Effects of changing temperatures on estuarine carbon cycling

Renee Lee[1,2], Amanda Vieillard[2], Michael Potter[4], Candace Oviatt[4], Robinson W. Fulweiler[2,3]

[1]North Hollywood High School, 5231 Colfax Ave, North Hollywood, CA, 19601

[2]Boston University Department of Earth and Environment, 725 Commonwealth Ave, Boston, MA, 02215

[3]Boston University Department of Biology, 5 Cummington Mall, Boston, MA, 02215

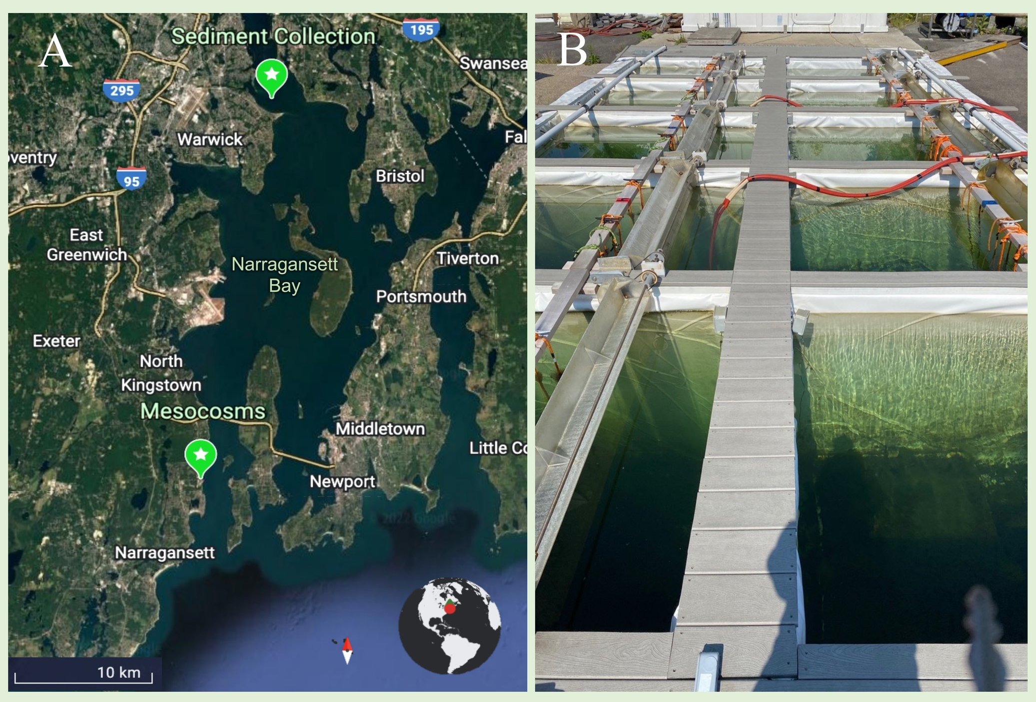
[4]Graduate School of Oceanography, University of Rhode Island, Narragansett, RI, 02852

