Vermont Water Resources and Lake Studies Center
Annual Technical Report
FY 2005

Introduction

The Annual Report for the Vermont Water Resources and Lake Studies Center for FY2005 is attached. The grant awarded under the State Water Resources Research Institute Program is 01HQGR0115.

Research Program

The Vermont Water Resources and Lake Studies Center supported two major research projects during FY2005. The Center supported the second and final year of a project entitled A Comparison of Fecal Concentrations in Streams: a Paired Watershed Study lead by Dr. Leslie A. Morrissey in the Rubenstein School of Environment and Natural Resources (UVM). This project started in FY2004 and was a complement to an ongoing paired watershed study that has focused on the effects of ski development on water quality. The ski industry is important to Vermonts economy. However, the numerous ski developments in the state exert pressures on water resources through associated developments. These developments are expanding in Vermont and there is concern that continued development might impair these healthy streams. Fieldwork completed in the first year of this project showed that counts of fecal bacteria in baseflow rarely exceeded the state standard. However, in over half of the sampled storm events, levels of fecal coliform bacteria were in excess of the state standards in stream water draining both the developed and undeveloped watershed. The sources of this contamination are currently not known. Early in the second year of this project (Spring 2005) a new stormwater detention pond was constructed as part of a new development at the ski area. E. coli concentrations measured below the stormwater pond were much higher than concentrations measured above the pond during monitored storm events. This was unexpected. While the stormwater pond BMP may have met its intended water quality targets (sediment and phosphorus), it not only failed to reduce downstream concentrations of E. coli but appears to have enhanced them by acting as a reservoir for fecal contaminants which were then flushed out during storm events. This is phenomenon that bears further examination in other settings. A land use/land cover classification using high-resolution IKONOS remote sensing data was completed. This analysis was used to help identify and assess the risks of fecal contamination from various sources in the watershed. This project supported one MS graduate student (Mathew Bruhns).

The Center also supported the first year of a two-year project entitled Trophic Status of Lake Champlain over 400 years of Changing Land Use: A Paleolimnological Study, lead by Andrea Lini in the Geology Department (UVM) and Suzanne Levine in the Rubenstein School of Environment and Natural Resources (UVM). This project seeks to establish historical changes in the trophic status of important sub-basins in Lake Champlain through analysis of sediment cores. Samples from the cores will be used to assess biological and chemical indicators of ecosystem health in Lake Champlain over the last four centuries. This project is viewed as important by a wide variety of stakeholders in the Lake Champlain basin for several reasons. In particular, land use has changed rapidly in the basin over the last several decades and there is mounting concern that these distributed changes are threatening the health of a regional natural resource that is highly valued for its recreational, aesthetic, economic, and educational values. In intense

blooms of cyanobacteria have developed in parts of the lake over recent years and are a worrisome indicator that may be symptomatic of wider degradation in the Lake Champlain environment. In the first year of this project, two long cores were extracted from opposite ends of the lake. One core was taken from an area that been developed for a relatively long period of time, while the second core was taken from an area that has been developed only relatively recently. Detailed patterns of total C and N in the sediments show similar trends, though the timing and rate of development impacts differ - as expected - with the core from the more recently developed area showing more recent changes. Interestingly, patterns in 13δC in the upper portions of these cores follow opposite trajectories, suggesting fundamental differences in the nature of the materials that have historically been deposited in these two areas of the lake. Long-term patterns in C/N ratios also differ at the two sites, suggesting fundamentally different deposition and diagenetic processes at the two sites. In the coming year two addition cores will be taken in two highly eutrophied embayments.

In addition to oversight of these two projects the Water Center continues to publish its newsletter in collaboration with the University of Vermont Sea Grant Program. It also continues to play a leadership role in evolving strategies of land and water management in Vermont. In particular, the Water Center has been instrumental in leveraging new funds from Federal (EPA) and state (Agency of Natural Resources) sources for research that is urgently needed to support management decisions about urban stormwater management and river corridor management in rapidly developing areas in Vermont. These projects include efforts to identify impairments to ecosystem functions in stormwater impacted streams, a project to identify key indicators of geomorphic change in urban streams, a project to find ways to better involve citizen stakeholders in decisions about local stormwater management, a project to develop new hydrological and GIS based tools to prioritize stormwater permitting activities, and a project to identify whether and how neighborhood types influence stream health. During FY2005 the Water Center provided minor support for several (4) graduate students who were working on some of these projects. All of these projects are relevant to key policy and management needs identified by local stakeholders. The Vermont Water Resources and Lake Studies Center continues to be a visible and trusted source of data and knowledge about these issues.

