

A Research and Monitoring Agenda for Lake Champlain



**Proceedings of a Workshop
December 17-19, 1991
Burlington, VT**

Prepared by
Lake Champlain Research Consortium

for
Lake Champlain Management Conference

May 1992

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INTRODUCTION AND WORKSHOP OVERVIEW

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Introduction

The passage of the Lake Champlain Special Designation Act of 1990 created an extraordinary opportunity to take strong and positive actions to protect and improve the status of Lake Champlain. The goal of that federal act is to bring together the various groups with interests in the lake to develop a comprehensive restoration and management plan for the lake. This management plan will outline strategies for protecting and enhancing the environmental, cultural, and recreational integrity of the lake.

The problems facing Lake Champlain are complex. Effective strategies for restoring and managing the lake will require the best technical information that is available. Last August, the Lake Champlain Research Consortium received a grant to plan and conduct a workshop to examine what research and monitoring should be initiated to support the development of the comprehensive management plan. That workshop was held December 17-19, 1991 in Burlington, Vermont. This volume represents the proceedings of that workshop.

Over 200 technical experts on lake issues attended the workshop: those in state and federal agencies, in colleges and universities, in local government, and in the private sector. Discussions focused on what is known about Lake Champlain, what additional information is needed, and the relative priorities of these information needs. The results of those discussions appear in the following pages.

In the remainder of this introductory section I would like to (1) provide background information on the Lake Champlain Special Designation Act, the Management Conference, and the comprehensive plan it mandates; and (2) describe the organization and tenor of the workshop, and the structure of this final report.

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Summary of the Lake Champlain Special Designation Act (Title III of the Great Lakes Critical Programs Act)

On November 15, 1990, the President signed the Lake Champlain Special Designation Act into law. The Act added Lake Champlain to the list of 10 waterbodies eligible for the establishment of a lake water quality demonstration program. Among that program's objectives are the following:

- develop cost effective technologies for the control of pollutants in order to preserve or enhance lake water quality while optimizing multiple lake uses,
- control nonpoint sources of pollution,
- evaluate the feasibility of complementing regional consolidated pollution control strategies, and
- develop improved methods for the removal of silt, stumps, aquatic growth, and other obstructions which impair the quality of lakes.

The Act directs the Administrator of the Environmental Protection Agency to establish a Lake Champlain Management Conference. Membership on the Management Conference consists of the Governors of New York and Vermont; representatives from interested federal agencies (not to exceed 5); chairpersons of the Vermont and New York Lake Champlain Citizens Advisory Committees; four representatives from each of the Vermont and New York Legislatures; six persons, appointed by the Governors, representing local governments within the Lake Champlain Basin; and eight persons representing industry, nongovernmental organizations, educational institutions and the general public, who were selected by the Joint Citizens Advisory Committee for the Environmental Management of Lake Champlain.

The Management Conference is charged with developing a Comprehensive Pollution Prevention, Control, and Restoration Plan for Lake Champlain. The plan must identify the corrective actions and compliance schedules necessary to address point and nonpoint sources of pollution in the lake in order to restore and maintain the following:

- the chemical, physical and biological integrity of the lake's waters,
- a balanced indigenous population of shellfish, fish and wildlife, and
- recreational and economic activities in and on the lake.

The legislative report accompanying the Special Designation Act makes it very clear that the Congressional intent was that the comprehensive plan be just as its name implies, in other words, it was not to address only water quality improvements, but all aspects of restoring and maintaining a healthy Lake Champlain ecosystem.

The Management Conference is directed to appoint a Technical Advisory Committee (TAC) consisting of officials from appropriate departments and agencies of the federal government, the state governments of New York and Vermont, governments of political subdivisions of these states; and public and private research institutions. The TAC will assist the Management Conference in developing the comprehensive plan.

The Management Conference is also required to establish a multidisciplinary environmental research program for Lake Champlain to be planned and conducted jointly with the existing Lake Champlain Research Consortium. The Lake Champlain Research Consortium is an independent organization formed by seven academic institutions in the Lake Champlain Basin to coordinate and facilitate research and scholarship on Lake Champlain, to provide for training and education of students on lake issues, and to aid in the dissemination of information gathered through lake research endeavors.

The Administrator of the EPA is authorized to administer grants in consultation with the Management Conference for assisting research, surveys, studies, and modeling and technical work necessary for the development of the plan. The grants require a 25% match by state or other nonfederal sources.

To accomplish the activities and objectives outlined above, the Act authorizes \$5 million to be appropriated for each of fiscal years 1991 - 1995 to be allocated as follows:

- \$2 million to the EPA to oversee the Management Conference, complete the development of the Plan, and administer the grant program,
- \$2 million to the U.S. Department of Agriculture for Agricultural Stabilization and Conservation Service and Soil Conservation Service efforts to control nonpoint sources of pollution,
- \$1 million to the Department of the Interior for the development of an integrated Geographic Information System, hydrologic monitoring, fisheries restoration and development, and related programs.

Lake Champlain Management Conference

The Management Conference formally convened in June, 1991, and has been meeting regularly since then. Mr. Ronald Manfredonia, Branch Chief for Water Quality in the Boston Regional Office of the Environmental Protection Agency and Chair of the Management Conference, reported to workshop participants on the activities of the Management Conference and their preliminary views about the goals and objectives that will be part of the comprehensive plan. Because these goals and objectives are continually being updated, they are not reproduced here.

The Management Conference has formally adopted a vision statement, which reads as follows:

"The Lake Champlain Management Conference, which represents a broad based diverse group of interests, shares in a common goal of developing a management program for the purpose of protecting and enhancing the environmental integrity of the lake and its basin, taking into consideration its social and economic benefits.

Through the work of the Management Conference, Lake Champlain will be managed to support multiple uses, including commerce, recreation such as swimming, fishing and boating, as well as drinking water supply and wildlife habitat. These diverse uses will be balanced to minimize stresses on any part of the lake system. Maintaining a vital economy which values the preservation of the agricultural sector is an integral part of the balanced management of the lake and its basin. The management plan will ensure that the lake and its basin will be protected, restored and maintained so that future generations will enjoy its full benefits."

The draft goals and objectives that the Management Conference is developing consider water resource issues (nutrients, toxic contaminants, pathogens, sediment, lake level, and water quantity), living resource issues (fish, wildlife, wetlands, and nuisance aquatic plants and animals), and the role, needs, and desires of the human population in the basin (recreation, cultural heritage, economics, and human health). Most of the goals are framed in ways that make it clear that the Conference is concerned about promoting and maintaining a healthy and diverse Lake Champlain ecosystem and providing for sustainable human use and enjoyment of the lake.

Structure of the Workshop

The workshop was organized into three sections: (1) an opening plenary session consisting of invited papers, (2) a series of concurrent working group sessions where research and monitoring needs in all topic areas were discussed and prioritized, and (3) a closing plenary session where workshop results were presented for discussion by all participants.

Participation. Over 200 participants, representing a broad spectrum of technical expertise and interest attended the workshop. Representatives included:

- federal agency scientists and managers, including those from the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, Soil Conservation Service, National Oceanic Atmospheric Administration, National Park Service, and the Forest Service,
- Vermont and New York state agency representatives, including those from branches of Water Quality, Fish and Wildlife, Wetlands, Agriculture, Air, Parks and Recreation, Historic Preservation, and Health,
- scientists from Environment Canada,
- academic scientists from 16 colleges and universities,
- representatives from at least 22 other organizations, including private industries, local government, interest groups, and others, and
- Management Conference members -- 7 attended at least part of the workshop. A majority of the members of the Management Conference's Technical Advisory Committee also participated actively in the workshop.

A tremendous diversity of opinion was expressed and participants were able to develop an impressive list of research and monitoring needs. More importantly, participants were also able to agree on the relative priority of those needs. What follows is the summary recommendations of this broad, representative group -- not the recommendations of any one constituency. They should bear that appropriate weight.

