Inorganic nitrogen dynamics in an urban constructed wetland under base-flow and high-flow conditions

Miranda A. Kearney[1*], Weixing Zhu[1], and Joseph Graney[2]

[1]Biological Sciences, State University of New York at Binghamton, Binghamton, NY

*(Miranda.Kearney@gmail.com)

[2]Geological Sciences, State University of New York at Binghamton, Binghamton, NY

Research Questions:

1. Can retention wetlands serve as nitrogen sinks?

   Hypothesis 1

   On an annual basis, there will be a net retention of N.

2. Is there seasonality in nitrogen input, output, and retention?

   Hypothesis 2

   Seasonal variation of wetland processes (eg. plant growth and microbial denitrification) will affect available nutrient concentrations in surface water and nutrient retention in the ecosystem.

3. How does water discharge rate (high-flow versus base-flow) affect retention?

   Hypothesis 3

   N retention is affected by the hydrological condition of the wetland; less N will be retained during storm events than under base flow conditions.

Site Description:

This study was conducted in an urban retention wetland (Lake Lieberman- LL) on the Binghamton University campus, Binghamton, NY. It is approximately 0.15 ha in size and receives inputs of a variety of contaminants that are flushed from the campus parking lots and roadways that it drains (Fig.1). The water that passes through the system is discharged into the Fuller Hollow Creek, a first-order stream, which drains directly into the Susquehanna River, the major tributary of the Chesapeake Bay.

Methods:

Base-flow:

Base-flow Water Sampling:

- Grab samples collected at inlet and outlet.
- Vacuum filtered and acidified for preservation.

Discharge Measurements:

- Height of water over weir
  $$Q = K (L - 0.2H) H^{1.5}$$
- Hand held flow meter and measuring tape to construct area weighted cross-sections

High-flow:

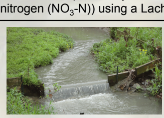
High-flow (storm event) sampling:

- ISCO 6712 automated samplers were installed at the inlet and outlet of the wetland and programmed to take samples during high flow events
- Vacuumed filtered and acidified for preservation.

Discharge Measurements:

- Use stage height to calculate
  $$Q = K (L - 0.2H) H^{1.5}$$

All water samples analyzed for total inorganic nitrogen (ammonium nitrogen (NH_4-N) + nitrate nitrogen (NO_3-N)) using a Lachat QuickChem Autoanalyzer 8000 Series.



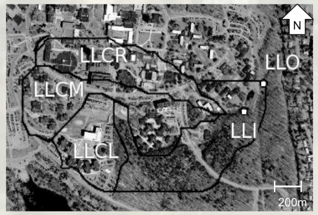


Figure 1: Arial view of Lake Lieberman (LL) drainage area (LLCR, LLCM and LLCL drain into LL through 3 culverts at LLI (Inlet). LLO; location of the outlet.

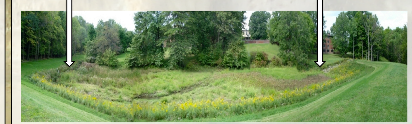


Figure 2: View of the wetland looking west with the inlet and outlet sampling locations indicated.

Results

Base-flow

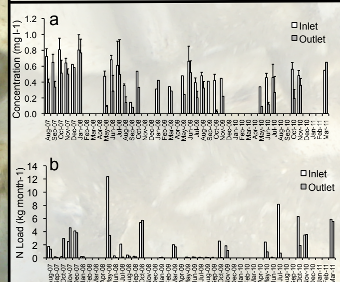


Figure 3: Surface water concentrations of N (a) and monthly N flux (b) at the inlet and outlet of the LL wetland. There was no data collected for 2/08-4/08, 11/08-12/08, 2/09, 4/09, 12/09-4/09, 8/10-9/10 and 12/10-2/11. Sampling intensity varied between 1 and 4 samples per month

1. 60 sampling events summarized on a monthly basis
2. 2 months where outlet concentration was higher than the inlet concentration
   - Winter months (Jan 09, March 11)
3. 4 months where the flux was higher at the outlet than the inlet
   - All autumn months (Oct 07, Nov 07, Oct 08, Nov 10)
   - Likely the result of seasonal variation in hydrology (groundwater source increasing discharge at the outlet)

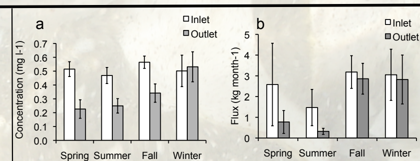
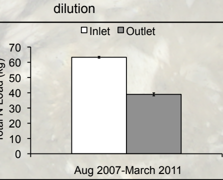


Figure 4: Seasonal variation (± 1 S.E.) in average surface water N concentration (a) and N flux (b) at the inlet and outlet of the LL wetland.