A Comparison of Bacterial Concentrations in Streams: a Paired Watershed Study

Basic Information

Title:	A Comparison of Bacterial Concentrations in Streams: a Paired Watershed Study
Project Number:	2004VT16B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Surface Water, Hydrology
Descriptors:	
Principal Investigators:	Leslie Morrissey, Alan Mcintosh

Publication

A Comparison of Fecal Concentrations in Streams: a Paired Watershed Study

PI: Leslie A. Morrissey

Final Progress Report

Reporting Period March 1, 2005 – February 28, 2006

Rationale: Throughout the U.S., high-elevation forested watersheds are facing the pressures of development for increased housing, year-round recreational use, water management, and timber. This research addresses how development-related disturbances may affect these highly sensitive ecosystems by evaluating fecal contamination in paired undeveloped and developed watersheds within a northeastern high-elevation forest.

Runoff from residential, agricultural, and forested lands carrying microorganisms from fecal sources can pose a serious risk to human health through contamination of drinking and recreational waters. Uncertainties in the relative importance of these fecal sources, however, have constrained federal and state agency efforts to understand and manage water quality. In particular, although fecal levels in streams are strongly correlated with development and agricultural runoff, there is considerable debate regarding the contribution of undeveloped areas (which in the northeastern U.S. often are represented by higher elevation forested lands). Limited observations, however, suggest that fecal levels in streams draining undeveloped forest lands may significantly contribute to downstream concentrations and may exceed water quality standards during storm events. To date, however, no studies have addressed fecal contamination in streams draining high-elevation forested watersheds in the northeastern U.S.

Goal: Quantification of stream fecal levels in the two paired, forested watersheds on Mt. Mansfield in northern Vermont will enable assessment of the contribution of developed and undeveloped forested lands to fecal levels in adjacent streams, providing improved understanding of downstream water quality and a baseline for planned future management of the two watersheds.

Progress to Date: Matthew Bruhns was recruited as a M.S. student in the Aquatic Ecology and Watershed Science concentration to conduct this research. Weekly *in situ* water samples (with replicates) were collected at the paired watersheds from snowmelt in April through freeze up in November of 2004 and 2005. *E. coli* and fecal coliforms were analyzed in the laboratory following EPA protocols. Water samples were also collected every 2 hours during select storm events.

Storm events resulted in more than a 10-fold increase *E. coli* concentrations compared to non-storm events (Figure 1), although streamflow alone was a weak predictor of *E. coli* concentrations ($r^2 = 0.33$; $n = 24$). Only 5% of the non-storm weekly water samples for the two watersheds violated VT Water Quality regulations (77 cfu/100mL). However, 58% of the water samples collected during storm events (defined as meeting a 20% exceedance rate) in both the developed (Stowe Ski Resort) and undeveloped watersheds were in violation.

