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science for a changing world

Saltwater Intrusion Impacts on Coastal Landscapes

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U.S. Geological Survey

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Overview of salinization impacts in coastal ecosystems

Coastal systems impacted:

Salt + Flood stress

1. Uplands
   a. Forest
   b. Agriculture
   c. Infrastructure

Salt stress

2. Wetlands
   a. Tidal fresh
   b. Saline

Coastal impacts on:

1. Vegetation
2. Soils and Microbial biogeochemistry
3. Animals

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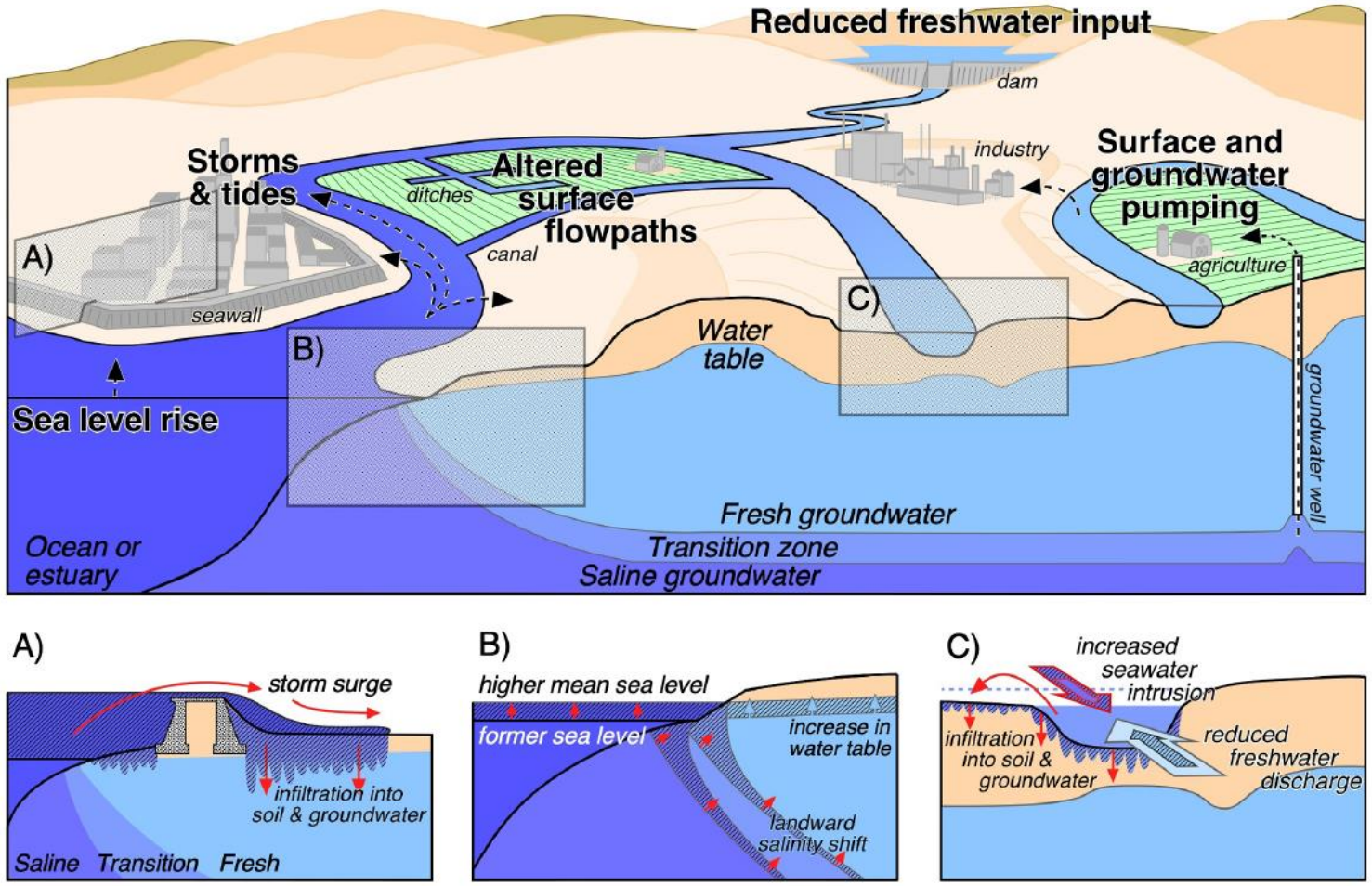
Causes of coastal salinization: "Over, Under, and Through"

Sea level rise, extreme weather (droughts and storms), groundwater pumping, and

human modifications to coastal waterways (ditching, tidal gates, dredging)

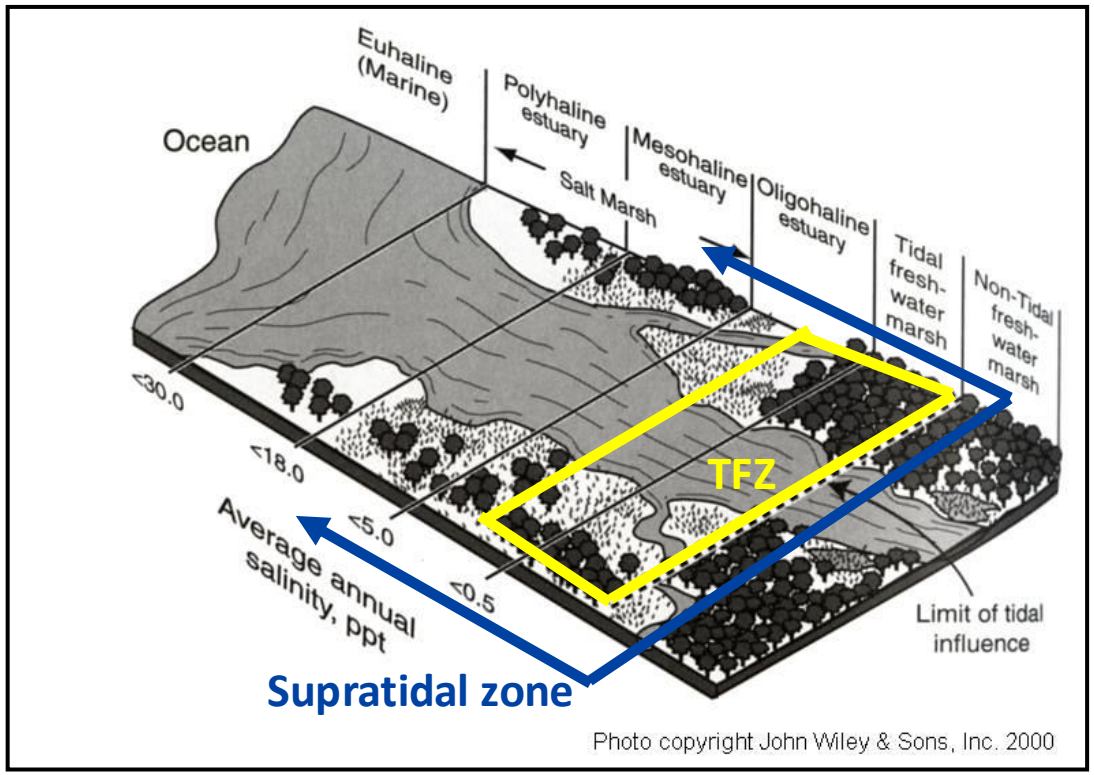
all interact to drive complex patterns of seawater intrusion

AGU ADVANCING EARTH AND SPACE SCIENCES
Water Resources Research
10.1029/2024WR038720

