Water Resources Research Center
Annual Technical Report
FY 2003

Introduction

The New Hampshire Water Resources Research Center, located on the campus of the University of New Hampshire, is an institute which 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 1950's 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 Shanna Fredyma, Jeff Merriam and Jody Potter. The NH WRRC is a stand alone organization, in that it is not directly affiliated with any other administrative unit at UNH. The NH WRRC has no dedicated space on campus and no formal library holdings. To overcome these potential limitations, our website (www.wrrc.unh.edu) is used heavily, and 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

Linking Lakes with the Landscape: The Fate of Terrestrial Organic Matter in Planktonic Food Webs

Basic Information

Title:	Linking Lakes with the Landscape: The Fate of Terrestrial Organic Matter in Planktonic Food Webs
Project Number:	2002NH1B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	Ecology, Models, Surface Water
Descriptors:	
Principal Investigators:	Kathryn L. Cottingham, Jay Terrence Lennon

Publication

1. Lennon, J.T., 2004, Experimental evidence that terrestrial carbon subsidies increase CO2 flux from lake ecosystems. Oecologia 138, 584-591.

WRRC FY 2003 Annual Progress Report

LINKING LAKES WITH THE LANDSCAPE: THE FATE OF TERRESTRIAL ORGANIC MATTER IN PLANKTONIC FOOD WEBS

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PROBLEMS AND OBJECTIVES

We are evaluating how terrestrially-derived dissolved organic matter (DOM) influences the functioning of lake ecosystems. Terrestrially-derived DOM is commonly the largest carbon pool in lakes. As such, terrestrial DOM represents a major source of potential energy for aquatic food webs that may subsidize higher trophic levels (including zooplankton and fish) and determine whether lake ecosystems act as sources or sinks of CO_2. Our project addresses three main factors that influence terrestrial carbon flow in lakes.

Objective 1: Determine whether the energetic importance of terrestrial DOM in lakes is ultimately determined by bacterial metabolism. In this study, we define bacterial metabolism as biomass production and respiration. We hypothesized that bacterial biomass production and respiration are affected by the quantity and quality of terrestrial DOM. Specifically, we predicted that bacterial metabolism is higher on DOM sources with low C:N and C:P ratios.

Objective 2: Objective 2 has changed slightly. Although we are still interested in how terrestrial carbon flows throughout the entire food web, we needed to better understand the dynamics of DOM-subsidized microbial food webs. We have conducted field experiments paired with a simulation model to examine how variability in DOM supply rates influence microbial metabolism. Terrestrial DOM supply to lakes is often variable and coincides with episodic rain events. We have simulated this variability in both the field and in computer simulation to assess how bacteria respond to short term changes in resource availability.

Objective 3: Use carbon stable isotopes ($\delta^{13}C$) in particulate organic matter (POM) and zooplankton to elucidate patterns of carbon and nutrient cycling along a terrestrial DOM gradient in New England lakes. We predicted that carbon stable isotope ratios in zooplankton and particulate organic matter would become more negative along the DOM gradient, reflecting a terrestrial $\delta^{13}C$ signal. We also predicted that cladoceran zooplankton would have lower $\delta^{13}C$ values than copepod zooplankton because they can feed on terrestrial subsidized bacteria.

METHODS

Objective 1***: DOM characteristics and bacterial metabolism*****—** We measured bacterial productivity (BP), bacterial respiration (BR), and bacterial growth efficiency (BGE) on six different sources of terrestrial-derived DOM. We collected soils from the organic (Oa/A) horizons in near-monoculture stands of six of the most common trees in New England forests (pine, maple, hemlock, beech, oak, birch). We dried these soil samples and then extracted the organic matter in 1L 0.1N NaOH. We removed particulate material (>0.7 μm) from the leachates via serial filtration, dialyzed each leachate (500 D) in a distilled water buffer to reduce concentrations of salts and inorganic nutrients, and then gamma-irradiated the leachates to kill soil-associated microbes.

We then characterized a suite of chemical properties in each leachate: dissolved organic carbon (DOC), total phosphorus (TP), total nitrogen (TN), polyphenolic compounds, humic acids, protein content, and high molecular weight DOC fractions. In addition, we determined the concentrations of 15 major elements using inductively coupled plasma (ICP) atomic emission spectroscopy (AES).

We used regrowth experiments to quantify bacterial production and bacterial respiration in response to different leachates along a DOC gradient (3-17 mg/L). Each experimental unit was filled with 450 mL of 0.22 μm-filtered lake water and 50 mL of 2.7 μm-filtered (Whatman GF/D filtered) lake water containing bacteria, then concentrated terrestrial leachate was added to create the target DOC concentration. We estimated bacterial productivity (BP) at 36 h by measuring the uptake and incorporation of ^{3}H radiolabeled leucine into bacterial protein. Bacterial respiration (BR) was estimated as the changes in dissolved oxygen concentrations in dark bottles between 24 and 48 h.

Objective 2: ***Variability in DOM supply and microbial metabolism* —** Originally, we planned to construct an entire plankton food web model to address Objective 2. However, this objective has been modified. We are now looking at the microbial part of the plankton food web in more detail. We have constructed a nonlinear deterministic simulation model in MatLab to assess how variability in DOM supply influences bacterial metabolism. Results from our field mesocosm experiments show that cumulative bacterial productivity was 2-5 fold greater when DOM was supplied as a single large pulse vs. smaller, but more frequent inputs.

Our simulation model has three state variables: recalcitrant carbon, labile carbon, and bacterial carbon. Terrestrial DOC is supplied to the system either as a "pulse" or a "press" over an experimental time period. We have been manipulating uptake rates, death rates, and mobilization rates and have found that, in general, our model captures the behavior of our experiments. We have conducted a sensitivity analysis by independently manipulating the model parameters in cross-factor simulations using parameter distributions from the literature.

Objective 3: ***Carbon stable isotope ratios along DOM gradients*—** During the summers of 2002 and 3003 we sampled ~80 lakes in VT, NH, CT, and ME. In 2002, we collected samples for $\delta^{13}C$ in particulate organic matter (POM) and crustacean zooplankton. In 2003, we collected $\delta^{13}C$ samples for POM, dissolved organic carbon (DOC), dissolved inorganic carbon (DIC) and crustacean zooplankton. In addition we collected $\delta^{15}N$ samples for POM, DOM, and crustacean zooplankton. At each lake, we recorded physical-chemical features of the lake water (i.e., pH, O_2, conductivity), then took depth-integrated water samples from the epilimnion of each lake. Samples for POM were filtered onto precombusted glass fiber filters in the field, and samples for DOC, TN,TP, and chlorophyll *a* were brought back to the laboratory. We also took depth integrated zooplankton samples (>80 μm) and separated animals into two functional groups (large cladocerans and large copepods) before filtering them onto precombusted glass fiber filters. Isotope ratios were obtained with a Finnigan MAT 252 Isotope Ratio Mass Spectrometer at the UC Davis Stable Isotope Facility. We measured DOC on a Tekmar-Dohrmann TIC/TOC analyzer after H_2SO_4 digestion. We measured TN and TP spectrophotometrically after persulfate digestion and determined chlorophyll *a* with methanol extraction on a Turner Designs TD700 fluorometer outfitted for Welshmeyer's method.

