Effect of chronic nitrogen enrichment and acidification on coupled nitrogen and phosphorous cycling: Insights from multiple spiraling techniques

Madeleine M. Mineau[1], K. S. Simon[1], D. T. Ely[2], R. L. Rancatti[1], I. J. Fernandez[1], S. A. Norton[1] & H. M. Valett[3]

1. University of Maine; 2. SUNY Orange; 3.University of Montana

Introduction

Increased nitrogen (N) deposition, due to anthropogenic activity, is often paired with acidification. These two stressors, N enrichment and acidification, interact to alter the balance among multiple element cycles. Chronic N enrichment may cause N saturation in streams. In acidified watersheds N saturation may be exacerbated by the scarcity of reactive phosphorus (P) caused by geochemical sequestration. In this study, we asked:

Are streams in watersheds experiencing chronic N enrichment N saturated?

Is P uptake greater in the N enriched stream compared to the reference?

Can N saturation be alleviated by increasing P availability?

How comparable are isotopic tracer, steady state, and slug additions as measures of nutrient spiraling?

Methods

We conducted measurements of N and P uptake in a stream draining a watershed experimentally enriched with ammonium sulfate for more than 20 years and a stream in a neighboring reference watershed. We used the following approaches to measure uptake of N and P and evaluate the effect of P availability on N uptake:

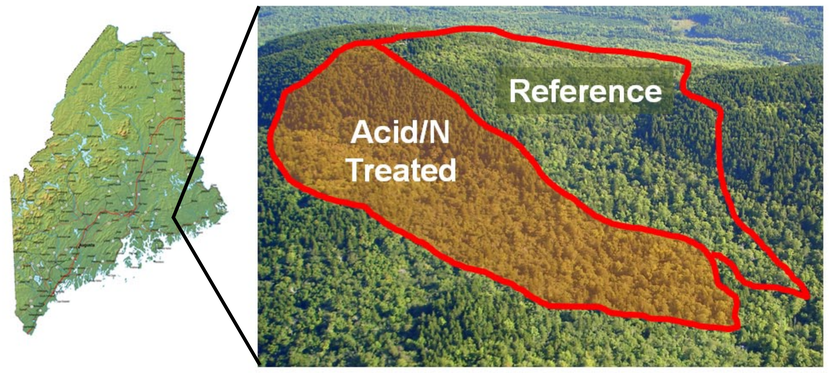
Steady state ^{15}N additions at ambient and multiple levels of experimentally elevated N and P availability

Steady state enrichment of N and P at multiple concentrations

Tracer additions for spiraling curve characterization (TASCC; Covino et al. 2010) for N and P added alone and together

