High Pollutant Removal in a Large Constructed Wetland Improves a Tidal Creek

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Background

- This constructed wetland site consists of open water, wetland and uplands totalling 4.7 ha (11.5 acres)
- The site treats 47% of the catchment entering the south branch of Hewletts Creek (238 ha (589 acres)
- The NC Clean Water Management Trust Fund supplied $2.76 million
- City of Wilmington supplied $576,000
- New Hanover County supplied $240,000
- Construction occurred in 2007; Stormwater was directed into the wetland by June 2007, aquatic vegetation (many species) was planted

Overview of the JEL Wade constructed wetland in Wilmington, NC. It drains 589 acres (238 ha) and includes 7.6 acres (3.0 ha) of wetland and open water. Designed to treat first inch of rainfall from watershed.

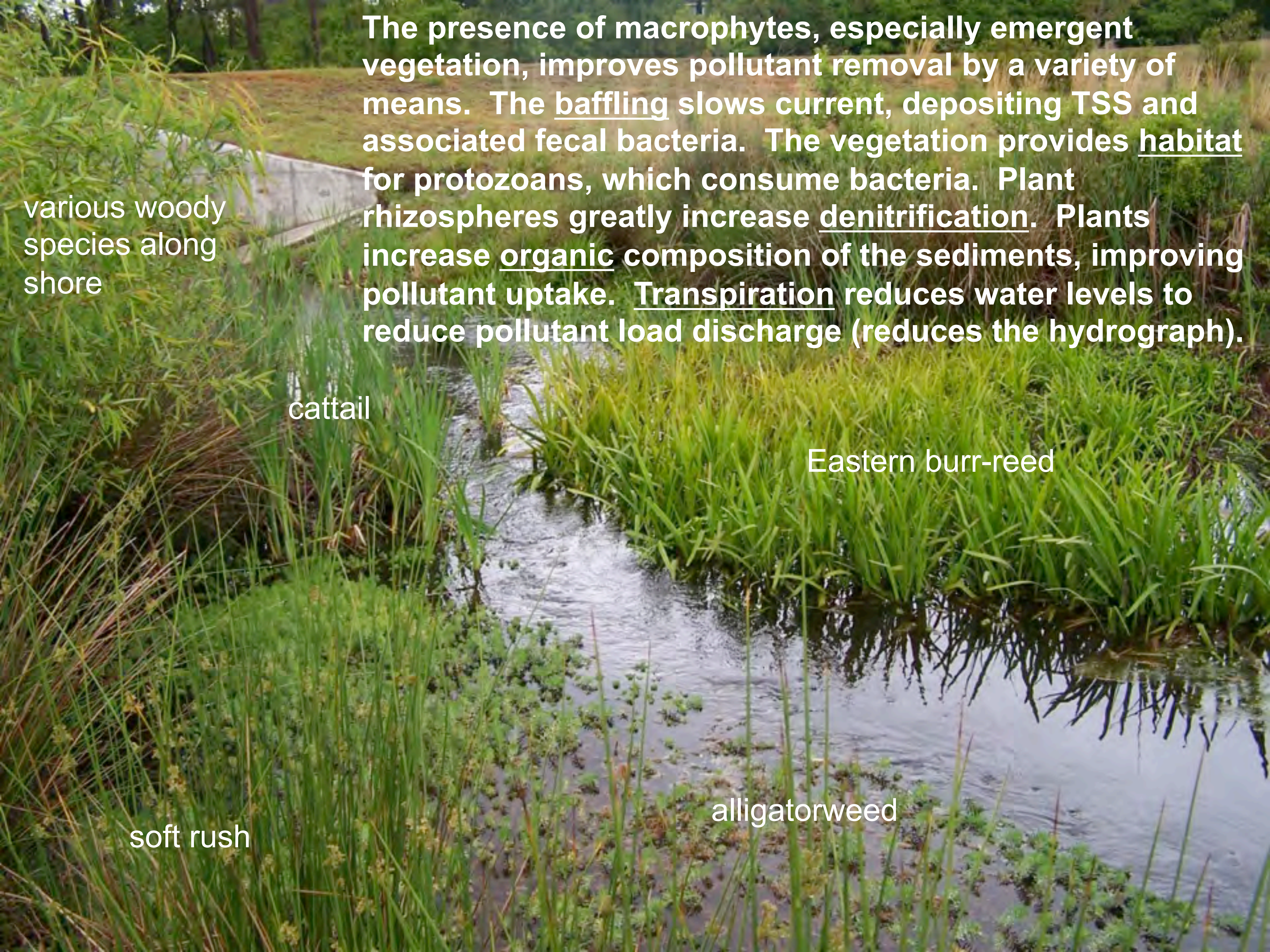
Part 1 – A program was initiated to determine efficacy of pollutant removal in this constructed wetland

