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Collaborative Research: Interactive Effects of Chronic N deposition, Acidification, and Phosphorus Limitation on Coupled Element Cycling in Streams

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Preview of Award 0841571 - Final Project Report

[Cover](#) |

[Accomplishments](#) |

[Products](#) |

[Participants/Organizations](#) |

[Impacts](#) |

[Changes/Problems](#)

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	0841571
Project Title:	COLLABORATIVE RESEARCH: Interactive effects of chronic N deposition, acidification, and phosphorus limitation on coupled element cycling in streams
PD/PI Name:	Kevin S Simon, Principal Investigator Ivan J Fernandez, Co-Principal Investigator Stephen A Norton, Co-Principal Investigator
Recipient Organization:	University of Maine
Project/Grant Period:	05/01/2009 - 04/30/2014
Reporting Period:	05/01/2013 - 04/30/2014
Submitting Official (if other than PD\PI):	Kevin S Simon Principal Investigator
Submission Date:	07/02/2014
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Kevin S Simon

Accomplishments

* What are the major goals of the project?

The overarching goal of this project is to understand how chronic acidification and nitrogen enrichment of watersheds influences coupled biogeochemical cycling in streams. Embedded in the project were two primary research elements: 1) examining nitrogen saturation and the extent of coupling between nitrogen and phosphorus cycling and 2) resolving the interactions among acidification, phosphorus bioavailability and biotic demand for nitrogen and phosphorus. The research involved a series of stable isotope tracer experiments to document nitrogen uptake under ambient and elevated phosphorous conditions and examination of a suite of key microbial processes (denitrification, decomposition, microbial enzyme activity) at two whole-watershed experiment sites. A microcosm experiment was used to examine the influence of acidity stress on animal and microbial stoichiometry.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities: The major activities in the final year of this project were completion of the microcosm experiment and data analysis from the series of stable isotope

additions undertaken over the prior two years. The microcosm experiment focusing on the interactions between acidity and resource stoichiometry was completed, the data have been analyzed and a manuscript has been drafted.

The stable isotope data analysis has been completed and the results are being drafted into a manuscript. Mixed results regarding stream nitrogen demand and an inability to measure whole-stream denitrification via isotopic enrichment led us to conduct a suite of denitrification potential assays across streams and soils at the Bear Brook Watershed and the Fernow Experimental Forest.

Specific Objectives: The specific objectives for the past reporting period focused on manuscripts and graduate student mentoring.

Significant Results: The microcosm experiments revealed mixed stoichiometric effects of acidity on microbial and animal stoichiometry. Microbial stoichiometry was strongly influenced by altered pH. In particular, acidity stress suppressed respiration and enhanced nitrogen demand by microbes. Changes in phosphorus availability modulated this interaction, particularly by enhancing N demand under reduced levels of acidity stress. Animal stoichiometry was highly flexible in the face of altered acidity and resource phosphorus availability. This result is counter to the classical consideration of homeostatic animal stoichiometry, but consistent with a growing body of literature on the topic.

Analysis of isotope addition experiments yielded mixed results. We found a clear pattern of nitrogen saturation with increasing ambient and experimental watershed nitrogen loading consistent with theoretical models of watershed nitrogen saturation. Despite clear patterns of nitrogen saturation, we found mixed effects of experimental phosphorus enrichment on stream nitrogen uptake. In some cases, P enrichment alleviated N saturation, but this response was not consistent. This contrasts with clear stoichiometric interactions between nitrogen and phosphorus we observed at the microbial scale and in decomposition experiments. We were unable to measure whole-stream denitrification rates with isotopic methods under ambient and elevated phosphorus availability. A series of denitrification potential assays with stream sediments revealed relatively low denitrification rates even in the most nitrate rich streams. These low rates, in combination with high stream gas diffusion rates, explains our inability to quantify denitrification at the stream reach scale. The more sensitive denitrification potential assays (done in stream and soils) revealed clear stimulation of watershed denitrification with increasing ambient and experimental atmospheric nitrogen loading. However, the responses to experimental nitrogen loading were greater than suggested by changes in response to increasing ambient loads. This suggests a potential, although undefined role, of acidification in modulating denitrification response to atmospheric nitrogen deposition.