Introduction

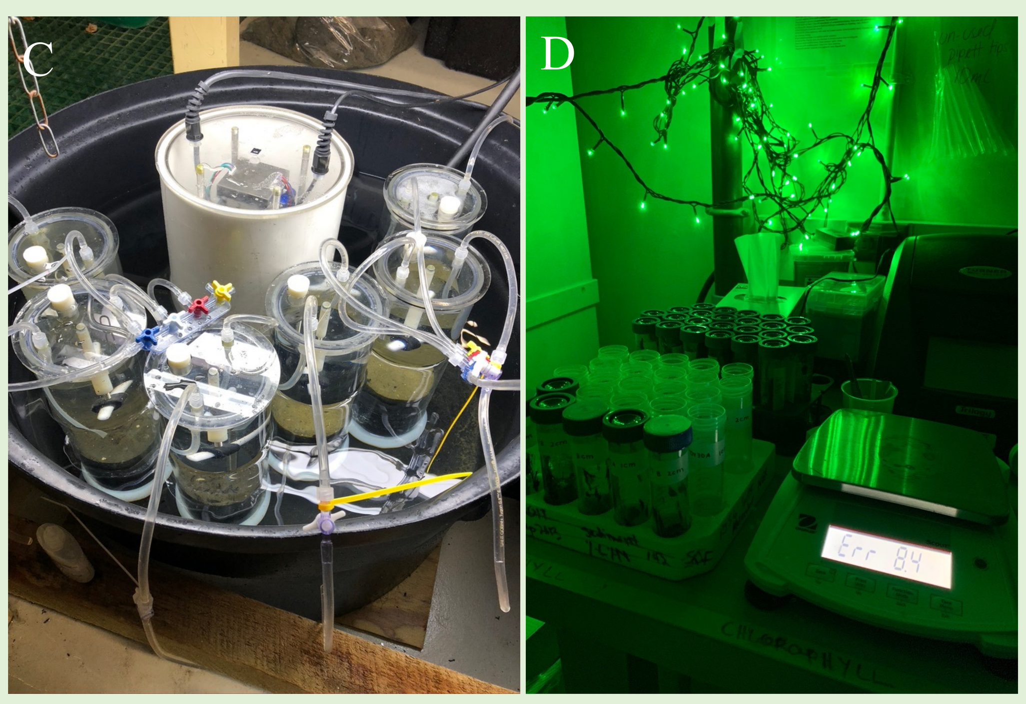
As water temperatures increase around the globe as a result of climate change, marine ecosystems have undergone changes to phytoplankton species composition[1] as well as the quantity/quality of organic matter in coastal sediments[2]. This decrease in organic matter poses a threat to many sediment communities[3]. Observational data, however, has not yet demonstrated that rising temperatures are the direct cause of these diminishing organic matter levels[2]. To confirm the impact of these temperature trends, a temperature manipulation experiment was conducted in seawater mesocosm tanks with sediment harvested from Narragansett Bay. The nine mesocosms had three different temperature treatments: ambient, -3 °C below ambient to mimic temperatures in the 1970s, and +3 °C above to mimic predicted future temperatures.

We hypothesized that warmer treatments would result in less water column chlorophyll and sediment organic matter (OM).

Methods



Sediment and seawater were collected from Narragansett Bay (A) and added to nine 8350 L mesocosms with 30 cm deep sediments (B). Three tanks were set to the ambient temperature of the bay, three were set 3 °C colder, and three were 3 °C warmer.



Intact cores were taken to sample the mesocosm sediments (C) on June 27, August 18, and September 29, 2021. Subsamples of sediment were taken for chlorophyll-a and phaeophytin (acetone extraction and fluorescence, D), as well as organic matter (loss on ignition). Water in the tanks was also sampled weekly for chlorophyll as well as day and nighttime metabolism.

