Biochar in Marsh Restoration (BiMRAC)

(Or: Do prescribed burns of *Phragmites australis* during salt marsh restoration increase C, N, and P storage ecosystem services?)

September 4, 2024

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And Chris Kelly, Pam Edris, Emma Leaseburg, UD

National Estuarine Research Reserve System Science Collaborative

University of Delaware

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https://nerrssciencecollaborative.org/

https://nerrssciencecollaborative.org/index.php/project/Wozniak21

https://nerrssciencecollaborative.org/guide/start

National Estuarine Research Reserve System Science Collaborative

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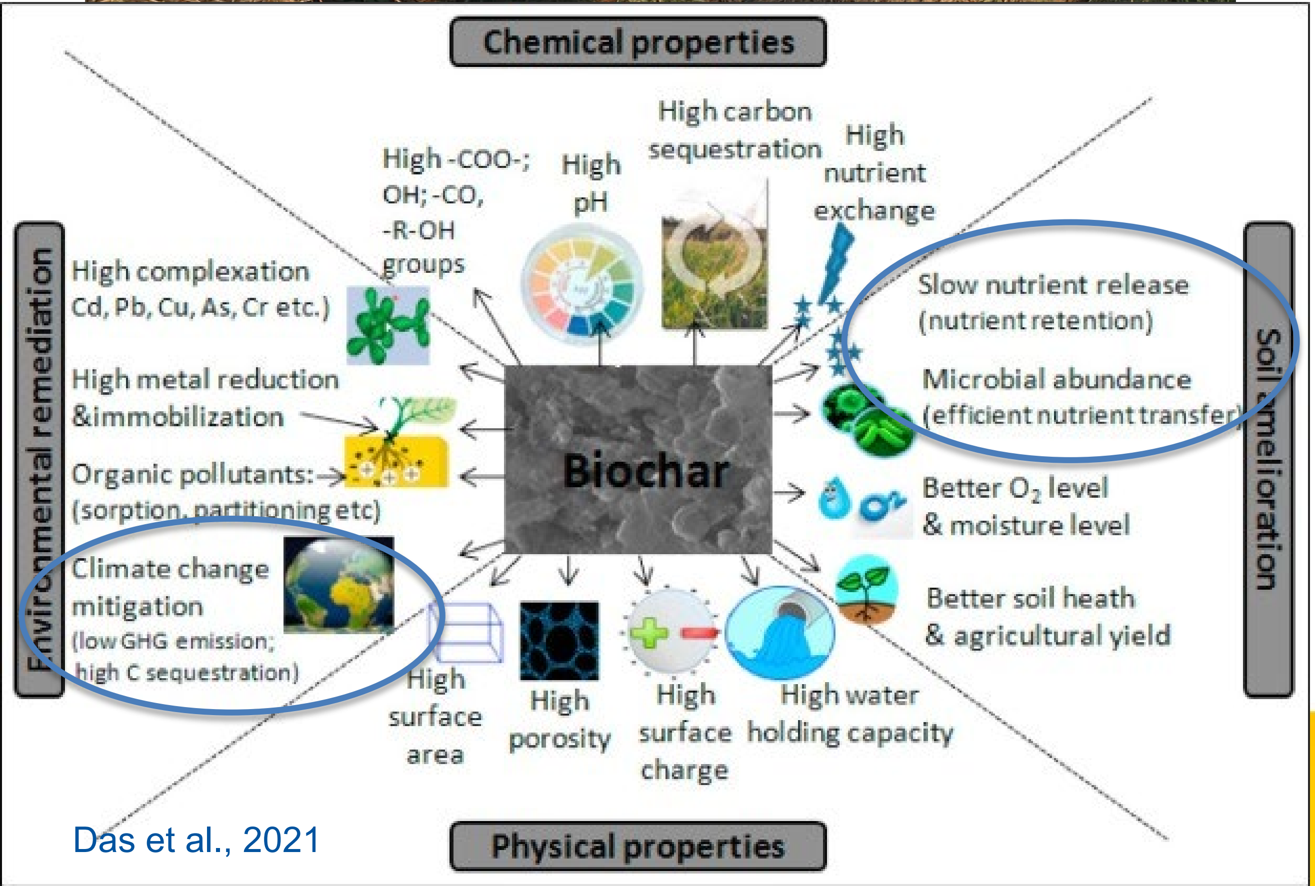
The National Estuarine Research Reserve System Science Collaborative supports science for estuarine and coastal decision-makers. Managed by the University of Michigan Water Center, through a cooperative agreement with NOAA, the Science Collaborative coordinates regular funding opportunities and supports user-driven collaborative research, assessment, and transfer activities that address critical coastal management needs identified by the reserves.

Mission

The NERRS Science Collaborative promotes science to support coastal decision-making about management problems important to the reserves. Our primary objectives:

1. **Deliver a comprehensive collaborative research program** that provides meaningful project opportunities and maximizes benefit to the NERRS and their end users;
2. **Support the sharing and transfer** of research outputs, monitoring information, and knowledge among the reserves, other stakeholders, the NERRS, and rest of the coastal community;
3. **Build the capacity of the reserves** to develop and participate in collaborative research projects; and

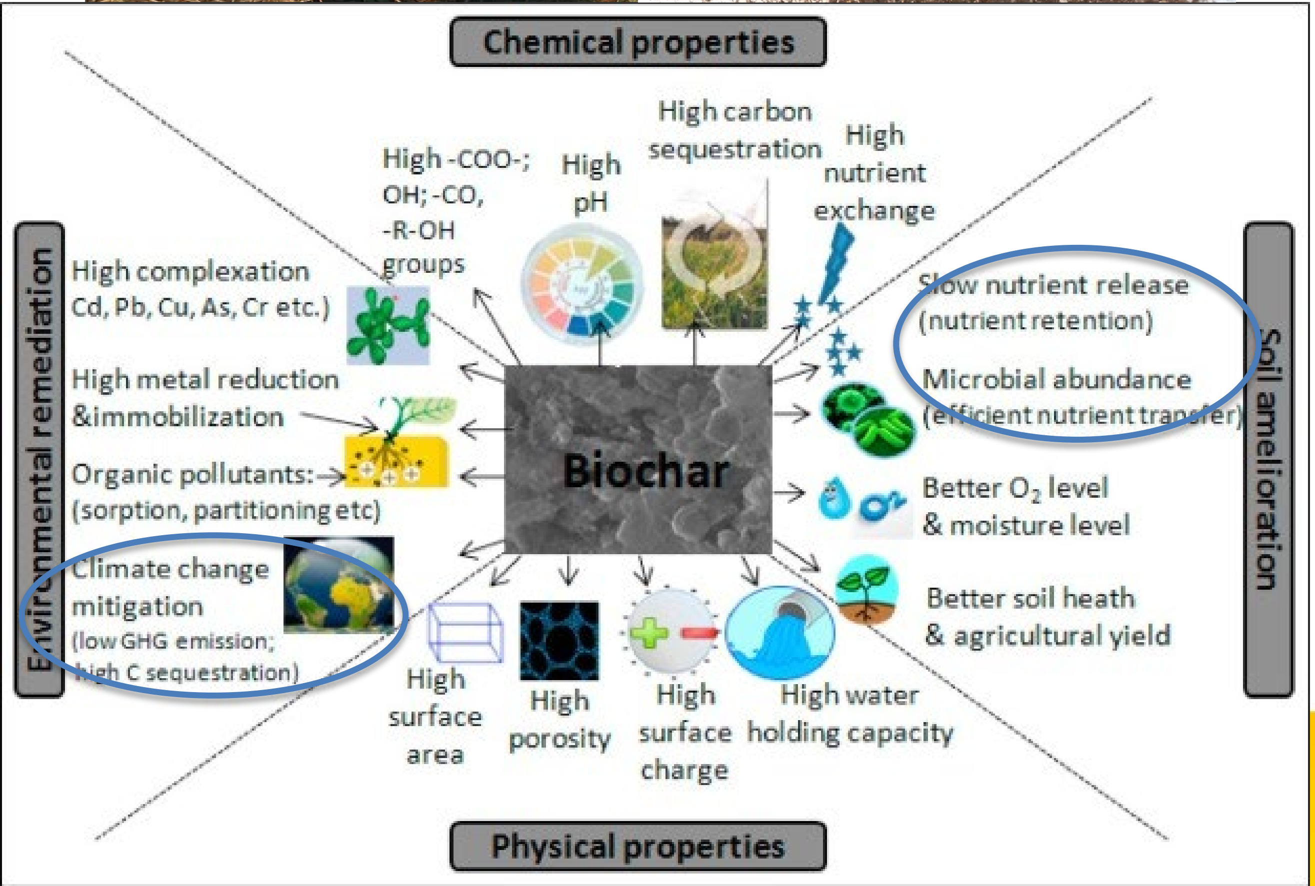
DNERR: How do controlled burns act to input biochar, impact erosion, and/or alter other tidal wetland processes?



Das et al., 2021

<u>Technical Research Question:</u>

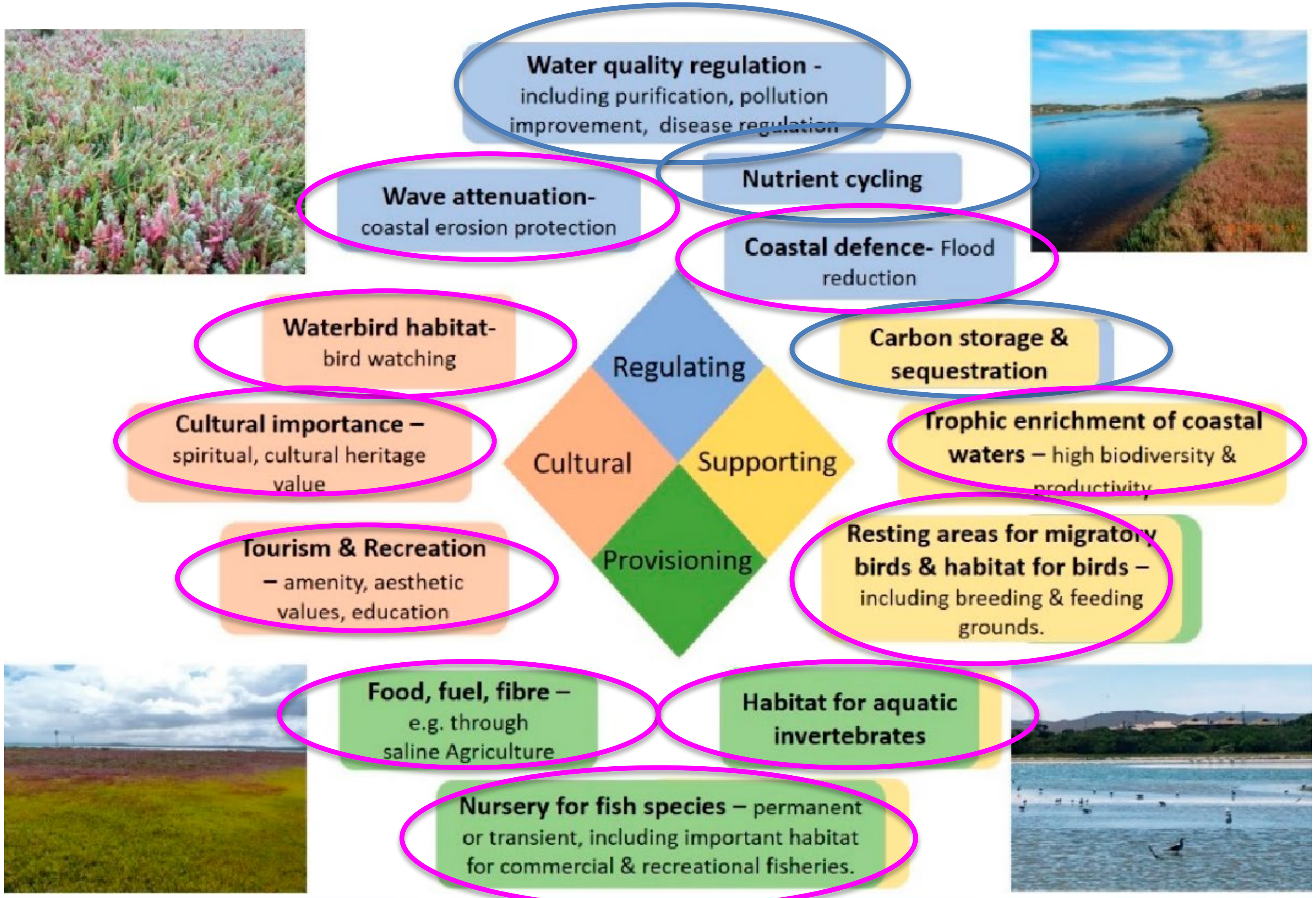
Do prescribed burns of *Phragmites* for tidal marsh restoration bring C, N, and P biogeochemical ecosystem services?



