Lake Champlain 2010: Our Lake, Our Future
June 7-8, 2010
Dudley H. Davis Center
University of Vermont
CONFERENCE HOSTS

The **Lake Champlain Research Consortium (LCRC)** is composed of seven academic institutions located within the Lake Champlain Basin. Its mission is to coordinate and facilitate research and scholarship of the Lake Champlain ecosystem and related issues; to provide opportunities for training and education of students on lake issues; and to aid in the dissemination of information gathered through lake endeavors. More information is available at [http://academics.smcvt.edu/lcrc/](http://academics.smcvt.edu/lcrc/).

The **Lake Champlain Basin Program (LCBP)** works in partnership with government agencies from New York, Vermont, and Quebec, private organizations, local communities, and individuals to coordinate and fund efforts which benefit the Lake Champlain Basin's water quality, fisheries, wetlands, wildlife, recreation, and cultural resources. More information is available at [http://www.lcbp.org/](http://www.lcbp.org/).

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Thank you very much for your participation in the **Lake Champlain 2010: Our Lake, Our Future** conference. Constructive feedback is very helpful as we consider future conferences, so please take a few minutes and complete the brief on-line survey at [http://www.surveymonkey.com/s/9M68RRC](http://www.surveymonkey.com/s/9M68RRC) before June 18. The survey should take less than 5 minutes.
MONDAY, JUNE 7

7:30 am  Registration opens

8:15 am  Welcoming comments

8:30 am  Nutrients (moderator – Mary Watzin)


Performance of wet detention stormwater pond in the Englesby Brook watershed - Joel Nipper1, Breck Bowden1, and James Shanley2 (1University of Vermont, Rubenstein School of Environment and Natural Resources, 2U.S. Geological Survey) ........................................10

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Native Rainbow Smelt vs. nonnative Alewife distribution and abundance in Lake Champlain - Paul Simonin¹, Donna Parrish², Lars Rudstam¹, Patrick Sullivan³, and Bernard Pientka⁴ (¹Cornell University Biological Field Station, Department of Natural Resources, ²U.S. Geological Survey/Vermont Cooperative Fish and Wildlife Research Unit, University of Vermont, Rubensteins School of Environment and Natural Resources, ³Department of Natural Resources, Cornell University, ⁴Vermont Department of Fish and Wildlife) .......................................................... 18

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TRENDS IN PHOSPHORUS CONCENTRATIONS AND LOADS IN LAKE CHAMPLAIN TRIBUTARIES
1990-2008: AN EVALUATION USING NEW STATISTICAL METHODS

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Phosphorus concentrations and loads for 18 tributaries to Lake Champlain were evaluated using new statistical techniques developed by the U.S. Geological Survey. The new techniques were designed to keep pace with evolving needs in hydrologic studies: extracting greater value from long-term data sets, describing the relative roles of point source versus non-point source pollution, incorporating groundwater into the depiction of surface-water quality, and presenting clear interpretations of progress towards achieving ecosystem restoration goals. Central to the new methods is the production of graphs showing the ever-evolving pattern of phosphorus concentrations as influenced by seasons, discharge, and long-term trend. Monthly and annual concentrations and loads are estimated using weighted regression; heavier weights are assigned to observations closer in time, season, and discharge to the estimates. In addition, “flow-randomized” annual estimates are made. These estimates eliminate the influence of the particular discharges that happened to occur and thus provide insight on the changing behavior of the watershed without the confounding influence of the very substantial year-to-year variations in streamflow. The flow-randomized loads can provide insights on water-quality improvements in the watersheds, whereas the loads themselves describe the actual year-by-year inputs of phosphorus to the Lake. Preliminary results on flow-randomized trend show that loads for 13 tributaries had overall decreases between 1990 and 2008, 9 tributaries had decreases between 1990 and 2000, and 15 tributaries had decreases between 2000 and 2008. Results for concentrations were similar. Three representative streams are analyzed in more detail: Missisquoi River in Vermont, Little Chazy River in New York, and Pike River in Quebec. Diagnostic graphics for these streams further explain the likely role of point or non-point sources in various seasons of the year.
PERFORMANCE OF WET DETENTION STORMWATER POND
IN THE ENGLESBY BROOK WATERSHED

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Runoff from urban areas is recognized as a major contributor to water quality impairment in the Lake Champlain Basin. Efforts to mitigate the effects of urban runoff on receiving waters have relied heavily on stormwater detention ponds. These ponds are typically designed to detain a volume of water for a period of time, thereby reducing peak runoff rates immediately downstream. Pollutants in stormwater pond influent are presumed to be removed from transport and stored in detention ponds, though the level to which this occurs is not typically assessed post-construction. In this study, we collected continuous measurements of flow and turbidity into and out of a wet detention pond in the Englesby Brook watershed, in Burlington, VT. We also collected flow weighted composite water samples during 41 storm events from pond influent and effluent. All samples were analyzed for total nitrogen (TN) and total phosphorus (TP). These data show the pond to reduce the peak runoff rates delivered to the receiving waters. Sample analyses showed pond effluent to have significantly lower event mean concentrations of TN and TP, and significantly lower variance in TN and TP concentration than the pond influent (p < 0.001 for all tests). These data suggest that wet detention ponds can be an effective means of reducing in-stream TN and TP concentrations during storm events.
**Spatial Variability of Riparian Soil Phosphorus at a Site Along the Rock River, Vermont**

Eric Young¹, Donald S. Ross², Caroline Alves³, and Thomas Villars³  
(¹W. H. Miner Agricultural Research Institute, ²University of Vermont, ³USDA- Natural Resources Conservation Service)  
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Riparian soil phosphorus (P) concentrations affect the potential for P mobilization from stream bank erosion. The objective of this study was to characterize the spatial variability of soil P and related properties at a riparian site along the Rock River in Franklin County, Vermont. Soil samples were systematically taken from eight transects across a 10 hectare site in 2008. At each of 71 locations, four depth intervals (0-15, 15-30, 30-45, and 45-60 cm) were sampled and analyzed for total P, Modified Morgan extractable P (MM-P; an estimate of soil solution P), and particle size. Results showed that both total and MM-P concentrations varied significantly across the site. The imperfectly drained soils had greater total and MM-P compared to the moderately well drained soil. Considerable variation in P was also noted within series. For example, the Buxton soil had greater average total P at the lowest sampling depth (45-60 cm), while Limerick had greater total P in the Ap horizon. Particle size was not well correlated with soil P concentrations. Ordinary kriging revealed broadly similar patterns for total P, MM-P, total Ca, and pH, reflecting the transition in soils across the site. The quantity of MM-P reported depended on whether it was defined as that measured by molybdate colorimetry or inductively coupled plasma spectroscopy (ICP). MM-P measured by ICP was 70% greater on average than MM-P measured by molybdate reaction. Soil organic matter was highly correlated with the difference in P concentrations between the methods, suggesting the importance of soluble organic P in the soils. Results show that soil variation influenced the concentration and forms of P at the site. With additional sampling and map verification efforts, soil maps may be an important tool for prioritizing river management practices aimed at P mitigation.
INTERNAL LOADING DYNAMICS OF PHOSPHORUS AND NITROGEN IN MISSISQUOI BAY
REVEALED BY TIME-DEPENDENT MASS BALANCE MODELING

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Lake Champlain long-term monitoring data were used to construct a mass balance model for total phosphorus and total nitrogen in Missisquoi Bay using a daily time step over the period of 2001-2008. Missisquoi Bay was modeled as a single mixed-reactor with exchange mixing occurring between the bay and the Northeast Arm portion of Lake Champlain, using the model structure and exchange flow rate derived from a previous steady-state analysis. Tributary flow data and sampling results were used to calculate a daily time series of flows and mass loads from the Missisquoi, Pike, and Rock Rivers. Net sedimentation coefficients in the model were derived from values calibrated to independent data from a set of nationally distributed reservoirs. Modeled bay phosphorus and nitrogen concentrations were compared with independent sampling results from Missisquoi Bay. Departures between modeled and observed concentrations were assumed to be caused by internal loading processes not represented by a constant net sedimentation term. The magnitude and seasonal patterns of modeled total nitrogen concentrations closely matched the observed data, indicating that internal loading processes were not a dominant component of the mass balance for nitrogen in Missisquoi Bay. In the case of phosphorus, there were major departures from model predictions, with increasing concentrations during the summer periods that were not accounted for by the external loads. The management implications of these findings are that internal loading processes could interfere with the bay’s response to phosphorus reductions from the watershed, but the bay should respond quickly to reductions in external nitrogen loads.
TOXIC SUBSTANCES AND PATHOGENS IN THE LAKE CHAMPLAIN BASIN:
POLICY OPTIONS AND OPPORTUNITIES TO PROMOTE MORE EFFECTIVE MONITORING

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Beach closings, fish-mercury contamination, and emerging contaminants are issues of considerable concern to Lake Champlain Basin residents. Regarding beach closures, short-term closures that result from indicator bacteria excursions above current Vermont water quality criteria are precautionary, but are unrelated to actual swimming risk. Successful management strategies that mitigate significant bacterial contamination of ambient waters must focus on known source contributors of actual pathogenic organisms that are found within the domestic and agricultural sectors. As new and more precise recreational risk assessment methods become available, resource managers in the Lake Champlain Basin should adopt these tools to provide more precision in swimming advisories and in Clean Water Act assessments.

Mercury in the Lake Champlain Basin has been well studied at multiple levels, though less well monitored. Much is known about mercury source, fate, transport, thanks to high-quality process studies. In Lake Champlain, fish trophic position and water trophic state are strong predictors of excessive fish mercury levels. Meaningful efforts to educate basin residents have promoted a high awareness of fish contamination, and current monitoring efforts do not necessarily support the high demand for information among residents and managers. Many mitigating strategies have been implemented in Vermont and New York, and remaining efforts focus upon smaller and more socially challenging sources such as dental use and crematoria emissions.

