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Determining Ideal Nitrogen Loads in Rerouted Drainage Water from the Pamlico Sound to Restored Forested Wetlands:

An Experimental and Modeling Approach

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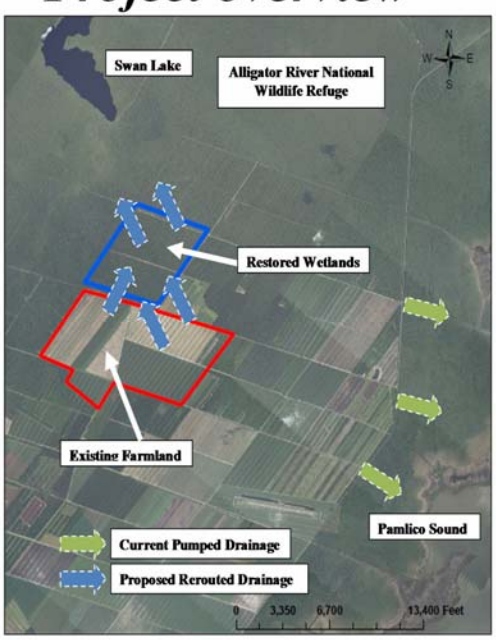
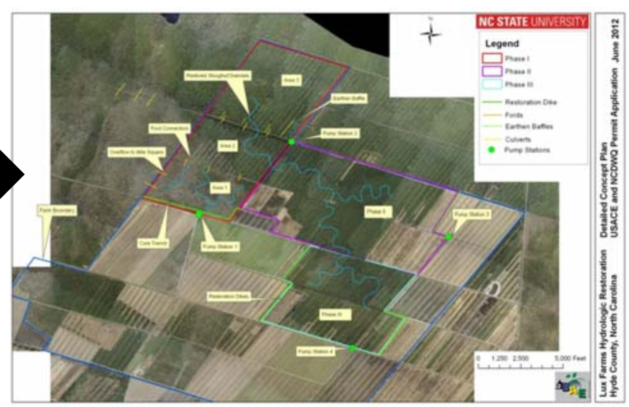
WRRI

Sea Grant North Carolina

Hyde county wetland restoration

Project overview





Stakeholder goals and concerns

- Hydrologic improvements to the restoration and surrounding refuge lands
  - Reduce pumping to Pamlico Sound
  - Improve wetland ecosystem structure
  - Reverse subsidence
  - Reduce threat of fire
  - Combat SLR/salt water intrusion

- **Concern:**

Water quality impacts of diverting drainage water through wetlands towards nitrogen-limited receiving waters (Swan Lake)

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Nutrient removal in forested wetlands

- Previous studies in the Albemarle-Pamlico peninsula have reported wetlands that received agricultural drainage water effectively store water and reduce nutrients up to 97% (Ardón *et al.,* 2010; Bruland *et al.,* 2006; Chescheir *et al.,* 1991).

- Available studies have evaluated wetland performance at the field scale *after* pumping to those areas began, with little control of how the areas were loaded with drainage water (Bruland *et al.*, 2006; Chescheir *et al.,* 1991).

- Studies are necessary to allow for a mass balance approach to accurately predict N transformations and appropriate hydraulic loads within wetland systems (Kovacic *et al.,* 2000).

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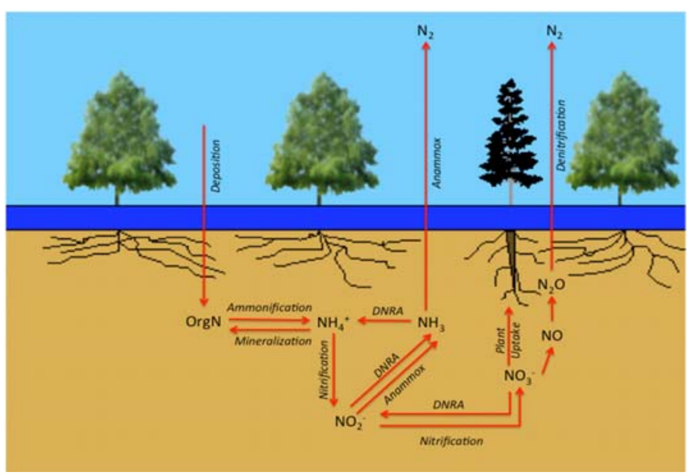
Overall Research Objectives