Key outcomes or Other achievements: This research represented an important contribution to these watershed studies by bringing a mechanistic understanding of in-stream processes in important NSF LTREB watersheds that have primarily focused on terrestrial ecosystem processes to date. Specific linkages evident were in the stream nitrogen and phosphorus interaction that allows us to develop an integrated terrestrial-aquatic framework for these two critical nutrients. Limited past research on denitrification lends itself to making the findings from this research, despite

analytical challenges, important steps forward in our understanding of watershed nitrogen mass balance. Together, these results allow us to target new research to understanding key mechanisms of the interaction among these nutrients. In addition, these findings refine our understanding of the role of phosphorus and acidity in nitrogen cycling, leading to improved models and more robust insights on the efficacy of environmental regulations from the Clean Air Act to renewable energy demands on our woodlands.

*** What opportunities for training and professional development has the project provided?**

The Ph.D. student (Rancatti) on the project is nearing completion and submission of her dissertation. We continue mentoring her through this process and her future career plans.

*** How have the results been disseminated to communities of interest?**

Dissemination of knowledge to the general public was facilitated primarily through a K-12 learning initiative (Nitrogen Cycling in Watersheds; see <http://participatoryscience.org/project/nitrogen-cycling-watersheds>). The project involved six high school teachers and over 100 students who participated in inquiry-based learning projects. The project uses data from this NSF award and others associated with the Bear Brook Watershed in Maine.

Products

Books

Book Chapters

Norton, S. A., Kopáček, J., and Fernandez, I. J. (2014). Acidification and Acid Rain. *Treatise on Geochemistry, 9 2nd Editi.* Holland, H. D. and Turekian K. K. (eds.). Pergamon Press. . Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

Conference Papers and Presentations

Inventions

Journals

Fernandez, I.J., M-C. Gruselle, K.S. Simon, M.M. Mineau, and S.A. Norton (). Decadal-Scale Experimental N Additions Alter 15N Natural Abundances at the Bear Brook Watershed in Maine, USA. *Ecosystems*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Mineau, M.M., Fatemi, F.R., Fernandez I.J., Simon K.S. (2014). Microbial enzyme activity at the watershed scale: response to chronic nitrogen deposition and acute phosphorous enrichment. *Biogeochemistry*. 117 (131-142), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s10533-013-9869-6

Licenses

Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Websites

The Bear Brook Watershed in Maine

<https://umaine.edu/bbwm/>

This is the Bear Brook Watershed in Maine web site with links to site data and a listing of manuscripts. This web will incorporate outputs from this project as they become finalized and available.

Participants/Organizations

Research Experience for Undergraduates (REU) funding

Form of REU funding support: REU supplement

How many REU applications were received during this reporting period? 0

How many REU applicants were selected and agreed to participate during this reporting period? 0

REU Comments:

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Simon, Kevin	PD/PI	1
Fernandez, Ivan	Co PD/PI	1
Norton, Stephen	Co PD/PI	0
Rancatti, Regina	Graduate Student (research assistant)	6

Full details of individuals who have worked on the project:

Kevin S Simon

Email: ksimon@maine.edu

Most Senior Project Role: PD/PI

Nearest Person Month Worked: 1

Contribution to the Project: Oversaw remaining data analysis and project completion. Mentored PhD student during her final phase of research and dissertation preparation.

Funding Support: NSF (LTREB-DEB-0639902, DEB-1056692)

International Collaboration: Yes, New Zealand

International Travel: Yes, New Zealand - 1 years, 0 months, 0 days

Ivan J Fernandez

Email: ivanjf@maine.edu

Most Senior Project Role: Co PD/PI

Nearest Person Month Worked: 1

Contribution to the Project: Assisted with data analysis and mentoring of Ph.D. student.