There is growing awareness of emerging contaminants in the Lake Champlain Basin. Low concentrations of pharmaceuticals, hormones, antibacterial agents, and personal care products occur in Lake Champlain’s tributaries, wastewater, and combined sewer overflow discharges. Compound degradates are common. The co-occurrence of these compounds with caffeine emphasizes the degree to which basin residents are both the source of and solution to this issue. The heretofore unpredictable fates of these compounds are being clarified by new science. For example, recent literature suggests that dioxin-like compounds found in sediments may be the product of waste treatment reactions with the common antibacterial triclosan. While many aspects of emerging contaminants remain to be assessed in the Lake Champlain Basin (e.g., incidence of agricultural hormones, admixture effects), the precautionary principal dictates that managers should actively promote strategies that reduce release of these compounds wherever practical.
Lake Champlain continues to experience mercury contamination problems resulting in public advisories to limit or curtail human consumption of top trophic level fish such as Walleye. Prior research suggested that mercury levels in top trophic level organisms could be modified by differences in ecosystem productivity as well as mercury loadings. We investigated relationships between mercury in different trophic levels in several segments of the Lake Champlain Ecosystem. We measured inorganic and methylmercury in water, seston, and 2 size fractions of zooplankton from 10 sampling stations of the Lake Champlain Monitoring Program representing a range of nutrient loading conditions and productivity within the lake. This information combined with information obtained by the Lake Champlain Monitoring Program and VTANR fish sampling allowed us to develop and parameterize a model for mercury transfers in the Lake Champlain food web which accounts for ecosystem productivity effects.

Productivity at the food-web base varied substantially across lake segments as did the proportion of seston biomass pools attributable to autotrophs and heterotrophs. Seston biomass was a function of Chl-a, terrestrial-source DOC, and cyanobacteria biovolume except in Missisquoi Bay where cyanobacteria dominate. The partitioning of the water column mercury pool into seston increased with seston biomass and decreasing water alkalinity. However, the concentration of mercury in seston decreased with increasing seston biomass (bloom dilution). The biomass of small zooplankton (herbivores and detritivores) correlated with cyanobacteria biovolume and an index of terrestrial dissolved carbon suggesting heterotroph biomass is important to the base of the food web in many lake segments. The biomass of large zooplankton (omnivores) was positively correlated with seston and small zooplankton biomass and negatively correlated with dissolved terrestrial carbon suggesting differences in food quality between lake segments. Mercury in small zooplankton was a function of mercury content of water and seston and showed dilution in relation to the amount of small zooplankton biomass. Mercury in large zooplankton was a complex function of the mercury content in seston and small zooplankton pools as well as an interaction between large and small zooplankton biomass. Mercury concentrations in top trophic level fish were highly correlated with the standing stock of mercury in large zooplankton. Fish from Malletts Bay were outliers (exhibiting higher fish-tissue mercury relative the standing stock of zooplankton mercury) from the lake-wide trend. This departure is readily explained by the oligotrophic status (very low productivity and lack of bloom dilution) of Malletts Bay.
RUNOFF LOSSES OF PATHOGENS FROM DAIRY MANURE APPLICATION SITES

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Improved manure management practices are needed to reduce export of indicator bacteria and pathogens from agricultural land to surface waters. The objectives of this research are to quantify the occurrence of generic *E. coli*, *E. coli* O157:H7, *Salmonella*, *Cryptosporidium*, and *Giardia* in representative dairy manure in Vermont; characterize and compare pathogen and indicator organism losses in surface runoff from hayland and cornland receiving manure at the field scale; and document the effects of improved management on runoff losses of microorganisms using a paired-watershed design. Beginning in October 2006, we collected monthly samples of fresh and stored manure at three Vermont dairy farms for a one-year period. Levels of generic *E. coli* ($10^4$ to $10^6$ MPN/g) were consistent with values reported elsewhere and were an order of magnitude lower in stored manure compared to fresh. No *E. coli* O157:H7 were detected, and low numbers of *Giardia* (<133 cysts/g) and *Cryptosporidium* (<86 oocysts/g) were observed only in occasional samples. Calibration period monitoring of 22 runoff events from paired corn and hay fields began in May 2007 and was completed in August 2008. Treatments applied in fall 2008 were prompt incorporation of manure applied to corn land and higher vegetation at manure application on hay land. Subsequently, 14 events were monitored in the treatment period, ending in November 2009. Over the entire study period, very low numbers of *Giardia* ($\leq$131 cysts/L), *Cryptosporidium* ($\leq$5 oocysts/L), and *Salmonella* ($\leq$120 organisms/100 ml) were detected in runoff. Generic *E. coli* counts in runoff from corn fields (median 2800 MPN/100 mL) were similar to those in hay field runoff (median 3000 MPN/100 mL). *E. coli* counts were highest (e.g., $1.1 \times 10^6$ MPN/100 mL) in runoff events that closely followed manure application for both crops; *E. coli* numbers in runoff declined to very low numbers ($\sim 10^2$) when runoff occurred 6 weeks or more after manure application. Storm event runoff from corn fields (median 154 m$^3$) was significantly higher than hayland runoff (median 25 m$^3$). As a result, *E. coli* export from corn fields was significantly higher than that from hay fields. Data analysis to evaluate treatment effects is in progress.
MICROBIAL SOURCE TRACKING TO IDENTIFY FECAL POLLUTION SOURCES IN TWO VERMONT WATERSHEDS

Leslie Matthews¹, Laura Medalie², Tim Clear¹, and Neil Kamman¹
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A feasibility study was conducted to develop bacteria Total Maximum Daily Loads for Vermont streams using Bacteroidales-based 16S ribosomal RNA-genetic markers. Two impaired watersheds, the Huntington and Metawee Rivers, were studied, each with different hypothetical bacterial sources based on land uses. Volunteer groups in these watersheds had documented intermittent exceedances of the Vermont water-quality standard for Escherichia coli in class B water (77 organisms per 100 mL) with 8 years of weekly (Huntington) and 4 years of biweekly (Mettawee) E. coli concentration data, respectively. Stream-water samples collected by the U.S. Geological Survey and the Vermont Department of Environmental Conservation during storm and base-flow conditions in 2009 were analyzed for 16S rRNA genetic markers (General AllBac, Human qHF183, Ruminant BoBac, Canine BacCan, and Human BacHum) using quantitative polymerase chain reaction (qPCR) to identify human, ruminant, and dog as potential sources of fecal bacterial pollution. Reference fecal samples were collected from each of the potential source groups, as well as from common species of wildlife found in the watersheds, in order to assess marker cross reactions that could generate false-positive source signals in water samples. Estimates of the relative contributions of potential fecal sources and a discussion of the feasibility of using this approach for TMDL development will be presented.
**COMBINED SEWER OVERFLOWS AS A SOURCE OF HORMONES TO SURFACE WATER**

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Some sources of hormones to surface water, such as wastewater-treatment-plant (WWTP) effluent, have been well documented, but other sources, particularly wet-weather discharges from combined-sewer-overflows (CSOs), are not well characterized. Flow-weighted composite samples of secondarily treated WWTP effluent and untreated sewage discharges from WWTP inflows and CSO discharges were collected during 12 storms and 6 non-storm conditions from November 2007-December 2008 at the main Burlington Vermont WWTP. Concentrations of many androgens and estrogens were highest in samples from untreated sewage, and lower in samples from treated sewage. For example, concentrations of estriol in CSO samples ranged from 5 to over 100 ng/L (nanograms per liter), but were generally less than 1 ng/L in treated sewage. Many androgens were detected in CSO discharge samples in concentrations ranging from 1 to over 1000 ng/L, but were not detected above 1 ng/L in treated samples. For many of the hormones, including androgens and estriol, CSO discharges comprised over half of the total load discharged by the WWTP, even though annual CSO discharge is less than 10% of the treated plant discharge. These results indicate that untreated discharges during CSO events can be a major source of some hormones and other wastewater compounds to the environment.
In the last 150 years, several fish species have severely declined or become extirpated in Lake Champlain, including Atlantic Salmon, Lake Trout, American Eel, Muskellunge, and Lake Sturgeon. Walleye harvest has declined in the northern portions of the lake in recent decades, and Lake Whitefish commercial fishing ceased in Missisquoi Bay in 2004 due to scarcity. Habitat alteration, particularly loss of access to spawning areas, was clearly a major factor in some of these declines, but the extirpation of Lake Trout by the early 1900s and loss of the whitefish fishery are more difficult to explain. Historically, commercial fishing was relatively small-scale, and mostly conducted by landowners using shoreline seines, fyke nets, pound nets, and trap nets; gillnetting and offshore fishing were almost unknown. However, fishing effort was focused during the spawning seasons of the major target species, and may have had significant population impacts. Hydrological connectivity of the lake was altered by construction of causeways beginning the mid-1800s; hydropower generation at or below the fall line of all major tributaries reduced access to spawning areas; stream habitats were impacted by dumping of sawdust and soil run-off from farming; portions of the northeast and southern portions of the lake have become highly eutrophic due to phosphorus inputs; benthos in the main lake has been substantially altered by Zebra Mussels since the mid 1990s; changes in the plankton food web may have depleted prey of larval fish. Fifteen non-native fish species have become established in the lake, and Sea Lamprey population numbers have risen to unprecedented levels. These biotic and abiotic changes in the lake may decrease ecological resilience to further impacts, particularly those caused by Alewife and new exotic species.
Rainbow Smelt (*Osmerus mordax*) and Alewife (*Alosa pseudoharengus*) are cannibalistic, pelagic fish species native to coastal regions of northeastern North America and elsewhere. Rainbow Smelt are native to Lake Champlain and have been the main forage species of salmonids and Walleye (*Sander vitreus*) the primary sport fish in the lake. However, Alewife have recently become established, and thus have the potential to dramatically alter the Lake Champlain ecosystem. We compared Rainbow Smelt and Alewife adult and young-of-year (YOY) distribution and abundance in relation to their physical environment across the season. In the main lake, YOY Rainbow Smelt were first observed June, whereas YOY Alewife not until late July. YOY Rainbow Smelt were most abundant in mid-July, and YOY Alewife in early-August. In Malletts Bay, YOY fish were most abundant earlier than in the main lake. YOY Alewife grew faster than YOY Rainbow Smelt. YOY and adult Alewife were in shallower water than their Rainbow Smelt counterparts. Adult Rainbow Smelt distribution overlapped with YOY Rainbow Smelt and YOY Alewife distributions most prominently before July, when the thermocline was not yet present. When the thermocline was present, overlap continued, to a lesser extent, around the thermocline. However, adult Alewife were shallower, at depths less than six meters. YOY and adult Rainbow Smelt, and YOY Alewife distributions were related to gradients of temperature, temperature change, and light. Adult and YOY Alewife concentrated in the warmest possible water (15-23 °C), adult Rainbow Smelt at hypolimnion temperatures of 4-6 °C, and YOY Rainbow Smelt at 10-15 °C. Our study provides a comprehensive description of seasonal and diel dynamics of interacting cannibalistic populations in relation to physical habitat gradients.
DIET ANALYSIS OF INVASIVE PLANKTIVOROUS FISH SPECIES IN
MISSISQUOI BAY, LAKE CHAMPLAIN

