How does saltwater intrusion alter anaerobic microbial metabolism in a freshwater wetland?

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Sea Level Rise Predictions for N.C.

By 2100, North Carolina will lose 2330 – 5180 sq. kilometers of coastline (900-2000 square miles)

Increasing air temperatures predicted to increase drought

What are the biogeochemical implications of SLR and salt water intrusion for coastal wetlands?

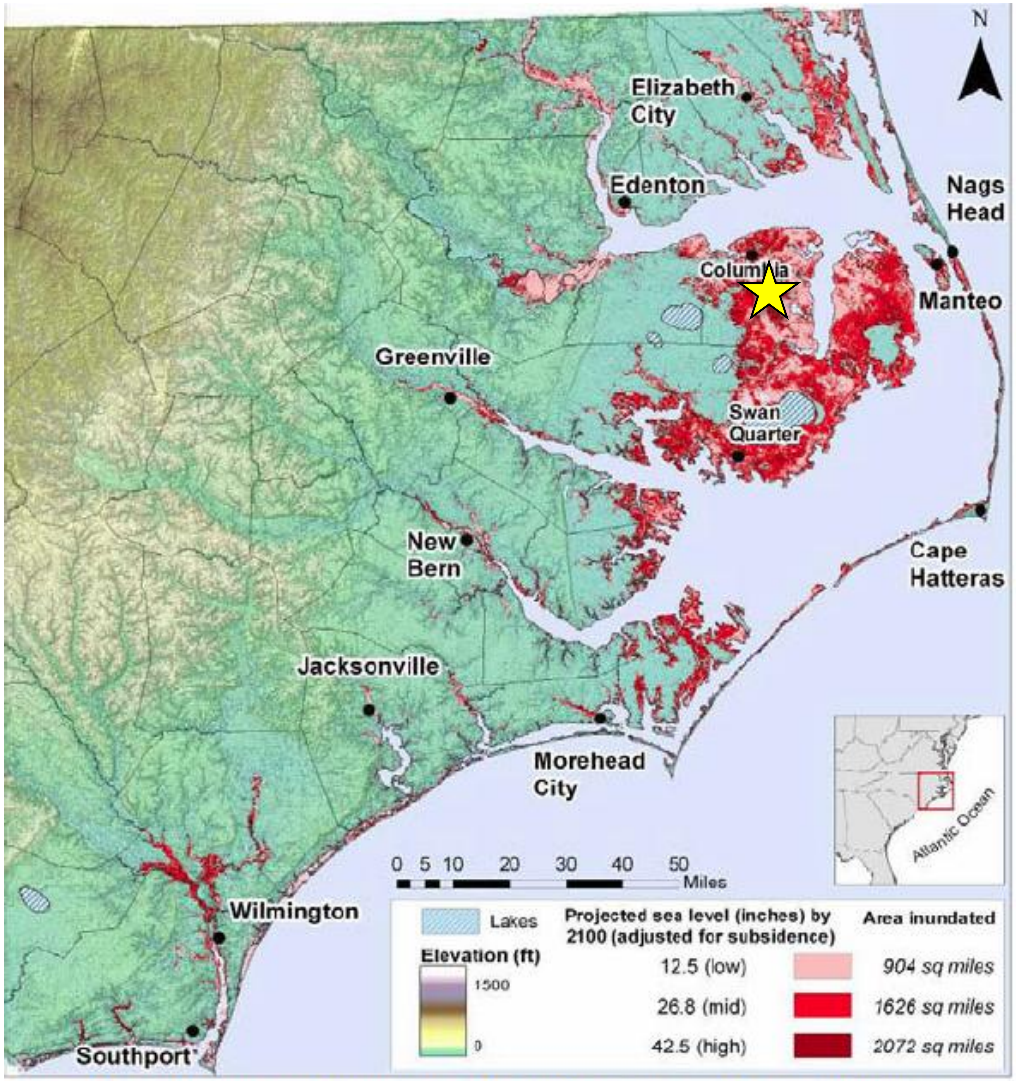
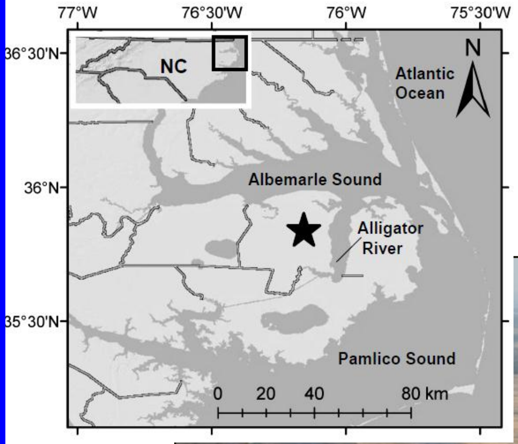


Figure 3: Map of Coastal North Carolina and Sea Level Rise (Source: Poulter and, Halpin 2008).

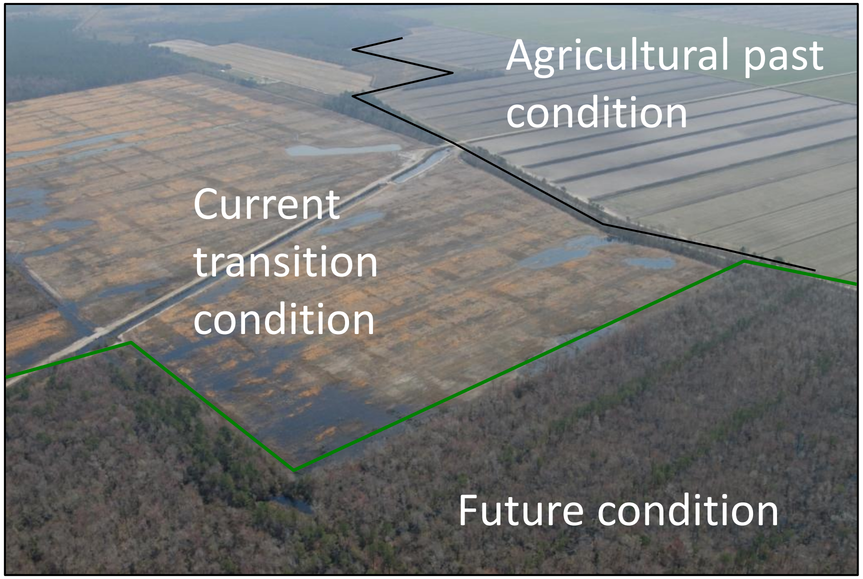
Timberlake Restoration Project

- Ashley Helton (11:20)
  - Simulating the Influence of Salt Water Intrusion on Coupled Elemental Cycles
- Valerie Schoepfer (11:40)
  - The Effect of Salt Water Intrusion on Coupled Iron and Sulfur Cycling
- Marcelo Ardón (2:20)
  - Salt Water Intrusion Alters N and C Export from a Restored Coastal Wetland
- Kristy Hopfensperger (4:00)
  - Plant Chemistry in a Freshwater Wetland Experiencing Salt Water Intrusion

Timberlake Restoration Project



- Privately owned 1000ha mitigation bank
- Focus → 440ha agricultural field (formerly pumped)
- <5 m range in surface elevation
- Freshwater with wind-driven tides & bidirectional flow