In addition, in 2003 we tested whether isotope results from 2002 were due to increasing methane (CH_4) along a DOC gradient. Lakes with high DOC often have anoxic epilimnia that favor methanogenesis. Methane has a very light isotopic signal that could be creating the patterns that we observed in 2002. Therefore, in 2003 we measured hypolimnetic methane concentrations on a flame ionization gas chromatograph. We measured the abundance and relative abundance of methanogenic bacteria in the lake sediments using fluorescence microscopy. We also measured the relative abundance of methane oxidizing bacteria at the lake oxycline using fluorescent in situ hybridization (FISH).

PRINCIPAL FINDINGS AND SIGNIFICANCE

Objective 1*: DOM characteristics and bacterial metabolism*— The chemical composition of the DOM sources (leachates) were significantly different from one another. One-way ANOVA revealed that there were significant differences among the leachates for all chemical attributes. Multivariate principal components analysis (PCA) also indicated that the DOM sources had different chemical compositions.

BP and BR responded strongly to the DOM treatments. A multiple regression model (using DOC and indicator variables for leachate type as the predictors) explained 87% of the variation in BP ($R^2 = 0.88$, R^2adj = 0.85, $F_{11,71} = 37.8$, $P < 0.0001$). This analysis revealed that differences in DOM sources explained much of the variability in BP. BP was highest when bacteria were grown on beech and oak DOM. Multiple regression explained 67% percent of the variation in BR ($R^2 = 0.67$, R^2adj = 0.61, $F_{11,70} = 10.9$, $P < 0.0001$), but was less affected by the different DOM sources as evidenced by overlapping confidence intervals for the slopes provided by the indicator variables (see Fig. 1).

As predicted, carbon:nutrient ratios were important in explaining variation in bacterial metabolism. Carbon specific rates of BP (i.e., the slope of the DOC-BP relationships) decreased exponentially with the carbon : phosphorus ratio of the DOM source.

Together, these results suggest that sources of DOM vary in their chemical composition and that this variability can have a large effect on bacterial metabolism. These differences may influence the degree to which higher trophic levels are subsidized by terrestrial DOM. A draft of this a manuscript is current in friendly review. I will be submitting this with Liza Pfaff (Dartmouth undergraduate) to either *Microbial Ecology* or *Limnology and Oceanography* within the next month.

Objective 2: *Variability in DOM supply and microbial metabolism* — Field experiments show that variability in DOM supply has a large effect on cumulative, or time integrated, bacterial productivity. Systems that were pulsed with a single DOM input had 2-5 times more bacterial production than systems that received smaller, but more frequent DOM inputs. We are able to replicate these results in our relatively simple simulation model. The results and behavior of the model seem to be most affected by two classes of parameters. First, the model seems to be sensitive to the productivity of the recipient lake ecosystem. Specifically, variability in DOM supply doesn't seem to affect highly productive lakes. Second, the model seems to be sensitive to parameters that are indicative of DOM quality. The size of the peaks following DOM additions are influenced by how labile the subsidies are and how quickly recalcitrant carbon become labile carbon. We are still in the process of analyzing data from the sensitivity analysis (~100,000 simulations).

Objective 3: ***Carbon stable isotope ratios along DOC gradients***—We obtained isotope samples from 37 of the 50 lakes visited in 2002. DOC concentrations in the lakes ranged from 3–15 mg/L. $\delta^{13}C$-POM declined over the DOC gradient from -24 to -36 ‰. Similarly, $\delta^{13}C$-zooplankton declined over the DOC gradient from -27 to -40 ‰ (see Fig. 2). A multiple regression model explained 63% of the variation in plankton $\delta^{13}C$ ($R^2 = 0.63$, $P < 0.0001$, n = 73). A paired t-test revealed that cladoceran vs. copepod zooplankton had similar $\delta^{13}C$ values ($P > 0.05$).

Published isotopic values of the POM and zooplankton are commonly less than terrestrial organic matter (-28‰). This observation, together with the relationship in Fig. 2, suggests that there is a progressively larger input of isotopically light carbon along the DOM gradient. We hypothesize that methane (CH_4) becomes more important for lake carbon cycling as terrestrial DOM inputs increase. Terrestrial DOM colors lake water and attenuates solar radiation, promoting anoxic conditions in the hypolimnia, which in turn favor methanogenic bacterial communities. Methanogenic bacteria convert H_2 and CO_2 to CH_4 and H_2O. CH_4 is then used by methanotrophic bacteria, creating isotopically light CO_2.

This past summer we added multiple components to our sampling of New England lakes. We are currently in the process of analyzing and interpreting these results. However, we can say a few things about the 2003 data. First, the regression patterns between DOC vs. δ^{13}-POM and DOC vs. $\delta^{13}C$-zooplankton still hold after adding 40 additional lake data points. This summer's sampling revealed that there is also a significant negative relationship between $\delta^{13}C$-DIC and DOC. This result suggests one of two things. First, it's possible that as lakes become more heterotrophic due to increases in DOC supply, that they also become less dependent on atmospheric CO_2. Instead photosynthetic organisms may be relying more upon heterotrophically-respired CO_2. Second, the negative relationship between $\delta^{13}C$ and DOC could arise because of increased methane contributions to the plankton. In support of this hypothesis, we found that hypolimnetic CH_4 increased along a DOC gradient. However, the absolute and relative abundances of methanogenic bacteria were negatively correlated with DOC, which does not support the CH_4 hypothesis. We just finished collecting data on the methane oxidizing bacteria, but have yet to analyze this information.

OTHER ACCOMPLISHMENTS

Students involved— To date, six undergraduate students have been involved in this project: Liza Pfaff, Nira Salant, Anna Weinberg, Megan Malgeri, and Richard Trierweiler. Liza Pfaff will be a co-author on one of the papers resulting from this research. Jay Lennon (Co-Pi) will be defending hi Ph.D. in May of 2004.

Papers—

Lennon, J.T. 2004. Experimental evidence that terrestrial carbon subsidies increase CO_2 flux from lake ecosystems. Oecologia 138: 584-591

Lennon, J.T. and Pfaff, L.E. Sources of terrestrial-derived subsidies affects aquatic bacterial metabolism. In preparation for submission to *Microbial Ecology* or *Limnology and Oceanography* in April 2004

Presentations—

Lennon , J.T. February 19m 2004. Invited seminar. Brown University, Department of Ecology & Evolutionary Biology

Lennon, J.T. February 10, 2004. Invited seminar. University of California, Berkeley, Division of Ecosystem Sciences

Lennon, J.T. November 4-7, 2003. Trophic state and plankton nutrition along a terrestrial DOM gradient in New England lakes. North American Lake Management Society. Mashantucket, CT. Recipient of the Best Student Presentation, North American Lake Management Society, National Meeting, $250

Lennon, J.T. June 10-14, 2002. Experimental evidence that terrestrial organic matter modifies plankton metabolism. American Society of Limnology and Oceanography, Victoria, British Columbia, oral presentation.