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Through stomach content analysis, we evaluated seasonal shifts in diet preferences of two species of invasive planktivorous fish in Lake Champlain. Missisquoi Bay is a shallow, eutrophic bay that has recently begun to experience toxic cyanobacteria blooms in summer months. Alewife (Alosa psuedoharengus) and White Perch (Morone americana) have only recently entered this system and their respective impacts on the lake food web remain to be fully understood. Fish were sampled monthly using multi-mesh gillnets during the summer months of 2009. Our results indicate remarkable plasticity and high diet overlap between the two species. Prey item selection shifts over the growing season are characterized by diets almost completely consisting of zooplankton in early summer, followed by a shift to benthic invertebrates in later months. High nutrient levels and selective predation on large zooplankton by the fish may be leading to a trophic cascade and algal blooms. Our study has implications for better understanding the mechanisms controlling bluegreen algal blooms and the impacts of invasive fish species.
RESTORING LAKE CHAMPLAIN’S NATIVE SALMONIDS: CHALLENGES, ACHIEVEMENTS, AND PLANS

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Habitat alteration and over-exploitation led to the extirpation of native strains of Lake Trout and Atlantic Salmon from Lake Champlain by the mid 19th century. A program to restore these species to the lake began in earnest the 1970s, but changes in available habitat and community assemblages presented formidable obstacles. These challenges have been addressed in many ways: strain evaluations and selective breeding have resulted in better-adapted stocks, fish passage projects have opened access to preferred habitats, research continues to provide information on early life history requirements, technological advancements have allowed better quantification of the forage base, Sea Lamprey control has reduced wounding rates from 99 to 31 per 100 Lake Trout, and thiamine injections have shown promise in restoring the reproductive success of affected Atlantic Salmon. Annual assessment data show that Atlantic Salmon have responded and are increasing in size-at-age and in number indicating that conditions have become more favorable. Despite some successes, river runs of Atlantic Salmon, recruitment of Lake Trout fry, and further suppression of Sea Lamprey have proved elusive. In response, changes and adjustments to stocking practices will be evaluated, opportunities to more effectively use available habitat will be assessed, and improvements and additional efforts in Sea Lamprey control are planned. Through a variety of partnerships and adaptive management practices, Lake Trout and Atlantic Salmon are becoming increasingly well-established in Lake Champlain.
Global warming due to the buildup of greenhouse gases is well documented and will continue to cause significant environmental changes worldwide throughout this century. However, global average patterns do not necessarily represent conditions on smaller geographic scales. A new generation of investigative tools is now available for the documentation and modeling of climatic changes on the scale of individual watersheds. High-quality weather records show that climate in the Champlain Basin has become significantly warmer and wetter in recent decades, and that the warming here has proceeded faster than the global average. Down-scaled projections driven by 16 global climate models also suggest that future mean annual temperatures here could rise 1–11°F by century's end, and that total annual precipitation could increase by as much as 10-15%, depending on the model and carbon emissions scenario used. However, inherent limitations of such models and the complexity of climate systems still leave some important questions unanswered. This work was funded by the Adirondack and Vermont chapters of The Nature Conservancy.
Keynote address

EFFECTS OF A CHANGING CLIMATE ON FRESHWATER FISH AND FISHERIES:
DRIVING ENVIRONMENTAL FACTORS AND SHIFTING BASELINES –
WHAT TO EXPECT, HOW TO ADAPT

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Fish, fisheries, and freshwater regimes are sensitive to, and powerful indicators of, climate change. Long-term data from the Laurentian Great Lakes Basin indicate that for the past five decades, inshore surface water temperatures during open water (Apr-Sep) increased 1.5°C, evaporation increased 9%, and ice cover decreased, most significantly since the thermal regime shift of the late 1970s. Modeling predicts that over the next 100 years, summer water temperatures will increase 4°C; summer flows of rivers will decrease by 44%, lasting 28% longer; and spring discharge will peak 7 weeks earlier and decrease by 28%, negatively affecting Walleye recruitment (-21%). With increasing midsummer temperatures, recruitment increases in warm-water fish (centrarchids, +1°C =+2.2x to +3°C =+10.6x) decreases in cool-water and fall-spawning cold-water fish (lake trout, +1 C =-1.5x to +3°C =-20.1x), the latter negatively affected by increasing fall temperatures (Dec). Some cold-water coregonids have been extirpated; northern expansion and invasion of thermally better-adapted warm-water centrarchids and cool-water esocids has accelerated. Esocid spawning behaviour is being affected by decreasing spring water levels, resulting in some adaptation and hybridization. With increasing temperature, body growth increases in warm- and cool-water species and decreases in cold-water species (+1°C=±9% to +3°C=±28%). Changes and challenges are unprecedented. Assessing and managing fish resources and fisheries in a changing climate necessitates monitoring more intensively; adapting management to use increasingly abundant warm-water fish while protecting decreasing cold-water species; proactively addressing these controlling, changing environmental factors and shifting baselines and mitigating by making local fish and fisheries part of our “100-mile diet.”
LONG-TERM PATTERNS IN LAKE CHAMPLAIN PHYTOPLANKTON AND ZOOPLANKTON COMMUNITIES

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The dynamics of Lake Champlain’s plankton communities are a critical element of our understanding of the Lake ecosystem and how it responds to internal and external stressors. To better understand long-term patterns in Lake Champlain’s plankton we compared both zooplankton (1992-present) and phytoplankton (1970 and 2005) assemblage structure. Long-term patterns in zooplankton at five monitoring locations in Lake Champlain indicate a shift in community composition in the mid-late 1990s with a decline in Rotifer richness and abundance, most likely a zebra-mussel mediated pattern. During the 1990s Rotifer decline other zooplankton groups (Copepods and Cladocera) showed few discernable patterns in abundance or richness. Since 2000 some recovery has occurred in Rotifer populations, particularly increases in species richness at a few lake locations. Zooplankton responses associated with the recent Alewife invasion into Lake Champlain are still under investigation but may include a reduction in large body sized taxa.

The composition and distribution of phytoplankton communities in Lake Champlain has been a growing concern for the past decade with the occurrence of toxic blue-green algal blooms. A comparison of historical (1970) to modern (2005) community composition at seven locations in Lake Champlain illustrates a long-term shift in community composition lake-wide. Blue-green algae abundance shifted from predominantly *Anabaena* in 1970 to *Microcystis* in 2005. Long-term patterns were evident in both the summer and early growth season especially among the Diatoms and Cyanobacteria. Community patterns, particularly those for blue-green algae, suggest long-term shifts toward taxa adapted for increased light penetration, shallow water depths, and salinity tolerance.
AN OVERVIEW OF LAKE CHAMPLAIN PHYTOPLANKTON:
CURRENT POPULATIONS AND RECENT TRENDS

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The Lake Champlain Long-term Water Quality and Biological Monitoring Program has collected and analyzed biweekly phytoplankton samples from 15 stations around the lake since 2006. Over the four years, Lake Champlain has exhibited a highly dynamic and diverse phytoplankton population. Typically, higher cell densities and biovolume are found in the more eutrophic areas such as Missisquoi Bay and the South Lake. Diatoms dominate the flora by volume in many locations, particularly in the spring. They are typically the largest phytoplankton collected in net tows. Cyanobacteria, with much smaller individual cell volume, are often the most abundant group when considering overall cell density. While direct comparison with historical phytoplankton data is not possible because of differences in collection methods, some areas of Lake Champlain such as the Inland Sea have more phytoplankton now than appear to have been present in the early 1990s. In other areas, such as outer Malletts Bay, cyanobacteria may now represent a larger proportion of the annual phytoplankton community than they have previously.
THE MOLECULAR DIVERSITY OF THE CYANOBACTERIUM MICROCYSTIS AND ITS RELATIONSHIP TO TOXIN PRODUCTION IN LAKE CHAMPLAIN

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For the last decade, Lake Champlain has experienced summer blooms of harmful cyanobacteria. Accumulations have been most dense in Missisquoi Bay, where blooms have occurred 9 of the last 10 years. The genus Microcystis is of particular concern because it produces a hepatotoxin (microcystin) that poses both public drinking water and recreational use threats. Our data set shows that higher cell densities are not always associated with higher toxin levels. Because not all cells will contain the genes necessary to produce microcystin, we are investigating what fraction of the Microcystis population is able to produce toxin. To determine which cells contain the toxin genes we have adapted a quantitative polymerase chain reaction (qPCR) assay for Microcystis, assaying for both the mcyD and MICR genes. Microcystin concentrations have also been measured by enzyme linked immunosorbent assay (ELISA) and vary from 0 to >1000 μg/L. Microcystin concentrations, cell densities and species composition, and abundance of the mcyD and MICR genes are being compared to estimate the fraction of the Microcystis population that contains the toxin gene. Finally, multivariate analyses of these data and environmental factors (i.e., nutrients, temperature, pH) will be used to explore which factors may be associated with toxin production.
We present an application of a clustering method for identifying factors that contribute to cyanobacteria blooms and toxin production in the Missisquoi Bay in Lake Champlain. The method is data-driven and based on an existing Artificial Neural Network (specifically, a Kohonen Self-Organizing-Map (SOM)) that performs cluster analysis. We have modified the SOM by adding a nonparametric MANOVA to help identify the number of clusters used for interpretation. We visualize the methodology using an air permeability dataset collected from a slab of Berea sandstone for estimating classified air permeability fields using related/correlated data.

