Assessing the biogeochemistry of a restoring macrotidal salt marsh: Implications for future restoration in the Bay of Fundy

Christa Skinner[1], MSc Candidate

Danika van Proosdij[1], David Burdick[2], Jeremy Lundholm[1], & Tony Bowron[2,3]

[1]Saint Mary's University, Halifax, NS, Canada

[2]University of New Hampshire, NH, USA

[3]CB Wetlands and Environmental Specialists Inc., Halifax, NS, Canada

Saint Mary's University Since 1802 One University. One World. Yours.

University of New Hampshire

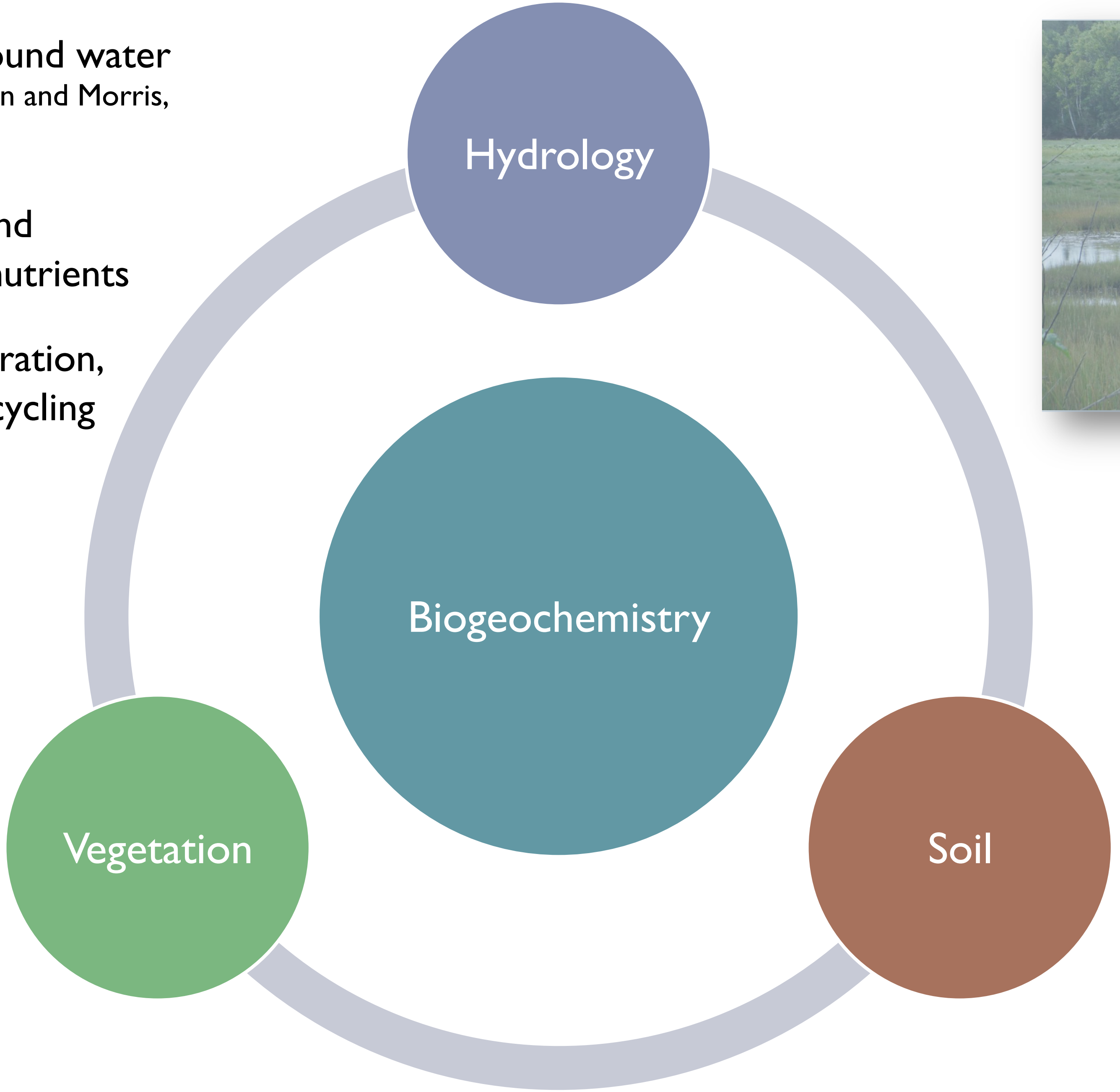
cbwes CB Wetlands & Environmental Specialists

InCoaST Intertidal Coastal Sediment Transport research unit

Wetlands: Key Components

Panne at Cheverie Creek (C.Skinner, 2014)

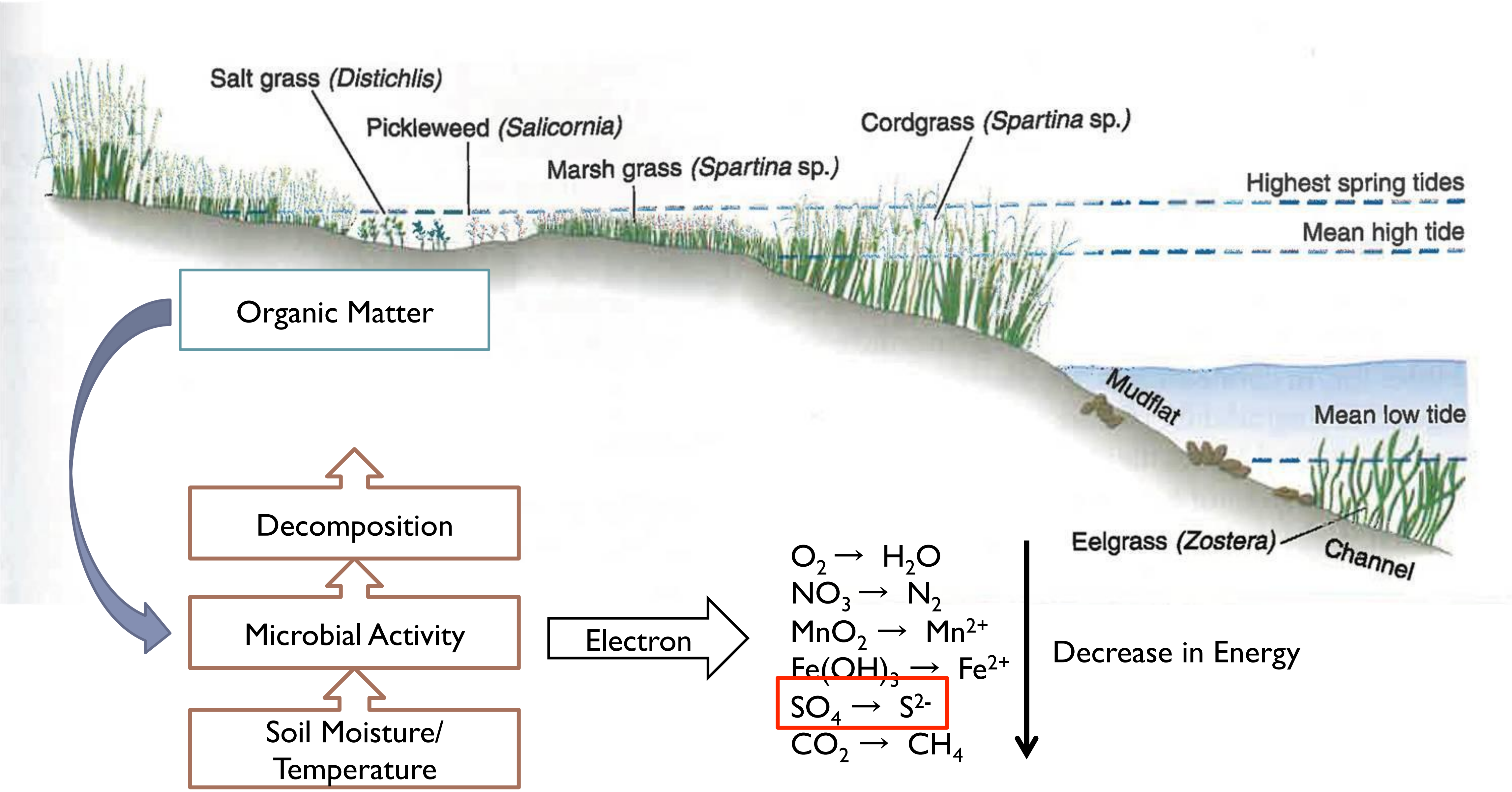
- Influenced by tidal and ground water (Reddy and DeLaune, 2008; Wilson and Morris, 2012)
- Influences physiochemical environment, vegetation and transports sediment and nutrients (Mitsch and Gosselink, 2007)
  - Redox potential, saturation, salinity and nutrient cycling



- Regulates carbon and nutrient inputs
- Provides oxygen to root zone
- Assists in the stabilization of the sediment and amount of sunlight reaching the soil surface (Seliskar et al., 2002)

- Organogenic vs. Minerogenic
- Foundation for platform development
- Influences zonation of vegetation (Reddy and DeLaune, 2008)