1. Utilize mesocosm-scale wetlands to determine the nitrogen fate and assimilation potential for wetland restoration projects

2. Improve our understanding of the fate of nitrogen in ***all*** wetland systems with advanced analytical techniques
   - Continuous WQ probes
   - ^{15}N isotope tracer studies

Focus: NO_3^--N reduction Mechanisms

- **Microbial denitrification** allows for a complete removal of NO_3^--N from the system
- **Denitrification requires**:
  - Anoxic conditions
  - Nitrate source
  - Suitable pH conditions
  - Carbon source
  - Suitable temperature
- **Plant Uptake**



Hypotheses

1. Nitrogen in drainage water will be assimilated at a high level through physical and biogeochemical transformations as drainage water flows through the restored wetlands.

2. Nitrogen removal will be influenced by nitrogen load, pH, temperature, carbon availability, and dissolved oxygen present in the water column.

Materials and Methods

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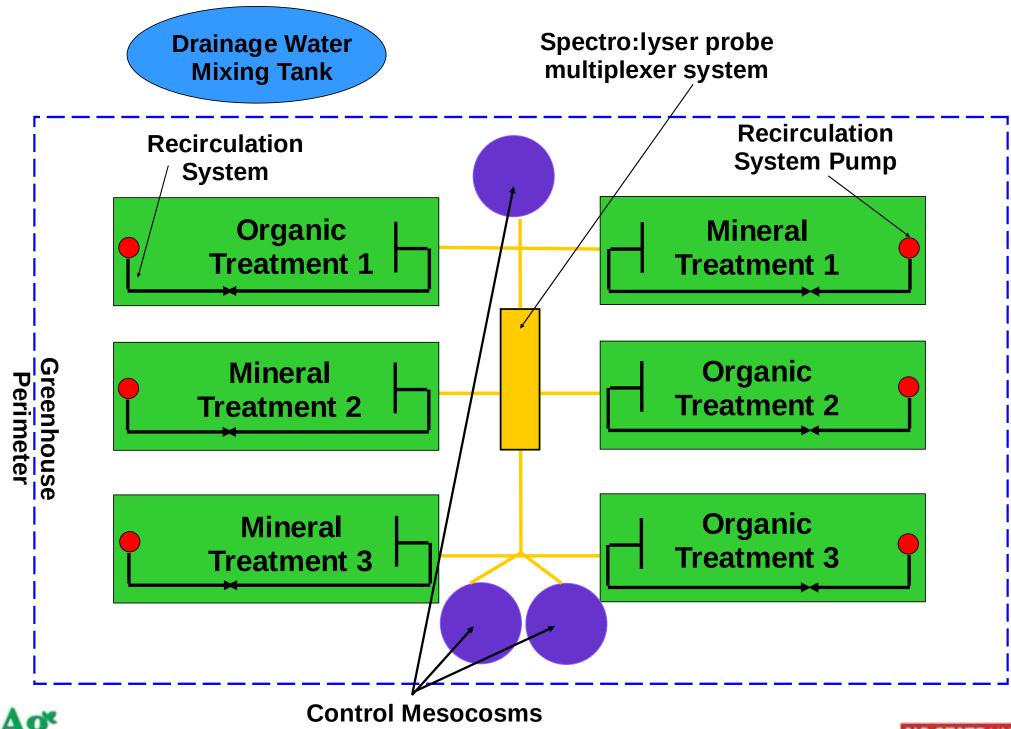
Experimental Schematic



Wetland Nitrogen Fate

Investigated Criteria

Denitrification

- Soil redox & Antecedent Conditions
- Carbon Availability
- Temperature
- pH
- Nitrogen Load

