6-1-2017

Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds 2016

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Basic Information

Title:	Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds
Project Number:	2003NH21B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	NH01
Research Category:	Water Quality
Focus Categories:	Non Point Pollution, Surface Water, Nutrients
Descriptors:	
Principal Investigators:	William H. McDowell, Michelle Daley Shattuck

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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 has experienced rapid growth in several counties. 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's population growth has slowed slightly and from 2000-2010 the state experienced a 6.5% population gain. This was still the largest gain among northeastern states and the fastest-growing areas in New England are concentrated in southern and central NH (Johnson 2012). 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

This project provides detailed, high-quality, long-term datasets which 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 where several estuarine waters are 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 report.

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.

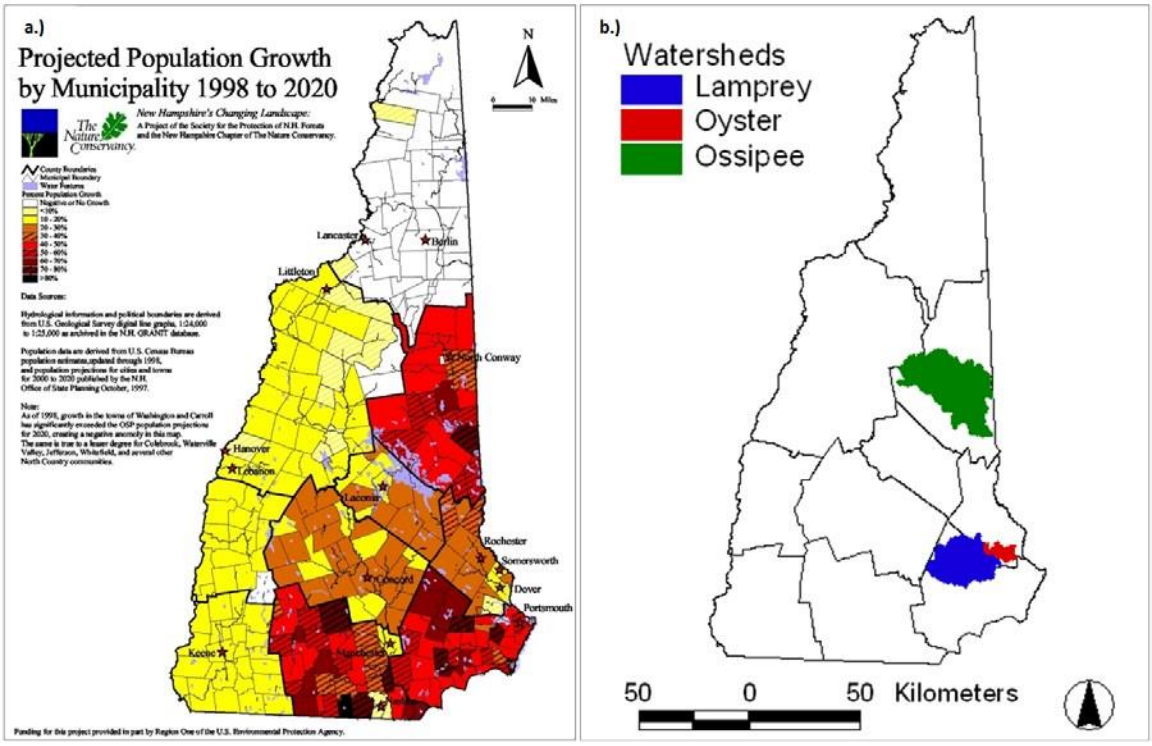

Figure 1. Projected population growth in New Hampshire (Figure from Sundquist and Stevens 1999; A) and study watersheds experiencing high population growth (B).

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 subbasins 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 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 43 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 2016 from the LRHO is approximately 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) flowadjusted nitrate concentrations (SKT $t = 0.28$, $p < 0.01$). There has also been a statistically significant increase in nitrate concentrations at LMP73 (Figure 2) over the entire study period (2000-2016), but not at WHB01. 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 study period. The watershed population density increased from 53 to 60 people/km^2 or by 12% from 2000 to 2010 (2000 and 2010 Census). The highest levels of nitrate at

LMP73 occurred in 2014. 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.