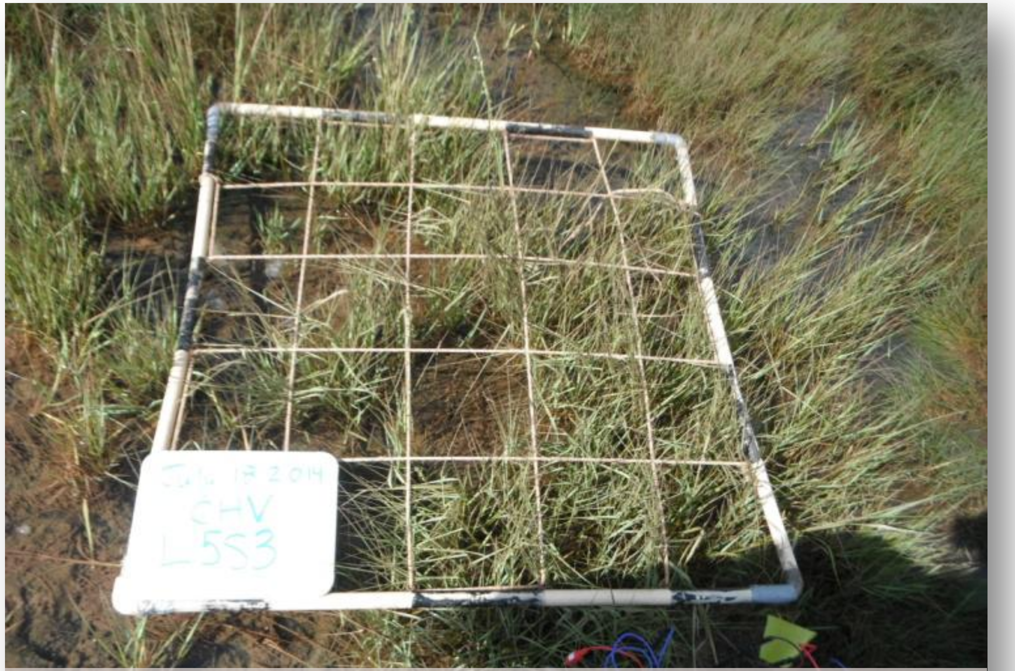
Biogeochemistry of Salt Marshes



Base Image: https://www.studyblue.com/notes/note/n/bu/deck/3325766

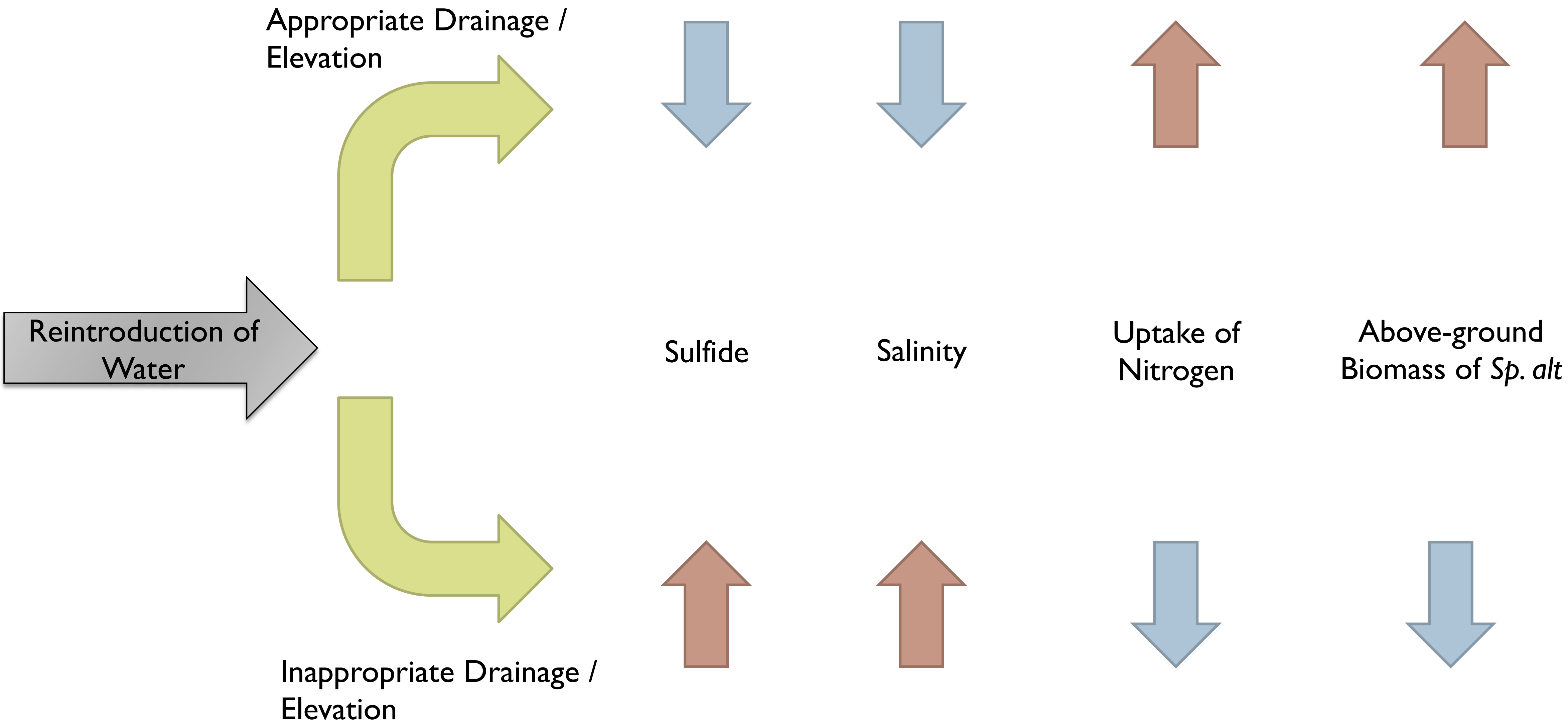
Morphology of *Spartina alterniflora*

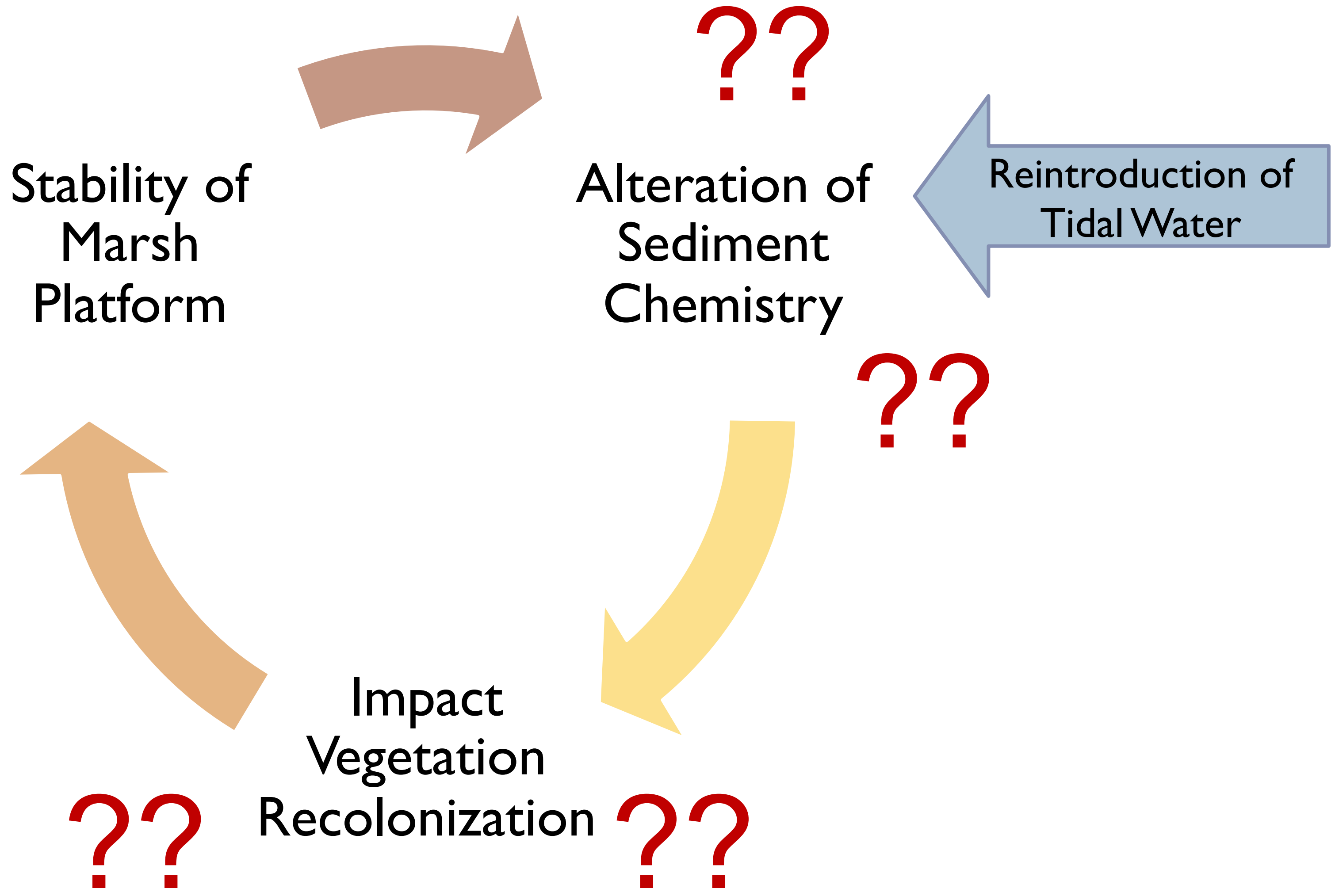
- Noticeable variation in morphology and height (Morris, 1980; Teal, 1962)
- Influenced by environmental factors (Seliskar et al., 2002; Burdick et al., 1989)
- Salinity
- Flooding
- Sulfide concentration
- Nitrogen concentration



Spartina alterniflora next to panne (C. Skinner, 2014)


Spartina alterniflora along creek edge (C. Skinner, 2014)


Appropriate Drainage / Elevation
Reintroduction of Water
Sulfide
Salinity
Uptake of Nitrogen
Above-ground Biomass of *Sp. alt*
Inappropriate Drainage / Elevation



