Saltwater intrusion into tidal freshwater wetlands initiates change across multiple levels of ecological organization

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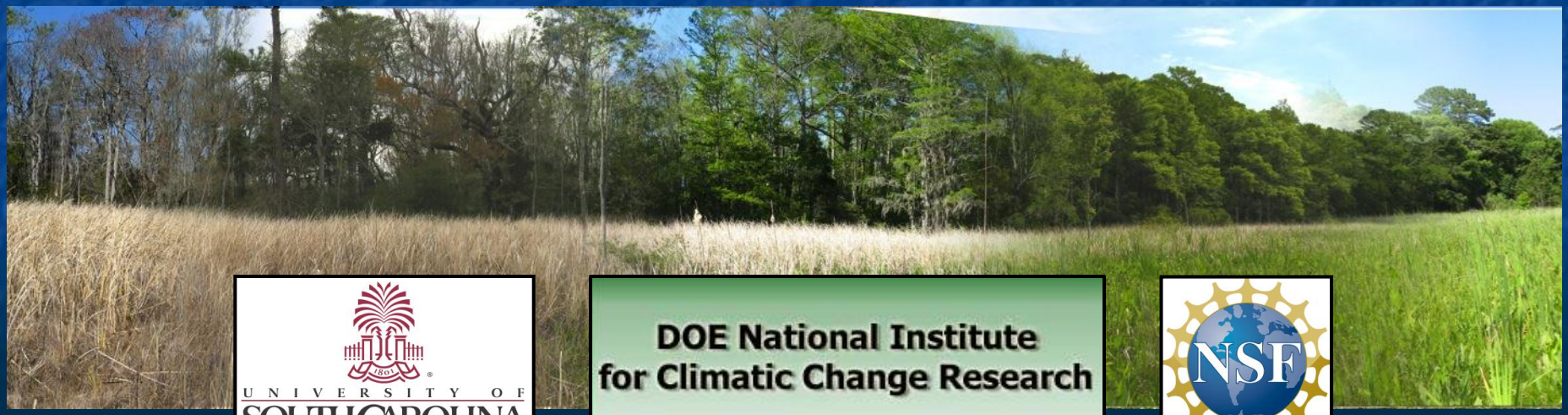

DOE National Institute for Climatic Change Research

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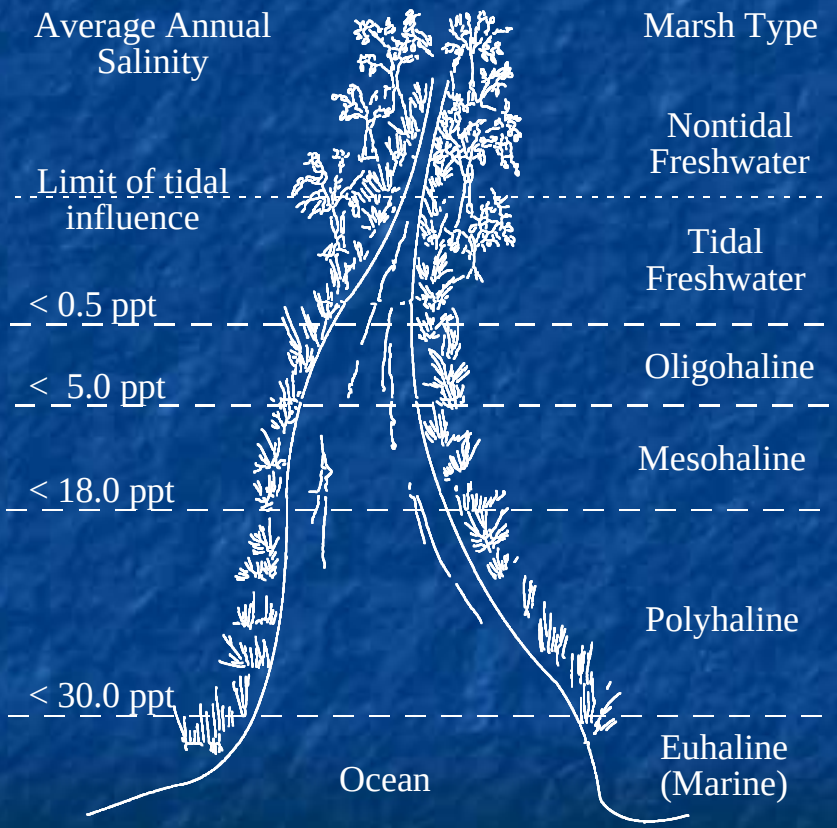
The diversity of coastal wetland types is tremendous



Odum et al. 1984. FWS/OBS-83/17

Research questions

How do saltwater intrusion and altered hydrology …

… affect soil microbial processes and dynamics ?

… modify wetland plant communities ?

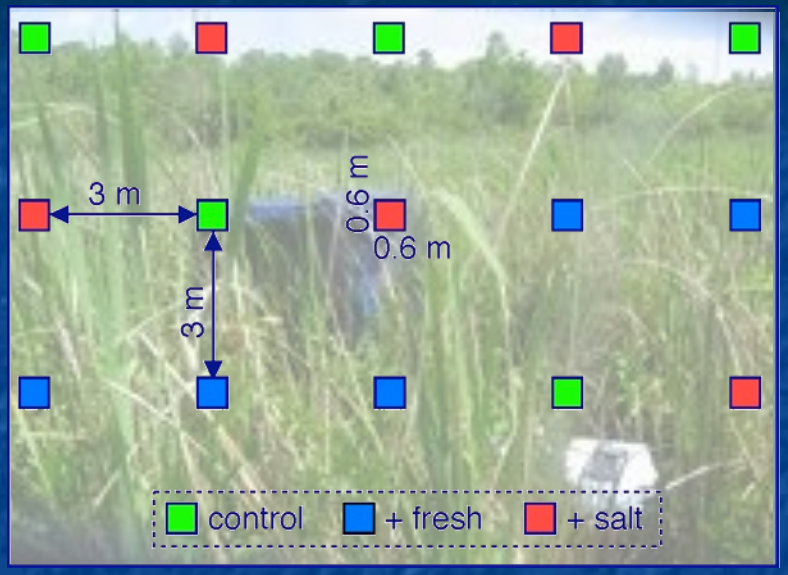
… impact ecosystem carbon cycling ?

… influence marsh resilience and sustainability ?

¿ Where am I working ?

- Tidal freshwater marsh
- 30+ herbaceous plant species
- Organic-rich soils (~60% organic, ~30% C)
- Semi-diurnal tides, doesn't flood every tide

Experimental design



» Started 16 June 2008, repeated ~2x per week through 15 Nov 2011

» Add 40 L fresh or brackish water to each +fresh and +salt plot
- freshwater from 180 m well
- brackish water is diluted seawater

» 338 water addition dates

» ~133,000 L water

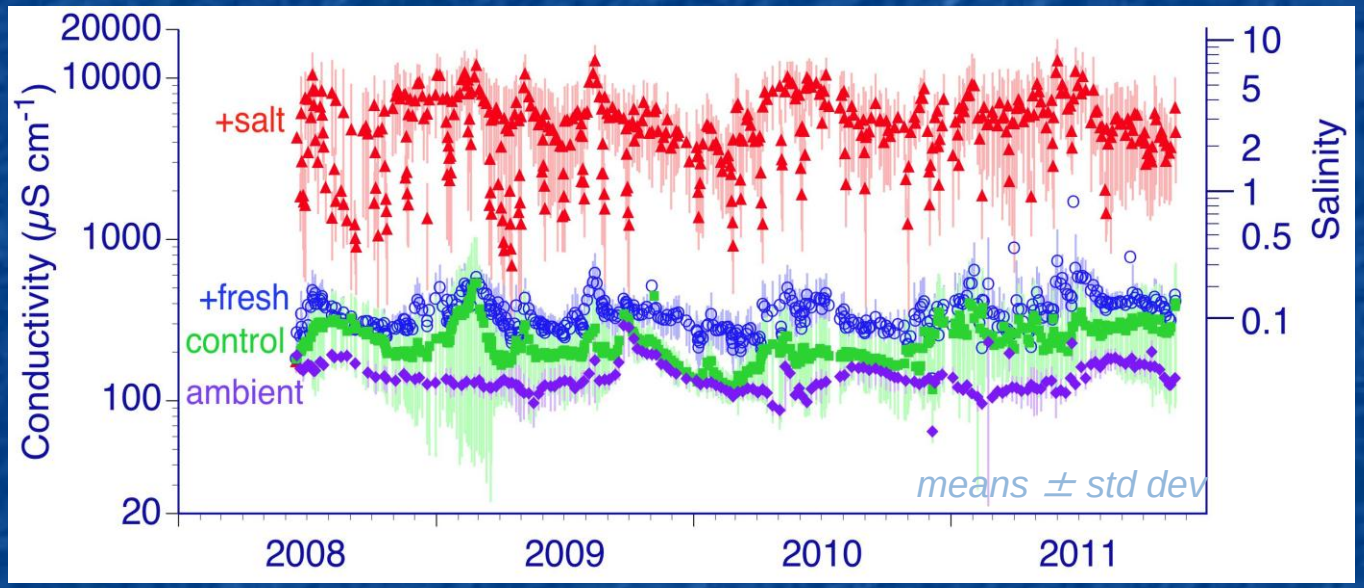
» 5 "control" plots = *no manipulation*

» 5 "+fresh" plots = *add fresh water*

» 5 "+salt" plots = *add brackish water*

¡ Salty marsh = success !

