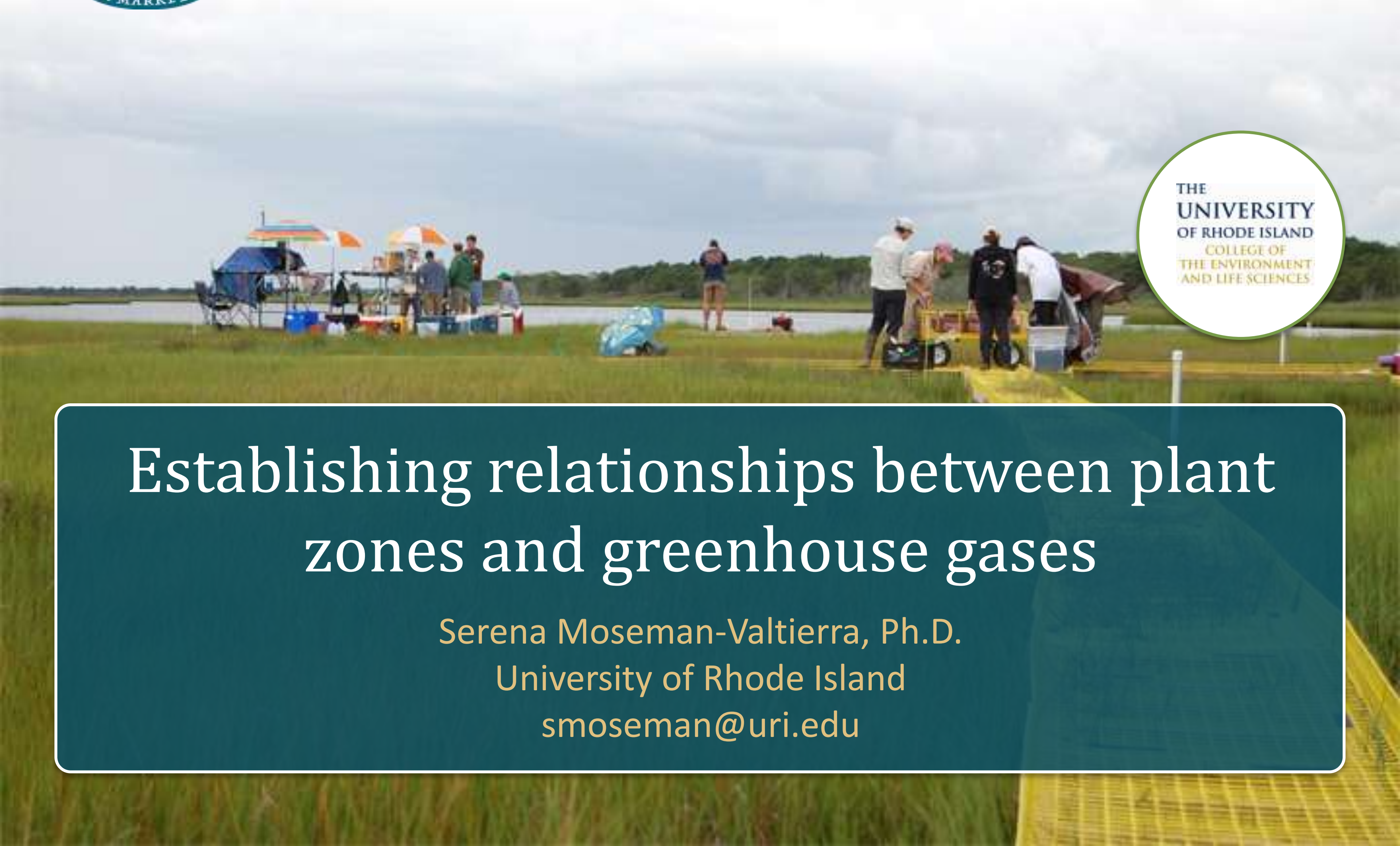
BRINGING WETLANDS to MARKET
Nitrogen & Coastal Blue Carbon

Capitalizing on Coastal Blue Carbon

The Conference Center at Massasoit Community College | *May 12-13, 2015*

WAQUOIT BAY
NATIONAL ESTUARINE RESEARCH RESERVE



THE UNIVERSITY OF RHODE ISLAND
COLLEGE OF THE ENVIRONMENT AND LIFE SCIENCES

Establishing relationships between plant zones and greenhouse gases

Serena Moseman-Valtierra, Ph.D.
University of Rhode Island
smoseman@uri.edu

Outline: Relating plant zones to GHGs

I. Overview of salt marsh zonation

A. Plant impacts on GHG fluxes

B. Potential roles of plants for Blue C accounting

II. Comparison of GHG fluxes across plant zones at Sage Lot Pond

III. Applications for the results

A. Scaling up

B. Modeling

Section #1

OVERVIEW OF SALT MARSH ZONATION

Salt marsh zonation reflects an ecological interplay

Bertness M.D. 1992. American Scientist 80: 260-268

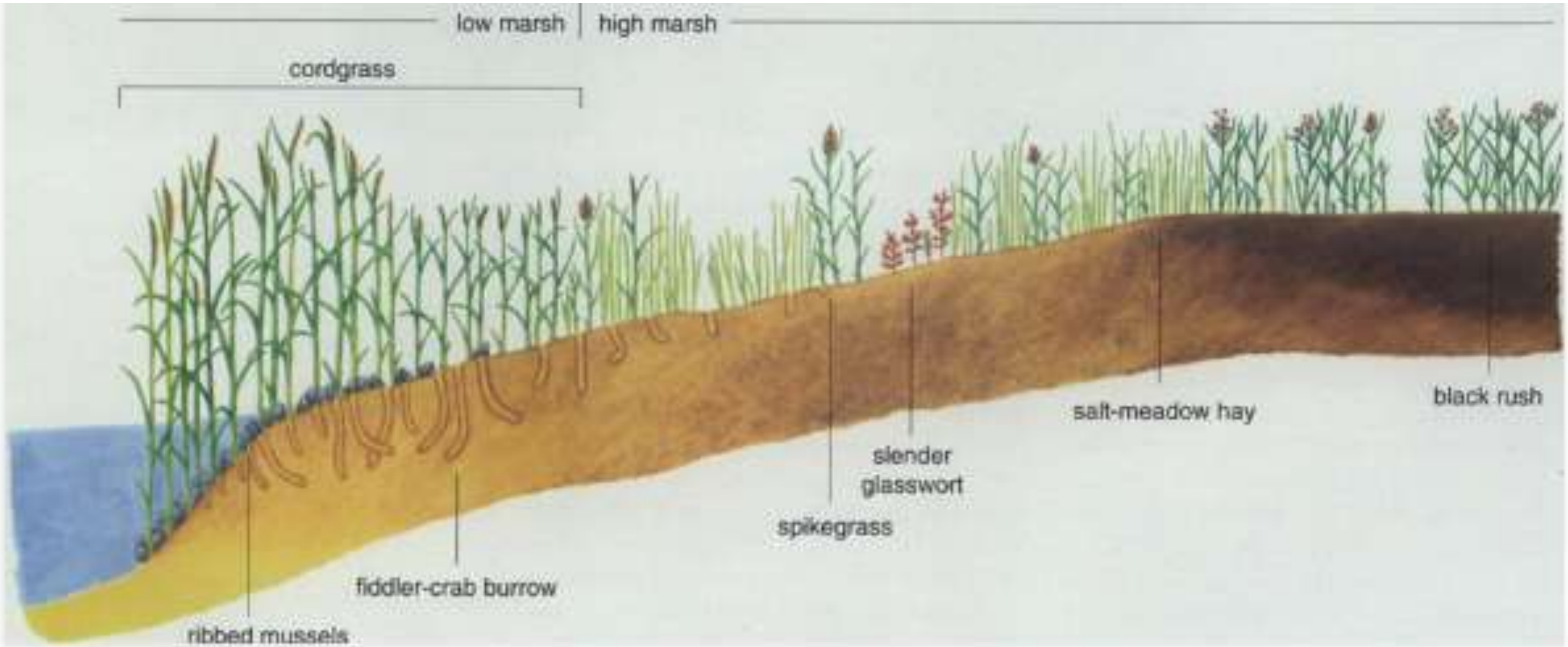


Figure 3. Distinct zones characterize a New England salt marsh, for animals as well as plants. On the coastal side of the low marsh, shown in cross section, thick beds of ribbed mussels are attached to the roots of cordgrass. The mussels decrease in abundance as one moves inland, and the marsh soil becomes dotted with small holes, the burrows of fiddler crabs. These too, however, are largely limited to the low marsh. Even the cordgrass of the low marsh is divided into two zones: The cordgrass closer to the sea is tall and the cordgrass farther from the sea is short because soil there is composed of compacted peat produced by the decay of the grass. The high-marsh zones of salt-meadow hay and black rush are primarily monocultures, but disturbed areas support small populations of spikegrass and slender glasswort.