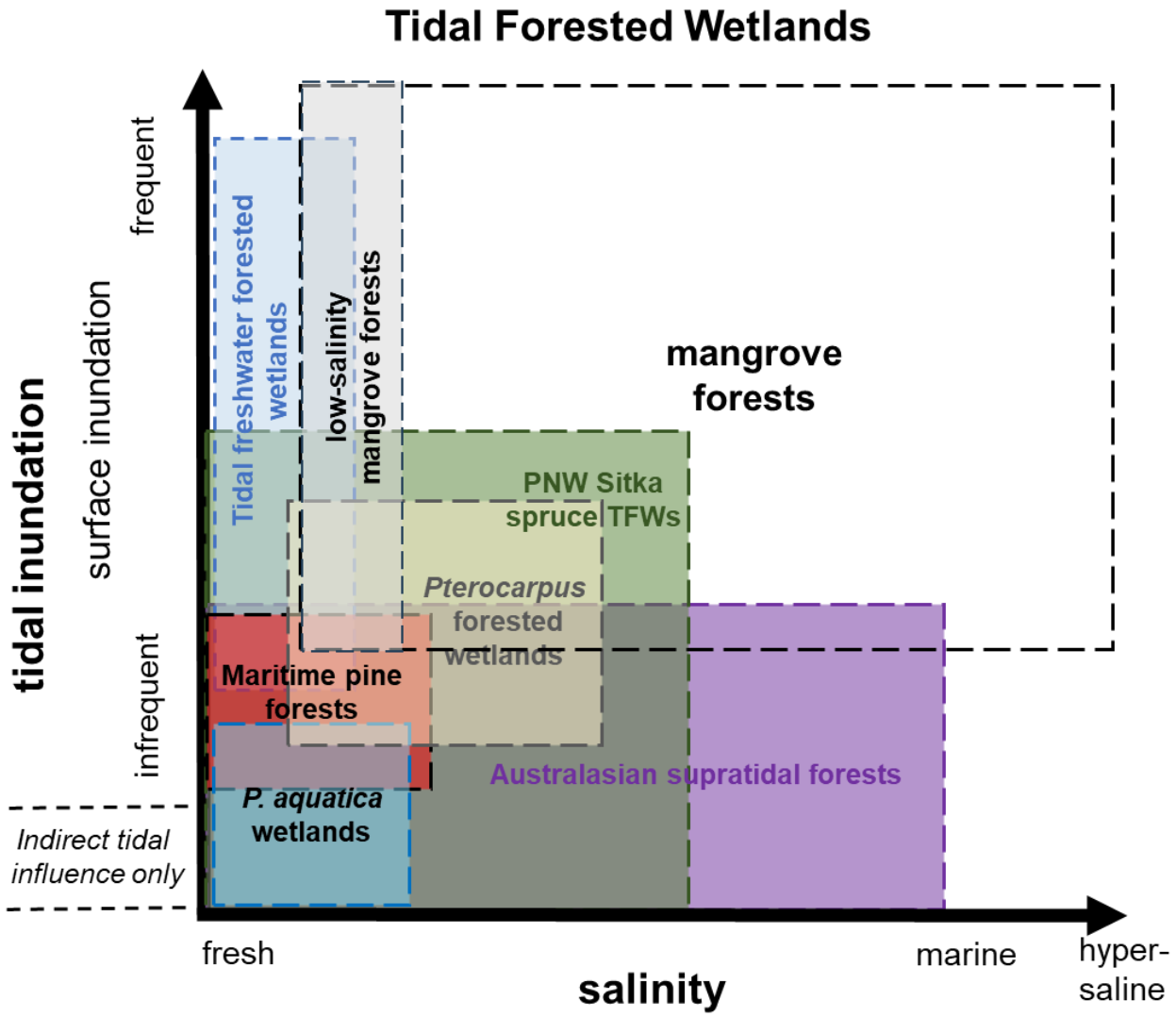


Helton et al. 2025 | *WRR*

Estuarine gradients: inundation and salinity distributions



Mitsch & Gosselink 2000



Kelleway et al. in revision | *Ecol. Mon.*

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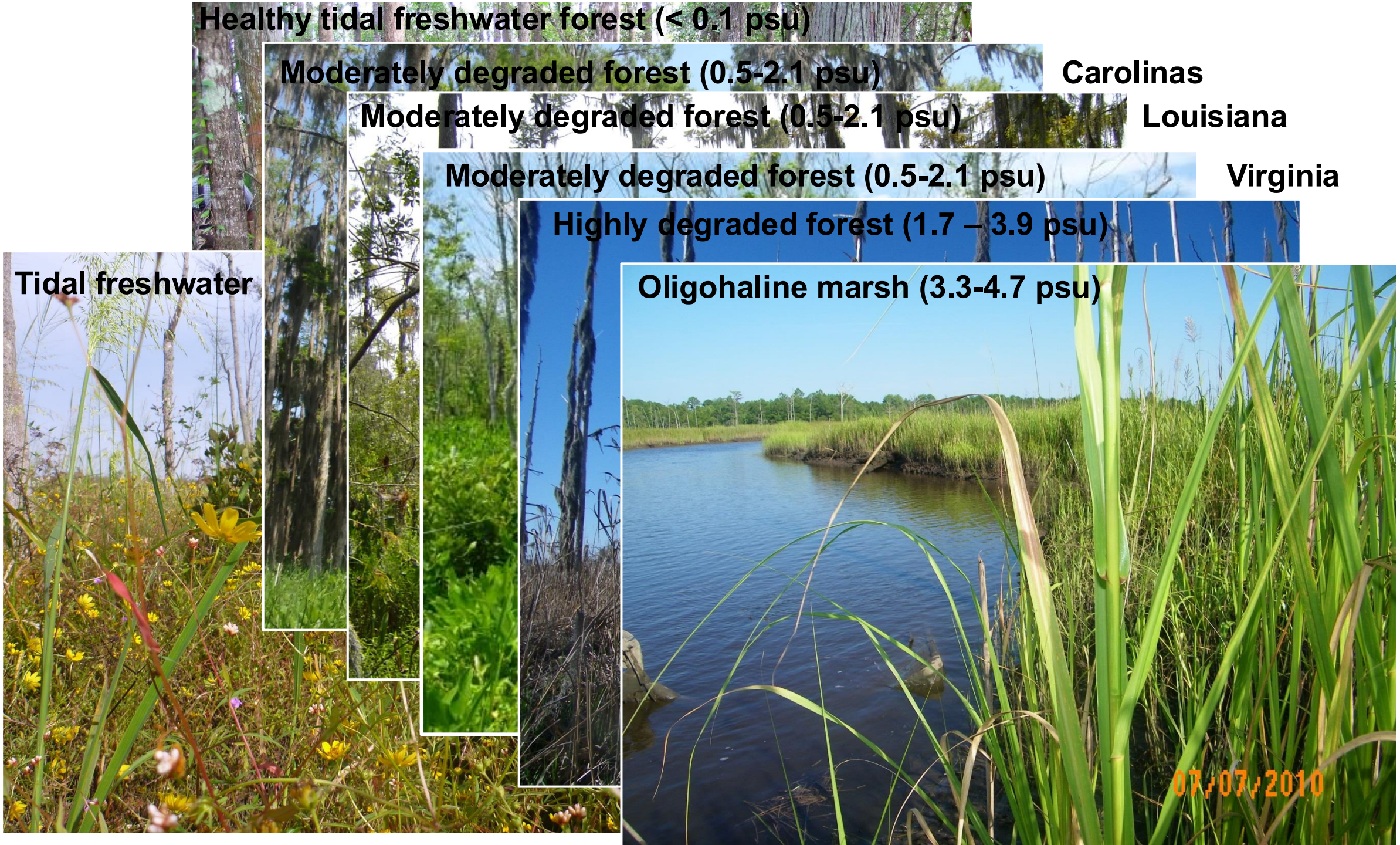
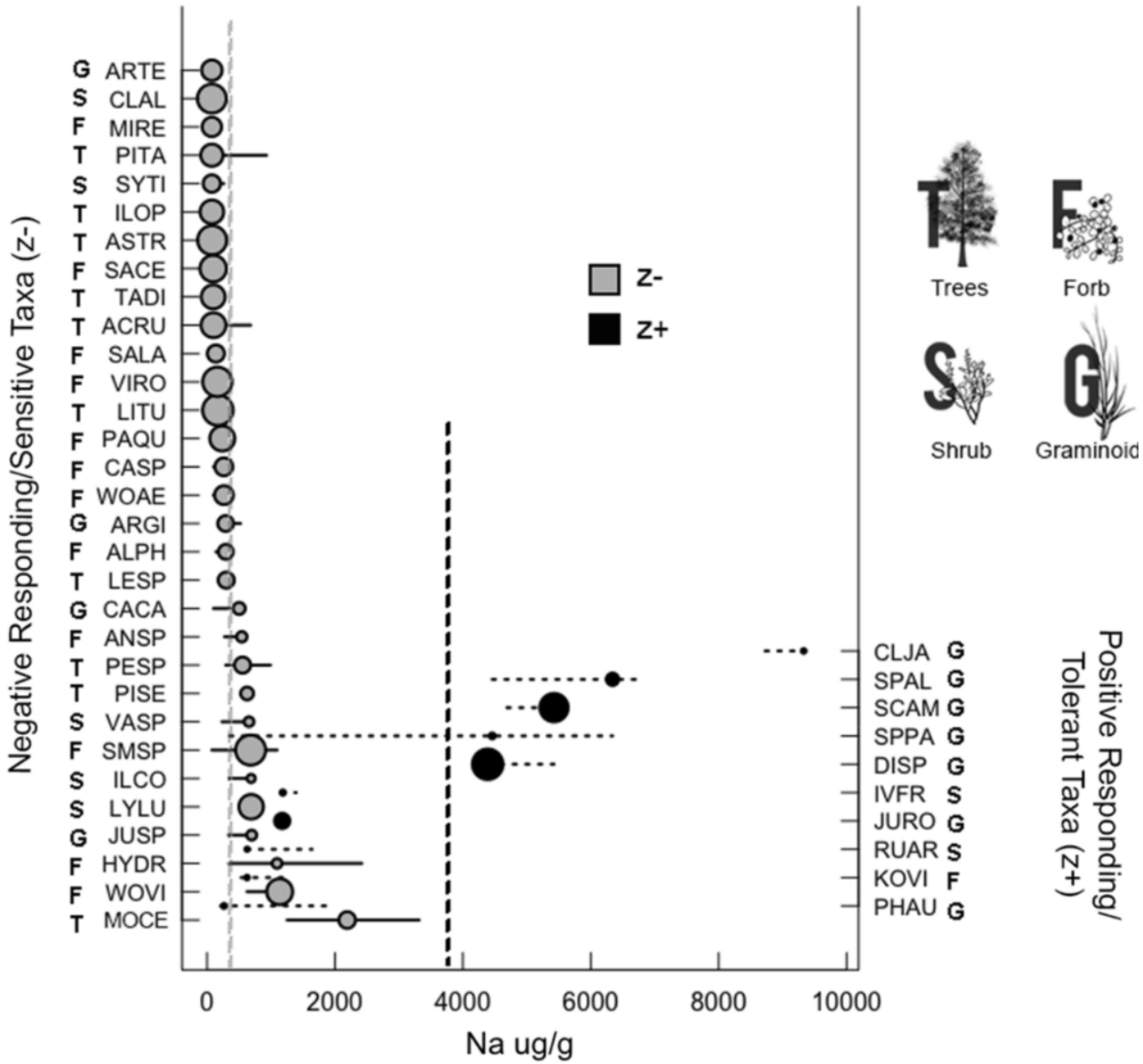
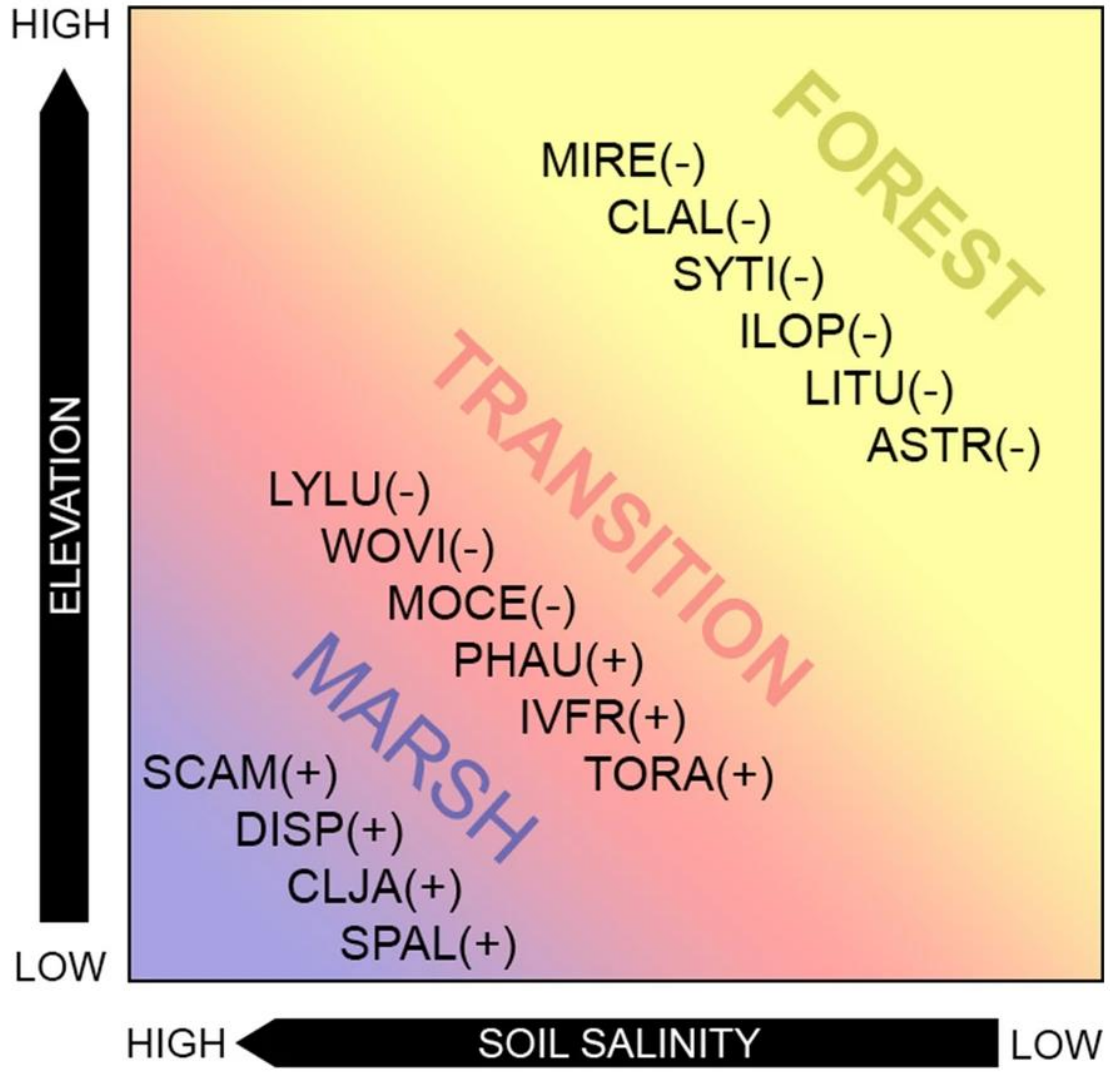

Healthy tidal freshwater forest (< 0.1 psu)
Moderately degraded forest (0.5-2.1 psu)
Carolinas
Moderately degraded forest (0.5-2.1 psu)
Louisiana
Moderately degraded forest (0.5-2.1 psu)
Virginia
Highly degraded forest (1.7 – 3.9 psu)
Tidal freshwater
Oligohaline marsh (3.3-4.7 psu)
07/07/2010

Vegetation changes: salinity gradients structure tidal wetlands

From: Salinity thresholds for understory plants in coastal wetlands





Anderson et al. 2022 | *Plant Ecology*

Biogeochemical changes: saltwater intrusion … pulse vs. press

Weston et al. 2006 | JGR	increased nutrient release, decreased methanogenesis and a rapid shift to sulfate reduction, with a coincident increase overall organic matter mineralization
Weston et al. 2010 | Biogeochemistry	stimulates microbial decomposition, accelerates the loss of organic C from TFM soils, and may put TFMs at risk of permanent inundation.
Neubauer et al. 2013 | Biogeosciences	affects the entire process of carbon mineralization, from the availability of organic carbon through its terminal metabolism to CO2 and/or CH4
Neubauer et al. 2018 | Ecosystems	reduces the … [conversion of] reactive nitrogen to dinitrogen gas
Herbert et al. 2018 | Biogeochemistry	reduced C fixation and the potential for increased nutrient (N, P) export

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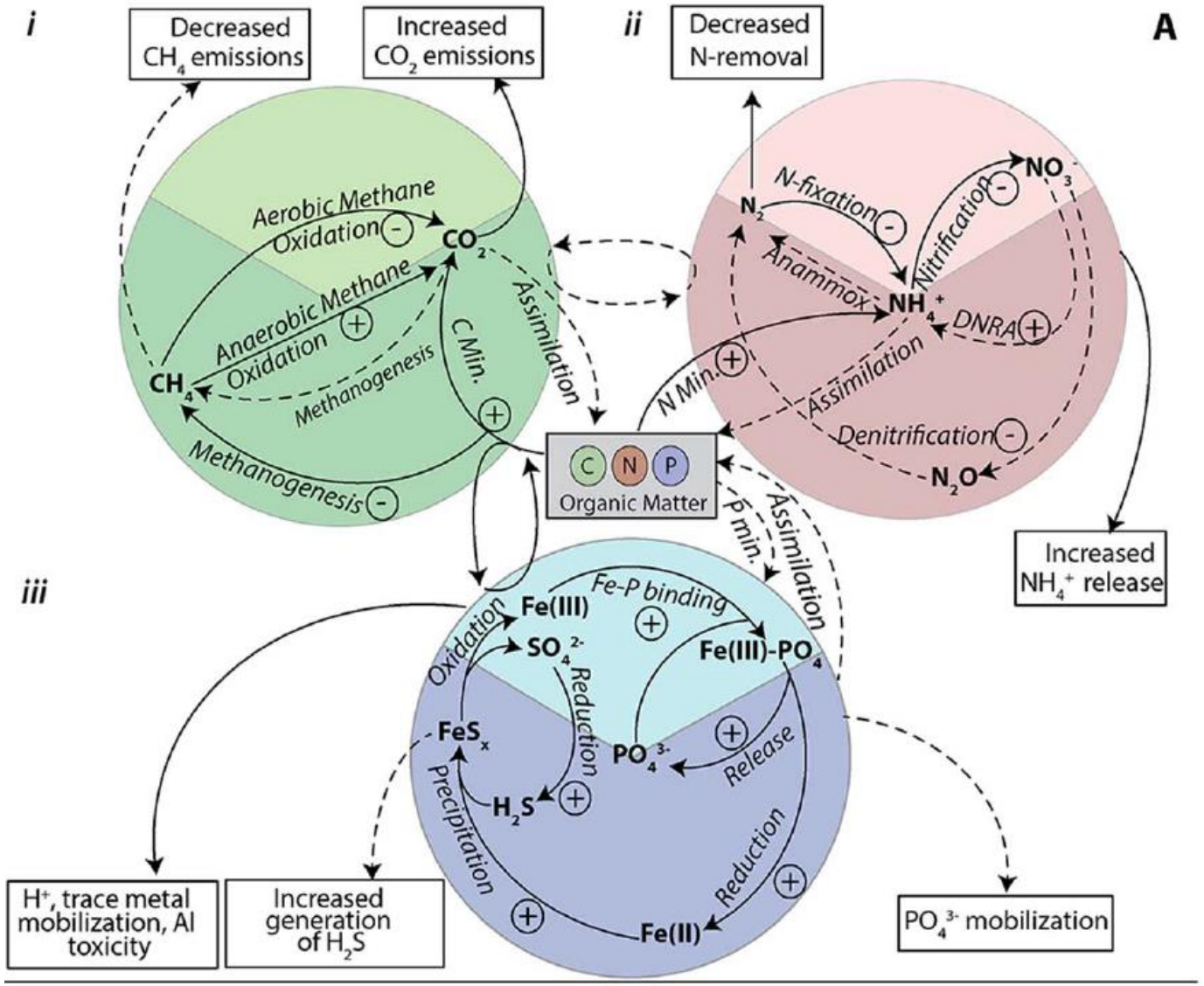
Biogeochemical changes: ion exchange, alternative electron acceptors, microbes



