New Hampshire Water Resources Research Center
Annual Technical Report
FY 2011

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. 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 the Associate Director, 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 all 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 four research projects with its 2011 104b funding:

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

2. Arsenic chemical dynamics in NH groundwater reservoirs: Insights from temporal variability in multi-element signatures of statewide samples

3. Nutrient Loading Coefficients for NH Watersheds: Development and Connectivity

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:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	NH01
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Surface Water, Nutrients
Descriptors:	
Principal Investigators:	William H H. McDowell

Publications

1. Buyofsky, L.A. 2006. Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed. M.S. Dissertation, Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH
2. Proto, Paul J. 2005, The Significance of High Flow Events in the Lamprey River Basin, New Hampshire, for Annual Elemental Export and Understanding Hydrologic Pathways. M.S. Dissertation, Department of Earth Sciences, College of Engineering and Physical Sciences, University of New Hampshire, Durham, NH, 176 pages.
3. Buyofsky, Lauren A. May 2006. Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, MS Dissertation, Department of Natural Resources, College of Life Sciences and Agriculture , University of New Hampshire, Durham, NH, .
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.
5. Traer, K. December 2007. Controls on denitrification in a northeastern coastal suburban riparian zone. Masters Thesis, University of New Hampshire, Durham, NH. 97 pages.
6. Buyofsky, Lauren A., 2006, Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, "MS Dissertation", Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 176 pages.
7. Daley, M.L., J.D. Potter, 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, submitted.
8. Buyofsky, Lauren A., 2006, Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, "MS Dissertation", Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 176 pages.
9. 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.

10. DiFranco, E. 2009. Spatial and temporal trends of dissolved nitrous oxide in the Lamprey River watershed and controls on the end-products of denitrification. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 108 pages.
11. Daley, M.L. and W.H. McDowell. In Preparation. Nitrogen saturation in highly retentive coastal urbanizing watersheds. Ecosystems.
12. Daley, M.L. 2009. Nitrogen Sources and Retention within the Lamprey River Watershed and Implications for Management. State of the Estuaries Conference. Somersworth, NH. October 2009.
13. Daley, M.L. 2009. Water Quality of Private Wells in Suburban NH and Impacts of Land Use. Northeast Private Well Symposium. Portland, ME. November, 2009.
14. Daley, M.L. 2009. Spatial and Temporal variability in nitrogen concentrations, export and retention in the Lamprey River watershed. Joint NH Water and Watershed Conference. Concord, NH. November, 2009.
15. Daley, M.L. and W.H. McDowell. 2009. Nitrogen Saturation in Highly Retentive Watersheds? American Geophysical Union Fall Conference, San Francisco, CA. December, 2009.
16. Buyofsky, Lauren A., 2006, Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, "MS Dissertation", Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 176 pages.
17. Daley, M.L., J.D. Potter and W.H. McDowell, 2010, Nitrogen Assessment for the Lamprey River Watershed, Report prepared for the New Hampshire Department of Environmental Services. http://des.nh.gov/organization/divisions/water/wmb/coastal/documents/unh_nitrogenassessment.pdf
18. Dunlap, K, 2010, Seasonal Nitrate Dynamics in an Agriculturally Influenced NH Headwater Stream, M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 102 pages.
19. Galvin, M, 2010, Hydrologic and nutrient dynamics in an agriculturally influenced New England floodplain, M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 94 pages.
20. Daley, M.L., W.H. McDowell, B. Sive, and R. Talbot, In Preparation, Factors controlling atmospheric deposition at a coastal suburban site, Journal of Geophysical Research (Atmospheres).
21. Daley, M.L. and W.H. McDowell, 2010, Landscape controls on dissolved nutrients, organic matter and major ions in a suburbanizing watershed, American Geophysical Union Fall Conference, San Francisco, CA, December, 2010.
22. Davis, J.M., W.H. McDowell, J.E. Campbell and A.N. Hristov, 2010, Hydrological and biogeochemical investigation of an agricultural watershed, southeast New Hampshire, USA, American Geophysical Union Fall Conference, San Francisco, CA, December, 2010.
23. Hope, A.J. 2010. Ecosystem Processes in a Piped Stream. Plum Island Ecosystems Long Term Ecological Research All Scientists Meeting, Woods Hole, MA. April 8, 2010.
24. Hope, A.J. and W.H. McDowell, 2010, Ecosystem Processes in a Piped Stream, Aquatic Sciences: Global Changes from Center to Edge, ASLO & NABS Joint Summer Meeting, Santa Fe, NM, June 2010.
25. Buyofsky, Lauren A., 2006, Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, "MS Dissertation", Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 176 pages.
26. McDowell, W.H., M.L. Daley and J.D. Potter, 2011, Dissolved organic matter dynamics in a suburban basin: wetlands and people drive quantity and quality, North American Benthological Society Meeting, Providence, RI, May 2011.
27. McDowell, W.H. and M.L. Daley, 2011, Net Manageable Nitrogen: Definition and Rationale for a new approach to nitrogen management in moderately impacted watersheds, American Geophysical Union Fall Conference, San Francisco, CA, December, 2011.
28. McDowell, W.H. and M.L. Daley, 2011, Net Manageable Nitrogen: Definition and Rationale for a new approach to nitrogen management in moderately impacted watersheds, National Academy Keck

Futures Initiative Ecosystem Services Conference, Irvine, CA, November, 2011.
29. Daley, M.L. and W.H. McDowell, In Preparation, Nitrogen saturation in highly retentive coastal urbanizing watersheds, Ecological Applications.

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.

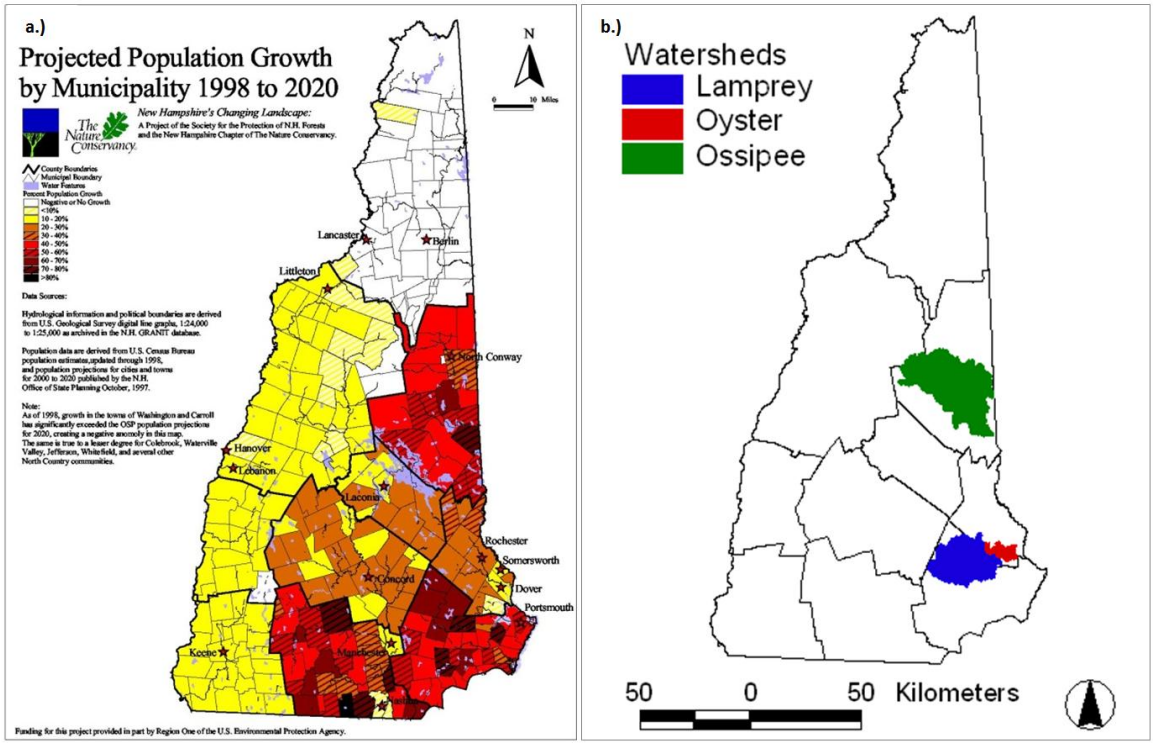


Figure 1. Projected population growth in New Hampshire (Figure from Sundquist and Stevens 1999; A) and study watersheds experiencing high population growth (B).