Lennon, J.T. October 16, 2002. Ecology of subsidies: role of terrestrial carbon in aquatic ecosystems. Colby-Sawyer College. Invited seminar.

Lennon, J.T. April 29, 2003. Terrestrial subsidies in aquatic ecosystems: is carbon flow to higher trophic levels regulated by microbial metabolism? Cary Conference, Institute of Ecosystem Studies, poster presentation.

Lennon, J.T. and Pfaff, L.E. August 3-8, 2003. Microbial constraints on the flow of terrestrial subsidies in lake ecosystems. Ecological Society of America, Savannah, GA, oral presentation.

Lennon, J.T. November 4-7, 2003. Trophic state and plankton nutrition along a terrestrial DOM gradient in New England lakes. North American Lake Management Society. Mashantucket, Connecticut, oral presentation.

Special session organizer—

Lennon co-organized a special session on "Ecological implications of terrestrial inputs into lakes and ponds" for the 2002 American Society of Limnology and Oceanography national meeting.

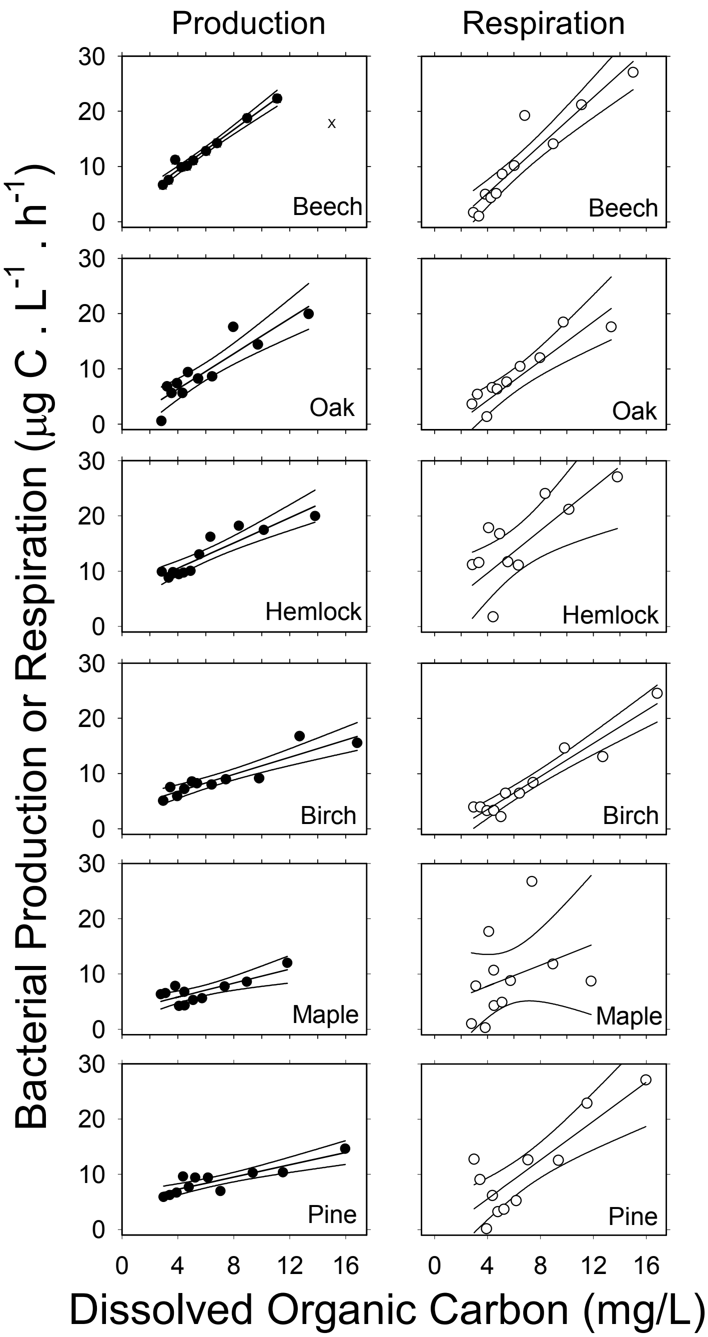
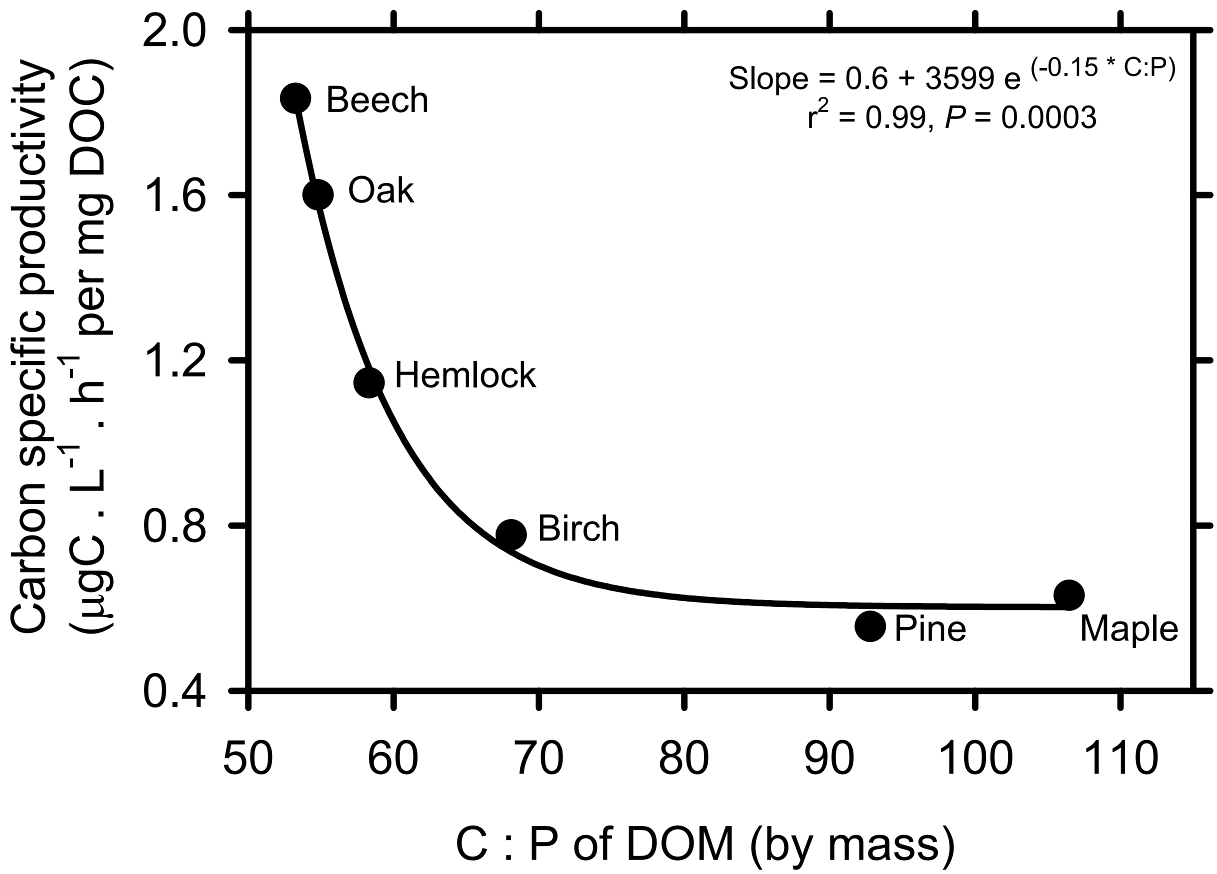
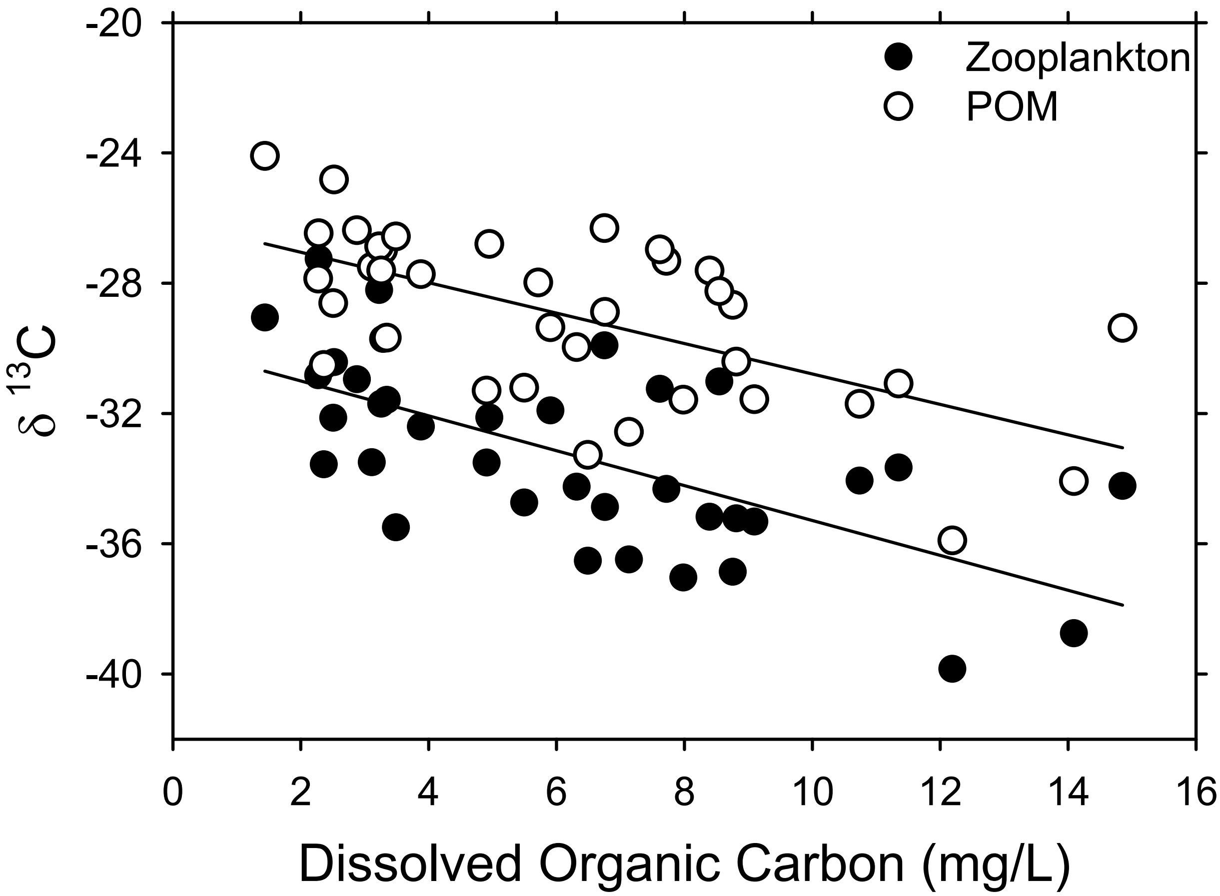