Results

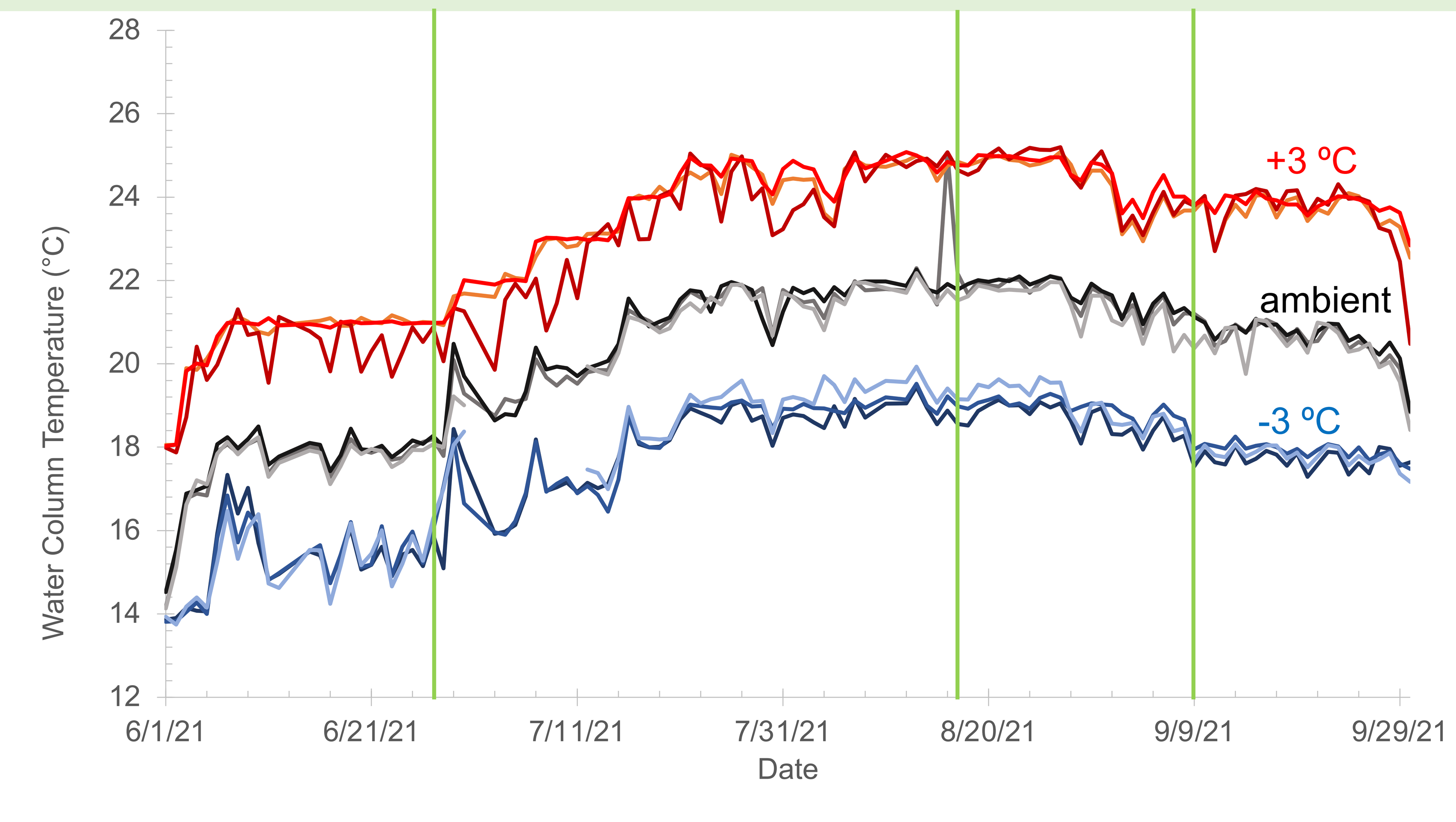


Figure 1. Mean daily water column temperature in each of the nine experimental mesocosms from June through September 2021. The mesocosms were exposed to three different temperature treatments: ambient (grey), -3 °C below ambient (blue), and +3 °C above (red). Samples for sediment carbon characteristics were collected on three different occasions in 2021 (June 27, August 17, September 21).

Table 1. Mean (± standard error) water column and sediment data over the three sample dates. For the water column we report temperature (°C), and chlorophyll-a concentration (Chla, mg L^{-1}), as well as net daytime and nighttime metabolism (mmol L^{-1} h^{-1}). For the sediment we report chlorophyll-a concentration (Chla, mg g^{-1}_{DW}), pheophytin concentration (Pheo , mg g^{-1}_{DW}), and percent organic matter (% OM) for 0-1 cm, 1-2 cm, and 2-3 cm depth.

