Coastal-Ocean and Estuarine Acidification in Long Bay, South Carolina: A Comparison of In-situ Water Quality Monitoring with Measured Carbonate System Parameters

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BACKGROUND

One of the major water-quality issues impacting our coast and estuaries is coastal-ocean and estuarine acidification. There is currently a lack of Coastal-Ocean Acidification (COA) research on the coast of South Carolina (SC) and therefore this project aims to provide the first characterization of COA through leveraging decade-long data sets from Long Bay, SC where low pH and low oxygen (Sanger et al. 2012) have already been documented.

STUDY GOALS

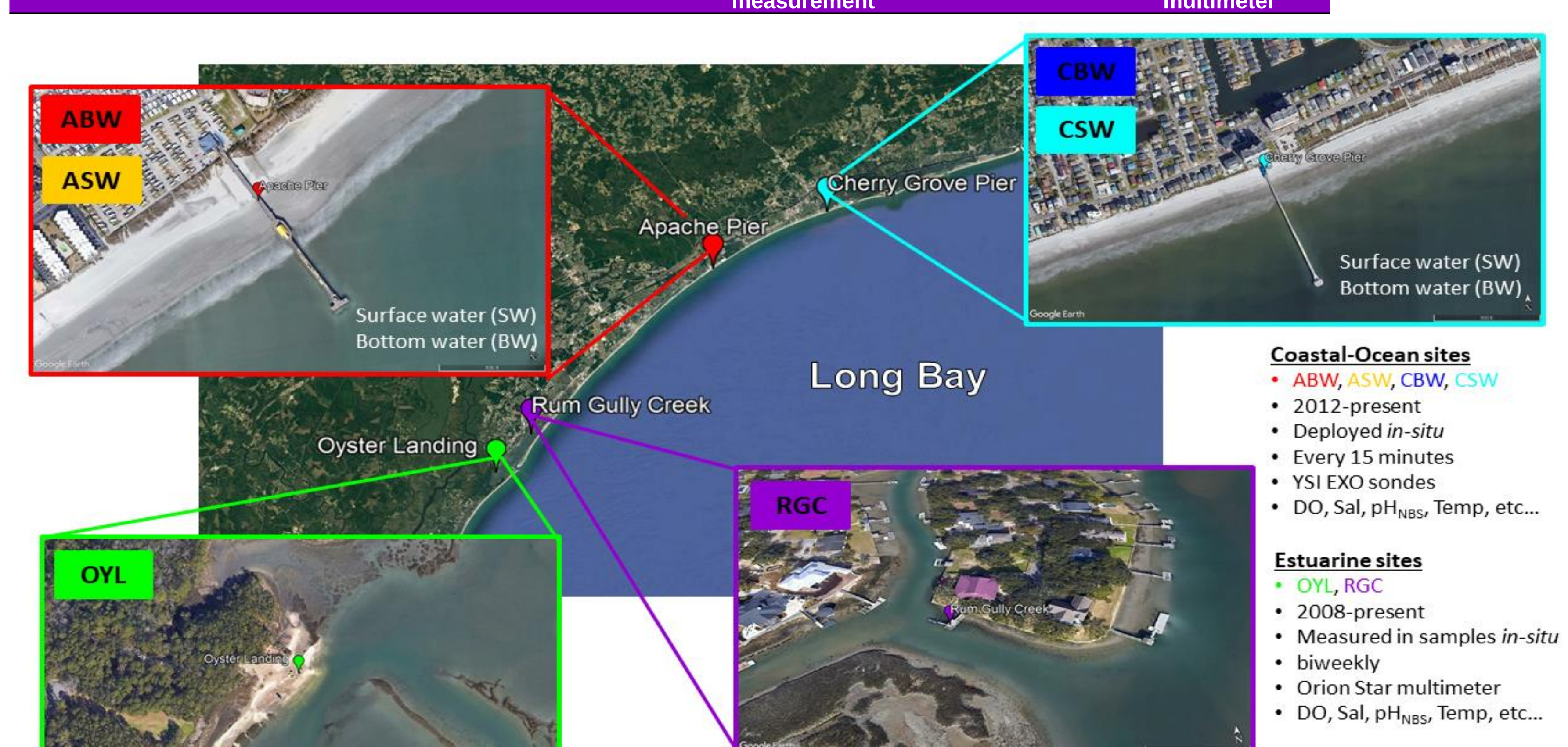
Provide the first characterization of temporal scales of COA in Long Bay, SC leveraging long term data sets at both coastal and estuarine sites. → Validate sensor measurements with contemporaneously collected discrete samples for Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA). → Show that water quality parameters as monitored by sensor technologies can be used for COA assessment.

