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6-1-2015

Natural dams and biogeochemistry at the river network scale: implications for water quality

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Basic Information

Title:	Natural dams and biogeochemistry at the river network scale: implications for water quality
Project Number:	2014NH183B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	NH-002
Research Category:	Water Quality
Focus Category:	Geomorphological Processes, Wetlands, Nitrate Contamination
Descriptors:	None
Principal Investigators:	Denise Burchsted, Mark B. Green, Jennifer Jacobs, Wil Wollheim

Publications

There are no publications.

Problem Statement

In the absence of modern humans, river networks are patchy systems, where free-flowing reaches are interspersed with ponds and meadows generated by "natural" dams. In New England, most of these dams are beaver dams, which create ponds and meadows that can extend over more than half of the length of a headwater stream network. Despite this patchy nature of river systems, our conception of the baseline river network is typically that of a system that is free-flowing and connected, which lies at the foundation of our infrastructure development and scientific models. As a result, when natural dams appear in a river network, both our infrastructure and scientific models tend to fail.

The impacts of natural dams on biogeochemical processing have dramatic implications for water quality. Degradation of water quality in New England is largely caused by non-point source pollution associated with high population density and land development pressures. Nitrogen enrichment of urban streams results in algal blooms that are devastating to coastal receiving waters; the biogeochemical impacts of natural dams, however, can dramatically alter nitrogen processing in the river network and should be taken into account when studying the problem and mitigation techniques. Specifically, decreased levels of oxygen in the impoundments increase denitrification rates but decrease nitrification, resulting in localized decreases in nitrate (NO3), increases in ammonium (NH4), and potential decreases in total nitrogen. The increased NH4, which accumulates when nitrification ceases under anoxic conditions, will be taken up quickly downstream. As this example demonstrates, the net result is a dramatic change in biogeochemical processing compared with the continuously oxygenated free-flowing river that is the basis for most scientific models applied to water quality.

Given both the significant site-scale impact of single natural dams on biogeochemistry and the high frequency of natural dams in river networks without direct human intervention, we must understand the role of these dams on biogeochemical processes at the river network scale

Objectives

This research addresses the broad research question of: What is the difference in biogeochemical regime between free-flowing river reaches and river reaches associated with natural dams, and what is the extent of this difference at the river network scale? The three specific research questions addressed by this research are: (Q1) Can free-flowing river reaches and river reaches associated with natural dams be classified according to biogeochemical regime? (Q2) What is the nature of the transition in biogeochemical regime downstream of a natural dam? (Q3) Which landscape and demographic factors control their presence and frequency of natural dams? To address these questions, the research includes both of the following: measurement of site-scale biogeochemistry parameters along river networks that include free-flowing reaches and natural dams; and examination of the landscape-scale parameters that control the presence of natural dams.

Methods

The methods include field work and GIS on river networks in the Ashuelot and Contoocook basins of southwestern New Hampshire. The river networks in these basins range from entirely protected through highly managed urban streams.

GIS: Impoundments along the Contoocook river network, in southwestern New Hampshire, have been visually digitized and classified as either: (1) closed canopy; (2) beaver pond; (3) beaver meadow; (4) pond at a human-built dam; (5) meadow at a human-built dam; (6) human-managed floodplain (ditched); (7) unmanaged floodplain (many natural dams); and (8) renaturalizing human-created impoundment.. The classifications were ground-truthed during the 2014 summer field season. An index of heterogeneity is being calculated for the river network based on these data.

Ongoing research involves assessment of physical and demographic parameters for the study reaches. The catchment size and slope for each reach will estimated using NHDPlus2. Relative stream power can be estimated as catchment area times channel gradient. The 2001 NH land cover assessment will be used to estimate percent forest, percent hardwoods, and percent developed and agricultural land within a buffer for each reach. Additional State GIS data will be used to estimate population density, density of roads and railroads within a buffer along each reach, and number of river crossings within 1km. ArcGIS ModelBuilder will be used to run any given analysis on all of the delineated reaches.

Field Research: Synoptic stream surveys were conducted in the summer of 2014 along 118 river reaches in the study area. The limits of the study reaches were defined by geomorphic features such as natural dams and the limits of the impoundments created by these dams. Field measurements in the study reaches include temperature, dissolved oxygen (DO), conductivity, pH, and oxidation-reduction potential (ORP) using an YSI Professional Plus multimeter. Water samples have been collected for laboratory analysis of stable water isotopes at the Plymouth State University Center for the Environment. Channel cross-sectional shape and heights and widths of dams have also been surveyed with a laser distance meter and stadia rod.

