New Hampshire Water Resources Research Center
Annual Technical Report
FY 2014

Introduction

The New Hampshire Water Resources Research Center (NH WRRC), located on the campus of the University of New Hampshire (UNH), is an institute that serves as a focal point for research and information on water issues in the state. The NH WRRC actually predates the Federal program. In the late 1950s Professor Gordon Byers (now retired) began a Water Center at UNH. This Center was incorporated into the Federal program in 1965 as one of the original 14 state institutes established under the Water Resource Research Act of 1964. The NH WRRC is currently directed by Dr. William McDowell with administrative and technical assistance from Associate Director Ms. Michelle Daley and Mr. Jody Potter (Water Quality Analysis Lab (WQAL) Manager). The NH WRRC is a standalone organization, in that it is not directly affiliated with any other administrative unit at UNH, and it reports to the Dean of the College of Life Sciences and Agriculture (COLSA). The NH WRRC has no dedicated laboratory or research space, and instead relies on space allocated for the research activities of the WRRC director by COLSA. The NH WRRC does have administrative space on campus, which houses WRRC files and short-term visiting staff and graduate students. The WRRC website (www.wrrc.unh.edu) serves as a focal point for information dissemination and includes NH WRRC publications and results from past research, as well as links to other sites of interest to NH citizens and researchers.

Research Program Introduction

The NH WRRC supported three research projects with its 2014 104b funding:

1. Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

2. Contribution of fluvial wetlands to nitrogen retention in urbanizing coastal watersheds in New England across multiple scales

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

The Water Quality Analysis Lab (WQAL) is affiliated with the NH WRRC and facilitates water resources research through technical assistance and sample analysis. The WQAL was established by the Department of Natural Resources in 1996 to meet the needs of various research and teaching projects both on and off the UNH campus. It is currently administered by the NH WRRC and housed in James Hall. The mission of the Water Quality Analysis Laboratory is to provide high-quality, reasonably priced analyses in support of research projects conducted by scientists and students from throughout the University, state, and nation. Past clients have included numerous research groups on the UNH campus, Federal agencies, scientists from other universities, and private firms. Many thousands of analyses are conducted each year.

Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

Basic Information

Title:	Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds
Project Number:	2003NH21B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	NH01
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Surface Water, Nutrients
Descriptors:	
Principal Investigators:	Michelle Daley

Publications

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4. Legere, K.A. September 2007. Nitrogen loading in coastal watersheds of New Hampshire: an application of the SPARROW model. Masters Thesis, University of New Hampshire, Durham, NH. 75 pages.
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Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

Statement of Critical Regional or State Water Problem

New Hampshire's surface waters are a very valuable resource, contributing to the state's economic base through recreation (fishing, boating, and swimming), tourism and real estate values, and drinking water supplies. New Hampshire is experiencing rapid growth in several counties and from 1990 to 2004 the state grew twice as fast as the rest of New England, with a state-wide average population increase of 17.2% during that period (Society for Protection of NH Forests 2005). New Hampshire watersheds rank among the most highly threatened watersheds in the nation because of the high potential for conversion of private forests to residential development. In fact, three of the four most threatened watersheds in the US which could experience the largest change in water quality as a result of increased residential development in private forests occur at least partially in New Hampshire (Stein et al. 2009).

The long-term impacts of this rapid population growth and the associated changes in land use on New Hampshire's surface waters are uncertain. Of particular concern are the impacts of non-point sources of pollution such as septic systems, urban runoff, stormwater, application of road salt and fertilizers, deforestation, and wetland conversion. Long-term datasets that include seasonal and year-to-year variability in precipitation, weather patterns and other factors are needed to adequately document the cumulative effects of land use change and quantify the effectiveness of watershed management programs. No other agency or research program (e.g. NH Department of Environmental Services (NH DES), US Geological Survey (USGS) or Environmental Protection Agency (EPA)) has implemented such a long-term program.

Statement of Results or Benefits

The proposed project will provide detailed, high-quality, long-term datasets which will allow for a better understanding of the impacts of land use change and development on surface water quality. These surface water datasets could support the development, testing and refinement of predictive models, accurately assess the impacts of watershed management practices on drinking water supplies, assess efforts to reduce surface water quality impairments, and be potential early warning signs of dramatic changes to surface water quality in the region resulting from rapid development. Long-term datasets from this project will be essential to adaptive management strategies that strive to reduce non-point sources of nitrogen pollution in New Hampshire's Great Bay watershed which is currently impaired by elevated nitrogen and in violation of the Federal Clean Water Act. A list of selected recent presentations, publications and press releases that utilize long-term datasets supported by NH WRRC funding for this project is included at the end of this proposal.

Objectives of the Project

This project allows for the continued collection of long-term water quality data in New Hampshire. It will use University of New Hampshire (UNH) staff, students and volunteers from local communities to collect samples from the Lamprey and Oyster River watersheds located in southeast NH and the Ossipee River watershed in central NH. All three watersheds are located in counties experiencing high population growth rates (Figure 1). Both the Lamprey and Ossipee watersheds are predicted to more than double in population from 1998 to 2020 (Sundquist and Stevens 1999). Surface water sites within each of the 3 watersheds and details on long-term datasets collected are described below. Together these 3 watersheds capture a broad range of urban, rural and agricultural land uses as well as a range of forests and wetland cover types.

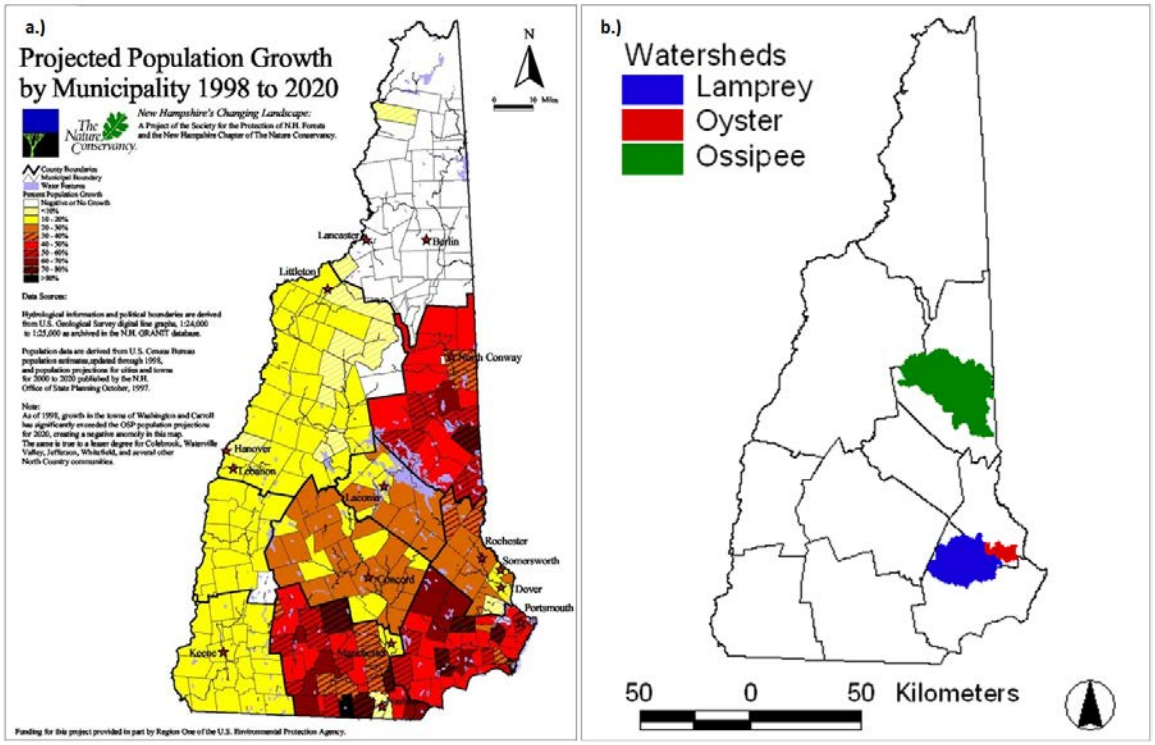

Figure 1. Projected population growth in New Hampshire (Figure from Sundquist and Stevens 1999; A) and study watersheds experiencing high population growth (B).

Methods, Procedures and Facilities

Lamprey River Hydrologic Observatory

The Lamprey River watershed (479 km^2) is a rural watershed located in southeastern NH and is under large development pressure as the greater area experiences the highest population growth in the state. The Lamprey River Hydrologic Observatory (LRHO) is a name given to the entire Lamprey River basin as it serves as a platform to study the hydrology and biogeochemistry of a suburban basin and is used by the UNH community as a focal point for student and faculty research, teaching and outreach. Our goal for the long-term Lamprey water quality monitoring program is to document

changes in water quality as the Lamprey watershed becomes increasingly more developed and to understand the controls on N transformations and losses.

The Lamprey River has been sampled weekly and during major runoff events since September 1999 at site LMP73 which is co-located with the Lamprey River USGS gauging station (01073500) in Durham, NH. Two additional sites were added to the long-term Lamprey River monitoring program in January 2004. One site (NOR27) was located on the North River, the Lamprey River's largest tributary, less than 1 km downstream from the USGS gauging station (01073460) in Epping, NH. The other site (Wednesday Hill Brook; site WHB01) drains a small suburban area in Lee, NH where residents rely solely on private wells and private septic systems for water supply and waste disposal. A stream gauge at WHB01 is operated by UNH staff and/or students. Sites NOR27 and WHB01 were sampled on a weekly basis through 2010 and in January 2011, the North River sampling frequency (site NOR27) was reduced to monthly because accurate measures of river discharge were no longer possible. Site WHB01 along with LMP73 remain at a weekly and major storm event sampling frequency. Several other sites have been sampled for multiple years on a less frequent basis to assess the spatial variability of water quality in sub-basins with various land uses and development intensities. In the past year, 14 additional sites were sampled on a monthly basis. All LRHO stream water samples are collected by UNH staff and/or students.

Oyster River watershed

The Oyster River watershed (80 km^2) is a small watershed in southeast NH where land use ranges from rural to urban. Two urban sub-basins, College Brook (CB) and Pettee Brook (PB), were selected for long-term sampling in January 2004. Both sub-basins are dominated by the University of New Hampshire (UNH) and receive a variety of non-point pollution from several different land uses. Three sites (CB00.5, CB01.5 and CB03.0) are sampled along College brook which drains the center of campus and one site (PB02.0) is located on Pettee Brook which drains the northern section of campus. Both sub-basins drain areas with high amounts of impervious surface and College Brook also drains the UNH dairy farm and athletic fields. Historic water quality data for these two sites are available from 1991. UNH staff and/or students currently sample these sites on a monthly basis.

Ossipee River watershed

The entire Ossipee River watershed (952 km^2) is classified as rural due to its low but increasing population. Seven sites in the watershed were selected for long-term monitoring in May of 2004. These sites are monitored monthly by volunteers and staff of the Green Mountain Conservation Group (GMCG) and were chosen to capture the areas of concentrated growth and monitor the major inputs and outputs from Ossipee Lake. Additional sites are selected by GMCG for volunteer monitoring during non-winter months (May to November). WRRC staff assist GMCG in site selection and data interpretation. In 2006, the GMCG worked with the Department of Environmental Services to establish a Volunteer Biological Assessment Program (VBAP) for the Ossipee Watershed. Numerous volunteers, including students from five local schools, assist with invertebrate sampling at a total of eleven sites.

Water Quality Analysis

Field parameters (pH, conductivity, dissolved oxygen (DO) and temperature) are measured at all sites. Water samples are filtered in the field using pre-combusted glass fiber filters (0.7 µm pore size), and frozen until analysis of dissolved constituents. Samples collected at all LRHO, CB, PB and the 7 long-term GMCG sites are analyzed for dissolved organic carbon (DOC), total dissolved nitrogen (TDN), nitrate (NO_3-N), ammonium (NH_4-N), dissolved organic nitrogen (DON), orthophosphate (PO_4-P), chloride (Cl^-), sulfate (SO_4-S), sodium (Na^+), potassium (K^+), magnesium (Mg^{+2}), calcium (Ca^{+2}), and silica (SiO_2). Water chemistry is also analyzed on a sub-set of the GMCG seasonal sites and turbidity is also measured in the field at all GMCG sites. Samples collected since October 2002 from LMP73 are also analyzed for total suspended sediment (TSS), particulate carbon (PC), particulate nitrogen (PN) and dissolved inorganic carbon (DIC). All samples are analyzed in the Water Quality Analysis Laboratory (WQAL) of the NH WRRC on the campus of UNH, Durham, NH. Methods for analyses include ion chromatography (Cl^-, NO_3^-, SO_4^{-2} and Na^+, K^+, Mg^{+2}, Ca^{+2}), discrete colorimetric analysis (NH_4, PO_4, NO_3/NO_2), and High Temperature Oxidation (DOC, TDN). All methods are widely accepted techniques for analysis of each analyte.

The WQAL was established by the Department of Natural Resources in 1996 to meet the needs of various research and teaching projects both on and off the UNH campus. It is currently administered by the NH Water Resources Research Center and housed in James Hall. Dr. William McDowell is the Laboratory Director and Mr. Jody Potter is the Laboratory Manager. Together, they have over 40 years of experience in water quality analysis, and have numerous publications in the fields of water quality, biogeochemistry, and aquatic ecology.

Principal Findings and Significance

Lamprey River Hydrologic Observatory

Analysis of samples collected in 2014 from the LRHO is 75% complete. Results of stream chemistry to date show a significant increase in weekly nitrate concentrations during the first 10 years (Water Years (WY) 2000-2009) of monitoring at LMP73 based on the Seasonal–Kendall Test (SKT; seasons set to 52) flow-adjusted nitrate concentrations (SKT $t = 0.28$, $p < 0.01$). However, there is no statistically significant change in nitrate concentrations over the entire study period (2009-2014; Figure 2). There was no significant change in nitrate concentrations at NOR27 or WHB01 over the last 10 years (2004-2013). We have shown previously that stream water nitrate is related to watershed population density (Daley 2002) and since suburbanization continues to occur throughout the greater Lamprey River watershed, population growth is likely responsible for the increase in stream water nitrate over the initial 10-year period. The watershed population density increased from 53 to 60 people/km^2 or by 12% from 2000 to 2010 (2000 and 2010 Census). Preliminary 2014 analysis suggests that nitrate levels are at or above the highest levels previously measured in 2007. We are uncertain if nitrate levels in LMP73 will remain relatively constant, increase or decrease with changing climate, land use and management in the watershed. Wednesday Hill Brook watershed is near its development capacity, unless the Town of Lee, NH changes its zoning regulations, and the lack of increase in WHB01 nitrate may be due to the limited

population growth in this watershed, that this watershed has reached nitrogen saturation or that the current time period of data collection is not reflective of long-term trends. Changes in Lamprey River nitrogen, especially nitrate, can have significant impacts for the downstream receiving water body, the Great Bay estuarine system which is impaired by elevated nitrogen and is currently in violation of the Federal Clean Water Act. Tidal tributaries to the bay are experiencing dangerously low dissolved oxygen levels and the bay is experiencing a significant loss of eelgrass which provides important habitat for aquatic life. The Lamprey River is the largest tributary to Great Bay, and thus the long-term data provided by the NH WRRC from the LRHO are of considerable interest for watershed management.

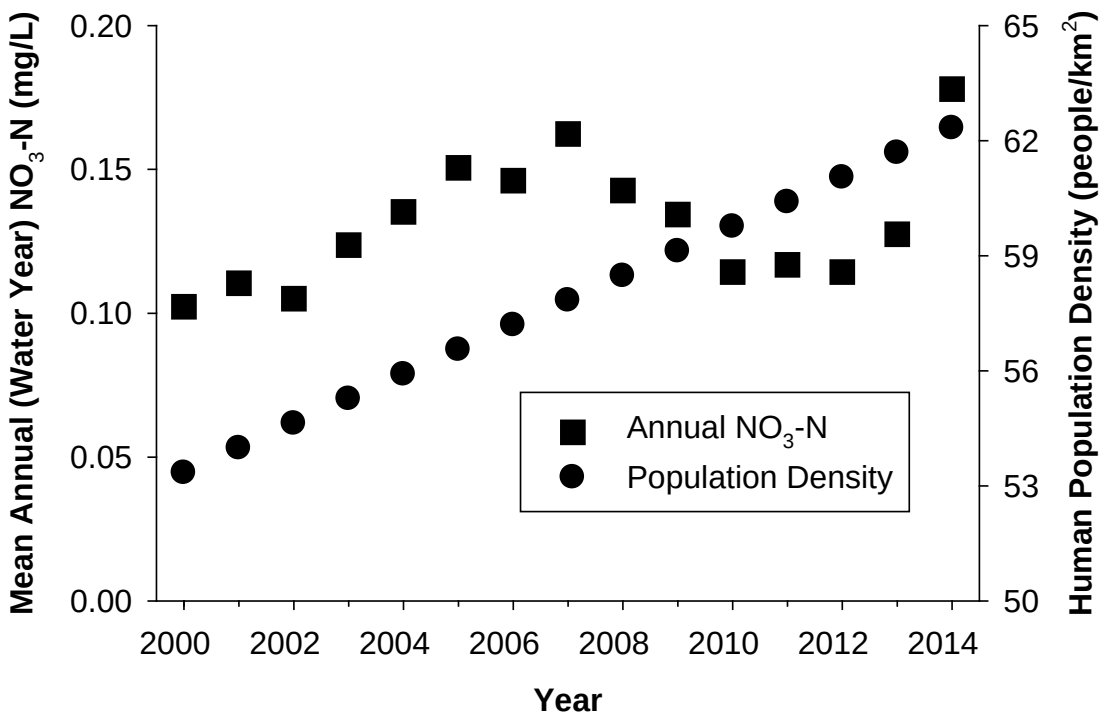

Figure 2. Annual (water year) mean nitrate concentration and estimated annual human population density from 2000-2014 (2000 and 2010 Census) in the Lamprey River basin. There is no statistically significant change in annual nitrate concentrations over the entire study period (2009-2014). Note that nitrate analysis for 2014 is 75% complete.