Opening Plenary Session. The keynote address and summary papers on the state of knowledge about Lake Champlain and on monitoring activities in the basin are presented in the following section. These papers were meant to set the stage for the working group

sessions that followed. The keynote speaker, Dr. Trefor Reynoldson, discussed various potential approaches to managing Lake Champlain as an integrated ecosystem, with a focus on the living components of the system, not simply on chemical criteria. He spoke about approaches being developed for the Great Lakes that use biological measures of a healthy ecosystem, not end-of-the-pipe chemical standards, as a basis for environmental management.

Working Group Sessions. Each working group was asked to answer the following questions:

1. Based on anticipated management objectives, is the information necessary to manage the lake effectively currently available?
2. If not, what further information is necessary and what research programs should be developed to provide it?
3. What are the relative priorities of those information needs?
4. Are current monitoring programs sufficient in order to:
 - a) evaluate the status of the resource (accounting for year-to-year and site variation),
 - b) detect any changes in the status of the resource, and
 - c) evaluate the efficacy of the anticipated management strategies.
5. What Quality Assurance/Quality Control guidelines should be established for data collected in this topic area?

There were a total of 16 technical sessions in six major topic areas -- social sciences, water quality, physical processes, living resources, modeling, and data management. The results of each of these sessions appear in the following sections of this report.

For the most part, the working groups were very focused. The needs of the comprehensive management plan guided the discussion and final recommendations. Some groups were very specific, some more general, depending in part on the state of knowledge in particular areas, but also on the personalities of the facilitators and session participants.

Closing Plenary Session. The highest priority research and monitoring needs identified in each session were presented in the final plenary session and discussed by all workshop participants. The discussion focused primarily on overlap among topic areas, consensus priorities, and some sense of the sequencing of the long term program. I summarize and expand on this discussion in the final section of these proceedings (Synthesis of Common Highest Priority Research Needs). The Lake Champlain Research Consortium is very interested in working with the Management Conference and its Technical Advisory Committee to reassess and interpret this information on a regular basis.

Acknowledgements

I would like to thank the many people who helped to put this workshop together: the members of the Lake Champlain Research Consortium who served on the planning committee; those who agreed to lead the discussions as facilitators; the outside resource people, Ken Minns, Doug Wilcox, Pete Richards, John Hassett, Lars Rudstan, William Walker, and Mary Henry, who generously came to share their expertise and experience with us; the staff of the Lake Champlain Management Conference, Lisa Borre, Jim Connelly, and Lee Steppacher; my secretary Marie MacLean; Susan Cobb, Barry Gruessner, and the other students and volunteers who took notes and performed the many other tasks at the workshop itself, and the innumerable others who helped with the logistics of the conference.

SETTING ENVIRONMENTAL MANAGEMENT TARGETS USING BIOLOGICAL ENDPOINTS

Summary of the Keynote Address
December 17, 1991

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Introduction

Historically, management of human utilization of ecosystems has been based around engineering and chemical approaches; waste treatment facilities are constructed and chemical concentration standards at both the ends of effluent pipes and in the aquatic environment are established. However, the continued general degradation of many ecosystems suggests that this approach alone is insufficient. In the Laurentian Great Lakes, recent modifications to the Great Lakes Water Quality Agreement tacitly acknowledge the problems of a chemical only approach by requiring and specifically identifying numerical ecosystem objectives. Ecosystem objectives in the Great Lakes have evolved from strictly numerical objectives, such as production of lake trout and abundance of the amphipod *Pontoporeia hoyi*, to include indicators for wildlife, habitat, human health and stewardship.

This paper describes an alternative approach to environmental decision making which uses biological, rather than chemical, endpoints. It particularly describes the lead that Environment Canada, through research being conducted at the National Water Research Institute, is taking in developing biological assessment methods. The bulk of this text has been previously published or submitted for publication (Reynoldson 1991; Reynoldson and Zarull 1992). The work described outlines efforts to develop ecosystem objectives as required by the Great Lakes Water Quality Agreement and a three-year program funded by the Great Lakes Action Plan to develop biological sediment criteria. The ecosystem objectives will be used as final measures of progress toward restoration of the Great Lakes. The biological sediment criteria will be used to determine both the need for and the success of sediment remediation undertaken in areas of concern.

Ecosystem Objectives for the Great Lakes

Initial Development - the International Joint Commission. In the Laurentian Great Lakes, the Great Lakes Water Quality Agreement was first signed in 1972 and ratified in 1978 and 1987. Among the provisions of the 1972 agreement was a requirement for the development of specific objectives for various properties of Great Lakes water quality. These were defined as "concentrations or quantities of substances that are recognized as maximum or minimum desired limits for defined bodies of water or portions thereof." These objectives take the traditional chemical and physical concentration-based approach to water quality regulation, with all their associated weaknesses. Some particular shortcomings include relying on laboratory data alone, using limited species in toxicity tests, testing chemical compounds singly, having insufficient data, and using direct effects only.

With the adoption of the ecosystem approach in the 1978 agreement, the weaknesses of the chemical objective approach were recognized and greater emphasis was placed on assuring the biological integrity of the Great Lakes Basin ecosystem. A major component of the "ecosystem approach" in the revised 1978 agreement was the requirement to develop ecosystem objectives. The 1978 revision required that such objectives should specify the level or condition of certain biological properties that could serve as indicators of the overall condition or health of the ecosystem and that the development of such indicators would require a detailed specification of the desired state of the ecosystem. Through discussion under the auspices of the IJC, it was determined that the requirement of the 1978 agreement to "restore and enhance the water quality of the Great Lakes" could best be met by setting a general objective directed toward the restoration and maintenance of a Great Lakes biological community as similar as was practical to that which was present before the influence of human intervention (Ryder and Edwards 1985). Language to this effect was proposed for the 1987 revised agreement but was not adopted. However, the concept of ecosystem objectives was reaffirmed and a commitment to their development was made.

The first activities in the development of ecosystem objectives were through the IJC. It was quickly recognized that one set of objectives could not be applied to the entire Great Lakes system. The same community of organisms is not now present throughout all areas of the lakes, nor was the same community present historically. In addition, physical and chemical properties in various parts of the Great Lakes are quite different from historical values. Therefore, no one indicator or objective can be expected to be appropriate everywhere. When initial steps were taken to develop ecosystem objectives and indicators it was recognized that offshore waters, particularly of the upper lakes, have a similar community and that this community was probably present in much of the lower lakes prior to European colonization. The major exceptions are the communities which have probably always existed

in western and central Lake Erie and other large embayments such as Green Bay, Saginaw Bay and the Bay of Quinte (Figure 1); and the communities of Lake Ontario, because of the barrier created by Niagara Falls. Accordingly, initial efforts to develop an objective and indicator for ecosystems focused on the open waters of the upper Great Lakes. This community is characterized by cold and nutrient poor waters and was defined as the oligotrophic community of the Great Lakes. Subsequent efforts (Ryder and Edwards 1990) were directed at the mesotrophic portions of the Great Lakes and, most recently, ecosystem objectives are being specifically derived for Lake Ontario. The first two efforts, for the oligotrophic and mesotrophic condition, were specifically concerned with the offshore portions of the lakes. The effort on Lake Ontario is addressing both the offshore and the more complex nearshore areas, as well as the land-water interface, and human and societal health.