HYPOTHESES

1. The relatively low-accuracy but high temporal-frequency pH_{NBS} measurements that have been collected over the past decade at four sites in Long Bay, SC, can be used as a proxy for total-scale pH (pH_T), the globally accepted pH property for acidification monitoring
   a. pH_{NBS} has a strong linear relationship with pH_T
2. Two coastal-ocean and two estuarine sites in Long Bay, SC have been experiencing decreasing pH and degree of saturation of calcite and aragonite over the past decade
   a. Total Alkalinity has a direct relationship with salinity (in addition to 1a)
3. Estuarine sites are more prone to acidification than coastal-ocean sites
4. pH at our study sites co-varies with temperature, dissolved oxygen and salinity
   a. pH has an inverse relationship with temperature
   b. pH has a direct relationship with dissolved oxygen
   c. pH co-varies with salinity

SENSOR SITES

Station	Acronym	Location in SC	Type	Platform	Sampling Frequency	Instrumentation
Apache Pier Bottom Water	ABW	Myrtle Beach	Coastal-ocean	In-situ deployed	15 minutes	YSI EXO sonde
Apache Pier Surface Water	ASW	Myrtle Beach	Coastal-ocean	In-situ deployed	15 minutes	YSI EXO sonde
Cherry Grove Pier Bottom Water	CBW	North Myrtle Beach	Coastal-ocean	In-situ deployed	15 minutes	YSI EXO sonde
Cherry Grove Pier Surface Water	CSW	North Myrtle Beach	Coastal-ocean	In-situ deployed	15 minutes	YSI EXO sonde
Oyster Landing	OYL	Murrells Inlet	Estuary	In-situ measurement	biweekly	Orion Star multimeter
Rum Gully Creek	RGC	Murrells Inlet	Estuary	In-situ measurement	biweekly	Orion Star multimeter

