Nitrogen and Phosphorus Dynamics in a Mixed-Use Ohio Watershed

Kay C. Stefanik, S. Mažeika P. Sullivan, Lauren M. Pintor, and Kaiguang Zhao
School of Environment and Natural Resources

THE OHIO STATE UNIVERSITY

ABSTRACT

Nutrient enrichment of inland aquatic ecosystems is a growing concern. Here, we assess nutrient loading of streams and their receiving reservoir within a mixed-use (urban, forested, and agricultural) catchment. Fifteen stream and three reservoir sites within the Big Walnut Creek watershed in central Ohio were surveyed for nutrients and oxygen isotopes of dissolved phosphate ($\delta^{18}O_p$) in the summer and fall of 2016, as well as in winter 2017. Initial stream data (summer through winter) show that total phosphorus (P) ranged from 0.03 to 0.68 mg L^{-1}, orthophosphate (PO_4) from 0.01 to 0.57 mg L^{-1}, total nitrogen (N) from 0.44 to 5.79 mg L^{-1}, and nitrate (NO_3) from 0.02 to 4.98 mg L^{-1}. Much less variability was observed in the reservoir for P compounds, possibly due to precipitation and biological uptake within the streams or the reservoir itself. Maximum reservoir values for total P and PO_4 were 0.1 mg L^{-1} and 0.06 mg L^{-1}, respectively. N compounds, however, were found at values equal to or higher than those of the streams (maximum total N: 5.46 mg L^{-1}; maximum NO_3 : 1.73 mg L^{-1}), pointing to nutrient transformations or release occurring within the reservoir. Preliminary results of equilibrium values and oxygen isotope signatures of dissolved PO_4 support the use of mixing models to identify sources of P within the watershed. We expect that this work will contribute to the current understanding of nutrient dynamics in urbanizing catchments.

BACKGROUND

Nutrient runoff and eutrophication has been a growing concern over the last few decades as incidents of harmful algal blooms have increased. Runoff from agriculture, urban areas, and industry are major anthropogenic stressors in watersheds (Fig. 1), which can alter not only the condition of stream and river ecosystems, but also the quality of the lakes they feed (Carpenter et al. 1998, Danz et al. 2007). Whereas nutrient inputs are most commonly linked to eutrophication, excess nutrients can exert bottom up controls within ecosystems that alter not only basal resources, but the entire food web, impacting biodiversity and community composition (Allan, 2004). An important step in reducing eutrophication, harmful algal blooms, and impairment of freshwater ecosystems is to understand where nutrients originate and the transformations these nutrients undergo as they ultimately flow into lakes and reservoirs. In Ohio, much of the research on nutrients and eutrophication has focused on the Lake Erie basin, yet, the Ohio River basin represents 70% of Ohio (Schiefer 2002), with eutrophication occurring in reservoirs in a variety of land-use types. **The objective of this study is to monitor N and P concentrations of inland rivers and lakes, targeting relative contributions from different land uses and examining how source contributions change on a seasonal basis.**

