Evaluation of Climate Induced Changes to Porewater Biogeochemistry in Mangrove/Saltmarsh Ecotone

Anna Beard[1], Tracey Schafer[1], Taryn Chaya[1], Samantha K. Chapman[2], Nikki Dix[3] and Todd Z. Osborne[1]

1. Whitney Laboratory for Marine Biosciences, St. Augustine, FL, USA
2. Villanova University, Villanova, PA, USA
3. Guana Tolomato Matanzas National Estuarine Research Reserve, Ponte Vedra FL, USA

Abstract

Northeast Florida coastal wetlands, historically dominated by salt marsh ecosystems, are experiencing mangrove encroachment as a result of climate change. The WETFEET (**W**arming **E**cosystem **T**emperatures in a **F**lorida **E**cotone **E**xperiencing **T**ransition) project is an NSF funded collaboration between Villanova University, Guana Tolomato Matanzas National Estuarine Research Reserve, University of Louisiana Lafayette, University of South Carolina, and the Smithsonian Environmental Research Center to investigate how coastal wetlands will fare in the face of climate change and sea level rise. This study, a sub-element of the WETFEET project, investigates soil porewater nutrient dynamics in these contrasting vegetation communities with an *in situ* warming experiment. Experimental warming chambers were designed to provide a 1.6 C° increase in mean ambient temperature at 3 coastal wetlands along a latitudinal gradient within salt marsh vegetation (*S. alterniflora, B. maritima*) and mangrove (*A. germinans*) plots over a yearlong study. Seasonal sampling, via pore water well, under mangrove or saltmarsh was conducted in warming vs. non warming plots. Results of total phosphorus, total nitrogen, dissolved organic carbon, and ammonia measurements showed no significant differences between warming and non-warming plots, potentially due to temperature insulating ability of soils and the relatively low change in overall temperature. Significant differences were found in seasonality and site comparisons, which suggests variability in biogeochemical processes. Surprisingly, no significant differences in porewater nutrients were observed between mangrove and saltmarsh vegetation, potentially due to differential uptake of limiting nutrients by mangroves. However, porewater nutrient dynamics under different coastal vegetation communities remain unclear.

Introduction

Coastal wetlands are recognized as one of the most valuable ecosystems in the world due to habitat value, ecological productivity, and carbon sequestration. These systems are dominated by vegetation adapted to saline environments, which varies across latitude. Saltmarshes dominate coastal wetlands in temperate zones, while mangroves are limited to subtropical and tropical latitudes by freeze-inducted mortality. With climate change intensifying, a lack of freezing events in NE Florida has led to a northward expansion of mangroves into historically saltmarsh ecosystems. This expansion of predominantly black mangrove (*Avicennia germinans*) has led to a displacement of saltmarsh vegetation (*Spartina alterniflora and Batis maritima*) raising significant ecological questions about coastal wetland form and function. Current research suggests that warmer temperatures will likely change ecosystem dynamics at many scales. Furthermore, a potential shift in temperature and vegetation could alter the mineralization of limiting nutrients stored in soil organic matter with significant ecological effect. This could be due to mangroves having plentiful pneumatophores that transport oxygen to the anaerobic root zone, while saltmarsh species do not have this adaptation and rely on diffusion through root tissue. The transition of coastal wetlands from one dominant vegetation type to another provides a unique opportunity to examine how coastal wetlands will respond to the changing environment.