Porewater



Control, +fresh, and +salt data: n = 5 plots x 2 depths (10 & 25 cm) per plot;
Ambient data: n = 2 locations x 2 depths per location

Research questions

How do saltwater intrusion and altered hydrology …

… affect soil microbial processes and dynamics ?

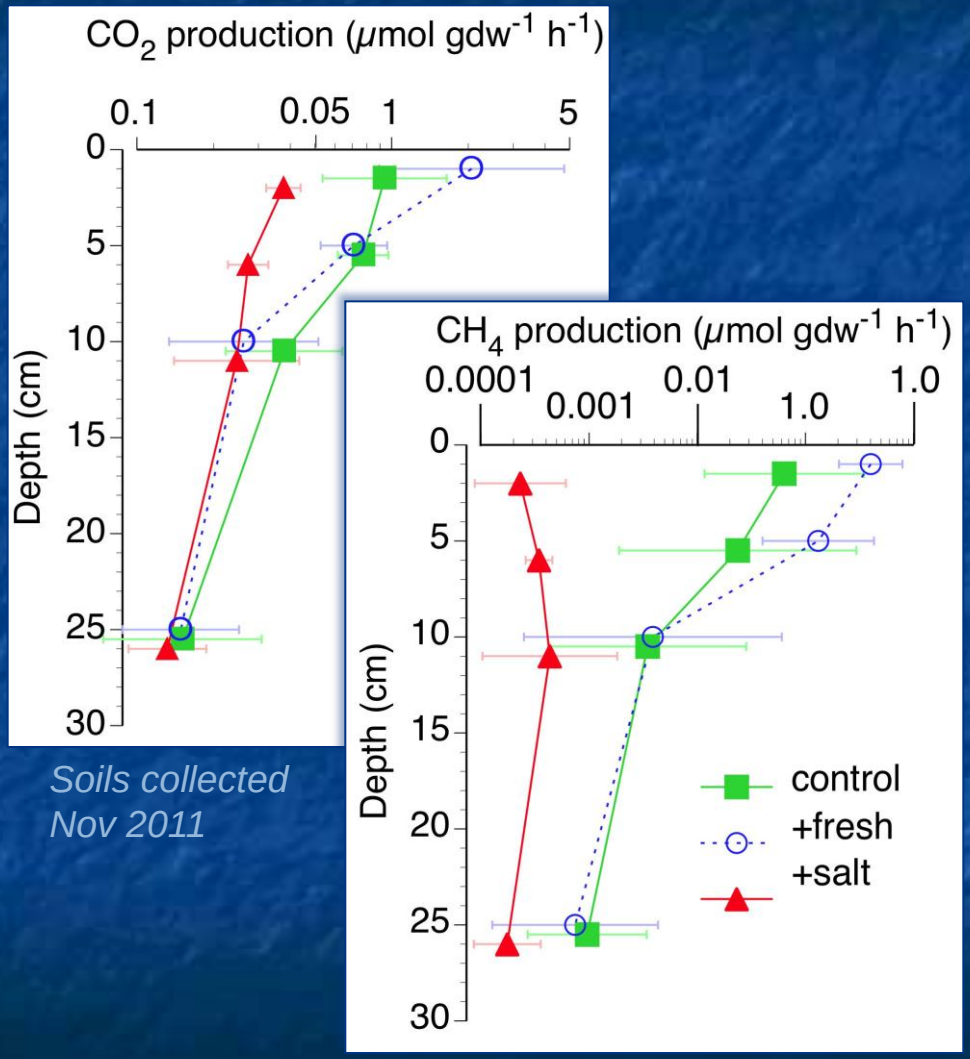
- Microbial community structure (TRFLP, qPCR)
- → Rates of CO_2 and CH_4 production, soil O_2 demand
- → Denitrification and DNRA
- Extracellular enzyme activity

… modify wetland plant communities ?

… impact ecosystem carbon cycling ?

… influence marsh resilience and sustainability ?

Soil CO_2 and CH_4 production



Soils collected Nov 2011

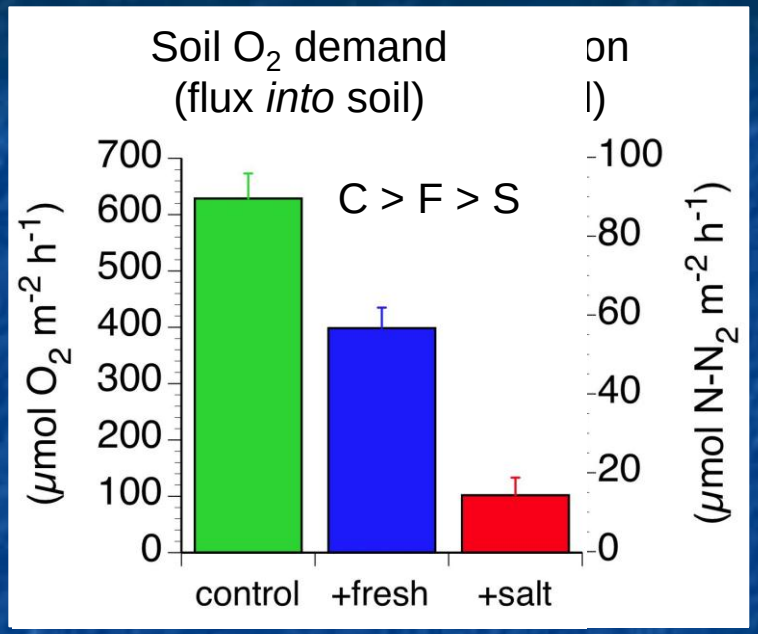
Soil slurries mimic field salinities (S = 0 for control and +fresh; S = 2 for +salt)

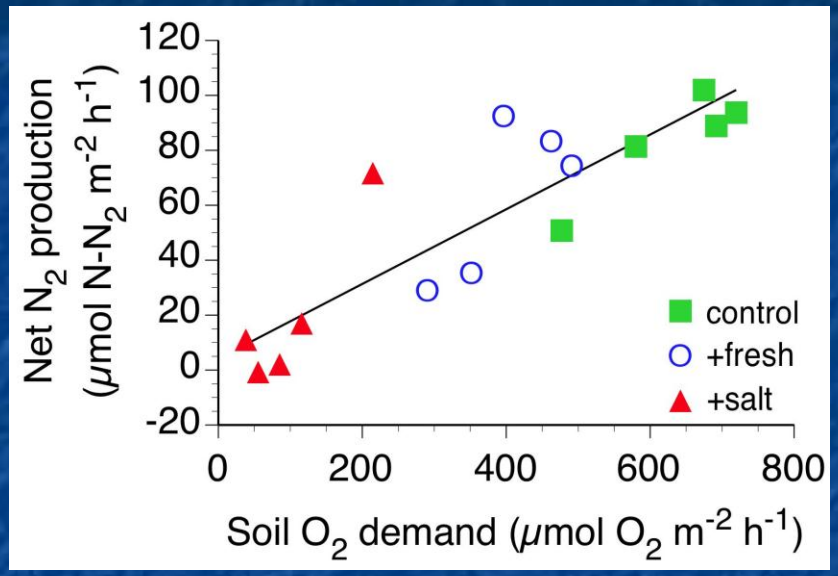
» CO_2 pro
… decrea
… in surfa est in control and +fres
… in deep rences

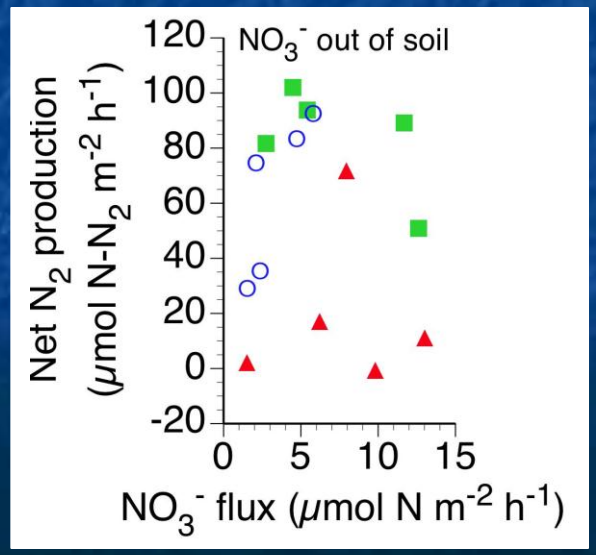
» CH_4 pro
… more variable than CO_2 prod.
… shows similar depth and treatment patterns

Treatment means ± standard deviation, n = 5 plots per data point

Aerobic–anaerobic coupling







» Aerobic biogeochemical activity …
… lowest in +salt plots
… ~6x higher in control plots
» "Denitrification" …
… highest in control plots
… lowest in +salt plots
… driven by nitrification rather than uptake of water-column NO_3^-

Whole-core incubations. Treatment means ± standard error, n = 5 plots

Research questions

How do saltwater intrusion and altered hydrology …

… affect soil microbial processes and dynamics ?