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 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 from the LRHO has been completed through 2011 and we are in the process of updating the LRHO website (http://www.wrrc.unh.edu/lrho/index.htm). Results of stream chemistry to date show a significant increase in nitrate concentrations during the first 10 years (Water Years (WY) 2000-2009) of monitoring at LMP73 and a slight decrease in nitrate concentrations in recent years, but nitrate levels have not declined to levels initially measured in 2000 (Figure 2). There was no significant change in nitrate concentrations at NOR27 or WHB01 over a shorter time period (2004-2011). 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 10-year period. We are unsure if the lower nitrate levels measured in LMP73 during 2010 and 2011 will persist, increase or decrease with changing 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 relatively short period of data collection is not reflective of long-term trends. The long-term increase in nitrate in the

Lamprey River from 2000-2009 has 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. The bay is experiencing dangerously low dissolved oxygen levels and 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. In fact, the NH WRRC recently provided the Town of Newmarket, NH and Underwood Engineers, Inc. with monthly average nitrogen concentrations in the Lamprey River to inform the town's comments to EPA on the draft National Pollutant Discharge Elimination System (NPDES) permit for Newmarket's wastewater treatment facility that would limit nitrogen in the effluent to 3 mg/L.

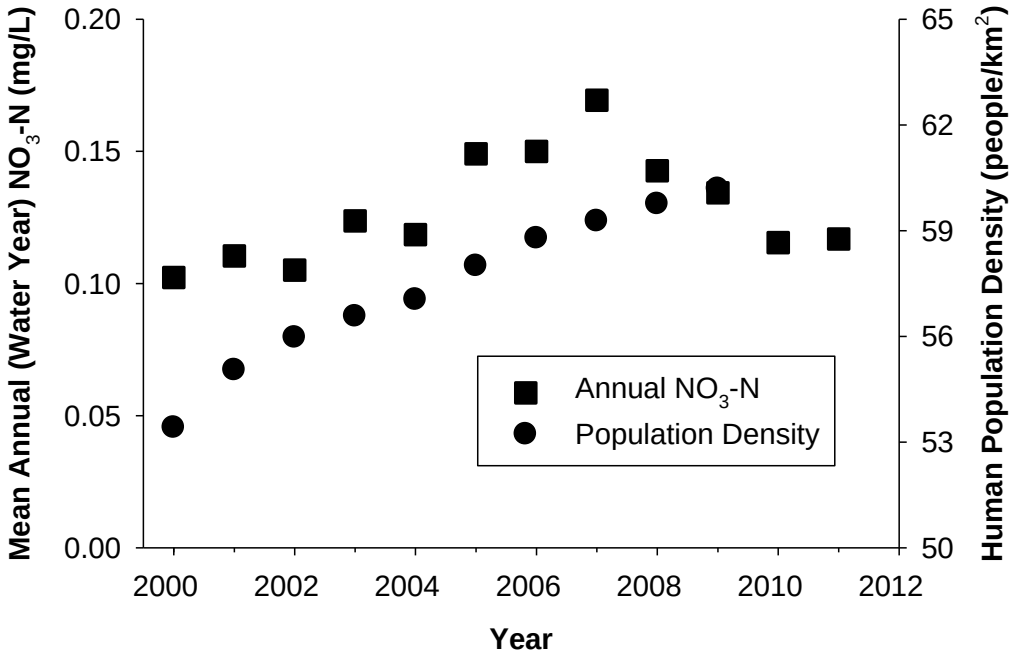


Figure 2. Annual (water year) nitrate concentration and estimated annual human population density over time in the Lamprey River basin. We have applied the Seasonal–Kendall Test (SKT; seasons set to 52) to weekly data from September 1999 through September 2009 and flow-adjusted nitrate concentrations have increased significantly over this time period (SKT $t = 0.28$, $p < 0.01$).

When we combine our specific conductance data (2002 – 2011) with data collected by the USGS (1978 - 1999), we see a long-term increase in specific conductance in the Lamprey River (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 NaCl. Sine 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 temporal change in streamwater NaCl.

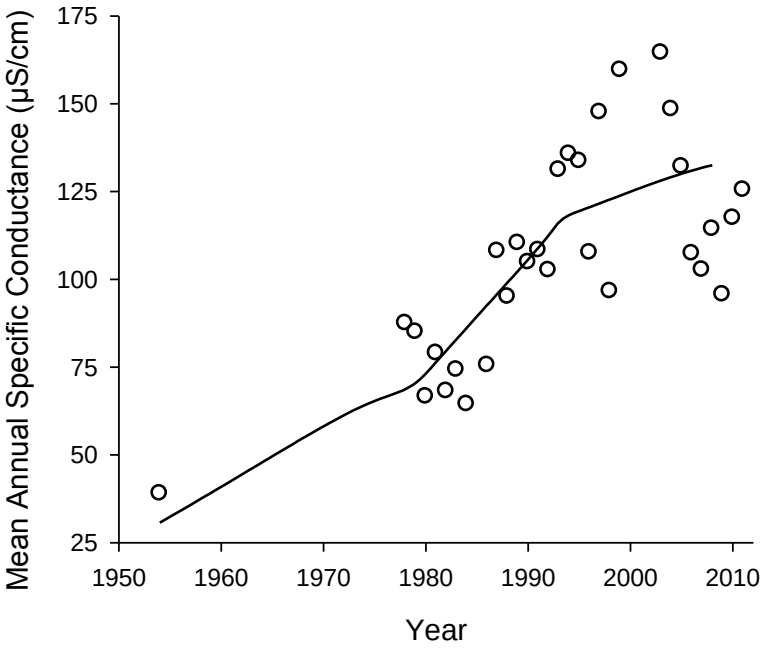


Figure 3. Mean annual specific conductance in the Lamprey River at LMP73 (co-located with the USGS gauging station in Durham, NH. (modified from Daley et al. 2009).

Oyster River watershed

Laboratory analysis of the monthly CB and PB samples is completed through 2010 and partially completed for 2011. We are now in the process of finalizing the 2011 analysis and updating our website: http://www.wrrc.unh.edu/current_research/collegebrook/collegebrookhome.htm.

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.

College Brook and Pettee Brook haves 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 indicating that nitrification is occurring in the stream channel. However, an increase in dissolved inorganic nitrogen (DIN; the sum of ammonium and nitrate) and total nitrogen indicates that there are additional sources of nitrogen to the stream as it flows though UNH and Durham. This is possibly from fertilization of the athletic fields and/or storm water runoff. There also appears to be a slight, but insignificant, increase in nitrate over time. This will need to be closely monitored as managers strive to reduce the nitrogen loading to Great Bay and Little Bay, which are impaired by elevated nitrogen. Excess nitrogen (especially in the form of nitrate) exported from the Oyster River watershed and its urban sub-basins (CB and PB) into Little Bay is cause for concern for watershed managers.

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 rivers and streams within the watershed.

Notable awards and achievements

Results from long-term water quality monitoring in the LHRO have helped leverage funding for additional research on nitrogen cycling in NH's suburbanizing watersheds. Because of the significant interest in nitrogen loading to Great Bay, existing information on the spatial and temporal variability of nitrogen concentrations in the LRHO that are driven by population growth and land use change and the relationships that the NH WRRC has formed with various stakeholders in NH, the NH WRRC faculty and staff (along with other UNH faculty and USGS colleagues) received a grant from NH Sea Grant. The objective of the new research project is to understand the mechanisms that control N exports from the Lamprey River watershed to the Great Bay over a range of climate/flow conditions and to share this understanding with local land use planners and decision makers to inform possible mitigation strategies for reducing locally

generated N inputs. This project will make use of newly developed *in situ* sensors to understand the large variability we have observed in N concentrations measured in weekly grab samples.

Number of students supported

Four Master's students (Michelle Galvin, Amanda Hope, Lucy Parham and Jason Bailio) and 3 undergraduate hourly employees (Sarah Brown, Daniella Williams, Marleigh Sullivan, Katie Swan and Katerina Messologitis).

References

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.

Society for Protection of NH Forests. 2005. New Hampshire's Changing landscape. Population growth and land use changes: What they mean for the Granite State. (Available at: http://www.spnhf.org/research/papers/nhcl2005es.pdf).

Stein, S.M., McRoberts, R.E., Mahal, L.G., Carr, M.A., Alig, R.J., Comas, S.J., Theobald, D.M. and Cundiff, A. 2009. Private forests, public benefits: increased housing density and other pressures on private forest contributions. Gen. Tech. Rep. PNW-GTR-795. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 74 p.

Sundquist D, 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

Publications

Daley, M.L. and W.H. McDowell, *In Preparation*, Nitrogen saturation in highly retentive coastal urbanizing watersheds, Ecological Applications.

Conference Proceedings & Abstracts

McDowell, W.H., M.L. Daley and J.D. Potter, 2011, Dissolved organic matter dynamics in a suburban basin: wetlands and people drive quantity and quality, North American Benthological Society Meeting, Providence, RI, May 2011.