Treatment	Water Column Temp	Water Column Chla	Daytime Oxygen	Nighttime Oxygen	Chla	Pheo	OM	Chla	Pheo	OM	Chla	Pheo	OM
	°C	µg L^{-1}	µmol L^{-1} h^{-1}	µmol L^{-1} h^{-1}	µg g^{-1}_{DW}	µg g^{-1}_{DW}	%	µg g^{-1}_{DW}	µg g^{-1}_{DW}	%	µg g^{-1}_{DW}	µg g^{-1}_{DW}	%
					1 cm			2 cm			3 cm		
Ambient	20.1 ± 0.6	0.9 ± 0.2	241.4 ± 151	-173.3 ± 108	8.9 ± 1.8	59.1 ± 5.0	9.1 ± 0.7	6.1 ± 0.5	55.0 ± 4.0	9.0 ± 0.7	4.9 ± 0.6	51.5 ± 2.3	8.5 ± 0.6
Plus 3	22.8 ± 0.7	0.6 ± 0.1	280.6 ± 162	-202.6 ± 104	16.5± 4.2	66.6 ± 6.9	9.1 ± 0.3	7.4 ± 1.4	59.7 ± 2.7	9.2 ± 0.4	13.7 ± 8.5	55.4 ± 4.2	9.4 ± 0.3
Minus 3	17.5 ± 0.5	0.6 ± 0.1	258.8 ± 156	-182.2 ± 112	23.8 ± 4.6	69.9 ± 5.7	10.1 ± 0.7	7.0 ± 0.6	58.0 ± 3.6	8.1 ± 0.4	5.3 ± 0.5	58.5 ± 4.6	8.4 ± 0.4

