

PRIME
PARTNERSHIP FOR RESEARCH AND INTEGRATION IN THE MISSISQUOI ECOSYSTEM
SEPTEMBER 12, 2005 – TYLER PLACE, HIGHGATE SPRINGS, VERMONT



Missisquoi River Delta

Cyanobacteria bloom

Rock River

Agenda for September 12, 2005

- 9:45 Welcoming comments
 - Doug Facey – Executive Director, LCRC
 - Pixley Tyler Hill – Tyler Place; President, Friends of Missisquoi Bay

- 10:00 Morning Presentations – General, Toxics, Community Structure

- 12:30 Lunch

- 1:15 Afternoon Presentations – Nutrients, Cyanobacteria Blooms

- 4:00 Discussion and Wrap-up

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List of Presentations and presenters

Morning Session

- Scientists, agencies, and citizens team up to clean up the Missisquoi Bay watershed -
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- Lake Champlain mercury mass balance project - trophic transfer investigations - Neil
Kamman
- Chemical and geochemical content of the sediments of the Missisquoi Bay: first insights
about modern stratigraphy - Gilbert Prichonnet
- Combined coagulation & capping as restoration method: research advances - Rosa
Galvez-Cloutier
- Missisquoi River geomorphic assessment projects - Staci Pomeroy
- The state of the bank and aquatic plants on the Quebec side of Missisquoi Bay - Chantal
d'Auteuil
- Long-term monitoring in Missisquoi Bay - Angela Shambaugh
- Effects of white perch on the plankton community of Missisquoi Bay - Sam Couture
- Diets of some common fishes in Missisquoi Bay - Doug Facey
- The spiny softshell turtle (*Apalone spinifera*) in Lake Champlain: conservation issues -
Patrick Galois
- Presentation on the *Lampsilis*, a new research boat - Gilbert Cabana

Afternoon Session

- Phosphorus transfers within Pike River experimental watersheds network: landscape
controls and management effects - Aubert Michaud
- Basin scale modeling of P dynamics within Pike River basin using SWAT - Isabelle
Beaudin
- Applying spatially explicit dynamic landscape modeling to watershed planning and
adaptive management - Hilary Harp
- Spatial and temporal complexity in P dynamics - a rationale for empiricism in the
Missisquoi Bay watershed - Deane Wang
- Influence of subsurface drainage on water and P movement at the field level - Peter
Enright
- Phosphorus removal by a small, constructed wetland (the Walbridge wetland) - Peter
Enright
- Isotopic tracing of animal wastes and fertilizers into waterbodies - Gilbert Cabana
- Implication of nitrogen in the problems of Missisquoi Bay - David Bird
- Methods to investigate sediment and water column redox chemistry changes associated
with nutrient availability - Greg Druschel
- Mapping cyanobacteria blooms in Lake Champlain using QuickBird, SPOT, and MERIS
satellite data - Leslie A. Morrissey
- Cyanobacteria abundances, cyanotoxin concentrations, and nutrient distribution in
Missisquoi Bay - Mary Watzin
- Herbicides as driving factors for blue-green algal blooms - Tiffany Basara

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Scientists, agencies, and citizens team up to clean up the Missisquoi Bay watershed

Barry Gruessner, Vermont Department of Environmental Conservation

(barry.gruessner@state.vt.us):

Collaborators: many groups and individuals

Local citizen groups, landowners, towns, and public agencies have been working for years to reduce pollution in the 767,000 acre Missisquoi Bay watershed (Missisquoi, Rock, and Pike Rivers). The State of Vermont is building on this work by supporting a collaborative planning and implementation process that brings together landowners, farmers, local officials, business people, scientists, and other concerned citizens to help determine how best to protect and restore water quality in Missisquoi Bay and its watershed. The top public water quality concerns include the impacts of excessive phosphorus and resulting algal blooms in Missisquoi Bay and Lake Carmi; soil erosion; phosphorus in runoff, bacteria, declines in fishing, and the lack of public awareness of how everyone's actions affect water quality. Intense public concern, the severity of the pollution problems, and the significant challenges associated with solving them have put the spotlight on the Missisquoi Bay. In addition to planning and project implementation efforts, research focusing on the Bay and its watershed will provide the information needed to develop the refined management tools needed to reduce the ecological and social impacts of pollution.

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Lake Champlain mercury mass balance project - trophic transfer investigations

Neil Kamman, VTANR - DEC, Water Quality Division
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Other authors/collaborators: Dr. Ning Gao, St. Lawrence Univ.; Dr. Jamie Shanley, USGS,
Montpelier; Dr. Celia Chen, Dartmouth College; Dr. Andrea Lini, UVM.

As part of a multidisciplinary effort to develop an operational mass balance model describing mercury fate and transfer in the Lake Champlain Basin, we are evaluating Hg in water, sediment, and biotic compartments of three Lake Champlain rivermouth-embayments, across a gradient of trophic state. The sites are: Malletts Bay/Lamoille (oligotrophic), Fields Bay/Otter (mesotrophic), Missisquoi Bay/Rock - eutrophic). Our operational hypothesis is that the river mouths and associated wetland deltas of the lake serve as important areas of methylation; this methylmercury ultimately being bioaccumulated via phyto and zooplankton, or benthic organisms, to forage fishes, gamefish, and piscivorous wildlife. We further hypothesize that algal bloom dilution serves to impede bioaccumulation in areas of higher trophic state, and our design specifically addresses this hypothesis. We are incorporating measurements of ancillary parameters and isotopic ratios to aid in interpretation of the patterns we observe. These data will be used to add a biological component to the existing physical model, which is in final review with the journal Environmental Science and Technology.

