LAKE CHAMPLAIN RESEARCH CONSORTIUM

1998 SPRING CONFERENCE

MAY 26-28

SHERATON CONFERENCE CENTER
BURLINGTON, VT

CASTLETON STATE COLLEGE • JOHNSON STATE COLLEGE • MIDDLEBURY COLLEGE • ST. MICHAEL'S COLLEGE
STATE UNIVERSITY OF NEW YORK, PLATTSBURGH • TRINITY COLLEGE • UNIVERSITY OF VERMONT

THE 1998 LCRC SPRING SYMPOSIUM

This meeting will provide a forum to create a comprehensive treatise on the basin research conducted over the past six years. A special American Geophysical Union monograph will be published from papers specifically submitted for this meeting.

This symposium will follow a similar format to the previously sponsored meeting nearly six years ago in which academic, government, private and student research was publicly presented.

A vast amount of information has been collected in the Lake Champlain basin over the past six years. Studies sponsored by the EPA, NOAA, or private foundations have never been compiled in a way that researchers, planners and administrators could understand all the diverse advances made in this complex system.

Invited overview talks by respected investigators in all major disciplines of research, from land use to complex numerical modeling, will provide the framework of the overall progress made since the last symposium held in 1992. Oral presentations and posters will complete the presentation and provide an excellent public outreach format.

GENERAL SESSIONS

Atmospherics
Cultural & Social Issues
Economics, Land Use & Management
Fisheries & Aquatic Biology
Hydrodynamics & Sediment Resuspension
Nutrients/Chemistry
Toxic Substances
Wildlife (non-aquatic)

From this meeting two documents will be produced. The first will be a bound volume of peer-reviewed papers from many of the symposium participants. This bound volume will be produced by the American Geophysical Union (AGU) as one of their special monograph series. It is expected that this monograph will finally supersede Myer and Gruendling's 1979 work, *The Limnology of Lake Champlain* (an unpublished manuscript) as a more definitive statement of our present knowledge.

In October of 1997, a two-day LCRC and Lake Champlain Basin Program sponsored workshop formulated a set of research priorities for the next several years in a wide range of disciplines. The May symposium will allow us to review and possibly refine these priorities in the light of newer information. While not as structured as the AGU monograph, the second formal document produced would list the updated basin research priorities. It is expected that this document will reside on the LCRC web page for all investigators to review, discuss, and plan with.

PLEASE COMPLETE AND SUBMIT
THE FINAL RESEARCH PRIORITIES REVIEW SHEET INSERTED

TABLE OF CONTENTS

WHAT IS THE LAKE CHAMPLAIN RESEARCH CONSORTIUM?

The Lake Champlain Research Consortium (LCRC) is comprised of seven colleges and universities in the Lake Champlain Basin. The major purpose of the LCRC is to advance basic research and scholarship of the Lake Champlain ecosystem and related issues; to provide opportunities for training and education of students on issues related to Lake Champlain; to aid in a dissemination of information gathered through research endeavors; to implement a program to strengthen scientific research and higher education in the States of Vermont and New York related to Lake Champlain; and to further these purposes through a spirit of cooperation and common commitment among institutions of higher education, state government and other interested parties.

The founding institutions of the LCRC are:

Castleton State College
Martha K. Farmer, President

Johnson State College
Robert Hahn, President
Bob Genter, Faculty Representative

Middlebury College
John M. McCardell, President
Patricia Manley, Faculty Representative

St. Michael's College
Marc vanderHeyden, President
Doug Facey, Faculty Representative

State University of New York-Plattsburgh
Judson Horace, President
Kathleen Lavoie, Faculty Representative

Trinity College
Lorna Duphiney Edmundson, President

University of Vermont
Judith A. Ramaley, President
Al McIntosh, Faculty Representative

LCRC Chairman of Directors: Doug Facey, St. Michael's College

LCRC Executive Director: Tom Manley, Middlebury College

1998 May Symposium Coordinator: Janet Wiseman

1998 LCRC Spring Symposium Schedule of Events
May 26th-28th
Sheraton conference center, Burlington, VT

Tuesday, May 26

7:30 AM-9:00 AM	Continental Breakfast	Emerald Ballroom III
8:00 AM-10:30 AM	Poster set-up	Emerald Ballroom III
9:00 AM-9:40 AM	Opening Session **Guest Speaker-Dr. Horace Judson, SUNY President**	Emerald Ballroom I
9:45 AM-10:25 AM	Featured Speaker *Atmospherics*-Tim Scherbatskoy, UVM	Emerald Ballroom I
10:30 AM-11:20 AM	Poster Sessions & coffee	Emerald Ballroom III
11:20 AM-12:20 PM	General Sessions	
	Atmospherics	Emerald Ballroom I
	Wildlife (Non-aquatic) (I)	Emerald Ballroom II
	Cultural & Social	Univ Amphitheatre
12:30 PM-1:30 PM	Lunch	Emerald Ballroom III
1:30 PM-2:10 PM	Featured Speaker *Nutrients & Chemistry*-James P. Hoffman, UVM	Emerald Ballroom I
2:15 PM-3:35 PM	General Sessions	
	Nutrients & Chemistry (I)	Emerald Ballroom I
	Wildlife (Non-aquatic) (II)	Emerald Ballroom II
	Hydrodynamics & Sediment Resuspension	Univ Amphitheatre
3:35 PM-4:30 PM	Poster Sessions & Coffee	Emerald Ballroom III
4:30 PM-5:10 PM	Featured Speaker *Toxic Substances*-Al McIntosh, UVM	Emerald Ballroom I
6:30 PM-9:00 PM	Dinner @ Sheraton Hotel Dr. William Crosby presents: "Lake Champlain: An Artist's View"	Emerald Ballroom III

Wednesday, May 27

7:30 AM-9:00 AM	Continental Breakfast	Emerald Ballroom III
9:00 AM-9:30 AM	**Guest Speaker-Vermont Senator Patrick Leahy**	Emerald Ballroom I
9:45 AM-10:25 AM	Featured Speaker *Cultural & Social Issues*-Art Cohn, L Champlain Maritime Museum	Emerald Ballroom I

10:30 AM-11:20 AM	Poster Sessions & coffee	Emerald Ballroom III
11:20 AM-12:20 PM	General Sessions	
	Nutrients & Chemistry (II)	Emerald Ballroom I
	Fisheries & Aquatic Biology (I)	Emerald Ballroom II
	Toxic Substances (I)	Univ Amphitheatre
12:30 PM-1:30 PM	Lunch	Emerald Ballroom III
1:30 PM-2:10 PM	Featured Speaker	Emerald Ballroom I
	Fisheries & Aquatic Biology-Mary Watzin, UVM	
2:15 PM-3:35 PM	General Sessions	
	Nutrients & Chemistry (III)	Emerald Ballroom I
	Fisheries & Aquatic Biology (II)	Emerald Ballroom II
	Toxic Substances (II)	Univ Amphitheatre
3:35 PM-4:30 PM	Poster Sessions & Coffee	Emerald Ballroom III
4:30 PM-5:10 PM	Featured Speaker	Emerald Ballroom I
	Hydrodynamics-Tom Manley, Middlebury College	
5:10 PM-6:00 PM	Poster Removal	Emerald Ballroom III
6:00 PM-8:00 PM	Reception	Basin Science Center

Thursday, May 28

7:30 AM-8:30 AM	Continental Breakfast	Diamond Foyer
8:30 AM-9:10 AM	Featured Speaker	Diamond Ballroom
	Management-Lee Steppacher, US EPA	
9:10 AM-10:10 AM	General Sessions	
	Nutrients & Chemistry (IV)	DIamond Ballroom
	Economics, Land Use & Management	Valcour Room
10:10 AM-11:00 AM	Coffee	Diamond Foyer
11:00 AM-11:30 AM	Research Priorities Review	Diamond Ballroom
11:30 AM-12:30 PM	**Guest Speaker-Dr. R. Baird, Director, Sea Grant**	Diamond Ballroom
12:30 PM-1:30 PM	Lunch	Emerald Ballroom III

SHERATON CONFERENCE CENTER

For your convenience, there is a telephone and message board at the LCRC registration desk for incoming calls. The main telephone number of the Sheraton is 802/865-6600.

SPECIAL EVENTS

DINNER AT THE SHERATON
Tuesday, May 26
6:30 P.M.-9:00 P.M.
Emerald Ballroom III
Guest speaker: Dr. William Crosby, Professor of Art, Plattsburgh State University presents his slide show "Lake Champlain: An Artist's View".

GUEST SPEAKER: VERMONT SENATOR PATRICK LEAHY
Wednesday, May 27
9:00 A.M.-9:30 A.M.
Emerald Ballroom I
Almost ten years ago Vermont Senator Patrick Leahy embarked on a campaign to reverse the environmental degradation of Lake Champlain. This campaign included access to the research and expertise of the National and Atmospheric Administration and the National Sea Grant program. This campaign turned into what would be the famous "Great Lakes" debate. Although Lake Champlain was not granted "Great Lakes" status, the campaign for fund access was successful. We welcome Senator Leahy as an important and enthusiastic supporter in the research and preservation of what Vermont will always consider the sixth Great Lake, Lake Champlain.

RECEPTION AT THE LAKE CHAMPLAIN BASIN SCIENCE CENTER
Wednesday, May 27
6:00 P.M.-8:00 P.M.
Join us for a social gathering and appetizers. The mission of the Science Center is to educate visitors about Lake Champlain basin ecology, history and culture in a dynamic hands-on environment. The Science Center is modeled on the ecomuseums of Scandinavia. The entire focus is on communicating a sense of place - providing an in-depth understanding of where the Science Center is located. This model is reflected in the Center's mission which goes beyond the ecology of the basin to include history and culture. As an ecomuseum, the Science Center serves as a mirror for the local population to discover its own image. It is an expression of the interaction of people and nature over time. It is also a learning environment that encourages people to study and understand their role in protecting resources for the future. **(Directions and Map on following page)**

GUEST SPEAKER: DR. ROBERT C. BAIRD, DIRECTOR, NATIONAL SEA GRANT
Thursday, May 28
11:30 AM-12:30 PM
Diamond Ballroom
Now that the colleges and universities in the Lake Champlain Basin have the option to apply for Sea Grant funding, Dr. Baird will present information about this program and how he envisions it can and will help Lake Champlain Basin Research.

Directions to the Lake Champlain Basin Science Center

Right out of the Sheraton Parking lot onto Route 2/Main Street. Follow Main Street to the intersection with Battery St.
Right onto Battery St.
Left onto College St.
The Science Center is down the hill on the left next to the Community Boathouse.

MAP:

NATIONAL SEA GRANT

Our oceans, lakes and bays offer boundless potential for food, for minerals, for medicines. At the same time they also provide the setting for very special places, places which help define who we are, places we revere as well as use.

To make the most of their promise while providing for their protection, the National Sea Grant Program encourages the wise stewardship of our marine resources through research, education, outreach and technology transfer. Sea Grant is a partnership between the nation's universities and National Oceanic and Atmospheric Administration (NOAA) that began in 1966, when the U.S. Congress passed the National Sea Grant College Program Act.

Today, the 29 Sea Grant Colleges are focused on making the United States the world leader in marine research and the sustainable development of marine resources.

Sea Grant meets national needs. It produces and makes available a wealth of information on marine topics - from public school curriculum materials to the most advanced scientific research.

Excepted from the National Sea Grant Web Page:
http://www.mdsg.umd.edu/NSGO/WhatisSeaGrant.html

1998 LCRC SPRING SYMPOSIUM SPONSORS

Lake Champlain Basin Program

Lintilhac Foundation

NOAA Hydrodynamics

NOAA Atmospherics

Middlebury College

Vermont Water Resources and Lake Studies Center

WE GRATEFULLY ACKNOWLEDGE YOUR SUPPORT

Key to Oral Presentations & Associated Abstracts

Keys to oral presentations are in the following format: **Session Hour Day**

Example: **ATM1120T** (Atmospherics at 1120h on Tuesday)

SESSIONS
ATM=Atmospherics
CUL=Cultural & Social Issues
ELM=Economics, Land Use & Management
FIS=Fisheries & Aquatic Biology
HYD=Hydrodynamics & Sediment Resuspension
NCH=Nutrients/Chemistry
TOX=Toxic Substances
WLF=Wildlife (non-aquatic)

T=Tuesday
W=Wednesday
R=Thursday

Key to Poster Presentations & Associated Abstracts

Keys to posters are in the following format: **Topic-P Sequence#**

Example: **H-P2** (Hydrodynamics Poster #2)

TOPICS
ATM=Atmospherics
CUL=Cultural & Social Issues
ELM=Economics, Land Use & Management
FIS=Fisheries & Aquatic Biology
HYD=Hydrodynamics & Sediment Resuspension
NCH=Nutrients/Chemistry
TOX=Toxic Substances
WLF=Wildlife (non-aquatic)

FEATURED SPEAKERS

TUESDAY 0945h Emerald Ballroom I

Atmospherics: Tim Scherbatskoy, University of Vermont

Current knowledge of air pollution and air resources issues in the Lake Champlain Basin - Tim Scherbatskoy, UVM; Rich Poirot, VT DEC and Richard Artz, NOAA **ATM0945T**

TUESDAY 1330h Emerald Ballroom I

Nutrients/Chemistry: James P. Hoffman, University of Vermont

Modeling phosphorus cycling, transport and storage in stream ecosystems typical of the Lake Champlain Basin - James P. Hoffmann, A.E. Cassell, UVM **NCH1330T**

TUESDAY 1630h Emerald Ballroom I

Toxic Substances: Al McIntosh, University of Vermont

Toxic substances in Lake Champlain: A review of research and monitoring efforts - Al McIntosh, Mary Watzin, UVM **TOX1630T**

WEDNESDAY 0945h Emerald Ballroom I

Cultural and Social Issues: Art Cohn, Lake Champlain Maritime Museum

Lake Champlain cultural and social resource management in the 1990's: you can't get to where you're going until you know where you've been - Art Cohn, Lake Champlain Maritime Museum; Susan Bulmer, Vt. Forest Parks and Recreation; Ann Cousins, Lake Champlain Basin Program **CUL0945W**

WEDNESDAY 1330h Emerald Ballroom I

Fisheries & Aquatic Biology: Mary Watzin, University of Vermont

Ecosystem Health in the Lake Champlain Basin: Moving Toward Holistic Management- Mary Watzin, UVM **FIS1330W**

WEDNESDAY 1630h Emerald Ballroom I

Hydrodynamics & Sediment Resuspension: Tom Manley, Middlebury College

Aspects of summertime and wintertime hydrodynamics of Lake Champlain - Thomas Manley, Middlebury College; K. Hunkins, Lamont-Doherty of Columbia University; J. Saylor, G. Miller, NOAA Great Lakes Environmental Research Lab; Patricia Manley, Middlebury College **HYD1630W**

THURSDAY 0830h Diamond Ballroom

Economics, Land Use & Management: Lee Steppacher, US Environmental Protection Agency

Watershed management at a crossroads: lessons learned and new challenges following seven years of cooperation through the Lake Champlain Basin Program - Lee Steppacher, US EPA; Eric Perkins, Lake Champlain Basin Program **ELM0830R**

DETAILED SESSION PROGRAM

TUESDAY A.M.

1120h ATMOSPHERICS
Emerald Ballroom I, Session Chair-Tim Scherbatskoy, UVM

1120h *Air trajectory pollution climatology for the Lake Champlain Basin* - Rich Poirot, Paul Wishinski, VT DEC; Bret Schichtel, Washington University; Phil Girton, VT Monitoring Cooperative **ATM1120T**

1140h *Atmospheric mercury transport and deposition in the Lake Champlain Basin: 1992-1997* - Gerald Keeler, Elizabeth Malcolm, Janet Burke, Scott Deboe, Univ. of Michigan Air Quality Laboratory, Timothy Scherbatskoy, UVM **ATM1140T**

1200h *Mercury cycling and transport in the Lake Champlain basin* - James B. Shanley, USGS; Timothy Scherbatskoy, Andrea Donlon, UVM; Gerald Keeler, Univ. of Michigan Air Quality Laboratory **ATM1200T**

1120h WILDLIFE (NON-AQUATIC) (I)
Emerald Ballroom II, Session Chair-TBD

1120h *Are Champlain Valley forest fragments acting as population sinks for migratory songbirds? Evidence from the Vermont Forest Bird Monitoring Program* - Steven D. Faccio, Kent P. McFarland, Christopher C. Rimmer, Vt. Institute of Natural Science **WLF1120T**

1140h *An assessment of genetic variation in beachpea populations (Lathyrus maritimus Bigel.) on Lake Champlain, Vermont*-Sonja Schmitz, Cathy Paris, David Barrington, UVM **WLF1140T**

1200h *Biogeography, systematics, and conservation biology of the Champlain beachgrass, a taxon endemic to Lake Champlain*-Cathy A. Paris, Peter J. Walker, Sonja Schmitz, David S. Barrington, UVM **WLF1200T**

1120h CULTURAL & SOCIAL ISSUES
University Amphitheatre, Session Chair-Catherine Halbrendt, CDAE, UVM

1120h *Lake Champlain basin education and outreach programs* - Thomas R. Hudspeth, and representatives from CBEI **CUL1120T**

1140h *Watershed planning and Lake Champlain: an examination of the geography of environmentalism*-Richard Kujawa, Saint Michael's College **CUL1140T**

1200h *Institutional arrangements for the Lake Champlain Basin*- James E. Connolly, NY DEC **CUL1200T**

TUESDAY P.M.

1415h NUTRIENTS AND CHEMISTRY (I)
Emerald Ballroom I, Session Chair-Andrea Lini, Geology Dept., UVM

1415h *Measurements of Phosphorus Uptake by Macrophytes and Epiphytes from the LaPlatte River (VT) using 32P in Stream Microcosms* - Deborah Pelton, CRREL; Suzanne Levine, UVM; Moshe Braner, Vermont Health Dept. **NCH1415T**

1435h *Phosphorus cycling, transport, and storage in the LaPlatte River, Vermont* - Deane Wang, E.A. Cassell, John C. Drake, James P. Hoffmann, Suzanne Levine, Donald W. Meals Jr., Adam Brown, Gregory Gustina, Deborah Pelton, Heather Shabunia, UVM **NCH1435T**

1455h *Storage, transport, and decomposition of detritus in the LaPlatte River, VT* - Heather Galarneau, UVM **NCH1455T**

1515h *Retention of spike additions of soluble phosphorus in the LaPlatte River, Vermont* - Donald Meals, James P. Hoffmann, Suzanne Levine, E.A. Cassell, Deane Wang, John C. Drake, Deborah Pelton, Heather Galarneau, Adam Brown, UVM **NCH1515T**

1415h WILDLIFE (NON-AQUATIC) (II)
Emerald Ballroom II, Session Chair-TBD

1415h *Nongame marsh bird abundance and habitat use in managed wetlands of the Lake Champlain Basin* - Nathaniel Shambaugh **WLF1415T**

1435h *Research and management of the common tern on Lake Champlain, Vermont: a case study* - Mark LaBarr, Green Mt. Audubon Society and Christopher Rimmer, VT Institute of Natural Science **WLF1435T**

1455h *Population growth & bioenergetics of double-crested cormoranths in Lake Champlain*-D. Capen, UVM **WLF1455T**

1415h HYDRODYNAMICS & SEDIMENT RESUSPENSION
University Amphitheatre, Session Chair-Glenn Myer, SUNY Plattsburgh

1415h *Numerical models of water movement in Lake Champlain* - Kenneth Hunkins, Lamont-Doherty Earth Observatory of Columbia University; Daniel Mendelson, ASA Inc. **HYD1415T**

1435h *Observations of Density Currents and Internal Surges in Lake Champlain* - James Saylor, NOAA; Ken Hunkins, Lamont-Doherty Earth Observatory of Columbia University; Thomas O. Manley, Patricia L. Manley, Middlebury College **HYD1435T**

1455h *Sediment dynamics in a furrow field, Lake Champlain* - Patricia L. Manley, Thomas O. Manley, Middlebury College; Kenneth L. Hunkins, Lamont-Doherty Earth Observatory of Columbia University; Jim Saylor, NOAA **HYD1455T**

1515h *The hydrology of the Lake Champlain Basin* - James B. Shanley, USGS; Jon C. Denner, USGS **HYD1515T**

1535h *Wind-generated oscillations in Lake Champlain*-Irina Marinov, Bob Prigo, Tom Manley, Middlebury College **HYD1535T**

WEDNESDAY A.M.

1120h NUTRIENTS & CHEMISTRY (II)
Emerald Ballroom I, Session Chair-Andrea Lini, Geology Dept., UVM

1120h *1993 and 1998 nonpoint source phosphorus load assessments* - Lenore Budd, Associates in Rural Development, Inc.; Donald Meals, UVM **NCH1120W**

1140h *Long-term trends in Secchi disk tranparency in Lake Champlain*-Eric Smeltzer,VT DEC **NCH1140W**

1200h *Modeling Benthic Phosphorus Cycling in Lake Champlain*-Richard R. Isleib, James J. Fitzpatrick, HydroQual, Inc. **NCH1200W**

1120h FISHERIES & AQUATIC BIOLOGY (I)
Emerald Ballroom II, Session Chair-Ellen Marsden, SNR, UVM

1120h *A plankton survey of Lake Champlain* - Angela de Ruiter Shambaugh, Alan Duchovnay, Alan McIntosh, UVM **FIS1120W**

1140h *Controls on phytoplankton biomass and species composition in Lake Champlain* - S.N. Levine, A.d. Shambaugh UVM; M.A. Borchardt, Marshfield Medical Foundation; M. Braner, VT Health Dept; S. Pomeroy, UVM **FIS1140W**

1200h *Lower trophic level interactions in Lake Champlain* - S.N. Levine UVM; M.A. Borchardt, Marshfield Medical Foundation; A.d. Shambaugh UVM; M. Braner, VT Health Dept. **FIS1200W**

1120h TOXIC SUBSTANCES (I)
University Amphitheatre, Session Chair-Mary Watzin, SNR, UVM

1120h *Distribution of PCB congeners in Cumberland Bay and the main lake of Lake Champlain* - R.D. Fuller, J. Jones, L.M. McIlroy, SUNY Plattsburgh; C.W. Callinan, NY DEC **TOX1120W**

1140h *Ecological effects of sediment-associated contaminants in Inner Burlington Harbor, Lake Champlain* - Jerome Diamond, Tetra Tech, Inc. **TOX1140W**

1200h *Management of toxic substances within the Lake Champlain Basin* - Cliff Callinan, NY DEC **TOX1200W**

WEDNESDAY P.M.