When we combine our specific conductance data (2003 – 2014) with data collected by the USGS (1978 - 1999), we see a long-term increase in specific conductance in the Lamprey River with a slight decline in recent years (Figure 3). Sodium and chloride concentrations are directly related to specific conductance (r^2 = 0.95, $p<0.01$ for Na^+; r^2 = 0.93, $p < 0.01$ for Cl^-) and we conclude that this increase in specific conductance indicates a corresponding increase in Lamprey River NaCl. Since Na^+ and Cl^- are strongly correlated with impervious surfaces in southeast NH (Daley et al. 2009) and road pavement among southeastern and central NH basins, we conclude that the associated road salt application to these surfaces is responsible for this long-term

increase in streamwater NaCl. The slight decline in recent years is likely due to the flushing effect of the 2006 and 2007 100-year flood events (Daley et al. 2009), but we are uncertain how long this slight decline will persist and thus continued monitoring is necessary to better understand how the interaction between human activities and climate variability affects water quality.

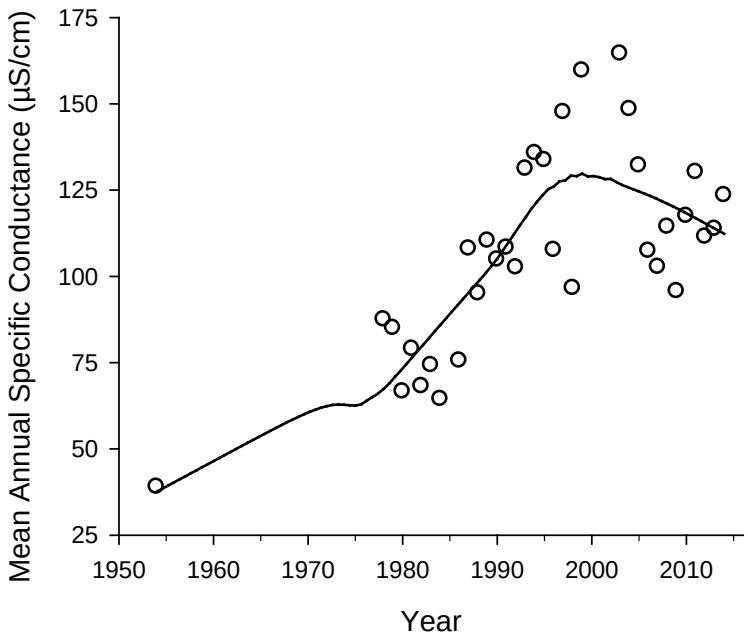

Figure 3. Mean annual specific conductance in the Lamprey River at LMP73 (co-located with the USGS gauging station in Durham, NH. (modified from Daley et al. 2009).

Oyster River watershed

Laboratory analysis of the monthly CB and PB samples collected in 2014 is 83% complete. Recent data show that DO is lowest at the CB upstream station (CB00.5) where it does drop below 5 mg/L (level that is necessary to support in-stream biota) during the summer months. The downstream stations do not drop below 5 mg/L and this difference is due to the hydrologic and biogeochemical properties of the upstream sampling location which has slow stream flow, high dissolved organic matter content and resembles a wetland. DO increases downstream as flow becomes faster and the stream is re-aerated. It is highly unlikely that historical incinerator operations are impacting present day DO levels in this brook as they have in the past.

Data from 2000 until now indicate that the steam is strongly impacted by road salt application at its origin, which is essentially a road-side ditch along the state highway leading to a wetland area, and by road salt applied by UNH and the town of Durham which drains to the middle and lower reaches of the brook. Average sodium and chloride concentrations, as well as specific conductance, appear to have remained reasonably constant since 2001, but are much higher than in 1991 (Daley et al. 2009). Concentrations are highest at the upstream stations and tend to decline downstream as the stream flows through the campus athletic fields and then increase as the stream passes through the heart of campus and downtown Durham. Concentrations are also highest during years of low flow. Data from this project have been used to list College Brook as impaired for excess chloride.

College Brook and Pettee Brook have noticeably higher nitrogen concentrations than many other local streams draining less developed or undeveloped watersheds. As College Brook flows from upstream to downstream where it becomes more aerated, ammonium decreases and nitrate increases (Figure 4) indicating that nitrification is occurring in the stream channel. However, an increase in total dissolved nitrogen (Figure 5) indicates that there are additional sources of nitrogen entering the stream as it flows downstream though UNH and Durham. This is possibly from fertilization of the athletic fields, storm water runoff or exfiltration from sewage lines. There is no statistically significant change in nitrate or TDN concentrations from 2000 to 2014 at the station with the longest record (CB01.5).

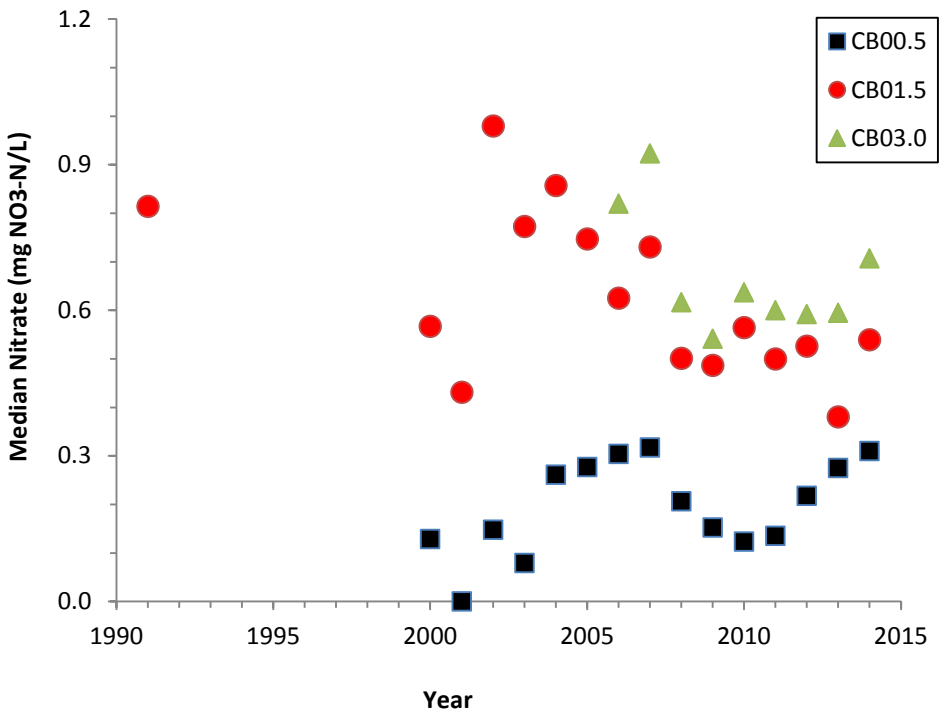

Figure 4. Median annual dissolved inorganic nitrogen (DIN) in College Brook from the headwaters (CB00.5) to the mouth (CB03.0).

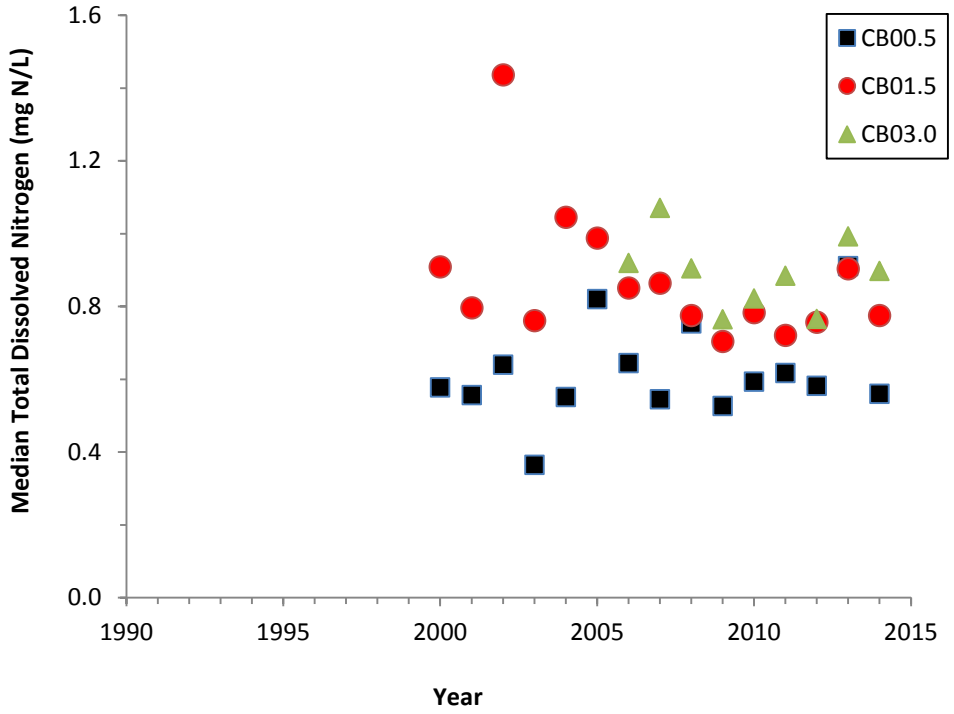

Figure 5. Median annual total dissolved nitrogen (TDN) in College Brook from the headwaters (CB00.5) to the mouth (CB03.0).

Ossipee Watershed

Collaboration with the Green Mountain Conservation Group (GMCG) and their sampling of the Ossipee River watershed provides much benefit to the NH WRRC and the long-term monitoring of rapidly developing suburban watersheds. Volunteers sampled streams within the watershed every 2 weeks from April through October, and monthly winter sampling was conducted by volunteers and GMCG staff at 7 sites. Over 100 samples were collected for analysis in the WQAL and additional field data was collected at over 40 sites throughout 6 towns using the help of many volunteers. Many presentations were made to planning boards, conservation commissions and other local government groups (see information transfer section below). Data have been used to heighten awareness of the impacts of excessive road salting and snow dumping in local streams. The impact of road salting in this central NH watershed is similar to what we see in coastal NH. Communication with local road agents has led to the remediation in one development where road salting was an issue. Samples collected and data generated from this funding have shown an improvement in water chemistry following reduced salting and snow dumping. Data have also been useful in promoting low impact development techniques and best management practices where new development has been proposed in proximity to lakes, rivers and streams within the watershed.

Notable awards and achievements

Currently NH has 47 watersheds listed as impaired due to elevate chloride levels resulting from salt use in winter road maintenance with the majority of those watershed

located in the southern part of the state. College Brook is one of the impaired watersheds and the impairment listing was based on data produced from this project. Starting in 2010 DES partnered with the UNH Technical Transfer Center to create the Green SnowPro Training program as a way to educate snow removal contractors on how to use salt efficiently to help reduce chloride pollution. The training course provides those who complete and pass the course with liability protection, absent gross negligence, from slip and fall lawsuits on properties they maintain. Currently there have been nearly 800 individuals who have taken the Green Snow Pro training and take the initiative to use less salt in the winter maintenance practices. This training was initiated based on the southern NH I-93 Expansion project in chloride impaired watersheds and also in response to the growing evidence for chloride contamination, especially in seacoast NH as documented by a publication from this project (Daley et al. 2009) and a study conducted by the USGS and the NH DES (Medalie 2013; http://pubs.usgs.gov/fs/2013/3011/).

Number of students supported

Three Master's students (Bianca Rodriguez, Nicholas Shonka and Marleigh Sullivan), 5 undergraduate hourly employees from the Department of Natural Resources & the Environment (Matthew Bosiak, Katie Swan, Shannen Miller, Colleen Dumphy, John Little) and 1 undergraduate hourly employee from the Engineering Department (Thomas Brigham). Two post-doctoral students were also supported by this project (Alison Appling and Adam Wymore).

References

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Information transfer activities that utilize long-term datasets supported by NH WRRC and matching funds

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Heffernan, J.B., P.A. Soranno, M.J. Angilletta, L.B. Buckley, D.S. Gruner, T.H. Keitt, J.R. Kellner, J.S. Kominoski, A.V. Rocha, J. Xiao, T.K. Harms, S.J. Goring, L.E. Koenig, W.H. McDowell, H. Powell, A.D. Richardson, C.A. Stow, R. Vargas, K.C. Weathers. 2014. Macrosystems ecology: understanding ecological patterns and processes at continental scales. Frontiers in Ecology and the Environment 12: 5-14.

Flint, S.F. and W.H. McDowell. 2015. Effects of headwater wetlands on dissolved nitrogen and dissolved organic carbon concentrations in a suburban New Hampshire watershed. Freshwater Science 34:456-471.

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Meyer, A. 2014. Response of ammonium uptake to carbon availability in an agriculturally influenced first order stream. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 50 pages.

Shonka, N. 2014. Water quality sensors provide insight into the suspended solids dynamics of high flow storm events in the Lamprey River. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 93 pages.

Sullivan, M. 2014. Groundwater nitrogen attenuation in suburban and urban riparian zones. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 94 pages.

Appling, A. Leon, M. and McDowell, W.H. 2014. Reducing bias and quantifying uncertainty in watershed flux estimates: The R package loadflex. Submitted December 2014 to Ecosphere.

Conference Proceedings & Abstracts:

Bucci, J. P., I. Sidor, A. Walant, M. Daley, J. Potter, W. McDowell. 2014. Detection of a Mitochondrial DNA Biomarker in Surface Water within Suburban Streams Impacted by Animal Fecal Waste: Does Flow Matter. American Society for Microbiology 2014 General Meeting. Boston, MA. May 2014.

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McDowell, W.H., Potter, J. D., Daley, M. L., Snyder, L., Mulukutla, G. 2014. Using sensors and sensor networks to quantify ecosystem services in developed and rural watersheds. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

McDowell, W.H. Freshwater Science: Lessons Learned and Looking Ahead. Plenary Address, First Annual Symposium on Aquatic Science, University of Maine, Orono, Maine. January 29, 2015. (CZO, LTER, EPSCoR, and NH AES)

Potter, J.D. Snyder, L., Mulukutla, G., McDowell, W. H. 2014. Addressing anthropogenic effects on aquatic biogeochemistry using a distributed sensor network in New Hampshire. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

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Shonka, N. 2014. Sensing Suspended Solids: Using in-situ water quality sensors to provide insight into the suspended solids dynamics of high flow storm events in the Lamprey River. Climate change poster session with William Hohenstein, USDA Climate Change Program Director, and David Hollinger, Hub Leader, Northeast Regional Hub for Risk Adaptation and Mitigation to Climate Change. University of New Hampshire. Durham, NH. May 13, 2014.

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Wymore, A.S. et al. 2014. Identifying the Sources of Dissolved Organic Matter in Streams Using Elemental Analysis Isotopic Ratio Mass Spectroscopy (EA-IRMS) Across a Land Use Gradient. American Geophysical Union Fall Meeting. San Fancisco, CA. December 2014.

Presentations/Information Transfer

Appling, A. 2015. Patterns and drivers of diel solute cycles in headwater streams. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Daley, M.L. 2014. Led field trip for undergraduate and graduate students to sites in the Lamprey River Hydrologic Observatory. September 16, 2014.

Daley, M.L. 2014. Water Quality Research in the Lamprey River Hydrologic Observatory. Presentation to University of New Hampshire undergraduate class: Studio Soils. October 25, 2014.

Daley, M.L. 2014. Great Bay watershed management. Presentation to University of New Hampshire class: Watershed Water Quality Management. December 2, 2014.