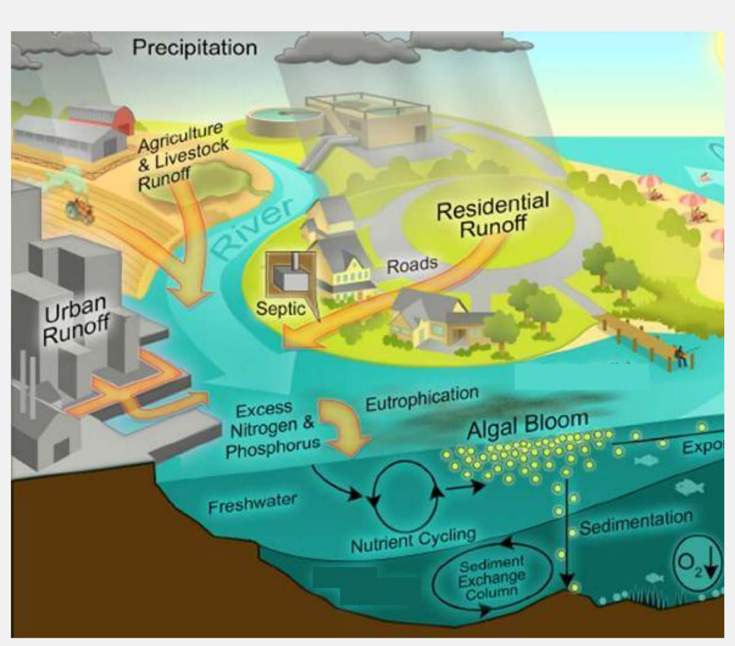

Figure 1. Sources and fates of nutrients within freshwater ecosystems. Modified from Paerl et al. (2006).

STUDY SYSTEM

This study was conducted in the mixed-use, upper portion of Big Walnut Creek Watershed near Columbus, Ohio. We monitored 15 stream reaches and 3 lake sites across land-use types (Fig. 2). Chemical water-quality samples were collected on a bimonthly basis from July 2016 to February 2017.

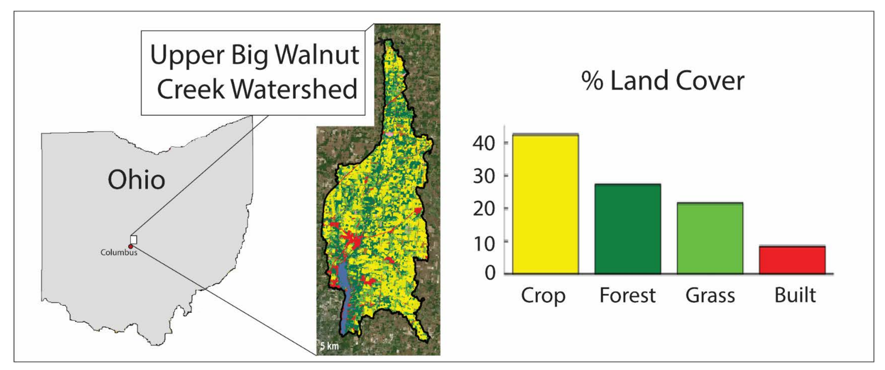

Figure 2. Study area and % land cover in the upper portion of Big Walnut Creek Watershed near Columbus, Ohio.

METHODS

- Temperature, conductivity, DO, pH, and ORP were measured using a YSI 600XL handheld water-quality sonde.
- Turbidity was measured in the lab using a Hach turbidimeter.
- Bulk water samples (Fig. 3a) were analyzed for total N, total P, ammonium (NH_4), NO_3, and PO_4 at the Ohio Agricultural Research and Development Center's STAR Lab.
- Streamflow velocity was measured using a Sontek FlowTracker Handheld ADV (Fig. 3b).
- $\delta^{18}O$ PO_4 samples were collected in fall of 2016 and analyzed at the University of Nebraska's Water Sciences Laboratory (Fig. 3c)

Figure 3. Water collection for nutrient analysis (a), measurement of streamflow velocity (b), and collection containers for $\delta^{18}O$ phosphate samples (c).

- The statistical program R was used for data analysis (R Core Team, 2014) .
- ANOVA and Tukey HSD were used to examine differences in nutrient concentrations by season and land-use type.
- Simple linear regression was used to explore potential relationship between water-quality parameters and nutrient concentrations.
- Patterns of water-quality parameters by site were examined with RDA using the R package vegan (Oksanen et al. 2015).