The method is then applied to a biological and hydrochemical dataset collected in Missisquoi Bay to explore factors related to cyanotoxin production by cyanobacteria. Cyanobacteria blooms in Lake Champlain are a complex phenomenon created by a non-linear combination of antecedent climate conditions, internal and external nutrient loading and the existing population of phytoplankton. Green algae and cyanobacteria communities have been documented by visual identification for comparison with environmental variables and cyanotoxin concentrations. Traditional statistical analyses have not been able to adequately describe observed relationships. Our non-linear, nonparametric approach is able to organize and assemble samples with similar traits.
MODELING CIRCULATION AND THERMAL STRUCTURE IN LAKE CHAMPLAIN

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The nonlinear three-dimensional hydrodynamic model (POM) is applied to Lake Champlain on a 200 m grid to study its circulation and thermal structure. The model was run for the July 2004 case with realistic winds but with zero heat flux to study internal seiches and wind-driven upwellings in the lake. Results showed that the model was able to simulate characteristic 4-day oscillations of thermocline well, and relatively little thermocline diffusion was observed. The model was run next in a hindcast mode to study seasonal variations of circulation and thermal structure in 2004. The model was initialized with uniform temperature of 2°C on April 1. The model was run with enhanced vertical resolution (39 sigma levels) and was able to simulate seasonal thermocline in early summer but excessive vertical diffusion resulted in a destruction of a thermocline by late August and creating vertically homogeneous temperature profile. Additional model runs with the same realistic meteorology but with a simple wedge-type bathymetry showed that excessive diffusion is caused by the steep lake bathymetry and even finer horizontal resolution is needed to maintain a thermocline at the end of summer.
For many years, the National Weather Service in Burlington, VT produced weather forecasts for the Lake Champlain Basin on a daily basis. Forecasts for specific marine elements of wind, waves, and sensible weather for the open waters of the lake were provided in a text-based format. Over the past 2 years, technological advances in the software the NWS uses to produce public weather forecasts has allowed forecasters to provide this marine forecast in a graphical format. To improve the forecasts for the complex terrain and water areas that exist in the basin, the NWS runs a 4 km horizontal resolution version of the Weather Research and Forecast model (WRF) and has made the output available on the World Wide Web. The wind output from the WRF is used as input to a local version of the Great Lakes Environmental Research Laboratory wave model that is widely used among NWS offices in the Great Lakes region for forecasting wave heights on the Great Lakes. We combine the WRF and GLERL wave models to create a new wind and wave model for the waters of Lake Champlain. This presentation will describe the use of real-time data and modeling for forecasts of marine weather conditions in the Lake Champlain Basin. We also describe the Lake Champlain Recreational Forecast suite of both text, graphical, and gridded forecasts of wind and wave height and plans for future improvements to this system.
FORCED CHANNELING IN THE CHAMPLAIN VALLEY AND IMPACTS TO MARINE FORECASTING

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Forecasters from the National Weather Service in Burlington have long noticed the existence of enhanced low level winds in the Champlain Valley of Vermont and northern New York. To better understand this phenomenon, the development of forced wind channeling within the valley will be discussed from a climatological perspective. Of particular interest is the evolution of a localized low-level jet within the broader channeled flow under southerly wind regimes. The physical mechanisms responsible for jet formation within the valley will be examined, including the possibility that the thermal wind gradient plays a contributing role. During these episodes the jet’s structure and orientation within the valley may have substantial impacts on marine weather conditions over the Lake Champlain open waters. Recognition of these features is important to both marine and aviation forecasting during the late summer and autumn when instability in the marine boundary layer is more prevalent.
A high-resolution seismic survey, using an EdgeTech Model 216 CHIRP system, revealed the presence of previously undocumented small-scaled lacustrine sediment drifts located within Juniper Deep basin in the Main Lake region of Lake Champlain, VT. These two north-south trending sediment deposits are positive features that differ from the normal drape sedimentation that characterizes deposition throughout the Main Lake. The drifts are comprised of highly laminated sediments with reflectors that can be traced throughout both drifts. Two basic drift geometries have been identified. Drift A, the eastern deposit, is a confined elongate drift, while Drift B, the western deposit, is a detached elongate drift. The southern portion of Drift A overlies a series of acoustically transparent in-fill trough sediments. Northern portions of Drift A, as well as the sediments of Drift B, overlie acoustically transparent, drape sediments. Flanking the drifts are moats to the east and west and north-south oriented furrows are located north of Drift B.

Acoustic Doppler Profilers were placed across the Drift A to determine flow dynamics. Drift A appears to be located at a shear zone between southward flowing and northward return flow conditions. Sediment cores taken across Drift A support these observations as the highest sedimentation rates occur within the shear boundary region. A basal reflector for both drifts has been correlated to an erosional feature believed to be the Champlain Sea- Lake Champlain sediment interface. This correlation suggest a starting time for drift formation beginning around 9,600 yrs. B.P.
Keynote Address

ECONOMICS, ENVIRONMENT, AND THE LAKE CHAMPLAIN BASIN

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(abstract not available at time of program printing)
DISTRIBUTION OF LAKE USERS AND RECREATIONAL ACTIVITIES ON LAKE CHAMPLAIN

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In summer, 2007, we sampled four groups of lake users to ask them several questions about their recreational uses of Lake Champlain, including regions of the lake where they spent their time. User groups sampled were anglers, boaters, members of environmental organizations, and lakeshore homeowners. Prior to conducting the survey, we compiled data on the capacities of boat launch areas and marinas throughout Lake Champlain. We also conducted three aerial surveys to count boats and map their distribution on the lake. Finally, we queried people launching boats about their activities on the lake. Together, these data were used to stratify different regions of the lake as the basis for selecting samples of users to receive a mail questionnaire. The primary objective of our study was to query people about their knowledge of and attitudes toward cormorants and gulls, although data gathered as part of our stratification scheme is of interest because it may reflect on carrying capacities for lake-based recreation and regions of the lake.

Aerial surveys resulted in counts of 914, 494, and 1382 boats on 6 June, 3 July, and 4 August, respectively. The first date was during the Lake Champlain Fishing Derby; the second was a holiday for Canadians and the day before a U.S holiday; the third was a nice, summer day during peak vacation time. Combining data from user interviews and aerial counts of boats, we calculated that fishing accounted for 62%, 14%, and 20% of boating activity in early summer, mid-summer, and late summer, respectively. Comparable figures for motor boating were 28%, 53%, and 49%, respectively. Non-motorized boats accounted for 21% of boating activity throughout summer. Of the five lake regions, the northern part of the main lake supported 35% of the total distribution of anglers and boaters. Responses from 769 mail surveys indicated that 61% participated in motor boating, 47% fishing, 34% kayaking, and 8% jet skiing.
Outdoor recreation has ecological and social dimensions. For example, recreation can cause environmental (e.g., soil compaction and erosion, water pollution) and social (e.g., crowding, conflict) impacts, and these impacts can degrade the quality of the visitor experience. Ecological and social dimensions were addressed and integrated in a study of the Lake Champlain Paddlers’ Trail (LCPT) in Vermont and New York. Structured interviews were conducted with paddlers during the fall of 2008 to identify potential indicators of a quality paddling experience. The relative importance of these indicator variables was assessed in a mail survey of LCPT paddlers during the summer of 2009. In addition, survey respondents were asked to render judgments about standards of quality for several indicator variables, including: 1) the number and types of boats on the lake, 2) the amount of shoreline development, and 3) the amount of impact to campsites along the LCPT. A range of conditions for each of these indicators was presented through a series of visual simulations. Concurrently, ecological assessments were conducted at eighteen primitive LCPT campsites. A condition class rating to reflect overall impact was assigned to each site, and specific characteristics were assessed, including vegetation cover, mineral soil exposure, tree damage, tree canopy cover, root exposure, and the presence of fire sites, human waste, and trash. A high-accuracy data point for each site was collected using GPS, which can be used for future relocation and monitoring of sites. Findings from the campsite assessment and visitor questionnaire were integrated and used to identify areas along the LCPT that violate visitors’ standards for campsite conditions. Study results have implications for the management of paddling on the lake, and provide baseline information that can be used in future monitoring efforts.
PUBLIC ATTITUDES TOWARD LAKE CHAMPLAIN CORMORANTS:
NUISANCE OR SCAPEGOAT?

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Why does a wildlife species achieve the status of “nuisance” species in the public’s perception? Is it the aesthetics of the animal (body shape, skin covering, color, call)? Is it the perceived utility of the animal (game species, indicator species, predators of valued species)? Is it the behavior of the animal (movement, nesting, foraging)? Is it demographics (overpopulation, territorial invasion)? This study explores public attitudes about cormorants in the Lake Champlain region to better understand why cormorants are perceived as a nuisance. The paper also explores the relationship between attitudes toward cormorants and knowledge about the biology of cormorants. Do people evaluate cormorants as a nuisance species because they know a lot about these birds, or because they know very little? And do people either support or oppose management efforts to control cormorant populations out of knowledge or ignorance?

This study surveyed four groups of Lake Champlain: anglers, boaters, environmental non-governmental organization (NGO) members, and lakeshore homeowners. Questionnaires were mailed to 1195 people. From this sampling frame, 769 people returned completed questionnaires (64% response rate). The results showed that knowledge of cormorant biology was relatively low, with anglers’ knowledge the lowest, and lakeshore homeowner knowledge the highest. There was strong agreement (75%) among the sample that cormorants are a nuisance species, and that there were too many of them on Lake Champlain. There was somewhat less agreement, however, about the aesthetics, utility, and behavior of cormorants. The analysis will model the multivariate relationships between knowledge, attitudes, and acceptability of management control of cormorants on Lake Champlain.
Six legal regimes have jurisdiction over Lake Champlain and its basin—the states of New York and Vermont, the province of Quebec, the federal governments of the United States and Canada, and the International Joint Commission. Joint efforts to address the needs of the Lake must initially work within - or around - the legal systems of the six jurisdictions and their similarities and differences. The similarities exist most notably in the historic origin of the laws and dispute resolution systems of New York, Vermont, the United States, and Canada, much of Quebec’s public law, and in some respects the International Joint Commission in the common law of England. The differences also have historic roots. The private law of Quebec is founded in the civil law brought by Quebec’s French founders. The federal constitutions of the United States and Canada allocate powers differently among the branches of government and between the national and state or provincial governments in part because the Canadian Constitution evolved from the British parliamentary form of government against which the framers of the US Constitution had revolted. Differences in detail exist in the laws of New York and Vermont despite their common origins. The International Joint Commission, created by the Boundary Waters Treaty of 1909, applies a special body of international law to resolve disputes and other issues between the United States and Canada. This presentation would spell out these similarities and difference in detail and would identify instances in which they may impede or facilitate transboundary solutions to the problems of Lake Champlain and its watershed.
The Vermont Lake Scorecard: The Final Step of the Scientific Method