Timberlake Timeline

1980
Swamps, pocosins drained

1985
First crops planted

1986-2001
Corn, soy

1996
GDSMB buys site

2004
Last crops

2005
Earth-moving
Seedlings planted

2007
Canals plugged; pumping stops

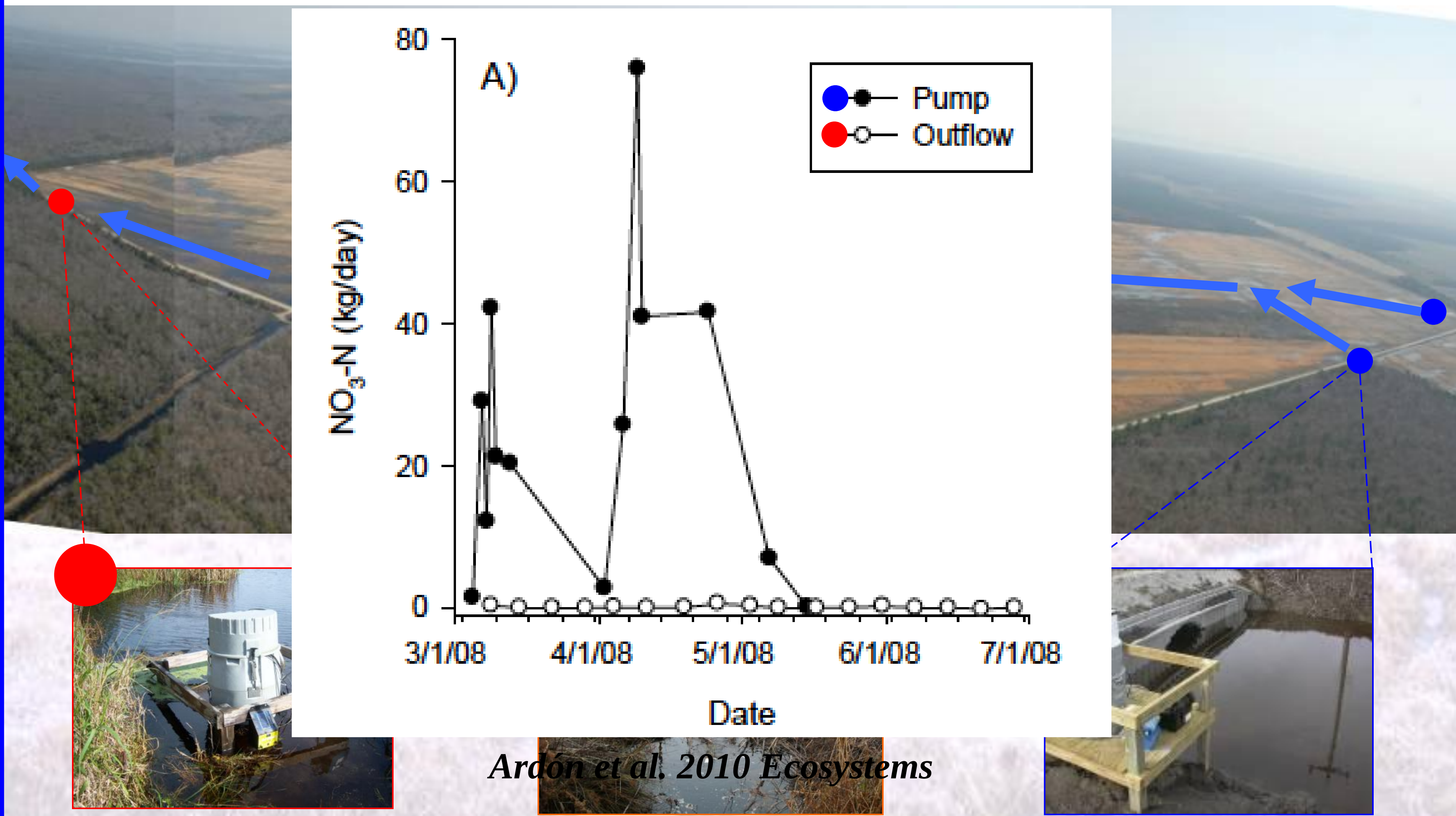
Timberlake Overview

OUTFLOW = SALT WATER EXPOSED

MIDPOINT

2 INFLOWS = MINIMAL SALT EXPOSURE

Timberlake Overview



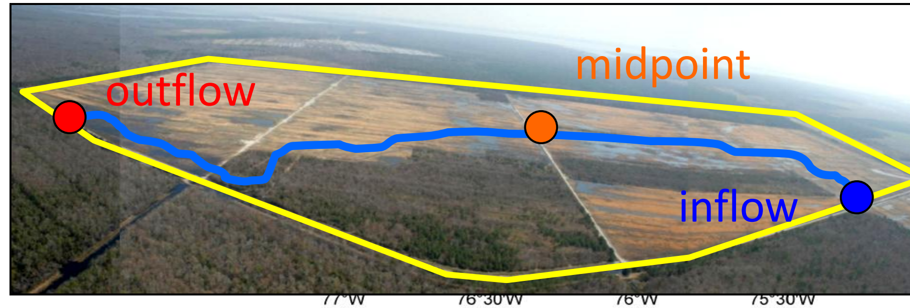
Ardón et al. 2010 Ecosystems

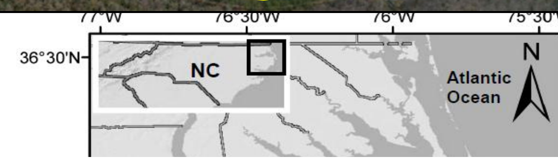
OUTFLOW = SALT WATER EXPOSED

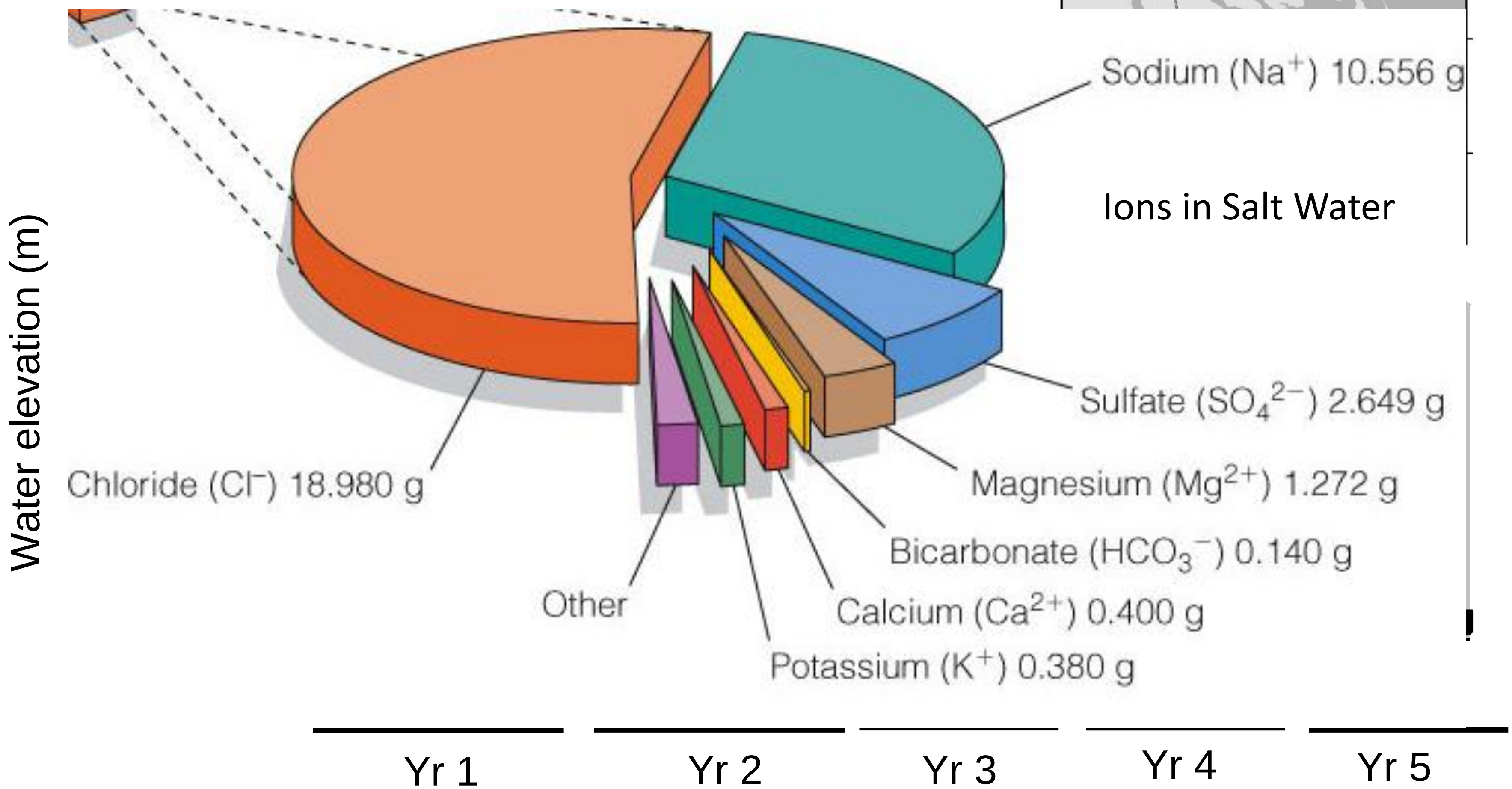
MIDPOINT

2 INFLOWS = MINIMAL SALT EXPOSURE

2007 & 2008 Drought = Saltwater intrusion

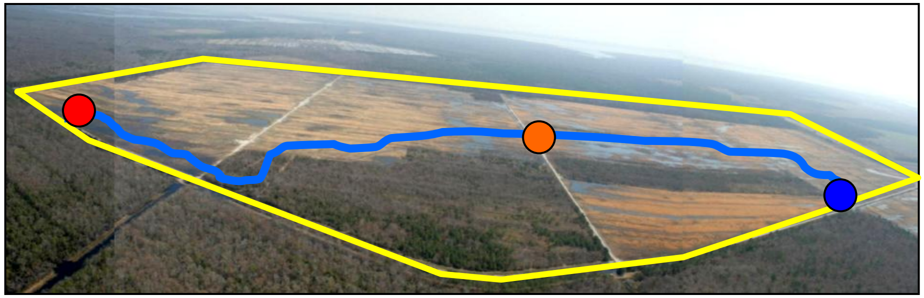




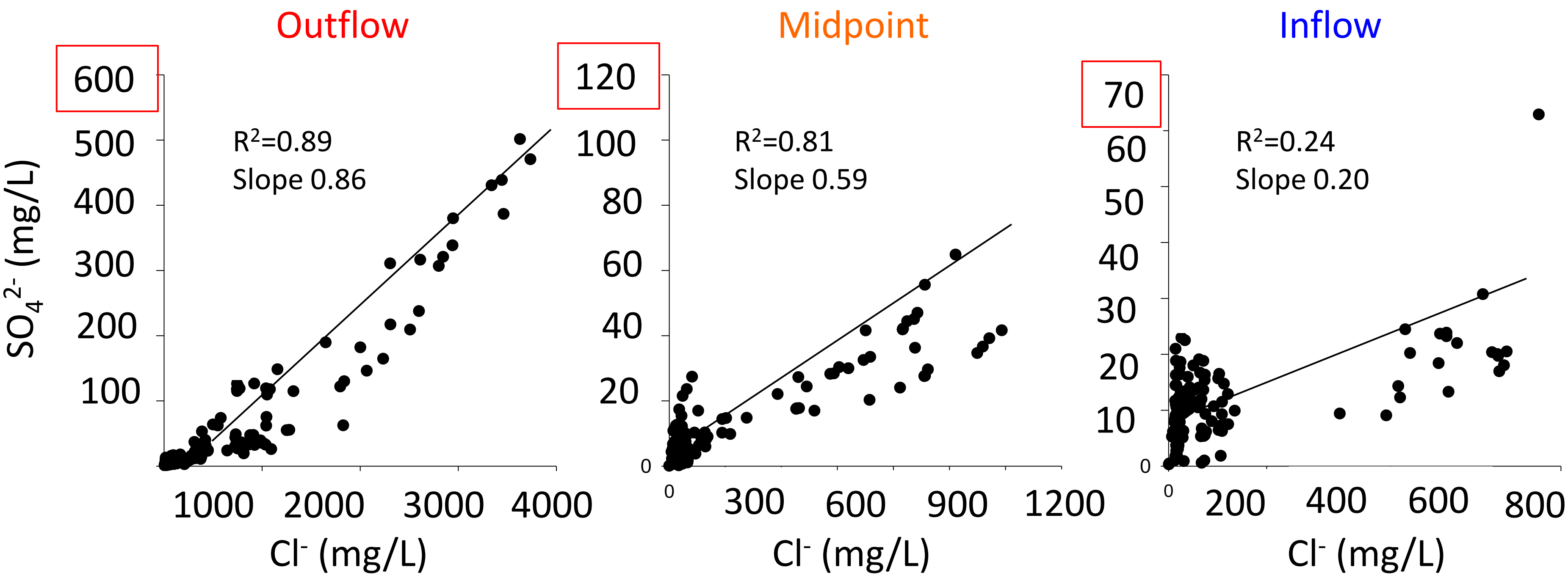


How does salt water intrusion affect the distribution of anaerobic microbial metabolism?

Increased SO_4^{2-} from SLR



Increased NO_3^- from Ag.