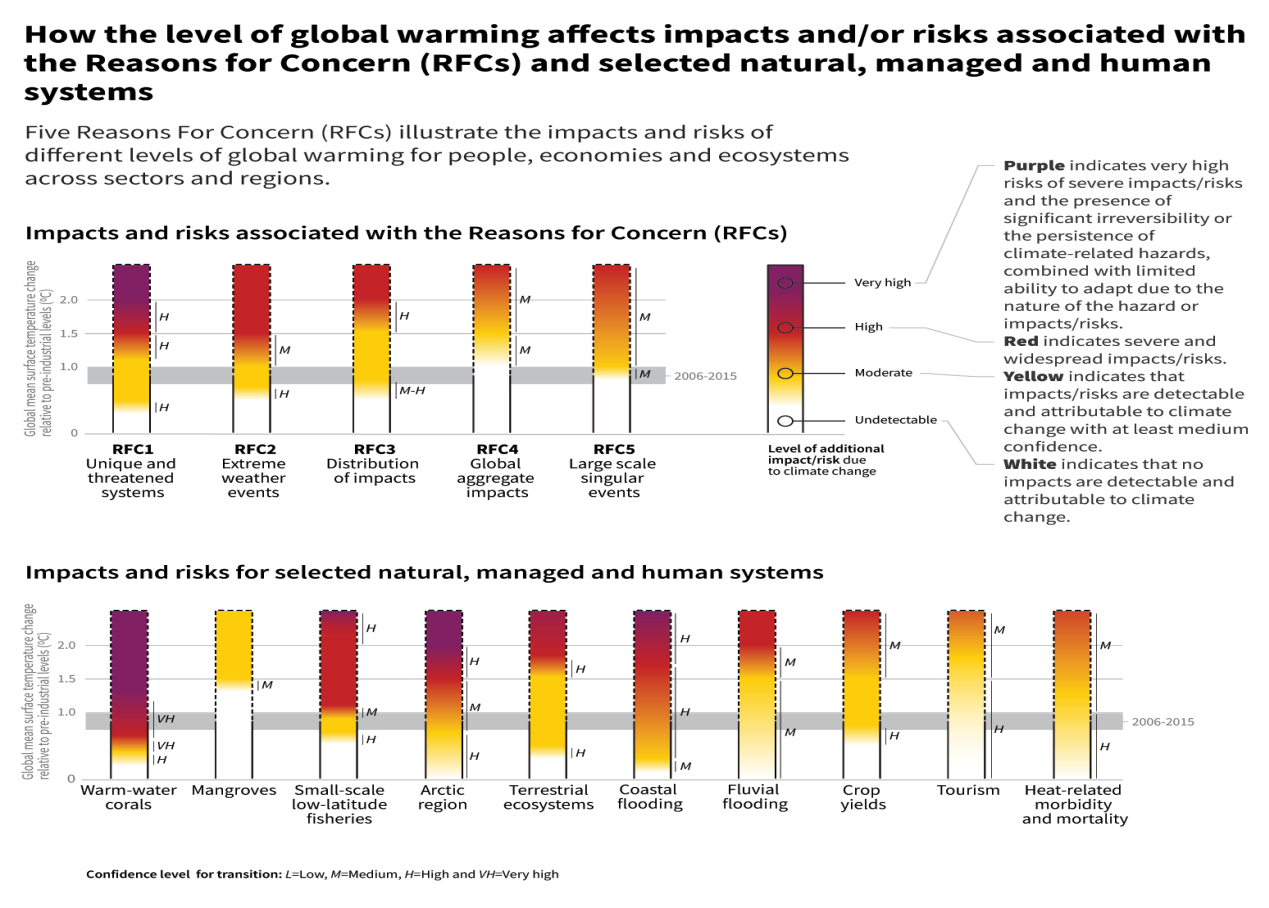

Figure 1: Five integrative reasons for concern (RFC) offer an outline for summarizing important impacts/risks across sectors and regions. RFCs illustrate the implications of global warming for people, economies, and ecosystems (IPCC 2019).

Figure 2: Mangrove encroachment (in yellow) into saltmarsh ecosystem (Chapman 2018).

Objective:

The goal of this research is to determine how *Avicennia germinans* expansion into salt marsh ecosystems, which are dominated by *Spartina alterniflora* and *Batis maritima*, effects porewater nutrient dynamics, and how this process may be further affected by climate change.

Hypotheses:

Changing Vegetation effects- *A. germinans* accelerates nutrient mineralization in salt marsh soils through increased root zone oxidation, resulting in higher nutrient concentrations than saltmarsh vegetation.

IPCC 1.6 C rise effects- Warming temperatures accelerate soil nutrient mineralization processes in both *A. germinans* and *S. alterniflora* communities resulting in higher nutrient concentrations than historic saltmarsh.

