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Effects of Development on Nutrient Loading Final Report

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Final Report: **covering March 1, 2010 through February 28, 2011**
Project Director: Jeffrey A. Schloss

Statement of Regional or State Water 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, shoreline re-development) our waters help to insure a high quality of life. As documented in the 2000 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. While many states are struggling to address surface waters that have been classified as "impaired waters" as a result of the EPA mandated 303d listing, New Hampshire has only a few 303d listed waters and stakeholders are more concerned with developing anti-degradation laws and policies to protect existing outstanding waters. To facilitate this, the relationships between land use, nutrient loading and lake nutrient response need to be established for these important watersheds of concern to allow for informed local decision-making.

Objectives:

1. To continue collection and analysis of long-term water quality data in selected watersheds with extended emphasis for the Newfound Lake, Acton-Wakefield and Winnipesaukee watersheds where current outreach work includes encouraging local decision-making to support anti-degradation practices.
2. To assist state agencies and communities in setting Total Phosphorous concentration targets as part of their lake watershed management plans
3. To disseminate results of the analysis to cooperating agencies, water managers, educators and the public on a local, statewide and regional basis.
4. To offer undergraduate and graduate students the opportunity to gain hands-on experience in water quality sampling, laboratory analysis, data management and interpretation.
5. 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.
6. To determine next steps for further analysis of long-term data sets and GIS spatial data on land cover.

Methods:

A few weeks following the ice-out in the spring of 2010, a cooperative single-day synoptic sampling for total phosphorus at the various major basins of Lake Winnipesaukee was initiated by UNH, the NH Department of Environmental Services and the Lake Winnipesaukee Association. Sampling was done at the time following mixis but at selected sites, samples were taken about 1 meter from the bottom. Results

were used to provide additional data for decision-making and calibration for the STEPL water quality model being used by the Lakes Region Planning Commission for the Towns of Meredith, Laconia and Guilford.

Emphasis on Lakes Lay Monitoring Program efforts was on expanding shallow water monitoring sampling to try to detect septic leachate influences and impervious runoff . 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 mixing. Water clarity (secchi disk), chlorophyll a, acid neutralizing capacity, dissolved organic color, dissolved oxygen and nutrients (total N, total P and nitrate) were the default suite of parameters measured for lakes while nutrients, turbidity, dissolved organic color and flow were 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 at the deepest sites which included temperature-oxygen-ph-specific-conductivity-ORP-chlorophyll a phycocyanin and turbidity profiles with depth. Detailed methods can be found in the Quality Assurance Project Plans cited in the publications section of this report.

Major Findings and Significance:

Winnipesaukee: The spatial pattern of nutrient concentrations (as measured by total phosphorus) on Lake Winnipesaukee was influenced by the local morphometry and development/ impervious cover extent; Those areas with more embayed and lower volumes of water, with greater shore-land and concentrated development, exhibited greater nutrient concentrations. Spring TP values for most areas of the lake remained within the levels indicative of pristine, low productivity waters. While this result was expected as it has been suggested by our long-term monitoring of selected sites of the lake, this was the first time a synoptic study allowed for samples taken at the same time and at a greater number of stations within the lake. This information was instrumental in not only testing the calibration of the modified STEPL nutrient loading model and the combined lake response predictive model (the latter as used and modified for this study in previous years 2008-2010) but served to further inform the stakeholders of the Towns of Meredith, Guilford and Laconia and supported their decision to move towards protecting their local areas with anti-degradation practices and policies.

Newfound: Lower order stream sampling in 2010 indicated the potential for development in upper areas of the watershed could have impacts downstream. While total phosphorus concentrations in undeveloped subwatersheds were typically very low and near or at the level of our detection, time integrated monitoring of periphyton samplers fitted with temperature and light loggers were able to detect even relatively low density development increased stream productivity. These results were a proof of concept on how even pristine subwatersheds may be monitored for increasing nutrient loading.

Additional Findings 2010 LLMP: The work by our volunteers continued to add to our long-term database which combined with our GIS watershed database will allow for a better understanding of how patterns of development and hydrological

connectedness influence nutrient loading to our surface waters which is the planned focus of future NIWR support..

Updated Findings from previous (2009) NIWR Supported Projects (Effects of Development on Nutrient Loading: Influence of Septic Systems and Boron as a Septic Source Tracer):

