Understanding Nitrogen Dynamics and Organic Matter Sources in the Jordan River

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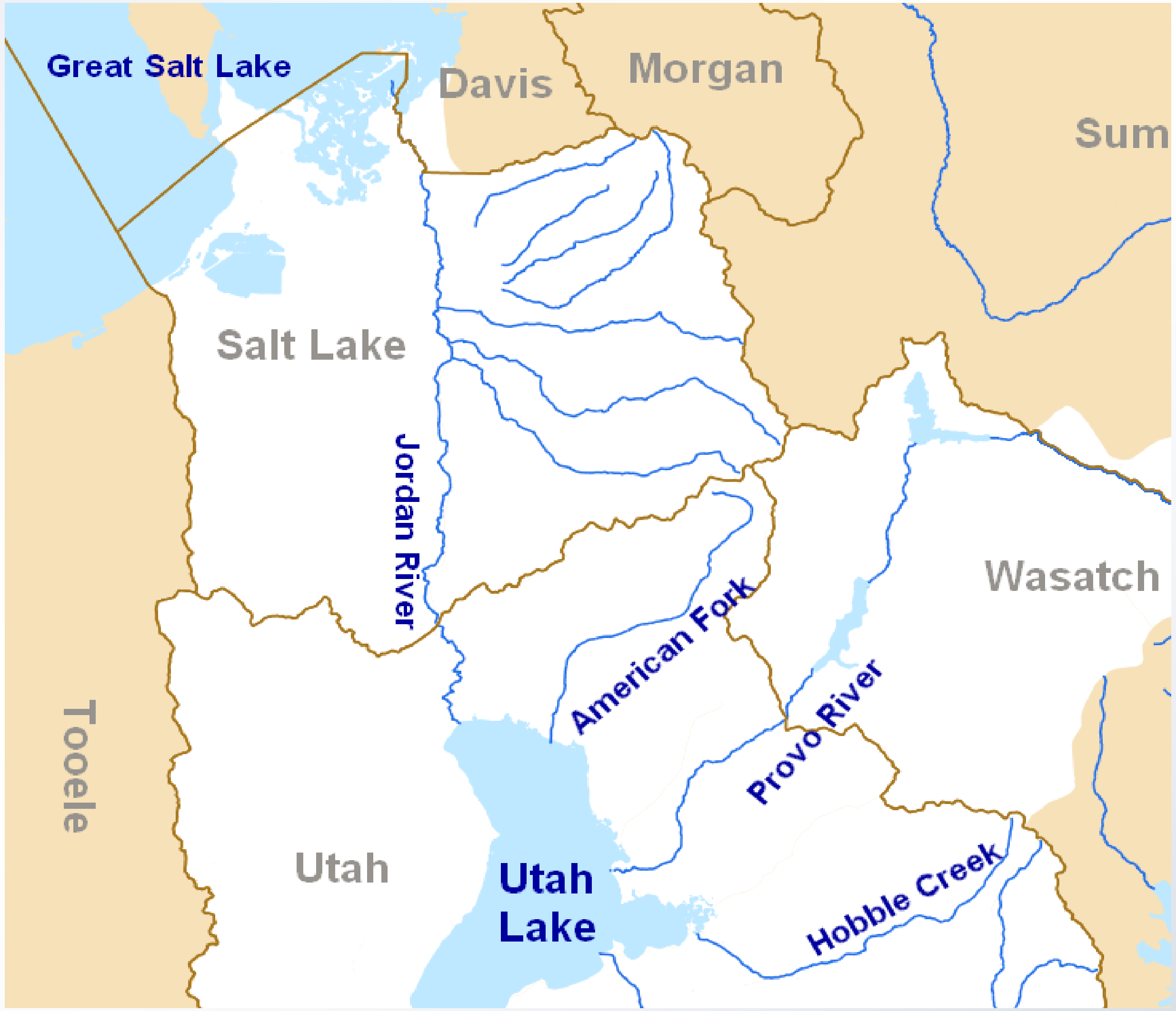
Presentation Outline

- Introduction to Jordan River
- Problem statement and objectives
- Studies on Nitrogen dynamics
  - Introduction
  - Methodology
  - Results
- Leaf Leachate studies
  - Introduction
  - Methodology
  - Results
- Conclusion

Introduction to Jordan River

- The Jordan River flows from Utah Lake through the urban Wasatch Front before entering a complex of constructed wetlands and finally draining into the terminal Great Salt Lake.
- During the months of March to June the **snowmelt and the spring runoff** contributes to a significant increase in the flow.
- The River passes through 15 municipalities, **10 diversion dams/weirs**, receives seven perennial & nine intermittent tributary streams and the direct discharge of **4 municipal wastewater treatment plants (WWTP).**
- This 52 mile 4^{th} order stream is a **highly managed** urban river that receives pollutants both anthropogenically and naturally.



Ailments of Jordan River

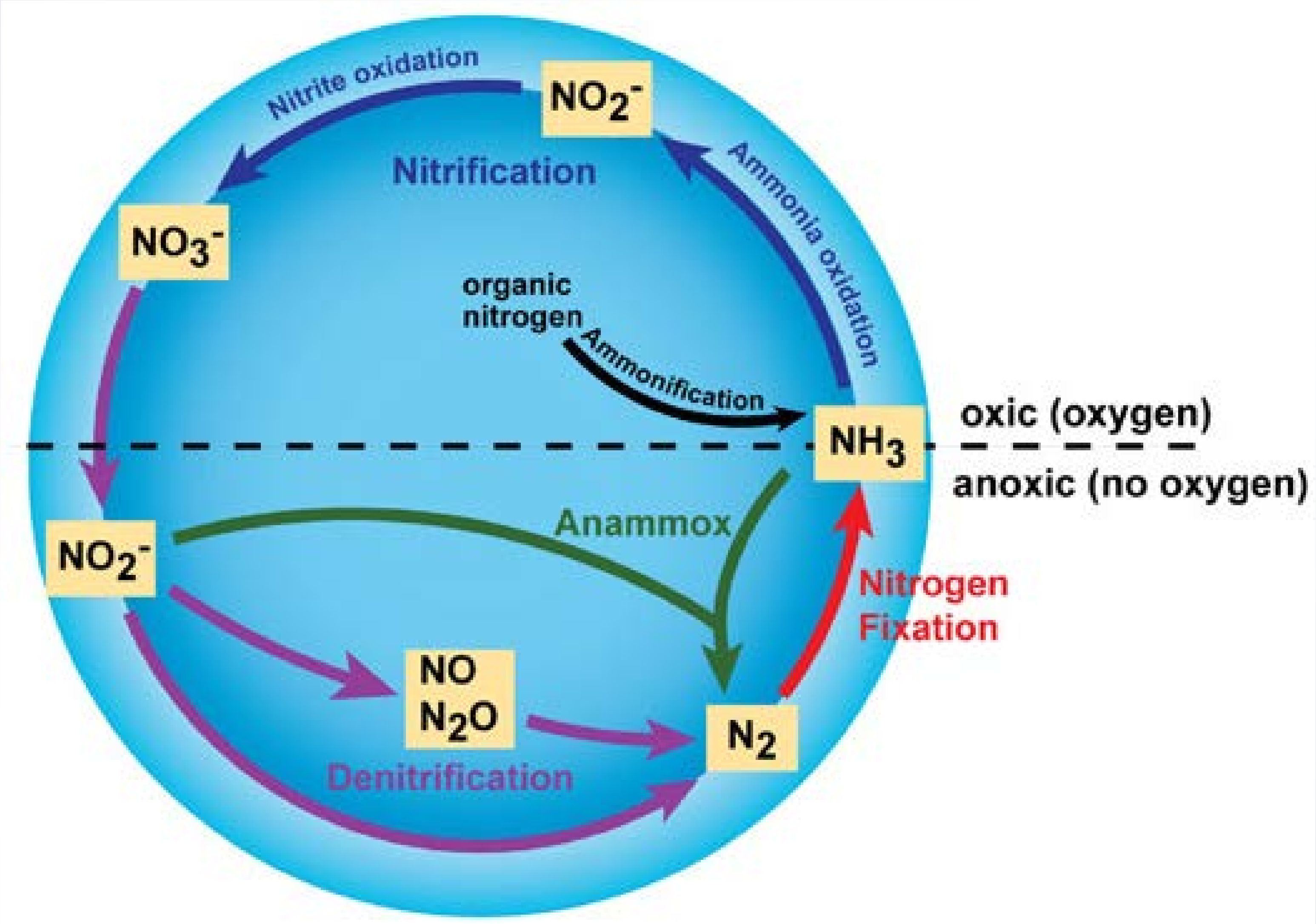
- The Jordan River has been classified as **impaired** by the division of water quality in Utah.
- This river experiences both '**chronic**' and 'acute' DO deficits (Utah DWQ TMDL, 2013).
    - The chronic ailment occurs when there is a **steady state of decomposition** in the sediments and water column.
    - It requires a **year-round source of OM** to maintain a 'steady state' DO deficit. (Diaz & Rosenberg, 2008, Paerl et al., 1998)
- This OM will decay at varying rates while consuming DO, **cycling nutrients**, and producing chemical byproducts.