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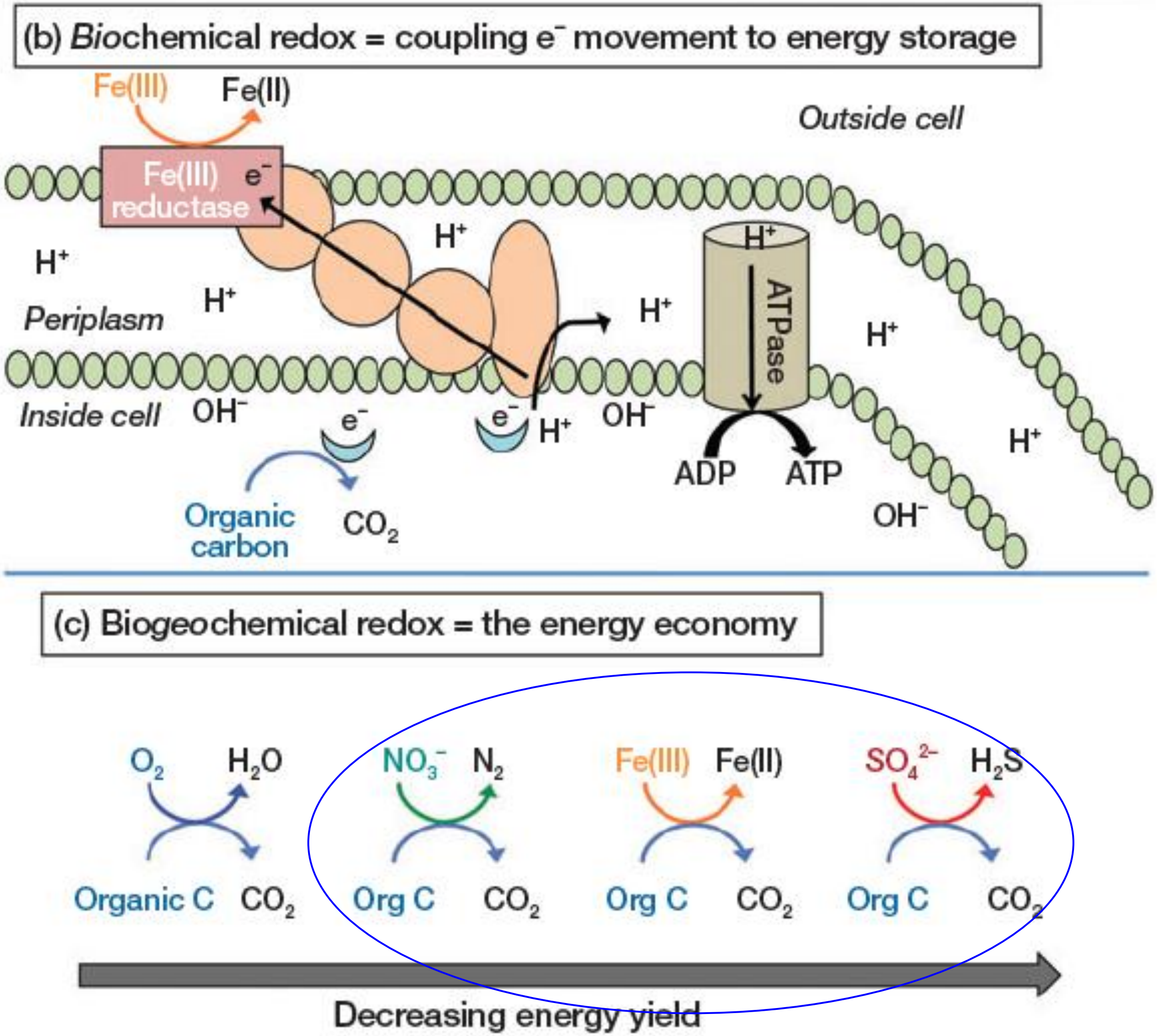
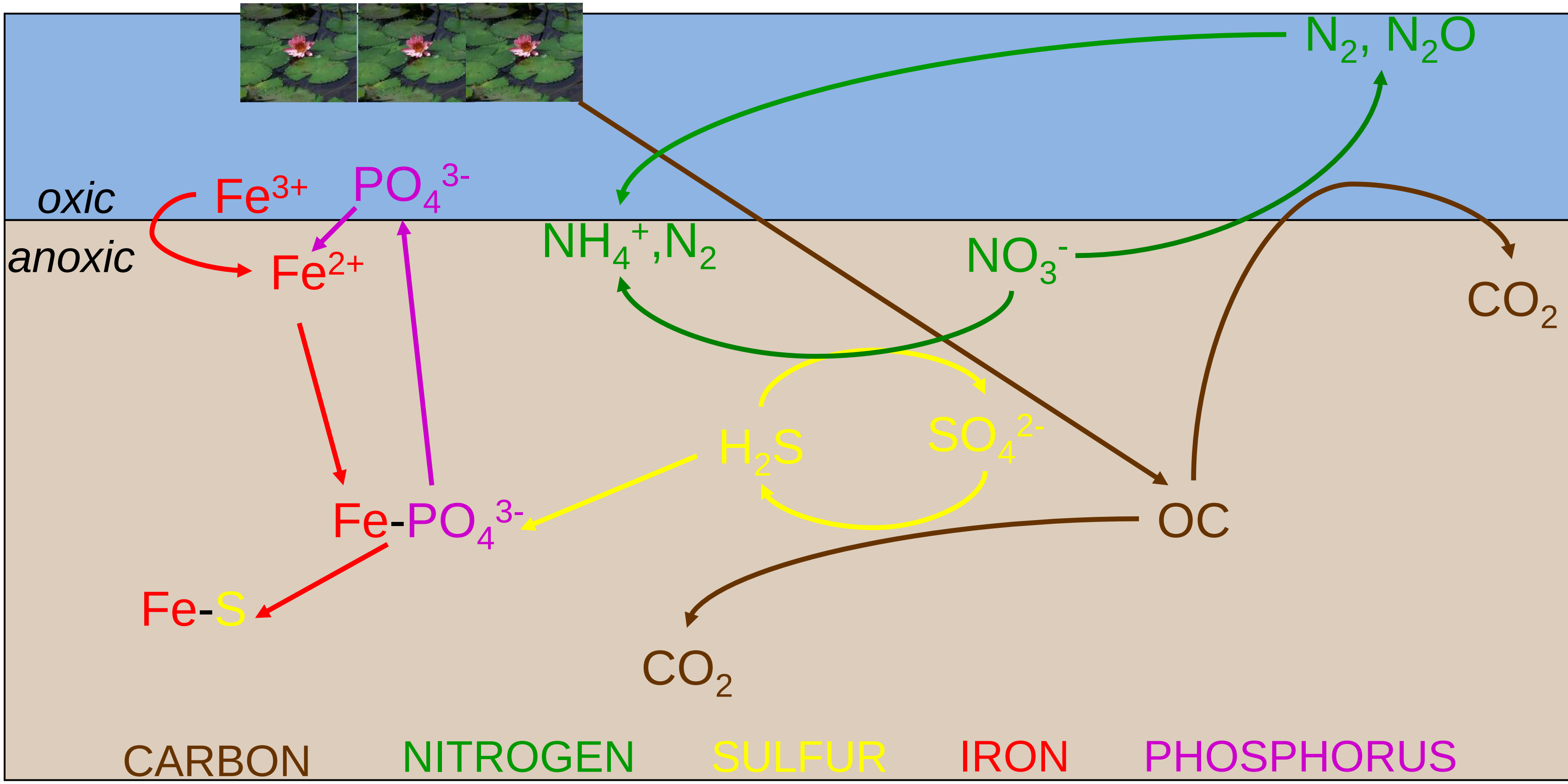


Burgin et al. (2011) *Frontiers in Ecology and the Environment*

How does salt water intrusion affect the distribution of anaerobic microbial metabolism?

Biogeochemical Reality is Messy:



How does salt water intrusion affect the distribution of anaerobic microbial metabolism?

Goal: Create a simplified reality to examine how individual components of nitrate, salt and sulfate inputs affect anaerobic pathways and microbial communities at Timberlake.

- Q_1: Does previous exposure to salt water affect how soil microbial communities react to simulated salt water intrusion?
- Q_2: Are their differential effects of salt and sulfate on anaerobic microbial communities?
- Q_3: How salt water intrusion affect the denitrification capacity of coastal wetlands?

"Simplified Reality" = Slurries

Exposed to Salt

Unexposed to Salt

Three-way Full Factorial:

$^{15}NO_3^-$ = 0.1, 1, 3 mg N L^{-1}
(7, 71, 214 µM)

Salt = 0 (fresh), 2, 4 ppt

SO_4^{2-} = 5, 50, 500 mg L^{-1}
(52, 520, 5205 µM)

+ 5g soil + 60 ml anoxic site water =

9 reps of the same trt combination
Destructively harvested over 3 days

Analyzed for: CH_4 (GC), NO_3^- (colorimetric)
$^{30}N_2$ = denitrification (MIMS)

"Simplified Reality" = Slurries

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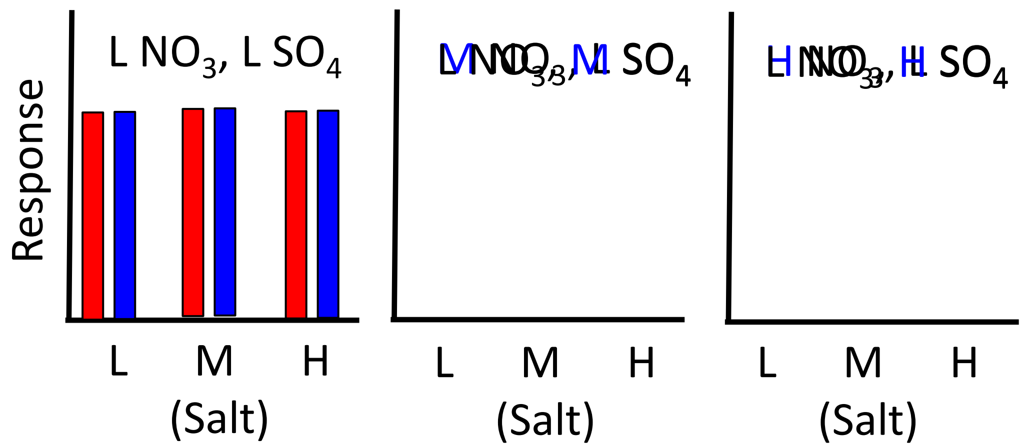
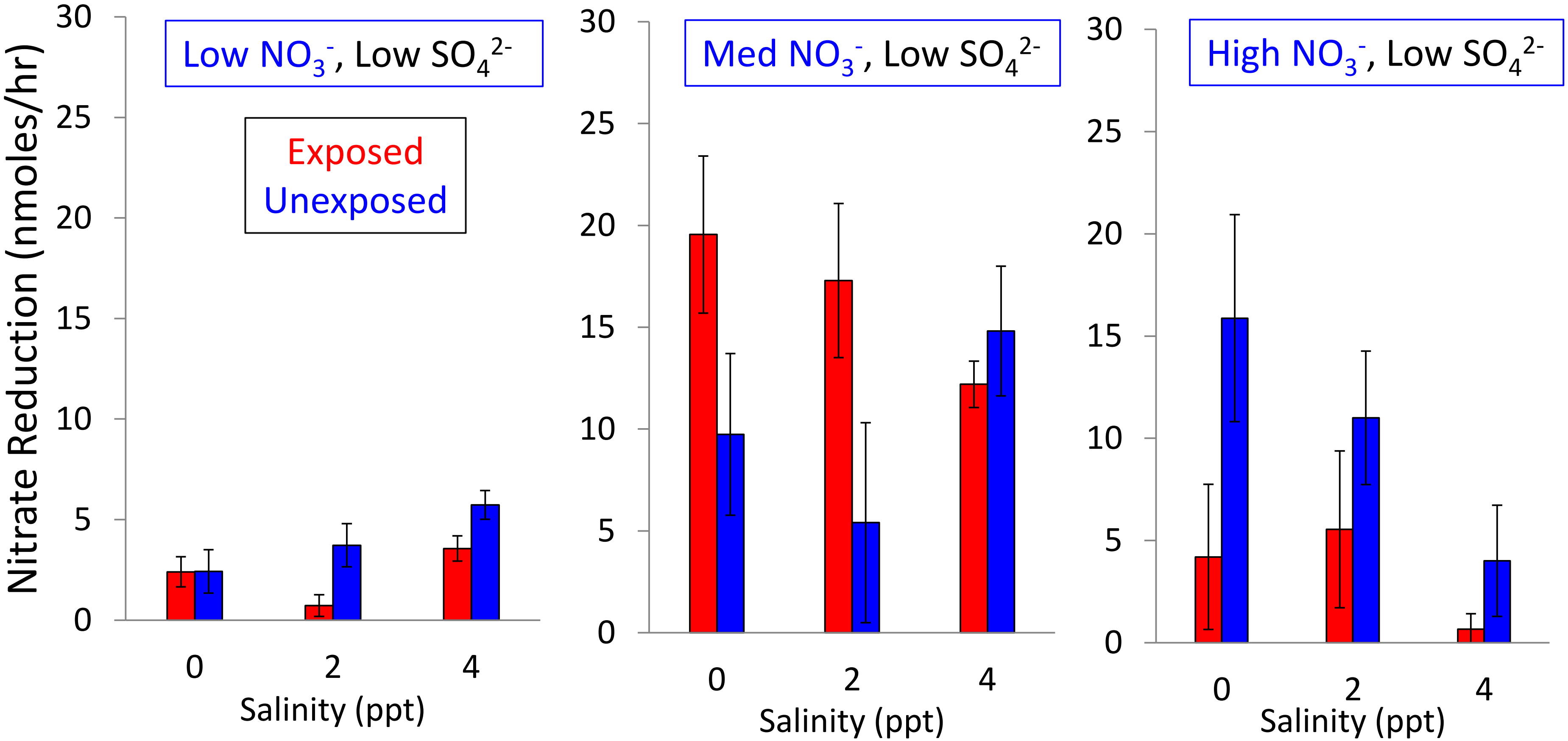