RESULTS

		Temp (°C)	Cond. (µS/cm)	DO (mg/L)	pH	ORP	Turbidity (NTU)	Total P (mg/L)	Total N (mg/L)	PO_4 (mg/L)	NO_3 (mg/L)	NH_4 (mg/L)
Summer	Streams	24.6 ± 0.5	722 ± 53	8.18 ± 0.04	8.24 ± 0.04	166 ± 3	4.49 ± 1.03	0.07 ± 0.01	0.98 ± 0.01	0.04 ± 0.01	0.24 ± 0.03	0.10 ± 0.01
	Lake	23.9 ± 0.5	327 ± 2	5.05 ± 1.4	8.34 ± 0.13	155 ± 18	5.99 ± 1.3	0.10 ± 0.00	3.35 ± 1.06	0.01 ± 0.01	0.64 ± 0.25	1.67 ± 1.35
Autumn	Streams	9.9 ± 1.3	764 ± 32	10.17 ± 0.5	7.91 ± 0.04	240 ± 5	4.09 ± 0.9	0.09 ± 0.02	2.21 ± 0.30	0.06 ± 0.02	1.37 ± 0.23	0.12 ± 0.02
	Lake	20.1 ± 1.3	348 ± 6	9.69 ± 1.1	8.30 ± 0.14	207 ± 15	4.77 ± 0.89	0.05 ± 0.00	1.14 ± 0.04	0.01 ± 0.00	0.23 ± 0.06	0.12 ± 0.04
Winter	Streams	2.6 ± 0.2	564 ± 30	11.30 ± 0.69	7.89 ± 0.06	265 ± 5	9.26 ± 2.12	0.05 ± 0.00	2.83 ± 0.32	0.04 ± 0.01	1.88 ± 0.28	0.08 ± 0.01
	Lake	5.0 ± 0.2	407 ± 2	6.87 ± 0.15	7.83 ± 0.06	237 ± 9	12.32 ± 1.05	0.08 ± 0.00	2.70 ± 0.02	0.05 ± 0.00	1.69 ± 0.02	0.11 ± 0.02

Figure 4. Water chemistry parameters (mean ± SE) during summer 2016 - winter 2017.

RESULTS

- **Streams**
  - Seasonal differences were seen for total N (ANOVA: $F = 9.09$, $p < 0.001$; Fig. 5a), NO_3 (ANOVA: $F = 9.811$, $p < 0.001$), turbidity (ANOVA: $F = 5.328$, $p = 0.008$), and conductivity (ANOVA: $F = 7.197$, $p = 0.002$).
  - Total P (ANOVA: $F = 3.72$, $p = 0.032$; Fig. 5b) and PO_4 (ANOVA: $F = 5.148$, $p = 0.010$) were different by land-use type, with significant differences seen between agricultural and built/developed areas.
  - Turbidity was positively related to total P ($R^2 = 0.06$, $p = 0.05$), total N ($R^2 = 0.21$, $p < 0.001$), PO_4 ($R^2 = 0.10$, $p = 0.017$), and NO_3 ($R^2 = 0.15$, $p = 0.003$).
  - Overall trends in water quality varied seasonally by site (Fig. 6)