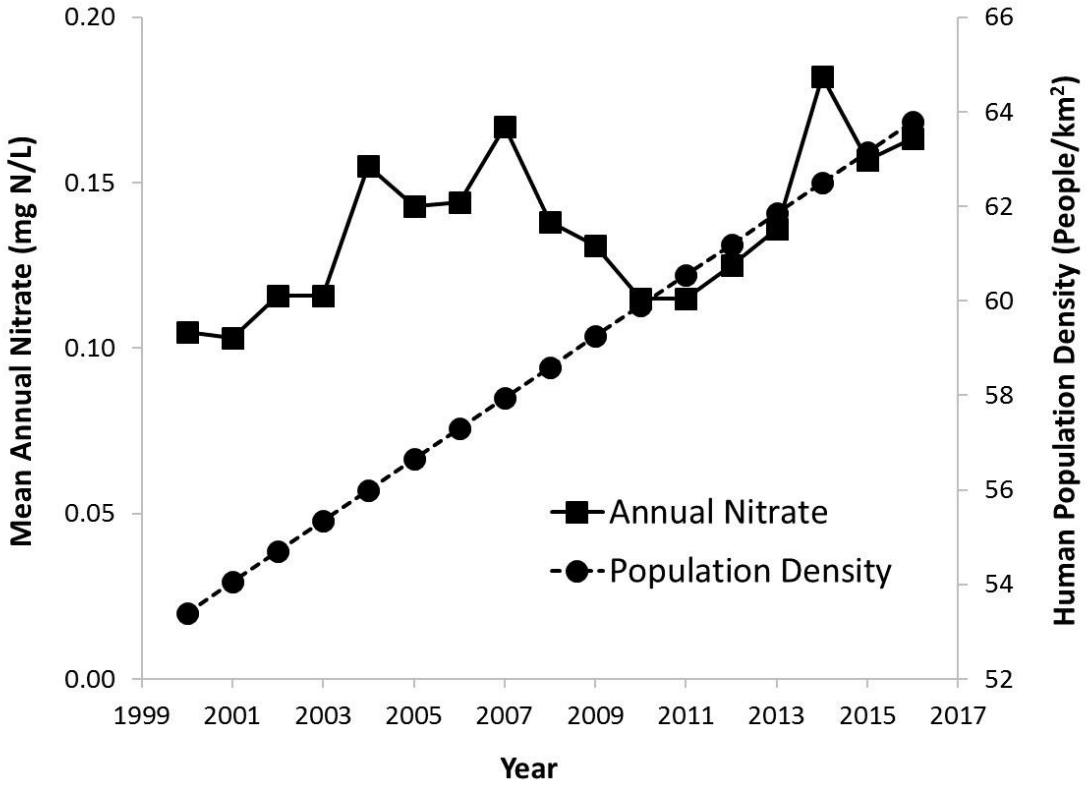

Figure 2. Annual mean nitrate concentration and estimated annual human population density (2000 and 2010 Census) from 2000-2016 in the Lamprey River basin. Note that nitrate analysis for 2016 is approximately 75% complete.

When we combine our specific conductance data (2003 – 2015) 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 stream water 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.