McDowell, W.H. and M.L. Daley, 2011, Net Manageable Nitrogen: Definition and Rationale for a new approach to nitrogen management in moderately impacted

watersheds, National Academy Keck Futures Initiative Ecosystem Services Conference, Irvine, CA, November, 2011.

McDowell, W.H. and M.L. Daley, 2011, Net Manageable Nitrogen: Definition and Rationale for a new approach to nitrogen management in moderately impacted watersheds, American Geophysical Union Fall Conference, San Francisco, CA, December, 2011.

Presentations

Daley, M.L., McDowell, W.H. and Bucci, J. 2011. Nitrogen inputs, outputs, retention and concentrations in watersheds of the Great Bay Estuary system. NH Water and Watershed Conference. Plymouth, NH. March 2011. Shared slides with an EPA employee and discussed nitrogen cycling with NHDES employees and a university professor.

Daley, M.L. and McDowell, W.H. 2011. Nitrogen Research in the Lamprey River Watershed and the Great Bay Estuarine Ecosystem. Southeast Watershed Alliance Science Symposium. Portsmouth, NH. May 2011. Shared slides with Zach Henderson for a presentation on nitrogen in the Great Bay watershed given by Woodard & Curran to the Southeast Watershed Alliance.

Daley and McDowell. 2011. Human induced threats to surface and groundwater supplies in NH: a focus on nitrogen and sodium chloride. Drinking Water Source Protection Workshop. Concord, NH. May 2011.

Daley, M.L. 2011. Shared PowerPoint slides on nitrogen cycling, a manuscript on road salt impacts and a nitrogen report from the Lamprey River watershed with Tom Irwin from the Conservation Law Foundation in New Hampshire. May 2011.

Daley, M.L. 2011. Previous Nitrogen Research in the Lamprey Watershed and Current research in the Great Bay Watershed. University of New Hampshire Balancing Resource Management, Land Use and Development Class. Durham, NH. June 23, 2011.

Daley, M.L. and McDowell, W.H. 2011. Identifying Non-Point Nitrogen sources in the Great Bay Watershed and Moving Towards Sustainability. Invited presentation. Joint EPA and NH DES Sustainability on a Shoestring meeting. Concord, NH. June 2011.

Daley, M.L. and McDowell, W.H. 2011. Non-Point Sources of Nitrogen in the Lamprey and Great Bay watershed. Invited presentation. Newington, NH. July 2011. Invitees included Newington conservation commission, selectmen, planning board, sewer commission, and interested residents.

Daley, M.L. and McDowell, W.H. 2011. Viewing Great Bay from a Nitrogen (and Watershed) Perspective. Invited presentation. Great Bay Stewards Bay Views. Greenland, NH. July 2011.

Daley, M.L. 2011. Urbanization and Suburbanization in NH watersheds. University of New Hampshire Watershed Water Quality Management class. Durham, NH. September 2011.

Daley, M.L. and McDowell, W.H. 2011. Non-Point Sources of Nitrogen in the Lamprey and Great Bay watershed. Invited presentation. Newmarket, NH. September 2011.

Daley, M.L. and McDowell, W.H. 2011. Nitrogen Research in the Lamprey and Great Bay watershed. Great Bay Dialogue. Greenland, NH. December 2011.

McDowell, W.H. and Daley, M.L. 2011. Nitrogen Research in the Lamprey River Watershed and the Great Bay Estuarine Ecosystem. US EPA Region 1 meeting. Boston, MA. May 6, 2011. Meet with EPA staff in Boston to discuss non-point N sources in the Lamprey and other watersheds.

McDowell, W.H. Biogeochemistry of a Suburban Basin. Chinese Research Academy of Environmental Sciences. Beijing, China. September 2011.

McDowell, W.H. Biogeochemistry of a Suburban Basin. Chinese University of Geosciences. Wuhan, China. September 2011.

McDowell, W.H. Biogeochemistry of a Suburban Basin. China Three Gorges University. Yichang, China. September 2011.

Press Releases

Daley, M.L. and McDowell, W.H. 2011. "Sewer Plants in Great Bay Face Tougher Clean Water Standards" by Amy Quinton NH Public Radio. http://www.nhpr.org/sewer-plants-great-bay-face-tougher-clean-water-standards May 20, 2011.

Green Mountain Conservation Group meetings, workshops and presentations March 2011 - February 2012.

March 4th Youth Coalition for Clean Water hosts Bag It film at local high schools
March (after school program on Weds.) Youth Coalition for clean water presents Cool Water Kids to Ossipee Middle School students. They create rain barrels and storm drain stenciling.
March 10th Ossipee Aquifer Steering Committee Meeting debrief from Aquifer ordinance
March 12th Effingham Students present VBAP to Town Meeting
March 29th GET Wet presentation at Ossipee Central School
March 16th Effingham Students present GET WET water information to town

March 30th Youth Coalition partners with Garden Club on BMP project-Rain Garden
April 16th Water Quality Monitoring 2011 Volunteer Training
April 29th Ossipee Aquifer Steering Committee final meeting to debrief after town meeting votes
April Training for GMCG Reps to deliver information to town officials about Water Quality
May 10th Source Water Conference in Concord
May 12th Ossipee Central School water testing program
May 15th Pequawket Foundation WQM presentation
May 20th Ossipee Watershed Coalition meeting with Ossipee BOS
June 1st Ossipee Central School GET WET! & water quality presentation
June 1st Camp Calumet Rain Barrel installation with Youth Coalition
June 3rd Duncan Lake BMP Project with Girl Scouts
June 8th Mustang Academy Madison WQM RIVERS program
June 9th Camp Director Meeting & Presentation/training for 2011 season
June 11th Ossipee Lake Alliance meeting ---economics of milfoil management
June 22th Drive Time Radio Program WQM 2011
June 25th NH Lakes Congress Conference
July 7, 8, 21, 22 Volunteer Lake Assessment Program & WQ Programs with Camps Cody, Huckins, Robin Hood, Marist & Danforth Bay
July 6, 20, Aug. 3 WQ Programs/Ossipee Lake & Tributary testing with Camp Calumet
July (once a week) Madison Library Kids Program on Macroinvertebrates
July 23 Presentation on priorities for water quality protection on Ossipee Lake and prep for possible Watershed Management Plan in 2013
August 6th House Hold Hazardous Waste Day and hand out of GET WET well sampling kits
August 9th State of the Lake forum on Water Quality
August 10 GET WET water sampling day at Huntress House (GMCG office)
August 24 VBAP, Trout in the Classroom & WQM Volunteer Training at Community School with NH Fish and Game
September 7-30th VBAP Programs & WQM daily with Ossipee Central School, Effingham Elementary, The Community School, Freedom Elementary, Sandwich Elementary School
October 4th Rain Garden Training with Garden Club
October 28th Salt workshop for road agents with UNH Storm Center T2
October 29th Regional Road Salt Reduction Workshop with UNH T2 in Chocorua
November 12th Ossipee Aquifer Steering Committee Meeting
December 1st Student WQM Presentation in Tamworth of VBAP & WQ for 2011
December 8th Trout in the Classroom training
December 10th Bald Eagle presentation with NH Audubon
January 14, Ossipee Aquifer Steering Committee Meeting
January 21 Annual meeting and Water Quality presentation
February Training for GET WET program
February 15th 2011 Kingswood Fair for Youth Coalition for Clean Water
February 20th Drive Time Radio Program
February 17th GET WET! & WQM Training Madison

Arsenic chemical dynamics in NH groundwater reservoirs: Insights from temporal variability in multi-element signatures of statewide samples

Basic Information

Title:	Arsenic chemical dynamics in NH groundwater reservoirs: Insights from temporal variability in multi-element signatures of statewide samples
Project Number:	2011NH141B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Geochemical Processes, Groundwater, Toxic Substances
Descriptors:	None
Principal Investigators:	Julia G Bryce

Publications

There are no publications.

Year 1 Project Report: "Arsenic chemical dynamics in NH groundwater reservoirs: Insights from temporal variability in multi-element signatures of statewide samples."

PI Julia G. Bryce, USGS Collaborator Joe Ayotte, UNH Staff Florencia Prado

1. Problem and Objectives

The purpose of this two-year project is to measure the concentrations of arsenic, a key regulated contaminant, in public and private groundwater wells distributed across the state of New Hampshire. In the first year of this two-year project, we focused on developing the arsenic method for analysis via hydride generation-high resolution inductively coupled plasma mass spectrometry. We have optimized our analytical protocol for "harvesting" arsenic out of water samples originally collected for a MTBE study, and we have optimized a set of procedures for investigating "leachable" arsenic from samples of local bedrock. Future analyses of other key geochemical parameters (e.g., Fe and Pb) coupled with ongoing laboratory experiments manipulating pH and redox conditions provide the opportunity to investigate geochemical controls on arsenic mobility in geochemical environments such as those found in the bedrock-hosted aquifers of southern NH.