Plant Uptake/ Soil Retention

- Plant Establishment Year
- Luxury Uptake
- Above and Below Ground Biomass
- Beginning and End of Growing Season Soil Sampling

Preliminary Results

NO_3-N Removal Data

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Wetland Run Summary (to date)

Batch Run	Date	Run Period (days)	Depth of Water Prior to Loading (cm)	Depth of Water Following Loading (cm)	Target NO_3-N Concentrations (mg L^{-1})	Temperature Range (C°) (Average)
1	9/25/12 to 10/4/12	9	4	30	2.5	14 – 28 (22)
2	10/16/12 to 10/26/12	10	4	17.5	5	9 – 27 (17)
3	11/5/12 to 11/15/12	10	12.5	30	7.5	8 – 16 (11)
4	1/22/13 to 2/1/13	10	4	15	2.5	1 – 25 (9)
5	2/11/13 to 2/21/13	10	4	17.5	5	2 - 23 (11)
6	5/27/13 to 6/7/13	10	4	17.5	2.5	16 – 28 (25)
7	7/2/13 to 7/12/13	10	4	30	2.5	25 - 31 (28)

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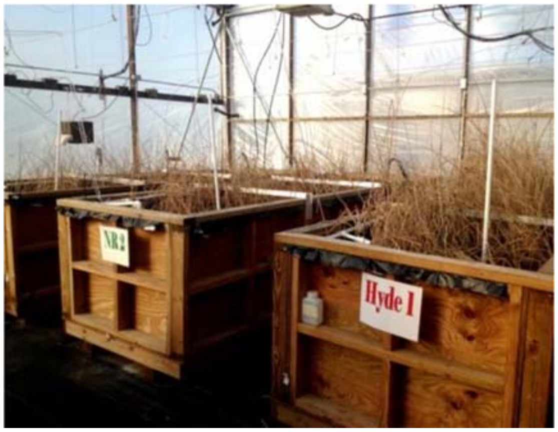
Bulrush Stage During Each Run



Run 4 (late Jan)

Run 6 (May-June)

**Schoenoplectus tabernaemontani*

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Run 4 and 6

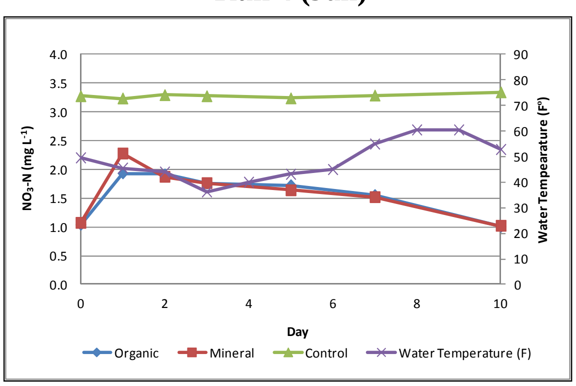
2.5 mg/L NO_3-N at 17.5 cm Depth

❖ Run 6 had a faster reduction in NO_3-N as expected.

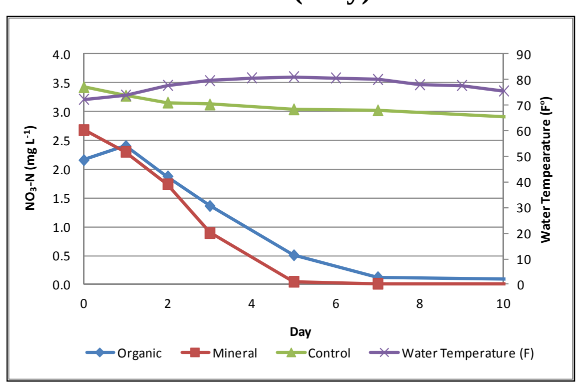
❖ Average temperature was 20-35 Fº higher in Run 6 compared to Run 4.

❖ Only Run 6 decreased NO_3-N below 1 mg/L.

