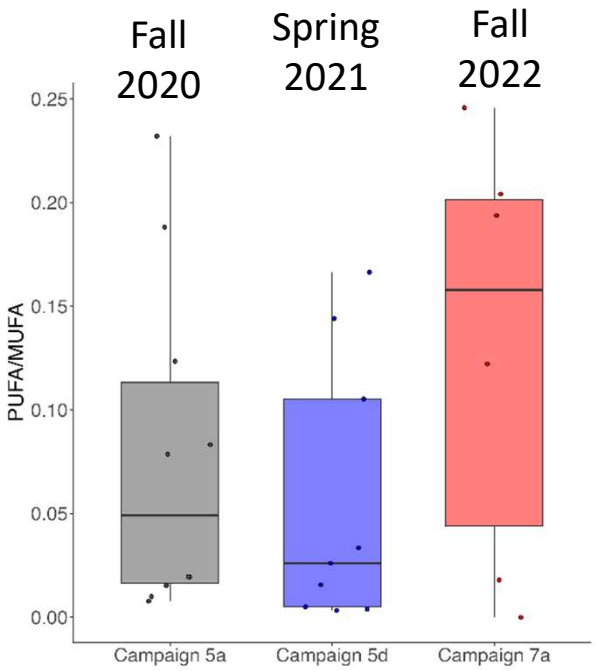
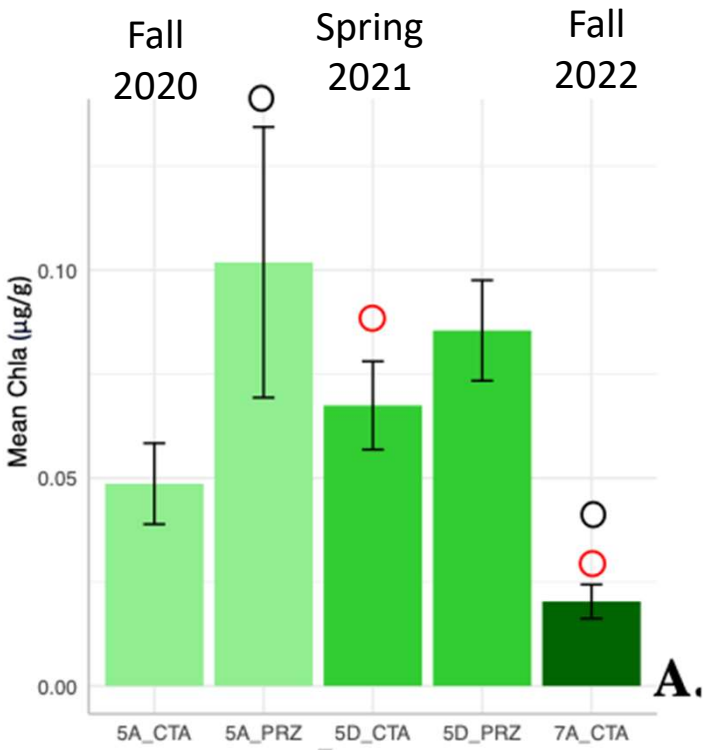
Sedimentary Carbon







- Reduced TOC and chlorophyll-a in 2022 despite peak primary productivity
- Suggests rapid utilisation in water column or lateral transport
- Fatty acids show ‘more reactive’ organic carbon