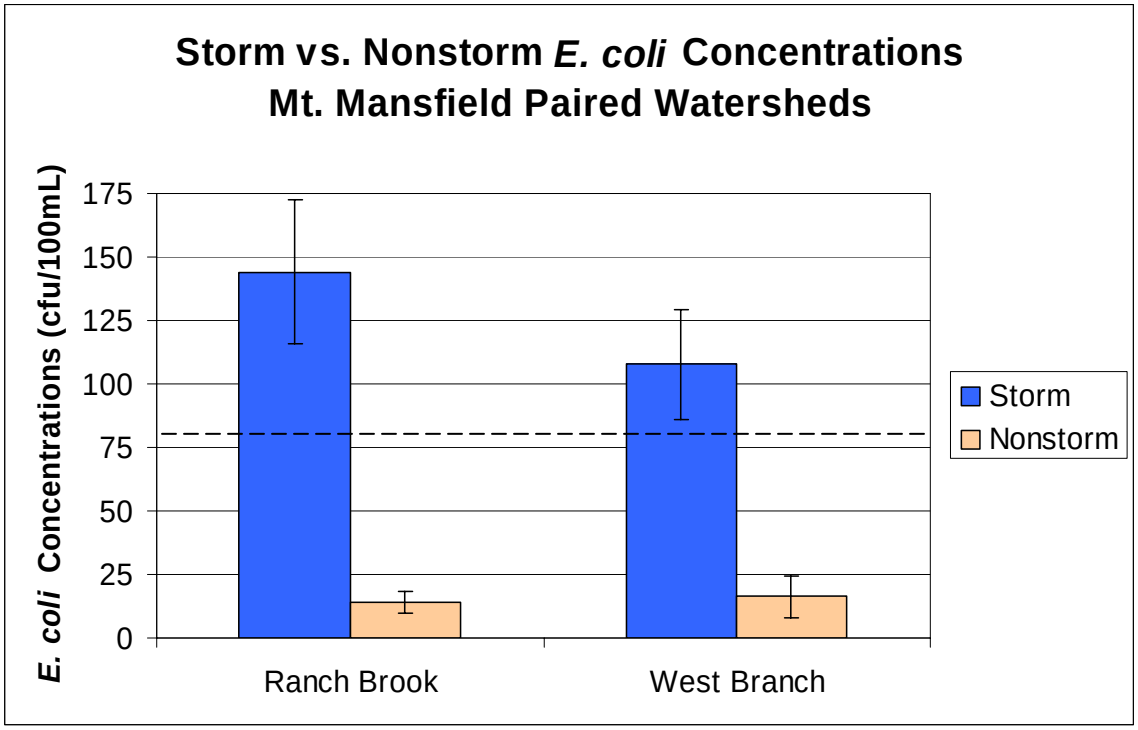

Figure 1. *E. coli* concentrations (mean ± 1 SD) for samples collected during storm and non-storm events in two paired watersheds (VT Water Quality Standard is indicated by the dashed line). Fecal contamination increased 10-fold during storm events for both the developed West Branch and undeveloped Ranch Brook watersheds. Although not statistically different, the undeveloped Ranch Brook concentrations appear higher than the developed West Branch during storm events.

A stormwater retention pond was built during the Spring of 2005. The building of the stormwater retention pond was a BMP instituted to reduce contaminants reaching the stream from areas under current development. This particular watershed, home to Stowe Ski Resort, is in the process of building new homes, condominiums, lodge, and parking garage – an anticipated doubling of the impervious surface area. As a result, the USGS gaging station was moved to a new location downstream of the 2004 location to incorporate output from the stormwater pond. This move provided an opportunity to sample above (areas of limited development) and below the stormwater pond (areas with current major development) within the same watershed. Although *E. coli* concentrations during non-storm events showed little difference for the two watersheds, significant differences were noted during storm events (Figure 2). The stormwater retention pond reduces contaminants reaching the stream during non-storm events by acting as a collection basin, however, during storms the pond acts as a reservoir for fecal contaminants which are then flushed out of the pond and into the stream resulting in exceedingly high fecal concentrations.