1415h NUTRIENTS & CHEMISTRY (III)
Emerald Ballroom I, Session Chair-Andrea Lini, Geology Dept., UVM

1415h *Phosphorus dynamics in vegetated buffer areas between cornfields and streams in the Lake Champlain Basin*-Catherine Borer, Jeffrey Hughes, William Jokela, Deane Wang, UVM **NCH1415W**

1435h *Phosphorus management in Lake Champlain* - Eric Smeltzer, VT DEC **NCH1435W**

1455h *Response of St. Albans Bay to a reduction in point source phosphorus loading* - Scott Martin, Richard J. Ciotala; Prashant Malla; N.G. Subramanyaraje Urs, Prakesh B. Kotwal, Youngstown State University **NCH1455W**

1415h FISHERIES & AQUATIC BIOLOGY (II)
Emerald Ballroom II, Session Chair-Ellen Marsden, SNR, UVM

1415h *Effects of disturbance frequency, intensity, and areal extent on lotic macroinvertebrate communities*-Declan McCabe, Nicholas J. Gotelli, UVM **FIS1415W**

1435h *Effects of _Neophylax_ spp. (Trichoptera: Uenoidae) aggregations on benthic communities; a field experiment*-Declan McCabe, Nicholas J. Gotelli, UVM **FIS1435W**

1455h *Recent observations of malformed frogs in Vermont* - Richard Levey, VT DEC **FIS1455W**

1515h *Differences in tolerance to and recovery from Zebra Mussel fouling by elliptio complanata and lumpsilis radiata*-David Hallac, Ellen Marsden, UVM **FIS1515W**

1415h TOXIC SUBSTANCES (II)
University Amphitheatre, Session Chair-Mary Watzin, SNR, UVM

1415h *Characteristics of land use, climatology and forest ecosystems affecting deposition and transport of atmospheric pollutants in the Lake Champlain basin* - Phil Girton, VT Monitoring Cooperative; Tim Scherbatskoy, UVM **TOX1415W**

1435h *Physiological indicators of stress among fishes exposed to contaminated sediments from Lake Champlain* - Douglas Facey, Cynthia Leclerc; Diana Dunbar; Denise Arruda; Joan Shaw, St. Michael's College; Vicki Blazer, USGS **TOX1435W**

1455h *The occurrence of arsenic in the sediments of the Lamoille drainage basin, northwest, Vermont* - Russell Schuck, The Johnson Co. **TOX1455W**

THURSDAY A.M.

0910h ECONOMICS, LAND USE & MANAGEMENT
Valcour Room, Session Chair-Eric Perkins, EPA

0910h *Economic considerations for on-going Lake Champlain protection and restoration activities* - Anthony Artuso, Univ. of Charleston; Timothy Holmes, Holmes & Assoc.; Douglas Thomas, Economic & Policy Resources Inc. **ELM0910R**

0910h NUTRIENTS & CHEMISTRY (IV)
Diamond Ballroom, Session Chair-Andrea Lini, Geology Dept., UVM

0910h *Is Sediment Recycling an Important Source of Water Column Soluble Reactive Phosphorus?*-Jeffrey C. Cornwell, Michael Owens, Univ. of Maryland **NCH0910R**

0930h *Trace element concentrations in foliage over time* - Ann Rea, Joseph Graney; Gerald Keeler, Univ. of Michigan Air Quality Laboratory; Tim Scherbatskoy, UVM **NCH0930R**

1998 LCRC Spring Symposium
Poster Presentations

EMERALD BALLROOM III
Tuesday, 10:30 AM-11:20 AM and 3:35 PM-4:30 PM
Wednesday, 10:30 AM-11:20 AM and 3:35PM-4:30 PM

Authors will be present for at least two of the four sessions

Atmospherics

Atmospheric pollutants as a source of trace metals to the microlayer of Lake Champlain - Lisa B. Cleckner, Gerald J. Keeler, Peter G. Meier, Joseph R. Graney, Elizabeth Esseks, Environmental and Industrial Health, Univ. of Michigan **ATM-P1**

Economics, Land Use & Management

Management-intensive Grazing in Vermont: Economic and Environmental Implications-Jonathan R. Winsten, Penn State Univ. **ELM-P1**
Geographic Information Systems (GIS) digital data developed by the U.S. Geological Survey (USGS) for the Lake Champlain Basin-Andy Cohen, USGS **ELM-P2**
NYS Adirondack Park Agency programs and data - John Banta, Raymond Curran, Adirondack Park Agency **ELM-P3**
Slurry sidedressing and topdressing can improve soil and water quality on a concentrated livestock watershed - D. Côté; A. Michaud, Ministère del'agriculture Québec, C. Bernard **ELM-P4**

Fisheries and Aquatic Biology

Effects of Environmental Contamination on the Reproductive System of Rock Bass, Ambloplites rupestris - Lori Anne Pyzocha, St. Michael's College **FIS-P1**
Missisquoi National Wildlife Refuge Native Mussel Quarantine Facility - 1997 - Madeleine M. Lyttle, US Fish and Wildlife; Steve Fiske, VT DEC **FIS-P2**
Spatial distribution of lipid content and congener specific PCB concentrations in Dreissena polymorpha soft tissue for the main and south lake regions of Lake Champlain - J.I. Jones, LCRI SUNY Plattsburgh and L. R. Walrath, NY DEC **FIS-P3**
The status of the Eastern Sand Darter, Ammocrypta pellucida, in Vermont - Doug Facey, St. Michael's College **FIS-P4**
Zebra Mussel (Dreissena polymorpha) colonization of Lake Champlain-Cathi Eliopoulos, Peter Stangel, UVM **FIS-P5**
Zebra Mussel Education and Outreach: Developing a Zebra Mussel Educational Curriculum for the Lake Champlain Basin Science Center-Leah Menzies, UVM **FIS-P6**
Zooplankton- Nitrogen:Phosphorus Relationships in Northeastern US Lakes-Richard S. Stemberger, Eric K. Miller, Dartmouth College **FIS-P7**

Hydrodynamics And Sediment Resuspension

Large pockmarks: evidence of ground water flux into Lake Champlain - Patricia L. Manley, S.E. Sayward, N. North, T. O. Manley, R. Pederson, Middlebury College **HYD-P1**

Effects of the internal seiche in the south main lake of Lake Champlain - Lawrence Klein, Tom Manley, Middlebury College **HYD-P2**

United States Geological Survey Streamflow-gaging Network in the Lake Champlain Basin-Andy Cohen, USGS **HYD-P3**

NUTRIENTS & CHEMISTRY

An analysis of the Relative Contribution of Atmospheric Nitrogen to Lake Phytoplankton Nutrition: Does Fixation Prevent Nitrogen Limitation?-Miranda M. Lescaze, S.N. Levine, Andrea Lini, J.E. Leech, UVM **NCH-P1**

Distribution of Phosphorus in Bed Sediments of the Winooski River Watershed, Vermont-Ann Chalmers, USGS **NCH-P2**

Improved Phosphorus Recommendations for Crop Production and Water Quality in the Champlain Valley-William E. Jokela, Frederick R. Magdoff, Robert P. Durieux, UVM **NCH-P3**

Lake Champlain Basin agricultural watersheds national monitoring program project - Donald Meals, Sally Ober, UVM **NCH-P4**

Phosphorous storage in the Winooski River flow corridor-Todd Menees, UVM **NCH-P5**

Seasonal patterns and environmental controls of Lake Champlain sediment-water solute and gas exchange-Michael Owens, Jeffrey C. Cornwell, Univ. of Maryland **NCH-P6**

Spatial Variability in Pb-210 Based Sedimentation and Phosphorus Burial in Lake Champlain Sediments-Jeffrey C. Cornwell, Michael Owens, Univ. of Maryland **NCH-P7**

What controls the carbon and nitrogen isotopic composition of lacustrine primary producers? A case study of VT lakes-Andrea Lini, Suzanne Levine, Miranda Lescaze, John Leech, UVM **NCH-P8**

TOXIC SUBSTANCES

Analysis of fish DNA integrity as an indicator of environmental stress - Glenn Bauer, Brian Dwyer, Leah Moyer, St. Michael's College **TOX-P1**

1998 LCRC SPRING SYMPOSIUM
ORAL AND POSTER PRESENTATION ABSTRACTS

ATMOSPHERICS

ATM0945T CURRENT KNOWLEDGE OF AIR POLLUTION AND AIR RESOURCE ISSUES IN THE LAKE CHAMPLAIN BASIN.

T. Scherbatskoy, SNR UVM, R. Poirot, VT Agency of Natural Resources; and R. Artz, Air Resources Laboratory, NOAA

The Lake Champlain basin, although predominately rural, is exposed to a variety of atmospheric pollutants and related environmental stresses. These include acid rain (annual average pH 4.4), dry deposition of acidifying substances, toxic trace metals and organic compounds in aerosols and gasses, tropospheric ozone, solar ultraviolet radiation, and climate change. There is a growing awareness of the potential for air pollution to affect Lake Champlain and ecosystems in the basin through direct and indirect processes. The relatively large land area of the Lake Champlain basin (19:1 land:water area) creates opportunities for airborn pollutants to be captured and transferred to the lake and other ecosystems in the basin. In addition, this region is home to a growing human population, and supports diverse northern temperate ecosystems. It is important, therefore, to assess the status and adequacy of our information about atmospheric contaminants in the basin. The first scientific studies of acid rain and air quality began in the Lake Champlain basin in the early 1980s. This report summarizes the relevant information on air quality, atmospheric deposition and meteorology that has been acquired in the past two decades. Since 1982 an increasing number of air quality monitoring programs have operated at the Vermont Forest Ecosystem Monitoring site in Underhill Center, VT. Other locations in the basin have provided additional data, including Whiteface and Willsboro, NY, Burlington, VT and Sutton Quebec. While some monitoring has been continuous, there have also been several shorter-term studies of historical importance. The data summarized here focus on concentration and deposition of precipitation-borne acids, nutrients, mercury and other trace metals; air concentration and limited dry deposition of aerosol and vapor forms of these substances; air concentrations of tropospheric ozone; and local and synoptic meteorology. Application of air transport and deposition models to these data and to contamination issues in the basin are also discussed. Finally, relationships between these data and studies examining the transport and fate of air contaminants in the basin are noted, and significant information gaps are identified.

ATM1120T AIR TRAJECTORY POLLUTION CLIMATOLOGY FOR THE LAKE CHAMPLAIN BASIN

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As part of an ongoing regional air pollution climatology study, a long-term (1989-96) database of backward air mass histories is being developed for selected rural air quality monitoring sites in the Northeastern US and Southeastern Canada. Ambient pollutant measurements at these monitoring sites include concurrent long-term records of ozone, wet deposition chemistry and aerosol chemistry. Four of the sites (Whiteface, Mtn., NY; Sutton, Quebec; Underhill, VT; and Lye Brook VT) are located in (or just outside of) the Lake Champlain watershed. This paper will examine characteristics of the Lake Champlain "airshed" through a merging of the ambient air quality and airmass history data for the Lake Champlain Basin sites. Prominant pollution transport pathways and "clean air corridors" for the various pollutant species will be summarized.

ATM1140T ATMOSPHERIC MERCURY TRANSPORT AND DEPOSITION IN THE LAKE CHAMPLAIN BASIN: 1992-1997

G. J. Keeler, E. Malcolm, J. Burke, S. Deboe, University of Michigan Air Quality Laboratory; T. Scherbatskoy, SNR, UVM

As progress has been made in recent years in understanding the cycling of Hg in aquatic and terrestrial ecosystems, the importance of the atmospheric pathway to these cycles has become well recognized. It is currently believed that only modest increases in atmospheric Hg loadings will lead directly to even more

elevated levels in the fish stock. Because atmospheric Hg species may be altered in response to changes in regional tropospheric chemistry and interactions with forested ecosystems, the distribution of atmospheric Hg species and the importance of dry deposition will be addressed. Since 1992, the University of Michigan Air Quality Laboratory (UMAQL), in cooperation with the University of Vermont, the Vermont Monitoring Cooperative (VMC), and the Lake Champlain Research Consortium have performed research and monitoring of atmospheric pollutant deposition to the Lake Champlain basin. The research has focused on the deposition, ecosystem cycling, and fate of atmospherically deposited mercury (Hg). The project has assembled one of the longest running high- quality Hg data bases (vapor, particulate, precipitation) in the world. The long-term data allow us to investigate and present the meteorological influences that control the levels of Hg measured in the Lake Champlain basin and to diagnose the source regions contributing to the Hg deposited to the watershed. Trace element data taken concurrently will be used to investigate the potential source types related to the Hg measured.

ATM1200T MERCURY CYCLING AND TRANSPORT IN THE LAKE CHAMPLAIN BASIN

J. B. Shanley, USGS; T. Scherbatskoy, A. Donlon, SNR UVM; G. Keeler, Univ. of Michigan

Bioaccumulation of mercury (Hg) from atmospheric deposition has led to health advisories on fish consumption in Lake Champlain. Given the 19:1 basin/lake ratio, we have been investigating how terrestrial processes regulate Hg release and transport to the lake. In an 11-ha deciduous forested catchment, atmospheric Hg deposition (wet + dry) averaged 134 mg/ha/yr during a two-year period (March 1994 through February 1996), whereas stream export of total Hg averaged 25 mg/ha/yr. Some of the Hg retained in the catchment may have volatilized to the atmosphere. Hg export from the catchment occurred primarily during high flow periods in association with the organic fraction of suspended particulate matter. Total (unfiltered) Hg concentrations were less than 3 ng/L during base flow but exceeded 10 ng/L during some high flows and reached 79 ng/L at peak snowmelt. By contrast, dissolved Hg was independent of flow and ranged only from 0.5 to 2.6 ng/L. The small but persistent flux of dissolved Hg accounted for approximately 30% of the total Hg export. Dissolved Hg in soil water (sampled in 1997) ranged up to 17 ng/L in the O-horizon but was consistently less than 4 ng/L in the B-horizon. Though most streamwater Hg is in the particulate phase, dissolved Hg transport in shallow soil water may be the primary mechanism of Hg movement from the forest floor to the stream. At downstream river sites, total Hg concentration was 10 to 50 ng/L during high flows. These elevated concentrations represent some mixture of Hg from upland forests and Hg from agricultural and residential areas. Accelerated erosion in the latter more developed landscape types may increase particulate Hg transport to the lake, but therein lies an opportunity to control Hg inputs through management strategies.

ATM-P1 ATMOSPHERIC POLLUTANTS AS A SOURCE OF TRACE METALS TO THE MICROLAYER OF LAKE CHAMPLAIN

L. B. Cleckner, G. J. Keeler, P. G. Meier, J. R. Graney and E. Esseks, Environmental and Industrial Health, University of Michigan

Although many sources of trace metals to surface waters have been identified including atmospheric deposition, re-suspension of contaminated sediments, and direct discharges, there are very few recent data on ambient concentrations in large lakes. An investigation of trace element concentrations in Lake Champlain was completed in 1993. Three depths of water including the microlayer or air-water interface, 30 cm below the surface and 1 m below the thermocline were collected using ultra-clean techniques at a site approximately 1.6 km west of Burlington, VT for 10 different sampling events. All samples were processed for filtered and unfiltered fractions in a portable plastic enclosure equipped with a HEPA filter. In addition, concurrent atmospheric samples for trace metals were collected at an onshore site. For analysis, water samples were analyzed for trace elements (Al, V, Cr, Mn, Ni, Cu, Zn, As, Rb, Sr, Cd, Ba, Pb) by an Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) while air samples were analyzed by X-Ray Fluorescence (XRF). In addition, Hg levels in both water and air were determined by cold vapor atomic fluorescence spectroscopy (CVAFS). Relationships between air and microlayer concentrations of trace elements as well as temporal changes in metals levels at the various water depths will be discussed. This study represents one of the first set of measurements of trace element concentrations using clean techniques

for Lake Champlain, and levels will be compared to other Great Lakes including Lake Michigan and Lake Superior.

CULTURAL AND SOCIAL ISSUES

CUL1120T LAKE CHAMPLAIN BASIN EDUCATION AND OUTREACH PROGRAMS

T. R. Hudspeth, SNR UVM and representatives from CBEI

While excellent education and outreach programs and curriculum materials existed for Chesapeake Bay, the Great Lakes, and other basins in the United States, little was available for the Lake Champlain Basin in l990. However, in the l990's efforts on a variety of fronts have led to:
the development of a curriculum handbook, This Lake Alive! by Amy Demarest;
a wide range of training programs for educators throughout the Basin conducted by the Champlain Education Initiative (CBEI); CBEI--a partnership of the Lake Champlain Basin Program, Shelburne Farms, Lake Champlain Basin Science CFederation, and Green Mountain Audubon Nature Center- has carried out workshops in the summer and throughout the school year at various venues in the basin, making use of nearby natural and cultural resources and bringing in experts from government, higher education, and non-governmental organizations;
University of Vermont (UVM) summer courses for middle school and elementary school teachers in Burlington focusing on the Lake Champlain Basin, linked with academic summer camp programs for elementary and secondary youth in Burlington;
"place-based" environmental education programs linking UVM students with area middle schools and utilizing the Lake Champlain Basin as an integrating theme in science, social studies, language arts, and mathematics;
and school programs and programs for the general public at the Lake Champlain Basin Science Center.

Most of these developments incorporate into their curriculum units and outreach materials research findings by science and social science investigators over the past several years. In addition, CBEI has conducted research in the form of needs assessments and focus groups to determine its action plan.

This presentation/paper describes each of these efforts and provides recommendations for building on these initiatives in the future.

CUL1140T WATERSHED PLANNING AND LAKE CHAMPLAIN: AN EXAMINATION OF THE GEOGRAPHY OF ENVIRONMENTALISM.

R. Kujawa, Saint Michael's College

This paper examines the planning process for the Lake Champlain Basin; offering an analytical viewpoint on the relationship between planning, public opinions and perceptions, and the tangible engagement of the public in the planning process. Key facets of both public opinion and focus group data related to Lake Champlain are presented and interpreted. These data are gathered from a number of sources including two studies in which the author was directly involved. Specifically, a geography of environmentalism is identified and confirmed. Then, synthesizing insights from the literature in water resources and ecosystem planning, the survey/focus group findings, and from Lake Champlain Basin planning documents, the author elucidates some disjunctures in the planning process and examines prospects for the future.

CUL1200T INSTITUTIONAL ARRANGEMENTS FOR THE LAKE CHAMPLAIN BASIN

James E. Connolly, LCBP, VT DEC

The Lake Champlain Management Conference commissioned an Institutional Arrangements report which was completed in January, 1995 by Yellow Wood Associates in collaboration with the Conservation Law Foundation and the Local Government Program and NYS Water Resources Institute of Cornell University. The focus of the study was to identify and analyze historic and existing institutional arrangements for the

Lake Champlain Basin, to compare them to other management programs in other areas of the country and to make recommendations on future management approaches for Lake Champlain. Some of the key issues identified in the study included the following: Watersheds are managed by multiple institutions, not by single institutions; Institutional arrangements must have the ability to capture the political will; commit local, state and federal political leadership to support goals and objectives; Funding mechanisms should be diverse, adequate, flexible and not tied to short public agency budget cycles; Complete stakeholder representation is key to workable solutions; an ecosystem approach to resource management should also be applied to Federal and State agency budgeting. The aim of this presentation will be to provide information on the current status of management institutions and arrangements to symposium attendees, describe some of the current initiatives of the Lake Champlain Basin Program and provide some insight into future direction and possible opportunities for improving existing programs and coordination between institutions in the Basin. The Lake Champlain Management Conference completed their work in October, 1996 when Opportunities for Action was approved by EPA, New York and Vermont. Responsibility for the plan's implementation now rests with the Lake Champlain Steering Committee, an institution that was originally formed in 1988 under a Memorandum of Understanding between New York, Vermont and Quebec. Their ability to identify and set priorities and to shape and direct funding available through EPA's Lake Champlain budget will be critical to the success or failure of implementation efforts.