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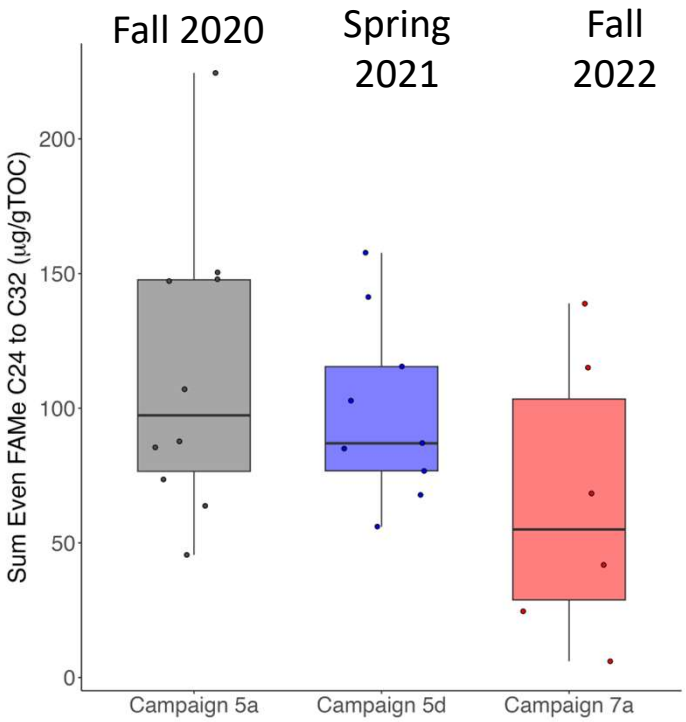
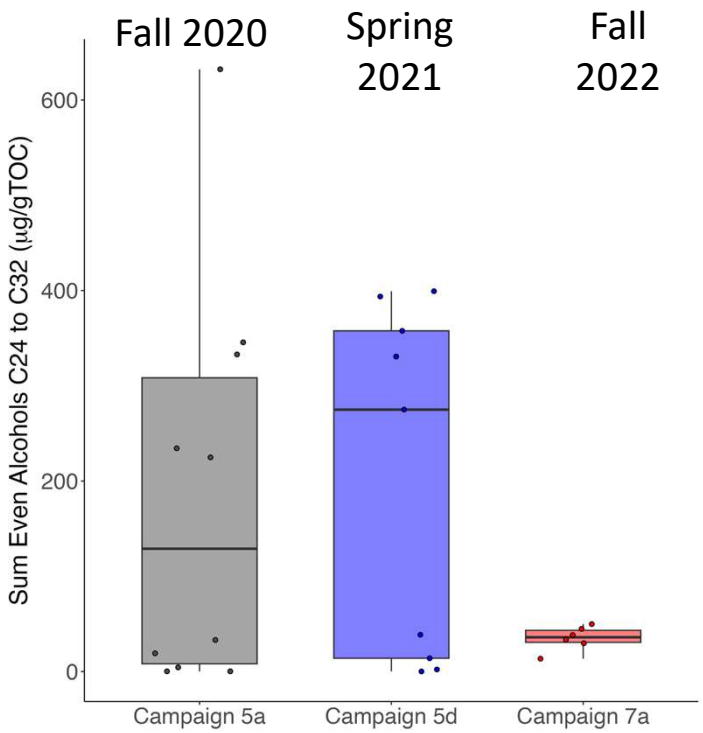
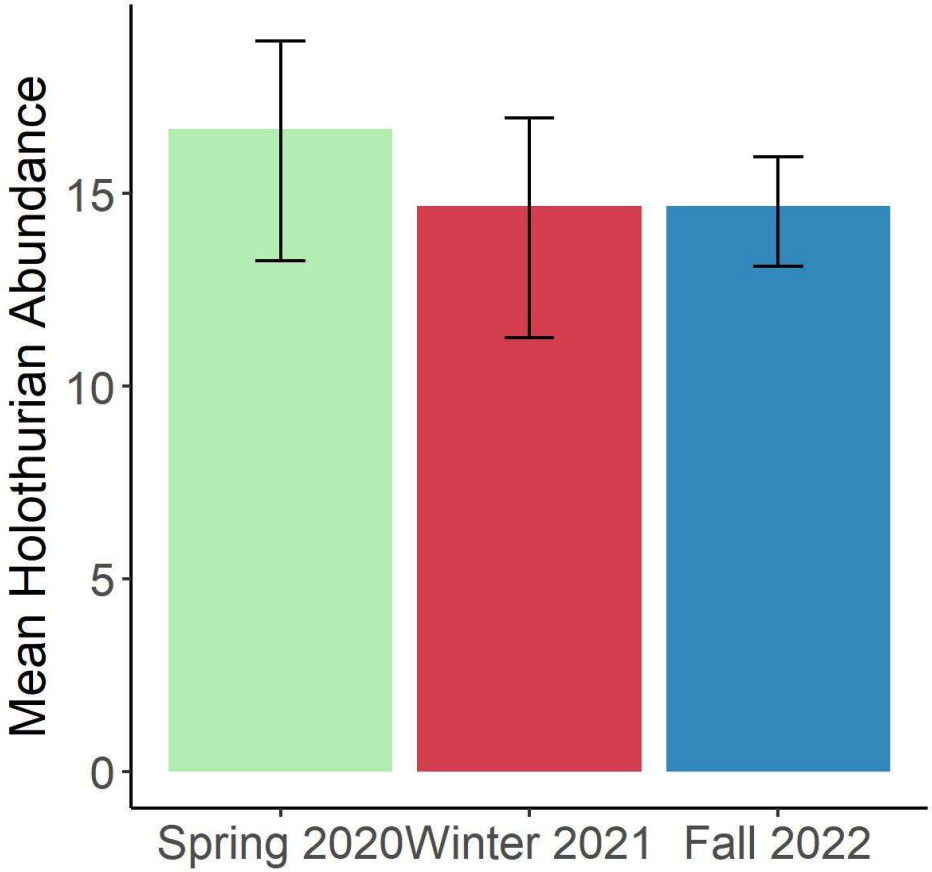
Sedimentary Carbon