"Collaborative" Research Question:

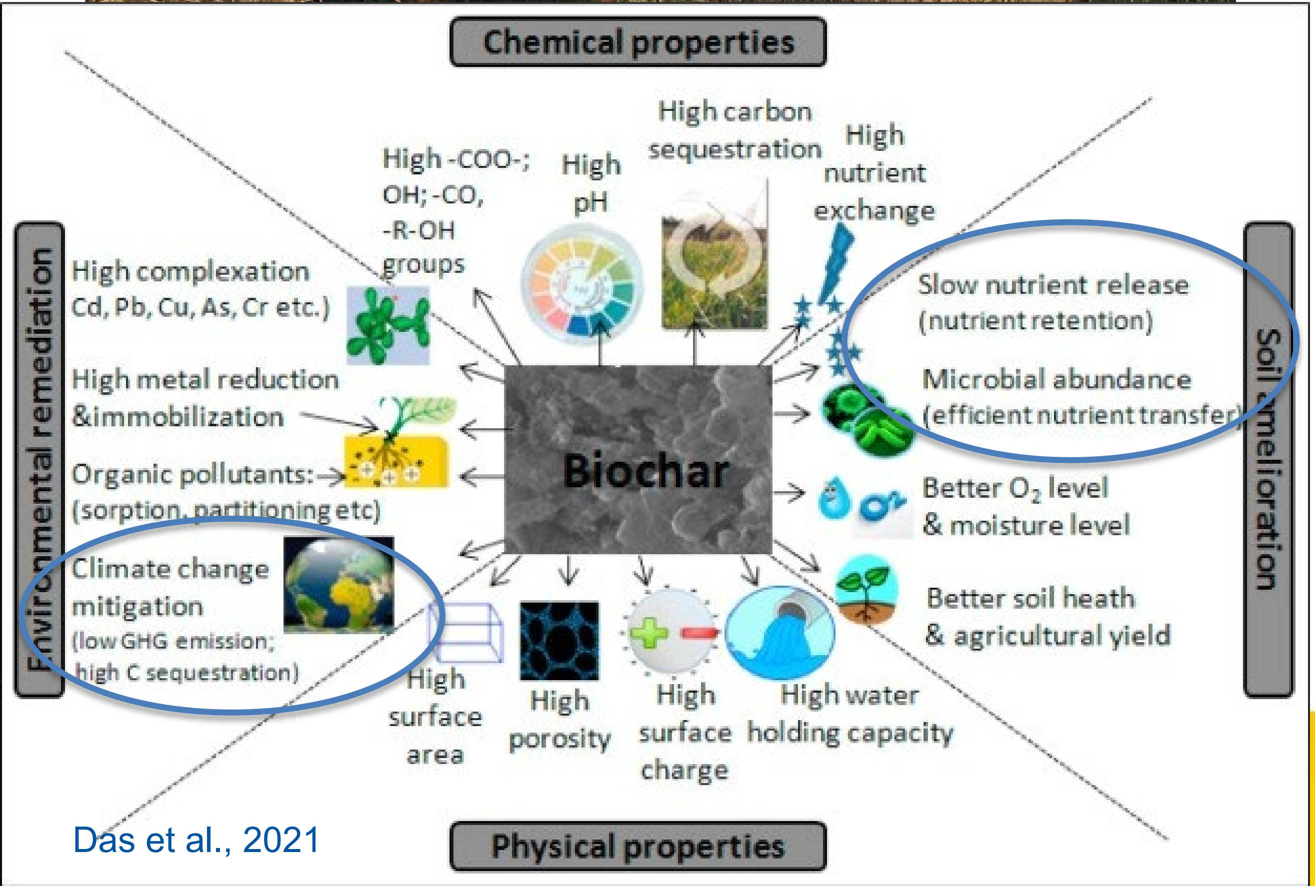
Where do prescribed burns and biochar fit within a climate adaptive restoration framework for Delaware (and beyond)?

Salt Marsh Ecosystem Services



Adams et al., 2021

University of Delaware



Das et al., 2021

Technical Research Question:

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Nitrogen Removal

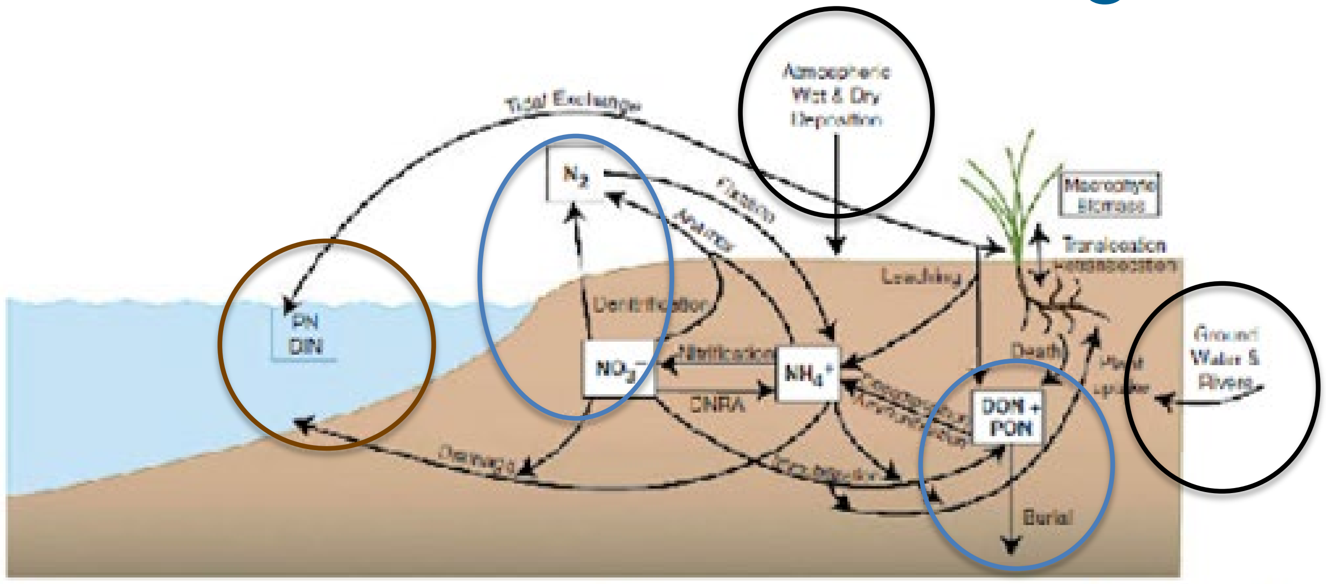


Figure 22.2 Diagram of major nitrogen stocks, fluxes and transformations in a salt marsh–tidal creek system.

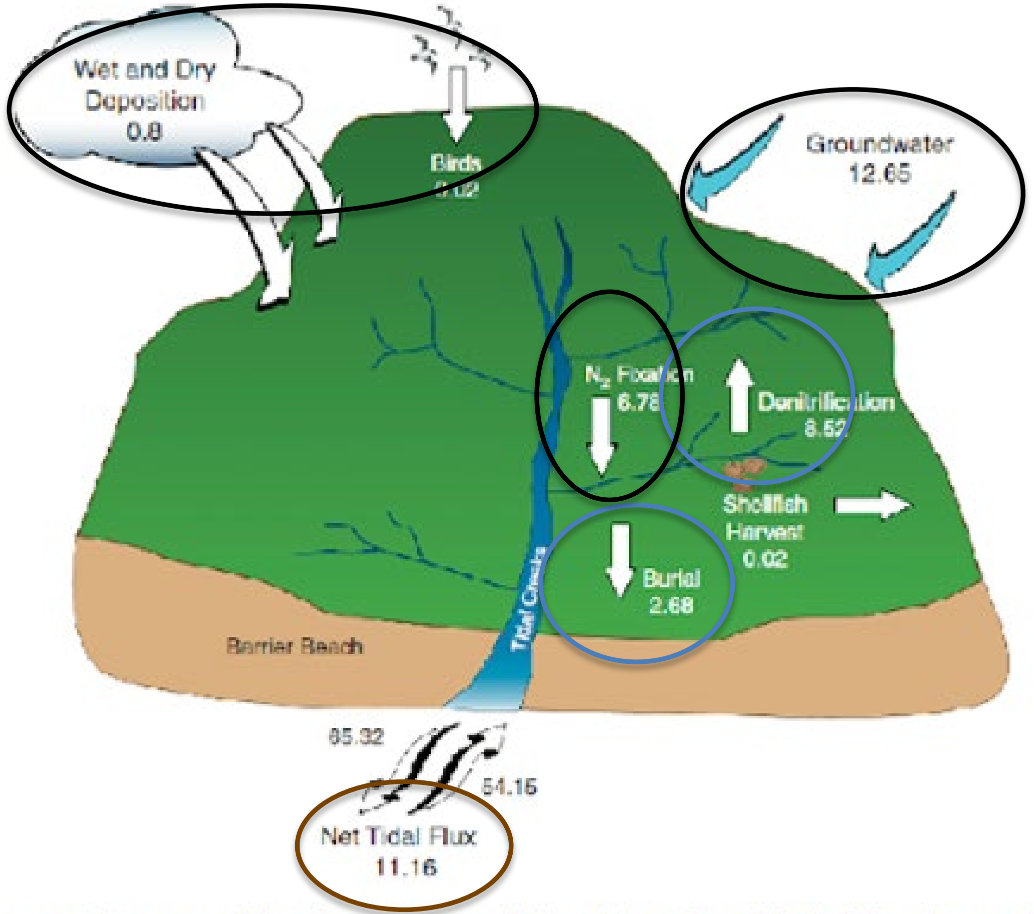


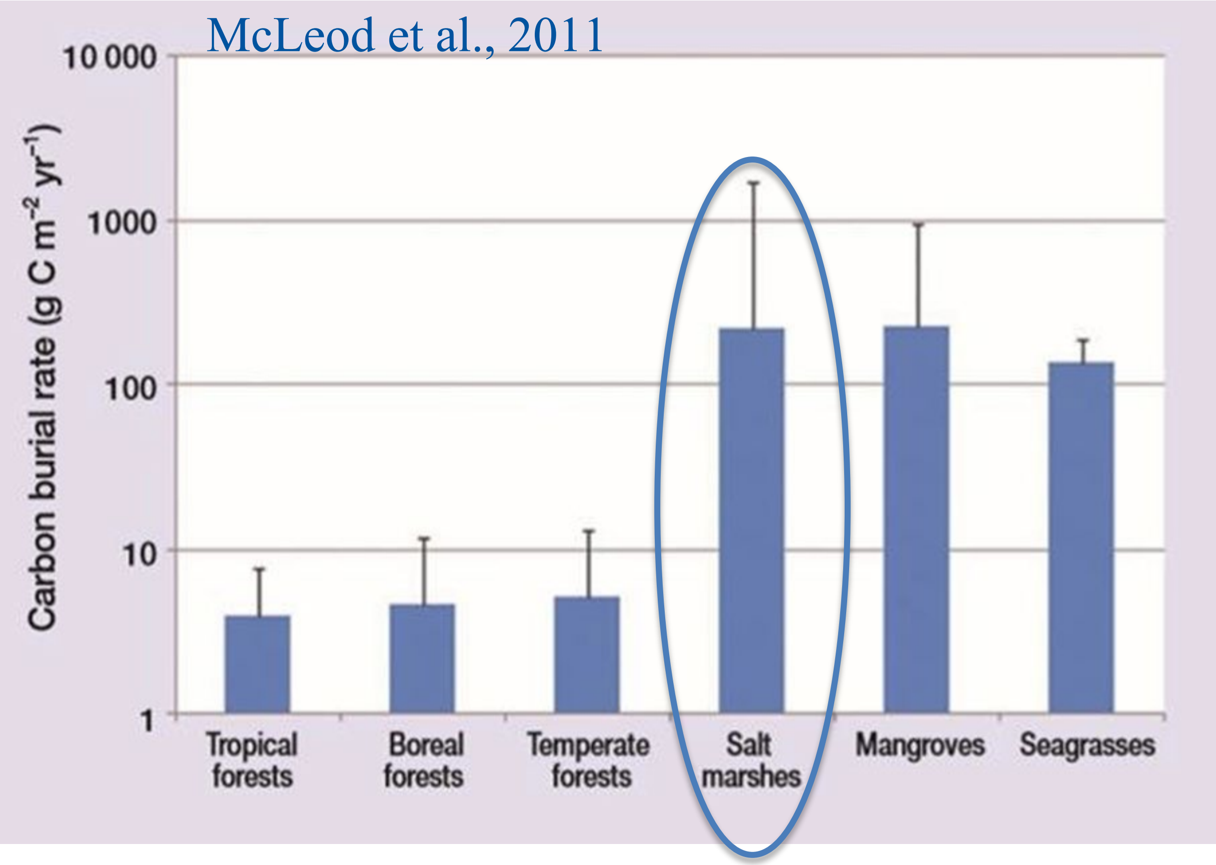
Figure 22.4 Summary of the nitrogen budget of Great Sippewissett Marsh, Massachusetts, USA (Valiela and Teal, 1979). All fluxes are in g N m² year⁻¹.

Marsh processes (denitrification, burial) remove ~17% of N inputs to MA marsh.

 reduces N inputs to estuary, **improving water quality**

Hopkinson and Giblin, 2008

Salt Marsh Blue C



- Salt marshes bury C at rates that are 10-40x those of forests.
- Global Mean: 218±24 g C m^{-2} y^{-1}
- Great Marsh, Lewes: 79±20 g C m^{-2} y^{-1} (Tucker, Owrutsky, unpublished data)