CUL0945W LAKE CHAMPLAIN CULTURAL AND SOCIAL RESOURCE MANAGEMENT IN THE 1990'S: YOU CAN'T GET TO WHERE YOU'RE GOING UNTIL YOU KNOW WHERE YOU'VE BEEN

A. Cohn, Lake Champlain Maritime Museum; S. Bulmer, Vt. Forest Parks & Recreation; A. Cousins, Lake Champlain Basin Program

In the decade of the 1990's, appreciation for the region's cultural and social resources was transformed. As the Lake Champlain Management Conference organized to define its mission, issues surrounding the Basin's historical, archeological and recreational resources were appreciated at a new level. Cultural resource managers and recreation planners were invited to the table with biologists, chemists, fisheries specialists, farmers and others to talk about the future of Lake Champlain. Recognizing the significant potential, recreation and cultural resource research projects received a share of the Basin Program's federal dollars, and the final pollution prevention, control and restoration Plan for Lake Champlain included sections on "Managing Recreation" and "Protecting Cultural Heritage Resources." The Champlain Basin is one of the most historic corridors in North America. Human activity has stretched over 10,000 years, beginning with Paleo-Indian occupation and extending into European settlement and a series of significant military episodes during the Colonial period, the American Revolution, and the War of 1812. As a commercial highway, the lake witnessed thousands of wooden sailboats, canalboats, ferries, and steamboats which moved people and goods along the Champlain waterway. Into the twentieth century, the lake evolved into a primarily recreational corridor, its commercial capacity steadily declining. The lake's historic timeline played a crucial role in world, national and regional events, and left a legacy of land and underwater sites that permit a scholarly expansion of the known historical record. Public access to these land and underwater sites has broadened the population's appreciation of the past, and also evolved into a powerful economic force through tourism opportunities. The Lake Champlain Basin Program helped define and fuel this social-economic re-awakening by providing funding for studies. In 1992, the landmark Mount Independence-Fort Ticonderoga Management Survey demonstrated the richness and fragile nature of the lake's submerged resources. The 1993 Recreation Survey highlighted the challenge to balance increasing recreational access with mechanisms to protect against over-use and user conflicts. The development of the Cultural Resources Working Group, bringing New York and Vermont citizens and managers together to identify and prioritize funding issues, has had a significant long-term effect. This paper will summarize the research and results of Social and Cultural resource management in the 1990's, and discuss how recreation planners and cultural resource managers are building on that foundation to highlight Lake Champlain as a heritage tourism destination point as they look to the Millennium.

ECONOMICS, LAND USE & MANAGEMENT

ELM0830R WATERSHED MANAGEMENT AT A CROSSROADS: LESSONS LEARNED AND NEW CHALLENGES FOLLOWING SEVEN YEARS OF COOPERATION THROUGH THE LAKE CHAMPLAIN BASIN PROGRAM

L. Steppacher, US EPA; E. Perkins, Lake Champlain Basin Program

The Lake Champlain Special Designation Act created a program built on partnerships. Local, state and federal agencies alongside nongovernmental organizations, academicians, individuals and businesses from two U.S. states and one Canadian province work together to make the Lake Champlain Basin Program (LCBP) a successful model of watershed management. Each partner has committed expertise, perspective and funds to manage Lake Champlain and its resources. Program activities addressing a multitude of issues including water quality, living resources, and recreational and cultural resources, are managed by a broad based coordinating committee. Over the past seven years, federal funding alone has surpassed 27 million dollars via six different agencies, and state and local entities contribute matching funds. Most funds allow individual agencies to focus their particular expertise on Lake Champlain issues. EPA funding (average $2 million/year) is used to support the overall program and is divided among education and outreach, planning, research, monitoring, demonstration projects and coordination activities. After seven years, the participating entities have learned many things about cooperative watershed planning and management. For example, environmental and economic issues can and must be integrated, communication is essential and can be fostered through effective partnerships, pollution prevention may be more effective than 'command and control' programs, public education and technical assistance are critical to voluntary implementation of management strategies, meaningful input from the public is essential for long term commitment to management decisions, and management decisions must be based on sound science that recognizes complex ecosystem relationships. As the LCBP focuses on implementation of the Plan that was completed in 1996, new challenges are presented. These include how to maintain public and financial support for management activities, how to evaluate progress, and how to institutionalize these efforts to make them self sustaining.

ELM0910R ECONOMIC CONSIDERATIONS FOR ON-GOING LAKE CHAMPLAIN PROTECTION AND RESTORATION ACTIVITIES

A. Artuso, Institute for Public Affairs and Policy Studies, University of Charleston; T. P. Holmes, Holmes & Associates; D. Thomas, Economic & Policy Resources, Inc.

Anthony Artuso and Timothy Holmes coordinated the work of 15 researchers between 1992 and 1996 in exploring the economic implications of protecting and restoring the water quality of Lake Champlain. In the Economic Analysis of the Draft Final Plan (July 1996) they teamed with economists at Economic & Policy Resources, Inc. of Williston, Vermont to quantify the economic benefits and costs of specific management plan recommendations. That detailed economic research and analysis effort played a significant role in the subsequent approval of the Lake Champlain Management Plan by interested parties in New York and Vermont. This paper outlines the various research methodologies employed in the research and reports on major findings. Special emphasis is placed on the techniques for measuring phosphorus control costs, especially as they relate to waste water treatment facilities and agriculture. Another area of focus is on measuring how the direct effects of improved water quality reverberate through the economy. The IMPLAN input-output modeling and findings are described, with discussion of how the economic value of recreational use was quantified in the model. Understanding the perceived economic implications of lake restoration and protection is also explored, highlighted by the findings from a series of economic focus groups held around the lake. The research resulted in a number of economic analysis models and databases that are responsive to incremental changes in any of the benefit or cost estimates, and that can be easily up-dated with new data, information and scenarios as they become available. Recommendations for future research are explored in detail, especially in terms of refining existing models and databases.

ELM-P1 MANGEMENT-INTENSIVE GRAZING IN VERMONT: ECONOMIC AND ENVIRONMENTAL IMPLICATIONS

J. R. Winsten, Penn State Univ.

The dairy farming sector in the Northeast is at a crossroads. High production costs relative to product prices for the average dairy farm have forced many producers to exit the industry during the 1990's. The trend among remaining dairy farms has been toward significantly larger herd sizes and capital-intensive, modern

milking and animal housing facilities. However, many traditional dairy producers are unable or unwilling to secure the necessary financing for this type of farm infrastructure. For these reasons and others, management-intensive grazing (MIG) has become an increasingly popular option among dairy farmers as a means for increasing farm profitability. In 1996 management-intensive grazing was being used by just over 11% of dairy farmers in Vermont {Winsten, Hanson and Parsons 1998}. Management-intensive grazing has the potential to make Vermont's dairy industry competitive with other regions of the U.S.A. as well as with other milk exporting nations. This is important for the health of Vermont's rural communities. Additionally, MIG has the potential to decrease soil erosion as well as agricultural chemicals and fertilizers which contribute to water quality problems relative to conventional farming practices. This poster will present the author's results from several research projects dealing with the economic performance of Vermont dairy farms using MIG, the farm and farmer characteristics of MIG adopters, and the economic and environmental trade-offs of increasing farm stocking density and per cow milk production levels.

ELM-P2 Geographic Information Systems (GIS) digital data developed by the U.S. Geological Survey (USGS) for the Lake Champlain Basin

A. Cohen, USGS

GIS digital data layers developed by the USGS with funding from the Lake Champlain Special Designation Act for the Lake Champlain Basin include hydrography at 1:24,000 scale and drainage-basin divides at 1:24,000 scale. These layers are considered "base" layers because they have wide application for mapping and spatial analyses.

ELM-P3 NYS Adirondack Park Agency Programs and Data

J. S. Banta, R. P. Curran, NYS Adirondack Park Agency

The Adirondack Park Agency is a State Agency that conducts programs under the NYS Adirondack Park Agency Act, authorizing State and private land use plans for the Adirondack Park; the NYS Freshwater Wetlands Act which provides for wetland mapping and protection; and the NYS Wild Scenic and Recreational Rivers Act which provides certain protections for legislatively designated rivers. The Agency proposes a poster session summarizing programs and data available from the Agency, including the current status of Adirondack wetland inventory and mapping, and related watershed characterization and analysis underway in cooperation with the Adirondack Lake Survey Corporation and SUNY Plattsburgh Remote Sensing Laboratory. GIS data that is described will be available through the NYS GIS Cooperative. The poster would describe program status for the entire Adirondack Park, with comparisons of data availability and analysis for all five major Park watersheds.

ELM-P4 Slurry sidedressing and topdressing can improve soil and water quality on a concentrated livestock watershed

D. Côté, T.S. Tran, A. Michaud and C. Bernard, Centre de recherche et d'expérimentation en sols, Ministère del'agriculture, des pêcheries et de l'alimentation du Québec

On Quèbec farms, slurry is now spread more frequently on growing crops in late spring and summer. Corn is side-dressed between the 4 and 8 leaves growing stage while oat, barley and wheat are top-dressed between 2 and 6 leaves and meadows shortly after first and second hay cuts. Research on manure nutrients efficiency for crop production, on long term nutrients accumulation in the soil and on impacts on surface water, have demonstrated the advantages of side-dressing and top-dressing (band spreading) techniques over fall and spring spreading. Increased nitrogen efficiency prevents P, K, Mg, Cu and Zn excessive accumulation in the plow layer, since lower rate of slurry application are used to meet nutrients requirements. Accumulation of available P and K in the top soil are respectively 8 and 5 kg/ha/year for corn fertilized solely with swine slurry. Side-dressed slurry between corn rows, incorporated in the top 5 to 10 cm depth by tines mounted on the tool bar behind the tanker, greatly reduces the risks of nutrients being lost in the runoff. Cereals top-dressing with 30 tons/ha of swine slurry, gives same grain yields as mineral fertilizer. Top-dressed slurry on cereals when done across the slope also reduces this risk. From a watershed rehabilitation perspective, top- and side-dress management strategy increases the acceptance of surplus manure by potential receiver farms due to negligeable impacts on soil physical condition, increased nitrogen fertilizer value and corresponding economy on mineral fertilizer imports. Liquid manure nitrogen fertilizer value increases by 47% from a dominantly (70%) fall broadcast scenario to a top- and side-dress manure management strategy. Higher manure nitrogen fertilizer value, together with sound nutrient management plan, enables the control of phosphorus saturation levels in soils, a critical issue of an eutrophication-focussed rehabilitation project such as the Pike river.

FISHERIES AND AQUATIC BIOLOGY

FIS1120W A PLANKTON SURVEY OF LAKE CHAMPLAIN

A. d. Shambaugh, Dept. of Botany, UVM; A. Duchovnay, VA Polytech; A. McIntosh, SNR, UVM

An evaluation of phytoplankton and macrozooplankton communities in Lake Champlain USA was undertaken in 1991 and 1992. Samples collected prior to, during and after stratification indicated that the phytoplankton communities were dominated in essentially all samples by the cryptophyte flagellate Chroomonas spp. The most abundant macrozooplankton were Bosmina longirostris, Daphnia retrocurva, and Diacyclops bicuspidatus thomasi. In contrast to the phytoplankton communities, composition of the macrozooplankton community varied with time of collection and location in the lake. This study also documented the first occurrence of Thermocyclops crassus North America and one of the limited occurrences of the calanoid copepods Diaptomus pygmaeus and D. oregonensis in the same body of water.

FIS1140W CONTROLS ON PHYTOPLANKTON BIOMASS AND SPECIES COMPOSITION IN LAKE CHAMPLAIN

S.N. Levine, SNR, UVM; A.d. Shambaugh, Botany Dept., UVM; M.A. Borchardt, Marshfield Medical Foundation; M. Braner, VT Health Dept.; S. Pomeroy, SNR, UVM

The species composition and overall biomass of phytoplankton in a lake are functions of the dynamics of cell division and mortality rates. Division rates are determined by temperature and the availability of critical resources, such as nitrogen, phosphorus, silica (for diatoms), and light; while major sources of mortality include grazing, sinking below the photic zone, and parasitism. During 1994 and 1995, we conducted experiments to determine the importance of nutrient availability and grazing by zooplankton as controls on phytoplankton in Lake Champlain. In addition, the possibility of light limitation was explored by comparing average light availability in the lake's mixed layer with the light required for photosynthesis (as determined in the lab by the 14C method). Assays for nutrient limitation indicated that phosphorus (P) is the nutrient most frequently limiting growth in Lake Champlain, but that co-limitation by P and nitrogen (N) is not uncommon. Physiological indicators of P status suggested fluctuations between P deficiency and P sufficiency among the phytoplankton. Light limitation of photosynthesis was evident in spring and late summer, when the lake's mixed layer depth was 70 and 18 m, respectively. We have no data for mid-summer. Measurement of zooplankton grazing on phytoplankton revealed major differences in the "edibility" of phytoplankton species. The phytoplankton community as a whole was grazed at a rate of 2-21% per day. An experiment in which grazer densities and nutrient concentrations were manipulated simultaneously in a factorial design suggested that phytoplankton are more affected by nutrient availability than grazing losses. Small increases in zooplankton density actually increased phytoplankton growth rates, probably because zooplankton excretion is a major source of recycled nutrients for phytoplankton. We conclude that P, N, light and grazing all affect the species composition and biomass of phytoplankton in Lake Champlain. Each factor deserves further study, as do the interactions between factors.

FIS1200W LOWER TROPHIC LEVEL INTERACTIONS IN LAKE CHAMPLAIN.

S.N. Levine, SNR, UVM; M.A. Borchardt, Marshfield Medical Foundation; A.d. Shambaugh, Botany Dept., UVM; M. Braner, VT Health Dept.

Pelagic foodwebs consist of numerous interacting species of phytoplankton, bacteria, protozoa, zooplankton, and fish. Carbon (C) fixed by phytoplankton reaches zooplankton along two pathways: via direct zooplankton herbivory, and via the "microbial loop". The microbial loop involves bacterial recovery of fixed C "leaked" from phytoplankton or lost as detritus, followed by consumption of bacteria, either by protozoa, which are subsequently consumed by zooplankton, or by the zooplankton directly. During 1994 and 1995, we examined the planktonic foodweb of Lake Champlain. We measured the standing stocks of zooplankton, protozoa, phytoplankton and bacteria, primary productivity, bacterial productivity, bactivory by protozoa, and rates of zooplankton feeding on phytoplankton, bacteria and protozoa. Of the C fixed by phytoplankton, anywhere from 3- 110% was consumed by zooplankton, while 10-30% entered the microbial loop. Bacterial losses to grazers ranged from 15-120% per day, with Cladocera and heterotrophic protozoa most active in the grazing. Rotifers and mixotrophic cryptomonads were less important bacterivores. While cyclopoid copepods consumed some protozoa, the most effective protozoan predators appeared to be Cladocera. Thus, the microbial loop may be most efficient in its funneling of C to higher trophic levels when Cladocera dominate the zooplankton. An experiment in which nutrient concentrations and grazer densities were manipulated in a 2x3 factorial design indicated that nutrient availability has a greater impact on phytoplankton and bacterial densities than grazer densities, while grazing has the greater impact on protozoa. Multiple complex interactions were noted during these studies, including cascades of predator-prey impacts and phytoplankton growth stimulation through nutrient recycling by zooplankton. These suggest that managers should be prepared for occasional unexpected outcomes following algal or fish manipulations.

FIS1330W Ecosystem Health in the Lake Champlain Basin: Moving Toward Holistic Management

Mary C. Watzin, SNR, UVM

In the Lake Champlain Basin, no research specifically targeted towards understanding and measuring ecosystem health has been conducted. However, after 7 years of defining management goals and conducting focused research and monitoring we are well-positioned to address this topic. For ecosystems, there is no single state that is healthy. Social values define what is "healthy, but human desires must be bounded by ecosystem capacity. We have set measurable goals for phosphorus in Lake Champlain, but do not yet understand what these targets mean for the living resources in the Lake. By linking water quality, physical process, and food web dynamics research, this question can and must be explored. We can also begin to identify measurable parameters that relate to the condition of the ecosystem and the effects of management on this condition. There are a variety of approaches that have been taken to develop indicators in the Great Lakes and other water bodies. Some of this work may also be appropriate for Lake Champlain. Ecological indicators must be linked to management actions in order to evaluate whether our management plan is achieving its goals. Ultimately, a hierarchy of indicators could be developed to accomplish this goal.

FIS1415W Effects of disturbance frequency, intensity, and areal extent on lotic macroinvertebrate communities

D. McCabe, N. J. Gotelli, Biology Dept., UVM

We manipulated disturbance intensity, frequency, and area on artificial substrates and measured the response of lotic macroinvertebrate communities in the LaPlatte River, Vermont. We used a paint brush to produce low-intensity disturbances and a scrubbing brush to produce high-intensity disturbances. Disturbances were applied once or twice weekly to 50% or 100% of the upper surface of concrete patio stones. We used a factorial design with all combinations of area, intensity, and frequency, plus an unmanipulated control, for a total of 9 treatments, with 10 replicates per treatment. All treatments were maintained for six weeks starting in August 1996 and there were no significant spates during this period. At the end of the experiment, macroinvertebrates were preserved for identification and later subsampled. Total abundance of macroinvertebrates was significantly affected by area, intensity, and frequency of disturbance (factorial ANOVA; $p<0.05$ for main effects tests). All treatments had reduced abundance compared to controls. In contrast, species richness, adjusted for differences in abundance, was significantly higher for all disturbed treatments than for unmanipulated controls. Our results support the hypothesis that disturbance enhances species richness.

FIS1435W Effects of _Neophylax_ spp. (Trichoptera: Uenoidae) aggregations on benthic communities; a field experiment.

D. McCabe, N. J. Gotelli, Biology Dept., UVM

We took benthic macroinvertebrate community samples in the La Platt River (VT, USA) in June 1996. Samples containing aggregations of _Neophylax_ spp. (Trichoptera, Uenoidae) had higher total abundance of organisms and higher species richness than samples lacking such aggregations. In August 1996 we manipulated aggregations to assess the effect of aggregations on community structure in the La Platt River. We varied caddisfly case density and spatial arrangement. We also established control and glue control treatments and a live _Neophylax_ Pre-pupae treatment. We placed the treatments in the river using a randomized block design. Ten replicates of 6 treatments were attached to fire bricks with silicone glue and placed in the river for 5 weeks. At the end of this period the macroinvertebrates associated with the treatments were preserved and identified. We also collected the communities associated with natural aggregations. We used analysis of variance to test for treatment effects. Total abundance and richness were highest in natural aggregations and lowest on controls. Chironomidae were more abundant on glue controls than on blank controls. We found a mite species at highest densities on treatments with high density empty _Neophylax_ cases and at lower densities on treatments where the living _Neophylax_ larvae were present. Elmid larvae (Coleoptera) were more common, by an order of magnitude in natural aggregations than on experimental treatments.

FIS1455W RECENT OBSERVATIONS OF MALFORMED FROGS IN VERMONT

R. Levey, VT DEC

In the late summer of 1996 malformed frogs were reported by the general public to the Vermont Agency of Natural Resources from 12 sites in five counties within the Lake Champlain Basin. VTANR surveyed four of the sites reported to have malformations and malformed frogs were found at all four sites. Of 290 Northern leopard (Rana pipiens) frogs examined, the incidence of malformations averaged 13.1 percent, ranging from 5 - 23 percent. Malformations were primarily missing and partial hind legs. In late July 1997, VTANR with help from USEPA, USFWS, USGS-BRD and Middlebury College surveyed over 50 sites in Vermont in an effort to document the extent and prevalence of frog malformations. An adequate sample size (>50) was achieved at 19 of the sites surveyed which covered 13 towns and 5 counties in the Lake Champlain Basin. The Northern leopard frog (Rana pipiens) was targeted, 1475 metamorphs (<4cm) were collected and examined. Roughly 8.0 percent of the frogs had malformations, the rates ranged from 2.0 to 45.4 percent. Categories of malformations were primarily missing/partial limbs and shortened/missing digits. Missing or partial hind limbs comprised 57 percent of the malformities encountered; followed by hind digits shortened at 11.2 percent. Malformed frogs from five of the sites surveyed were sent to the National Wildlife Health Lab for characterization of both external and internal malformations, parasites and viral and bacterial diseases. In September 1997, VTANR et al. re-surveyed 15 of the 19 sites surveyed in July. The overall malformation rate was similar to the July survey. Of 1063 Rana pipiens metamorphs examined, 7.3 percent had malformations. However, rates of malformations observed at several sites varied significantly higher or lower from the July results. Categories of malformations were similar to the July findings, consisting of primarily missing/partial limbs and shortened/missing digits. Vermont citizens and volunteers in 1997 reported malformed frogs from 53 towns representing all 14 counties. Species reported with malformations include: the Northern leopard frog, Green frog, Pickerel frog, Bullfrog, Wood frog and American toad. While these reports are valuable, most are not verified and may not be accurately representing the incidence of malformed frogs above the "normal" background level of ~1.0 percent, due to a very small sample size. The widespread reports of malformed frogs in Vermont has made it difficult to link a particular land use correlation with reported "malformed" frog sites. Chemical characterization of water and sediment from select "control" and "affected" sites is currently being tested. Water and sediment from these sites is also being screened using the Frog Embryo Teratogenesis Assay- Xenopus (FETAX), a developmental toxicity test. Field investigations documenting the extent and prevalence of "malformed" frogs in Vermont and research as to the causation of the frog malformations will be continued in the coming year.