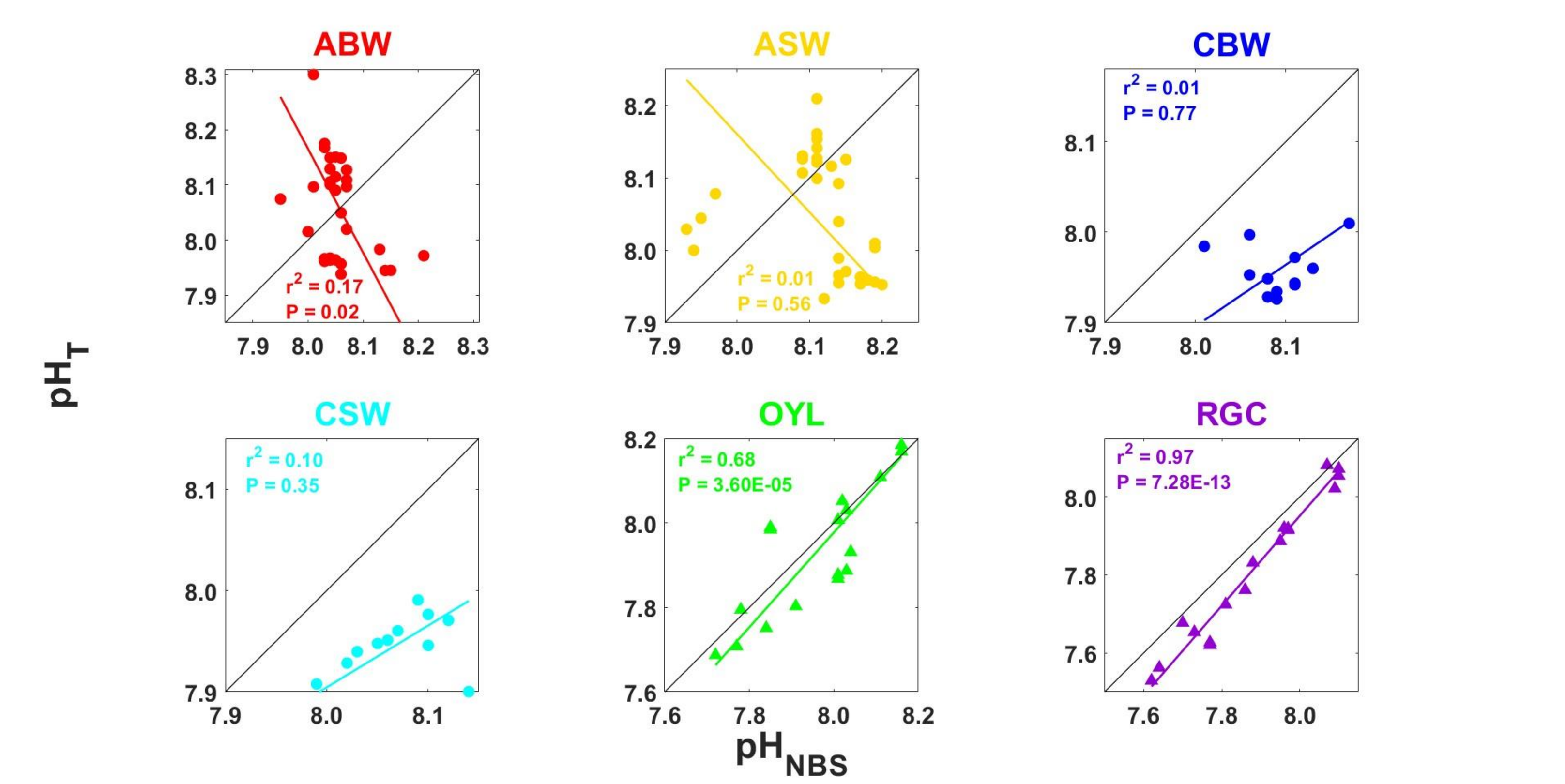


Coastal-Ocean sites
- ABW, ASW, CBW, CSW
- 2012-present
- Deployed *in-situ*
- Every 15 minutes
- YSI EXO sondes
- DO, Sal, pH_{NBS}, Temp, etc…

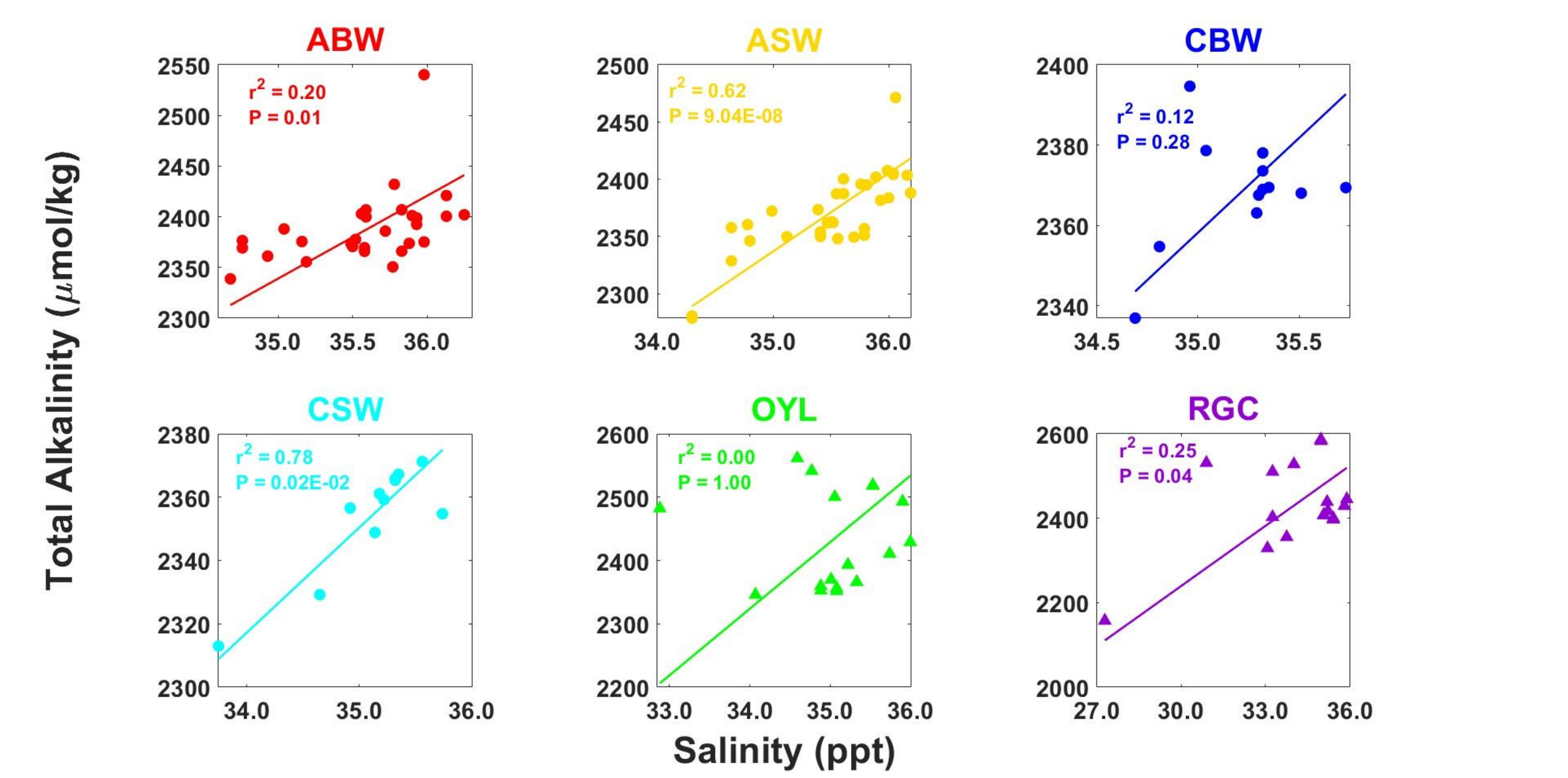
Estuarine sites
- OYL, RGC
- 2008-present
- Measured in samples *in-situ*
- biweekly
- Orion Star multimeter
- DO, Sal, pH_{NBS}, Temp, etc…