The Lake Ontario Process. The development of ecosystem objectives has been an evolutionary process. There is a great need to be specific about language and to differentiate between goals, objectives and indicators, as each is different and requires a different approach. Goals are the broadest, the least defined by natural processes, and are established largely as a result of political discussion. The goals have, by and large, been set by the Great Lakes Water Quality Agreement itself and have been agreed to by the Governments of Canada and the United States. The primary goal is stated as " ...to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem." To develop site-specific ecosystem objectives for Lake Ontario, this primary goal was further developed through a public process and more specifically stated as three goals:

1. The Lake Ontario ecosystem should be maintained and, as necessary, restored or enhanced to support self-reproducing diverse biological communities.
2. The presence of contaminants shall not limit the use of fish, wildlife and waters of the Lake Ontario Basin by humans and shall not cause adverse health effects in plants and animals.
3. We as a society shall recognize our capacity to cause great changes in the ecosystem and we shall conduct our activities with responsible stewardship for the Lake Ontario Basin.

These goals reflect the societal values in and around Lake Ontario and were established through a lengthy consultative process with various groups within Lake Ontario society. Ecosystem objectives were subsequently determined to ensure the achievement of these

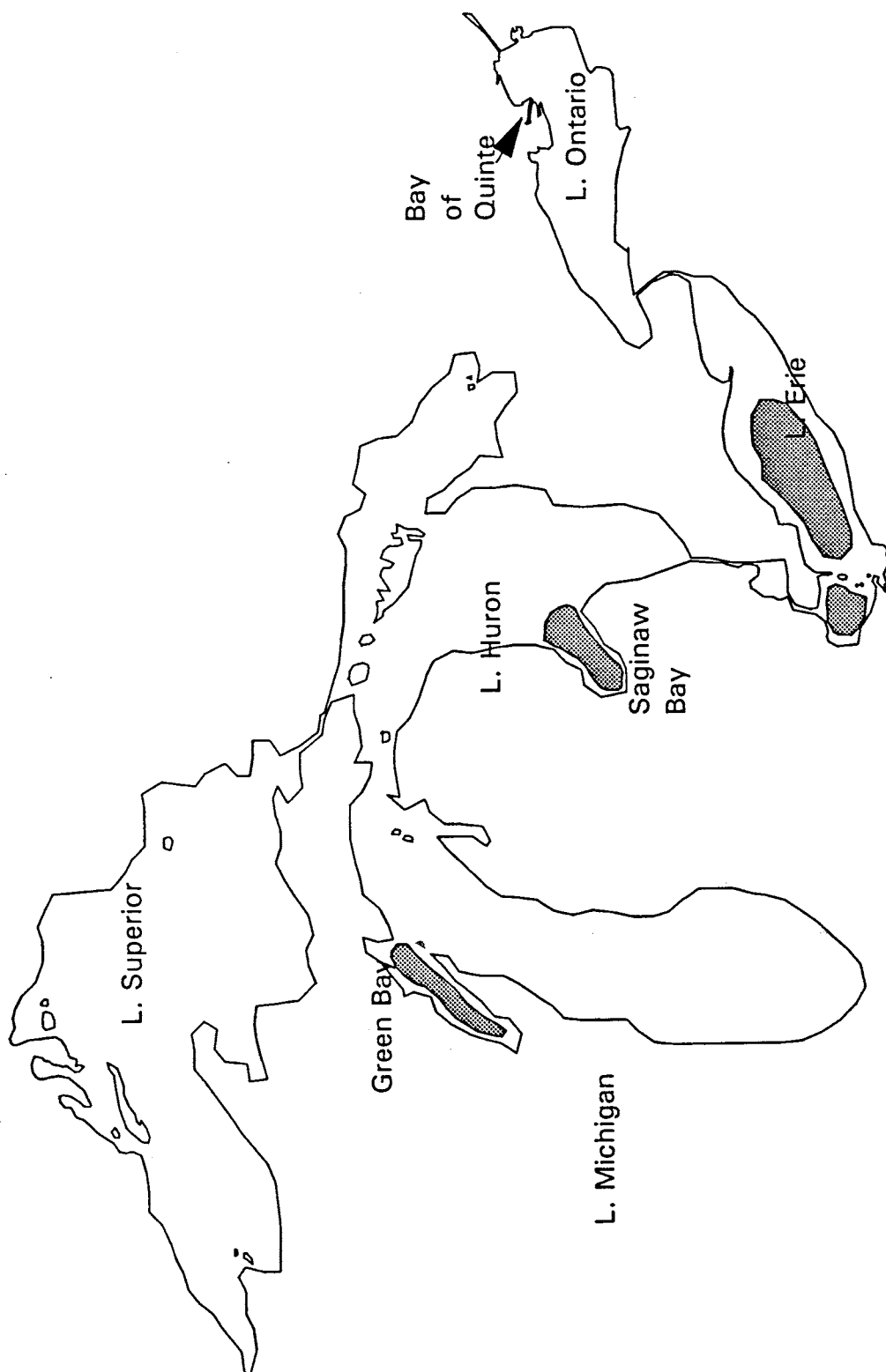


Figure 1. Regions in the Great Lakes, shaded areas indicate potentially mesotrophic ecosystems.

goals. Determining the scope of ecosystem objectives is a considerable challenge. Because ecosystems are by definition open systems (despite obvious differences between adjacent ecosystems), they are strongly dependent upon each other. The development of ecosystem objectives for Lake Ontario targeted the aquatic ecosystem of the lake and included the surrounding basin as it is necessary for wildlife species using the lake for habitat or food. Human health in the basin is considered as it is affected by the waters of Lake Ontario in the broadest sense, including use of the lake for drinking water and swimming, as well as the consumption of fish and wildlife from the lake. Five ecosystem objectives were defined for Lake Ontario based on the stresses to which the ecosystem has been subjected and the attainment of the goals.

1. Aquatic Communities -- the waters of Lake Ontario shall support diverse, healthy, reproducing, and self-sustaining communities in dynamic equilibrium, with an emphasis on native species.
2. Wildlife -- the perpetuation of a healthy, diverse and self-sustaining wildlife community that utilizes the lake for habitat and/or food shall be ensured by attaining and sustaining the waters, coastal wetlands and upland habitats of the Lake Ontario Basin in sufficient quality and quantity.
3. Human Health -- the waters, plants and animals of Lake Ontario shall be free from contaminants and organisms resulting from human activities at levels that affect human health or aesthetic factors such as tainting, odor and turbidity.
4. Habitat -- Lake Ontario offshore and nearshore zones and surrounding tributary, wetland, and upland habitats shall be of sufficient quality and quantity to support ecosystem objectives for health, productivity, and distribution of plants and animals in and adjacent to Lake Ontario.
5. Stewardship -- human activities and decisions shall embrace environmental ethics and a commitment to responsible stewardship.

To determine whether or not these objectives are being achieved requires a set of measurable and quantitative indicators. Development of these indicators is now in progress.

Ecosystem Indicators. In a paper describing the development of mesotrophic indicators, Reynoldson *et al.* (1989) identified three requirements for indicators of ecosystem objectives: they should provide an appropriate and interpretable objective; they should be achievable

if corrective measures are taken, that is they should be within the expected environmental range of the system; and they should allow measurement of progress toward the objective. The implicit assumption is that these indicators will be biological in nature. Ryder and Edwards (1985) describe two categories into which indicator organisms fall: specialized organisms with narrow tolerances for most environmental properties (specialists), and less specialized organisms that have relatively broad tolerances for many environmental properties (opportunists). As systems are subjected to increasing stress, the numbers of "specialists" decline and those of "opportunists" increase. To assist in the selection of appropriate indicators, Ryder and Edwards (1985) identified a number of characteristics required by suitable indicator organisms, some of which include:

1. they have a wide distribution,
2. they are well integrated within the ecosystem, with many linkages within the system,
3. they are an indigenous and stable component of the ecosystem, thus reflecting unperturbed conditions,
4. their niche characteristics and habitat requirements are well understood,
5. they thrive in high quality habitat and exhibit a graded response to increasing stress over part of the range,
6. they are easily collected and measured for purposes of quantifying populations,
7. they respond to stress in a way that is readily identifiable, and
8. they should be important to humans.