- Eight storm events were sampled between August 2009 and June 2010
- Target storms were between 0.5 and 1.5 inches
- Fecal coliforms sampled one hour after onset (first flush)
- All other parameters sampled hourly for <u>six</u> hours
- Sampling was done by hand
- Flows measured concurrent with sample collection

Water Retention and Removal in the Wetland

- During the 6-hr period, the percent of inflowing stormwater volume **retained** in the wetland averaged 63$\pm$10%, range 50-75%
- This retention is due to wetland infilling, plant uptake and transpiration, evaporation, and infiltration into the ground above the water table
- Amount of inflow retained was positively correlated with water temperature ($r = 0.45$, $p = 0.005$). Increased evaporation and plant transpiration are associated with increased temperatures.
- Having **sufficient space** available for a wetland of sufficient size to properly treat the watershed runoff is clearly a key factor

The presence of macrophytes, especially emergent vegetation, improves pollutant removal by a variety of means. The baffling slows current, depositing TSS and associated fecal bacteria. The vegetation provides habitat for protozoans, which consume bacteria. Plant rhizospheres greatly increase denitrification. Plants increase organic composition of the sediments, improving pollutant uptake. Transpiration reduces water levels to reduce pollutant load discharge (reduces the hydrograph).



An Effective Stormwater Wetland

- **The JEL Wade Wetland, is very effective in removing pollutants from stormwater, reduces both load and concentrations**
- **Retains/removes 50-75% of inflowing stormwater volume**
- **Average fecal coliform load reduction of 99%, concentration reduction >90%**
- **>90% removal of ammonium and nitrate**
- **89% TP removal, >90% orthophosphate removal**
- **88% TSS removal**
- **Significant reductions of nitrate, ammonium and fecal coliforms in the downstream tidal creek proper achieved**

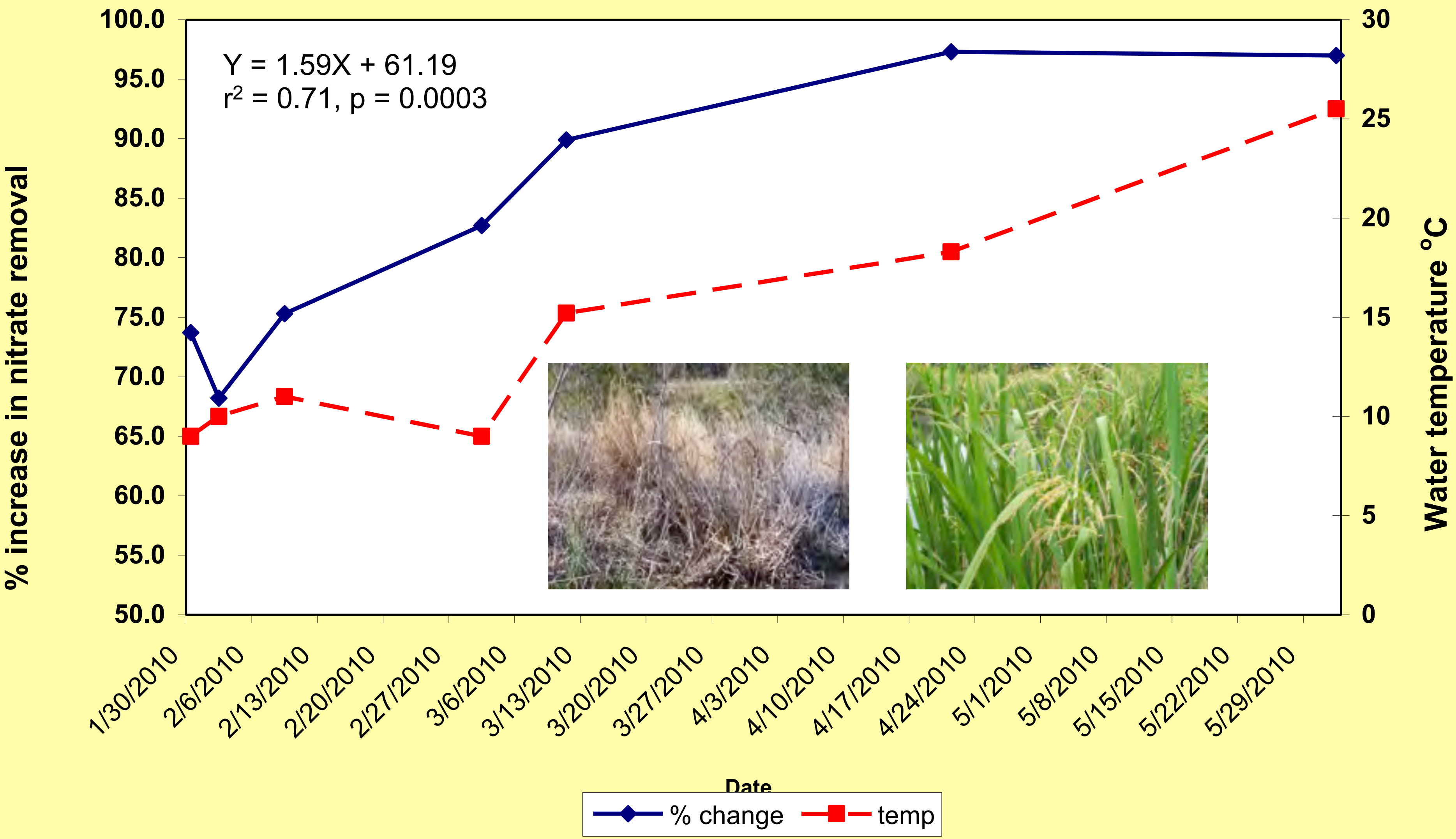
Mallin, M.A., J. McAuliffe, M.R. McIver, D. Mayes and M.R. Hanson. 2012. High pollutant removal efficacy of a large constructed wetland leads to receiving stream improvements. *Journal of Environmental Quality* 41:2046-2055.