Daley, M.L. 2015. Non-point nitrogen sources and transport in the Great Bay watershed. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Daley, M.L. 2015. Forests, Farms, and People: How different sources contribute nitrogen to Great Bay. 2015 NH Farm & Forest Exposition. February 9, 2015. Manchester, NH.

Koenig, Lauren. 2014. Served as an instructor for the STEM mini-course offered August 25-29th through the CONNECT program at UNH (http://www.unh.edu/connect/). The objective of the course is to help incoming freshmen that come from groups with historically low retention in STEM majors (e.g. low-income, multicultural, first-generation college students) build skills that are needed to succeed in their academic programs (e.g., writing of lab/research reports, basic math and statistics for analyzing scientific data). There were 12 students in the class, but the broader CONNECT program serves approximately 100 students.

- Students measured soluble reactive phosphorus (SRP) concentrations across sites with different land uses for their project (WHB, LMP73, Burley Demeritt, College Brook and Pettee Brook). They had to give a general presentation to the entire CONNECT program (including non-STEM majors), so to best communicate their study, they chose to combine a traditional science powerpoint presentation with a music video. Their version of "These boots were made for sampling" - http://www.youtube.com/watch?v=lQCZ4XEwj7c&feature=share.

McDowell, William H. September 12, 2014. Interviewed live by John Dankosky from Connecticut Public Radio along with Dr. Kaushal on "Understanding the Urban Ecosystem". http://sciencefriday.com/segment/09/12/2014/understanding-the-urban-ecosystem.html.

McDowell, W.H. 2015. Do sensors matter? Improved precision in flux estimates with continuous data. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Snyder, L. 2015. Enhanced protocols for managing a network of modern water quality sensors. Poster. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Wymore, A. 2015. Identifying sources of dissolved organic matter (DOM) in streams using EA-IRMS and Py-GC/MS across a land-use gradient. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Press Releases

Humphries, C. 2014. The city is an ecosystem, pipes and all. What scientists are finding when they treat the urban landscape as an evolving environment of its own. McDowell, W.H. interviewed for article on October 6, 2014. Published in The Boston Globe on November 7, 2014. http://www.bostonglobe.com/ideas/2014/11/07/the-city-ecosystem-pipes-and-all/HjLVemBs9nPiuE53PjPSLK/story.html.

McDowell September 10, 2014. UNH Scientists Find Urban Ecosystems "Evolve," Require Sustainable Management. University of New Hampshire press release. September 10, 2014. http://www.unh.edu/news/releases/2014/09/ds10evolve.cfm#ixzz3D10ttLHP.

McDowell, W.H. 2014. A river runs through it: U.S. cities' waterways show consistent patterns of evolution. NSF press release. September 10, 2014. http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=132583&org=NSF

McDowell, William H. September 23, 2014. Interviewed for the "University of Maryland professor tailors watershed test to urban areas like College Park" press release. The Diamondback. The University of Maryland's Independent Student Newspaper. http://www.diamondbackonline.com/news/article_5128a2e2-42b5-11e4-b909-001a4bcf6878.html.

Green Mountain Conservation Group meetings, workshops and presentations supported by matching funds

2014

March 20th 6:30-8 pm. Putting water where it belongs—septic systems and catch basins. with Russ Lanoie Ossipee Library

April 6th 4-8 pm 16th GMCG ANNUAL MEETING -Harry Vogel Guest speaker about the health of loons

April 18th 9-11am RIVERS Water Quality Monitoring Volunteer Training at GMCG

May 8th 7pm The State of Bobcats in New Hampshire UNH professor of Wildlife Biology, John Litvaitis – Thurs. Ossipee Library

June 14th1-6pm Bikers for Clean Water Green Mountain Conservation Group celebrates "Aquifer Appreciation Day" on Saturday at the Yankee Smokehouse.

July 12th 9-12 Watershed Management Plan & 10 year WQM report-- Totem Pole, Freedom

August 2nd Hazardous Waste Day at the Ossipee Town Garage

August 20th 9-12:30 Macroinvertebrate Workshop -GMCG and NH Fish and Game

August 27th 4:00 Rain Barrel workshop with GALA at Huntress House

August 28th Well Water Testing. Promote a healthy aquifer- collect and deliver well water samples to NHDES for testing

August 23rd 5pm 2014 Fund Raiser, w/Denver Holt presenting from the Owl Research Institute – Sat. Wolfeboro

September 15th – 24th Volunteer Biological Assessment Program (VBAP) stream studies with 4 watershed schools

October 28th Well Water Testing. Promote a healthy aquifer- collect and deliver well water samples to NHDES for testing

November 6th 6-8 pm Natural Resource Based Planning workshop with Steve Whitman. Runnells Hall - Open to the public and municipal officials especially encouraged to attend

December 4th 6-8 pm Youth Water Quality Community Presentation with 4 schools at Ossipee Town Hall

2015

February 21st What Lives in your backyard? with Naturalist Barbara Bald

February 26th 6-7:30 How Climate Change is Impacting Water Quality of Ossipee Lake - with Dr. Lisa Doner and Plymouth State University graduate student Melanie Perello

Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.

Basic Information

Title:	Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.
Project Number:	2011NH164S
USGS Grant Number:	G11AP20128
Sponsoring Agency:	None
Start Date:	3/28/2011
End Date:	4/30/2014
Funding Source:	Supplemental
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	Acid Deposition, Surface Water, Law, Institutions, and Policy
Descriptors:	
Principal Investigators:	William H. McDowell, Steve Kahl

Publications

1. Sanclements, M., G. Oelsner, D. McKnight, S.J. Nelson, J. Stoddard, 2012, New insights into the source of decadal increases of dissolved organic matter (DOM) in acid-sensitive lakes, Environmental Science and Technology, in press.
2. Nelson, S.J., P. Vaux, M.J. James-Pirri, and G. Giese, 2011, Assessment of natural resource conditions in and adjacent to Cape Cod National Seashore, Massachusetts, Natural Resource [Technical] Report NPS/XXXX/ NRXX—20XX/XXX, National Park Service, Fort Collins, Colorado, In press.
3. Kerr, J.G., M.C. Eimers, I.F. Creed, M.B. Adams, F. Beall, D. Burns, J.L. Campbell, S.F. Christopher, T.A. Clair, F. Courchesne, L. Duchesne, I. Fernandez, D. Houle, D.S. Jeffries, G.E. Likens, M.J. Mitchell, J. Shanley, H. Yao, 2011, The effects of seasonal drying on sulphate dynamics in streams across southeastern Canada and the northeastern USA, Biogeochemistry DOI 10.1007/s10533-011-9664-1.
4. Sanclements, M., G. Oelsner, D. McKnight, S.J. Nelson, J. Stoddard, 2012, New insights into the source of decadal increases of dissolved organic matter (DOM) in acid-sensitive lakes of the northeastern U.S., Environmental Science and Technology, 46(6): 3212–3219, DOI: 10.1007/s11356-009-0176-7.
5. Nelson, S.J., P. Vaux, M.J. James-Pirri, and G. Giese, 2012, Natural resource condition assessment: Cape Cod National Seashore, Massachusetts, Natural Resource Report NPS/NER/NRR—2012/605, National Park Service, Fort Collins, Colorado.
6. Kerr, J.G., M.C. Eimers, I.F. Creed, M.B. Adams, F. Beall, D. Burns, J.L. Campbell, S.F. Christopher, T.A. Clair, F. Courchesne, L. Duchesne, I. Fernandez, D. Houle, D.S. Jeffries, G.E. Likens, M.J. Mitchell, J. Shanley, H. Yao, 2011, The effects of seasonal drying on sulphate dynamics in streams

across southeastern Canada and the northeastern USA, 111(1-3): 393-409, Biogeochemistry, DOI 10.1007/s10533-011-9664-1.

7. James-Pirri, M. J., S. J. Nelson, and P. D. Vaux, June 2011, Natural Resource Condition Assessment for Saugus Iron Works National Historic Site. Natural Resource Report NPS/NER/NRR—2011/457, National Park Service, Fort Collins, Colorado.
8. Sanclements, M., G. Oelsner, D. McKnight, S.J. Nelson, J. Stoddard, 2012, New insights into the source of decadal increases of dissolved organic matter (DOM) in acid-sensitive lakes of the northeastern U.S., Environmental Science and Technology, 46(6): 3212–3219, DOI: 10.1007/s11356-009-0176-7.
9. Nelson, S.J., P. Vaux, M.J. James-Pirri, and G. Giese, 2012, Natural resource condition assessment: Cape Cod National Seashore, Massachusetts, Natural Resource Report NPS/NER/NRR—2012/605, National Park Service, Fort Collins, Colorado.
10. Kerr, J.G., M.C. Eimers, I.F. Creed, M.B. Adams, F. Beall, D. Burns, J.L. Campbell, S.F. Christopher, T.A. Clair, F. Courchesne, L. Duchesne, I. Fernandez, D. Houle, D.S. Jeffries, G.E. Likens, M.J. Mitchell, J. Shanley, H. Yao, 2011, The effects of seasonal drying on sulphate dynamics in streams across southeastern Canada and the northeastern USA, 111(1-3): 393-409, Biogeochemistry, DOI 10.1007/s10533-011-9664-1.
11. James-Pirri, M. J., S. J. Nelson, and P. D. Vaux, June 2011, Natural Resource Condition Assessment for Saugus Iron Works National Historic Site. Natural Resource Report NPS/NER/NRR—2011/457, National Park Service, Fort Collins, Colorado.
12. Strock, K., S. Nelson, J. Kahl, J. Saros, W. McDowell, 2014. Decadal trends reveal recent acceleration in the rate of recovery from acidification in the northeastern US. Environ. Sci. Technol. 48(9):4681-4689.
13. Strock, K.E. 2013. Deciphering Climate-Mediated Changes in Boreal Lake Ecosystems. Ph.D. Dissertation, University of Maine, Orono, Maine.
14. Boeff, K. 2014. Evaluating the effect of a changing climate on thermocline depth in Maine s Great Ponds. Master s thesis, University of Maine, Orono, Maine.
15. Sanclements, M., G. Oelsner, D. McKnight, S.J. Nelson, J. Stoddard, 2012, New insights into the source of decadal increases of dissolved organic matter (DOM) in acid-sensitive lakes of the northeastern U.S., Environmental Science and Technology, 46(6): 3212–3219, DOI: 10.1007/s11356-009-0176-7.
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17. Kerr, J.G., M.C. Eimers, I.F. Creed, M.B. Adams, F. Beall, D. Burns, J.L. Campbell, S.F. Christopher, T.A. Clair, F. Courchesne, L. Duchesne, I. Fernandez, D. Houle, D.S. Jeffries, G.E. Likens, M.J. Mitchell, J. Shanley, H. Yao, 2011, The effects of seasonal drying on sulphate dynamics in streams across southeastern Canada and the northeastern USA, 111(1-3): 393-409, Biogeochemistry, DOI 10.1007/s10533-011-9664-1.
18. James-Pirri, M. J., S. J. Nelson, and P. D. Vaux, June 2011, Natural Resource Condition Assessment for Saugus Iron Works National Historic Site. Natural Resource Report NPS/NER/NRR—2011/457, National Park Service, Fort Collins, Colorado.
19. Strock, K., S. Nelson, J. Kahl, J. Saros, W. McDowell, 2014. Decadal trends reveal recent acceleration in the rate of recovery from acidification in the northeastern US. Environ. Sci. Technol. 48(9):4681-4689.
20. Strock, K.E. 2013. Deciphering Climate-Mediated Changes in Boreal Lake Ecosystems. Ph.D. Dissertation, University of Maine, Orono, Maine.
21. Boeff, K. 2014. Evaluating the effect of a changing climate on thermocline depth in Maine s Great Ponds. Master s thesis, University of Maine, Orono, Maine.
22. Brown, R. 2014. Assessing the ecological effects of increased dissolved organic carbon in Maine lakes over recent decades. Master's thesis, University of Maine, Orono, Maine.

Annual Report to

USGS WRD WRRI, Reston, VA
US EPA, CAMD, Washington DC
and US EPA, ORD, Corvallis OR

June, 2015

Determining the effectiveness of the Clean Air Act and Amendments on the recovery of surface waters in the northeastern US

IAG 06HQGR0143

Principal Investigators: *William H. McDowell[1], Sarah J. Nelson[2], J. Steve Kahl[1], J. Saros[2]*
[1]Univ. of New Hampshire, [2]Univ. of Maine

Overview of activities during 2014-2015. A schematic summary of progress on the project plan is provided below (Table 1) and discussed on the following pages. We have concluded the fourth year of five for the most current project agreement, which supports the continuing needs of EPA to assess the effectiveness of the Clean Air Act Amendments of 1990 (CAAA). Field work and data assessment continue on schedule. Project coordination as well as most analytical chemistry, and some field sampling are conducted by the University of New Hampshire. Additional field sampling, data quality assurance, and data reporting are conducted by the University of Maine. This year the project is partially funding a Postdoctoral Researcher who is evaluating biotic and abiotic changes in the LTM and TIME lakes. Three graduate students at the University of Maine were partly funded through this project, or in research leveraged on this project. Kristin Strock completed a Ph.D. with Saros, Nelson et al. in fall 2013, and published one manuscript in Environmental Science and Technology based on the long-term data (Strock et al., 2014). Two M.S. students completed theses, working with PIs Saros and Nelson, in 2014. M.S. student Kelsey Boeff successfully defended a thesis in Quaternary Studies dealing with changes in diatom community structure in LTM site Tunk Lake as well as other large lakes in Maine. M.S. student Rob Brown is completed a thesis that evaluates changes in lake thermal structure at three pairs of LTM lakes and a public water supply lake. Both M.S. students paired coring (proxy) measurements with contemporary chemical and physical data. Additionally, this project continues to fund a portion of the base program of stream chemistry monitoring at Bear Brook Watershed in Maine (BBWM), for the reference watershed, East Bear. BBWM is partway through a three-year NSF DEB grant that is evaluating nitrogen dynamics in both watersheds using ^{15}N tracer studies. The base funding through this IAG project created continuity that was key in securing the NSF award.

Table 1. 2011-2015 Project plan progress to date.

	2011				2012				2013				2014				2015				2016
Project Activity	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
project period	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	▨	▒	▒	▒
funding received	■				■				■						▨		▒		▨		
RLTM drainage		■	■	■		■	■	■		■	■	■		▨	■	■		▨	▒	▒	
RLTM seepage		■	■	■		■	■	■		■	■	■		▨	■	■		▨	▒	▒	
original LTM				■				■				■				■				▒	
HELM subset				■				■				■				■				▒	
BBWM - EB	■	■	■	■	■	■	■	■	■	■	■	■	■	▨	■	■	■	▨	▒	▒	▒
TIME New England			■				■				■				■				▒		
TIME Adirondacks			■				■				■				■				▒		
sample analyses	■	■	■	■	■	■	■	■	■	■	■	■	■	▨	■	■	■	▨	▒	▒	▒
Data submission		■				■				■					■				▒		▒
annual report		■				■				■				▨				▨			

▒ = project plan ▨ = in progress ■ = completed ⁘ = cancelled (weather)

Project background

Objectives. This research is part of EPA CAMD programs that are verifying the effectiveness of emission controls at reducing acidification of surface waters. Our approach is to collect long-term high-quality data that characterize the trends and patterns of response in low ionic-strength surface waters. We have specifically targeted waters that have been classified as being sensitive to acidic deposition and will represent lakes across the Northeast in varying landscape settings. The goals and methods are hierarchical, ranging from intensive site-specific investigations to regional assessment of sites that have been chosen to provide a statistically rigorous sample of regional surface waters. The objectives are to:

1) document the changes and patterns in aquatic chemistry for defined sub-populations and sites that are known to be susceptible to acidification or recovery;
2) evaluate the extent to which changes in surface waters, if any, can be linked to changes in deposition that are driven by regulatory actions;
3) characterize the effectiveness of the CAAA in meeting goals of reducing acidification of surface waters and improving biologically-relevant chemistry in the northeastern US;
4) provide information for assessment of the need for future reductions in atmospheric deposition based on the long-term trajectories of the systems under study; and
5) assess the extent to which increased variability in precipitation events will play a role in the long-term sustainability of CAAA success in these sensitive surface waters. This is leveraged through other funded research.

Approach. The schedule of tasks ranges from weekly to annual, continuing data records that now range from 22 to 33 years. We evaluate chemistry on a weekly basis year-round at the small watershed-scale at BBWM, quarterly in LTM, and annually during the historical index period for the TIME and HELM lakes. These project components provide a *statistical framework* for inferring regional patterns in chemistry using TIME and LTM (and ELS-II under separate funding). The *long-term records* of LTM, HELM and BBWM provide information on seasonal and annual variability, and thus provide a seasonal context for the annual surveys.