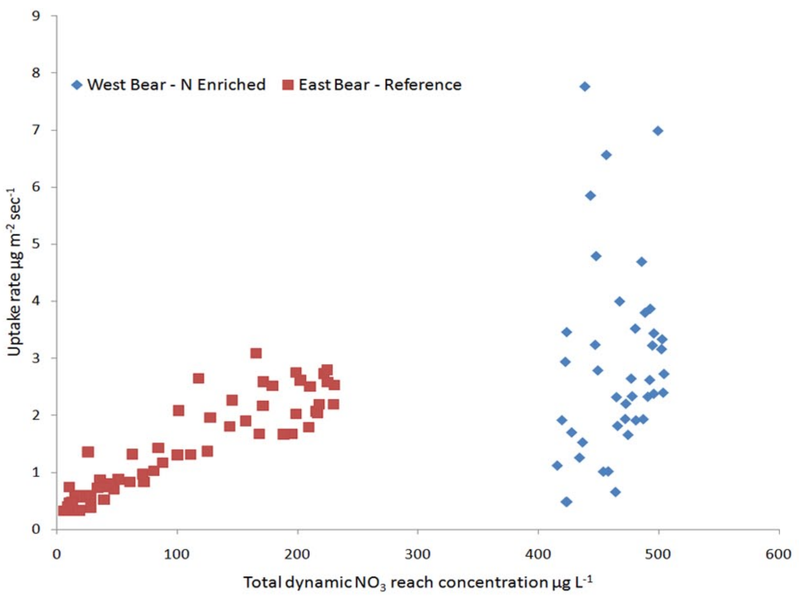
Study Site

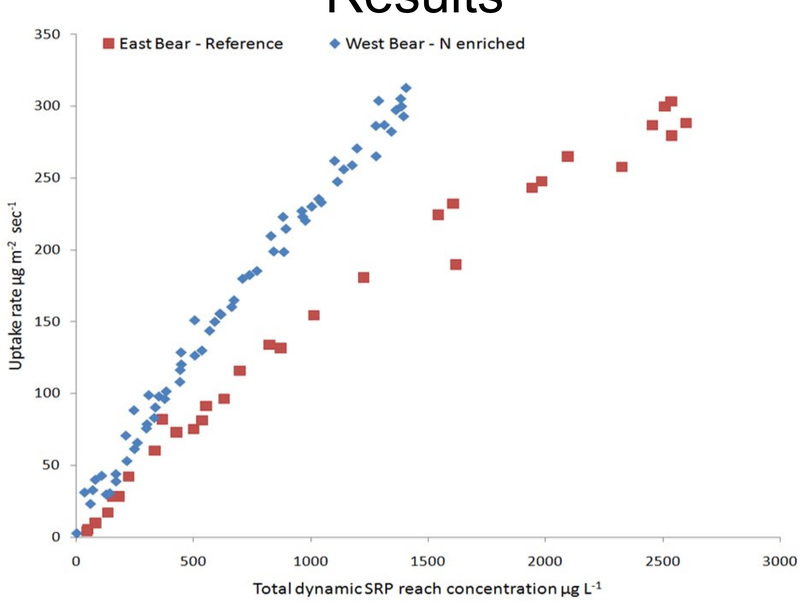
Bear Brook Watershed in Maine



	pH	NO_3 µg L^{-1}	SRP µg L^{-1}
Reference	5.4	~2	<1
Treated	4.7	~250	<1

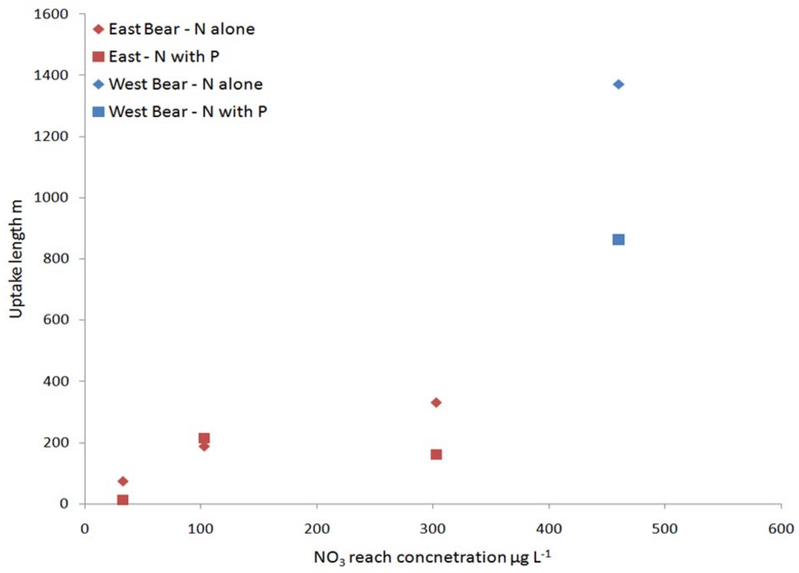
Results





N saturation and P uptake

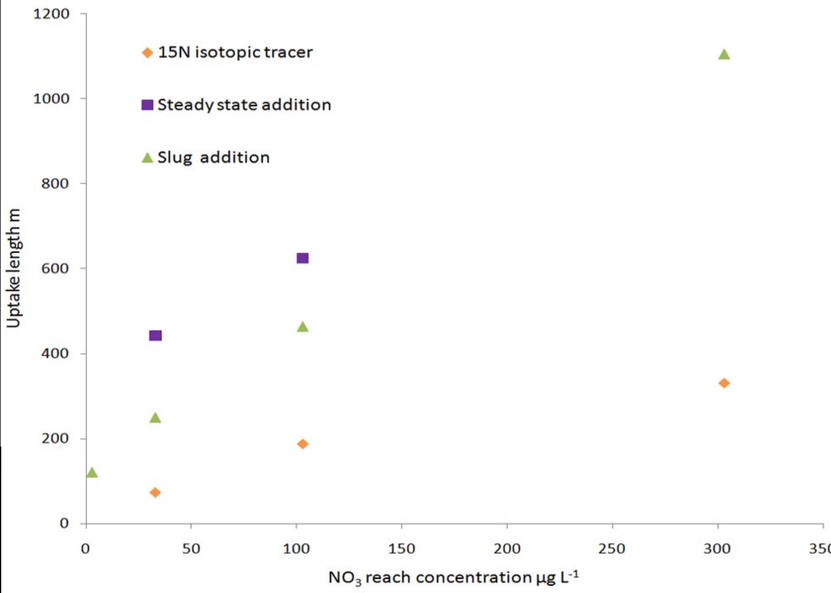
TASCC showed that the reference stream exhibited a positive relationship between N uptake and N concentration (left). However, there was no relationship between uptake and concentration in the N-enriched stream, suggesting saturation. Steady state additions revealed no significant uptake of N in the N-enriched stream supporting N saturation. TASCC also showed that P uptake rate is greater in the N enriched stream across a wide range of reach SRP concentrations compared to the reference stream (right). Furthermore, P uptake lengths measured during steady state additions are at least twice as long in the reference stream (58 - 119 m) than in the N-enriched stream (29 - 40 m).



N and P coupling

In the reference stream, increasing P availability resulted in shorter N uptake lengths at 30 and 300 but not at 100 µg L^{-1} reach NO_3 concentration. In the N-enriched stream, increasing P availability resulted in a much shorter N uptake length at background NO_3 concentration and there was no measurable uptake of $^{15}NO_3$, with or without added P, when NO_3 concentration was increased above background.
Very high P demand in the N-enriched stream, limited the reach length in which we could successfully elevate P availability and measure N uptake.