Nitrogen dynamics

- Nitrogen is of particular interest to ecologists because availability of nitrogen can affect the rate of key processes in the ecosystem.

- Redfield ratio C:N:P= 106:16:1

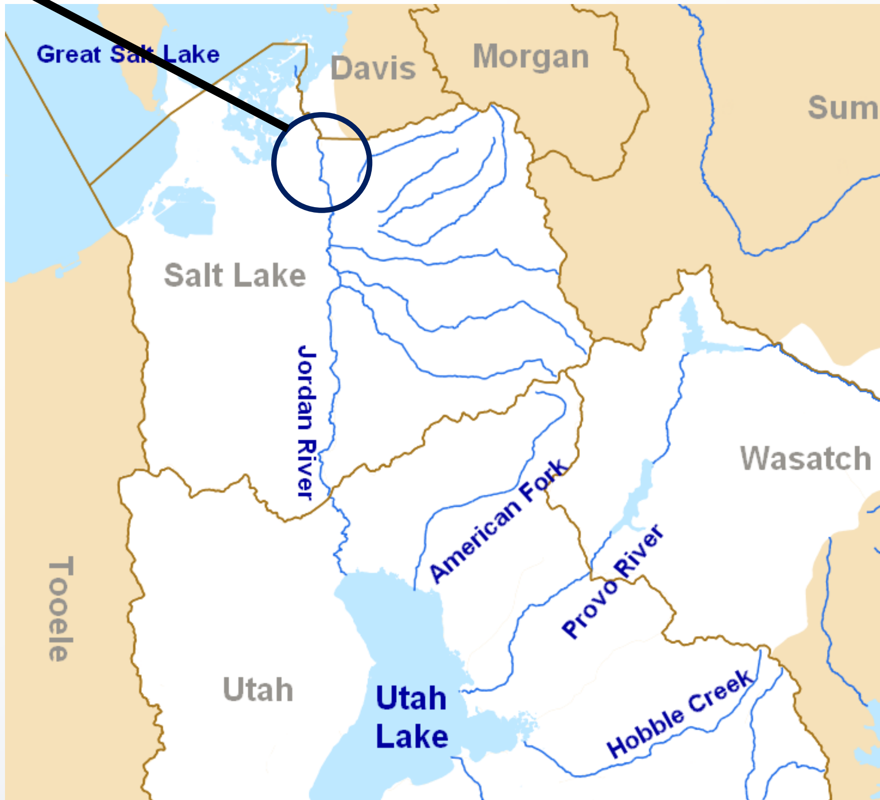
- Nitrogen enters the water through precipitation, runoff, or as N_2 from the atmosphere.



Objectives of this study

1. Nitrogen dynamics in the aquatic ecosystem
   - Nitrification rate in Jordan River sediment
   - Denitrification rate in Jordan river sediment
   - Moelcular analysis on sediment
2. Leaf Leachate as an organic carbon source for denitrifiers
   - Characteristics of leaf leachate
   - Biodegradability of leaf leachate

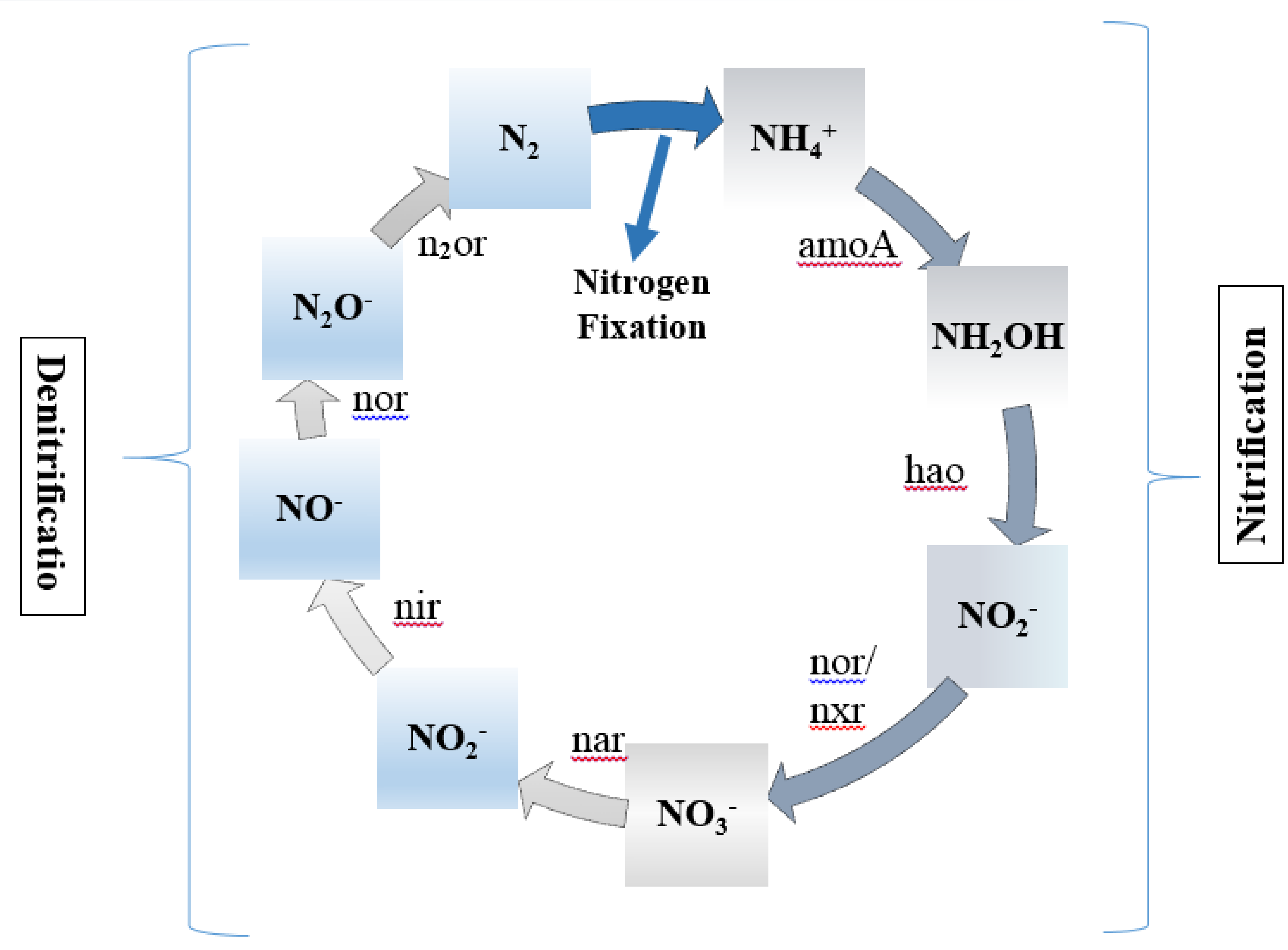
Research Area



Process of Nitrification & Denitrification

- Nitrification is an **aerobic process** performed by chemo-autotrophic bacteria where ammonia is oxidized to nitrite followed by the oxidation of nitrite to nitrate. .
- Denitrification is the dissimilatory reduction of nitrogen oxides (NO_3^-, NO_2^-) to the gaseous oxides (nitric oxide NO, and nitrous oxide N_2O), which may themselves be further **reduced to dinitrogen** (N_2).
- Stoichiometry of Denitrification with acetate:

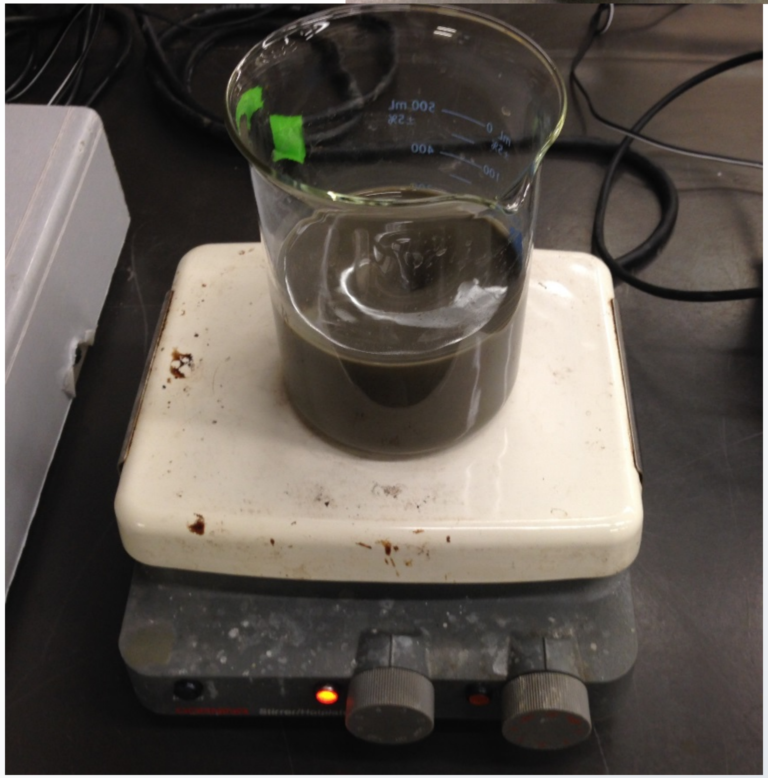
$$0.125\ CH_3COO^- + 0.1438\ NO_3^- + 0.1438H^+ \rightarrow 0.0122C_5H_7O_2N + 0.0658\ N_2 + 0.125HCO_3^- + 0.0639CO_2 + 0.1543\ H_2O$$



Methodology for Nitrification

Nitrification experiments were performed using sediments collected from the top 5-cm of river bed. Ammonium Chloride was added as a source of nitrogen.

- Sediment is homogenized
- Nitrification experiment is performed
  - with ammonia spike
  - without ammonia spike
- Nitrification inhibition is performed using 50 mg/L allylthiourea.
- Each batches were stirred and aerated continuously
- Volatile solids were measured to express the rate



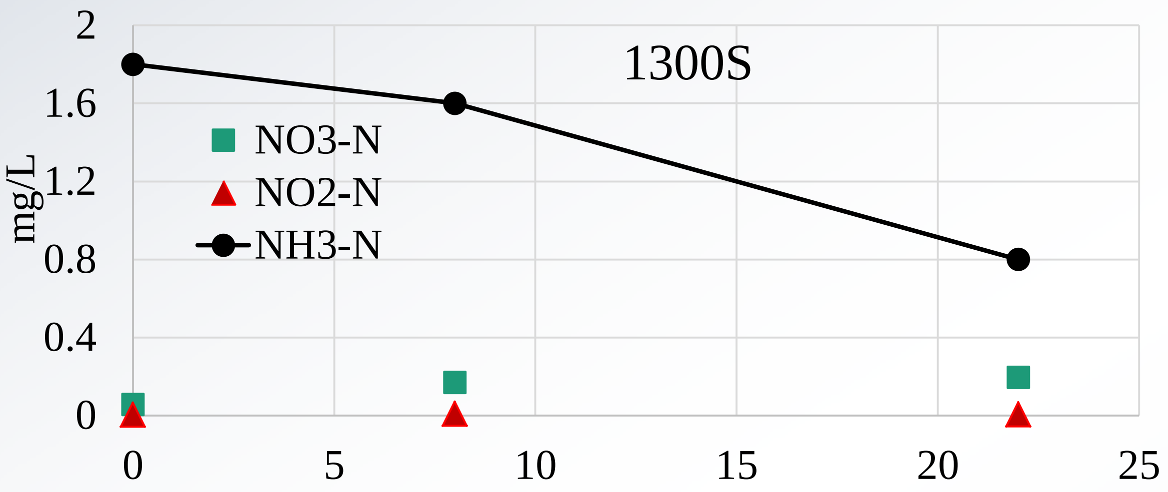
Methodology for Denitrification

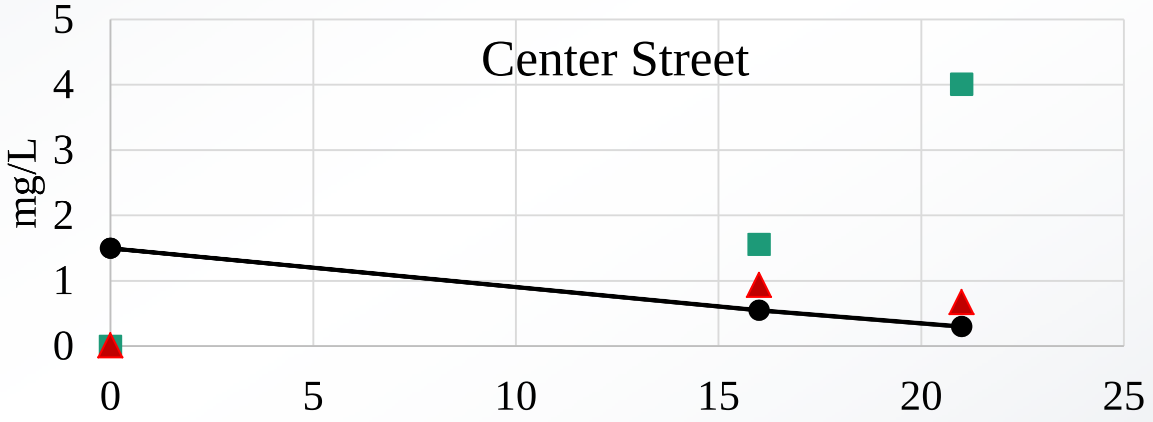
Sediments were used from 5-10 cm depth of the Jordan River

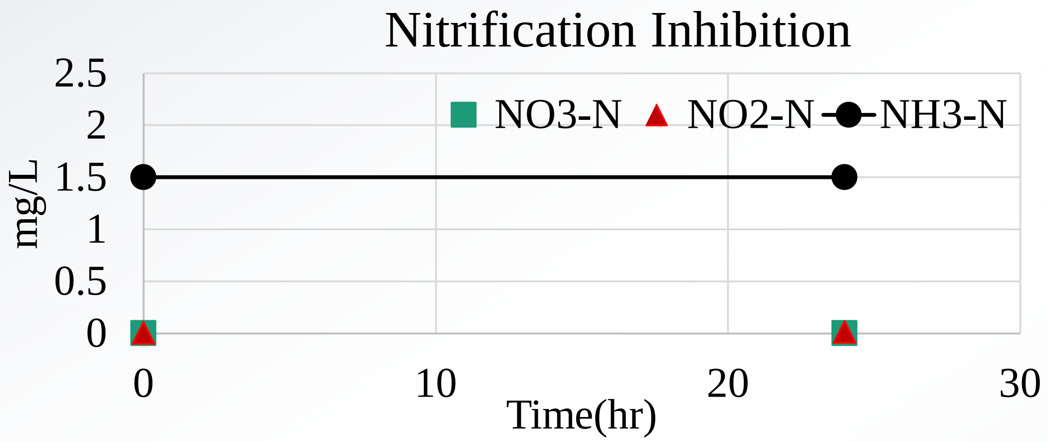
- Slurry was homogenized
- Serum bottles were prepared in two different batches
    i. Nitrate Spike without carbon source
    ii. Nitrate Spike with Acetate as carbon source
- N_2 gas was purged to make each system anoxic
- Volatile solids were measured to express the rate