To date four indicator organisms have been selected, in part based on these criteria, as ecosystem indicators in the Great Lakes. For oligotrophic systems, lake trout (*Salvelinus namaycush*) and the amphipod *Pontoporeia hoyi* were chosen, and for mesotrophic systems, walleye (*Stizostedion vitreum*) and the mayfly *Hexagenia limbata* were chosen.

1. Lake Trout -- A number of candidate species for an indicator of oligotrophic conditions were considered, including lake trout, deep water sculpins, *Mysis relicta*, and *Pontoporeia hoyi*. Of these, the lake trout best met the criteria for an indicator organism. Prior to major development of the Great Lakes, the lake trout occupied almost every major habitat type associated with oligotrophic conditions. As a top predator, this species interacts with many components of the food web. The niche characteristics and habitat requirements are well understood. Historic data sets exist on the abundance of lake trout in each of the Great Lakes, some extending as far back as the 1800's. The species thrives and reproduces well in pristine oligotrophic systems and exhibits a graded response to stresses such as eutrophication (Loftus and Regier 1972). It is, therefore, an excellent indicator of general ecosystem state and also provides a diagnostic capability.

2. *Pontoporeia hoyi* -- This amphipod is a major component of the benthic community in the oligotrophic regions of the Great Lakes. It was selected to complement the lake trout and satisfies many of the same criteria. It responds to a variety of stresses such as contaminants and eutrophication. This organism is not of direct importance to humans and, therefore, is not subject to direct exploitation. This makes interpretation of population data simpler and easier.

3. **Walleye** -- The walleye was chosen as an indicator of a healthy mesotrophic ecosystem as it has many of the same characteristics as the lake trout. It was selected for its key role in the aquatic community rather than for its individual biological or demographic properties, and is considered a surrogate for a harmonious percoid community.

3. *Hexagenia limbata* -- The burrowing mayfly is considered representative of a diverse benthic community. Its former abundance in many mesotrophic areas of the Great lakes and its requirement for clean, well oxygenated sediments make it diagnostic of a healthy sediment-water interface. It is also an important food item for walleye in various life history stages as well as for other fish species. These attributes made it an ideal complementary indicator to the walleye.

The process of selecting an appropriate indicator is well illustrated by the procedure used in identifying *H. limbata* as appropriate for mesotrophic ecosystems. Examination of historic data bases for benthic invertebrates showed an almost continuous data set for western Lake Erie beginning in 1929. Since that time, sampling has been continued by various authors, the greatest interval without samples being the six years between 1944 and 1950. These data and data from sediment cores show *H. limbata* to have been the most important component of the benthic fauna prior to stresses imposed by human activities. Similar trends have been reported from less extensive data bases in other mesotrophic areas in the Great Lakes and other systems. The data suggest, therefore, that this species is widespread and the response to stress is predictable. It also suggests that *H. limbata* is an appropriate endpoint for a mesotrophic state. Finally, data are available to show that the burrowing mayfly can return to habitats where it was formerly abundant, that is, the target is achievable.

In addition to *H. limbata*, the benthic community as a whole can be used to measure change. Recent alterations in the oligochaete species complex in western Lake Erie show a recovery towards mesotrophy and can be used to track progress towards the point where *H. limbata* may return.

Other Indicators. The indicators discussed above and recommended at the present time rely on structural attributes of the ecosystem to provide indicators of ecosystem health. Consideration was given to other approaches, however, it was generally found that the data bases were either unavailable or insufficient. Size spectra were considered based on the theoretical concept that there is a relationship between organism size and biomass and that, on a log 10 size interval basis, organisms occur at approximately equal biomass. The effects of stress are the loss of the larger organisms or a disruption of the particle-size ratios.

The efficiency of trophic structure might also be used, but again, few data are available, particularly in temporal series, to define changes and a normal state for the Great Lakes. Therefore, at the present time, the use of indicator and surrogate organisms seems the most pragmatic approach.

Biological Sediment Guidelines

In a second approach to developing biological endpoints for environmental decision making, alternatives to chemical concentration-based sediment criteria are being developed in Canada. Agencies such as the U.S. Environmental Protection Agency and the Ontario Ministry of Environment are currently developing criteria for remediation of contaminated sediments based on a chemical by chemical concentration approach. An alternative proposal is to use benthic invertebrate community structure and invertebrate toxicity response as decision making criteria. In this approach, numerical criteria are derived from a reference site data matrix. Characteristic invertebrate assemblages are determined and related to geophysical variables. Similarly, a set of values from toxicity tests are characterized and related to environmental parameters. At a new site, measurements of the geophysical variables allow prediction of both the community assemblage that should occur and the expected test response. These predicted values form the criteria to which the actual biological characteristics of the test site are compared.

A major objection to employing benthic community structure analysis to set sediment criteria is their lack of universality (i.e., they are completely site-specific) and the inability of researchers to establish quantitative objectives for their application (i.e., what should the community 'look' like?). However, the very nature and complexity of sediment-contaminant-biota relationships means universal guidelines and/or objectives are not possible. Recent developments in the application of multivariate analysis show extremely promising results in interpreting changes in community structure.

Table 1. Performance of classification and discrimination analysis in predicting benthic invertebrate community assemblages from physico-chemical data.

Habitat	Sites	Communities	Predictor Variables	% Correct	Author
Rivers	268	16	28	76.1	Wright et al 1974
Rivers	268	8	28	79.1	Moss et al 1974
Streams	79	5	26	70.9	Corkum & Currie 1987
Rivers	45	6	5	68.9	Ormerod & Edwards 1987
Rivers	54	5	9	79.6	King 1981
Lakes	68	7	11	90.0	Johnson & Wielderholm 1989
Rivers	29	3	4	83.0	This paper