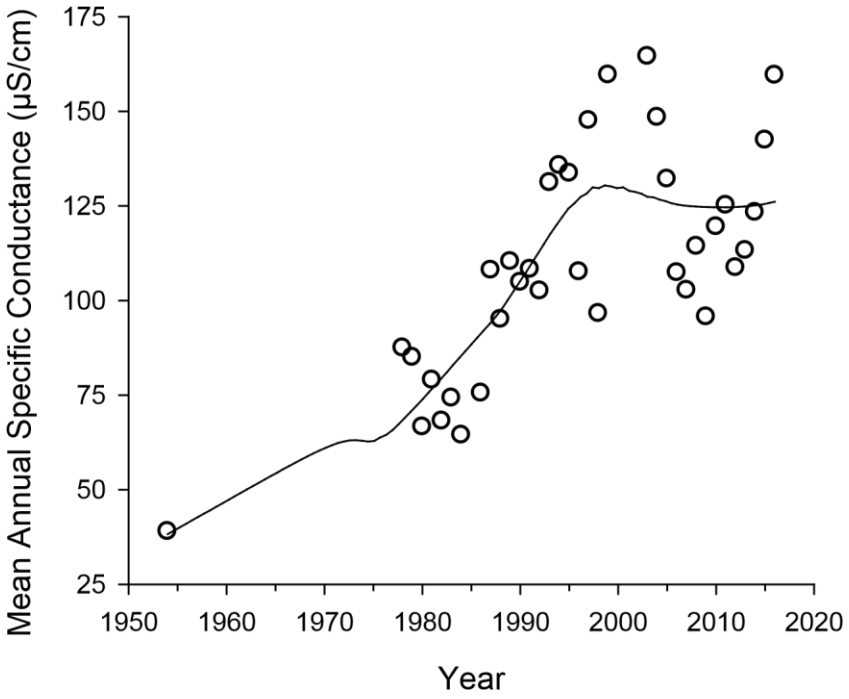

Figure 3. Mean annual specific conductance in the Lamprey River at LMP73 (co-located with the USGS gauging station in Durham, NH. (modified from Daley et al. 2009).

Oyster River watershed

Laboratory analysis of the monthly CB and PB samples collected in 2016 is still in progress, but will be completed soon. 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.

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 (Figure 4). 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.

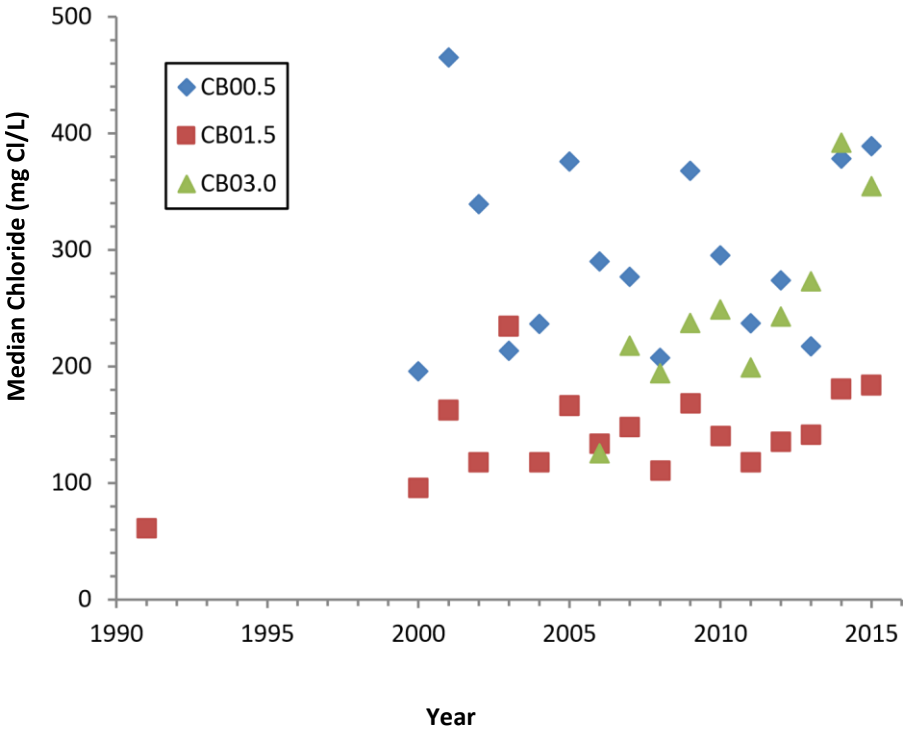

Figure 4. Median annual chloride in College Brook from the headwaters (CB00.5) to the mouth (CB03.0).

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 5) indicating that nitrification is occurring in the stream channel. However, an increase in total dissolved nitrogen (Figure 6) 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 2015 at the station with the longest record (CB01.5).