Environments differ between marsh zones

Zone	Avg. salinity (psu) +/- stand. Error	Avg. moisture (%) +/- stand. error	Avg. redox (mV) +/- stand. error	H_2S (mM) +/- stand. error
High	33.2 +/- 1.3	55.6 +/- 2.7	207 +/- 24.0	565.3 +/- 284
Low	27.9 +/- 1.4	62.9 +/- 0.8	102 +/- 55.0	2437.9 +/- 490

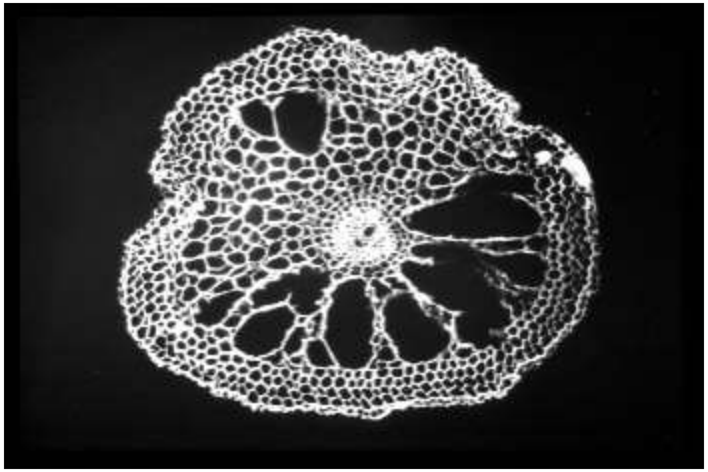


Photo: Irv Mendelssohn
http://life.bio.sunysb.edu/marinebio/spartina.html

Dominant plant species

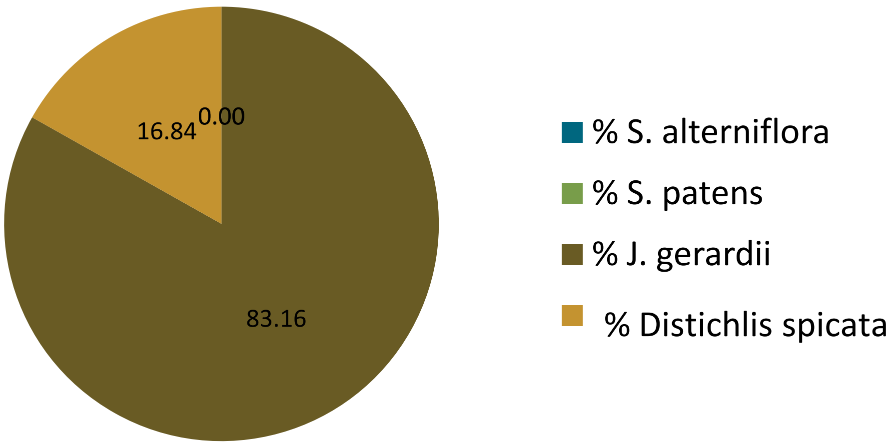
High marsh

- *Distichlis spicata*
- *Juncus gerardii*

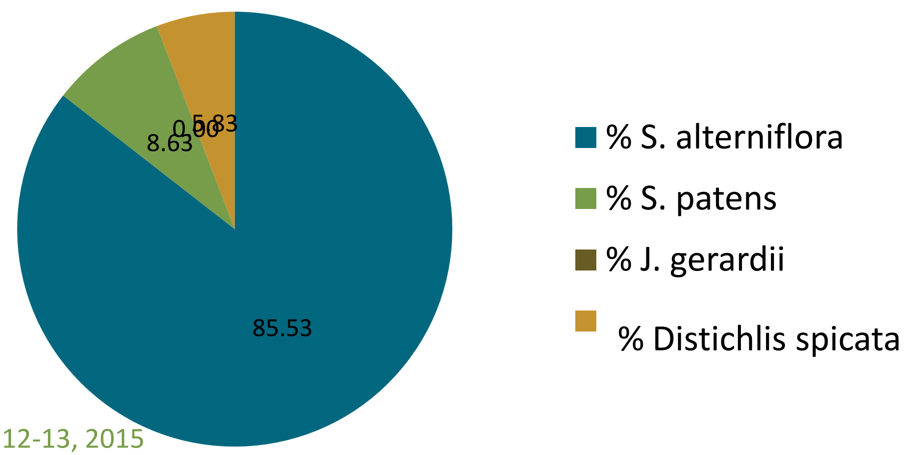
Low marsh

- *Spartina alterniflora*

Plant Cover High Marsh



Plant Cover Low Marsh



Contrasting morphologies of high marsh plants

Bertness M.D. 1992. American Scientist 80: 260-268

Left:
Distichlis spicata
(spike grass)

Figure 4. Plant morphology affects competitive ability. Spikegrass stems are separated by lengths of belowground runners *(left)*. This makes for a less densely growing plant, but one well adapted for colonizing new areas. Black rush *(right)* has turf morphology—dense groups of stems arising from a belowground mat of roots and rhizomes. Turf grasses do not rapidly invade new areas, but turf morphology is competitively superior to runner morphology over time.

Right: Juncus gerardii
(black rush)

Physiological adaptations to different marsh zones

Oxygen transport by roots

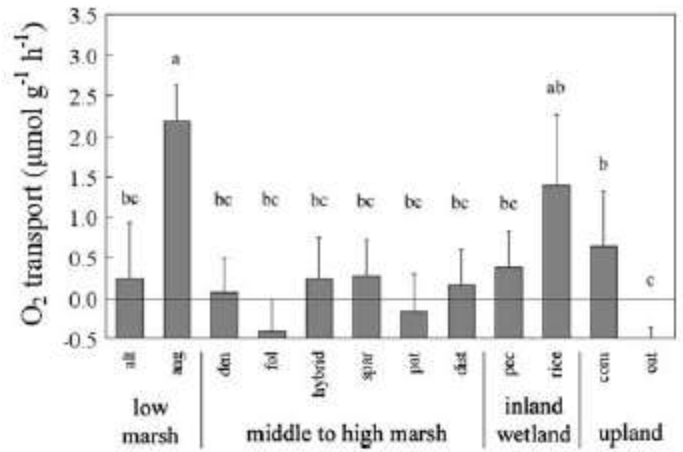


Fig. 2 Rates of internal oxygen transport (μmol g^{-1} h^{-1}) for the species in the study, grouped by ecological functional type. Oxygen transport rates were found by comparing oxygen consumption around root tissue when plants were exposed to air and when shoots were cut off and sealed with paraffin oil, thereby stopping the flow of oxygen. Shown is the least squares mean of 3–15 plants ± s.e. *Letters* indicate significant differences between species at $\alpha = 0.05$. Species abbreviations are as follows: *alt Spartina alterniflora*, *ang S. anglica*, *den S. densiflora*, *fol S. foliosa*, *hybrid S. alterniflora* × *S. foliosa* F1 hybrid, *spar S. spartinae*, *pat S. patens*, *dist Distichlis spicata*, *pec S. pectinata*, *rice Oryza sativa*, *corn Zea mays*, and *oat Avena sativa*

Oxidative stress in leaves

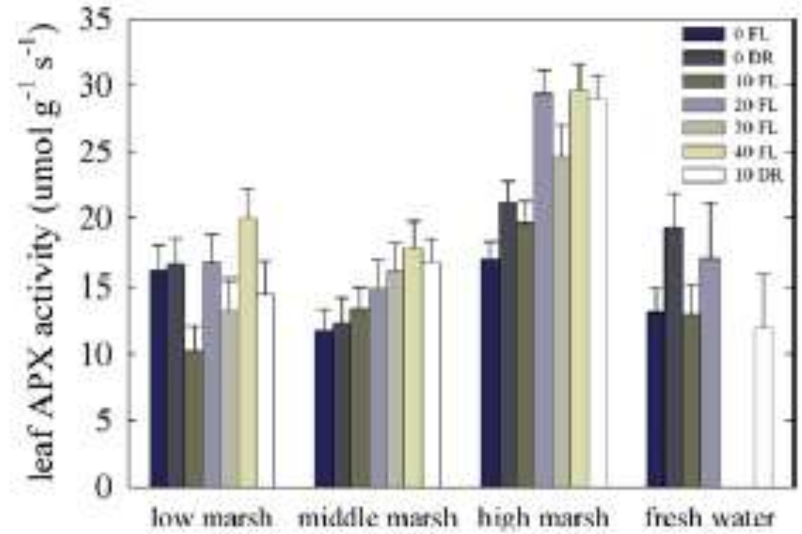


Fig. 7. The effect of decreasing soil Ψ on leaf ascorbate peroxidase (APX) activities. Bars indicate ± S.E. (n=3–15). Species are grouped by ecological functional type; treatments are arranged by decreasing Ψ and are labeled as in Fig. 2.

Maricle and Lee 2007 Mar. Biol.

Maricle et al. 2007 Environ. Exp. Bot.