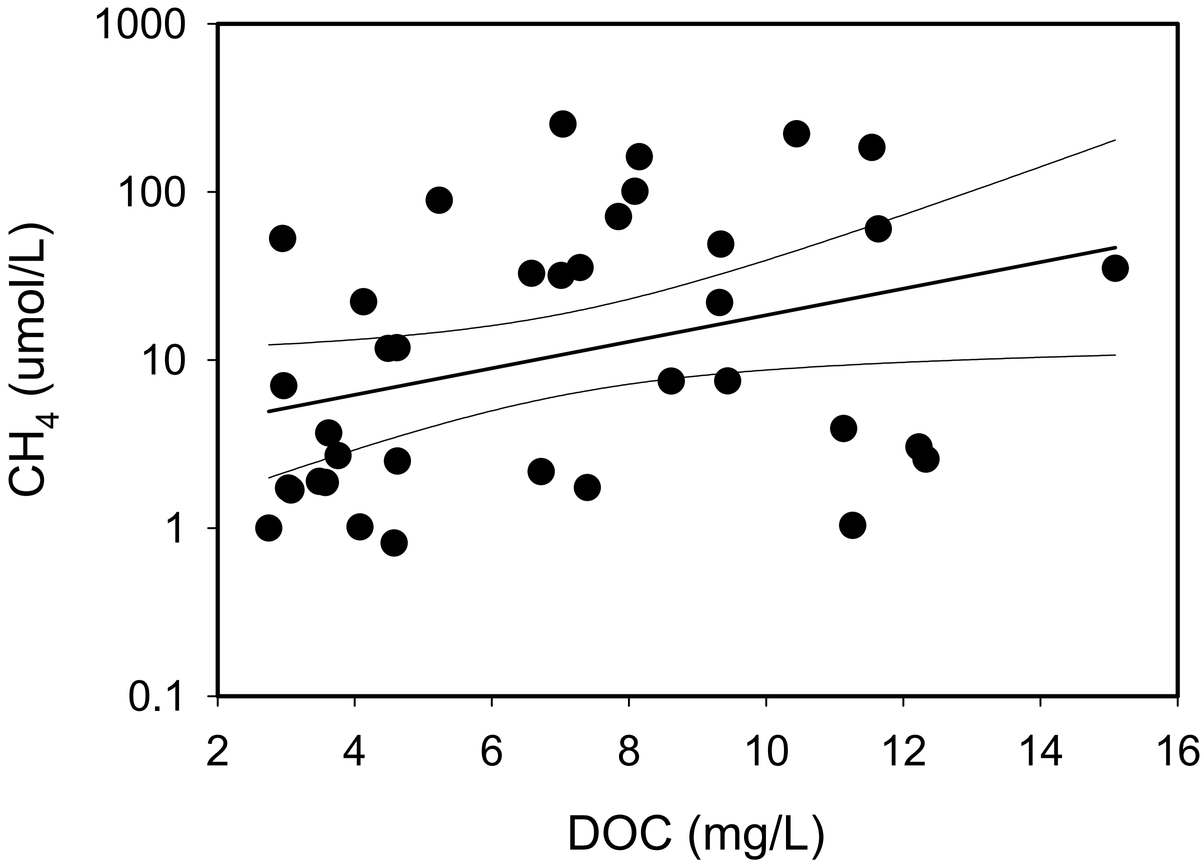
Figure 1. Bacterial production (●) and bacterial respiration (○) in response to varying quantities and sources of terrestrial-derived DOM. Bacterial production and bacterial respiration increased with dissolved organic carbon (DOC). Bacterial production was affected by different DOM sources (slopes are ranked highest to lowest along the vertical panels); bacterial production was greatest on beech and oak DOM sources. Bacterial respiration was not affected by DOM source.