***Chemical and geochemical content of the sediments of the Missisquoi Bay:
first insights about modern stratigraphy.***

Gilbert Prichonnet, UQAM
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Most of the results exposed here have been presented in the first report on the subject to the Gouvernement du Québec in 2003 (Prichonnet, 2003/ CBVBM, 2003 Vol.2). The current research on the cores are concerning specifically ^{210}Pb and ^{137}C . Sedimentologic analyses have been executed at GEOTERAP(UQAM) laboratories. Metal data are from “SM Inc.”, and geochemical data provided by GEOTOP-UQAM McGill.

The Missisquoi Bay is a very flat and shallow lake basin (4.75m), during the low-water mark. The 4 m isobath is parallel to the 3m, and allows to recognize the prodelta of the Missisquoi River. No specific anomaly has been recorded on the bottom. Finest sediments (silt and clay) brought by the rivers are predominant in comparison with the coarser sediments eroded from the shore. As soon as upon entering the bay, the sandy material, winnowed by wave current, are quickly sorted. On the other hand, silt and clay will be trapped in the distal sedimentation. The thickness of the mud is at least 10 cm everywhere in the deepest part of the basin (60 grabs have been performed). However, 6 of the 7 cores picked up 25 to 40 cm of fine material, almost homogeneous and “very muddy”; generally reduced, with abundant C, N, P and K content. These muddy sediments are found below the 3m isobath. A few molluscs have been observed in the samples.

The finer the sediment, the higher the phosphorous content is: the values increase with the lateral graded bedding. Nevertheless coarser sediments in the protected bays have also an alarming geochemistry! Actually, the N content is too high in surface mud (0,5%), as well as in deeper material. In the deep basin, P(t) (=P total) content of 11 samples reaches 1,3 kg/t. It may be almost as high as 2 kg/t. The C(t) (=C total) content varies between 3 and 4,5%. The aquatic plant production, along with the organic material brought by the eroded soils are causing this situation.

The BMg-91 core has revealed a 136% increase in P(t) content and a 35% increase in K, from the base to the top (40 cm). For the 10-12 upper cm, rate of sedimentation may be as high as 1 $\text{cm}^{-\text{y}}$, but it is only 0,1 $\text{cm}^{-\text{y}}$ for the rest of the datable core: the limit of the ^{210}Pb being of 100-110 years. Among the increase in chemical content, the P and K may appear during the 1940-1945 period, then one can recognise the increase in lead (Pb) which seems to decrease at the top of the core: results which may be attributed to the modern history of gas consumption. The ^{137}Cs content of the BMg-88 core shows a good relationship between the rate of sedimentation (lower in this case, because the core has been drilled near the bay axis of Venise, which is outside – or too far from the river path) and the thermonuclear experiences during the XXe century.

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The P, C, N and K surplus content in the sediments should alarm us about the future of the Bay, which acts like a trap for eroded material. The excess of P(d) (=P dissolved) in running waters is well known. The metals are concentrated in the finest and organic sediments. The good news is that there is no anomaly in the Cd content, in the surface as well as in the deeper sediments. Other heavy metals analysed stay below the “no-effect limit”, but except for two cases for the Ni, and a few cases for the Pb: however the values are below the “minor-effect limit”. The P is everywhere. But it will be convenient to precisely evaluate the natural contribution by the crushed minerals, brought by the glacial flour, which is the primary material of “recent” sediments.

Thanks are extended to: FAQDD Program, people involved in CBVBM and research assistants.

Contenu chimique et géochimique des sédiments dans la baie Missisquoi, Québec, Canada.
Stratigraphie des sédiments récents.

Gilbert Prichonnet, UQAM
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La majorité des résultats présentés ici sobrement sont extraits du premier rapport au Gouvernement du Québec sur le sujet en 2003 (Prichonnet, G., 2003 / CBVBM, 2003, Vol.2). Les travaux en cours sur les carottes incluent en particulier des analyses de ²¹⁰Pb et ¹³⁷Cs. Les analyses sédimentologiques ont été réalisées au GEOTERAP (UQAM). Les données sur les métaux proviennent de « SM Inc. », et la géochimie (C,N et isotopes) a été réalisée au GEOTOP.