… modify wetland plant communities ?

- Species presence/absence, richness, stem density)
- Aboveground biomass (non-destructive)
- Leaf-level photosynthesis and fluorescence
- Belowground root/rhizome biomass

… impact ecosystem carbon cycling ?

… influence marsh resilience and sustainability ?

Plant responses …

1) … to salinity ⊖
… to freshwater ⊙

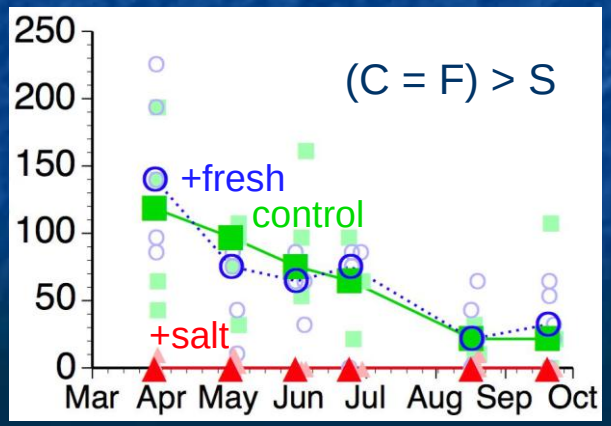
2) … to salinity ⊖
… to freshwater ⊕⊖

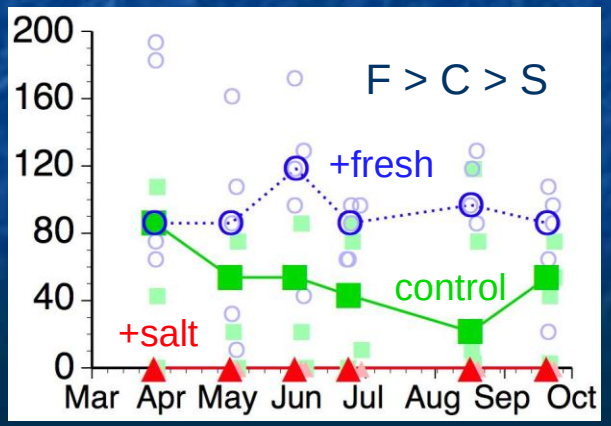
3) … to salinity ⊕⊙
… to freshwater ⊙

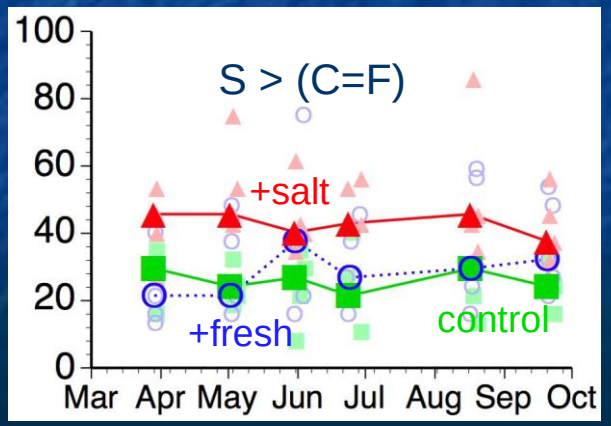
Cicuta maculata
Spotted water hemlock

Symphyotrichum sp.
Aster

Zizaniopsis miliacea
Giant cutgrass



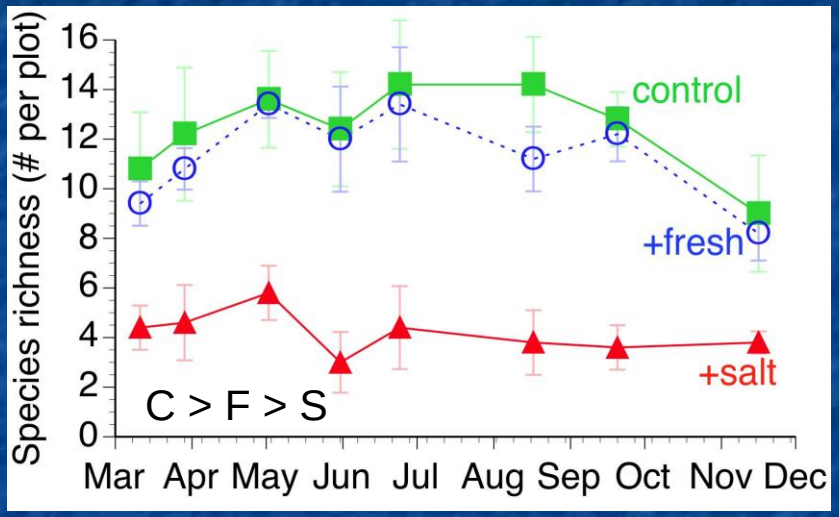




Bold points are treatment medians; faint symbols are for individual plots

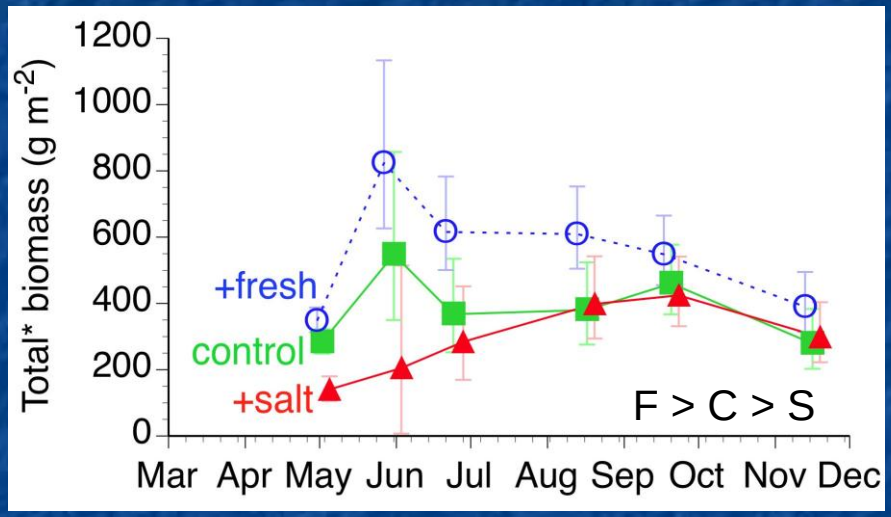
Community richness and biomass

Species richness



- Salinity reduced species richness by 50-75%
- Richness was slightly lower in +fresh plots relative to controls

Total* biomass



- Freshwater inputs increased total* biomass
- Elevated salinity decreased total* biomass
- Total* biomass ~85% of total plot biomass (range: 42-97%, 5 external plots each in Aug and Sep 2011; all treatment plots in Nov 2011)

Points are means ± standard deviation, n = 5 plots per data point.

Research questions

How do saltwater intrusion and altered hydrology …

… affect soil microbial processes and dynamics ?

… modify wetland plant communities ?

… impact ecosystem carbon cycling ?

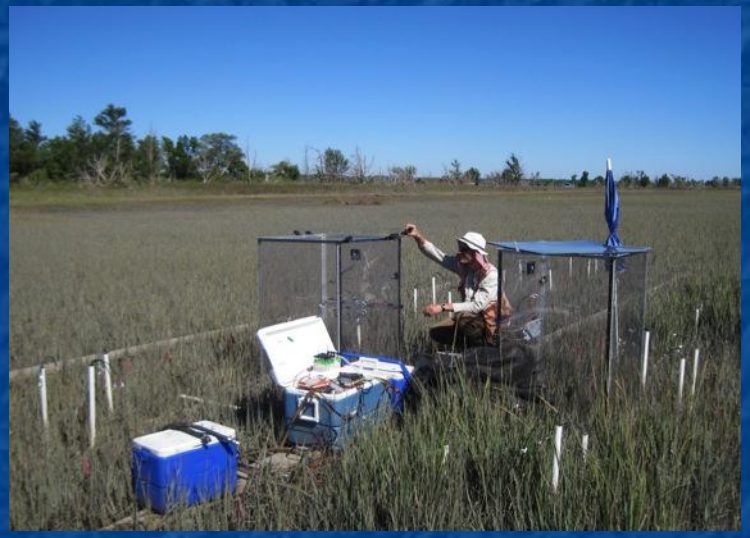
… influence marsh resilience and sustainability ?