Adding P with N during TASCC measurements did not affect estimates of N uptake in either stream.



Methods comparison

TASCC measurements have not previously been compared to isotopic tracer uptake estimates. In the reference stream, we found that the TASCC method over estimated uptake length for a given reach concentration compared to the isotopic tracer approach. However, TASCC uptake length estimates were shorter than steady state addition estimates. There was no significant uptake detectable using the steady state method at the highest NO_3 addition concentration.

Conclusions

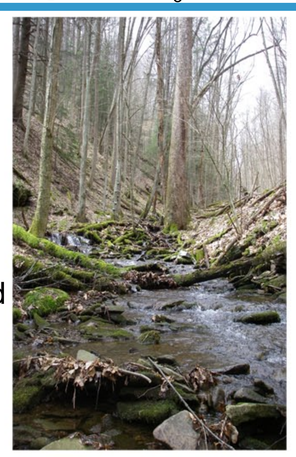
Simulated chronic N and acid deposition at the watershed scale lead to N saturation in the stream.

P uptake was greater in the N enriched and acidified stream over a wide range of reach P concentrations

Increased P availability sometimes reduced N uptake length but not consistently

Both steady state and TASCC methods over-estimated uptake length relative to the isotopic tracer method

Neither steady state additions nor TASCC perform well in streams at or near saturation.



What's next?

High enrichment ^{15}N additions at ambient and elevated P

Repeat measurements at Fernow experimental forest, WV, in a similar N-enriched and acidified watershed.

Acknowledgements

Thanks to Dennis Anderson, Cathy Herr and Simon lab for assistance in the field and lab.
Funding provided by NSF grant DEB-0841571 and DEB-0639902