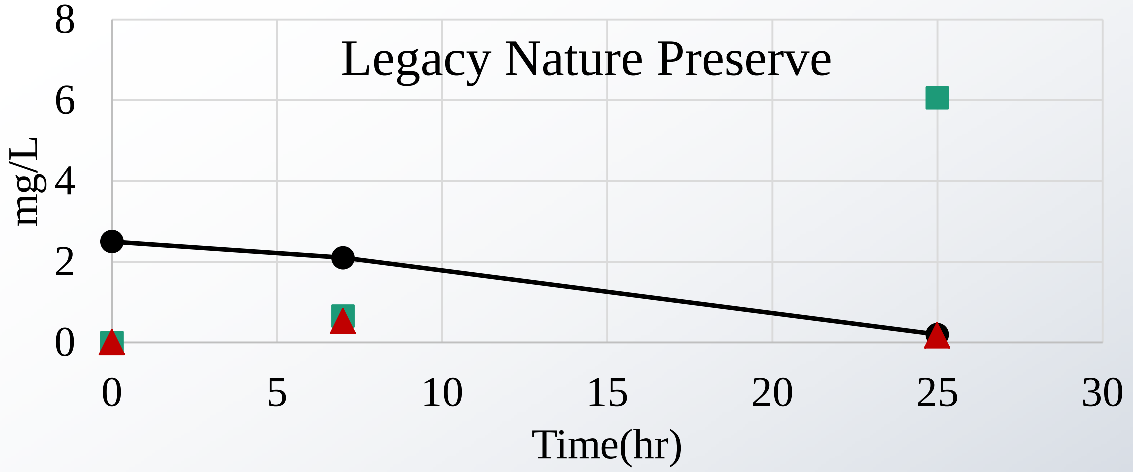
Nitrification

- Ammonia-nitrogen decreased from 2.5 to 0.2 mg/L for LNP, from 1.5 to 0.3 mg/L for Center Street and from 1.8 to 0.8 mg/L for the 1300 S site respectively.
- Nitrification confirmed in all sites
- Increase in Nitrate-nitrogen is non-stoichiometric. A release in ammonia from sediment or ammonification could occur which is oxidized in to nitrate.



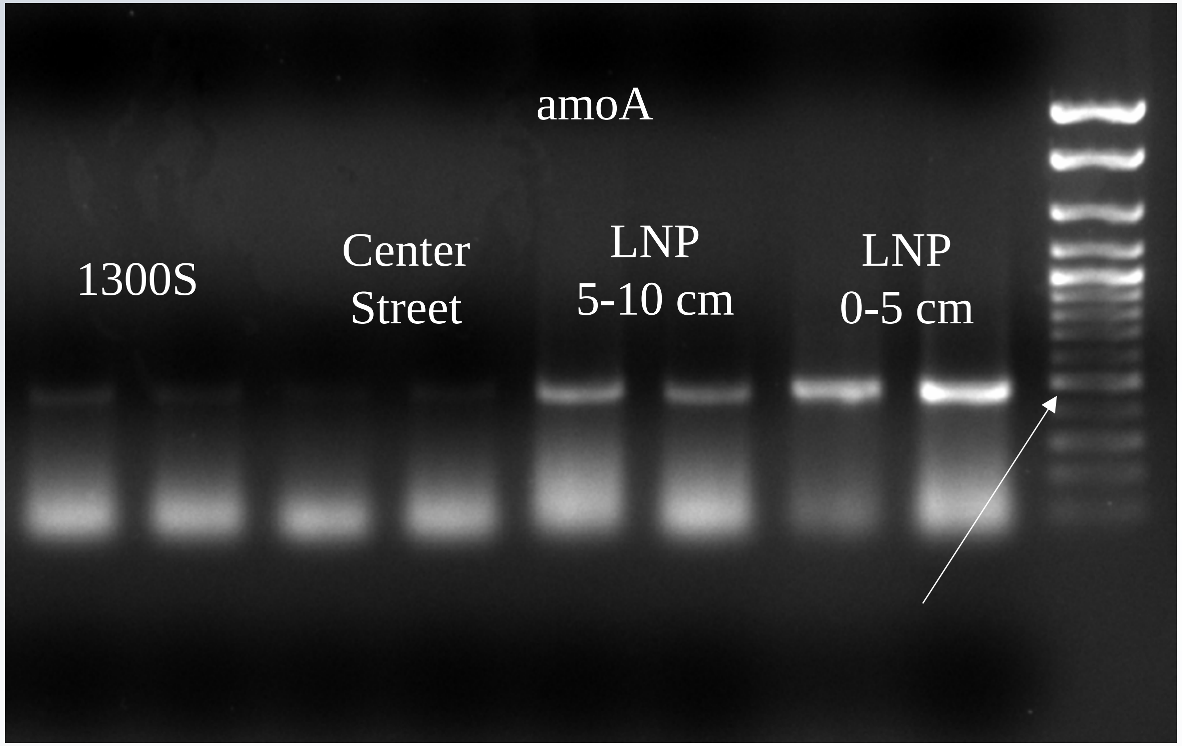






Molecular analysis

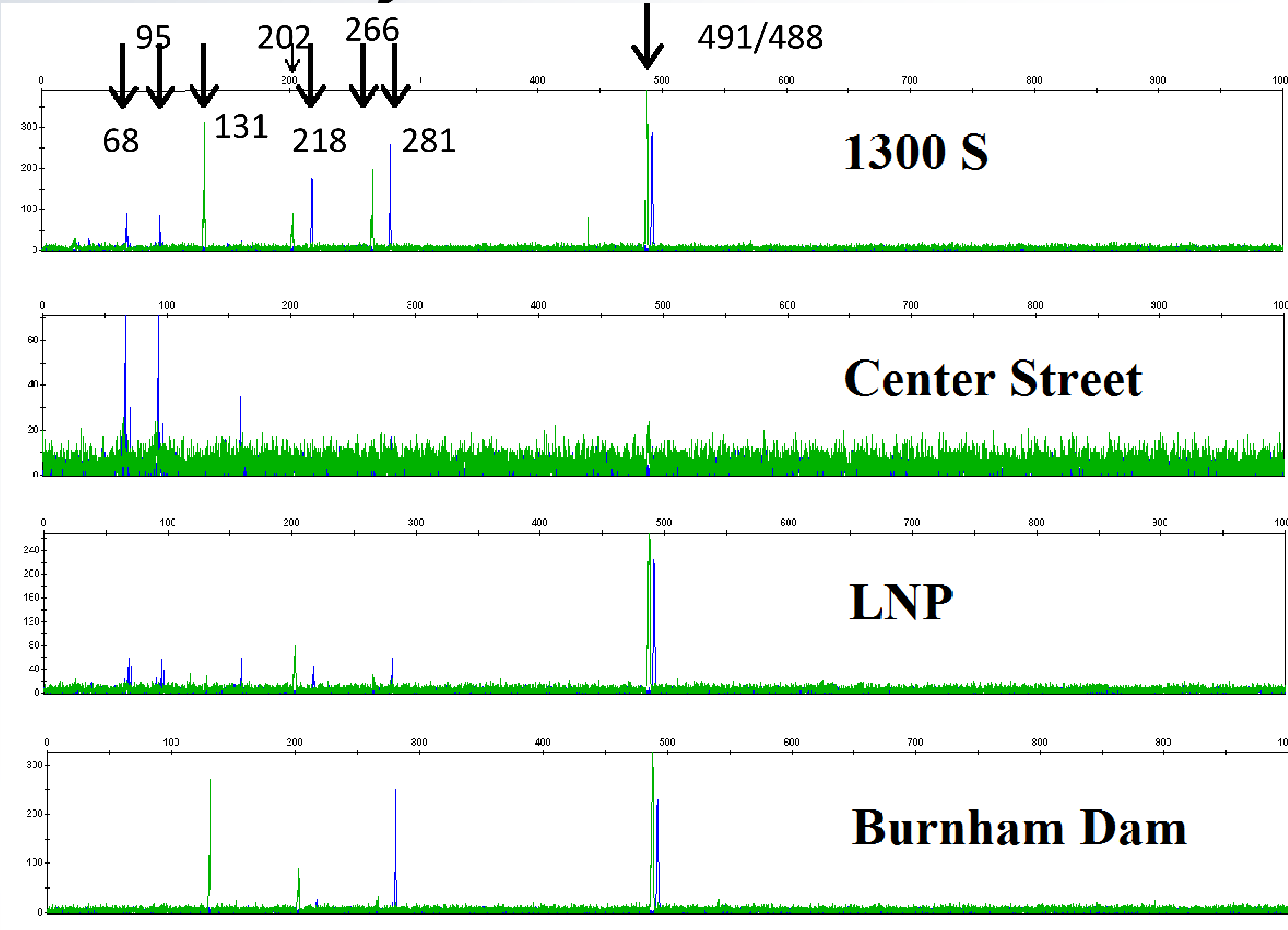
Legacy nature preserve site has the highest amount of amoA gene copy number supporting the fact that this site has higher nitrification rate than other 2 sites.