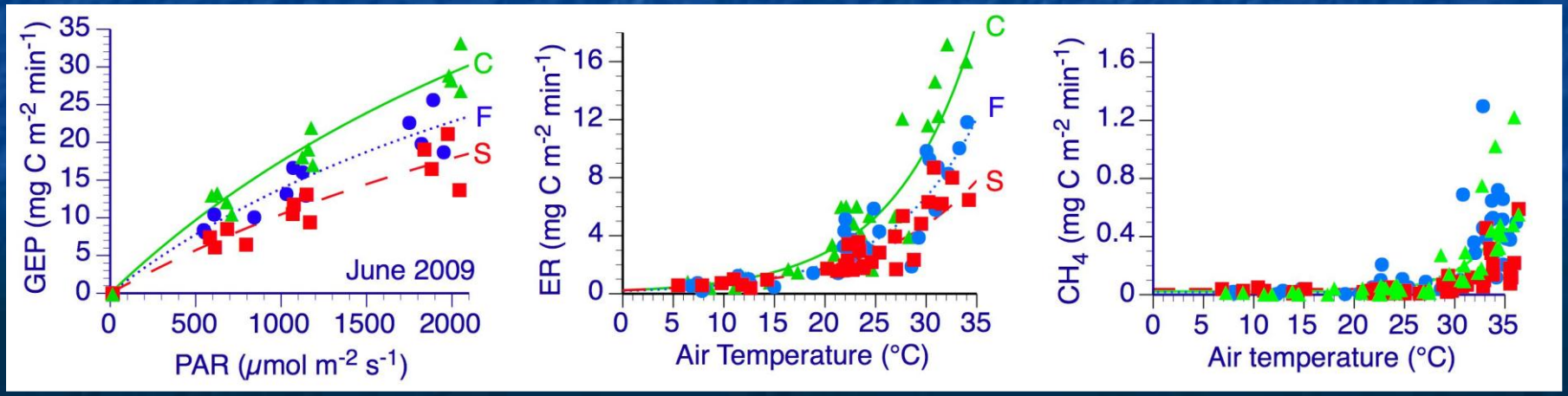
- → • Gross ecosystem production
- → • Ecosystem CO_2 and CH_4 emissions
- → • Net ecosystem production
- • Soil C/N inventories, ^{137}Cs accretion

Ecosystem carbon fluxes

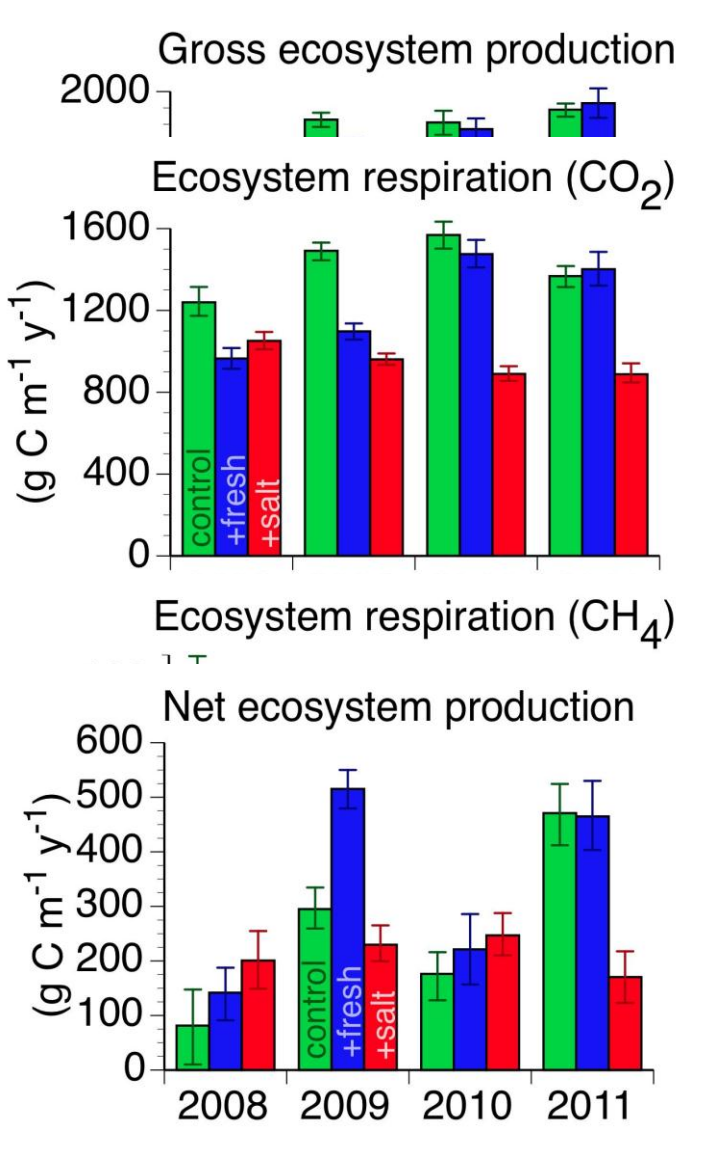
» Marsh-atmosphere CO_2 and CH_4 exchanges
… temperature-controlled chambers
… ~ monthly from May 2008 thru Nov 2011

» Modeled monthly and annual fluxes
… photosynthesis vs. light curves
… respiration vs. temperature relationships
… weather data





Annual flux summary



» Gross ecosystem production
… consistently lowest in +salt treatment
… similar between control and +fresh plots

» Ecosystem respiration
… CO_2 and CH_4: lowest in +salt treatment
… CO_2
- 2008/09: higher in control than +fresh
- 2010/11: similar in control and +fresh

… CH_4 generally similar in control and +fresh

» Net ecosystem production
… positive in all treatments and all years
… lowest in +salt treatment in some years, but not others

Thanks!

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- Leigh McCallister
- Lindsey Koren

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- Shan Deeter
- Troy Washam
- Michelle, Isabella, Ryleigh Neubauer
- Dorothy Silvernail
- staff of Brookgreen Gardens

UNC – IMS

- Ashley Smyth

VIMS

- Lori Sutter

UNIVERSITY OF SOUTH CAROLINA

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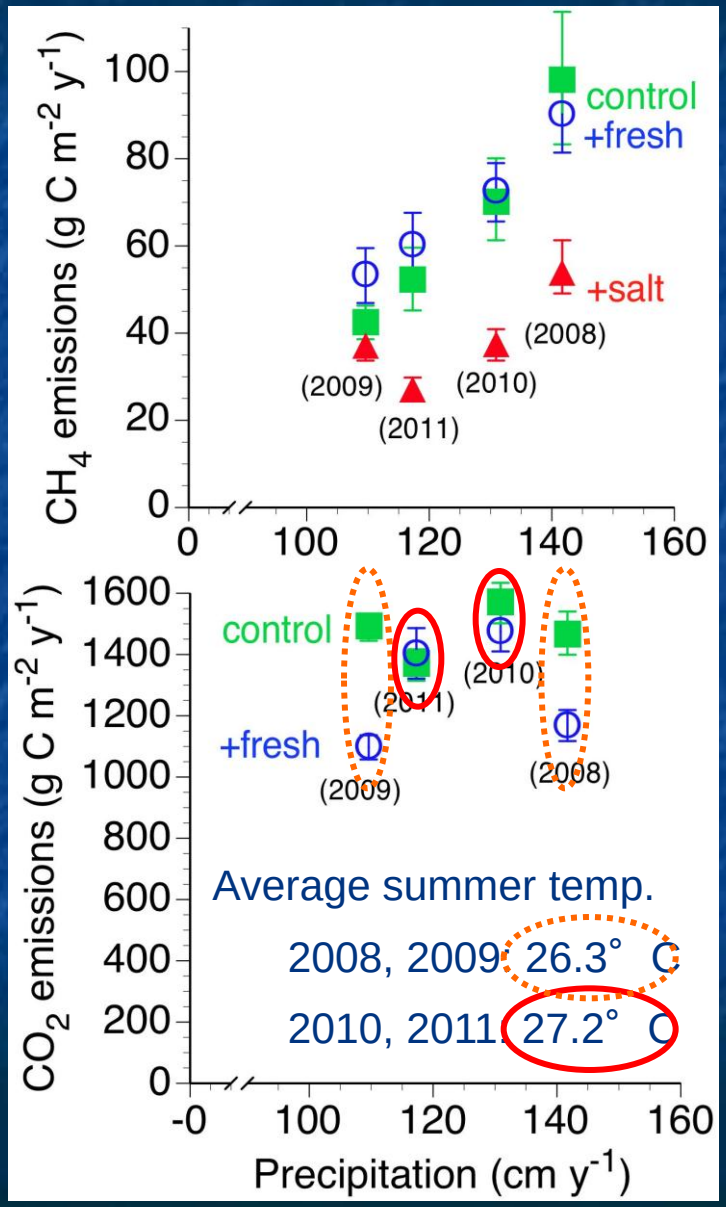
Drivers of ecosystem processes



» Tight coupling between CH_4 emissions and precipitation

… rainfall affects soil oxygenation?