2. Methods and Project Activities

Our work is focused on developing analytical protocols to measure arsenic contents in existing samples. Nearly 900 samples exist from sampling campaigns led by J. Ayotte originally designed to study MTBE occurrences in groundwaters sampled from public and private drinking water supplies. Since some of the existing samples are older than recommended "hold" times for water samples, we first needed to ensure no arsenic has been lost from the system, via selective adsorption onto the bottle sides and/or via co-precipitation with other elements. Our approach to ensuring all arsenic is in solution is as follows. First we acidified the samples to 5% nitric acid, and then let sit for several days and shoot and mixed via ultrasonic mixing. We then took a (quantified) cut for which we measured the arsenic concentration. We subsequently transferred the sample to a cleaned bottle and acidified to 10% nitric, let sit, and then ran the results for arsenic concentration. We repeated this last bottle-leaching with 15% nitric.

We have developed the analysis of arsenic on the hydride generator (Klaue and Blum, 1999) that is plumbed into a high resolution inductively coupled plasma mass spectrometry. Generally our detection limits are $\sim <$ 0.025 μg/kg, but during some of our runs our detection limit was as high as 0.09 μg/kg (likely due to a high blank on one of our reagents, which we then replaced). We used standard-sample-standard bracketing to correct for within-run drift, and developed a standard curve using diluted natural water samples.

In a second part of our work, we carried out leaching experiments with chipped bedrock samples to elucidate the geochemical controls on the contributions of arsenic from metasedimentary bedrock units. Our first analyses in support of these investigations include the analysis of environmentally mobile arsenic in the Kittery formation. Our

approach is adapted from that described in Peters and Blum (2003); we use partial leaching in dilute acid to identify the readily mobilized As fractions. In addition to the acid leaching (carried out at pH ≤ 1), we carried out a subsequent study exposing the samples to solutions of elevated pH to test for the role of pH-selective absorption onto minerals on As mobilization (e.g., Peters and Blum, 2003 and references therein).

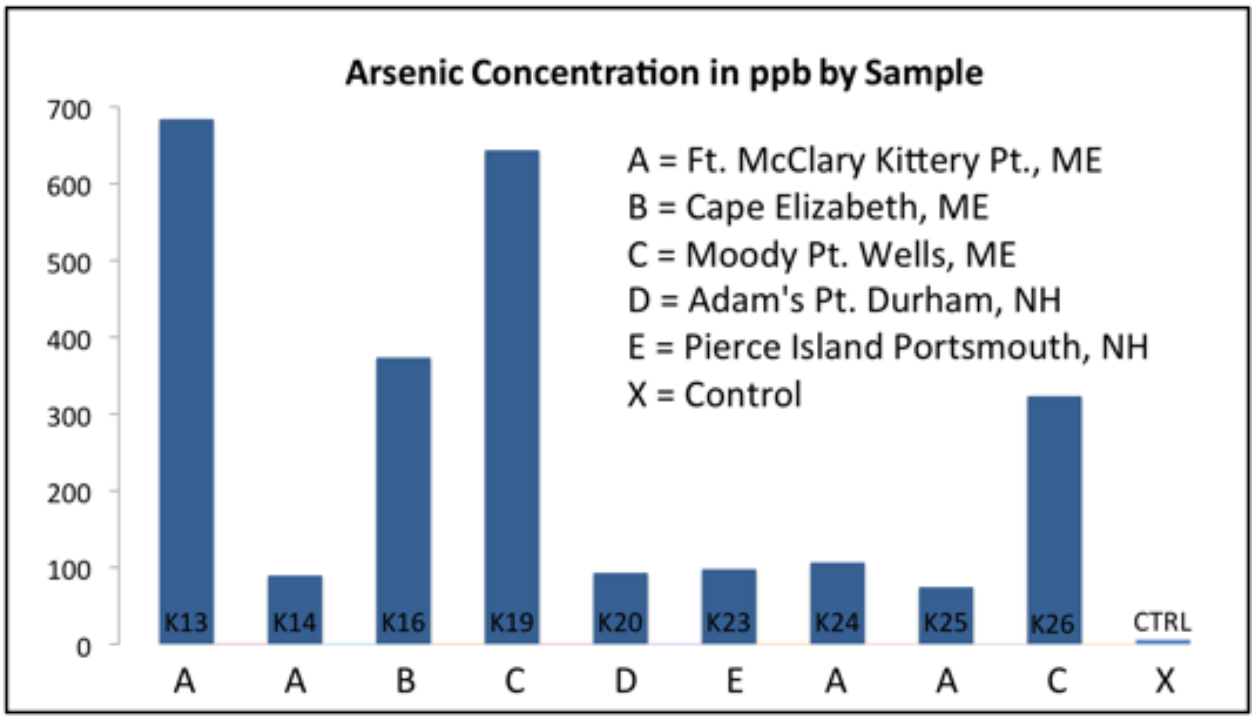
3. Findings and Future work

In our assessments of accuracy and precision we ran a standard (NIST SRM 1643e, Trace elements in water) and found excellent accuracy and reproducibility. We also participated in the USGS Round Robin measurements for standards. Following procedures we have developed, we reported our assessment of the standard, which came in below the median value reported for the unknown standard we were assigned. Though it is difficult to address the meaningfulness of the "median" value as it includes several different types of analytical approaches (some of which would not be used validly for samples with As of low abundance), we are continuing to run the standard using other techniques (e.g., standard addition) to ensure that we are accurately measuring sample values. Any offset in our values likely comes from a mismatch between the matrix of the standard we are using and the matrix of unknowns. Accordingly we will be carrying out investigations of the influence of several different "matrix"-modifiers to ensure that our analytical protocols are not impacted by the high abundance of certain elements (e.g., Fe).

In terms of ensuring that we have no sample biasing issues with the shelf life of our samples, we spent the time on a subset of our samples to ensure we can establish a protocol for future measurements of our 900 groundwater samples. Analyses of five samples showed, in cases where the original sample is above the detection limit, that we have a > 99% yield for the total arsenic in the system during the acidification to 5% nitric. Accordingly we will adopt these protocols with the rest of the unknown samples.

Our initial investigations of the environmentally mobile arsenic confirm the extreme range in arsenic that we can find over relatively short spatial scales in metasedimentary bedrock (Figure 1), as well as the strong sensitivity of subsequent arsenic remobilization due to changing pH in oxidizing conditions . We will complement our existing results on the Kittery with leaching studies of additional sub-samples from two existing ~100-foot six-inch drill cores through the Kittery and Elliot formations around the Great Bay in Southeastern NH and potentially from other bedrock units that host samples we have collected in the southern NH region.

Figure 1 (following page). Arsenic concentrations in bedrock-leaching solutions from the Kittery formation. Note the extreme variability in the arsenic that is potentially environmentally mobile from different localities in the Kittery formation medasedimentary bedrock as well as the variability within individual localities. Forthcoming elemental analyses will help to identify the geochemical processes responsible for these wide variations.



4. Presentation

Results of the bedrock-leaching were presented at the 2012 UNH Undergraduate research project by Mr. John Clark (UNH BA-Earth Sciences Teaching, 2012). Clark started his activities on the project in summer 2011 and continued during the 2011-2012 academic year. We anticipate that we will submit an abstract to the 2013 Northeastern Regional GSA meeting to be held in NH next spring.

5. Outreach efforts

Clark is training to be a teacher, and his involvement in this project has provided him the opportunity to participate in "genuine" scientific research such that he can model it with his future middle school students. He originally participated in this project as part of a summer research internship provided by a National Science Foundation grant for which Bryce is a co-PI. His attraction to the project came because of his belief that this was a project that he involved chemistry, public health and environmental sciences, in such a way that he could engage his future students. His continued involvement during the academic year is a testimony to his long-standing interest. He has committed to continuing to work on the bedrock leaching projects during this upcoming summer and his year working for his M.Ed., the final steps in the process of teacher certification.

6. Personnel development- students, faculty and staff

In addition to Mr. Clark, whose analytical efforts were supported by this project, this project is responsible for convincing Ms. Florencia Prado, a talented staff member to apply to work on her Ph.D. The arsenic project will constitute part of her Ph.D. thesis. Prado has developed the analytical techniques and worked with Bryce to supervise and develop Clark's project.