La baie Missisquoi est une cuvette lacustre de faible profondeur (4,75m - à l'étiage). L'isobathe de 4 m est parallèle à celle de 3m, et marque l'avancée du prodelta de la Missisquoi, le long de la frontière. Aucune anomalie du fond n'a été décelée. L'apport des sédiments fins (silt et argile) par le réseau hydrographique est très dominant sur la contribution littorale plus grossière. À l'arrivée dans la baie, les sédiments sableux, tractés par la charge de fond, vont subir de nouveaux tris. Le silt et l'argile vont participer à la sédimentation distale. L'épaisseur des boues atteint au moins 10 cm dans l'ensemble de la cuvette profonde (plus de 60 prélèvements par benne). En outre, 6 des 7 carottes contiennent de 25 à 40 cm d'un matériel fin, presque homogène et très “boueux”, généralement réduit, très riche en C, N, P et K. Ces sédiments boueux coïncident à peu près avec l'isobathe de 3 m. Peu de mollusques ont été observés dans les prélèvements.

L'augmentation du P(t) (=Ptotal) est parallèle au granoclassement latéral des particules, bien que les sédiments des fonds des baies montrent aussi une géochimie inquiétante. Il y a surabondance d'azote (0,5% en surface), tant en surface qu'en profondeur.

Au pied du talus qui borde la cuvette “profonde”, la teneur en P(t) montre une moyenne de 1,3 kg/t pour 11 analyses. On peut approcher 2 kg/t. La teneur en C(t) (=Ctotal) est comprise entre 3

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et 4,5%.. La production végétale, combinée à un apport de particules des sols agricoles en voie d'érosion, est responsable de cet état.

La carotte BMG-91 a révélé une augmentation de 116% en P(t) et 35% en K, entre sa base et son sommet (40 cm). Sur 10-12 cm, au sommet, le taux de sédimentation pourrait être de 1 cm/an, et seulement de 0,1 cm/an jusqu'à la limite de détection du ^{210}Pb . Parmi les augmentations en apport chimique, on notera celles du P(t) et du K (vers 1940-1945?), puis l'arrivée du Pb, qui diminue au sommet de la colonne : en relation probable avec l'histoire de l'essence consommée. Le contenu en ^{137}Cs de la carotte BMg-88 montre la relation entre la vitesse de sédimentation (plus faible, car dans l'axe de la baie de Venise, abritée ou trop loin des apports des rivières) et l'événement historique des explosions thermonucléaires au XXe siècle.

Les surplus de P(t), C(t) et N dans les sédiments nous questionnent sur le devenir du milieu semi-fermé que constitue la baie. Le surplus du P(d) (=Pdissous) dans l'eau de surface est bien connu. Les métaux se concentrent dans les sédiments les plus fins, organiques. Fait encourageant, les analyses de cadmium n'ont révélé aucune anomalie, tant en surface qu'en profondeur. Les autres métaux lourds recherchés restent en-dessous du « seuil sans effet », sauf dans 2 cas pour le nickel et quelques cas pour le plomb: mais on reste en-dessous du « seuil à effets mineurs ». Le P est présent partout. Mais il conviendra d'évaluer avec plus de précision la contribution naturelle par les minéraux broyés et transportés dans la farine glaciaire à l'origine des sédiments "naturels".

Remerciements : Fonds FAQDD. CBVBM : personnel, partenaires. Assistants/tes de recherche.

Combined coagulation & capping as restoration method: research advances

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Numerous Canadian lakes suffer from water contamination, acidification and early degradation. Forty three areas in the Great Lakes, 5 ports along the St-Lawrence River present bottom sediments that are considered contaminated. Since 1998, fish consumption advisories have been issued for more than 2,506 bodies of water in Canada and USA. Based on early research results, this project proposes to demonstrate that the combined use of coagulation and enhanced capping (using natural reactive materials) can serve as a technique to stop the migration of pollutants contained in bottom sediments and in the water column in polluted lakes and bays. Two sites are proposed as models for the demonstration: Lake St-Augustin, which is the last natural lake in urbanized Quebec Region and is highly contaminated and Missisquoi Bay in Champlain Lake which is subject of an international agreement for restoration. This technique will ensure: 1) clean-up of water column, 2) isolation of bottom contaminated sediments and retention of their contaminants and 3) attenuation of input contaminants carried by groundwater or surface water fluxes. The proposed technique presents an innovative solution to recuperate degraded ecosystems and water usages (e.g. as source of drinking water, better aesthetics, and recreational activities). This method constitutes a curative approach where preventive measures have been proven insufficient. The method is developed using not only a rich pluridisciplinary approach but equally importantly a transdisciplinary multilevel approach. The technical design of the 'active capping/coagulation method' will be developed by civil engineers and scientists in areas of geology, hydrogeology and geochemistry. The solution will be evaluated for its biological compatibility by toxicologists and ecologists using the innovative microcosm tool. The research team is in close contact with both model sites stakeholders (politicians, citizens, water users, economical actors). This contact have been ongoing in the last 5 years by close discussion, conferences, informal vulgarisation meetings with the members of the Watershed Association of St-Augustin lake and Corporation of Bay Missisquoi which are active partners in this project. This interaction has resulted in continuous feedback and mutual agreement during work progress. This method of developing knowledge, science and technology and direct knowledge transfer is compatible with sustainable development.