RESULTS

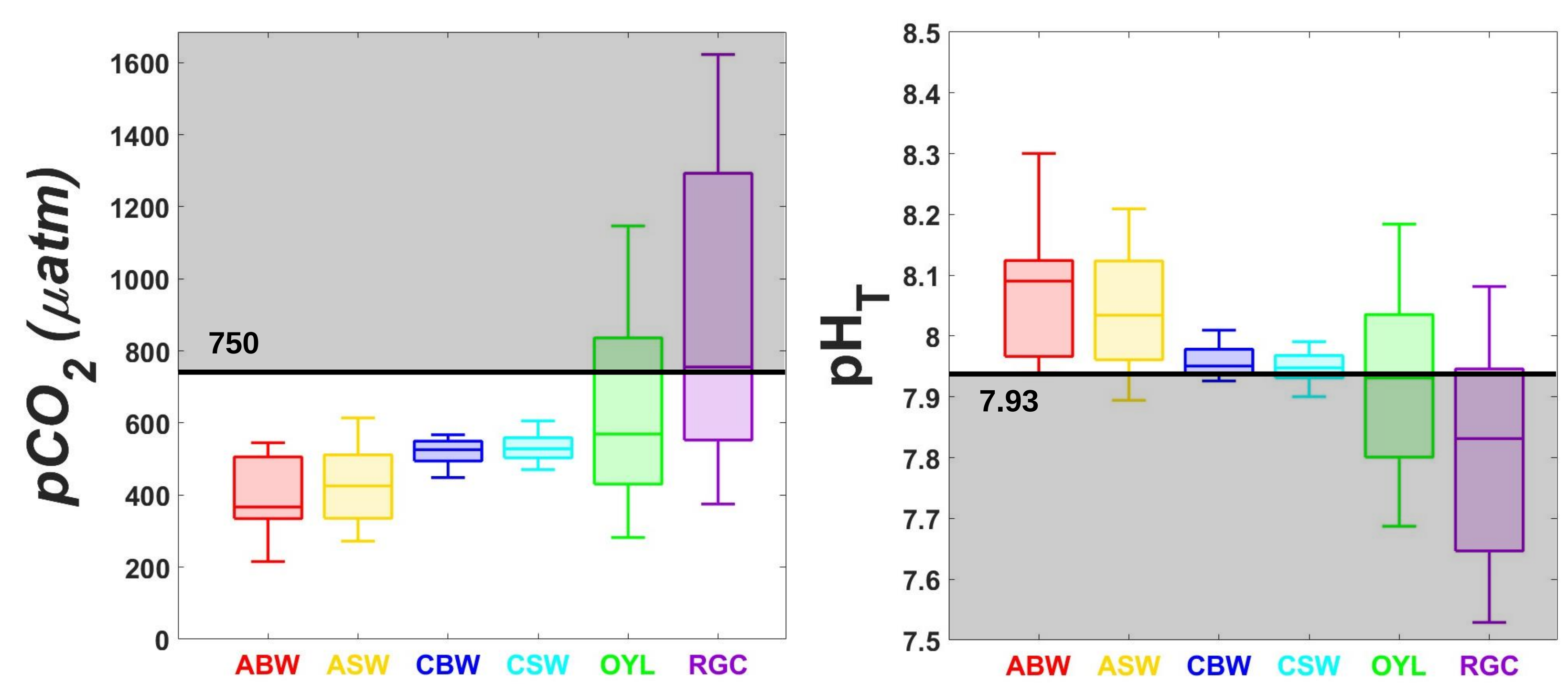
Sample Calculated pH (pH_T) vs. Sensor Measured pH (pH_{NBS}) (Figure 1)