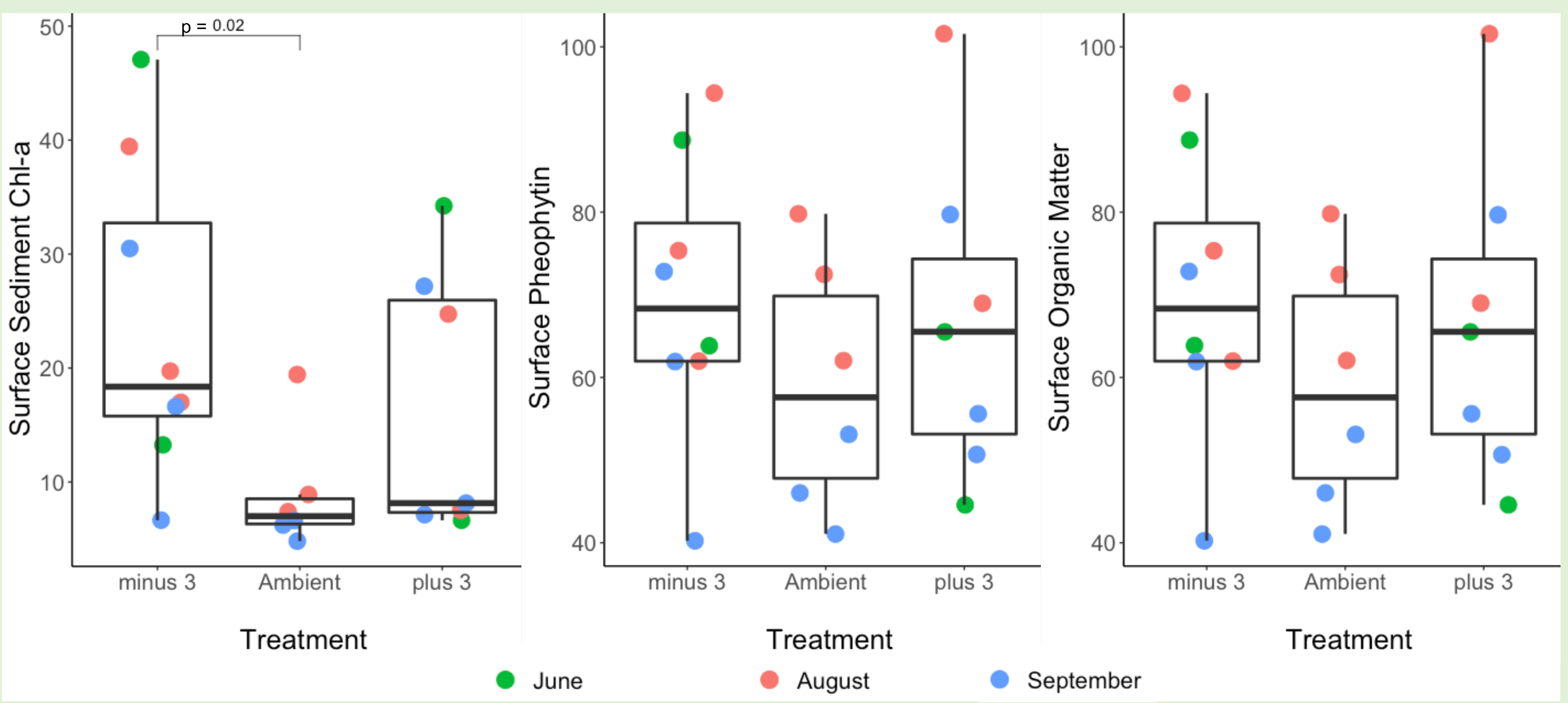


Figure 2. Surface (0-1 cm) sediment chlorophyll a (µg g^{-1}_{DW}), pheophytin (µg g^{-1}_{DW}), and organic matter (%) content. Green points show values from June, coral points show values from August, and blue points show values from September. Chlorophyll-a content was significantly greater than ambient for all dates combined (p = 0.02). Note the different y-axis scale on the chlorophyll plot.