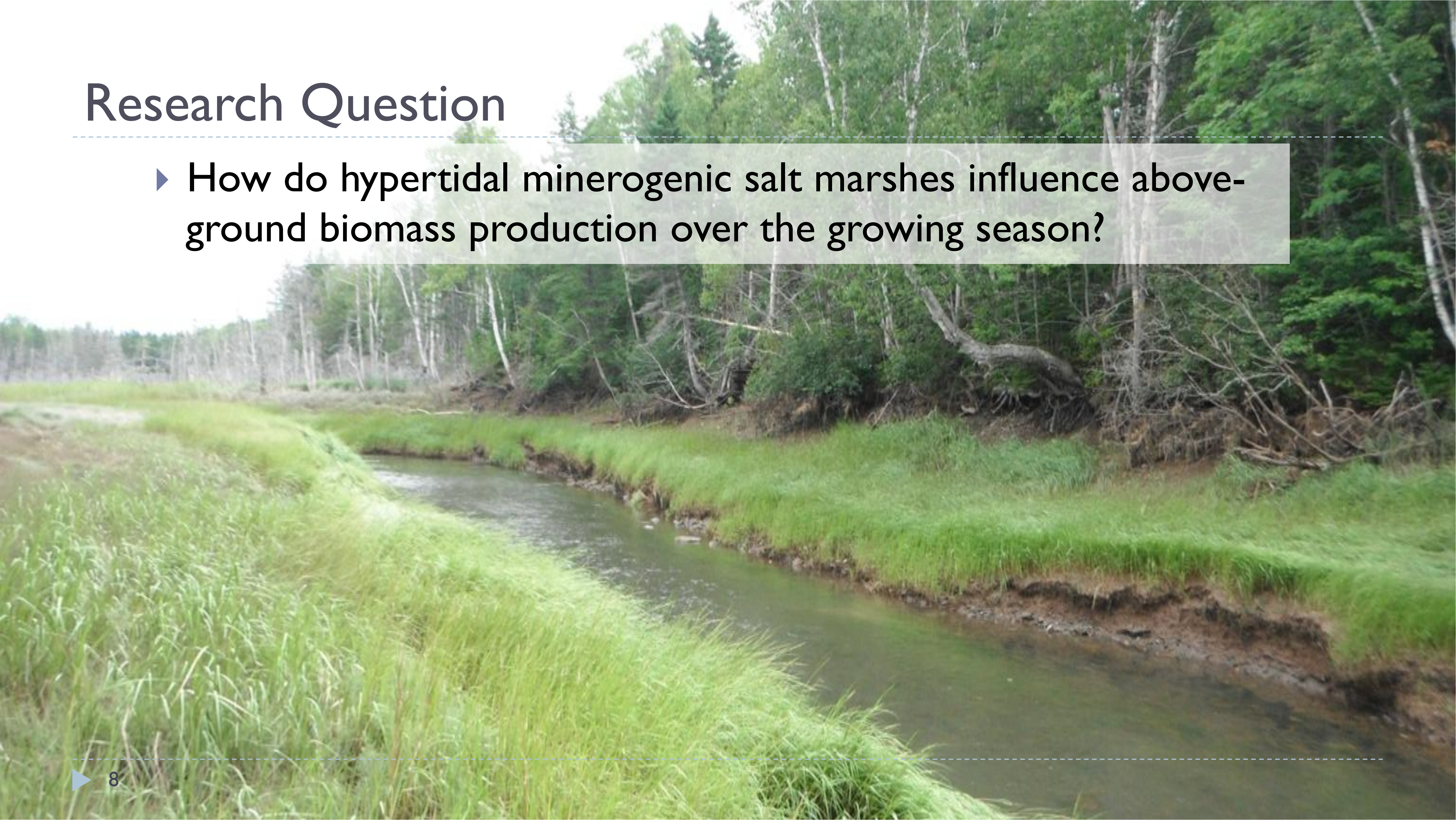
Rationale

- Studies conducted in New England & the UK to determine impact abiotic factors had on biomass production (Tempest et al., 2015; Portnoy, 1999; Mora and Burdick, 2013a,b)

- Has not been conducted in a high suspended sediment concentration, hypertidal (>8 m tidal range) system

Research Question

- How do hypertidal minerogenic salt marshes influence above-ground biomass production over the growing season?



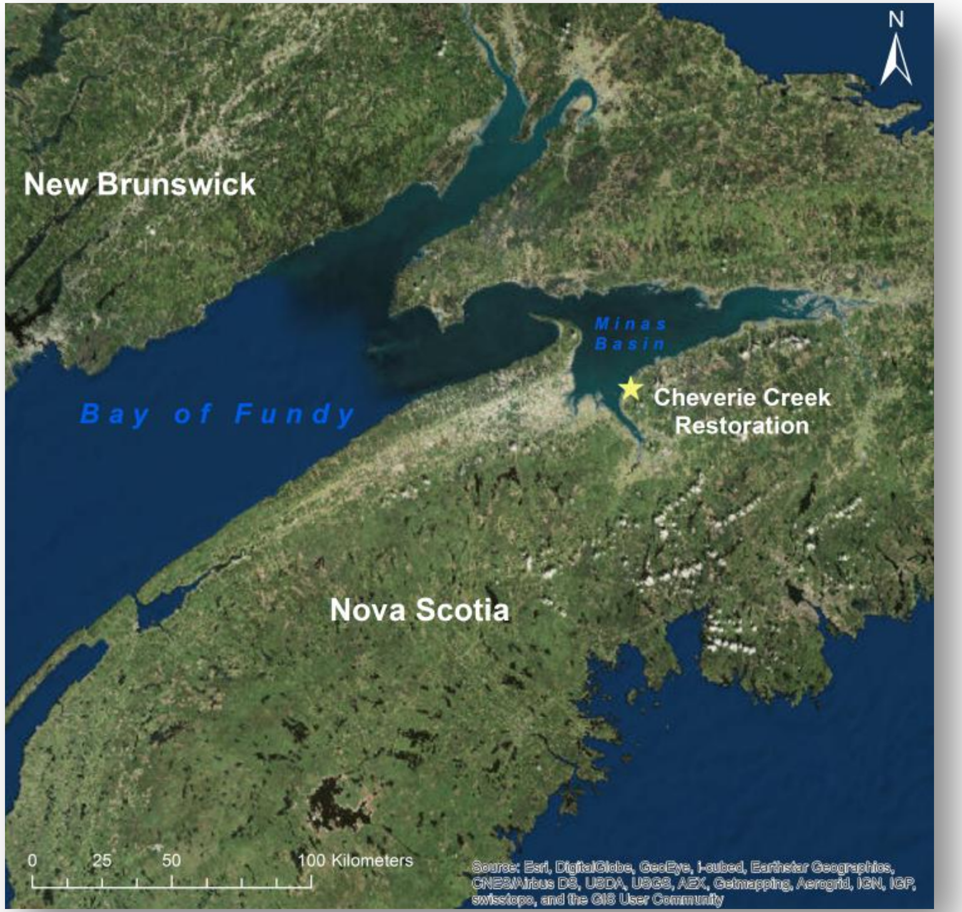
Study Area

Cheverie Creek Salt Marsh Restoration Site

- Hypertidal – 16 m tidal range
- Historically dyked (Bowron et al., 2009)
- Tidal restriction caused by box culvert (1960)
- Upland and freshwater vegetation encroached over 25 years (Bowron et al., 2009)
- Prior to restoration 5 ha flooded → Culvert replaced (2005) → 43 ha flooded

4.7 m²

32.6 m²



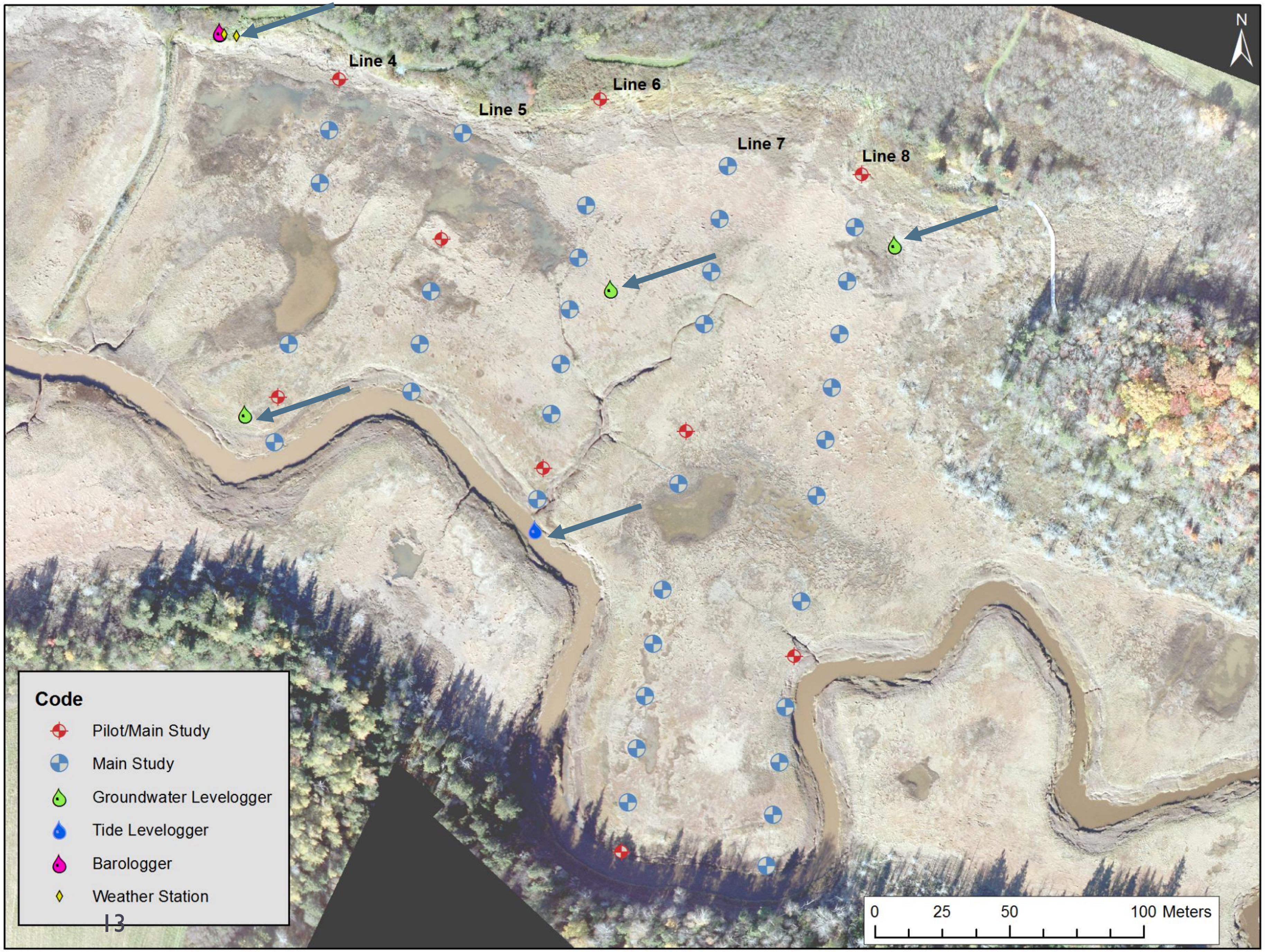
Bowron et al. 2013

Cheverie Creek: 7 years post restoration (2012)

- Restoration was successful
  - Die-off of freshwater and terrestrial vegetation
  - Recolonization by early successional salt marsh species
  - Increase in nekton
  - Extensive panne system
- However
  - Soil chemistry not included

Panne network at Cheverie Creek (C. Skinner, 2014)

Methods



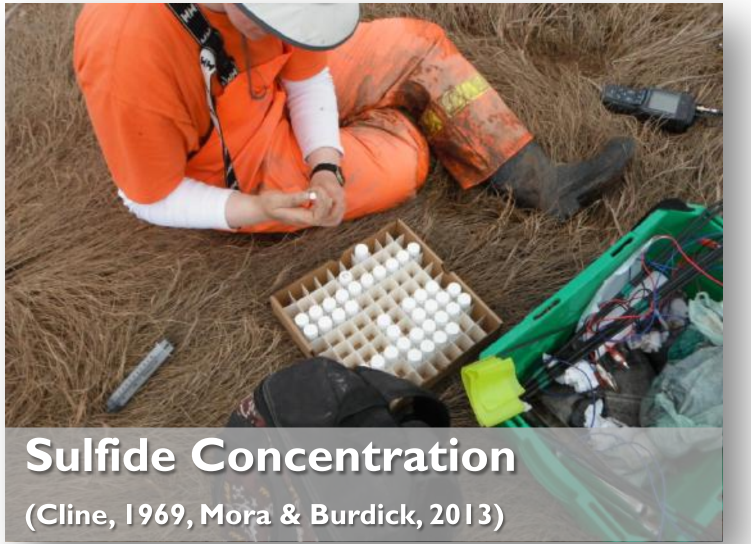
Pilot Marsh Study:

- Sample Locations = 9
- Replicates = 2
- Number of Sampling Days = 6
- Total: 108

Marsh Extent Study:

- Sample Locations = 42
- Replicates = 3
- Number of Sampling Days = 2
- Total: 252

Methodology



Sulfide Concentration
(Cline, 1969, Mora & Burdick, 2013)

Salinity

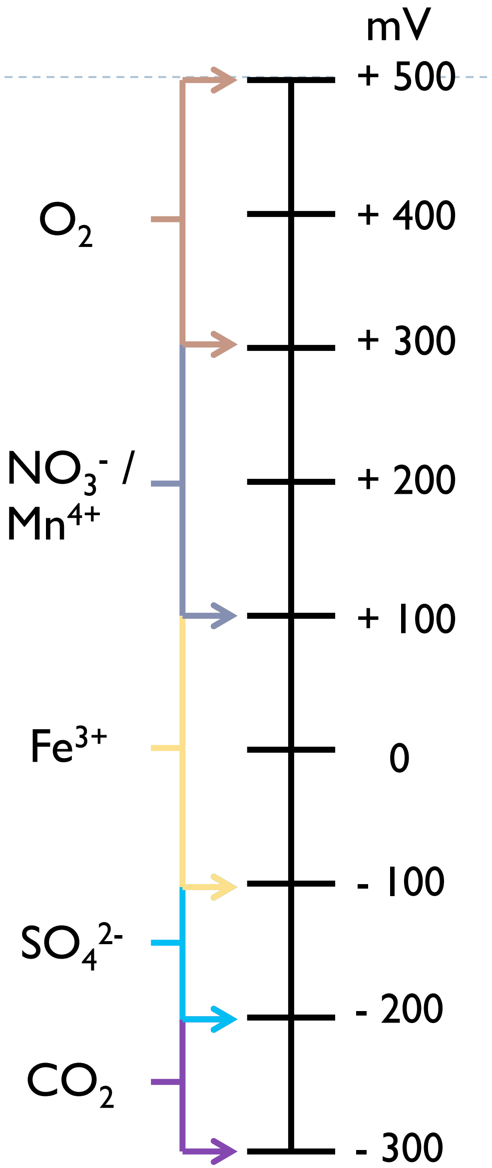
Above-ground Biomass

Sediment Characteristics

Redox Potential

Conducting redox potential measurements (E. Keast, 2014)

Millivolt meter, platinum tipped probe & Calomel reference electrode (C. Skinner, 2013)

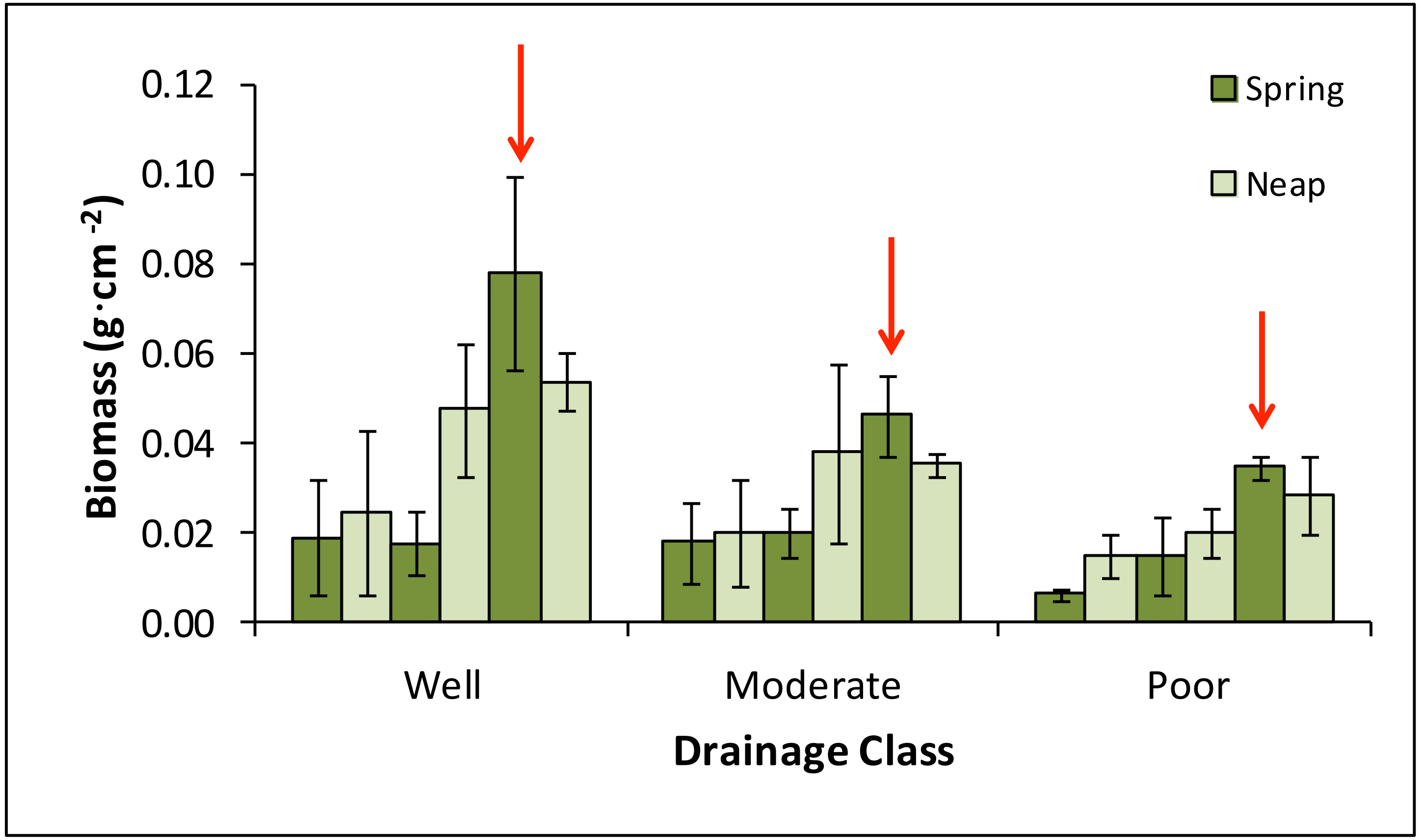


- Indicate intensity of anaerobic conditions within soil (de la Cruz et al., 1989)
- Represent dominant redox reduction at that time (Reddy and DeLaune, 2008)

Results & Discussion

Over the Growing Season

Above-ground Biomass

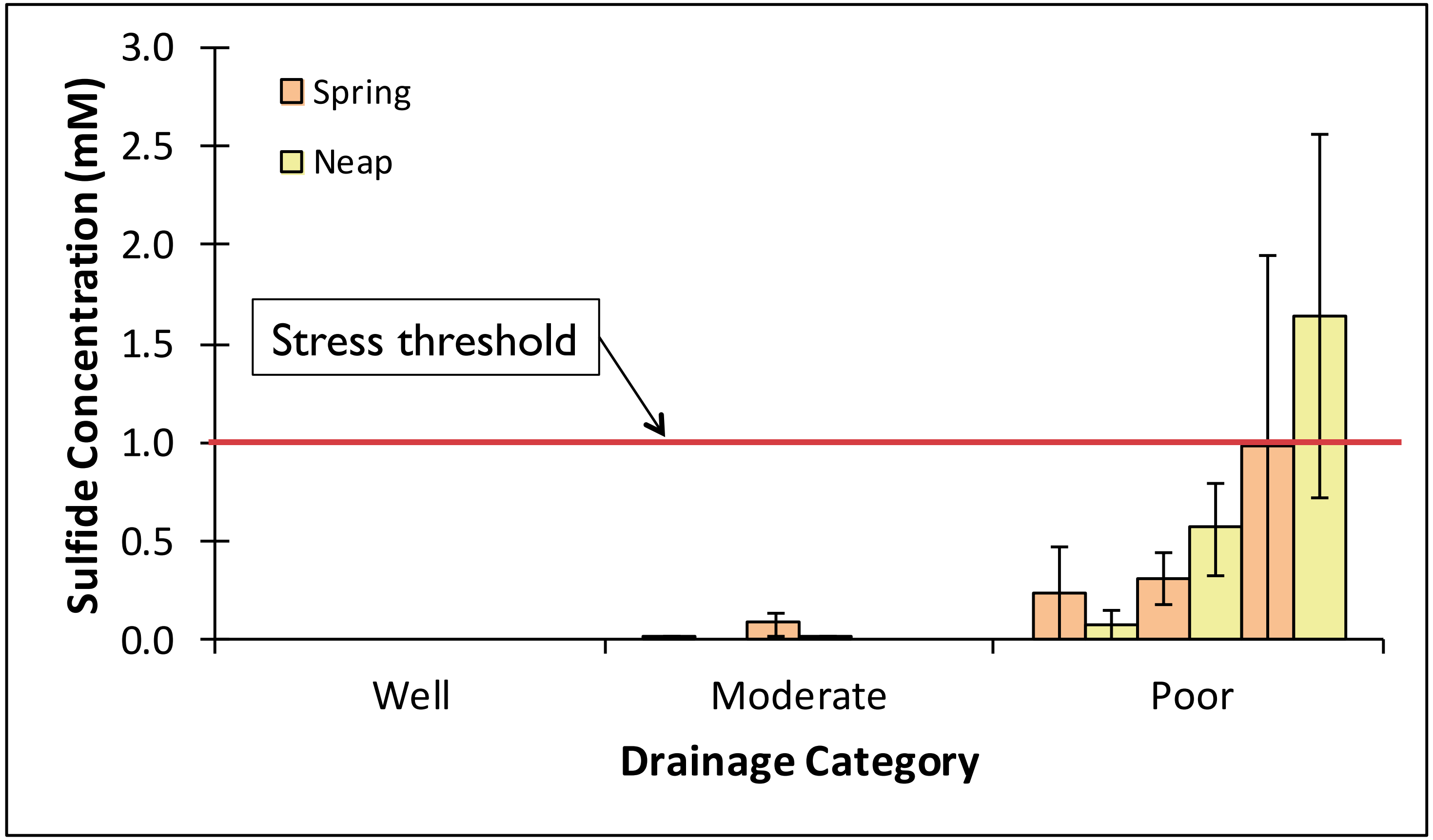


- ANOVA on peak biomass (July 18, 2014)
  - No significant difference (α : 0.05; p-value: 0.196; df: 2)

