WETLAND CARBON SERVICES: IMPLICATIONS FOR CONSERVATION & MANAGEMENT

BETH LAWRENCE

UNIVERSITY OF CONNECTICUT

DEPARTMENT OF NATURAL RESOURCES

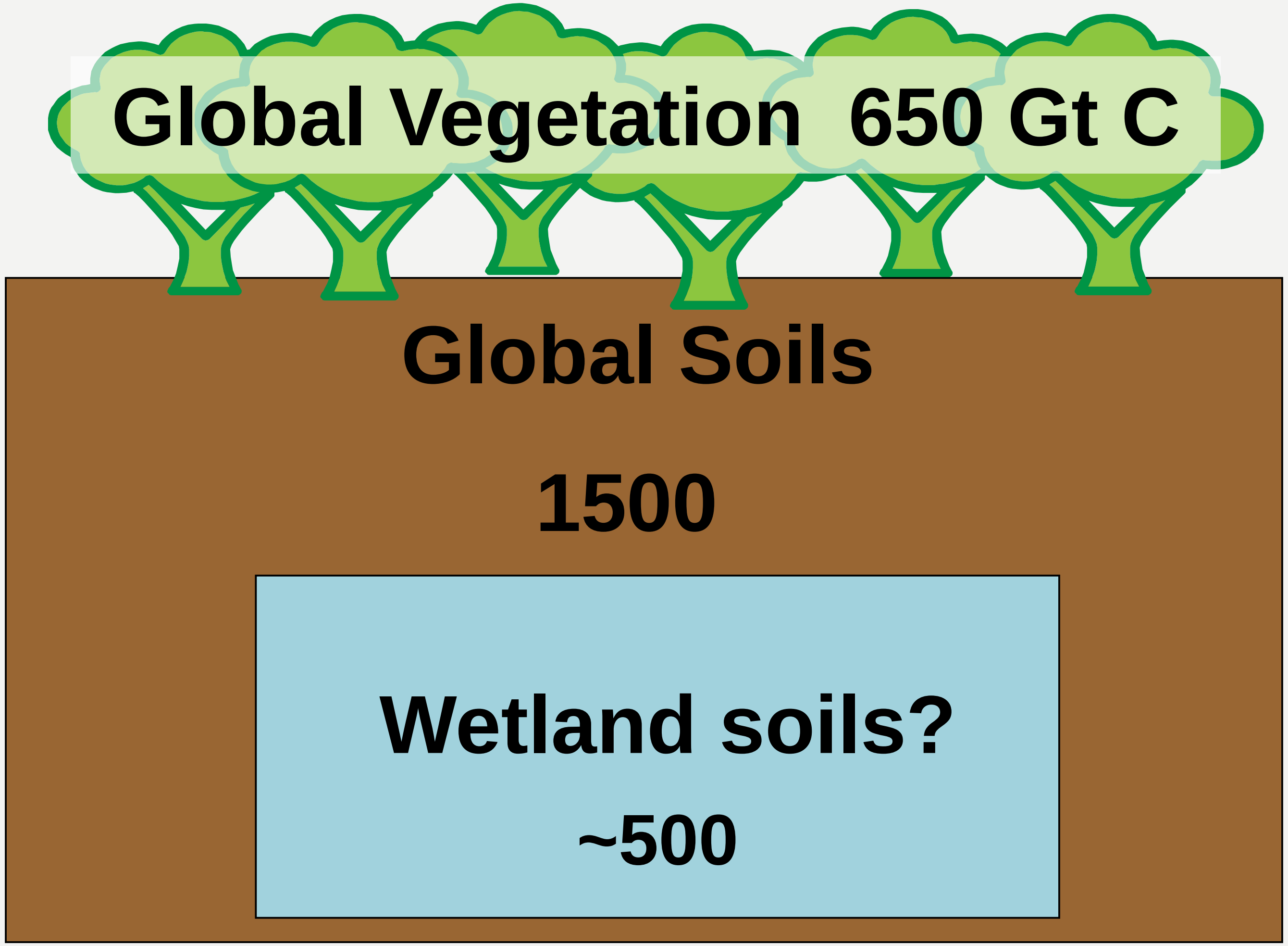
BETH.LAWRENCE@UCONN.EDU

Hammonasset,
Madison, CT

OUTLINE

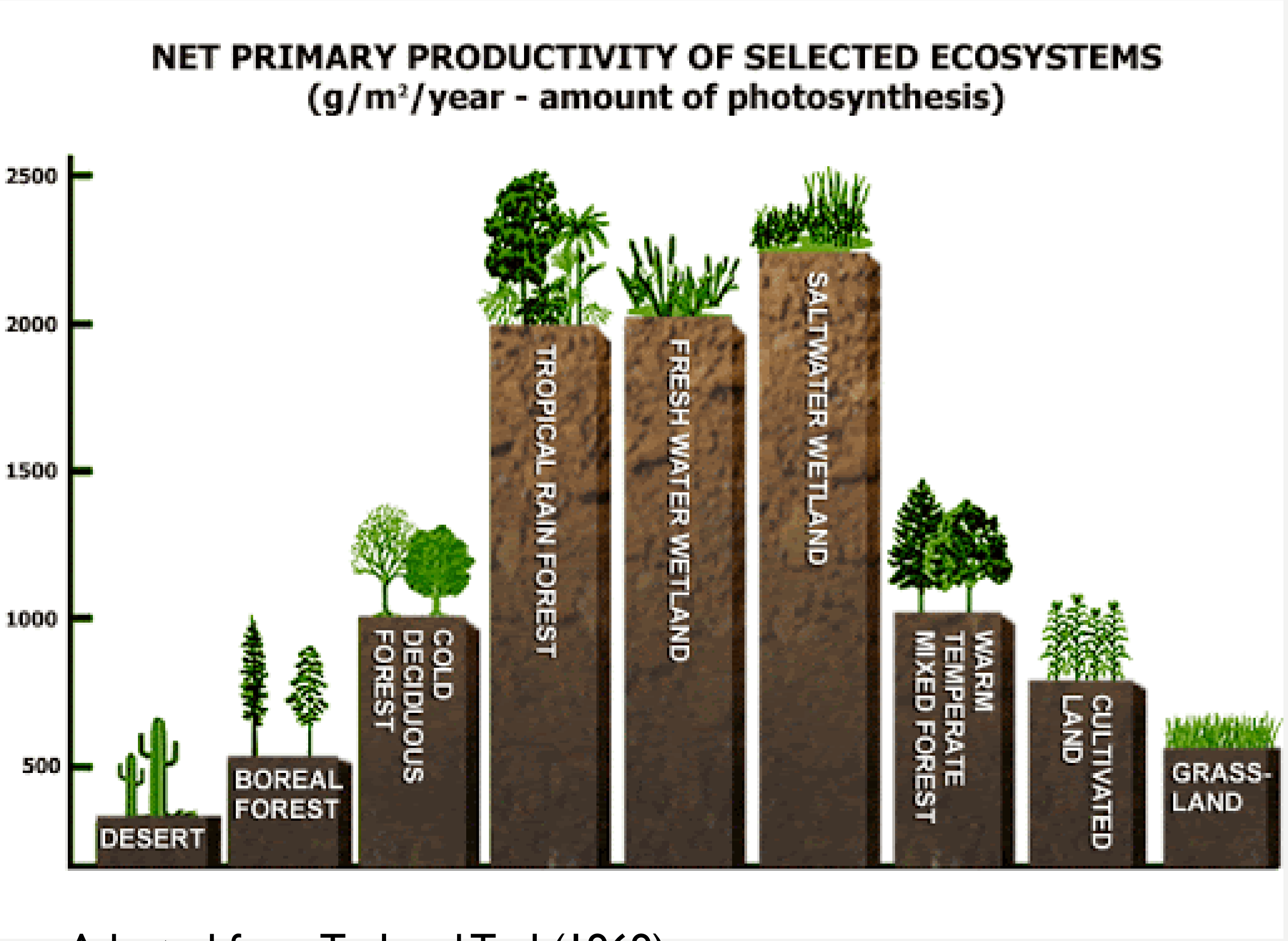
- Role of wetlands in C cycle
  - fresh vs. saline
- Connecticut wetlands
- Potential effects of management and SLR
  - Ongoing and needed research

Barn Island, Stonington, CT



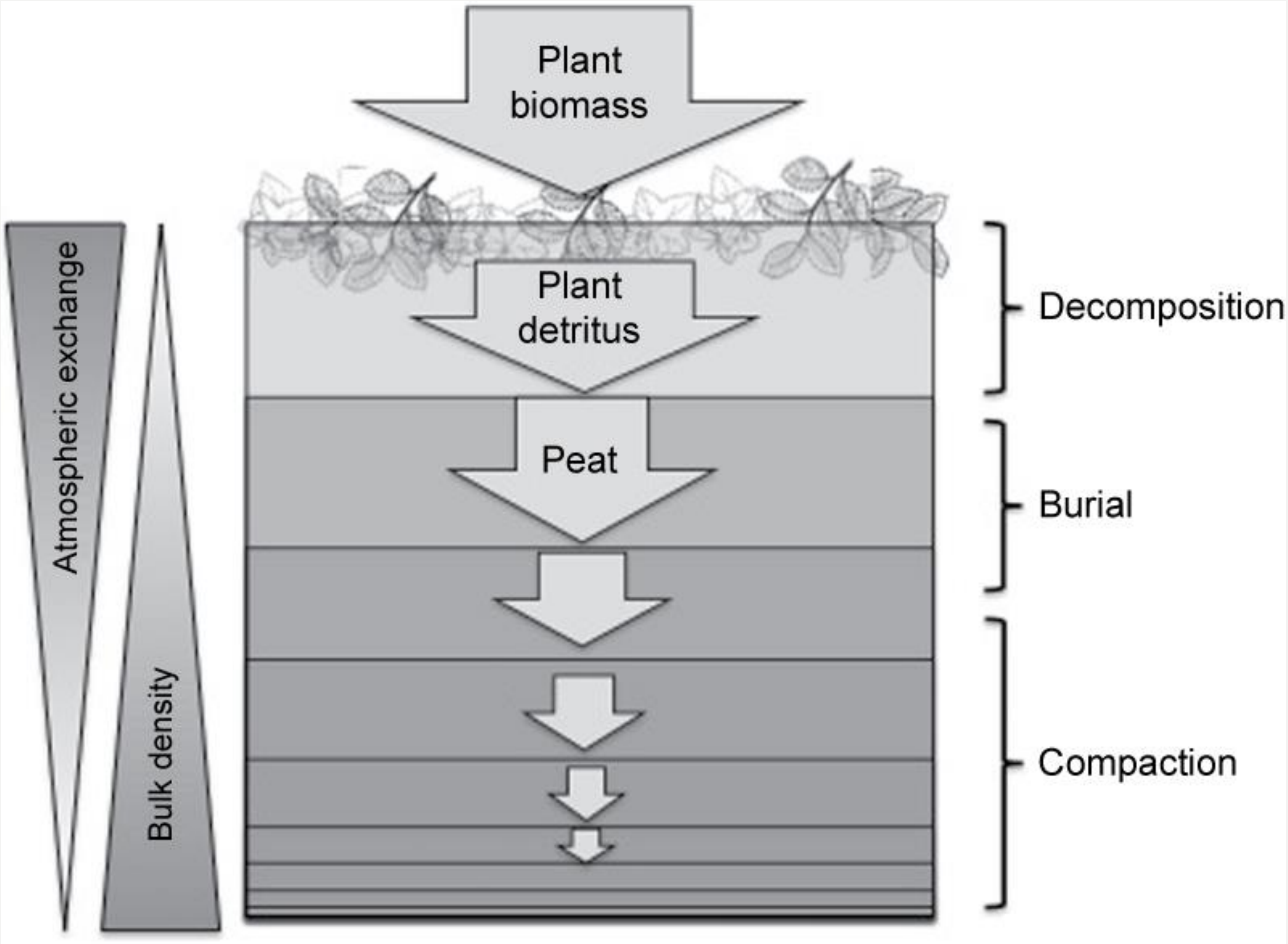
- Wetlands only cover ~5% of global land area, but contain about 33% of the terrestrial carbon pool in their soils (Gorham 1991, Mitra et al. 2005