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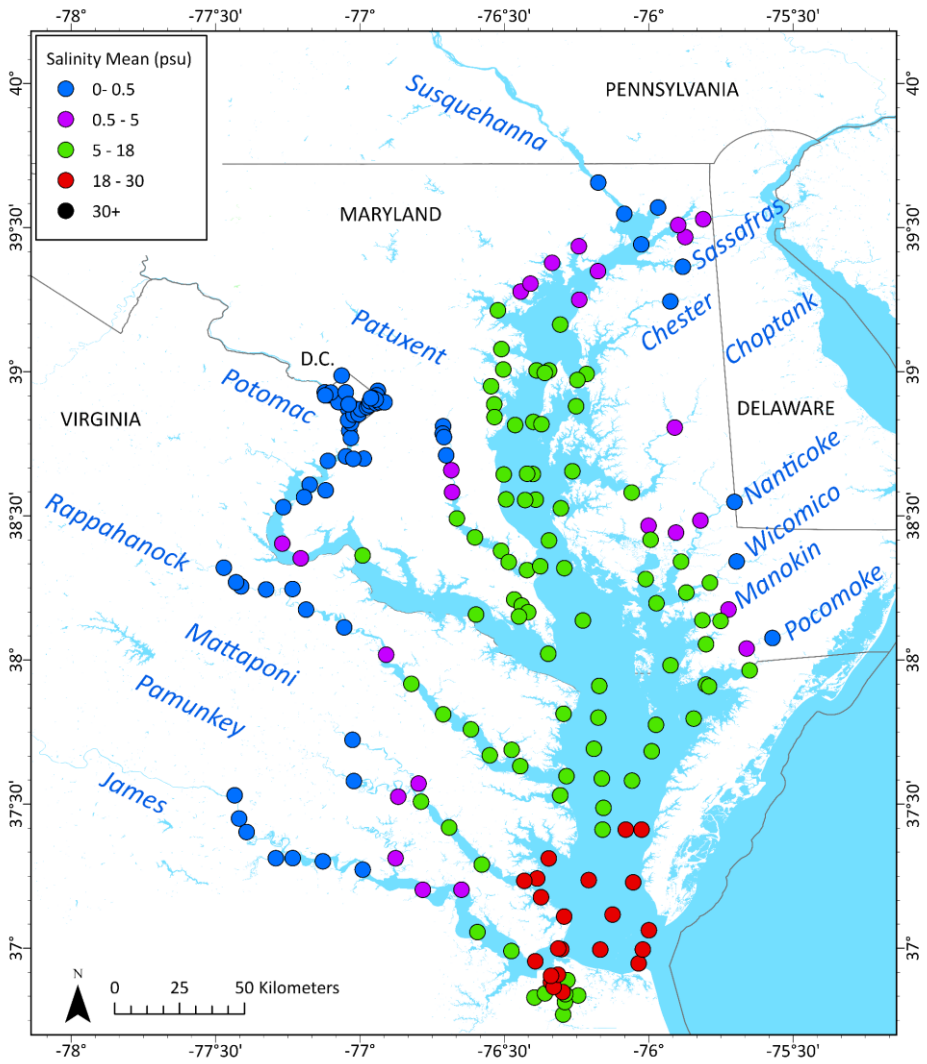
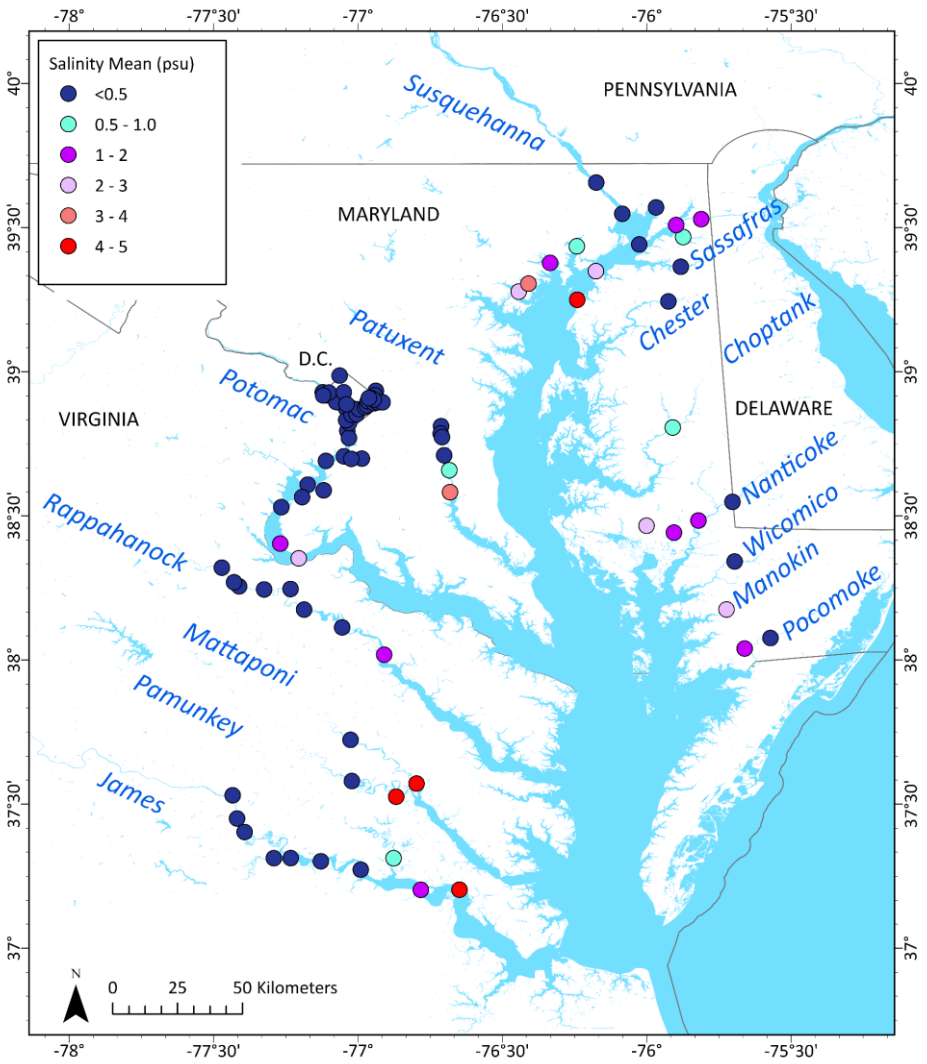
Herbert et al. 2015 | *Ecosphere*

Chesapeake Bay Program (CBP) long-term data (1984-current)





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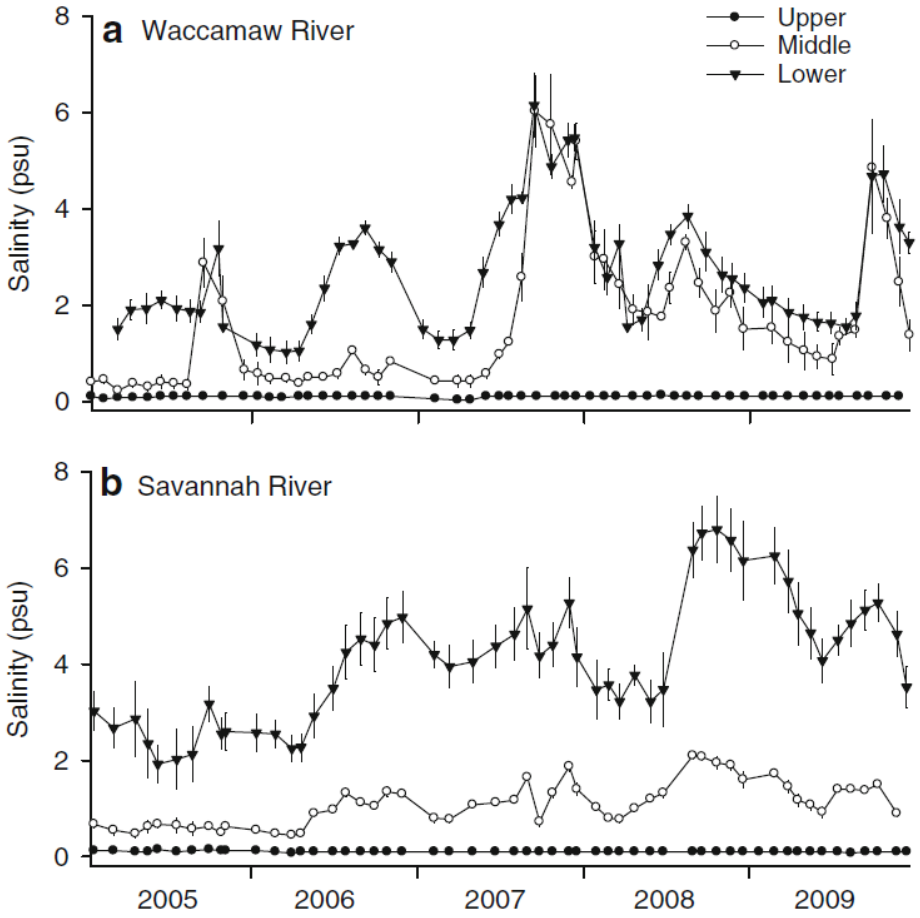
adapted from Noe et al. 2026 | *ECSS*

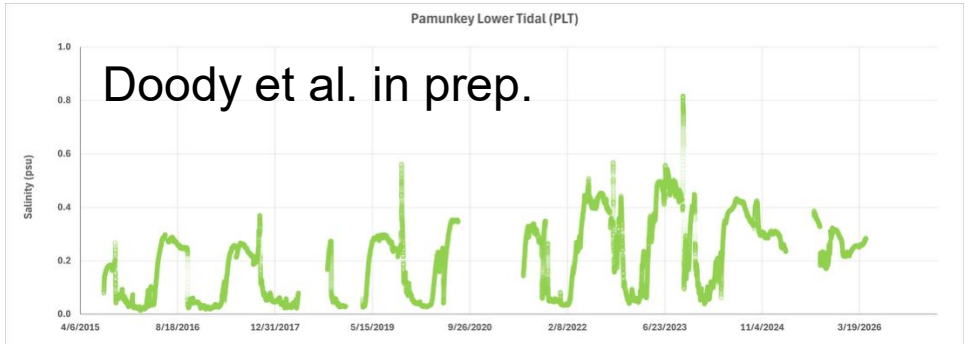
TFZ salinization patterns

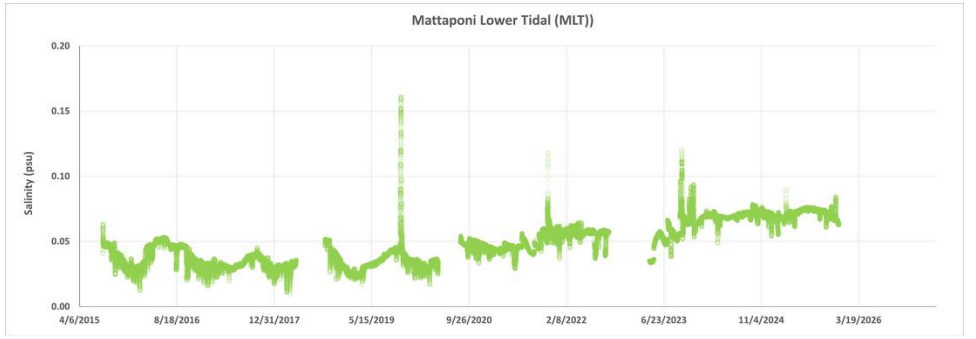


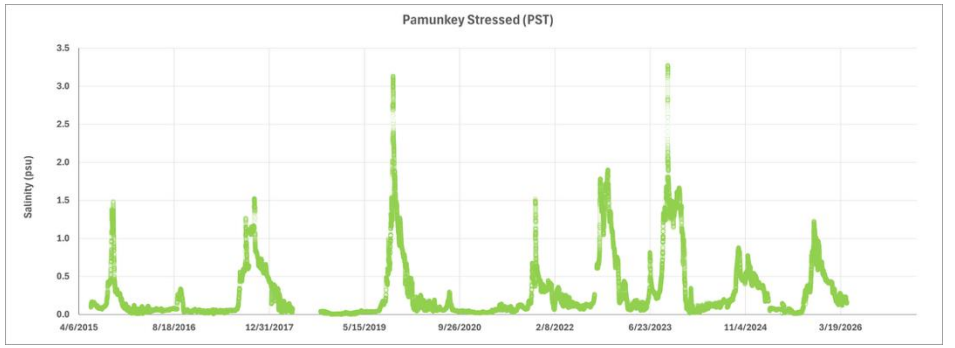
Cormier et al. 2012 | *Estuaries & Coasts*

