A Mesocosm Study to Explore the Enhancement of Nitrate Dissipation Capacity in Treatment Wetlands

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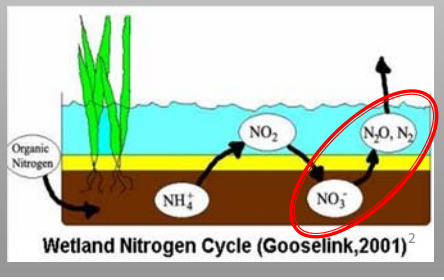
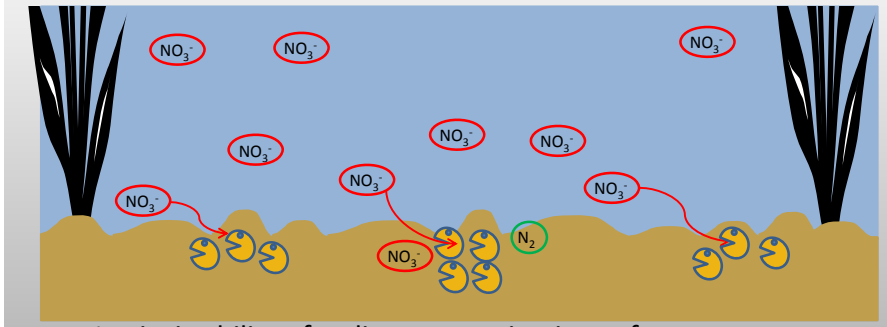
Wetlands as Treatment Systems

- Wetlands have:
  - Large production of Organic Matter (OM).
  - Microbes use OM for energy, need electron acceptors.
  - Oxygen used up first, then microbes will use nitrate.
  - End-product of this process is N_2 gas, leaves the wetland.
  - Beneficial due to mass removal from aquatic system.



Wetland Nitrogen Cycle (Gooselink,2001)[2]

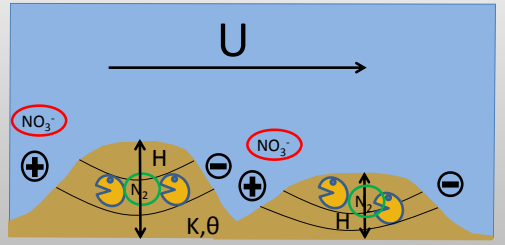
Treatment Factors Improvement

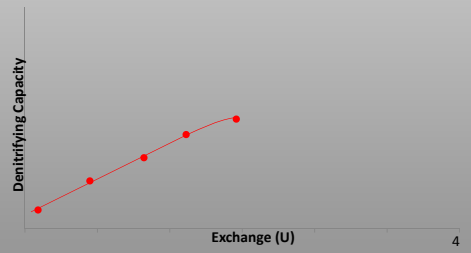


- Intrinsic ability of sediment to strip nitrate from water.
- Ability of nitrate to be transported near denitrifying microsites.
- Residence time near microsites.
- Proportion of total hydraulic load that has a chance to be processed.

Higher Exchange, Increased Nitrate Transport

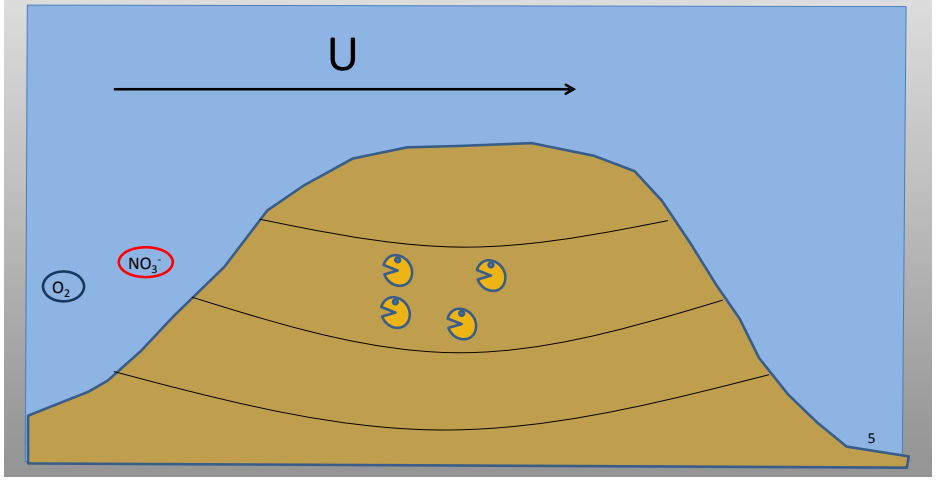
- Recent stream ecology work has demonstrated that advective transport increases nitrate transfer into sediment.
- **Exchange = f(K,H,U^2,1/θ)**
- Overlaying water velocity (U) is the most economical and influential parameter to change.