FIS1515W DIFFERENCES IN TOLERANCE TO AND RECOVERY FROM ZEBRA MUSSEL FOULING BY ELLIPTIO COMPLANATA AND LUMPSILIS RADIATA-D. Hallac, J. E. Marsden, UVM

Since their discovery in 1993, zebra mussels (*Dreissena polymorpha*) in Lake Champlain have colonized the shells of many native unionids. Periodically cleaning zebra mussels from unionids may be an effective conservation technique if unionids can recover from the stress induced by zebra mussels. Conservation efforts will need to target those species that are most vulnerable to fouling and subsequent energetic losses. Because glycogen is the primary energy store in many bivalves, a decrease in glycogen content indicates loss of fitness. As dreissenid-unionid mass ratios increase in *Elliptio complanata* from Button Bay Vermont, there is no evidence that glycogen levels decrease even with mass ratios as high as 1.25. In contrast, dreissenid-unionid mass ratios as low as 0.25 in *Lampsilis radiata* are correlated with a significant decline in glycogen content. Results are consistent with a higher mortality of *L. radiata* than *E. complanata* in wild populations. In a second experiment, 32 mussels from each species were collected from the mouth of Lewis Creek, cleaned of zebra mussels (mean mass ratio: 1.45 +/-0.57) and returned to the creek. After 10 weeks, cleaned mussels and an equivalent number of heavily fouled mussels (mean mass ratio: 1.76 +/-0.71) of each species were collected. Twenty *E. complanata* and *L. radiata* were also collected from the Lamoille River where zebra mussels are absent. Mean glycogen levels in heavily fouled populations of both species were lower than control levels while cleaned mussels did not differ from controls. Results suggest that heavily fouled *E. complanata* and *L. radiata* can recover glycogen levels if cleaned of zebra mussels.

FIS-P1 EFFECTS OF ENVIRONMENTAL CONTAMINATION ON THE REPRODUCTIVE SYSTEM OF ROCK BASS, AMBLOPLITES RUPESTRIS

L. A. Pyzocha, St. Michael's College

Toxins in the environment may cause complications in different fish systems such as the endocrine, circulatory, nervous or digestive system. Examining the effects of environmental contaminants on fishes can help in understanding the interference toxins may have on populations. Reports on the effects of toxins on the reproductive systems of aquatic animals have been surfacing since the 1980s. These toxins have been noted in females to decrease fecundity, reduce embryo size, delay ovulation, cause abnormal oocytes and, in some cases, abnormal male gonad development in females. Other observations that have been noted are testicular atrophy, lower sperm counts and feminization in males. The contaminants that have been linked to such effects are PCBs, PAHs and heavy metals. These toxins have become recognized to have estrogenic effects on wildlife and are suspected of mimicking natural estrogens and causing behavioral and physiological effects on fish's reproductive system. Burlington Harbor is known to contain elevated levels of PAHs, PCBs and heavy metals in its sediment. Previous studies have shown that rock bass, Ambloplites rupestris, from Burlington Harbor showed evidence of physiological stress when compared to the rock bass from less contaminated sites. This raised the question of whether there might be any effects on reproductive systems in the rock bass from these same areas. In this study I looked for evidence of disruption of the reproductive system among rock bass from Burlington Harbor. This was compared to a reference site, the Inland Sea. I measured fecundity, egg diameter, and gonad weight of females, and histologically observed the testes of males for evidence of intersex development. No significant differences were found in fecundity, egg diameter, gonad weight or histological observations of the testes. Therefore, there is no evidence of reproductive effects from sediment contamination on rock bass from Burlington Harbor.

FIS-P2 MISSISQUOI NATIONAL WILDLIFE REFUGE NATIVE MUSSEL QUARANTINE FACILITY - 1997

M. M. Lyttle, US Fish and Wildlife Resources; S. Fiske, VT DEC

The Lake Champlain Native Mussel Working Group identified Lewis Creek Delta as an area with a unique and important native mussel community. The Delta is also highly colonized by zebra mussels (*Dreissena polymorpha*). In June 1997, several biologists and volunteers spent a day on the Delta cleaning the less common mussels to place into a quarantine facility located on the Missisquoi National Wildlife Refuge in Swanton, Vermont. The quarantine facility consists of a 17 x 13.5 ft. fenced-in area large enough to house a holding tank, drainage barrels, and periphery equipment needed for the project. The five foot diameter, 12" deep holding tank was equipped with a small fountain aerator. The water used in the quarantine tank was taken from the Missisquoi River. Two hundred and twenty-five mussels were placed in quarantine. The species selected were: 62 fragile papershell (*Leptodea fragilis*), 2 giant floaters (*Pyganodon grandis*), 144 pink heelsplitters (*Potamilus alatus*), 3 pocketbooks (*Lampsilis ovata*) and 14 triangle floaters (*Alasmidonta undulata*). These mussels were re-inspected for zebra mussels, measured, and tagged with unique numbers. The mussels were fed algae culture at least three times a week while in quarantine. The mussels were inspected weekly for zebra mussels for five weeks. The water was changed in conjunction with the inspections. Additionally, the tank water was drained through a filter and examined for any evidence of zebra mussel veligers. No adult zebra mussels or veligers were found on the native mussels, or in the water samples taken from the tank drainage. Biologists from the US Fish and Wildlife Service and the Vermont Department of Environmental Conservation returned the native mussels to Lewis Creek in locations directly above and below Greenbush Road in August 1997. These locations were selected because the mussels could be easily monitored and there was low potential for zebra mussel infestation.

FIS-P3 Spatial Distribution of Lipid Content and Congener Specific PCB Concentrations in Dreissena polymorpha Soft Tissue for the Main and South Lake Regions of Lake Champlain

Jones, J. I., SUNY Plattsburgh; L. R. Walrath, NY DEC

The zebra mussel (Dreissena polymorpha) is an invasive exotic bivalve which was introduced into the Great Lakes over a decade ago. Since then, large zebra mussel populations have been responsible for dramatic ecological changes in North American waters through a number of processes including biofouling, oxygen depletion, and shifts in the food web interactions. With high individual filtration rates as well as high filtration efficiency, zebra mussels also have the potential to bioaccumulate high concentrations of contaminates, including PCB's, thereby creating additional ecological as well as public health concerns. In 1993 zebra mussel populations became established in the South Lake Region of Lake Champlain and, in less than two years, had spread throughout much of the South and Main Lake Regions. Today zebra mussels are ubiquitous in these regions with populations typically consisting of several year classes. We collected zebra mussels from various locations within these two regions in the fall of 1997 for the determination of lipid content and congener specific PCB concentration of soft tissue. Concentrations will be compared on the basis of sample location and age class.

FIS-P4 The status of the Eastern sand darter, Ammocrypta pellucida , in Vermont

D. E. Facey, St. Michael's College

Four major tributaries of Lake Champlain support populations of Eastern sand darter (Ammocrypta pellucida) in Vermont -- the Poultney River (which forms part of the border between Vermont and New York), the Winooski River, the Lamoille River, and the Missisquoi River. The Eastern sand darter inhabits areas with sandy substrate in the lower portion of these rivers (below the first dam). In most cases, the fish were found in shallow water with low velocity, and often along the downstream portion of sand bars along the depositional side of a bend in the river. Length-frequency distribution histograms suggest three age classes. The youngest class (presumably young-of-the-year) was underrepresented, probably due to sampling gear bias. Repeated sampling at one site in the Winooski River during May and June of 1995 suggested that spawning took place between June 6 and June 26, when water temperatures were between 20.5 and 25.5˚ C. The Eastern sand darter appears to be quite specific to fine sand substrates. Therefore, upstream flow alteration or land use practices that are likely to result in removal or silting-over of sand bars, or vegetative encroachment on those sand bars, is likely to reduce habitat for this species.

FIS-P5 Zebra Mussel (Dreissena polymorpha) Colonization of Lake Champlain

C. Eliopoulos, VT DEC; P.Stangel, VT DEC

The Vermont Department of Environmental Conservation, in cooperation with the Lake Champlain Basin Program, monitored zebra mussel veliger densities in Lake Champlain at 12 open water lake stations and 13 near shore stations during 1994-1997. Occurrence and density of settled juveniles were determined at 13 near shore sites using dark colored PVC settling plates. Mask and snorkel surveys were conducted to characterize adult zebra mussel densities. Zebra mussels have continued to increase in density and expand their range during each year of monitoring. During 1997, peak veliger densities exceeded those in 1996 at all but two stations. Peak settled juvenile densities for the settling plates in 1997 were greater than peaks found in 1996 at 3 of 6 stations. Adult zebra mussels are now common to very abundant on most firm substrates in the south, central and northwest regions of Lake Champlain. In contrast, relatively few adults have been found in the northeast region of the lake. Inland lakes and tributaries within the Lake Champlain basin were sampled for veligers and/or settled juveniles. No veligers were found in any of the inland lakes sampled. Veligers and/or juveniles were found in four of the eight tributaries sampled at sites located within 2500 meters upstream from the lake. Water quality data collected in conjunction with this program show a significant increasing trend in recent years in mean Secchi disk transparency in the southern region of the lake. Recent downward trends in mean chlorophyll-a and total phosphorus concentrations are also somewhat apparent. These results suggest that filtration by zebra mussels may be having an effect on water quality in the southern region of Lake Champlain. It has been reported that zebra mussels cannot successfully reproduce at calcium levels below 20 mg/l. Calcium concentrations throughout most of Lake Champlain, with the exception of the South Lake region are below 20 mg/l. However, findings of high veliger densities in areas of low calcium suggest that local reproductio may be occurring in these areas.

FIS-P6 Zebra Mussel Education and Outreach: Developing a Zebra Mussel Educational Curriculum for the Lake Champlain Basin Science Center

L. Menzies, UVM

Exotic species pose a serious threat to the Lake Champlain Basin. Unfortunately, few people in the Champlain Basin comprehend the grave danger posed by exotic species such as zebra mussels. Through this project, I hope to increase awareness of the serious threat to the Lake Champlain Basin posed by the introduced species. I have worked in conjunction with the Lake Champlain Basin Science Center to create additional curriculum for the Zebra Mussel Mania Travelling Trunk, a youth-education resource which focuses on the impacts of zebra mussels and other exotic species in Lake Champlain. If successful, this program will be instrumental in spreading information around the Champlain valley on the dangers of exotic species. The first zebra mussel found in Lake Champlain was discovered by Matt Toomey, a 13-year old boy who had only recently learned about the threats posed by zebra mussels. Prior to my development of zebra mussel curriculum for the Science Center, the trunk contained general information on zebra mussels, but nothing specific to Lake Champlain. It is my hope that by connecting the zebra mussel issue to Lake Champlain, more students will take interest in the problem and may make similar discoveries on their own in the future. As discussed in the curriculum, quagga mussels have yet to be found in Lake Champlain. With the aid of new, Lake Champlain-specific curriculum in the Zebra Mussel Mania Travelling Trunk, there is hope that maybe another student will be as resourceful as Matt was just a few years ago and find the first quagga mussel in Lake Champlain.

FIS-P7 Zooplankton-Nitrogen:Phosphorus Relationships in Northeastern US Lakes

Richard S. Stemberger and Eric K. Miller, Dartmouth College

The composition of the freshwater zooplankton of northeastern US lakes (US EPA EMAP pilot survey) is strongly linked to ambient nitrogen to phosphorus (N:P) supply ratios. Relative differences in N to P requirements among common zooplankton species are affected by body size, taxonomic affiliation, life history mode, and trophic position in the food web (i.e. omnivore or herbivore). These criteria permit simple metrics which incorporate the underlying N:P ratio relationships to be constructed from complex species assemblages. We argue that N:P supply ratios in over 380 NE lakes are primarily influenced by external watershed loadings associated with land use, vegetation cover and type, riparian development, and atmospheric inputs. We demonstrate that the strong empirical relationships between the N:P ratio of lake water and zooplankton provides a potential indicator for monitoring lake ecosystem integrity. Zooplankton metrics have a high percentage of their variance explained by the lake component of variance.
Hence, detection of a small but meaningful change in the metric is likely. Some zooplankton metrics also show significant variance due to temporal factors that reflect climate. These same metrics when modeled as a function of the N:P ratio show very high signal to noise ratios. This property further supports the power of the N:P ratio for predicting and tracking zooplankton assemblages as a function of external watershed influences. We conclude that the N:P ratio in lake water has significant potential as an indicator for lake monitoring studies.

HYDRODYNAMICS AND SEDIMENT RESUSPENSION

HYD1415T Numerical Models Of Water Movement In Lake Champlain

K. Hunkins, Lamont-Doherty Earth Observatory of Columbia University; D. Mendelson, Applied Science Associates, Inc.

Two different types of numerical hydrodynamic models have been developed to simulate horizontal currents and thermocline motion in Lake Champlain. Both types are wind-driven with two layers of constant density and both employ the nonlinear shallow- water equations for momentum and continuity. A one-dimensional model developed by the first authoris aimed at finding the simplest system which provides a good approximation of the response to wind stress observed along the lake axis. The lake is represented as a rectangular basin. Internal seiches with thermocline excursions of 20m and peak currents of 25 cm/s are of particular interest. When this model is forced with winds recorded at Burlington Airport, model output shows quite good agreement with observed thermocline motion at both the Valcour Island and Thompson Point sites. This simple approach contains just sufficient complexity to produce motions which nearly match those in the actual lake. The conclusion is that continuous forcing with synoptically varying winds results in a complex synthesis of both free and forced waves with a predominant period of four days corresponding to the fundamental internal standing wave. Another more complete model, developed by Applied Science Associates, is two- dimensional and includes the details of shoreline and bathymetry for this lake. It provides not only current and thermocline movements but also includes mixing and transport calculations. This model was tested against results of field studies with good results when driven by Burlington Airport winds. High-level graphics are provided to make the program useful to managers of lake resources who need to predict the consequences of natural and man-made disturbances.

HYD1435T OBSERVATIONS OF DENSITY CURRENTS AND INTERNAL SURGES IN LAKE CHAMPLAIN

J. Saylor, NOAA Great Lakes Environmental Research Lab; K. Hunkins, Lamont-Doherty Earth Observatory of Columbia University; P. L. Manley, T. O. Manley, Middlebury College

The shape of lake basins, with their large variety of configurations, plays a strong role in determining their current patterns. Elongated and narrow basins such as Lake Champlain can exhibit extremely large thermocline displacements and oscillations in response to wind forcing during seasons of density stratification. Time series of currents and water temperature variations in Lake Champlain have been recorded during several summer seasons. The measurements were made with arrays of Acoustic Doppler Current Profilers and thermistor chains moored along the lake's thalweg which forms the boundary between the states of New York and Vermont. The long axis of the lake is oriented approximately north-south and is nearly 120 km long. The lake is about 6.3 km wide and has a mean depth of about 30 m . The depth decreases monotonically toward its north end from a maximum depth of 120 m at a location in the south. During seasons of weak stratification in early summer and fall, strong winds from the south were observed to transport much of the less dense surface layer toward the north end of the lake and cause upwelling in the south. The resulting density distribution is similar to that observed in a lock exchange experiment, and a gravity current flows northward along the lake floor after the wind stress relaxes. The propagation of the current was detected as it progressed past current meter moorings toward the shoaling north end. Evolution of the gravity currents into bore-like waves traveling on the weak near bottom stratification occurred at the northernmost measurement station.

HYD1455T SEDIMENT DYNAMICS IN A FURROW FIELD, LAKE CHAMPLAIN

P. L. Manley, T. O. Manley, Middlebury College; K. L. Hunkins, Lamont-Doherty Earth Observatory of Columbia University; J. Saylor, NOAA Great Lakes Environmental Research Lab

High-resolution side-scan sonar surveys conducted in 1991 and 1994, permitted the assessment of a large furrow field located east of Valcour Island in Lake Champlain. These furrows have a width-spacing ratio of 1:4.6 which classifies them as type 1C. Furrow lengths range from 16 to 828 m with over 50% of them less than 200 m in length. Morphological differences can be seen across the furrow field from east to west, with the width spacing increasing to the west as a consequence of bathymetric variation. Comparison between the two surveys shows little change. A mooring array was deployed within the furrow field containing a pair of stereo cameras, sediment traps, thermistor chain, and an Acoustic Doppler Current Profiler (ADCP). The cameras took pictures for 23 days, at 4 hour intervals while all other apparatus operated for 4 months between June and October 1994. Correlation between the thermistor chain and the ADCP allow for analysis of currents near the bottom boundary layer. Comparison of the stereo pair with relation to current data gives quantifiable and visible information of erosion and deposition. A high current speed event on June 22, shows erosion occurring within the bottom camera area. Though not documented by photographs, due to a camera malfunction, other high-speed events recorded by the ADCP suggest the occurrence of erosional events within the survey region. The documentation of these erosional events indicates that furrow development occurs via high speed internal-sieche driven current activity within the bottom boundary layer separated by longer periods of deposition.

HYD1515T THE HYDROLOGY OF THE LAKE CHAMPLAIN BASIN

J. B. Shanley, J. C. Denner, USGS

The Lake Champlain basin comprises 21,326 km2 (8,234 mi2) in Vermont, New York, and a small part of Quebec. The lake occupies 5.3% of the basin. Elevations range from 29 m (95 ft) at the lake to more than 1,200 m (4,000 ft) in the Adirondack Mountains of New York and the Green Mountains of Vermont. The basin is mostly forested, with agricultural activity concentrated in the lowlands of Vermont near the lake. Glaciation left thick surficial deposits of lacustrine clays in the lowlands, dense silty glacial till in the uplands, and scattered sandy to gravelly outwash deposits in transitional areas. Because these surficial deposits do not support extensive aquifers, most rural homeowners and some municipalities obtain groundwater from fractured bedrock or springs. Most municipalities rely on surface-water supplies, including Lake Champlain itself. Annual precipitation ranges from a low of 800 mm (30 in) at low elevations to greater than 1250 mm (50 in) on the mountain summits. Several months of precipitation is stored in the snowpack, which melts and releases its water during a relatively short time span. Spring snowmelt nearly always causes the annual high water level in Lake Champlain. Lake level averages 29 m (95 ft) and typically ranges from 28.7 m (94 ft) to 30.2 m (99 ft) each year. In years with appreciable snowpack in both the lowlands and the mountains, spring snowmelt may cause lake levels to approach 30.8 m (101 ft), at which point flood damage occurs. On April 27, 1993, Lake Champlain water level reached 31.05 m (101.86 ft), its second highest in 120 years of record. The resulting flood was surprising in that the peak occurred after the main inlet streams were in recession. The 1993 flood will be analyzed using the expanded network of USGS stream gages in the basin since 1990, with special attention to the effects of the lowland snowpack and groundwater inputs.

HYD1535T WIND-GENERATED OSCILLATIONS IN LAKE CHAMPLAIN

I. Marinov, R. Prigo, T. Manley, Middlebury College

Kenneth Hunkins, Lamont-Doherty, has developed a numerical, two-layer, shallow-water, one-dimensional model, which includes non-linear and frictional effects, for describing the wind-generated oscillations in both the surface and internal seiches (standing waves in the epilimnion and metalimnion, respectively) in Lake Champlain. Hunkins used wind data from Burlington Airport, VT, as an input into the model. It is not clear that this data set is best for describing the actual wind shear on the Lake. The present work refines the Hunkins model. The refined model was used to make predictions about the epilimnion and metalimnion oscillations and currents. Unlike Hunkins work, real bottom topography of Lake Champlain was used in the present model. Predictions using the revised model, based on new sets of wind data taken from other locations in and around the Lake, were made. Recent (1997) temperature and current data allowed comparison of the model predicted thermocline oscillations with the actual thermocline oscillations in the Lake. The observed thermocline oscillations fit extremely well the modeled hypolimnion oscillations, driven by Burlington or Colchester Reef wind forcing. A slightly better fit is obtained in the case when the model is driven by Burlington winds. The most powerful signals in the wind spectra are present in the modeled and observed thermocline oscillations. Even though the most powerful signal in the density spectrum of wind velocity is the bimodal 2.67 day oscillation, the Lake has other preferred frequencies at which it oscillates. The preferred response of the Lake is the 10.67 day wind forced mode and the 5.33 day oscillation. The strong 5.33 day and 2.67 day signals in both modeled and observed thermocline oscillations were the signatures for the first and second mode of the Lake, respectively, and are close to those observed in 1993 and 1992 Champlain Lake thermal data.