… effect of freshwater additions greatest in drier years

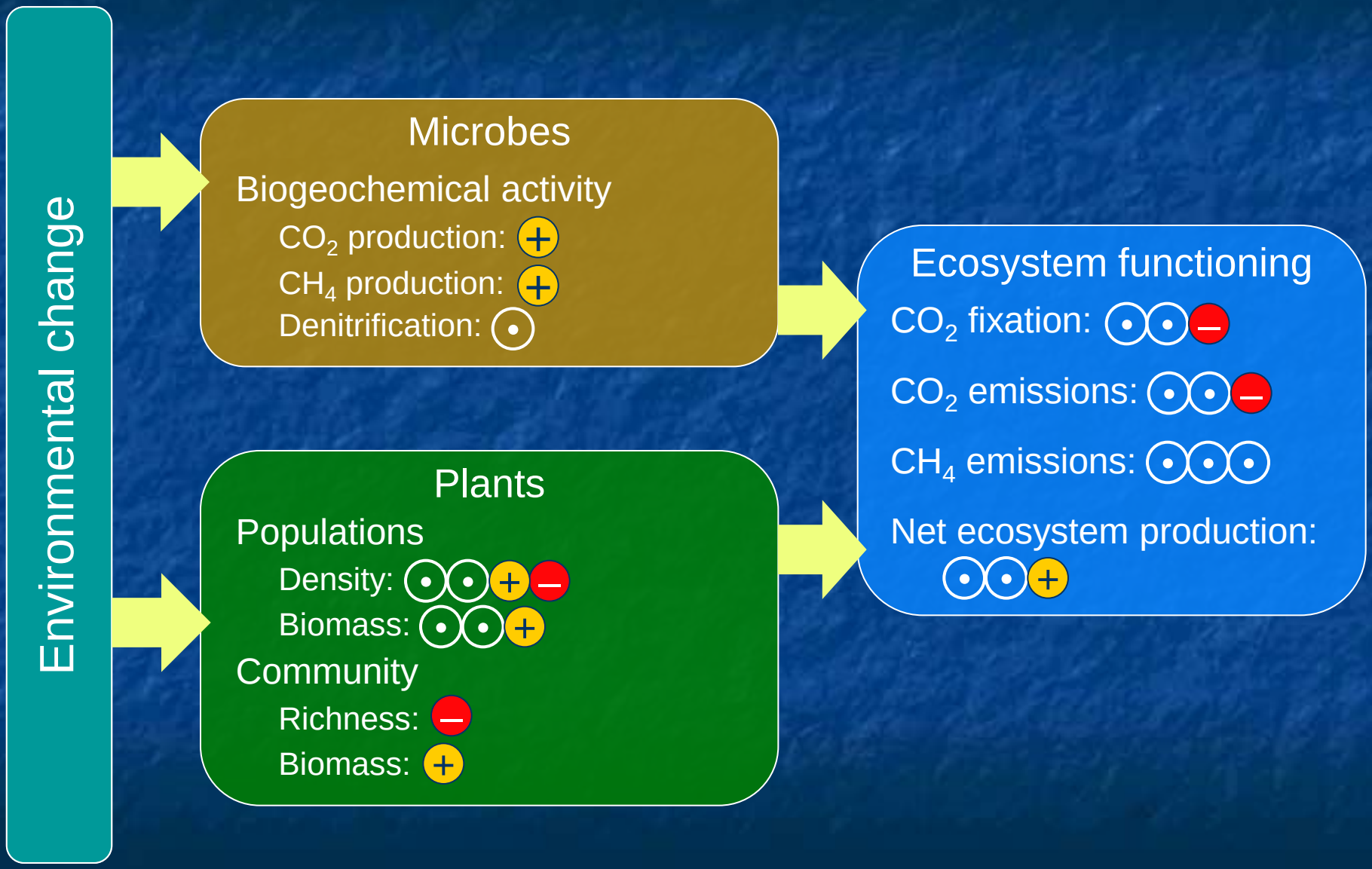
… emissions from +salt plots consistently low

» "Rainfall effect" not seen in CO_2 fluxes

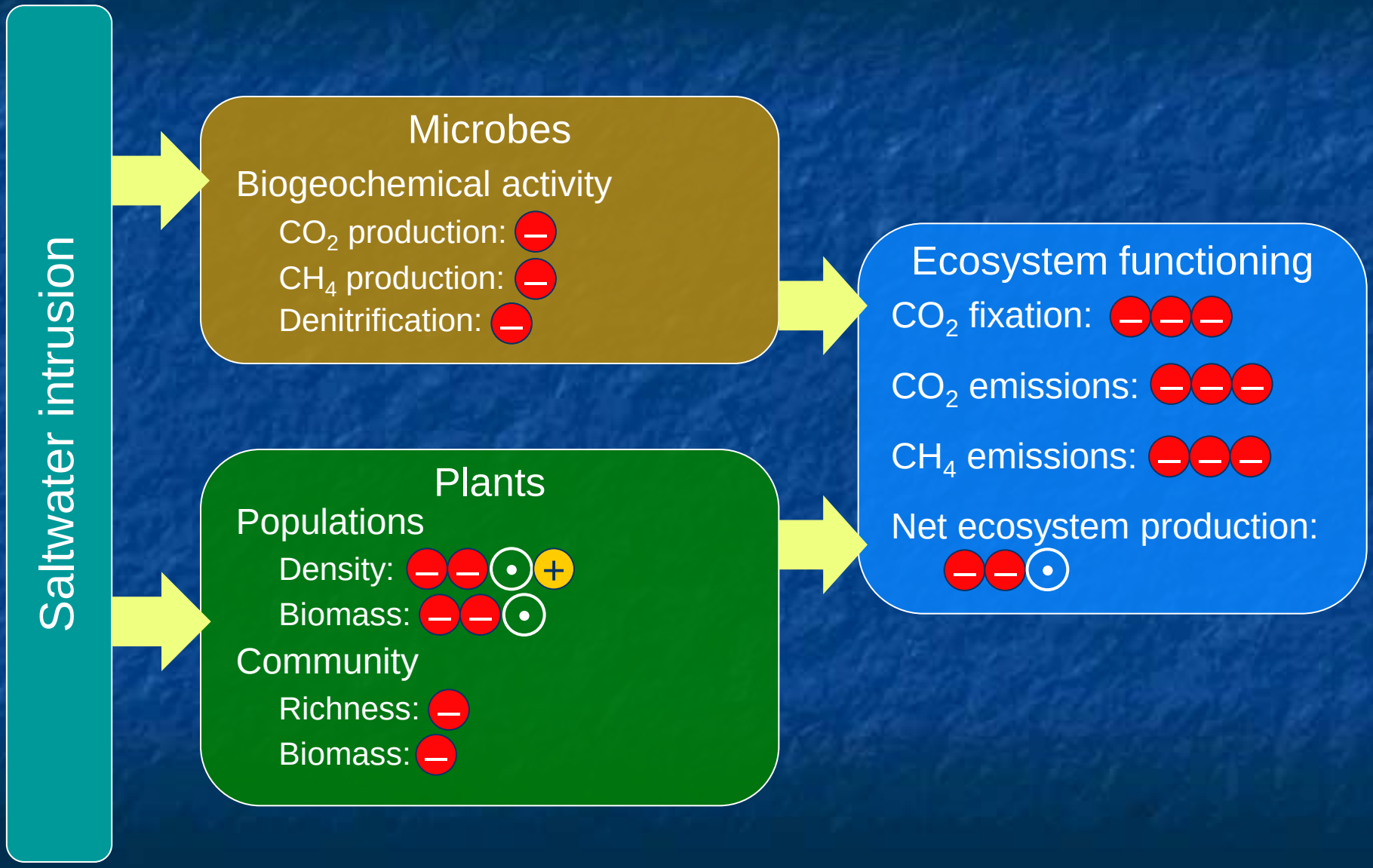
… greatest effect of freshwater additions in cooler years (2008/2009)

… temperature x treatment interaction?