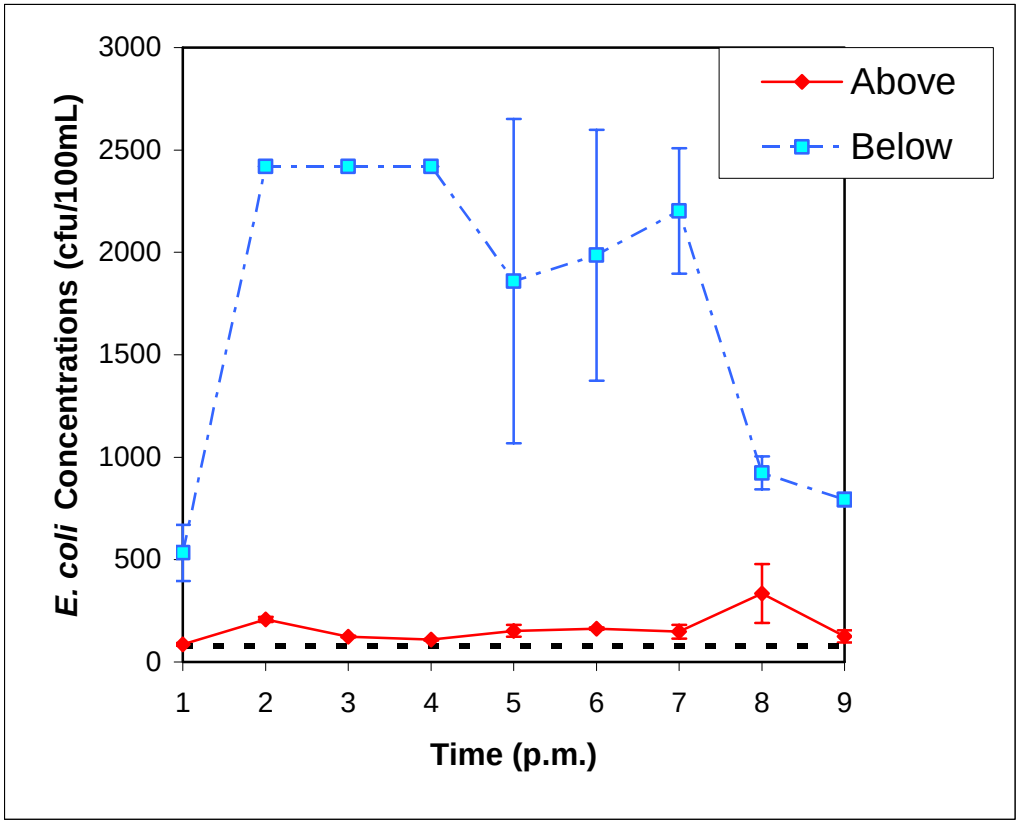

Figure 2. *E. coli* concentrations (mean ± 1 SD) measured below the stormwater pond were much higher than concentrations measured below the pond during this storm event. The VT Water Quality Standard is indicated by the dashed line. The stormwater pond BMP not only failed to reduce downstream water pollution but may have enhanced it by acting as a reservoir for fecal contaminants which were then flushed out during the storm.

In collaboration with B. Wemple (University of Vermont), water samples were also collected during storm events and baseline flow to analyze suspended sediment as a second potential predictor variable. Analyses of these data, however, are still underway. Access to near-real-time meteorological and stream gage data was provided by collaborator Dr. J. Shanley (USGS).

In parallel with field sampling efforts, IKONOS high resolution satellite data acquired on September 17, 2004 were orthorectified to a map base. Classification of land use and land cover (LULC) using eCognition object oriented classification software has also been completed providing recent and detailed LULC information for the two watersheds. GIS data layers (1:5000 roads, buildings, surface water, digital elevation data, and digital orthophotography) were also compiled for both watersheds.

Final Tasks: Complete analyses and preparation of manuscript for thesis and publication.

Trophic status of Lake Champlain over 400 years of changing land use: A paleolomnological study

Basic Information

Title:	Trophic status of Lake Champlain over 400 years of changing land use: A paleolomnological study
Project Number:	2005VT22B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Sediments
Descriptors:	
Principal Investigators:	Andrea Lini, Suzanne Levine

Publication

Trophic Status of Lake Champlain over 400 years of Changing Land Use: A Paleolimnological Study

First Year progress Report and Plans for Second Year of Funding

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Project Objectives:

The purpose of this project is to use paleolimnological techniques to uncover the history of Lake Champlain's response to changing land use and eutrophication since European settlement. Our intent is to obtain and analyze sediment cores from several basins and bays in Lake Champlain that currently differ in trophic status, or have received waters from areas with different land uses in the past. Our hope is to provide managers with such important background information as the initial water quality and biological composition of the lake, and the lake's response to specific stressors, including the placement of causeways.
Our specific objectives are:

1) To determine pre-settlement trophic conditions across the lake
2) To document changes in trophic state and algal assemblages over the period since settlement
3) To relate these changes to land use practices or other indicators of human activity

The results of this study also will benefit public education. We plan to work with the staff of ECHO (Burlington's science museum) to create two linked displays. One will provide a time line comparing lake condition to activities in the Basin; the other will highlight the role of the paleolimnologist as a sort of environmental detective. Our goal is to have these displays in place by 2009, when Vermont will celebrate the 400th anniversary of Samuel Champlain's voyage of discovery into the lake.

Approach:

We have asked the Water Centers Program for financial support to analyze four cores, two from regions of the lake where algal blooms are problematic (St. Albans and Missisquoi Bays) and two from open water areas that have been less stressed by excess nutrients and represent large expanses of water. For each location we are assessing the following trophic state indicators over a 400 to 450 year period, with sediment age and accumulation rates determined by a combination of ^{210}Pb and ^{14}C dating:

- Sediment organic matter content (%C, %N, C/N)
- Stable carbon isotopes
- Nutrients (Phosphorous and Silica)
- Fossil pigment assemblages
- Diatom assemblages
- Soft algae

Records of forest cover, agricultural crops and livestock density, industrial and municipal discharges, human population density, and weather are gathered as well so that the relative impacts of these stressors can be evaluated. Our procedures are described in more detail in our original proposal (October 2004).