PLANT PRODUCTION > DECOMPOSITION = SOIL C ACCUMULATION



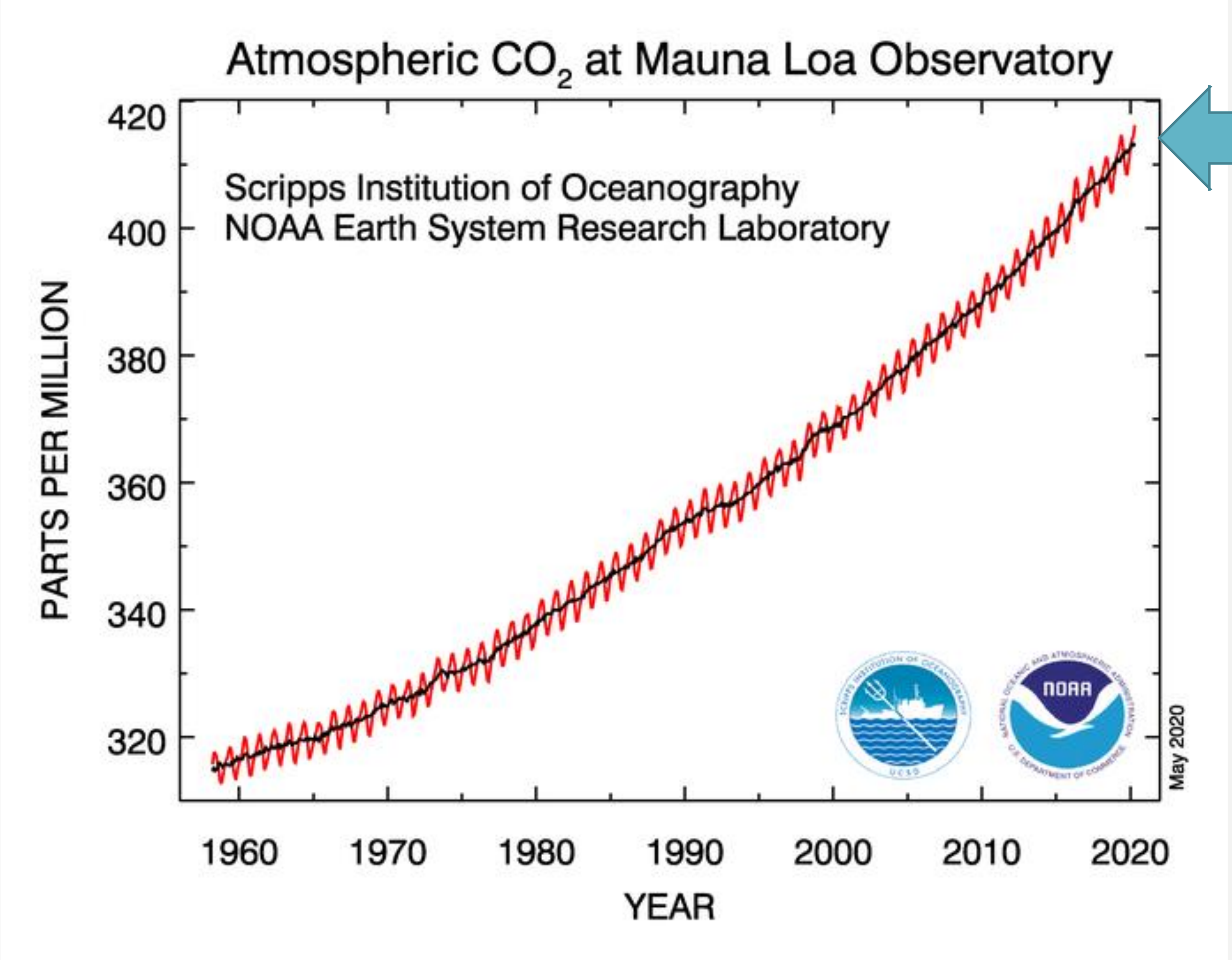
Adapted from Teal and Teal (1969)

- High productivity coupled with low decomposition rates in low O_2 soils results in C dense soils



Adapted from Clymo (1984)

CAN WETLAND CONSERVATION & MANAGEMENT MITIGATE CLIMATE CHANGE?

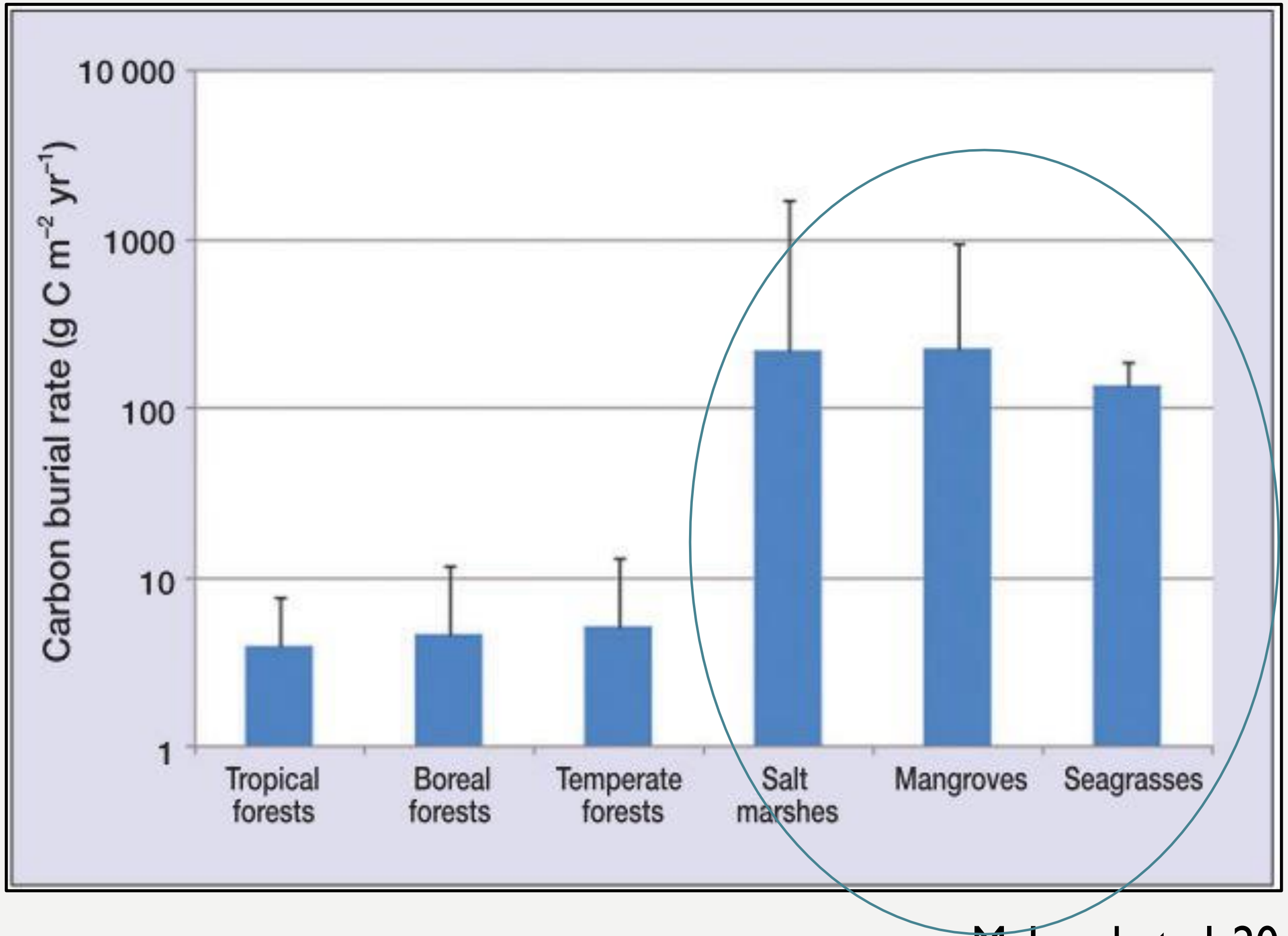


April 2020: 416.2 ppm

C STORAGE VS. SEQUESTRATION?

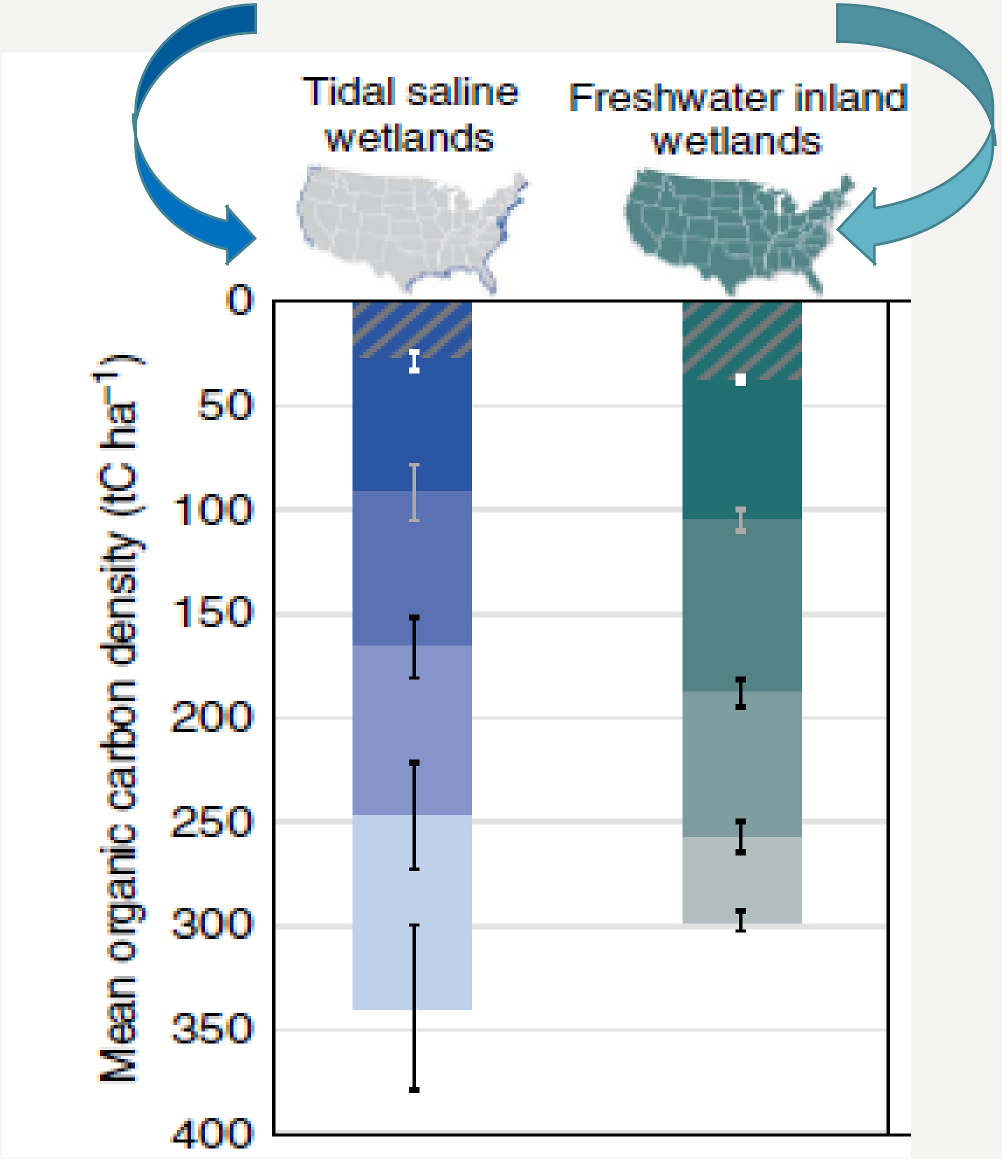
- *Storage*: amount of C in a given reservoir
  - units: mass, mass/area, mass/volume (density)
  - Biggest pools?
    - Peatlands
- *Sequestration*: rate of CO_2 uptake or SOC accumulation
  - units: mass/area*time (eg: g-C m^{-2} $year^{-1}$)
  - Fastest accumulators?
    - Coastal salt marshes & mangroves = "Blue carbon"