Nutrient Loading Coefficients for NH Watersheds: Development and Connectivity

Basic Information

Title:	Nutrient Loading Coefficients for NH Watersheds: Development and Connectivity
Project Number:	2011NH148B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Nutrients, Non Point Pollution, Management and Planning
Descriptors:	None
Principal Investigators:	Jeffrey Schloss

Publications

1. Craycraft, Robert and Jeffrey A. Schloss, 2011, Site Specific Project Plan: Lake Wentworth/Crescent Lake Watershed Management Plan Implementation-Phase I, Operated Under: the University of New Hampshire Center for Freshwater Biology and Lakes Lay Monitoring Program Programmatic Quality Assurance Project Plan, UNH Center for Freshwater Biology and Cooperative Extension, Durham, NH, 19pps.
2. Craycraft, Robert and Jeffrey A.Schloss, 2011, Baboosic Lake Annual Lake Report for 2010, New Hampshire Lakes Lay Monitoring Program, UNH Center for Freshwater Biology and UNH Cooperative Extension, Durham, NH, 122 pps.
3. Craycraft, Robert and Jeffrey A.Schloss, 2011, Bow Lake Annual Lake Report for 2010, New Hampshire Lakes Lay Monitoring Program, UNH Center for Freshwater Biology and UNH Cooeprative Extension, Durham, NH, 65 pps.
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19. Craycraft, Robert and Jeffrey A.Schloss, 2011, Squam Lakes Annual Lake Report for 2010, New Hampshire Lakes Lay Monitoring Program, UNH Center for Freshwater Biology and UNH Cooperative Extension, Durham, NH, 160 pps.
20. Craycraft, Robert and Jeffrey A.Schloss, 2011, Sunset Lake Annual Lake Report for 2010, New Hampshire Lakes Lay Monitoring Program, UNH Center for Freshwater Biology and UNH Cooperative Extension, Durham, NH, 63 pps.
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27. Craycraft, Robert and Jeffrey A.Schloss, 2011, Lake Winnisquam Annual Lake Report for 2010, New Hampshire Lakes Lay Monitoring Program, UNH Center for Freshwater Biology and UNH Cooperative Extension, Durham, NH, 74 pps.

2011NH148B

Nutrient Loading Coefficients for New Hampshire Watersheds: Development and Connectivity

Problem:

The waters of New Hampshire represent a valuable water resource contributing to the state's economic base through recreation, tourism, and real estate revenues. Some lakes and rivers serve as current or potential water supplies. For most residents (as indicated by boating and fishing registrations and shoreline re-development) our waters help to insure a high quality of life. As documented in the 2010 Census, New Hampshire currently leads all of the New England states in the rate of new development and redevelopment. The long-term consequences of the resulting pressure and demands on the state's precious water resources remain unknown. Of particular concern is the response of our waters to increasing non-point source pollutant loadings due to watershed development and land use activities.

Through previous NIWR (USGS; NH WRRC) and EPA funded projects we have conducted volunteer assisted watershed nutrient budget studies and catalogued those studies previously undertaken by other agencies/organizations. While these investigations have allowed us to document the range of nutrient export coefficients for particular land use/land covers that occur in our state further analysis is needed to determine the influence of various factors such as percent imperviousness, riparian buffer extent and use of best management practices. Recent investigations have also suggested that drainage connectivity at the local (subwatershed) scale can have a large influence on these loadings.

In addition the funds will continue to support our long-term monitoring program conducted through differing weather years at both shallow and deep sites that offer the potential to cost effectively estimate the lake response to the loadings due to development over time.

Objectives:

The funds provided by the WRRC provided continued partial support of our long term citizen science participatory monitoring effort, the NH Lakes Lay Monitoring Program (LLMP). Additional support for this effort is provided by UNH Cooperative Extension, The UNH College of Life Sciences and Agriculture, USDA National Institute of Food and Agriculture, New Hampshire Department of Environmental Services (NH DES; from US EPA section 319 funding) and from towns, municipalities and lake associations throughout the state.

1- To expand our investigation into land use impacts on nutrient loading by analyzing subwatershed nutrient loading data and GIS based land use/land cover data particularly looking at impervious cover, development density, riparian buffers and best management practices (where information is available) and drainage connectivity.

2- To refine our current land cover nutrient loading coefficient recommendations based on the project results.

3- The continued collection and analysis of long-term water quality data in selected watersheds.

4- The dissemination of the results of the analysis to cooperating agencies, water managers, educators and the public on a local, statewide and regional basis.

5- To offer undergraduate and graduate students the opportunity to gain hands-on experience in water quality sampling, laboratory analysis, data management and interpretation.
6- To further document the changing water quality in a variety of watersheds throughout the state in the face of land use changes and best management efforts.

Methods

The project utilized an extensive GIS database for the study subwatersheds created through previous NIWR and EPA funding to the PI. Updated and additional GIS data(high resolution imagery) was made available through the UNH Complex Systems Research Center, which manages the NH GRANIT statewide GIS data depository. A dedicated GIS PC Windows 7 workstation provided the analysis software including ArcGIS and ArcView Software (version 10), ArcView Extensions: Spatial Analyst, 3-D Analyst, Image Analysis and ArcPress. The software was used to confirm the spatial, hydrological, land cover and land use characteristics of the various subwatersheds previously catalogued in our studies. Additional data analyses and statistics was performed using JMP statistical software (SAS institute).

Lake and stream monitoring through the LLMP generally involved a minimum of monthly sampling starting at spring runoff through to lake stratification and weekly to bi-weekly sampling through to fall mixis. Water clarity, chlorophyll a, acid neutralizing capacity, dissolved organic color, dissolved oxygen and nutrients (total N, total P and nitrate) will be the default suite of parameters measured for lakes while nutrients, turbidity, dissolved organic color and flow will be the parameters of choice for the lake tributary work. On occasion, student field teams traveled to join the volunteer monitors to perform quality assurance checks and do more in-depth analysis and lake profiling. All LLMP field sampling and laboratory analysis follows approved Quality Assurance Projects Plans and Site Specific Project Plans reviewed by NH DES and US EPA New England and are on file with both agencies.

As stated above the primary scope of this project was to maintain the long-term data collection effort of the LLMP but in addition, land cover changes to study subwatersheds will be documented on our established GIS data base and any new management practices or conservation efforts were documented

Principal findings and significance

Focus of this year's efforts was on the Newfound Lake Watershed and the Squam Lakes Watershed. Emphasis of the Newfound study was on mapping road connectivity and culverts as well as investigating forestry best management practices in the headwater streams. In collaborative work with the Society for the Preservation of New Hampshire's Forests, the UNH Center for Freshwater Biology and the Newfound Lake Regional Association it was found that steep slopes combined with lack of long-term maintenance of BMPS were contributing to higher nutrient loads into the headwater streams of Newfound Lake. Significant sediment and associated nutrient loadings were also associated where under designed culverts received storm runoff from roads in the steeper areas of the watershed.

These research findings supported an innovative approach used by the Newfound Lake Regional Association to have the watershed towns consider changing their current

development ordinances to utilize variable buffer width requirements based on slope. To date 2 towns have incorporated this recommendation and additional towns are considering the measure. In addition, a summit hosted by UNH Cooperative Extension Forestry and Wildlife staff is currently planned between local consulting foresters, landowners, loggers and interested persons to discuss the need to maintain best management practices especially on steep sloped lands.

The Squam Lake Watershed work updated land use landcover and explored the relative impacts of nearshore Shoreland zone vs total subwatershed influence on water quality. This work will be reported as part of the PIs dissertation defense.

Publications and Presentations

Reports:

Craycraft, Robert and Jeffrey A. Schloss. 2011.Site Specific Project Plan:: Lake Wentworth/Crescent Lake Watershed Management Plan Implementation-Phase I Operated Under: the University of New Hampshire Center for Freshwater Biology and Lakes Lay Monitoring Program Programmatic Quality Assurance Project Plan. UNH Center for Freshwater Biology and Cooperative Extension. Durham, NH.. Approved May 23, 2011 by NH DES and US EPA New England. 19pps.

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Presentations:

Schloss Jeffrey A. 2011. "An Ecological Approach to Landscaping Shoreland Properties" I- Water Quality, Water Movement and Drainage on Landscaped Sites. II- Site Assessment for Reigning in Stormwater Runoff. Invited workshop presenter Rutgers University, New Brunswick, NJ. April 13, 2011.

Schloss, Jeffrey A. 2011. Design Considerations for Rain Gardens. For Rain Garden Workshop. Urban Forestry Center, Portsmouth, NH. UNH Cooperative Extension June 1, 2011.

Schloss, Jeffrey A. 2011. Cyanobacteria Monitoring: What Current Research Tells Us. Invited presentation. New England Chapter, North American Lake Management Society Annual New England Lakes Conference, University of Rhode Island, Kinston, RI June 4, 2011.

Schloss, Jeffrey A. 2011. Reigning In Runoff Through Landscaping. Invited speaker. Goose Pond Association, (Canaan and Hanover NH) June 11, 2011.