Run 4 (Jan)



Run 6 (May)



*** Data presented is an average of the 3 mesocosm samples.**

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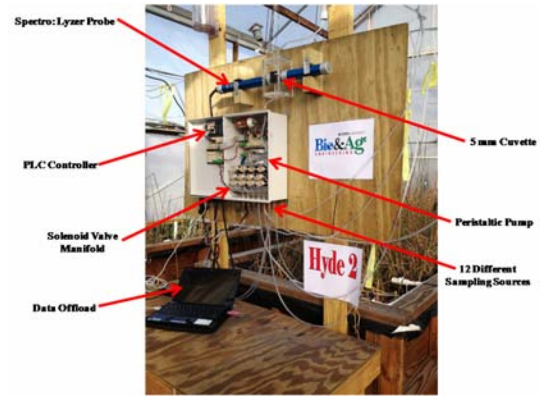
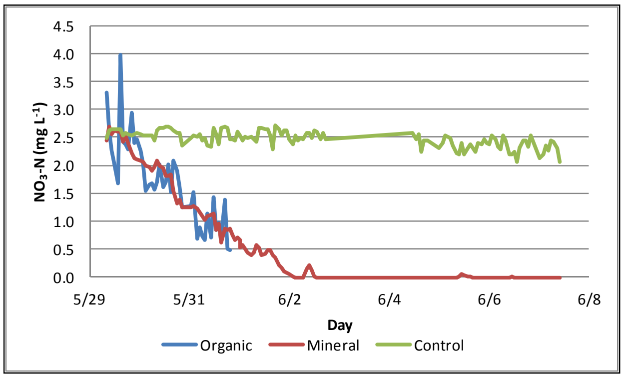
UV-Spectrometer

Continuous WQ data



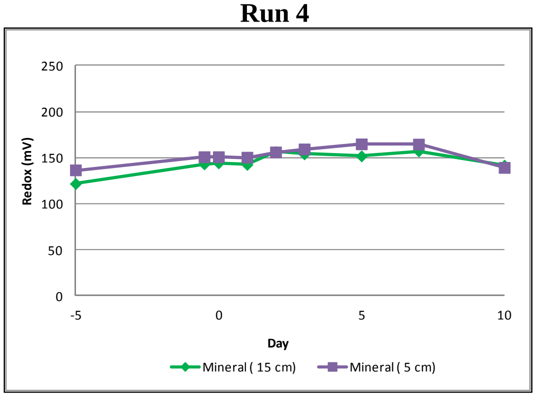
Run 6



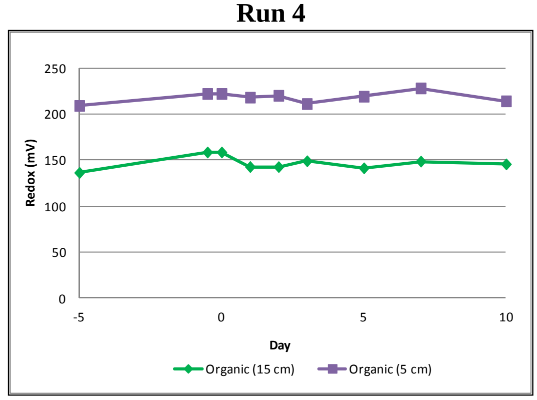
Soil Redox Potentials

- Redox potentials stayed below 250 mV in both the mineral and organic mesocosms in all batch runs.
- The mineral mesocosms had slightly lower overall redox potentials.
- The 15 cm redox potentials were consistently lower than the 5 cm redox potentials in both the mineral and organic mesocosms.