- Fatty acids and alcohols suggest a reduction in input from terrestrial plants in fall 2022, allowing 'more reactive' marine carbon to dominate
- Likely linked to La Nina wind patterns

Faunal Response - Megafauna



- Holothurian abundances showed no significant differences across years.
- Suggests that megafaunal deposit feeders are not sensitive to changes in sedimentary TOC over these time scales.

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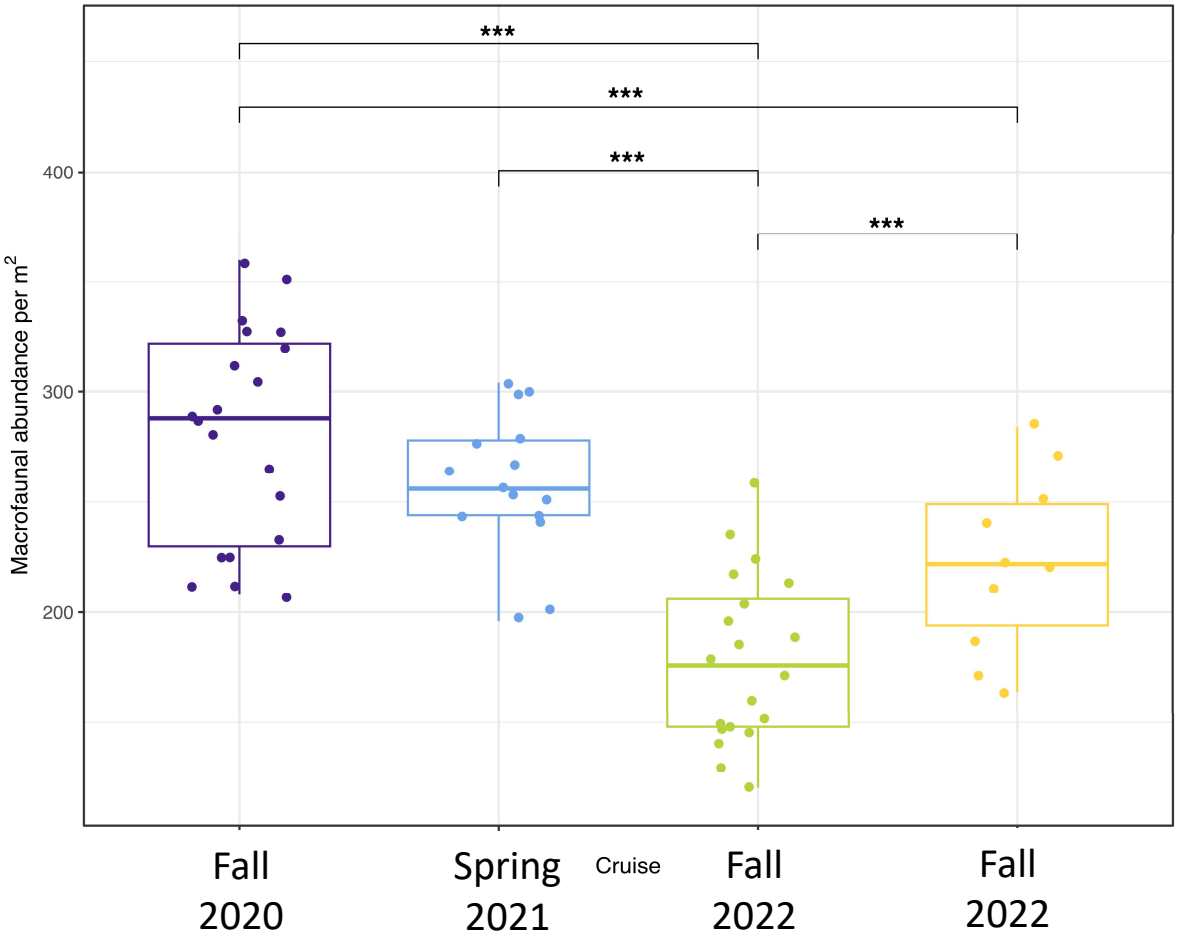
Faunal Response - Macrofauna