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Missisquoi River geomorphic assessment projects

Staci Pomeroy, VT DEC
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(Summary not available)

The state of the bank and aquatic plants on the Quebec side of Missisquoi Bay

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Other authors/collaborators: Gilbert Prichonnet, Sylvain Arsenault

The study of the state of the bank of Missisquoi Bay during the summer 2001, by Mr. Gilbert Prichonnet and two students, demonstrates that almost all of the shoreline is occupied by property development. The inventory divided the state of the bank into 3 categories: stone pitching, retaining walls, and natural or vegetation bank. A mapping was done and some details were collected on each of the 500 properties, such as erosion, deterioration of the stabilization work, falling trees, etc. The natural sections are principally located in Saint-Armand and are represented by a cliff to the South and a wetland at the mouth of the Pike River. Those natural sites are protected by vegetation and erosion is not a real problem. The artificial bank presents alternated sections of stone pitching and retaining walls. Walls are in good shape along the roads but generally not along the waterside properties. A lot of rock embankments in Saint-Georges-de-Clarenceville are covered with some vegetation, which is better for the water quality of the shore.

The study of the aquatic plants presents the results of aquatic vegetation inventories performed in 2001 and 2002 at 771 sampling sites in Missisquoi Bay (Sylvain Arsenault, EXXEP Environnement). A complete cartography of the aquatic plant communities observed is also presented. The results obtained confirm that the dominant vegetal species of the area is the American eel-grass (*Vallisneria americana*). The Eurasian watermilfoil, an introduced species considered problematic in many water bodies of the Quebec province, is also found in most areas of the Bay. However, its density is generally low. The aquatic vegetation density map demonstrates the covering percentage by the vegetation is lower in the east portion of the Bay, whereas it increases significantly in the western portion, particularly in the Venise Bay.

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Long-term monitoring in Missisquoi Bay

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Coauthors/collaborators: Pete Stangel and Eric Smeltzer (VT DEC),
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The Lake Champlain Long-Term Water Quality and Biological Monitoring Program was established in 1992 by the Lake Champlain Basin Program, in cooperation with the Vermont and New York Departments of Environmental Conservation. Currently, 14 stations are monitored for more than a dozen water quality and biological parameters, at roughly two week intervals from May through October. A full description and data from this program are available on-line (www.anr.state.vt.us/dec/waterq/lakes/htm/lp_longterm.htm). A single station in Missisquoi Bay has been monitored as part of this program since 1992. We will present summaries of available plankton information as well as pertinent long-term water quality data.

Effects of white perch on the plankton community of Missisquoi Bay

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Collaborator: Mary Watzin

White perch invaded Missisquoi Bay over the last decade and have become extremely abundant in most areas of the bay. The objective of this study is to determine the diet of white perch (*Morone americana*) in Missisquoi Bay in order to investigate whether the establishment of this white perch population has contributed to cyanobacteria dominance of the phytoplankton community through changes in the trophic structure. The effect of a large population of white perch feeding heavily on daphnids in Missisquoi Bay may have shifted trophic conditions to a state in which summer dominance by cyanobacteria is favored through various mechanisms.

Two types of data have been collected. First, white perch adults and zooplankton were collected at approximately weekly intervals from May through August 2005. White perch were collected in the early morning by gill net and hook and line. Zooplankton were collected using 202 μm vertical net tows. White perch gut contents will be compared to relative abundances of zooplankton to determine the prey selectivity of white perch adults and to look for changes in zooplankton composition over time that may be resulting from those selections. Second, laboratory feeding experiments were conducted to measure selectivity more precisely and to determine the ability of white perch to deplete daphnid or other zooplankton populations through grazing. Experiments were conducted in 200 L experimental tanks. Pairs of fish were offered differing densities and size distribution of zooplankton in 12 hour feeding trials. Zooplankton samples were collected at the beginning and end of each experiment. By combining the field and laboratory data, we hope to develop a comprehensive picture of the potential effects of white perch on zooplankton community in Missisquoi Bay.

Diets of some common fishes in Missisquoi Bay
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 Coauthors: Leilani Courtney, Ann Gulka

We studied stomach contents of four common fishes caught in Missisquoi Bay during the late spring and early summer of 2005. This will provide a better understanding of the Missisquoi Bay food web, including the impact of non-native fishes on the Bay's biological community and the potential link between food web dynamics and cyanobacteria blooms. White perch, yellow perch, and pumpkinseed sunfish were captured from the southern part of the Bay in late April, 2005 by seining by Vermont Fish and Wildlife Department personnel. These three species and some golden shiners were capture in Goose Bay and Rock River Bay in the northeastern part of Missisquoi Bay in early June by electrofishing with US Fish and Wildlife personnel. Our results show considerable overlap among the diets of the invasive white perch and the native yellow perch and pumpkinseed sunfish; these three species fed primarily on benthic invertebrates. Golden shiner looked at thus far ate almost exclusively the cladoceran *Bosmina longirostris*.

Table 1. Mean percent diet, based on number of items in the stomach, of four common fishes in Missisquoi Bay. Values shown are rounded off, and only items making up at least 5% of the diet of one of the fish species studied are included in the table.