Schloss, Jeffrey A. Landscaping at the Water's Edge. Presentation and field training at the NH Lakes Congress, Windham, NH. New Hampshire Lakes Association. .June 24, 2011.

Schloss, Jeffrey A. 2011. Adventures in Volunteer Monitoring: Lessons learned in 30+ years with the NH Lakes Lay Monitoring Program. North American Lake Management Society. 31st International Symposium. Spokane, Washington. October 26-28, 2011.

Craycraft, Robert. 2011. Water Quality and You. Woods, Water and Wildlife Festival. Moose Mountain Regional Greenways. August 2011.

Craycraft, Robert 2011. Roundtable Discussion: Town Implementation of Watershed Protection Measures.. NH Lakes Congress, Windham, NH. New Hampshire Lakes Association. .June 24, 2011.

Publications/Presentations from previous WRRC support not reported:

Harvey, Rebecca. 2011. Pharmaceuticals and Personal Care Products in New Hampshire Water Resources; Poster presented at: Science to Inform Pharmaceutical and Personal Care Product Management, April 27-29, 2011, Holiday Inn by the Bay, Portland, Maine. New England Interstate Water Pollution Control Commission.

Outreach/Information Transfer

August 9, 2011- Presented "Cyanobacteria: What's the Worry" at the request of the Meredith NH Town manager in response to a beach closure that occurred that summer. – Over 100 citizens/decision-makers attended- Schloss

September 12, 2011- Invited to present on the importance of riparian buffers and the research behind the recommendations to the Comprehensive Shoreland Protection Act Study Commission, Concord, NH -Schloss

December 19, 2011- Met with Tuftonboro Conservation Commission and Lakes Region Planning Commission reps to discuss assessment of Wolfeboro subsurface discharge on surrounding wetlands, lakes and groundwater supply-Schloss.

February 13, 2011- Met with representatives from Moultonboro and Center Sandwich to discuss monitoring of upper Moultonboro Bay (Winnipesaukeee) Watershed.-Schloss

Various Dates March 2011/February 2012- worked with Lake Wentworth Association (Craycraft, Lake Winnipesaukee Association (Schloss)) and Newfound Regional Association (Craycraft and Schloss) to plan further activities under Watershed Assistance Grants (NH DES)..

July 2011- Met with Pine River Pond Board of Directors to discuss water quality goals with emphasis on current water quality data. –Craycraft.

Students Supported

While no WRRC support was provided for direct undergraduate student support, the following students were indirect beneficiaries of WRRC support to the NH LLMP:
Undergraduate Students

Michel Henlou	Environmental Conservation	Senior (Spring 2012 Grad)
Emma Leslie	Zoology	Senior (Spring 2012 Grad)
Ashley Lupus	Medical Science	Senior (Spring 2012 Grad)
Cara McGuire	Environmental Conservation	Senior (Spring 2012 Grad)
Emily Ramlow	Environmental Conservation	Senior (Dec. 2011 Grad)
Jessica Waller	Marine Biology	Junior

Graduate Students (directly supported):

Jeff Schloss	Natural Resources and Environmental Studies	PhD candidate

Faculty Staff Supported

Directly: Jeff Schloss- Extension Professor in Biological Science
Indirectly: Robert Craycraft, Educational Program Coordinator, LLMP UNH Cooperative Extension.

USGS Award No. G11AP20128 Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.

Basic Information

Title:	USGS Award No. G11AP20128 Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.
Project Number:	2011NH164S
Start Date:	3/28/2011
End Date:	3/27/2012
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 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.

Annual Report to

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

June, 2012

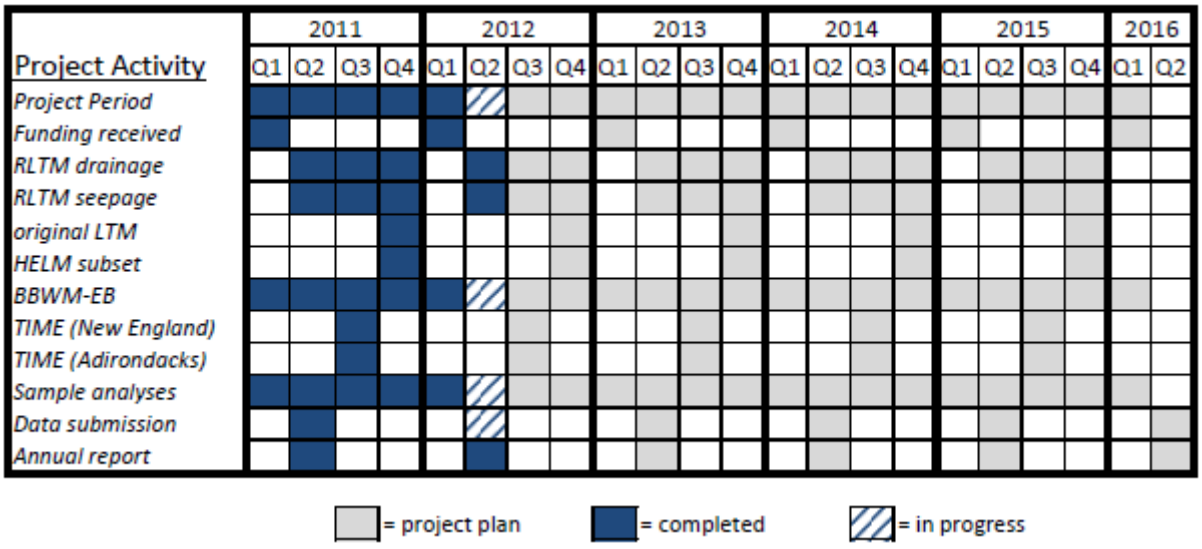
Determining the effectiveness of the Clean Air Act and Amendments on the recovery of surface waters in the northeastern US

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 2011. A schematic summary of progress on the project plan is provided below (Table 1) and discussed on the following pages. We have concluded the first 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 Ph.D. candidate who is evaluating recent trends in the LTM and TIME lakes' responses to changes in atmospheric deposition.

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



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.

Approach. The schedule of tasks ranges from weekly to annual, continuing data records that now range from 17 to 30 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 2011 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	9	3	UMaine/UNH	X		X			X
	LTM lakes	3	1	UMaine						X
TIME										
	New England	31	1	UNH			X	X	X	
	Adirondacks	42	1	ALSC			X	X	X	
HELM		25-30	1	UNH						X

Analytical. Analyses are complete for all samples collected through 2011. 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, Adam Baumann as has been the case since 2006.

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 Environmental Chemistry Research Lab.

Data reporting. All data collected through 2010 have been delivered to EPA. The next delivery of data to EPA is expected before August 2012, after evaluation of inter-laboratory comparisons and regular QA analyses by UNH and UMaine. Additionally, PI Nelson has been working with EPA-CAMD to improve the legacy database through improved formatting, metadata, and reporting of an expanded and re-checked legacy database.

Presentation of findings. Several publications and presentations continue to result from this project and are listed at the end of this report. The recent completion of a Master's Thesis (Baumann) further highlights the significance of this research award.

New developments: During the past year 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. Analyses of archived samples from the LTM lakes led to a publication now in press in Environmental Science and Technology (Sanclements et al.), based on carbon quality measured as fluorescence index. This paper reports that (1) five of the nine lake samples analyzed had increasing DOC trends during 1993-2009, and (2) in these five lakes with increasing DOC, fluorescence indices suggest the source of DOC has become increasingly terrestrially-derived.

Conversations with the Adirondack Lake Survey Corporation (ALSC) at our periodic TIME/LTM cooperators meeting opened conversations about streamlining the collection and analysis of TIME-Adirondack samples. Many years of duplicate analyses provide ample opportunity for interlaboratory comparisons between ALSC and UMaine and UNH that we are hopeful will allow for analytical responsibility to shift mainly to the ALSC lab in the near future.

Data are being provided to a team including former EPA-LTM PI Katherine Webster (with P.A. Soranno, K.S. Cheruvelil, E.H. Stanley, J.A. Downing, N. Lottig, and P-N Tan), who are working on the NSF Macrosystems Biology Project "studying large-scale and long-term dynamics of lakes."

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

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.

Nelson, S.J., Vaux, P., 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.

James-Pirri, M.J., S.J. Nelson, and P.D. Vaux. July 2010. Natural Resource Assessment for Saugus Iron Works National Historic Site. Natural Resources Report NPS/NER/NRR—2010/XXX. National Park Service. Boston, MA, in press.

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.

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.

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.

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.

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

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 Pollut., 151:373-396.

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.

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.

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.

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 Pollut. 164:383-389.

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.

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.

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

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

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.

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.