Boron has a high potential for use in NH watersheds as a tracer for septic system influence (as well as sewage treatment outflows) but both ambient and septic/sewage influenced Boron levels are at concentrations too low to produce consistent results for Boron isotope analysis. However, as the concentration differences between control samples (lakewater/riverwater) and impacted site samples were at least on a range of 1 to 2 orders of magnitude. Lake sites suspected of being influenced by old/failing septic system had Boron concentrations at least twice that of control samples and were often at least 1 order of magnitude greater. Other metals and specific ions that were elevated in the septic system and sewage plant effluent included (with order of magnitude): Li, Mg, K, Ca, TDN (1 order); Na, Sr (2 orders); Cl, NH_4, ortho-$P0_4$, TP (3 orders). As lake water samples tended to have lower concentrations of most constituents measured, the highest probability of the use of any of these markers would be lakes with moderate to significant septic failures. Tryclosan, a common indicator for detergents and antiseptics were also assessed through ELISA techniques. Concentrations of this marker were found to be the highest in the septic system junction box (2.5-2.7 ppb) which was two to three orders of magnitude greater than lake and river water controls. The treatment plant effluent samples were generally one to two orders of magnitude greater. All of the below sewage treatment plant water samples indicated that all concentrations were diluted sufficiently a small distance downriver so any impacts from these substances would be very local to the outflow. PCPP study (see below) indicated that although some concentrations from the wastewater effluent were found in levels in the range that chronic effects may occur, they also get diluted quickly after introduction.

As an offshoot of this study a graduate student from Plymouth State University was supported through NIWR funding to explore additional potential indicators of septic and wastewater pollution. She developed a modified solid phase extraction HPLC/MS method for the analysis of four pharmaceutical and personal care compounds and conducted a pilot survey for these compounds at locations in Squam Lake (lake sites and a septic system), and above, below and the outflow of two waste water treatment plants in the Merrimack River Watershed. The abstract of this work is reproduced below to summarize this work. Additional details can be found in the actual Master's Thesis (Harvey 2010) cited elsewhere in this report:

Pharmaceuticals and personal care products (PPCPs) are a class of emerging contaminants that include, but are not limited to, prescription and non-prescription drugs, perfumes, detergents and soaps, body lotions and sun block. PPCPs reach the environment primarily through two routes, the release of treated waste via wastewater treatment plants' effluent stream and through agricultural run-off. Since the 1980s, PPCPs have been recognized as having the potential to cause adverse effects in the environment and are identified by the US EPA as potentially hazardous

compounds, even at low parts-per-billion or parts-per trillion concentrations. Among other effects, studies have linked PPCPs to antibiotic resistance in bacteria and viruses and to the feminization of certain fish species. Unfortunately there is a significant limit in the peer reviewed literature on both the occurrence of these compounds and their effects in the environment.

One reason for this information gap is the lack of analytical equipment/protocols with sensitivities low enough to detect these compounds at their environmental concentrations. The purpose of this study was to establish a reliable method to detect four PPCPs in aquatic samples within the state of New Hampshire, and to pilot test the method on environmental samples from rivers, lakes and private septic systems in Central New Hampshire.

The method this study adapted was originally established by the US Geological Survey's (USGS) National Water Quality Lab in Denver, CO. It uses solid phase extraction (SPE) and high performance liquid chromatography coupled with mass spectroscopy (HPLC/MS) to identify and quantitatively measure 14 different PPCPs. Generally, SPE separates compound targets from the sample of water, while HPLC separates the target compounds from each other and MS produces a signal from each compound that is proportional to its concentration. This study adapted the USGS method to use methanol instead of acetonitrile as the HPLC mobile phase and limited the detection to four PPCPs, each from different therapeutic drug classes: acetaminophen (a common analgesic), caffeine (a stimulant), carbamazepine (an anti-epileptic, mood stabilizer) and trimethoprim (an antibiotic).

As a result of these adaptations, many instrumental parameters were optimized for instrument sensitivity. The adapted method has interim reporting levels ranging between 8 and 100 ng/L for the targeted compounds while the USGS reports detection limits of 25 ng/L to 40 ng/L for these compounds. The adapted method demonstrates fair accuracy; mean percent recovery of compounds in reagent-free water was within 20% of the true value, while fortified environmental samples had mean percent recoveries within 35% of the true value. A standard operating procedure for this method was written and is on-file with the NH Department of Environmental Services.

A pilot study used this adapted method to document the occurrence of these four compounds in water resources in Central New Hampshire, US. A total of 16 samples were collected: 6 lake samples were collected along with 7 river samples, 2 samples from wastewater treatment plants' wastewater effluent stream and 1 from the distribution box of a private septic system. None of the compounds were detected in any of the lake samples. One river sample had 79 ng/L caffeine. One wastewater treatment plant was found to have acetaminophen (720 ng/L), caffeine (1200 ng/L) and carbamazepine (280 ng/L) while the other was found to have only carbamazepine (330 ng/L). The private septic system's distribution box was found to have >2,000ng/L of both acetaminophen and caffeine. The most commonly occurring PPCP was caffeine (three occurrences: 19%), followed by carbamazepine and acetaminophen (two occurrences each: 12.5%), trimethoprim was not detected in any of the 16 samples collected.

Publications, Presentations, Awards:

Reports:

Craycraft, R. and J.A.Schloss, 2010, New Hampshire Lakes Lay Monitoring Program Yearly Report 2009, 27 individual lake reports 18 to 160 pages each, UNH Center for Freshwater Biology, University of NH, Durham, NH.