HYD1630W ASPECTS OF SUMMERTIME AND WINTERTIME HYDRODYNAMICS OF LAKE CHAMPLAIN

T. O. Manley, Middlebury College; K. Hunkins, Lamont-Doherty Earth Observatory of Columbia University; J. Saylor, G. Miller, NOAA Great Lakes Environmental Research Lab; P. Manley, Middlebury College

Two and a half years of temperature and current observations obtained from longterm moorings within the central region of Lake Champlain were analyzed for wintertime and summertime circulation patterns. During two wintertime periods, currents were consistently weaker than summertime observations. The presence of a weak counterclockwise deep flow appears to be present while near-surface circulation is less organized. Near bottom or lateral boundaries, flow closely followed bathymetric contours. Water columns at individual sites were nearly isothermal with coldest temperatures approaching 0.5 oC, however thermal imbalances within the lake were apparent. It is suggested that these imbalances create weak but consistent currents that can enhance or reverse the net northward flow of water through the lake. Observations taken at a natural restriction approximately 30 km from the southern end of the Main Lake show an unexpected and consistent southward flow, however a hypothesized return flow has not been observed. From early Spring to late Fall, the hydrodynamics of the Main Lake were dominated by the presence of an internal seiche; the most dominant being the first mode. Spectral and cross-spectral analysis of temperature, currents and wind showed the dominance of atmospherically controlled oscillations (7.1 and 10.7 days) and basin dominated modes (4.3, 2.7 and 1.8 days). These shorter periods can be related to the uninodal, binodal and trinodal modes of the along-axis (N-S) internal seiche. Cross-axis internal seiches did not appear to be significant. A shifting of dominant periods inter- as well as intra-annually can be accounted for by varying conditions of the metalimnion as well as atmospheric forcing. Both the period of the internal seiche as well as the ratio of the internal Rossby radius of deformation to basin with indicate that the seiche possess a rotary component. Bimodal orientation of currents associated with the oscillatory motion of the internal seiche was evident. Bottom currents, with bimodal orientation, tend to be preferentially aligned with bottom topography. Nonlinear aspects of the internal seiche in the form of internal surges and bores were observed. Wave heights exceeding 10 m showed pronounced asymmetry of wave shape along with departures between the zero-velocity crossing interface and metalimnion. Similar periods of the internal seiche and atmospheric forcing have the potential to create a resonant system. Highly nonlinear events where maximum metalimnion displacements exceed 60 m have been observed. Sudden increases in hypolimnic temperature appear to be tied to these events,. Whether these deep temperature shifts were a direct result of surface outcropping of the hypolimnion and/or significant internal mixing at the shoaling ends of the lake has yet to be determined. Accompanying near-bottom velocities of 30-50 cm/s are sufficient to resuspend sediment within the Main Lake

HYD-P1 LARGE POCKMARKS: EVIDENCE OF GROUND WATER FLUX INTO LAKE CHAMPLAIN

P.L. Manley, S. E. Sayward, N. North, T. O. Manley, and R. Pederson, Middlebury College

High-resolution side-scan sonar surveys conducted since 1990 have identified several significant sedimentary bedforms in Lake Champlain. One particular bedform which has been studied in detail are large pockmarks. Side-scan sonar mosaic of Burlington Bay has shown the existence of pockmarks. Pockmarks range is size from <1 m in diameter to over 30 m in diameter. They exist as single features, in chains 50 m in length and ~ 1 km^2 aerial extent. Two pockmark fields are located directly over the Champlain Thrust, while several pockmarks lie 250 m to the east. Aligned often in chains, these features have a northeast linear trend. Cores taken inside and outside the largest pockmark show coarser material of sand and silt within the pockmark in comparison to a silty clay found outside the pockmark. Side scan sonar profiles obtained during the 1996 summer Lake Champlain Shipwreck Survey, revealed two pockmarks fields near Cumberland Head. One field is 0.75 km^2 in aerial distribution and the second field is 1.75 km^2. The pockmarks within the fields are on average 20 m in diameter and a few meters deep. The pockmarks are arranged along a linear trend that run southeast to northwest which matches the region tectonic fabric of the bedrock geology. Three cores (7.62 cm in diameter and ranging in length from 167 cm to 204 cm) were taken in the smaller pockmark field to investigate the formation of these pockmarks. The cores were positioned to obtain samples directly inside a pockmark (core 3), close to the edge of a pockmark (core 1)

and within the intervening pockmark-free field (core 2). Physical properties, magnetic susceptibility, conductivity, pore water chemistry and grain size of the cores were measured. The core taken inside the pockmark show distinctly different results than those taken outside of it. Linear distribution aligned with basement faults, core physical properties and pore water chemistry suggest that the these large pockmarks are created by ground water migrating upward and through the lake sediment.

HYD-P2 EFFECTS OF THE INTERNAL SEICHE IN THE SOUTH MAIN LAKE OF LAKE CHAMPLAIN

L. Klein and T. O. Manley, Middlebury College

The seiche system has been found to have remarkable effects on Lake Champlain. One area in particular that hasn't been researched in any detail is the south end of the lake. With eight mooring points along the length of the test area, devices such as temperature sensors, current meters, and even cameras have been implaced at different locations and depths throughout the thermoclines. After these data recorders have been retrieved, the information stored within will then be downloaded onto computers. Once on the computers the results will be interpreted and it will be determined how the shallower, south end of the lake is effected by the seiche. Do the internal thermoclines break like waves? Does the colder, deeper water ever reach the surface? Is there a strong undercurrent on the lake floor responsible for sediment storms? With the data retrieved, new information can be used to help answer these questions.

HYD-P3 UNITED STATES GEOLOGICAL SURVEY STREAMFLOW-GAGING NETWORK IN THE LAKE CHAMPLAIN BASIN

A. Cohen, USGS

The U.S. Geological Survey (USGS) operates a network of 35 streamflow-gaging stations in the Lake Champlain Basin in the States of New York and Vermont. Of these stations, 17 are jointly funded by the Lake Champlain Special Designation Act and the USGS and are operated primarily to supply continuous streamflow information to other Federal, State, and local government agencies for use in planning and operating water-resources projects and regulatory programs. Other uses of continuous streamflow data include day-to-day administering and managing of water resources, determining the extent and severity of droughts, and characterizing and predicting conditions during floods.

NUTRIENTS AND CHEMISTRY

NCH1330T MODELING PHOSPHORUS CYCLING, TRANSPORT AND STORAGE IN STREAM ECOSYSTEMS TYPICAL OF THE LAKE CHAMPLAIN BASIN.

J. P. Hoffmann, Botany Dept.; A. E. Cassell, SNR, UVM

A computer simulation model that describes dynamics of phosphorus (P) in streams was developed as part of a coordinated effort to understand movement of P within the LaPlatte River, Vermont. This effort included seasonal field assessment of P stocks, and the use of laboratory mesocosms for determining P fluxes. The model was the integrator of this effort and incorporated theory and parameters of stream dynamics from the literature, and parameters measured during this study. The model was constructed with the object-oriented program STELLA II. The model structure allows tracking of P dynamics in a stream by providing graphical and tabular outputs for a variety of variables. The main objective of the modeling effort was to simulate P dynamics under conditions of variable discharge and P concentrations, during the growing and non-growing seasons. The stream reach was modeled as an open system, with P inputs entering the system and P outputs leaving the reach. At any instant in time, all P in the reach was assumed to be located within five compartments (water, sediment, periphyton, macrophytes and detritus) and major physical, chemical, and biological processes operating within the reach to move and transport P among the compartments and through the reach are modeled. Simulations were run using USGS hydrograph data and output was found to favorably compare to seasonally measured P stocks and fluxes. The model was used to predict P retention and transport through a 3 km reach of the river in which P pulse experiments were conducted during the winter and summer seasons. The predicted magnitude and duration of the P pulse through the reach again compared favorably to the measured pulse. The model appears capable of simulating P cycling, transformation, transport and storage of many of the stream flows and reaches found in the Lake Champlain Basin.

NCH1415T Measurements of Phosphorus Uptake by Macrophytes and Epiphytes from the LaPlatte River (VT) using 32P in Stream Microcosms

D. K. Pelton, Cold Regions Research and Engineering Laboratory; S. Levine, SNR UVM; M. Braner, Vt. Dept. of Health

Phosphorus (P) uptake by macrophytes and epiphytes from the LaPlatte River (VT) was examined in the laboratory by adding 32PO4-P to recirculating stream microcosms. Water, plugs of sediment, and plants were removed from the river and placed into the microcosms. 32PO4-P was then added either to the water or the sediment, and its incorporation into plants and epiphytes was monitored over three days. Uptake was examined at both ambient (5 µg l-1) and increased (50 µg l-1) soluble reactive phosphorus (SRP) concentrations. A computer program was developed to fit curves to the radiotracer data and calculate rate constants for the simultaneous transfer of 32P among compartments. Both macrophytes and epiphytes removed P from the water, but epiphyte uptake of P was more rapid. Phosphate enrichment stimulated P uptake by both macrophytes and epiphytes. Macrophytes also obtained P from the sediment. The relative contribution of P to macrophytes from the water versus that from the sediment appeared to vary with SRP in the overlying water. Accurate estimates of rates of P uptake from sediments by macrophytes were difficult to obtain, however, due to very low and highly variable unit rate constants for P uptake and uncertainty about the magnitude of the phosphate pool available for uptake. SRP concentrations were greater in the overlying water than in the sediment pore water of our stream microcosms. Numerous reports in the literature have suggested that this condition favors uptake by macrophyte stems and leaves rather than by roots. Phosphate uptake from the water by macrophytes in shallow streams may be more common than for macrophytes in lakes. Temporary storage of P in the stream macrophyte-epiphyte complex may help decrease P loading to Lake Champlain during the growing season.

NCH1435T Phosphorus Cycling, Transport, and Storage in the LaPlatte River, Vermont

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To assist managers to reduce P fluxes to Lake Champlain, a three year study was conducted to evaluate the potential of the LaPlatte River to store and release P over time. P stocks and dynamics in water, sediment, periphyton, macrophytes, and detritus were measured over the study period in two selected reaches of the river. In a soft-bottom, slow-flowing pool environment an average of 33.3 g/m2 of P was measured. This was ten times the average 2.8 g/m2 stored in a cobble-dominated, fast-flowing stream at Spear St. The majority of P was stored in sediments at both reaches, (97% and 80%, respectively, considering the top 5 cm of sediment). While sediment is the most important stock, biological uptake of dissolved P by epilithon, macrophytes, and associated epiphytes exceeded sediment uptake by a factor of 10 as estimated using radioactive tracers in microcosms. Field studies using an addition of concentrated P and Rhodamine WT dye documented a 30% uptake of P during the growing season, and negligible long-term uptake of P by sediment during the dormant season. These two results support the concept that the biological component of the river appears to have the most important seasonal role in modifying P concentrations in stream water. Using a dynamic simulation model to extrapolate to a larger river section, prediction of P retention and transport in the river following a pulse addition of P in winter approximated empirical observations. This suggests our concepts of important sinks and their dynamics may be relevant to larger reaches of the river than those we selected for intensive study. Extending our data on P stocks to the river as a whole using GIS descriptions of the LaPlatte River network, we estimate that about the same magnitude of P is stored in the stocks we measured in the river, 8 Mg P (Mg = metric ton) as is estimated to leave the river in a year, 7.6 Mg P/yr. Thus the potential for long-term P storage in river by the mechanisms we studied is probably much less than the annual flux.

NCH1455T Storage, Transport, and Decomposition of Detritus in the LaPlatte River, VT

H. L. Galarneau, SNR UVM

The transport, storage, and processing of detritus was examined in a riffle and a pool reach of the LaPlatte River, a stream in an agricultural region of Vermont which flows into Shelburne Bay of Lake Champlain. Storage was assessed by removing and weighing all visible detritus (1 cm) from randomly placed quadrats and by measuring the dimensions of logs and branches in stream transects. Transport was assessed with a trap which caught detritus moving in suspension and separated it according to size. Litter bags filled with locally common macrophytes and tree leaves were incubated in the stream to estimate detritus processing rates. In addition, the radiotracer 32P was used to estimate the extent to which microbes associated with stream detritus remove P from solution to support their growth. The results suggest that the LaPlatte shares many characteristics with streams in forested regions: tree leaves make up a considerable proportion of the small-sized detritus on the stream bottom, especially in fall, and dead wood (logs and branches) is the largest detrital store. However, the overall detritus store is lower in the LaPlatte than in forested streams. Detritus transport rates were flow dependent in the LaPlatte, with leaves being an important component of the suspended load during the fall, as in forested streams. In summer, macrophyte fragments were common at the pool site and algal fragments at the riffle reach. Tree leaves and macrophytes were processed at similar rates, with the exception of Elodea, which decomposed exceptionally quickly. All litter bags accumulated fine inorganic material which could strongly bias estimates of detrital processing if not removed from detritus prior to weight measurements. The microbial community on the surface of detritus, particularly aquatic plant debris, played a major role in removing P from solution. As with forested streams, an increase in P storage on an areal basis was observed during the fall in the LaPlatte, due to increased storage of terrestrial leaves during that season. Agricultural streams appear to be more similar to forested streams than generally believed, perhaps because their woody riparian zones strongly influence the detritus they receive.

NCH1515T Retention Of Spike Additions Of Soluble Phosphorus In The LaPlatte River, Vermont

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We conducted two experiments to evaluate phosphorus transport through a third-order eutrophic stream under different seasonal conditions, adding spikes of dissolved P and a dye tracer at the head of a 3 km reach. The winter experiment was conducted when the stream was ice-covered and biological growth was minimal; the summer experiment occurred when plant growth was abundant. The dye and P plumes were delayed and spread out in space and time due to transient storage phenomena. Initial reversible short-term P retention was demonstrated in both experiments. In winter, 35% of the added P was retained in the reach for about 11 hours; estimated P uptake rate was 0.042 mg P/m2/min. In summer, 66% of added P was retained for 20 hours, at an estimated uptake rate of 0.054 mg P/m2/min. All the P added in winter was exported from the reach within 24 hours; 31% of added P (12 mg P/m2) was still retained in the stream reach at the end of the 38 hour summer experiment. P retention was influenced by flow, temperature, concentration gradient, and biological activity. Short-term retention probably resulted from sorption by inorganic sediments and organic biofilms; long-term retention may have been due to active biological uptake, as well as enhanced sediment sorption. In-stream P retention processes may not be capable of influencing P transport during high flows and cold temperatures, but may potentially attenuate spikes of P delivered to the stream in small stormflows during the growing season.

NCH1120W 1993 and 1998 Nonpoint Source Phosphorus Load Assessments

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In 1993, the best available land use data for the Lake Champlain Basin were used to estimate nonpoint source phosphorus (P) loads to the lake in a loading function model that combined P concentration coefficients with regional hydrologic data. The estimates were verified against monitored loading data, then used to assess the relative magnitudes of P loads contributed by the major land uses and sub-watersheds that comprise the Basin. According to the 1973-76 GIRAS land cover data, the Basin was 62% forest, 28% agricultural land, 3% urban, and 7% water. The best fit model estimated an annual total P load of 457 mt/year, which did not differ significantly from the 458 mt/year measured for an average hydrologic year, and accurately predicted loads from major tributaries. Agriculture contributed 66% of the annual nonpoint P load, with urban and forest land contributing 18% and 16% respectively. Because agricultural lands contribute the bulk of the nonpoint source P load, efforts to reduce P loads will need to focus on agricultural sources. However, because urban land comprised only 3% of the Basin and yet contributed 18% of the estimated load, load reduction efficiency may be greater in urban areas. The 1993 assessment clearly demonstrated to the Lake Champlain Management Conference and the public the relationship between land use and nonpoint P loads in the Lake Champlain Basin which was a prerequisite for reaching consensus on a P load reduction strategy. Now a new Basin-wide P assessment is underway largely following the same methodology. Differences include the use of: 1993 satellite-derived land use data for the entire Basin; a more detailed delineation of hydrologic units; and a raster (rather than a vector) GIS environment. This new study should result in a higher resolution determination of nonpoint P sources which will help to more specifically target areas for P load reduction efforts.

NCH1140W Long-term Trends in secchi disk transparency in lake champlain

E. Smeltzer, VT DEC

Secchi disk transparency monitoring data obtained throughout Lake Champlain during 1964-1974 by Henson and Potash were combined with results from more recent monitoring programs to create a 34-year record of water clarity in the lake. The long-term data were analyzed to determine whether there have been transparency changes in Lake Champlain as a result of lake management efforts or other factors. The general trend over the past three decades has been one of improving Secchi disk transparency in Lake Champlain. However, each area of the lake has responded differently within this overall long-term trend. In the South Lake, Secchi disk transparency remained statistically unchanged until the last few years when the zebra mussel invasion produced water clarity unprecedented for that region of the lake. In the Main Lake and Northwest Lake regions, there were significant improvements in transparency during the 1980s, relative to the earlier data set. These improvements can probably be attributed to phosphorus load reduction efforts in the Lake Champlain Basin, including the passage of phosphorus detergent bans and the construction of advanced wastewater treatment facilities. In Missisquoi Bay and the Northeast Arm, the finding of deteriorating water transparency in recent years emphasizes the need for further phosphorus reductions in the Missisquoi Bay watershed.

NCH1200W Modeling Benthic Phosphorus Cycling in Lake Champlain

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Eutrophication caused by phosphorus enrichment is a major water quality management issue for Lake Champlain. Previous studies have suggested that phosphorus release from the sediment may be an important component of the overall phosphorus mass balance, particularly in eutrophied regions of the lake such as St. Albans Bay. However, the role of lake sediments in the phosphorus cycle and the potential for release of phosphorus from the sediment is not well understood. In order to better understand the role of the sediment in the phosphorus cycle in the lake, the Lake Champlain Basin Commission issued a contract in support of field studies and mathematical modeling. While a companion paper will detail results from the field effort, this paper will focus on the water quality model developed under this funding. A quasi-three-dimensional time-variable coupled water quality/sediment model has been developed and calibrated which relates phosphorus loading, phytoplankton biomass and dissolved oxygen. The model includes a coupled sediment nutrient flux sub-model which accounts for organic matter deposition to the sediment, its subsequent diagenesis and the flux of resulting end-products (i.e.,phosphate) back to the overlying water column. The calibrated model reproduces many of the features of the phosphorus cycle in Lake Champlain. For the majority of the lake, the model computes the magnitude of the total phosphorus and properly distributes the phosphorus between the dissolved inorganic, dissolved organic and particulate organic fractions in both the sediment and the water column. The model also reproduces, for many regions of the lake, the seasonal cycles in phosphorus loading, algal biomass and resilting dissolved oxygen. Model computations suggest that sediment recycling of phosphorus may be important in certain localized embayments but is probably small on the whole-lake basis.

NCH1415W Phosphorus dynamics in vegetated buffer areas between cornfields and streams in the Lake Champlain Basin.

C. Borer, SNR; J. Hughes, SNR; W. Jokela, Plant and Soil Science Dept.; D. Wang, SNR, UVM

Phosphorus (P) in runoff from crop fields can enter adjacent streams and contribute significantly to P loading and resultant water quality problems in Lake Champlain. Vegetated buffers between field and stream, however, may retain P and reduce its movement into surface waters. We conducted a study to a) categorize the types of riparian zones that occur in the Champlain Basin and their relative importance, and b) measure the effect of existing buffers on runoff P concentrations. A systematic sampling of 5% of the orthophotos in the Vermont portion of the Champlain Basin (NY and Que. not available), led to the development of a classification scheme of buffer types and the identification of "critical" factors that determine the effectiveness of buffers in P retention. Narrow buffers with primarily grassy or herbaceous vegetation were quite common. These buffers may provide minimal P retention potential because of their limited width. To assess the effect of buffer width on P runoff concentrations, we established three study areas on medium to fine textured soils with grassy/herbaceous buffers adjacent to manured cornfields. Water samples were collected from approximately 45 runoff events from late summer 1996 through mid-summer 1997, using collectors at varying distances from the field. In addition, grab samples were collected during 18 relatively heavy events. Water samples were analyzed for total P (TP), and selected samples were analyzed for total suspended solids (TSS), pH, soluble reactive P (SRP), and bioavailable P (BP). Results were variable but there was a trend toward reduction in TP and solids with distance across the buffer. There may also be a threshold distance beyond which concentrations tend to be acceptably low. Highest TP concentrations tended to occur in high intensity storms or thaw events. TP and TSS concentrations were strongly correlated at all sites, indicating most P in runoff was adsorbed to soil particles.

NCH1435W PHOSPHORUS MANAGEMENT IN LAKE CHAMPLAIN

E. Smeltzer, VT DEC

Eutrophication management in Lake Champlain has expanded over the past several years into a comprehensive approach involving the analysis of lakewide response to multiple point and nonpoint sources of phosphorus. A user survey analysis of the relationship between phosphorus levels and recreational use impairment was used to derive in-lake total phosphorus criteria for 13 segments of Lake Champlain. Annual water, chloride, and phosphorus loadings to the lake were measured by a field sampling program and used to support the development of a whole-lake phosphorus mass balance model. The model used a minimum-cost optimization procedure to identify the load reductions needed in each sub-watershed to attain the in-lake phosphorus criteria. Watershed phosphorus loading targets established by the model provided the basis for a Lake Champlain phosphorus reduction agreement negotiated by the States of Vermont and New York and the U.S. Environmental Protection Agency in 1996.

NCH1455W RESPONSE OF ST. ALBANS BAY TO A REDUCTION IN POINT SOURCE PHOSPHORUS LOADING

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For many years, St. Albans Bay, Lake Champlain (VT) exhibited highly eutrophic conditions resulting from excessive phosphorus (P) enrichment. During the 1980’s, point source phosphorus loadings from the City of St. Albans Wastewater Treatment Facility (WWTF) were reduced by about 94% through a combination of an industry closing and treatment process improvements. However, recovery of the Bay was delayed by release of accumulated phosphorus from the bottom sediments. In this study, decreases in sediment phosphorus levels between 1982 and 1992 were measured, and future water quality improvements were projected using a mass-balance model. Sediment cores were collected at 43 locations in St. Albans Bay and an adjacent wetland, including 25 sites sampled for a similar study in 1982. Sediments from depths of 0 to 12 cm were analyzed for total P, organic matter, porosity, total iron and phosphorus fractionation using an extraction sequence of NH4Cl-NaOH-HCl. Total P concentrations averaged 1239 mg/g for all samples. Biologically available inorganic P (BAIP) accounted for an average of 37.0% of total P, organic P for 20.3%, and HCl-P for 42.7%. Total P and BAIP showed considerable spatial variation within the Bay/Wetland system. Between 1982 and 1992, total sediment P decreased by an average of 350 mg/g. Of this, 50% came from the organic P fraction, 30% from the BAIP fraction, and 20% from the HCl-P fraction. A mass-balance model for total phosphorus in the water column and bottom sediments was calibrated using historical data. The model was used to gain further insight into phosphorus cycling within the Bay, and to predict the extent of future water quality improvements. These results indicate that the 'effective' phosphorus loading from the bottom sediments has decreased substantially due to the point source reduction, and further decrease is expected in the future.

NCH0910R IS SEDIMENT RECYCLING AN IMPORTANT SOURCE OF WATER COLUMN SOLUBLE REACTIVE PHOSPHORUS?