Methods

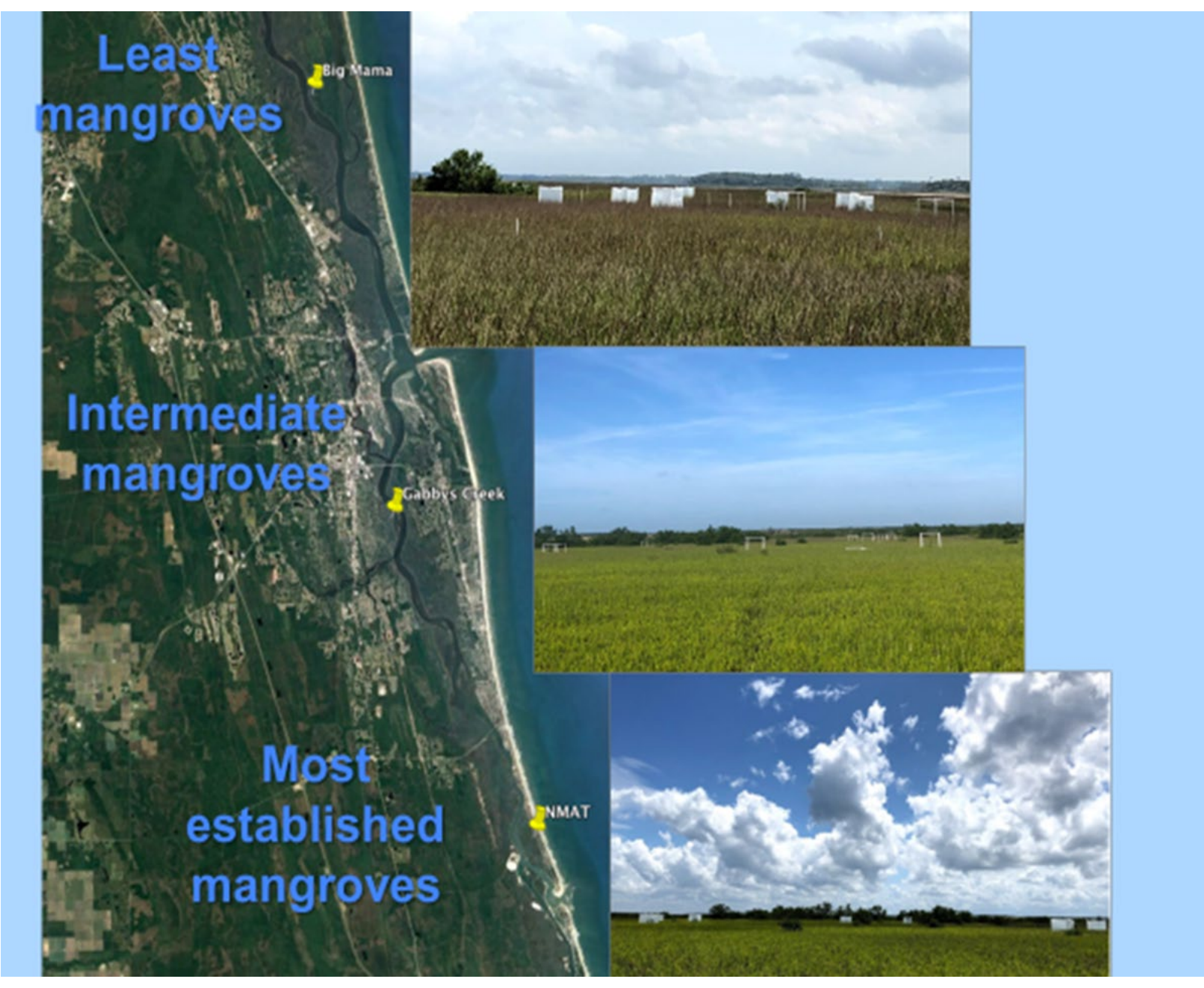

Figure 3: Sites sampled differed in extent of mangrove encroachment; Sites span Northern portion of mangrove-salt marsh ecotone (Chapman et al. 2018).