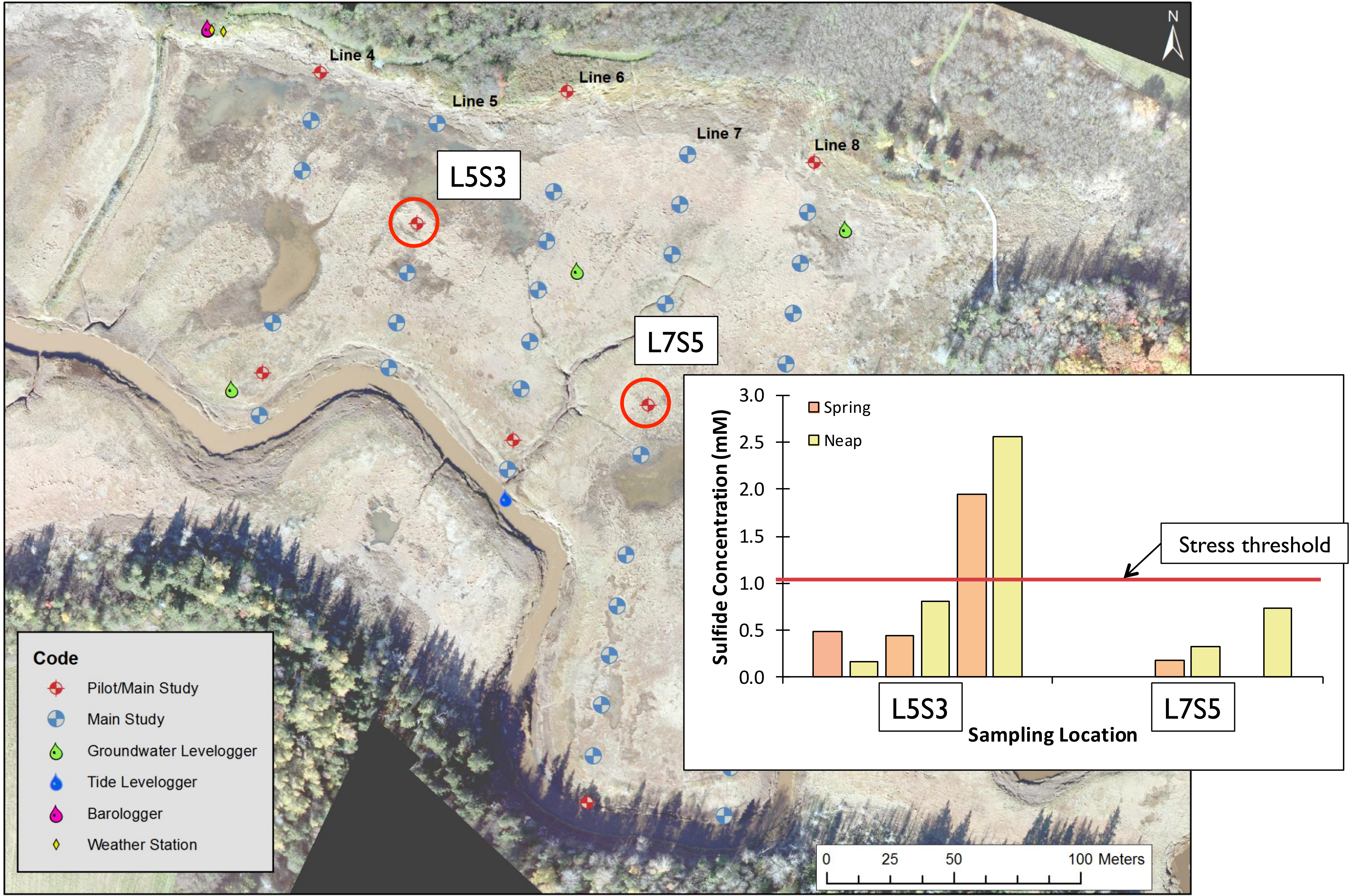
Spartina alterniflora along Cheverie Creek
(C. Skinner, 2014)

Error bars = Standard error

Sulfide

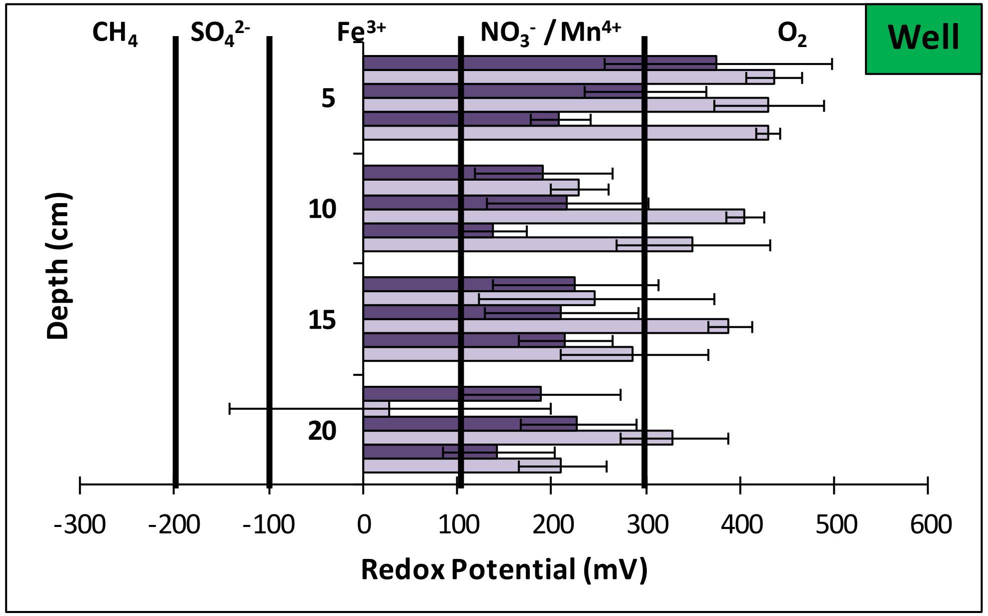


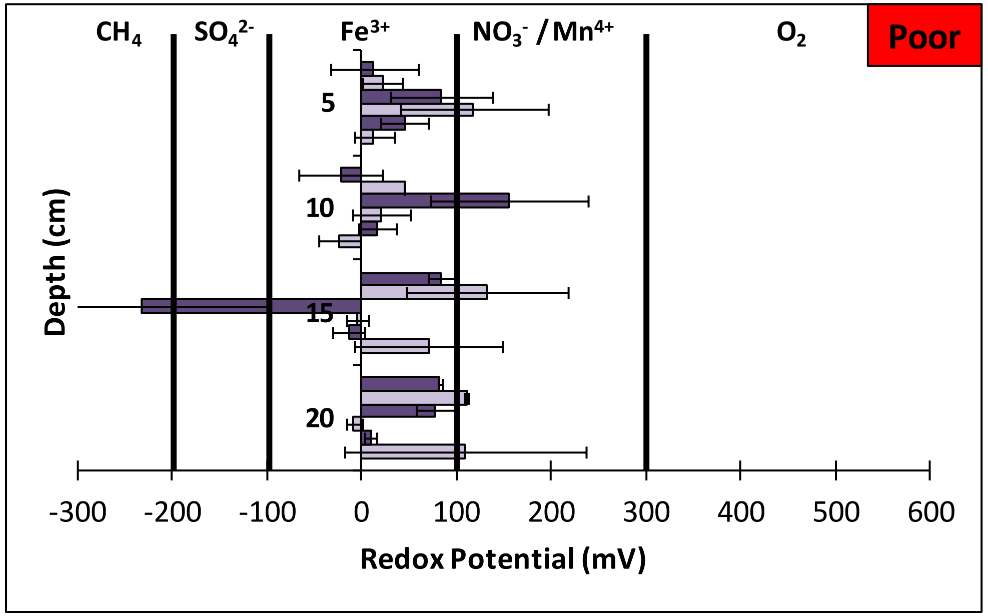
Error bars = Standard error

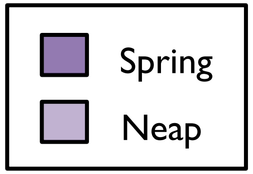


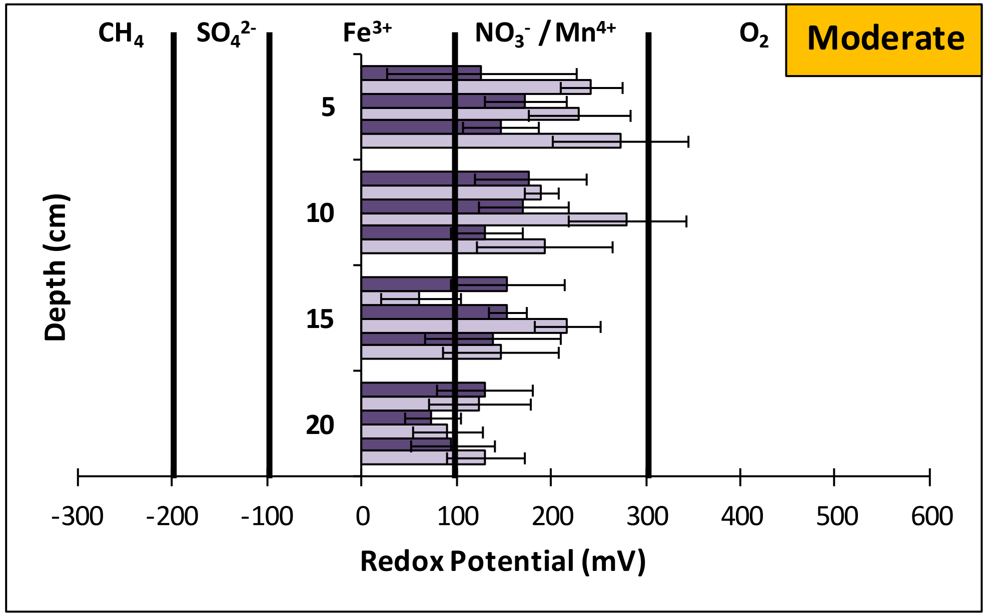
N
Line 4
Line 5
Line 6
Line 7
Line 8
L5S3
L7S5
Code
Pilot/Main Study
Main Study
Groundwater Levelogger
Tide Levelogger
Barologger
Weather Station
0 25 50 100 Meters
Spring
Neap
Sulfide Concentration (mM)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Stress threshold
L5S3
L7S5
Sampling Location

