Biogeochemistry of a recently restored macrotidal salt marsh: Cheverie Creek, Nova Scotia

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InCoaST Intertidal Coastal Sediment Transport research unit

The Case for Salt Marsh Restoration

Cheverie Creek at high tide

- Salt marshes, Bay of Fundy (Gordon, 1989)
  - 80 to 85% lost
- Significant loss of species, habitat and productivity
- Need for restoration
- BUT
  - Restoration of tidal flow = changes to biogeochemisty = effects vegetation, nekton and other wildlife (Anisfeld, 2012)
- Cheverie Creek was first monitored and planned restoration
  - Soil chemistry was not addressed

Research Questions

- How does sediment chemistry (sulfide, redox potential and salinity) and above ground biomass vary over the growing season?
- How does hydrology, sediment characteristics and soil chemistry within a newly restored macrotidal salt marsh related to above ground biomass production?

Salt Marsh Importance

- Highly productive and lie at interface between land and ocean (Townend et al., 2010; Butler and Weis, 2009)
- Provide unique habitat (Allen, 2000; Townend et al., 2010)
- Carbon sequestration, protection from storm surges and coastal erosion, (Townend et al., 2010; Chmura et al., 2003; Butler and Weis, 2009) and limit nutrient exchange between ocean and upland (Kostka et al., 2002)

Cogmagun River restoration site at high tide

Sediment

- Organogenic vs. Minerogenic (Reddy and DeLaune, 2008)
- Importance for salt marsh function (Reddy and DeLaune, 2008):
  - Foundation for platform development
  - Influences zonation of vegetation
- Sediment deposition
  - Hydrology
  - Vegetation
  - Topography

Cheverie Creek

Biogeochemistry

"Study of the exchange or flux of materials between living and nonliving components of the biosphere" (Reddy and DeLaune, 2008)

- Organic matter at the core (Reddy and DeLaune, 2008)
- Oxidation and reduction reactions
- Dominated by reduced forms (Reddy and DeLaune, 2008)
- Controlled by:
  - Microbial communities, carbon supply (Teasdale et al., 1998; Craft, 2001; Fieldler, et al., 2007)
  - Temperature, pH, and concentration of electron acceptors (Reddy and DeLaune, 2008, Tiner, 1991)

Small waterfall in creek at Cheverie Creek

Hydrology

- Importance for salt marsh function:
  - Influences physiochemical environment, vegetation and transports sediment and nutrients (Mitsch and Gosselink, 2007)
    - Redox potential, saturation, salinity and nutrient cycling
- Influenced by:
  - Tidal and ground water (Reddy and DeLaune, 2008; Wilson and Morris, 2012)
  - Tidal range
  - Geomorphology
  - Vegetation

Cheverie Creek looking towards causeway

Vegetation

- Importance for salt marsh function:
  - Regulates carbon and nutrient inputs (Seliskar et al., 2002)
  - Provides oxygen to root zone (Seliskar et al., 2002)
  - Assists in the stabilization of the sediment and amount of sunlight reaching the soil surface (Seliskar et al., 2002)
- Distribution influenced by:
  - Hydrology
  - Sediment characteristics
  - Soil chemistry
  - Vegetation species

Looking towards upland from creek edge at Cheverie Creek

Spartina alterniflora: Uptake of Nitrogen

- Chambers et al. 1998
  - unaffected by extremely high sulfide concentration
  - decreased with an increase in salinity
- Koch and Mendelsshn, 1989; Mendelssohn and Seneca, 1980
  - decreased productivity and uptake with high sulfide concentrations

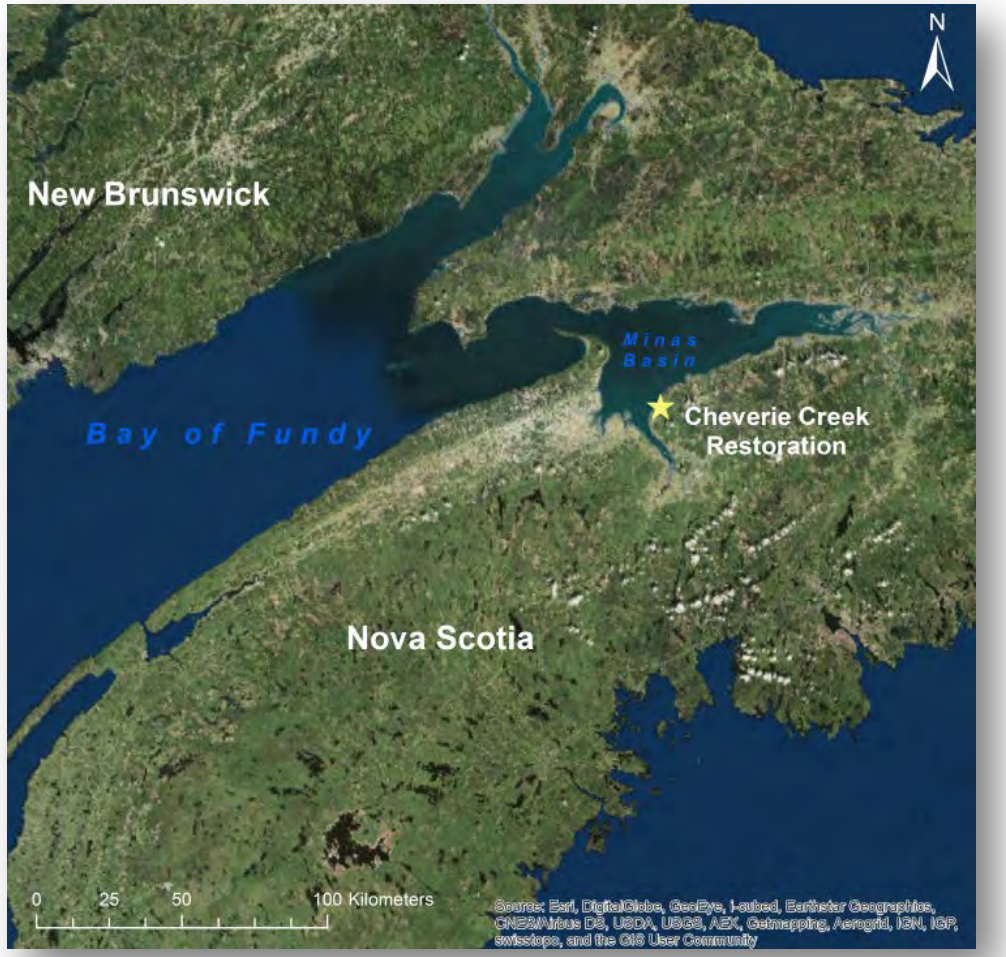
Spartina alterniflora along Cheverie Creek