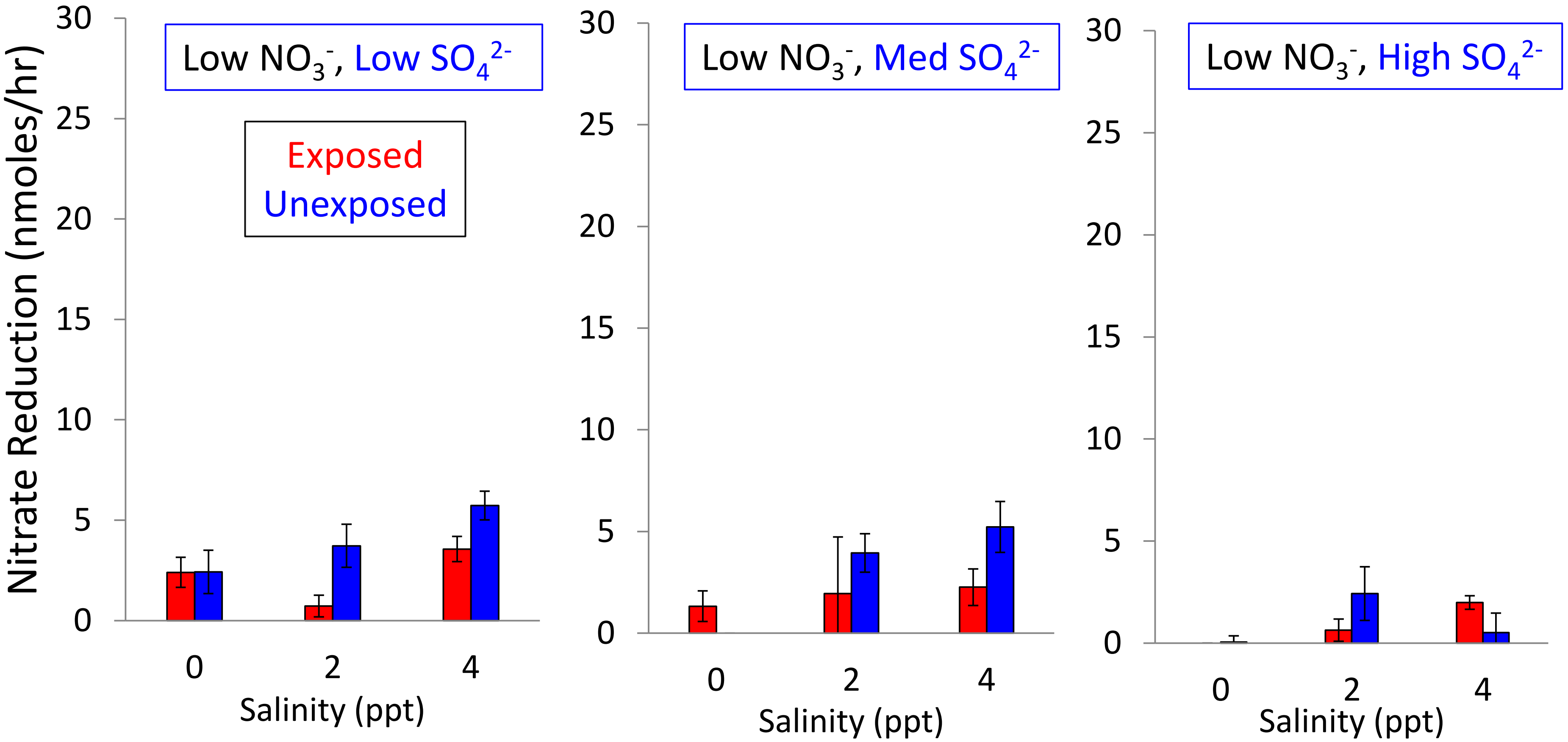
Nitrate Reduction – Salt & Nitrate Effects



[NO_3] controls nitrate reduction rates.

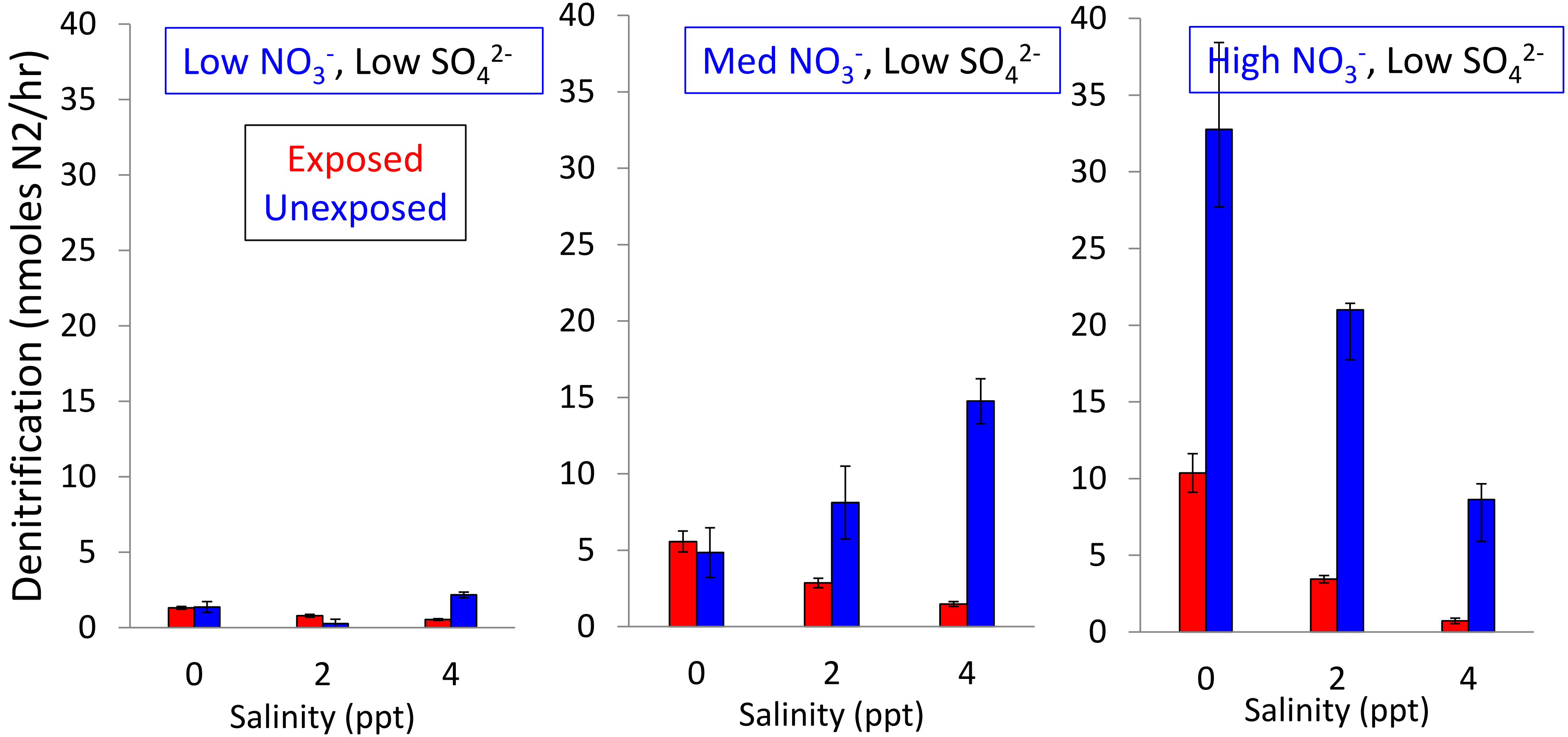
Salt does not consistently influence nitrate reduction capacity.

Nitrate Reduction – Salt & Sulfate Effects



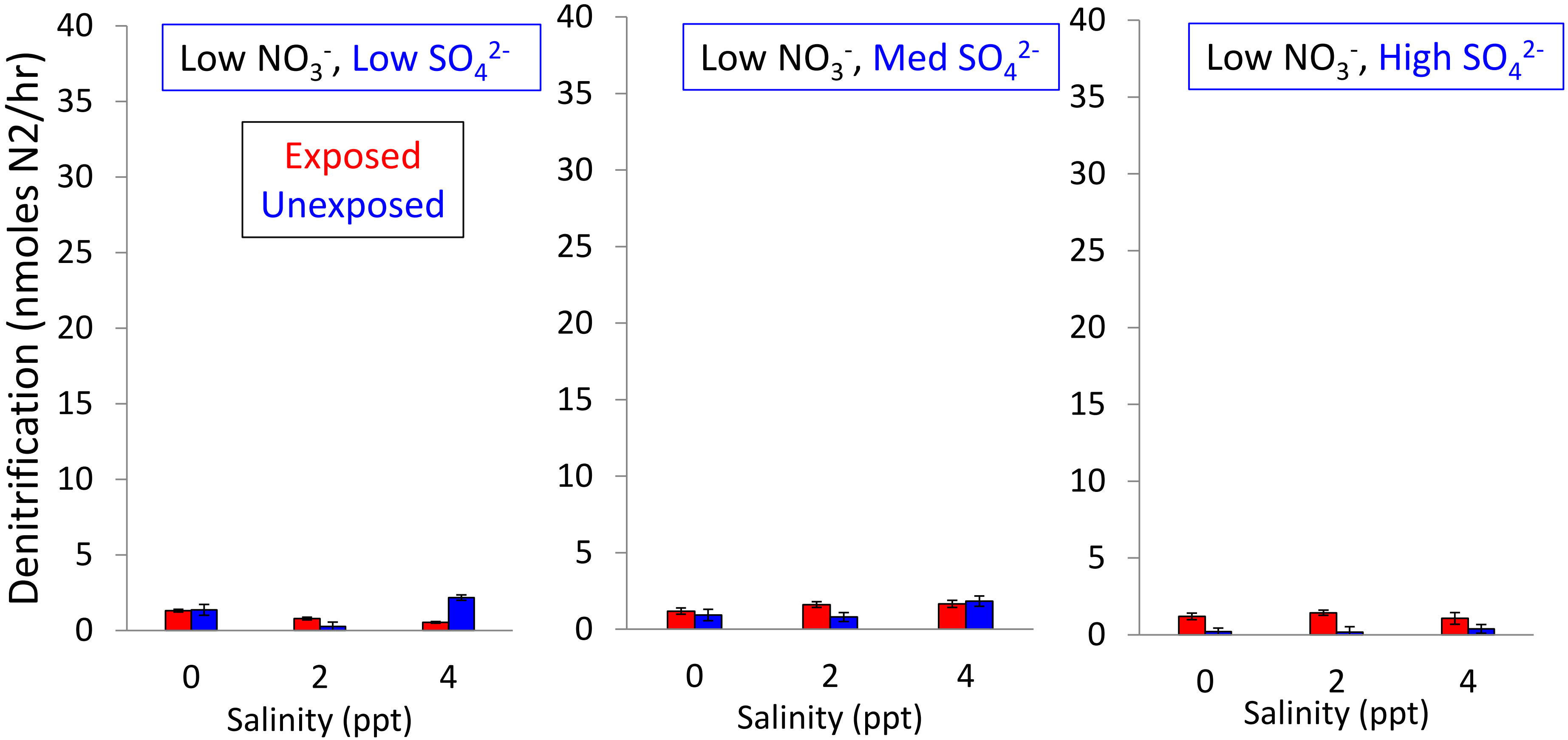
Neither SO_4^{2-} nor Salt influence nitrate reduction capacity.