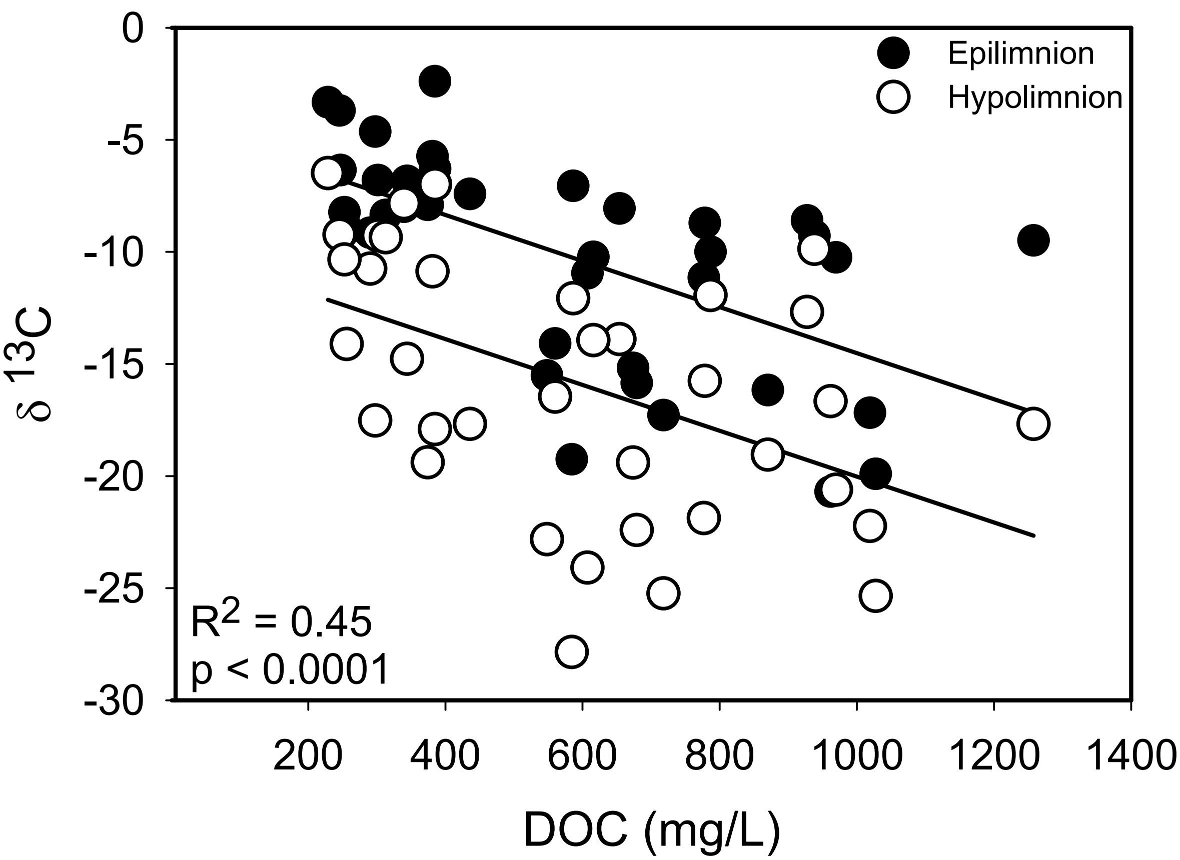
Results from Objective 1. Carbon specific bacterial productivity decreased exponentially with the C:P ratio (mass) the different DOM sources. Carbon specific bacterial productivity was measured as the slopes of the BP vs. DOC relationships for the six different DOM sources.



Results from Objective 3. $\delta^{13}C$ of zooplankton (•) and POM (○) along a DOC gradient in 37 New England lakes. Multiple regression revealed that $\delta^{13}C$ of zooplankton and POM decreased at the same rate along the DOM gradient. However, the zooplankton intercept is significantly less than the POM source suggesting that POM does not perfectly reflect zooplankton diets.



Results from Objective 3. Hypolimnetic CH_4 increased along a DOC gradient in ~40 New England lakes.



Results from Objective 3. $\delta^{13}C$-DIC decreased with DOC concentrations in both epilimnetic and hypolimnetic samples.

Effects of Land Use on Water Quality in a Changing Landscape

Basic Information

Title:	Effects of Land Use on Water Quality in a Changing Landscape
Project Number:	2002NH4B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Nutrients
Descriptors:	
Principal Investigators:	Jeffrey Schloss

Publication

1. Schloss, J., 2003, "Top-Down/Bottom-Up, High Tech/Low Tech, Participatory Monitoring and GIS Watershed Inventories", in Proceedings of the 2003 USDA Water Quality Conference, Web.
2. Schloss, J., 2003, "Motorized Boating on Lakes: What are the environmental Impacts?", Proceedings of the 12th annual North American Lakes Management Society Southeast Lakes Management Conference, web.
3. Schloss, J., E. Ely, 2004, Measuring clarity transparency, turbidity, and TSS. Volunteer Monitor Newsletter, Winter 2004, 16:1, pg 17-22.
4. Schloss, J. 2003, Participatory Research: Linking Citizens to Scientists. Volunteer Monitor Newsletter, Winter 2003, 15:1 pg 22-23.

USGS UNH Water Resources Research Center Project
Effects of Land Use on Water Quality in a Changing Landscape-II

Annual Report: March 1, 2003 through February 29, 2004

PI: Jeffrey Schloss, Extension Associate Professor, Zoology.

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) 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 in-depth watershed nutrient budget measurements and modeling have been attempted on a small number of watersheds scattered throughout the state, these studies represent only short-term examinations of non-point source pollution nutrient loading. A longer-term monitoring program conducted through differing weather years as well as before and after changes on the landscape occur and watershed management programs are implemented is required. This serves better document impacts of land use changes and management efforts that have happened and to better model and predict future impacts and successes.