q-PCR	amoA Gene copies per mg sediment	Nitrification rate(mg-N/gm VS/day)
1300 S	No Peak	0.178
Center Street	No Peak	0.251
Legacy Nature Preserve	7.34E+05	0.468

Molecular analysis : T-RFLP

Lineage	Base pair	Site Name
Nitrosomonas europaea/eutropha lineage	218/266, 491/488	1300 S
		LNP
Nitrosospira lineage	281/202, 491/488	1300 S
		LNP
		Burnham Dam
N. oligotropha/N. europaea lineage	~/130, ~131, 491/488	1300 S
		Burnham Dam

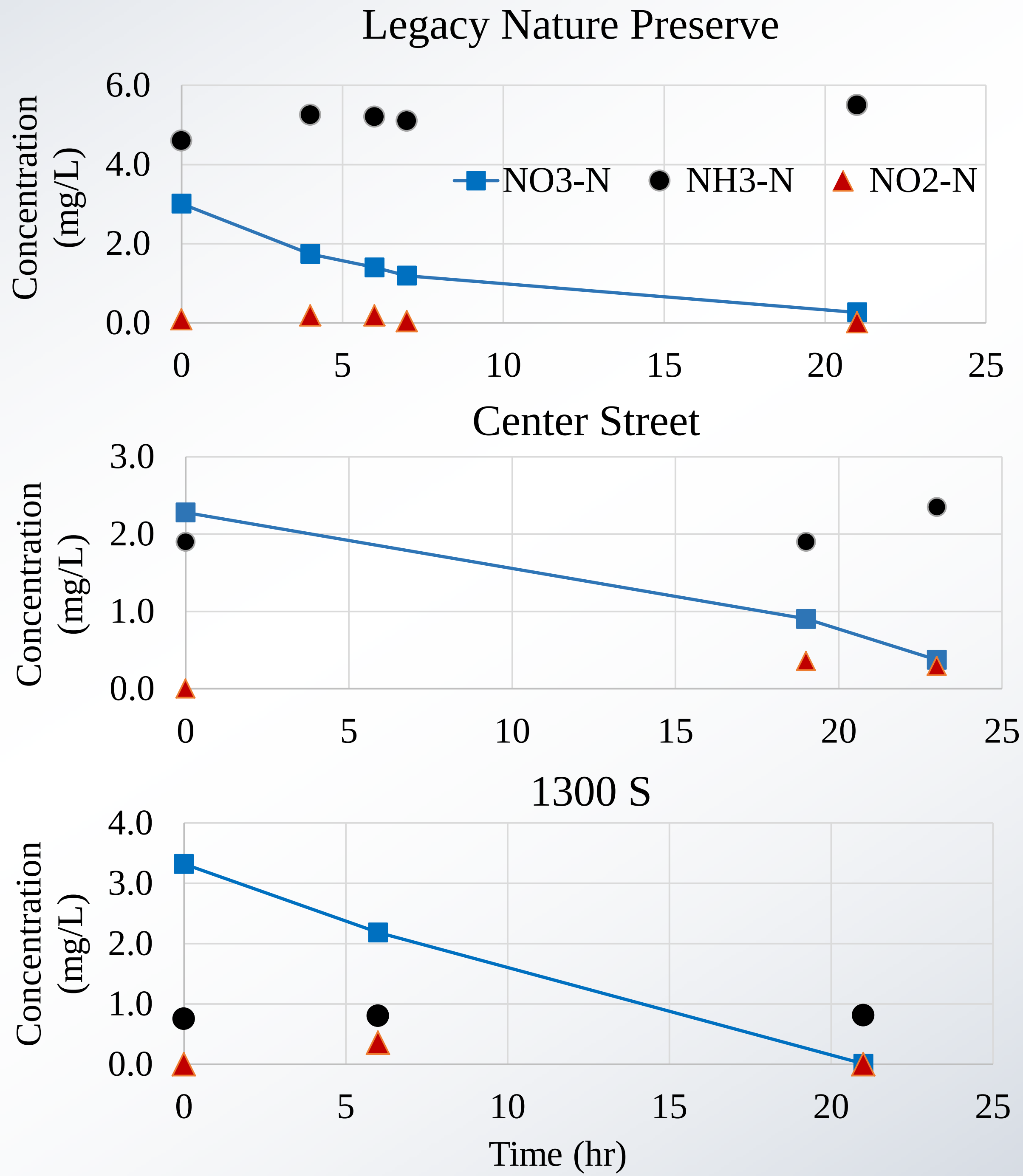


Denitrification

No added carbon source

Denitrification kinetics without using any added carbon source

- NO_3^-N concentration decreased in all experiments corresponding to each sites
- The decreases in NO_3^--N concentrations were 3.0 to 0.26 mg/L for LNP, from 2.3 to 0.37 mg/L for Center Street and from 3.3 to 0.01 mg/L for the 1300 S site
- This concludes significant denitrification activities in the sediment