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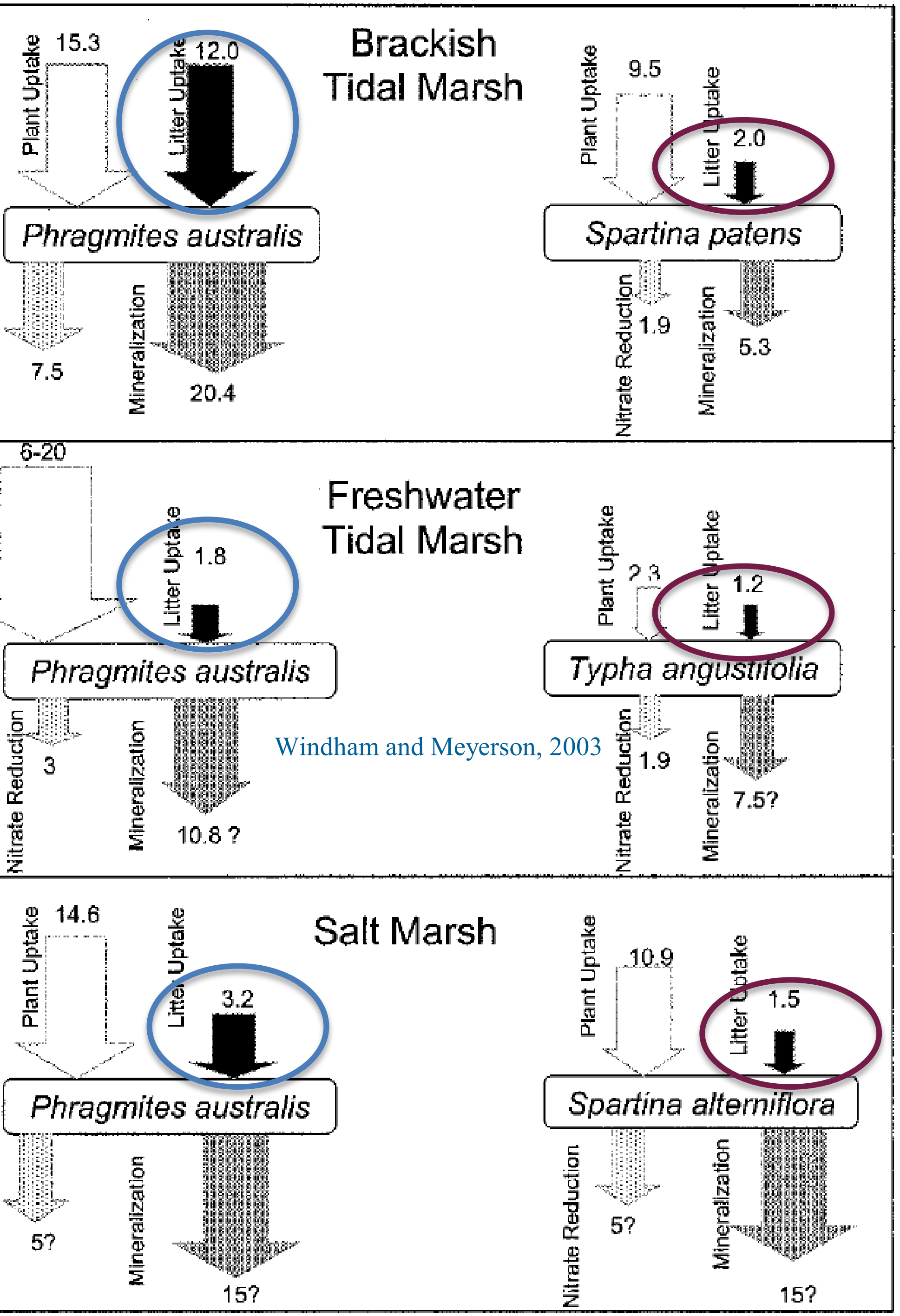
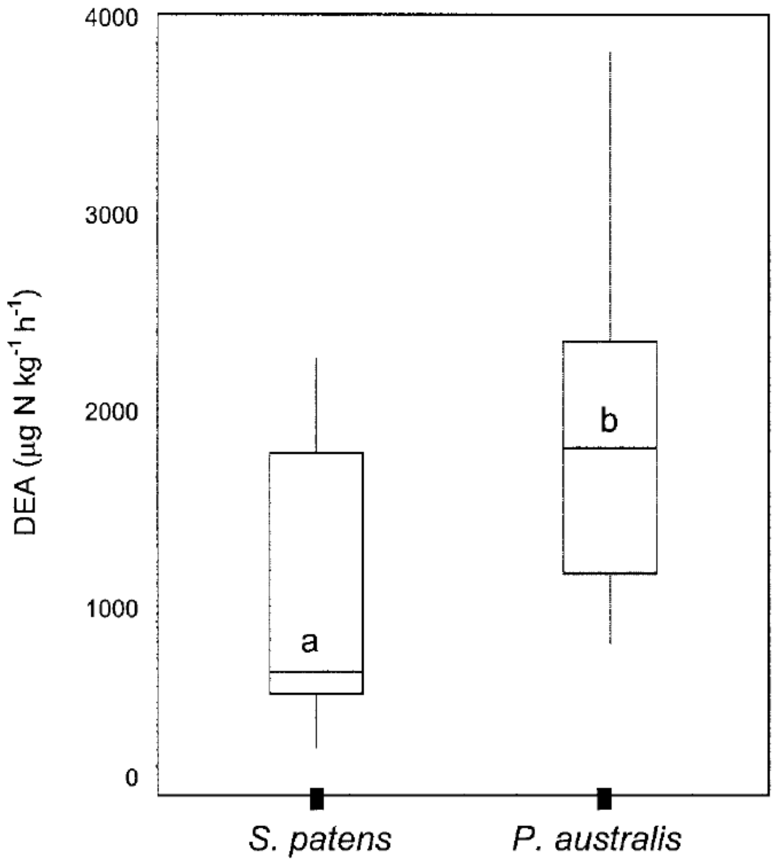
Phragmites N storage Ecosystem Service



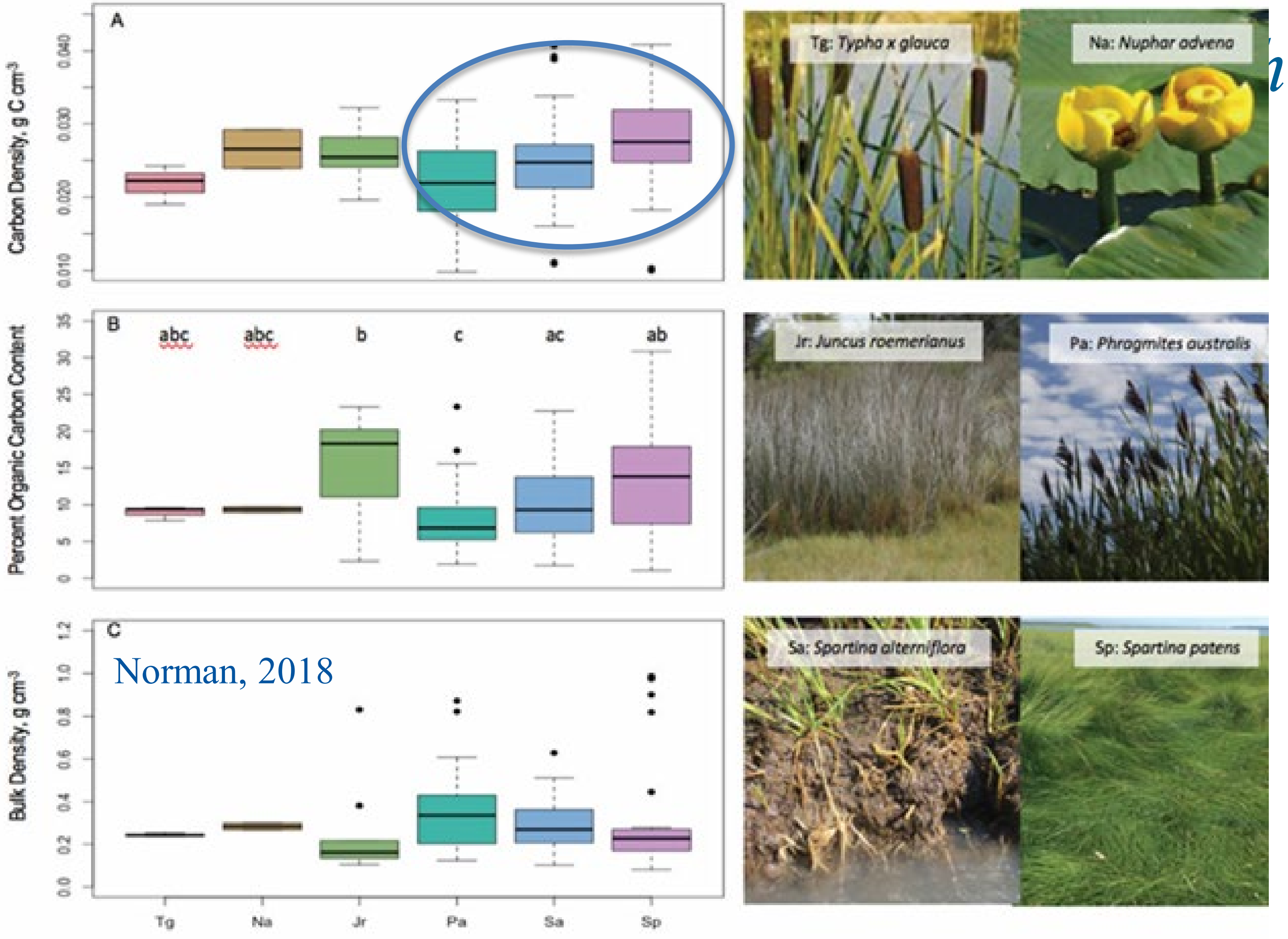
Windham and Meyerson, 2003

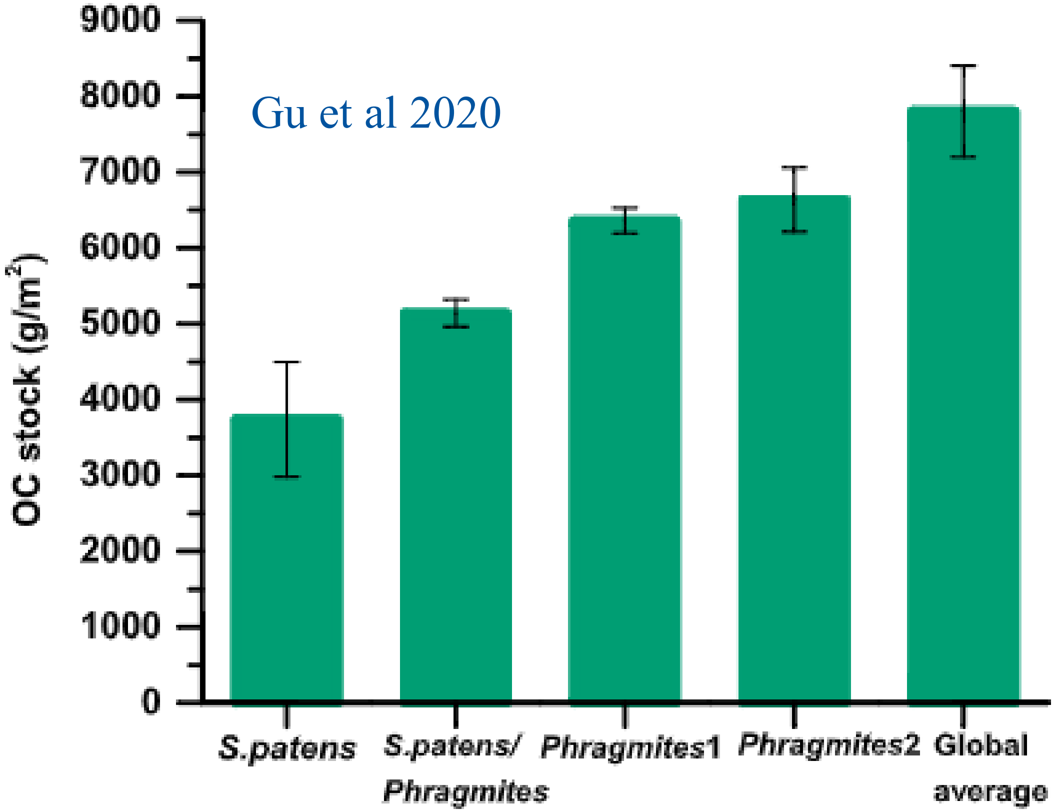
Relative to native vegetation, *Phragmites* may