	Insects			Crustacea				Mollusks		Annelids
	<i>Hexagenia</i>	Chironomids	Caddisflies	Amphipods	Isopods	Chydoroidea	<i>Bosmina</i>	Gastropods	Bivalves	Leeches
April 23-30 - southern Missisquoi Bay										
white perch (n=25; 20-29 cm TL)	39	39	2	7	6	0	0	0	0	7
yellow perch (n=25; 16-22 cm TL)	6	41	0	0	11	0	0	16	2	0
pumpkinseed (n=25; 13-21 cm TL)	15	34	0	4	3	0	0	26	10	5
June 8 - Rock River Bay										
white perch (n=14; 18-23 cm TL)	0	35	1	22	2	29	0	1	7	0
yellow perch (n=25; 12-19 cm TL)	1	32	0	40	<1	13	0	2	2	0
pumpkinseed (n=20; 10-18 cm TL)	1	15	1	12	1	2	0	40	23	1
golden shiner (n=8; 7-21 cm TL)	0	0	0	0	0	0	100	0	0	0
June 8 - Goose Bay										
white perch (n=5; 15-20 cm TL)	42	42	5	5	0	0	0	0	0	0
yellow perch (n=25; 13-22 cm TL)	1	30	10	21	12	17	0	0	4	0
pumpkinseed (n=25; 13-18 cm TL)	2	7	5	10	5	12	0	25	17	2
golden shiner – yet to be determined										

The spiny softshell turtle (*Apalone spinifera*) in Lake Champlain : conservation issues

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Between 1995 and 1999 a study was conducted on the Eastern Spiny Softshell Turtle (*Apalone spinifera*) in the northern part of Lake Champlain (Québec, Vermont) where it is at the northern limit of its distribution range and considered threatened. Telemetry revealed that home ranges were generally made of a spring-summer habitat and a fall-winter habitat. The turtles migrate between these two areas at the beginning of May and at the end of August. The different areas used by the turtles were spread over a large territory during the spring-summer period and associated with natural habitats. Telemetry data allowed us to determine that most turtles spent fall and winter in a common habitat located less than 50 meters south of the East Alburg bridge. The area served as a major overwintering site. Different threats such as habitat alteration and loss, nest over predation, boat injuries and collisions, and fishing were documented. An awareness and education campaign and a stewardship program were implemented involving different local partners. In 2004, major construction work leading to the construction of a new bridge and the demolition of the old one began. The Québec Spiny Softshell Turtle Recovery Team started a new study in spring 2004 in order to document the impact of this bridge construction on the turtles. Different questions were raised on the use of the site prior to construction, during and after construction; the potential impact of the bridge construction on the rest of the home range; the possible direct deaths (machinery) or indirect deaths (use of lower quality habitats); how the turtles may adapt to the new conditions; and if the observed changes will be temporary or permanent. Preliminary results from the first year of the study (2004) suggest that less turtles stayed at the hibernation site of East Alburg bridge, as compared with the results obtained in the past. Moreover, larger movements of turtles in late fall suggest disturbance by the construction. Telemetry monitoring and bridge construction continued in 2005, and more data will help in better assessing the impact on turtles use of the area and winter survival.

La tortue-molle à épines (*Apalone spinifera*) au lac Champlain : enjeux de conservation.

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De 1995 à 1999, une étude a été menée sur la tortue-molle à épines (*Apalone spinifera*) au nord du lac Champlain, soit à la limite nord de répartition de l'espèce où elle est considérée menacée. La télémétrie a montré que les domaines vitaux étaient généralement constitués d'une aire de printemps et d'été et d'une aire d'automne et d'hiver. Les tortues se déplaçaient entre ces deux aires au début du mois de mai et à la fin du mois d'août. Ces différentes aires utilisées par les tortues étaient réparties sur un large territoire durant la période de printemps et d'été et associées à des habitats naturels. La télémétrie nous a également permis de montrer que la plupart des tortues se concentraient dans un habitat situé à 50 m au sud du pont d'East Alburg, et ce durant l'automne et l'hiver. Ce secteur constitue en fait un site d'hibernation majeur. Différentes menaces ont également été documentées comme la modification et la perte d'habitat, la prédation excessive des nids, les blessures et les collisions de bateaux et la pêche. Des programmes de sensibilisation et d'éducation ainsi que d'intendance ont été mis en place avec des partenaires locaux. En 2004, des travaux majeurs de construction d'un nouveau pont et de la démolition du vieux pont d'East Alburg ont débuté. L'équipe de rétablissement de la tortue-molle à épines du Québec a démarré une étude au printemps 2004 visant à documenter l'impact de ces travaux sur les tortues. L'équipe souhaitait répondre à plusieurs questions sur l'utilisation du site avant, pendant et après la construction, l'impact potentiel sur le reste du domaine vital, la possibilité de mortalités directes (machinerie) et indirectes (utilisation d'habitats de moindre qualité), sur l'adaptation des tortues aux nouvelles conditions et sur la persistance des changements observés. Les résultats de la première année d'étude (2004) suggèrent que moins de tortues ont hiberné au site du pont d'East Alburg comparés aux années antérieures. De plus, les tortues ont effectué des mouvements importants tard en automne, probablement en réaction aux travaux de construction. Le suivi télémétrique et la construction ont continué en 2005 et la collecte de données additionnelles devrait permettre de mieux évaluer l'impact sur l'utilisation du site par les tortues et sur leur survie à l'hibernation.