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The Vermont Lay Monitoring Program has sampled Vermont lakes and Lake Champlain for nutrient enrichment concentration for 31 consecutive years. These long-term trends tell varying lake stories and will be presented through a colorful poster about the program. The poster also credits and features the many volunteer monitors who have documented important trends in Vermont lakes and in 20 locations on Lake Champlain.
An overview of watershed studies undertaken in the Quebec portion of Pike River Basin is presented. Monitoring of stream ecosystems, remote sensing of landscapes and spatial representation of cropping systems enabled 1) to better understand non point P sources and pathways at watershed scale 2) to relate the spatial variability in P mobility to landscape and cropping system descriptors, and 3) to evaluate the effectiveness of structural runoff control on P transfer. Continuous hydrometric and geochemical monitoring allowed a description of the temporal and spatial patterns in phosphorus exports from the Castors (10 km²), Walbridge twin watersheds (6-8 km²) and Ewing watersheds (30 km²). Statistical analysis of phosphorus data using stream flow as covariate (ANCOVA) highlighted contrasting C:Q signatures of individual watersheds, which were related to various drivers of P mobility, including land use pattern, landscape gradient and terrestrial P mass balance. Most of the annual loads in TP are associated with flashy peak flow events in late winter and early spring period, when saturation-excess runoff develops on hydro-active zones of the watershed. Airborne remote sensing techniques (multi-spectral imagery and LiDAR) provide efficient support in targeting and treating these critical runoff emission zones. ANCOVA of water quality data provided detections of P concentration response to these structural runoff treatments, using stream flow (Castors) or control watershed data as covariate (Walbridge twins). Stream and field monitoring data also provided evidences of significant subsurface P transfers and indicated that surface runoff and erosion processes may not be the dominant P pathways under flat clayey landscapes subjected to preferential flows. From an operational perspective, this research demonstrates that planning and implementation of measures to prevent agricultural non-point P exports must document landscape drivers of hydrological activity and address both nutrient and runoff management. Long-term control of topsoil P enrichment as well as timely incorporation of manure remain of critical importance. Conservation cropping techniques, stream bank buffers, and structural runoff controls provide the second agri-environmental line of defence, by keeping topsoil and nutrient in the field.
QUANTIFYING STREAMBANK-DERIVED NUTRIENT AND SEDIMENT LOADINGS IN THE MISSISQUOI RIVER WATERSHED

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The Missisquoi River contributes a significant amount of the phosphorus that is, in part, responsible for nutrification of Lake Champlain. Identification of effective solutions for reducing the rate of phosphorus delivery to Lake Champlain requires an understanding of the sources and fate of the sediment-bound phosphorus transported by the Missisquoi River. Streambank erosion along the Missisquoi River may be an important source of sediment and associated nutrients.

Tests of the geotechnical and hydraulic-erosion resistance of bank materials were conducted at each of 20 sites selected for detailed investigation. Nutrient-concentration data were provided by VDEC. Surveys of bank geometry and vegetation characteristics (species, age and density) were also conducted. These data were used as input parameters for each stratigraphic layer for bank-stability modeling. The major controlling processes responsible for bank erosion are being modeled iteratively using the Bank-Stability and Toe-Erosion Model (BSTEM). Simulations under existing bank conditions along the main stem and tributaries are being conducted for each site over a range of annual hydrographs representing the 99th, 95th, 90th, 75th, 50th, and 25th percentile flow years. Hydraulic erosion of the bank toe and mass failure of the bank mass are then simulated for each event at each site in an iterative fashion. Results are extrapolated temporally using magnitude-frequency analysis of the modeled flow years, and spatially to the remainder of the channel using a geo-referenced aerial video of the extent of streambank failures. These modeling results provide estimates of the streambank-derived sediment and nutrient loadings for the Missisquoi River and selected tributaries. Comparing these values with calculated suspended-sediment loadings (from USGS data) provides an estimate of the role of streambank erosion in total suspended-sediment transport in the Missisquoi River. A future study to quantify the effectiveness of alternative strategies to mitigate streambank erosion and reduce streambank loadings is proposed.
RIVER/FLOODPLAIN RESTORATION TO REDUCE SEDIMENT AND PHOSPHORUS CONTRIBUTIONS

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Sediments and associated phosphorus derived from river channels are thought to represent a significant portion of the overall load delivered to Lake Champlain. As a result of hundreds of years of destabilizing in-stream and upland management activities, the extent and rate of river bank and bed erosion exceeds natural levels throughout Vermont. Many of Vermont’s rivers and brooks have been straightened and dredged and as a result have become deeply incised. Vertically separated from adjacent floodplains and contained within incised channels, flood flows achieve much greater depths and shearing stresses than they would in non-incised channels. The result is tremendous vertical and lateral erosion of the channel.

The Wanzer Brook as it runs through the Boomhower Farm in Fairfield, Vermont has a long history of being straightened and dredged as part of a management regime intended to minimize the amount of acreage consumed by an otherwise meandering and regularly flooding river. This management history had resulted in a very unstable channel that was actively incising and widening. As a result of these channel adjustments, water quality and in-stream habitat had been significantly degraded. From the farmers perspective the unstable brook represented a constant threat to adjacent fence lines and valuable fields.

In 2007 the VT DEC, USFWS and USDA NRCS partnered to implement a restoration of the Wanzer Brook on the Boomhower Farm. A conservation easement was purchased from the landowner that would prevent any future channel management activities, 6,000 cubic yards of alluvium was excavated to reconnect the floodplain and channel, the floodplain was vegetated with willows, cow exclusion fences were installed and a culvert on a tributary was replaced. Two years of monitoring results suggest the restoration has facilitated the establishment of natural processes that will over time result in greatly improved water quality, in-stream and riparian habitat.
CRITICAL SOURCES OF NUTRIENTS AND SEDIMENT IN THE ROCK RIVER WATERSHED 
(TRIBUTARY TO MISSISQUOI BAY, LAKE CHAMPLAIN) DETERMINED BY 
SIMPLE MONITORING AND GEOSPATIAL ANALYSIS

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A synoptic sampling program was conducted in the Rock River watershed, a tributary to Missisquoi Bay (Lake Champlain) known for excessive loading of phosphorus, nitrogen, and sediment from primarily agricultural sources. Thirteen independent (un-nested) catchments ranging from 75-633 ha in size were sampled for concentrations of total phosphorus, total dissolved phosphorus, total nitrogen, and total suspended solids on 12 dates during 2008-2009. The purpose of the study was to determine whether this simple monitoring approach, involving concentration results only without accompanying flow measurements, would be useful in identifying catchment areas that are critical source areas of nutrient and sediment loading. A further purpose was to interpret the water quality monitoring results in relation to the physical and land use characteristics of each catchment area, in order to determine why certain catchments are contributing disproportionately large amounts of pollutants. Tests for statistical association were conducted between the nutrient and sediment concentrations (dependent variables) and catchment features potentially correlated with pollutant loading (independent variables). The independent variables were quantified for each catchment area using geospatial analysis, and included features such as precipitation rates, soil groups, stream drainage density, land slope, livestock density, human population, percent of land in corn, hay, wetland, roads, and forest, number of farmsteads, stream geomorphic status, and extent of riparian buffers. Combinations of factors (e.g., percent of corn land on steep slopes or proximate to streams) were also tested.
**THE EUTROPHICATION OF THE MAIN BASIN AND SOUTHERN ARM OF LAKE CHAMPLAIN: A PALEOLIMNOLOGICAL ASSESSMENT**

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Changing land use and human population growth in the Lake Champlain Basin since 1760 have had significant impacts on the trophic status of the lake. Due to the lake's large size, multiple basins and complex mixing patterns, however, the timing and intensity of eutrophication have varied between lake regions. To assess eutrophication at a decadal scale, we have collected sediment cores from twelve widely spaced sites and analyzed them for a suite of paleolimnological indicators of productivity, nutrient conditions, and algal community structure. Here we present results for eight sites within the Main Lake Basin and Southern Arm of the lake. All analyses suggest that these sub-basins of Lake Champlain are naturally oligotrophic and that despite substantial deforestation, and agricultural and commercial activity on and around the lake, productivity and nutrient accumulation rates changed little prior to late 19th century. Increased organic matter accumulation in sediments is first apparent in layers deposited in the late 19th century, although logging and land clearing had begun more than a century earlier and had deforested ~70% of the basin by 1870. C/N and C stable isotopes point to a progressive increase in the contribution of autochthonous organic matter to the sediment. This is especially evident for the post-1950 records. Enhanced aquatic productivity can also be inferred from the algal pigment accumulation profiles. These show low values until ca. 1930, after which pigment accumulation rapidly increases to reach peak values between 1970 and 1990, depending on lake region. Locally, productivity appears to have declined during the past decade. This is in agreement with the sediment P concentration data, which also show signs of amelioration after peaking in the’80s and ‘90s. Total sediment accumulation rates are highly variable within Lake Champlain but at all sites are greater at present than they were pre-settlement.
EXAMINING PHOSPHORUS CONTRIBUTIONS FROM ALLUVIAL SOILS:
A COMPARISON OF THREE VERMONT RIVER CORRIDORS

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The distribution of soils in the floodplain environment is highly complex. The often extreme spatial variability of alluvial soils, in both the vertical and lateral dimensions, creates challenges to adequately capture the range in P values found in the riverine environment. It is important to take samples from a wide range of geographic locations and soil series. Soil is the medium that water moves through before reaching the groundwater. Moreover, soil is the source of sediment that washes into streams and rivers which then flow into Lake Champlain. Lack of data on phosphorus levels in floodplain soils impede research efforts aimed at reducing the rate of P delivery to Lake Champlain. Once estimates for sediment loading rates have been derived, it is crucial to know the P values of the eroded material. Results from soil sampling projects in 2007 and 2008 along the Rock River, Rugg Brook / Mill River and Lewis Creek corridors have greatly expanded the soil database. NRCS profile characterization gives a wealth of chemical and physical data for 28 sites, along with soil descriptions complete with photographs. Additional related tests have been run by University of Vermont researchers. Preliminary results highlight some important differences between the three study areas. Levels of soluble P, which approximates the concentration in the soil solution – the mobile fraction, were higher in the Rock River samples. Across all sites, percent carbon and silt content tend to be correlated with higher P values. Numerous soil profiles display discontinuities in the type of parent material, borne out by the particle size analysis data, which in turn have an effect on levels of soil P. Building a robust database allows more accurate calculations of P contributions from eroding stream banks and sheds light on the complexities of soil and water interactions.
TRANSFORMATION AND LEACHING OF ORGANIC PHOSPHORUS IN A POULTRY MANURE-AMENDED VERMONT SOIL