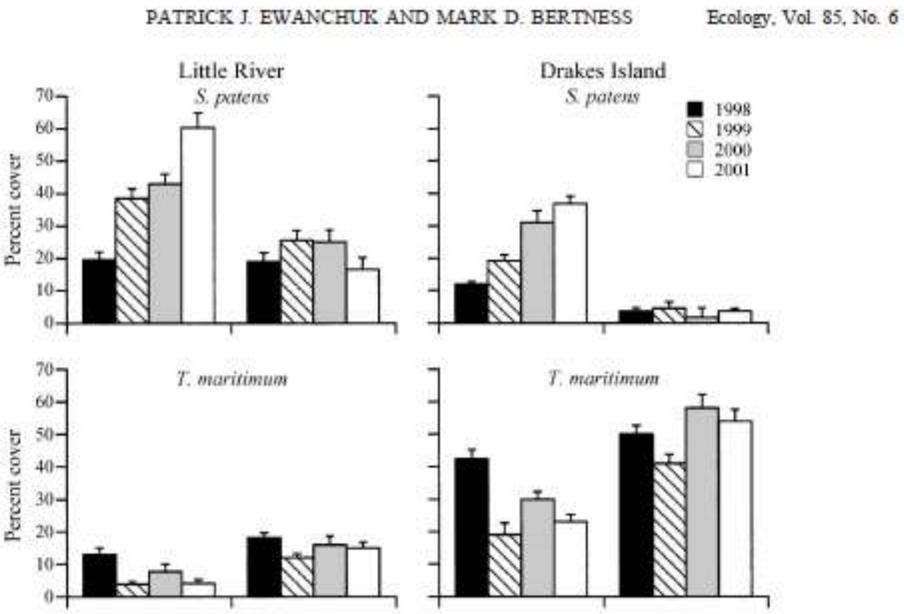
Waterlogging impacts plant diversity and composition

Ecology, 85(6), 2004, pp. 1568–1574

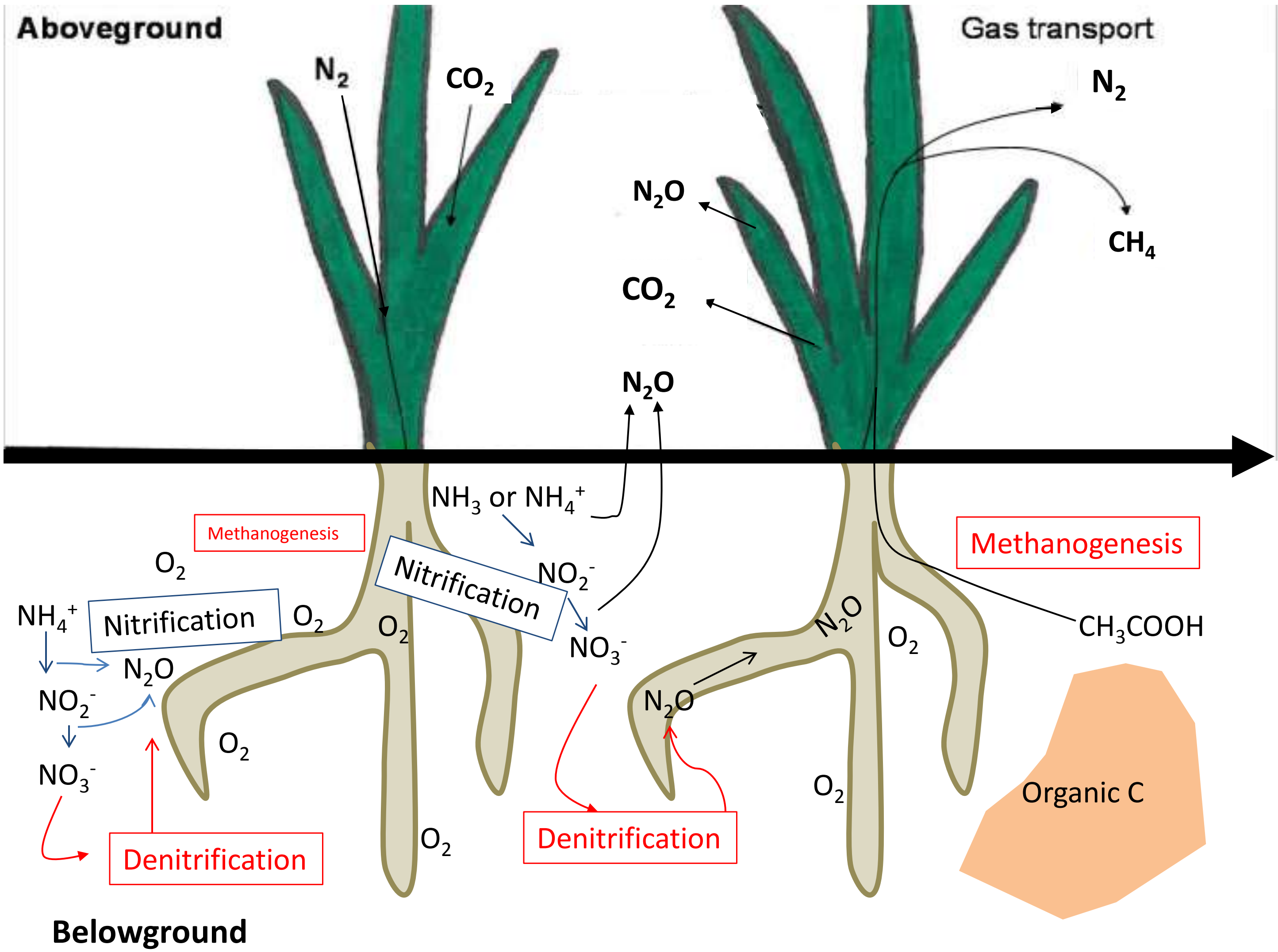
THE ROLE OF WATERLOGGING IN MAINTAINING FORB PANNES IN NORTHERN NEW ENGLAND SALT MARSHES

Patrick J. Ewanchuk[1] and Mark D. Bertness
Brown University, Department of Ecology and Evolutionary Biology, Providence, Rhode Island 02912 USA