Objectives

- Determine appropriate depth for redox potential and salinity levels
- Determine variation of sulfide concentration, salinity and redox potential, aboveground biomass, inundation time, and inundation frequency over the growing season
- Determine indicators of aboveground biomass

Study Area: Bay of Fundy

- Macrotidal: up to 16 m in upper Bay of Fundy
- Salt marshes minerogenic in origin
  - Substantial suspended sediment concentration and deposition in the intertidal zone (van Proosdij et al., 2010)
    - 150 mgl^{-1} on the marsh surface
    - 4000 mgl^{-1} in the upper reaches of the Minas Basin



Cheverie Creek Salt Marsh Restoration Site

- Historically dyked (Bowron et al., 2009)
- Causeway blocks mouth of river
  - Bridge replaced with box culvert (1960)
  - Flap gate removed in 1980s
- Upland and freshwater vegetation encroached over 25 years (Bowron et al., 2009)
- Prior to restoration 4-5 ha flooded → Culvert replaced (2005) → 43 ha flooded

4.7 m^2

32.6 m^2

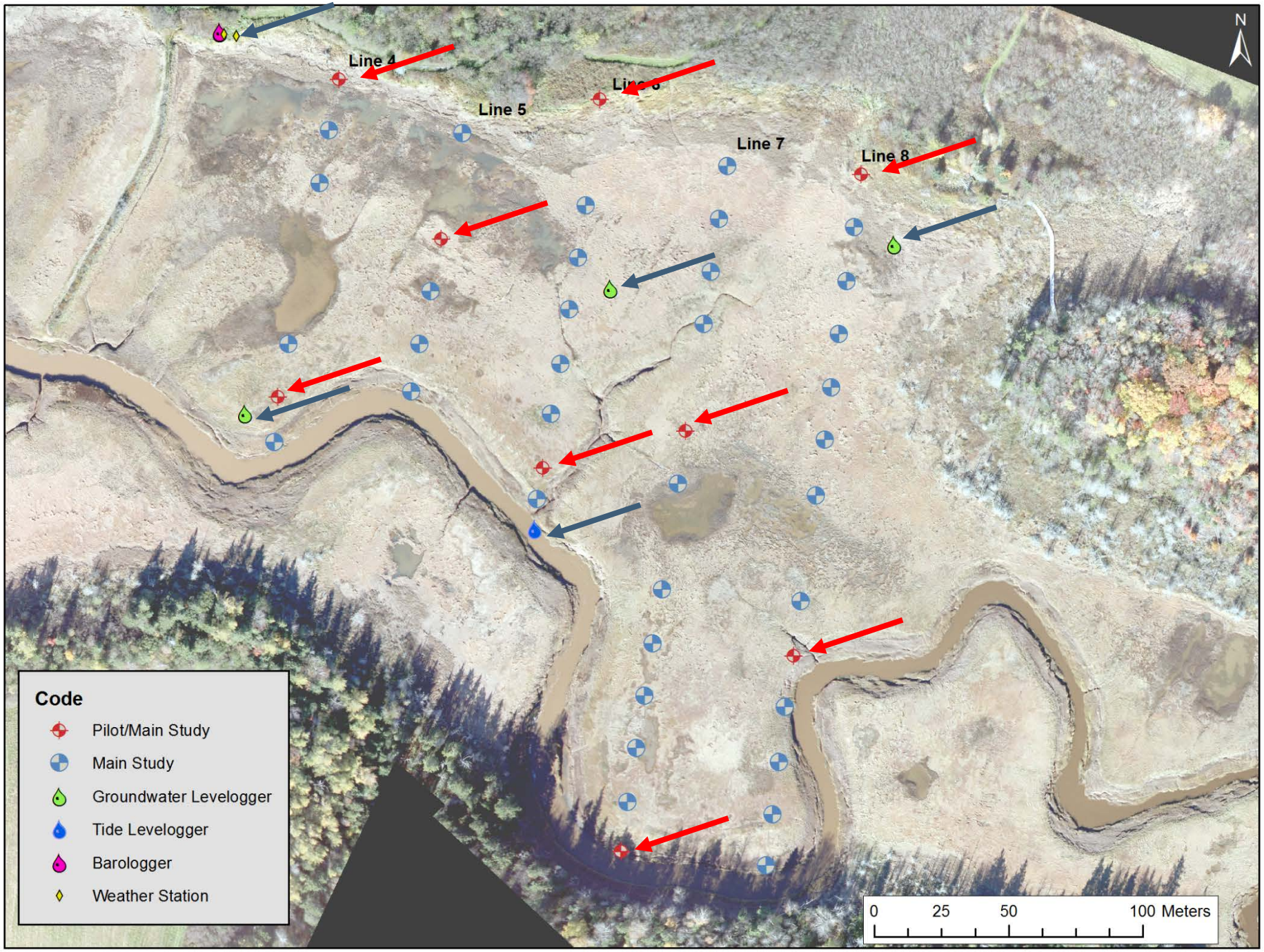
Bowron et al. 2013

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

Panne network at Cheverie Creek

Methodology


N
Line 4
Line 5
Line 7
Line 8
Code
Pilot/Main Study
Main Study
Groundwater Levelogger
Tide Levelogger
Barologger
Weather Station
0
25
50
100 Meters

Methodology

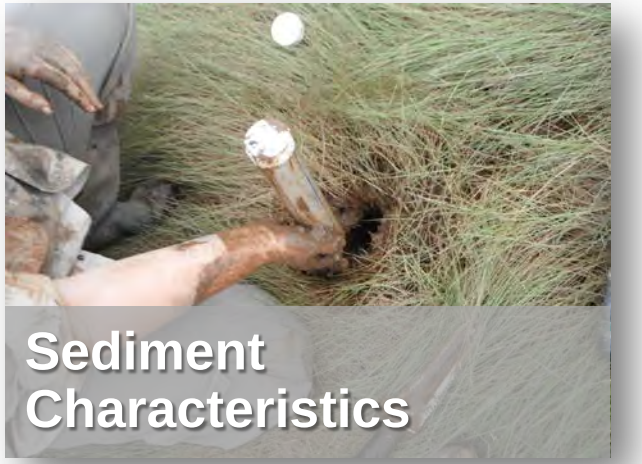
Sulfide Concentration

(Cline, 1969, Mora & Burdick, 2013)