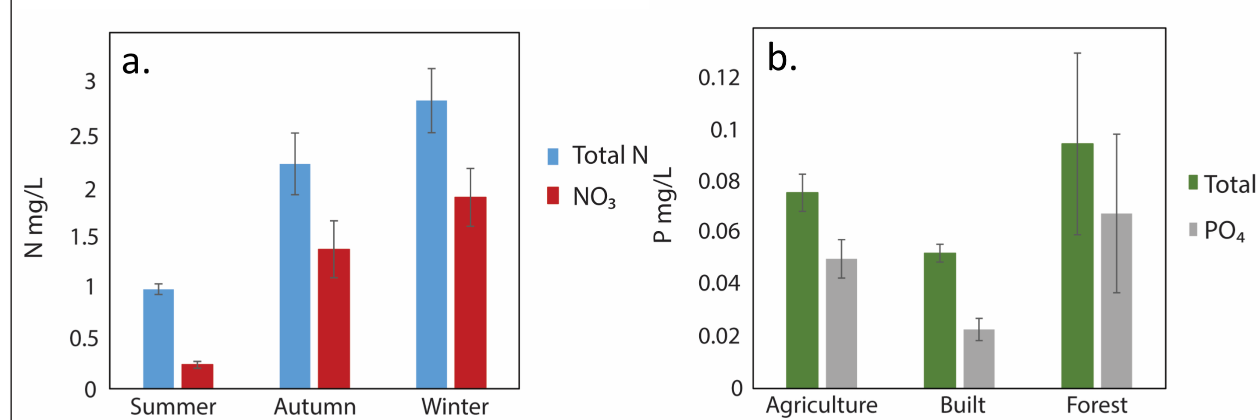

Figure 5. Changes in stream N concentrations by season (a) and P concentrations by land use type (b). Error bars indicate +/- 1 SE.

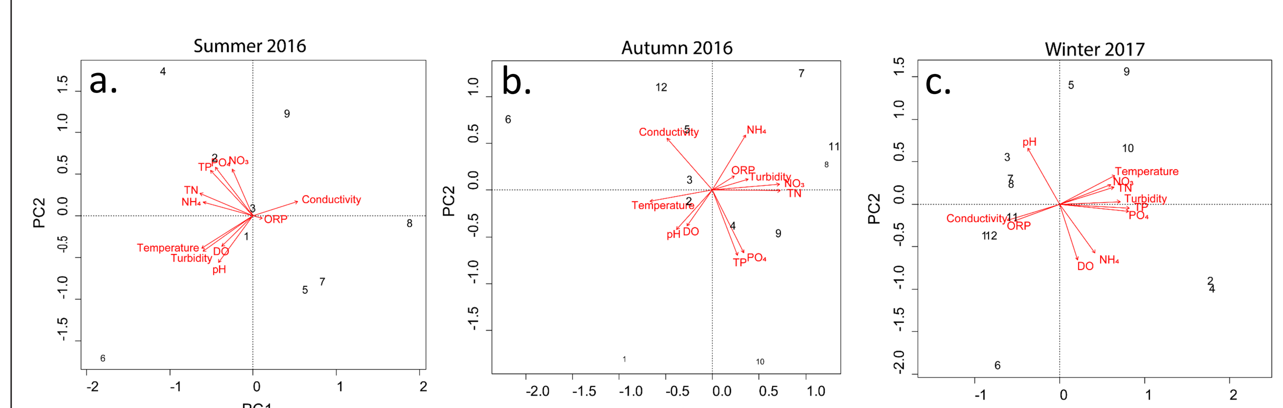

Figure 6. RDA of stream water-quality parameters by season and site. Numbers represent stream sites.

- **Lake**
  - Seasonal differences were seen for total P (ANOVA: $F = 43.36$, $p < 0.001$), total N (ANOVA: $F = 19.99$, $p < 0.001$), PO_4 (ANOVA: $F = 15.84$, $p = 0.001$), NH_4 (ANOVA: $F = 6.354$, $p = 0.019$) , turbidity (ANOVA: $F = 12.64$, $p = 0.002$), and conductivity (ANOVA: $F = 14.84$, $p = 0.001$).
  - No differences in nutrient concentration, turbidity, or conductivity were observed among reservoir sampling sites.