Photo: Olivier Prichard

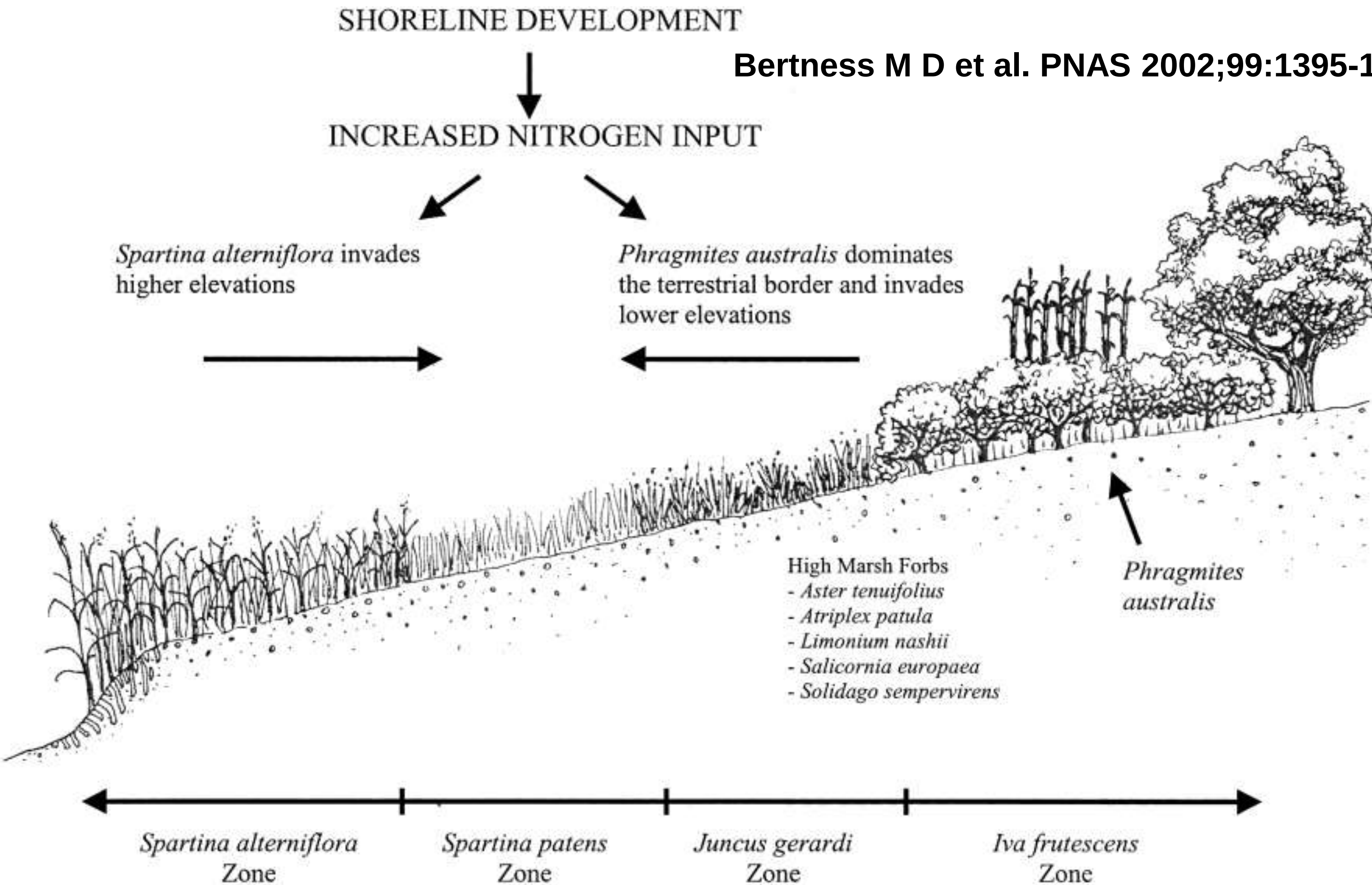


Plant-microbe interactions mediate C and N cycling



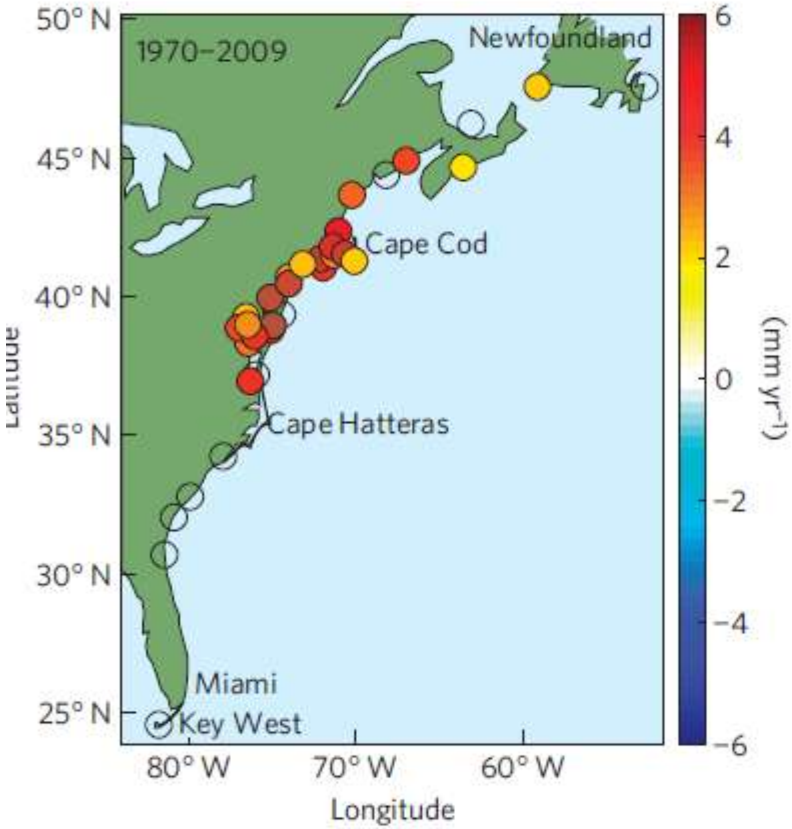
Zonation shifts in response to disturbance

Bertness M D et al. PNAS 2002;99:1395-1398



Vulnerability of Northeastern US Marshes

Figure: "Hotspot of accelerated sea level rise"
Sallenger et al. 2012. Nature Climate Change



- High relative rates of sea level rise:
  - Avg. 3.8 mm/y
  - Global <1 mm/y
- Low sediment supply (Weston 2014, Meade 1982)
- Limited transgression opportunity

What is the fate of Blue C? Uncertain futures for coastal marshes

Venice Lagoon, Italy

?

Plum Island, MA

Jamestown, RI

How can zonation studies serve Blue Carbon efforts?

- Are plants simple proxies?
- Does stratification improve C accounting?
- Mechanistic understanding of changes:
  die back, invasion, sea level rise

Section #2

COMPARING GHGS ACROSS PLANT ZONES- SAGE LOT POND

Objectives: To characterize GHG fluxes across major zones

2012-2013

1. High and low marsh zones
   - Light and dark, diel cycles
   - Growing season for both zones
   - Monthly in low marsh zone

2013-2014 (summer)

2. Unvegetated ponds

3. Invasive Phragmites upland border
   - See Rose Martin poster

Waquoit Bay NERR Salt Marsh Observatory Boardwalk

Boardwalk Features

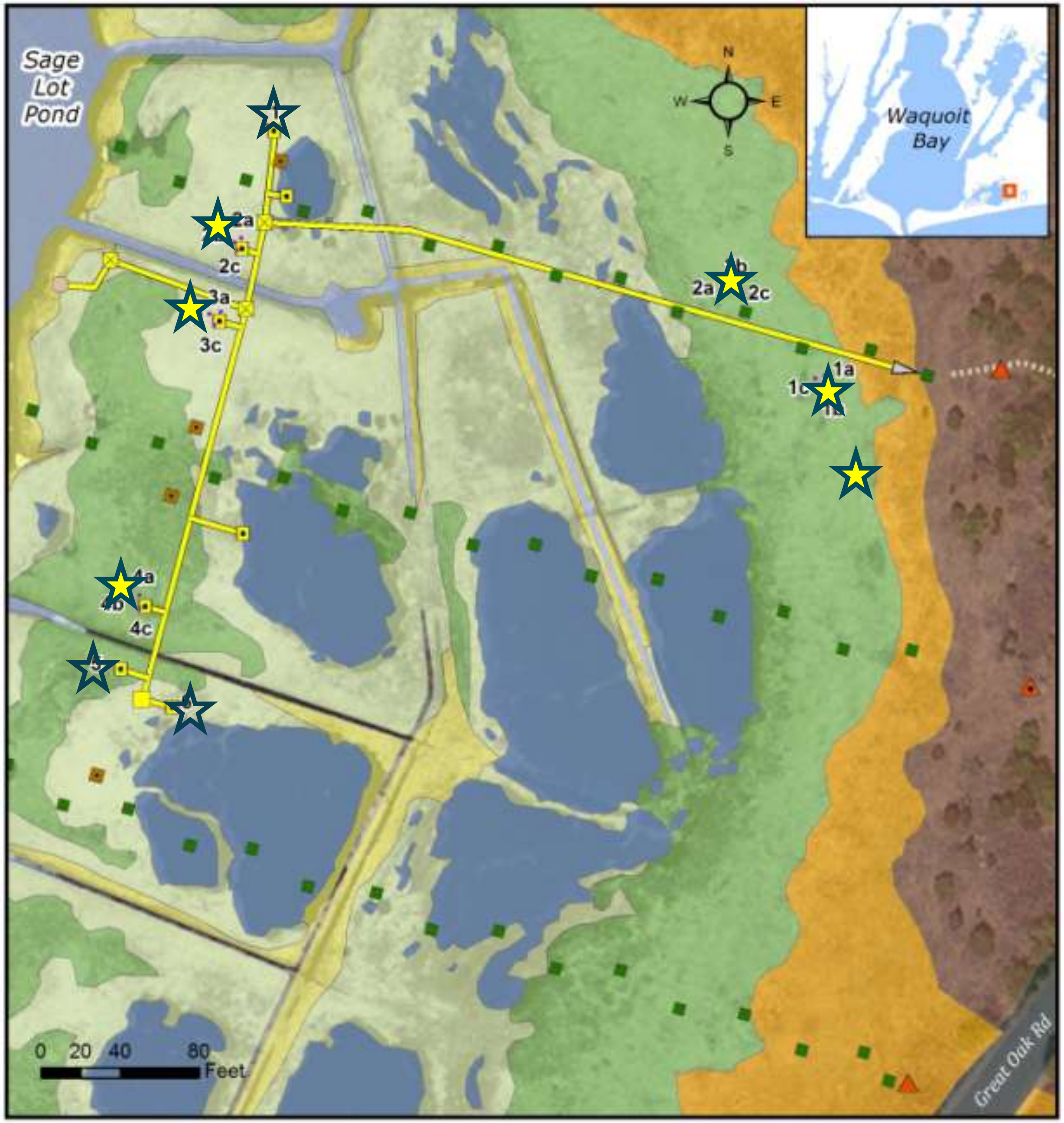
- Dock
- Endpoint
- Intersection
- Platform
- Ramp
- Walkway
- Cleared Trail
- SCcollars

Land Cover

- Upland Forest
- Roadway
- High Marsh - High
- High Marsh - Low
- Low Marsh
- Marsh Border
- Salt Marsh Pools

Pre-existing Biomonitoring Design

- Vertical Control: Concrete Monument
- Vertical Control: Deep-driven Rod
- Surface Elevation Tables
- Vegetation Plots



Created by: J. Mora, July 2012
Habitat data (2004) source: WBNERR
USGS orthos (2009) source: MassGIS

Sage Lot Pond-field sites

Photos: Rose Martin




Environmental Data (2012-2013)