Expected Results. This information is needed for EPA to meet its Congressional mandate to assess the effectiveness of the CAAA. The combination of site-specific data within the regional context provides a rigorous assessment of the effects of declining pollutant emissions on SO_4 concentrations, base cation depletion, and changes in N-saturation or DOC contributions to acid-base status. The results are also central to assessing whether additional emission reductions may be needed to produce recovery.

Project Status: Water Chemistry

Field sampling. All project field objectives in 2014 were accomplished as planned. A summary of the annual field schedule for this project is provided below (Table 2).

Table 2. Annual project field schedule for lake sampling

Project	sub-project	n	Times Sampled	Field work	May	June	July	Aug.	Sept.	Oct.
RLTM-Maine										
	seepage	3	3	UMaine	X		X			X
	drainage	10	3	UMaine/UNH	X		X			X
	LTM lakes	3	1	UMaine						X
TIME										
	New England	31	1	UNH			X	X	X	
	Adirondacks	43	1	ALSC			X	X	X	
HELM		25-30	1	UNH						X

Analytical. Analyses are complete for all samples collected through 2014. All laboratory analyses for TIME, RLTM, and HELM are conducted at the University of New Hampshire Water Quality Analysis Laboratory (WQAL) except for aluminum. Total and organic aluminum samples are processed on an ICP at the USDA Forest Service Region 1 laboratory in Durham, NH. All analyses for TIME, RLTM, and HELM continue to be conducted by, or under the supervision of, Jody Potter as has been the case since 2012.

Samples from East Bear Brook at BBWM, which are collected on a regular basis year-round, continue to be analyzed at the University of Maine Sawyer Water Research Lab.

Data reporting. All data collected through 2013 have been delivered to EPA. The next delivery of data to EPA is expected before August 2015, after evaluation of inter-laboratory comparisons and regular QA analyses by UNH and UMaine.

Presentation of findings. Several publications and presentations continue to result from this project and are listed at the end of this report. Recent leveraged funding is supporting portions of two M.S. theses and a Ph.D. dissertation at UMaine under the supervision of co-PI Saros.

New developments: During the past three years we were able to make routine two new sets of analyses to continue to extract new and innovative information from these study sites. A subset of lakes were analyzed for DOC quality using SUVA and fluorescence (EEMS) analysis, as well as concentrations of the dissolved greenhouse gases (CH_4, CO_2, and N_2O) in surface waters. Moving forward this data will provide valuable insight into changes in organic sources to acid-base status as well as the influence of precipitation event variability on long-term changes in surface water chemistry.

Publications using related project information ***(recent publications in bold):***

Strock, K., S. Nelson, J. Kahl, J. Saros, W. McDowell, 2014. Decadal trends reveal recent acceleration in the rate of recovery from acidification in the northeastern US. Environ. Sci. Technol. 48(9):4681-4689.

Sanclements, M., G. Oelsner, D. McKnight, S.J. Nelson, J. Stoddard, 2012. New insights into the source of decadal increases of dissolved organic matter (DOM) in acid-sensitive lakes of the northeastern U.S. Environmental Science and Technology 46(6): 3212–3219; DOI: 10.1007/s11356-009-0176-7.

Nelson, S.J., P. Vaux, M.J. James-Pirri, and G. Giese. 2012. Natural resource condition assessment: Cape Cod National Seashore, Massachusetts. Natural Resource Report NPS/NER/NRR—2012/605. National Park Service, Fort Collins, Colorado.

James-Pirri, M. J., S. J. Nelson, and P. D. Vaux. June 2011. Natural Resource Condition Assessment for Saugus Iron Works National Historic Site. Natural Resource Report NPS/NER/NRR—2011/457. National Park Service. Fort Collins, Colorado.

Kerr, J.G., M.C. Eimers, I.F. Creed, M.B. Adams, F. Beall, D. Burns, J.L. Campbell, S.F. Christopher, T.A. Clair, F. Courchesne, L. Duchesne, I. Fernandez, D. Houle, D.S. Jeffries, G.E. Likens, M.J. Mitchell, J. Shanley, H. Yao, 2011, The effects of seasonal drying on sulphate dynamics in streams across southeastern Canada and the northeastern USA, Biogeochemistry DOI 10.1007/s10533-011-9664-1.

Navrátil, T., S.A. Norton, I.J. Fernandez, S.J. Nelson, 2010. Twenty-year inter-annual trends and seasonal variations in precipitation and stream water chemistry at the Bear Brook Watershed in Maine, USA. Environ. Monit. Assess. 171:3-21.

Norton, S.; Fernandez, I.; Kahl, J.; Rustad, L.; Navratil, Tomas; Almquist, H., 2010. The evolution of the science of Bear Brook Watershed in Maine, USA. Environmental Monitoring and Assessment, 171(1-4): 3-21.

Vaux, P.D., S.J. Nelson, N. Rajakaruna, G. Mittelhauser, K. Bell, B. Kopp, J. Peckenham, G. Longsworth, 2008. Assessment of natural resource conditions in and adjacent to Acadia National Park, Maine. Natural Resource Report NPS/NRPC/WRD/NRR—2008/069. National Park Service, Fort Collins, Colorado.

Baumann, A.J. and J.S. Kahl, 2007. Chemical trends in Maine High Elevation Lakes. LakeLine 27:30-34.

Hunt, K., J.S. Kahl, J. Rubin, and D. Mageean, 2007. Assessing the science-based needs of stakeholders; a case study on acid rain research and policy. Journal of Contemporary Water Research and Education, 136: 68-79.

Rosfjord, C., K. Webster, J.S. Kahl, S.A. Norton, I. Fernandez, and A. Herlihy, 2007. Anthropogenically-driven changes in chloride complicate interpretation of base cation trends in lakes recovering from acidic deposition. Environ Sci Technol, 41:7688 -7693.

Rosfjord, C., J.S. Kahl, K. Webster, S. Nelson, I. Fernandez, L. Rustad, and R. Stemberger, 2006. Acidic deposition-relevant changes in lake chemistry in the EPA Eastern Lake Survey, 1984-2004. Final report to USDA NSRC, Durham, NH. 69 p.

Campbell, J, J. Hornbeck, M. Mitchell, M. Adams, M. Castro, C. Driscoll, J.S. Kahl, and others, 2004. Input-output budgets for inorganic nitrogen for 24 watersheds in the northeastern United States. Water Air Soil Pollution, 151:373-396.

Lawler, J., J. Rubin, B.J. Cosby, I. Fernandez, J.S. Kahl, S. Norton, 2005. Predicting recovery from acidic deposition: Applying a modified TAF (Tracking Analysis Framework) Model to Maine High Elevation Lakes, Water Air Soil Pollution. 164:383-389.

Dupont, J., T. Clair, C. Gagnon, D. Jeffries, J.S. Kahl, S. Nelson, and J Peckenham, 2005. Estimation of critical loads of acidity in the northeastern US and eastern Canada. Environ. Monit. Assess. 109:275-291.

Kahl, J.S., J. Stoddard, R. Haeuber, S. Paulsen, R. Birnbaum, F. Deviney, D. DeWalle, C. Driscoll, A. Herlihy, J. Kellogg, P. Murdoch, K. Roy, W. Sharpe, S. Urquhart, R. Webb, and K. Webster, 2004. Response of surface water chemistry to changes in acidic deposition: implications for future amendments to Clean Air Act. Environmental Science and Technology, Feature Article 38:484A-490A.

Norton, S., I. Fernandez, J.S. Kahl, and R. Reinhardt, 2004. Acidification trends and the evolution of neutralization mechanisms through time at the Bear Brook Watershed, Maine, USA. Water, Air, Soil, Pollution Focus 4:289-310.

Dissertations/theses:

Strock, K.E. 2013. Deciphering Climate-Mediated Changes in Boreal Lake Ecosystems. Ph.D. Dissertation, University of Maine, Orono, Maine.

Boeff, K. 2014. Evaluating the effect of a changing climate on thermocline depth in Maine's Great Ponds. Master's thesis, University of Maine, Orono, Maine.

Brown, R. 2014. Assessing the ecological effects of increased dissolved organic carbon in Maine lakes over recent decades. Master's thesis, University of Maine, Orono, Maine.

Presentations using related project information ***(recent presentations in bold)****:*

McDowell, W.G., K. Webster, S.J. Nelson, W.H. McDowell, J. Haney. Regulation and results: biotic and abiotic changes to northeastern lakes following tightening of air emission rules. Society for Freshwater Science, Milwaukee, WI, May 17- 21, 2015.

Appling, A.P., W.H. McDowell, J.D. Potter, S.J. Nelson, J.S. Kahl, 2014. From the frying pan into the fire? Lake greenhouse gas responses to acid rain recovery. Joint Aquatic Sciences Meeting. Portland, OR, May 18 – 23, 2014.

Brown, R.E., Saros, J.E. & S.J. Nelson. 2014. Algal community response to increases in dissolved organic carbon over recent decades. Poster presentation. Association for the Sciences of Limnology & Oceanography, Portland, OR, May, 2014.

Boeff, K. & J.E. Saros. 2014. Evaluating the effect of a changing climate on thermocline depth in Maine's Great Ponds. Poster presentation. Association for the Sciences of Limnology & Oceanography, Portland, OR, May, 2014.

Brown, R.E., Saros, J.E. & S.J. Nelson. 2014. Algal community response to increases in dissolved organic carbon over recent decades. Poster presentation. Maine Water Conference, Augusta, ME, March, 2014.

Strock, K.E., Saros, J.E., Nelson, S.J. & S. Birkel. 2014. Interactive effects of extreme weather and reduced sulfate deposition: accelerated recovery from acidification and increased brownification in lakes of the Northeast U.S. Association for the Sciences of Limnology & Oceanography, Portland, OR, May, 2014.

Boeff, K. & J.E. Saros. Evaluating the effect of changing wind strength on thermocline depth in Maine's Great Ponds. 22nd Annual Harold W. Borns Jr. Symposium, Orono, ME, USA, April, 2014.

Brown, R.E., Saros, J.E. & S.J. Nelson. 2014. Algal community response to increases in dissolved organic carbon over recent decades. 22nd Annual Harold W. Borns Jr. Symposium, Orono, ME, USA, April, 2014.

S.J. Nelson, 2013. School of Forest Resources Faculty Blitz. Sept. 13, 2013.

Boeff, K. & J.E. Saros. 2013. Evaluating the effect of a changing climate on thermocline depth in Maine's Great Ponds. Poster presentation. North American Diatom Symposium, Bar Harbor, ME, August, 2013.

Brown, R.E., Saros, J.E. & S.J. Nelson. 2013. Algal community response to increases in dissolved organic carbon: Implications for drinking water utilities. Poster presentation. North American Diatom Symposium, Bar Harbor, ME, August, 2013.

Nelson, S.J., C. Chen, D.P. Krabbenhoft, J.S. Kahl, B. Zoellick, 2013. Validating landscape models for mercury in northeastern US lakes using dragonfly larvae as mercury bio-sentinels. Accepted for poster presentation at the ICMGP - International Conference on Mercury as a Global Pollutant, July 28- Aug. 3, 2013, Edinburgh, Scotland.

Boeff, K., J. Saros. 2013. Evaluating the Effect of Changing Wind Strength on Thermocline Depth in Maine's Great Ponds. 21st Annual Harold W. Borns Jr. Symposium, Orono, ME, USA, April, 2013.

Brown, R.E., J.E. Saros, S.J. Nelson. Algal community response to increases in dissolved organic carbon in Maine lakes: implications for drinking water utilities. 21st Annual Harold W. Borns Jr. Symposium, Orono, ME, USA, April, 2013.

Strock, K.E., J.E. Saros, S. Birkel, S.J. Nelson, 2013. Exploring the effects of extreme hydrologic events in the northeastern U.S.: Implications for brownification and episodic acidification in Maine Lakes. 21st Annual Harold W. Borns Jr. Symposium, Orono, ME, USA, April, 2013.

Nelson, S.J., C. Chen, D.P. Krabbenhoft, J.S. Kahl, 2013. Dragonfly larvae as mercury bio-sentinels: a statistical survey of northeast lakes reveals landscape-driven patterns in water and biota mercury concentrations. NERC (Northeastern Ecosystems Research Cooperative) meeting, March 19 – 20, 2013, Saratoga Springs, NY.

Strock, K.E.D., J.E. Saros, S.J. Nelson. 2013. The effects of extreme climate events on lakewater chemistry: Implications for "brownification" in Maine lakes. Maine Water Conference. Augusta, Maine, March 19, 2013.

Strock, K.E.D., J.E. Saros, S.J. Nelson, S.D. Birkel. 2013. The effects of extreme climate events on lakewater chemistry: implications for dissolved organic carbon trends in the northeast

U.S. American Society of Limnology and Oceanography Meeting. New Orleans, Louisiana, February 17-22, 2013.

Sanclements, M., G. Oelsner, D. McKnight, I.J. Fernandez, S.J. Nelson, M.B. Adams, M. Mineau, K. Simon, 2012. The effects of acidification and recovery on DOM quality and source in temperate forested watersheds. BIOGEOMON 2012, July 15-20, 2012, Northport, ME.

Strock, K.E., J.E. Saros, S.J. Nelson, 2012. Analyzing Legacy Data in a Climate Context to Decipher Modern Changes in Lakewater Chemistry. Poster presentation. BIOGEOMON 2012, July 15-20, 2012, Northport, ME.

Fernandez, I.J., Norton, S.A., Nelson, S.J., Salvino, C., 2012. Evidence of Transient Alteration of N Dynamics From an Ice Storm at the Bear Brook Watershed in Maine, USA. Poster presentation. BIOGEOMON 2012, July 15-20, 2012, Northport, ME.

Saros, J.E., K.E.D. Strock, S. Birkel & S.J. Nelson. 2012. Deciphering the effects of extreme hydrologic events on the response of northeastern lakes to reduced sulfur deposition. 20th annual Harold W. Borns Symposium, University of Maine.

Nelson, S.J., J.S. Kahl, A.J. Baumann, K.B. Johnson, 2012. "Rugged shores and clear waters": Interpreting biogeochemical response to environmental stressors using the lakes and ponds of Maine's Baxter State Park. Maine Water Conference, Augusta, ME, March 14, 2012.

Strock, K.E., J.E. Saros, S. Nelson. Why climate matters in recovery from acidification in northeastern US surface waters. Maine Water Conference, Augusta, ME, March 14, 2012.

Baumann, A.J., J.S. Kahl, T.R. Boucher, S.J. Nelson, and K.J. McGuire, 2012. "Changes in surface water chemistry in Maine high elevation lakes in response to the 1990 Clean Air Act Amendments. Maine Water Conference, Augusta, ME, March 14, 2012.

Mineau, M. M., K. S. Simon, D. T. Ely; R. L. Rancatti, I. J. Fernandez, S. A. Norton, and H. M. Valett. 2011. Effects of chronic nitrogen enrichment and acidification on coupled nitrogen and phosphorus cycling in streams: Insights from multiple spiraling techniques. Annual meeting, North American Benthological Society, Providence, RI.

Nelson, S.J., P. Vaux, M.J. James-Pirri. Data-driven assessments of National Park resources. (Invited). Acadian Internship in Regional Conservation and Stewardship, July 15, 2011.

Schneider, S.B., I.J. Fernandez, S.A. Norton, K.S. Simon. 2011. Soil base cation response to two decades of change at the Bear Brook Watershed in Maine. Gordon Conference on Catchment Science: Interactions of Hydrology, Biology and Chemistry. Bates College, Lewiston, Maine. July 10-15.

Nelson, S.J., C. Chen, H. Roebuck, B. Zoellick. Sensible sentinels: Preliminary mercury data for dragonfly nymphs (*Odonata: anisoptera*) across northern New England corroborate expected spatial pattern. The 10th International Conference on Mercury as a Global Pollutant (ICMGP), Halifax, NS, July 24-29, 2011; and presented at the Acadia Science Symposium, October 26, 2011.

Baumann, A.J., and J.S. Kahl, 2009. Assessing the effectiveness of federal acid rain policy using remote and high elevation lakes in northern New England. North American Lake Management Society International Symposium, Hartford, CT, October 29, 2009.

Kahl, J.S., 2009. Changes in base cations related to long-term changes in Cl distribution in northeastern lakes. Gordon Research Conference, Forested Catchments, July 12-17, 2009, Proctor Academy, NH.

Kahl, J.S., 2008 (invited). Twenty year changes in spatial patterns of Cl distribution in the northeastern US. NH Water Conference, April, 2008.

Kahl, J.S., 2007 (invited). Using societal-based incentives to address new threats to New England Lakes. Day-long short course in New England Lake Science Academy, Camp Kieve, Maine. July, 2007.