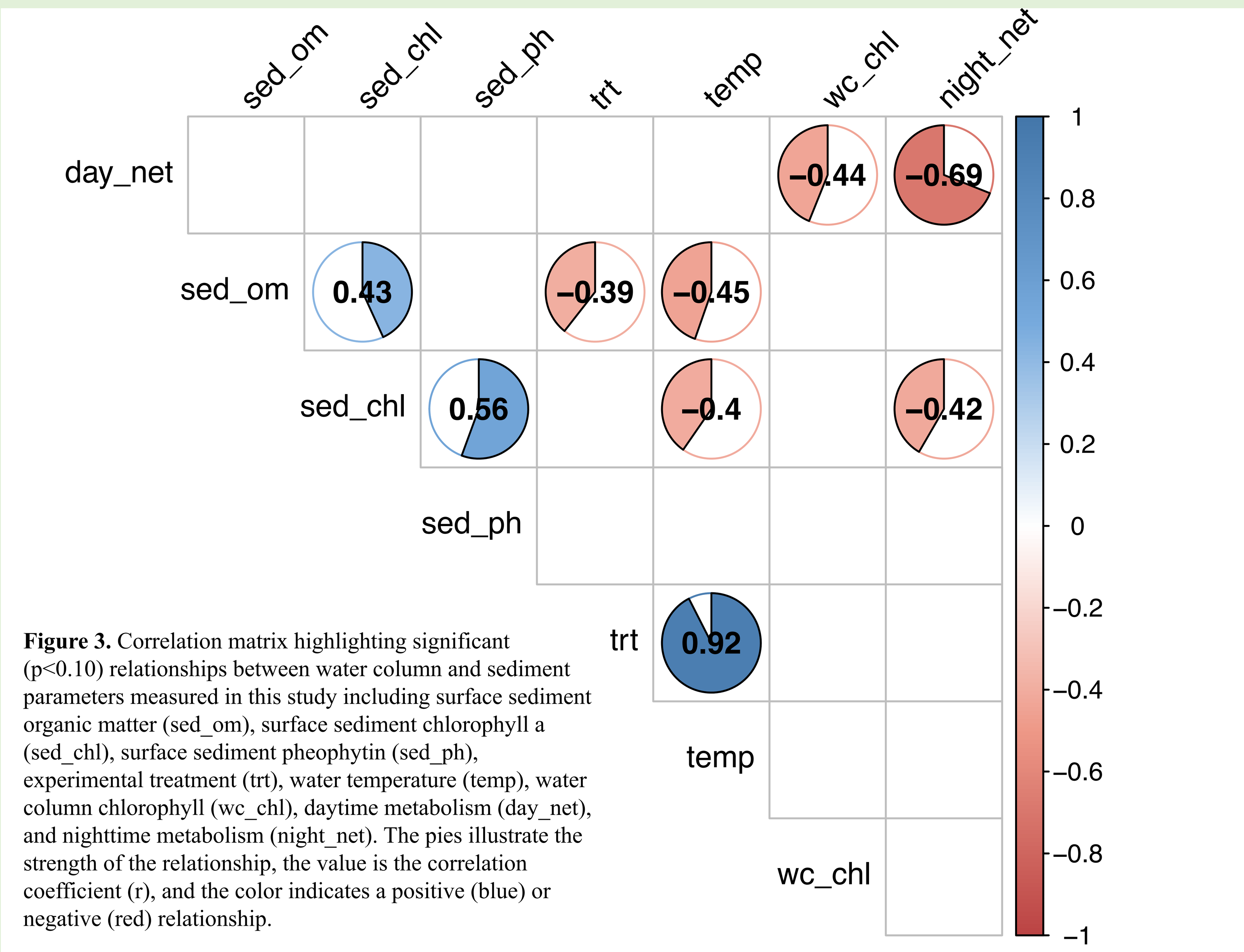


Figure 3. Correlation matrix highlighting significant (p<0.10) relationships between water column and sediment parameters measured in this study including surface sediment organic matter (sed_om), surface sediment chlorophyll a (sed_chl), surface sediment pheophytin (sed_ph), experimental treatment (trt), water temperature (temp), water column chlorophyll (wc_chl), daytime metabolism (day_net), and nighttime metabolism (night_net). The pies illustrate the strength of the relationship, the value is the correlation coefficient (r), and the color indicates a positive (blue) or negative (red) relationship.

Discussion

The mesocosm temperature manipulation successfully altered water column temperature (Figure 1). We hypothesized that the cold tanks would have more sediment chlorophyll-a, pheophytin, and %OM. While we measured sediment properties from the surface to 3 cm (Table 1), we focus here on the surface (0-1 cm) as most change should be observed here. As predicted, levels of surface chla were significantly (p= 0.02) higher in cooler treatments compared to ambient or warmer water. Despite these findings, we observed no significant differences in phaeophytin or %OM (Figure 2). Our collective data, however, displayed a noteworthy negative correlation between temperature/treatment and sediment organic matter as well as chla concentrations (Figure 3).

Conclusions

These mesocosm data validate our observations in the field and clarify the importance of temperature in altering carbon content in sediment. However, the data suggest that this relationship is more complex than simply the negative impact on increasing temperatures. For example, we did not address *in situ* primary production from benthic microalgae, which likely also plays a role in changing carbon content as temperatures rise[4].

References

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Acknowledgements

I offer my gratitude to postdoc Amanda Vieillard and Dr. Fulweiler, without whom this project would not have been made possible—thank you for guiding me every step of the way through these six weeks. I would also like to specially thank Ed Baker, the University of Rhode Island, and its affiliated Graduate School of Oceanography for lending us their facilities to make this research possible. Funding was provided by the Rhode Island Sea Grant.

Last but not least…a warm thank you to Boston University and the RISE Program for connecting me with the Fulweiler lab and offering this summer opportunity.