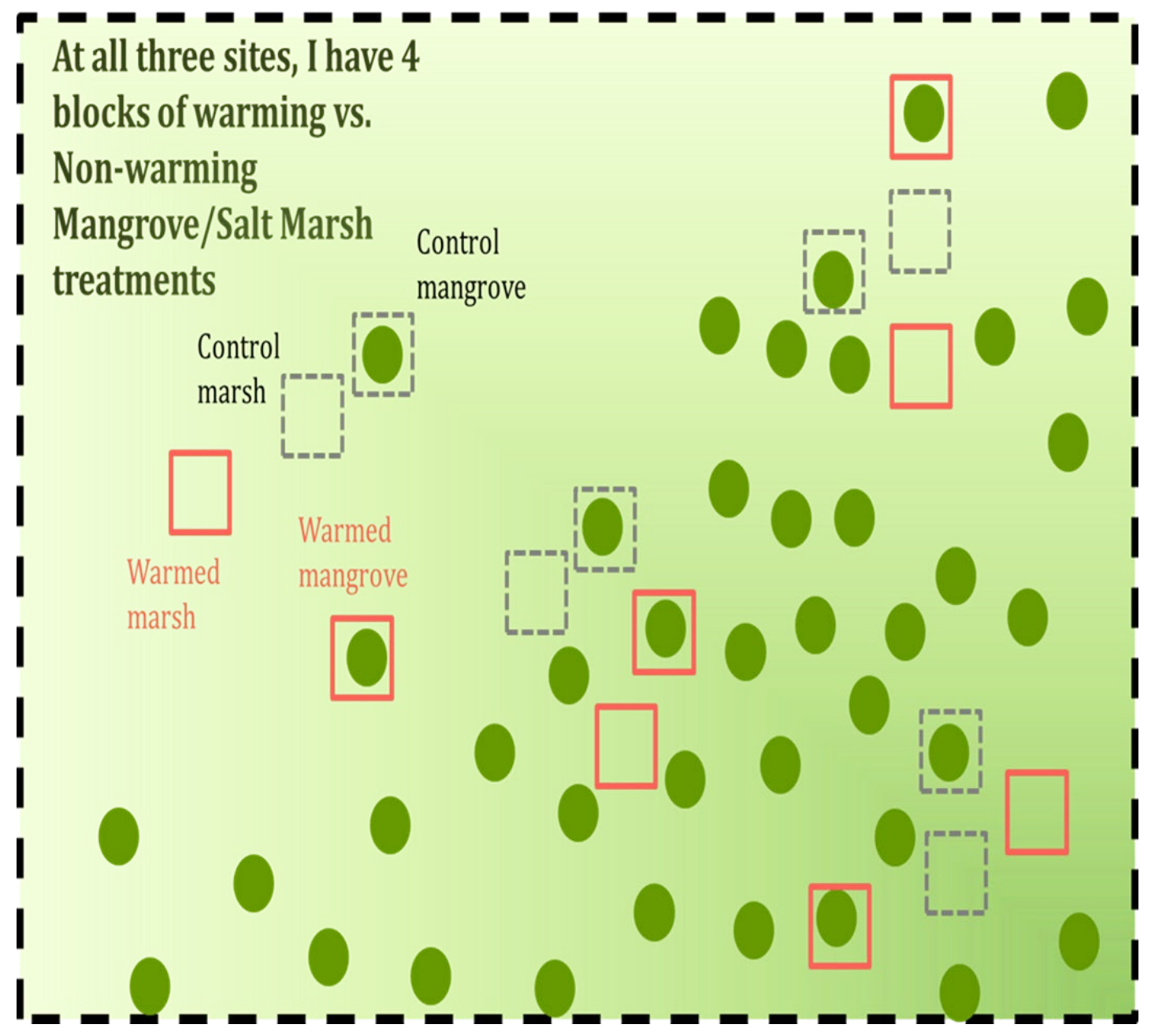

Figure 4: Experimental block design of four control/warming vegetation replicates (Chapman et al. 2018).

Site	Latitude	Porewater Salinity (ppm)	Elevation (cm NAVD88)	Air temp. range	Soil temp range	Dominant vegetation
North	30°00'41.37" N	31.5	41	1.0-30.3°C	21.6-33.1°C	*S. alterniflora*
Middle	29°50'10.30" N	40.4	57	0.5-30.8°C	24.7-27.7°C	*Mix of S. alterniflora and Batis maritima*
South	29°43'38.53" N	39.1	47	1.5-31.0°C	20.8-30.0°C	*Mix of S. alterniflora and Batis maritima*

Table 1: WETFEET site physiognomies

Figure 5: Warming chamber experimental design: $1.5 m^3$ PVC chamber covered with 6 mil (152-µm) plastic film (Green-tek, Bladwin, Georgia, USA) to simulate average 2°C warming effect. Film allows 90% PAR thus trapping infrared radiation. (Chapman et al. 2018)