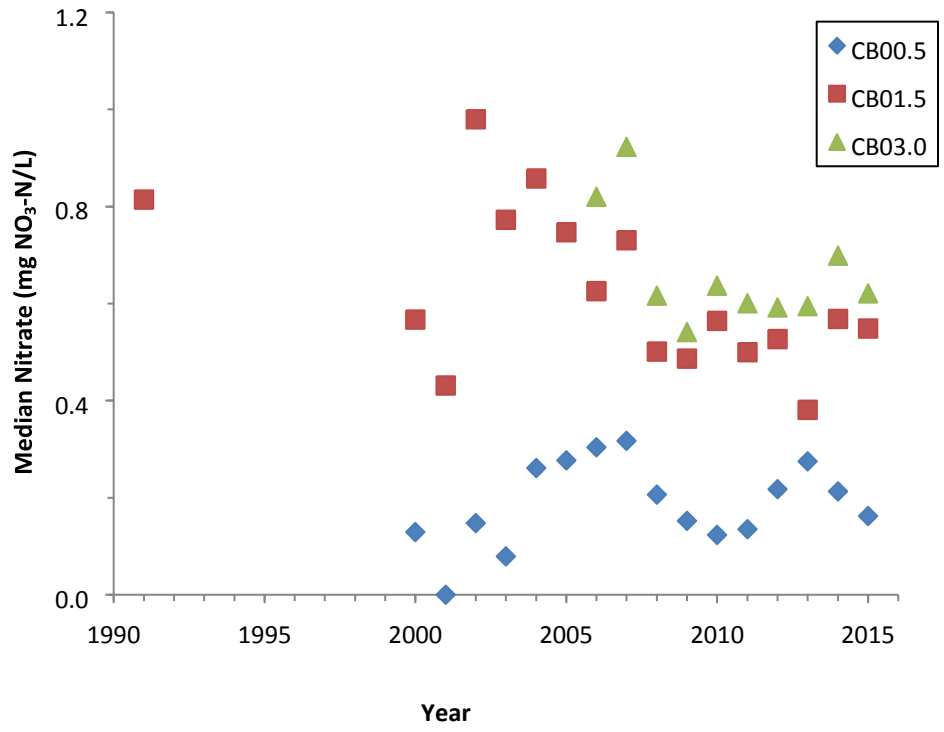

Figure 5. Median annual dissolved inorganic nitrogen (DIN) in College Brook from the headwaters (CB00.5) to the mouth (CB03.0).

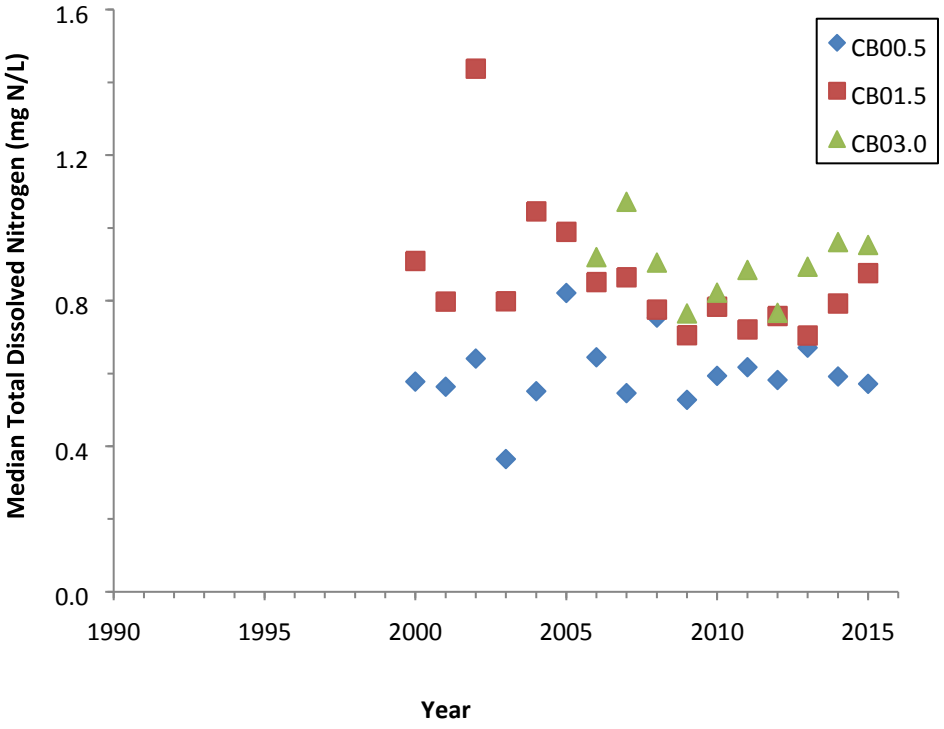

Figure 6. Median annual total dissolved nitrogen (TDN) in College Brook from the headwaters (CB00.5) to the mouth (CB03.0).

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 9 sites. Over 100 samples were collected for analysis in the WQAL and additional field data were 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). The impact of road salting in this central NH watershed is similar to what we see in coastal NH (Daley et al. 2009). Data have been used to heighten awareness of the impacts of excessive road salting and snow dumping in local streams. 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

Lauren Koenig was awarded the Mulholland Award from the Society for Freshwater Science. March 2016.