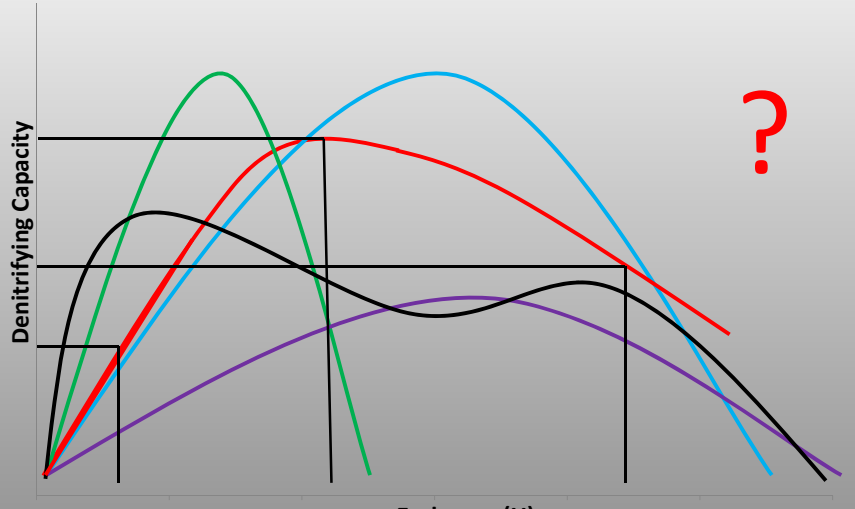


Is High Exchange the Answer?

Not Always! O_2 inhibition reduces effect of high exchange.