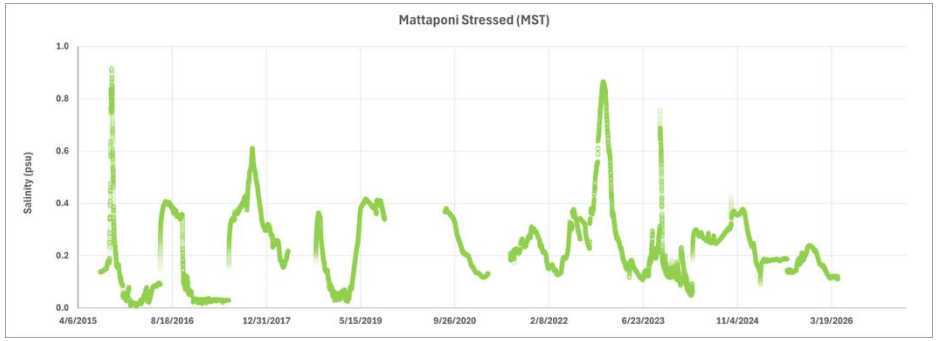
Doody et al. in prep.

PSU	Mattaponi	Pamunkey
Nontidal	0.0	0.4
Upper TFFW	0.1	0.3
Lower TFFW	0.1	0.2
Stressed TFFW	0.2	0.3
Oligohaline marsh	1.4	2.2









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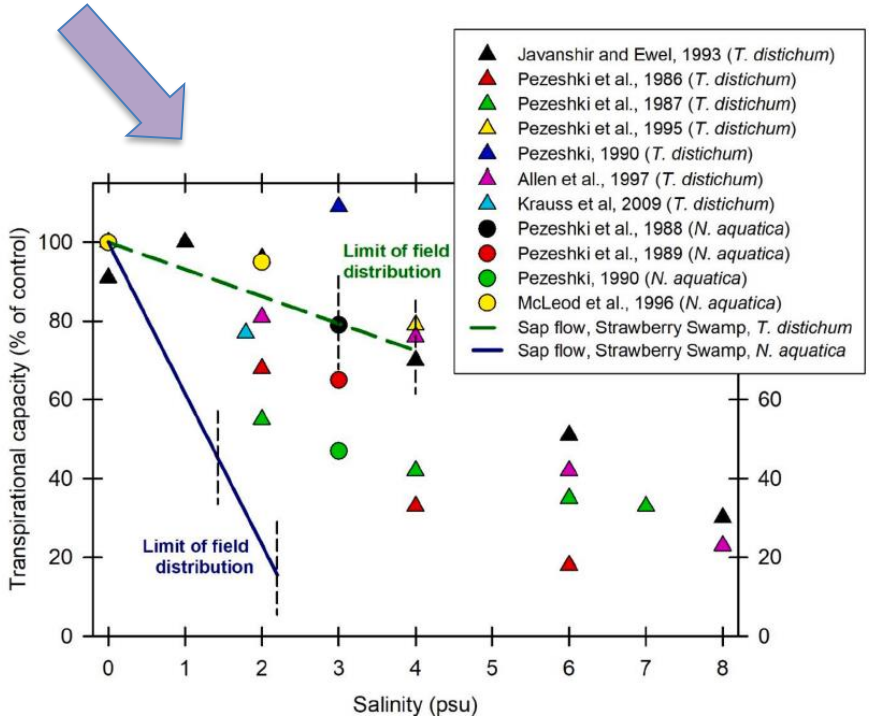
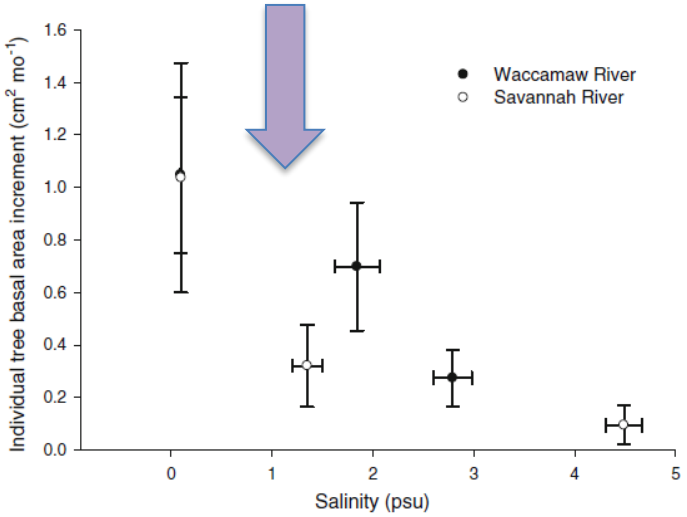
Vegetation changes: tidal freshwater tree salinity thresholds

Field thresholds < Lab thresholds

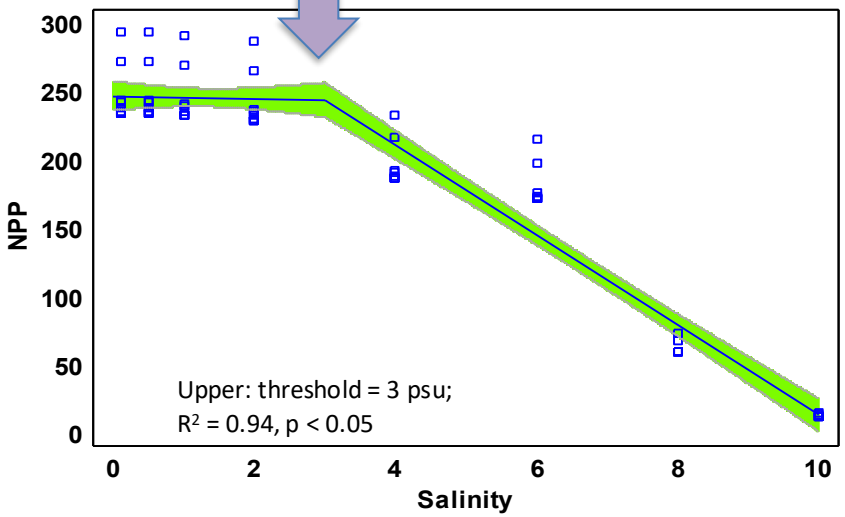


Duberstein et al. 2020 | *Forest Ecol. & Man.*

Cormier et al. 2012 | *Estuaries & Coasts*



soil salinity of 2-3 psu is the tipping point for ecosystem level functional changes in low salinity tidal swamp forests.



Wang et al. 2023 | *Ecol. Appl.*

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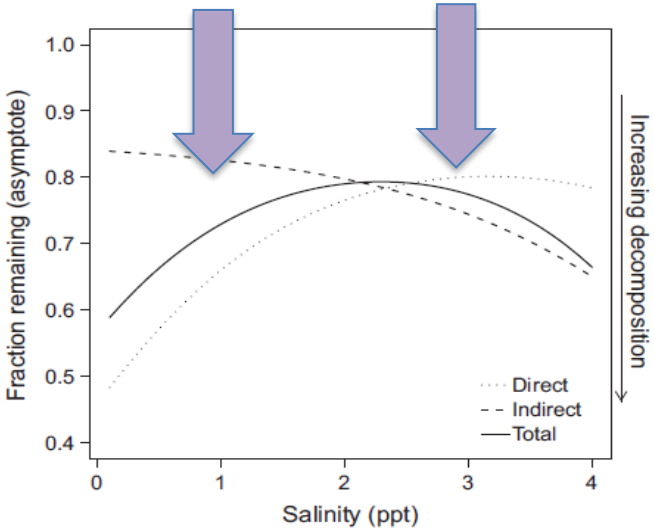
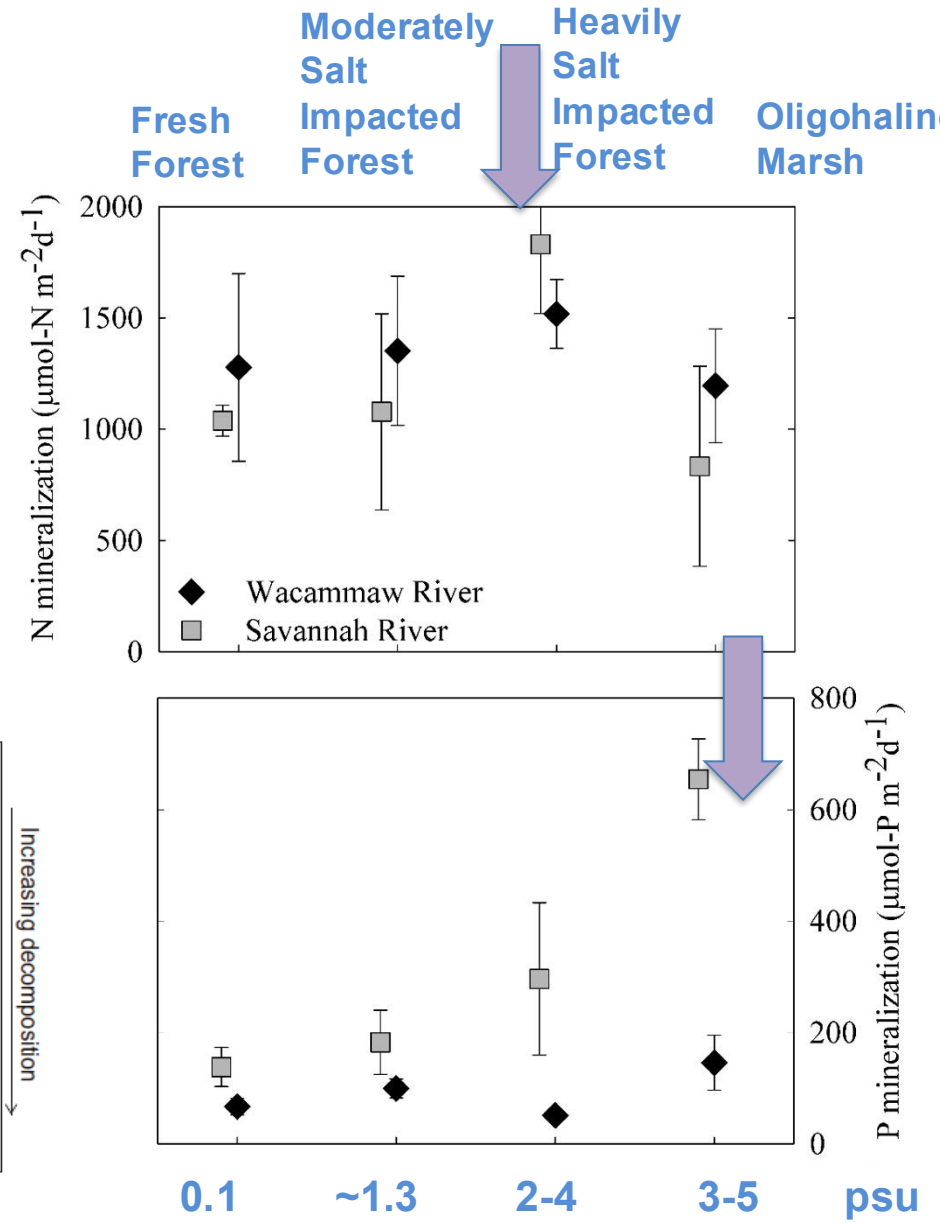
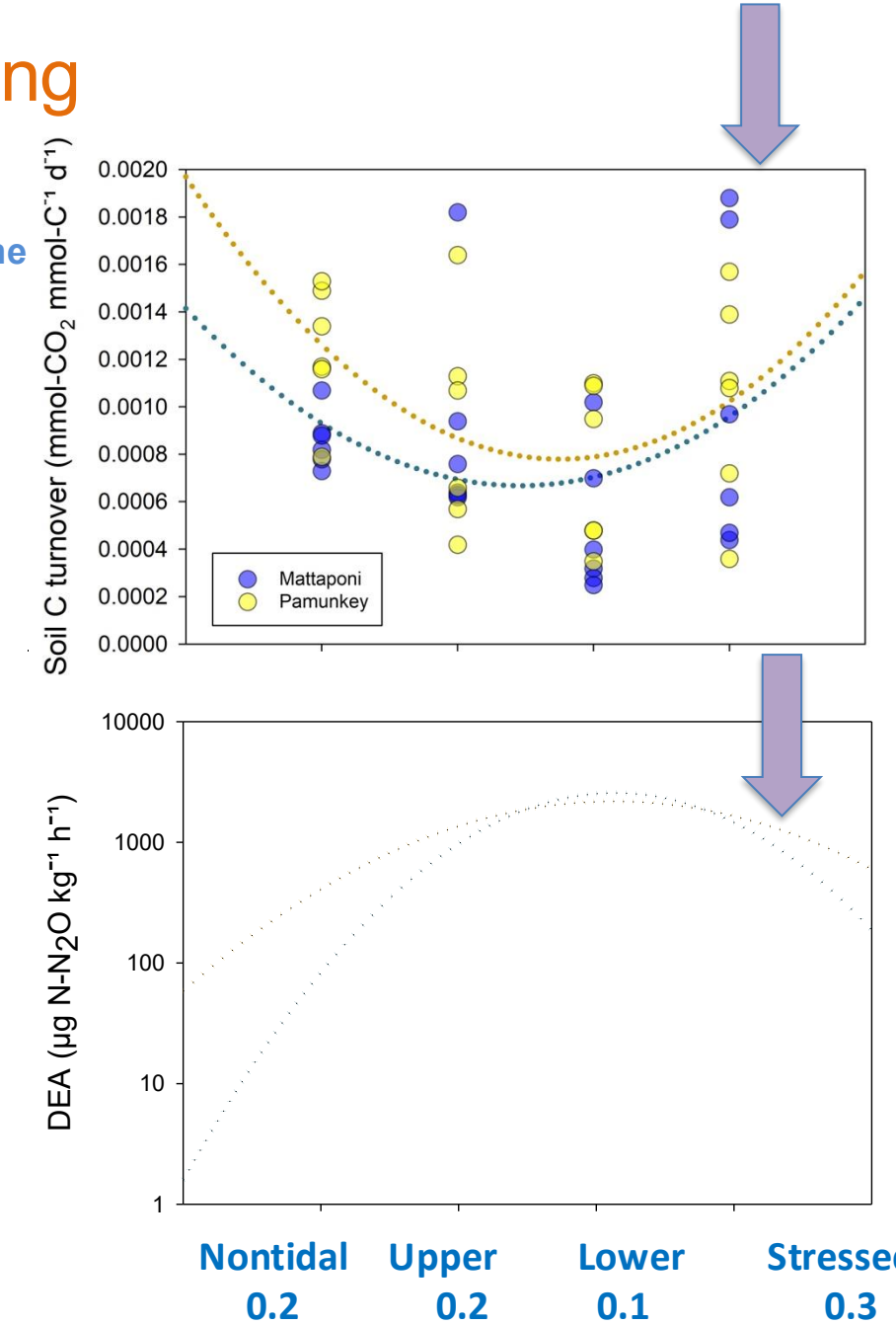
Biogeochemical changes: soil C and N cycling