- **So what factors maximize the N removal?**

Average parameter concentrations in wetland 2009-2010 inflows and outflow compared with receiving creek concentrations prior to and after July 2007 wetland completion

	Wetland			Receiving stream	
Parameter	Inflow 1	Inflow 2	Outflow	S. branch tidal creek pre-wetland	S. branch tidal creek post-wetland
Ammonium mg/L	0.229	0.143	0.043	0.048	0.014** sig. $p<0.01$
Nitrate mg/L	0.123	0.159	0.066	0.051	0.029** sig. $p<0.01$
Phosphate mg/L	0.020	0.093	0.013	0.024	0.018 non-sig.
Fecal coliforms CFU/100 mL	605	437	42	144	62* sig. $p<0.05$

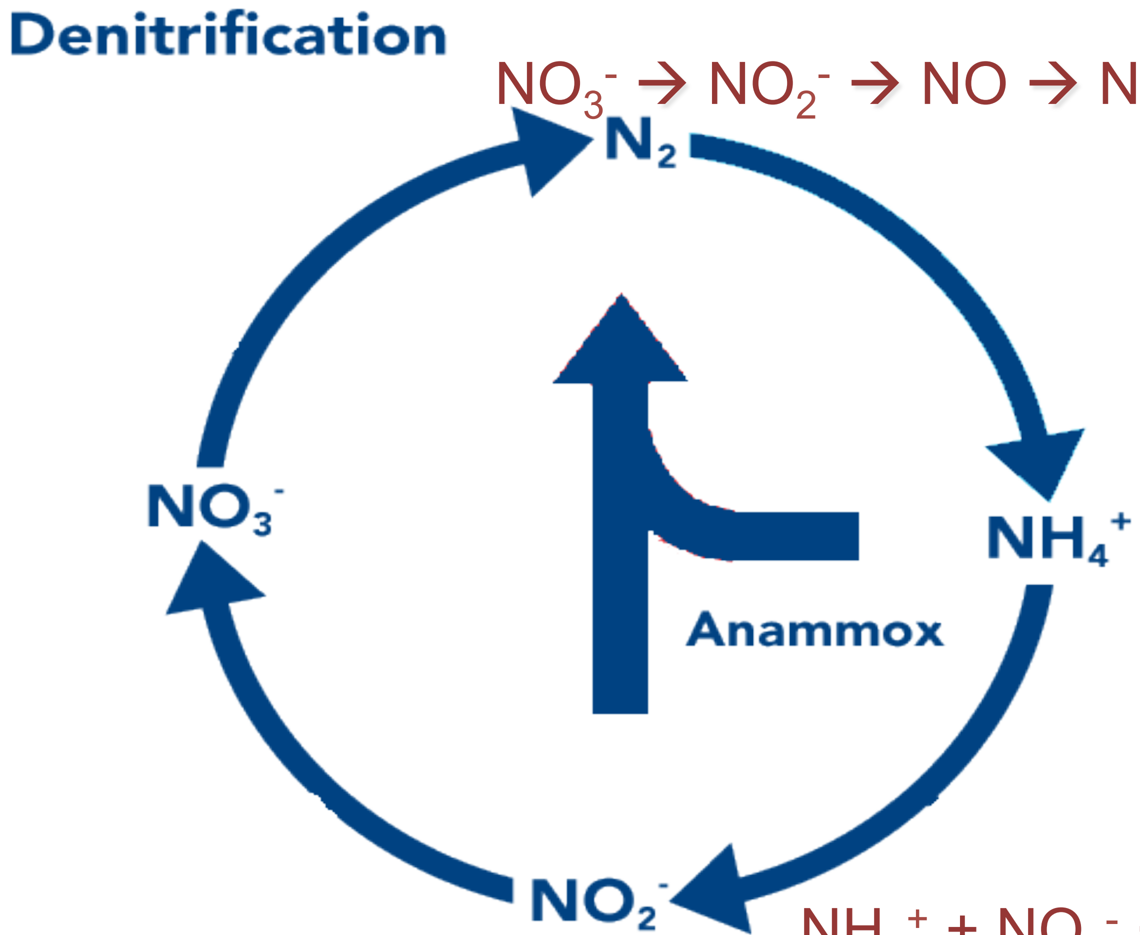
Figure 11. Increase in nitrate removal with water temperature increase in JEL Wade wetland during 2010.



Part 2. Objectives for nitrogen removal study (WRRI supported)