- Macrofaunal abundance coupled to sediment TOC
- Seasonal variability not present
- Interannual variability is present.

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Faunal Response - Foraminifera

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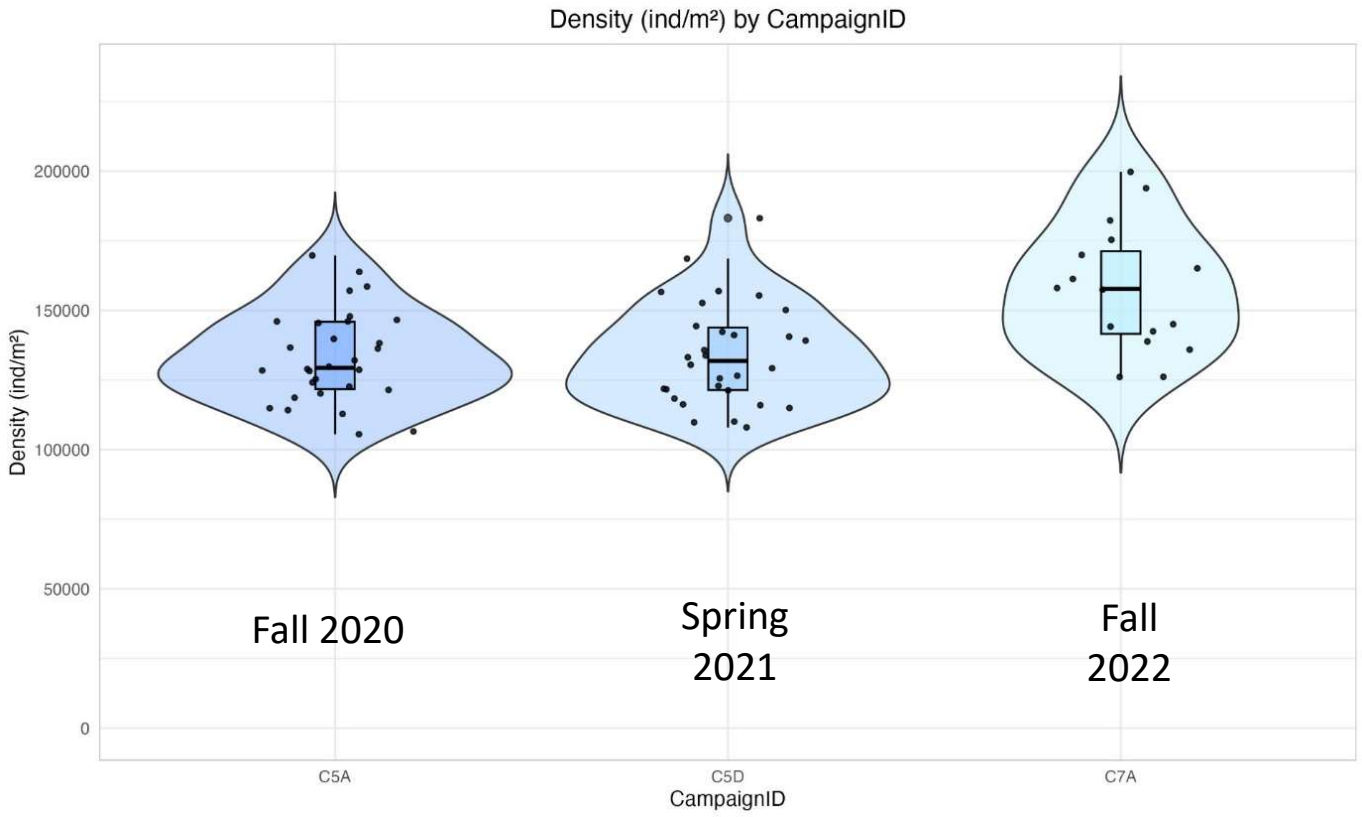

- No seasonal variability
- Increase in fall 2022
- Release from predation / competition?
- Rapid response to OC input?