Salinity

Redox Potential

Aboveground Biomass

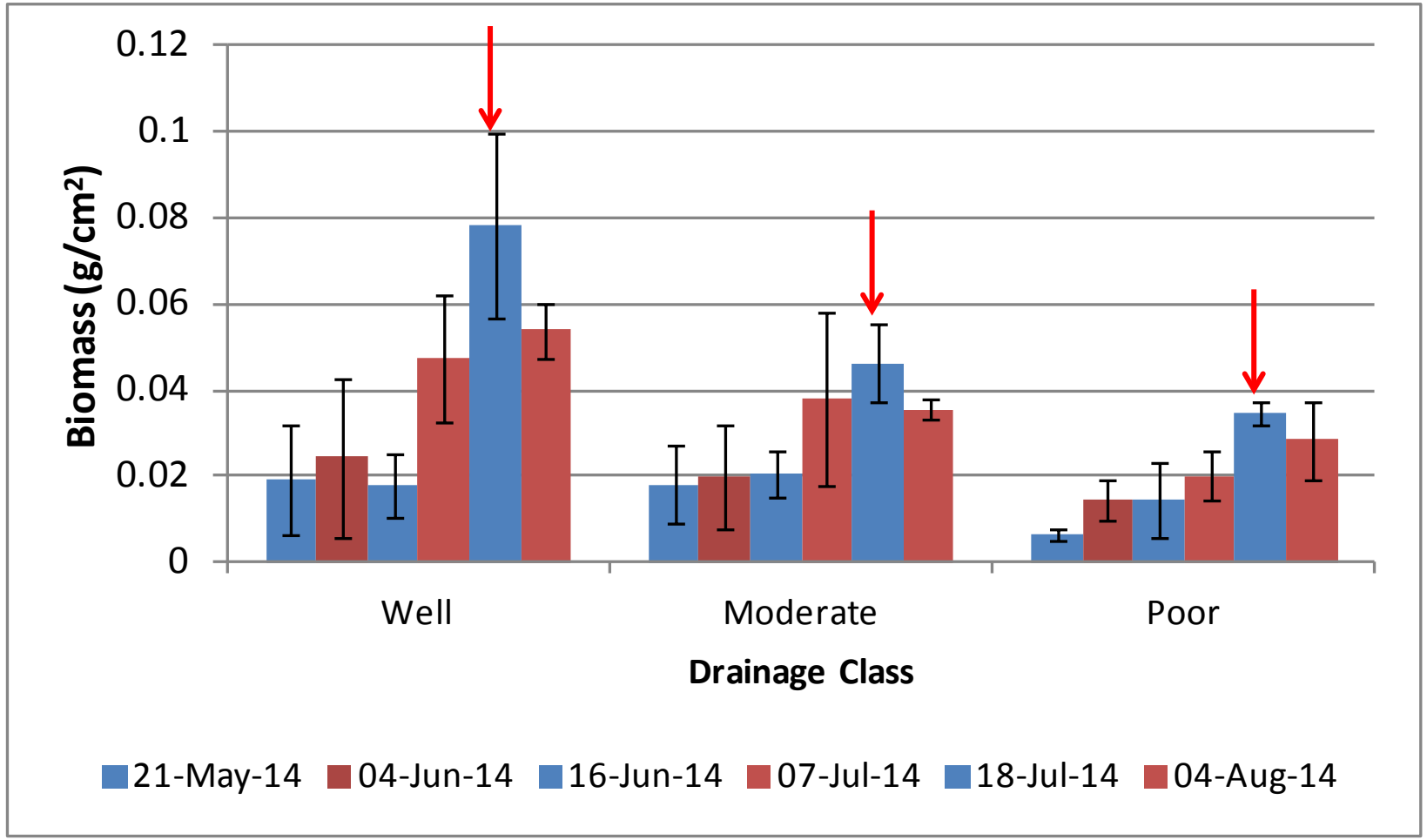


Sediment Characteristics

Root Depth

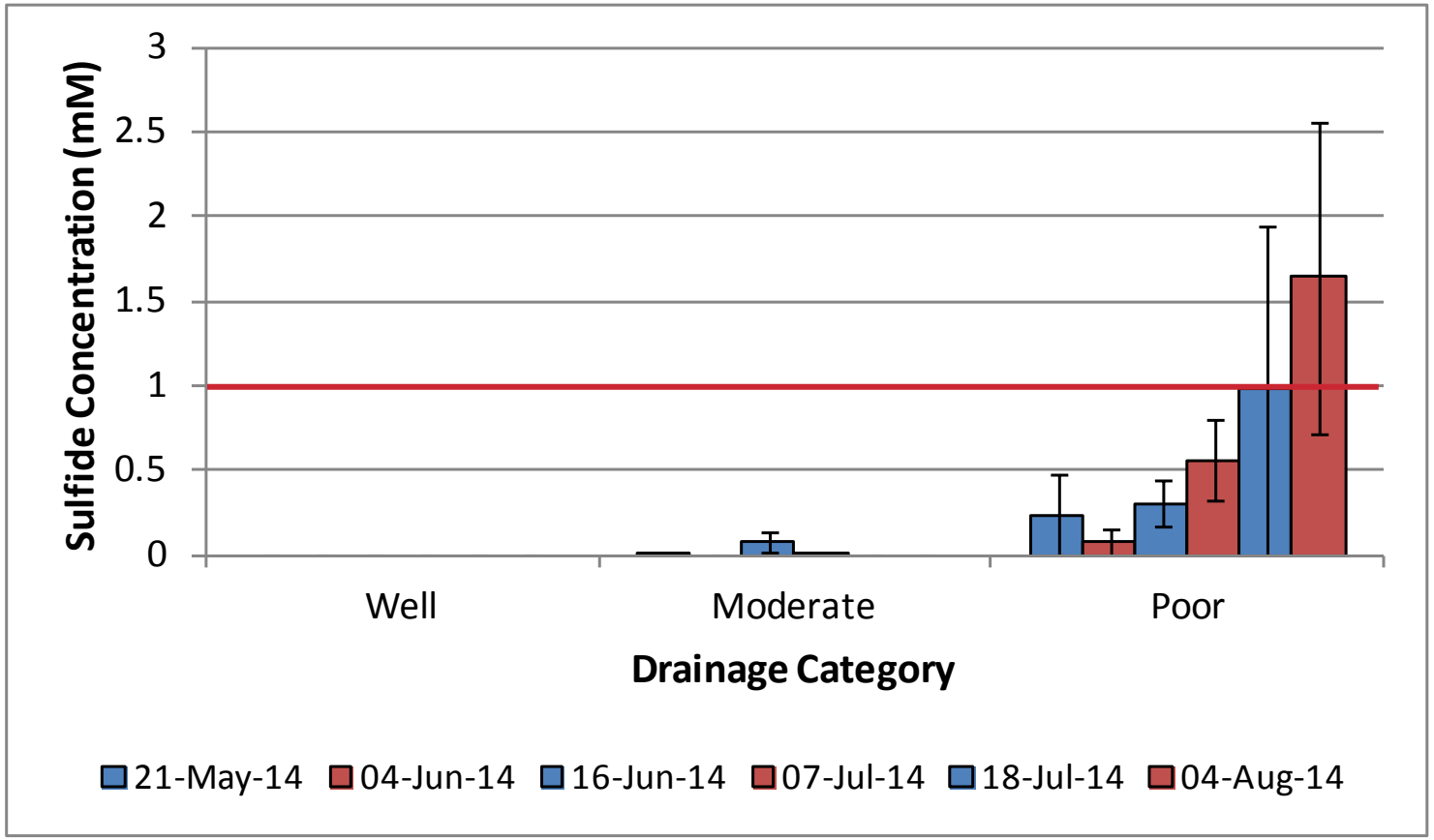
Results: Pilot Study

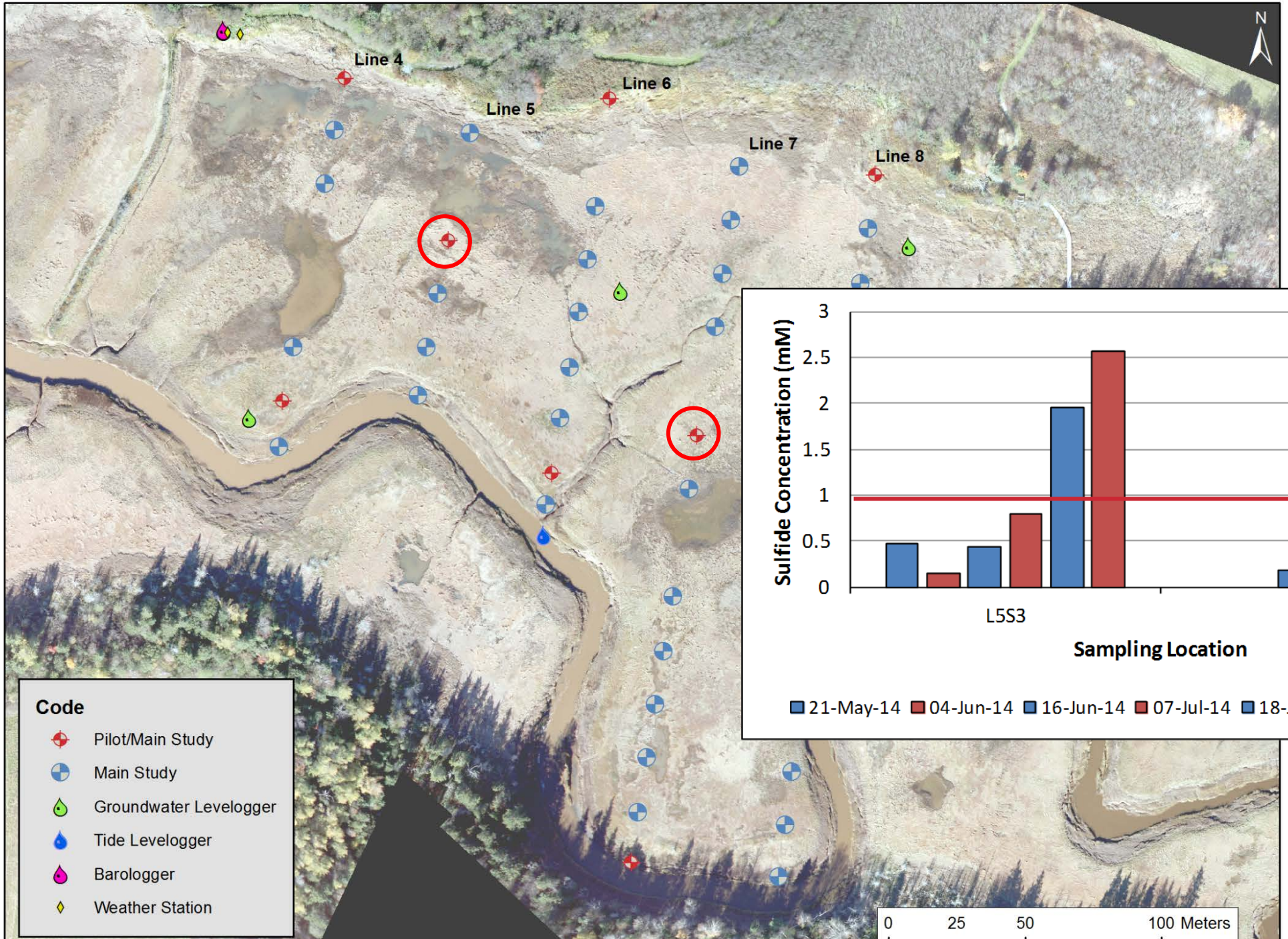