- store more N in biomass/litter
- yield higher denitrification removal rates



…ragmites C storage Ecosystem Service

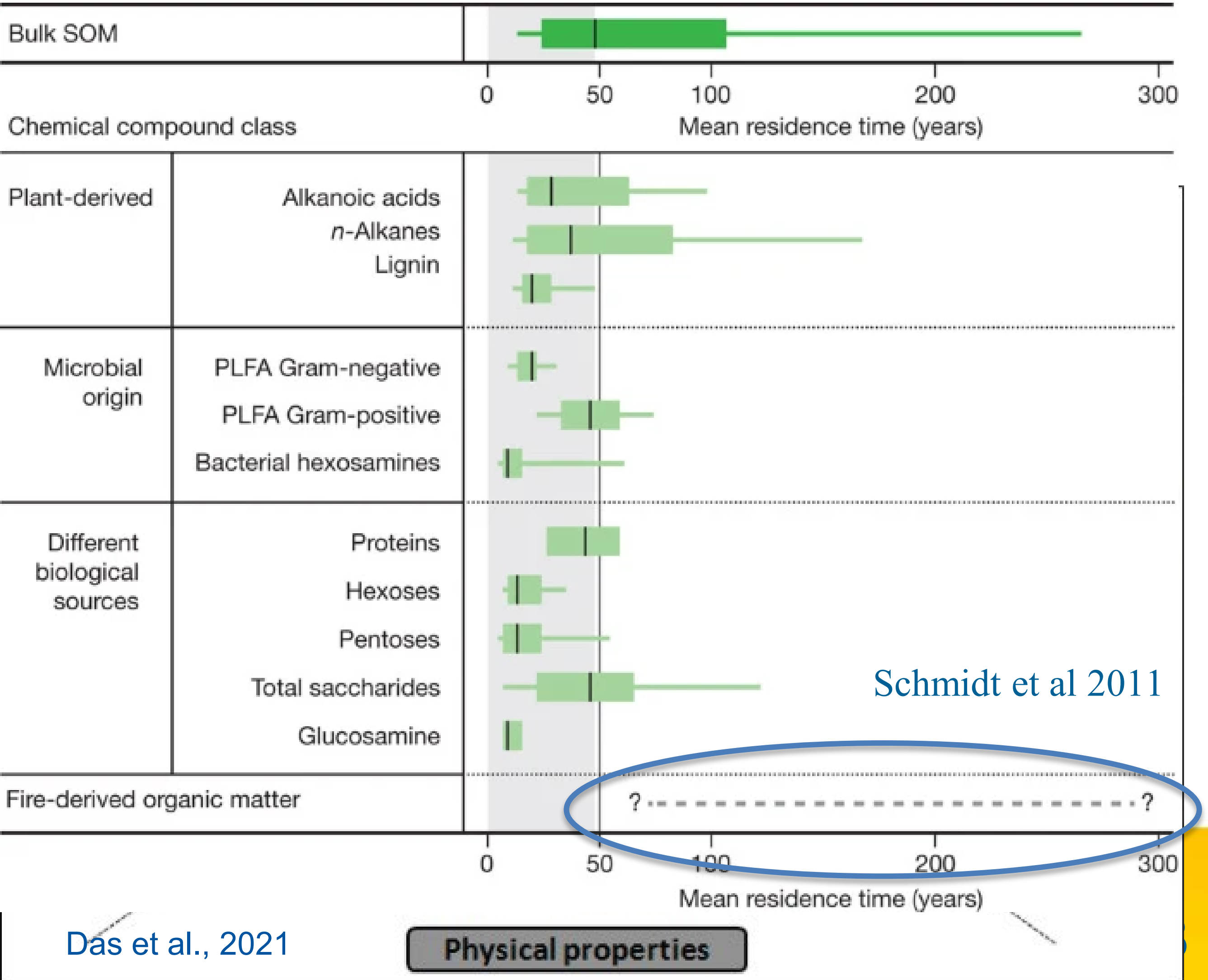


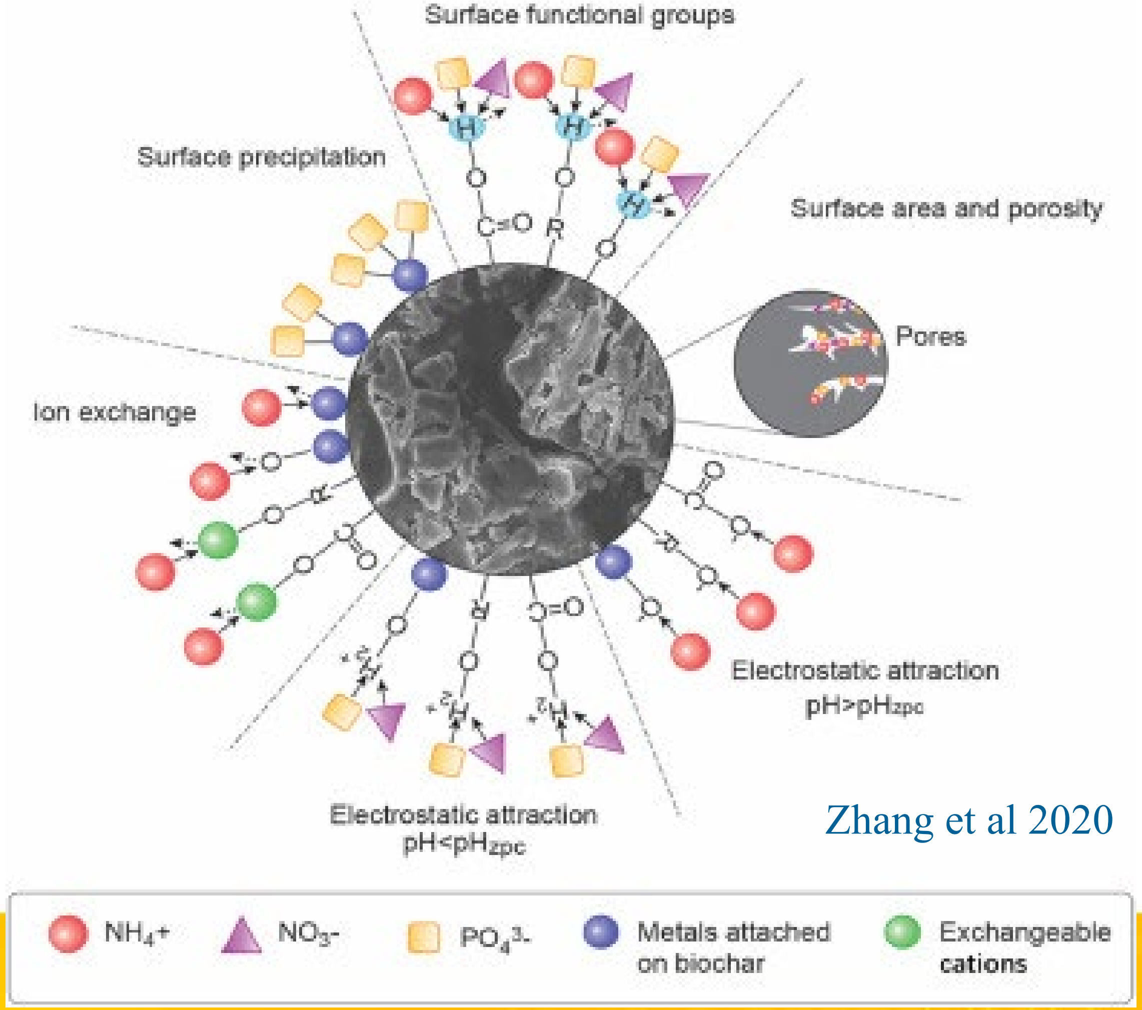


Phragmites often stores more N and C than native vegetation

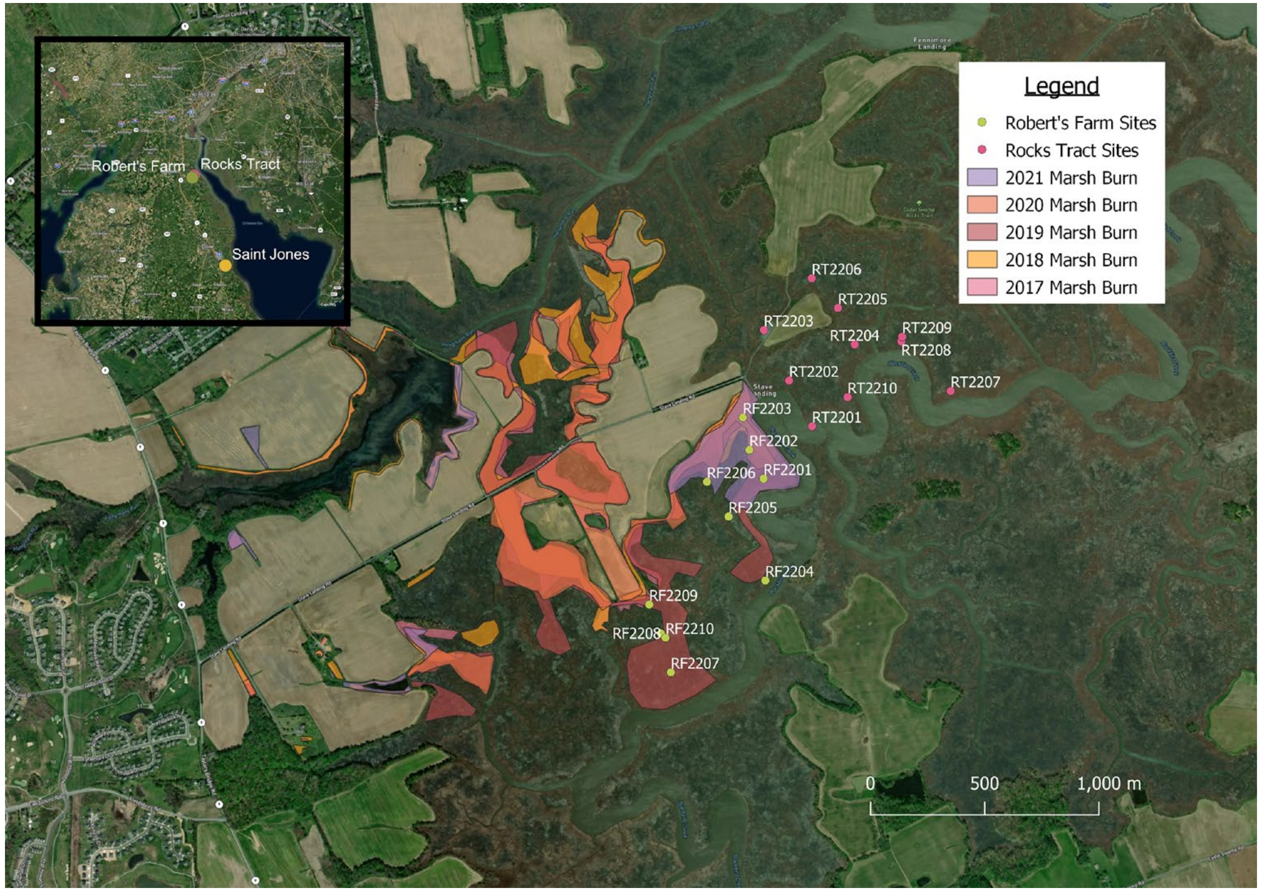
Phragmites removal may reduce N, C ecosystem services.

Could Biochar (from burns) recoup C, N, P Ecosystem Services?





Objective 1: Quantify biochar inputs to areas within and adjacent to marsh burn sites and monitor retention rates.



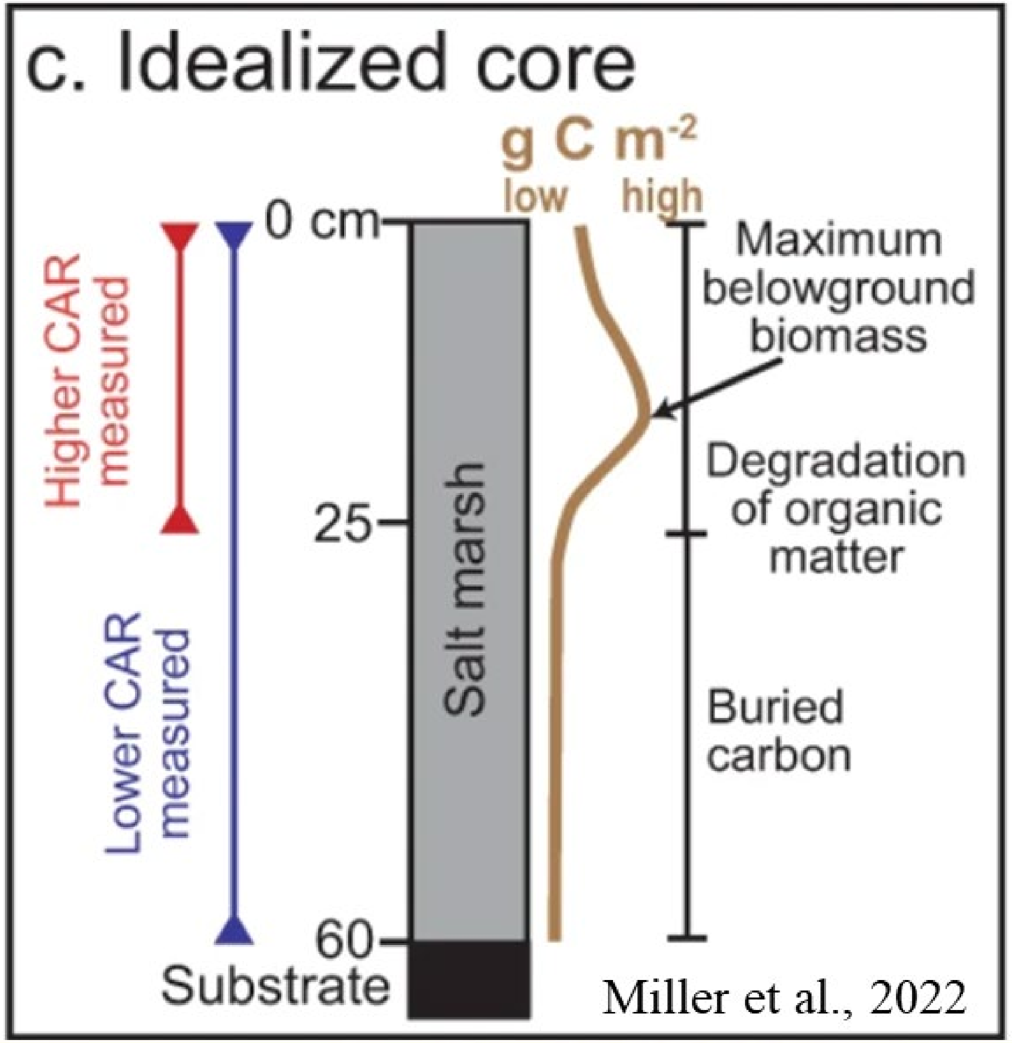
Evaluate C, Black C, N, and P in 10 cores collected @ each site over 2 collection periods (Jan./Feb. 2022, Nov. 2022)

Expectations

If burns provide added C, N, P storage ecosystem service, *C, N, P densities will be higher at Roberts Farm compared to adjacent Rocks Tract.*

Biochar 'Black C' represents long-lived C expected to be buried efficiently.

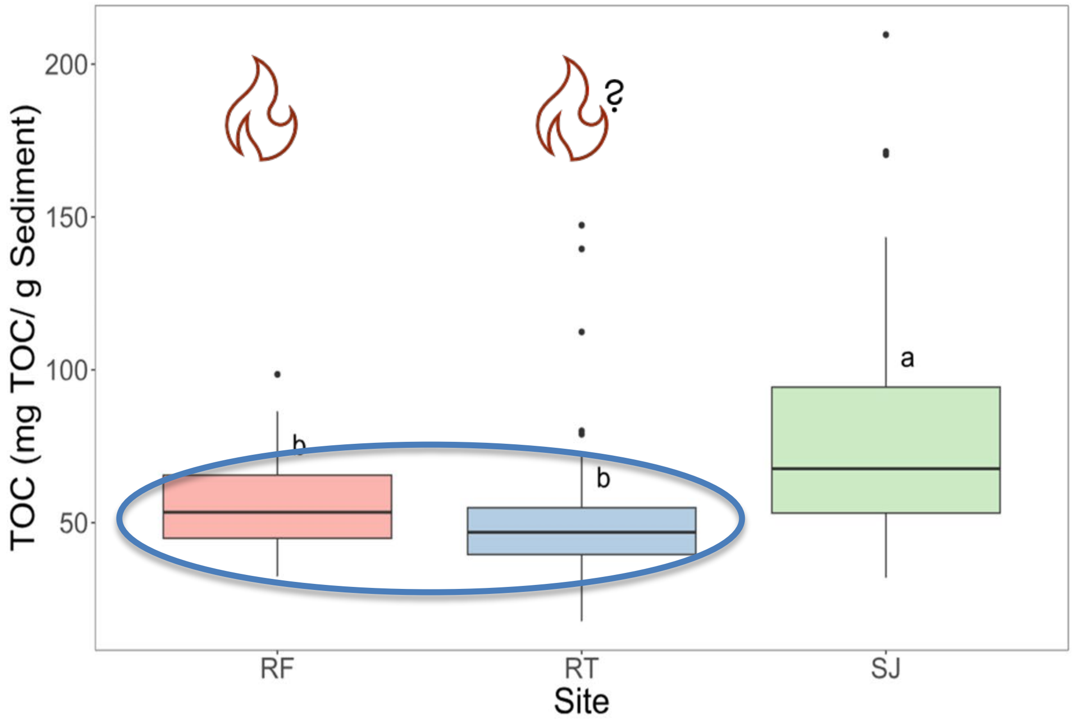
- *also expected to be higher at Roberts Farm*