Funding Support: NSF (LTREB-DEB-0639902, DEB-1056692)

International Collaboration: No

International Travel: No

Stephen A Norton

Email: norton@maine.edu

Most Senior Project Role: Co PD/PI

Nearest Person Month Worked: 0

Contribution to the Project: Assisted with data analysis and mentoring of Ph.D. student.

Funding Support: NSF (LTREB-DEB-0639902, DEB-1056692)

International Collaboration: No

International Travel: No

Regina Rancatti

Email: Regina_Rancatti@umit.maine.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Conducts and has primary oversight of research related to aluminum-phosphorus biogeochemistry, denitrification and stress stoichiometry projects.

Funding Support: none

International Collaboration: No

International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
US Forest Service, Northern Research Station	Other Organizations (foreign or domestic)	West Virginia

Full details of organizations that have been involved as partners:

US Forest Service, Northern Research Station

Organization Type: Other Organizations (foreign or domestic)

Organization Location: West Virginia

Partner's Contribution to the Project:

Facilities

Collaborative Research

More Detail on Partner and Contribution: Collaboration on field work at the Fernow Experimental Forest in West Virginia. Provided logistical and data support for field work and data analysis.

Have other collaborators or contacts been involved? No

Impacts**What is the impact on the development of the principal discipline(s) of the project?**

A key outcome of this project is an enhanced understanding of stoichiometric interactions amongst multiple elements and environmental stressors (i.e. acidification and nitrogen enrichment). While this project focused primarily on stream responses to watershed nitrogen and acid loading, expansion of the research into terrestrial environments and linkage to other, ongoing terrestrial research at the two LTREB sites permits consideration of this topic at true watershed scales. Across our research we have found coherent stoichiometric linkages amongst nitrogen, phosphorus and aluminum that suggest watershed acidification alters the nature of microbial nitrogen and phosphorus demand and uptake capacity. However, patterns of response can be quite dissimilar between terrestrial and aquatic environments. Stoichiometric patterns are generally more consistent in aquatic environments at the microbial and process (e.g. decomposition, nutrient uptake) scale than is evident in terrestrial habitats. The most likely causes of this are alternative environmental constraints, such as desiccation and temperature fluctuation, and greater phosphorus availability in terrestrial habitats. These types of contrasts were facilitated by the large scale nature of the experiments at the Bear Brook Watershed in Maine and the Fernow Experimental Forest in West Virginia.

What is the impact on other disciplines?

The continued development of our understanding of both terrestrial and stream biogeochemical linkages allows ongoing research to be more integrated and informed. Thus, the findings of this research influence studies of whole-watershed biogeochemistry, and have encouraged more multi-elemental frameworks for understanding individual nutrient responses in future research. This cuts across forest ecology, microbial ecology, geochemistry, hydrology, soil science and climate science within the research of these watersheds.

What is the impact on the development of human resources?

The final year of this project continued the development of two women scientists. One, a postdoctoral fellow in the project, successfully published two papers, participated in an international workshop and now holds a position as a research scientist at the University of New Hampshire. The second scientist, the Ph.D. student on the project, is on track to successfully defend her dissertation by August 2014.

What is the impact on physical resources that form infrastructure?

This research continues to be a part of the collective of activities that builds on these long-term NSF LTREB research sites, leveraging those investments for cost-effective science.

What is the impact on institutional resources that form infrastructure?

This research adds to the body of discovery and funding that continues to make it possible to retain institutional support for these long-term studies.

What is the impact on information resources that form infrastructure?

Finds from these studies will be incorporated into these watershed reference lists and made accessible through project web sites.

What is the impact on technology transfer?

Nothing to report.

What is the impact on society beyond science and technology?

The two field sites used in this research directly address the issues of atmospheric pollution in forested environments. As such this research directly informs debate over regulatory controls, such as the Clean Air Act, dealing with atmospheric pollutants.

Changes/Problems

Changes in approach and reason for change

Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them

The lead PI on the project (Simon) shifted to a new academic position overseas. This has slowed the pace of data analysis somewhat although mentoring of the PhD student continues on track.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.