Redox Potential







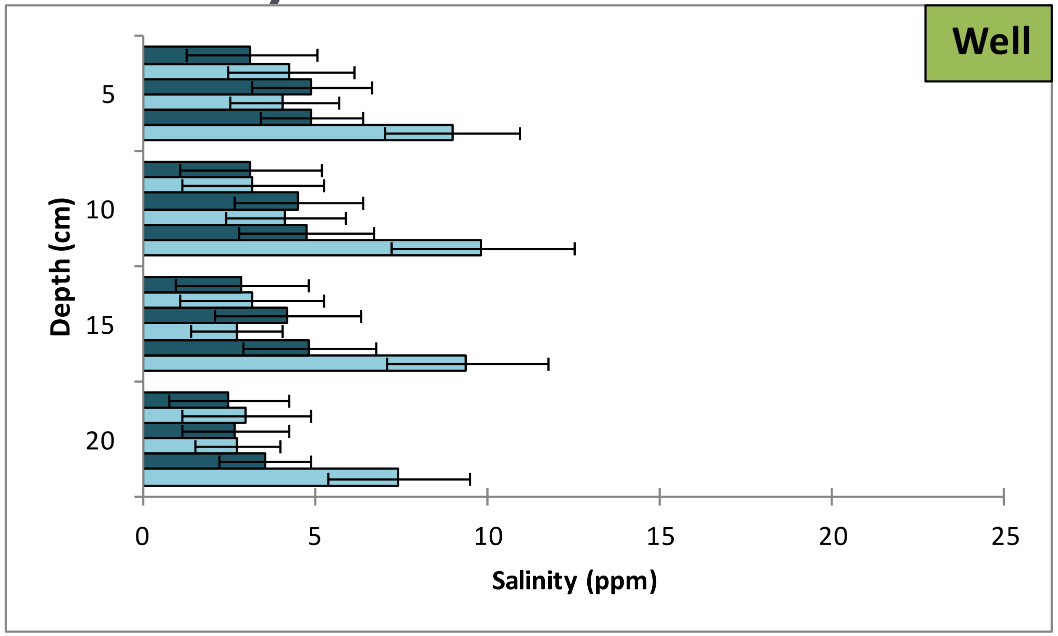


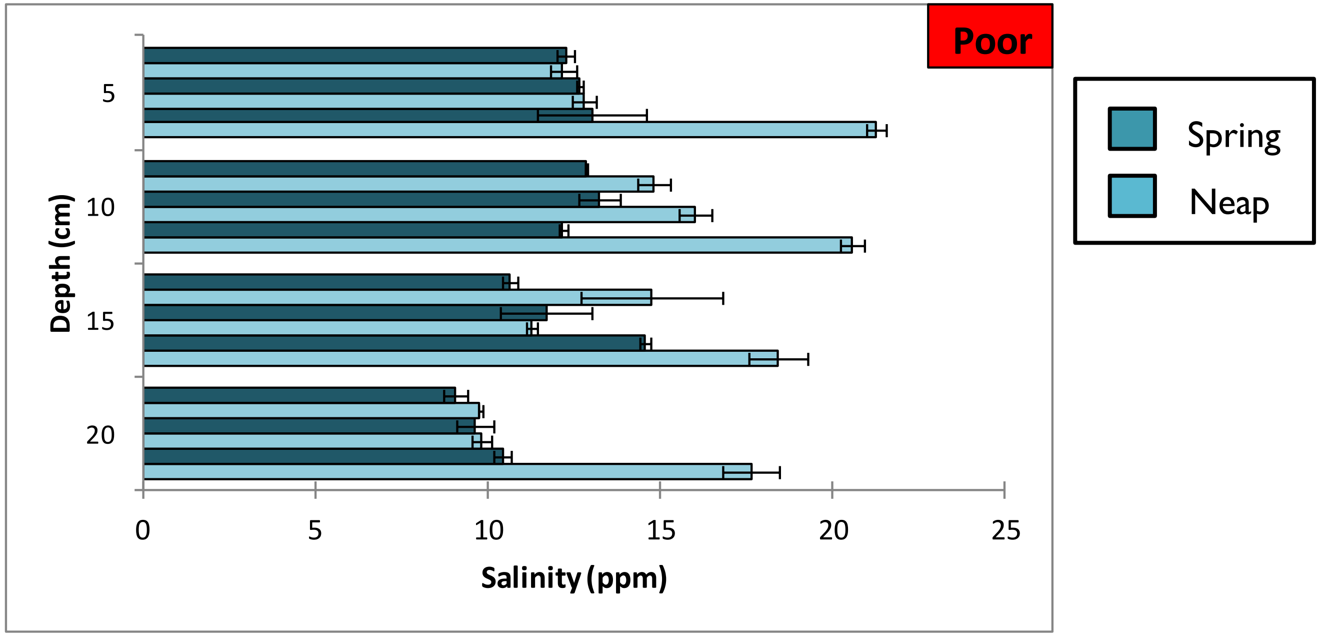
- Neap tides = higher redox; more decomposition
- Spring tides = lower redox; decrease decomposition
- Decrease in redox with depth

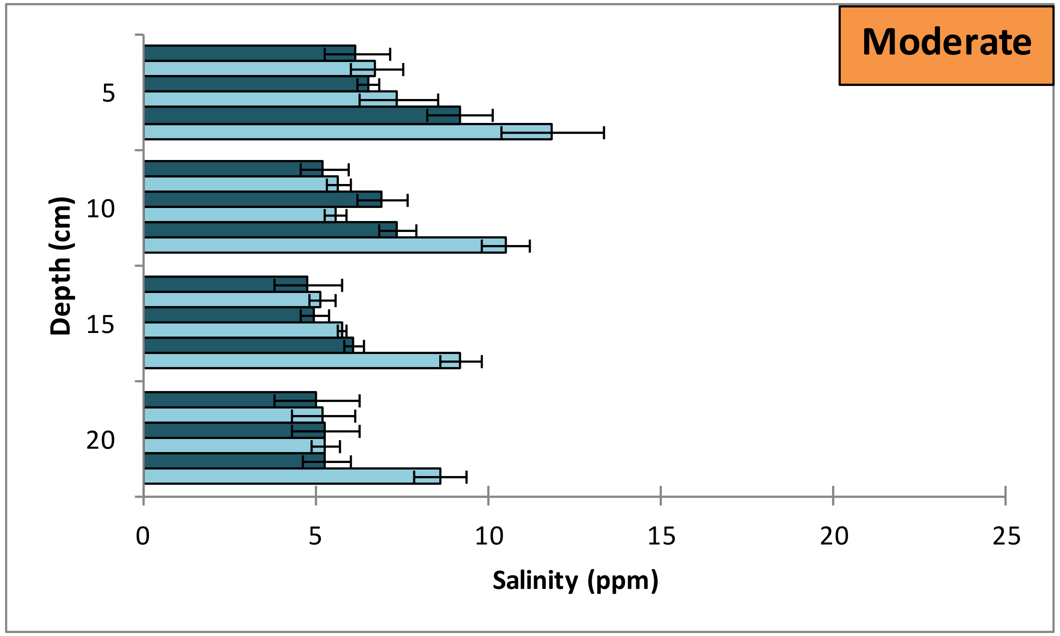
- Significant difference
  - Drainage classes (α : 0.05; p-value: 0.000; df: 2)
  - Neap versus spring tides (α : 0.05; p-value: 0.008; df: 1)
  - Varying depth (α : 0.05; p-value: 0.000; df: 3)
  - Depth and drainage class (α : 0.05; p-value: 0.000; df: 6)