***Phosphorus transfers within Pike River experimental watersheds network:
landscape controls and management effects.***

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The objectives of a research program conducted on a network of three experimental watersheds within the Pike river basin, were 1) to describe the non-point source P transfer to the aquatic ecosystem, 2) relate spatial variability in P mobility to landscape and agricultural production systems descriptors and 2) to evaluate the effectiveness of BMP's implementation on P transfer. Spatial sampling of Beaver Brook subwatersheds (11 km²) and outlet monitoring highlighted a landscape-driven hydrologic control on the spatial pattern in P transfer, as well as an influence of manure P sources management. Following implementation of riparian buffers and catch basins along most hydrologically active areas of watershed, temporal trend in water quality from the downstream station indicated a 25% reduction in total P flow-weighted concentration during peak flow events from a reference period (1997-1999) to successive assessment periods 1999-2001 and 2001-2003. The Walbridge twin-watershed experiment (2 X 6-8 km²) was established in 2001 to more specifically asses P loads reduction related to structural runoff controls and riparian buffer management. ANCOVA analysis of P concentration data with respect to stream flow highlighted significantly different patterns in P Concentration/stream flow (C/Q) at the watersheds outlets, related to distinctive landscape pattern and P mass balance. Planning and implementation of best management practices (BMP's) on test watershed were based on spatially-referenced data including 1) a precision-scale digital elevation model (DEM) and derived surface runoff flow paths, 2) hydrologically active areas revealed by multispectral airborne photography and 3) erosion marks photographed in early spring and located by GPS. Data were integrated within user-friendly electronic atlas and delivered to farm managers and extension personnel in order to support treatment of critical erosion and runoff-sensitive areas. On-going outlet monitoring of twin watersheds through the evaluation period (2005-2007) will enable an evaluation of BMP's efficiency. Installation of multi-probes at the monitoring stations in fall 2004 will also support the investigation, on a runoff event base, of surface/subsurface flow paths, retention/release of in-stream P stock and C/Q hysteresis.

Basin scale modeling of P dynamics within Pike River basin using SWAT

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The sensitivity and predictive capacity of SWAT were tested on the Pike River basin (630 km²) and at a smaller scale on the Beaver Brook (11 km²) and Walbridge twins (6-8 km²) sub-basins, which present contrasting landscape attributes. The hydrologic response units and input parameters required by SWAT were derived from DEM, soil maps, remote sensing data and from spatially referenced farm census and soil test data. The model reproduced satisfactorily the actual flows over the entire watershed. The monthly sediment and P results for the Beaver and Walbridge sub-basins also demonstrate a good agreement between the modelled and measured yields. These results offer a solid asset for the simulation, with SWAT, of optimal management scenarios that could meet the target phosphorus loads set for the Missisquoi Bay. On-going modeling of agri-environmental scenarios includes various levels of BMP's implementation related to cropping systems, conservation tillage, nutrient management, riparian buffers and structural runoff controls.

***Applying spatially explicit dynamic landscape modeling to watershed planning
and adaptive management***

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The Gund Institute for Ecological Economics at the University of Vermont has developed interactive computer modeling tools that capture relationships of ecological and economic processes in watersheds. The modeling framework is designed to include stakeholder participation at all stages of development. In this way, the process provides a platform for discussing policy scenarios for nutrient and stormwater management among diverse groups. We are now developing a series of models for the St. Albans watershed with an emphasis on issues related to phosphorus sources, transport, and management. This work is funded by the Northeast States Research Cooperative. Water quality and flow data are being collected by citizen volunteers in St. Albans and will be used to calibrate the model for this watershed. This monitoring project is designed to identify actual loads of pollutants from agricultural, residential, and urban areas.

The goal of the modeling framework is to identify the best places to locate technologies and management practices for remediation of non-point sources from agricultural, residential, and urban land areas.

The model will help communities maximize reduction of nutrients and sediment at a minimal cost. Our framework will also provide a mechanism to evaluate new policy scenarios for their effects on water quality. As stakeholders and community members from St. Albans work together to learn more about water pollution issues, their experiences will also be evaluated to better understand how collaborative relationships form in situations with high levels of scientific uncertainty and conflict in the context of computer modeling. It is hoped that the results will be used by local governmental bodies to develop more effective policies and education plans for remediation of phosphorus.

***Spatial and temporal complexity in P dynamics - a rationale for empiricism
in the Missisquoi Bay watershed.***

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The spatial and temporal complexity in diffuse P emission and transport in streams draining several large lake basins suggests that pattern-process interactions may account for a large proportion of the spatial and temporal variability in P loading to these lakes. Given these important deviations from more linear model predictions of P loading, additional empirical work examining the patterns of variation over space and critical P loading times may be warranted to better characterize the nature of the interactions. A spatially extensive, synoptic sampling program for the Missisquoi Basin looking at 1st and 2nd order streams could provide the basis for more targeted P control strategies.