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Organic phosphorus (OP) is an overlooked nutrient that leaches from agricultural soils. To assess the spatial and temporal mobility of P in poultry manure-amended soil, columns were leached weekly and sampled at three depths biweekly for ten weeks. Solution $^{31}$P nuclear magnetic resonance spectroscopy indicated that phytate-P, which did not change with time or depth, represented the major organic P fraction. Microbial activity in the 0-5 cm depth, as indicated by pyrophosphate and orthophosphate diester trends, likely contributed to the solubilization of OP during the ten weeks. Soluble P pools in soil (water- and bicarbonate-extractable) increased during this period. In leachate fractions, decreases in dissolved unreactive P were complimented by increases in dissolved molybdate reactive P. This study provides valuable information on the timeline and causes of OP leaching and transformation in soils with a long-term history of poultry manure amendment.
P MODELING AT THE EWING WATERSHED OUTLET USING THE WATER ELECTRICAL CONDUCTIVITY AS AN INDICATOR OF THE SURFACE AND SUBSURFACE FLOW CONTRIBUTION

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The majority (87\%) of P exported from Quebec to the Mississquoi Bay was estimated to originate from agricultural non-point source pollution (Mimeault 2002). Surface and subsurface (tile drain) runoffs are the major flow pathway that contribute to the P transfer to surface water body from agricultural fields. The water quality efforts to reduce P loads following the implementation of best management practices (BMPs) in a watershed needs to be validated at the outlet. The use of the electrical conductivity (EC) to predict source (surface vs subsurface) of P transfer was readily used by Michaud et al. (2009). Although, no validation of this procedure was realised in relation to the runoff water quality from agricultural plots.

Runoff water quality was measured from sandy loam soils (5 fields) and clay loam soils (5 fields) in the Ewing watershed, a subwatershed of the Pike River. The sites were sampled (19 discrete sampling) from October 2008 to May 2009. Drainage and runoff water samples were sampled simultaneously. At the same moment, the water quality of the Ewing Stream (P speciation, conductivity, pH, turbidity, water flow rate and height) was monitored at the watershed exit.

Hydrographs from the Ewing watershed were plotted in relation to the P composition (ortho, bioavailable, particulate and total P forms). Predicted P concentration at the Ewing outlet using fields’ water quality and a segmentation procedure using water EC gave a satisfying model. This approach confirmed our ability to estimate the impact of BMPs on the surface and subsurface water quality over a large agricultural watershed.
USING A GENERALIZED REGRESSION NEURAL NETWORK TO LINK GEOMORPHIC AND HABITAT ASSESSMENTS IN THE MISSISQUOI RIVER WATERSHED

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The ability to identify streams with high environmental risk is essential for a proactive adaptive watershed management approach. In efforts to describe the conditions of streams, environmental managers must gather and assess various forms of information - quantitative, qualitative and subjective. We research and develop a classification tool to identify stream habitat values based on several geomorphic and biological parameters. In the development of this work, we are using the rapid geomorphic assessment protocols (RGA), as well as, the rapid habitat assessment protocols (RHA) from 1412 Vermont stream reaches assessed by the Vermont Agency of Natural Resources (VTANR).

Geomorphic and biological health information (e.g., fish density, macroinvertebrate density) is traditionally researched separately by different experts. We build upon previous work (Besaw et al., 2009) by including biological data to assess habitat conditions. We explore the relationships between the RGA and RHA. GIS is used to visualize the results in the Missisquoi River watershed. The GRNN architecture allows for (1) sufficient flexibility to allow for continual updates and refinements as understanding/condition of fluvial geomorphology evolves, (2) the combination of data often collected separately, and (3) the potential to save time and resources, while enabling a truly adaptive management approach using expert opinion.
USING SWAT FOR THE EVALUATION OF THE SYNERGETIC AND ANTAGONISTIC EFFECT ON SEDIMENT, PHOSPHORUS AND NITROGEN OF COMBINING BEST MANAGEMENT PRACTICES:  AN EXAMPLE IN THE MISSISQUOI BAY BASIN

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Protecting ecosystems by establishing sustainable agri-environmental practices is a major challenge that demands effort from agricultural producers, their advisors and farmland managers. Over the last decades, several best management practices (BMP), have been used to reduce the impact of agriculture on its surrounding environment. However, many questions remain unanswered about the impact of applying several BMP at once on the various natural environment quality parameters, and the influence of the biophysical properties of the land on the interaction among these BMPs.

Given the limited scientific literature on BMP interaction, the purpose of this study was to use the SWAT model to explore the effects of various combinations of BMPs on non-point source exports of sediment, phosphorus (P) and nitrogen (N) toward surface water in the Walbridge watersheds; two areas of comparable size but different physiographical characteristics.

The simple effects and interactions of the BMP studied were analyzed in relation to the risk of non-point source exports of sediment, P and N. A base scenario, in this case a conventional grain corn crop, was used as a basis for comparison in evaluating the effect of the BMPs. Four types of BMP were evaluated, singly and in combinations: 1) tillage BMPs (direct seeding, minimum spring tillage and minimum fall tillage); 2) fertilization BMPs (manure spreading in spring or postemergence); 3) vegetation cover BMPs (grain crop followed by a crucifer and perennial cover crop); and 4) field development BMPs.

Overall, combinations exhibited more advantages than single BMPs alone, even when the combined BMPs did not necessarily interact synergetically (positive interaction) or even cumulatively (zero interaction) with a given water quality parameter. As for antagonistic interactions noted among the BMPs, the two primary interactions predicted by the model pertain to BMP fertilization combinations with direct seeding and with cover crops.
POTENTIAL IMPACT OF CLIMATE CHANGE ON THE WATER QUALITY OF PIKE RIVER WATERSHED

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The potential impact of climate change on the water quality of the Pike River was simulated using the Soil and Water Assessment Tool (SWAT) and output data of the Canadian Regional Climate Model (CRCM). The Pike River strongly contributes to the overloading of nutrients of Mississquoi Bay, northern Lake Champlain. SWAT hydrology and water quality was first calibrated and validated against observed data from 2001 to 2006 for sub-basins of the Pike River watershed. A final validation was performed on water flow near its outlet from data covering the 1980 to 2000 period. The model was subsequently run with daily precipitation and temperature data from four CRCM historical (1971-2000) scenarios and their four corresponding future (2041-2070) projections. Resulting water flow and nutrient loads simulated at the outlet were compared between the two periods in order to assess the impact of climate change. Calibration results showed a good adjustment of the model for monthly water discharges, total phosphorus loadings and nitrogen loadings, with corresponding R² of 0.7, 0.67, 0.74, and corresponding NS of 0.67, 0.63, 0.68, respectively. Similarly, the model validation for the water discharge parameter at watershed outlet showed a good adjustment with respective R² and NS of 0.61, 0.55. The four climate change scenarios produce an annual increase of water flow between 7 and 12 %, an increase of total phosphorus within 5 to 14 % and an increase of nitrogen within 3 to 17 %. A visual assessment of hydrograms and nutrient loads shows a longer snow melt period starting earlier but with lower water flow peak in April. There is generally a lower water discharge during summer and a slight increase in the fall. This can be explained by the increase in temperature during winter months. Seasonal total phosphorus and nitrogen loads follow a similar trend.
EVALUATION OF GIS TOOLS FOR SOIL AND WATER MANAGEMENT: SCALE EFFECTS ON PREDICTED OUTPUTS AND OPERATIONAL EVALUATION BY FARM MANAGERS

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Over the last 10 years, several tools have been developed to support the planning of agri-environmental actions within Pike river watershed, Québec. The Green Belt Project implemented by the Pike basin COOP provided the opportunity to assess and compare different GIS tools developed by IRDA and its partners. SWAT, GRISE and P-EDiT model outputs have been compared on the Ewing watershed (30 km²) and assessed in terms of their operability in the pursuit of concerted actions on water quality. SWAT (Soil and water assessment tool) is a macro-scale (basin) hydrological model used for quantitative soil and nutrient losses predictions; P-EDiT (Phosphorus export diagnostic tool) is a meso- (field) scale tool used for indexing runoff, sediment and phosphorus exports. GRISE is micro-scale (precision) soil and water management tool derived from multispectral imagery and LiDAR-DTM and used for drainage diagnosis and land development. Comparison of the sediment yields predictions derived from these three distinct tools highlighted the effects of scale and precision of input data on the spatial pattern of predicted outputs. From an operational perspective, SWAT tool was identified as a quantitative, strategic planning tool best adapted for basin scale, while meso- and micro-scales P-EDiT and GRISE tools are best suited for tactic implementation of best management practices at field scale.