Plant properties

-community composition
 (% cover)
- biomass
-density
-Height
-Leaf area

Soil properties

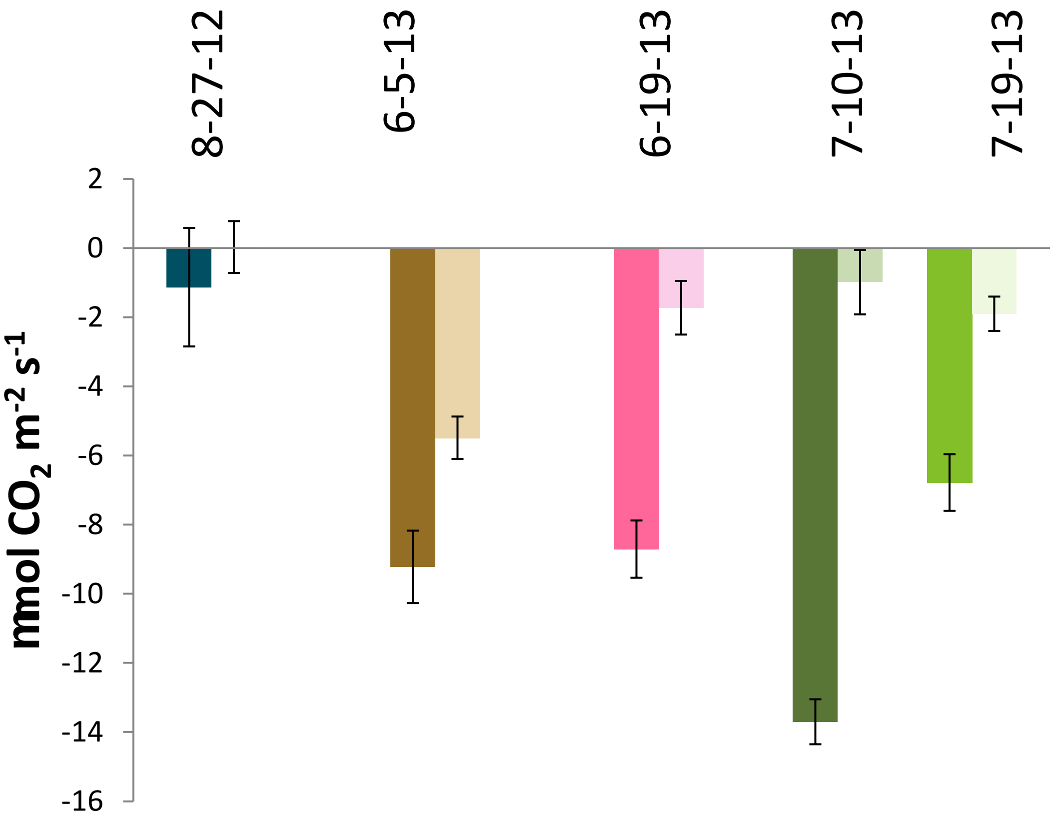
-Sediment moisture, salinity, temperature
-oxidation-reduction
 potential, pH
-Soil organic content
-Sulfide, nitrate, ammonium
-Water level (depth relative to marsh surface)

Climatic properties

-Precipitation, air temperature
-Wind
--Photosynthetically Active Radiation (PAR)

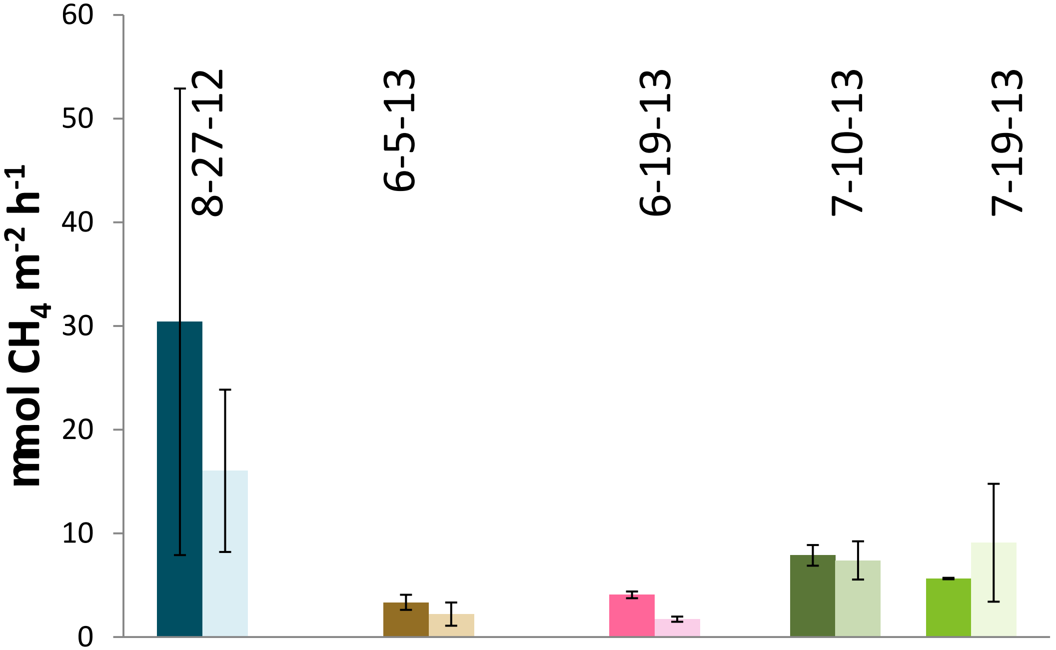
CO_2 uptake is significantly greater in the low marsh than the high marsh and the fluxes vary over time.

Dark colors: Low Marsh
Light colors: High Marsh



Date: $p<0.001$
Zone: $p<0.001$
Date X Zone: 0.003

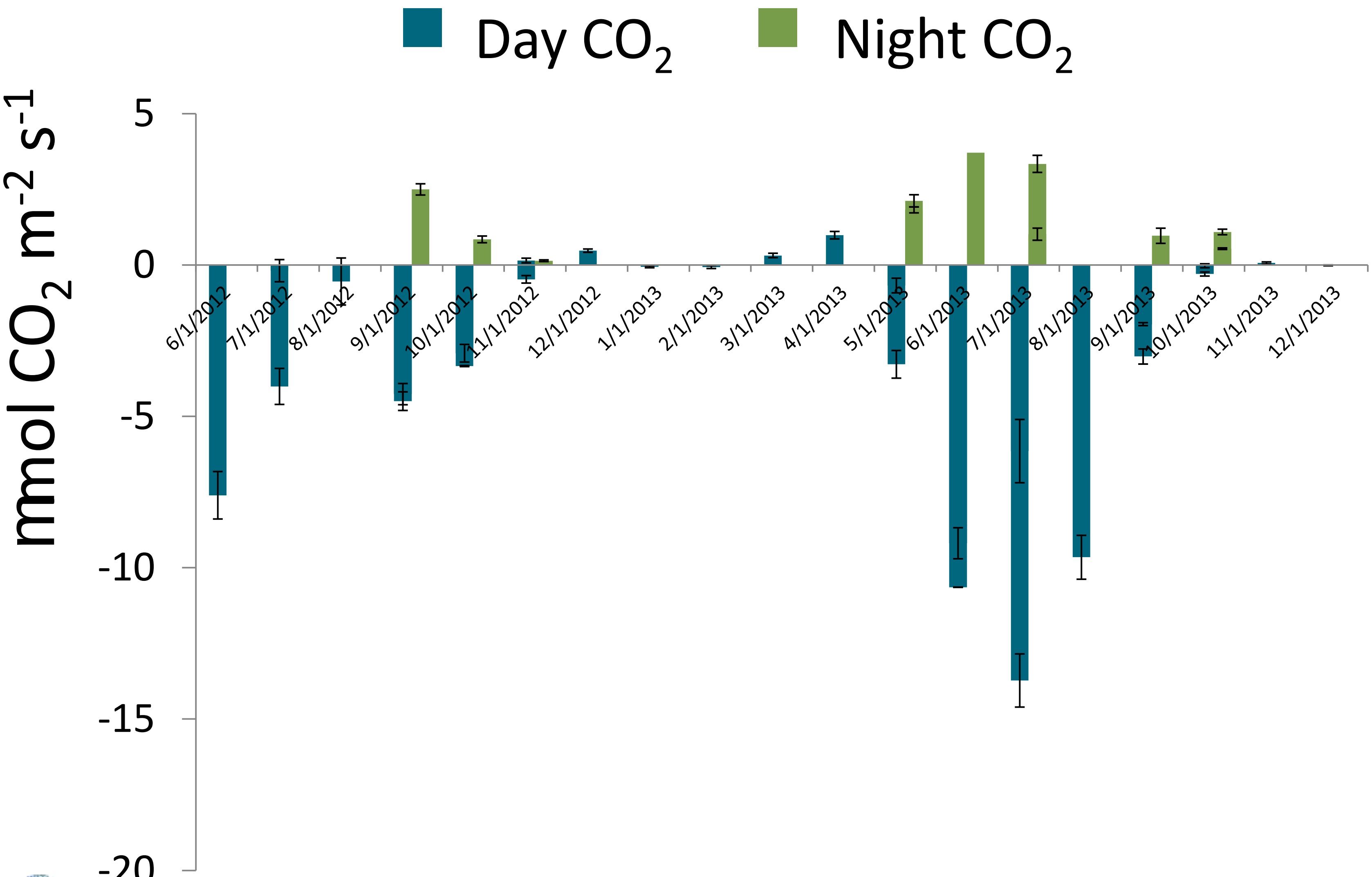
Methane emissions do not significantly differ between low and high marsh zones.