Objectives

This project allows for the continued collection of long-term water quality data over a substantial spatial and temporal scale. It utilizes a combination of students and volunteer citizen water quality monitors to collect samples (and preserve for analysis) from a wide range of lake and stream watersheds throughout the state which are part of the NH Lakes Lay Monitoring Program (LLMP), a 25+ year long-term sampling effort.

Emphasis on LLMP efforts was placed on evaluating the impacts of recently introduced best management practices in the Chocorua Lake Watershed. These BMP's were implemented through a successful multi-agency Clean Water Action Plan Critical Watershed project, which included an analysis of a watershed nutrient budget facilitated in part from funds received through a previous Water Resources Research Institute Program award.

As other funding sources were available for water quality analysis costs and related expenses, funding from this project provided support for student lab and field technicians and for supervision, data management and data analysis by the project director.

NOTE: We envision this effort as providing the foundation to further assess the impacts of land use and the effectiveness of watershed management strategies using long-term data sets in future years.

To summarize, objectives of this study include:
1- The continued collection and analysis of long-term water quality data in selected watersheds.
2- The dissemination of the results of the analysis to cooperating agencies, water managers, educators and the public on a local, statewide and regional basis.
3- To offer undergraduate and graduate students the opportunity to gain hands-on experience in water quality sampling, laboratory analysis, data management and interpretation.
4- 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.
5- To continue to document the effectiveness of constructed BMPs in the Chocorua Lake Watershed.
6- To determine next steps for further analysis of long-term data sets and GIS spatial data on land cover.

Methods

Lake and stream monitoring through the LLMP 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) 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.

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

This project was coordinated from the University of New Hampshire, which supplied the office and laboratory space (analytical and computer). The Center for Freshwater Biology Analytical Water Quality Laboratory has a Quality Assurance Project Plan for surface water analysis on file with the US Environmental Protection Agency Region 1 Office (EPA New England). Besides nutrient analysis (Total Phosphorus, Total Nitrogen, Nitrate), other water quality capabilities include chlorophyll a, dissolved oxygen, dissolved CO_2, acid neutralizing capacity, specific conductivity, pH, ORP, turbidity, water clarity, iron and E.coli. The lab can also provide field sampling, field water quality instruments, automated data loggers and water velocity measurement equipment. The lab can also provide the use of Real-Time Differential GPS units for watershed surveying and ground truth sampling.

The Water Resource Center Laboratory, which follows standard methods, has the capability to perform ion chromatography for a variety of anions and cations, organic carbon analysis and total nitrogen analysis. It also can provide field and automated sampling equipment.

UNH Cooperative Extension provided vehicles for travel for PI's, students and interns at a cost (mileage) basis. A dedicated GIS PC Windows 2000 workstation was provided for use including ArcGIS and ArcView Software, ArcView Extensions: Spatial Analyst, 3-D

Analyst, Image Analysis and ArcPress. This was used in addition to other data input PC stations, laser printers and a large format (36" wide) ink jet plotter that was made available for the project.

The project utilized an extensive GIS database for the study subwatersheds created through previous WRRC funding to the PI. Updated and additional GIS data can be made available through the UNH Complex Systems Research Center, which manages the NH GRANIT statewide GIS data depository. The extensive data directory contains statewide GIS data layers (usually at 1:24,000 scale) including hydrology, geology, soils, National Wetlands Inventory, land-use, land cover, and digital elevation models. Also available are Landsat Thematic Mapper, SPOT Panchromatic and digital orthophoto imagery.

Major findings and significance

1. Properly designed road runoff BMPs (including stabilization, plunge pools, day-lighting culverts, diversion ditching and containment swales) reduced sediment load and Total Phosphorus loading by over 90% during spring runoff conditions. Even under a major fall storm event (100 year storm) with flood conditions and overflow the system reduced loading by over 50 percent. The Chocorua Lake Project from which these results were monitored has become a model demonstration project and was the site of a road management workshop for road agents in the fall of 2003 attended by road agents from NH., Maine and Massachusetts.
2. Preliminary data show that wetlands vary their ability to shunt water flow and nutrients dependent upon the flow conditions during the growing season. Higher flows in the summer cause less nutrient and water attenuation than when drier conditions exist. This has major implications for land use/water interaction and nutrient modeling activities such as TMDL modeling. Care must be taken in models that are based on yearly vs seasonal rain flow conditions.
3. The use of "in-lake" periphyton samplers has shown promise as a sensitive means for determining small differences in productivity in oligotrophic waters. This method may prove more useful in trophic change assessments and land use impact change detection.

Publications, presentations, awards.

Publications:

Newsletters:

Schloss, J. and E. Ely- 2004. Measuring clarity transparency, turbidity, and TSS. Volunteer M*onitor Newsletter* Winter 2004 16:1 pp.17-22

Schloss, J. 2003. Participatory Research: Linking Citizens to Scientists. *Volunteer Monitor Newsletter* Winter 2003 15:1 pp.22-23.

Proceedings:

J. Schloss. 2003 "Top-Down / Bottom Up, High Tech / Low Tech, Participatory Monitoring and GIS Watershed Inventories" Proceedings of the 2003 USDA Water Quality Conference. (web)

J. Schloss. 2003. "Motorized Boating on Lakes: What are the environmental Impacts?" Proceedings of the 12th Annual North American Lakes Management Society Southeast Lakes Management Conference. (hard copy and web).

<u>*Reports:*</u>

R. Craycraft and J. Schloss. 2003. Lakes Lay Monitoring Program Annual Report for 2002. A series of more than 50 individual lake reports distributed to lake associations, towns, conservation and planning commissions, and state agencies.

<u>Presentations:</u>

Conferences:

North American Lake Management Society/EPA/ Florida Lake Management Society.	Southeastern Lake Management Conference	June 2003 Orlando, FL	"Motorized Boating on Lakes: What are the environmental Impacts?"
New Hampshire Lakes Association	Annual Lakes Congress	June 2003 Wolfeboro, NH	"Canaries of the Lake- plankton and bugs"; and Carry Capacity of NH Lakes".
North American Lake Management Society (NALMS)	Lake and Watershed Research and Management International Symposia	November 2003 Mashantucket, CT.	"Touring Your Watershed with GIS" Post Conference Workshop.

NH LLMP Presentations:

Lake Winnipesaukee Association- Gulford, NH;.Squam Lakes Association- Holderness NH; Bow Lake Campowners Association- Strafford, NH, Chocorua Lake Association/Chocorua Foundation- Tamworth, NH: Green Mountain Conservation Group- Ossipee, NH; Great East Lake Association- Sanborton, NH; Great Bay Coast Watch- Madbury NH, Riverwoods Senior Home- Exeter NH; and the Science Center of New Hampshire- Holderness, NH.