Kahl, S., K. Webster, D. Sassan, C. Rosfjord, S. Nelson, M. Greenawalt-Yelle, 2007. Increasing Cl in northeastern surface waters: an indicator of increasing development pressure. Maine Water Conference, Augusta, ME, March 21, 2007.

Kahl, J.S. 2006 (invited). Acid rain in New England: using high elevation lakes as sentinels of change. Maine Mountain Conference, October 21, 2006. Rangeley, Maine

Kahl, J.S., *et al*., 2006 (invited). The design of a national mercury monitoring network: Learning from the EPA acid rain experience. The Eighth International Mercury Conference, Madison WI, August 8, 2006.

Kahl, J.S. *et al*., 2006. Obfuscation of trends in base cations by regional salt contamination. Hubbard Brook Committee of Scientists annual meeting, July 12, 2006.

Kahl, J.S., 2006 (invited). 'Natural and human-derived sources of acidity in Maine Atlantic Salmon Rivers'. Atlantic Salmon Commission workshop on acidity, Bangor ME. April 10, 2006.

Kahl, J.S., 2005 (invited). The intersection of environmental science and environmental policy. NH Charitable Foundation Lakes Region annual meeting, Meredith, NH, September, 2005.

Kahl, J.S., 2005 (invited). Tracking response and recovery in surface waters in the northeastern US. Annual meeting of the Ecological Society of America, Montreal, August, 2005.

Kahl, J.S., and Catherine Rosfjord, 2005 (invited). Acid rain and the Clean Air Act in the northeastern US. Annual meeting of the NH-ME Androscoggin River Watershed Council, Bethel, June, 2005

Kahl, J.S., 2005 (invited). Developing a lake research agenda for NH. NSF workshop on lake research infrastructure in the northeast, Colby Sawyer College, April 2005.

Kahl, J.S., S. Nelson, and A. Grygo, 2004. Surface water chemistry data for the northeastern US for interpreting climate and acid rain trends. Northeast Ecosystems Research Consortium meeting, Durham, NH, October, 2004.

Kahl, J.S., K. Webster, M. Diehl, and C. Rosfjord, 2004. Successes of the Clean Air Act Amendments of 1990. Maine Water Conference invited plenary talk, Augusta, ME, 2004.

Kahl, J.S. and K. Johnson, 2004. Acid-Base Chemistry and Historical Trends in Downeast Salmon Rivers. Maine Water Conference, Augusta ME, April 2004.

Kahl, J.S., 2004 (invited). The Clean Air Act Amendments of 1990; testing a program designed to evaluate environmental policy. Lecture, Colby College. April, 2004

S.J. Nelson, J.S. Kahl, N.C. Kamman, D.P. Krabbenhoft, W.H. Halteman, 2009. (Poster) Predicting mercury concentrations in northeast lakes using hydrogeomorphic features, landscape setting and chemical co-variates. Gordon Research Conference, Forested Catchments, July 12-17, 2009, Proctor Academy, NH.

Nelson, S.J., I. Fernandez, S. Norton, B. Wiersma, L. Rustad, J.S. Kahl, 2008. The Bear Brook Watershed in Maine: Long-term research supporting climate change inquiry. Hydroclimatic effects on ecosystem response: participant workshop, Syracuse, NY, September 19, 2008.

Nelson, S.J., N. Kamman, D. Krabbenhoft, J.S. Kahl, K. Webster, 2008. Evaluating spatial patterns in mercury and methyl mercury in northeastern lakes: Landscape setting, chemical climate, and human influences. Northeastern Ecosystem Research Cooperative Conference, Durham, NH, November 12-13, 2008.

Nelson, S.J. 2008. Evaluating spatial patterns in mercury and methyl mercury in northeastern lakes: landscape setting, chemical climate, and human influences. Maine Water Conference, Augusta, ME, March 19, 2008.

Recent Bear Brook publications and presentations that include "base program" data (East Bear Brook stream chemistry partly funded through this grant):

Mineau M. M., F. R. Fatemi, I. J. Fernandez and K. S. Simon. 2014. Microbial enzyme activity at the watershed scale: Response to chronic nitrogen deposition and acute phosphorous enrichment. Biogeochemistry 117:131-142.

Mineau, Madeleine M., Chad M. Grigsby, Damon T. Ely, Ivan J. Fernandez, Stephen A. Norton, Tsutomu Ohno, H. Maurice Valett, and Kevin S. Simon. 2013. Chronic catchment nitrogen enrichment and stoichiometric constraints on the bioavailability of dissolved organic matter from leaf leachate. Freshwater Biology 58:248-260.

Gruselle, Marie-Cecile, Cayce Salvino, Ivan J. Fernandez, Kevin Simon and Corianne Tartariw. 2013. Does Chronic N Fertilization Increase P Limitation in Northeastern U.S. Forest Soils? (Paper 383-4). Presented at the ASA-CSSA-SSSA International Meetings. Tampa, Florida. November 3-6. ASA, CSSA, SSSA, Madison, WI.

Fatemi, Farrah, Michael D. SanClements, and Ivan J. Fernandez. 2013. Microbial Carbon Cycling Along a Drainage Sequence in a New England Forested Watershed. (Paper 252-2). Presented at the ASA-CSSA-SSSA International Meetings. Tampa, Florida. November 3-6. ASA, CSSA, SSSA, Madison, WI.

Morse, Jennifer L., Jorge Duran, Fred Beall, Irena Creed, Eric Enanga, Ivan Fernandez, and Peter M. Groffman. 2013. Soil denitrification fluxes and oxygen dynamics in three contrasting northeastern North American forests. Ecological Society of America. Minneapolis, Minnesota 8/4-8/9.

SanClements, Michael, Ivan Fernandez, Mary Beth Adams, and Jenny Erwin. 2013. Linking Stream DOM Quality and Source to Watershed Acidification and Recovery in Temperate Forests of the Northeastern United States. 12th North American Forest Soils Conference, Whitefish, Montana. p. 112.

Gruselle, Marie-Cecile, Ivan Fernandez, and Corianne Tatariw. 2013. Manganese Dynamics in the Third Decade of Forest Ecosystem Experimental Acidification and Nitrogen Enrichment. 12th North American Forest Soils Conference, Whitefish, Montana. p. 35

MacRae, J.D., C. Tatariw, D. Rothenheber, S. Nelson, I.J. Fernandez. The effects of nitrogen enrichment on forest soil microbial communities and their activities, 2013 AEESP 50th Anniversary Conference, July 14-16, Golden, CO.

Boca, Antra, Mercedes Roman Dobarco, Helga Van Miegroet, Marie-Cecile Gruselle, Beate Michalzik, and Ivan Fernandez. 2013. Linking Overstory, Soil and Climate Characteristics to Explain C Storage in Forest Soils. 12th North American Forest Soils Conference, Whitefish, Montana. p. 29.

Gruselle, M.-C., Fernandez, I., Simon, K., Norton S., 2013. The effects of long-term ecosystem N enrichment on 15N dynamics at the Bear Brook Watershed in Maine. NERC 2013 Conference, Saratoga Springs, NY.

Minocha, Rakesh, Swathi A. Turlapati, Stephanie Long, Mohammad M. Bataineh, Aaron Weiskittel, Ivan Fernandez, and Lindsey Rustad. 2013. Chronic N and S additions impact foliar physiology of forest trees at the Bear Brook Watershed in Maine, USA. Hubbard Brook Experimental Forest Annual Meeting, Thornton, NH.

Ohno, Tsutomu, Ivan J. Fernandez, Rachel L. Sleighter, and Patrick G. Hatcher. Influence of depth on soil organic matter characteristics: An ultrahigh resolution mass spectrometry study. Advanced Analytical Characterization of Natural Organic Matter, Goldscmidt 2013, Florence, Italy, August 25-30, 2013.

Fernandez, Ivan J. and Sarah J. Nelson. 2013. Bear Brook, Backpack Sprayers, and What's More Fun Than Gym Class? Invited seminar at the School of Forest Resources noon-time seminar series. University of Maine, Orono, Maine.

Mayewski, Paul, Ivan J. Fernandez, Stephen A. Norton and Sean Birkel. 2013. Presentation on Climate Change and Maine to the Allagash Wilderness Waterway Advisory Council. March 22. Augusta, Maine.

Fatemi, Farrah R., Ivan J. Fernandez, Stephen A. Norton and Lindsey E. Rustad. 2013. Soil solution response to two decades of experimental acidification at the Bear Brook Watershed in Maine. Water Air Soil Pollution. 223:6171–6186.

Mineau, Madeleine M., Chad M. Grigsby, Damon T. Ely, Ivan J. Fernandez, Stephen A. Norton, Tsutomu Ohno, H. Maurice Valett, and Kevin S. Simon. 2013. Chronic catchment nitrogen enrichment and stoichiometric constraints on the bioavailability of dissolved organic matter from leaf leachate. Freshwater Biology (in press).

Fernandez, Ivan J., Stephen A. Norton, and Tiffany Wilson (eds.). 2012. BIOGEOMON 2012, The 7th International Symposium on Ecosystem Behavior. Northport, Maine. ISBN 978-0-87723-108-0. 261 pp.

Fernandez, Ivan J., Madeleine M. Mineau, Kevin S. Simon, and Stephen A. Norton. 2012. The influence of decadal-scale N enrichment on N dynamics and 15N discrimination in a New England Forested Watershed. (Paper 302-2). Presented at the ASA-CSSA-SSSA International Meetings. Cincinnati, Ohio. October 22-25. ASA, CSSA, SSSA, Madison, WI.

Mineau, M.M., K.S. Simon, I.J. Fernandez, S.A. Norton, and H.M. Valett. The effect of chronic watershed nitrogen deposition and acidification on the interaction among phosphorus, carbon, and nitrogen uptake in streams. BIOGEOMON 2012, The 7th International Symposium on Ecosystem Behavior. Northport, Maine. ISBN 978-0-87723-108-0. p. 167.

Norton, S.A., I.J. Fernandez, T. Navratil, K.S. Simon, and S. Jain. 2012. The Bear Brook Watershed in Maine (BBWM) at 25: manipulation, monitoring, mechanisms, and modeling. BIOGEOMON 2012, The 7th International Symposium on Ecosystem Behavior. Northport, Maine. ISBN 978-0-87723-108-0. p. 177.

Rancatti, R., K. Simon, M. Mineau, D. Anderson, I.J. Fernandez, S.A. Norton, and M.B. Adams. 2012. Effects of watershed acidification on abiotic and biotic phosphorus uptake in streams draining two whole-watershed experimental forests. BIOGEOMON 2012, The 7th International Symposium on Ecosystem Behavior. Northport, Maine. ISBN 978-0-87723-108-0. p. 204.

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

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.

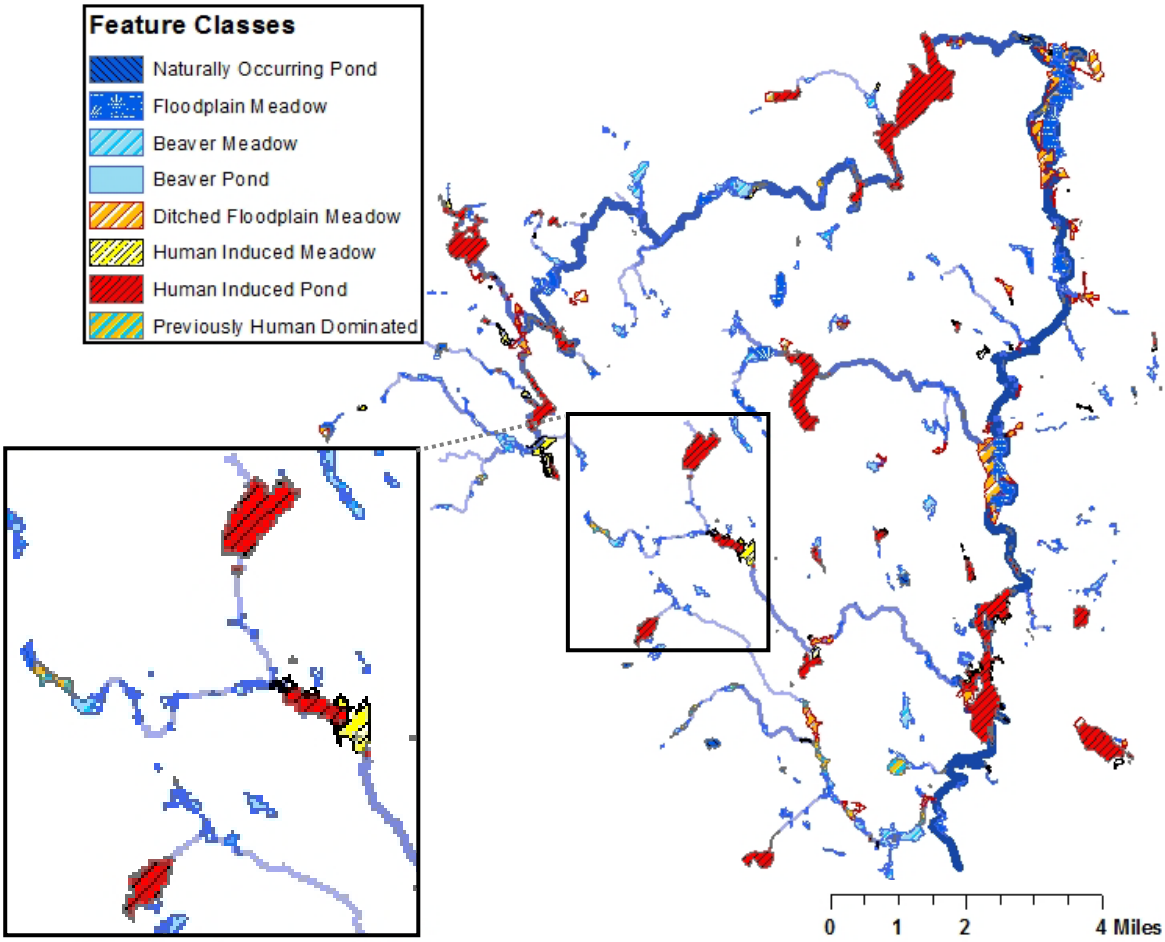


Figure 1. Impoundments along the river network for the Contoocook River, southwestern New Hampshire, digitized in Year 1 of this study. Inset shows typical detail. These digitized data will be used as the foundation for calculations of river network heterogeneity, of correlation between heterogeneity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

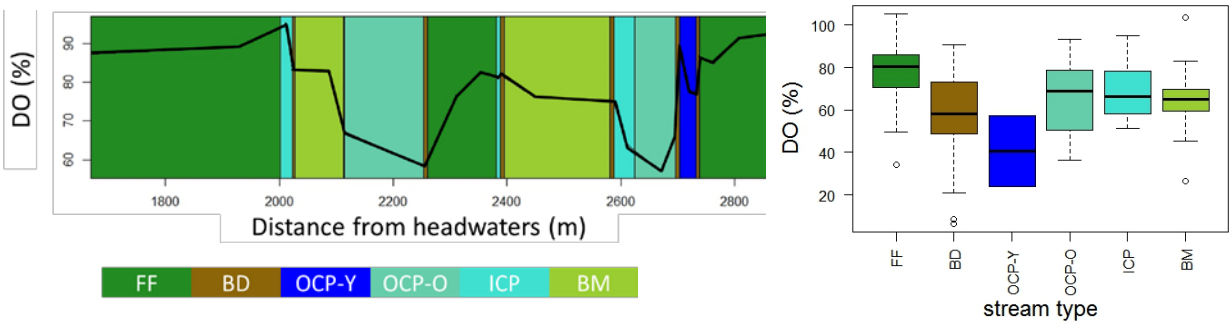


Figure 2. Left: example of dissolved oxygen profile along one study river (Hosley Brook, Hancock, NH). Right: comparison of DO across various feature types for all study reaches. Legend: FF—free-flowing; BD—beaver dam; OCP-Y—out of channel beaver pond, young; OCP-O—out of channel beaver pond, old; ICP—in-channel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

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

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.

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.

Contribution of fluvial wetlands to nitrogen retention in urbanizing coastal watersheds in New England across multiple scales

Basic Information

Title:	Contribution of fluvial wetlands to nitrogen retention in urbanizing coastal watersheds in New England across multiple scales
Project Number:	2014NH185B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	NH 1st
Research Category:	Water Quality
Focus Category:	Nitrate Contamination, Hydrology, Wetlands
Descriptors:	None
Principal Investigators:	Anne Lightbody, Linda Kalnejais, Wil Wollheim

Publications

There are no publications.