Progress to date:

This project began in March 2005 and has proceeded "on schedule". We received funding to collect two cores in 2005. These were taken in summer from opposite ends of the lake, one near Port Henry and Crown Point, where settlement of the Lake Champlain Basin began (and thus where we expect to find the longest record of impacts) and one in the Northeast Arm (just north of Savage Island), a lake region settled late and thus likely to show pristine conditions until relatively recently (Fig. 1A). The cores were sectioned at 1 cm intervals and have been analyzed in our laboratory for %C, %N, C/N ratios, carbon stable isotopes (Fig 1B and C), total and bioavailable P, Fe and Mn. Paleopigment analysis at the University of Regina also is completed, but assessment of diatoms and soft algae will not be completed until summer 2006. Neil Kamman of the Vermont DEC is currently analyzing metals (Hg, V, As, Zn, Pb, Cd, Cr, Ni) from cores taken alongside ours.

Stable isotope and organic matter records

Preliminary results suggest that the sediment archive from Lake Champlain can be divided into three general periods. The first period encompasses the oldest sediments, and exhibits geochemical stability within the cores. The second period, beginning around the turn of the 19th century, and corresponding to early settlement and deforestation, demonstrates minor trends towards nutrient enrichment. This is indicated by gradually increasing accumulation of organic matter. Increases in productivity are more pronounced during the third period, the last half of the 20th century, corresponding to the advent of chemical fertilizer and large-scale suburban development. The $\delta^{13}C$ records show opposite trends in the youngest portions of the two cores, suggesting more substantial eutrophication in the Northeast arm of the lake, where the Savage Island core was collected.

Biological Indicators

The biological data corroborate conclusions based on stable isotope ratios, organic matter and biogeochemistry. Lake Champlain responded little to changing land use and municipal practices up until the middle of the twentieth century. Beginning roughly in the 1950's, however, total algal biomass (as indicated by *B*-carotene and phaeophytin *a*) has risen throughout the lake, and water transparency (as indicated by a pigment-based UV index) has declined. Pigment analysis indicates that the principal algal groups favored by eutrophication have been cyanobacteria, cryptophytes and diatoms. Recent eutrophication may be related to use of artificial fertilizers and phosphate-based cleaning products and/or to greater shoreline development. The diatom record indicates persistent dominance by eutrophic species and thus cannot be used as evidence for recent eutrophication.

Nutrients

Total phosphorus concentrations are greatest near the surface (1500 –2500 ug/g sediment dry wt) and rapidly decrease to approximately 750 ug/g with increasing depth. Total iron and manganese show similar patterns with highest concentrations (~50 and ~2 mg/g, respectively)

near the surface and decreasing with depth (to ~40 and 0.5 mg/g, respectively). Biologically available phosphorus concentrations are up to 50% of the total phosphorus near the surface, but decline to about 10% with increasing sediment depth.
Biogenic silica (BSi) concentrations, often used as a proxy for diatom productivity, are greatest near the surface in both cores, but show high variability among the sites, ranging from less than 50 to greater than 100 mg BSi/g sediment dry wt. Historical concentrations at greater core depths are also highly variable (from 2 to 30 mg BSi/g) indicating large, pre-settlement differences in diatom productivity throughout the lake. Biogenic silica concentrations show no evidence of silica limitation, in spite of many-fold increases in other indicators of lake trophic status.

Plans for 2006-2007:

We plan to obtain our two 2006 cores from regions of the lake that are currently strongly impacted by phosphorus inputs and cyanobacterial blooms, St. Albans and Missisquoi Bays. Because we know from previous coring in these bays that sedimentation rates are high, we will obtain 1.5-2 meter rather than 80 cm long cores, and take them from the more stable platform of ice cover. These cores will be analyzed as in 2005. In addition, we will begin the historical component of this study in early 2006.
Detailed time line of the remaining tasks:

Jan-Feb 2006	Retrieve cores from St. Albans and Missisquoi Bays from the ice.
March-June 2006	Analyze for paleopigments, soft algae, nutrients, and elemental composition. Begin stable isotopic and diatom analyses.
Summer 2006	Continue analyses. Report results to date at 10th. International Paleolimnology Symposium, Duluth, MN.
Fall and Winter 2006-07	Complete all analyses. Perform statistical analyses and any modeling needed to relate trends in trophic status to land use, the building of causeways and other activities. Begin (or complete) journal articles related to the study. Work with ECHO in the development of a museum display.