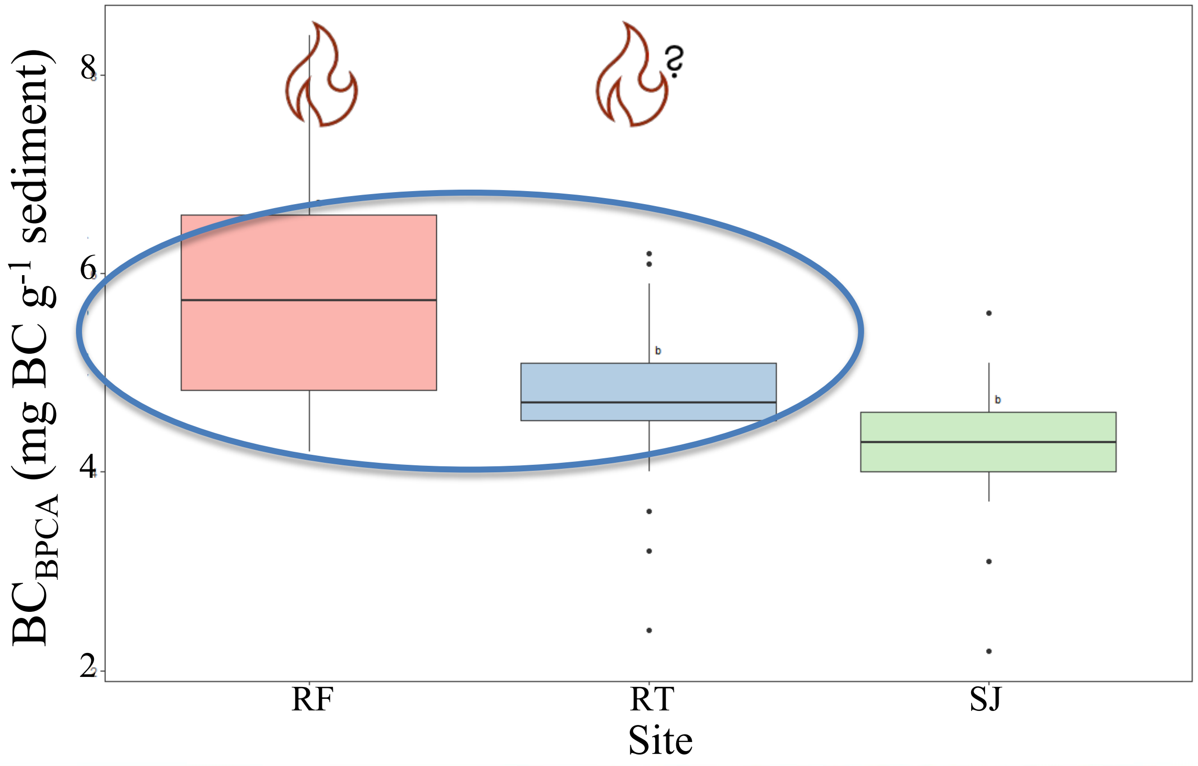


Miller et al., 2022

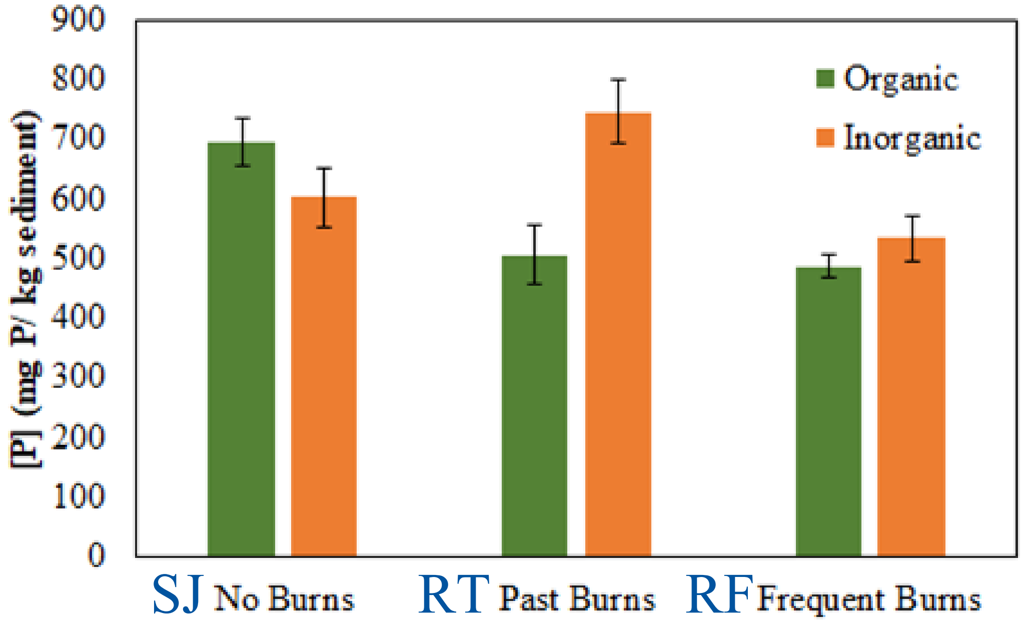
Carbon, Nitrogen Concentrations

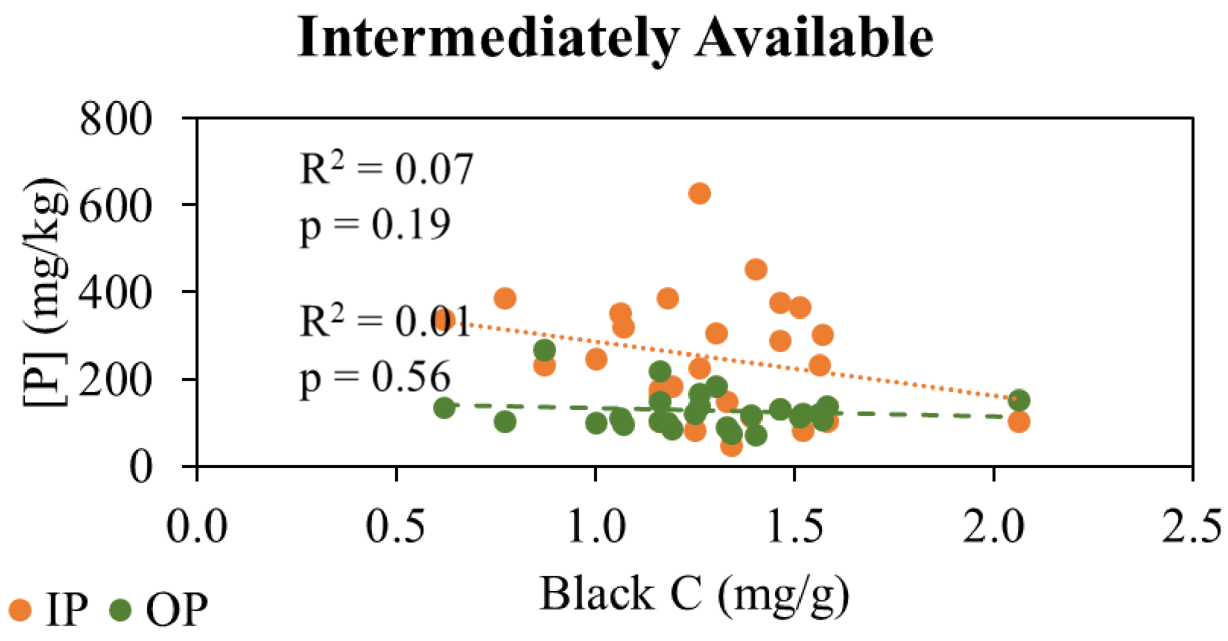
- TOC concentrations similar @ RF and RT (but larger at RF), TN higher at RF
- TOC, TN highest at SJ likely due to location
- Burned RF site showed higher BC concentrations

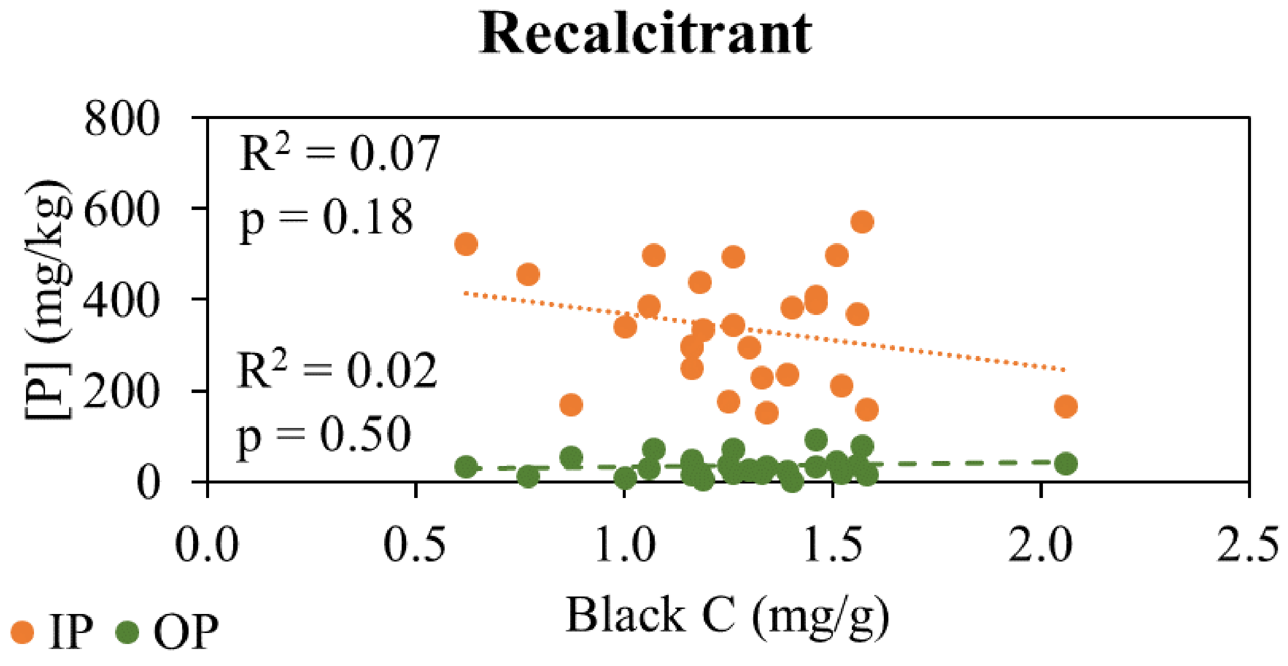




Phosphorus







- No statistical differences in [IP], [OP], or P lability pools due to marsh/burn history.
- No meaningful correlations with BC burn markers either.

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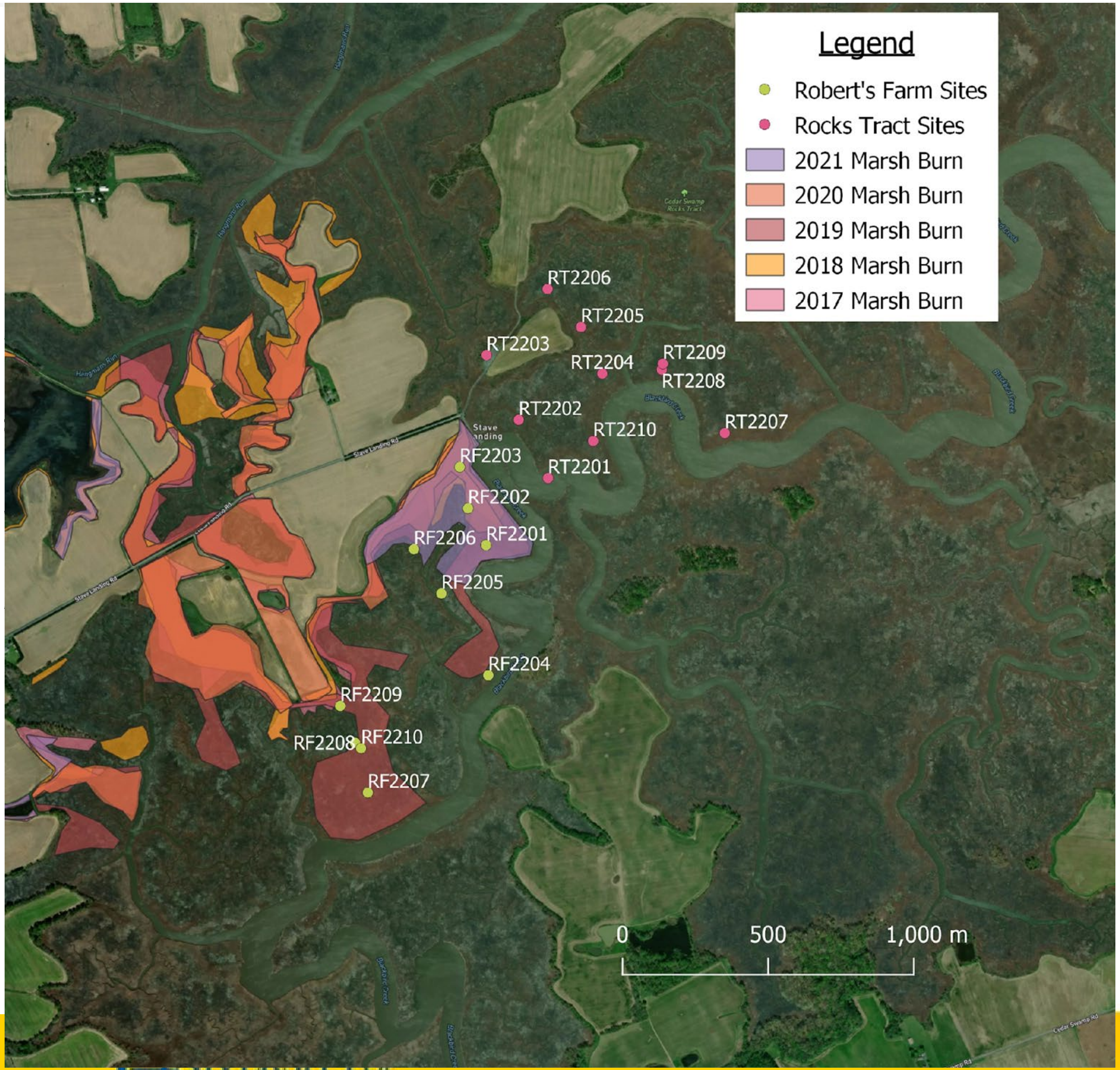
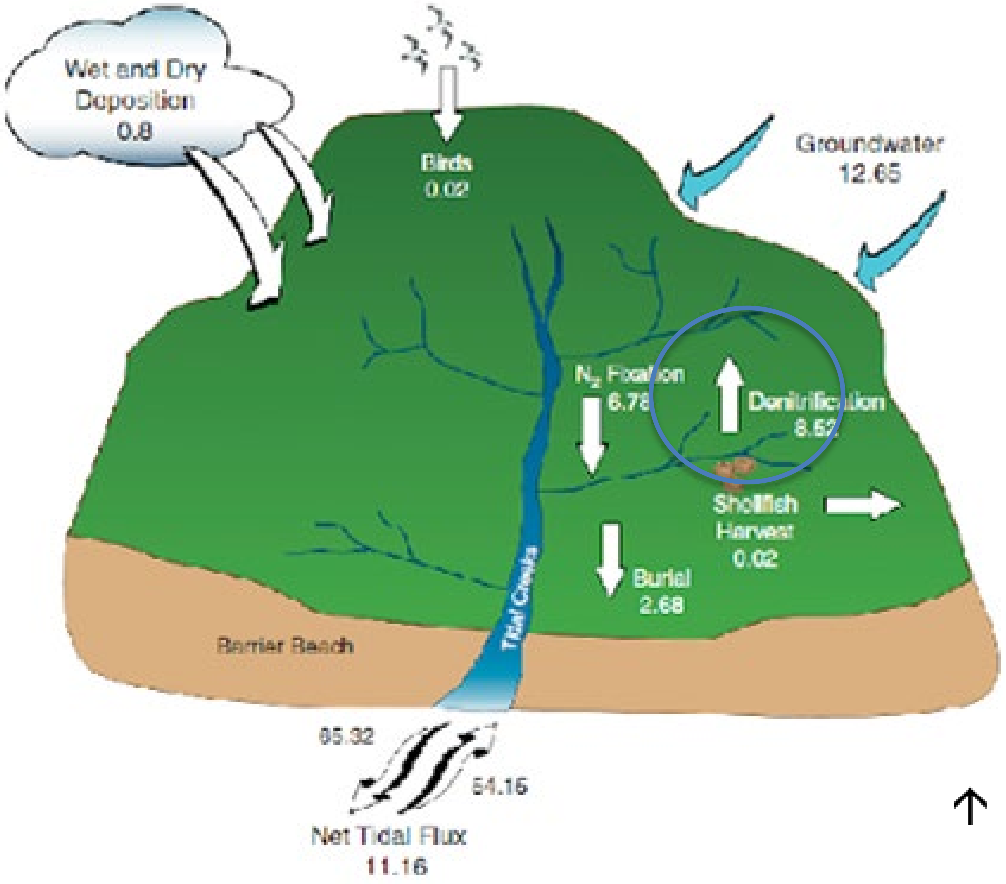
Objective 1: Summary