Denitrification – Salt & Nitrate Effects



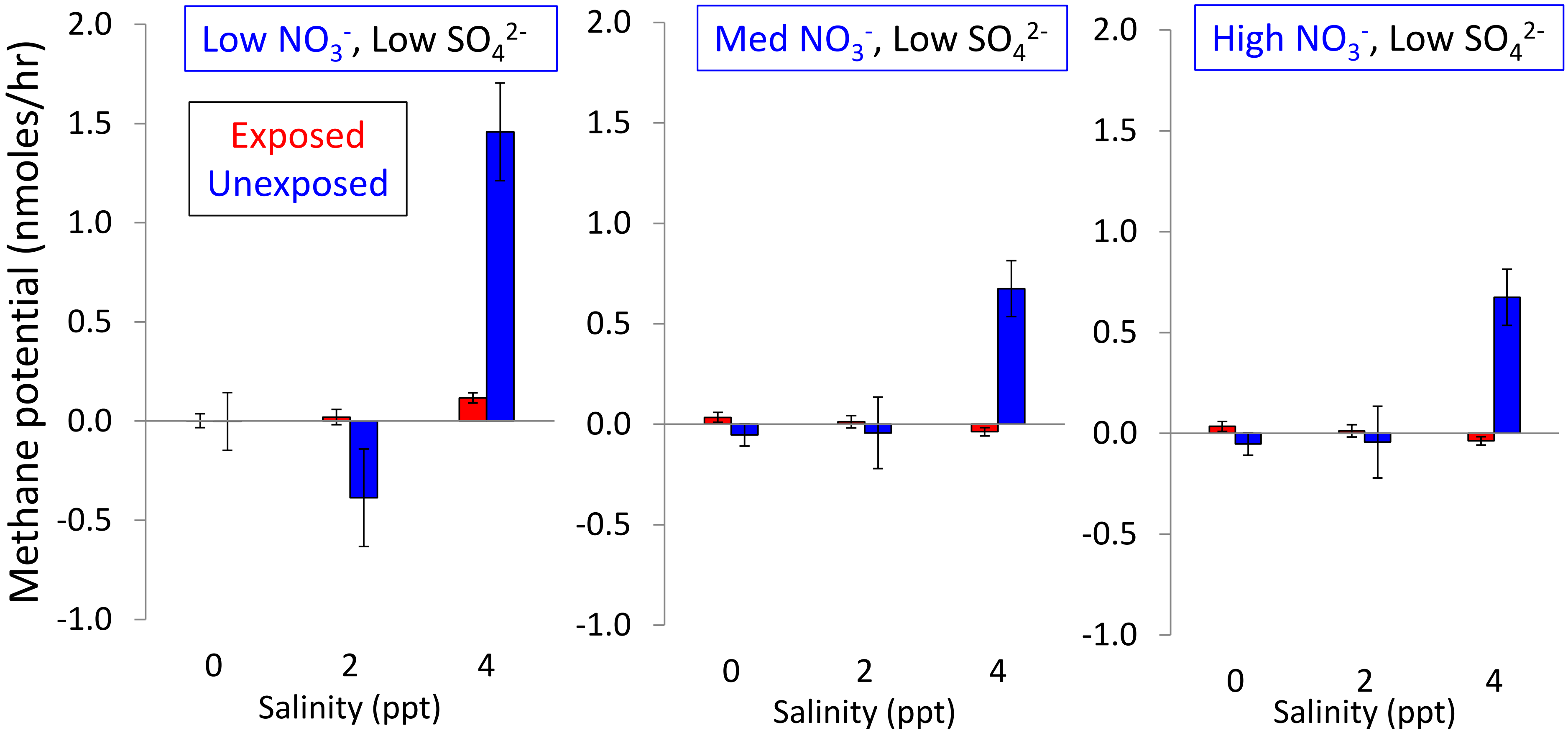
[NO_3] controls denitrification rates
Clear salt effect on denitrification with excess NO_3-
Unexposed > Exposed denitrification rates

Denitrification – Salt & Sulfate Effects



Increased SO_4^{2-} does not effect denitrification rates.

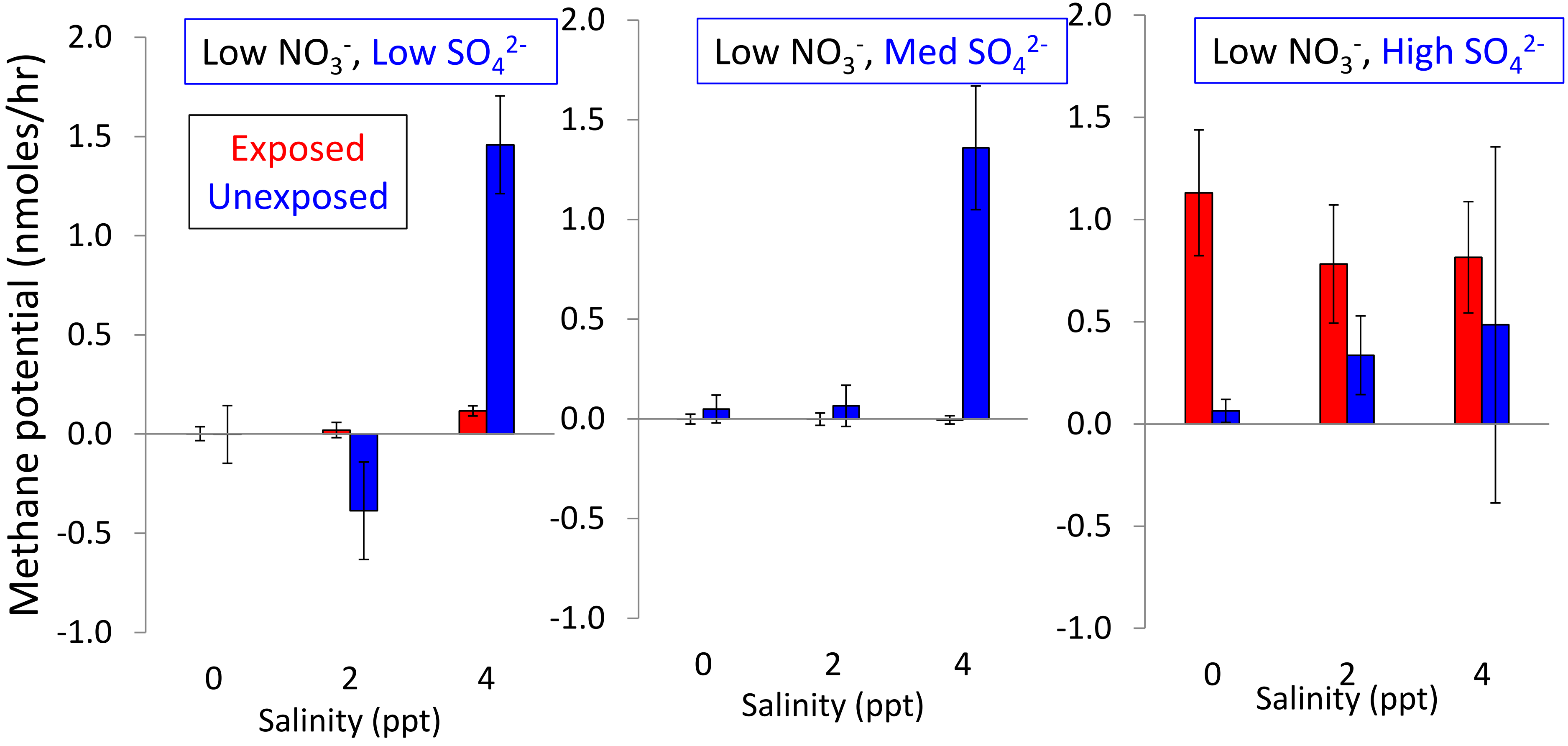
Methanogenesis – Salt & Nitrate Effects



Salt stimulates methane in the unexposed, but not exposed

At high salt, increasing [NO_3^-] decreases methane

Methanogenesis – Salt & Sulfate Effects



High sulfate stimulates methane in exposed, but not unexposed

At high salt, increasing $[NO_3^-]$ decreases methane

Summary of Findings

- Q_1: Does previous exposure to salt water affect how soil microbial communities react to simulated salt water intrusion?
  - Yes, particularly for methane production.
- Q_2: Are their differential effects of salt and sulfate on anaerobic microbial communities?
  - Yes, particularly for methane production. Exposed sites responded to increased sulfate, unexposed responded to increased salt.
- Q_3: How salt water intrusion affect the denitrification capacity of coastal wetlands?
  - Maybe. Does not affect nitrate reduction, but may affect denitrification.

Implications for Coastal Wetland Biogeochemistry under Salt Water Intrusion

- Increased methane production in areas previously exposed and under continual exposure
- Wetlands may still reduce/remove nitrate, but increased salt may shift the reduction away from denitrification to other retention processes