Error bars = Standard error

Salinity





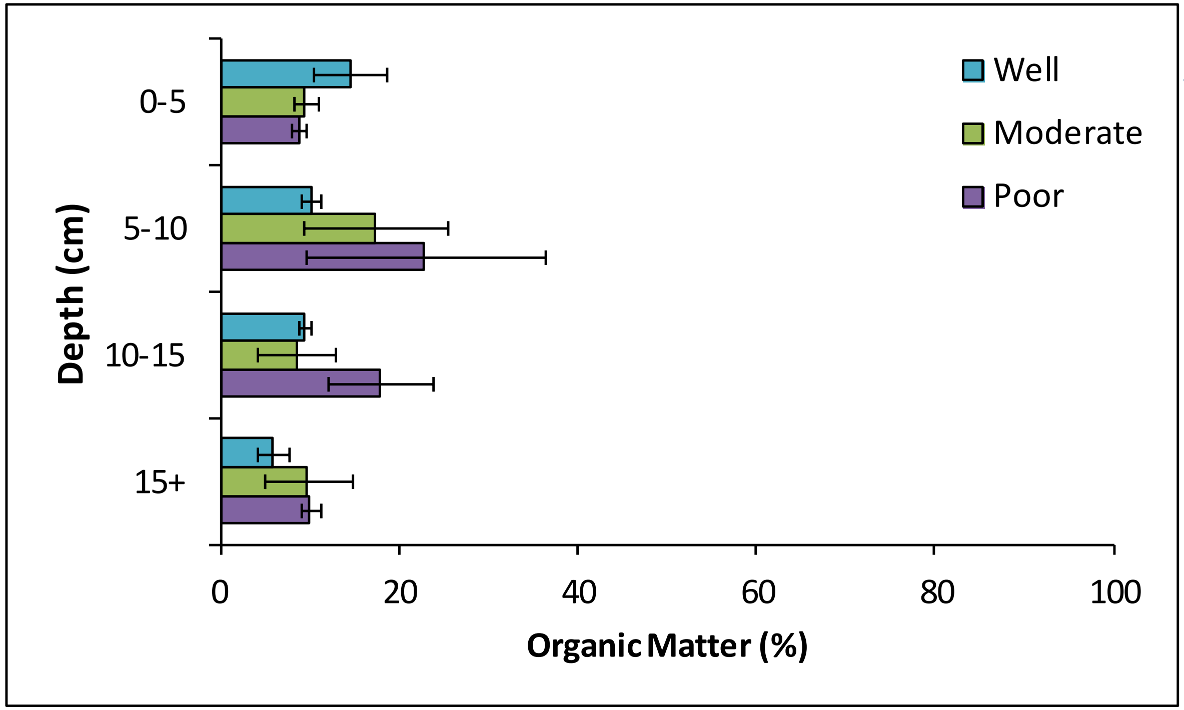


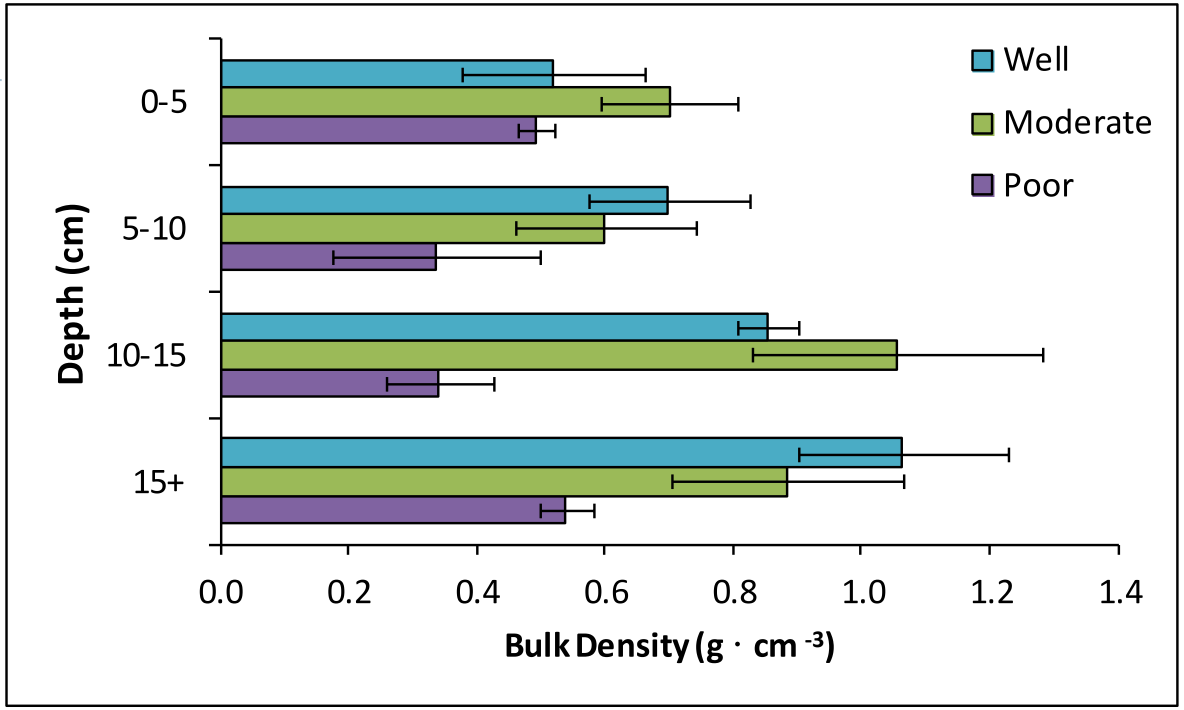
- Spring tides = Lower salinity
- Neap tides = Higher salinity
- Decrease with depth

- Significant difference
  - Drainage classes (α : 0.05; p-value: 0.000; df: 2)
  - Neap versus spring tides (α : 0.05; p-value: 0.015; df: 1)
  - Varying depth (α : 0.05; p-value: 0.000; df: 3)
  - Varying depth and drainage class (α : 0.05; p-value: 0.000; df: 6)

Error bars = Standard error

Sediment Characteristics





- Organic Matter
  - Highest found in the poorly drained sites
  - Decrease with depth in well drained sites
  - Similar pattern in moderately and poorly drained sites
- Bulk Density
  - Significant difference with varying depth (α: 0.05; p-value: 0.002; df: 3)
  - Significant difference with depth and drainage class (α: 0.05; p-value: 0.029; df: 6).

Error bars = Standard error

Drainage Class	Above-ground Biomass			…e	Dominate Redox Reaction	Organic Matter	Bulk Density
Well	Largest	*Sp…*			Oxygen & Nitrate/ Manganese	↓ with depth	↑ with depth
Moderate	Similar to Poor	*Spartina patens & Juncus gerardii*	Similar to Well	Minimal	Nitrate/ Manganese	Similar through-out	↑ with depth
Poor	Lowest		…st	Exceeds 1mM	Iron	Highest just below surface	↑ with depth

Minerogenic marshes have been found to have high concentrations of iron and manganese (Reddy and DeLaune, 2008, Hung and Chmura, 2006).

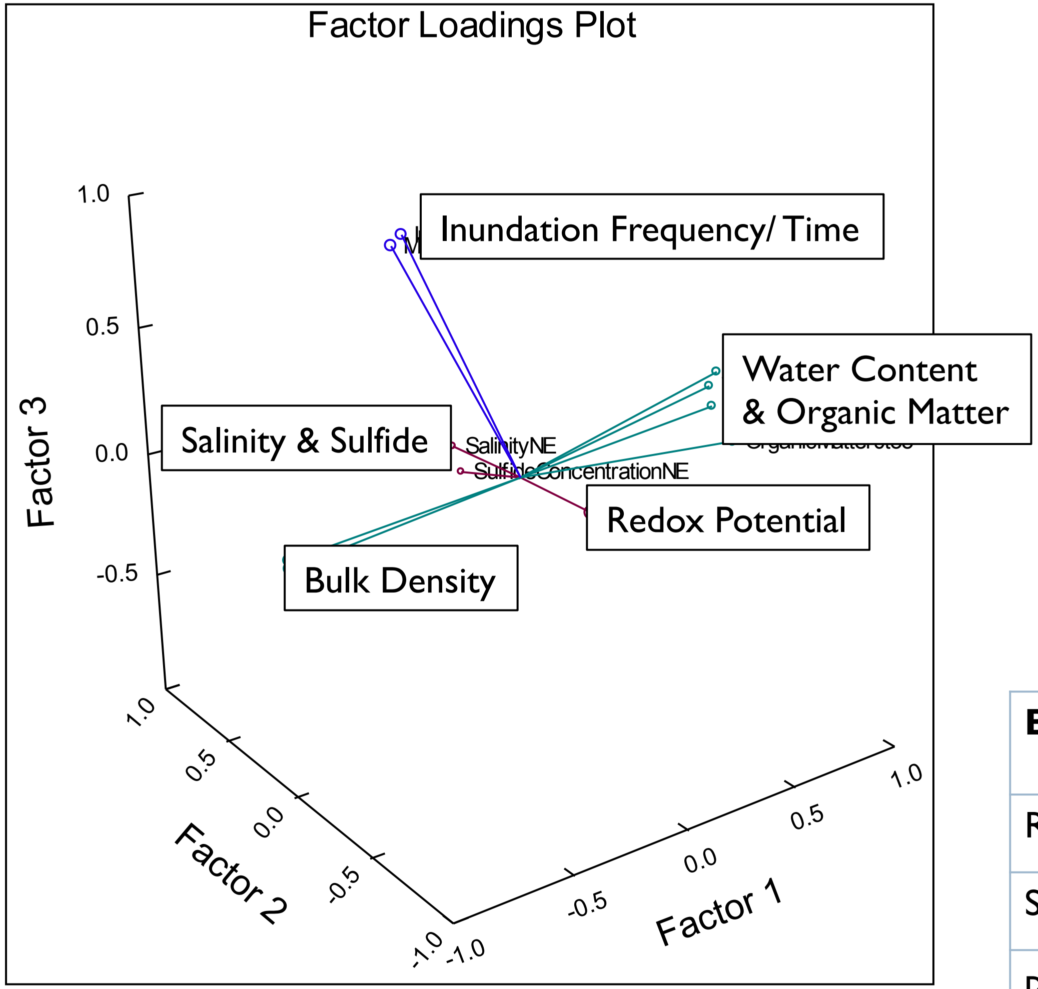
- Buffer the redox potential (Reddy and DeLaune, 2008)
- Limits ability of phytotoxin formation
- Iron bonds with sulfide to render it inert (Schoepfer, et al., 2014).

Exceedance of 1mM of sulfide would impact nitrogen uptake for *Spartina alterniflora* (Koch et al., 1999)

Results & Discussion

What influenced above ground biomass production?

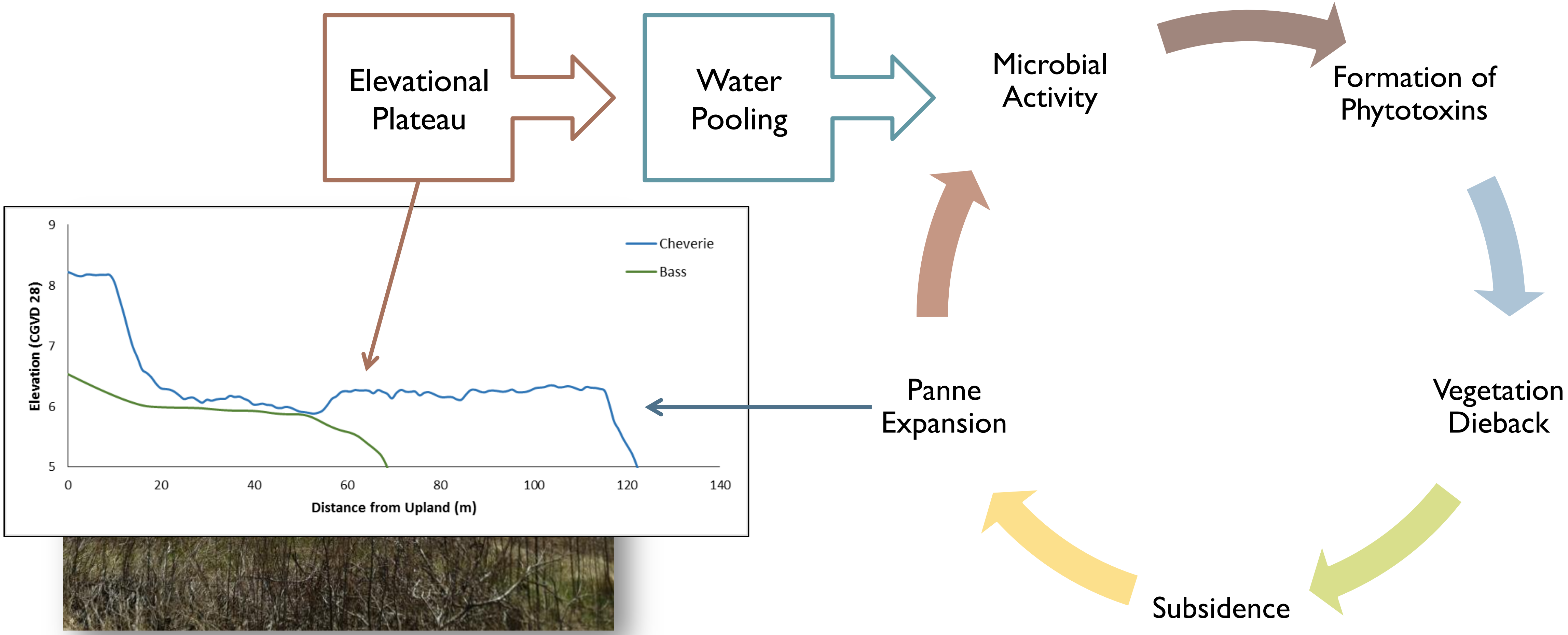
PCA and Backwards Stepwise Regression



- Above-ground Biomass Production
  - Positive Relationship
    - Bulk Density
    - Redox Potential
  - Negative Relationship
    - Water Content
    - Organic Matter
    - Salinity
    - Sulfide Concentration