Information Transfer Program Introduction

The NH WRRC supported one information transfer project with its 2011 104b funding: New Hampshire WRRC Information Transfer

New Hampshire WRRC Information Transfer

Basic Information

Title:	New Hampshire WRRC Information Transfer
Project Number:	2008NH97B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Management and Planning, Water Quality, Non Point Pollution
Descriptors:	None
Principal Investigators:	William H H. McDowell

Publications

There are no publications.

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 Director and Associate Director to meet with state representatives, local town officials, watershed 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 7, 2011 the NH WRRC totally funded and organized the F**ifth Annual Lamprey River Symposium** (see also below). Presentations focused on water quality, hydrology, geomorphology, stormwater, climate and landuse change, aquatic species and habitat, watershed planning and nitrogen cycling in coastal New Hampshire. The symposium attracted approximately 100 attendees, including scientists, regional leaders, town officials, members of state agencies, and federal agencies. The agenda can be found on the NH WRRC website at: http://www.wrrc.unh.edu/lrho/symposium.htm. 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.

Examples of Information Transferred

Data for Public Water Supplies

The NH WRRC's long-term water quality data on the rapidly developing suburban Lamprey River watershed has been shared with local towns as they investigate new potential sources for public water supply. Several towns in the watershed are investigating new water supplies to support the increased demand for water from their growing populations. Newmarket, NH is under considerable pressure to develop new water supplies, as its surface water treatment plant was shut down several years ago due to high concentrations of dissolved organic carbon (DOC). This DOC, although of largely natural origin from wetlands in the Lamprey River basin, results in production of dangerous trihalomethanes upon chlorination. Trihalomethanes are known carcinogens and the town of Newmarket was required to shut down the water treatment plant and rely solely on the two town wells.

Newmarket has contracted with Emery & Garrett Groundwater, Inc (EGGI) to increase their town water supply. Emery & Garrett Groundwater, Inc has suggested that the town withdraw water from the Lamprey River in Lee NH during high flow periods and artificially "recharge" their town wells to generate an underground storage supply that would meet the town

water needs even during dry summer conditions. The NH WRRC has provided EGGI with long-term Lamprey River data to assess whether seasonality and year to year variability in water quality (especially DOC) made it appropriate for artificial recharge. The town of Newmarket has not been able to appropriate funding to further develop this artificial recharge project, but the long-term dataset provided by the NH WRRC was instrumental in this water supply decision-making process and will be relied on as the town assesses how to increase its public water supply.

The town of Durham (including the University of New Hampshire) relies heavily on the Lamprey River for water supply since the town's local surface water source, the Oyster River, is often unable to meet the town's demand. Like Newmarket, Durham has also contracted with EGGI to determine if artificial recharge of their Spruce Hole Aquifer with Lamprey River water is an appropriate and viable option to meet the town's water supply needs. The NH WRRC continues to provide EGGI with long-term water quality data on the Lamprey River to inform this water supply decision-making process in Durham. As more towns in the future look to the Lamprey for water supply, the long-term dataset provided by the NH WRRC will become increasingly valuable.

Nitrogen Data in New Hampshire's Great Bay watershed

Over the three 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 June 2009, numeric nitrogen criteria were established for Great Bay and 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 a draft version of a waste load allocation report prepared by Philip Trowbridge (NH DES 2010), only 27% of the nitrogen entering Great Bay and Little Bay is from point sources; the majority (73%) 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 11+ 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 DES, the Piscataqua Region Estuaries Partnership (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 to discuss the Great Bay nitrogen issue and also the EPA's draft National Pollutant Discharge Elimination System (NPDES) permits that were issued to Exeter, Newmarket and Dover which limit nitrogen in the towns' wastewater treatment plant effluent to 3 mg/L. The NH WRRC provided the town of Newmarket, NH and Underwood Engineers, Inc. with monthly average nitrogen concentrations in the Lamprey River to inform the town's comments to EPA on the draft NPDES permit for Newmarket's wastewater treatment facility.

Symposia, Conferences and Seminars Organized and Funded

The NH WRRC totally funded and organized the "**Fifth Annual Lamprey River Symposium**" held January 6, 2012 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 100 attendees, including researchers, legislators, water system operators, town officials, regional leaders and government officials. The symposium contained 13 presentations split up over three sessions. There was a break out session on nitrogen cycling and a poster session during lunch (5 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 totally funded and organized by the NH WRRC. Staff from UNH cooperative extension and Great Bay National Estuarine Research Reserve helped moderate the open discussions. Survey results indicate that over 90% 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 25-26, 2011. This unique two-day 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 2011 conference was on effective strategies at the local, regional, state, and federal levels that address the changing environmental and societal conditions and their effects on New Hampshire's aquatic environment. The NH WRRC co-Sponsored this conference along with FB Environmental Associates, GeoInsight Inc., Hach Hydromet, In-Situ Inc., New England EnviroStrategies, New Hampshire Department of Environmental Services, New Hampshire Fish and Game Department, Plymouth State University, Squam Lakes Association, United States Geological Survey Water Resources of NH and VT, Vanasse Hangen Brustlin, Inc. (VHB), Weston & Sampson Engineers Inc., Waterline Companies and the White Mountain National Forest. The conference contained 4 or 5 tracks each day including headwaters, streams and rivers; lakes wetlands and the coastal zone; wastewater and stormwater infrastructure; groundwater; land use change; local, regional, statewide and national strategies and skill building. The conference drew over 250 people, including researchers, legislators, water system operators, land use planners, and government officials.

Outcomes of Information Transferred

In June 2009, the NH WRRC together with the Great Bay National Estuarine Research Reserve (GBNERR) Coastal Training Program, Lamprey River Watershed Association (LRWA), Lamprey River Advisory Committee (LRAC) and Piscataqua Region Estuaries Partnership (PREP) formed the Lamprey River Watershed Outreach Collaborative and co-sponsored an outreach conference in June 2009 focusing on pressing water issues for the residents of the 14 towns that make up the watershed. The conference was titled "Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes $ense For Protecting Our Water" and drew over 70 people including teachers, legislators, town officials, regional leaders and government officials. Topics covered were 1) issues and challenges to land use decision making in the 14 towns that share the Lamprey watershed (presented by Erika Washburn, UNH PhD candidate) 2) water quality issues with road salt use and elevated nitrogen levels (presented by NH WRRC associate director) 3) consistency of environmental planning and regulation between towns in the watershed (presented by PREP).

The Lamprey River Outreach Collaborative conference highlighted the need for watershed wide land use planning and decision making and gave momentum to an earlier idea that the entire Lamprey should be nominated into the NH Rivers Management and Protection Program (RMPP). Previously, the Lamprey River only had 17.5 km (in Durham and Lee) of the 78 km mainstem reach designated into the NH RMPP. Following the Lamprey River Outreach Conference, a Lamprey River Nomination Committee (LRNC) was formed and in June 2010, a nomination package was submitted by the LRNC, LRWA and the LRAC to the NH Department of Environmental Services (DES) to designate the remaining portions of the Lamprey River and all its major tributaries into the NH RMPP. This nomination represented a total of 141 river km and the major tributaries included were the North Branch, Pawtuckaway, North, Little and Piscassic Rivers. Together, these nominated rivers capture 14 towns, two counties and 3 regional planning commissions that all share the Lamprey River watershed. This nomination package was the most complex nomination that the NH State Rivers Management Committee had ever seen and the first one to push for a watershed approach (as opposed to nominating a segment of a river or the main stem of a river, but not its tributaries). The committee was extremely impressed that elected officials from all of the watershed towns wrote letters of support and by the number and variety of individual support letters. On September 28, 2010, the NH State Rivers Management Committee voted to approve the nomination and the resulting House Bill has passed in both the House and the Senate. The Governor signed this Bill into law on June 7, 2011. A watershed wide local advisory committee has now been formed with representatives from each of the 14 towns. The designation will give the Lamprey watershed preferential eligibility over non-designated rivers for state funding and technical resources.

The progressive movement of this nomination represents significant outreach efforts of the NH WRRC, all the partners of the Lamprey River Outreach Collaborative (http://www.wrrc.unh.edu/lrho/outreach.html) and also the social science work of Erika Washburn (PhD dissertation "To pave or not to pave: a social landscape analysis of land use decision-making in the Lamprey River watershed", December 2009). The LRNC, LRWA and LRAC made considerable efforts to put the nomination package together, but the public support for this nomination which is necessary for state designation would not have been possible without the extensive outreach of the Lamprey River Outreach Collaborative of which the NH WRRC plays a large role (http://www.wrrc.unh.edu/lrho/outreach.html). The concept of land use decision-making and natural resource management from a watershed perspective instead of solely by political boundaries with no regard to upstream or downstream neighbors is one that is gaining traction in southeast NH and is an outcome that the NH WRRC as well as other organizations is very proud of. This type of approach is the only to solve some of the current water quality impairments in New Hampshire (e.g. road salt contamination and elevated nitrogen and phosphorous in several water bodies).