NH WRRC Annual Report, 2015
Project title: Contribution of fluvial wetlands to nitrogen retention in urbanizing coastal watersheds in New England across multiple scales
PIs: Anne Lightbody, Linda Kalnejais, & Wil Wollheim

Problem

Surface water quality in rapidly urbanizing coastal watersheds in New England is at risk due to excess anthropogenic nutrient inputs, which threaten downstream water uses and could lead to fluvial and estuarine eutrophication (Bricker et al. 1999, Caraco and Cole 2003). Fluvial wetlands, which are biologically reactive and have long residence times (Vidon and Hill 2001), can remove excess nitrate, thus providing an important ecosystem service (Wollheim et al. 2005, Rabalais et al. 2009). Flow-through wetlands consist of an advective main channel, plus slow-flowing off-channel areas collectively termed "transient storage." Wetlands with higher lateral connectivity between the main stream channel and transient storage are especially important because they may retain more nitrate than wetlands that receive little direct stream discharge (Racchetti et al. 2011). However, wetland connectivity and reactivity is still poorly understood, thus limiting our ability to predict the impact of future changes in land use and climate change on watershed retention of nitrogen inputs.

Project Objectives

1) Determine contribution of wetland-dominated stream reaches to surface transient storage as a function of inundation and season
2) Quantify nitrate uptake rate constants from model generalization among the different reaches.
3) Scale biogeochemical and hydrologic insights to wetland-dominated reaches throughout New England
4) Share results with local and regional policy makers

Methods

During the first year of study, 2014-2015, this project focused on eight wetland-dominated reaches (Figure 1) in four different watersheds in coastal New Hampshire and Massachusetts, with preference given to wetlands that have one channelized stream inlet and one channelized stream

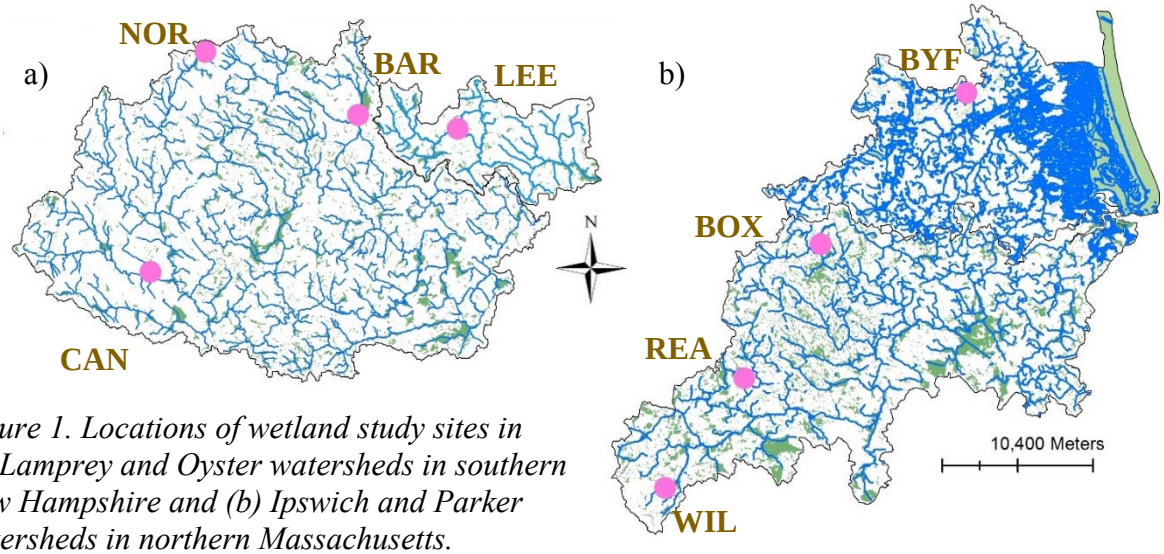


Figure 1. Locations of wetland study sites in (a) Lamprey and Oyster watersheds in southern New Hampshire and (b) Ipswich and Parker watersheds in northern Massachusetts.

outlet. The eight wetlands used in this study are of varying sizes and shapes. Wetland geometrical characteristics were calculated from delineation of aerial photography (Figure 2) for all eight study wetlands plus a randomly chosen subset of 50 wetlands in the neighboring Charles, Concord, Merrimack, and Piscataqua-Salmon watersheds. Watershed area was delineated from Light Detection and Ranging (LiDAR) digital elevation models. Due to the fine resolution of the LiDAR and the relatively flat terrain, watersheds were delineated at multiple points across the stream outlet and then total area for each was summed. Wetland area and main wetland channel length were delineated from aerial photography based on vegetation differences. National Wetland Inventory (NWI) datasets were used to obtain another measurement of wetland area. Specifically, all NWI polygons that shared a boundary with the target wetland were combined to create one large polygon. Wetland length was obtained by smoothing the main channel length. Average wetland width was then calculated from the wetland area divided by the length of the main channel. Width-to-length ratio was calculated as the wetland width divided by wetland length. Finally, sinuosity was measured as the length of the main channel divided by the sm oothed length of the wetland. All geographical analyses were performed using ArcMap 10.1 Spatial Analyst Toolbox.

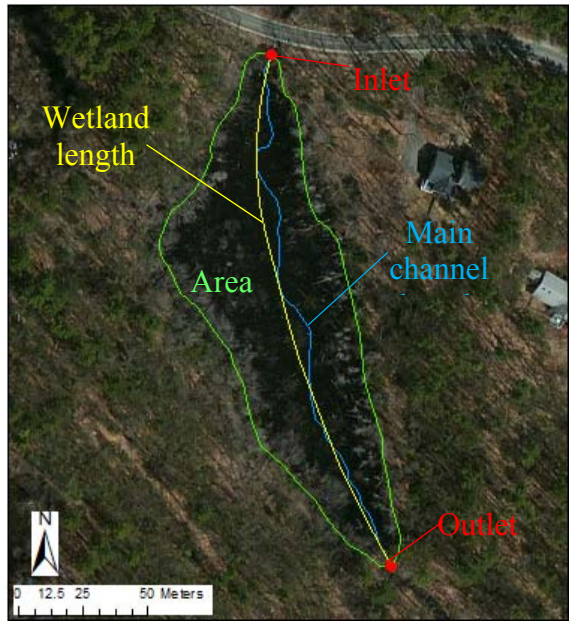


Figure 2. Aerial photograph of wetland site BOX in Boxford, MA, showing delineated geometrical parameters. Flow is from north to south; tracer was released at the wetland inlet and recorded exiting the wetland at the outlet.

Wetland connectivity was measured with the use of whole-reach slug releases of the nontoxic fluorescent tracer dye rhodamine WT (RWT). Tracer releases were performed between May and November 2014 during baseflow conditions. Three of the eight sites were studied twice to examine seasonal changes in baseflow connectivity, resulting in 11 studies in total. During each study, rhodamine was released into the stream feeding the wetland, then measured *in-situ* at the wetland outlet with a Turner C3 fluorometer set to record every 15, 30, or 60 seconds for at least 2 and typically 5 times the advective time scale of the wetland channel. Measured fluorescence at the wetland outlet was converted to excess rhodamine concentration using calibration curves and accounting for background fluorescence, instrument fouling, retardation, and photodegradation. Additionally, stage was measured at the inlet and outlet of each wetland at 12-15 minute intervals and converted to a continuous discharge record.

Tracer flux exiting the wetland was calculated by multiplying together tracer concentration and stream discharge (Figure 3). The mass of tracer recovered was calculated by integrating exit flux over time. The residence time distribution (RTD) of tracer in the wetland was calculated by dividing the exit flux by the mass recovered. The detention time (median travel time within the wetland) was calculated as the first moment of the RTD. Because studies occurred during steady base-flow conditions, it was assumed that the movement of the introduced fluorescent tracer was representative of other dissolved substances (in particular, dissolved inorganic nitrogen) also moving through the wetland at the same time.

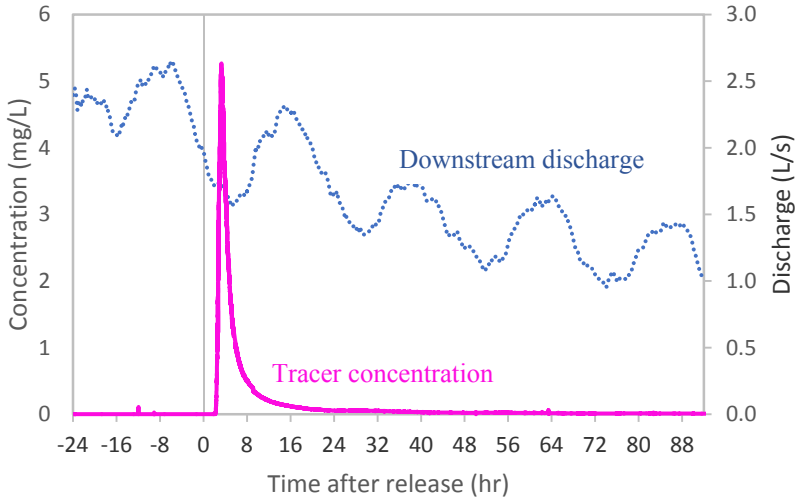


Figure 3. Continuous breakthrough curve of rhodamine WT (RWT) tracer concentration measured at the outlet of wetland study site BAR from June 18-23, 2014. The peak tracer concentration reached the outlet 3.5 hours after the release. Half of the dye exited by 9.7 hours. Discharge generally declined during the steady period.

Transient storage characteristics at the reach scale were determined from inverse modeling of each reach-scale tracer RTDs using the transient storage model STAMMT-L (Haggerty 2009). This approach conceptually divides the wetland into a main advective channel that exchanges water with stationary transient storage zones. The number of transient storage zones is specified in advance, and their size and connectivity are estimated by trying different parameter values until obtaining the best fit between the observed tracer RTD and a semi-analytical solution to the underlying partial differential transport equations. Three different transient storage models (Figure 4) were compared:

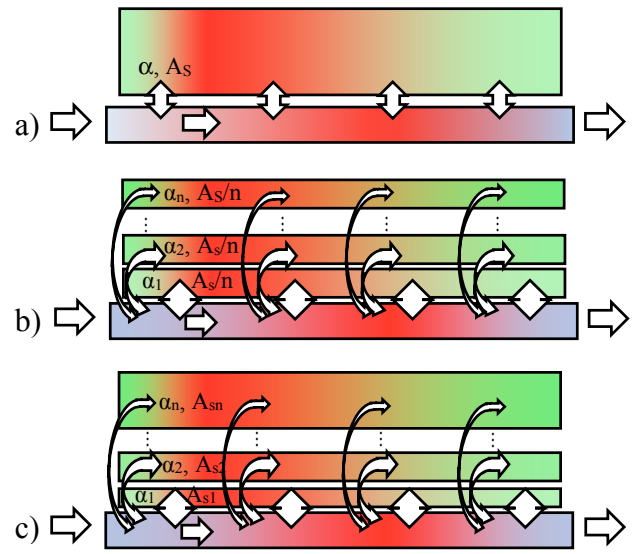
1. single-zone model, which allows for one transient storage zone adjoining the advective main channel. There is only one connectivity parameter (α) which represents the first-order exchange coefficient between the main channel and the storage zone.
2. multiple-zone single-size model, which divides the storage area into many zones of equal size but different connectivity ($\alpha_1, \alpha_2 ... \alpha_N$) which are distributed according to a power-law function.
3. multiple-zone different-size model, which maintains a power-law distribution of transient storage zone connectivities but also assumes that zone size is inversely proportional to zone connectivity. That is, as the zone size increases, the connectivity decreases.

The multiple-zone models reflect the field observation that some regions of transient storage (e.g., channel margins) are more connected than others (e.g., pools far from the main channel). For the multiple-zone models, 30 different zones were used (cf. Haggerty 2009); preliminary testing showed no difference in model parameter estimates for 30, 40, 50, or 60 zones.

Nitrate samples were collected at the inlet and the outlet of each wetland once during each tracer study. Samples were filtered in the field, placed on ice, then analyzed at the UNH Water Quality Analysis Laboratory using standard methods. Nitrate flux at the wetland inlet and outlet was calculated by multiplying concentration measurements by stream discharge.

Nitrate uptake rate constants was estimated by combining the optimized transport parameters determined from the slug releases of rhodamine with the observed inlet and outlet fluxes of nitrate. Specifically, the models were re-implemented assuming steady discharge conditions and the measured inlet flux of nitrate. The nitrate uptake rate constant was increased until the steady modeled outlet concentration matched the measured outlet concentration. Two scenarios were considered to apportion uptake between the main channel and the storage zones. First, whole-wetland uptake rate constants were calculated assuming the same rate constant for

Figure 4. Conceptual model of the different model geometries used to parameterize transient storage connectivity α and size A_s: (a) single-zone model, (b) multiple-zone single-size model, and (c) multiple-zone different-size model. Red color represents the conservative tracer added to the main channel, which advects and disperses in the main channel and is also transferred to and back from the transient storage zones.



both the channel and the storage. Second, maximum storage uptake rate constants were determined by assuming no uptake in the channel, which forced all the uptake to occur in the storage zones.

Principal findings and significance

The watershed area of the study wetlands ranged from 0.5 to 210 km^2. Wetland area ranged from 2,400 to 40,00 m^2, NWI area ranged from 1,200 to 52,000 m^2, wetland length ranged from 120 to 650 m, average width ranged from 18 to 50 m, width-to-length ratio ranged from 0.07 to 0.24, and wetland channel sinuosity ranged from 1.0 to 1.4. Only width was statistically different from (specifically, smaller than) a broad selection of other New England wetlands.

Following each tracer release, the time to tracer peak concentration (a measure of transport in the main wetland channel) ranged from 0.7 hours to 55 hours. Preliminary analysis indicates that the amount of RWT recovered ranged from 63 % to 137% of the amount released. If the tracer were truly conservative then 100% should have been recovered, but error resulted from uncertainty in both tracer concentration and discharge. Detention times ranged from 1.8 to 70 hours and were 1.3–3.7 times longer than the times to peak concentration, indicating long tails reflecting the influence of transient storage.

Transient storage models were successfully fit to all measured tracer breakthrough curves. For nearly all studies, the multiple-zone models better matched experimental data, especially in matching tracer concentration in the tail of the breakthrough (Figure 5). The tail of the tracer breakthrough curve at the wetland outlet exhibits the most sensitive response to different transport pathways including exchange with transient storage zones (Wang and Jawitz 2006, Gooseff et al. 2011); the better fit of the multiple-zone models confirmed that different types of transient storage were present in the study wetlands. The fraction of median travel time due to transient storage (Runkel 2002) ranged from 42–95%, indicating that most solutes moving through these reaches spent half or more of their time traveling through transient storage areas that may have exhibited high biogeochemical reactivity.

Single-zone transient storage zone size and connectivity values were consistent with previous observations in small fluvial wetlands in Wisconsin (Powers et al. 2012; Figure 6). The ratio of the transient storage area to the area of the main channel, A_s/A, was statistically correlated to the width-to-length ratio ($p=0.04$) for the multiple-zone single-size model. Few other significant relationships were found between optimized transport parameters and wetland geometry measured

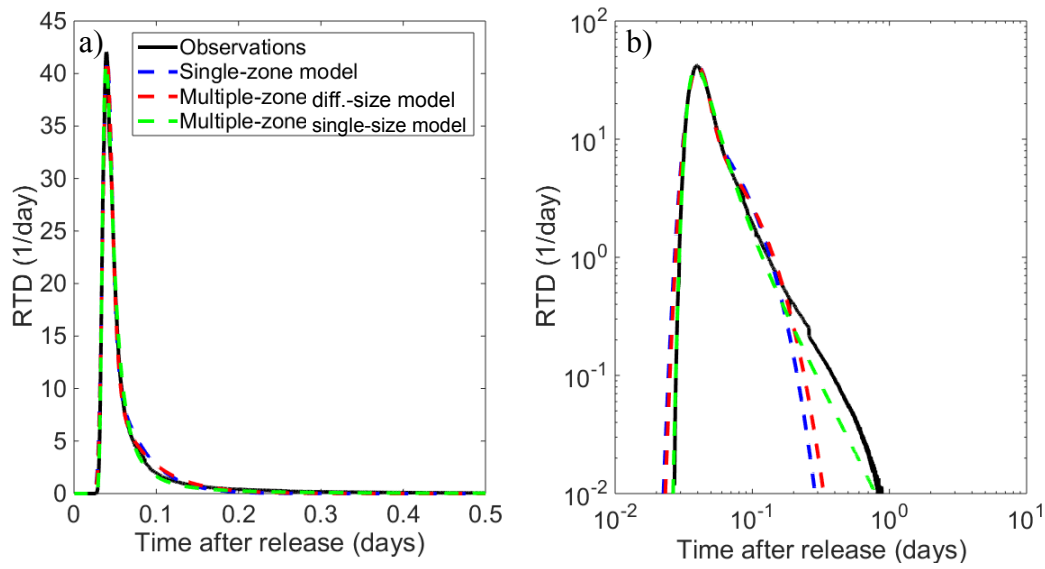


Figure 5. Measured and modeled residence time distribution (RTD) on (a) linear and (b) logarithmic axes for study REA2.

from aerial photographs. Instead, during summertime low-flow conditions, off- channel areas of study wetlands became disconnected from the main channel, and nitrate processing was limited to channel margins, the near-bed region of the channel, and the hyporheic zone. Increases in discharge can reconnect additional transient storage areas: for the multiple-zone different-size model, the minimum connectivity α_{min} and maximum connectivity α_{max} were correlated with discharge (p=0.02).