Stagg et al. 2017 | *Ecology*



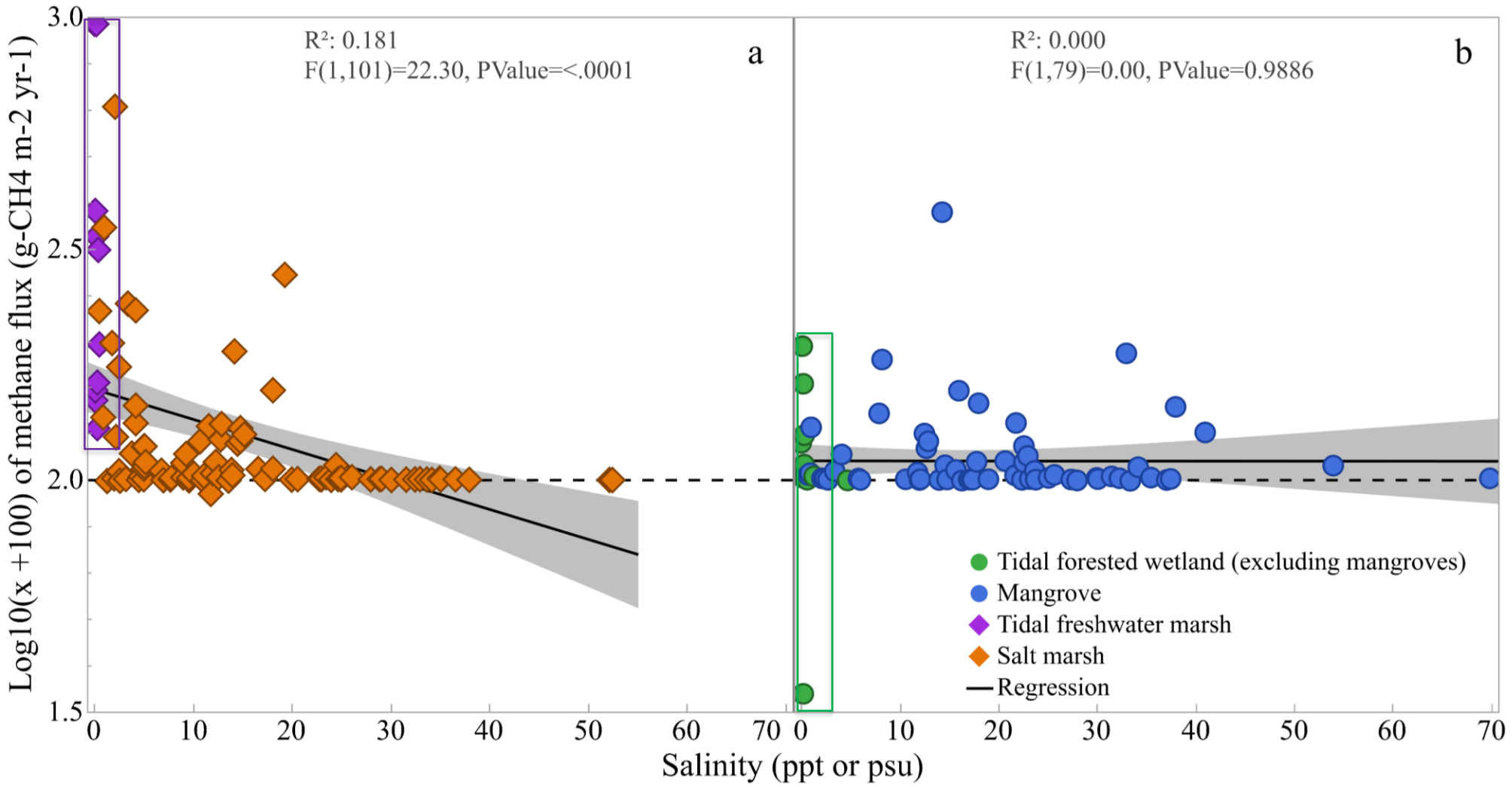


Noe et al. 2013 | *Biogeochemistry*



Korol and Noe 2020 | *Estuaries & Coasts*

But what about methane?!: Field flux measurements



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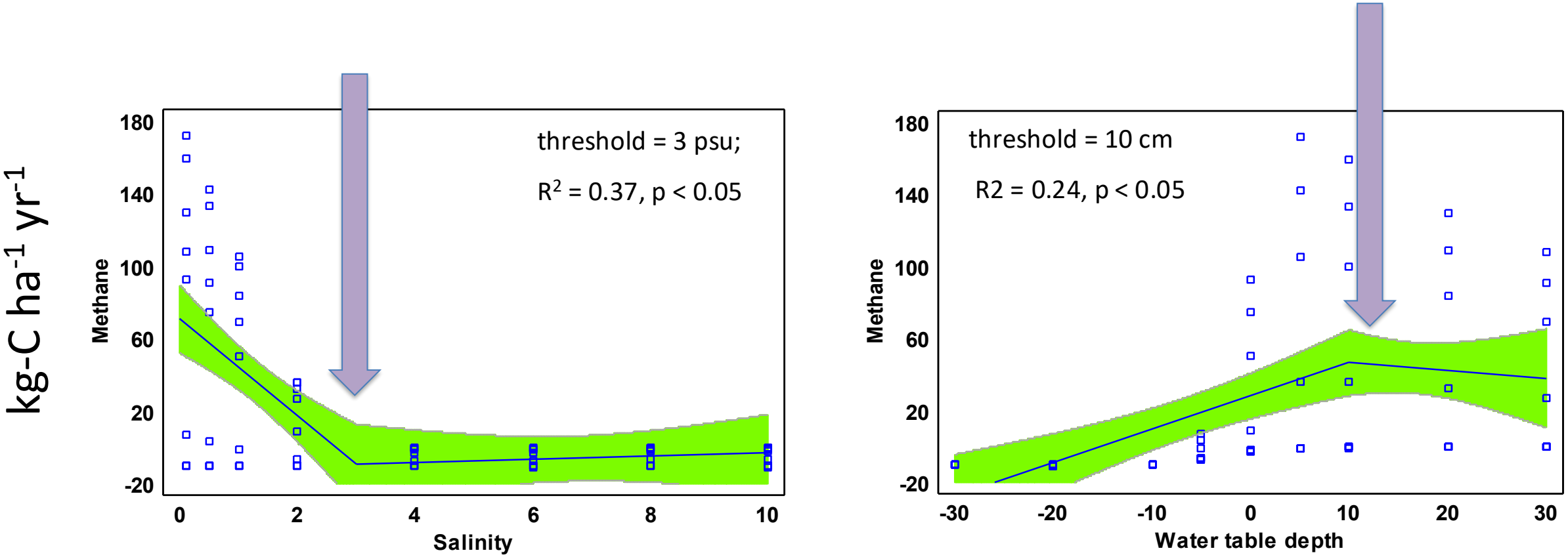
Friess et al. 2026 | *Current Forestry Reports*

But what about methane?!: models



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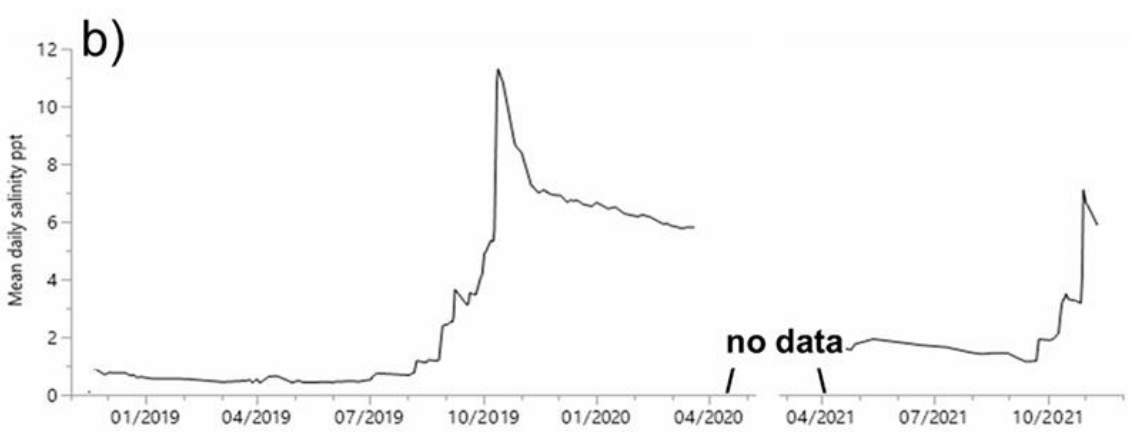
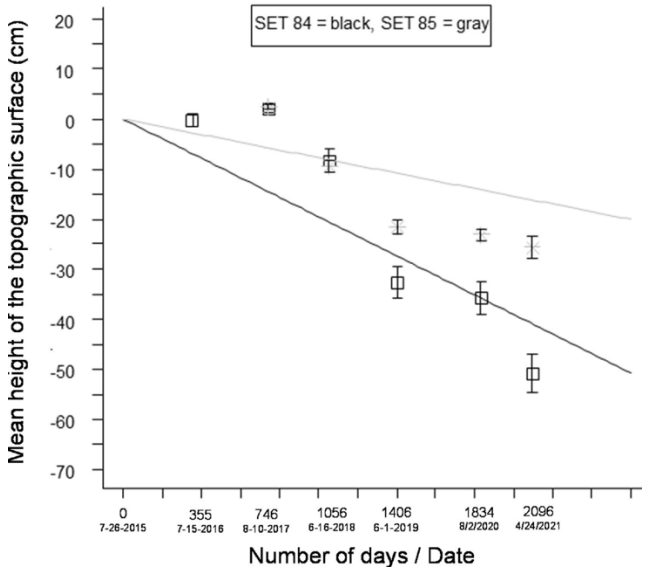
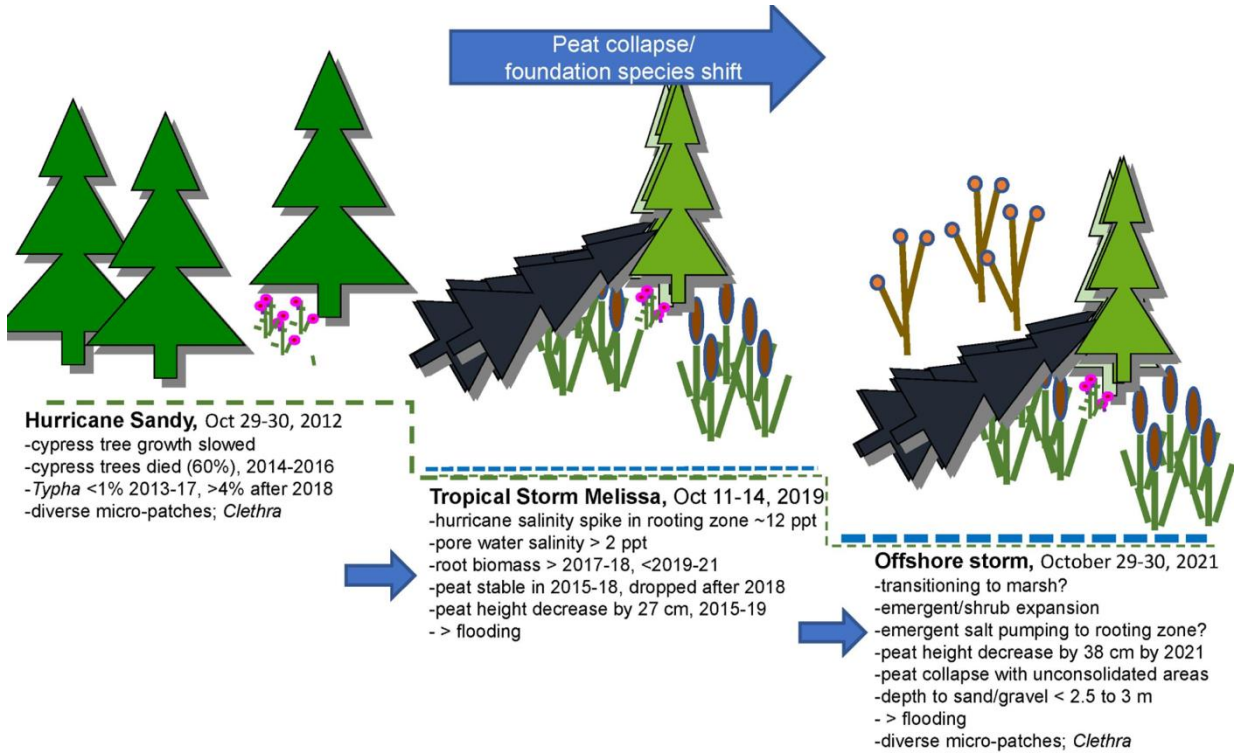
Wang et al. 2023 | *Ecol. Appl.*