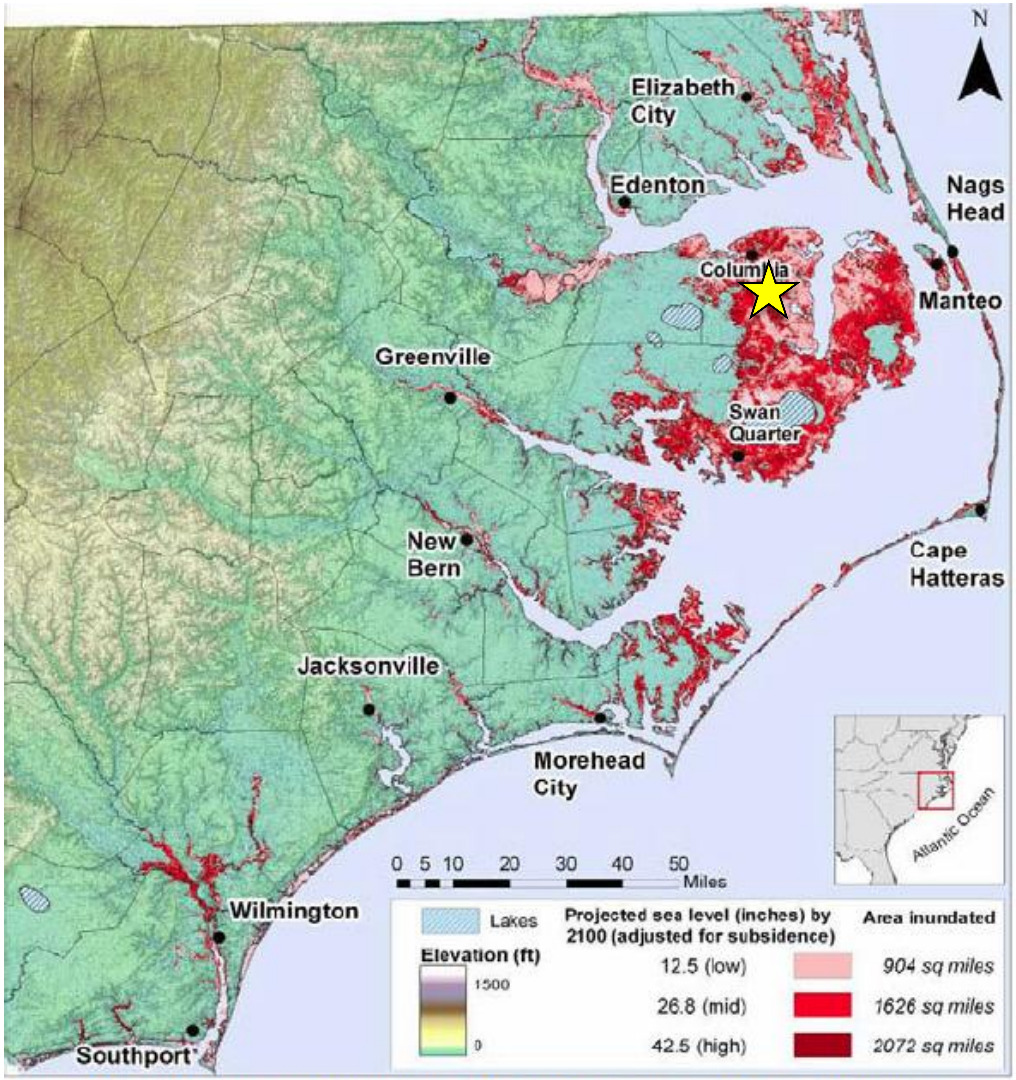
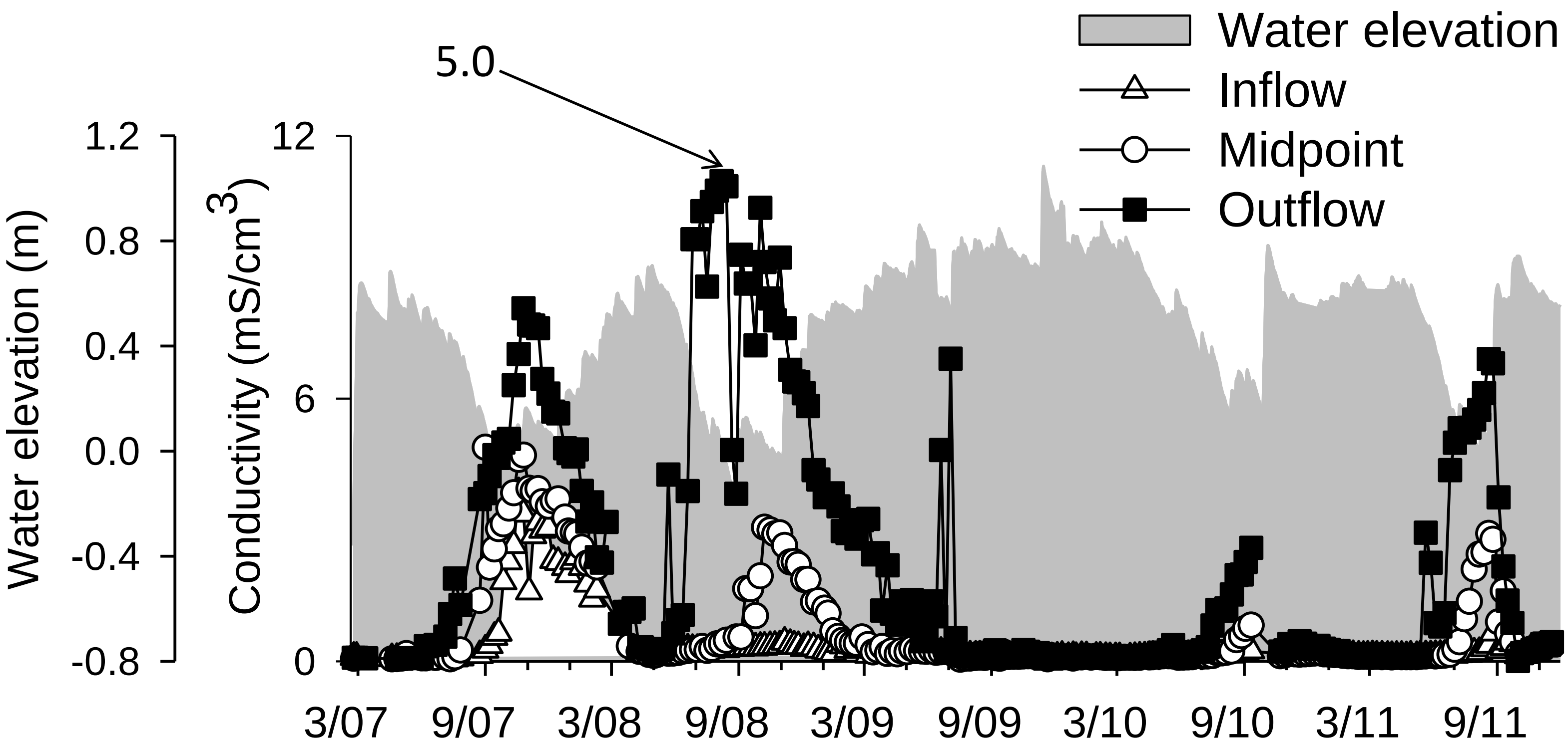


Figure 3: Map of Coastal North Carolina and Sea Level Rise (Source: Poulter and, Halpin 2008).

Acknowledgements

- Medora Burke-Scoll and Anna Fedders
- Terry Loecke
- Kristy Hopfensperger
- Sarah Harvey, Erin Cull, Melanie Stall, James Detraz, and Geraldine Nogaro
- NSF Ecosystems