Moreover, GRISE and P-EDiT tools have been assessed by 23 farmers, under the supervision of an agronomist from the local agri-environmental extension club. Drainage problems identified from multi-spectral imagery were systematically validated by participating farmers. Landscape depression, soil compaction and heavy soil textures were identified as primes of drainage problems. Most farm managers were considering investment into surface drainage (83%) and structural runoff controls (53%). GIS tools derived from LiDAR and aerial imagery are considered well adapted in providing interpretation of runoff emission zones explanation and mitigation scenarios.
VERMONT STORMWATER FLOW MONITORING PROJECT: A COMPARISON OF RUNOFF IN IMPAIRED VS. ATTAINMENT WATERSHEDS

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Few records exist for small streams that are impacted by stormwater runoff from urban, suburban, and recreational developments in Vermont. Efforts made by the Vermont Agency of Natural Resources (VTANR) to develop Total Maximum Daily Load (TMDL) allocations for streams listed with EPA as being impaired by stormwater, highlighted the need for long-term measured precipitation and streamflow data for these impaired streams and for comparable streams that are not impaired. In 2006, VTANR contracted with the University of Vermont to collect streamflow and precipitation data for 15 stormwater-impaired and 11 “attainment” streams throughout Vermont. Simple and relatively inexpensive devices were used to measure rainfall and stream stage at the monitoring sites with “open-channel” gauging methods to determine streamflow. This equipment proved to be 95.6% reliable for rainfall data and 95.4% reliable for streamflow data over the entire monitoring period. Results from monitoring efforts in all three seasons share some similarities, but differ in other important respects. In general, the total rainfall in each year and at each station did not differ significantly. However, the distribution of rainfall over space (i.e. among stations) and over time (i.e., within and among years) differed substantially. In summary, 2006 and 2008 were “wetter” years when compared with 2007. This is probably due to a higher frequency of storm events in 2006 and 2008 than in 2007. Overall, we found that the cumulative runoff as a percentage of rainfall from impaired watersheds was significantly greater than from attainment watersheds (45.3% versus 37.0%, P=0.083). However, this result depended on the nature of the water year. Runoff was greater from the impaired watersheds in the “wetter” 2006 and 2008 seasons and was indistinguishable from the attainment watersheds in the somewhat “drier” 2007 season.
STREAMBANK EROSION IN CHITTENDEN COUNTY, VT: APPLICATION OF VERY HIGH RESOLUTION REMOTE SENSING AND GIS MODELING

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High spatial resolution digital orthophotography acquired over a 9-year study period and detailed LiDAR elevation data were combined to quantify lateral stream channel migration over time and associated sediment loss in 15 watersheds within Chittenden County, VT. Extensive channel migration was observed in all watersheds, although differences from reach to reach and between attainment and impaired streams were significant. For example, within Indian Brook 111 lateral migrations were observed ranging in size from 2 - 59m. Lateral migrations within Allen Brook in comparison were smaller although nonetheless substantial (n = 71, range = 2.5-49m). By combining LiDAR-derived streambank and channel heights, areal estimates of bank retreat, and measured soil bulk density, we estimated soil volume and mass loss as a preliminary step to estimate annual sediment loading from impaired and attainment watersheds. Erosion “hot spots” within each watershed were identified and linked to watershed and corridor stressors. Our results are preliminary but demonstrate the value of remote sensing to quantify spatial and temporal variability in fluvial geomorphic change at watershed scales and a potentially viable methodology to evaluate sediment loading to streams at subreach to watershed scales.
IMPACTS OF TRANSPORTATION INFRASTRUCTURE ON STORMWATER AND SURFACE WATERS

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Transportation infrastructure is a major source of stormwater runoff that can alter hydrology and contribute significant loading of nutrients, sediment, and other pollutants to surface waters. These increased loads can contribute to impairment of these streams and ultimately Lake Champlain. In this study we selected six watersheds that represent a range of road types (gravel and paved) and road densities (rural, suburban, and urban) present in Chittenden County. Road networks were characterized and quantified for each watershed using GIS analysis. Monitoring stations in each watershed were constructed and instrumented to measure discharge and water quality parameters continuously from spring through early winter. Storm event composite samples and monthly water chemistry grab samples were collected and analyzed for total nutrients, chloride, and total suspended sediments. Preliminary results from two field seasons of monitoring suggest that road type and road density may be closely linked with the level of impairment in each watershed. Water quality data from storm event composite samples and monthly grab samples show a significant increase in total phosphorus and total nitrogen along a gradient of increasing road network density. Chloride concentrations increase several orders of magnitude along this same gradient. Total suspended sediment levels are highest in the urban and suburban watersheds but the presence of gravel roads in rural watersheds may result in increased sediment loading relative to other water quality parameters.
MONITORING THE EFFECT OF TILE DRAINAGE ON PHOSPHORUS LOSSES FROM AGRICULTURAL FIELDS

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This poster summarizes key findings from a long-term field study (2001-2007) conducted by the Brace Centre for Water Resources Management at McGill University. The main objective of the study was to improve current understanding of field-scale nutrient dynamics, especially phosphorus, as influenced by agricultural management practices. This was achieved by quantifying non-point source pollution (sediments, phosphorus and nitrates) from surface runoff and tile drainage losses from agricultural fields in the Pike River Watershed of Southern Quebec, which drains into the Missisquoi Bay of Lake Champlain. Four fields were instrumented to monitor surface and subsurface hydrology all year round, and water quality samples were analyzed for nutrient concentrations, which were translated to annual loads. Tile drainage was installed at two of these fields whereas the other two fields were naturally drained. The fields used were characterized by sandy loam and clay loam soils, and crops grown ranged from corn, soybean, alfalfa, cereals (wheat, barley) and hay (pasture).
START-UP PERFORMANCE OF A STORMWATER TREATMENT SYSTEM FOR DAIRY BARNYARD RUNOFF AT SHELBURNE FARMS

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Controlling agricultural runoff from dairy farm barnyards is critical for protecting downstream water quality and minimizing agricultural pollution. This study assessed the start-up performance of a stormwater treatment system (consisting of an inlet pond, gravel wetland, and outlet pond connected in series) at reducing pollutants in agricultural runoff from a 5-ha dairy barnyard catchment on a 110-head dairy farm in northwestern Vermont. Between July and December 2009, treatment performance was assessed by 1) comparing pollutant concentrations at the inlet and outlet of the treatment system during storm flows and non-event flows, and 2) determining pollutant removal efficiencies for the gravel wetland during two storms. Mean concentrations at the treatment system’s outlet were significantly lower ($p < 0.05$) than at the inlet during storm flows for total phosphorus (TP), particulate phosphorus (PP), total dissolved phosphorus (TDP), dissolved reactive phosphorus (DRP), and total suspended solids (TSS). Mean storm flow concentration reductions for TP (n=12), PP (n=10), TDP (n=10), DRP (n=10), and TSS (n=12) were 43, 47, 37, 52, and 25%, respectively. Outlet \textit{E. coli} concentrations were not significantly lower ($p = 0.2065$) than at the inlet but were lower for 8 of 11 sampled storm events. Pollutant concentrations at the treatment system’s outlet were sometimes higher than at the inlet, possibly because of post-construction erosion of the inlet pond overflow. For two intensively sampled storm flows in mid-November and early December, the gravel wetland retained, respectively, 130 and 80 g of P and 7.2 and 9.2 kg of TSS, which represented P removal efficiencies of 39 and 13% and TSS removal efficiencies of 42 and 38%. Our results demonstrate that the gravel wetland reduced TSS and P loads during two storms and that the stormwater treatment system often reduced outlet pollutant concentrations in runoff during its first five months in operation. Start-up performance data provide promising evidence that the treatment system is likely to continue reducing pollutants in agricultural runoff as the system re-vegetates and matures.
HYDROPEDOLOGICAL CLASSIFICATION OF LANDSCAPE USING DIGITAL TERRAIN MODEL AND MULTISPECTRAL DATA

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Agricultural landscapes vulnerable to surface runoff are significant sources of sediment and phosphorus exports to aquatic ecosystems. Spatial distribution of these non-point exports in response to runoff events vary significantly according to soils physico-chemical properties and their relative position occupied within the landscape. Current soil data available for the Missisquoi Bay region in Quebec does not portray adequately the spatial distribution in soil properties in order to support site specific, optimal cropping systems. Recent acquisition of LiDAR elevation data and digital soil mapping techniques provide valuable opportunities to better picture the spatial variability in soil properties and moisture regime. The objective of this study is to develop and validate a hydropedological classification of the landscape adapted to precision conservation cropping. The approach combines the spatial analysis of a high resolution digital terrain model (LiDAR-DTM) as well as multi-date airborne and satellite images to subdivide the Ewing watershed (45 km2) into homogeneous management units having similar soil type and drainage classes. A laboratory experiment first provides the calibration of the reflectance signal of 120 undisturbed core samples with respect to varying soil moisture and soil physico-chemical properties. At watershed scale, the landscape is segmented using fuzzy classification of DEM and reflectance data, thanks to LandMapR© spatial tool kit. The validation of the landscape classification is supported through 269 morphologic field observations. From an operational perspective, potential outcomes of this study are a better use of farm inputs and increased farm profits, while reducing environmental impacts of cropping systems.
A COMPARATIVE STUDY OF WETLAND VEGETATION IN THE
AUSABLE AND BOQUET RIVER WATERSHEDS

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The Ausable and Boquet Rivers are two of New York’s major tributaries to Lake Champlain and are often referred to as the Ausable/Boquet Subbasin. The subbasin receives drainage from 795 square miles and includes many wetlands with diverse habitat types. A total of 768 sampling sites within 56 wetlands, 324 in Ausable and 444 in Boquet, were surveyed in summers 2005-2006 and 2008-2009. Sampling locations were selected in each wetland in order to survey as many different vegetation associations as possible. A total of 470 plant species were recorded including 138 species of woody plants, 85 species of graminoids, 23 species of pteridophytes, and 224 species of herbaceous. We noted 50 exotic species, 14 invasive species, two threatened (New York State) species and two endangered (New York State) species. An additional 34 species are listed as Exploitably Vulnerable by New York State Natural Heritage Program. Herbaceous plants were the most abundant group and accounted for 48% of all species found in the Subbasin (45% Ausable, 49% Boquet). The least abundant group is pteridophytes (5%).

The Ausable housed a greater number of plant species (368) than the Boquet (332) as well as greater numbers of native, exotic, invasive and vulnerable species. Chi Square statistics were used to find the differences in the presence of plant species between the two watersheds. A statistically significant difference was observed between the species present in the two watersheds ($p < 0.001$). Statistically significant differences were also observed between native ($p < 0.001$), exotic ($p = 0.001$) and vulnerable ($p = 0.005$) plant species. However, no significant difference was found between invasive plant species ($p = 0.505$). Differences in plant species between the two watersheds might have resulted from sampling and variations of multiple environmental factors including elevation, land use, nutrient levels, traffic, human populations, etc.
Subaqueous soils support rooted aquatic vegetation and are formed in shallow water sediments that have been exposed to subtle soil-forming processes. They have been classified within the NRCS Soil Taxonomy system under organic or mineral soil orders. Subaqueous soils have a topographic relationship to subaqueous landforms similar to the relationships terrestrial soils have to their landscapes, but are also subject to on-going underwater sedimentation and erosion processes.

A cooperative pilot project in Vermont will test the concept of using SAS as a tool for identifying, mapping, and characterizing types of shallow sediments in Missisquoi Bay. The project is one of the first efforts in the country to test this approach in freshwater sediments. Subaqueous soil maps and supporting data may be of great value in lake management and water quality and groundwater discharge issues, providing new information to better understand nutrient cycling, carbon sequestration, and potential invasive aquatic species habitats. If successful, it is hoped that this study will be applied to other waterbodies in the state.