Teaching:

In addition NHLLMP program information, data and findings were incorporated into the following UNH classes as full courses, "guest lectures", short courses and workshops:

Biology 602 - Project Lake Watch: GIS for Watershed Analysis (summer course; data used)
Community Development 614 - Fundamentals of Planning (guest lecture)
Natural Resources 702A/802A- Watershed Ecology
Natural Resources 504 - Freshwater Resources (guest lecture)
Natural Resources 604 - Watershed Hydrology (guest lecture and data use)
Natural Resources 702E/802E- Community Mapping w/ GIS (team taught 10% of course)
Natural Resources 703/803 - Watershed Water Quality Management (guest lecture)

Natural Resources 821 - Ecology of Polluted Waters (NPS Assessment Lab; data used)
Plant Biology/Zoology. 717/817 Limnology (guest lecture; data used)
Plant Biology/Zoology. 719/819 Field Limnology (GIS lab; data used)
Plant Biology/Zoology. 732/832 - Lake Management: A Multidisciplinary Approach (full course).

Number of students supported (and degree level, undergrad, Master, PhD)

Name	**Major**	**Class**
Shane Brandt	Zoology	Ph'D
Carl Chaimberlan	Marine & Freshwater Biology	Junior
William Clark	WARM*	Senior
Jonathan Gravel	WARM	Senior
Matt Hinderlitter	Zoology	MS
Kara Houghton	English	Junior
Josh Lamson	Environmental Conservation	Junior
Caitlin Milone	Psychology/French	Freshman
Amy Suprenant	Liberal Arts	Sophomore

*Water Resources Management (Natural Resources)

Pathogens in Biosolids: Evaluation of Clostidium perfringens as an indicator organism to assess the efficiency of biosolid disinfection processes

Basic Information

Title:	Pathogens in Biosolids: Evaluation of Clostidium perfringens as an indicator organism to assess the efficiency of biosolid disinfection processes
Project Number:	2003NH20B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Treatment, Waste Water, Toxic Substances
Descriptors:	
Principal Investigators:	Christine L Bean

Publication

PATHOGENS IN BIOSOLIDS: EVALUATION OF *CLOSTRIDIUM PERFRINGENS* AS AN INDICATOR ORGANISM TO ASSESS THE EFFICIENCY OF BIOSOLIDS DISINFECTION PROCESSES

Principal Investigators: Dr. Christine L. Bean and Kristen Belanger, University of New Hampshire

Problems and Research Objectives:

The treatment and disposal of biosolids have been ongoing issues for both public and private wastewater treatment plants. The main objective of many wastewater treatment plants is to find an indicator organism that can be used in processes to evaluate treatment efficiency. This organism should be ubiquitous in fecal material, and not be a public health risk if used in treatment challenges. *Clostridium perfringens*, a non-pathogenic component of all fecal material, has been of interest for some time. By examining the effects of anaerobic digestion on this organism, strong inferences can be made on how the treatment will affect other microbial contaminants found in sewage.

Background Information:

The process of anaerobic digestion can be broken down into two categories based on temperature; mesophilic digestion, which takes place at 35°C, and thermophilic digestion, which takes place at a temperature between 48 and 62°C. The combination of high temperatures and high level of methane produced by the system creates an effective environment for inactivating potentially pathogenic fecal contaminants. The process is fueled by the metabolic by-products of anaerobic organisms, such as *C. perfringens*.

C. perfringens is a gram-positive rod-shaped anaerobe that is part of the normal flora of the human digestive tract. Its most desirable quality, in the interest of this study, is its ability to form environmentally stable endospores. This stability can be compared to the stability of the ova of *A. lumbricoides*, the cysts of *G. lamblia*, and the oocysts of *C. parvum*. *C. parvum* is a small parasite, measuring about 3-5 µm. It lives in the intestinal tract of a variety of animals. The infectious form of this organism is the oocyst, those infected develop Cryptosporidiosis. *G. lamblia* infects humans in the cyst form, causing them to develop a disease known as Giardiasis. It is found all over the northeast U.S. and is commonly related to Beavers. *A. lumbricoides* is one of the largest and most common parasites found in humans. The adult worms live in the small intestine and ova are passed in the feces as the infectious form.

Testing Process:

The testing process can be broken down into the following four phases;

-Recovery of Environmental Strain of *C. perfringens*:

Fresh, raw influent from the Durham Wastewater Treatment Plant was filtered through a small-pore filter by suction filtration. This filter was then applied and incubated on mCP media, selective for *Clostridium* and differential for *C. perfringens*. Colonies were then identified by reverse cAMP testing and identification of double-zone beta hemolysis.

-Spore Induction for *C. perfringens:*

Spore induction for C. perfringens was achieved by inoculating a freshly heat-shocked culture of the bacteria into Modified Duncan-Strong media. Spores were observed under phase contrast microscopy.

-Anaerobic Digestion System:

A two liter dialysis bag was filled with raw influent water spiked known concentrations of *C. parvum*, *G. lamblia*, *A. lumbricoides*, *E. coli*, and *C. perfringens* spores and vegetative cells. Samples were taken from the bag and tested on days 1-4, 7, 11, and 15

-Monitoring the Digestion System:

Spores and vegetative cells of *C. perfringens* were serially diluted and a titer was performed on mCP agar, *E. coli* was assayed according to the EPA approved method for multiple tube fermentation (MPN) technique, *G. lamblia* and *C. parvum* were tested for viability with the DAPI/PI staining method, and *A. lumbricoides viability* was tested by observation for viable helminth ova, microscopically. All results were obtained in duplicate and then converted to percent reduction for each pull.

Conclusions:

The major conclusions made to date include;

>Spore reduction is an indication of the percent reduction of protozoa

>The ova of *A. lumbricoides* remained viable longer than the spores or the protozoa.

>Anaerobic digestion effectively inactivates protozoa and bacterial spores within 4 days

Future Research Objectives:

-Induction of more heat-resistant spores with the addition of activated charcoal to the modified Duncan-Strong sporulation medium.

-Adding MS2 bacteriophage and B40-8 bacteriophage into the anaerobic digestion system and comparing the percent reduction of phage to the percent reduction of spores and protozoa.

-Perform aerobic digestion experiments using an aerobic spore forming bacterium, such as *Bacillus subtilis*, and comparing the effects of digestion on these spores to the effects on *C. parvum*, *A. lumbricoides*, and *G. lamblia*.

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:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Surface Water, Nutrients
Descriptors:	
Principal Investigators:	William H. McDowell

Publication

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. Many rivers and lakes also serve as local water supplies. New Hampshire currently leads all New England states in the rate of development and redevelopment (2000 Census). The long-term impacts of population growth and the associated changes in land use to New Hampshire's surface waters are uncertain. Of particular concern are the impacts of non-point source pollution to the state's surface waters (e.g. septic, urban run off, road salt application, deforestation and wetland conversion). Long-term datasets that include year-to-year variability in precipitation, weather patterns and other factors will allow adequate documentation of the cumulative effects of land use change and quantification of the effectiveness of watershed management programs.