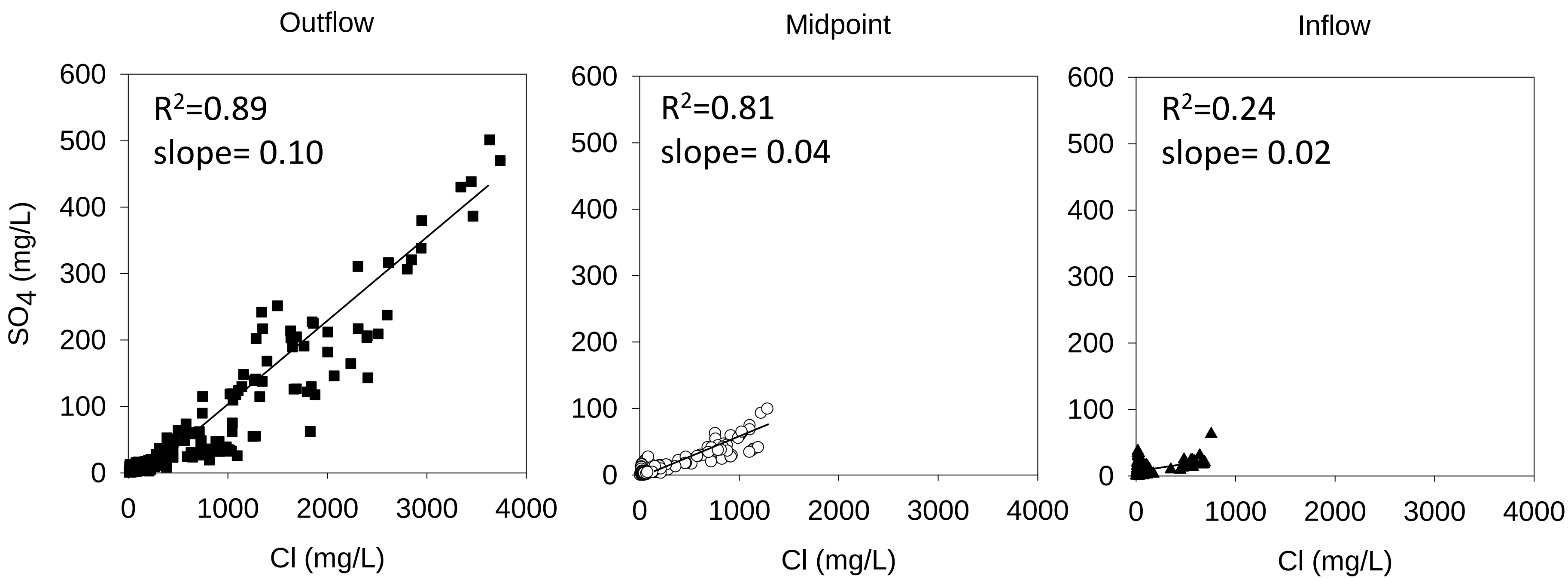
Drought-induced saltwater intrusion



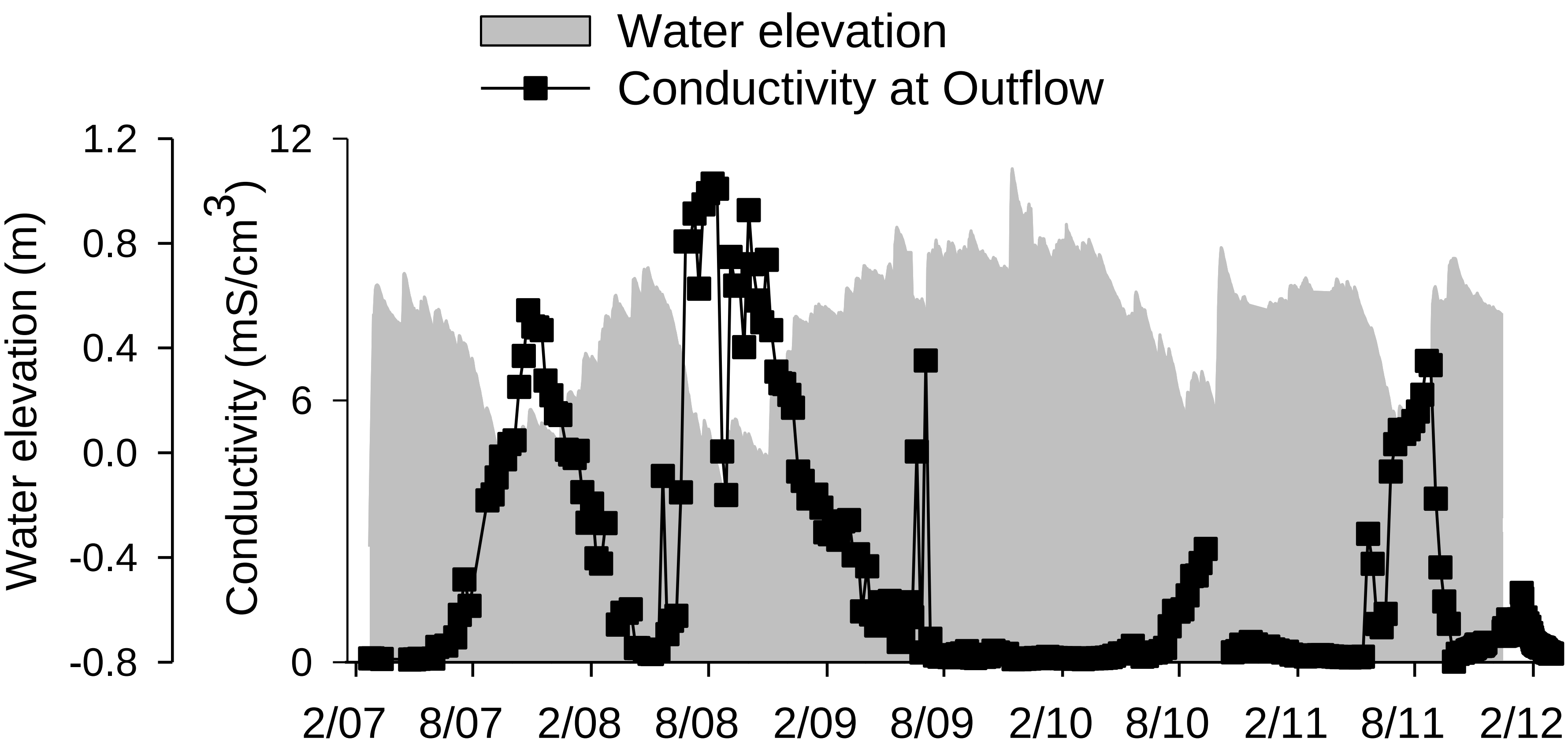
Outflow

Inflows

Spatial and temporal variability in SWI

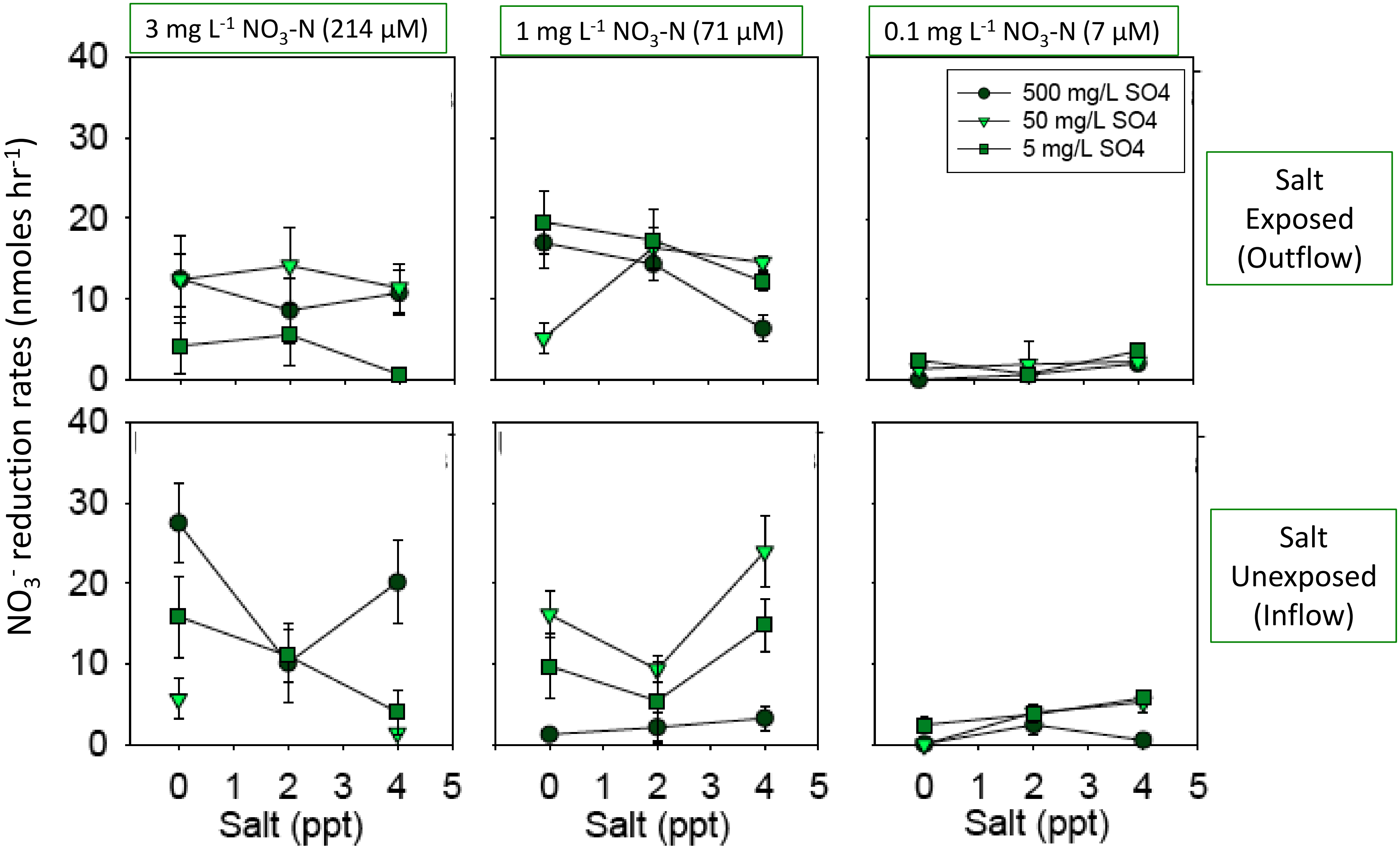


5 Year Outflow Conductivity Record



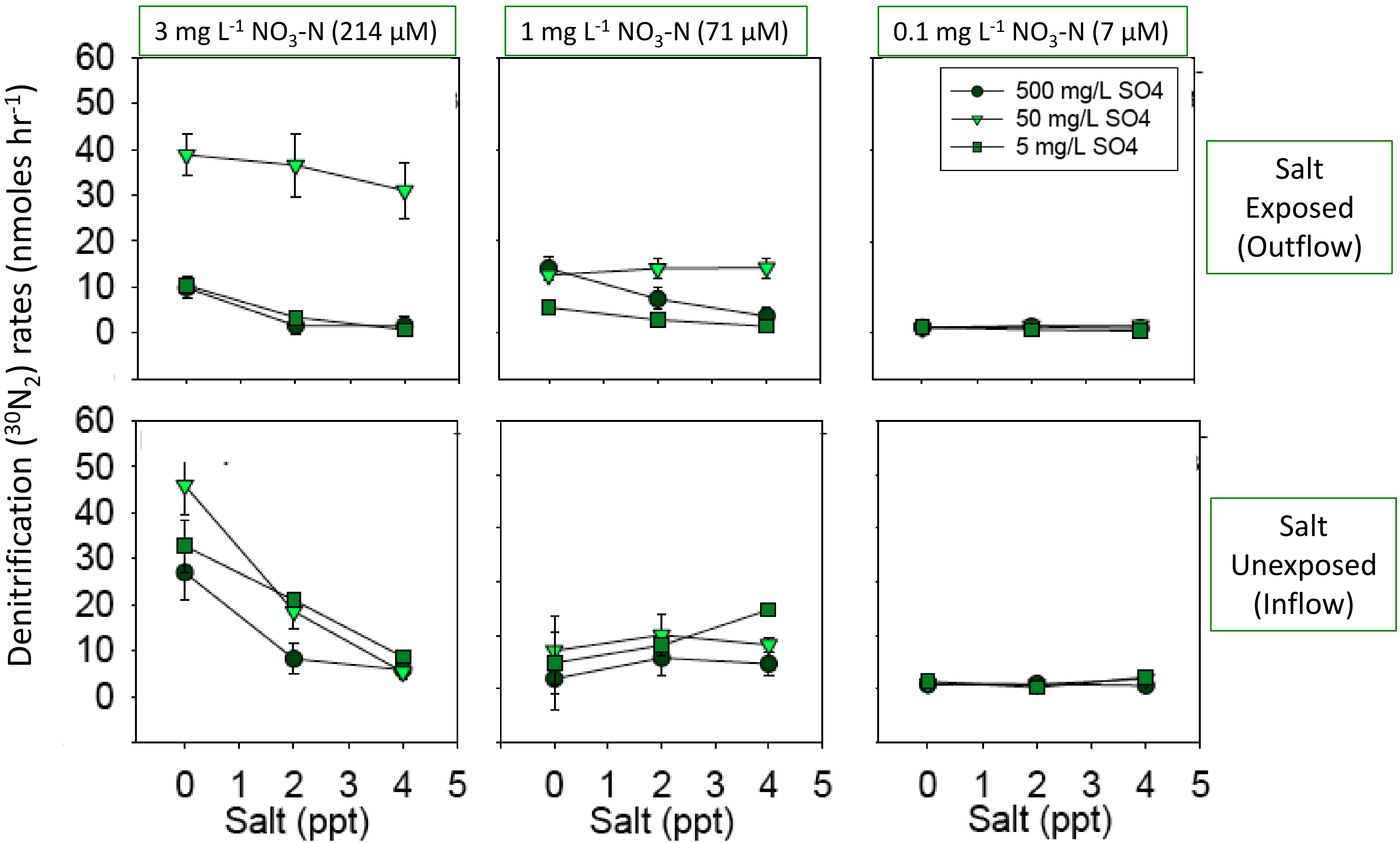
Nitrate Reduction Rates

⇧[NO_3^-] = Higher NO_3^- reduction rates; no site difference



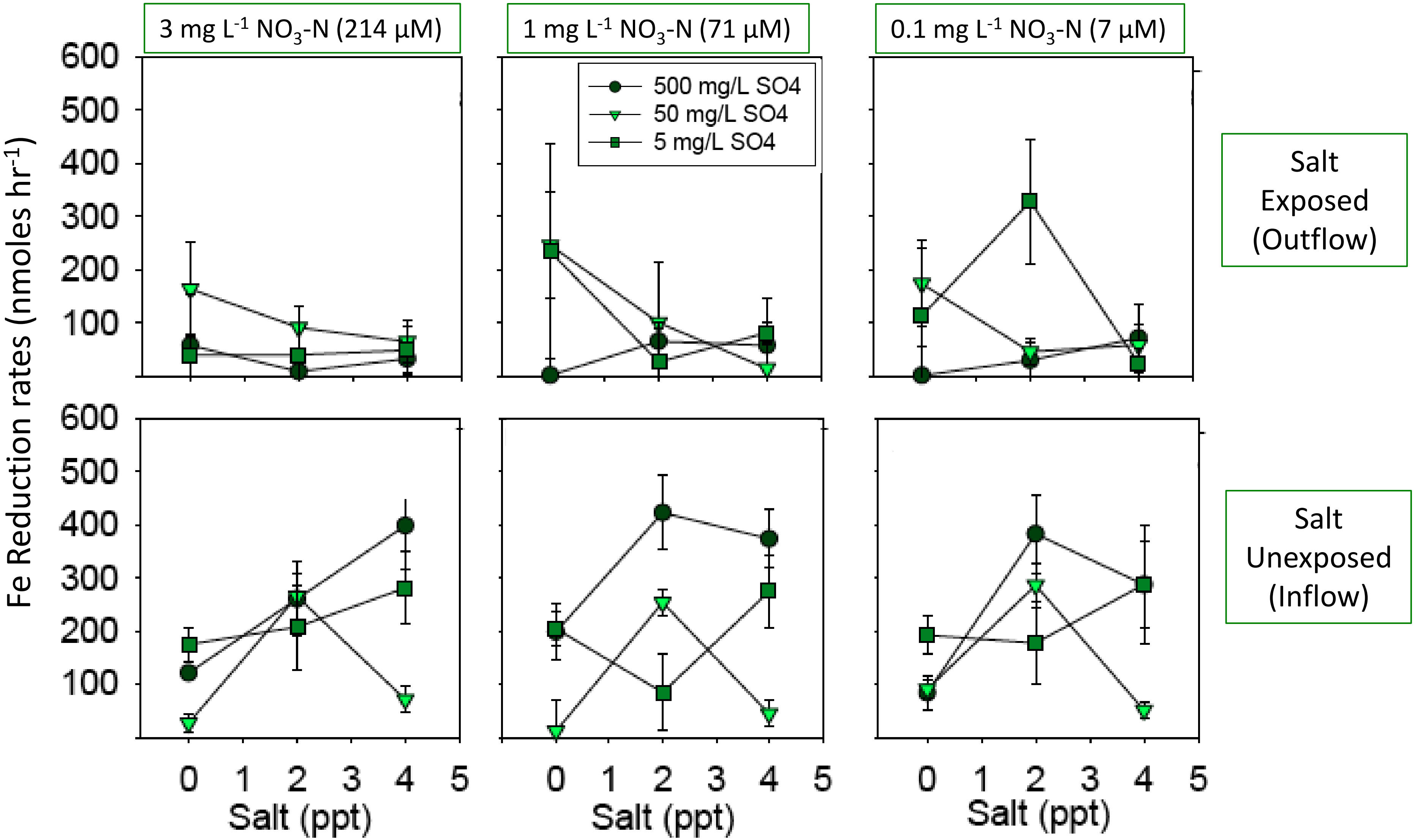
Denitrification Rates

$[NO_3]$ controls dnt rates; at ⇧ NO3, ⇧ salt decreases dnt
Effects Unexposed more than Exposed