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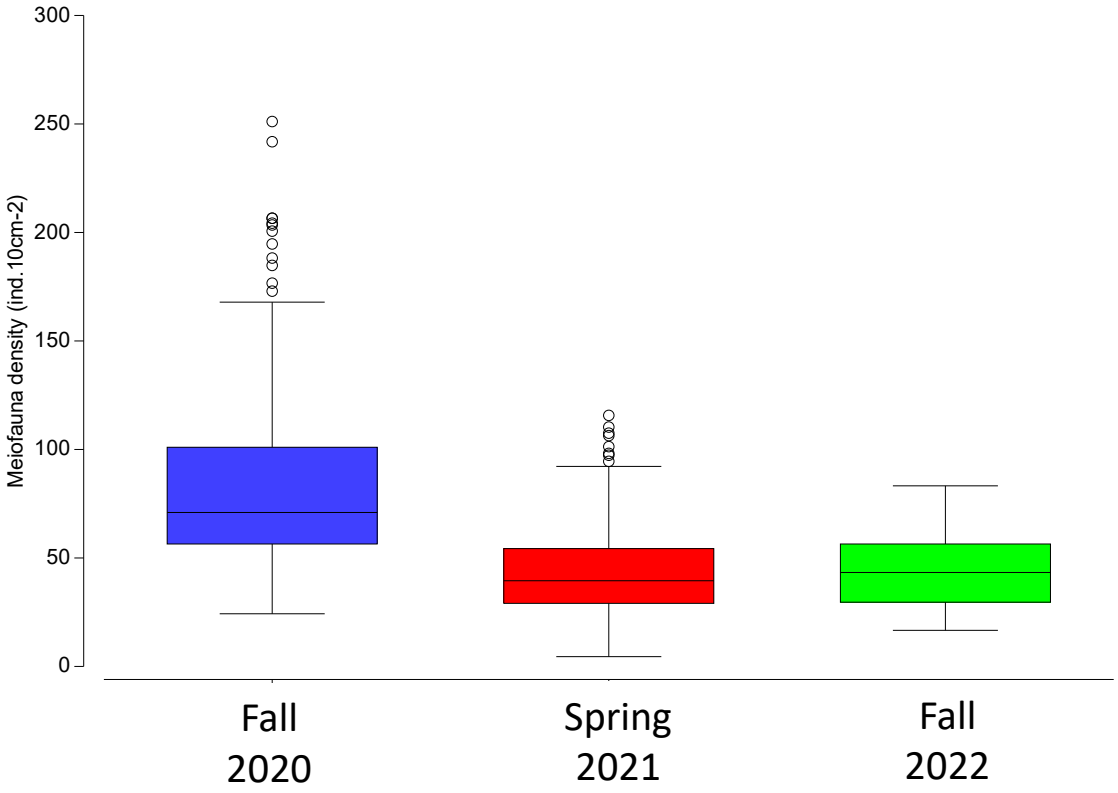
Faunal Response - Meiofauna



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- Large decrease from Fall 2020 to Spring 2021; similar densities in Fall 2022 compared to Spring 2021
- Meiofauna potentially in 'starvation' mode, or for other reasons not able to respond to spring 2021 or 2022 productivity
- Significant seasonal variability present (based on 337 cores)
- Potentially trophic interactions present

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Summary

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- Seasonal and inter-annual variability in primary productivity
- Export flux coupled to seasonal variability
- Organic carbon consumption during sinking leads to pelagic and benthic carbon pools being largely de-coupled
- Sediment carbon pool does not vary seasonally, but shows inter-annual variation
- Sediment carbon pool shows very limited coupling to surface ocean productivity
- Faunal groups respond differently to organic carbon supply changes, revealing importance of life stages / styles, and interactions between groups

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- Thanks to all technical and support colleagues who contributed to data production

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