Tidal swamp persistence: storms with salt and wind lead to loss







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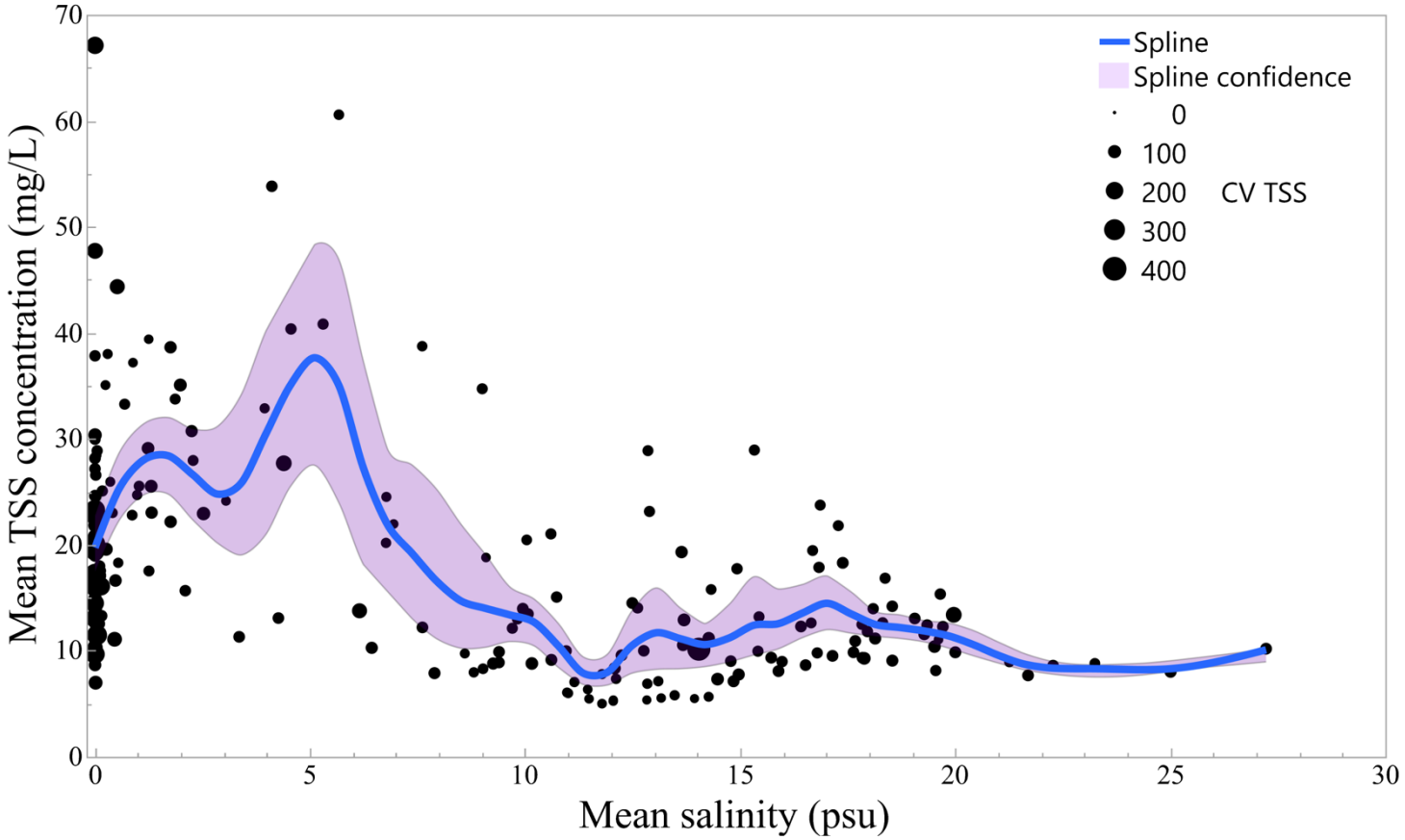
Middleton 2016 | *Ecol. Eng.*
Middleton and David | 2022, *Ecol. Ind.*

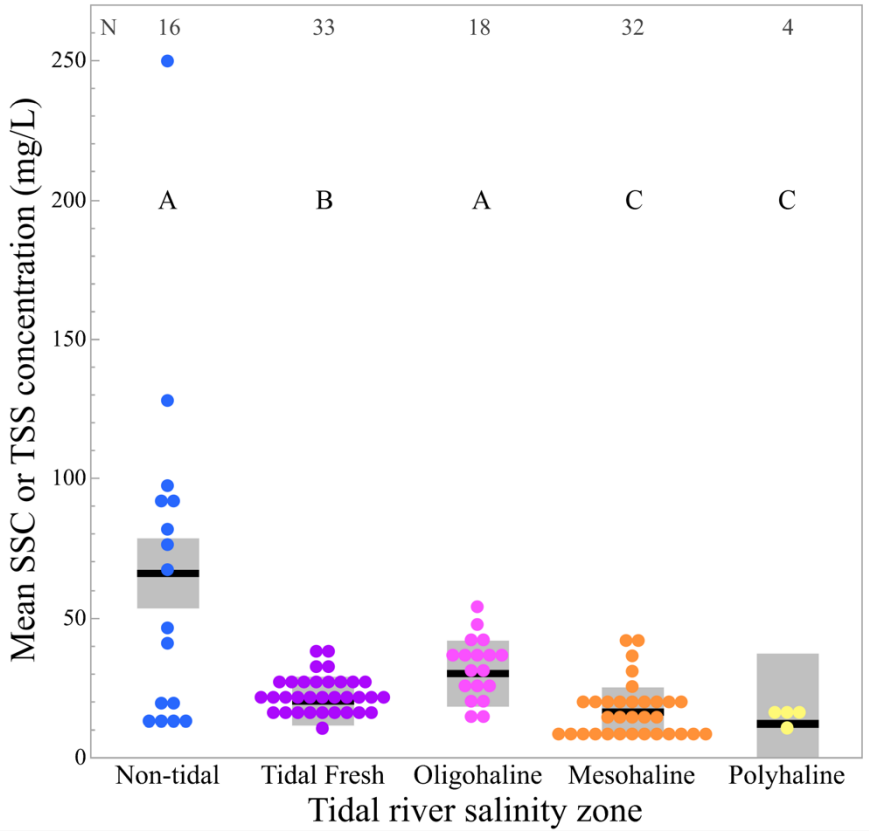
Chesapeake Bay Program (CBP) long-term data (1984-current)

Nontidal watershed inputs

Whole estuary



Tidal rivers only



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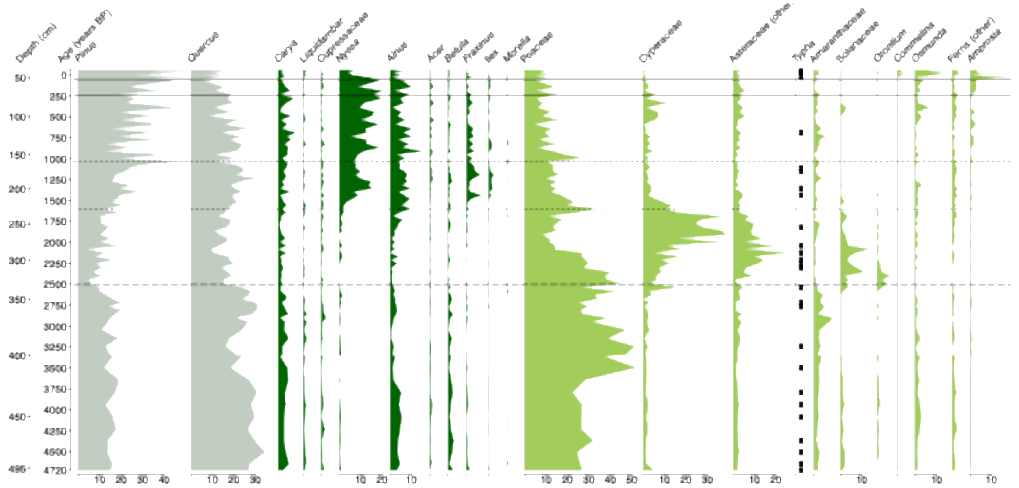
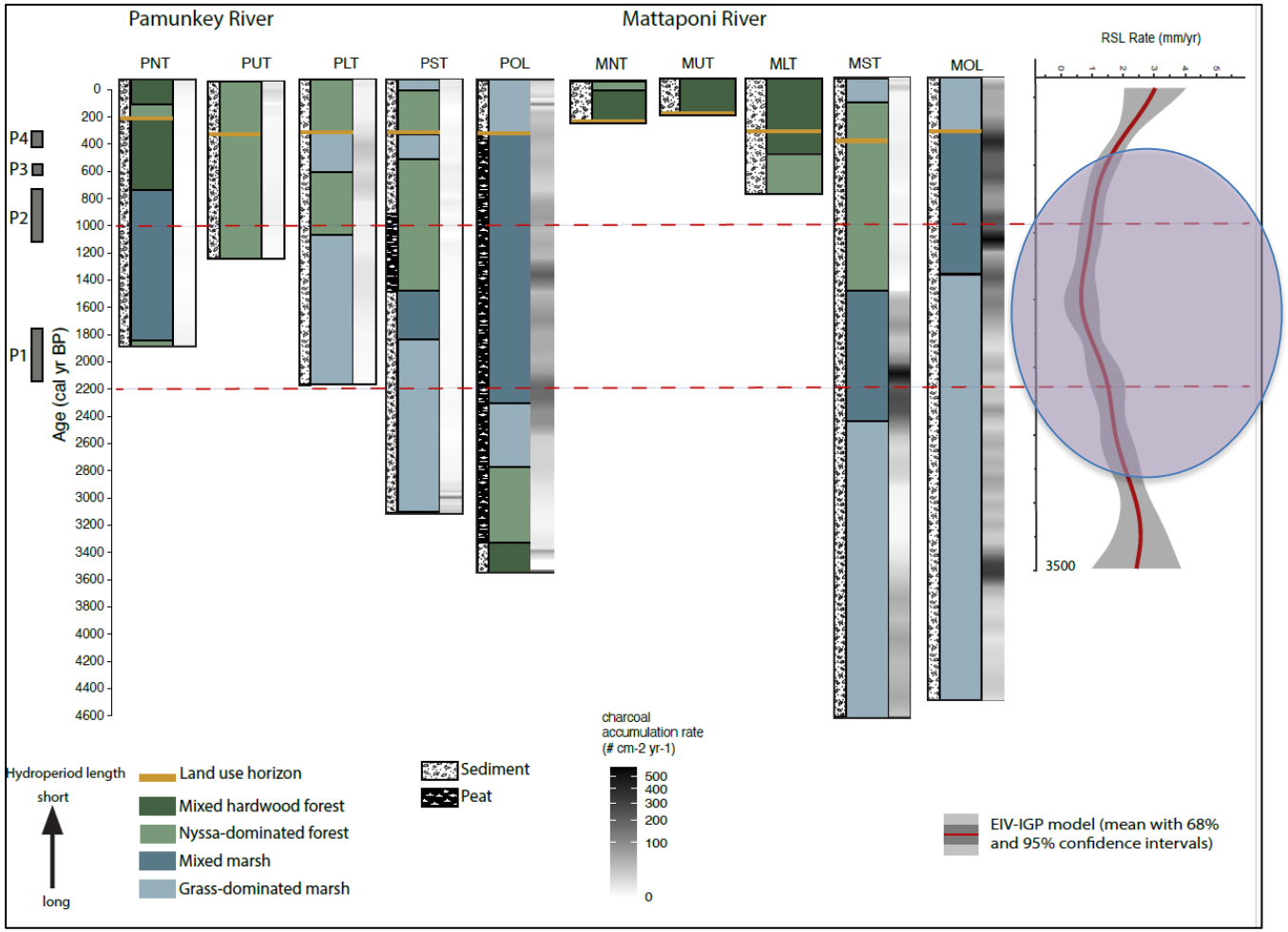
Noe et al. 2026 | *ECSS*

Deep core paleo-reconstruction: marsh and swamp state changes





Ecosystems are very responsive to SLR (salinization + inundation)

Jones et al. in prep.