J. C. Cornwell and M. Owens, University of Maryland

To examine the role of sediment biogeochemical processes in the Lake Champlain P cycle, we used 1) core incubations and in situ chambers to examine the exchange of oxygen, nitrogen and phosphorus across the sediment-water interface, 2) the pore water chemistry of P, N, Mn, Fe, and S to provide a better picture of redox cycling and 3) solid phase analyses with Pb-210 sediment dating to calculate P burial rates. Sediment releases of soluble reactive P (SRP) are generally low (< 5 umol m-2 h-1) throughout the lake, with the exception of sites in St. Albans and Missisquoi Bays. Pore water and solid phase data suggest that Fe oxide phases may exert a strong influence on P remobilization within the sediments. Our whole-lake P burial estimates are ~50% higher than published 1990-92 mass balance P retention data, in reasonable agreement considering the extrapolation of 17 cores to the entire lake bottom. Pore water P gradient-based calculations of SRP exchange were significantly correlated with incubated core fluxes, but were a poor predictor of actual fluxes. At the intensive sites with high water column P concentrations, 50% of sedimented P was recycled to the water column. In contrast, the other sites had a P recycling rate of 10%. The recycling of P to the water column of Lake Champlain is an important local process; on a whole lake basis, recycling rates are low.

NCH0930R TRACE ELEMENT CONCENTRATIONS IN FOLIAGE OVER TIME

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Trace elements in hardwood foliage were sampled in the Lake Champlain Watershed during the 1995 growing season. The species sampled were Acer saccharum Marsh. (sugar maple), Betula alleghaniensis Britt. (yellow birch), and Fagus grandifolia Ehrh. (American beech). Foliage samples were collected from mid-canopy (9-12 m) from a meteorological tower located within the forest. Four sampling times were chosen: as leaves were emerging from the buds (May), fully emerged leaves (June), late summer leaves (August), and pre-senescing leaves (September). Litterfall was collected during October, 1995 and composited into early and late season samples. Trends were observed in elemental concentrations over the growing season and in litterfall. In foliage, most elements exhibited differences between species, suggesting physiological processes were influencing uptake (Rb, Zn, Sr, and Ba). Mercury was the only element which consistently increased in the foliage of all species throughout the growing season and peaked in litterfall. This behavior suggests the uptake of gas-phase Hg from the atmosphere; a pathway which is not available for the other elements measured in this study.

NCH-P1 AN ANALYSIS OF THE RELATIVE CONTRIBUTION OF ATMOSPHERIC NITROGEN TO LAKE PHYTOPLANKTON NUTRITION: DOES FIXATION PREVENT NITROGEN LIMITATION?

M.M. Lescaze, SNR; S.N. Levine, SNR; A. Lini, Geology Dept.; J.E. Leech, SNR, UVM

A major question of limnology is whether the nitrogen fixation initiated by blue green algae during periods of low dissolved inorganic nitrogen (DIN) availability is sufficient to prevent nitrogen limitation in lakes. The relative amounts of nitrogen available to phytoplankton through fixation versus dissolved inorganic sources can be determined through the comparison of the stable isotope composition (d15N) of phytoplankton with the d15N signatures of the two sources. Phytoplankton concentrated on filters and ammonium and nitrate extracted from lake water were analyzed for three Vermont lakes known to have nitrogen-fixing activity. Phytoplankton d15N signatures ranged from 3.19 to 5.17 in mesotrophic Indian Brook Reservoir, from 3.41 to 8.08 in eutrophic St. Albans Bay in Lake Champlain, and from -0.13 to 4.55 in hypereutrophic Shelburne Pond. Seasonal trends in d15N were inversely correlated with heterocyst densities, with the lowest d15N signatures obtained during periods of blue green algal abundance. In addition, the d15N of phytoplankton was correlated with chlorophyll a concentration in blue-green-dominated St. Albans Bay and Shelburne Pond (but not in Indian Brook Reservoir). These trends are currently being compared with the d15N of DIN and atmospheric N2 to quantitatively assess the relative contribution of nitrogen fixation to nitrogen nutrition in the three lakes. Nutrient limitation in each lake was assessed through nutrient enrichment experiments in cubitainers incubated in situ and through analysis of TN:TP ratios.

NCH-P2 Distribution Of Phosphorus In Bed Sediments Of The Winooski River Watershed, Vermont

A. Chalmers, USGS

The concentrations of total phosphorus (TP) and grain-size distribution of streambed sediments were analyzed in the Winooski River watershed, Vermont during summer low flow, 1997. Concentrations of TP in fine-grained bed sediment ranged from 650 to 1,180 milligrams per kilogram (mg/kg). A general increase in the concentrations of TP from the headwaters to the watershed outlet is probably the result of cumulative effects of wastewater discharges and urban and agricultural runoff to the streams. The watershed was characterized in terms of land use, soil type, basin slope, and flow regime to determine the controls on storage and transport of TP in bed sediment. Land use appeared to have the greatest influence on TP distribution. Concentrations of TP in bed sediments were higher in urban and agricultural areas than in forested areas. Concentrations of TP in bed sediment related to grain-size; sediment of less than 62-micrometer-sieve diameter (silt and clays) had a median TP concentration of 950 mg/kg, whereas sediment between 62-micrometer and 2-millimeter-sieve diameter (sands) had a median TP concentration of 300 mg/kg. Flow regime strongly influenced grain-size distribution. Bed sediments in impoundments consisted of fine sand, silt and clay, whereas bed sediment in depositional areas in rivers consisted of medium and fine sands. These data indicate that there is a significant TP storage in impoundments that would be an important factor in predicting TP loads in the watershed.

NCH-P3 Improved Phosphorus Recommendations for Crop Production and Water Quality in the Champlain Valley

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The need for reliable recommendations for phosphorus application on cropland has become increasingly important in recent years with the need to optimize economic inputs and minimize adverse water quality impacts. We used results from a series of recent laboratory and field experiments with Champlain Valley soils, combined with those of earlier work, to revise state recommendations for P application on field crops. Based on results of field and greenhouse studies, we established a critical value of 4 mg/kg (optimum range of 4 to 7) using modified Morgan extractant (1.25 M NH4OAc, pH 4.8) as a measure of plant-available P. Aluminum in the same extractant ("reactive" Al) correlated well with the amount of added P needed to increase soil test P. Consequently, P rate recommended for soils below 4 mg/kg is based on a combination of extractable P and Al. Within the optimum range only a low rate of P is recommended. Modified Morgan P also correlated well with P desorbed into water or CaCl2 solution, suggesting it is a good indicator of the potential for a soil to release P into runoff. These research results support use of modified Morgan-extractable P and Al for P fertilizer recommendations for crop production and water quality purposes in Champlain Valley of Vermont and New York.

NCH-P4 Lake Champlain Basin Agricultural Watersheds National Monitoring Program Project

D. W. Meals, New England Interstate Water Pollution Control Commission; S. Ober, SNR UVM

Achievement of management goals for Lake Champlain will require significant reduction of nonpoint source phosphorus loads, particularly from agriculture, the dominant nonpoint source activity in the Basin. Among all Lake tributaries, the Missisquoi River basin contributes the greatest proportional share of phosphorus to Lake Champlain and is itself impacted by nutrients, organic matter, and bacteria from animal wastes originating from dairies, cropland, and livestock activity within streams and riparian areas. Reliable treatment approaches beyond basic cropland and waste management practices must be explored as part of a cost-effective phosphorus reduction strategy for the Missisquoi River Basin and for Lake Champlain. The Lake Champlain Basin Agricultural Watersheds National Monitoring Program (NMP) Project is one of twenty special nonpoint source pollution control projects across the nation, funded by the U.S. Environmental Protection Agency under Section 319 of the Clean Water Act. The NMP projects are designed to have a high probability of documenting water quality improvements resulting from nonpoint source controls through intensive water quality monitoring over a five to ten year project lifetime. The Vermont project is designed to foster the voluntary implementation of livestock exclusion, streambank protection, and riparian restoration practices among watershed landowners and to evaluate treatment effectiveness in reducing concentrations and loads of sediment, nutrients, and bacteria in surface waters. One control and two treatment watersheds of 690 to 1422 ha in Berkshire and Richford, Vermont, have been monitored since 1994 according to a paired-watershed design. Results of successful calibration monitoring are presented. The progress of land treatment implementation, including installation of riparian fencing, protected stream crossings, and streambank bioengineering is discussed. Post-treatment monitoring of both agricultural activity and water quality is scheduled through 1999.

NCH-P5 PHOSPHOROUS STORAGE IN THE WINOOSKI RIVER FLOW CORRIDOR

T. Menees, SNR UVM

Phosphorous (P) exported from drainage networks into lakes contributes to eutrophication. Much research has focused on stormwater runoff from urban, agricultural and forest lands as sources of P exported from watersheds. Additional knowledge is needed to better understand particulate P transport through watershed drainage networks. Stream channels, riparian ecosystems and floodplains comprise flow corridors and store P over long or short time periods in P transport from its source to the watershed outlet. This project will study spatial distributions of particulate phosphorous in the watershed flow corridor. Areas of sediment and P storage will be identified in the flow corridor to assess spatial patterns of P storage along river reaches dominated by meanders. Five meander reaches will be targeted as areas of active erosion in the Winooski River Watershed in Northern Vermont. Watershed conditions will be represented based on channel sinuosity, floodplain soil type and adjacent land-use. Study reaches include a major tributary, two upper Winooski River reaches, and two downstream main-stem reaches. August, 1997 sample collection included 24 site transects across river meander bends. Samples were collected from A and B Horizons in floodplains, concave outer banks and convex inner banks. Samples were collected from point bars and July 15, 1997 storm sediment deposits. All samples were analyzed for Total P and general textural classification. Erosion and sedimentation processes in flow corridors have spatial and temporal variability and result in sediments and soils of different particle distributions. Particulate P concentrations have been linked with grain size and vary with position in stream channels, riparian ecosystems and floodplains. Estimates of spatial distribution of particulate phosphorous concentrations in sediments and flow corridor soils may lead to a better understanding of the importance of terrestrial and aquatic linkages in phosphorous cycling, transport and storage for lotic and lentic ecosystem management.

NCH-P6 SEASONAL PATTERNS AND ENVIRONMENTAL CONTROLS OF LAKE CHAMPLAIN SEDIMENT-WATER SOLUTE AND GAS EXCHANGE

M. Owens and J. C. Cornwell, University of Maryland

Core incubations were used to estimate the sediment-water exchange of nutrients and oxygen. At six main station locations, we observed strong seasonal and interannual differences in the fluxes of oxygen, nitrate, ammnium and soluble reactive P (SRP) exchange. Spring rates of oxygen consumption were generally < 500 umol m-2 h-1, while summer rates generally exceeded that value. Large differences were observed between experiments conducted in summer 1994 and 1996. Ammnonium flux rates were generally low, with some stations indicating substantial nitrification and denitrification. Most nitrate fluxes were low and directed out of the sediment. Oxygen fluxes increased only slightly with the presence of bivalves, but the fluxes of SRP and ammonium increased dramatically. A comparison of in situ and core incubations showed no difference in the fluxes of oxygen and SRP.

NCH-P7 SPATIAL VARIABILITY IN PB-210 BASED SEDIMENTATION AND PHOSPHORUS BURIAL IN LAKE CHAMPLAIN SEDIMENTS

J. C. Cornwell and M. Owens, University of Maryland

We measured profiles of Pb-210 and a series of biogeochemical pools (C, N, Fe, Mn, Pb and total and inorganic P) at 17 sites in Lake Champlain. Using the CIC model, we successfully measured a broad range of sedimentation rates (333-5567 g m-2 y-1) in the lake. The highest sedimentation rates were found in the southern part of the lake and in Missisquoi Bay. The wide range of Pb-210 inventories suggest that preferential deposition of Pb-210 and sediment occur at some sites, at the expense of others. The calculation of P burial rates is complicated by post-depositional migration. Using the average P concentration in the top 10 cm of sediment, we estimated P burial rates of 0.47 to 4.10 g P m-2 y-1. By correcting for sediment focusing and using spatially-normalized burial rates, we estimate a whole lake P burial rate of 0.94 g m-2 y-1. Examination of the chronology of Pb contamination of each core indicates that there is a consistent pattern of Pb input, with most peaks corresponding to the 1970-1980 time period.

NCH-P8 WHAT CONTROLS THE CARBON AND NITROGEN ISOTOPIC COMPOSITION OF LACUSTRINE PRIMARY PRODUCERS? A CASE STUDY OF VT LAKES

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In order to gain a better understanding of the physical, chemical, and biological parameters that control the isotopic composition of primary producers in lacustrine ecosystems we have analyzed the C and N isotopic composition of terrestrial plants (for comparison), aquatic macrophytes, algae, and dissolved inorganic C (DIC) in fourteen Vermont lakes. Terrestrial plants yield delta-13C values of -29.5 ± 2 per mil. Aquatic macrophytes, algae, and DIC show a larger variability in their delta-13C values (-20.3 ± 6, -26.2 ± 5, and -6.3 ± 3 per mil respectively). The most positive delta-13C values for aquatic plants and DIC are observed in eutrophic to hypertrophic lakes, indicating a general relationship between trophic status and C-isotopic composition. Despite the observed fluctuations in isotopic composition, the difference between DIC and phytoplankton delta-13C values appears remarkably constant in all lakes (21.3 ± 1 per mil). Analyses of nitrogen isotopes show distinct ranges for terrestrial and aquatic plants (-0.7 ± 1 and 3.2 ± 3 permil, respectively) reflecting the different source of nutrient N (soil N vs dissolved inorganic N). Blue-green algae represent a unique case because of their ability to fix atmospheric N. Fixation of atmospheric N is clearly indicated by their N-isotopic composition. Three lakes (L. Champlain, Indian Brook Reservoir, and Shelburne Pond) have been sampled bi-weekly since Spring 1997 to investigate seasonal variations in the isotopic composition of phytoplankton. Significant seasonal variability in delta-13C and delta-15N is found in Shelburne Pond and Lake Champlain, whereas Indian Brook R. does not show much change. The isotopic data strongly correlates with Chl a data, suggesting that the isotopic composition varies in response to seasonal changes in primary productivity. The correlation between isotopic composition and productivity levels can be used in studies of recent sediments to monitor the response of lake ecosystems to documented increases and/or decreases in nutrient loads.

TOXIC SUBSTANCES

TOX1630T TOXIC SUBSTANCES IN LAKE CHAMPLAIN: A REVIEW OF RESEARCH AND MONITORING EFFORTS

A. McIntosh and M. Watzin, SNR, UVM

After years of comparatively little evaluation of the problems posed by toxic substances in the Lake Champlain, the past five years have seen a dramatic increase in both research and monitoring related to this issue. Early efforts prior to 1990 included routine monitoring by the states of Vermont and New York and the Province of Quebec of contaminant levels in various lake components, including fish tissue (mercury) and water, sediments and biota at the mouths of New York tributaries and in the Richelieu River (various substances). More recent efforts have focused on assessing the lake-wide distribution of toxic substances in surface sediments; an in-depth examination of nine sites where surface sediment levels are elevated; and a detailed chemical and biological evaluation of three sites of greatest concern: Cumberland Bay; Outer Malletts Bay; and Inner Burlington Harbor. While high PCB levels in sediments of Cumberland Bay make this location a candidate for immediate cleanup, both Burlington Harbor and Outer Malletts Bay merit continued scrutiny due to elevated levels of such substances as arsenic, nickel and manganese (Outer Malletts Bay) and silver, PCBs and DDE (Inner Burlington Harbor). Recent monitoring efforts related to toxic substances include tributary monitoring by the USGS, measurements of mercury in atmospheric samples collected in the basin, and intensive surveys of PCBs in the Cumberland Bay region. Assessments of effects of toxic substances have included surveys of fish condition at several contaminated sites and an evaluation of the sublethal impacts of mercury on juvenile walleye.

TOX1120W Distribution of PCB Congeners in Cumberland Bay and the Main Lake of Lake Champlain

R.D. Fuller, Center for Earth and Environmental; J. Jones, Lake Champlain Research Institute; L.M. McIlroy, Center for Earth and Environmental Science, SUNY Plattsburgh; C. W. Callinan, NY DEC

Polychlorinated biphenyl congeners (PCBs) were measured in aqueous and suspended, particulate-bound fractions in the water column of Cumberland Bay and the central main lake portion of Lake Champlain (Four Brothers Islands to Pt. Au Roche) in the summer of 1996. Large volume water samples (160L) were filtered through glass fiber filters, followed by XAD resin partitioning, soxhlet extraction, cleanup by silica gel/alumina and concentration by rotary evaporation to a final volume of 0.5 ml. Samples, procedural blanks, duplicates and matrix spikes were analyzed by gas chromatography/electron capture detection on a 50m HP-5 capillary column. Samples approximately 500 M from the edge of the class 2 hazardous waste site at Wilcox Dock in Cumberland Bay ranged in concentration from 2.22 to 5.96 ng/L whereas concentrations at a site in the center of Cumberland Bay ranged from 0.26 to 0.66 ng/L. In the main lake, concentrations were highest near the mouth of Cumberland Bay (0.21 to 0.38 ng/L) and decreased to the south near Four Brothers Island (0.071 and 0.073 ng/L). Congener patterns near Wilcox dock, as well as those at the Four Brothers site were dominated by light congeners characteristic of Aroclor 1242. Some main lake samples, however, showed evidence of contamination with a heavier Aroclor pattern, the source of which is unknown.

TOX1140W Ecological effects of sediment-associated contaminants in Inner Burlington Harbor, Lake Champlain

J. Diamond, Tetra Tech, Inc.; A. Richardson, C. Daly

The objectives of this project are to: (1) analyze and compare current sediment and benthic ecological conditions in the harbor with results obtained prior to the relocation of the sewage treatment outfall outside of the harbor and implementation of nonpoint source storm water controls in the adjacent watershed; (2) determine the potential for chronic sediment quality effects on biota in the harbor; and (3) evaluate potential long-term risks to aquatic biota in the harbor and begin developing management alternatives. Twenty sites (10 reference [relatively clean] and 10 possibly impaired sites) were sampled in summer 1997 with the assistance of trained volunteers from the Burlington, VT area. Samples were analyzed for whole sediment toxicity, polynuclear aromatic hydrocarbons (PAHs), select metals, and several interpretive parameters, vertical profile water quality characteristics, organism tissue PAHs, lead, and protein expression (biomarkers), and benthic macroinvertebrate community integrity. Eight of the 20 sites were sampled previously in 1993-1994 so as to examine whether ecological changes have occurred in surficial sediments in the harbor. Two striking changes that have been observed thus far are: (a) significantly lower concentrations of most pollutants in surficial sediments presently as compared to 3-4 years ago and (b) a substantial increase in the number of zebra mussels in the harbor. The decrease in sediment pollutants is believed to be directly related to the relocation of the sewage outfall as sites in the vicinity of the old discharge point appeared to exhibit the largest decreases in pollutant concentrations. The spatial pattern of pollutants in the harbor was consistent with earlier results; the southern end of the harbor and the break wall had the highest metal and PAH concentrations and also the highest concentration of mussel tissue PAH metabolites. Chronic larval fish survival and growth in lab tests were related to SEM/AVS and percent fines in the sediment while Hyalella (amphipod) survival was related to zinc and lead concentrations. Hyalella was more sensitive to sediment characteristics than the fish. Zebra mussels were most abundant in water depths <20 ft, particularly in association with macrophytes near shore. Benthic community integrity appeared to be related to the distribution of several contaminants, physical sediment properties (% fines), as observed previously, and perhaps zebra mussel abundance and distribution. Follow-up chronic toxicity, bioaccumulation, and protein expression testing at select sites sampled in the spring 1998 will be used to discern long-term risk potential and causes of risk to aquatic fauna in the harbor.

TOX1200W MANAGEMENT OF TOXIC SUBSTANCES WITHIN THE LAKE CHAMPLAIN BASIN

C. Callinan, NY DEC

The Lake Champlain Basin is a diverse and complex ecosystem. The watershed ranges from the near pristine wilderness of the Adirondack and Green Mountains to the relatively urban surroundings of Plattsburgh and Burlington. With a drainage area of 8,234 square miles, the watershed is slightly larger than the State of Massachusetts. The basin is in fairly good condition with respect to toxic substances. However, given both the diversity and expanse of the watershed, significant. There is a broad range of toxic substances which could potentially reach the basin ecosystem. These include both inorganic substances such as metals (lead, mercury, arsenic, etc.), and organic substances such as chlorinated organics (polychlorinated biphenyls, dioxins, etc.). The Lake Champlain Toxics Action Plan (LCBP-Draft, 1996) categorizes many of the toxic substances which might pose a threat to the Basin into one of four categories. The toxic substances of highest priority and concern within the Lake Champlain Basin are Mercury (Hg) and Polychlorinated biphenyls (PCBs), refered to as Group 1 contaminants. The primary justification for including Mercury and PCBs in Group 1 relates to fish consumption advisories issued by both New York and Vermont. Initial studies within the Basin have provided significant insight concerning the extent and relative importance of various toxic substances present in the Basin. The purpose of this paper will be to summarize the work to date, to discuss the relevance of these efforts to management actions concerning toxic substances, and to discuss future study needs and priorities concerning the management of toxic substances within the Lake Champlain Basin.