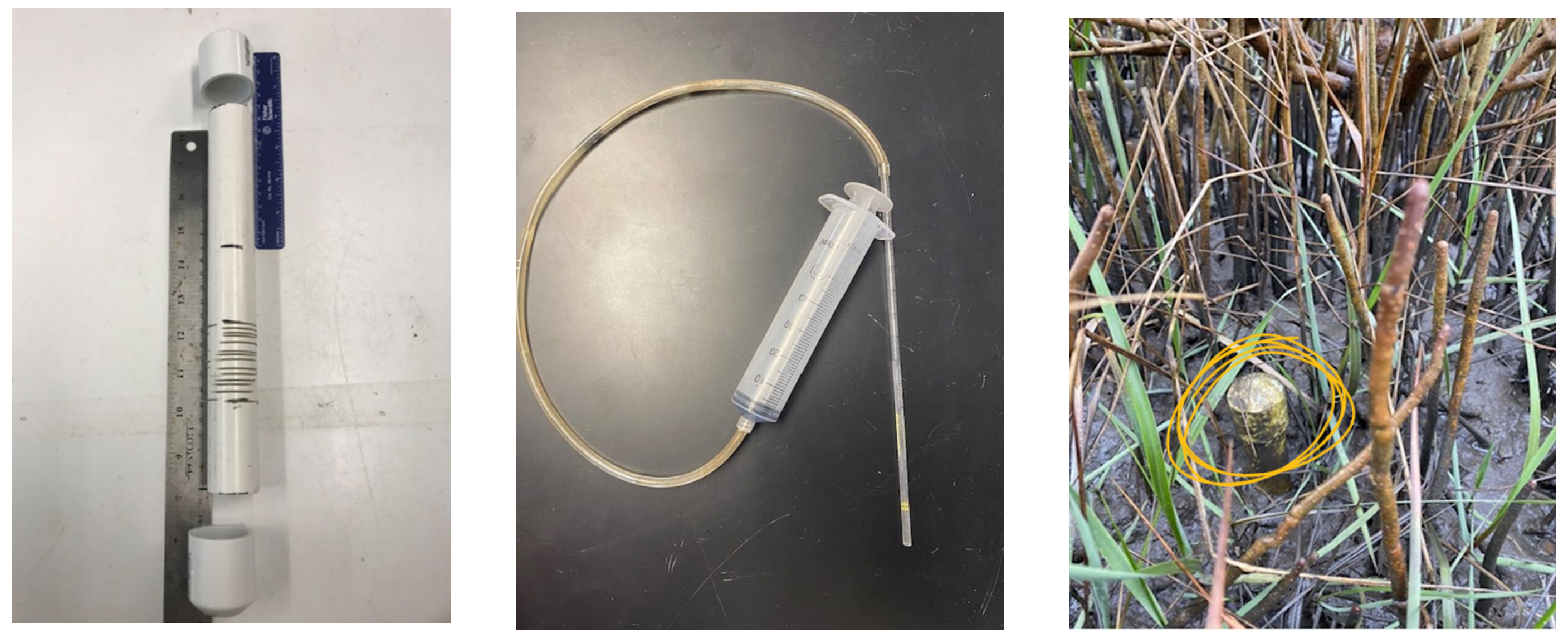

Figure 6: Schematic of porewater well & sipper design: 25cm long, 2.5'diameter PVC. Wells were placed 10cm in soil, slits were made between 5-10cm below the initial above ground section to collect at root zone. Wells were purged immediately prior to sampling.

Conclusion/Discussion

- Significance was found in seasonality and among individual sites which suggests variability in biogeochemical processes with much need for continued studies.
- Results of porewater nutrients i.e., total phosphorus, total nitrogen, dissolved organic carbon, and ammonia measurements showed no significant differences in warming vs. non-warming plots and between mangrove and saltmarsh vegetation.
- The warming results can potentially be due to temperature insulating ability of soils and the relatively low change in overall temperature. In contrast, the vegetation results could be due to differential uptake of limiting nutrients by mangroves, however, dynamics of porewater nutrients under different coastal vegetation communities remains unclear.
- ***Future studies-*** Ideally this study should continue for 2-5 years while sampling multiple time throughout the season to better understand nutrient dynamics, for this study's sampling length, it is possible we are not detecting the nutrient differences that are most impactful in just one seasonal year of sampling.

Results

Nutrient by Season	**P-value**
TN (Total Nitrogen)	1.988e-05
TP (Total Phosphorus)	7.051e-14
Salinity	2.705e-06
Ammonia	8.812e-15
Dissolved Organic Carbon	3.392e-12

Nutrient vs. Vegetation	**P-value**
TN (Total Nitrogen)	0.05901
TP (Total Phosphorus)	0.8377
Salinity	0.6436
Ammonia	0.4889
Dissolved Organic Carbon	0.3886

Nutrient vs. Treatment	**P-value**
TN (Total Nitrogen)	0.6085
TP (Total Phosphorus)	0.4737
Salinity	0.138
Ammonia	0.517
Dissolved Organic Carbon	0.1238

Figure 7: Results of Kruskal Wallace analysis p-values for seasonal, warming, and vegetation comparisons.