Thank you!

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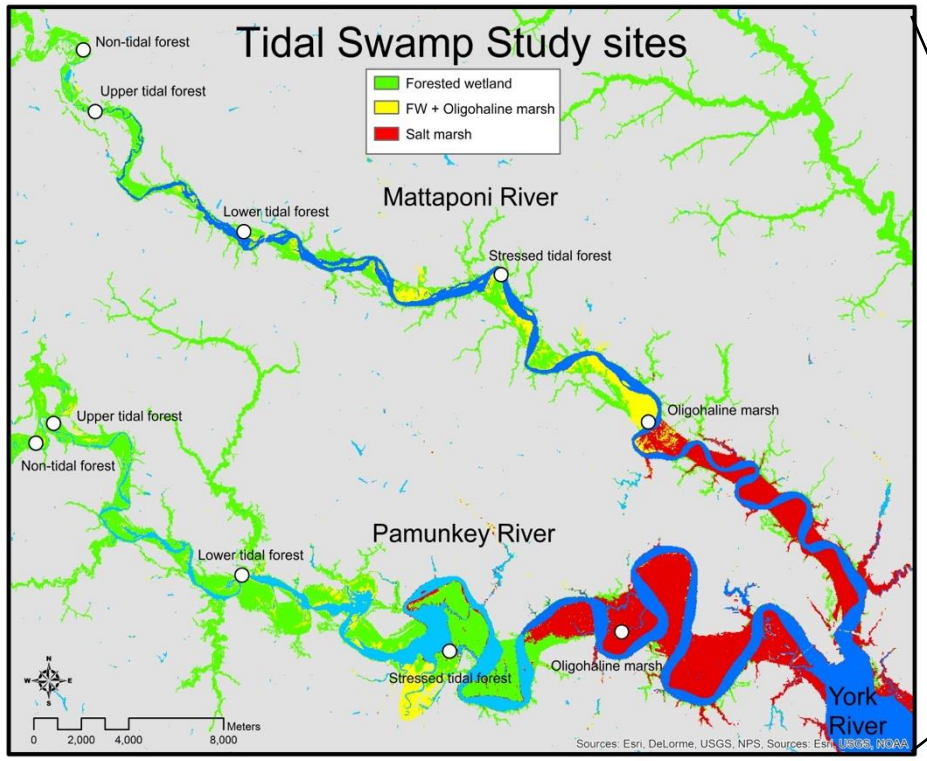
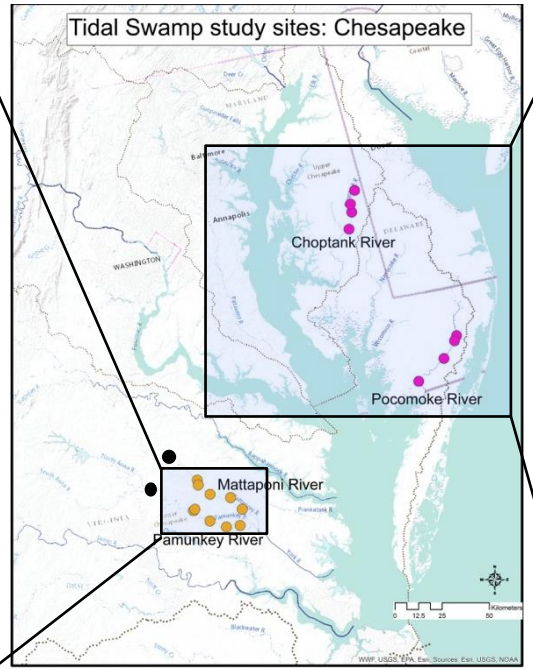
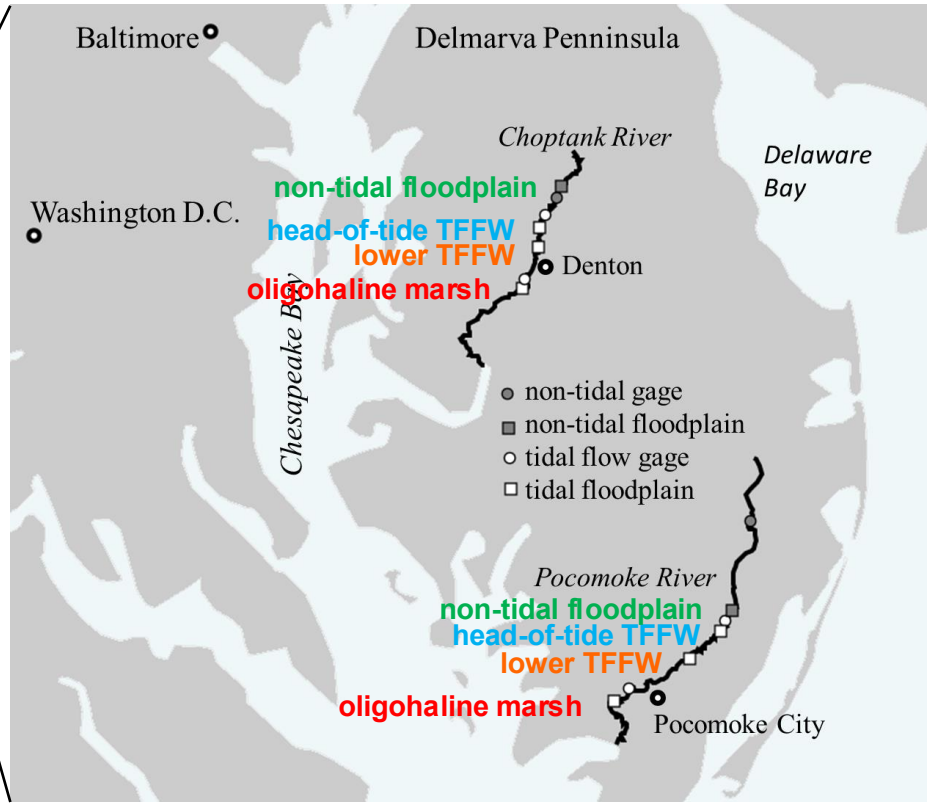
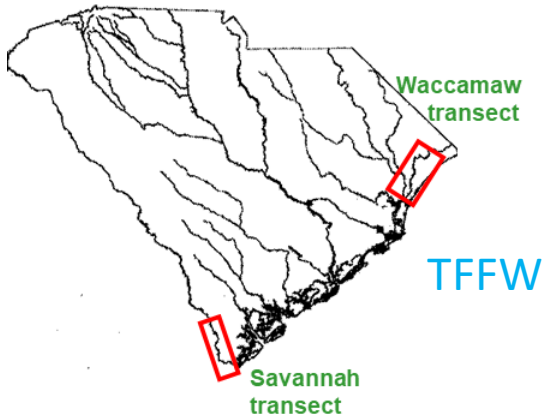
Landscape gradients: nontidal → TFFW → oligohaline measuring ecosystem processes









TFFW → oligohaline

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Vegetation changes: TFFW tree growth responses

Watershed influence

Estuarine influence

	Nontidal		Upper Tidal		Lower Tidal		Stressed Tidal	
	Terms	Sign and sig.	Terms	Sign and sig.	Terms	Sign and sig.	Terms	Sign and sig.
Mattaponi mean BAIs: all species	River TN River flow Estuarine Water Level (n = 31, p = 0.0085, R^2 = 0.35, Adj. R^2 = 0.27)	-** +* -*	Estuarine Water Level (n = 31, p <0.0001, R^2 = 0.69, Adj. R^2 = 0.68)	+****	River TN Max Salinity TF4.4 (n = 26, p < 0.0001, R^2 = 0.77, Adj. R^2 = 0.75)	-**** +	Estuarine Water Level Max Salinity RET4.2 (n = 26, p = 0.006, R^2 = 0.53, Adj. R^2 = 0.48)	+* +
Pamunkey mean BAIs: all species	Estuarine Water Level River Flow (n = 31, p = 0.0002, R^2 = 0.56, Adj. R^2 = 0.53)	+*** -	River Flow Estuarine Water Level (n = 31, p = 0.027, R^2 = 0.31, Adj. R^2 = 0.26)	+** -$^{\wedge}$	River TP Max Salinity RET4.1 River Flow (n = 28, p = 0.006, R^2 = 0.53, Adj. R^2 = 0.47)	+ + +	Estuarine Water Level River TP Max Salinity TF4.2 (n = 28, p = 0.005, R^2 = 0.49, Adj. R^2 = 0.43)	+*** -* +$^{\wedge}$

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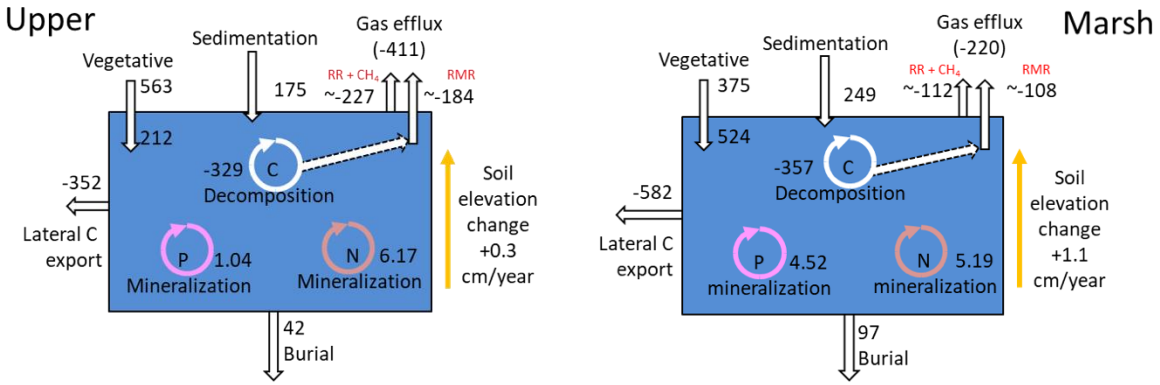
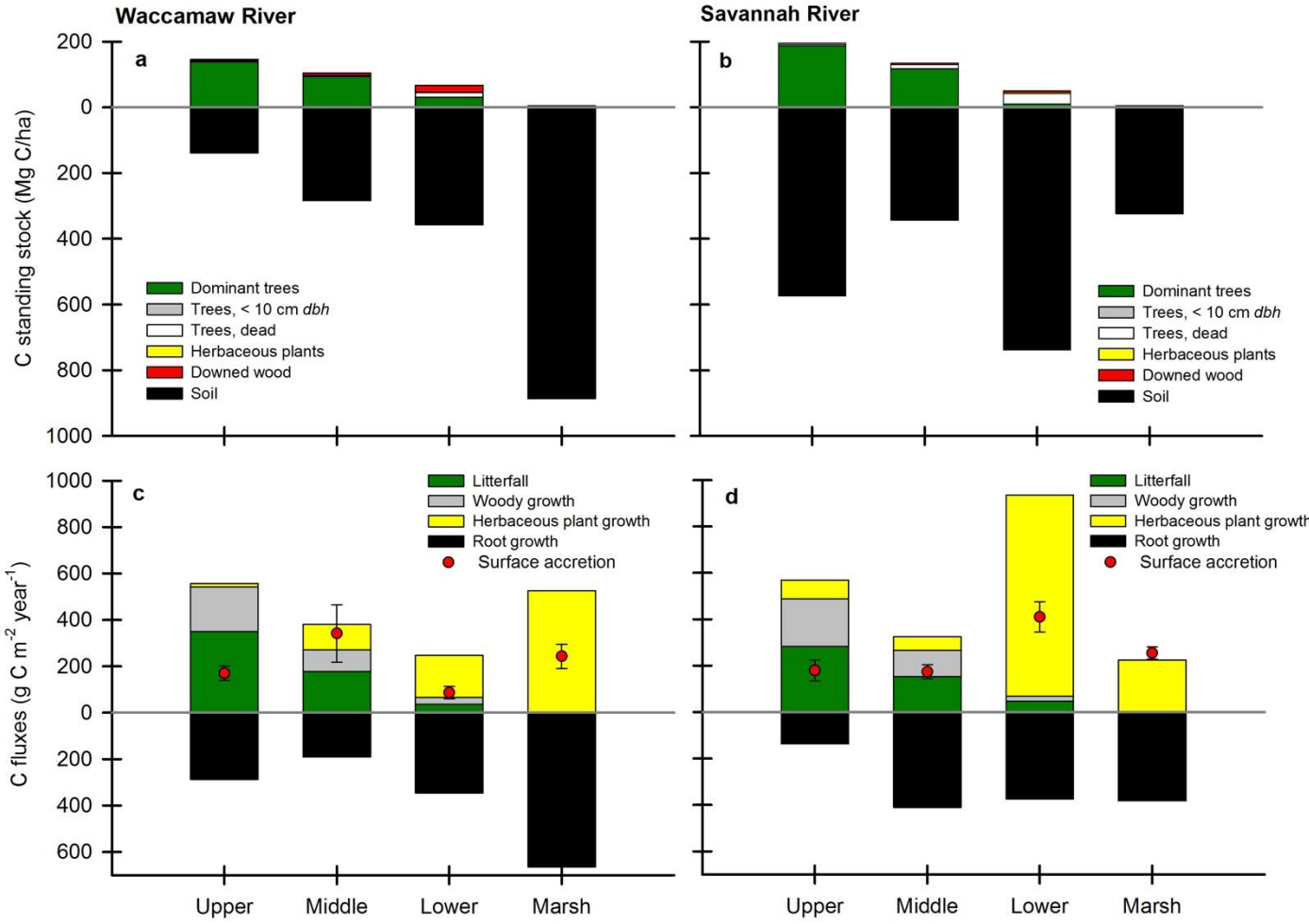
Noe et al. 2021, *Forests*