"BLUE CARBON ECOSYSTEMS": HIGH C SEQUESTRATION/ACCUMULATION RATES



McLeod et al. 2011

BLUE VS "TEAL" CARBON STORAGE…

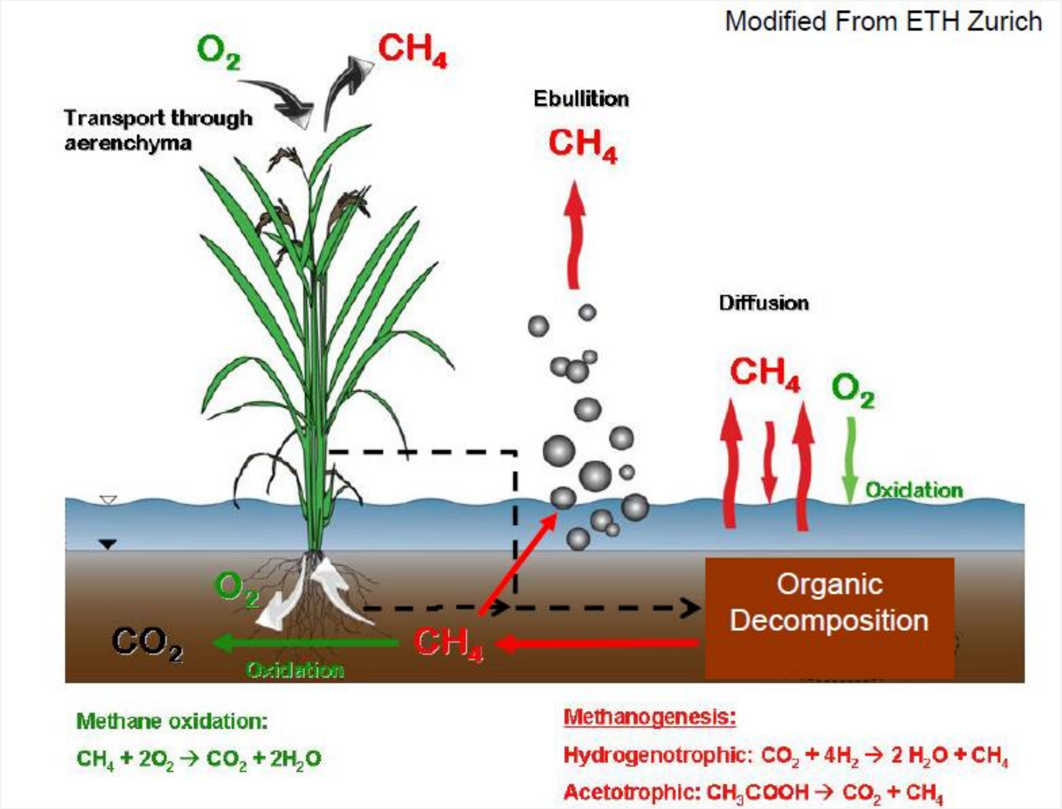


Nahlik & Fennessy 2016

- After scaling by extent, freshwater "teal" wetlands store ~11X more C than "blue" C wetlands in coterminous US

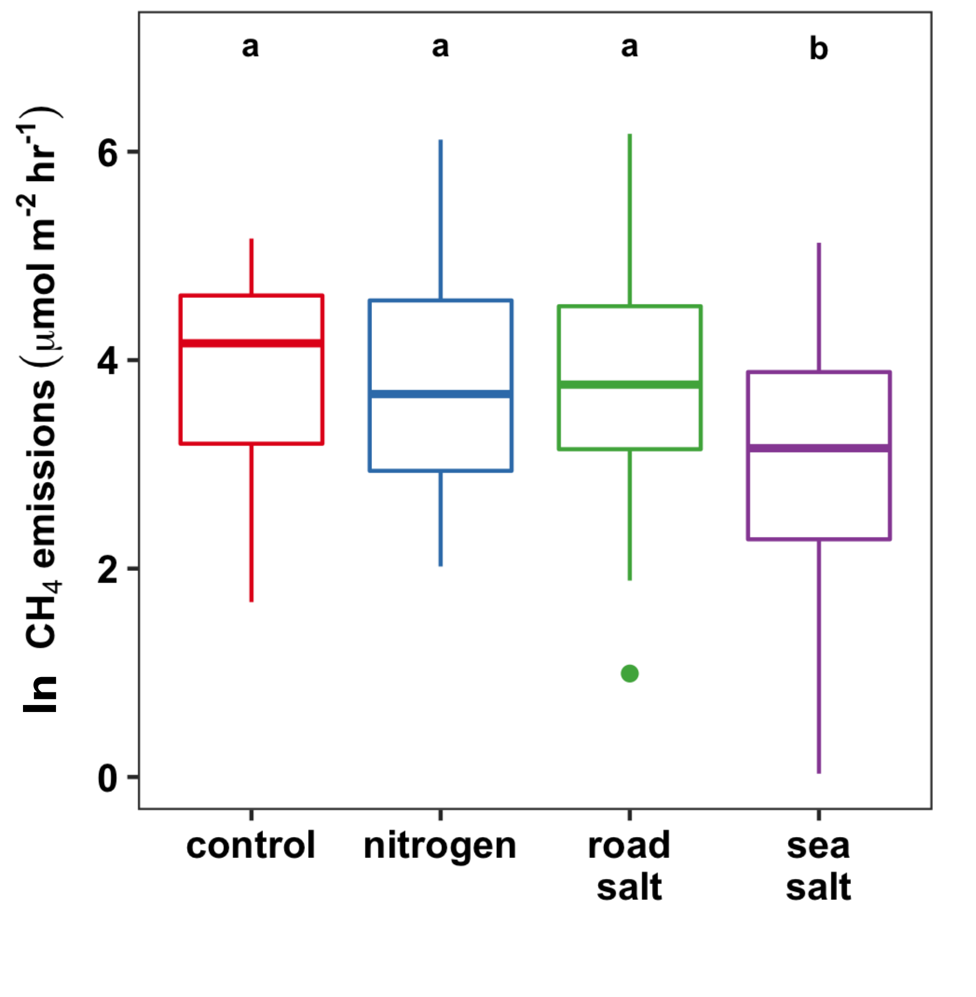
WETLANDS LARGEST NATURAL SOURCE OF CH_4

- 28x more potent than CO_2
- CH_4 emissions from fresh >> salty wetlands
  - High sulfate in seawater
  - Sulfate reduction thermodynamically more favorable than methanogenesis



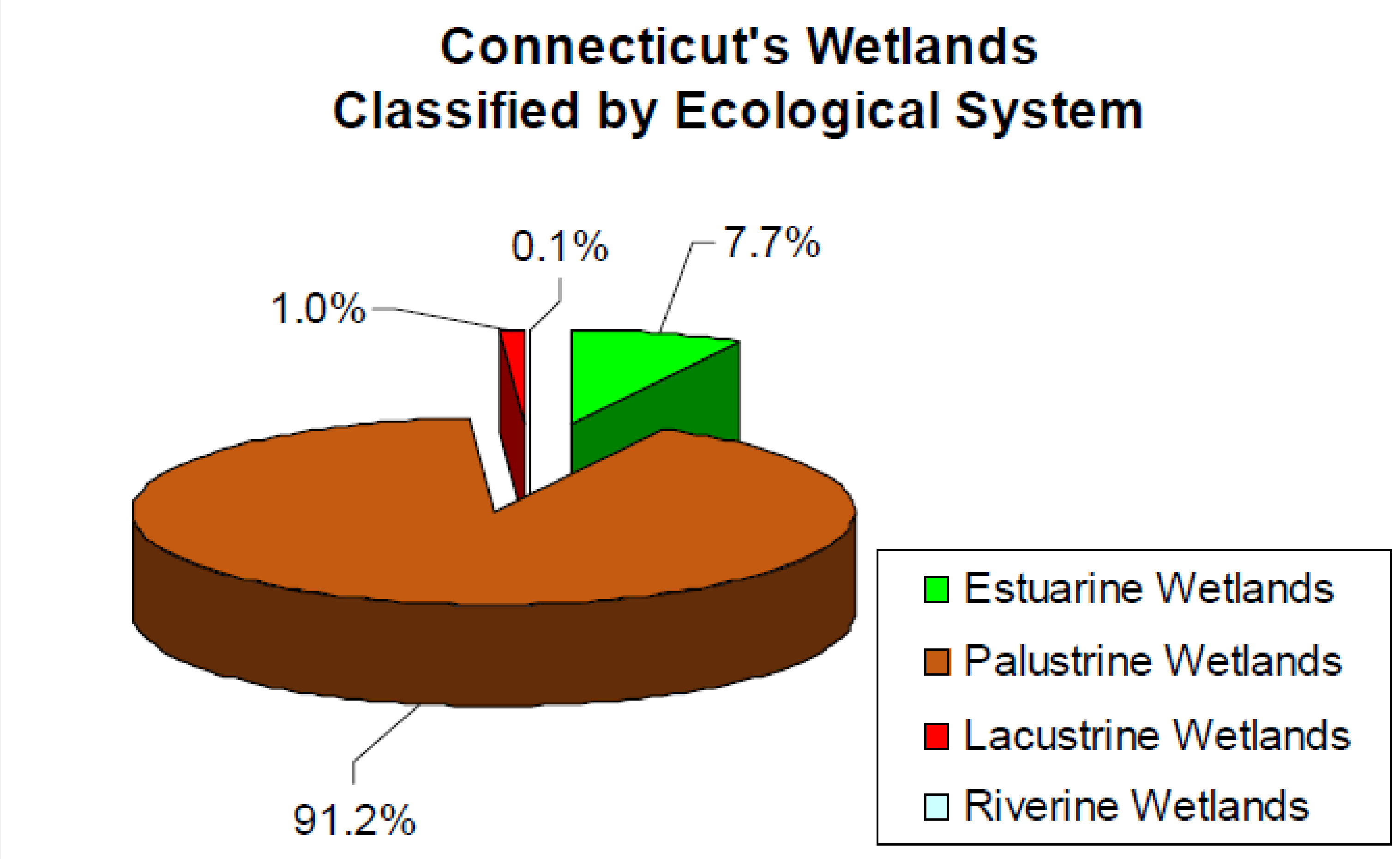
Poffengarger et al. 2011

SALT WATER INTRUSION REDUCES CH_4 EMISSIONS



Donato et al. *in revision*

WETLANDS IN CONNECTICUT 2010: ~220,000 ACRES, COVERING ~7% STATE



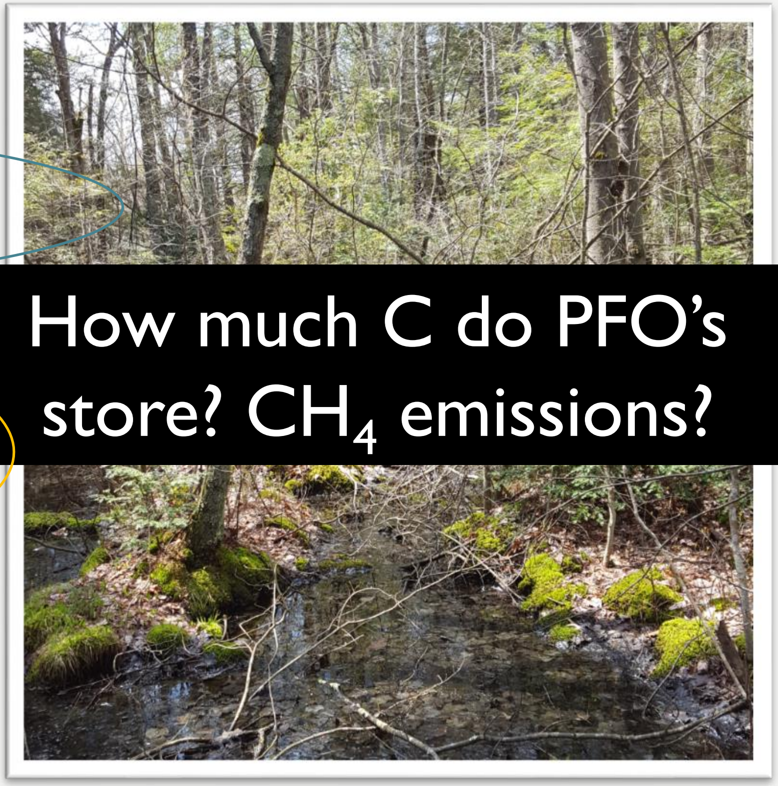
Tiner et al. 2013

FRESHWATER WETLANDS DOMINATE CONNECTICUT

Vegetated Wetland Class	Acreage	% Total
Palustrine Forested	122,942	51.4%
Palustrine Emergent	27,337	12.5%
Palustrine Shrub-Scrub	25,474	11.6%
Estuarine Emergent	12,417	5.7%

Tiner et al. 2013

Red maple swamp



How much C do PFO's store? CH_4 emissions?