Ten HOBO data logger arrays are collecting water level, temperature and conductivity at 5-15 minute intervals at three beaver ponds and one beaver meadow. The data logger arrays are upstream, downstream, and within each impoundment. An additional 27 temperature loggers are capturing additional data within the transient storage location at the same ponds and meadow and at an additional six ponds and meadows. These data will be used both to characterize biogeochemical state at the logger locations and to explore the possibility of using temperature to assess the extent of surface transient storage.

Findings

These activities cover year one of a two-year grant, and so the findings are preliminary.

GIS: A surprising finding as part of the GIS research is the occurrence of "naturalizing" river reaches that were once impounded by humans, where the impoundment has filled in with sediment and beavers have moved in to create small ponds within the human-created wet meadow. The GIS research has produced a complete data layer (see Figure 1) that has been created as a linearly referenced network. Calculation of simple metrics and development of an index of heterogeneity are underway as part of the Year 2 activities.

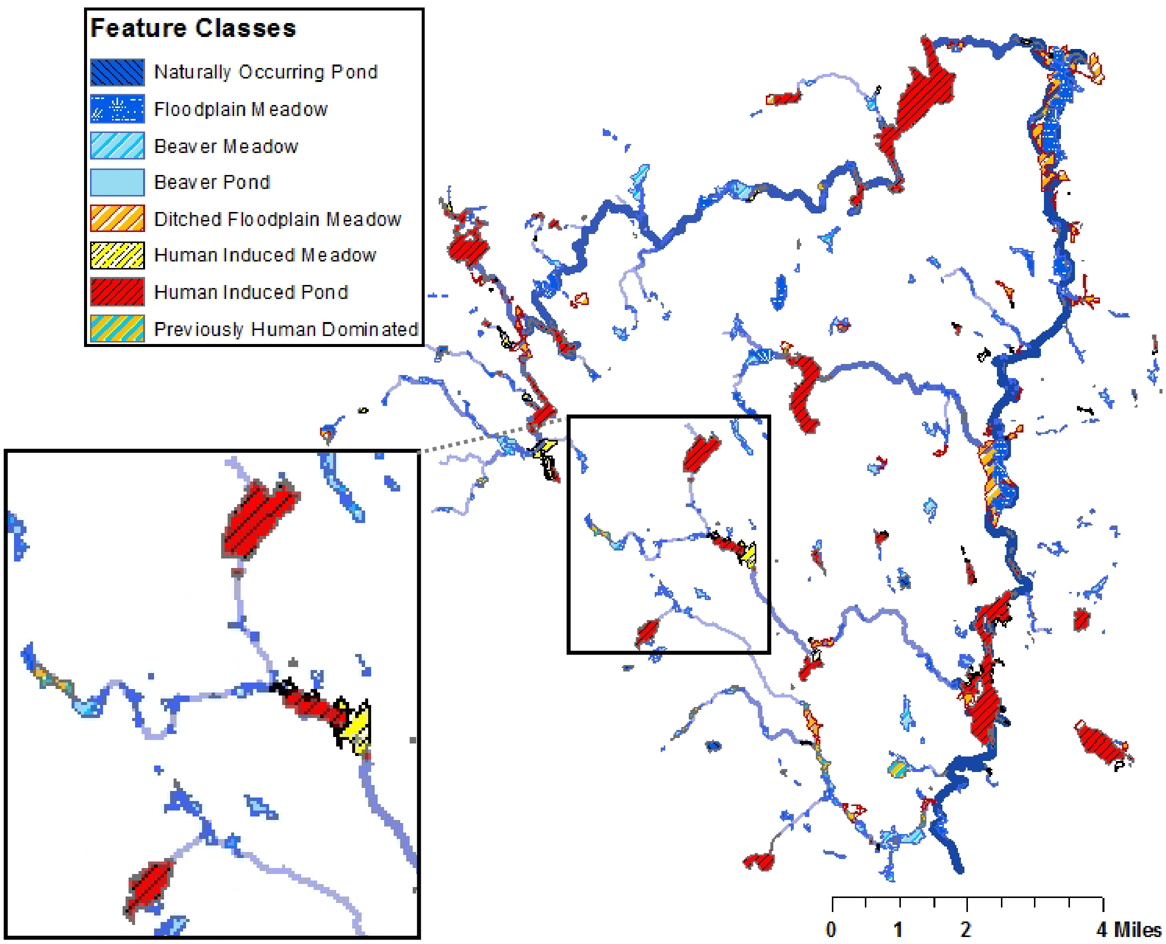

Figure 1. Impoundments along the river network for the Contoocook River, southwestern New Hampshire, digitized in Year 1 of this study. Inset shows typical detail. These digitized data will be used as the foundation for calculations of river network heterogeneity, of correlation between heterogeneity and land use, and for a predictive model of natural dam location.