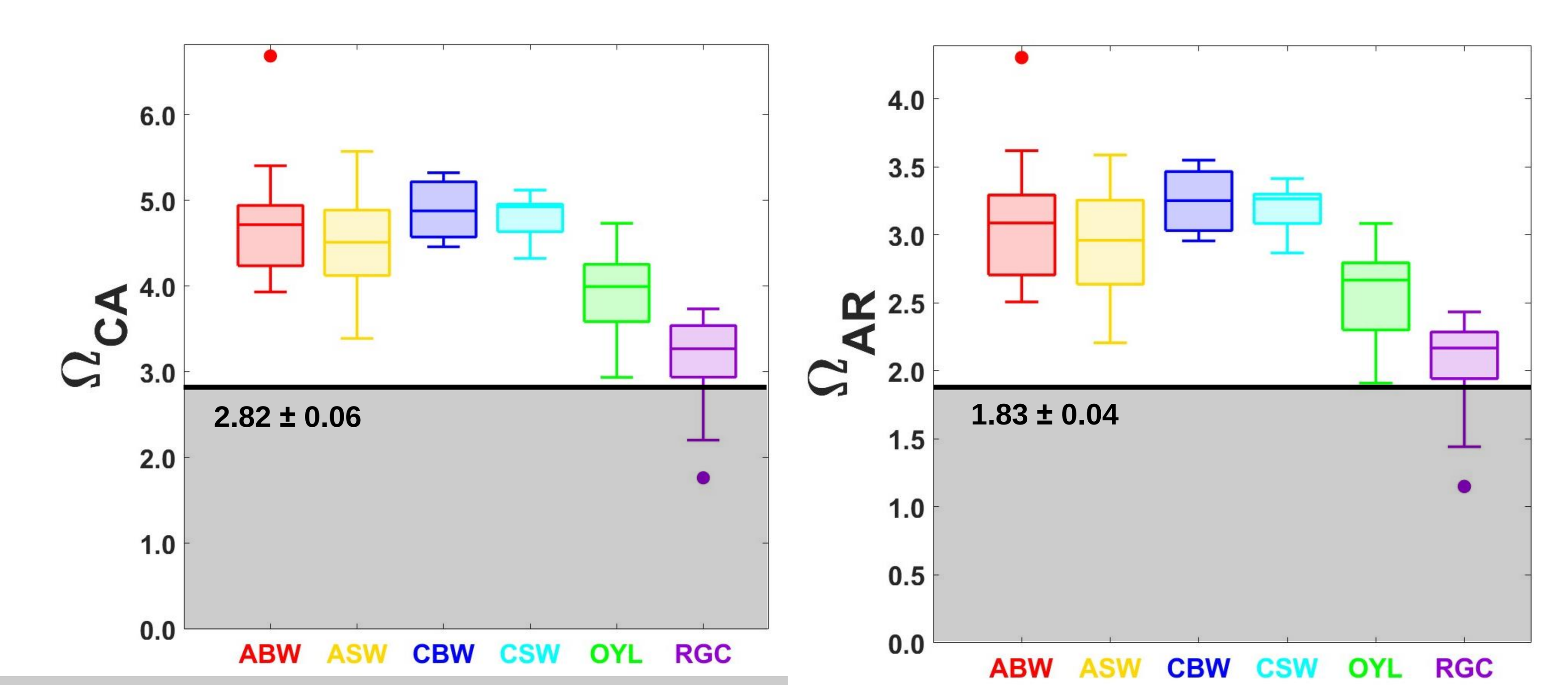
Total Alkalinity (TA) vs. Salinity (Figure 2)