MONOTYPIC GRAMINOIDS INCREASINGLY DOMINATE FRESHWATER EMERGENT MARSHES

Typha spp.

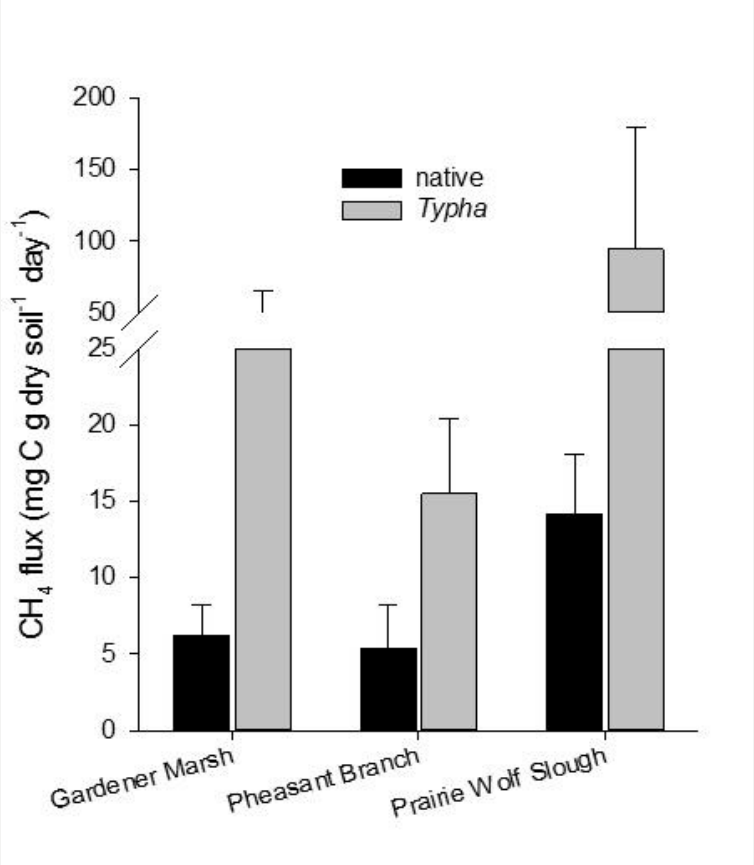
Phragmites australis

Phalaris arundiancea

- Nutrient enrichment shifts resource limitation from nutrients to light, favoring tall productive species
- Road salt runoff promotes salt tolerant species

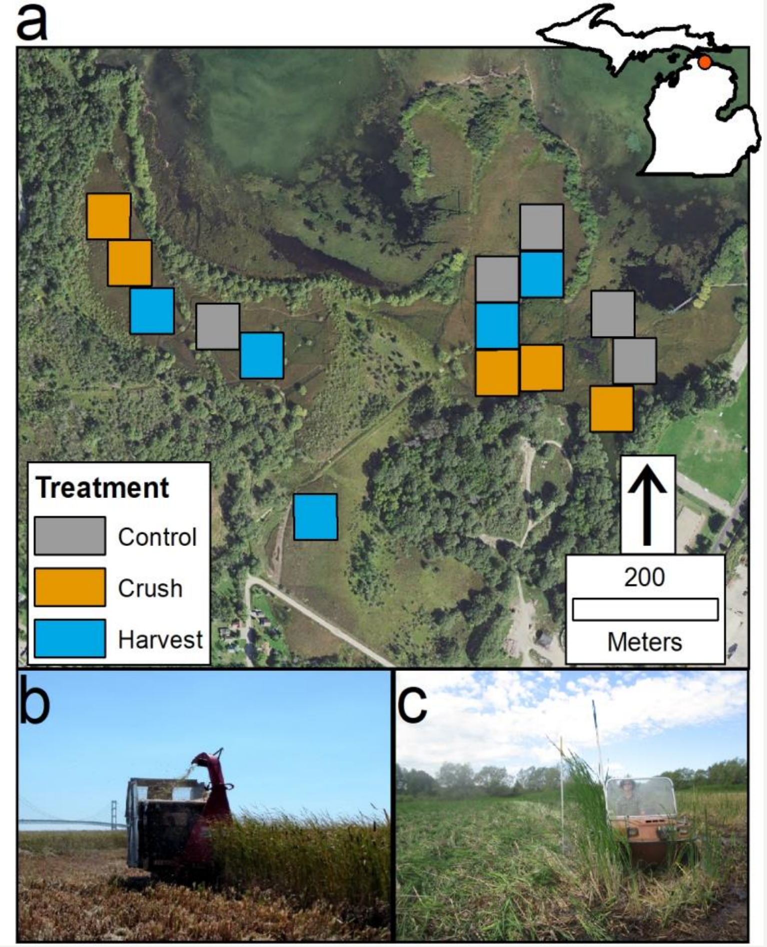
PLANT INVASION ALTERS C CYCLING

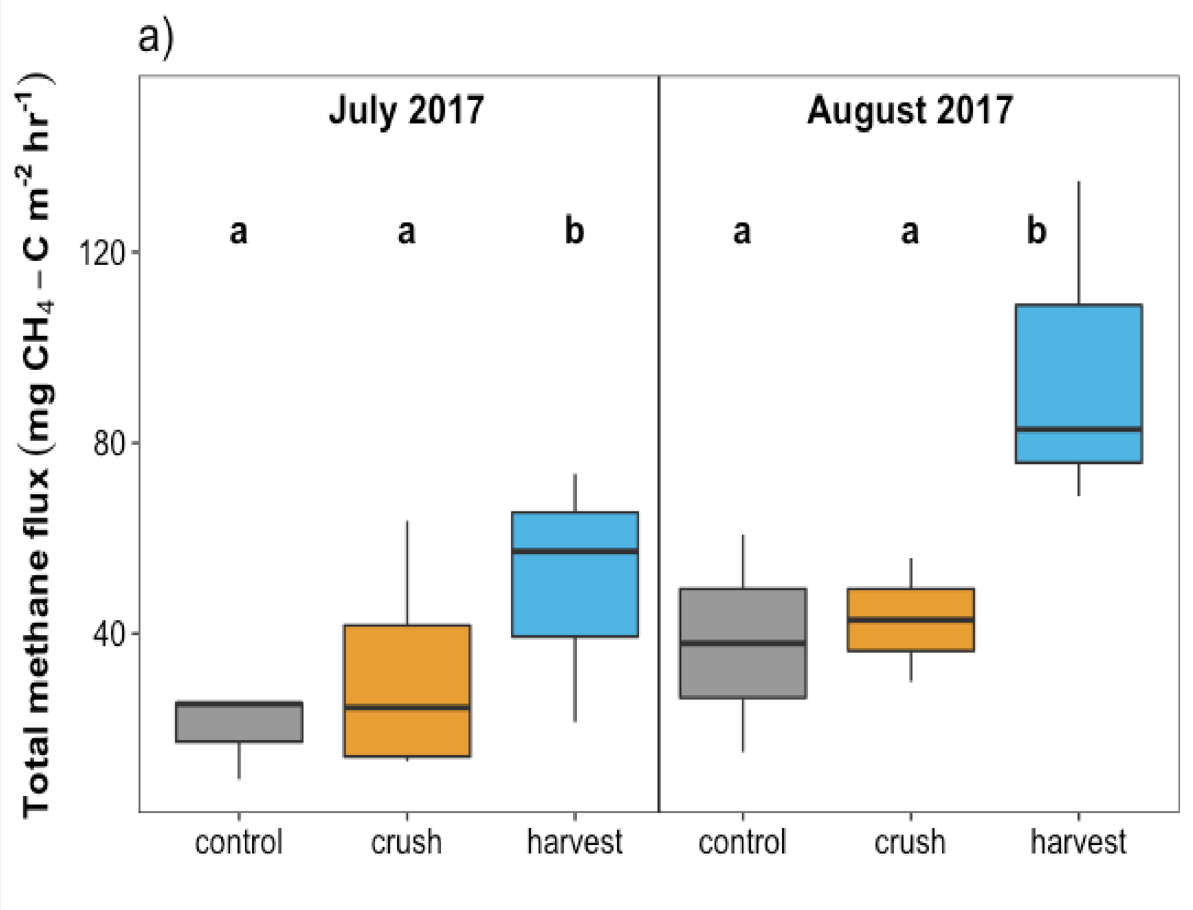
- Invasion increases
  - C pools (Liao et al. 2007, Ehrenfeld 2010, Vila et al. 2011)
  - Methane flux (Zhang et al. 2010, Modzder and Megonigal 2013)



Lawrence et al. 2017

INVASIVE MANAGEMENT CAN ALTER CH_4 EMISSIONS





Johnson et al. *in prep*

WHY ARE SALT MARSHES IMPORTANT?