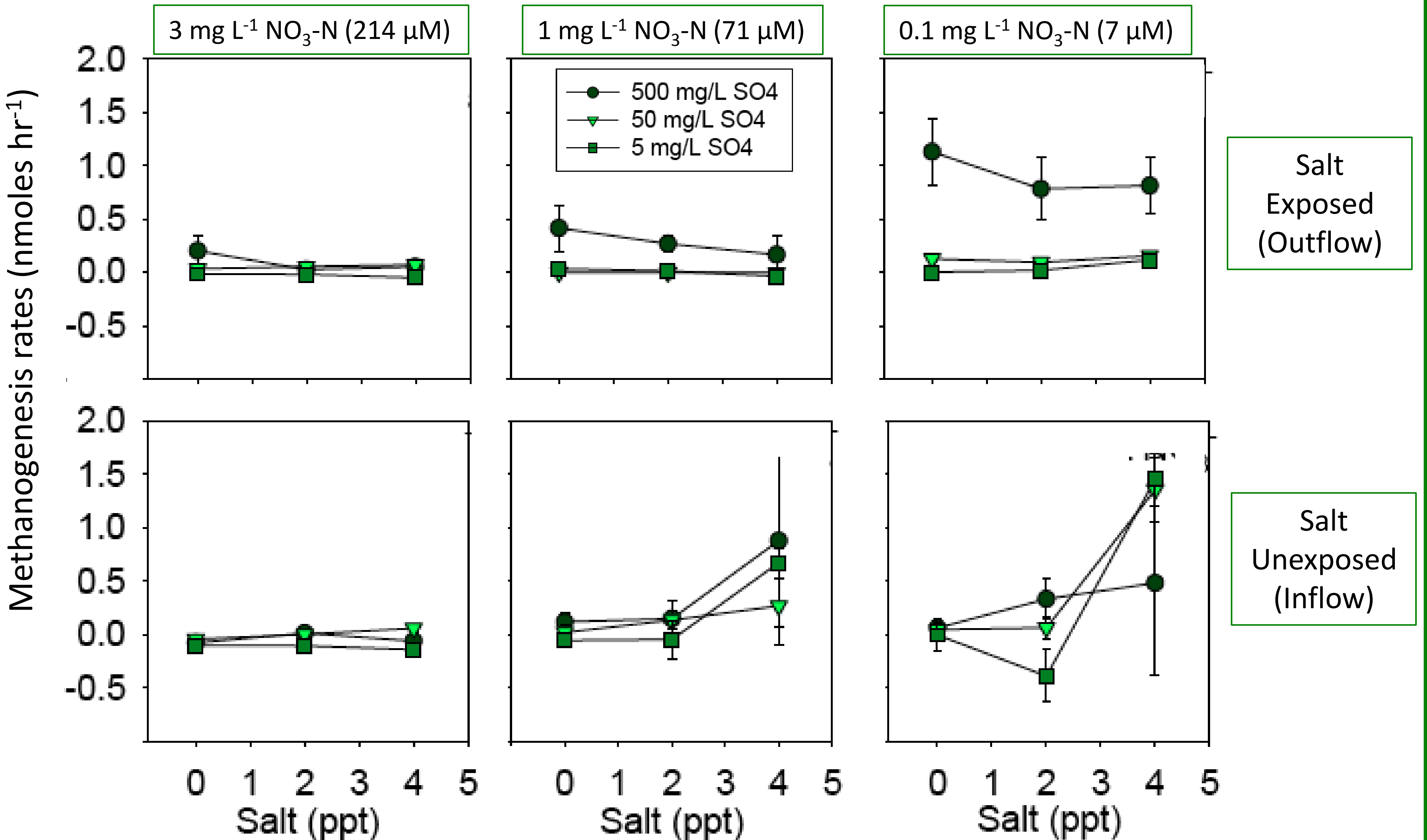
Fe Reduction

No influence of $[NO_3]$; salt*site interaction
Unexposed > Exposed?



Methanogenesis

Everything effects Methane, mostly [NO_3^-]
Salt vs. [SO_4^{2-}] mechanisms in different sites



Timberlake Overview

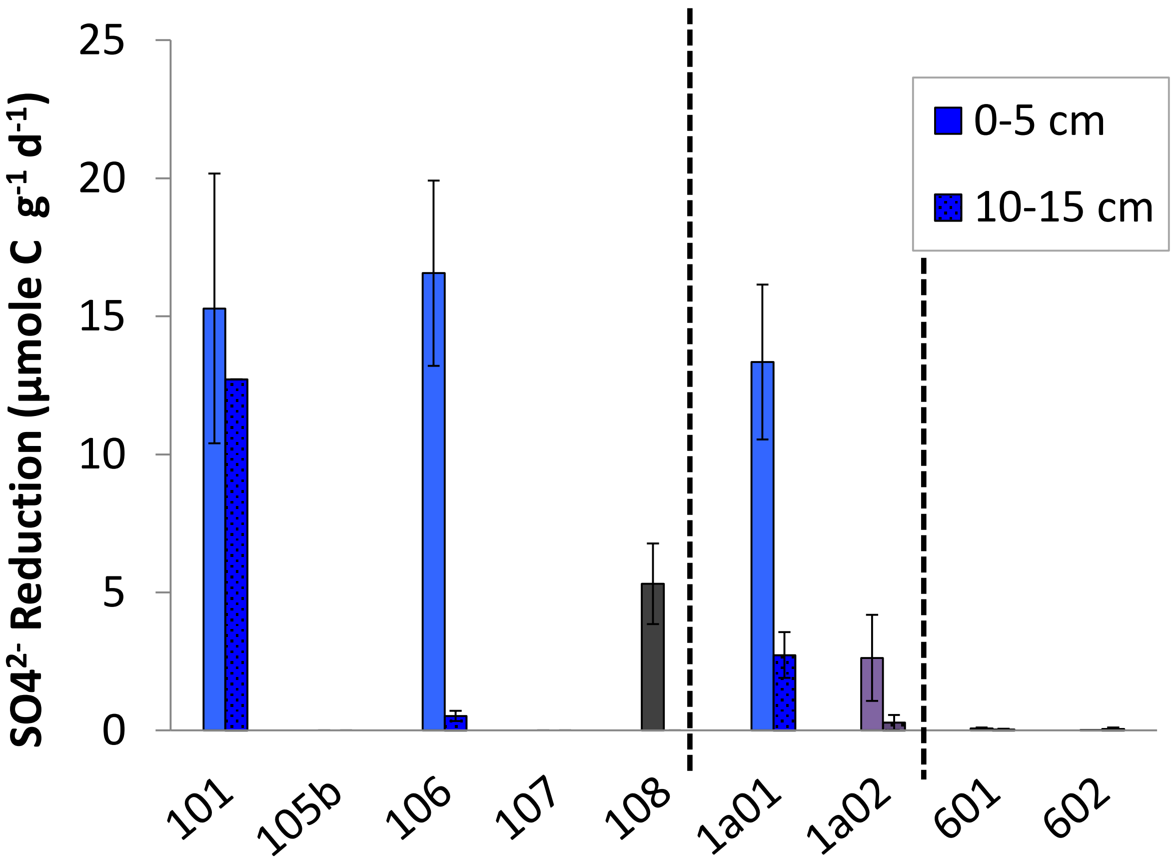
OUTFLOW

2 INFLOWS

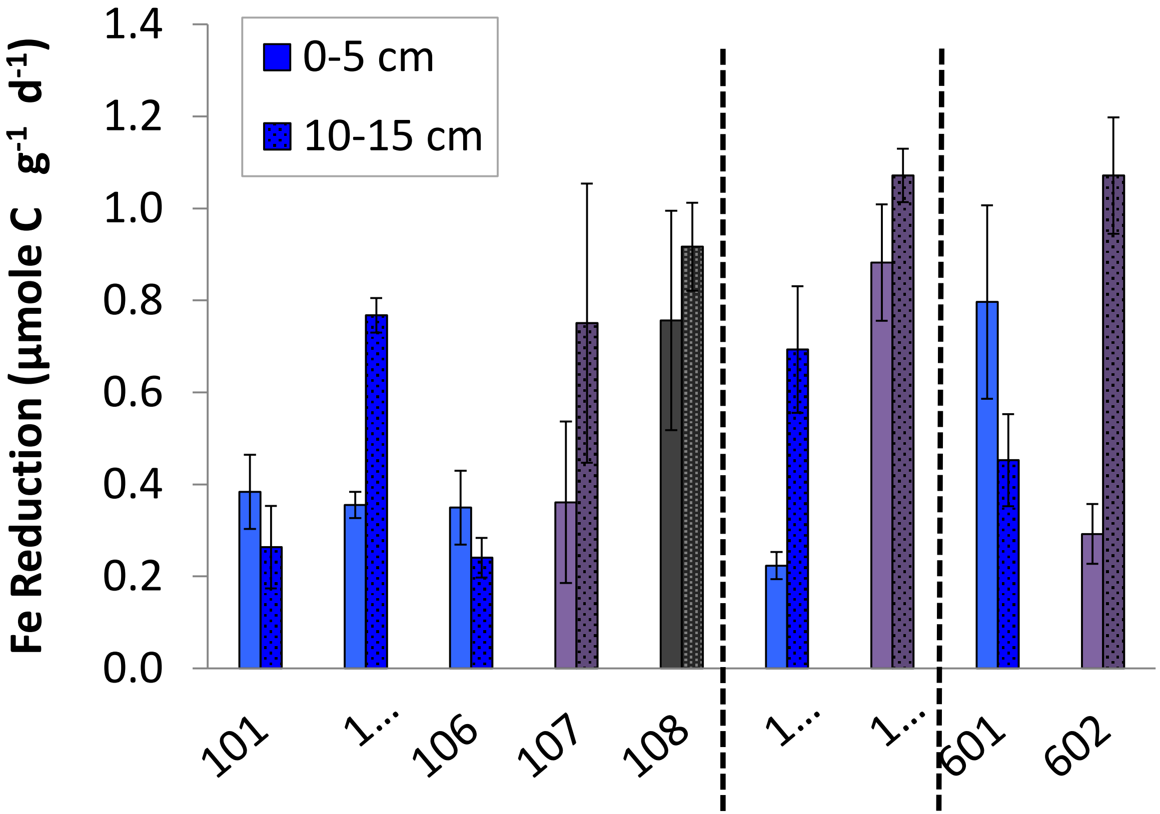
Testing Mechanisms at Multiple Scales

- Field-scale
  - hydrologic (wet to dry) and saltwater (fresh to 4 ppt) gradients with 2 depths (0-5, 10-15 cm)
  - June during early intrusion
  - Sulfate reduction rates, Fe reduction potential, Methanogenesis potential
- Bench-scale manipulations
  - NO_3^-, SO_4^-, NaCl at 3 levels (L, M, H)
  - Exposed and Unexposed sediments
  - Sulfate reduction rates, Fe reduction, Methanogenesis potential

Sulfate Reduction Rates (^{35}S)



Fe Reduction Potential



Methanogenesis Potential