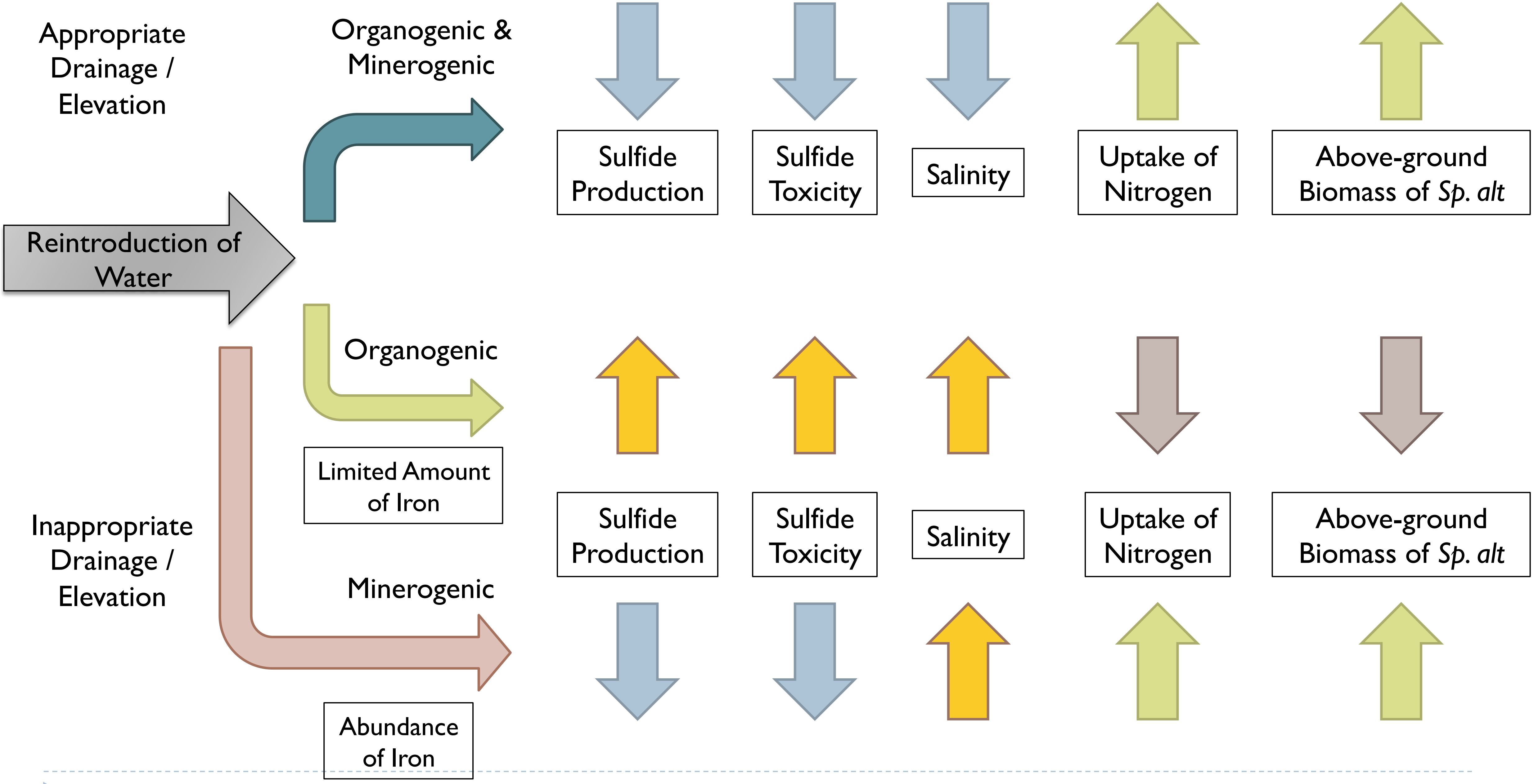
Biomass	**Effect**	**Coefficient**	**Standard Error**	**Standard Coefficient**	**P**
R^2 = 0.179	Constant	-2.949	0.102	0.000	0.000
SE = 0.664	P1	-0.199	0.104	-0.279	0.062
p-value = 0.021	P2	-0.227	0.104	-0.318	0.035

Implications for Restoration: Case of Cheverie Creek



Large panne between line 3 & 5 (C. Skinner, 2014)

Conclusions and Future Directions



Appropriate Drainage / Elevation
Organogenic & Minerogenic
Reintroduction of Water
Sulfide Production
Sulfide Toxicity
Salinity
Uptake of Nitrogen
Above-ground Biomass of *Sp. alt*
Organogenic
Limited Amount of Iron
Inappropriate Drainage / Elevation
Minerogenic
Abundance of Iron
Sulfide Production
Sulfide Toxicity
Salinity
Uptake of Nitrogen
Above-ground Biomass of *Sp. alt*

Conclusions

- Variables associated with panne formation
  - Lowest above-ground biomass production
  - Highest salinity/sulfide
  - Low redox potential
- Sediment characteristics can predict soil chemistry
  - High organic matter → low redox and high sulfide concentration → decline in above-ground biomass

Future Directions

- Quantify iron and manganese in Atlantic and Bay of Fundy marshes
- Incorporation of salinity loggers in groundwater wells
- Expand study to incorporate Atlantic, and Northumberland Strait marshes
- Conduct study over multiple growing seasons at multiple sites

Great blue heron in panne system at Cheverie
(C.Skinner, 2014)

References

- Bowron, T., Neatt, N., Graham, J., van Proosdij, D., Lundholm, J., and Lemieux, B. 2013. Post-restoration monitoring (year 7) of the Cheverie Creek Salt Marsh Restoration Project. A report for Nova Scotia Department of Transportation and Infrastructure Renewal.
- Bowron, T., Neatt, N., van Proosdij, D., Lundholm, J., and Graham, J. 2009. Macro-tidal salt marsh ecosystem response to culvert expansion. *Restoration Ecology*, 19(13): 307-322 doi: 10.1111/j.1526-100X.2009.00602.x
- Burdick, D.M., Mendelssohn, I.A. and McKee, K.L. 1989. Edaphic factors in a brackish, mixed marsh community in Louisiana. *Estuaries*, 12(3): 195-204.
- Cline, J. D. 1969. Spectrophotometric determination of hydrogen sulfide in natural waters. Limnology and Oceanography, 14(3), 454-458.
- de la Cruz, A.A., Hackney, C.T. and Bhardwaj, N. 1989. Temporal and spatial patterns of redox potential (Eh) in three tidal marsh communities. *Wetlands*, 9(2): 181-190.
- Hung, G.A. and Chmura, G.L. 2006. Mercury accumulation in surface sediments of salt marshes of the Bay of Fundy. *Environmental Pollution*, 142: 418-431 doi:10.1016/j.envpol.2005.10.044
- Koch, M.S. and Mendelssohn, I.A. 1989. Sulfide as a soil phytotoxin: Differential responses in two marsh species. *Journal of Ecology*, 77(2): 565-578.
- Mitsch, W.J. and Gooselink, J.G. 2007. Wetlands, 4th Edition. John Wiley & Sons, Inc. Hoboken, New Jersey.
- Mora, J.W., & Burdick, D. M. 2013. The impact of man-made earthen barriers on the physical structure of New England tidal marshes (USA). *Wetlands ecology and management*, 21(6): 387-398 DOI 10.1007/s11273-013-9309-3
- Morris, J.T. 1980. The nitrogen uptake kinetics of *Spartina alterniflora* in culture. *Ecology*, 61(5): 1114-1121.
- Portnoy, J. 1999. Salt marsh diking and restoration: Biogeochemical implications of altered wetland hydrology. *Environmental Management*, 24(1): 111-120.
- Reddy, K. R. and R. D. DeLaune. 2008. *Biogeochemistry of Wetlands*. Taylor & Francis Group, LLC: Boca Raton, Florida.
- Schoepfer, V., Bernhardt, E., and Burgin, A. 2014. Iron clad wetlands: Soil iron-sulfur buffering determines coastal wetland response to salt water incursion. *Journal of Geophysical Research: Biogeosciences*, 119: 2209-2219. doi: 10.1002/2014JG002739
- Seliskar, D.M., Gallagher, J.L. Burdick, D.M. and Mutz, L.A. 2002. The regulation of ecosystem functions by ecotypic variation in the dominant plant: a *Spartina alterniflora* salt-marsh case study. Journal of Ecology, 90: 1-11.
- Teal, J.M. 1962. Energy flow in the salt marsh ecosystem of Georgia. *Ecology*, 43(4): 614-624.
- Tempest, J.A., Harvey, G.L. and Spencer, K.L. 2015. Modified sediments and subsurface in natural and recreated salt marshes and implications for delivery of ecosystem services. *Hydrological Processes*, 29: 2346-2357. doi: 10.1002/hyp.10368
- Wilson A.M. and Morris, J.T. 2012. The influence of tidal forcing on groundwater flow and nutrient exchange in a salt marsh-dominated estuary. Biogeochemistry, 108: 27-38. DOI: 10.1007/s10533-010-9570-y

Questions?

Acknowledgements

Carly Wrathall, CBWES Inc. (Tony Bowron, Nancy Neatt, Jennie Graham), Chris Peter (UNH), Connie Clarke (SMU), Emma Poirier, Erin Keast, Greame Matheson, Greg Baker (Mp_SPARC), Hazel Dill (Cheverie Crossway Salt Marsh Society), Hilary Neckles (USGS), Kevin Keys (NSDNR), Matthew and Tom Skinner, Department of Transportation and Infrastructure Renewal, Nova Scotia Research and Innovation Graduate Scholarship

Saint Mary's University Since 1802 — One University. One World. Yours.

University of New Hampshire

cbwes — CB Wetlands & Environmental Specialists

InCoaST — Intertidal Coastal Sediment Transport research unit