- Quantify denitrification and anammox in wetland sediments
- Test bare sediments vs. macrophyte rhizospheres for N removal activity
- Test between dominant macrophyte species for N removal activity
- Assess seasonal variation of N removal capacities (June, August, October, February)
- Determine the environmental factors enhancing N removal capacities in wetlands

Microbial N Removal in Wetlands – plant uptake, sedimentation, but especially……



$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$

http://www.paques.nl/websites/implementatie/mediadepot/15804bd677f.gif

Stable Isotope Analysis used for N-loss experiments

$^{15}NO_3^-$ tracer incubation

- Anammox:

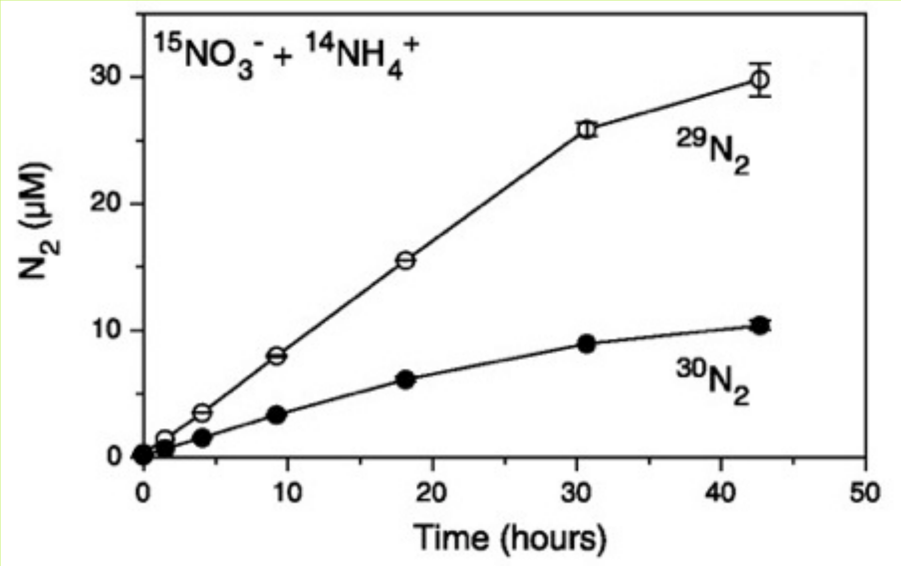
  $^{15}NO_2^- + ^{14}NH_4^+ \rightarrow ^{29}N_2$