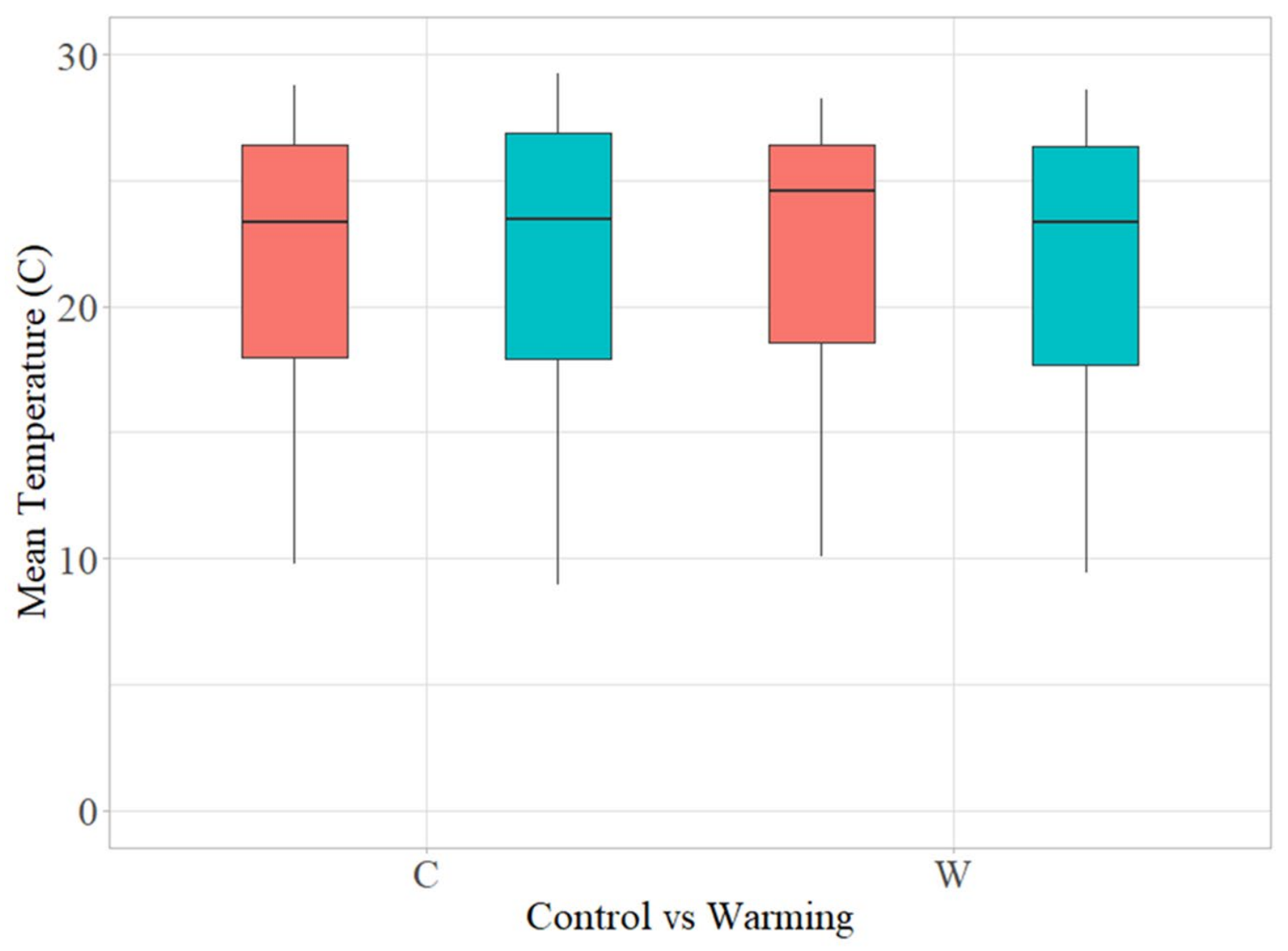

Figure 8: Below ground mean temperatures of two sites (middle and south.) No statistical significance was found in marsh/mangrove vegetation or temperature treatments i.e., control or warming.