Rodriguez-Cardona, B. 2016. Received a fellowship from the CZO SAVI program (a NSF funded program) to support her proposal "Cross-biome comparison of nitrogen uptake and carbon dynamics in streams". March 2016. $7,000.

McDowell, W.H. 2017. Received the 2017 Distinguished Professor Award. The purpose of this award is to identify and honor longstanding members of the faculty. This singular university-wide award will be given each year to the faculty member whose overall record of excellent teaching, caring about students, devotion to the university community and substantial record of scholarly achievement exemplifies what we would call a 'distinguished career'.

Wymore, A. and Kaushal, S. were awarded a Long Term Ecological Research Network Communications Office working group proposal "Stream Elemental Cycling: Global Patterns in Stream Energy and Nutrient Cycling". National Center for Ecological Analysis and Synthesis (NCEAS) working group. $78,000 from the LTER National Office.

Wymore, A. was awarded $4,000 from the Luquillo Long Term Ecological Research: Research Experience for Undergraduates (REU) program. Using field-based manipulative biogeochemistry to introduce undergraduates to environmental research in a tropical landscape.

Number of students supported

Three PhD students (Lauren Koenig, Bianca Rodriguez, Rich Brereton) and 7 undergraduate hourly employees from the Department of Natural Resources & the Environment (John Ciaburri, James Casey, Margaret Phillips, Christina Mroz, Justin Sherman, Liam Waldron, Christina Lyons). Two post-doctoral students were also supported by this project (Adam Wymore and Ashley Coble).

References

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Daley, M.L., J.D. Potter and W.H. McDowell. 2009. Salinization of urbanizing New Hampshire streams and groundwater: impacts of road salt and hydrologic variability. Journal of the North American Benthological Society 28(4):929–940.

Johnson, K.M. 2012. New Hampshire Demographic Trends in the Twenty-First Century. The Carsey Institute, University of New Hampshire. Durham, NH. 31 p.

Medalie, L. 2013. Concentrations of chloride and sodium in groundwater in New Hampshire from 1960 through 2011. USGS Fact Sheet 2013-3011. (Available at: http://pubs.usgs.gov/fs/2013/3011/).

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Sundquist D and Stevens M. 1999. New Hampshire's changing landscape. Population growth, land use conservation, and resource fragmentation in the Granite State. Society for the Protection of New Hampshire Forests, Concord, New Hampshire. 110 pp.

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

Contosta, A. R., Adolph, A., Burchsted, D., Burakowski, E., Green, M., Guerra, D., Albert, M., Dibb, K., Martin, M., McDowell, W.H., Routhier, M., Wake, C., Whitaker, R., and Wollheim, W. 2016. A longer vernal window: the role of winter coldness and snowpack in driving spring transitions and lags. Global Change Biology. DOI: 10.1111/gcb.13517.

Hunt, C. W., Snyder, L., Salisbury, J.E., Vandemark, D., McDowell, W.H. 2017. SIPCO2: A simple, inexpensive surface water pCO2 sensor. Limnology and Oceanography Methods. doi: 10.1002/lom3.10157.

Koenig, L.E., Shattuck, M.D., Snyder, L.E., Potter, J.D. and McDowell, W.H. 2017. Deconstructing the effects of flow on stream solute interactions using a highfrequency aquatic sensor network. In review for Water Resources Research. Special issue "Continuous nutrient sensing in research and management: applications and lessons learned across aquatic environments and watersheds".

Snyder, L.E., Potter, J.D. and McDowell, W.H. 2017. An Evaluation of Nitrate, fDOM, and Turbidity Sensors in New Hampshire Streams. In review Water Resources Research. Special issue "Continuous nutrient sensing in research and management: applications and lessons learned across aquatic environments and watersheds".

Wymore, AS, B Rodríguez-Cardona, and WH McDowell. 2016. Understanding dissolved organic matter biogeochemistry through in situ nutrient manipulations in stream ecosystems. Journal of Visualized Experiments. 116: doi: 10.3791/54704, http://www.jove.com/video/54704.

Wymore, AS**,** J Potter, L Snyder, B Rodríguez-Cardona, and WH McDowell. 2017. Using *in-situ* optical sensors to understand the coupled biogeochemistry of carbon and nitrogen across a stream network. *In review Water Resources Research.* Special issue "Continuous nutrient sensing in research and management: applications and lessons learned across aquatic environments and watersheds".