TOX1415W CHARACTERISTICS OF LAND USE, CLIMATOLOGY AND FOREST ECOSYSTEMS AFFECTING DEPOSITION AND TRANSPORT OF ATMOSPHERIC POLLUTANTS IN THE LAKE CHAMPLAIN BASIN

P. Girton, Vermont Monitoring Cooperative; T. Scherbatskoy, SNR UVM

While atmospheric loading of pollutants to the water surface of Lake Champlain can be assessed directly, land cover types and land use in the rest of the basin play a very important role in transferring pollutants tothe lake. This has been shown in other lake systems. The relatively large land area of the Lake Champlain basin (19:1 land:water area) suggests that a detailed accounting of land uses and ecosystem processes is needed to assess total loadings of atmospheric pollutants to the lake. The processes involved in this transfer include meterology, wet and dry deposition of nutrients and pollutants, elemental cycling, hydrology, and interactions with various natural and agricultural plant communities. This study assembles, characterizes and spatially integrates information on land use, cover type, species composition, climatology, meterology and edaphic factors in the two million hectare (ha) Lake Champlain basin. Using GIS data layers, we have developed an accurate accounting of the various land use and cover types that can differentially affect atmopsheric pollutant deposition and transport in the basin. These data are integrated with geographic, edaphic, atmospheric deposition and climatological information to produce data sets and summaries that can be used by land use analysts and atmospheric modelers to better identify factors affecting atmospheric pollutant deposition and fate in the Lake Champlain biosphere.

TOX1435W PHYSIOLOGICAL INDICATORS OF STRESS AMONG FISHES EXPOSED TO CONTAMINATED SEDIMENTS FROM LAKE CHAMPLAIN.

D. E. Facey, C. Leclerc, D. Dunbar, D. Arruda, J. Shaw, St. Michael's College; V. Blazer, USGS

From 1992 to 1998, we conducted a series of field and laboratory investigations designed to see whether or not fishes exposed to contaminated sediments in Lake Champlain showed physiological evidence of stress. We focused primarily on macrophage aggregates, discrete structures often located in the liver, spleen, and head kidney. They are believed to have an immunological function similar to that of the lymph nodes of mammals. Several published studies in the late 1980s and early 1990s had suggested that macrophage aggregates might be good biomarkers of fish exposure to contaminants because fishes from contaminated sites exhibited larger and more abundant macrophage aggregates than conspecifics from less contaminated reference sites. Our field studies included comparing yellow perch (Perca flavescens), brown bullhead (Ameiurus nebulosus), and rock bass (Ambloplites rupestris) from known contaminated sites (inner

Cumberland Bay, inner Burlington Harbor, at the mouth of the LaChute River) to reference sites with lower contaminant levels. Yellow perch showed no significant differences in macrophage aggregate parameters among sites, probably because they are a highly mobile species that is not likely to spend much time in any single location. Brown bullhead from inner Cumberland Bay and rock bass from Burlington Harbor, however, did show significantly higher macrophage aggregate parameters than fish from reference sites. Fishes from contaminated sites also showed significantly larger livers than fishes from reference sites, suggesting liver hypertrophy or hyperplasia due to the need to detoxify large amounts of contaminants. Brown bullhead from inner Cumberland Bay also showed high rates of external lesions and barbel deformities which were not observed at the reference site. In a separate study, we raised juvenile fallfish (Semotilus corporalis) in tanks containing Burlington Harbor sediment and tanks containing commercial aquarium sand. There was no significant difference in macrophage aggregate parameters between the two treatment groups at 2 weeks and at 4 weeks. Fish sampled at 8 weeks from the Burlington Harbor sediment tanks exhibited significantly greater macrophage aggregates parameters than fish from the sand tanks. However, at 12 weeks the fish from the sand tanks had significantly higher macrophage aggregate parameters. Therefore, the results of this experiment are inconclusive. Our results suggest that macrophage aggregates are good biomarkers of fish exposure to contaminants, and that fishes exposed to contaminated sediments from Lake Champlain do show evidence of physiological stress.

TOX1455W THE OCCURRENCE OF ARSENIC IN THE SEDIMENTS OF THE LAMOILLE DRAINAGE BASIN, NORTHWEST, VERMONT

R. Schuck, The Johnson Company

Two sediment cores from Arrowhead Mountain lake were analyzed for arsenic and 11 other trace metals (Ag, Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn), grain size and percent organic content. The cores were dated using the radioactive isotope, cesium 137. Both cores revealed a peak arsenic concentration at the 26 to 28 centimeter interval, which correlates to a date of approximately 1964. The input of arsenic has decreased since this time and appears to have stabilized at approximately 8 g cm-2 yr-1. Arsenic concentrations show a strong positive correlation with Cr, Ni, Pb, and Ag. Arsenic does not show a significant correlation with Fe or Mn which indicates that geochemical remobilization associated with these metals is not responsible for the arsenic distribution in the cores. Arsenic concentrations in the most recent sediments of Arrowhead Mountain Lake are below levels determined to be toxic to benthic organisms. Dredging of the lake sediments or similar disturbance may introduce elevated arsenic concentrations into the near surface sediments, creating a toxic environment. Analysis of stream sediment samples within the lake's drainage basin indicate a marked increase in arsenic concentrations in the Lamoille River immediately downstream of Johnson, Vermont. The sediments in the Gihon River, which enters the Lamoille in Johnson, also show elevated arsenic concentrations. The marked increase in Johnson is attributed to inputs from the Gihon River watershed which contains a talc mine that was active from 1906 until 1984 and from the talc processing mill in Johnson, which operated from 1906 until 1993. Analyses of talc mine spoils exhibit average arsenic concentrations of 248.5 g/g. Analyses of these same spoils with a scanning electron microscope indicates arsenopyrite as a potential source of arsenic. Earlier studies (Clemmer 1936; Cline 1960; Chidester 1962) have identified arsenic associated with the sulfides, pyrite and pyrrhotite. The talc processing mill discharged tailings directly into the Lamoille river until 1967. Since that time, the mill has stored tailings in a large tailings pile located adjacent to the Lamoille River. The decrease in arsenic concentrations in more recent sediments of Arrowhead Mountain Lake is attributed to reduced discharge from the mill upon stockpiling of the tailings. Background arsenic concentrations for the Lamoille River drainage basin are enriched by a factor of 3? compared to the rest of the Lake Champlain basin. These high background levels indicate that the bedrock deposits of talc have been a natural source of arsenic since before the mining operations were initiated.

TOX-P1 ANALYSIS OF FISH DNA INTEGRITY AS AN INDICATOR OF ENVIRONMENTAL STRESS

G. A. Bauer, B. Dwyer, L. Moyer, St. Michael’s College

Through the use of an alkaline unwinding assay, the integrity of DNA molecules (extent of nicking) can be determined. Over the course of the past three years we have been investigating the use of DNA integrity as a measure of environmental stress on fish (i.e. as a bio-marker). Our first study consisted of collecting rock bass (Ambloplites rupestris) from Burlington Harbor and the Inland Sea, followed by measuring the integrity of their liver DNA. The results from this study indicated that fish from a contaminated site (i.e. Burlington Harbor) had a higher level of DNA integrity (fewer nicks) than fish from a less-contaminated site (i.e. the Inland Sea). We followed-up on this observation with a controlled experiment in which fallfish (Semotilus corporalis) were raised in aquaria containing either clean sand or sludge dredged from Burlington Harbor. Once again, we found that fish from the clean tanks had more nicks in their DNA than the fish containing the Burlington Harbor sludge. These results are in contrast to those found by other workers, where contaminants cause a transient increase in the number of nicks in DNA. We propose that fish from contaminated sites have their DNA repair systems working at a higher rate than those fish from relatively less-contaminated sites. Further work to explore this question will require molecular analysis of DNA repair genes to see if their expression is higher in fish from a contaminated site when compared to fish from a less-contaminated site. We are also currently exploring the feasibility of using DNA obtained from blood samples so fish will no longer need to be sacrificed in order to obtain DNA integrity measurements.

WILDLIFE (NON-AQUATIC)

WLF1120T ARE CHAMPLAIN VALLEY FOREST FRAGMENTS ACTING AS POPULATION SINKS FOR MIGRATORY SONGBIRDS? EVIDENCE FROM THE VERMONT FOREST BIRD MONITORING PROGRAM.

S. D. Faccio, K. P. McFarland, C. C. Rimmer, Vermont Institute of Natural Science

Using breeding bird census data collected during the Vermont Forest Bird Monitoring Program (FBMP) from 1989 - 1997, we evaluated the number of Brown-headed Cowbird (Molothrus ater) occurrences by study site and physiographic region. Data were collected at 17 study sites located in large tracts (40.5 ha) of mature, forested habitats in 6 different physiographic regions of the state. Most cowbirds (95.3%) occurred at the 5 FBMP sites located in the Champlain Lowlands, suggesting that even relatively large forested tracts in this region may be subject to high rates of cowbird parasitism. It seems likely that other pressures associated with forest fragmentation may also be negatively affecting the breeding bird populations of the Champlain Basin, including high rates of nest predation, and reduced food supply. We suspect that the fragmented forests of this region are population sinks, resulting in reproductive rates far below the levels necessary to compensate for adult mortality. At the same time, the large interior forests of nearby areas may support source populations which produce enough surplus birds to sustain the losses of the sinks. Further research is needed to investigate this and to develop effective conservation measures.

WLF1140T AN ASSESSMENT OF GENETIC VARIATION IN BEACHPEA POPULATIONS (LATHYRUS MARITIMUS BIGEL.) ON LAKE CHAMPLAIN, VERMONT

S. Schmitz, C. Paris, D. Barrington, UVM

Lathyrus maritimus (beachpea) is a prominent member of dune plant communities which typically inhabit the Atlantic coast from Labrador to New Jersey. Interestingly, this species is also found in disjunct populations along the sandy shores of lacustrine environments such as the Great Lakes and Lake Champlain. Lake Champlain in the late Pleistocene was part of a marine estuary that included the St. Lawrence river, the Lake Champlain basin, and the Great Lakes. Today these areas retain remnants of their maritime floras in spite of their isolation from the sea. Although little has been done to elucidate the genetic relationship of these presumed relicts to conspecific coastal populations, naturalists retain the prejudice that these inland populations are waifs derived from their maritime ancestors. The objectives of the present study were two: 1) To test the hypothesis that the Lake Champlain beachpea populations are more similar to each other than they are to populations on the Atlantic coast; and 2) to determine how genetic variation is distributed within and among the Lake Champlain beachpea populations. This information would be valuable to natural resource managers in the development of a sound conservation strategy for this species, which is listed as threatened in the State of Vermont. Allozyme diversity and population structure were determined for 9 populations of beachpea; four from the Atlantic coast, and all five populations from Lake Champlain. Results from 19 allozyme loci indicate that in the Atlantic populations the genetic diversity parameters resemble those for a species that reproduces by self pollination. In the Champlain basin, these parameters reduced, and what genetic diversity exists is highly subdivided among the five populations. Phenetic analysis indicates that the Lake Champlain populations are more similar to each other than to populations on the Atlantic coast.

WLF1200T BIOGEOGRAPHY, SYSTEMATICS, AND CONSERVATION BIOLOGY OF THE CHAMPLAIN BEACHGRASS, A TAXON ENDEMIC TO LAKE CHAMPLAIN.

P. J. Walker, S. Schmitz, C. A. Paris, D. S. Barrington, UVM

The North American beachgrass, Ammophila breviligulata, is widespread along the Atlantic coast. Beachgrass populations also occur around the Great Lakes and Lake Champlain. Seymour recognized the Champlain plants as a species distinct from Ammophila breviligulata, however the specific status of the Champlain beachgrass has remained in question. All of the inland populations are presumed to have been derived from coastal populations following the retreat of the Laurentide ice sheet. To reconstruct the biogeographical history of the North American beachgrasses and to resolve the relationship of the Champlain beachgrass to the rest of the group, we undertook a study of DNA sequence variation in the ITS region of nuclear ribosomal DNA. Parsimony analyses of ITS sequence variation revealed four separate lineages within North American Ammophila, a northern coastal lineage, a southern coastal lineage, a Great Lakes lineage, and a Champlain/St. Lawrence lineage. Although these four clades were well supported, the relationship among them was not fully resolved. Topology of the ITS trees for Ammophila suggests that there was a single incursion of coastal beachgrasses into the continental interior. Further, the association of Champlain and St. Lawrence ITS variants supports the hypothesis that interior populations were derived from populations in the northern Atlantic via the St. Lawrence Seaway. Finally, nucleotide diversity is highest in the northern Atlantic lineage, which suggests that the Pleistocene refugium for beachgrass was located in that region. With respect to the status of the Champlain beachgrass, evidence from ITS sequence variation and a morphometric analysis of beachgrass structural characters suggests that the Champlain beachgrass is most appropriately interpreted as a subspecific variant of Ammophila breviligulata. We recommend that conservation efforts for this taxon focus on protection of the sand dune habitat around Lake Champlain. Such an emphasis would protect one of the rarest natural community types in the State of Vermont.

WLF1415T NONGAME MARSH BIRD ABUNDANCE AND HABITAT USE IN MANAGED WETLANDS OF THE LAKE CHAMPLAIN BASIN

N. Shambaugh

Investigations into the black tern (Chlidonias niger) population in Vermont have been performed since 1990 with the aim of gaining an understanding of the causes for the recent decline in numbers of this marsh nesting bird. Efforts have involved annual censuses as well as estimates of reproductive success and habitat use. Since 1995 this work has been expanded to include other marsh nesting birds such as bitterns and rails. Vegetation management within several public Wildlife Management Areas by the Vermont Dept. of Fish and Wildlife is currently attempting to improve habitat for waterfowl and other marsh birds. Recent activities by this researcher have concentrated on describing preferred marsh habitat structure and determining the effect of marsh vegetation control on nongame birds. The implications of these management activities for nongame marsh birds and the future of these impounded wetlands will be discussed.

WLF1435T RESEARCH AND MANAGEMENT OF THE COMMON TERN ON LAKE CHAMPLAIN, VERMONT: A CASE STUDY

M. S. LaBarr, Green Mountain Audubon Society; C. C. Rimmer, Vermont Institute of Natural Science

The Common Tern is a colonial waterbird that annually nests on Lake Champlain, Vermont. This species was listed as a Vermont endangered species in 1989 due to declining population levels. This decline was due to extremely low reproductive success during the 1970's and 1980's. Reasons for the decline include the direct and indirect effects of nocturnal avian predation, competition for nesting space with Ringbilled Gulls and human disturbance. Intensive monitoring and management began in 1987 and has resulted in increased adult tern numbers and higher reproductive success.
Population levels have gone from a low of about 50 breeding pairs in 1988 to approximately 170 breeding pairs in 1997. This paper discusses the reasons for the decline, research and management techniques and future prospects and concerns for this population.

WLF1455T Population Growth and Bioenergetics of Double-crested Cormorants in Lake Champlain

D. E. Capen, M. R. Fowle, SNR UVM

The population of double-crested cormorants in Lake Champlain has increased steadily since the birds first nested in 1982. In 1996, 3,079 pairs nested on 8 islands in the lake. We estimated the total Lake Champlain cormorant population by calculating the ratio of breeders to non-breeders in foraging flocks, which was 0.23, and estimating the productivity of the population, an average of 2.54 young per nest. With these data, we built a simple exponential population model to compare predicted growth rates with those observed on Lake Champlain and to evaluate proposed methods of controlling population growth. We estimated the intrinsic rate of increase, r, to be 0.21, and a population doubling time of 3.3 years. We then constructed a bioenergetics model that estimated the total annual fish consumption of cormorants in Lake Champlain. The model predicted that cormorants consumed 913,248 kg of fish in 1996, of which 765,778 were yellow perch averaging 11 cm in length. This is almost twice the annual harvest of yellow perch by anglers.

FINAL RESEARCH PRIORITIES
REVIEW SHEET

IMPORTANT-WE NEED YOUR HELP!

Last fall, the Lake Champlain Research Consortium met to discuss research progress on the Lake Champlain ecosystem. One product of the workshop is a set of priorities designed to guide future research on the topics being discussed at this symposium. Please review the following lists of priorities carefully and complete the following for your own research speciality. If you would like to make comments or suggestions on topics outside of your speciality, please use the back of this page. Al McIntosh will present these results for discussion on Thursday at 11:00 AM. Thank you for your time and input.

1) I believe the priorities as stated are appropriate ________________

2) I recommend the following changes:

Research Priority Area:

Suggested addition, deletion or change:

Research Priority Area:

Suggested addition, deletion or change:

Research Priority Area:

Suggested addition, deletion or change:

Research Priority Area:

Suggested addition, deletion or change:

Research Priority Area:

Suggested addition, deletion or change:

PLEASE RETURN TO THE REGISTRATION DESK BY 5:00 PM WED.

Final Research Priorities
Introduction

Al McIntosh, University of Vermont

A two-day workshop to review the status of recent research and monitoring on the Lake Champlain ecosystem and to develop priorities for future efforts was held on October 31 and November 1, 1997 at the Bishop Booth Conference Center in Burlington, Vermont. The event was co-sponsored by the Lake Champlain Basin Program and the Vermont Water Resources and Lake Studies Center.

On the first day of the program, researchers and state federal regulators presented brief summaries of relevant research and monitoring activities undertaken since the passage of the Lake Champlain Special Designation Act. The areas of endeavor discussed and the speakers were the following:

Topic	**Speakers**
Atmospherics	Tim Scherbatskoy/Rich Poirot
Cultural/Social Issues	Art Cohn/Ann Cousins
Economics/Land Use	Art Woolf/John Banta
Ecosystem Health	Mary Watzin/Dave Tilton
Fisheries	Donna Parrish/Larry Nashett
Hydrodynamics/Sediments	Tom Manley/Jamie Shanley
Nutrients	Suzanne Levine/Eric Smeltzer
Toxic Substances	Alan McIntosh/Fred Dunlap

On the second day of the workshop, participants discussed priorities developed by Friday's speakers. The following pages contain a listing and brief description of priority research needs identified for each area. In addition to those areas listed above, we have included an additional set of priorities related to biodiversity issues. Listed priorities represent the best current thinking of experts in each area and are intended to serve as a basis for decisions regarding the allocation of future research funding within the basin.

Readers of this document should note the following: (a) there has not been an attempt to rank priorities in any area; and (b) there is substantial overlap between priorities in many areas. For example, research in the areas of toxic contamination and nutrient enrichment would benefit from additional data generated by research describing the flow patterns in the lake. Similarly, information about the impact of zebra mussels on the lake's ecosystem would benefit both investigations of the lake's fish communities and the problem of nutrient enrichment. It is important for researchers in the various areas to communicate to insure that research results can be useful in all relevant areas of endeavor. Hopefully, the Lake Champlain Research Consortium can facilitate such coordination.

A final point relates to information management. Over the past six years, we have made substantial progress using technologies like GIS and remote sensing to display data on a variety of aspects of the Lake Champlain ecosystem. We have included a list of data management priorities developed by Bruce Westcott of the VT Center for Geographic Information, Inc., John Banta of the Adirondack Park Agency and Lenore Budd of ARD, Inc. in our list of research priorities. All investigators are encouraged to take advantage of these resources as they plan research projects or interpret data from on-going work. Contact the Vermont Center for Geographic Information, Inc. at 802-656-4277 or visit their web site at http://geo-vt.uvm.edu for more information.

Atmospheric Research Priorities

Tim Scherbatskoy, University of Vermont

1. *What are the atmospheric processes that are important to Lake Champlain?*

Atmospheric processes are important in the Lake Champlain basin because the atmosphere is a constant source of nutrients, pollutants and energy. The Lake Champlain basin is in a substantially polluted airshed, and the lake itself is in a relatively large watershed (19:1 watershed:lake area) which is affected by the atmosphere. Within the basin there are multiple ecosystem functions and human uses that are directly and indirectly affected by atmospheric processes.

Atmospheric deposition of acidifying substances, toxics and nutrients continues to affect the basin. The main pathways for deposition include wet deposition (precipitation, cloud water) and dry deposition (gasses and particles). The fate of these atmospheric substances is affected by a number of ecosystem properties, including landscape structure, complex atmosphere-surface interactions, biogeochemistry, energy flow and cycling, and food web processes. Finally, climate change is probably having significant direct and indirect effects on the ecosystems of the basin and their responses to atmospheric and other factors. These include changes in the physical (precipitation, temperature, radiation) and chemical climate (nutrients, pollutants).

2. *What are currently the most pressing atmospheric issues in the Lake Champlain basin?*

Toxic contaminants (including Hg, PCBs, PAHs, and fine particulate trace metals) pose the greatest threats to the organisms and ecosystems in the basin, and processes affecting their transport and accumulation are not well understood. Nutrients are an emerging atmospheric problem, as nitrogen deposition continues to be high and calcium deposition (important to upland forested watersheds) may be declining. Climate change, although still difficult to quantify, can alter ecosystem processes and affect atmospheric loadings to the basin by changing hydrologic patterns, chemical fluxes, and UV-B flux.

Two important issues needing attention are the transport of contaminants within the basin and source-receptor relationships. Other factors that could modify the impacts of atmospheric contaminants in the basin include pollution control/prevention, remediation, and climate change. Although controlling interstate pollution affecting the basin is difficult, efforts to address this are making headway. Pollution control and prevention at the local level should also be addressed, as perhaps 30-50% of atmospheric Hg deposition is thought to be of local (<100 km) origin. Remediation of air pollution impacts is extremely difficult, although we do know that forests in the Lake Champlain basin seem to help reduce the movement of Hg to the lake, and healthy ecosystems generally ameliorate stresses better than degraded ones. Climate change is likely to complicate both our understanding and management of atmospheric influences in the basin. For example, we can readily speculate that increased precipitation will stimulate mixing and transport processes, and climatic warming will exacerbate Hg transport through forested watersheds.