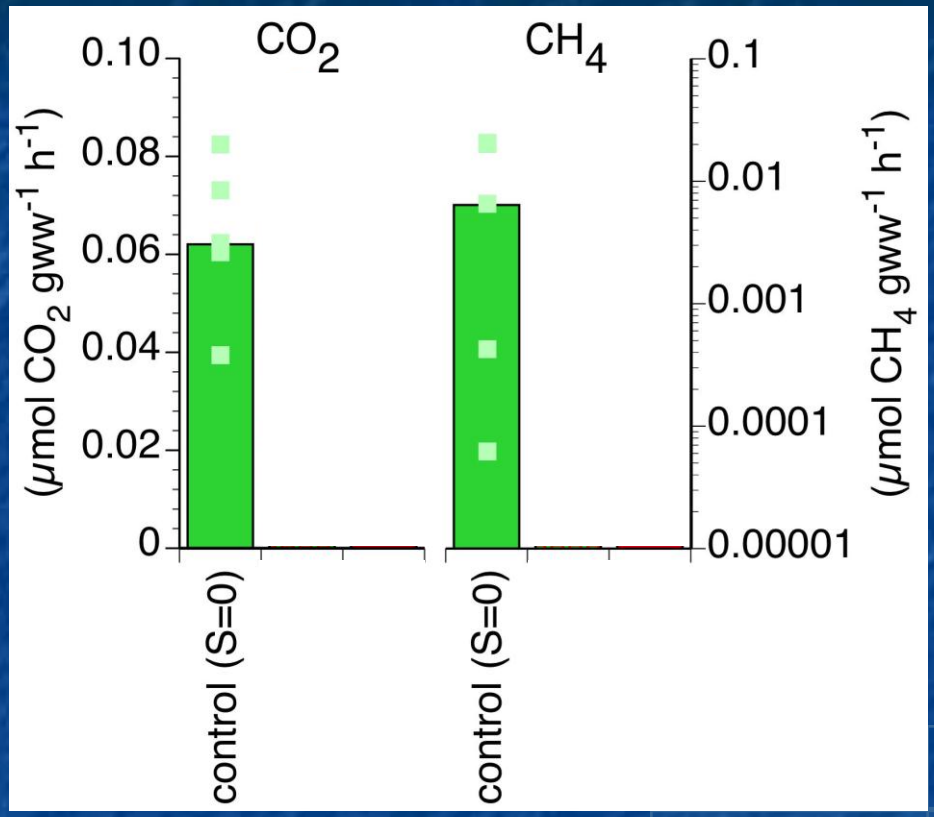
Disturbance effects across scales



Disturbance effects across scales



Soil CO_2 and CH_4 production



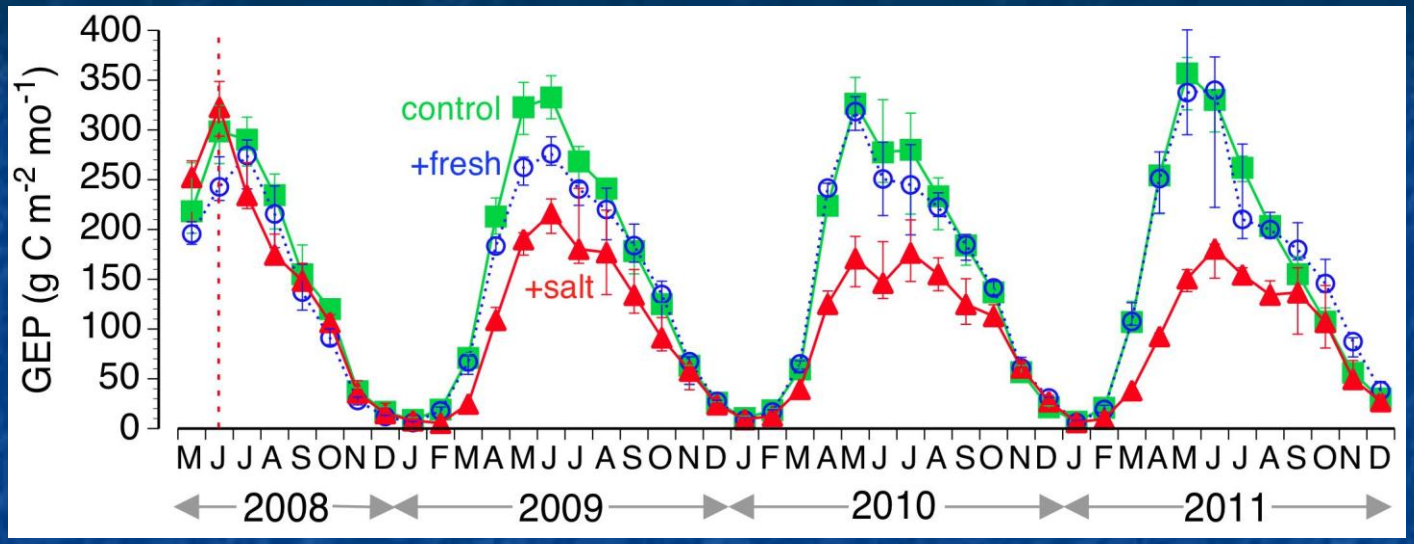
Experiment #2:

Incubate soils at multiple salinities (S = 0, 2, 5)

	Change in flux	
Time scale	CO_2 production	CH_4 production
Short-term	(no effect)	96% decrease
Long-term	60% decrease	85% decrease

3-8 cm soil layer, bars are treatment medians; symbols are values for each plot.

Gross ecosystem production



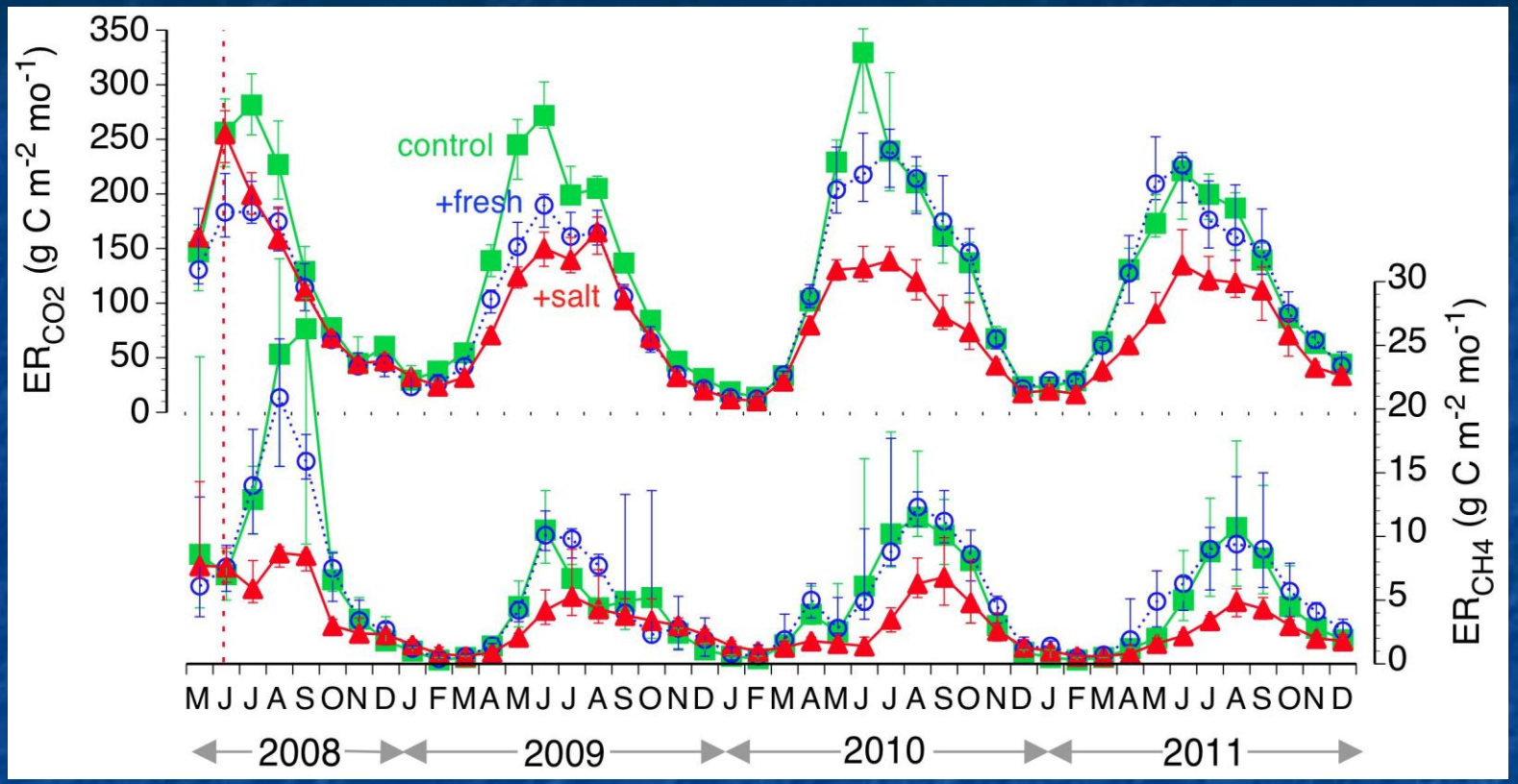
(2008 and 2009 data in Neubauer, Online First article, Estuaries and Coasts*)*