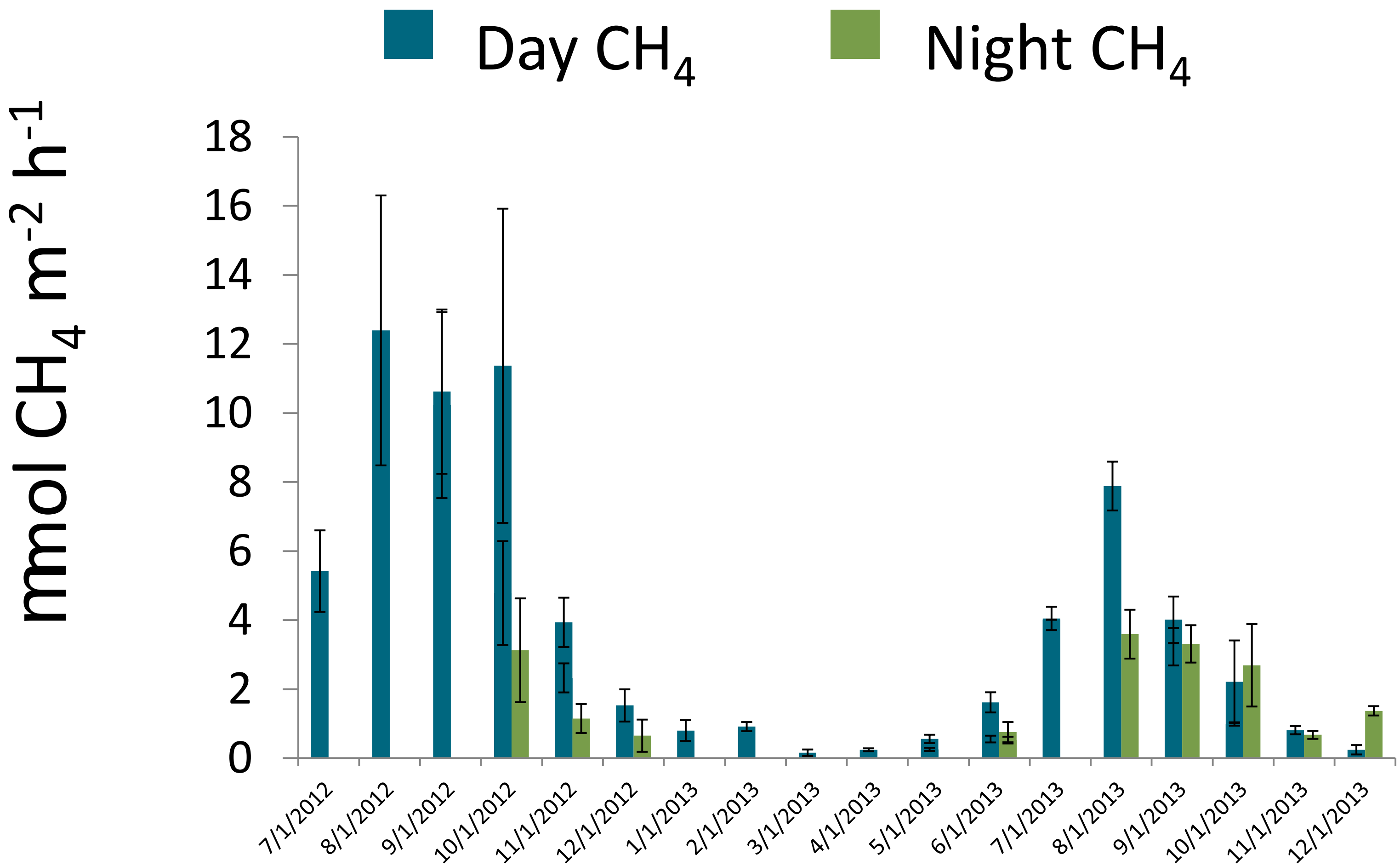
Dark colors: Low Marsh
Light colors: High Marsh