Above Ground Biomass



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

Sulfide


Sulfide Concentration (mM)
3
2.5
2
1.5
1
0.5
0
Well
Moderate
Poor
Drainage Category
21-May-14
04-Jun-14
16-Jun-14
07-Jul-14
18-Jul-14
04-Aug-14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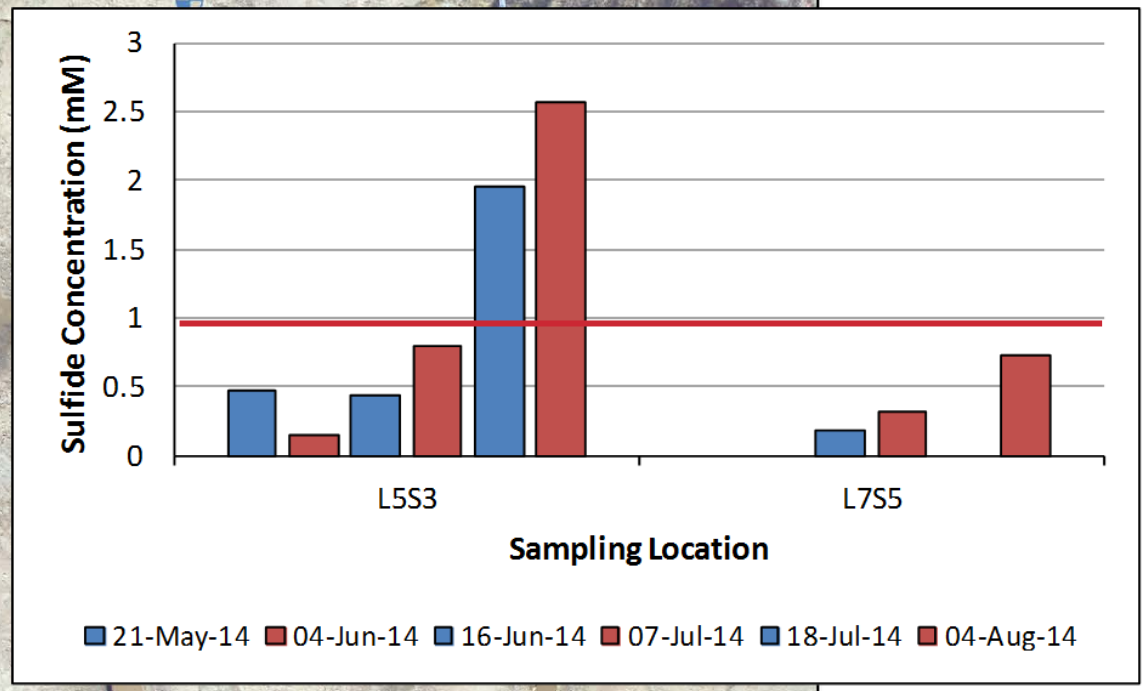
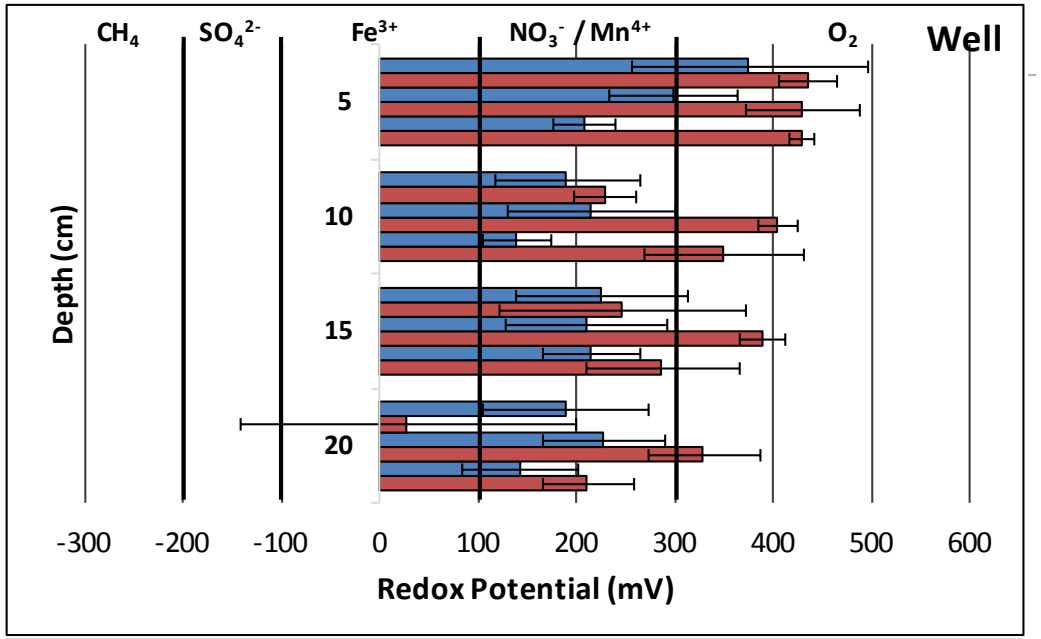
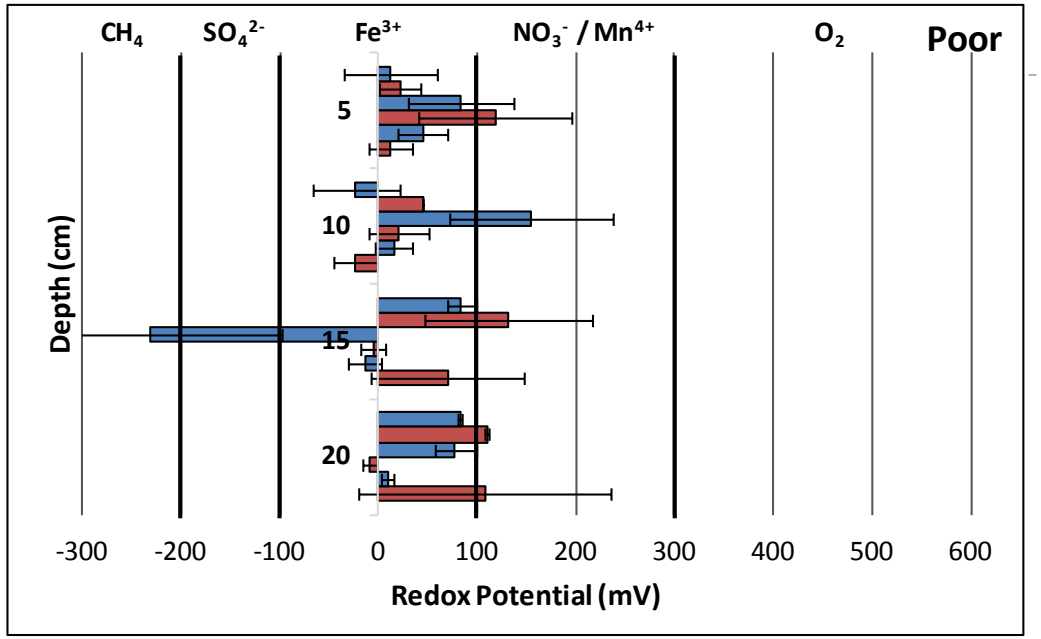
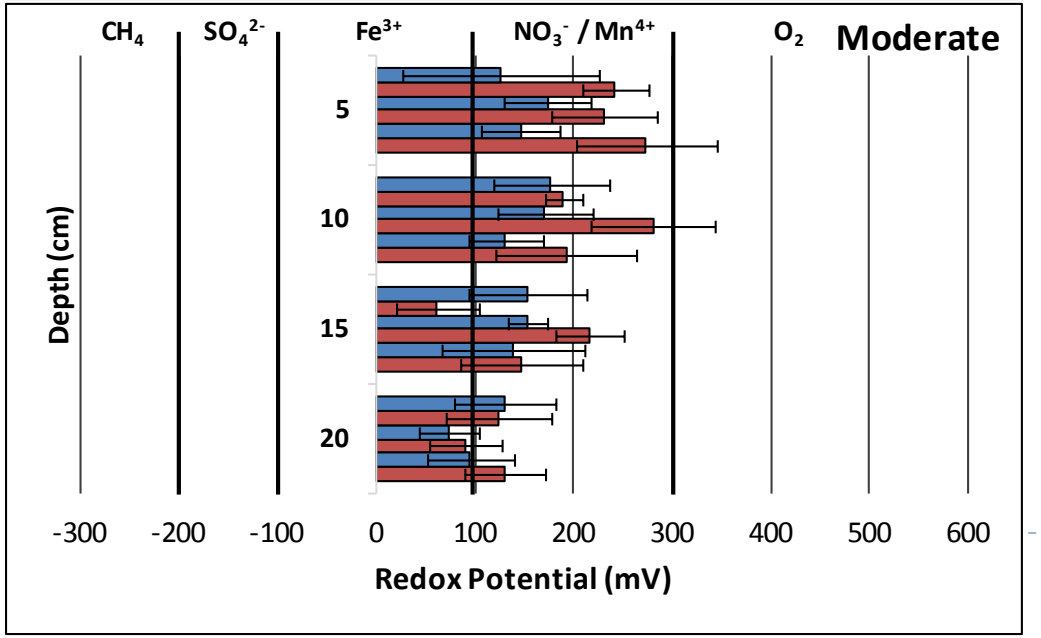