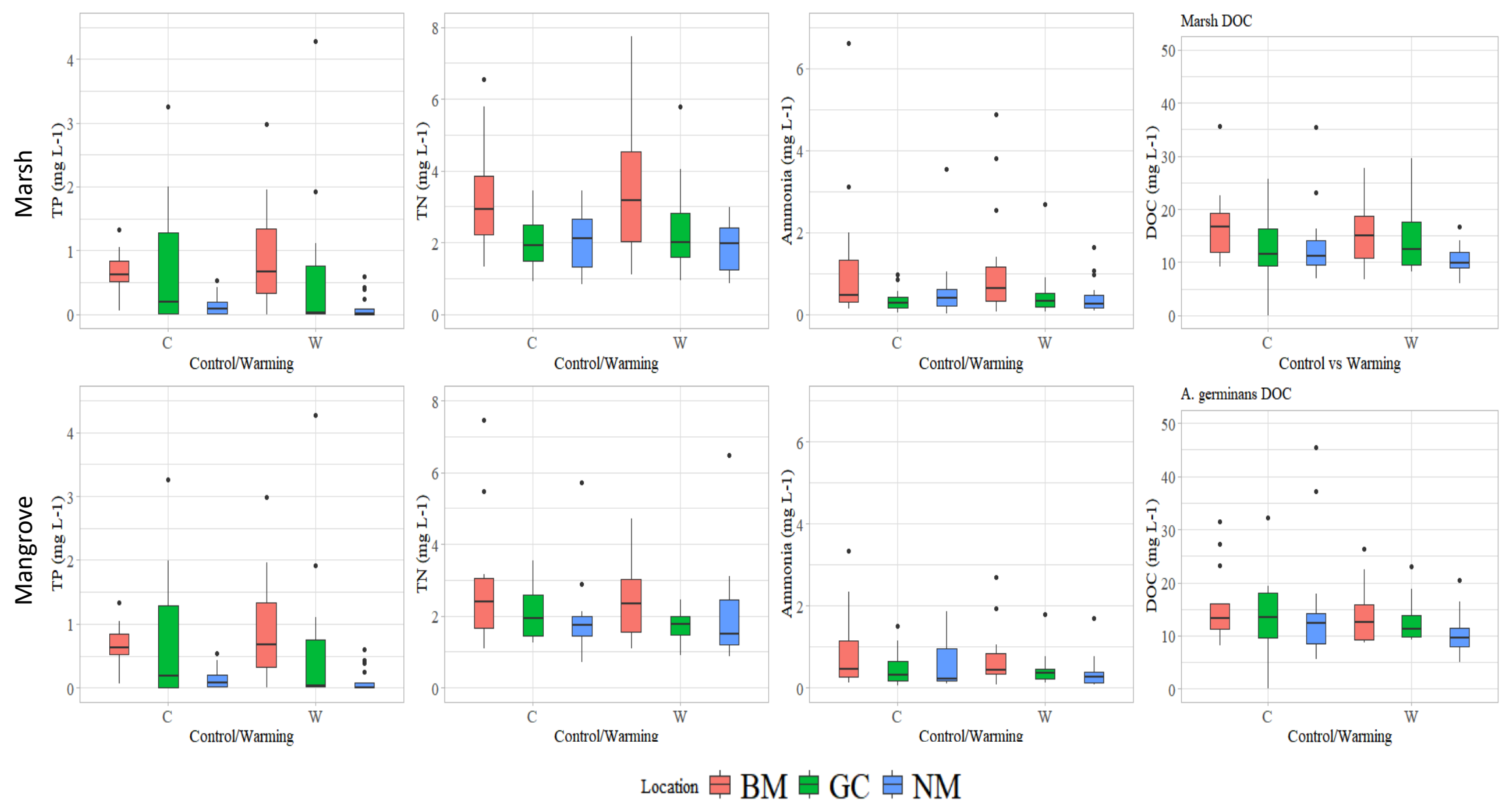

Figure 9: Box plots average and range of analyte concentrations for control/warming ambient temperature treatments with different vegetation at each individual site

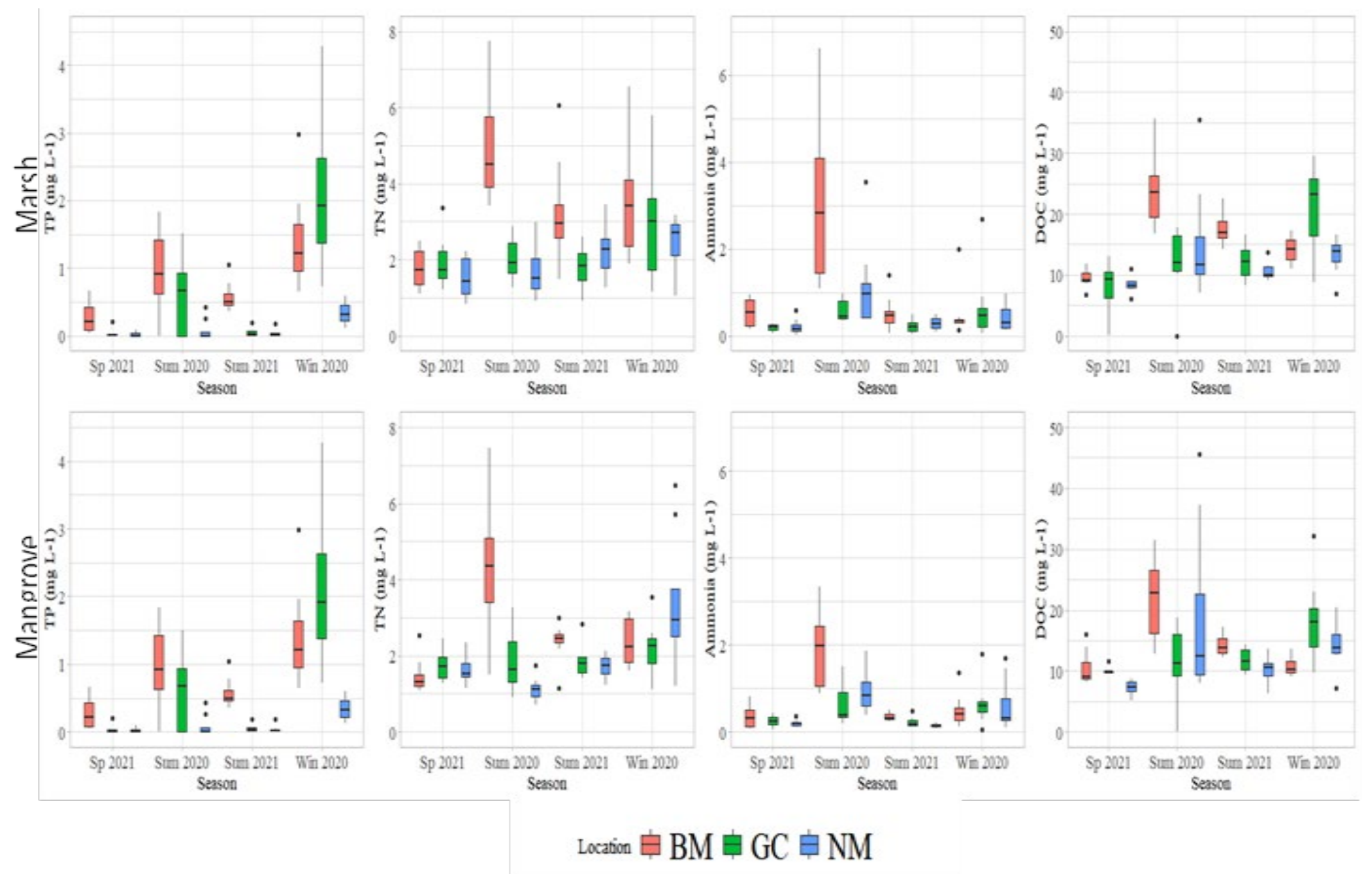

Figure 10: Box plots average and range of analyte concentrations per season sampling event with different vegetation at each individual site.