Peer Reviewed Reports:

Craycraft, R. and J.A.Schloss, 2010, Newfound Lake Watershed Assessment Project Quality Assurance Project Plan Amendment Sampling Program, UNH Center for Freshwater Biology, University of NH, Durham, NH. 20pp. (approved 3/8/2010)

Craycraft, R. and J.A.Schloss, 2010, Acton/Wakefield Watershed Alliance Quality Assurance Project Plan Amendment, UNH Center for Freshwater Biology, University of NH, Durham, NH, 77pp. (approved 3/10/2010)

Craycraft, R. and J.A.Schloss, 2010, Newfound Lake Culvert Assessment and Site Specific Project Plan, UNH Center for Freshwater Biology, University of NH, Durham, NH, 16pp. (approved 8/18/2010)

Craycraft, R. and J.A.Schloss, 2010, New Hampshire Center for Freshwater Biology and Lakes Lay Monitoring Programmatic Quality Assurance Project Plan, UNH Center for Freshwater Biology, University of NH, Durham, NH, 80pp. (approved 10/20/2010)

Craycraft, R. and J.A.Schloss, 2010, Mirror Lake Water Quality Site Specific Project Plan, UNH Center for Freshwater Biology, University of NH, Durham, NH, 14pp. (approved 11/9/2010)

Thesis:

Harvey, Rebecca, 2010, Pharmaceuticals and Personal Care Products in the Environment, Masers Thesis, Plymouth State University, Plymouth NH, 93pp.

Outreach Materials:

Harvey, R, 2010, Pharmaceuticals and Personal Care Products in the Environment, Fact Sheet, Squam Lakes Association, Holderness, NH, 4pp.

Presentations:

April 17, 2010. Global Awareness Local Action earth day event held at the Carpenter School gymnasium in Wolfeboro. Topic: Lake Water Quality Monitoring in NH.

May 19, 2010. Angle Pond Association Annual Meeting (Sandown): A Lake is a reflection of Its Watershed (for the UNH Speakers Bureau).

June 25, 2010. New Hampshire Lakes Association NH Lakes Congress (Holderness). Craycraft: Lake sampling- provided an overview of common lake sampling measurements and rationale; Schloss- presentation on the science behind the Comprehensive Shoreland Protection Act and a presentation- Over 30 Years of Research on Squam Lake: What have we learned?

June 26, 2010. Naturally Newfound Fair (Alexandria) -- discussed Newfound Watershed water quality sampling results with interested residents, recruited potential volunteers.

July 3, 2010- Goose Pond Association Annual Meeting (Enfield): Landscaping at the Water's Edge: reigning in storm runoff.

July 10, 2010. Laural Lake Association Annual Meeting Lake friendly landscaping presentation.

July 17, 2010. Attended Lake Wentworth Foundation Business Meeting (Wolfeboro) to answer questions related to water quality assessment as part of a proposed WMP 319 Grant Application

July 19, 2010. Pond ecology presentation at Shannon Pond (sponsored by Castle in the Clouds, Moultonboro)) as part of their weekly summer "walks and talks" series.

July 2010. Pharmaceuticals and Personal Care Products in New Hampshire Waters. Pakistani Educational Leaders Institute Conference, Plymouth State University, Plymouth NH. Presented by Rebecca Harvey.

August 13, 2010. Moose Mountain Regional Greenway: Water quality talk during the Woods, Water and Wildlife Festival -- discussed potential for water quality impacts in Salmon Falls Watershed and actions local residents can take to minimize impacts.

August 14, 2010. Half Moon Pond Association (Alton)- Landscaping at the Water's Edge.

September 26, 2010. Lake Winnipesaukee talk on the Winnipesaukee Belle sponsored by the Moose Mountain Regional Greenway. Discussed water quality, threats and lake friendly practices for watershed residents.

October 10, 2010. Pharmaceuticals and Personal Care Products in the New Hampshire Environment. Northeastern Ecosystem Research Collaborative Conference. Sarasota Springs, New York. Presenter: Rebecca Harvey.

February 26, 2011. Newfound Lakes Region Association Winterfest (February 2011) - Discussed Newfound Watershed water quality and viewed potential threats (i.e. sanding of gravel roads, steep sloped terrain, etc) while outdoors.

Ongoing monthly meetings with Lake Winnipesaukee Watershed Project Steering Committee concerning P modeling for local decision-makers to set target lake P concentrations (Meredith, Guilford and Laconia).

Ongoing monthly meetings for Lake Wentworth 319 Grant project planning.

Number of students supported:

Directly: (partial wage/salary funding)
Graduate:

Jeff Schloss	PhD	Natural Resources and Earth Systems Science
Rebecca Harvey	MS	Environmental Science and Policy (Plymouth State) Graduated: May 2010

Undergraduate:

Emma Leslie	BS	Zoology

Indirectly (supplies and support to LLMP project)
Undergraduate:

Gabrielle Hodgman	BS	Biology (General)*
Lejla Kadic	BS	Biology (pre-med)*
Andrew Middleton	BS	Environmental Conservation**
Jessica Waller	BS	Marine Biology
Emma Carrol	BA	Sociology
Emily Ramlow	BS	Environmental Conservation

*- Graduated May 2010
** Graduated December 2010