Denitrification versus Exchange

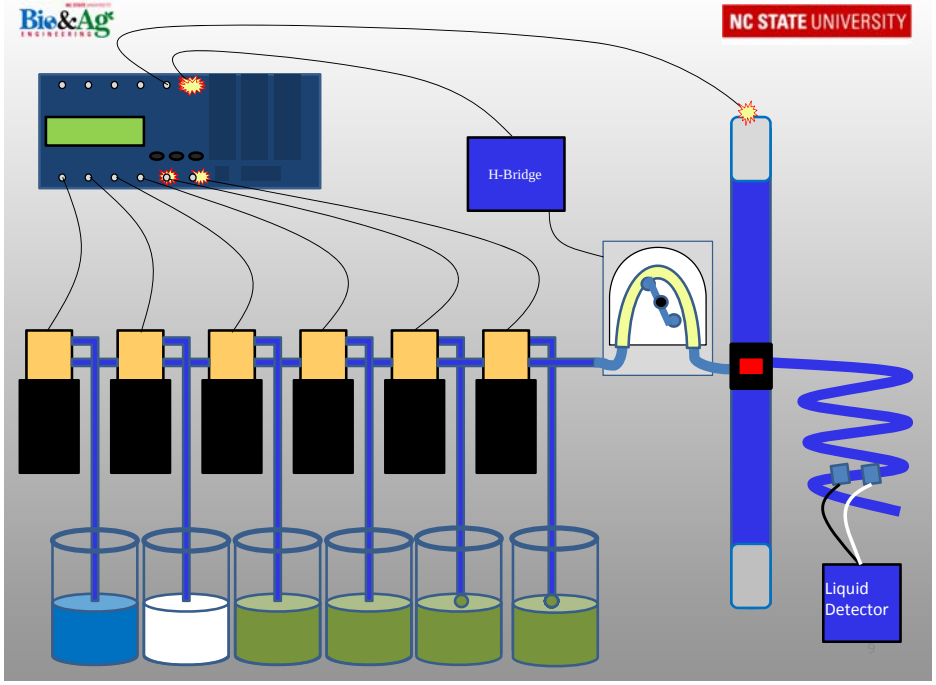


Experimental Objectives

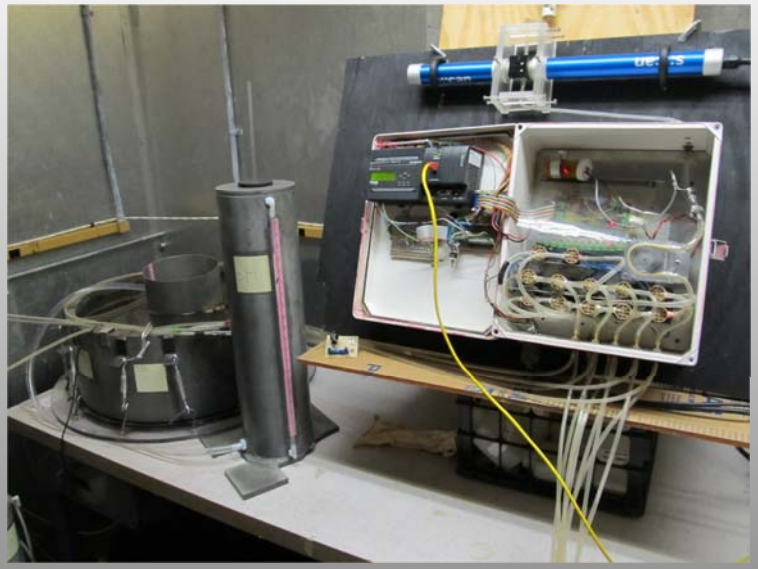
- Can we determine if increased surface-subsurface exchange results in higher nitrate dissipation?
- If a relationship does exist, can we define types of correlation via amplitudes and optimal ranges of this relationship curve?

Methodology

- Three whole-core, undisturbed wetland soil sample replicates.
- The 56 cm diameter mesocosm cores were filled with stream water.
- Control mesocosm consists of stream water only.
- Stream water was recirculated at different velocities using pumps.
- Nitrate concentration decrease was measured over time sequentially for all three replicates.



Multiplexer Water Quality Sampler

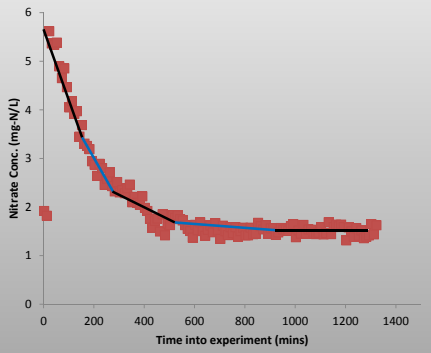


Theoretical Equations

- General Reaction Hypothesis:
  - Reaction Rate = $\rho[NO_3^-]$

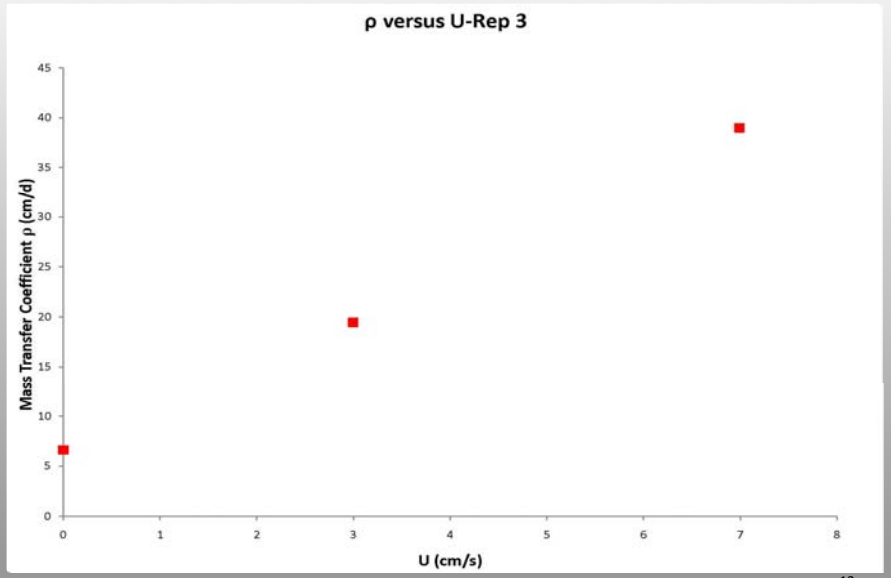
$$[NO_3^-] = Co * e^{\frac{-\rho}{D}t}$$

Birgand, F., Skaggs, R. W., Chescheir, G. M., & Gilliam, J. W. (2007). Nitrogen removal in streams of agricultural catchments - A literature review. *Critical Reviews in Environmental Science and Technology*,*37*(5), 381-487.