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. This could occur through the development, testing and refinement of predictive models, accurately assessing the impacts of watershed management practices, and potentially early warning of dramatic changes to surface water quality in the region resulting from rapid development.

Objectives of the Project

This project allows for the continued collection of long-term water quality data in New Hampshire. It will use UNH staff, students and volunteers from local communities to collect samples from the College Brook watershed (Durham, NH), the Lamprey River Watershed, the Oyster River watershed, and the Ossipee Watershed.

The College Brook watershed, which is dominated by the University of New Hampshire, receives a variety of non-point pollution from several different land uses. Suspended sediments, pH, conductivity, biological oxygen demand (BOD) and nutrient concentrations (Cl^-, SO_4^{-2}, Na^+, K^+, Mg^{+2}, Ca^{+2}, NO_3, NH_4, PO_4, DOC, TDN) will be measured to assess water quality. Samples from 7 sites will be collected monthly throughout the year. Sampling of College Brook began in 1991. Sample collection will be done by UNH staff and/or students, with analyses done by UNH staff at the Water Quality Analysis Lab (WQAL) of the WRRC.

The Lamprey River will be sampled weekly throughout the year and during major storm events. Samples will be measured for suspended sediments, pH, conductivity, and nutrient concentrations (Cl^-, SO_4^{-2}, Na^+, K^+, Mg^{+2}, Ca^{+2}, NO_3, NH_4, PO_4, DOC, TDN). Sampling and analyses will be done by UNH staff. Weekly sampling of the Lamprey River began in 1999.

Several locations along the Oyster River (the drinking water supply for Durham) will be sampled by volunteers from the Oyster River Monitoring Group. Samples will be collected monthly from June to October. Sample analysis (Cl^-, SO_4^{-2}, Na^+, K^+, Mg^{+2}, Ca^{+2}, NO_3, NO_2, NH_4, PO_4) will be done at the Water Quality Analysis Lab (WQAL) at UNH on a cost per sample basis. Additional analyses (DOC and TDN) will be done by the WQAL as part of the cost share for this project. Staff of the WRRC will also aid in data interpretation and analysis.

Samples will also be collected monthly (when surface streams are present) at Moore Fields, a 42 acre agricultural property near the Oyster River. Moore Fields is owned by UNH and is used for soil science courses and research as well as growing feed for the university's livestock. Sampling began here when a land use change to soccer fields was proposed. This proposal has since been withdrawn. Samples will be collected and analyzed by UNH staff at the WQAL.

Streams within the Ossipee watershed of New Hampshire will be sampled by volunteers of the Green Mountain Conservation Group. Samples will be collected every 2 weeks from May to November. Water chemistry (Cl^-, SO_4^{-2}, Na^+, K^+, Mg^{+2}, Ca^{+2}, NO_3, NH_4, PO_4, DOC, TDN) will be measured by the WQAL at a per sample cost. WRRC staff will assist in data interpretation.

Principal Findings and Significance

College Brook

Samples have been collected from College Brook as planned during 2003-2004. However, data analysis was not complete at the time this report was due. Previous work on College Brook in the early 1990's (McDowell unpublished) shows that the UNH campus had a severe impact on water quality and was negatively affecting stream biota and the integrity of downstream ecosystems. By any yardstick, campus operations could not be considered sustainable. There was clear evidence that the UNH incinerator was causing excessive organic matter loading, resulting in high biochemical oxygen demand (BOD) and low dissolved oxygen in stream water. Other practices, such as washing of waste art materials (slip, poster paint, etc.) into street drains near the Service Building, were also impacting College Brook.

Comparisons between data collected in 1991 and 2000-present have indicated that overall water quality has improved in College Brook with the closing of the UNH incinerator and greater ecological awareness on campus. Recent water quality analysis (2000-2003) indicates that the drought of 2001 has a significant effect on water quality. It was the third driest year for the state of New Hampshire for 1895-2003 and water chemistry indicated that the health of the stream was at its lowest for some parameters (TDN, nitrate, ammonium, BOD, etc…). Construction on campus has also likely had an impact on stream quality and in 2001 construction occurred in close proximity to the stream in the watershed. Construction accidents (i.e. - water main break) caused large runoff discharges into College Brook and likely had effects on the stream, which further complicates the picture. Further analysis of the data and continued monitoring of College

Brook is scheduled to continue. The College Brook web site can be viewed at http://www.wrrc.unh.edu/current_research/collegebrook/collegebrookhome.htm.

Weekly Lamprey Sampling and the Lamprey River Hydrologic Observatory

Weekly sampling of the Lamprey River has continued as planned as part of the baseline data for the Lamprey River Hydrologic Observatory (LRHO). The LRHO serves as a platform for studying biogeochemistry in a rapidly developing suburban watershed. Riparian groundwater wells and precipitation collectors have been installed throughout the watershed. Two graduate students have recently begun working on projects within the LRHO, one investigating variation in stormwater chemistry (relative to stream size, land use, seasonal variations, etc.) and the other groundwater chemistry and landuse.

Another graduate student has nearly completed her thesis research titled "Suburbanization, Water Quality and Property Values in Three Northern Forest Watersheds". This study examines the effects that suburbanization has on surface water quality in three New Hampshire watersheds by investigating the relationship between five water quality indicators and landscape characteristics. The main goal of this project is to explain the relationship between water quality (characterized by nitrate, phosphate, ammonia, dissolved organic carbon and dissolved organic nitrogen) and landscape characteristics (characterized by impervious area, land use, population density and property value).

Thirty-one streams were sampled over a year period. Fifteen of these streams fell within the larger Lamprey River watershed, 8 fell within the Oyster River watershed and 8 within the Ossipee River watershed. The watersheds chosen had varying degrees and types of development. The water quality indicators collected in this study were nitrate, phosphate, ammonia, dissolved organic nitrogen (DON) and dissolved organic carbon (DOC). The 31 watersheds were characterized by the following land use data: amount of impervious area within each watershed and the percentage of land that is agricultural, forested, developed, wetlands and open water (NH GRANIT). The watersheds were also characterized by the population and housing density (Census 2000) and property value data collected from each town.

The working hypotheses for this project are:

1. Property values can explain the residual variation seen when population density is used to explain water quality.
2. Property values can predict water quality.

Ossipee River watershed sampling

Streams within the Ossipee River watershed were sampled every two weeks by volunteers of the Green Mountain Conservation Group. Samples were analyzed by the WRRC's Water Quality Analysis Lab. Our interaction has allowed for the continuation of this sampling in the upcoming year.

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	14	0	0	0	14
Masters	5	0	0	0	5
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	21	0	0	0	21

Notable Awards and Achievements

J.T. Lennon received the Best Student Presentation Award at the National meeting of the North American Lake Management Society in November 2003 for his presentation titled "Trophic state and plankton nutrition along a terrestrial DOM gradient in New England lakes.

Publications from Prior Projects

None