» Initially, gross ecosystem production initially higher in +salt plots

» During last 3 years, GEP consistently lower in +salt plots than in other treatments

(median model results with bars indicating 25th-75th percentiles)

Ecosystem respiration



(2008 and 2009 data in Neubauer, Online First article, Estuaries and Coasts*)*

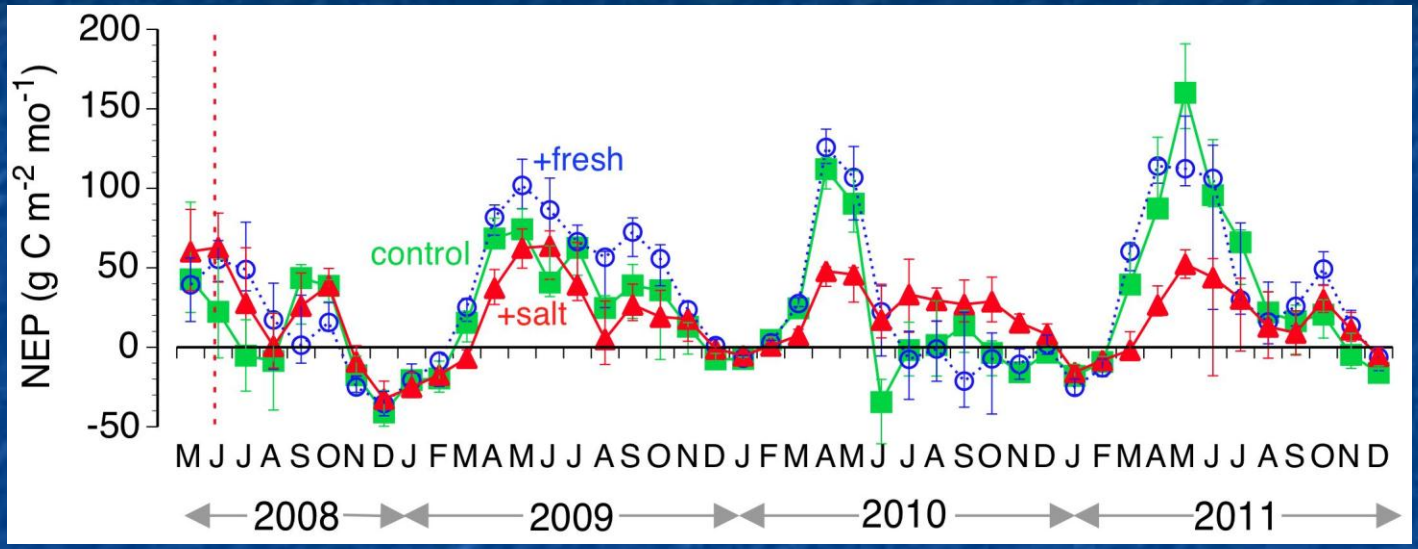
» Growing season CO_2 emissions higher in control and +fresh plots

» Summer peak in CH_4 emissions not as pronounced in +salt plots

» Respiration is dominated by non-methanogenic pathways, regardless of treatment.

(median model results with bars indicating 25th-75th percentiles)

Net ecosystem production



(2008 and 2009 data in Neubauer, Online First article, Estuaries and Coasts*)*

(median model results with bars indicating 25th-75th percentiles)

Soil enzyme activity

"*labile*"

Enzymes for degrading cellulose
… ß-glucosidase, cellobiosidase

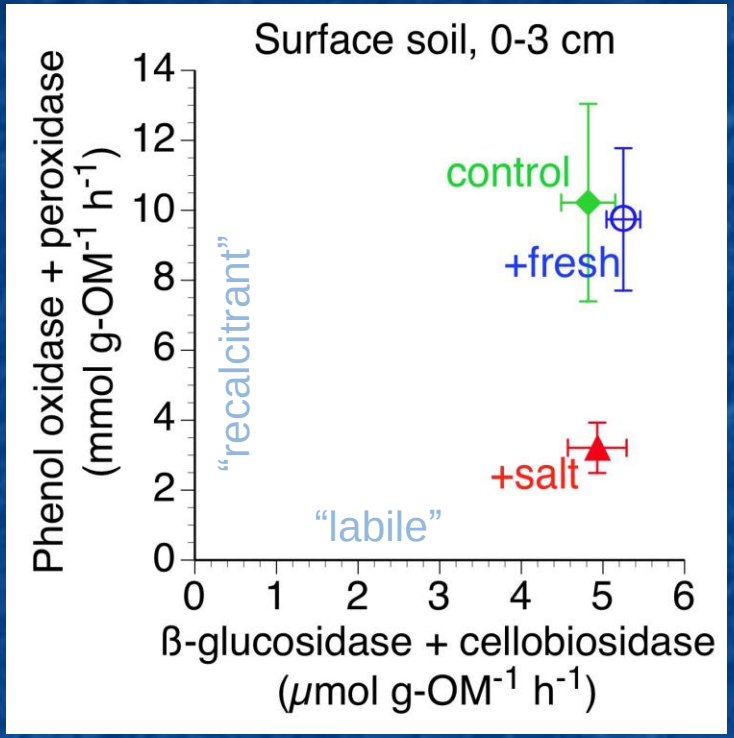
Enzymes for degrading lignin
… phenol oxidase, peroxidase

"*recalcitrant*"

» No treatment differences in "labile" enzyme activity

» Considerably lower activity of enzymes for degrading "recalcitrant' lignin in +salt plots

» Similar patterns at 8-13 cm, but few differences at 23-28 cm



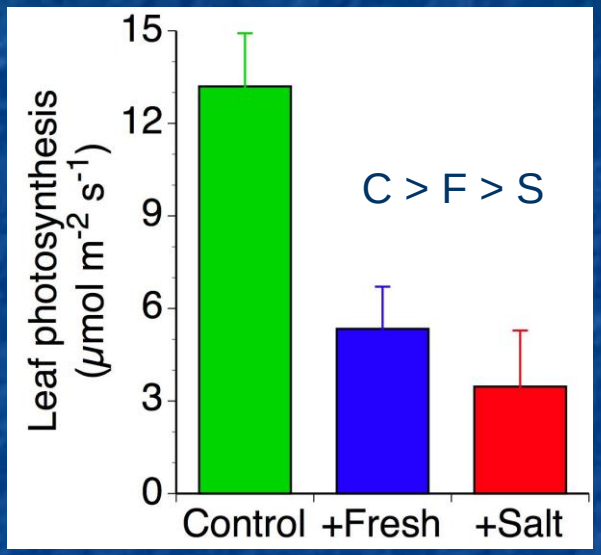
Soils collected Nov 2011

» Patterns may reflect inhibition of phenol oxidase and peroxidase by
… low O_2 ?
… salt ?
… sulfide ?

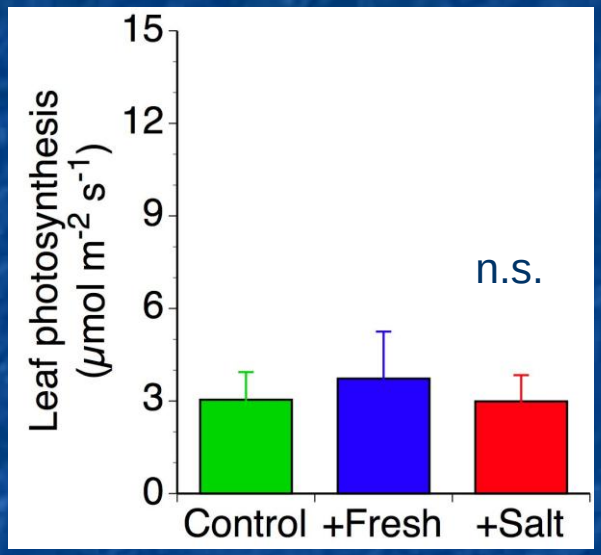
Data from RB Franklin. Treatment means ± standard error, n = 5.