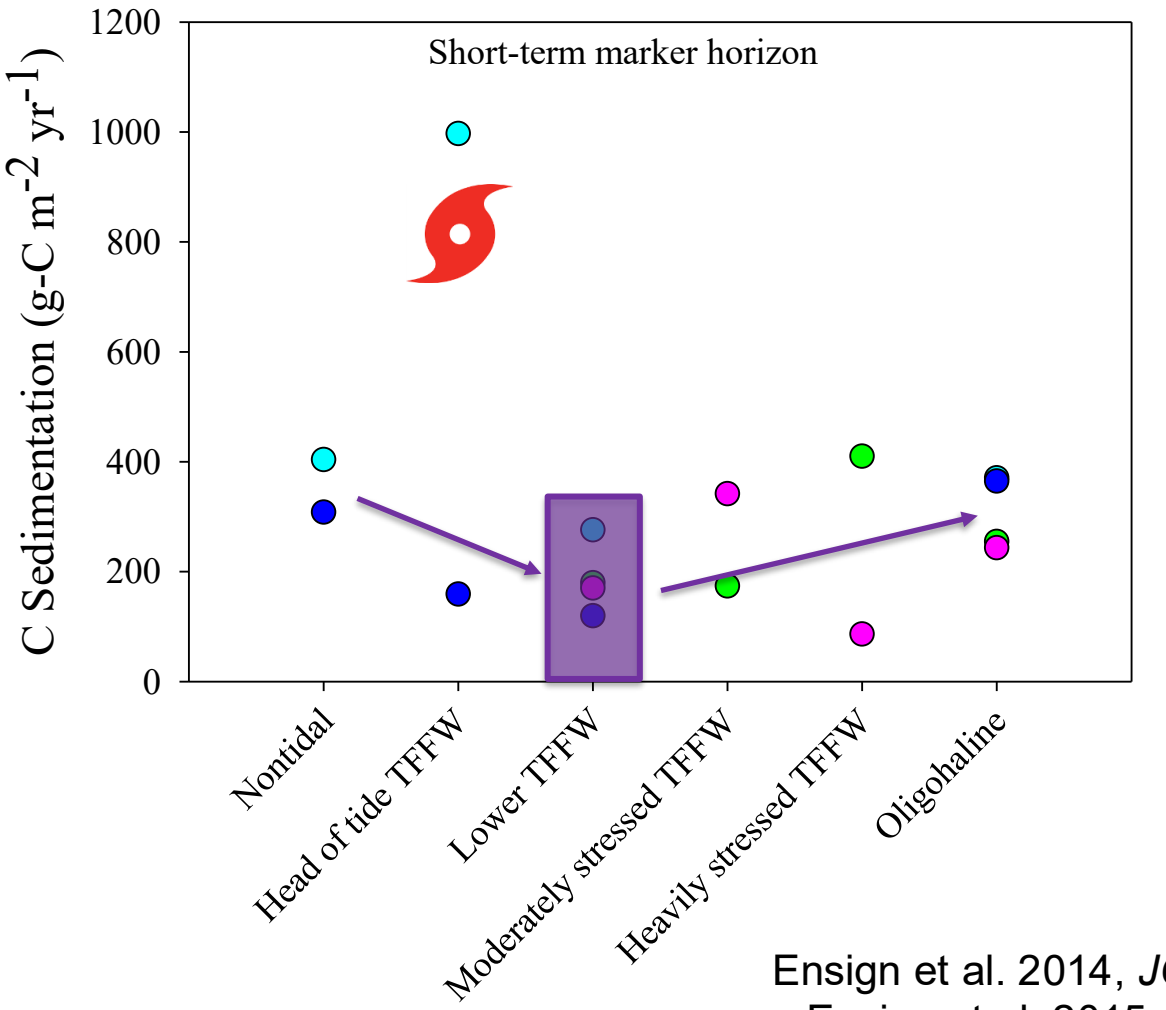
TFFW C pools and fluxes change with salinization

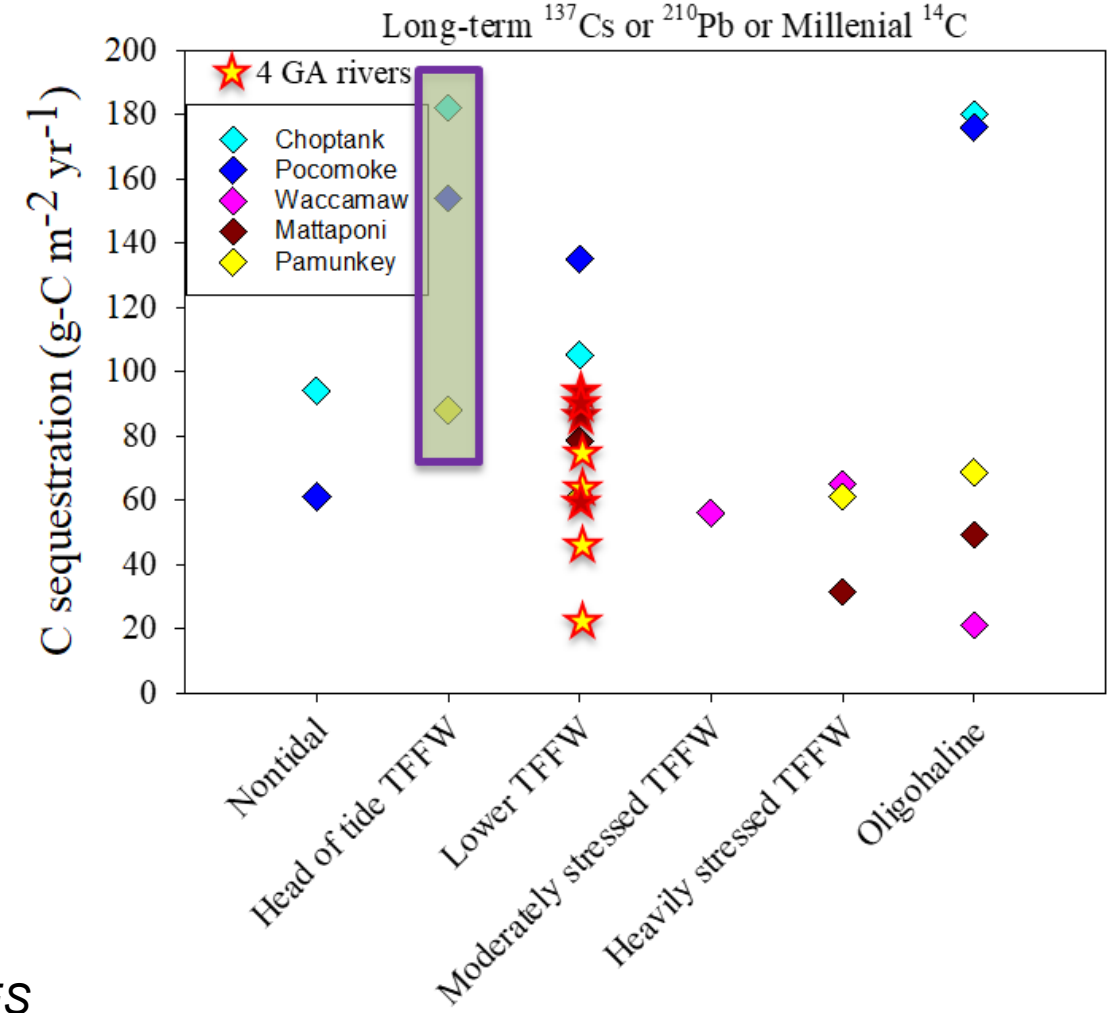


Krauss et al. 2018, *GBC*



Geomorphic/BGC changes: soil C accumulation



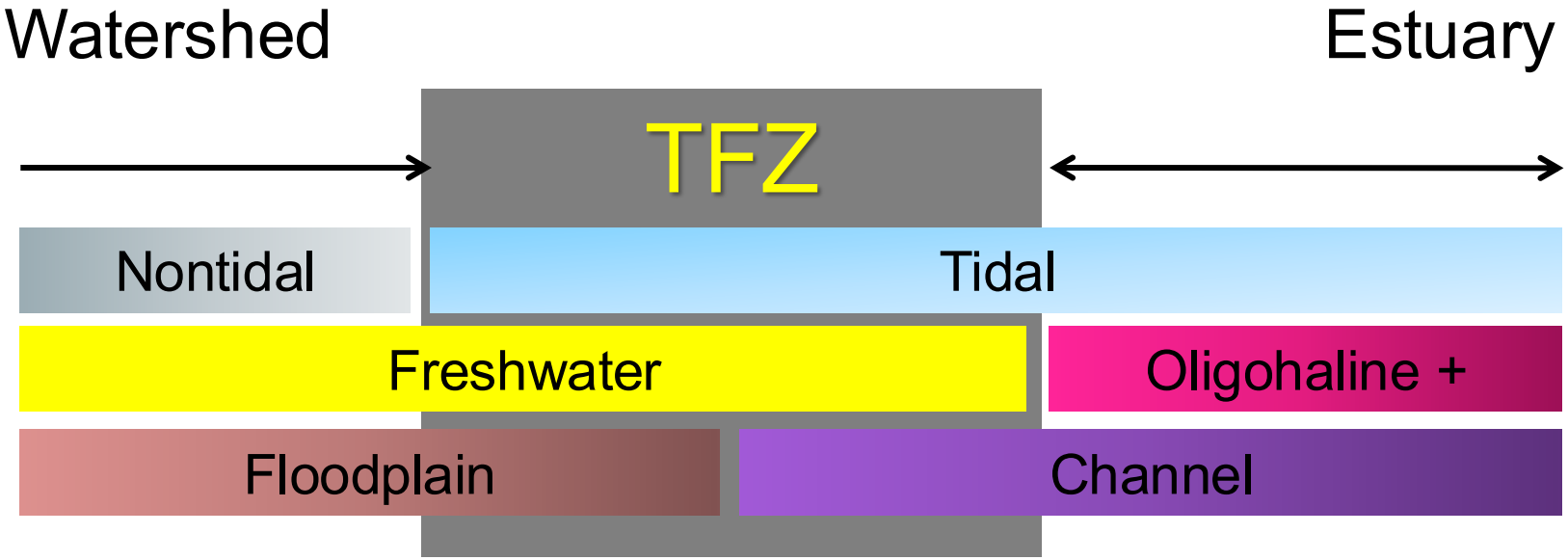


Ensign et al. 2014, *JGR-ES*
Ensign et al. 2015, *GRL*
Noe et al. 2016, *Estuaries & Coasts*
Miriam Jones, *unpubl. Data*
Craft 2012, *GCB*

Mangrove = 180
Salt marsh = 212
Seagrass = 221

Alongi 2023

~ 3,000 km of tidal freshwater river along US Atlantic Coast (Ensign and Noe 2018)



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