Date: p=0.008
Zone: p= 0.27
Date X Zone: 0.90

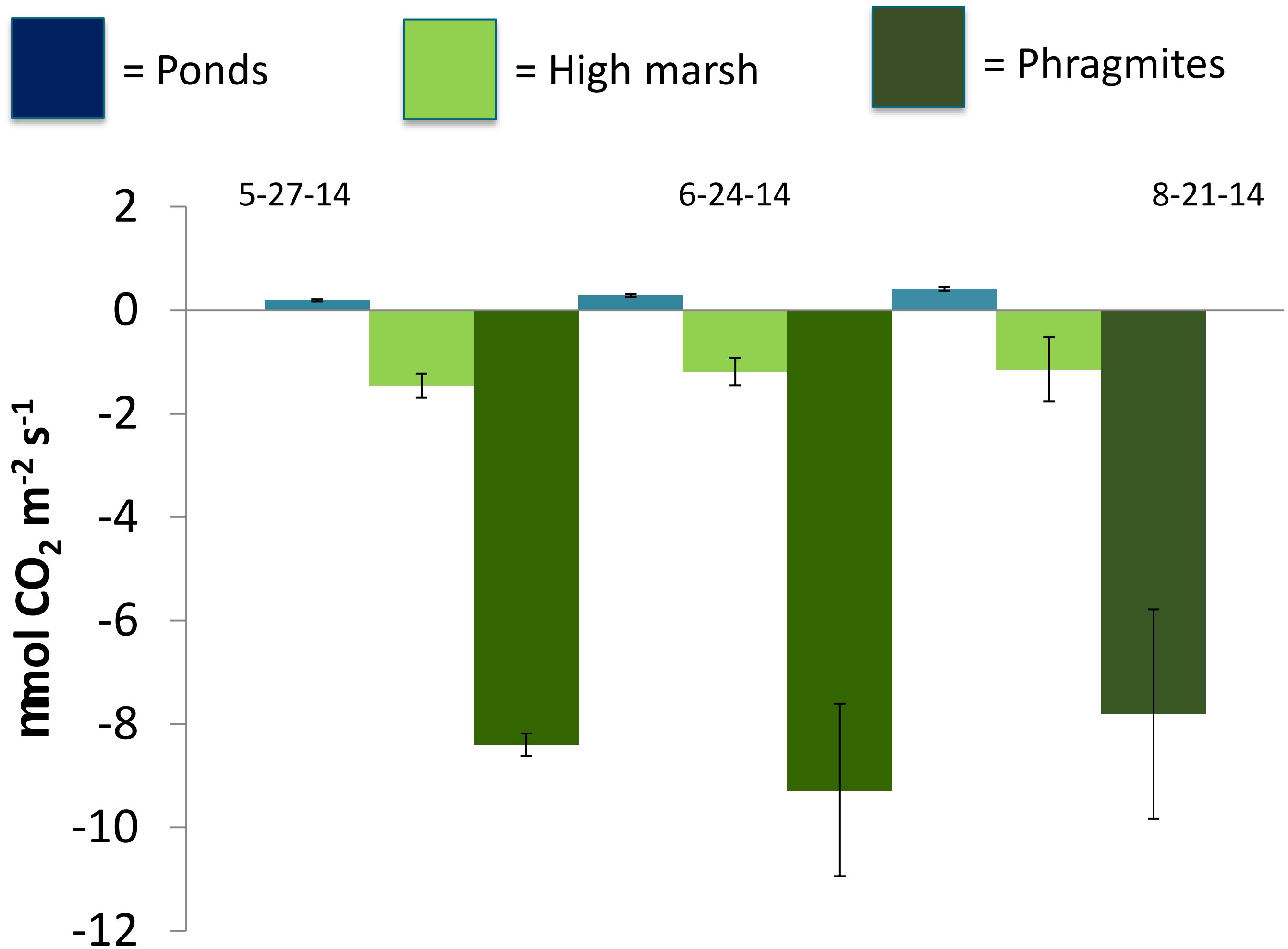
Temporal patterns for CO_2 in low marsh



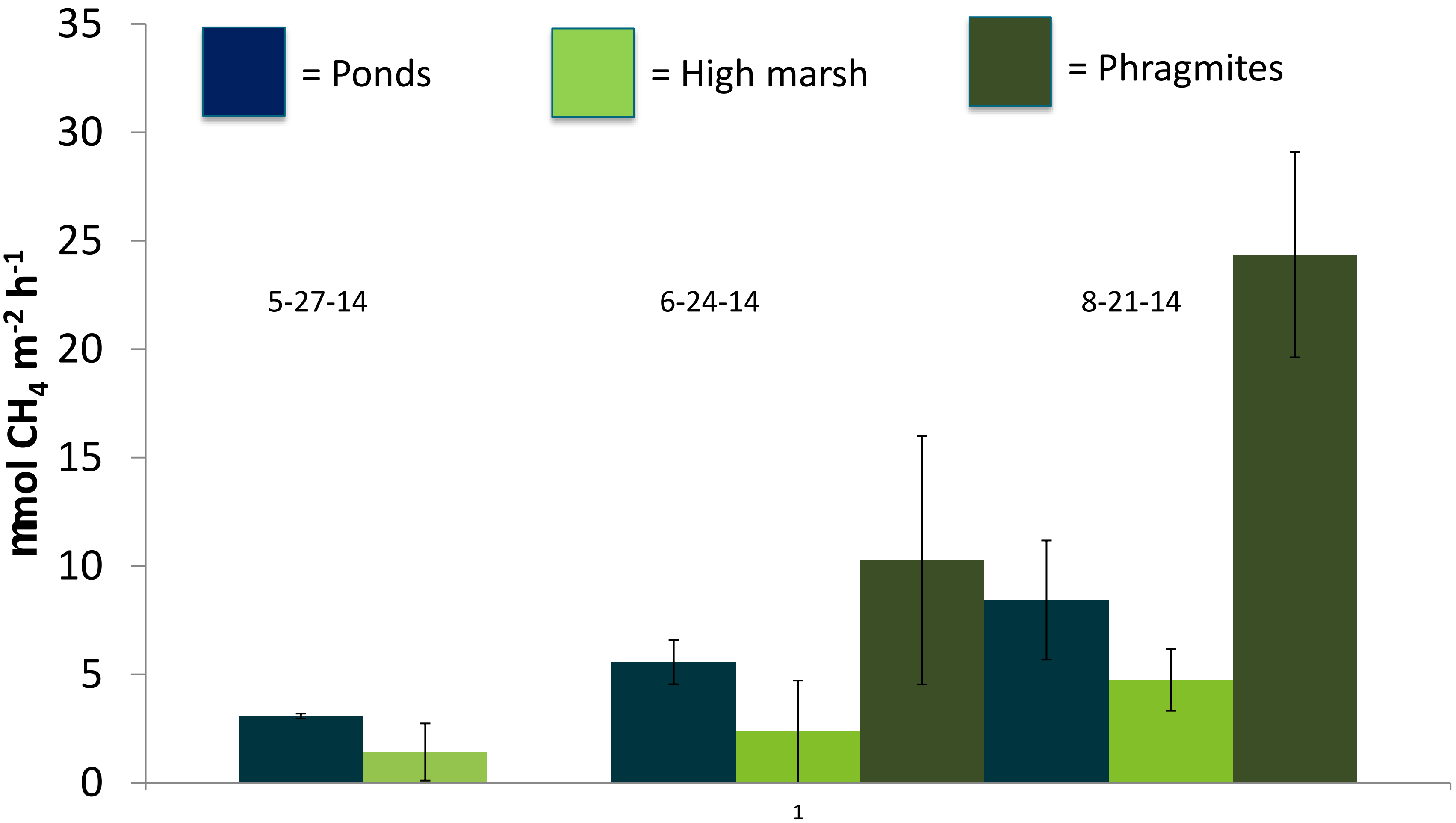
Temporal patterns for CH4 in low marsh



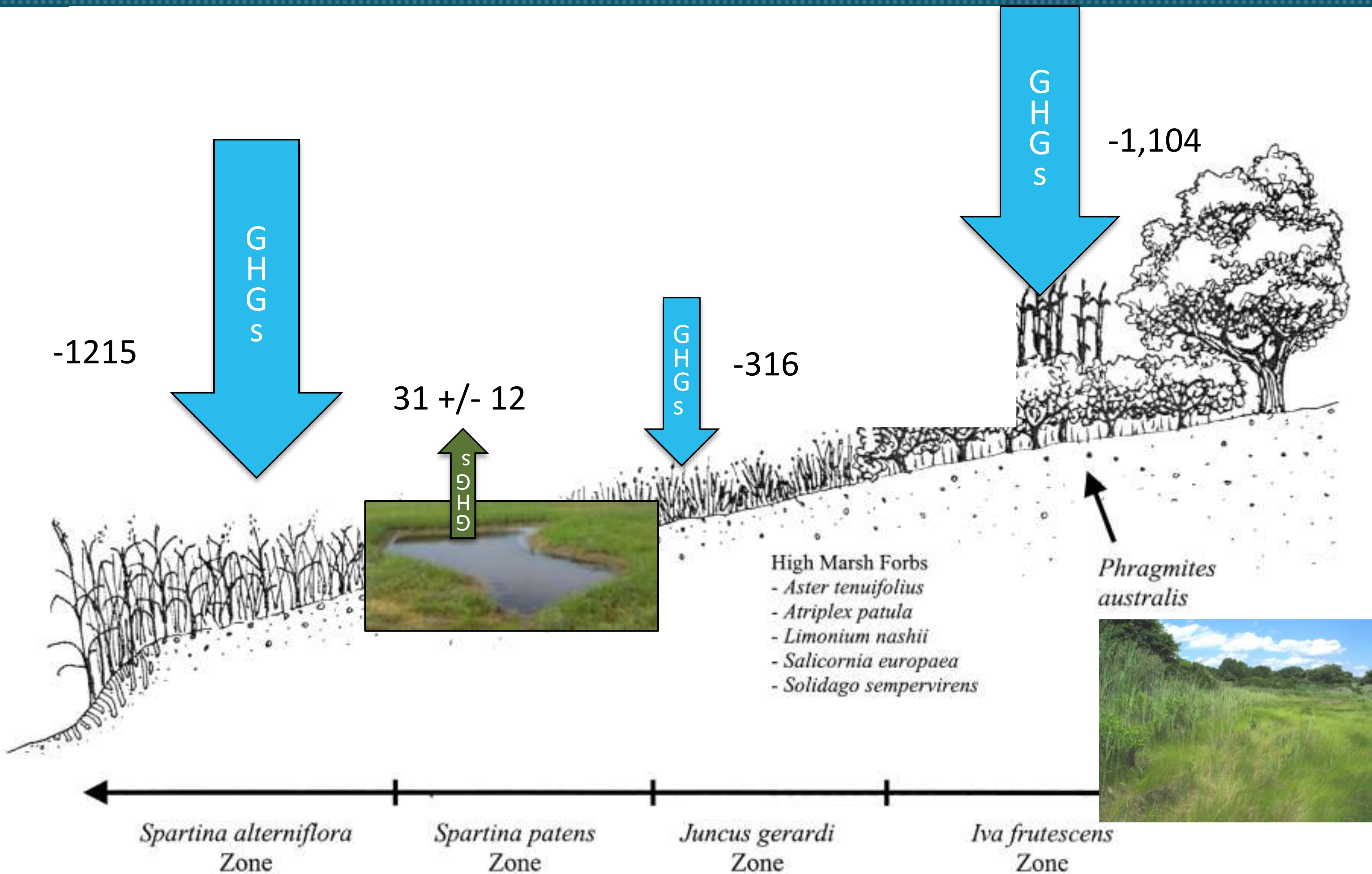
CO_2 fluxes in ponds, high marsh & Phragmites



Methane fluxes in ponds, high marsh & Phragmites zones



Zonation patterns for Net GHG Fluxes in Sage Lot (Waquoit Bay) (mg CO_2eq. m^{-2} h^{-1})



Summary of results from Sage Lot

- Are plants simple proxies?

Not quite.

- Does stratification improve C accounting?

Yes, CO_2 fluxes vary significantly between marsh zones.
(Highest CO_2 uptake in low marsh and Phragmites zones)

- Mechanistic understanding of changes:

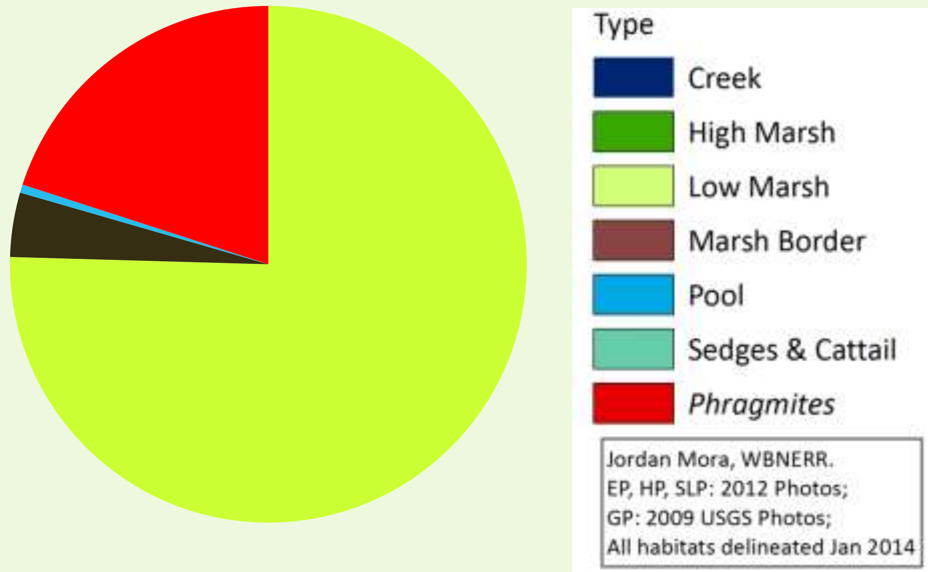
Die back and sea level rise will decrease CO2 uptake,

Invasion by Phragmites may maintain or increase it!