During 8 out of 11 studies, the outlet concentration of nitrate was less than the inlet concentration. In addition, in 7 out of 11 studies, nitrate fluxes (concentration × discharge) entering the wetlands were smaller than fluxes out of the wetlands. Thus, nitrate was retained within most of the study reaches during the period of observation.

Reach-scale nitrate uptake rate constants (Figure 7) calculated for study sites exhibiting retention were within the range of previous results from flow-through wetlands in Massachusetts (Wollheim et al. 2014) and Wisconsin (Powers et al. 2012) and, with the exception of study LEE, are higher than uptake rate constants for streams (Wollheim et al. 2014), confirming that small wetlands do play a large role in providing the important ecosystem service of nitrate retention. In general, nitrate uptake rate constants were similar between sites. There was no significant relationship between nitrate uptake rate constants and wetland geometry.

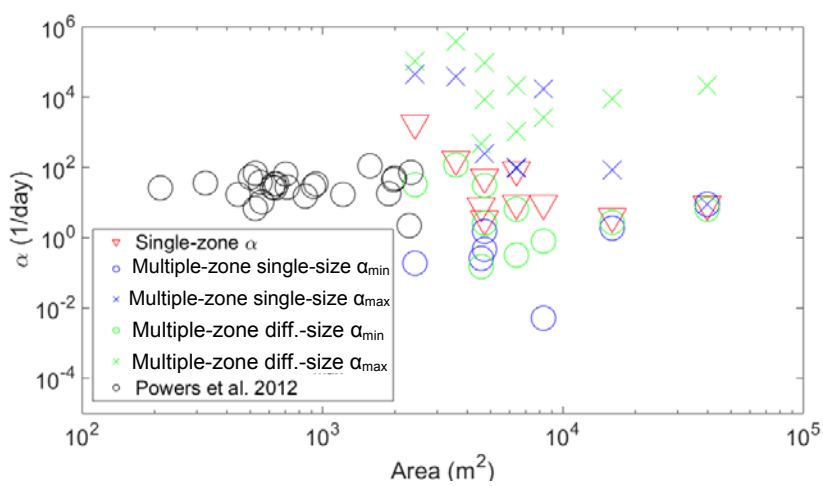


Figure 6. Comparison of connectivity parameters as a function of wetland area for study wetlands in NH and MA as well as Powers et al. (2012) data from small wetlands in Wisconsin.

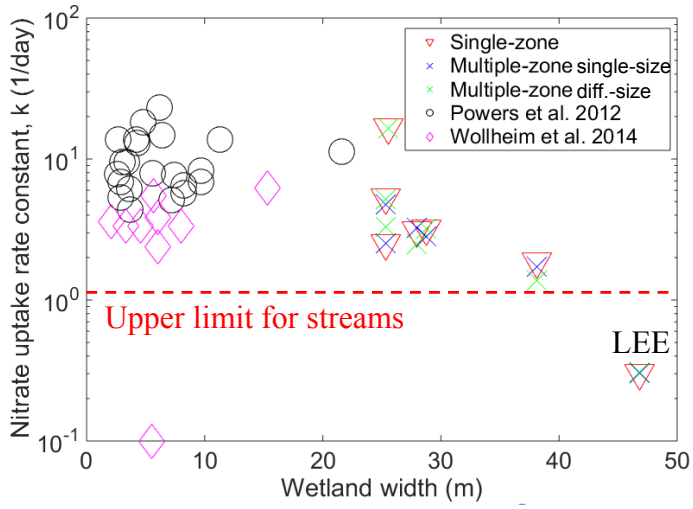


Figure 7. Reach-scale nitrate uptake rate constants for study wetlands, calculated assuming constant removal rates throughout the wetland. Results are compared to previous observations in fluvial wetlands (Wollheim 2014, Powers 2012) and streams.

When retention was assumed constant in the wetland channel and storage zones, different storage zone models resulted in similar reach-scale nitrate uptake rate constants (Figure 7). When all the nutrient uptake was forced to occur in the storage zones, however, the different models (which assumed different storage zone contributions) resulted in different effective storage zone uptake rate constants: a small or poorly connected storage zone would need to provide rapid uptake to result in the same observed reach-scale retention. The role of different aquatic patches in contributing to reach-scale uptake is still poorly understood.

Previous research has suggested seasonal cycles in nutrient uptake and release in coastal New England (Claessens et al. 2009). In this study, all three of the instances when nitrate was produced occurred in fall, when uptake rates tended to be low as well (Figure 8).

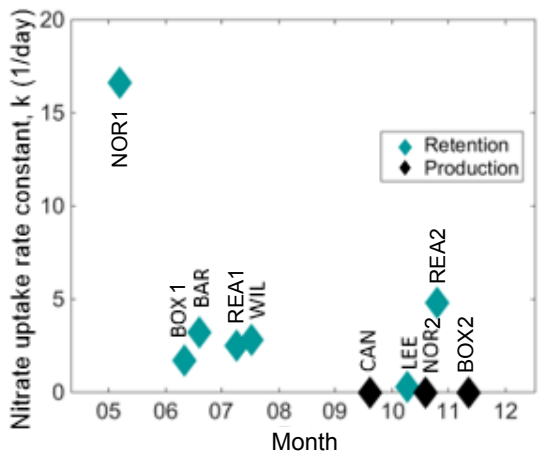


Figure 8. Uptake rate constants for studies that had measured nitrate retention, and the timing of studies with nitrate production.

Study Plans

During our second and final year of this study, 2015-2016, we are building on the above results to better characterize seasonal and spatial patterns of nitrate retention. Specifically, at 2 of these 8 wetlands, we will use *in-situ* chamber and core experiments to measure nitrate uptake in different wetland zones during the growth season (June) and the senescing season (October), which will help determine the variability of rate constants over the year. These rate constants will then be combined with estimates of the fraction of flow that accesses each wetland zone, along with the residence time distribution of flow in that zone. We will validate the ability of this approach to provide a reach-average bulk uptake rate constant by comparison with upstream and downstream grab samples from the same time period. We will also share results with local and regional policy makers to assist in on-going efforts to manage and mitigate nitrate loading in coastal New England rivers.

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Presentations

Dougherty, Michael P. Analysis of the photodegradation and sorption of Rhodamine WT in New Hampshire wetlands. UNH Undergraduate Research Conference. April 22, 2015.

May, Christian J. Using diurnal variations of stream discharge in small wetlands to determine water lost to evapotranspiration in New Hampshire and Massachusetts. UNH Undergraduate Research Conference. April 22, 2015.

Lightbody, A., Wilderotter, S., Wollheim, W. M., Kalnejais, L. Contribution of surface transient storage to nitrogen retention within wetland-dominated stream reaches in New England. Northeast Section Meeting of the Geological Society of America. March 23, 2015.

Wilderotter, S., Lightbody, A., Zuidema, S., Kalnejais, L. H., Wollheim, W. M. Predicting nitrate retention in wetland-dominated stream reaches using a conservative tracer. Conference on Partnerships for Environmental Progress, New England Association of Environmental Biologists. March 18, 2015.

Lightbody, A., Wilderotter, S., Rosengarten, D., Lawrence, K. Contribution of fluvial wetlands to nitrogen retention in urbanizing coastal watersheds. Lamprey River Research Symposium, NH Water Resources Research Center. January 9, 2015.

Wilderotter, S., Lightbody, A. F., Kalnejais, L. H., Wollheim, W. M., Zuidema, S. Transient Storage Parameterization of Wetland-dominated Stream Reaches. Lamprey River Research Symposium, NH Water Resources Research Center. January 9, 2015.

Wilderotter, S., Lightbody, A. F., Kalnejais, L. H., Wollheim, W. M., Zuidema, S. Transient Storage Parameterization of Wetland-dominated Stream Reaches. American Geophysical Union Fall Meeting. December 15, 2014.

Outreach

Presentation of watershed hydrology and water quality to 40 elementary school students as part of the UNH Leitzel Center, Kids Eager for Engineering Program with Elementary Research-based Science (KEEPERS) program, July 2014. Unit featured on KEEPERS promotional materials: http://www.leitzelcenter.unh.edu/pdf/carmelina_cestrone.pdf

Hydrology and water quality presentations to over 300 elementary and middle students and the public through UNH Ocean Discovery Day, Oyster River Girls' STEM Club, Hampstead Middle School, Moharimet Elementary School Science Friday, etc.

Participation in the Lamprey River Advisory Committee, and discussion with volunteers/staff from the Ipswich River Watershed Association and Oyster River Watershed Association

Initiation of collaboration with Peter Steckler at the Nature Conservancy, who is currently updating the Land Use Plan for New Hampshire's Coastal Watersheds to account for differences in wetland ability to retain nitrogen

Students supported

Sophie Wilderotter, MS Hydrology, Department of Earth Sciences, University of New Hampshire

Christian May, BS Environmental Sciences: Hydrology, Department of Earth Sciences, University of New Hampshire

Michael Dougherty, BS Environmental Sciences: Hydrology, Department of Earth Sciences, University of New Hampshire

Adam Moskal, BS Civil and Environmental Engineering, University of New Hampshire

Nathan Battey, BS Biology, University of New Hampshire

Faculty

Anne Lightbody, Assistant Professor

Linda Kalnejais, Assistant Professor

Wil Wollheim, Assistant Professor

Information Transfer Program Introduction

The NH WRRC supported one information transfer projects with its 2014 104b funding:

1. New Hampshire WRRC Information Transfer

New Hampshire WRRC Information Transfer

Basic Information

Title:	New Hampshire WRRC Information Transfer
Project Number:	2008NH97B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	01
Research Category:	Not Applicable
Focus Category:	Management and Planning, Education, Non Point Pollution
Descriptors:	None
Principal Investigators:	Michelle Daley

Publications

1. Baillio, J. 2012. 2012. Controls on variability of dissolved greenhouse gas concentration and emissions from small streams in southeastern New Hampshire. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 111 pages.
2. Daley, M.L. and W.H. McDowell, In Preparation, Human impacts on stream nitrogen chemistry and watershed N retention across a wide range of rural to urban catchments, Ecological Applications.
3. Hope, A.J., W.H. McDowell, W.M. Wollheim, Submitted, Ecosystem metabolism and nutrient uptake in an urban, piped headwater stream, Biogeochemistry.
4. Liptzin, D., M.L. Daley, and W.H. McDowell. Accepted. A comparison of wet deposition collectors at a coastal rural site. Submitted to Water, Air, & Soil Pollution. April 2013.
5. Parham, L. 2012. Spatial and temporal variation in degradation of dissolved organic carbon on the main stem of the Lamprey River. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 66 pages.
6. Hope, A.J., W.H. McDowell, W.M. Wollheim. 2013. Ecosystem metabolism and nutrient uptake in an urban, piped headwater stream. Biogeochemistry. September 2013. DOI 10.1007/s10533-013-9900-y
7. Liptzin, D., M.L. Daley, and W.H. McDowell. 2013. A comparison of wet deposition collectors at a coastal rural site. Water, Air, & Soil Pollution. 224(5):1558. 2013.
8. Heffernan, J.B., P.A. Soranno, M.J. Angilletta, L.B. Buckley, D.S. Gruner, T.H. Keitt, J.R. Kellner, J.S. Kominoski, A.V. Rocha, J. Xiao, T.K. Harms, S.J. Goring, L.E. Koenig, W.H. McDowell, H. Powell, A.D. Richardson, C.A. Stow, R. Vargas, K.C. Weathers. 2014. Macrosystems ecology: understanding ecological patterns and processes at continental scales. Frontiers in Ecology and the Environment 12: 5-14.
9. Kaushal, S.S., W.H. McDowell, and W.M. Wollheim. 2014. Tracking evolution of urban biogeochemical cycles: past, present, and future. Biogeochemistry 121:1-21.
10. Koenig, L.E., A.J. Baumann, and W.H. McDowell. 2014. Improving automated phosphorus measurements in freshwater: an analytical approach to eliminating silica interference. Limnology and Oceanography: Methods. Limnology and Oceanography: Methods. 12:223–231. DOI: 10.4319/lom.2014.12.223. March 2014.
11. McDowell, W.H. 2014. NEON and STREON: opportunities and challenges for the aquatic sciences. Freshwater Science 34:386-391.

12. Meyer, A. 2014. Response of ammonium uptake to carbon availability in an agriculturally influenced first order stream. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 50 pages.
13. Shonka, N. 2014. Water quality sensors provide insight into the suspended solids dynamics of high flow storm events in the Lamprey River. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 93 pages.
14. Sullivan, M. 2014. Groundwater nitrogen attenuation in suburban and urban riparian zones. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 94 pages.
15. Appling, A. Leon, M. and McDowell, W.H. 2014. Reducing bias and quantifying uncertainty in watershed flux estimates: The R package loadflex. Submitted December 2014 to Ecosphere.

Information Transfer

Unbridled development and population growth can have detrimental impacts to water resources and ecosystem services. Rapid population growth is occurring in New Hampshire and state regulations, planning board decisions and zoning classifications all attempt to minimize the environmental impact of this rapid population growth. Most land use planning decisions are made at the local level on a town by town basis, often by volunteers who serve on various boards, commissions and committees. Decisions by these various resource managers are often made without a full understanding of the consequences that their decisions will have on water resources or ecosystem services.

This project provided salary for the Center's Associate Director to meet with state representatives, local town officials, watershed groups, school groups, the general public and scientists to discuss WRRC findings that relate to population growth and land use change. The NH WRRC website (http://www.wrrc.unh.edu/) is also used to disseminate information on water resources, and is updated and maintained by salary provided by this project. The time of the Director and Associate Director is increasingly spent discussing current and future research in the Lamprey River Hydrologic Observatory, which is partially funded by the longstanding 104B project "Water Quality and the Landscape: Long-term monitoring of a rapidly developing suburban watershed" and on nitrogen dynamics in New Hampshire's Great Bay watershed. On January 9, 2015 the NH WRRC totally funded and organized the **Eighth Annual Lamprey River Symposium** (see also below). Presentations focused on water quality, hydrology, stormwater, climate and landuse change, aquatic species and habitat, watershed planning and nitrogen cycling in coastal New Hampshire. The symposium attracted approximately 90 attendees, including scientists, regional leaders, town officials, members of state agencies, and federal agencies. The agenda can be found on the NH WRRC Lamprey River Hydrologic Observatory Symposium website. This annual symposium and other discussions in which the Center's Director and Associate Director participate further the research and information transfer goals of the NH WRRC.

2014 Information Transfer Activities Supported by Section 104b Funding and Matching Funds

Data sharing with Lamprey River watershed local advisory committee

The Lamprey River Advisory Committee (LRAC) is undergoing a long-term analysis of Lamprey River water quality data collected by both the Lamprey River Watershed Association's (LRWA) volunteer monitoring program and the NH WRRC 104B project "Water Quality and the Landscape: Long-term monitoring of a rapidly developing suburban watershed". The NH WRRC associate director serves on the LRAC and is a member of the water quality sub-committee which is advising a LRAC funded intern who is conducting the long-term water quality analysis. Preliminary temporal and spatial trends in dissolved oxygen and pH have been examined thus far and further analysis is underway.

Nitrogen Data in New Hampshire's Great Bay watershed

Over the six years, there has been significant focus on nitrogen loading to New

Hampshire's largest estuary, the Great Bay estuary, and the impairment to aquatic life it has caused. In August 2009, Great Bay, Little Bay and the tidal rivers were added to the New Hampshire 2008 303d list of impaired waters rendering them in violation of the federal Clean Water Act. Based on the most recent "State of Our Estuaries Report" prepared by the Piscataqua Region Estuaries Partnership (PREP 2013), 32% of the nitrogen entering Great Bay and Little Bay is from point sources; the majority (68%) enters via non-point sources of pollution. The Lamprey River is the largest tributary to Great Bay, and thus the long-term data provided by the NH WRRC from the LRHO are of considerable value for watershed management. The NH WRRC provides the best dataset in NH for assessing the spatial and temporal variability in N concentrations and export in response to suburbanization and changes in land use. These 14+ years of data will be instrumental in assessing the success of current and future efforts to reduce non-point sources of nitrogen pollution reaching Great Bay. There is much interest in LRHO datasets from NH Department of Environmental Services (DES), PREP, the Environmental Protection Agency (EPA) and other municipal, regional, state and federal agents. Many of the presentations and meetings listed below focused on transferring information on nitrogen cycling to stakeholders throughout NH's coastal watershed and beyond. The NH WRRC has received several phone calls and meeting requests to discuss the Great Bay nitrogen issue. The NH WRRC has been specifically asked to present coastal NH nitrogen data to the following groups: the NH Shoreland Advisory Committee, the Water Integration for Squamscott-Exeter (WISE) and Green Infrastructure (GI) NERRS Science Collaborative projects and the Southeast Watershed Alliance.