Sediments in the lake have been studied before. In the past, researchers have taken cores and have wondered about the spatial variation of sediment types in the lake. They have also wished for more detailed bathymetry. In the pilot project, the first step will be to create a detailed bathymetric survey of the study area. Based on that information, subaqueous landforms will be identified, and their soils sampled. A detailed sampling and characterization effort (mineralogical, chemical, biological) will provide data to support new taxonomic criteria for freshwater subaqueous soils.

One of the goals of this project is to test the utility of various products and develop a set that will meet the needs of many constituents. The initial products planned include:

1. Maps of the subaqueous soil types that occupy the shallow water areas
2. Lab datasets for subaqueous soil types, including textural analysis, chemical data, mineral characterization, and nutrient analysis
3. Characterization criteria to describe subaqueous soil types
4. Interpretive information for various resource concerns
AN ADAPTIVE APPROACH FOR MANAGING COLONIAL BIRDS ON FOUR BROTHERS ISLANDS, LAKE CHAMPLAIN

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Four Brothers Islands support the most diverse population of colonial birds in Lake Champlain, but also one of the densest. More than 10,000 pairs of gulls and 4,000 pairs of double-crested cormorants nest on these islands. So do some uncommon species, such as Caspian Terns, Black-crowned Night Herons, and Great Egrets. Large numbers of gulls have coexisted with rarer species for many years, but growing numbers of cormorants is a recent phenomenon and one that has led to substantial habitat loss. In 2008, we initiated an effort to modify both numbers and distribution of cormorants among the four islands, with an objective of protecting tree cover on two islands, A and B, that provide important habitat for herons and egrets. The approach involved an experimental program of applying corn oil to eggs of selected cormorant nests. The goal was to reduce habitat damage on two islands in two ways: (1) by suppressing reproduction of cormorants, and (2) by encouraging cormorants to abandon islands A and B and nest on the two islands, C and D, with few live trees. An associated goal was to conduct this population management without dispersing cormorants to other sites in Lake Champlain.

In 2008, cormorants laid eggs in 3833 nests; 2221 of these were treated with corn oil. Numbers were similar in 2009, with 2161 of 3996 nests being oiled. Reproductive success is being monitored, and colored bands with unique codes have been attached to nearly 2000 adult cormorants. Repeated observations of banded birds throughout the nesting season is providing data that indicate our success in encouraging birds from islands A and B to shift their nesting sites to islands C and D. Data on survival, fecundity, and dispersal are being analyzed to simulate long-term effects of this experimental management and to provide guidance in adapting treatments as the management continues.
AMATEUR BASS TOURNAMENT ANGLERS AND THEIR KNOWLEDGE OF AQUATIC INVASIVE SPECIES

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Knowledge of aquatic invasive species (AIS), and AIS spread prevention behavior of boaters and anglers continues to be of interest to natural resource managers. We have previously reported on the knowledge and behaviors of Lake Champlain boaters and professional tournament anglers. More recently we began a survey of amateur tournament anglers (i.e. NY Bass Chapter Federation; n=986). We gathered data about their knowledge of AIS spread prevention measures, and the degree to which they have adopted these measures. Preliminary analysis of the survey responses suggests that amateur tournament anglers are quite knowledgeable about AIS. Between 77% and 91% reported they could identify such important species as Eurasian Watermilfoil, Water Chestnut, Hydrilla, Water Hyacinth, Brazilian Elodea, Fanwort, Alewife, Round Goby, White Perch, Northern Snakehead, and Zebra/Quagga Mussels. Respondents were diverse in their assessment of the degree of harm many of these species cause. Not surprisingly, AIS known to favor Largemouth Bass (i.e. Eurasian Watermilfoil, Hydrilla) were generally not labeled harmful, though 35% strongly agreed that Water Chestnut is harmful to fish and aquatic wildlife. Slightly over half (51%) did not know if Spiny Waterflea were harmful to fish and aquatic wildlife, though 74% strongly agreed that viral hemorrhagic septicemia did represent an important threat. Respondents were largely knowledgeable about AIS vectors with 53% ranking the Erie Canal system, and 67% ranking aquaria releases as very important pathways. Thirty nine percent ranked tournament angling as a very important AIS pathway. As expected, lake visitation was high with 42% of respondents reporting visiting between 9 and 12 lakes annually. When polled about the average number of days their boat was out of water between fishing trips, 13% indicated an average of 1 to 3 days, while 43.5% reported an average of 5 or more days.
LOOOOONG-TERM TRENDS IN VERMONT LAKES

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The Vermont Lay Monitoring Program has sampled Vermont lakes and Lake Champlain for nutrient enrichment concentration for 31 consecutive years. These long-term trends tell varying lake stories and will be presented through a colorful poster about the program. The poster also credits and features the many volunteer monitors who have documented important trends in Vermont lakes and in 20 locations on Lake Champlain.
THE COMPOSITION AND ABUNDANCE OF BENTHIC MACROINVERTEBRATES IN THE METTAWEE RIVER: A STUDY OF WATER QUALITY IN THE LOWER LAKE CHAMPLAIN BASIN

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The Mettawee River in Southern Vermont drains approximately 400 square miles of land and is a major contributor to water quality in lower Lake Champlain. Numerous studies have documented that macroinvertebrates serve as efficient indicators of water quality. The present study uses macroinvertebrates to evaluate water quality along a 12 km length of the Mettawee River. For this study, a total of four sampling sites were selected and included a forested site (Fs1) near the headwaters, a mixed-use site (Mu1) 4 km down river, an agricultural site (Ag1) 4 km down river from Mu1, and another agricultural site (Ag2) 4 km down river from Ag1. Four samples were collected in September, 2009 from each site using the Vermont Department of Conservation protocol. Macroinvertebrates were sorted and identified to the family taxonomic level. Biotic indices (indicators of water quality), including the total number of taxa, Ephemeroptera/Plecoptera/Trichoptera (EPT) index, and Hilsenhoff Biotic Index (HBI) were calculated from the macroinvertebrate data. Results show a distinct community difference between the four sites with increased filter feeder abundance and increased numbers of pollution tolerant taxa at each successive down-river site. Total number of taxa and EPT richness were highest in the head water site (Fs1) and lowest in the down-river site (Ag2). The HBI indices ranged from 3.54 (Fs1) to 4.53 (Ag2), indicating very good to good overall water quality. The biotic indices reveal a trend toward higher water quality in the head water site and slightly lower water quality in the down stream agricultural sites. These results provide important baseline data for water quality in the Mettawee River and the impact the Mettawee River has on water quality in Lake Champlain. The relationship between land use, levels of growth-limiting nutrients, and water quality in the Mettawee River and Lake Champlain will be discussed.
Diet Selectivity of White Perch (Morone Americana) in Lake Champlain

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White Perch are an established invasive species in Lake Champlain, and the effects of their establishment on the lake’s ecosystem are still not completely clear. We analyzed the gut contents of White Perch and took plankton tows during the summer of 2009 to determine if the largely zooplanktivorous White Perch were feeding selectively. During the months of June and July, White Perch showed preferential selection of Daphnia over other types of zooplankton, even when Daphnia were not the most abundant type in the environment. The overall diet of the White Perch in 2009 was not similar to that found three years earlier by White and Facey (2009), when Leptodora were abundant in the diet of White Perch in late June and mid July. Couture and Watzin (2008) found positive selection for Leptodora in mid-late July. Recently, another invasive species, Alewife (Alosa pseudoharengus), has become established in Lake Champlain. Both of these species are zooplanktivores and perhaps the presence of Alewife has led to changes in zooplankton assemblages. In further studies it would be valuable to also study the stomach contents of Alewife to determine diet overlap between these two zooplanktivores in Missisquoi Bay, as well as other parts of Lake Champlain. The relative abundance and impact of Alewife on Missisquoi Bay is unclear, but the diet of White Perch has changed.
THE EFFECT OF THE INVASIVE ALEWIFE (ALOSA PSEUDOHARENGUS) ON ZOOPLANKTON IN LAKE CHAMPLAIN

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Lake Champlain contains a diverse assemblage of zooplankton taxa, including Copepods (12 taxa), Cladocera (14 taxa), and Rotifers (19 taxa). Lake Champlain also suffers from an array of threats from invasive species. One of these threats, the Alewife (Alosa pseudoharengus), has recently invaded Lake Champlain. The overall impact of this new pelagic fish on zooplankton communities in Lake Champlain remains uncertain. However, it has been shown that once populations become established, they can quickly dominate the forage fish community in deep temperate lakes (Wells 1970).

The population trends in this study support previous findings that alewife are size selective predators of zooplankton, and that this form of predation is having an effect on zooplankton populations within temperate lake systems. Following 2006, when Alewife became abundant in Lake Champlain the average length, individual biovolume, and total population biovolume for several of the larger species of zooplankton (Leptodiaptomus spp., Macrocylops spp., and Daphnia retrocurva) decreased.
TEMPORAL AND SPATIAL COMPARISONS OF DOUBLE-CRESTED CORMORANT DIETS FOLLOWING THE ESTABLISHMENT OF ALEWIVES IN LAKE CHAMPLAIN

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Double-crested Cormorants receive much attention due to their increasing population numbers in the Great Lakes region and on Lake Champlain. Previous diet studies of cormorants on Lake Champlain indicated potential negative impacts to the yellow perch population. However, with the invasion of Alewife into the lake in 2003, the fish community has changed and cormorants may be feeding on the new forage fish available. We examine the diet of cormorants from four areas of Lake Champlain to assess the current and potential future impacts of cormorants to the changing fish community. During the breeding seasons of 2008 and 2009, spatial and temporal differences in cormorant diets were observed, as well as differences between the years. Alewife were heavily consumed at Four Brothers Islands (54% and 69% yearly weight totals) and South Sea (65% and 61%) sites in both years, with Yellow Perch predominately consumed at Young Island (43% and 58%). Other frequently occurring diet items were Rainbow Smelt, cyprinids, White Perch, and Lepomis spp. The relative importance index values of specific diet items changed as the season progressed. These data demonstrate that the diet of piscivorous birds may vary significantly within a single large water body, and that ideally, management efforts should be site specific.