Conference Proceedings & Abstracts:

Coble, A.A., Koenig LE, Potter, J.D., Parham, L.M. and McDowell, W.H. 2017. Dissolved organic matter composition in the Lamprey Watershed: headwaters to mouth. Lamprey River Science Symposium. January 9, 2017. Durham, NH.

Koenig, L. 2016. Dissolved organic matter dynamics in a suburbanizing watershed: the importance of wetlands, people, and flowpaths. Graduate Research Conference. University of New Hampshire. Durham, NH. April 12, 2016.

Koenig, L., Hunt, C., Synder, L., Potter, J.D. and McDowell, W.H. 2017. Response of metabolism and fluvial carbon flux to anomalous low flows in New Hampshire streams. Poster Presentation. AGU Chapman Conference on Extreme Climate Event Impacts on Aquatic Biogeochemical Cycles and Fluxes. San Juan Puerto Rico, USA. 22-27 January 2017.

McDowell, W.H. 2016. Unraveling the mystery of DON. Technical University of Dresden, Dresden, Germany May 4, 2016.

McDowell, W.H. and Shattuck, M.D. 2017. Lamprey River Hydrologic Observatory Past and Present: What have we learned, where are we headed? Lamprey River Science Symposium. January 9, 2017. Durham, NH.

Potter, J.D., Wymore, A.S., Rodríguez-Cardona, B., Coble, A.A., López Lloreda, C., Pérez Rivera, K., De Jesús Román, A., Bernal, S., Martí, E., Krám, P., Hruška, J., Prokushkin, A. and McDowell, W.H. 2017. Examining the role of dissolved organic nitrogen in stream ecosystems across biomes and Critical Zone gradients. Lamprey River Science Symposium. January 9, 2017. Durham, NH.

Shanley, J. and McDowell W.H. 2016. Making sense of in-stream sensors. Annual Hubbard Brook Cooperators' Meeting. Woodstock, NH. July 13-14, 2016.

Shattuck, M.D., J.D. Potter, A. Kobylinski, C. French, S. Miller, C. Keely, J. Bucci and W.H. McDowell 2016. Non-Point Nitrogen Sources and Transport in the Great Bay Watershed. NH Water and Watershed Conference. Plymouth, NH. March 18, 2016.

Shattuck, M.D., Koenig, L. Potter, J.D., Snyder, L.E. and McDowell, W.H. 2017. Regional coherence in solute interactions during stormflow in a statewide aquatic sensor network. Lamprey River Science Symposium. January 9, 2017. Durham, NH.

Sullivan, B.N., Wymore, A., Schade, J.D. and McDowell, W.H. 2016. Dissolved Organic Carbon: Nitrate Ratios as a Driver of Methane Fluxes in Stream Ecosystems. American Geophysical Union Fall Meeting. San Francisco, CA. December 2016.

Wymore, A., Rodriguez-Cardona, B., Coble, A.A., Potter, J.D., Lopez Lloreda, C., Perez Rivera, K., De Jesus Roman, A. Bernal, S., Martí Roca, E., Kram, P., Hruska, J., Stanislavovich Prokishkin, A. and McDowell, W.H. 2016. Examining the role of dissolved organic nitrogen in stream ecosystems across biomes and Critical Zone gradients. American Geophysical Union Fall Meeting. San Francisco, CA. December 2016.

Wymore, A., Rodriguez-Cardona, B., Kram, P., Hruska, J. and McDowell, W.H. 2016. Examining the role of dissolved organic nitrogen in stream ecosystems across biomes. Society for Freshwater Science Annual Meeting. Sacramento, CA. May 24, 2016.

Presentations/Information Transfer

Shattuck, M.D. 2016. Shared Wednesday Hill Brook and organic dairy farm data with Katie Slebodnik for use in Aqueous Geochemistry class project and directed her to the NH EPSCoR DDC. September 2016.

Koenig, L. 2016. For the fourth consecutive year, Koenig served as the instructor for the STEM mini-course offered August 22-26th, 2016 through the CONNECT program

at UNH (http://www.unh.edu/connect/). The objective of the course is to provide an opportunity for incoming freshmen that come from groups with historically low retention in STEM majors (e.g. low-income, multicultural, firstgeneration college students) to build community, discover college resources, and bolster 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.

McDowell, W.H. 2016. Dissolved Organic Carbon (DOC) over the Decades. Departmental Seminar, Technical University of Dresden, 25 October 2016.