Partial Pressure of CO_2 (pCO_2) and pH_T (Figure 3)



Calcite and Aragonite Saturation (Ω_{CA} and Ω_{AR}) (Figure 4)



Eastern Oysters (*Crassostrea virginica*) thresholds (Gobler and Talmage 2014)

DISCUSSION AND CONCLUSIONS

pH_T vs. pH_{NBS} (Figure 1)
- Coastal-Ocean Sites (ABW, ASW, CBW, CSW):
  - No strong linear relationships found at these sites
- Estuarine Sites (OYL, RGC):
  - pH_{NBS} can be used as a proxy for pH_T

TA vs. Salinity (Figure 2)
- No linear relationships were found at all sites, potentially due to:
  - Carbonate chemistry more complex and more dynamic (Kerr et al. 2021)
  - Biogeochemical processes, esp. respiration (Pimenta and Grear 2018)
  - Riverine inputs (Xia et al. 2007)
  - Terrestrial runoff (Dafner et al. 2007)
  - Upwelling groundwater (Viso et al. 2010)
  - Wind driven ocean surface currents (Troup et al. 2017)
  - Offshore water masses (Sanger et al. 2012)
  - Organic alkalinity: organic molecules that contribute to TA (Kerr et al. 2021)

Eastern Oysters (Gobler and Talmage 2014) (Figures 3 and 4)
- In their early life stages, Eastern Oysters exposed to:
  - **pCO_2** > 750 µatm, **pH** < 7.93, **Ω_{CA}** < 2.82 ± 0.06 and **Ω_{AR}** < 1.83 ± 0.04
    - Smaller, slower to metamorphose and less calcified
    - Thinner shells and more vulnerable to predation
- Estuarine Sites (OYL, RGC):
  - Fell within the detrimental thresholds for pCO_2, pH, Ω_{CA} and Ω_{AR}
    - Indicating periodic events where the Eastern Oysters could be exposed to acidification events

FUTURE STUDIES

- Need more observations and sampling to detect potential acidification trends (Pimenta and Grear 2018)
- Key biogeochemical properties
  - Nutrients (Wanninkhof et al. 2015, Cai et al. 2021, Kerr et al. 2021, Hall et al. 2024)
  - Chl a (Borges and Gypens 2010, Hall et al. 2024)
- Direct measurements of pH_T (Dickson et al. 2007, Fassbender et al. 2017)
- Organic alkalinity (Fassbender et al. 2017)
  - Blackwater rivers
    - River plumes (Xia et al. 2007)
  - Saltwater marshes
- Capturing seasonal variations, diurnal biogeochemical processes (respiration and photosynthesis) and tidal influences (Baumann et al. 2015)
  - Capture low pH and low DO events
- The dynamic nature of these systems makes them extremely difficult and expensive to study
  - Higher temporal and spatial variability of the carbonate system
  - Holistic data collection
    - Nutrients, carbonate parameters, water quality parameters, etc.

ACKNOWLEDGMENTS

This research was sponsored by the South Carolina Sea Grant Consortium and the State of South Carolina pursuant to National Oceanic and Atmospheric Administration Award NA22OAR4170114. We want to thank the Southeast Ocean and Coastal Acidification Network, Mote Marine Laboratory, Environmental Quality Lab, Waccamaw Watershed Academy and Coastal Carolina University for their collaboration on this project. Monitoring at our two pier stations is conducted with funding from Horry County (Apache Pier) and the City of North Myrtle Beach (Cherry Grove Pier), while the Murrells Inlet Volunteer Water Quality Monitoring Program is funded by Georgetown County and Horry County.

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