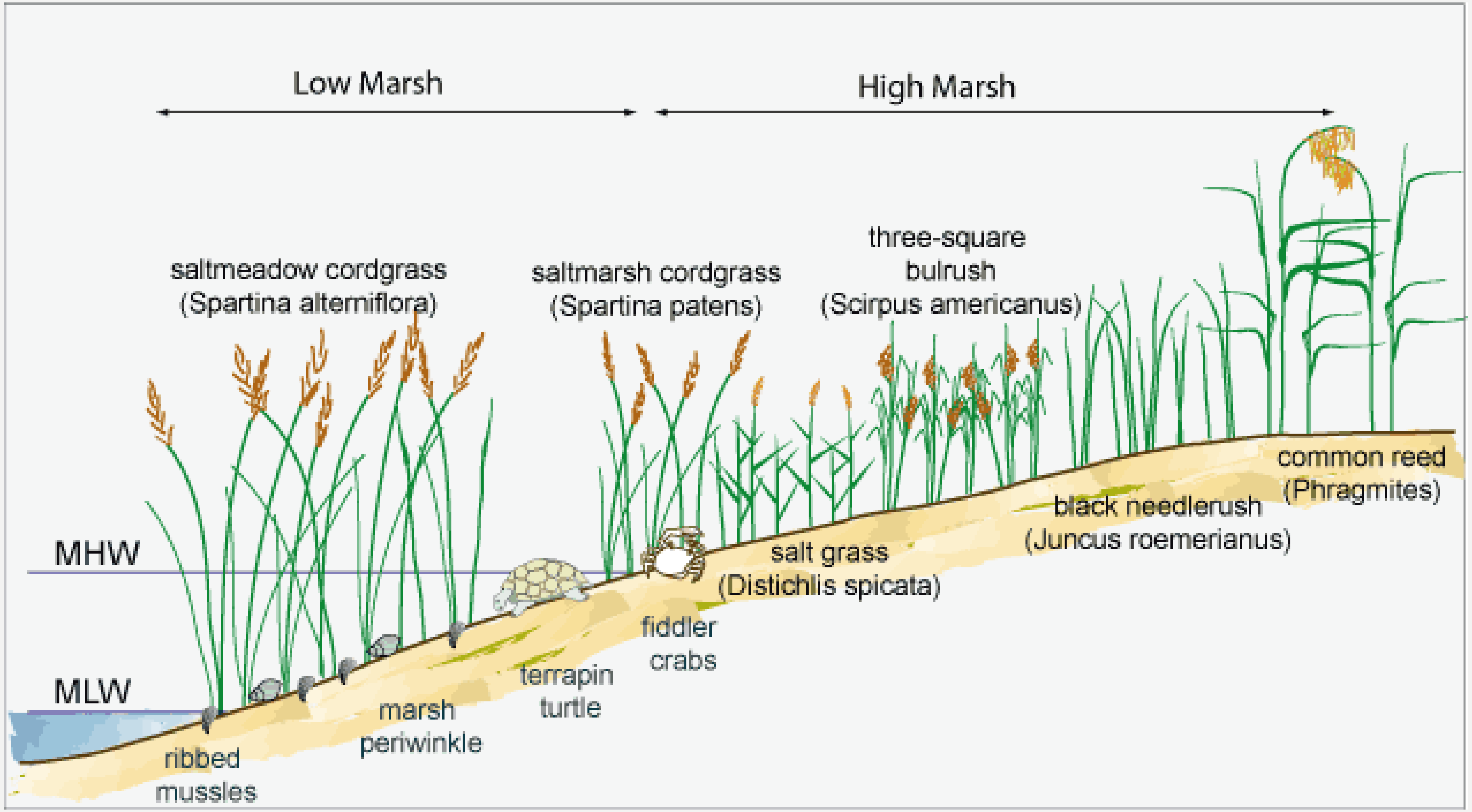
- Carbon storage
- Nitrogen removal
- Buffer storms
- Flood mitigation
- Shore stabilization
- Habitat- shellfish, fisheries, T&E species
- Recreational opportunities

NYTimes, Jim Zipp

Cheasapeakebay.net

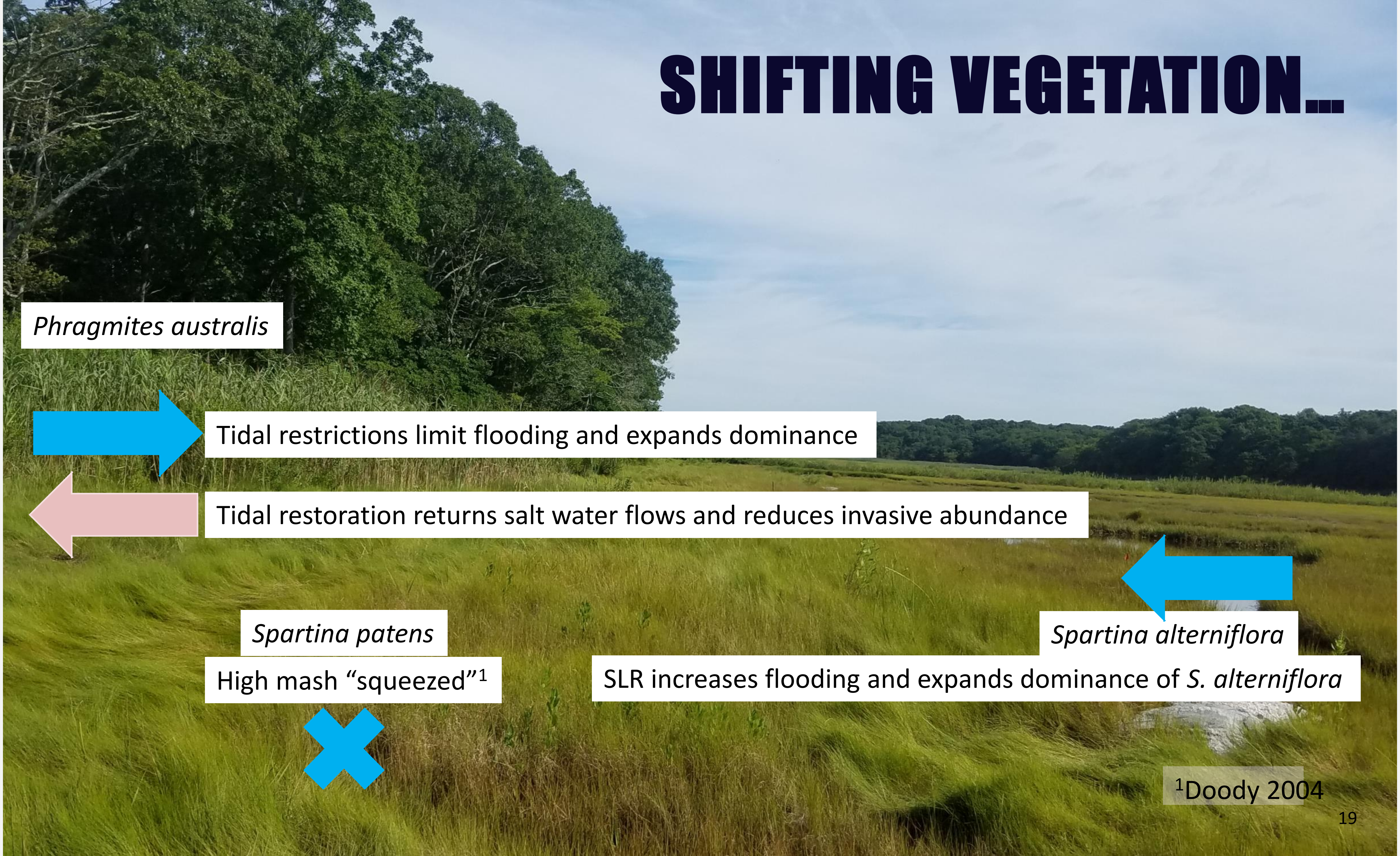
McLeod et al. 2011
Barbier et al. 2011

SALTMARSHES HAVE STRONG ZONATION



https://commons.wikimedia.org/wiki/File%3ASalt_pannes_and_pools_high_and_low_tide.gif

SHIFTING VEGETATION…



HOW DO SHIFTS IN VEGETATION ASSOCIATED WITH TIDAL RESTORATION AND SLR EFFECT C AND N-BASED SERVICES?

- **Field survey**
  - dominant vegetation
  - tidal restoration

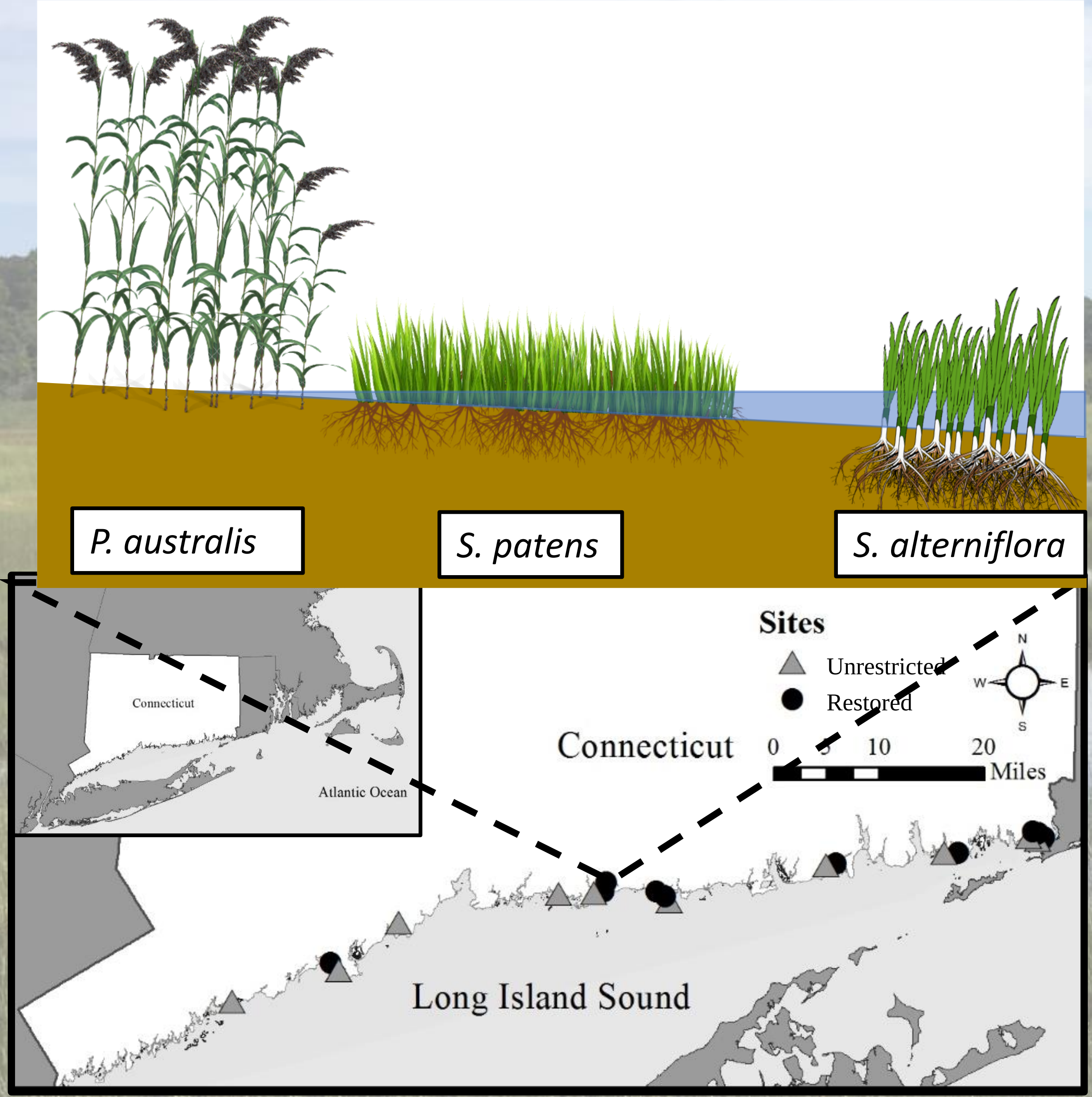
- **Marsh organ experiment**
  - dominant vegetation
  - SLR scenarios

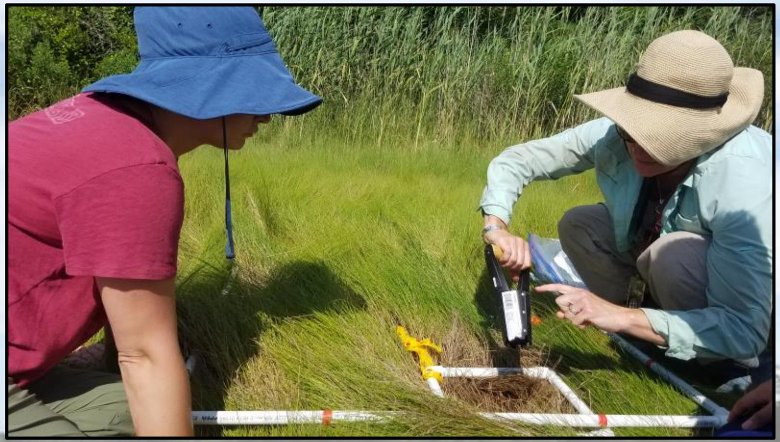
Long Island Sound Study
A Partnership to Restore and Protect the Sound