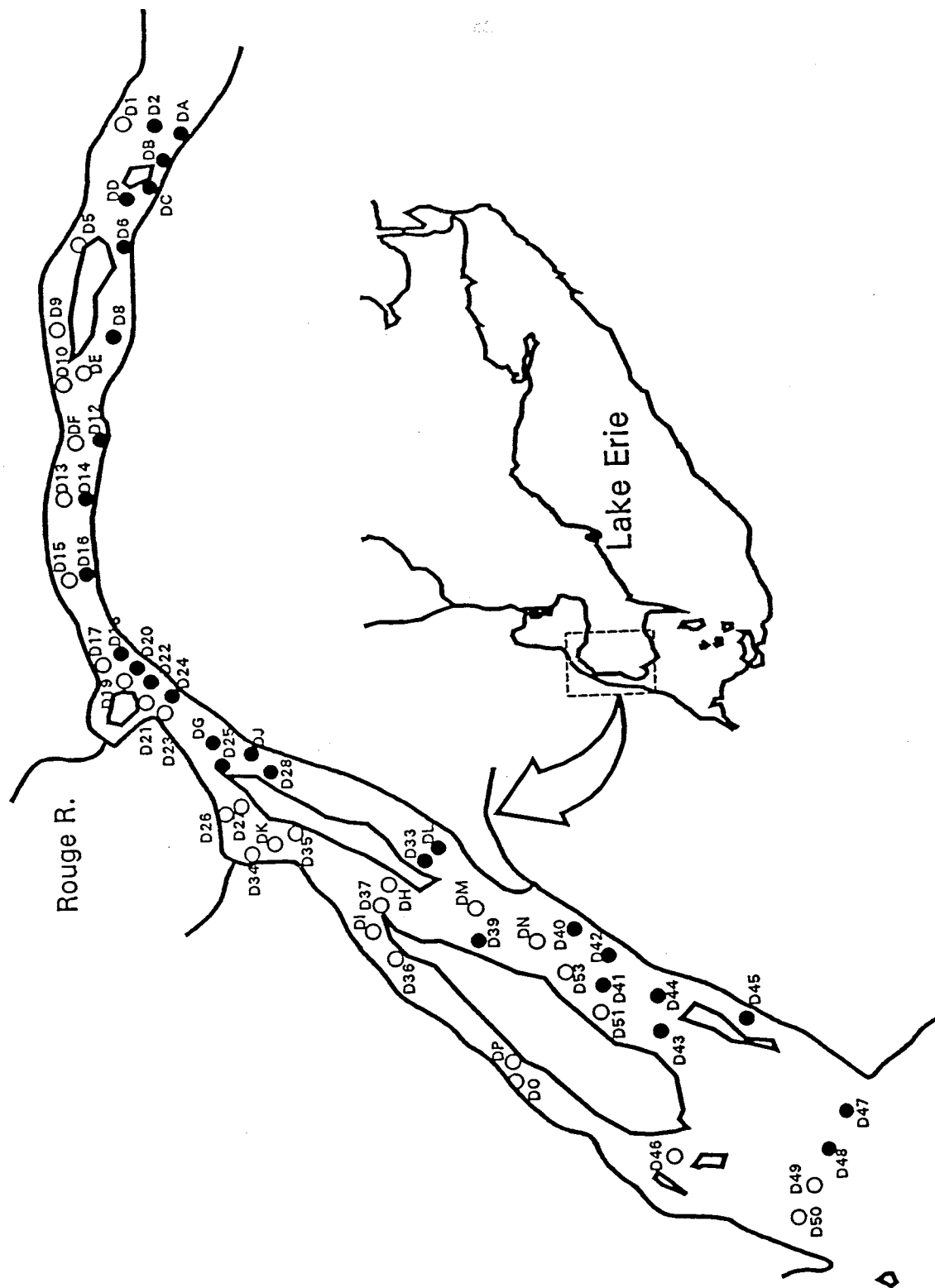


Figure 2. Sample site locations in the Detroit River (open circles - test sites, closed circles - reference sites).

Means analysis, three communities (clusters) were defined (Figure 3). Five taxa contributed significantly to differentiating between these communities (Table 2), and were used as a basis for numerical criteria to represent the three community assemblages.

Prediction of Expected Community Assemblages. With chemical approaches, the same concentration guidelines can be used for numerous diverse sites. An overriding problem in the application of biological guidelines is the much greater site specificity, which requires a series of biological values. In this example, three sets of guidelines would be developed based on the three community assemblages. Selecting the most appropriate set of guidelines for any given site, based upon the local environmental conditions, requires a method that allows the prediction of the type of biological community that is expected at a site. Discriminant analysis is a statistical technique that permits groups to be distinguished using a set of variables on which the groups are expected to differ. In the case of benthic invertebrate community structure, the discriminating variables will be values that measure differences in the physical and chemical characteristics of the sediment that are likely to result in different species being present. For the purposes of sediment guidelines, it is important that the discriminating variables are minimally impacted by pollution, as it is necessary to determine the community that is most likely to be present if the site were clean.

In this example, four potentially important discriminating variables were used: the percent of sand, silt, and clay, and the percent loss on ignition (LOI). The first three variables describe the physical form of the sediment. For example, a silty habitat could be expected to be dominated by burrowing organisms such as tubificid oligochaetes and chironomids, whereas a sandy or rocky substrate is more likely to be dominated by amphipods and Ephemeroptera. The fourth discriminating variable, LOI, is an estimate of the amount of organic carbon present in the sediment. It is related to food availability and thus may relate to the abundance of organisms. Using these discriminating variables, the percentage of reference sites correctly predicted using three clusters was 83%, suggesting they are good discriminators for the reference sites (Table 3).

Predicting Test Sites. The third component in the development and use of biological guidelines is the application of the model to the test sites and a comparison of the predicted community with the actual species present. Application of the multiple discriminant model to the 30 test sites resulted in 22 being predicted as having community 1, four as having community 2, and four as having community 3. To determine whether sites are impacted, a method other than simple comparison is required to compare the observed community with that predicted by multiple discriminant analysis from the reference set of sites.

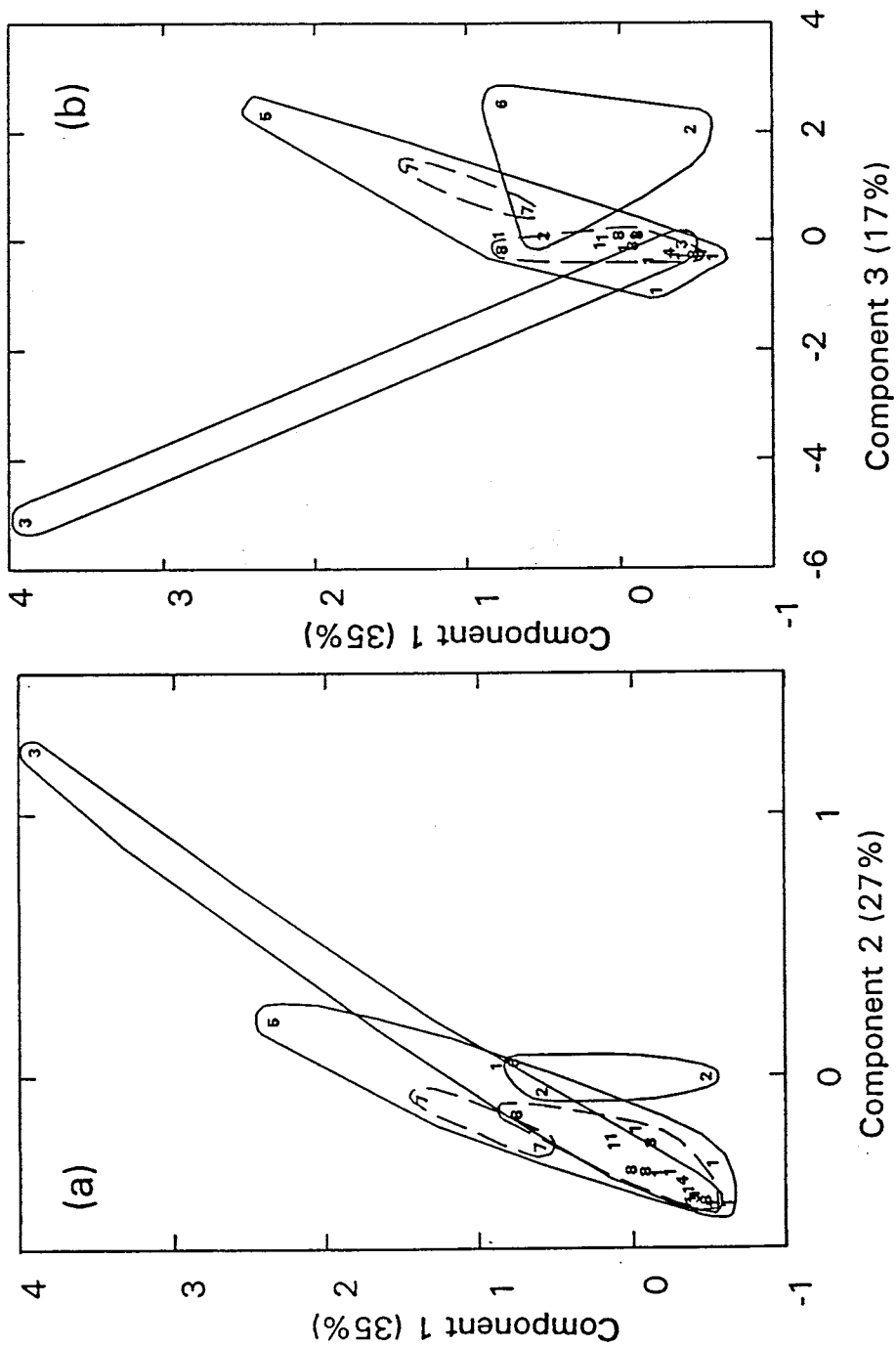


Figure 3. Ordination plots (PCA) of reference sites showing cluster boundaries (solid lines - 3 cluster solution, dashed lines - 8 clusters), on the first three components (numbers indicate cluster associations).