- Denitrification:

  $2\,^{15}NO_3^- \rightarrow 2\,^{15}NO_2^- \rightarrow ^{30}N_2$

$^{30}N_2$ for Denitrification

$^{29}N_2$ for Anammox



Dalsgaard & Thamdrup, Appl Environ Microbiol 68:3802


Harvesting rhizospheres for N-loss experiments

N loss by month / season

N removal as nmol N/g sed. wet wt./hr

Denitrification: <u>Plant rhizomes</u>

- *August* 16.7 ± 8.4*
- *June* 16.0 ± 8.3
- *October* 8.9 ± 4.2

Aug > October

Denitrification: <u>Sediments</u>

- *February* 4.6 ± 0.3*
- *October* 3.8 ± 2.5*
- *August* 0.7 ± 1.1

Feb, Oct > August

Anammox: <u>Plant rhizomes</u>

- *June* 2.4 ± 1.8
- *August* 1.9 ± 1.9
- *October* 1.7 ± 1.7

NSD

Anammox: <u>Sediments</u>

- *February* 0.65 ± 0.63*
- *October* 0.20 ± 0.12*
- *August* 0.04 ± 0.07

Feb, Oct > August

* Indicates significantly greater N removal than other months ($p < 0.05$)

Environmental factors influencing N removal

For all data combined:

Denitrification was **positively** correlated with water temperature ($r = 0.33$, $p = 0.019$)

No significant relationship between temperature and anammox

For macrophyte **rhizosphere** data only:

Denitrification **positively** correlated with water temperature

($r = 0.40$, $p = 0.04$)

No sig. relationship between temperature and anammox

For **bare sediment** samples only:

Denitrification **negatively** correlated with temperature ($r = -0.704$, $p = 0.0003$); anammox also **negatively** correlated with temperature ($r = -0.739$, p , 0.0001)

*No significant relationships between N loss and water column nutrient or DO concentrations

Wetland Species Matter!

N removal as nmol N/g sed. as wet wt./hr

Denitrification

- *Pontederia* 27.4 ± 2.7*
- *Alternanthera* 16.9 ± 3.6
- *Sparganium* 13.7 ± 9.3
- *Zizaniopsis* 12.4 ± 2.4
- *Typha* 11.9 ± 3.9
- *Juncus* 11.7 ± 5.5

Myriophyllum 4.6 ± 0.1

Pont. > Spar., Zizan., Typha, Juncus, Myrio.
Alt. > Myrio.

Anammox

- *Pontederia* 3.7 ± 2.3*
- *Typha* 2.9 ± 1.5*
- *Zizaniopsis* 2.9 ± 1.6*
- *Sparganium* 2.2 ± 1.3*
- *Alternanthera* 1.5 ± 2.1
- *Myriophyllum* 0.6 ± 0.1
- *Juncus* 0.3 ± 0.3

Pont., Typha, Zizan., Spar. > Alt., Juncus

Conclusions

- Denitrification is a major N_2 production pathway in the wetland, about 10X anammox rates
- Higher N_2 production was observed in rhizospheric sediments compared with bare sediments (by an order of magnitude).
- Plant rhizosphere denitrification was significantly greater in summer than winter; however rhizosphere anammox showed no seasonal difference
- Bare sediments showed significantly greater denitrification and anammox rates in winter than during summer
- Denitrification and annamox were not significantly correlated ($p > 0.05$) with sediment grain size in this wetland, likely a result of limited particle size range.

Conclusions continued

- Increased water temperature stimulated denitrification in macrophyte rhizospheres, but had no effect on anammox.
- In sediment samples both denitrification and anammox were negatively correlated with water temperature.
- Pickerelweed *Pontederia* had overall highest denitrification, with alligatorweed *Alternanthera* (an invasive) second.
- *Pontederia*, cattail *Typha*, giant cutgrass *Zizaniopsis*, and bur-reed *Sparganium* had highest anammox.
- Parrott feather *Myriophyllum* had poorest N removal for both processes
- Note: of the 7 major species tested, only 3 (*Pontederia*, *Zizaniopsis*, *Sparganium*) were planted, the rest were opportunistic invaders; i.e. sometimes invasives can be useful!

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