Sulfide Concentration (mM)
3
2.5
2
1.5
1
0.5
0
L5S3
L7S5
Sampling Location
21-May-14
04-Jun-14
16-Jun-14
07-Jul-14
18-Jul-14
04-Aug-14

Redox Potential



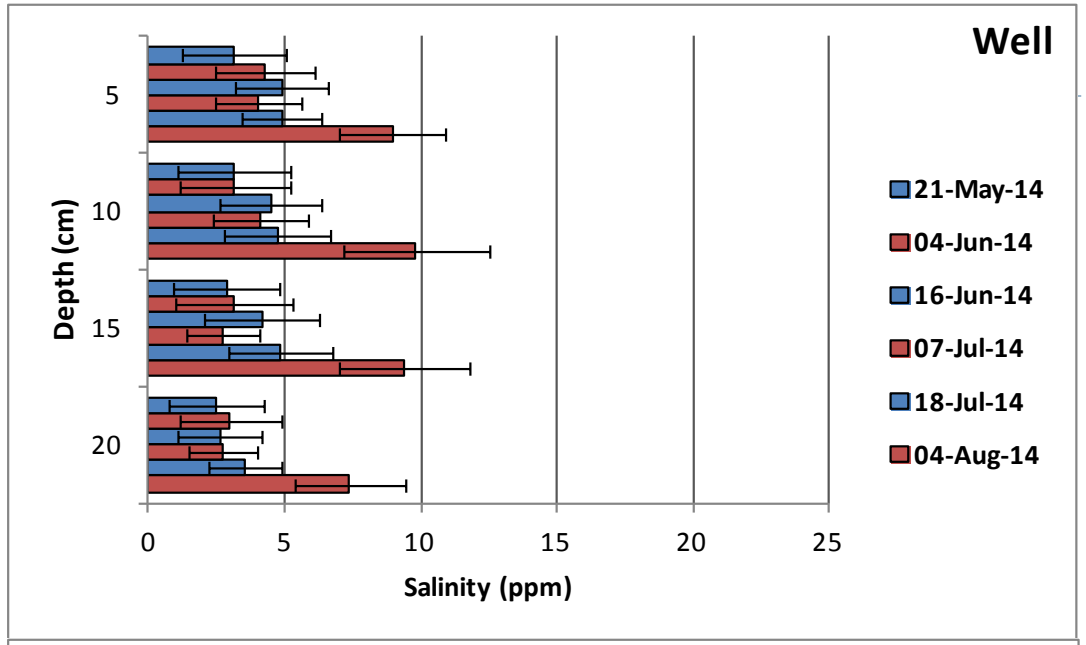


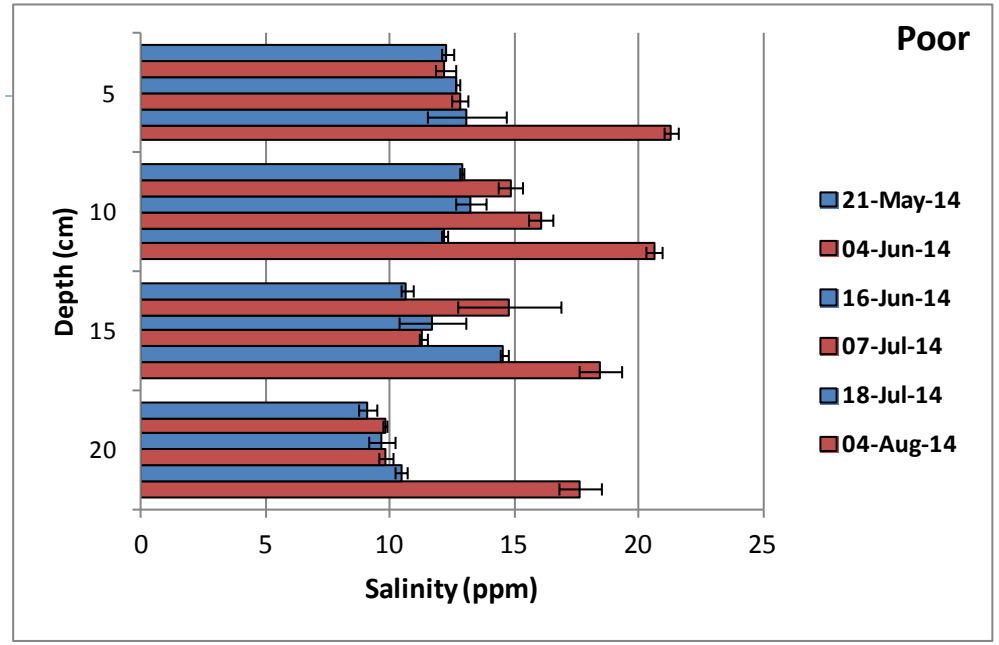


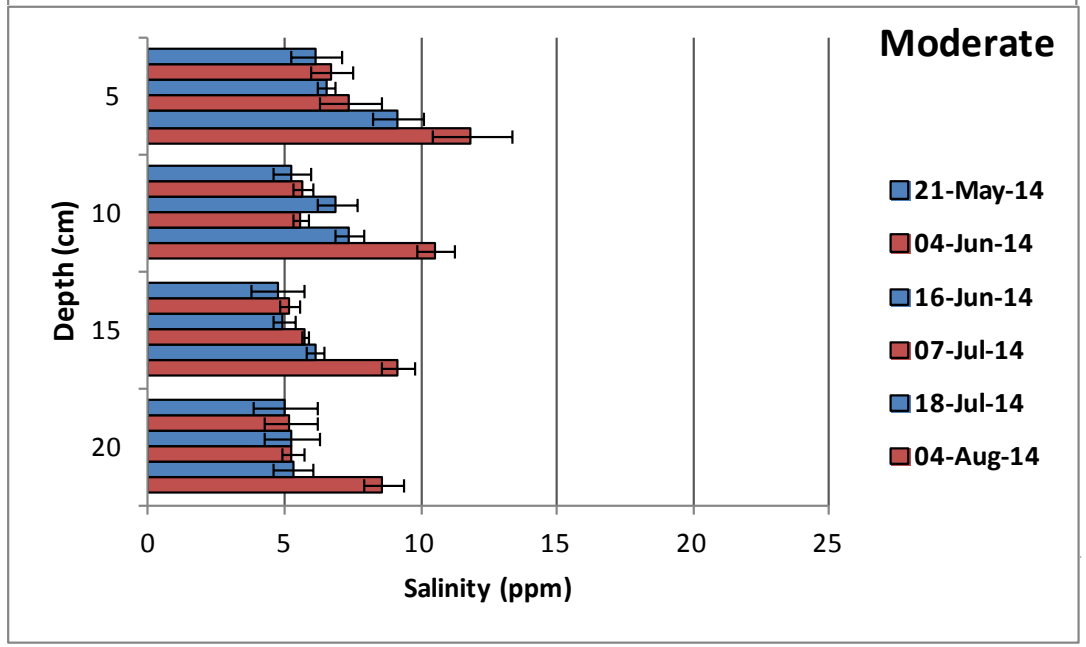
- Neap tides = higher redox
- Spring tides = lower redox
- Decrease in redox with depth

- 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)