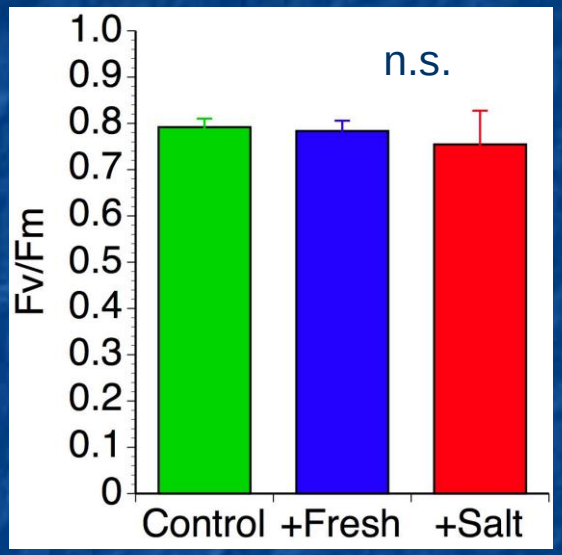
Photosynthesis and fluorescence

P. virginica (Apr 2011)



Z. miliacea (Oct 2011)





Peltandra virginica

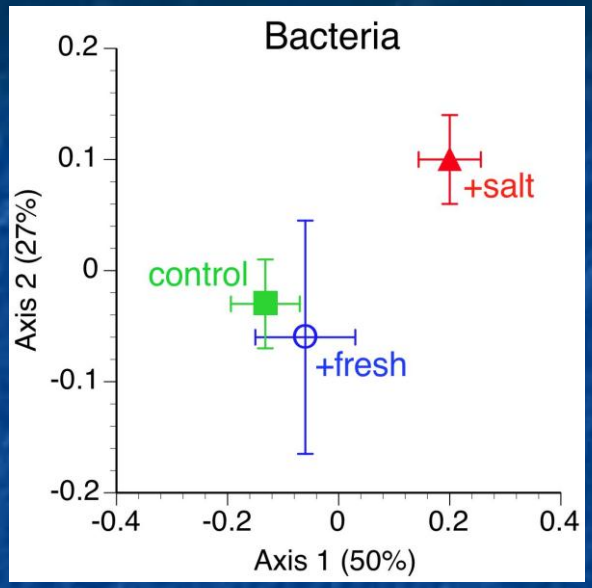
- » Increased water inputs decreased leaf photosynthesis by 60%
- » Salinity decreased photosynthesis by another 35%

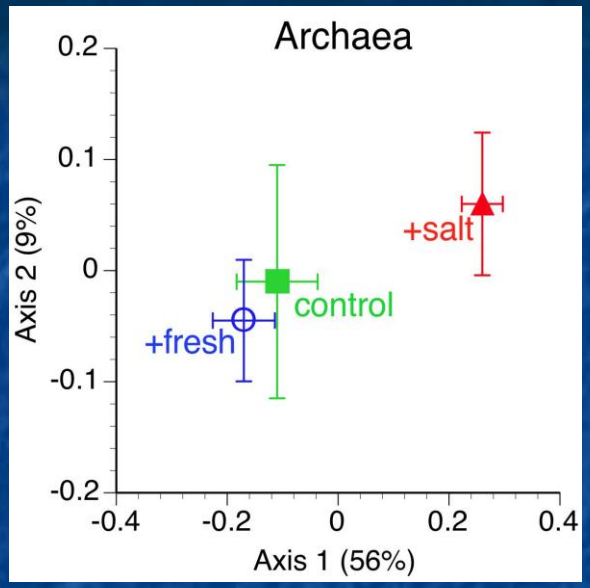
Zizaniopsis miliacea

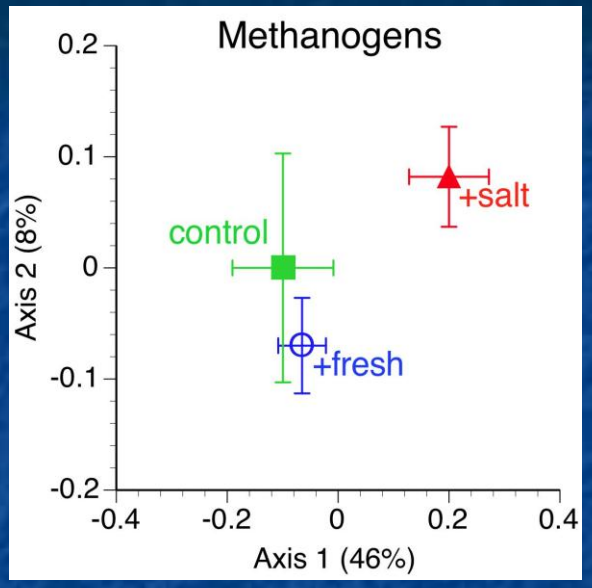
- » No effect of salinity or increased water inputs on …
  - … leaf photosynthesis
  - … leaf fluorescence

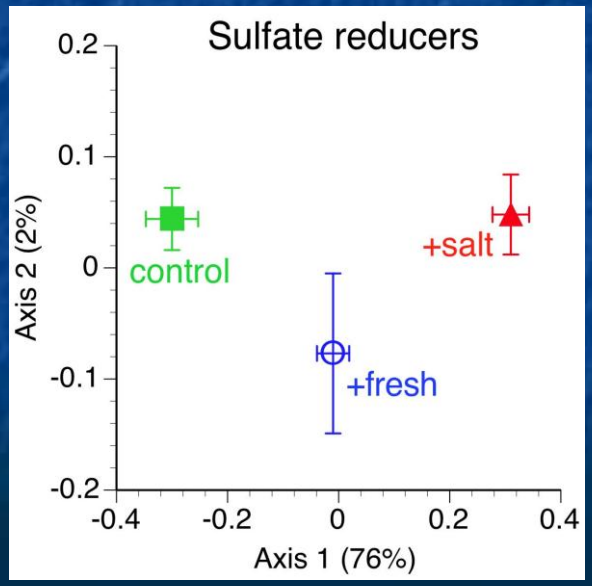
Data from LA Sutter, VIMS

Microbial community composition









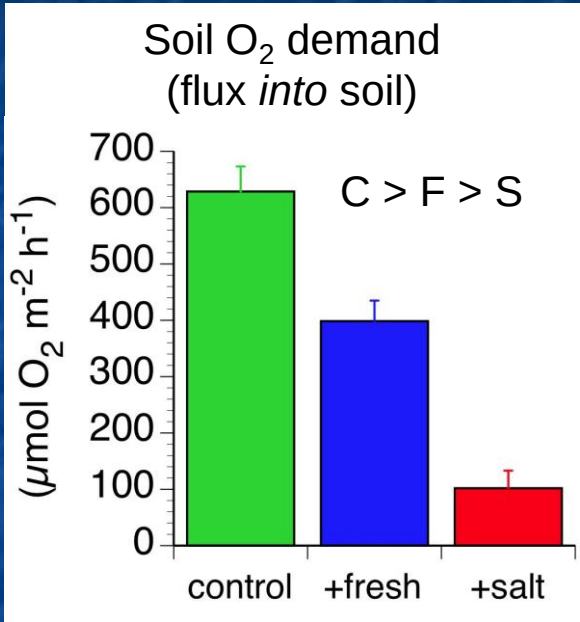
» DNA fingerprinting (TRFLP)
… significant community shifts due to saltwater intrusion

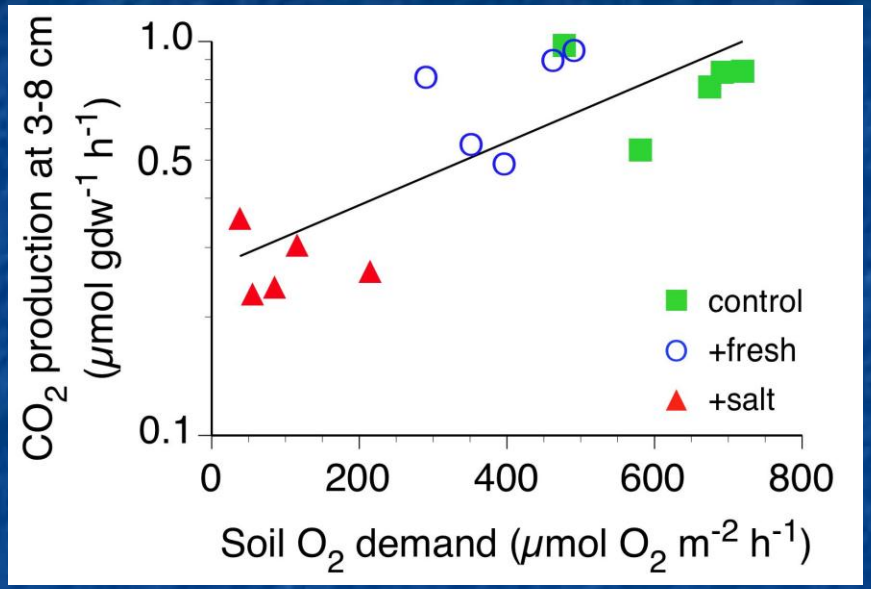
» Do communities vary with depth?

» Have there been additional changes in community composition over time?

Surface soils collected Oct 2009

Aerobic and anaerobic activity





» Aerobic biogeochemical activity …
… lowest in +salt plots
… ~6x higher in control plots

» Both aerobic and anaerobic activity show similar treatment differences …
… but only in near-surface soils
… no correlation in deeper soils

Whole-core incubations. Treatment means ± standard error, n = 5 plots per column.