Sea Grant
Connecticut

CIRCA

Field Survey (20 sites)





★ : Vegetation effect

★ : Restoration effect

Soils

- pH
- NO_3^-
- NH_4^+
- EC ★
- Cl^- ★
- SO_4^{2-} ★
- Bulk density ★
- Soil moisture ★
- Sediment %C ★
- Sediment %N
- Carbon density ★

Vegetation

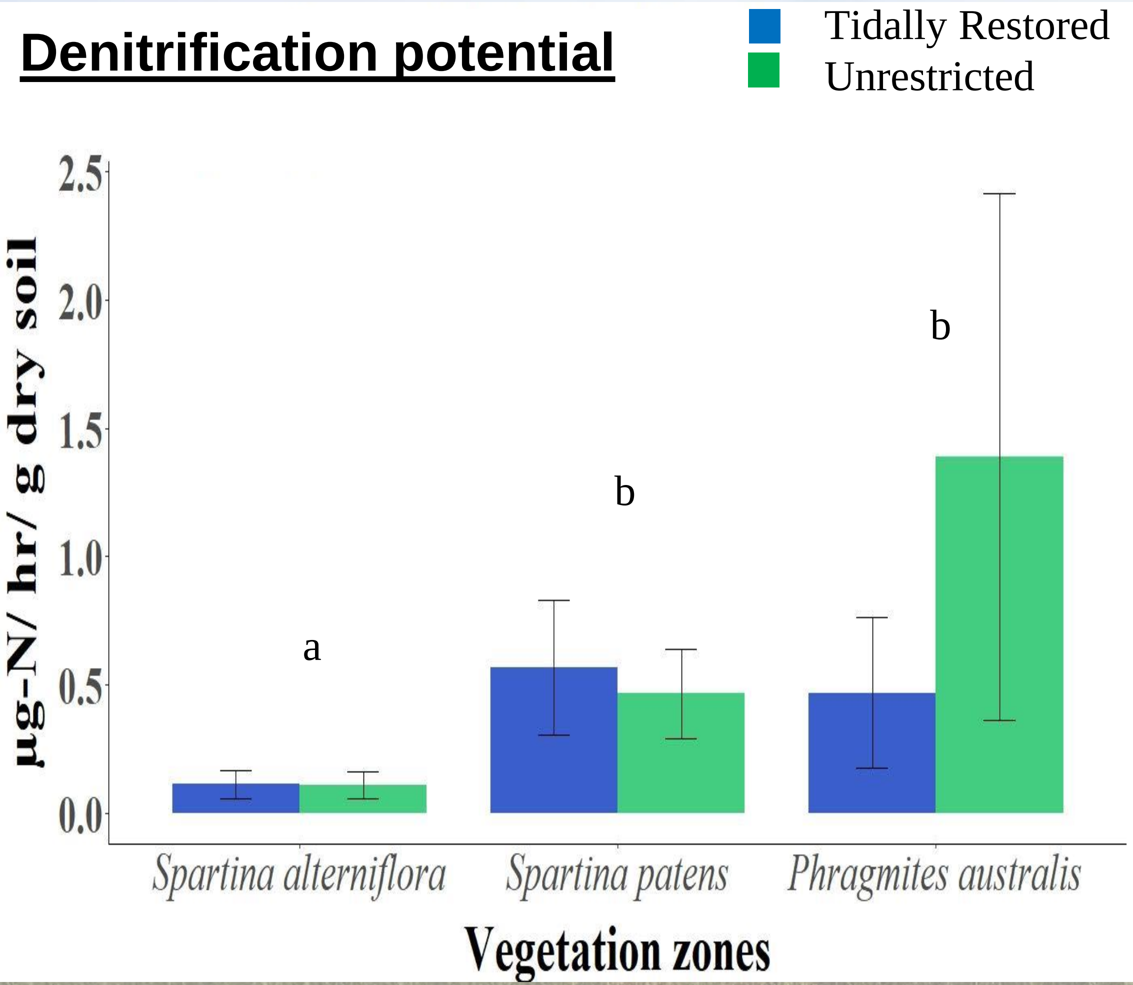
- Aboveground biomass ★
- AGB %C ★
- AGB %N
- Belowground biomass ★
- BGB %C ★
- BGB %N

Microorganisms

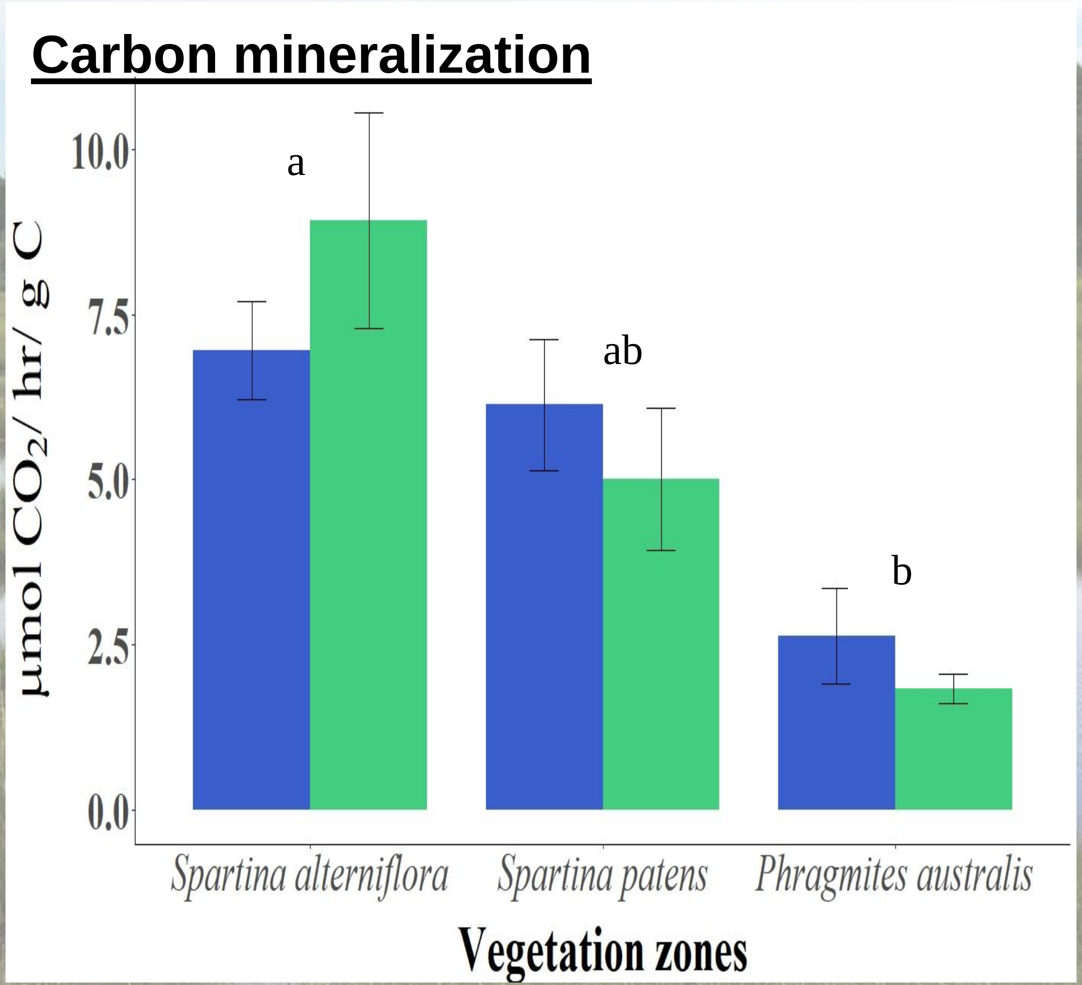
- Carbon mineralization ★
- Substrate-induced respiration ★
- Denitrification potential ★
- 16S rRNA bacterial communities ★

Barry et al. *in review*

Microbial process rates differ among vegetation zones, but not between tidally restored and unrestricted marshes



Ooi et al. *in prep*



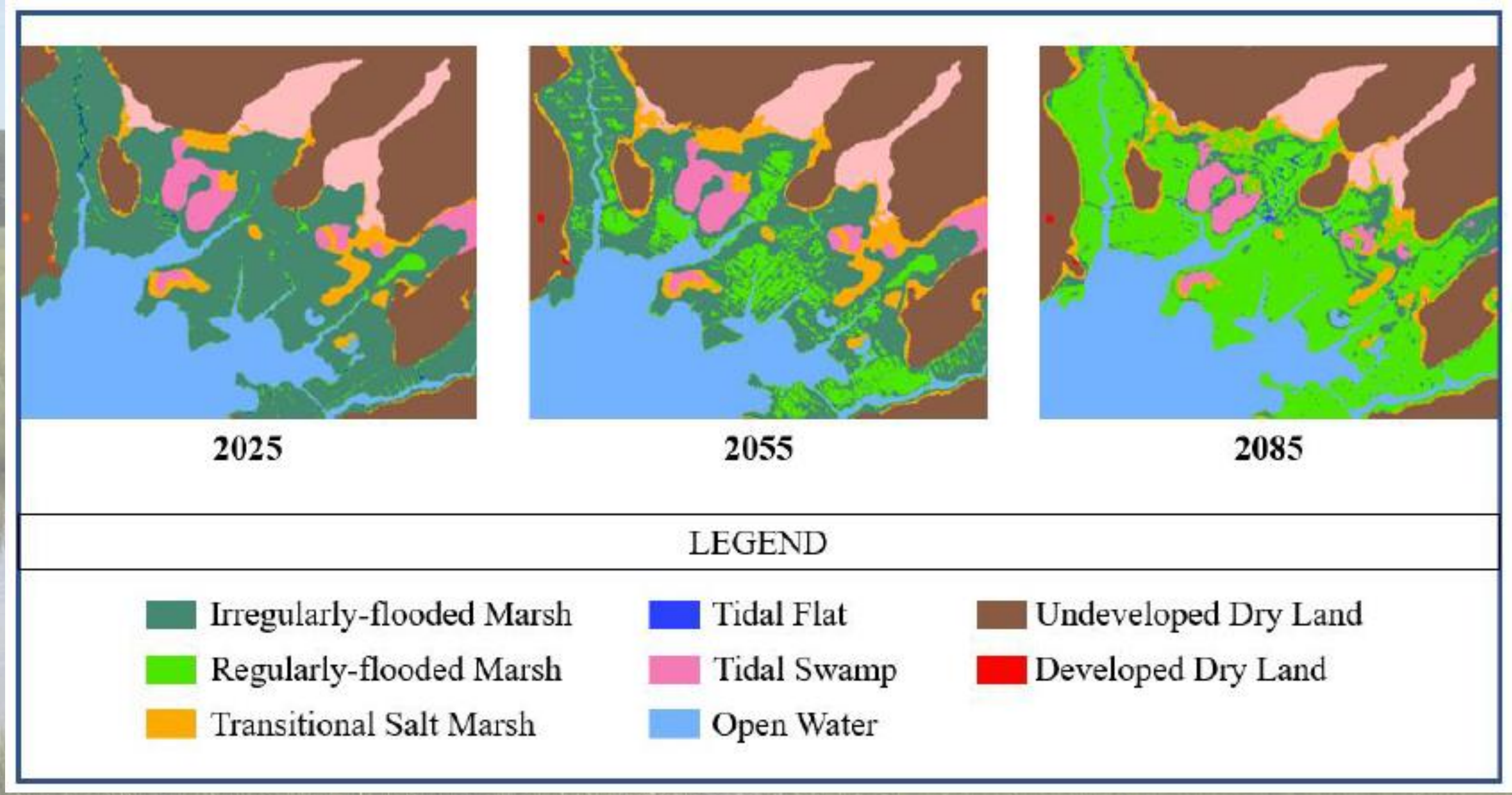
Barry et al. *in review*

Vegetation zones good indicators of microbial process rates

- *S. alterniflora* expansion may decrease C storage & N removal
- *Phragmites* invasion may increase these services
- Need to scale by vegetation extent to better examine effects of vegetation shifts