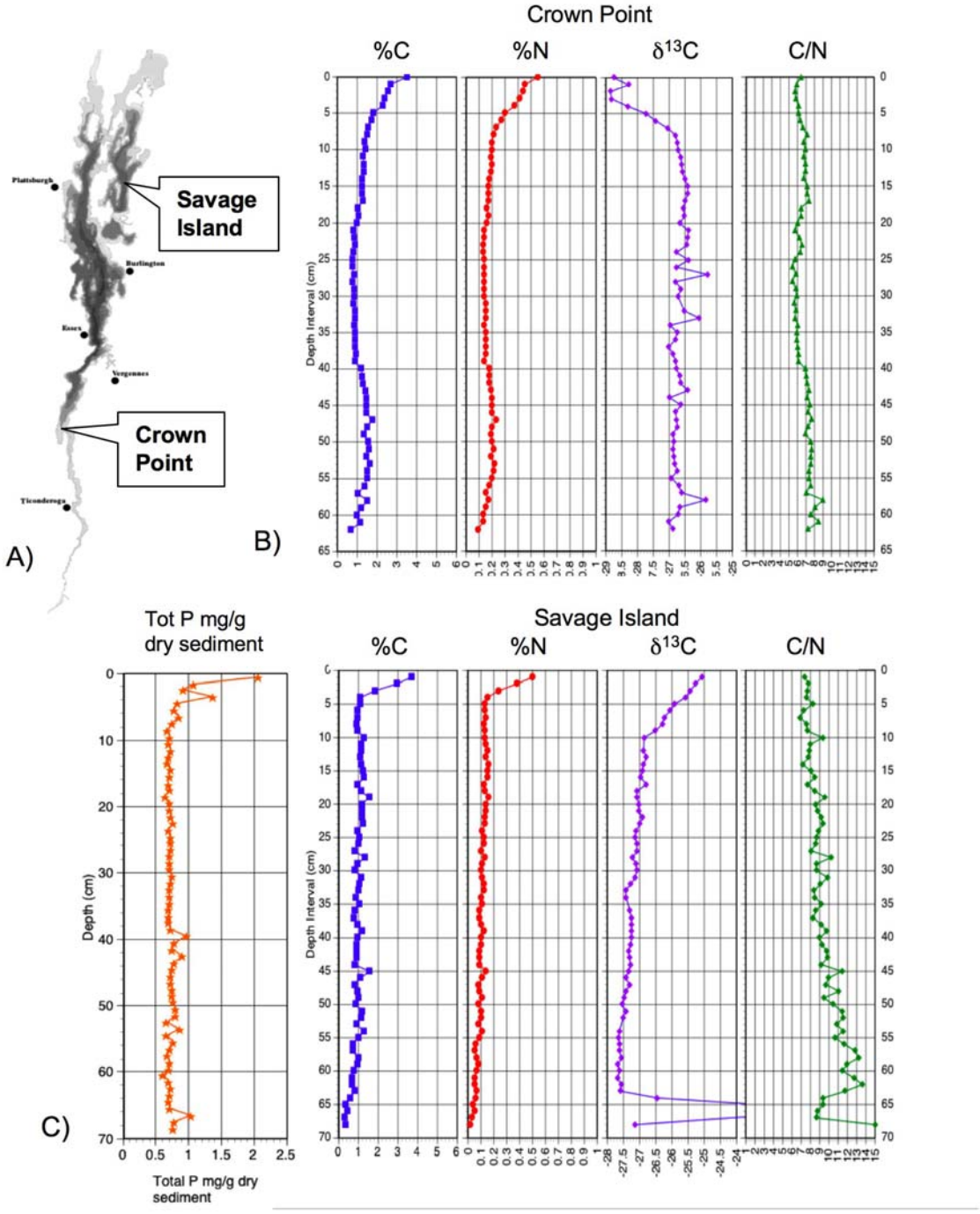

Fig. 1: A) Location of the summer 2005 coring sites in Lake Champlain. B) and C) %C, %N, $\delta^{13}C$, and C/N ratio depth profiles for the Crown Point and Savage Island cores. Also shown is Total P data for Savage Island.

Information Transfer Program

Student Support

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

Notable Awards and Achievements

Publications from Prior Projects

None