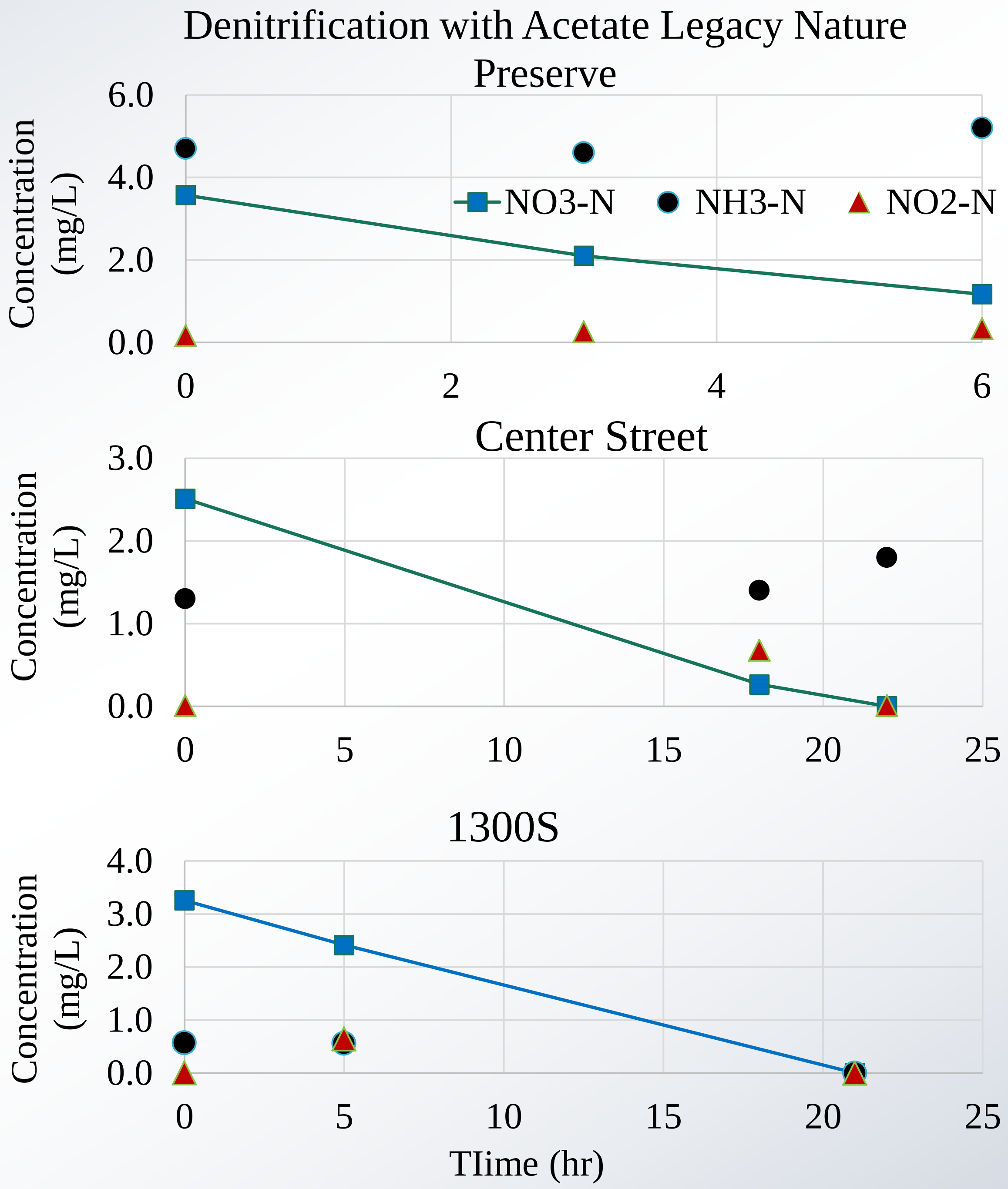


Denitrification

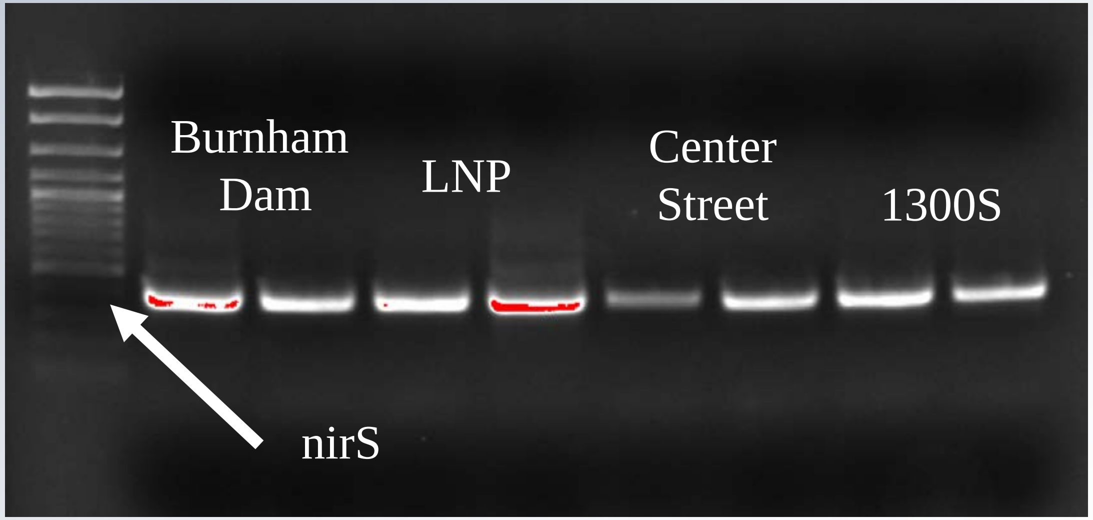
Sodium acetate as carbon source

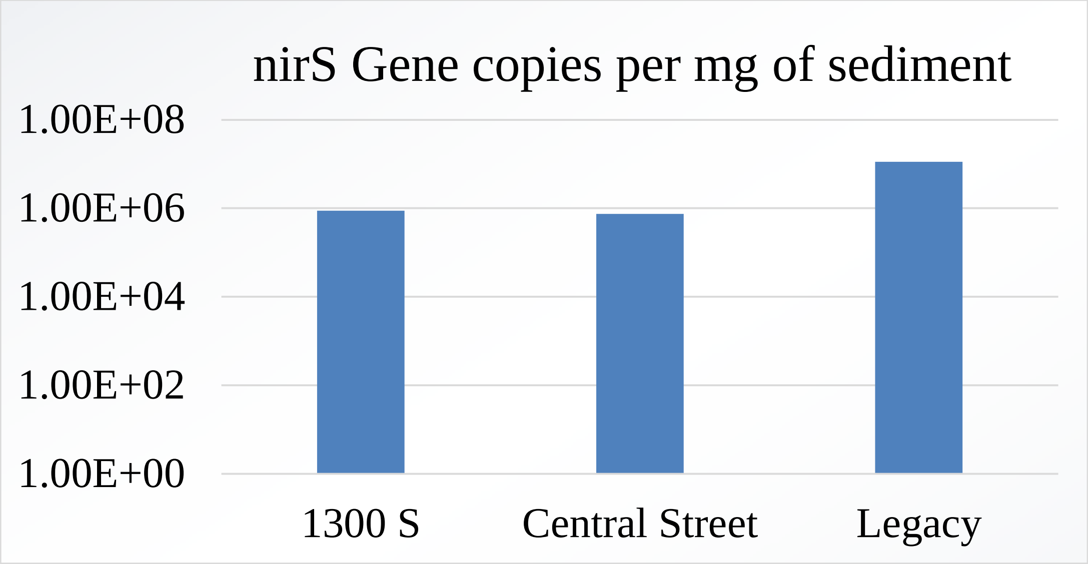
Denitrification kinetics using sodium acetate as an organic carbon source

- Denitrification was significantly enhanced by the addition of acetate at LNP site
- For the Center Street site the denitrification rates increased from 0.847 mg-N/g VS/day to 1.10 mg-N/g VS/day with the addition of acetate.
- For the 1300 S site the denitrification rate were 0.713 mg-N/g VS/day without adding acetate and 0.734 mg-N/g VS/day after adding of acetate.
- On the other hand, for the LNP site, the denitrification rate increased from 1.092 to 2.11 mg-N/g VS/day in the batches with the addition of acetate.



Molecular analysis



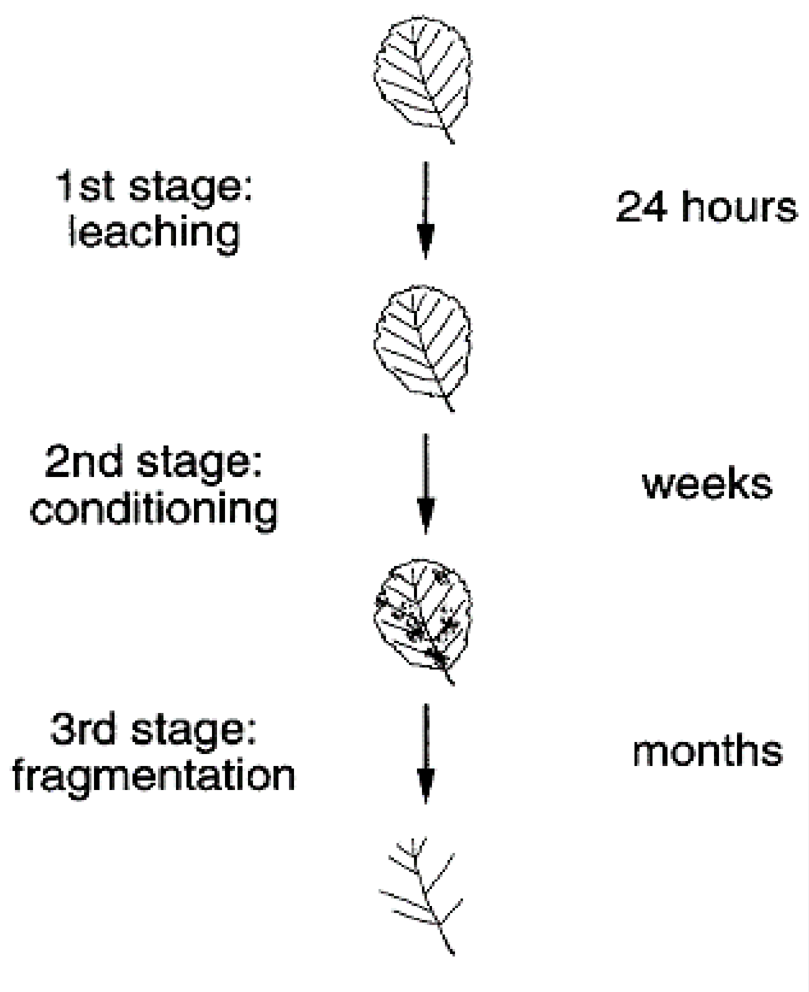


Site name	nirS Gene copies per mg of sediment	Denitrification rate(mg-N/gm VS/day)	
		C Source: None	C source: Acetate
1300 S	8.84E+05	0.713	0.734
Center Street	7.50E+05	0.847	1.10
Legacy Nature Preserve	1.12E+07	1.092	2.11

- nirK gene was not present in any site. Denitrification rate was compared with nirS gene copy number.
- Higher Denitrification rate at LNP site is supported by its higher gene copy number

Leaf Leachate

- Leaching is considered to be the characteristic mechanism initiating leaf breakdown in aquatic environments
- Substantial mass loss within 24 hour after immersion of leaves (Petersen and Cummins 1974, Benfield 1996)
- Considerable variation in leaching behavior in relation to riparian tree species composition, climate, and a variety of other factors
- The high nutrient levels in urban runoff are thought to result from the leaching of piles of leaves in street gutters by the runoff (Cowen and Lee, 1973).