Field work: Preliminary analysis of the field data show a clear and distinct relationship between low oxygen and beaver meadows and ponds, with oxygen levels responding quickly as water flows into or out of a pond (see Figure 2). Continued research with these data involve lab analysis of water samples, more detailed data analysis to assess the extent of change of oxygen and other parameters (e.g., pH) in sequence along the river network. Given the importance of oxygen in controlling biogeochemical reactions, particularly in the nitrogen cycle, these data strongly suggest that the patchiness of river networks could alter nitrogen concentrations in rivers. Upcoming lab analyses of collected water samples will test this hypothesis.

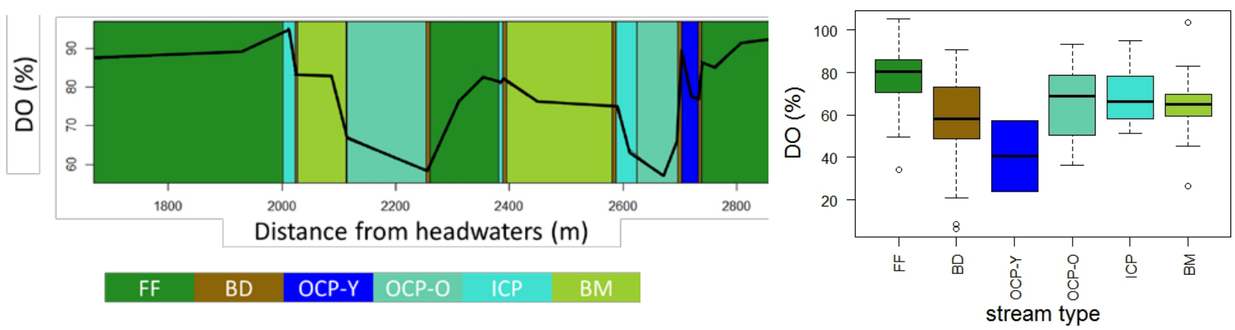

Figure 2. Left: example of dissolved oxygen profile along one study river (Hosley Brook, Hancock, NH). Right: comparison of DO across various feature types for all study reaches. Legend: FF—free-flowing; BD—beaver dam; OCP-Y—out of channel beaver pond, young; OCP-O—out of channel beaver pond, old; ICP—in-channel beaver pond; BM—beaver meadow.

Publications and presentations

Presentations at professional society meetings

Brehme, Christopher; Stoll, Charles; Burchsted, Denise, 2014, *Using photo interpretation and linear referencing to quantify stream heterogeneity*, NESTVAL 2014: Water in a Changing World, New England-St. Lawrence Valley Geographical Society, Durham, NH.

Brehme, Christopher; Stoll, Charles, 2014, *A classification and analysis of river channel conditions using aerial photos and network analysis*, American Association of Geographers Annual Meeting, Paper session 3567—Remote Sensing Applications for Characterizing Wetlands, Chicago, IL.

Presentations at local scientific meetings

Burchsted, Denise. 2014. *Patchy rivers: Implications for ecosystem function and services,* NH EPSCoR Ecosystems & Society All Hands Meeting, Concord, NH.

Burchsted, Denise. 2014. *Natural dams: Fluvial geomorphology and biogeochemistry,* Hubbard Brook Experimental Forest Cooperator's Meeting, Woodstock, NH.

Burchsted, Denise, 2015, *Natural dams and river network heterogeneity*. NH EPSCoR Ecosystems & Society All Hands Meeting, Durham, NH.

Dallesander, Joshua; Thorndike, Olivia; St. Pierre, Lindsay; Burchsted, Denise. 2014. *Characterizing biogeochemical regime in river networks.* Council of Public Liberal Arts Colleges, Northeast Regional Undergraduate Research Conference.