Table 2. Numbers of various taxa and their relative contribution in three community assemblages from reference sites in the Detroit River.

TAXA (No. m ²)	F Ratio (K means)	Cluster 1 (n = 23)		Cluster 2 (n = 3)		Cluster 3 (n = 2) Avg.	P.C. 1	P.C. 2	P.C. 3
		Mean	S.D.	Mean	S.D.				
Ephemeroptera	5.5	126	(99)	304	(193)	582	0.832	0.420	-0.079
Tubificidae	144.5	385	(409)	5523	(843)	2546	0.687	-0.561	0.220
Isopoda	10.2	1	(2)	0	(0)	23	0.686	0.465	-0.477
Hirudinoidea	5.0	1	(2)	7	(5)	4	0.626	-0.455	-0.271
Odonata	22.3	0	(0)	5	(3)	0	0.466	-0.687	0.247
Amphipoda	0.9	44	(64)	7	(5)	88	0.373	0.659	0.247
Chironomidae	0.1	270	(448)	338	(232)	141	0.243	0.312	0.839

Guideline Development and Determination of Impairment. It is suggested that numerical biological guidelines should be based on the abundance and variance of those taxa that are most representative of the community assemblage (Table 2), or those taxa that are most abundant. For example, although the Isopoda, Hirudinoidea, and Odonata are important in discriminating between the three communities, they are relatively rare. On the other hand, the Amphipoda and Chironomidae, although less discriminating, are numerically more abundant and likely of more ecological importance. Four approaches to developing numerical guidelines for comparison of observed and expected communities are considered: 1) a simple scoring system; 2) percent difference in reference and test site means (\pm the standard deviation) for each taxa from the reference community; 3) calculation of chi-squared values and; 4) comparison in multivariate space. These approaches are examined below.

1. Scoring System -- This is a simple and subjective method and is similar to the approach described by the U.S. EPA (1990) in their rapid biological assessment and the approach used by Karr *et al.* (1986) in developing indices of biological integrity. The method assigns a score value to each of the taxa based upon their numerical importance and their contribution to differentiating between communities. For example, the Ephemeroptera and Tubificidae were assigned a score of 25 as they were both abundant and discriminatory (Table 2). Other taxa were assigned a score of 10, as they were either rare or not as important in discriminating between assemblages. If the observed number of a taxon at a test site was within 1 S.D. of the mean for the reference community (Table 2), then the full score for the taxon was assigned to that test site (either 25 or 10). If the number was higher than 1 S.D. above the mean, then 5 was subtracted from the score; if lower than 1 S.D. below the mean, then 0 was scored for the taxon. The scores were summed for each taxon and a site score assigned (maximum of 100). The scores can then be ranked, but there is no way of measuring the significance of differences and determination of impairment is subjective.

For illustrative purposes, a score of 75-100 was considered a pass, 50-75 as indecisive, and 0-50 as a fail. Of 22 sites predicted as being community 1, twelve met the guidelines, nine were indecisive, and one failed. All the community 2 sites failed, and the community 3 sites were indecisive. The sites that were deemed as unimpaired are largely those upstream of the Rouge River (Figure 4); however, many of the downstream sites that have been described as having impacted communities (Reynoldson and Zarull 1989) are in the indecisive range.

This result is an artifact of the scoring, which simply provides a ranking of the degree of difference. The method would require a great deal of data to calibrate and would always be open to criticism because of its subjective nature.

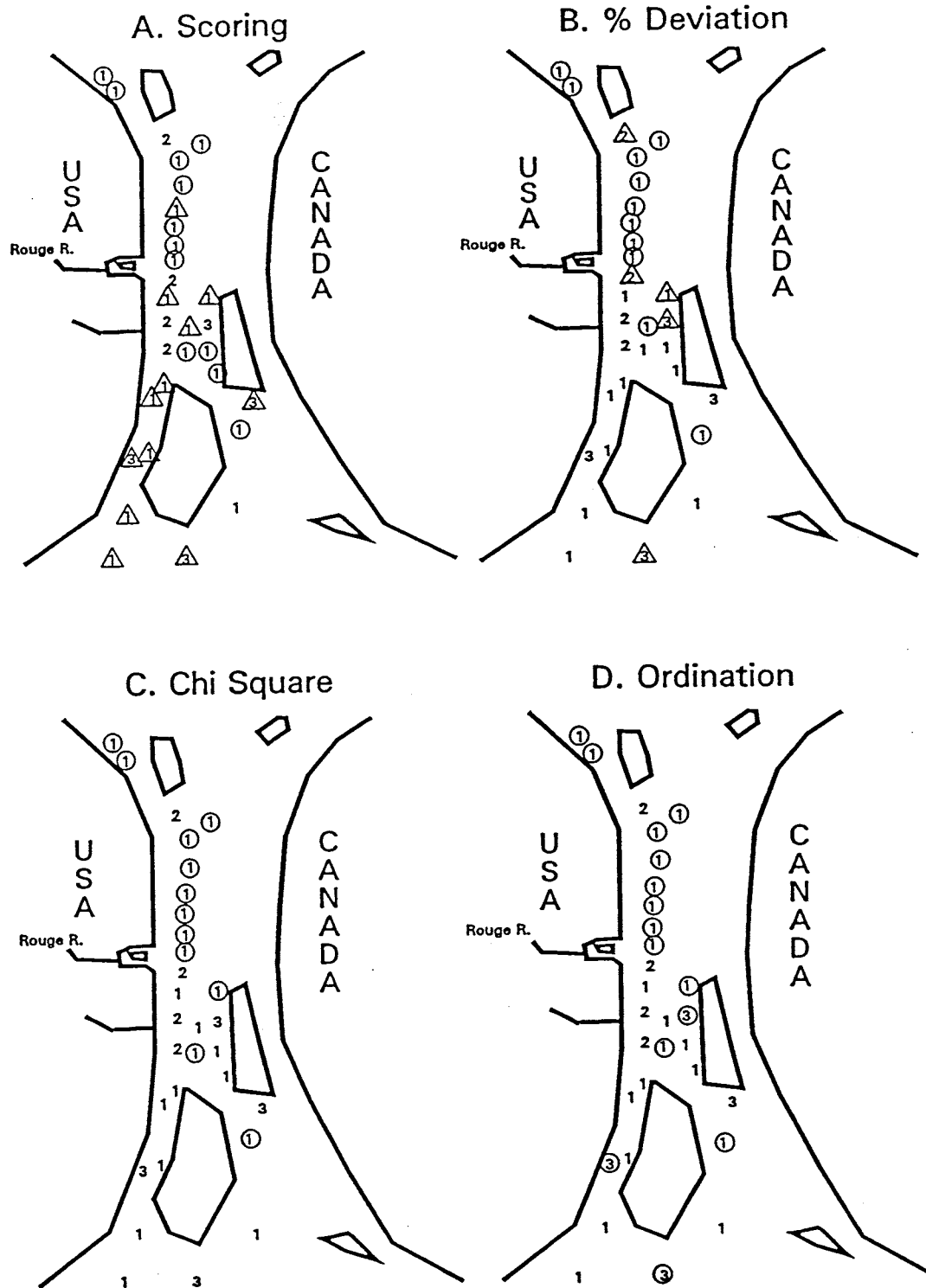


Figure 4. Predicted community (indicated by number) at 30 test sites in the Detroit River. Sites that met guidelines are circled, undecisive sites are indicated by a triangle and failed sites are unmarked.