1. Concentration at the inlet and outlet significantly different in spring, summer and fall but not in winter (Paired t-test: P< 0.001)
   - Biological uptake (plants/microbes)?

     or
   - A dilution effect?
2. Flux at the inlet and outlet significantly different in the spring and summer but not in fall and winter (Kruskall-Wallis: P= 0.019)
   - Spring and summer concentration reduction likely the result of biological uptake
   - Fall concentration reduction is probably the result of dilution



<u>Over 4-year sampling period:</u>

IN: 63.29 kg N

OUT: 38.97 kg N

38% removal

Wilcoxon signed-rank test: n=27; P= 0.005

High-flow (Storm Events)

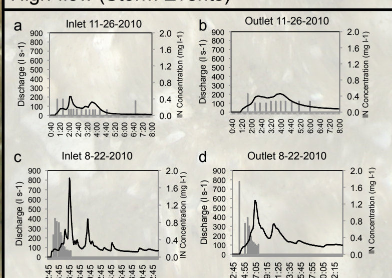


Figure 5: Hydrographs (solid black lines) and IN concentrations (gray bars) measured at the inlet and outlet during two different storm events (Nov 26 and Aug 22). (a) and (b) are examples of an event where samples were collected across the entire storm. (c) and (d) are examples of an event where sampling capacity was exhausted before the end of the storm.

Table 1: Discharge, load, flow weighted average concentration and total precipitation for each recorded high-flow storm event in the wetland. *Indicates a fully sampled storm event (a complete set of samples was collected across the hydrograph).

	Discharge (m^3)		Flow Weighted Mean IN Concentration ($mg\ l^{-1}$)		N Load (kg)		N-Export (kg)	Total Precipitation (cm)
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet		
2010								
Jul 14	3929	5638	1.041	0.612	4.09	3.45	-0.64	1.30
Jul 22	6780	6452	0.354	0.630	2.40	4.07	1.66	2.11
Aug 22	8758	11859	0.334	0.592	2.92	7.02	4.10	2.49
*Sept 22	2492	2111	0.973	0.862	2.20	1.79	-0.41	0.20
*Oct 27	1891	2753	0.330	0.461	0.62	1.27	0.65	0.89
*Nov 26	1672	3576	0.192	0.272	0.27	0.70	0.43	1.09
2011								
Mar 5 & 6	10058	9646	0.155	0.329	1.56	3.18	1.61	1.70

<u>7 Storm Events:</u>

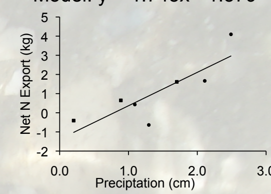
IN: 15.33 kg N

OUT: 23.00 kg N

N export was 34% greater than the input during the 7 storm events.

Storm-events:

Model: $y = 1.745x - 1.379$



1. N-export increases with increasing precipitation
2. Threshold for retention: 0.791 cm

Daily precipitation values obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center at Binghamton, NY (ID: US1NYBM0011, Binghamton 1.8 SW, 42.083º, -75.933º)

<u>July 2010-March 2011 (monitoring period)</u>

- 108 precipitation events
- 32 events > threshold for N retention
- 28 trace precipitation events (precipitation of less than 0.025 cm)
- 2 events outside the range of model (5.2 cm and 12.7 cm) not included
- **Calculated <u>net retention</u> of 39.98 kg N**

<u>January 2011-December 2011</u>

- 163 precipitation events
- 60 events > threshold for N retention
- 16 trace precipitation events
- 3 events outside the range of model (5.2cm, 5.2cm, and 18.2cm) not included
- **Calculated <u>net export</u> of 32.98 kg N**

Conclusions:

1. N retention and N export are highly dependent on hydrologic discharge.
2. Constructed wetlands retain N under base-flow (low discharge) conditions.
3. Reduction of NPS pollution during storms is dependent on storm size and intensity.
4. More detailed studies of urban constructed wetland systems under variable hydrologic conditions, including extreme storm events, are needed to determine the impact of storms on annual N-export budgets.

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