Wetland Mesocosms (Mineral soils)
Run 4



Wetland Mesocosms (Organic soils)
Run 4



*** Data presented is an average of the 3 mesocosm readings.**

Carbon Availability, pH, and DO

	Batch Run	Day of Run	Water Surface DO (mg L^{-1})	Soil Surface DO (mg L^{-1})	pH	DOC (mg L^{-1})
Mineral	4	0	12.87	12.63	7.31	10.25
		10	10.9	8.75	7.38	9.38
	6	0	9.99	10.13	8.16	11.92
		10	3.11	2.95	6.52	7.5
Organic	4	0	13.07	12.84	6.36	60.43
		10	12.62	8.69	6.62	48.80
	6	0	9.95	10.13	7.65	28.67
		10	2.95	2.78	5.64	54.25

*** Data presented is an average of the 3 mesocosm readings.**

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Discuss Rate Constants

$$\frac{C_e}{C_0} = \exp\left(-K_t * t\right)$$

C_e: Effluent Concentration (mg L^{-1})
C_o: Outlet Concentration (mg L^{-1})
K_t: Rate constant (day^{-1})
t: hydraulic residence time (d)

- Developing rate constants to apply to future wetland restoration project.
- Currently using simple 1^{st} order decay constants
- Plan to investigate several different wetland models and possibly create model to fit results.

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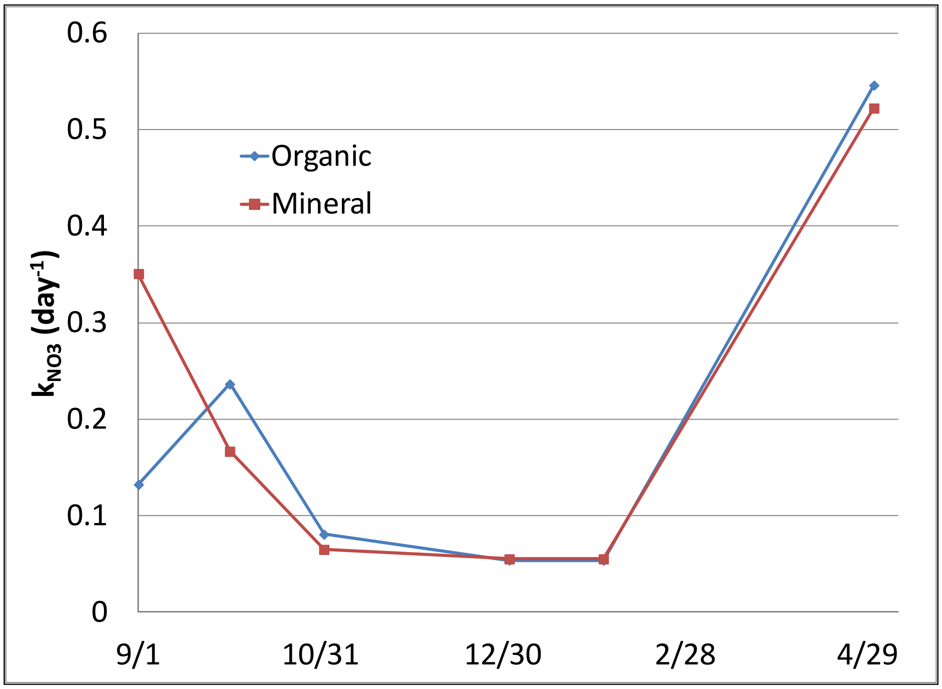
Rate Constants (k)



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Preliminary Conclusions

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Conclusions

- The seven batch runs indicate that both the organic and mineral mesocosms are reducing NO_3-N. Rates are limited in the winter as expected. No major differences were observed between the mineral and organic soils most likely because DOC was not limited in both systems.

- Based on preliminary observations, majority of the nitrogen reduction (particularly in Batch 3, 4, and 5) are believed to be due to denitrification since plants were dormant in these runs.

- The batch runs exhibit the importance of temperature and season on NO_3-N reduction in these systems.

- Water management plan for the wetland restoration sites will incorporate higher drainage water retention times in winter

Important Future Evaluations

- More batch runs are planned for the summer, fall, and winter seasons of 2013 to fully access seasonal variability.
- ^{15}N tracer study is planned to begin in August of 2013 to improve our understanding the N transformations occurring within wetlands (i.e. the impacts of plant uptake and denitrification using a mass balance approach).
- *** Rate constants and temperature coefficients will be applied to water management models to estimate seasonal loading rates for the restored wetlands.

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Questions?

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