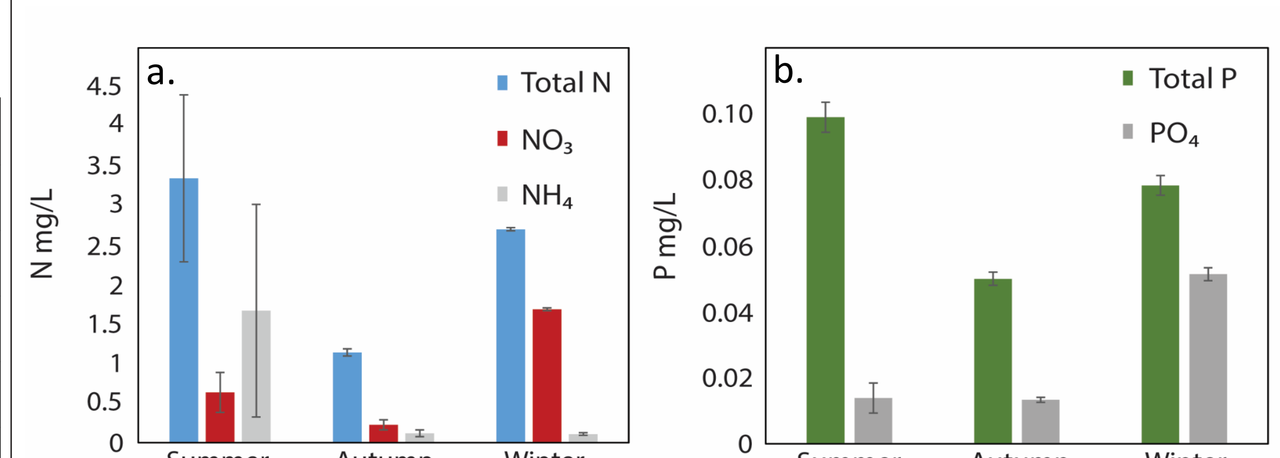

Figure 7. Seasonal differences in nitrogen (a) and phosphorus (b) species within Hoover reservoir. Error bars indicate +/- 1 SE.

CONCLUSIONS

- Stream N species concentrations were seasonally dependent, with increasing levels of total N and NO_3 as seasons changed from summer through winter. These increases may be associated with increased levels of turbidity resulting from higher rates of runoff during wetter months. While in-stream P species were not seasonally dependent, they varied by land-type. Although no differences were observed between agricultural and forested areas, lower levels of total P and PO_4 were associated with built areas.
- Nutrient concentration patterns within the lake did not follow the same trends as in streams. Seasonal patterns were observed within the lake for all three N species and both P species. This difference in trends may be related to nutrient spiraling, transformation, and sequestration of nutrients within streams prior to entering the lake.

NEXT STEPS

- Utilize mixing models with $\delta^{18}O_p$ data to determine relative contributions of PO_4 from different sources based on land use and land cover in the watershed.
- Preliminary data suggest that equilibrium values and variability in isotope signatures will enable differentiation of sources.

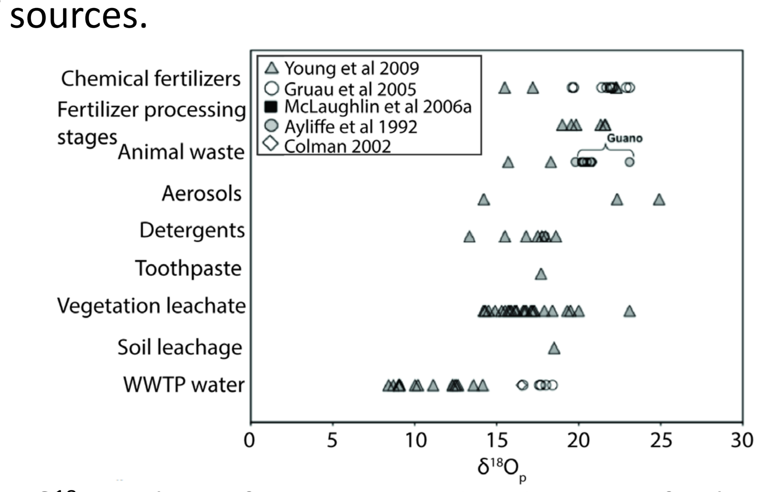

Figure 8. $\delta^{18}O_p$ values of common nutrient inputs to freshwater aquatic ecosystems. Modified from Young et al. (2009).

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Contact:
Kay C. Stefanik
stefanik.13@osu.edu