N.H. Sea Grant Research Project Progress Report

**Today’s date:** 2013-01-08

**Project number:** R/CC-1

**Project title:** Understanding the Mechanisms Controlling Storm Event Nitrogen Fluxes from the Lamprey River Watershed Using Continuous in situ Sensors

**Project initiation date:** 2/1/2012

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**Partner(s) and affiliation(s):** (List any collaborators, sponsors, industry partners, municipalities, etc. associated with this project.)
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**Brief project overview/Abstract:**
The Great Bay of New Hampshire has been classified as nitrogen impaired due to elevated nitrogen loads from its surrounding watershed. Elevated nitrogen loads result from both point and non-point sources associated with intensified suburbanization as well as residual agricultural activity. A large proportion of non-point nitrogen exports occur during storm events due to enhanced mobilization and transport. Yet, very little information regarding storm event nutrient dynamics exists due to logistical difficulties of collecting sufficient samples throughout entire storm event hydrographs across seasons. New in situ optical sensor technology is now available that allows continuous nutrient monitoring in streams and rivers, offering the potential to better understand sources and fate of non-point nutrient pollution. The overarching objective of this research 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 information about likely source conditions and possible mitigation strategies with local land use planners and decision makers responsible for reducing locally generated N inputs.** Our approach is to permanently and continuously deploy in situ sensors at the USGS discharge gauging station near Newmarket to monitor nitrogen and carbon fluxes across storms, seasons, and years.
Sensors will include a Satlantic SUNA (for nitrate), a Turner Designs C6 (for fluorescent dissolved organic matter, turbidity, chlorophyll A) and a Hydrolab Multisonde (for dissolved oxygen, conductivity, pH, and water temperature). Steps will be taken to ensure the highest quality data, including regular cleaning to minimize biofouling; blank and standard checks; and grab sample collection and analysis to validate sensor measurements, and to develop proxies for dissolved and particulate organic nitrogen. We will combine these measurements in the Lamprey River mainstem with identical measurements in headwater catchments of varying land use (e.g. suburban, forest, agriculture) and in the Great Bay itself, offering the potential to link nonpoint source dynamics across scales. Measurements will be telemetered to project specific web sites making the information available in real time for use in outreach campaigns.

These measurements will improve quantification of non-point nutrient inputs to the Great Bay and will provide greater sensitivity to monitoring of change over time, either due to natural climate changes, or to changing human activities, including management specifically targeting nitrogen control. Our objectives are directly related to the N.H. Sea Grant Strategic Plan’s emphasis on Sustainable Coastal Development with the specific goal that: Coastal communities in New Hampshire’s coastal watersheds employ strategies that protect ocean and coastal resources from degradation associated with the built environment and growing demands on coastal resources. Both undergraduate and graduate students will benefit from knowledge of the operation, quality assessment, and data interpretation associated with the deployment of novel sensor technology. Our outreach objective will be to increase the knowledge and confidence levels of community leaders by providing them with better access to and interpretation of local, real-time and rigorous research on nutrient dynamics within the Great Bay system.

**Objectives:**
Specific research and outreach objectives for this proposal are to:

1) Quantify the amount of nitrate, dissolved organic carbon (DOC), dissolved organic nitrogen (DON), suspended sediments, and particulate nitrogen (PN) exported from the Lamprey River throughout the year and during storm events using *in situ* sensors continuously deployed near the mouth of the watershed at a long-term discharge gauging station. Grab samples will be analyzed to validate sensor measurements and develop proxies for DON and PN, allow estimation of total N flux from the watershed (from FDOM-DON and Turbidity-PN relationships).

2) Compare nitrate, DOC, DON, PN, and sediment concentrations and fluxes near the mouth of the Lamprey under varying stream flow conditions (from storm to base flows) with those occurring a) upstream in headwater streams draining different land use types, b) in point source dominated watersheds draining to the Great Bay (e.g. Cocheco River), and c) in the receiving Great Bay estuary itself.

3) Make the *in situ* nutrient and related information available in real time via telemetry and targeted web pages. In turn, this information will be highlighted, translated and disseminated for use by planners and land use decision makers who are considering an array of N reduction strategies that could be implemented at the local and regional level. As a result of outreach efforts, planners and land use decision makers will report greater knowledge about nutrient dynamics in Great Bay, greater confidence in the scientific underpinnings and greater awareness of options for reducing N inputs.
Research findings/progress to date:

Accomplishments:

Our overarching approach is to deploy in situ nutrient sensors at strategic locations to better understand biogeochemical fluxes through the watershed. This first year we accomplished two major activities that address our objectives: 1) deployment of sensors in the Lamprey River mainstem beginning in August 2012. 2) deployment of sensors in several headwater catchments of differing land use, including forested, agriculture (organic dairy), and suburban between April 2012 and December 2012. Activities and preliminary results are detailed below.