Influence of subsurface drainage on water and P movement at the field level

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Concentrations of phosphorus (P) above the water quality guideline of 0.03 mg L⁻¹ are commonly found in rivers draining agricultural lands in Quebec. Agricultural non-point source pollution is the dominant source of this P. While the links between P losses, surface runoff, erosion and manure management are reasonably well understood, there is far less information available on the movement of P via subsurface tile drainage systems. Since the majority of intensively managed agricultural lands in Quebec are subsurface drained, this represents a major knowledge gap. Two field sites, located near Bedford, were instrumented to measure and sample surface runoff and tile drainage waters. Site #1 (6 ha) is located on a dairy farm. The soil is a sandy loam with a soil test value of 360 kg Mehlich III (MIII) P ha⁻¹ and a P saturation level of 23%. Site #2 has a surface drainage area of 10.2 ha and a subsurface drainage area of 7.8 ha, and is managed in a corn/wheat/soya rotation. The soil is a sandy clay loam, with a soil test value of 140 kg MIII P ha⁻¹ and a P saturation of 7%. The average slope on site #1 is 1.5% and the average slope on site #2 is 0.8%. Monitoring has been ongoing since October 2000. Results are reported here for the six site-years of data.

Subsurface drainage was the dominant pathway by which water left the fields. On average, tile drainage accounted for 81% of the total annual drainage. Surface runoff was responsible for majority of the annual P losses. It accounted for 60% of the annual total, which was on average 1.09 kg/ha. The flow weighted average annual P concentration in subsurface drainage waters ranged between 0.06 mg L⁻¹ and 0.37 mg L⁻¹. The flow weighted average annual P concentration in surface runoff waters ranged between 0.20 mg L⁻¹ and 2.15 mg L⁻¹. On average, P concentrations in surface runoff were 10.9 times higher than those found in subsurface drainage waters, indicating that subsurface drainage may reduce annual P losses. These results also reveal that soil test P and percent P saturation are, on their own, inadequate indicators of potential for P pollution.

Phosphorus removal by a small, constructed wetland (The Walbridge wetland)

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The Walbridge Wetland (0.12 ha) was constructed during the fall of 2002 in the Mystic sector of Saint Ignace de Stanbridge, and was monitored from May to November, 2003 and 2004, to assess the sediment and nutrient removal efficiencies. The wetland consists of a sedimentation basin (76 m²), a horizontal subsurface flow section (369 m²) and an open water body (1215 m²). Flow into and through the system is gravity controlled. A gated control structure allows for variable inflow rates, and flow rates are monitored using composite V-notch weirs located at the outlet of each section. Flow rates are monitored continually and automated samplers operate during storm events. Grab samples were obtained bi-monthly at each of the sampling points: in stream, the intake control structure, and the outlets of the sedimentation basin, submerged flow section, and open water body, and analyzed at the IRDA laboratory for ammonia, nitrates, orthophosphates, total dissolved and particulate P, Total P, bio-available P, K, Ca, Mg, Na, pH and material in suspension.

The average flow rate in the wetland system was 4.83 l/s (0.005 to 35.8) in 2003 and 4.42 l/s (0.11 to 31.7) in 2004. For **2003**, the mean annual TP concentration decreased from 125 to 84 µg/l (**-33%**) from the inlet to the outlet. The seasonal reductions were 13% (spring), 54% (summer) and 25% (fall). The sedimentation basin had attained a 42% annual reduction, with the submerged flow section achieving a 12% reduction. For **2004**, the mean annual TP concentrations decreasing from 69 to 42 µg/l (**-40%**) with seasonal reductions of 46%, 43% and 28% being observed for spring, summer and fall, respectively. The subsurface flow section had the highest annual reduction rate (28%), followed by the open water body (14%) and the sedimentation basin (12%).

In **2003**, there was a **33.6% reduction** in annual TP load from intake to outlet with a deposition rate of 2.23 g m⁻² operational year⁻¹. In **2004**, annually, there was a **reduction of 42.8%** in TP loads from intake to outlet with a deposition rate of 1.56 g m⁻² operational year⁻¹. Compared to 2003. Within the wetland, both the submerged flow section and open water basin showed similar and significant reduction of TP load in 2003 and 2004 annually and seasonally.

Implication of nitrogen in the problems of Missisquoi Bay

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(Summary not available)

Methods to investigate sediment and water column redox chemistry changes associated with nutrient availability

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Seasonal changes in redox chemistry within sediments and the water column of eutrophic waterways has been shown to influence the flux and availability of nutrients such as phosphorus released by changes in iron and manganese minerals (Rozan et al., 2002). We have recently completed a study in St. Albans Bay documenting phosphorus mobility associated with these processes. While nutrient binding/release associated with bottom sediments is only one of several pathways by which nutrients may be introduced into the water column to drive algal activity, sediment-bound nutrients may play a critical role in the health of some waters. Understanding the pathways and dynamics of reactions that are responsible for nutrient mobility will facilitate better definition of nutrient fluxes from bottom sediments and perhaps shed light on controlling factors that determine N/P ratios, which appear to be correlated with algal ecology (Watzin et al., 2004). We are currently investigating new techniques to characterize nutrient fluxes that may occur as discrete events in time as opposed to constant fluxes, which would significantly impact any modeling formulation of nutrient dynamics. We will discuss the use of voltammetric microelectrodes to determine redox zonation in profile for samples and their potential use as an *in situ* monitoring tool, as well as methods used for extraction and analysis of sediment nutrients and associated elements of concern (such as iron and manganese).