Half of CT marshes will likely covert from high to low marsh by 2085

- Shift in vegetation may result in loss of denitrification potential
  - 156-639 kg-N/hr



Ooi et al. *in prep*

Marsh Organ Experiment

★: Vegetation effect
☆: SLR effect

<u>3 SLR treatments</u>

- Present Day
- 10-Year SLR (7.5cm)[1]
- 20-Year SLR (15cm)[1]

<u>5 Vegetation treatments</u>

- *S. alterniflora*
- Low marsh control
- *S. patens*
- *P. australis*
- High marsh control

<u>Soils</u>

- EC
- Cl^-
- SO_4^-
- soil moisture
- pH
- %C
- %N

<u>Biomass</u>

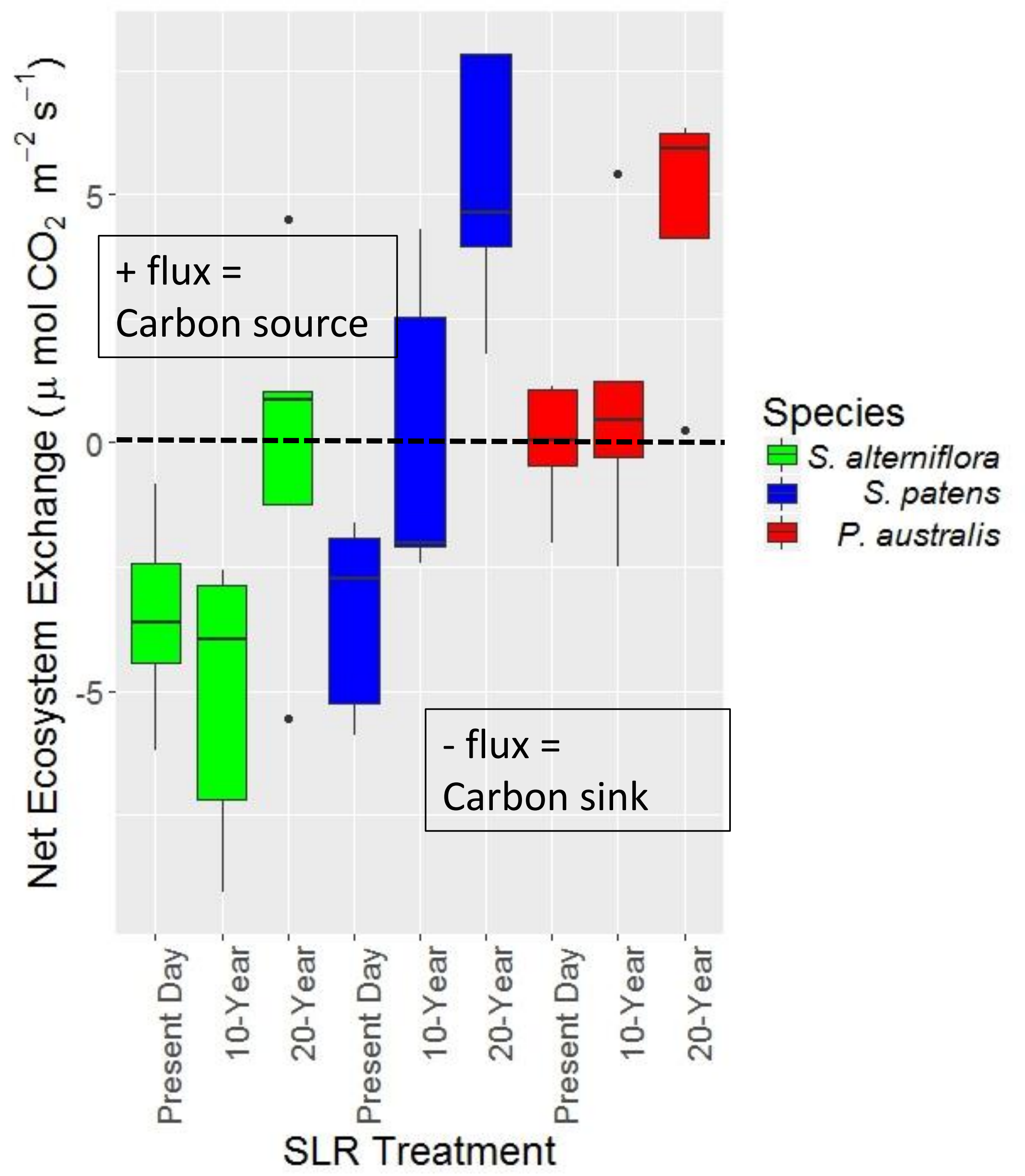
- Aboveground ★
- Belowground

<u>Gas fluxes</u>

- Net ecosystem exchange ★☆
- Ecosystem respiration ★
- Carbon mineralization ★
- Denitrification

[1]Clough *et al.* 2015

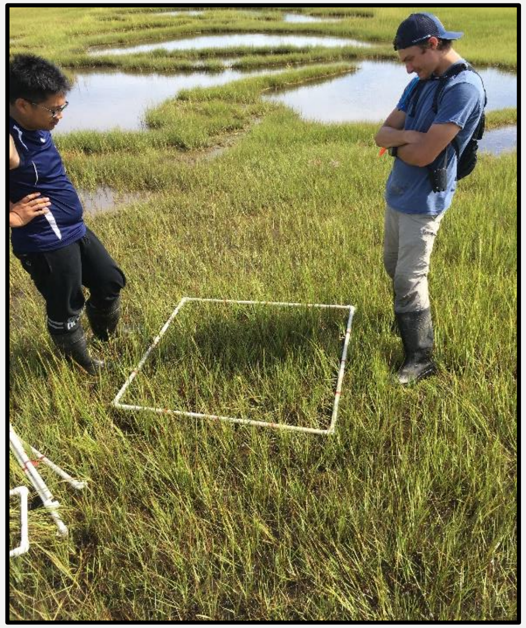
In-situ carbon flux



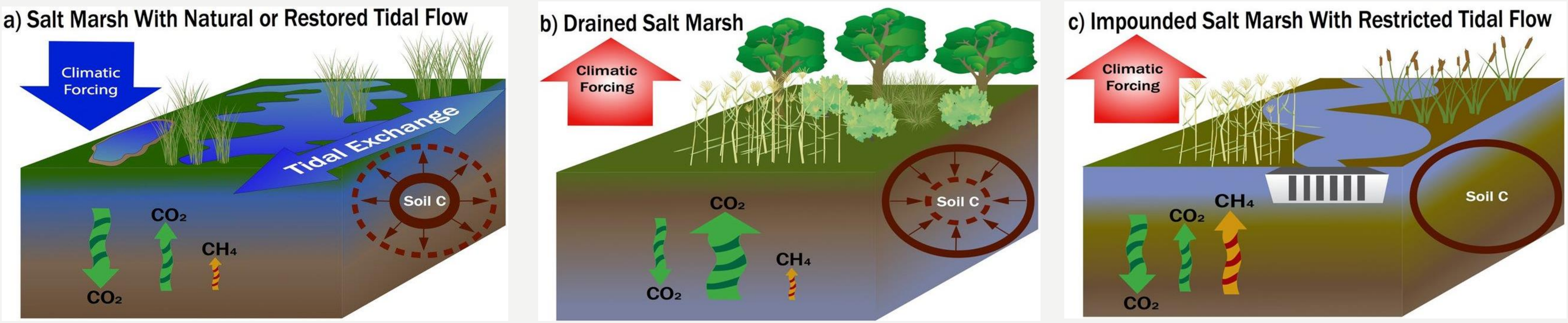
Barry et al. *in prep*

KEY FINDINGS

- Flooding frequency alone not driving carbon cycling
- Feedbacks with plant community mediate carbon turnover
  - Differential rhizosphere oxidation and exudation
  - Increased *Spartina* spp. dominance associated with SLR may increase C turnover rates



PROMOTING BLUE CARBON SERVICES…



Kroeger et al. 2017

COASTAL DEVELOPMENT AND TIDAL RESTRICTIONS PERVASIVE IN CT

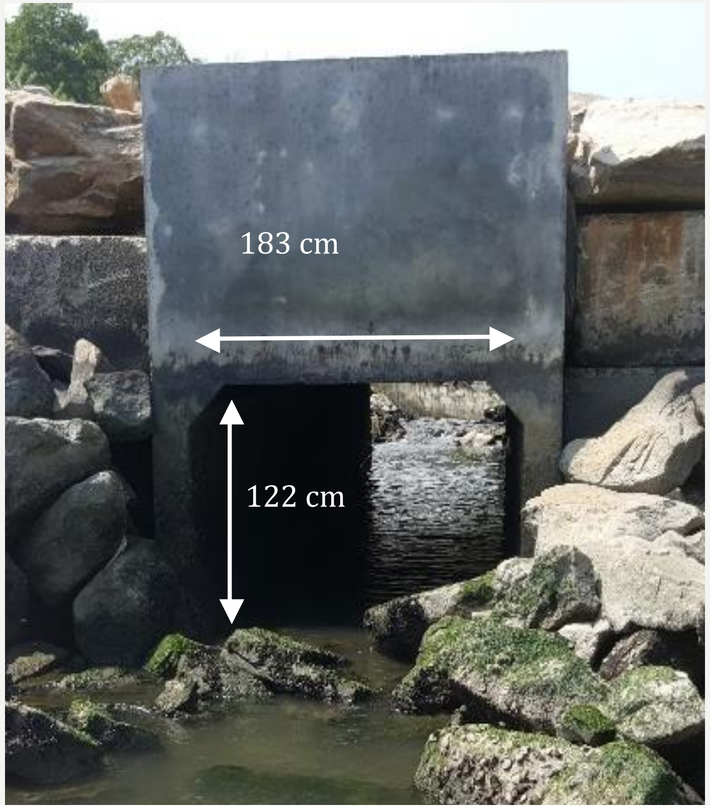
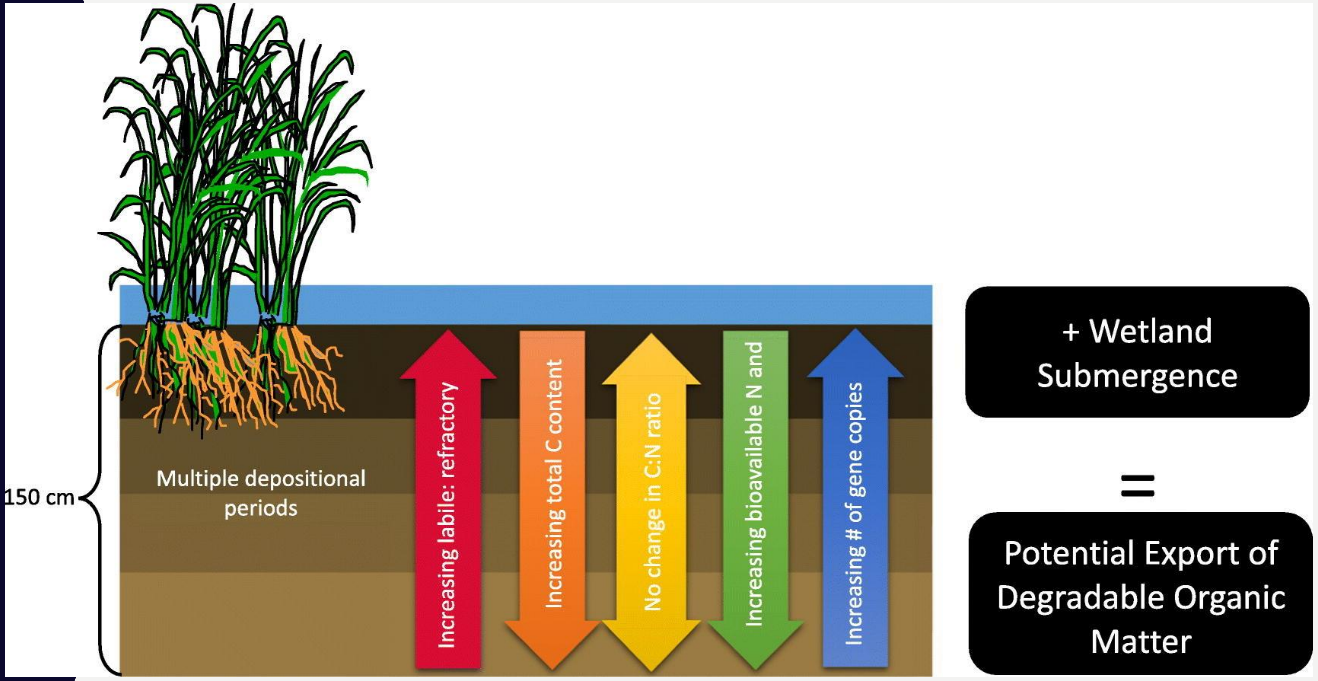


Photo: Jim O'Donnell

Culvert restricting tidal flow into a tidal marsh; >60% of CT marshes tidally restricted to some degree

- How do tidal restriction and SLR interact to:
  - Alter the magnitude and frequency of flooding?
  - Consequences for marsh migration and C and N cycling?