The U.S. Geological Survey (USGS), in collaboration with UNH and the Town of Durham, installed an all-season water-quality monitoring station with in-situ sensors on the Lamprey River at Wiswall Dam in Durham, NH. Measurements are controlled and stored by an electronic datalogger, which transmits the data hourly by cell-phone modem to a USGS server, from where the data are processed into the USGS National Water Information System (NWIS). Data from the water-quality site (USGS Station No. 01073495) are associated with the streamflow gaging station a half-mile downstream (USGS Station No. 01073500), so that parameters can be correlated with discharge and loads computed. The in-situ measurements are made by optical sensors (using the absorption, fluorescence, or scatter of appropriate wavelengths of light), and include values of nitrate, colored dissolved organic matter (CDOM), dissolved oxygen, and turbidity. In addition, temperature, pH, and specific conductance are measured by electrical methods. Measurements are made every 15 minutes, and data collection began at the end of August 2012. Routine sensor calibrations and comparisons with grab samples (described below) are used to quality assure the data. Equipment has been powered by a solar panel and gel-cell battery, but will soon be connected to AC line power that was recently installed at the site.

Weekly samples at site LMP72 (the Lamprey River at Wiswall Dam, Durham, NH; USGS site 01073495) were collected since September and analyzed for nitrate (NO$_3^-$) and dissolved organic carbon (DOC) for comparison with in situ measurements of NO$_3^-$ and colored dissolved organic matter (CDOM). Field measurements of temperature, specific conductance, dissolved oxygen (DO) and % DO saturation were also made with an YSI 556 handheld multiparameter instrument for comparison with in situ sensors. There is a strong relationship between the in situ NO$_3^-$ data and the laboratory analyzed NO$_3^-$, but the in situ sensor over-predicts NO$_3^-$ (Figure 1). This offset will be corrected once more data are collected. There is a significant, but variable ($r^2=0.475$) relationship between CDOM and DOC. This relationship will be improved using turbidity and temperature corrections (Downing et al. 2012). There is good agreement between temperature measured in situ and with the YSI handheld instrument (Figure 2). There is also a strong relationship between the in situ specific conductance measurements and the specific conductance measured with the handheld instrument, but the in situ sensor reports levels that are slightly higher. This slight offset will be investigated to ensure that both meters are functioning properly. The relationships between in situ %DO saturation and pH and handheld measurements are not as strong as we would expect and these will also be investigated (Figure 2).
Figure 1. Regressions for in situ measurements of NO₃⁻ and colored dissolved organic matter (CDOM) vs. grab sample analysis of NO₃⁻ (a) and dissolved organic carbon (DOC; b). The 1:1 line is shown as a dashed line.

The second major activity of this project is to monitor water quality in headwater streams draining three land use types, particularly the streams’ response to storm events. The three sites selected for this study are Saddleback Brook in Deerfield, NH (forested reference); Wednesday Hill Brook in Lee, NH (suburban with septic waste); and Burley Demeritt Creek in Lee, NH (organic dairy). We used in situ sensors to continuously monitor a suite of water quality parameters, with particular focus on nitrate, dissolved organic matter, and specific conductivity. Results from this component will be linked to the previous and ongoing measurements in the mainstem of the Lamprey River to improve catchment-scale knowledge of watershed processes and inform nutrient flux models.

Major preliminary findings so far include:

- In the Lamprey River during fall 2012, there were two major flushes of nitrate (i.e. increasing concentration) during early September storms. Nitrate concentrations increased by up to 0.6 mg N/L. This contrasts with fall 2011, where only minor increases occurred during the storms (<0.1 mg N/L). Storms after September 2012 registered only minor responses.

- In the headwaters, the agricultural site had higher baseflow nitrate than did the suburban site, which was well above the forested site. Both the agricultural and suburban catchment showed a storm dilution response (declining nitrate concentrations) during spring and summer, though overall fluxes still increased during storms. The forested catchment showed no nitrate concentration response during storms. Both the suburban and agricultural stream showed diurnal patterns in nitrate during baseflow conditions, which we suspect is due to instream or near stream riparian uptake of nitrate that is evident under low flow conditions.
Figure 2. Regressions for in situ measurements of temperature (a), specific conductance (b), dissolved oxygen (DO; c) % DO saturation (d) and pH (e) vs. measurements made with a YSI 556 handheld multiparameter instrument. The 1:1 line is shown as a dashed line.
**Impacts:**

Relevant outputs include participation in outreach activities, demonstrations, news articles, videos, field trips, class activities, advice given to local communities, graduate students advised (as major advisor and committee member) and presentations at conferences and workshops.

As part of this grant, a video was produced and published on line, in conjunction with the NH-EPSCoR project. The video features our work deploying sensors on the Lamprey River watershed, a direct goal of this project. The video explains why we are making the effort for this monitoring activity and is meant for the wider New Hampshire public. The video can be seen at: http://www.youtube.com/user/nhepscor.

This work was also featured in the newsletter for the Institute for the Study of Earth Ocean and Space (Spheres) this fall. The article, entitled "Composing an Aquatic Symphony", explains what is novel about deploying these new in situ nutrient sensors, and how they can help us better understand watershed and aquatic processes. The article can be viewed at: http://www.eos.unh.edu/Spheres_1012/aquatic.shtml.