Stoll, Charles; Brehme, Christopher; Burchsted, Denise, 2014, *Classifying riverine heterogeneity using photo interpretation*, NH EPSCoR Ecosystems & Society All Hands Meeting, Concord, NH.

Outreach or Information Transferred

Training sessions: Seminars

Burchsted, Denise, July 12, 2014, *Beaver dams as "natural dams" and the river dis-continuum*, Lake Nubanusit Watershed Association, Hancock, NH.

Burchsted, Denise, October 16, 2014, *Beavers: Nuisance species or ecosystem engineers?* Harris Center for Conservation Education Speaker Series, Hancock, NH.

Students

Joshua Dallesander, BS in progress, Environmental Studies, Keene State College

Michael McGuinness, BA 2015, Biology, Keene State College

Lindsay St. Pierre, PhD in progress, Environmental Science, Antioch University New England

Charles Stoll, BA 2015, Geography, Keene State College (first-generation student)

Olivia Thorndike, BS in progress, Environmental Studies, Keene State College

Faculty

Christopher Brehme, Associate Professor, Keene State College

Denise Burchsted, Assistant Professor, Keene State College

Special Story

Charles Stoll, one of the students supported through this research, is a first-generation student who worked for the first ten years of his adult life as a plumber. He is largely responsible for the GIS conducted as part of this research, and has presented his work at three meetings: locally (NH EPSCoR), regionally (NESTVAL), and nationally (AAG). Charles received his BA in May 2015 and is continuing to work on this research project this summer. We anticipate that, by the end of the summer of 2015, Charles will submit an undergraduate first-author manuscript for review for publication in *Northeastern Geographer*.

The attached Keene State news story (http://www.keene.edu/news/stories/detail/1412192838303/) provides some highlights regarding Charles' decision to restart his career as a student. The research mentioned in the news article is complementary summer research funded under a different grant. His work on the WRRC research was conducted primarily in the academic year.

Keene
STATE COLLEGE

From Plumber to Geography Major, Charles Stoll Finds Himself. Here.

October 1, 2014

After spending 10 grueling years as a plumber and suffering three fairly significant injuries, **Charles Stoll** decided he needed a change of direction—something a little more rewarding and less physically taxing. So he enrolled at Keene State, thinking he'd pursue a career in engineering or business management.

But, even for a non-traditional student with his feet well planted beneath him, the opportunities and avenues for exploration that KSC laid before him let Stoll discover an even more engaging path. "After taking a few ISP courses throughout my first two semesters, I decided that I was more lent to the sciences and figured that was the direction I needed to follow," he explained. He found himself especially drawn to his Does the Earth Have a Fever? Integrative Quantitative Literacy (IQL) course, an entry-level earth systems science course, and Introduction to Geography.

Charles Stoll gathers data logger downloads for Prof. Burchsted's EPSCoR research project. (Photo by Mark Reynolds)

It was in that geography course that Stoll found his predilection. "I was motivated to pursue a bachelors in geography because I feel as though I can relate to that spatial mindset," he recalled. "Geography is a spatial science, and given my previous occupation, I tend to think about things more analytically I think—processes and patterns, relationships and positioning. I also really enjoy history, and the cultural and/or sociopolitical aspects of geography help to satisfy those curiosities. It helps that I am also an anthropology minor, because learning about and developing an understanding of the human relationship with the environment is a story I have become more and more fascinated with."

Along with his geography major, Stoll is pursuing GIS certification. GIS (geographic information system) is a computer system designed to capture, store, manipulate, analyze, manage, and present spatial or geographical data. In the spring semester of 2014, he got an opportunity to put his science aptitude and geography skills to work when he began working with Assistant Professor of Environmental Studies **Denise Burchsted** on her EPSCoR research project on natural dams. "She enlisted me to analyze aerial photography of southwestern New Hampshire and to begin classifying watersheds for land cover, specifically for ponds and meadows caused by natural dams like those created by beavers, and for similar, though less natural, ponds and meadow systems created by humans," Stoll said.

That work led to a summer internship that saw Stoll in the field collecting data for the project. "I have to say it has been a truly awesome experience, and I feel very fortunate to have been involved with it. I have been learning about how river systems function, and what some of the influences on river characteristics are," he said.

Though Stoll hasn't decided exactly where he wants to go with his new career path, he's confident with the many options his education has opened for him. "I do feel as though the education that I have been receiving through KSC has more than fully prepared me for anywhere I choose," he said.