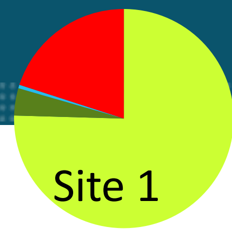
Section #3

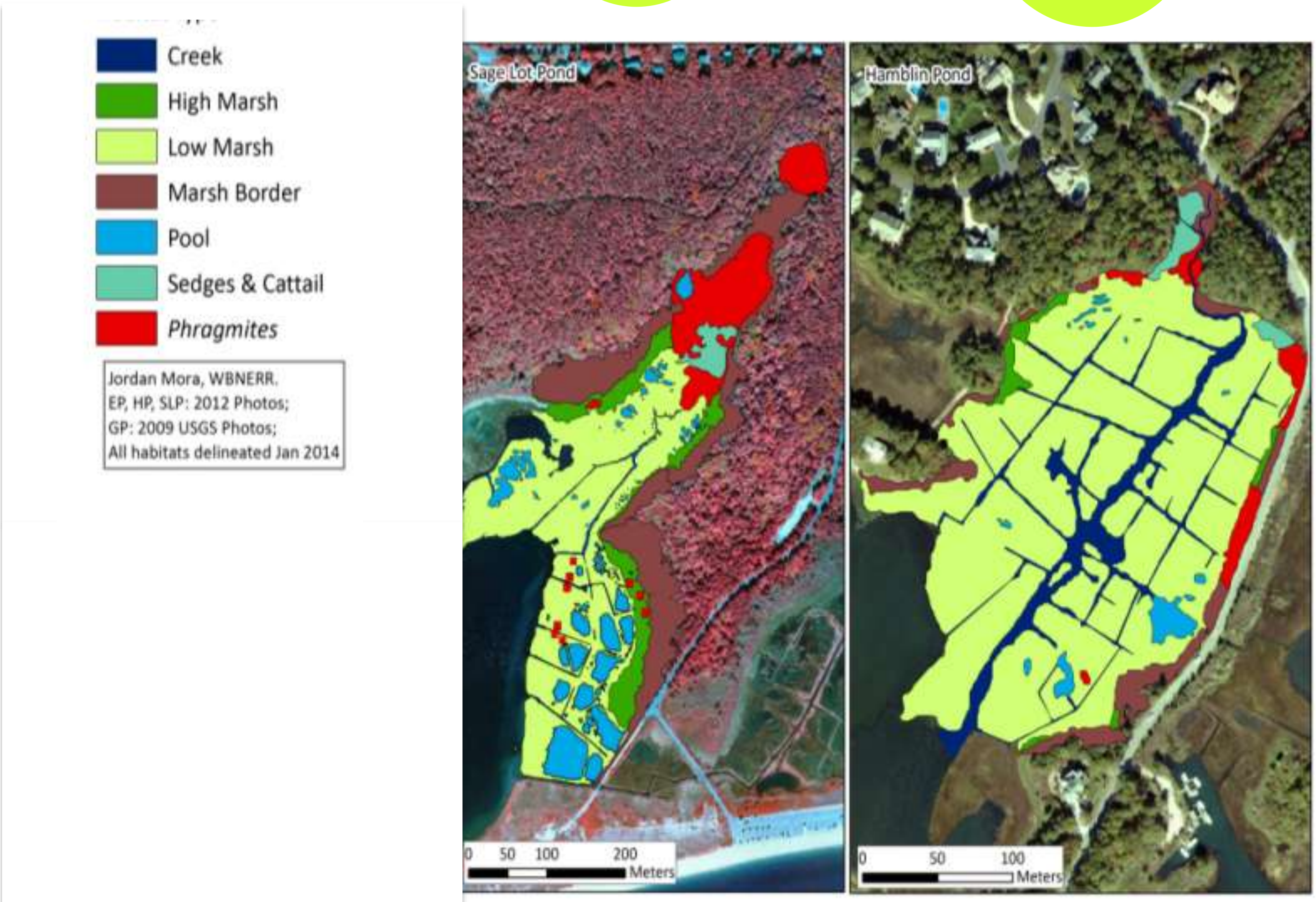
APPLICATIONS FOR DATA ON GHGS AND PLANT ZONES

Estimated % of overall carbon uptake rates (g C per hour)



Estimated % of overall carbon uptake rates (g C per hour)



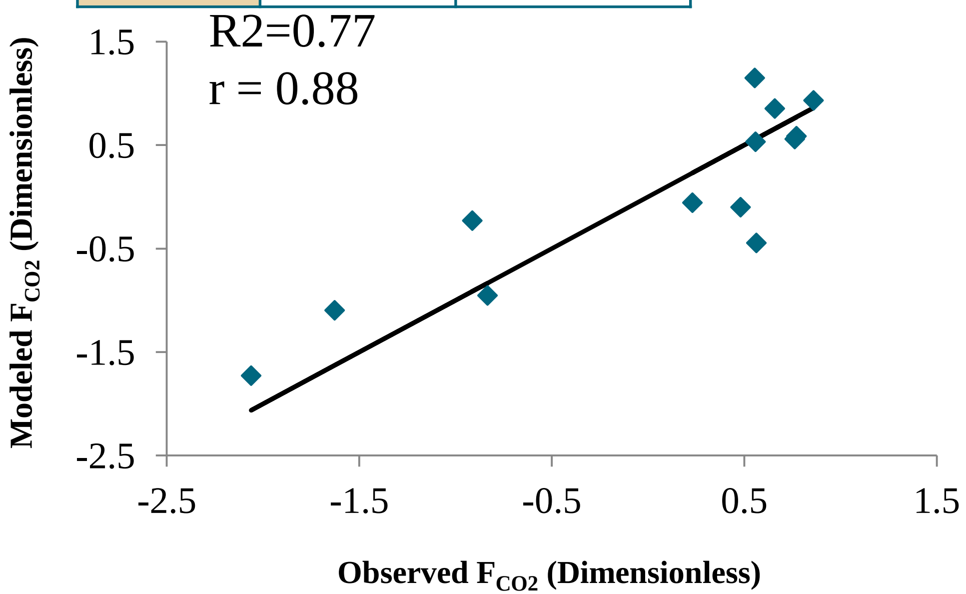


Modeling CO_2 sequestration from plant variables

Dr. Omar Abdul- Aziz, K. S. Ishtiaqu

$$F_{CO2} = [SD]^{-0.19}[AGB]^{-0.27}[BGB]^{0.58}$$

Variables	Coefficients	p-value
Stem density (SD)	-0.19	0.32
AGB	-0.27	0.20
BGB	**0.58**	**0.02**



- Biomass and plant related variables explained 77% of the F_{CO2}.
- BGB is the most dominant and significant driver in the regression
- SD and AGB had low and moderate dominance on F_{CO2}.

R2= Coefficient of determination; r= correlation between observed and predicted FCO2

Future directions for research

Hand dug runnels at Narrow River, RI

- Predicting longer-term feedbacks with SLR
  - What are irreversible thresholds?
  - Which factors influence marsh resilience?
  - What is the fate of carbon?
- Marsh restoration: Predict impact of converting fresh/brackish Phragmites marsh to native saline marsh
  - Multiple factors change:
  - What is strongest driver? On what time scale?

Acknowledgements

My email: smoseman@uri.edu

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WHERE DISCOVERIES BEGIN

Comparisons to similar studies: Sage Lot is a conservative reference

CH4 (mmol $m^{-2} h^{-1}$)	*Spartina alterniflora*	*Spartina patens*/ High marsh	*Phragmites australis*
SAGE LOT	0.1 to 12 (3)	-4 to 45 (6)	-20 to 47 (-8)
Narragansett Bay	5 to 620 (150) 4 to 44 (17)	2 to 40 (10) 2 to 13 (5)	see Martin poster
Moseman-Valtierra Plum Island estuary	n/a	3 to 91 (30)	n/a
Emery and Fulweiler Plum Island estuary	0 to 50 *	n/a	0 to 50

CO2 (mmol $m^{-2} s^{-1}$)	*Spartina alterniflora*	*Spartina patens*/ High marsh	*Phragmites australis*
SAGE LOT	-13 to 1 (3)	-4 to 4 (0.3)	-20 to 7 (-8)
Narragansett Bay	-31 to -1 (-12) -12 to 1 (-5)	-17 to 6.0 (-3) -9 to 1 (-3)	See Martin poster
Moseman-Valtierra Plum Island estuary	n/a	3 to 6 (4.3)	n/a
Emery and Fulweiler Plum Island estuary	-14 to 2	n/a	-14 to 2