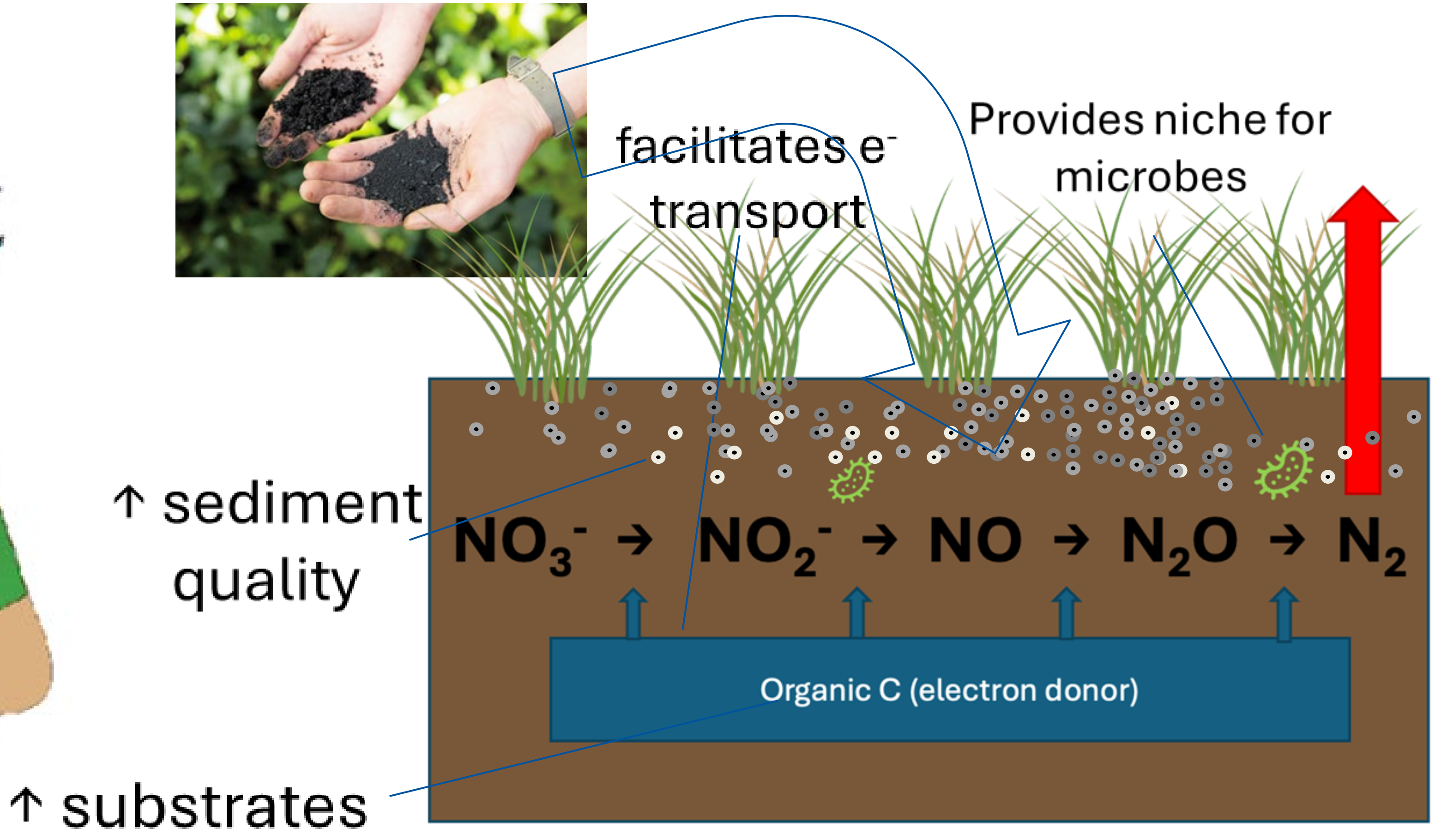


- **Burning provides potential N, C storage benefit**
  - TN, TOC, and BC are higher at burned Roberts Farm compared to unburned Rocks Tract.

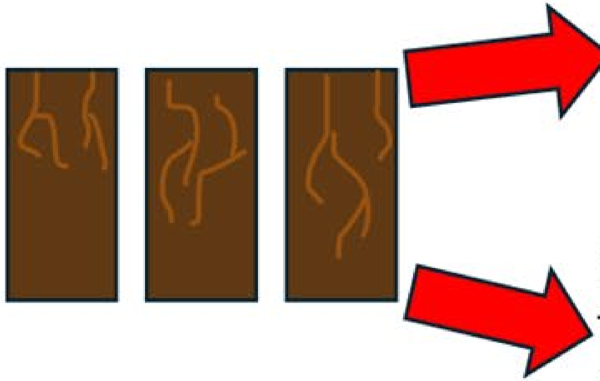
- **No apparent influence on P.**
  - Char characteristics, environmental pH, other factors at play.

Objective 2: Quantify denitrification rates (and P storage) in marsh plots with and without biochar TLP additions.





Experimental Design



Subsampled for microbial analysis

Rest of sample bagged for Denitrification potential, [P], BC, BGB ancillary measurements

May 2023 (11 months)

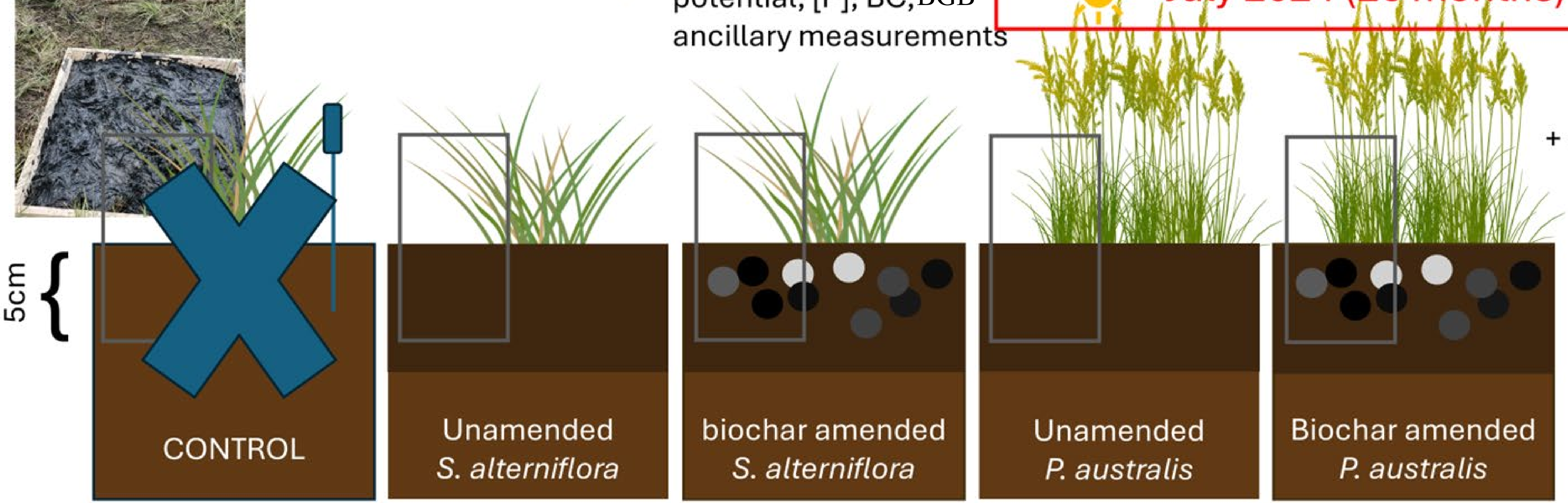
July 2023 (13 months)

October 2023 (16 months)

May 2024 (22 months)

2[nd] growing season

July 2024 (26 months)



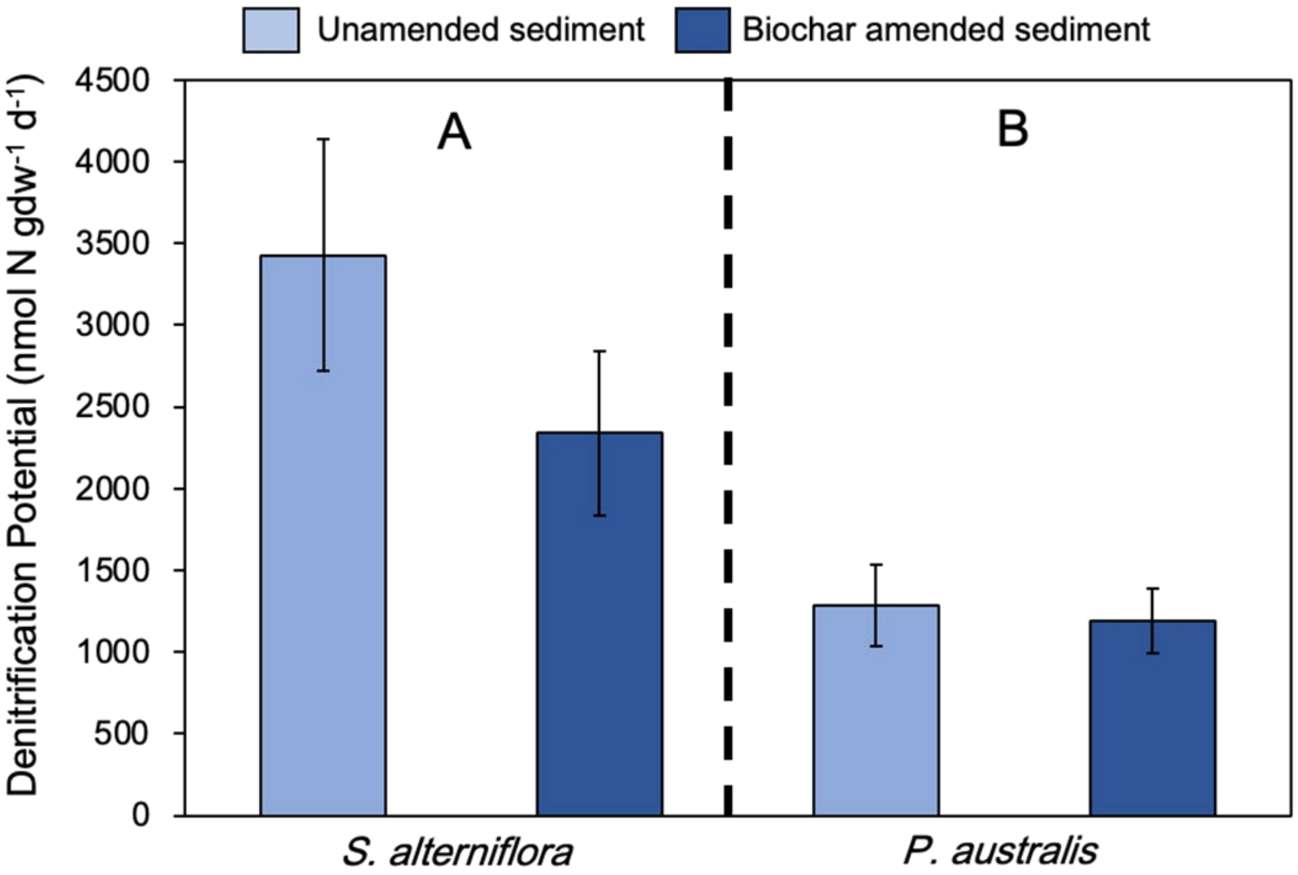
+ reference plots

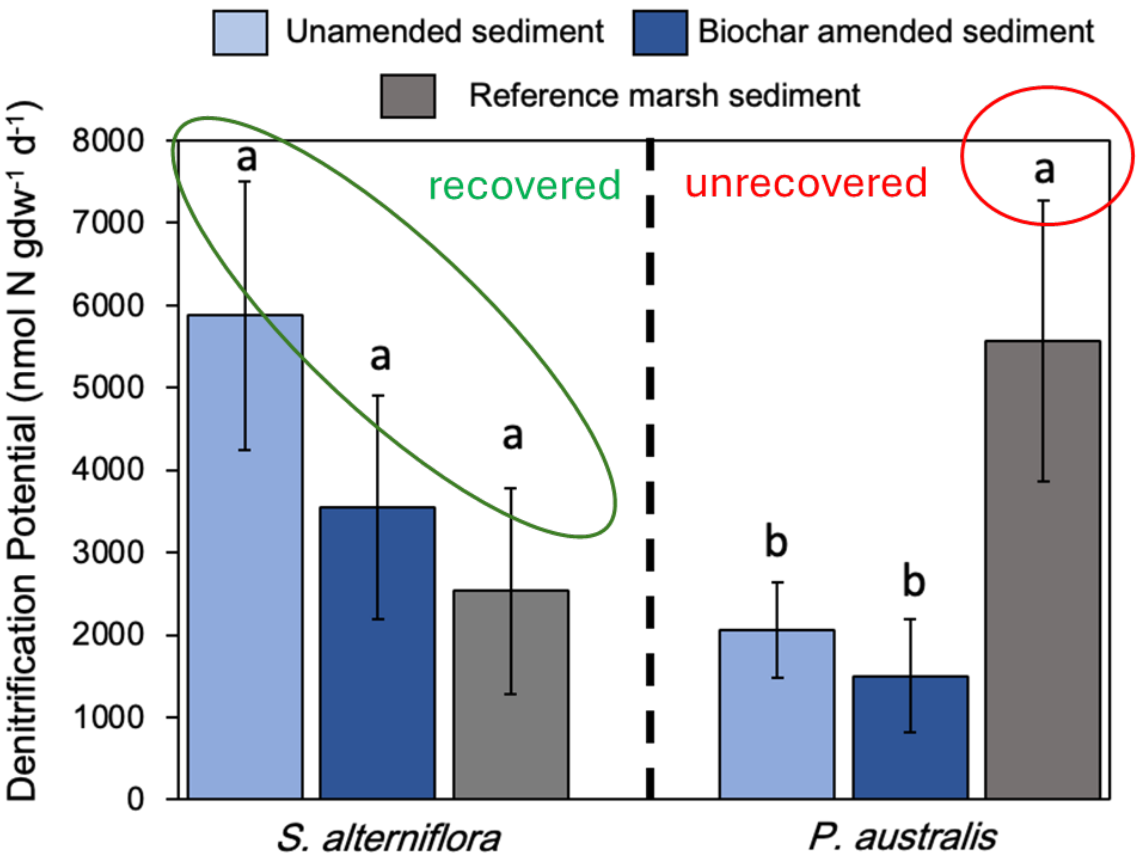
Phragmites char produced at <400 °C by Sustainable Material Solutions