3. *What research is needed to address these atmospheric issues in the Lake Champlain basin?*

Two broad areas are outlined below for additional research which is needed to better understand the behavior and risks of atmospheric contaminants in the Lake Champlain basin, as well as indicate appropriate pollution control and management strategies. Specific research tasks are prioritized according to urgency.

In addition, several strategic recommendations were identified to facilitate this research, including : (a) seek the assistance of a visiting atmospheric scientist to conduct air transport and deposition modeling in the basin and region; (b) increase the attention on these issues in the basin, including financial assistance, under the clean air regulations of the state and the Clean Air Act (section 112m); (c) increase spending on assessment of research data; and (d) address shorter-term, more feasible issues first.

I. Understand the transport mechanisms for hazardous air pollutants within the basin.

(a) Measure concentrations and loadings of Hg and other trace metals in representative sub-basins, land uses, and surface waters of the basin. This task should be coordinated with research on toxics.

(b) Identify mechanisms affecting Hg transport and accumulation, particularly the role of dissolved organic carbon, sediment transport, hydrology, and entry into food webs.

(c) Characterize the behavior of other important hazardous air pollutants in the basin, including measuring surface-atmosphere exchange rates of PCBs in the lake, and screening for other contaminants in the basin. This task should be coordinated with research on toxics.

(d) Identify physical and chemical impacts of climate change on transport processes and loadings of pollutants in the basin, including changes in : hydrologic and sediment transport to the lake, acid rain pollutants, seasonal temperature regimes, and UV-B exposures. This task should be coordinated with research on lake hydrodynamics and ecosystem health.

II. Clarify source-receptor relationships for atmospheric contaminants in the basin.

(a) Calculate direct and indirect loadings of Hg, nutrients, and other hazardous air pollutants to the lake and basin, including deposition fluxes and pools in representative land use types and streams, better dry deposition estimates, comparison with existing data on contaminants in sediment cores, and mass-balance calculations for Hg and possibly other hazardous air pollutants. This task should be coordinated with research on toxics and nutrients.

(b) Identify sources of atmospheric contaminants in the basin, including characterizing air trajectories and air mass chemical signatures, distinguishing local and distant sources, adding additional weather monitoring in the northern and southern lake to support transport modeling, measuring water chemical signatures to link with the air data, and screening for as-yet unrecognized problem contaminants. This task should be coordinated with research on lake hydrodynamics.

(c) Determine risk factors from the combined effects of exposure to multiple sources of contaminants in the basin (e.g., food+water+air), including identifying and quantifying exposure pathways, and coordinating research with state air toxics and health initiatives. This task should be coordinated with research on toxics and ecosystem health.

(d) Assess possible strategies for pollution control and remediation in light of source-target linkages and ecosystem pollutant retention/release processes, including quantifying effectiveness of various strategies, conducting uncertainty analysis, and identifying effects of climate change on strategies. This task should be coordinated with research on nutrients and ecosystem health.

Cultural/Social Research Priorities

Art Cohn, Lake Champlain Maritime Museum
Ann Cousins, Lake Champlain Basin Program

1. *Museums and historic places (including historic districts, villages and agricultural properties) have recently been the focus of cultural heritage tourism initiatives, yet anecdotal feedback suggests that while cultural heritage tourism is the leading niche tourism interest in the Basin, historic sites are not enjoying the direct economic benefit initially hoped for. What is the economic value of cultural heritage places to the region? How can that value be translated into public private investment?*

The value of cultural heritage places to the tourism industry can be assessed by querying existing tourism data. Additional research could identify 1) examples of museums, galleries and historic districts that have translated increased visitation and tourism exposure into revenue; and 2) models of public investment and private patronage resulting from an appreciation of that value.

2. *Given the increased technological and biological pressures, how can we protect underwater cultural resources?*

To supplement the Impact of Zebra Mussels on Shipwrecks archival study completed in 1995 by the Lake Champlain Maritime Museum, researchers can field test predictions through a monitoring program. Simultaneously, researchers should continue the systematic lake bottom survey to complete the inventory of Lake Champlain shipwrecks. Based on the combined information gleaned from the inventory and impact study, a task force can develop management options and implementation criteria, ranging from doing nothing to raising and conserving the resource.

3. *Vermont and New York have balanced protection vs. public access to historic shipwrecks through the Underwater Historic Preserves and educational programs. What is the value of these programs? How can they be enhanced to better address public interest and State responsibility?*

Using existing diver registration forms, researchers can survey the diving community to assess the economic, recreational, and historic preservation value of the Lake Champlain and Lake George preserves. Simultaneously, researchers can identify and extrapolate economic and value data from comparable underwater preserve models to predict the potential of an enhanced Lake Champlain-Lake George underwater preserve system.

4. *What is the impact of marinas on Lake Champlain water quality?*

Researchers can identify pollutants likely associated with marinas and monitor water quality to determine the impact of marinas on Lake Champlain water quality.

5. *What is the impact of zebra mussels on recreational uses, resources, and places?*

Municipal and state beach managers can be queried to determine the impact of zebra mussels on swimming areas. Using boat registration information, researchers can survey boaters to determine the economic impact of zebra mussels on boaters. Geographic data will provide a tool to predict economic and recreational impact in areas of Lake Champlain not yet saturated.

6. *With increasing recreational pressure on areas of the lake, how can planners assure a balance between access and protection, particularly related to ecologically sensitive and congested areas?*

To follow up the Malletts Bay Recreation Planning Project, researchers can build a computerized model to predict the impact of changes in land and recreation uses on the lake. This predictive model will be key in developing management plans, which could consider criteria and standards for recreational uses in areas of the lake.

Data Management Research Priorities

Bruce Westcott, VT Center for Geographic Information, Inc.
John Banta, Adirondack Park Agency
Lenore Budd, ARD, Inc.

1. *How can Lake Champlain Basin Program managers assure that all public digital data developed for or used by LCBP projects -- whether that data is in geographic, tabular, image, or other forms -- be included in a logically-centralized indexing system?*

Researchers, public officials, and the public are entitled to access this wealth of information[1], and the potential cost-savings and improved decisions that can result from its use will only be realized if users can learn that it exists.

2. *For each data base developed or used by LCBP projects, what is the essential information about each data base which should be recorded and maintained by the data developer, and should be accessible to query and indexing systems?*

3. *Can LCBP researchers and managers identify data bases which are not currently available but which -- if developed -- could be shared and used by a variety of researchers and agencies?*

4. *How can LCBP researchers and managers assure that data developed through LCBP efforts are better understood and more often used by commercial entities and public agencies operating within the Basin in order to improve the quality of their plans and decisions?*

Economics and Land Use Research Priorities

Art Woolf, University of Vermont

1. *Can we design market-based incentives to more effectively reduce the overall level of phosphorus loading at the lowest possible cost? How can these incentives be used to economically allocate the reductions among the point, non point agricultural, and other non point sources?*

We need better data on point and non point control costs and the impacts of reducing phosphorus loading from each. This means better technical and cost data on specific treatment plants, a better understanding of the level of loadings from non-agricultural non point sources and better data on agricultural loading. The agricultural loading data could include information on different land and soil types, distances of farms from major and minor watercourses, and similar technical data. This would allow us to better analyze the costs and effectiveness of different control strategies and therefore advise us on where control techniques can best be placed and resources best be directed.

2. *Can we further refine the economic benefits that result from a cleaner lake?*

Economic benefit studies are important because the costs of pollution control strategies need to be balanced against the benefits. The costs are specific to treatment plants, farms, and other sources of pollutants. The benefits are much more diffuse across industry groupings, economic activities, and sectors of the economy. Benefit studies have focused on fishing and boating and other activities. These can be expanded and other benefits such as swimming and beach values can be quantified. Other benefits should also be identified and explored.

3. *Can we get a better breakdown of benefits to visitors (tourists) and benefits to local residents from a cleaner lake (or the costs of not having tourists and the costs to residents from a dirtier lake)?*

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[1] Standardized "metadata" records relating to each GIS data base are becoming more ubiquitous, thanks to the efforts of the Federal Geographic Data Committee (http://www.fgdc.gov). The National Institute of Standards and Technology (http://www.nist.gov/) and the International Standards Organization (http://www.iso.ch/) also champion activities related to standardized documentation of many forms of data resources.

As tourism becomes more important to the economy and the lake becomes a central focus of that tourism economy in the basin, better information on the economic impacts of tourists will help target resources and enhance the value of the lake. Benefits to local residents will allow for a better understanding of the direct local impacts.

4. *Given a fixed amount of resources available to implement basin strategies, where should they be used to correspond to the values, risks, and priorities of area residents?*

The costs to the public and private sectors of pollution control strategies should be based on the best use of the resources to control pollution. A mechanism should be put in place to help determine the optimal use of resources used to mitigate and reduce pollution of different types.

5. *How can we maintain an ongoing database with current socioeconomic data relevant to the basin?*

The 2000 Census will provide us with much new information on the basin, but the Census data are not easily transformed from the two states to a basin wide area, not to mention the lack of information for Quebec. Other data are collected by state and federal agencies, but it is time consuming to transform those into basin wide information. The Census data should be used to give us year 2000 baseline data and, if possible, it should be enhanced and updated.

Ecosystem Health Research Priorities

Mary Watzin, University of Vermont
Dave Tilton, US Fish and Wildlife Service

1. *How can the Lake Champlain Basin Program's management goals be translated into a reference condition for Lake Champlain? Is there agreement among the people of the Lake Champlain Basin as to what they want their lake to look like?*

These questions could be answered through a combination of sociological research into human values in Basin communities and scientific research and interpretation of what ecological conditions are necessary to provide these values.

2. *What are appropriate measures of the ecological quality or integrity of Lake Champlain? Are there ecosystem measures that can be used to tell us whether Lake Champlain is healthy or not?*

Research is needed to identify appropriate indicators of ecosystem health. There are a variety of approaches that have been taken to develop indicators in the Great Lakes and other water bodies. Basic information on reference community composition and the tolerances of organisms to anthropogenic stresses is needed.

3. *How can ecological indicators be linked to management actions in order to evaluate the success of the Lake Champlain Basin Program?*

Ecological indicators must be linked to management actions in order to evaluate whether our management plan is achieving its goals. A hierarchy of indicators could be developed to accomplish this goal.

4. *How are phosphorus and nitrogen concentrations linked to the composition of the aquatic community in Lake Champlain? Are the in-lake phosphorus criteria appropriate for the biological community we want in Lake Champlain?*

Additional research on trophic transfer and trophic dynamics in Lake Champlain are needed to answer these questions. A model that links all the trophic levels in the lake could be used to explore the implications of various phosphorus and nitrogen concentrations for upper levels of the food web would be a valuable management tool. Additional research is also needed on the effects of zebra mussels on phosphorus dynamics.

5. *Data on biological, chemical, and physical anthropogenic changes are scattered and patchy. What techniques can best evaluate the degree of impairment of the Lake Champlain ecosystem?*

Managers and researchers in the Great Lakes have explored a variety of habitat assessment approaches to quantify impairment. Some are based on long term data sets and some are based on "best professional judgment" and other more qualitative approaches. Research is needed to explore the best options for the Lake Champlain Basin.

Fisheries Research Priorities

The Lake Champlain Fish and Wildlife Management Cooperative
Fisheries Technical Committee

1. *What contribution does walleye stocking make to the adult population?*

Researchers need to establish an effective long-term mark to apply to fry and fingerling walleye to evaluate stocking effectiveness and assess recruitment to the adult population. Through bioenergetics modeling they should establish the A yearling equivalency of stocked walleye (similar to that for stocked salmonids) and establish stocking caps to protect the forage base.

2. *How should we sample walleye?*

Researchers need to determine gear, locations and sampling methodology required to collect adequate samples of juvenile and non-spawning adult walleye for establishing population estimates within 25% of actual value with 95% confidence. These abundance estimates and associated biological data will allow managers to better regulate the fishery harvest and refine bioenergetics models.

3. *Are smelt populations different among basins?*

There is a need for research to determine, possibly via genetic techniques, if the Lake Champlain smelt population is a homogeneous mix or if various basins support discrete populations. If populations are discrete, the salmonid and walleye fisheries must be managed basin-by-basin to optimize populations of both smelt and predators.

4. *What level of predation can smelt sustain in Lake Champlain?*

Research, using a combination of modeling techniques and literature review, is needed to establish a mortality rate threshold beyond which the smelt population is in jeopardy of collapse. Managers could reduce predation on smelt, if necessary, by reducing stocking levels of salmonids and walleye.

5. *Are lake trout naturally reproducing, and if not, why not?*

There is a need to determine if viable spawning products are deposited in appropriate spawning habitat, and, if so, why they are not contributing to recruitment into the adult population. To date, nearly all lake trout collected during sampling activities have been fin-clipped, indicating they were stocked.

Hydrodynamics Research Priorities

Tom Manley, Middlebury College
Jamie Shanley, USGS

1. *What is the circulation within Lake Champlain and how does it change over space and time? What are the forces that create/modify these circulation patterns?*

In this context, circulation implies not only the observations of water flow, but also that of exchange between the various 'closed bays' and the central lake. Observations of temperature and currents should be continuos (~1 hr) and long term (>1 year) in order to better understand seasonal and inter-annual variations. Aside from our ability to observe currents at a specific location (utilizing free drifters). Since wind is the most dominant forcing function in lake circulation, correlation between observed winds and currents must always be examined. Satellite imagery should also be utilized whenever possible.

2. *The long-term goal of the hydrodynamic program is to develop the capability of predictive modeling so that management issues could be investigated and potential solutions discussed. Examples could be the impact of an accidental toxic release into the lake, or the optimization of effluent and drinking water intake pipes within close proximity of each other.*

The development of hydrodynamic models that are capable of reproducing all of the relevant circulation patterns observed in the lake is essential. This includes linear and nonlinear aspects of the internal seiche as well as sluggish flow during winter time. Interactions between the south lake and the main lake as well as the main lake and the restricted bays should also be defined. Changing stratification within the lake as a function of atmospheric forcing should also be considered important. With regards to modeling input and verification, strong interaction between observational programs must be maintained. Additionally, new in-lake meteorological stations as well as lake level gauges at both the northern and southern extremities of the lake should be installed.

3. *As more detailed morphology of the lake bottom is being gathered, so is our knowledge that specific regions (in some cases at depths greater than 200 ft) have long term histories (10-1,000 years) of bottom erosion / resuspension. It is just as clear that potentially toxic laden sediment can be redistributed within the lake. While new regions of erosion are being documented each year, very little is known about how much time this sediment remains in water column, distance traveled, or if there are preferred depositional sites.*

Research needs to be focused on further documentation of these erosional sites, as well as the net depositional trends within the lake. Additional efforts should also be spent in areas of shallow water, and river inlets. Of particular importance is that of the inflow of sediment laden water from the south lake. Recent evidence shows that this sediment is not evenly distributed within the southern part of the main lake (Port Henry to Thompson's Point), but concentrated on the eastern Lake Champlain.

4. *What are the sources of sediment to Lake Champlain? What are the dominant forms of the sediment? What are the principal sediment transport processes?*

Much of the phosphorus and mercury entering Lake Champlain is in particulate form. Our current understanding of sediment sources and transport processes in the basin is inadequate. It may be easiest to reduce loading of some pollutants and toxins through better management practices of sediment loads.

5. *What are the key factors that lead to high lake levels? Can we develop a predictive model for lake level forecasting? What are the gaps in current data collection?*

Recent high water events on Lake Champlain caught authorities and lake shore residents of guard and caused extensive property damage. Flow data from the several new stream gauges installed on lake inlets in 1989-90 need to be synthesized into numeric models to predict lake level changes.

Nutrients Research Priorities

Suzanne Levine, University of Vermont
Eric Smeltzer, Vermont Department of Environmental Conservation

1. *Is the trophic status of Lake Champlain changing?*

Continue existing long term monitoring programs on the lake and tributaries. Develop and apply statistical trend analysis methods to the data gathered, and incorporate the data into existing phosphorus (P) models for the lake.

2. *How do in-lake processes affect lake ecosystem response to phosphorus loading?*

Analyze in-lake processes that affect phytoplankton use of P, including growth limitation by other nutrients or light, bioavailability of dissolved organic phosphorus (DOP), and recycling via decomposition and animal excretion. As part of this analysis, determine optimal P levels for achieving the algal levels and grazing relationships desired for the lake (those promoting a productive salmonid fishery, diverse planktonic and benthic communities, and water clarity). Use the results to inform future revisions or refinements to in-lake water quality criteria.[*]

3. *What nonpoint source phosphorus control practices are most effective?*

Research and demonstrate the effectiveness of nonpoint source best management practices (BMPs) in reducing the loads of phosphorus and other pollutants delivered to streams. Select agricultural and urban BMPs most in need of demonstration of their effectiveness. Identify sites where implementation of BMPs is planned and water quality monitoring is feasible. Design and implement multi-year monitoring studies at selected sites using sound experimental design, including adequate pre-implementation data, paired watershed or upstream-downstream sampling design, and provision for continuous flow measurement.

4. *How are nutrients recycled within the lake?*

Better quantify P and nitrogen (N) return from sediments and from the metalimnion, and controls on flux rates. The role of benthic invertebrates and macrophytes is in special need of quantification.[*]

5. *Are blue green blooms associated with N limitation as the N-fixing abilities of the algae involved suggest? Could we avoid these blooms by managing N:P supply ratios?*

Examine the relationship between blue-green algal blooms and N dynamics.[*]

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[*] Make fuller use of existing water quality databases and recently developed modeling tools for Lake Champlain (e.g. long term water quality and biological monitoring program, hydrodynamic and water quality model, benthic phosphorus cycling model) to support research on these processes. Provide support for local investigators to work with these data sets and models.

Toxic Substances Research Priorities

Alan McIntosh, University of Vermont

1. *What is the importance of various sources of toxic substances?*

We need to understand more about the comparative importance of the different sources of such toxic substances as mercury and PCBs within the Lake Champlain Basin. For example, we have yet to demonstrate the role of atmospheric inputs of PCBs, nor do we fully understand how historic sources like contaminated sediments contribute to the overall budget of major contaminants.

2. *What processes control the fate of toxic substances in the basin?*

The size and diversity of the Lake Champlain basin and the complex physical environment of the lake itself significantly influence the fate and ultimate effects of toxic substances present within the basin. For example, we could better understand contaminant behavior if we could identify key transformations of trace elements like mercury and arsenic that occur within the watershed and determine how in-lake processes such as the internal seiche and sediment conversions affect such substances as PCBs. We should also assess how the presence of zebra mussels in the lake will affect contaminant cycling.

3. *How important are existing sites in the lake where contamination has already been documented?*

The recently completed lake-wide assessment of toxic substances identified several sites with elevated levels of sediment-associated contaminants. These locations merit continued attention. For example, we need to understand what effect the remediation of Cumberland Bay will have on the dynamics of PCBs in the lake and whether or not the sharply elevated levels of arsenic, manganese and nickel pose a long-term threat to Outer Malletts Bay. The potential for contaminant movement off-site from areas like Inner Burlington is also an important issue.

4. *What are the long-term impacts of toxic substances on the Lake Champlain ecosystem?*

There still are comparatively few data on the chronic effects of toxic substances on the lake's ecosystem. It would be useful to identify indicators or biomarkers to detect unacceptable exposures of lake biota to toxic substances. We should also determine if levels of mercury and PCBs carried by walleye and lake trout are sufficiently high to cause sublethal effects, particularly on sensitive life stages. More intensive assessments of the chronic effects from existing point source discharges should be undertaken as well.

5. *What are the future issues?*

There may well be concerns in this area that have not yet surfaced. Some capability to do proactive research to identify emerging issues would seem a wise investment.

Wildlife/Biodiversity Research Priorities

The Lake Champlain Fish and Wildlife Management Cooperative
Wildlife Technical Committee

1. *How do we (does society) make better informed decisions about management of our living natural resources?*

Development of methodology to monitor ecological change in selected natural community types, e.g. development of terrestrial Index of Biological Integrity (IBI) or methodologies to select indicator species.

2. *How do we increase our ability to locate rare natural communities?*

Develop and test model for locating and characterizing rare natural community types, e.g. vernal woodland pools, lakeshore grasslands, calcareous fens, using remote sensing and ground-based field work.

3. *What exotic terrestrial plant species are having the greatest impact on the native vegetation and animals of the Lake Champlain watershed?*

Assess the relative threats to natural communities of alien invasive species, e.g. glossy buckthorn, common buckthorn, Morrow's honeysuckle, Tartanian honeysuckle, Japanese knotweed, and goutweed, in the Lake Champlain Basin through literature review and comparative habitat studies.

4. *Have PCBs entered the food chain in the Cumberland Bay area of Lake Champlain?*

Monitor and assess PCB contamination within the food chain in Cumberland Bay, NY, especially as it relates to levels found in higher order predators, e.g. mink and river otter.

5. *What are the effects of the expanding cormorant population on Lake Champlain?*

Continued research on cormorant ecology on Lake Champlain

- i. Effects of control measures on cormorant breeding ecology and movements
- ii. Development of nonlethal control measures
- iii. Continued assessment of feeding ecology on Lake Champlain, e.g. food habits during pre nesting (Apr.-May), food habits during post nesting (Aug.-Sep.), food habits of non-breeding subadults (Apr.-Sep.), assessment of impacts of cormorant feeding on local fish populations.
- iv. Assessment of impact of cormorant nesting on Lake Champlain island vegetation.

6. *What can we do to assist ongoing exotic vegetation control efforts in the Lake Champlain watershed?*

- i. Assessment of purple loosestrife biocontrol program (release of exotic insects) on native wetland flora and fauna (invertebrates).

- ii. Development of new methodologies to control water chestnut.

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