2. **Mean Difference Method** -- This method is quantitative and provides a measure of absolute difference between a test site and the predicted community. Values are calculated as percent difference in the means for each taxon from the reference community assemblage, in two steps:

1. Calculate the percent difference in the means for each taxon.

$$\%Difference = \left(\left(\frac{\bar{x}_{test}}{\bar{x}_{reference}} \right) * 100 \right) - 100 \quad (1)$$

2. Adjust for variation in the reference community.

$$\%Difference = \%Difference_{(eqn1)} - \%S.D._{(ref)} \quad (2)$$

Percent differences from Equation 2 are only counted if > 1 , as scores of 0 or < 1 indicate the percent difference for that taxon are within 1 S.D. of the mean for the reference community and thus should be counted as zero. The difference is calculated for each taxon and an average difference determined for the site. Average differences of 10% or less are considered as meeting the guideline and differences of 100% or more can be categorized as failure. The intermediate range has to be considered as indecisive, depending on the management decision to be taken. For example, if navigational dredging is being considered where open water disposal could have an impact, then erring on the side of safety is desirable and the indecisive (10-100%) sites should be considered as unsuitable. On the other hand, if remediation is being considered, which normally has high associated costs, then one would only consider those sites that clearly fail. With this system of guidelines, of the 22 community 1 sites, 11 pass, 10 fail, and one is indecisive; for both communities 2 and 3, two sites fail and two sites are indecisive. There are fewer indecisive sites than with the scoring method and the distinction between sites up and down stream of the Rouge River is more evident (Figure 4).

3. **Chi-Squared Method** -- Using this predictive approach produces an expected community of key taxa (Table 2) based on the reference communities and measured or observed numbers of the same taxa at the test site(s). Such data lend themselves to the determination of the probability of difference between reference and test sites using a chi-

squared test, thus allowing an estimation of the significance of the difference of the test site from its predicted state, with known probability. Chi-squared values were calculated for each station where the expected value for a taxon at a test site was the mean of the reference sites for that community, and the observed was the measured value for the same taxon at the test site. Chi-squared values were calculated for each of the key taxa (Table 2). The chi-squared was calculated using the mean value for the reference community (Table 2), yet the reference community has a variation associated with it, as expressed by the S.D. for each taxon. Therefore, a chi-squared was also calculated for the mean ± 1 S.D. and the calculated chi-squared for each test site was adjusted by those values. Twelve of the 22 community 1 sites were significantly different from the reference community. Those sites that supported the predicted community ($P > 0.05$) were upstream of the Rouge River, and all but three downstream stations were significantly ($P < 0.05$) impacted (Figure 4).

4. Multivariate Method -- The final approach to comparing test sites to reference conditions uses ordination methods. Both the reference sites and test sites were ordinated using Principal Components Analysis (Table 3). The results for test sites predicted as community 1 (Figure 5) show a large number of test sites (solid squares) falling within the boundary of the reference sites (open squares) on the first two components, which explained over 60% of the variance. The degree of difference can be determined by the distance from the reference cluster centroid. For example, sites D-K, D-P, and D-H are clearly different, while site D-I is marginally different. Results are similarly shown for test sites predicted as being community 2 or 3 (Figure 5). Examination of the geographic location of the sites (Figure 4) shows again that the upstream stations support the predicted communities and those in the vicinity and downstream of the Rouge River are different from that predicted.

These four approaches represent the first attempt to develop numerical biological sediment guidelines. Other proposed biological objectives, guidelines, or criteria have either been narrative statements (U.S. EPA 1990) or more broadly ecosystemic (Hughes *et al.* 1986; Karr *et al.* 1986). While in the example of the Detroit River we include only benthic invertebrate community structure data, this approach could easily be adapted to other biological data matrices. To develop sediment guidelines, reference sites should be classified based on both benthic invertebrate community structure and sediment bioassay response, where the assay endpoints are the classifying variables and a similar sediment data matrix is used to predict the response category. At a test site, the predicted response to the assay would be determined and measured against the actual response as described above.

The four proposed methods for actually developing guidelines show good concordance: of the 30 test sites, 14 showed complete concordance. Another 10 sites showed 75% concordance between three of the four proposed systems. In 8 of those 10 sites the scoring

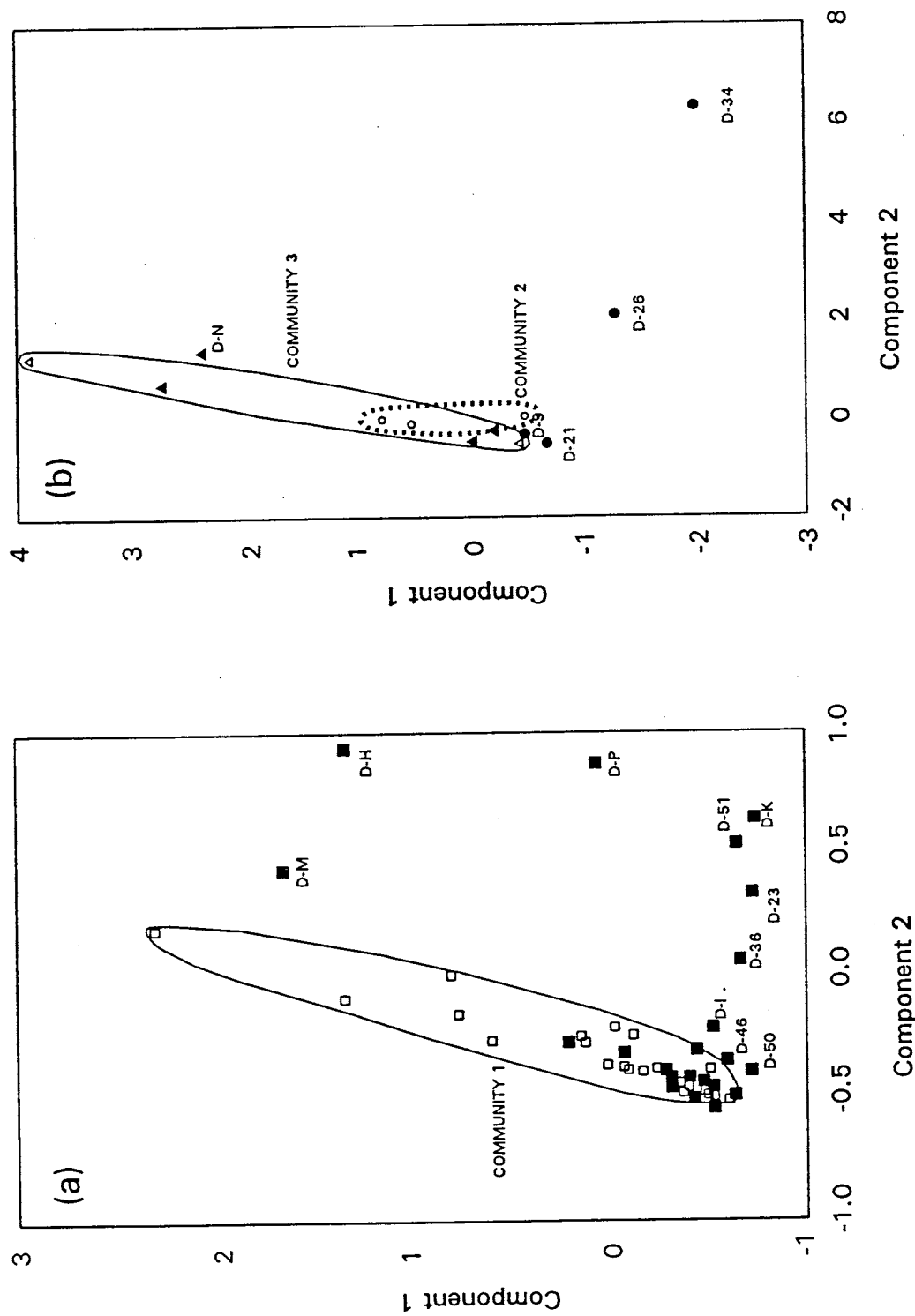


Figure 5. Ordination plots (PCA) for three reference communities (open symbols) and test sites (closed symbols). Reference community boundaries are hand-drawn. (a) Sites represented by community 1 (squares). (b) Sites represented by community 2 (circles) and 3 (triangles).