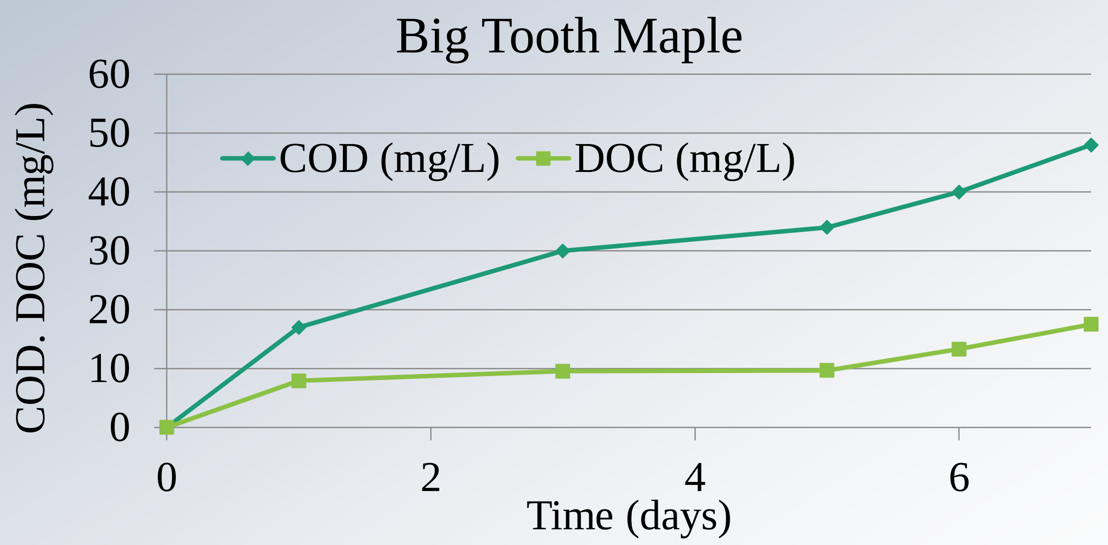


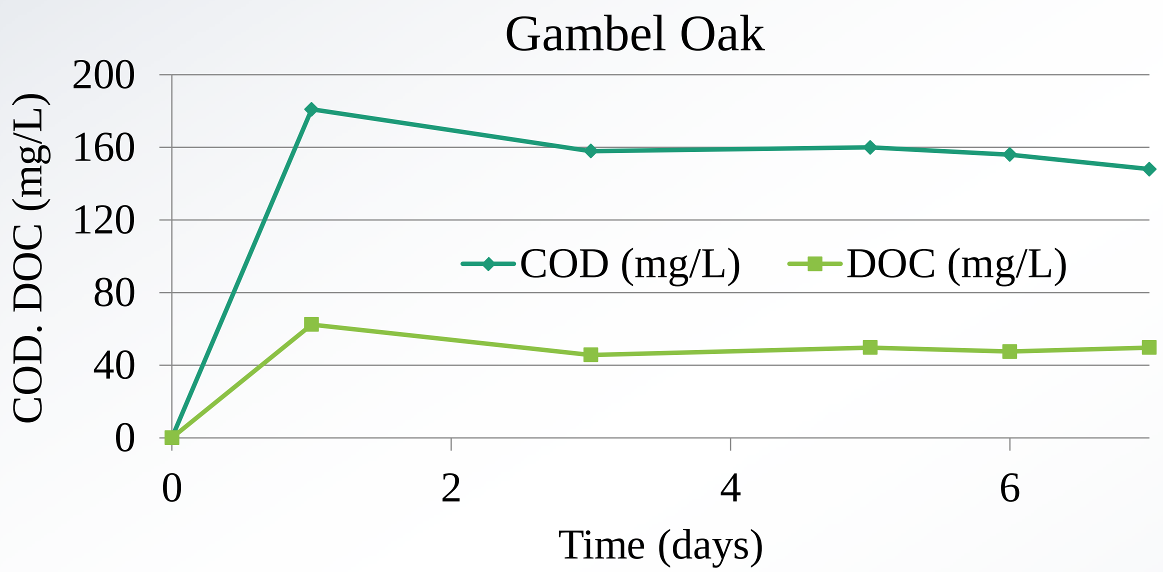
Methodology

- Big-tooth Maple (*Acer grandidentatum)* and Gambel Oak (*Quercus gambelii*) were taken in to account for this study
- Leaves are washed with DI water and dried at 65℃ overnight
- Dried leaves are immersed in to deionized water for each reactor batch.
- Water was stirred to replicate environmental condition
- Sample water was taken at 24 hour interval for 7 days.This water sample was filtered and used to measure different characteristic parameters.
- Serum bottle denitrification experiments has been run using this leachate as an organic carbon source.

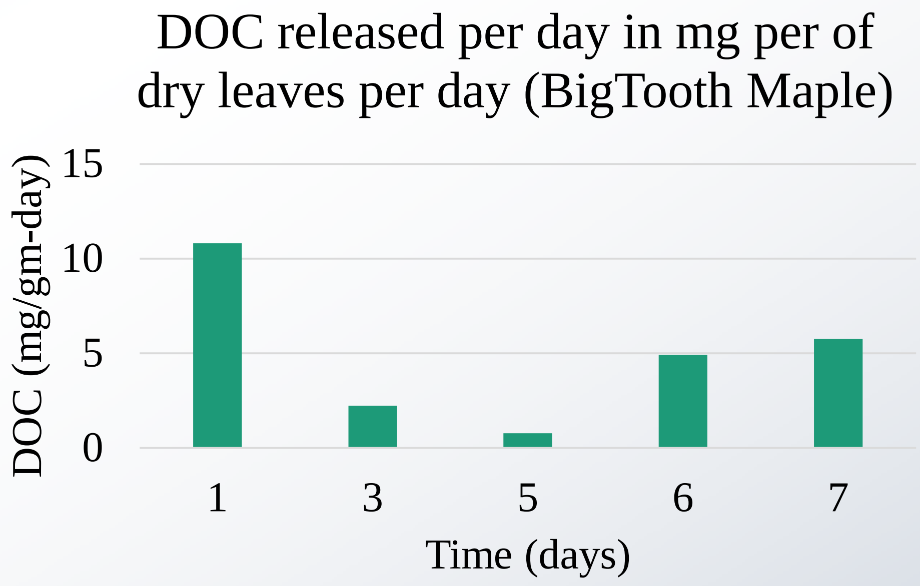
Experimental Set up

Leached Organic Carbon



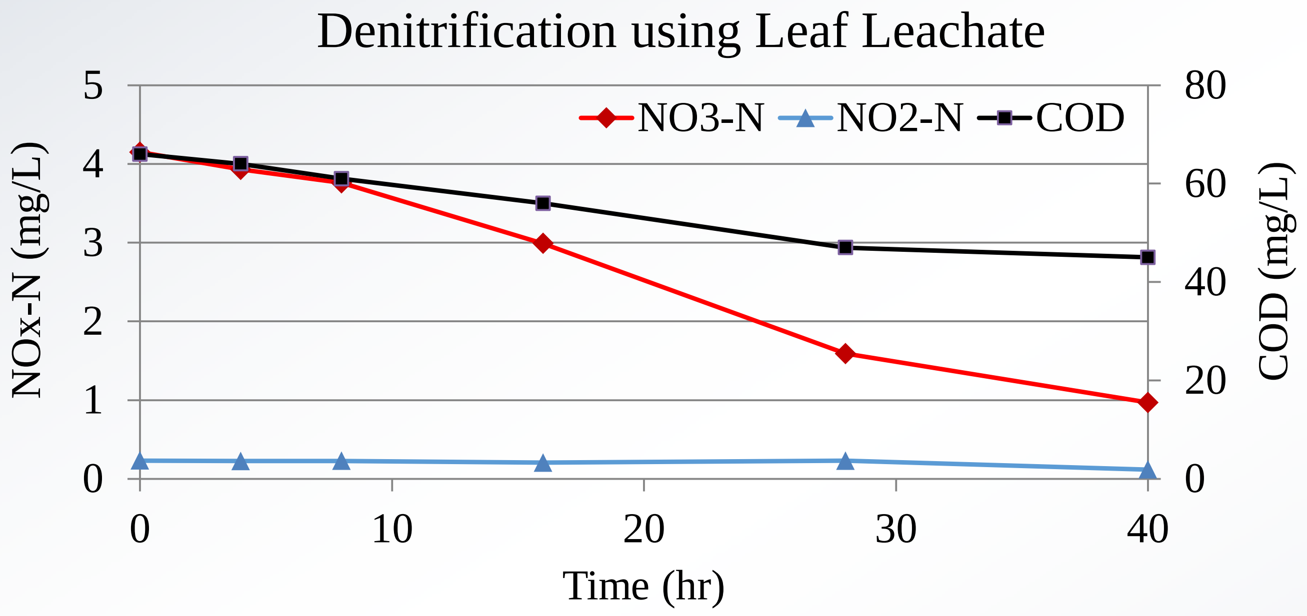


- For Gambel Oak leaves, most of the organic carbon is leached within 24 hour time where Bigtooth Maple leached organic carbon slowly with time.
- 10.8 mg of dissolved organic carbon is leached from 1gm of dry Bigtooth maple leaves in a day
- COD to DOC ratio is almost 3.0