Vegetation Recovery

Vegetation zone	Sediment Treatment	July 2022 (1 month)	May 2023 (11 months)	July 2023 (13 months)	October 2023 (16 months)
S.alterniflora	Unamended				
	Biochar amended				
P. australis	Unamended				
	Biochar amended				

Denitrification Potentials

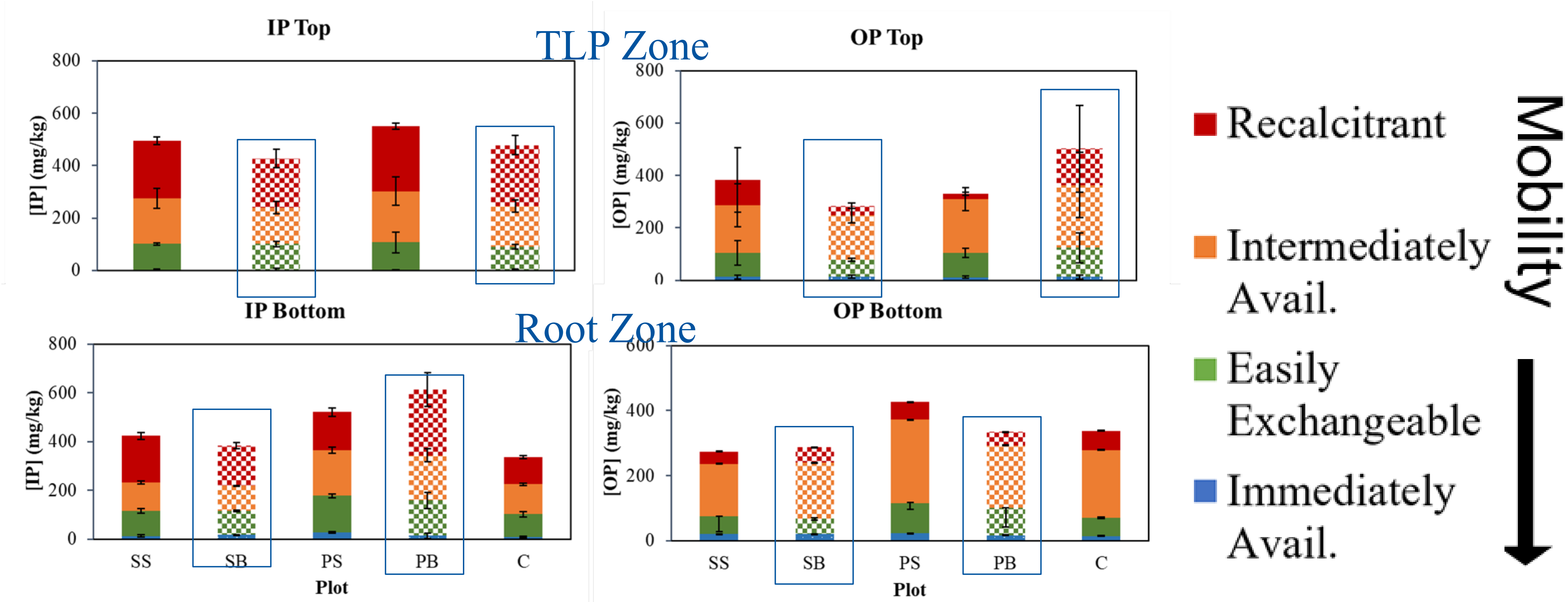




Fall 2023 (16 months after TLP)

- **Biochar did not improve denitrification potential rates.**
- Functional recovery occurred at different rates for *Phrag, Spartina*
- May 2024, July 2024 data is being analyzed.

Phosphorus in TLP Experiment

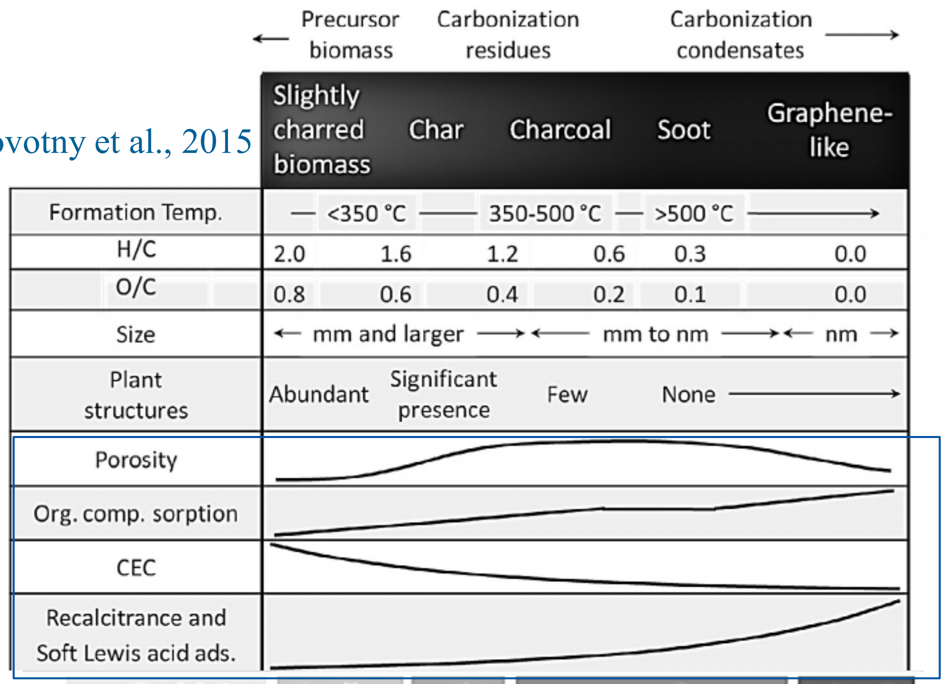


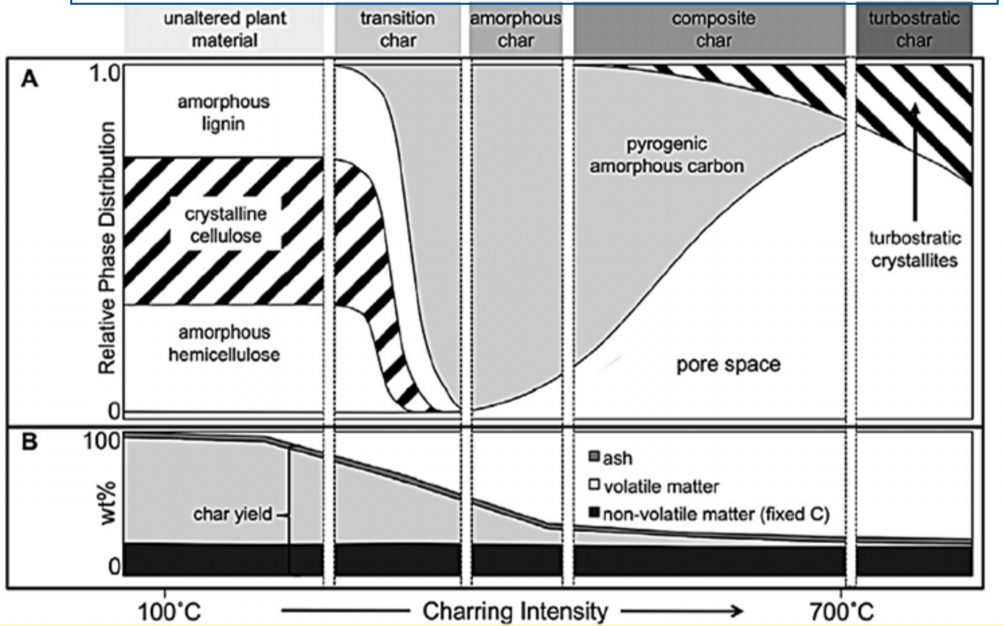
No statistical difference in P between char and no char treatments in TLP or root zone.

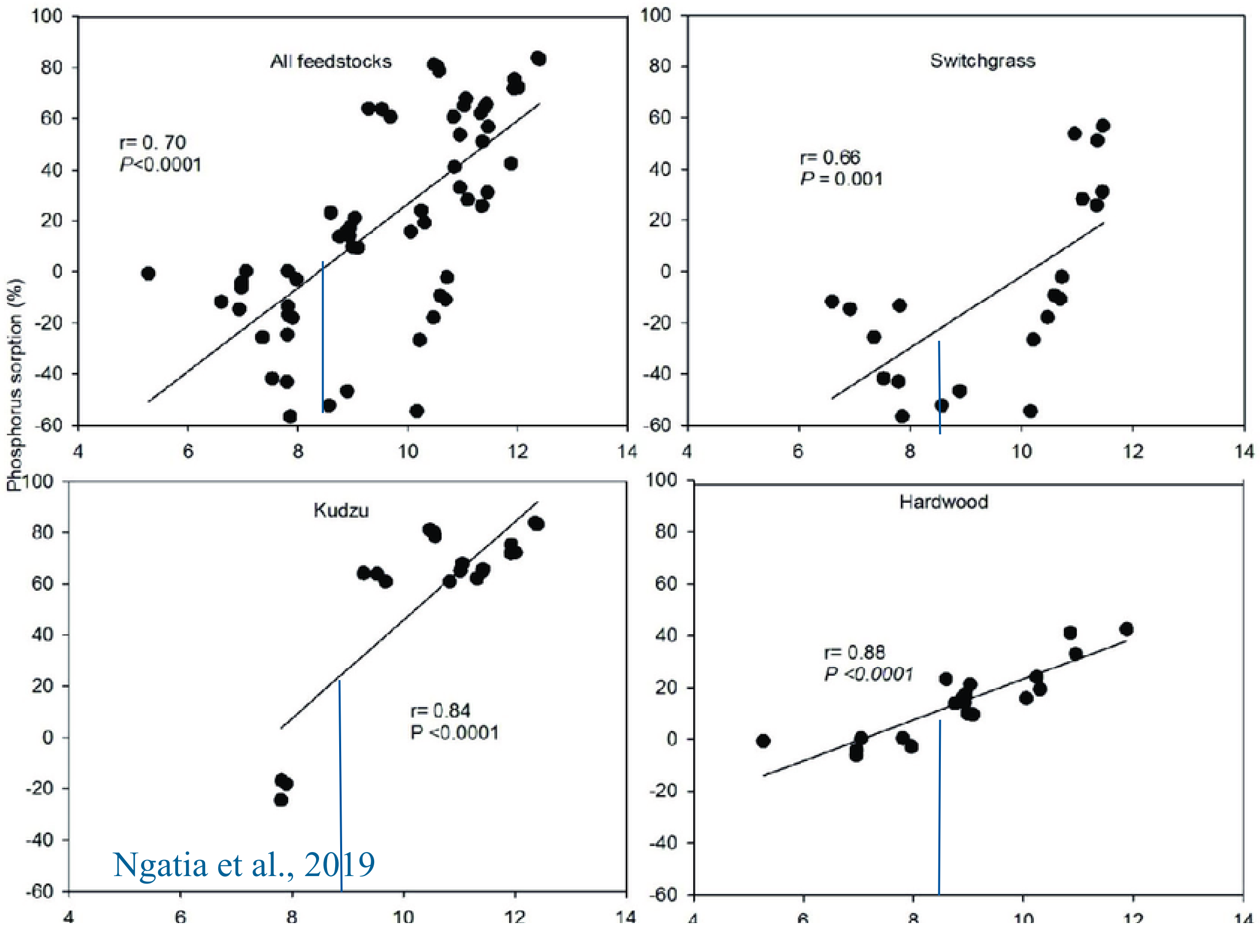
Lack of effect on P: pH? low T char?