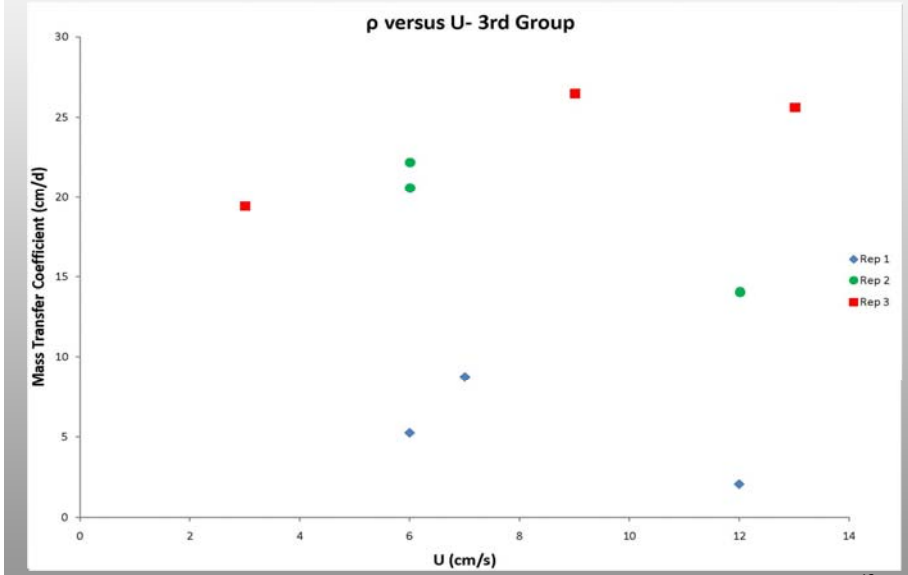


- $\ln(\frac{C}{Co})$ should be linear with slope $\frac{-\rho}{D}t$
- ρ acts as a "lumped" term, but should change with U.

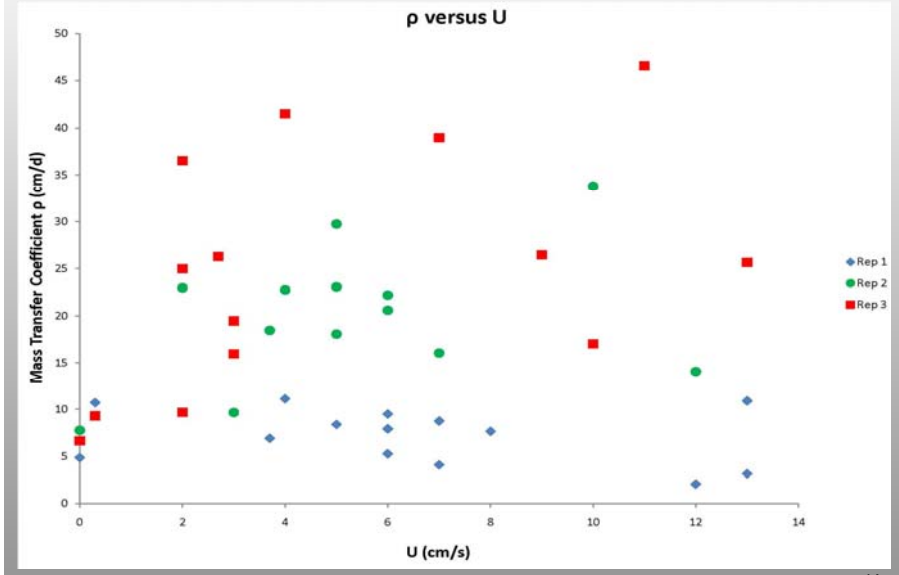
Nitrate Dissipation Kinetics



ρ versus U: Progress over Time



Composite ρ Relationships



Experimental Summary

- Relationship of ρ = f(U):
  - Still very fuzzy relationship
    - Rep 1: ρ = no pattern
    - Rep 2: ρ ≈ f(U)
    - Rep 3: ρ ≈ f(U^2)

- Possible Effects:
  - Cores were “aging” (bioturbation) .
  - Plant labile carbon used up.
  - Conductivity increased over time.

Implications/Future Work

- With all else being equal, a wetland with Hydraulic Loading Rate of 20 m/day and with a ρ of 6.5 cm/day (for U of 0 cm/s), has a nitrate removal efficiency of 30%.
- Increasing U to 4-8 cm/s in this same wetland would increase ρ to 20-35 cm/day, which would increase the nitrate removal efficiency to 63% to 83%.

However:

- Investigations on how to handle plants and the “aging” of cores still needs to be determined.
- Field studies still need to be performed to determine optimal wetland designs.

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Questions?