Salinity



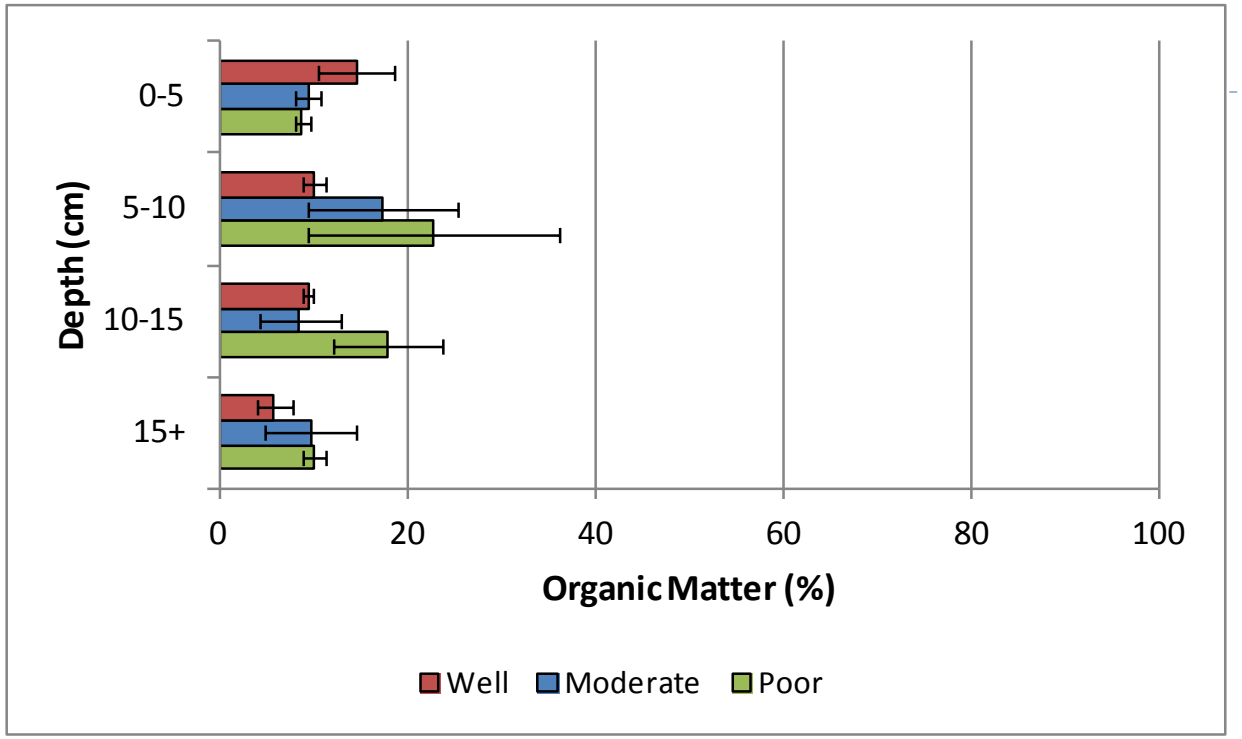


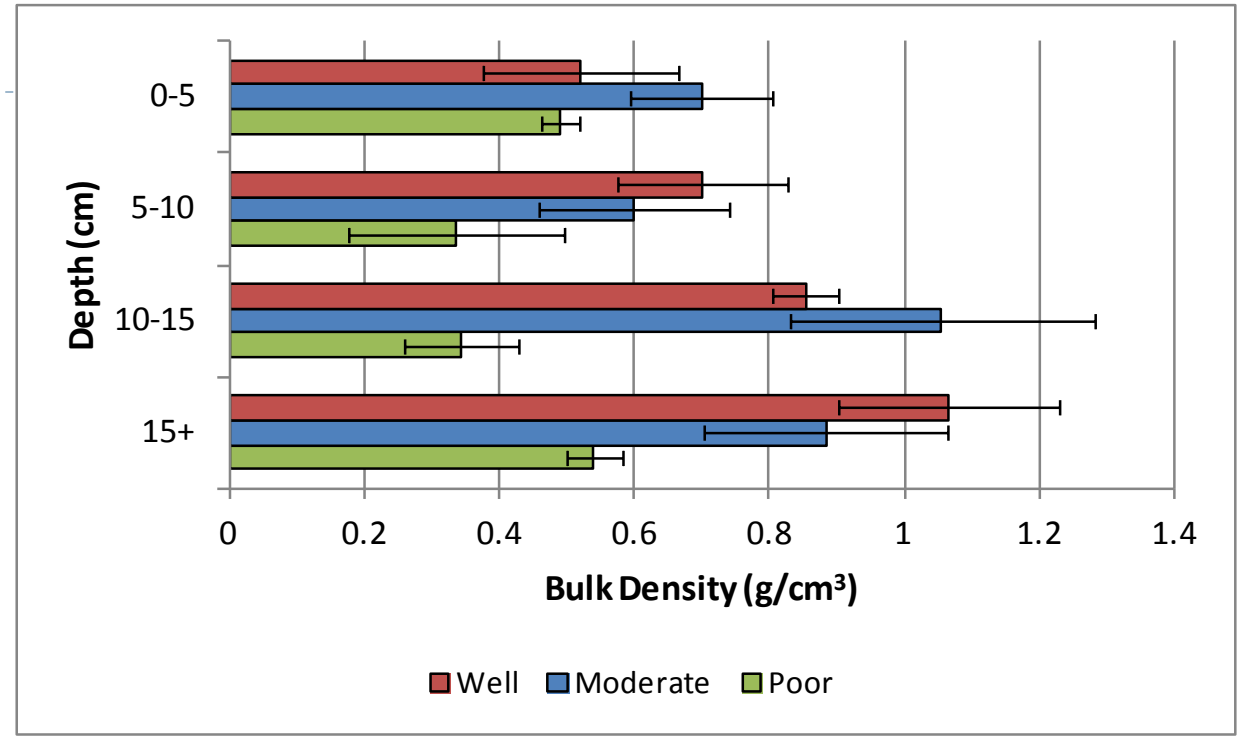


- Spring tides = Lower salinity
- Neap tides = Higher salinity
- Decrease with depth

- 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)

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).

Discussion and Conclusions

Well Drained Sites

- Low salinity levels
- Dominated by oxygen and nitrate/manganese reduction
- No sulfide
- Decreasing organic matter and increasing bulk density with depth
- Largest biomass values

Moderately Drained Sites

- Moderate salinity levels
- Dominated by nitrate/manganese reduction
- Minimal sulfide
- Similar organic matter throughout and increasing bulk density with depth
- Above ground biomass is similar to poorly drained sites

Poorly Drained Sites

- High salinity levels
- Dominated by iron reduction
- High sulfide level
- Organic matter highest just below surface and bulk density increasing with depth
- Smallest biomass values

Conclusions

- Soil chemistry directly impacts vegetation and vise versa
- Spring and neap tide signal
- Atlantic marshes differ from Bay of Fundy marshes

References

- Allen, J.R.L. 2000. Morphodynamics of Holocene salt marshes: a review sketch from the Atlantic and Southern North Sea coasts of Europe. Quaternanry Science Reviews 19: 1155-1231
- Anisfeld, S.C. 2012. Biogeochemical responses to tidal restoration. In *Tidal Marsh Restoration* eds. Roman, C.T. and Burdick, D.M. pp. 39-58.
- 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
- Butler, C. and Weis, J. 2009. *Salt marshes: a natural and unnatural history*. Rutgers University Press.
- Chambers, R. M., Mozdzer, T.J, and Ambrose, J.C. 1998. Effects of salinity and sulfide on the distribution of *Phargmites australis* and *Spartina alterniflora* in a tidal saltmarsh. Aquatic Botany, 62: 161-169
- Chmura, G.L., Anisfeld, S.C., Cahoon, D.R. and Lynch, J.C. 2003. Global Carbon Sequestration in Tidal, Saline Wetland Soils. Glob. Biogeochem. Cycles, 17 (4), doi: 10.1029/2002GB001917.
- Cline, J. D. 1969. Spectrophotometric determination of hydrogen sulfide in natural waters. Limnology and Oceanography, 14(3), 454-458.