Biodegradability

- Denitrification experiments were done in serum bottle using leaf leachate as organic carbon source and activated sludge as biomass.
- Results illustrates a decrease in nitrate nitrogen from 4.1mg/L to 1mg/L in 40 hours.
- Denitrification rate is higher when sodium acetate is used as a source of carbon



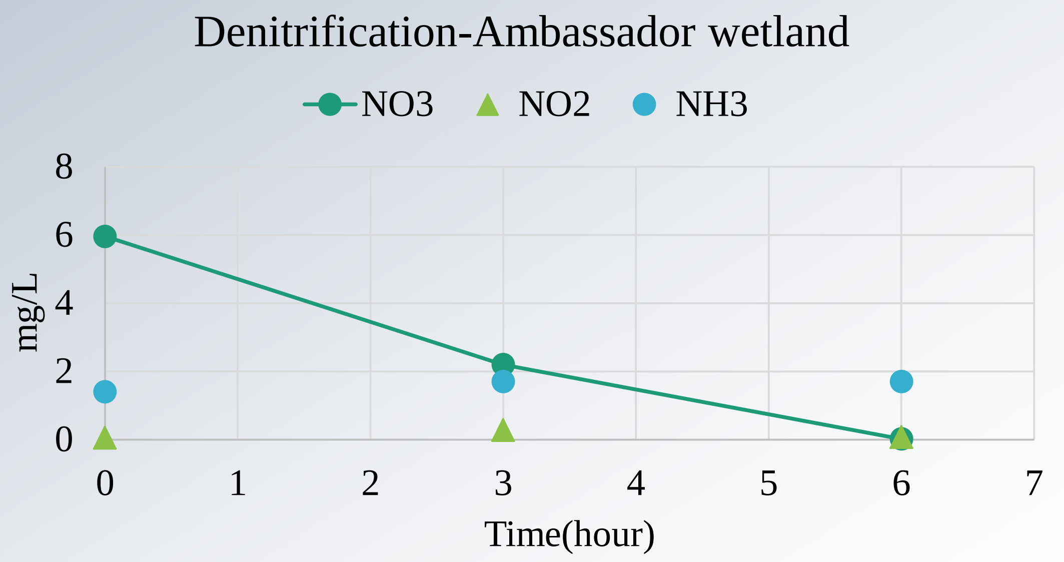
- Denitrification rates were also measured using Jordan river sediment as biomass and i) leaf leachate as carbon sources, ii) sodium acetate as a carbon source and iii) no carbon source.
- In all cases denitrification rates were higher when leaf was used as carbon source than that when no carbon sources were used

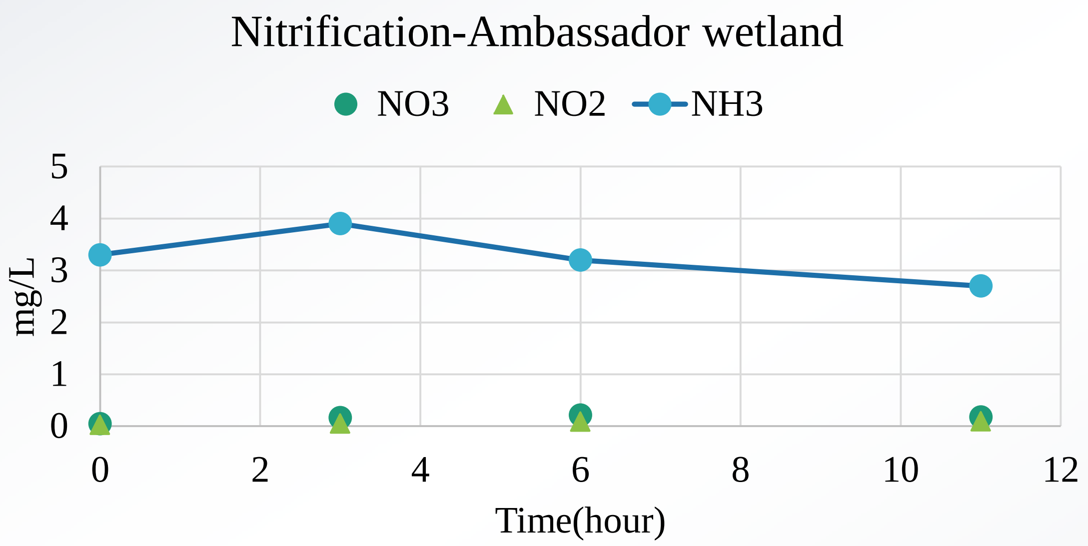
Denitrification rates (mg-N/gm VSS/day)			
Biomass	Carbon Source		
	Leaf Leachate	Acetate	None
1300 S	1.85	2.47	0.713
Legacy Nature Preserve	1.78	2.88	1.09
In-house ASP	2.21	58.8	N/A

Conclusion

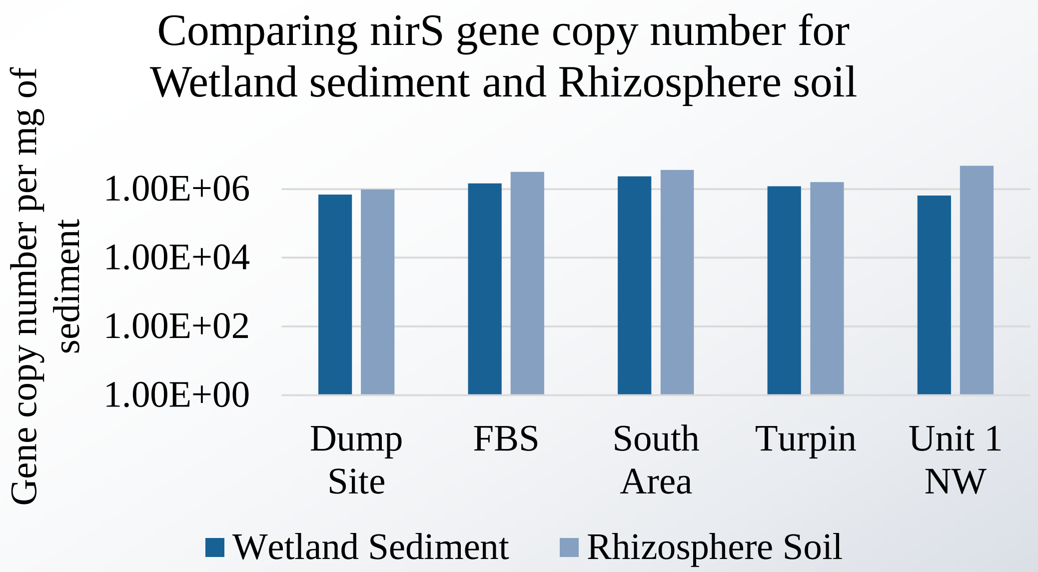
- Jordan River sediment is active in ammonia oxidation. Legacy Nature Preserve site has the highest rate of nitrification along with the highest amoA gene copy number.
- Jordan River sediment is active in Nitrate reduction. Legacy Nature Preserve site has the highest rate of denitrification along with the highest nirS gene copy number.
- nirS gene dominates in the Jordan River. nirK was not detectable
- Leaf leaches biodegradable organic carbon.
- Leached organic carbon is biodegradable and helps increase denitrification rate in river sediment.
- Characteristics of leaf leachate differs depending on the species of leaves.

Other research, Future Works





- Denitrification Experiments using N15
- C13/N15 analysis on various samples including algae, leaf, sediment, waste water effluent along Jordan River.



Acknowledgement

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Thank you

Questions ?