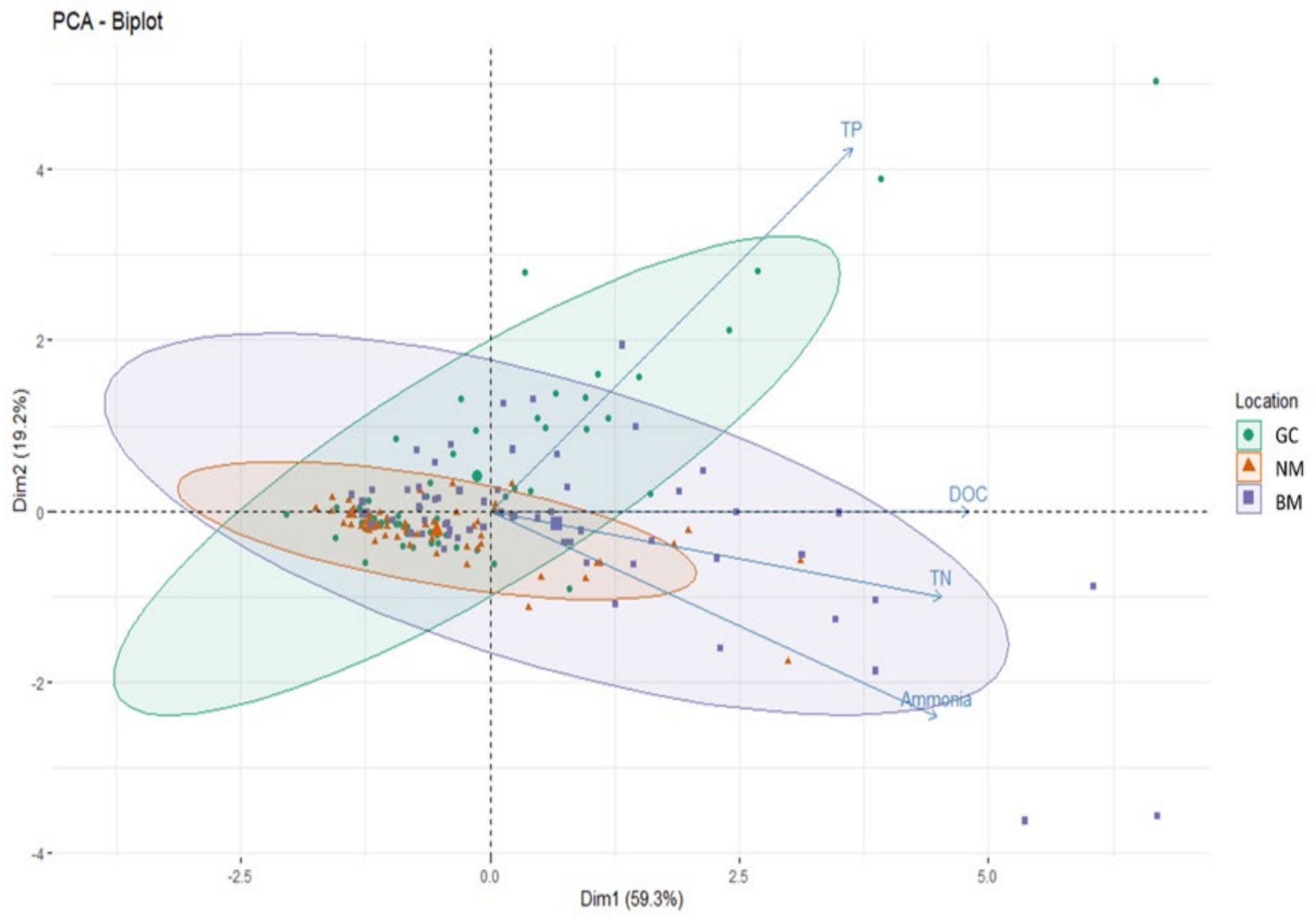

Figure 11: PCA Biplot analysis of site vs. nutrient assumptions. Dimension 1 explains 59.3% of variability while dimension 2 explains 19.2%. Arrows show correlations between nutrients while color of ellipses indicate site, ellipses also show groupings based on site and indicate similarities. Nmat/BM show similarities while GC seems to separate out.

Acknowledgements

Thank you, Dr. Samantha Chapman, for access to the WETFEET project and to the GTMNERR for access to this amazing project and sites. Additionally, I would like to thank the Whitney Laboratory for Marine Biosciences and Dr. Todd Z. Osborne for their help and support throughout this study. I would also like to thank my co-authors Dr. Tracey Schafer and Taryn Chaya for their hard work and help throughout this project.

References

- Chapman, S.K., Feller, I.C., Canas, G., Hayes, M.A., Dix, N., Hester, M., Morris, J. and Langley, J.A., 2021. Mangrove growth response to experimental warming is greatest near the range limit in northeast Florida. *Ecology*, *102*(6), p.e03320.
- IPCC Intergovernmental Panel on Climate Change. Global Warming of 1.5 C°. © Intergovernmental Panel on Climate Change. 2019 Switzerland. pg. 13.