- Craft, C. B. 2001. Biology of wetland soils. In J. L. Richardson and M. J. Vepraskas, Eds. *Wetland soils – Genesis, Hydrology, Landscapes and Classification*, pp. 107–135. Lewis Publishers, Boca Raton, London, New York, Washington, DC.
- Fieldler, S., Vepraskas, M.J. and Richardson, J.L. 2007. Soil redox potential: Importance, field measurements, and observations. Advances in Agronomy, 94: 1-54.
- Gordon, D. C. Jr. 1989. Habitat loss in the Gulf of Maine. Pages 106–119. Sustaining our common heritage. Proceedings of the Gulf of Maine Conference. December 10–12. Gulf of Maine Council on the Marine Environment, Portland, Maine.
- 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.
- Kostka, J.E., Roychoudhury, A. and van Cappellen, P. 2002. Rates and controls of anaerobic microbial respiration across spatial and temporal gradients in saltmarsh sediments. Biogeochemistry, 60: 49-76.
- Mendelssohn, I. A., and Seneca, E. D. 1980. The influence of soil drainage on the growth of salt marsh cordgrass *Spartina alterniflora* in North Carolina. *Estuarine and Coastal Marine Science*, *11*(1): 27-40.
- 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
- Reddy, K. R. and R. D. DeLaune. 2008. *Biogeochemistry of Wetlands*. Taylor & Francis Group, LLC: Boca Raton, Florida.
- 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.
- Teasdale, P.R., Minett, A.I., Dixon, K., Lewis, T.W., and Batley, G.E. 1998. Practical improvements for redox potential (Eh) measurements and the application of a multiple-electrode redox probe (MERP) for characterizing sediment in situ. Analytica Chemica Acta, 367 (1-3): 201-213.
- Townend, I., Fletcher, C., Knappen, M., and Rossington, K., 2010. A review of salt marsh dynamics. Water and Environmental Journal, 25: 477-488, doi:10.1111/j.1747-6593.2010.00243.x
- Tiner, R.W. 1991. Wetland indiactors: A guide to wetland identification, deliniation, classification and mapping. Lewis publishers: New York
- van Proosdij, D., Lundholm, J., Neatt, N., Bowron, T., Graham, J. 2010. Ecological re-engineering of a freshwater impoundment for salt marsh restoration in a hypertidal system. Ecological Engineering 36: 1314-1332. doi:10.1016/j.ecoleng.2010.06.008
- 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

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