In a further development, Wollheim will be reaching graduate students in the Spring of 2013 through a new Natural Resources "Hot Topics" course entitled "An Aquatic Symphony: Exploring New Insights from Continuous In Situ Measurements In Aquatic Ecosystems". This will be a two credit discussion course focused on reading the literature and exploring the theories of watershed and aquatic ecosystem ecology that can now be tested with this new means of "seeing" the environment using the types of sensors we've deployed on this project.

Wollheim, graduate student Allison Price, Research Scientist Gopal Mulukutla, and Post-Doctoral Scholar Richard Carey organized a sensor demonstration exhibit for middle school students and the general public as part of "Know the Coast Day" on October 19 2012 sponsored by the UNH Marine Program, the New Hampshire Sea Grant College Program and the UNH Marine Docents. The hands on exhibit demonstrated water quality monitoring techniques and what in situ sensor technology can reveal to elementary and middle school students visiting the university. Demonstrations were explained in a manner understandable to elementary aged school children, including: road salt from winter snow storms washing off to groundwater and streams (why we measure conductivity), breathing of rivers and lakes over day and night through photosynthesis and decomposition (why we measure dissolved oxygen), and how "tea" is leached from forests and wetlands into streams and lakes, which provides energy for aquatic organisms (why we measure Chromophoric Dissolved Organic Matter).

The research has supported the course Wollheim teaches at UNH, Aquatic Ecosystem (NR 751/851). The field installations were the basis of two field trips during Fall 2012: 1) one field trip was a headwater survey of water quality in streams draining different land uses. We visited the Burley-Demerit (Organic Dairy) and Wednesday Hill Brook (Suburban) sites, two of the major study sites on the project. As part of the trip we had a demo of the sensor installation at each site given by graduate student Allison Price. 2) a field trip to the Wiswall where have worked with the USGS to install a permanent, long term sensor array. Mulukutla gave a detailed demonstration of sensor operation during this field trip.
Tools, technologies or information services resulting from this project that are being used to improve ecosystem-based management (e.g., that reduce contaminants that harm coastal ecosystems and seafood consumers; that track changes in ecosystem processes, biological responses and conditions):

The USGS is providing information services to the public by hosting an internet-accessible database of in-situ water-quality data from the Lamprey River, and operating the equipment that collects, transmits, and presents this data on the web in near real-time. This data is stored and edited in the USGS NWIS-Web database, which provides public access to both present water-quality values and all data for the site's period of record. In addition to water-quality parameters (including nitrate, dissolved oxygen, etc., as described in previous sections), the NWIS web interface also provides public access to Lamprey River discharge data (real-time and historical) from the nearby USGS streamflow gaging station. Thus water managers, researchers, watershed associations, and other interested parties have ready access to important and current data to help address watershed management issues in the Lamprey River watershed. The web site can be accessed at:
http://nwis.waterdata.usgs.gov/nh/nwis/uv/?cb_63680=on&cb_32295=on&cb_00010=on&cb_00095=on&cb_00400=on&cb_00301=on&cb_00300=on&cb_99137=on&format=gif_default&period=&begin_date=2012-08-04&end_date=2012-12-11&site_no=01073495

As part of this project a new method of determining the hysteresis relationship of nutrient concentration and stream discharge has been developed. Concentration-Discharge hysteresis loops provide valuable information about the source and behavior of nutrients and whether they vary of seasons. They also will provide one of the first signatures of changes in sources of pollutants (such as nitrogen from runoff). Often high temporal resolutions (< 1 hour) continuous measurements of concentration and discharge measurements made in rivers and streams contain variations such as diel fluctuations that obscure the underlying trends. As part of this work, we have developed a new method to process the data that allows the clear visualization of Concentration-Discharge hysteresis. Work is underway to catalog all hysteresis information collected, and incorporate them in educational and dissemination activities.

Related grants and contracts (Other grants and contracts that funded this research or that were obtained as a result of this research.):
NSF EPSCOR - Interactions Among Climate, Land Use, Ecosystem Services and Society
NASA - Analyses of biogeochemical and optical time series across an impaired estuary to inform the next generation of ocean color satellites (PENDING)

Publications to date:

Peer reviewed publications:
Presentations to date, with published abstract citation if applicable:


Students Supported (see next page)
## Students Supported

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<tr>
<th>Student Name</th>
<th>Where is he/she now?</th>
<th>Institution/Department</th>
<th>Duration of support</th>
<th>Type of support (stipend, travel, supplies, etc.)</th>
<th>Type of degree: Undergrad/ Master's/ PhD</th>
<th>Year degree awarded</th>
<th>Title of thesis/dissertation if supported by N.H. Sea Grant</th>
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<td>Allison Price</td>
<td>UNH Master's Student</td>
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<td>Fall 2011 to present</td>
<td>Stipend, travel, supplies, equipment</td>
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