Presentations

Daley, M.L., McDowell, W.H. and Bucci, J. 2011. Nitrogen inputs, outputs, retention and concentrations in watersheds of the Great Bay Estuary system. NH Water and Watershed Conference. Plymouth, NH. March 2011. Shared slides with an EPA employee and discussed nitrogen cycling with NHDES employees and a university professor.

Daley, M.L. and McDowell, W.H. 2011. Nitrogen Research in the Lamprey River Watershed and the Great Bay Estuarine Ecosystem. Southeast Watershed Alliance Science Symposium. Portsmouth, NH. May 2011. Shared slides with Zach Henderson for a presentation on nitrogen in the Great Bay watershed given by Woodard & Curran to the Southeast Watershed Alliance.

Daley and McDowell. 2011. Human induced threats to surface and groundwater supplies in NH: a focus on nitrogen and sodium chloride. Drinking Water Source Protection Workshop. Concord, NH. May 2011.

Daley, M.L. 2011. Shared PowerPoint slides on nitrogen cycling, a manuscript on road salt impacts and a nitrogen report from the Lamprey River watershed with Tom Irwin from the Conservation Law Foundation in New Hampshire. May 2011.

Daley, M.L. 2011. Previous Nitrogen Research in the Lamprey Watershed and Current research in the Great Bay Watershed. University of New Hampshire Balancing Resource Management, Land Use and Development Class. Durham, NH. June 23, 2011.

Daley, M.L. and McDowell, W.H. 2011. Identifying Non-Point Nitrogen sources in the Great Bay Watershed and Moving Towards Sustainability. Invited presentation. Joint EPA and NH DES Sustainability on a Shoestring meeting. Concord, NH. June 2011.

Daley, M.L., Dr. John Bucci, McDowell, W.H., Dr. Erik Hobbie, Dr. Charlie French, Jody Potter and Steve Miller. Great Bay Nitrogen Sources and Transport presentations to Nitrogen Sources Collaborative Advisory Board. June 2011, November 2011 and February 2012. Greenland, NH.

Daley, M.L. and McDowell, W.H. 2011. Non-Point Sources of Nitrogen in the Lamprey and Great Bay watershed. Invited presentation. Newington, NH. July 2011. Invitees included Newington conservation commission, selectmen, planning board, sewer commission, and interested residents.

Daley, M.L. and McDowell, W.H. 2011. Viewing Great Bay from a Nitrogen (and Watershed) Perspective. Invited presentation. Great Bay Stewards Bay Views. Greenland, NH. July 2011.

Daley, M.L. 2011. Urbanization and Suburbanization in NH watersheds. University of New Hampshire Watershed Water Quality Management class. Durham, NH. September 2011.

Daley, M.L. and McDowell, W.H. 2011. Non-Point Sources of Nitrogen in the Lamprey and Great Bay watershed. Invited presentation. Newmarket, NH. September 2011.

Daley, M.L. 2011. Watershed management in practice: Great Bay. University of New Hampshire Watershed Water Quality Management class. Durham, NH. December 2011.

Daley, M.L. and McDowell, W.H. 2011. Nitrogen Research in the Lamprey and Great Bay watershed. Great Bay Dialogue. Greenland, NH. December 2011.

Daley, M.L. McDowell, W.H., Bucci, J., Hobbie, E., French, C., Potter, J. and Miller, S. 2012. Detecting non-point nitrogen sources and transport pathways in the Great Bay watershed and engaging decision makers in the science. Annual Lamprey River Science Symposium. Durham, NH. January 2012.

Daley, M.L. McDowell, W.H., Bucci, J., Hobbie, E., French, C., Potter, J. and Miller, S. 2012. Detecting non-point nitrogen sources and transport pathways in the Great Bay watershed and engaging decision makers in the science. Southeast Watershed Alliance quarterly meeting. Newington, NH. February 2012.

McDowell, W.H. and Daley, M.L. 2011. Nitrogen Research in the Lamprey River Watershed and the Great Bay Estuarine Ecosystem. US EPA Region 1 meeting. Boston, MA. May 6, 2011. Meet with EPA staff in Boston to discuss non-point N sources in the Lamprey and other watersheds.

McDowell, W.H. Biogeochemistry of a Suburban Basin. Chinese Research Academy of Environmental Sciences, Beijing, China 19 September 2011.

McDowell, W.H. Biogeochemistry of a Suburban Basin. Chinese University of Geosciences, Wuhan, China, September 25 2011.

McDowell, W.H. Biogeochemistry of a Suburban Basin. China Three Gorges University, Yichang, China, 26 Sept. 2011

Press Releases

Daley, M.L. and McDowell, W.H. 2011. "Sewer Plants in Great Bay Face Tougher Clean Water Standards" by Amy Quinton NH Public Radio. http://www.nhpr.org/sewer-plants-great-bay-face-tougher-clean-water-standards May 20, 2011.

Meetings Attended:

Daley, M.L. 2011. Attended several of the Ecosystem Task Force meetings that occur monthly during the academic year at UNH. Durham, NH.

Daley, M.L. 2011. Attended several of the PREP Technical Advisory Committee meetings that occur approximately bi-monthly in either Durham or Portsmouth, NH.

Daley, M.L. 2011. Lamprey River Instream Flow Public Hearing. Durham, NH. May 2011.

Daley, M.L. 2011. Sustainability Research Collaboratory workshop, Durham, NH May 24-25, 2011.

Daley, M.L. 2011. Meet with US EPA Region 1 scientists to investigate potential field sites for tracing sources of non-point N pollution delivered to streams in the Great Bay watershed. May 2011.

Daley, M.L. and McDowell, W.H. 2011. September 14, 2011. Met with Rob Wofchuck from Brentwood Town Council and Gershon Peleg, who is the Chairman of the Society for the Protection of Nature in Israel to talk about water resource issues in Israel and in New Hampshire.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	10	0	0	1	11
Masters	4	0	0	1	5
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	16	0	0	2	18

Notable Awards and Achievements

In 2009, a conference focused on the Lamprey River watershed (titled "Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes $ense For Protecting Our Water") was co-sponsored by the NH WRRC. The conference highlighted the need for watershed wide land use planning and decision making and gave momentum to an earlier idea that the entire Lamprey should be nominated into the NH Rivers Management and Protection Program (RMPP). Until recently, the Lamprey only had 17.5 km (in Durham and Lee) of the 78 km mainstem reach designated into the NH RMPP. Following the conference, a Lamprey River Nomination Committee (LRNC) was formed and in June 2010, a nomination package was submitted by the LRNC, LRWA and the LRAC to the NH Department of Environmental Services (DES) to designate the remaining portions of the Lamprey River and all its major tributaries into the NH RMPP. This nomination represented a total of 141 river km and captured 14 towns, two counties and 3 regional planning commissions that all share the Lamprey River watershed. This nomination package was the most complex nomination that the NH State Rivers Management Committee had ever seen and the first one to push for a watershed approach (as opposed to nominating a segment of a river or the main stem of a river, but not its tributaries). The NH State Rivers Management Committee was extremely impressed that elected officials from all of the watershed towns wrote letters of support and by the number and variety of individual support letters. The NH State Rivers Management Committee voted to approve the nomination and the resulting House Bill passed in both the House and the Senate in 2011. The Governor signed this Bill into law on June 7, 2011. A watershed wide local advisory committee has now been formed with representatives from each of the 14 towns. This designation will give the Lamprey watershed preferential eligibility over non-designated rivers for state funding and technical resources. The concept of land use decision-making and natural resource management from a watershed perspective instead of solely by political boundaries with no regard to upstream or downstream neighbors is one that is gaining traction in southeast NH and is an outcome of outreach efforts made by the NH WRRC and other organizations and individuals. This outcome is one that the NH WRRC is very proud of.

Results from long-term water quality monitoring in the Lamprey River hydrologic observatory supported by the project Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds have helped leverage funding for additional research on nitrogen cycling in NH's coastal watersheds. Because of the significant interest in nitrogen loading to the Great Bay estuary, existing information on the spatial and temporal variability of nitrogen concentrations in the LRHO that are driven by population growth and land use change and the relationships that the NH WRRC has formed with various stakeholders in NH, the NH WRRC faculty and staff (along with other UNH faculty and USGS colleagues) received a $200,000 grant from NH Sea Grant. The objective of the new research project is to understand the mechanisms that control N exports from the Lamprey River watershed to Great Bay, the downstream receiving estuary, over a range of climate/flow conditions and to share this understanding with local land use planners and decision makers to inform possible mitigation strategies for reducing locally generated N inputs. This project will make use of newly developed in situ sensors to understand the large variability we have observed in N concentrations measured in weekly grab samples supported by 104b funding.