WHAT HAPPENS TO C WHEN PLANTS CAN'T KEEP UP WITH SLR?



Steinmuller and Chambers 2019

- Following submergence, C can be lost via:
  - – Mineralization
  - – Reburied within adjacent subtidal sediments
  - – Exported into coastal ocean
    - Fate in LIS?

THIN LAYER PLACEMENT TO LIMIT MARSH DROWNING?

Sediment addition:

- Adds elevation capital
- Decreases water depth
- Increases redox potential, reducing phytotoxins (e.g., sulfides)
- Increases plant growth (Mendelssohn & Kuhn, 2003)

- No experimental evaluation of TLP in CT

TLP IN CONNECTICUT?

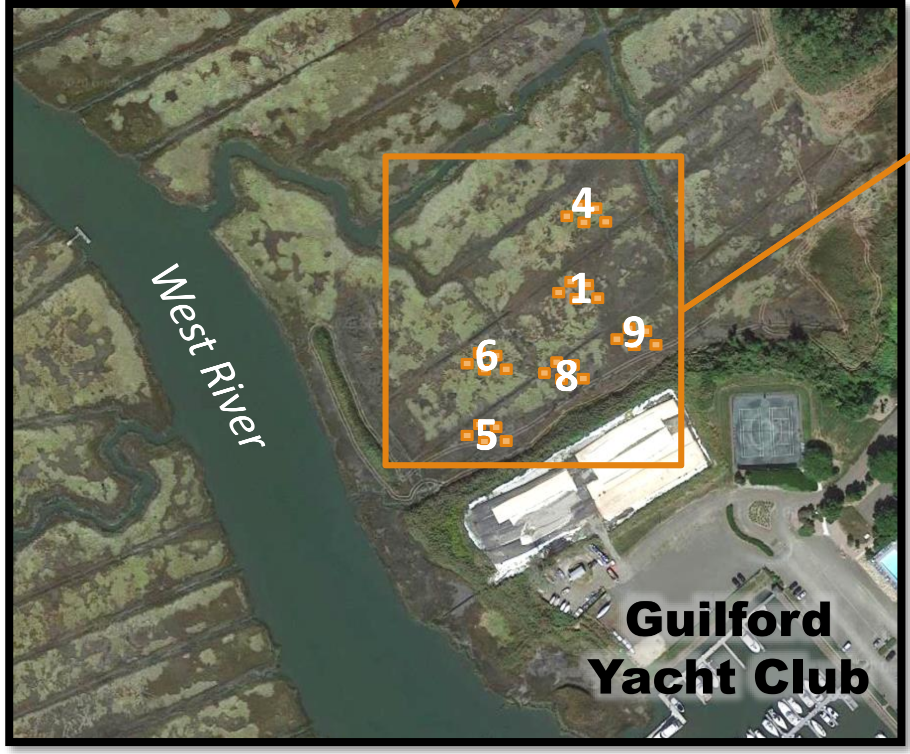
CHALLENG

- Sediment sou
- Permitting
- Accessibility c
- Sediment con chemistry

O'Donnell et al. 2018

S

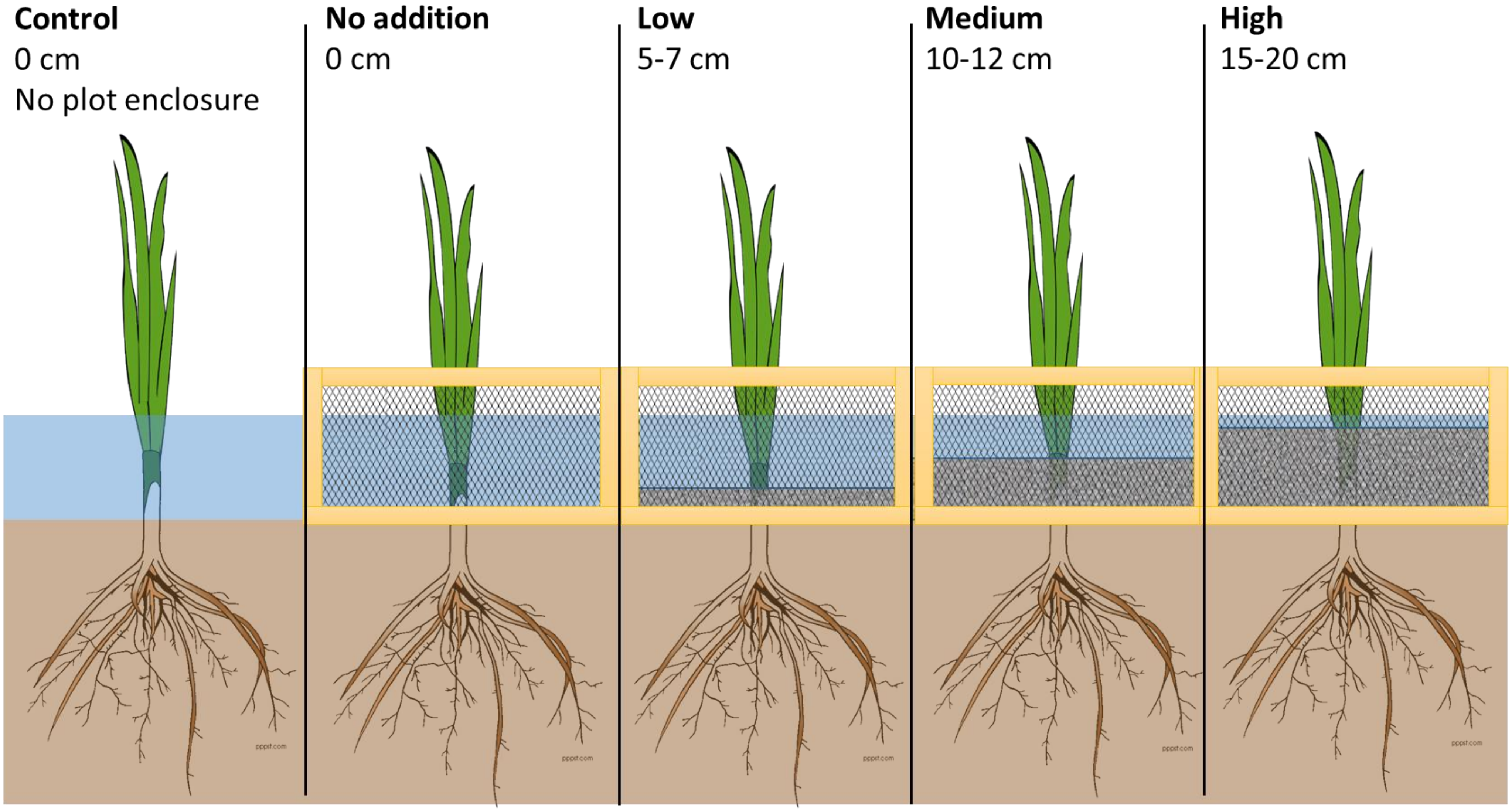
- liment
- lience
- services
- n habitat

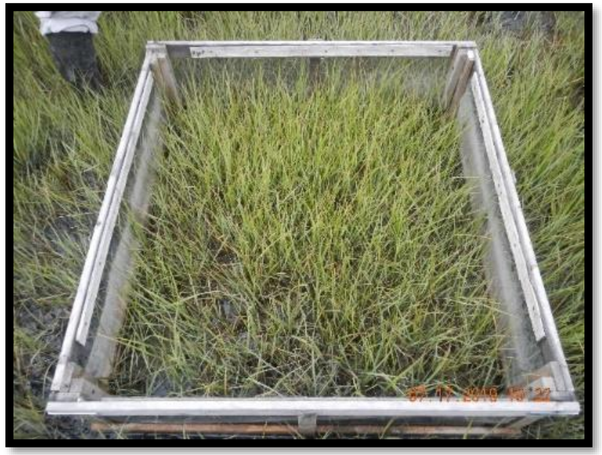


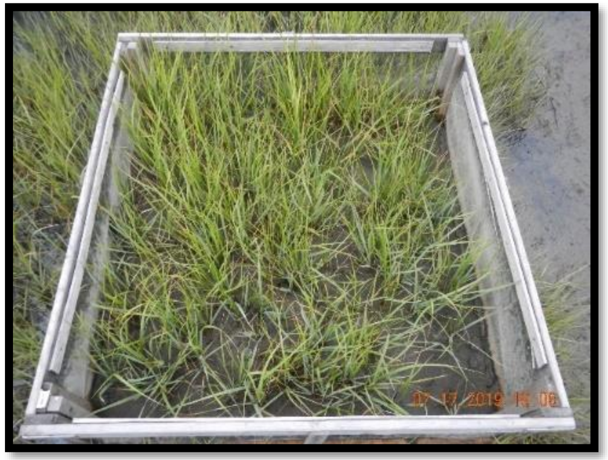
Study Site – Guilford, CT

Experimental Setup – May 2019

- Randomized Complete Block Design
- Replicates blocked by elevation (n=6)







No addition

Low

Medium

3/6 plots with vegetation

High

July 17^{th}, 2019 – 9 weeks after application

MANAGING WETLAND C SERVICES

- Role of forested wetlands?
- Strategic invasive plant management
  - *Phragmites* may provide beneficial C services, eradication not feasible…
  - Management techniques may have unintended consequences (increased CH_4 emissions, nutrient export)
- Restore/maintain tidal flow where possible
  - Restores plant community and C and N services, reduces CH_4 emissions
  - Need to examine how restriction interacts with SLR to affect transgression and C and N services
- Thin Layer Deposition?
  - Need larger scale, longer-term examination across tidal range of CT, different sediment types, etc.

Funding

- EPA Great Lakes Restoration Initiative (GL00E01295)
- EPA Long Island Sound Study, Connecticut/New York Sea Grant (project R/CMB-42-CTNY funded under award LI96172701)
- Connecticut Institute for Resilience and Coastal Adaptation Matching funds program
- USFWS Coastal Program (F20AC00105)

Collaborators/Grad Students/Technicians:

- Shane Lishawa, Ashley Helton, Chris Elphick, Blaire Steven, Nancy Tuchman, Drew Monks
- Olivia Johnson, Aidan Barry, Sean Ooi, Sammy Walker, Anna Puchkoff
- Mary Donato, Alaina Bisson, Kayleigh Granville, Yi Liu, Cooper Hernsdorf, Emily Couture, Fiona Liu

QUESTIONS?

- Beth Lawrence (beth.lawrence@uconn.edu)