No P sorption, denitrification benefits: *Char properties?*

Novotny et al., 2015







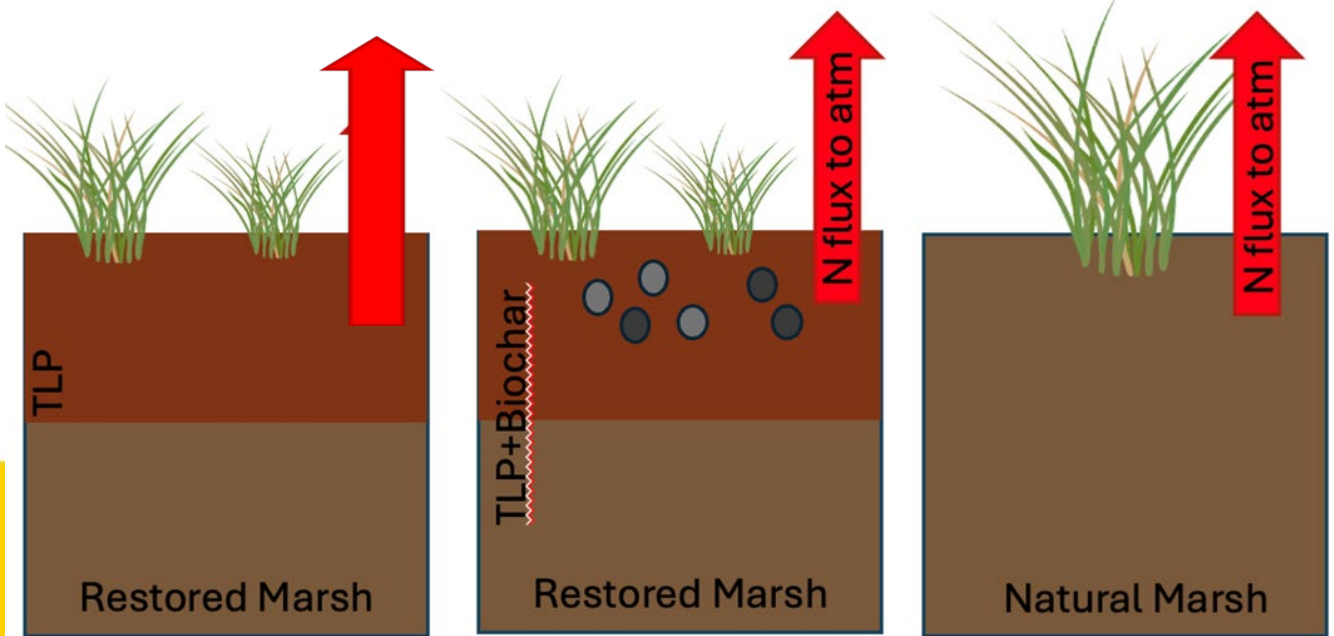
Ngatia et al., 2019

Phragmites char used in this study:

- low T (<400C) char, pH = 8.43
- 'designer' char may yield better results
- Marsh burns will be low T

Objective 2: Summary

- **Vegetation recovery matters**: denitrification potentials restored once vegetation restored.
- **Quality over quantity**: Denitrification potentials restored within 16 months with labile C + happy microbes* (data not shown)
- **Not all biochar is created equal:** physicochemical properties determine performance.
  - biochar treatments did not improve P sorption, denitrification potentials
  - designer chars may improve marsh N, P biogeochemical ecosystem services
  - marsh burns - may not produce the right char properties.



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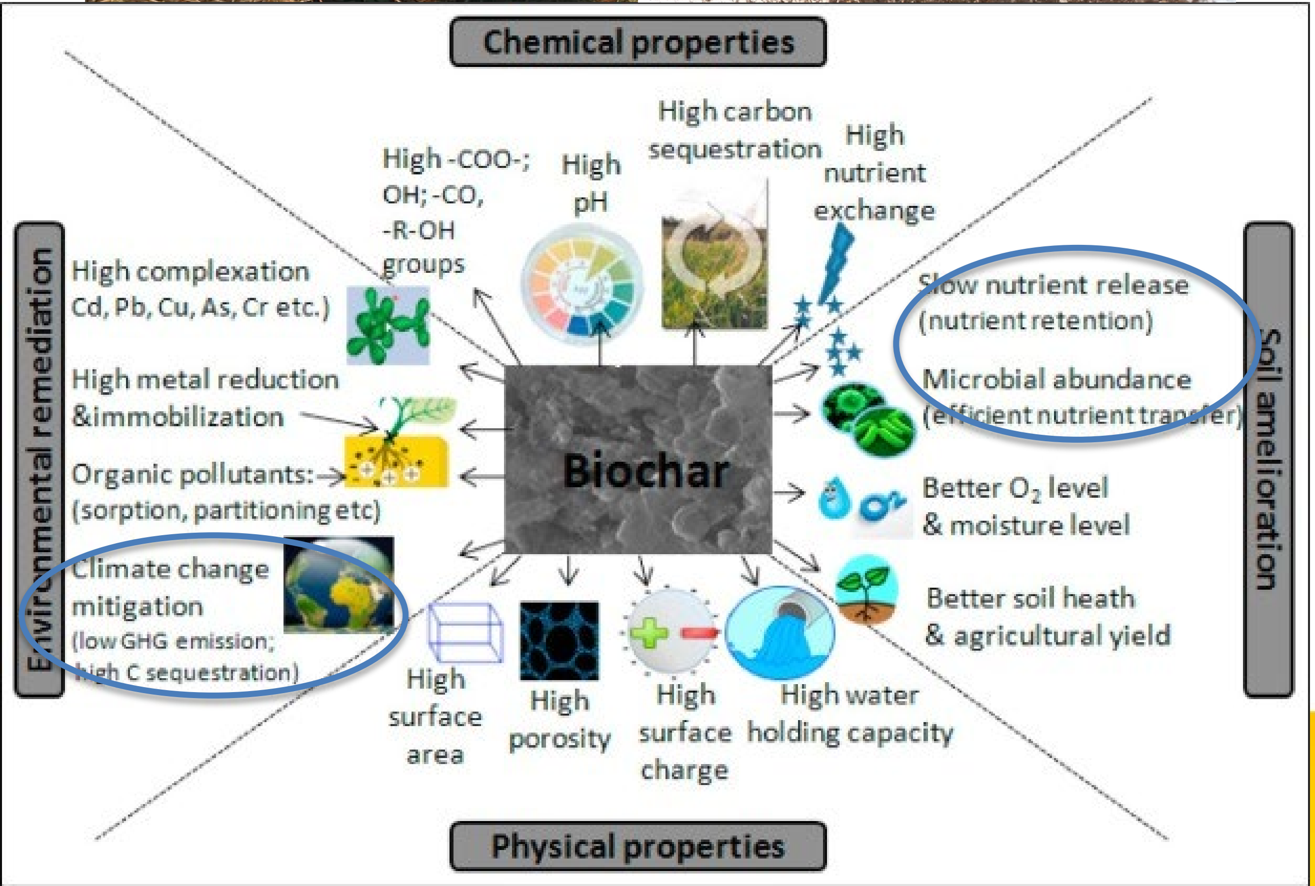
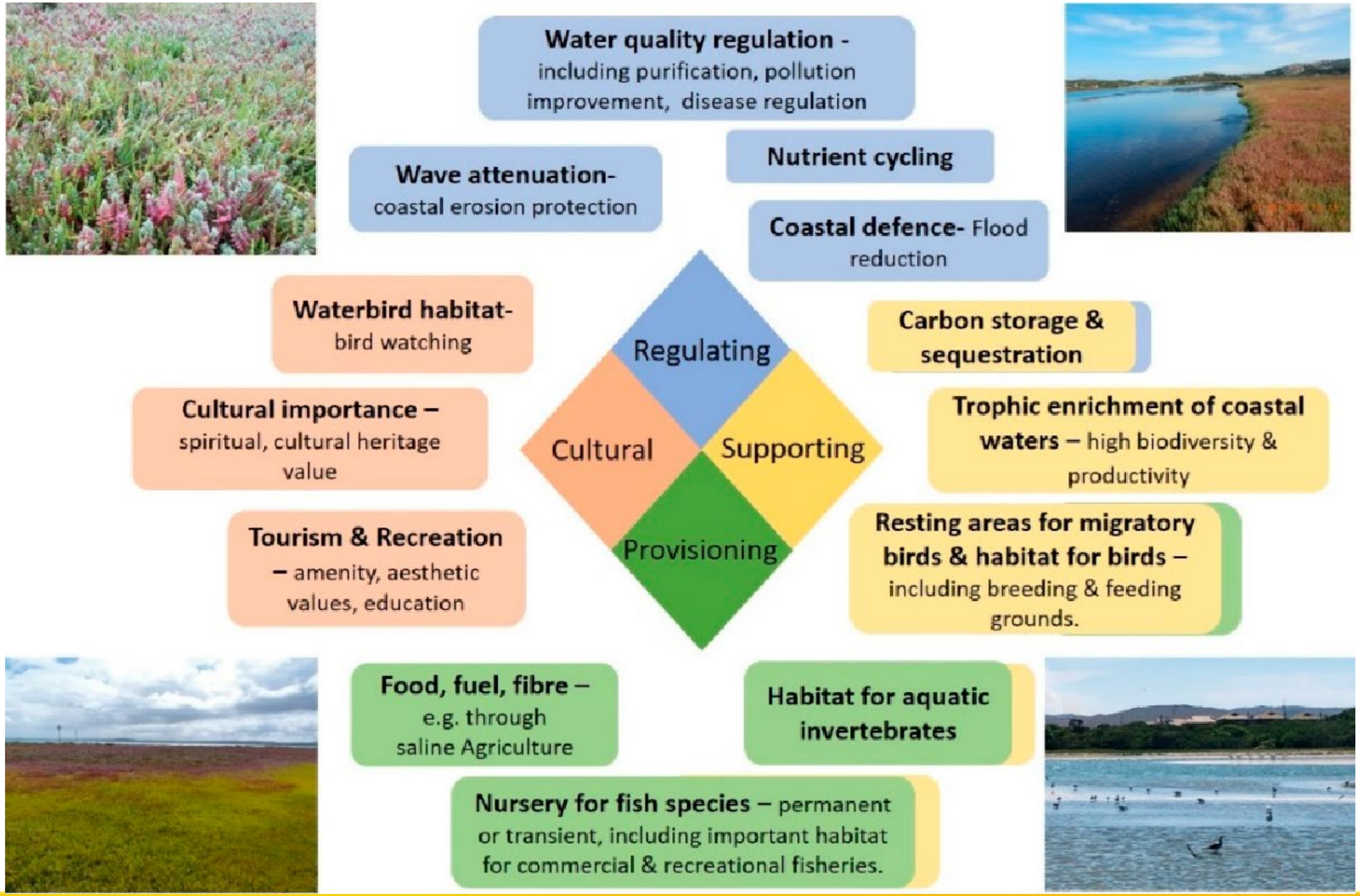


"Collaborative" Research Question:

Where do prescribed burns and biochar fit within a climate adaptive restoration framework for Delaware (and beyond)?

Salt Marsh Ecosystem Services



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Adams et al., 2021

Technical Document

- Being drafted based on outline from Oct. ‘22 workshop
- Audience – tidal marsh management community
- Working draft distributed Fall ‘23;
  - Edits, comments, suggestions from BiMRAC in Winter ‘24
- Document to be finalized following Fall ‘24 Workshop

Goals & Objectives

- Seek to place the role of prescribed burns into a climate-adaptive tidal marsh restoration framework.
- Assess the state of knowledge of the effect of tidal marsh restorations that employ prescribed burns on ecosystem service categories identified as important to end users within the state of Delaware.
- Intends to be of value to land managers and policy makers exploring solutions for marshes impacted by *Phragmites* invasion and who may consider the use of burns for *Phragmites* removal.

Methodology

- Comprehensive literature review of studies on ecosystem services likely to be impacted by *Phragmites* burning
  - Emphasis on Delaware and Mid-Atlantic studies as possible
- Assigned grades to each ecosystem service based on existing literature in terms of:
  - Impact of *Phragmites* burning/removal
  - Confidence of impact score
  - Priority for future research

Prescribed Burn Matrix

Ecosystem Service	Effect (+,-,0,?)	Degree of Certainty (0-3)	Priority for Research (1-3)	Relevant Citation
Biogeochemical				
Physical				
Recreational				
Biological				
Economic				

Grading Scale for Impact Scores

Score	Description	Reasoning
-	negative impact	Available data displays clear, net negative impacts on the service of interest.
+	positive impact	Available data displays clear, net positive impacts on the service of interest.
0	inconclusive data	Available data displays both positive and negative impacts, or no conclusive impacts on the service of interest.
?	unknown impact	There is no data currently available that sufficiently explains the impact on the service of interest.

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Grading Scale for Confidence Levels

Confidence Level	Description	Reasoning
1	Not Confident	Little to no data is available on the service of interest. Little to no regional specific data as well as prescribed burn related data is available and as well.
2	Confident	Sufficient data is available on the service of interest. Regional and prescribed burn specific data on the service of interest may be available as well
3	Very Confident	Sufficient data is available. Regional and prescribed burn related data on the service of interest is available as well.

Biogeochemical

- Nitrogen cycling – water quality
  - -/3
- Phosphorus Cycling – water quality
  - 0/2
- Pollutant removal – water quality
  - +/2
  - Critical Research Need:
    - Regional data
    - Burn data
- Carbon Storage
  - 0/3
- Greenhouse Gas Emissions
  - -/2
  - Non Critical Research Need
    - Regional data

Biological

- Native Vegetation
  - +/2
- Invertebrates
  - +/2
- Fish
  - +/2
- Birds
  - +/3

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Physical

- Sedimentation
  - -/2
- Elevation changes
  - 0/2
- Hydrology
  - ?/1
  - Critical Research Need:
    - Regional data
    - Burn data
- Coastal resilience
  - 0/1

Recreational

- Ecotourism
  - +/1
- Outreach/Education
  - ?/1
- Hunting
  - +/1
- Fishing
  - ?/1
- Critical Research Need (all categories):
  - General data
  - Regional data
  - Burn data

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Cultural

- Connection to the land
  - ?/1
- Spiritual
  - ?/1
- Critical Research Need (all categories):
  - General data
  - Regional data
  - Burn data

Economical

- Biogeochemical – Carbon + Nitrogen Markets
  - ?/1
- Biological – Hunting
  - ?/1
- Recreational – Ecotourism
  - ?/1
- Physical – Flood Insurance
  - ?/1
- Critical Research Need (all categories):
  - General data
  - Regional data
  - Burn Specific data

Recommendations

- Increase monitoring of the combined effects of prescribed burns and other *Phragmites* management methods
- Increase long term monitoring (5-10 years) to account for lags in recovery time post-burn
- Increased public education on how *Phragmites* presence versus removal may impact valuation and utilization of marsh systems
- Assess public's willingness to pay for conversion of *Phragmites* to native vegetation

Challenges & Assumptions

- Does not consider changes across spatial & temporal scales
- Climate change, anthropogenic disturbances, sea level rise, marsh drowning, etc.
- Assessment is based on available scientific study & evidence
- Anecdotal and qualitative evidence has lower score for certainty
- Scores are based on the net and may carry a level of error
- We account for the concomitant impacts of herbicide application alongside prescribed burns when assigning these scores.

Acknowledgements

- NOAA/NERRS Science Collaborative - Maeghan Brass and team
- Wozniak Research Team - Pam Edris, Emma Leaseburg, Chris Kelly, Alina Ebling, Kyle Krezdorn, Jacob Ukropec, Jackalyn Wyrobek
- DNERR Team - Lynne Pusey, Mollie Yacano, Taylor Beck, Kari St. Laurent, Jenn Holmes

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