Water quality monitoring advice for wood restoration projects in NH streams

The Natural Resources Conservation Service (NRCS) and Trout Unlimited (TU) have selected 23 Wetlands Reserve Program (WRP) properties in NH for possible wood loading restoration work. The project plan is to add wood into small segments of 1st and 2nd order stream channels (averaging about 1,000 feet) on 15 properties in the summer of 2015 with the goal of recreating and increasing fish spawning and rearing habitat. A supplemental goal of this work is to study the changes in water quality and nutrient uptake which may be enhanced by adding carbon (in the form of wood) to streams. The NH WRRC Director, Associate Director and the WQAL manager have been advising the NRCS and TU on how to best understand changes in water quality and nutrient dynamics with existing financial resources.

Symposia, Conferences and Seminars Organized and Funded

The NH WRRC funded and organized the "**Eight Annual Lamprey River Symposium**" held January 9, 2015 in Durham, NH. The symposium is dedicated to exchanging the results of recent research on the water quality, hydrology, water resources issues, and management of the Lamprey River basin. The Symposium is a vehicle for researchers to share data and insights with other researchers, as well as those in the management and policy arena who would benefit from exposure to the latest research on the watershed. The symposium drew approximately 90 attendees, including researchers, legislators, water system operators, town officials, regional leaders and government officials. The symposium contained 14 presentations split up over three sessions. There was a poster session during and after lunch where 7 posters and displays were exhibited. The day ended with an open discussion on research priorities in the Lamprey

watershed and southeast NH. This event was funded and organized by the NH WRRC. Staff from UNH cooperative extension and Great Bay National Estuarine Research Reserve helped moderate the open discussions and NH EPSCoR assisted with registration and printing. Survey results indicate that most of the attendees found the topics covered to be either helpful or very helpful.

The NH WRRC sponsored the "**NH Water and Watershed Conference**" in Plymouth, NH on March 21, 2015. This event was designed to meet the information and networking needs of lake, river, and watershed groups; environmental organizations; volunteer monitors; municipal board and staff members; elected officials; local and regional planners; policy makers; scientists; educators; consultants and students. The focus for the 2014 conference was on the sustainability of New Hampshire's water resources. The NH WRRC co-sponsored this conference along with Plymouth State University and the Center for the Environment, NH EPSCoR, NH DES, US Geological Survey New England Water Science Center and a few others. The conference contained 5 concurrent sessions including the sustainability of New Hampshire's water resources, integrating science with decision making for water resources, climate change and water resources, emerging issues in water and public health and integrated land use planning for water resources. The conference drew approximately 250 people, including researchers, legislators, water system operators, land use planners, and government officials.

Publications

Heffernan, J.B., P.A. Soranno, M.J. Angilletta, L.B. Buckley, D.S. Gruner, T.H. Keitt, J.R. Kellner, J.S. Kominoski, A.V. Rocha, J. Xiao, T.K. Harms, S.J. Goring, L.E. Koenig, W.H. McDowell, H. Powell, A.D. Richardson, C.A. Stow, R. Vargas, K.C. Weathers. 2014. Macrosystems ecology: understanding ecological patterns and processes at continental scales. Frontiers in Ecology and the Environment 12: 5-14.

Flint, S.F. and W.H. McDowell. 2015. Effects of headwater wetlands on dissolved nitrogen and dissolved organic carbon concentrations in a suburban New Hampshire watershed. Freshwater Science 34:456-471.

Kaushal, S.S., W.H. McDowell, and W.M. Wollheim. 2014. Tracking evolution of urban biogeochemical cycles: past, present, and future. Biogeochemistry 121:1-21.

Koenig, L.E., A.J. Baumann, and W.H. McDowell. 2014. Improving automated phosphorus measurements in freshwater: an analytical approach to eliminating silica interference. Limnology and Oceanography: Methods. Limnology and Oceanography: Methods. 12:223–231. DOI: 10.4319/lom.2014.12.223. March 2014.

McDowell, W.H. 2014. NEON and STREON: opportunities and challenges for the aquatic sciences. Freshwater Science 34:386-391.

Meyer, A. 2014. Response of ammonium uptake to carbon availability in an agriculturally influenced first order stream. M.S. Dissertation, Department of Natural Resources & the

Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 50 pages.

Shonka, N. 2014. Water quality sensors provide insight into the suspended solids dynamics of high flow storm events in the Lamprey River. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 93 pages.

Sullivan, M. 2014. Groundwater nitrogen attenuation in suburban and urban riparian zones. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 94 pages.

Appling, A. Leon, M. and McDowell, W.H. 2014. Reducing bias and quantifying uncertainty in watershed flux estimates: The R package loadflex. Submitted December 2014 to Ecosphere.

Conference Proceedings & Abstracts:

Appling, A.P. McDowell, W. H., Potter, J. D., Nelson, S. J., Kahl, J. S. 2014. From the frying pan into the fire? Lake greenhouse gas responses to acid rain recovery. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

Bucci, J. P., I. Sidor, A. Walant, M. Daley, J. Potter, W. McDowell. 2014. Detection of a Mitochondrial DNA Biomarker in Surface Water within Suburban Streams Impacted by Animal Fecal Waste: Does Flow Matter. American Society for Microbiology 2014 General Meeting. Boston, MA. May 2014.

Daley, M.L., J.D. Potter, A. Kobylinski, C. French, S. Miller, C. Keely, J. Bucci, W.H. McDowell. 2014. Collaborative science to identify non-point nitrogen sources in a coastal New England watershed and reduce nitrogen delivery to an impaired estuary. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

Diemer, L. A., McDowell, W. H., Prokushkin, A. S. 2014. Nutrient uptake decreases along a gradient of DOC:NO_3 in arctic streams of central Siberia. Aquatic Sciences Meeting. Portland, OR. May 2014.

Koenig L.E., A. Ramirez and W.H. McDowell. 2014. Quantifying carbon losses from tropical watersheds: The effects of urbanization on organic and inorganic carbon flux. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

McDowell, W.H., Potter, J. D., Daley, M. L., Snyder, L., Mulukutla, G. 2014. Using sensors and sensor networks to quantify ecosystem services in developed and rural watersheds. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

McDowell, W.H. Freshwater Science: Lessons Learned and Looking Ahead. Plenary Address, First Annual Symposium on Aquatic Science, University of Maine, Orono, Maine. January 29, 2015. (CZO, LTER, EPSCoR, and NH AES)

Potter, J.D. Snyder, L., Mulukutla, G., McDowell, W. H. 2014. Addressing anthropogenic effects on aquatic biogeochemistry using a distributed sensor network in New Hampshire. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

Rodriguez-Cardona, B. and McDowell, W.H. 2014. Nitrate uptake kinetics in suburban streams of New Hampshire. NH Water and Watershed Conference. Plymouth, NH. March 21, 2014.

Rodriguez-Cardona, B., McDowell, W. H. 2014. Nitrate uptake kinetics in suburban streams of New Hampshire. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

Shonka, N. 2014. Water quality sensors provide insight into the suspended solids dynamics during high flow events in the Lamprey River, NH. NH Water and Watershed Conference. Plymouth, NH. March 21, 2014.

Shonka, N. and McDowell, W.H. 2014. Using In-situ water quality sensors to provide insight into the suspended solids dynamics of high flow storm events in the Lamprey River, New Hampshire. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

Shonka, N., Potter, J., Daley, M., McDowell, W., Snyder, L. and Mulukutla, G. 2014. New Hampshire EPSCoR Intensive Aquatic Sensor Network: The Data are Flowing Fast. Climate change poster session with William Hohenstein, USDA Climate Change Program Director, and David Hollinger, Hub Leader, Northeast Regional Hub for Risk Adaptation and Mitigation to Climate Change. University of New Hampshire. Durham, NH. May 13, 2014.

Shonka, N. 2014. Sensing Suspended Solids: Using in-situ water quality sensors to provide insight into the suspended solids dynamics of high flow storm events in the Lamprey River. Climate change poster session with William Hohenstein, USDA Climate Change Program Director, and David Hollinger, Hub Leader, Northeast Regional Hub for Risk Adaptation and Mitigation to Climate Change. University of New Hampshire. Durham, NH. May 13, 2014.

Wymore, A. S., Mineau, M. M., Potter, J. D., Marks, J. C., McDowell, W. H. 2014. Leaf litter leachate controls bacterial communities and ecosystem processing rates. Joint Aquatic Sciences Meeting. Portland, OR. May 2014.

Wymore, A.S. et al. 2014. Identifying the Sources of Dissolved Organic Matter in Streams Using Elemental Analysis Isotopic Ratio Mass Spectroscopy (EA-IRMS) Across a Land Use Gradient. American Geophysical Union Fall Meeting. San Fancisco, CA. December 2014.

Presentations/Information Transfer

Appling, A. 2015. Patterns and drivers of diel solute cycles in headwater streams. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Daley, M.L. 2014. Shared preliminary Great Bay N Sources and Transport NERRS Science Collaborative project results with Brian Giles and Mitch Kalter who are representatives of the Piscataqua Region Estuaries Partnership serving as ad hoc science advisory committee members of the NH Shoreland Advisory Committee. The purpose was to see how the latest science from the project can be used to evaluate the current shoreland standards embodied in RSA 483-B, Shoreland Water Quality and Protection Act. April 16, 2014.

Daley, M.L. 2014. Presentation and field trip on "What it's like to be a scientist and how I became a water quality scientist" with 20 3rd graders from the Maple Street Magnet School Rochester NH. Students learned how to measure pH, temperature, dissolved oxygen and conductivity in the Cocheco River using field meters and they gained an understanding of how to interoperate these water quality values. June 18, 2014.

Daley, M.L. 2014. Research on nitrogen in the Great Bay watershed: Learn how diffuse sources of nitrogen pollution travel from our communities to the Great Bay. Scheduled for Contemporary Coastal Issues sail on the Gundalow in Portsmouth, NH on July 23, 2014 but sail was cancelled last minute due to thunderstorms. Will reschedule.

Daley, M.L. 2014. Advised Bauneg Beg Lake Association on lake sampling for dissolved oxygen and phosphorus. August 4, 2014.

Daley, M.L. 2014. Led field trip for undergraduate and graduate students to sites in the Lamprey River Hydrologic Observatory. September 16, 2014.

Daley, M.L. 2014. Water Quality Research in the Lamprey River Hydrologic Observatory. Presentation to University of New Hampshire undergraduate class: Studio Soils. October 25, 2014.

Daley, M.L. 2014. Presented Great Bay N Sources and Transport project results to members of the Water Integration for Squamscott-Exeter (WISE) and Green Infrastructure (GI) NERRS Science Collaborative projects to facilitate collaboration on water resource issues. October 30, 2014.

Daley, M.L. 2014. Great Bay watershed management. Presentation to University of New Hampshire class: Watershed Water Quality Management. December 2, 2014.

Daley, M.L. 2014. Presented Great Bay N Sources and Transport project results to the PREP management committee. Kittery, ME. December 9, 2014.

Daley, M.L. 2015. Non-point nitrogen sources and transport in the Great Bay watershed. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Daley, M.L. 2015. Non-Point Nitrogen Sources and Transport in the Great Bay watershed. Southeast Watershed Alliance Quarterly Meeting. February 4, 2015. Lee, NH.

Daley, M.L. 2015. Forests, Farms, and People: How different sources contribute nitrogen to Great Bay. 2015 NH Farm & Forest Exposition. February 9, 2015. Manchester, NH.

Koenig, Lauren. 2014. Co-lead the NH Envirothon Aquatics portion (training day). Approximately 75 middle to high school students and 5-10 secondary ed. teachers in attendance from across NH. Sanborn Farm, Pittsfield, NH. April 5, 2014.

Koenig, Lauren. 2014. Served as an instructor for the STEM mini-course offered August 25-29th through the CONNECT program at UNH (http://www.unh.edu/connect/). The objective of the course is to help incoming freshmen that come from groups with historically low retention in STEM majors (e.g. low-income, multicultural, first-generation college students) build skills that are needed to succeed in their academic programs (e.g., writing of lab/research reports, basic math and statistics for analyzing scientific data). There were 12 students in the class, but the broader CONNECT program serves approximately 100 students.

- Students measured soluble reactive phosphorus (SRP) concentrations across sites with different land uses for their project (WHB, LMP73, Burley Demeritt, College Brook and Pettee Brook). They had to give a general presentation to the entire CONNECT program (including non-STEM majors), so to best communicate their study, they chose to combine a traditional science powerpoint presentation with a music video. Their version of "These boots were made for sampling" - http://www.youtube.com/watch?v=lQCZ4XEwj7c&feature=share.

McDowell, William H. July 22, 2014. Interviewed by NHPR for The Exchange talk show with Laura Knoy about the continued recovery of New England's lakes after several decades of pollution.

McDowell, William H. September 12, 2014. Interviewed live by John Dankosky from Connecticut Public Radio along with Dr. Kaushal on "Understanding the Urban Ecosystem". http://sciencefriday.com/segment/09/12/2014/understanding-the-urban-ecosystem.html.

McDowell W.H. 2014. McIntire Stennis one pager for REE Mission booth at the IUFRO World Congress featured outcomes from the "Water Quality in a Fragmenting Forested Landscape" McIntire Stennis project. September 2014.

McDowell, W.H. 2015. Do sensors matter? Improved precision in flux estimates with continuous data. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

McDowell, W.H. 2015. Served on a panel discussion: "Building a Scholarly Agenda" University of New Hampshire Research and Engagement Academy. January, 23 2015. Durham, NH.

Snyder, L. 2015. Enhanced protocols for managing a network of modern water quality sensors. Poster. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Wymore, A. 2015. Identifying sources of dissolved organic matter (DOM) in streams using EA-IRMS and Py-GC/MS across a land-use gradient. Annual Lamprey River Science Symposium. University of New Hampshire, Durham, NH. January 9, 2015.

Press Releases

Humphries, C. 2014. The city is an ecosystem, pipes and all. What scientists are finding when they treat the urban landscape as an evolving environment of its own. McDowell, W.H. interviewed for article on October 6, 2014. Published in The Boston Globe on November 7, 2014. http://www.bostonglobe.com/ideas/2014/11/07/the-city-ecosystem-pipes-and-all/HjLVemBs9nPiuE53PjPSLK/story.html.

McDowell September 10, 2014. UNH Scientists Find Urban Ecosystems "Evolve," Require Sustainable Management. University of New Hampshire press release. September 10, 2014. http://www.unh.edu/news/releases/2014/09/ds10evolve.cfm#ixzz3D10ttLHP.

McDowell, W.H. 2014. A river runs through it: U.S. cities' waterways show consistent patterns of evolution. NSF press release. September 10, 2014. http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=132583&org=NSF

McDowell, William H. September 23, 2014. Interviewed for the "University of Maryland professor tailors watershed test to urban areas like College Park" press release. The Diamondback. The University of Maryland's Independent Student Newspaper. http://www.diamondbackonline.com/news/article_5128a2e2-42b5-11e4-b909-001a4bcf6878.html.

Meetings attended

Daley, M.L. 2014. NH Water and Watershed Conference. Plymouth, NH. March 21, 2014.
Daley, M.L. 2014. Models of the Great Bay Symposium. Hosted by SWA. Greenland, NH. April 18, 2014.
Daley, M.L. 2014. Met with NH Fish and Game, NRCS and Trout Unlimited to discuss water quality monitoring of adding wood to streams for stream restoration. May 5, 2014.
Daley, M.L. 2014. Met with Lamprey River Advisory Committee water quality sub-committee to discuss long-term trends in dissolved oxygen levels in the Lamprey. May 4, 2014.
Daley, M.L. 2015. Met with Green Mountain Conservation Group to discuss 10 year water quality report. December 16, 2015.

Daley, M.L. 2015. Met with NH Fish and Game, NRCS and Trout Unlimited to discuss water quality monitoring of adding wood to streams for stream restoration. January 20, 2015.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	14	0	0	3	17
Masters	4	0	0	2	6
Ph.D.	1	0	0	1	2
Post-Doc.	2	0	0	1	3
Total	21	0	0	7	28

Notable Awards and Achievements

NH Department of Environmental Science Coastal Program Manager tributes his interest in water to NH WRRC Director Dr. Bill McDowell's Ecology of Polluted Waters undergraduate class. Piscataqua Region Estuaries Partnership Newsletter October 2014.