Shattuck, M.D, W.H. McDowell, J. Potter, and R. Brereton. 2016. Organic dairy groundwater and stream water chemistry. Organic Dairy Research Farm Symposium. Durham, NH. August 25, 2016.

Shattuck, M.D. 2016. Water Quality Research in the Lamprey River Hydrologic Observatory. Presentation to University of New Hampshire undergraduate class: Studio Soils. October 28, 2016.

Shattuck, M.D. 2016. Shared water quality information on the Lamprey River, Oyster River and Great Bay watersheds with Todd Piskovitz from the town of Exeter, NH. December 7, 2016.

Press Releases

McDowell, W.H. and Potter, J.D. 2016. Interviewed for UNH Today article "Parched - Drought leaves some researchers thirsty for data." Written by Beth Potier. University of New Hampshire. September 7, 2016. https://www.unh.edu/unhtoday/2016/09/parched

Shattuck, M.D. 2016. Interviewed by Max Sullivan from seacoast online for article: Going dry: Drought threatens homeowners' wells. July 31, 2016. http://www.seacoastonline.com/article/20160731/NEWS/160739950

Shattuck, M.D. 2016. Interviewed on Great Bay by UNH Sustainable Engineering Class. October 31, 2016.

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

2016

Saturday, April 16th 10:00am RIVERS Annual Water Quality Monitoring volunteer training. This RIVERS training and refresher will teach volunteers how to use the testing meters, sample collection procedures and other data collection protocols according to GMCG's and Saco River Corridor Commission's shared Quality Assurance Project Plan (QAPP).

Friday June 17th 6:30pm. How the Ossipee Aquifer was formed: Learn about how the glacier formed this extensive aquifer with Dr. Robert Newton , Geologist from Smith College. The evening presentation will also be GMCG's kickoff meeting to form the **Ossipee Watershed Groundwater Protection Advisory Committee**. Meeting will take place at Runnells Hall in Chocorua at 6:30 pm. Call GMCG for more information at 539-1859.

Saturday August 27th 2pm-8pm Summer Music Festival "Loons and Tunes" at Camp Calumet in West Ossipee. Family friendly fun event. A selection of local music and local produce will be available. There will also be Pontoon boat tours of Ossipee Lake and a presentation on Loon Habitat by the Loon Preservation Association.

Thursday July 7th at 7pm No Impact Man Please join us at the GMCG office for a treehugging, polar bear saving, bicycle composting movie about how one man dragged his family to live a life of zero impact. This is a sensational, funny, and consciousness-raising story of how they managed this in the middle of Manhattan. After the showing, Aislinn Pluta from Global Awareness Local Action (GALA) will be leading the discussion about how someone can live a less impactful life like the one Colin did through personal experience with him.

Monday July 25th Hike up Mt. Katherine with the Wonalancet Out Door Club Come join GMCG and WODC for a guided hike starting at the Wonalancet Chapel. This is about a 2.5 mile round trip with a great view and picnic at the top. We will be talking abou the conservation easements that GMCG holds in the area.

Thursday August 8th at 7pm Gasland You are invited to the GMCG office for the last of our summer movies. Gasland is a urgent, cautionary and sometimes darkly comic that looks at the largest domestic natural gas drilling campaign in history, which is currently sweeping the county by promising landowners a quick payoff." This film describes how Josh Fox reacts to being offered $100,000 for the natural gas drilling rights to his property in the Delaware River Basin. Join us for a closer look at how Fox traveled through 24 states to investigate the environmental effects of hydraulic fracking. What he uncovers is mind-boggling.

Thursday August 11th Volunteer BBQ 5 pm; GMCG invites all Board, Committee, WQM, and special projects volunteers and GMCG supporters to the annual volunteerism party at the GMCG Office. Help us celebrate all the hard work you pu tin for this organization. Bring yourselves and a chair. GMCG will provide the BBQ and plenty of conversation about the summer's successful projects.

Wednesday, December 7th: Youth Water Quality Presentation 6:30 at Effingham Elementary School
Monday, December 19: Annual Cookie Swap and global celebration of "Take a Break from Plastic" 3-6 pm. GMCG will partner with local and international friends on this event—details to follow on GMCG Website.

2017

Wednesday, January 11, 2017: Aquifer Protection Committee Meeting Are you interested in learning more about how you can protect the Ossipee Aquifer? Attend the next Aquifer Protection Committee to learn how you can make a difference.