***Mapping cyanobacteria blooms in Lake Champlain using QuickBird, SPOT, and MERIS
satellite data***

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Harmful algal blooms in Lake Champlain (VT-NY-QC) are a serious concern to scientists and the public. Such blooms impact drinking water supplies, recreational use of lake waters, and, if toxic, pose a threat to animal and human health. Current fixed point sampling efforts are of limited value in assessing the spatial distribution and extent of such blooms. Remote sensing, in contrast, offers significant advantages for monitoring the distribution and movement of blooms. Current operational satellite sensors, however, are limited in their spectral or spatial resolution for freshwater applications. This study assessed the utility of three satellite sensors to detect and quantify cyanobacteria blooms in Lake Champlain. Data from QuickBird, SPOT, and MERIS multispectral sensors were acquired coincident with *in situ* water samples in the summers of 2003 and 2004. *In-vivo* fluorescence of chlorophyll and phycocyanin, and transmissivity were measured along 5-15km transects located with GPS. Regression models linking cyanobacteria concentrations and satellite radiances were developed using single band, band ratios, and principal components. QuickBird (2.4m) and SPOT (10m), although designed for terrestrial applications, showed promise for monitoring the heterogeneous spatial distribution of algal blooms and their chlorophyll-*a* concentrations. Designed for marine applications, MERIS proved successful in detecting the presence or absence of blooms in the entire Lake Champlain, although its coarse 300m spatial resolution is of limited value in smaller bays and lakes.

***Cyanobacteria abundances, cyanotoxin concentrations, and nutrient distribution
in Missisquoi Bay***

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We have been systematically monitoring phytoplankton, cyanotoxins and nutrients in Missisquoi Bay since 2002. Blooms of toxic cyanobacteria have been documented in Missisquoi Bay in each of these years. In 2003 and 2004, *Microcystis* spp. dominated the phytoplankton for most of summer, often comprising over 90% of the cell density. Both microcystin and anatoxin *a* have been found in the bay, but anatoxin concentrations remain very low. Microcystin concentrations have varied from year to year and across the summer season. The seasonal average for microcystin in Missisquoi Bay in 2004 was 49 µg/L, but concentrations as high as 6,490 µg/L were found during the height of the bloom. In contrast, *Microcystis* spp. is less dominant in St. Albans Bay, and the seasonal average of microcystin for St. Albans Bay in 2004 was just 2.2 µg/L. Although most high toxin concentrations were found in dense surface accumulations of algae or in shoreline scums, not all scums contained high toxin concentrations. Chlorophyll *a* concentration was not a good indicator of the density of potential toxin-producing cyanobacteria in Missisquoi Bay or other sections of the lake.

Total phosphorus concentrations in Missisquoi Bay frequently exceeded 100 µg/L in late summer and fall in 2003 and 2004. Highest concentrations were generally found in the east side of the bay, and lowest concentrations on the west or southwest side of the bay. TN concentrations were more variable, with highest average concentrations in 2004 near Alburg, on the west side of the bay. DEC Station 50 had low average TP and TN concentrations compared to the other sites we monitored. We have also calculated the ratio of TN:TP in Burlington Bay, St. Albans Bay, and Missisquoi Bay. We found significantly lower ratios at Missisquoi Bay and St. Albans Bay compared to Burlington Bay. Ratios calculated for both Missisquoi Bay and St. Albans Bay suggest nitrogen limitation.

Herbicides as driving factors for blue-green algal blooms

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In 1999, harmful algal blooms (HABs) caused by cyanobacteria, also known as blue-green algae, occurred in the northern parts of Lake Champlain. These blooms produced toxins potentially harmful to humans and other organisms. While the specific cyanobacteria (*Microcystis* sp.) that can generate these toxins have been present in the lake for decades, only recently in the past few years has the lake undergone an ecological change that selects for these species. It is not currently known what specific factors are contributing to the formation of these toxic blooms. Many hypotheses have been suggested, such as the idea that herbicides that have leached into the water are causing selective factors for adaptive species. Previous research has suggested that cyanobacteria may be more resistant to herbicides than eukaryotic algae. Laboratory tests are being done to establish herbicide toxicity levels to species commonly found in Lake Champlain, specifically the Missisquoi Bay region. Some tests were done with atrazine, an herbicide that has been used in great proportions since the mid-1960s, and is found in measurable amounts in many bodies of water. The other herbicides being tested are “new generation” herbicides, which are characterized by high potency to higher plants at very low concentrations (ppb). These include rimsulfuron, nicosulfuron, mesotrione, flumetsulam, and dimethenamid. To date, the new generation herbicides have had no observable effect on our first test species, *Chlorella* sp., a eukaryotic alga. A series of other tests, the Selective Algal Limitation and Distribution (SALAD) experiments, seek to determine if the selective factor is strong enough to be a main trigger of the HABs by observing the composition of phytoplankton in water from Missisquoi Bay over a period of one week after having herbicides added in different concentrations. The SALAD experiments reveal seasonal differences in response to atrazine.