Table 3. Performance of multiple discriminant analysis in predicting community assemblages at three levels of clustering and predicted cluster membership for reference sites for the three cluster solution.

Number of Clusters	Discriminant Statistics Probability of significance for the F statistic.		Sites Correctly Predicted (%)
	Wilks Λ	Hotellings T^2	
3	0.032	0.026	83
4	0.149	0.115	59
8	0.750	0.740	35

Cluster	No. of Sites	Predicted Cluster Membership			Percent Correct Predictions
		1	2	3	
1	24	21	2	1	87.5
2	3	1	1	1	33.3
3	2	0	0	2	100

system gave an indecisive result and in two sites the percent mean difference was indecisive. Five sites showed disagreement in whether the guidelines indicated pass or fail. In two cases (community 1), three of the guidelines indicated fail and the score system a pass; and in three cases (community 3), there was disagreement between ordination (pass) and two other methods. However, in the case of community 3, the reference community was only defined from two stations, and thus the ordination boundaries of that community are imprecise. There is general agreement between all the methods, which is particularly surprising given the subjective nature of the scoring system and the subjective decision points for the mean difference approach.

The two more favored methods are the chi-squared, which is quantitative and objective, and the ordination technique, which integrates all the available information from the sites and places the test sites in the same environment as the reference sites. The ordination technique also provides a clear pass or fail criteria, either within or outside the reference community boundaries, and a measure of the extent of failure, by the degree to which the test site is outside the reference community boundary.

Full scale application of biological sediment guidelines would require a much larger data set of reference sites. A river classification project in the U.K. (Wright *et al.* 1984) initially used 268 sites to produce 16 community assemblages. Subsequently, the data base was expanded to include 370 sites defining 30 community assemblages (Armitage *et al.* 1987). In Canada, in a project currently in progress (Reynoldson and Day), we are assembling a data set of 250 reference sites for the Great Lakes using both community structure and sediment toxicity. This initially large effort is required only once, and can be gradually added to and refined as data are acquired. This fundamental approach of reference site classification, development of a predictive model, prediction of test sites, and comparison with guidelines derived from the reference sites can be used in any type of environment for estimation of ecological integrity. The approach simply requires the selection of appropriate biological data matrices. It will not replace a chemically based approach, particularly for "end of pipe" application, but it does resolve many of the inherent problems associated with chemical guidelines, objectives, and criteria.

Conclusions

It is my belief that biological variables can have equal utility for determining decision points as the more traditional chemical concentration approach used in setting water and sediment quality objectives, criteria, or guidelines. In fact, the cost of this approach is potentially less, the interpretation is more obvious, and the biological approach directly achieves our goals and interests. This, combined with the more traditional approach, could greatly enhance our ability to harmonize societal goals and interests with the ability of the ecosystem, on which we depend, to support them.

Literature Cited

- Armitage, P.D., R.J.M. Gunn, M.T. Furse, J.F. Wright, and D. Moss. 1987. The use of prediction to assess macroinvertebrate response to river regulation. *Hydrobiol.* 144:25-32.
- Corkum, L.D. and D.C. Currie. 1987. Distributional patterns of immature Simuliidae (Diptera) in northwestern N. America. *Freshw. Biol.* 17:201-221.
- Hughes, R.M., D.P. Larsen, and J.M. Omernik. 1986. Regional reference sites: a method for assessing stream pollution. *Environ. Manage.* 9:253-262.
- Johnson, R.K. and T. Wiederholm. 1989. Classification and ordination of profundal macroinvertebrate communities in nutrient poor, oligo-mesohumic lakes in relation to environmental data. *Freshw. Biol.* 21:375-386.
- Karr, J.R., P.L. Fuasch, P.L. Angermier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Spec. Publ. 5. Ill. Nat. Hist. Surv.
- King, J.M. 1981. The distribution of invertebrate communities in a small South African river. *Hydrobiol.* 83:43-65
- Loftus, K.H. and H.A. Regier. 1972. Introduction to the proceedings of the 1971 symposium on salmonid communities in oligotrophic lakes. *J. Fish. Res. Bd. Can.* 29:613-616.
- Moss, D., M.T. Furse, J.F. Wright, and P.D. Armitage. 1987. The prediction of the macro-invertebrate fauna of unpolluted running water sites in Great Britain using environmental data. *Freshw. Biol.* 17:41-52.
- Ormerod, S.J. and R.W. Edwards. 1987. The ordination and classification of macroinvertebrate assemblages in the catchment of the River Wye in relation to environmental factors. *Freshw. Biol.* 17:533-546.
- Reynoldson, T.B. 1991. The development of ecosystem objectives as part of an ecosystem approach to the management of human impact on the Laurentian Great Lakes. United Nations Economic Commission for Europe.
- Reynoldson, T.B. and M.A. Zarull. 1992. An approach to the development of biological sediment guidelines. In press, Lewis Inc, Ann Arbor, Mi.

- Reynoldson, T.B. and Zarull, M.A. 1989. The biological assessment of contaminated sediments - the Detroit River example. *Hydrobiol.* 188/189:463-476.
- Reynoldson, T.B., D.W. Schloesser, and B.A. Manny. 1989. Development of a benthic invertebrate objective for mesotrophic Great Lakes waters. *J. Great Lakes Res.* 15(4):669-686.
- Ryder, R.A. and C.J. Edwards. 1985. A conceptual approach for the application of biological indicators of ecosystem quality in the Great Lakes basin. International Joint Commission, Windsor, Ont. 169pp.
- Ryder, R.A. and C.J. Edwards. 1990. Biological surrogates of mesotrophic ecosystem health in the Laurentian Great Lakes. International Joint Commission, Windsor, Ont. 69pp. United States Environmental Protection Agency (USEPA). 1990. Biological Criteria. EPA-440/5-90-004 Washington D.C. 57pp.
- U.S. Environmental Protection Agency. 1990. Biological Criteria. EPA-440/5-90-004. Washington, DC. 57pp.
- Wilkinson, L. 1990. SYSTAT: The system for statistics. SYSTAT Inc. Evanston, Ill.
- Wright, J.F., D. Moss, P.D. Armitage, and M.T. Furse. 1984. A preliminary classification of running water sites in Great Britain based on macro-invertebrate species and the prediction of community type using environmental data. *Freshw. Biol.* 14:221-256.

STATE OF KNOWLEDGE ABOUT LAKE CHAMPLAIN

Summary of Address
December 17, 1991

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School of Natural Resources
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It is my pleasure to introduce you to what we know about Lake Champlain. If I were to give you a health report on the lake based on the knowledge at hand, I would have to say that the state of the lake is questionable. It certainly does not need "intensive care," but it clearly suffers some serious ills. Lake Champlain has not received anywhere near the attention the Great Lakes have, and there is much we still do not know. But what we do know is substantial, and I would like to start by reviewing this information in 4 major areas:

1. the lake setting and human uses of the basin,
2. the physical processes in the lake,
3. water quality, and
4. the living resources of the lake.

After discussing what we do know, I would then like to begin to set the stage for what we don't know by listing some critical gaps in our understanding in at least some of these areas.

Introduction to the Lake and its Human Uses

After the five Great Lakes, Lake Champlain is the sixth largest natural fresh water lake in the United States. The lake is some 120 miles long, and 12 miles across at its widest point; it drains more than 8,000 square miles, including portions of New York, Vermont, and Quebec (Figure 1). The Lake Champlain Basin is home to over 500,000 permanent residents and hosts over 1 million visitors each year.

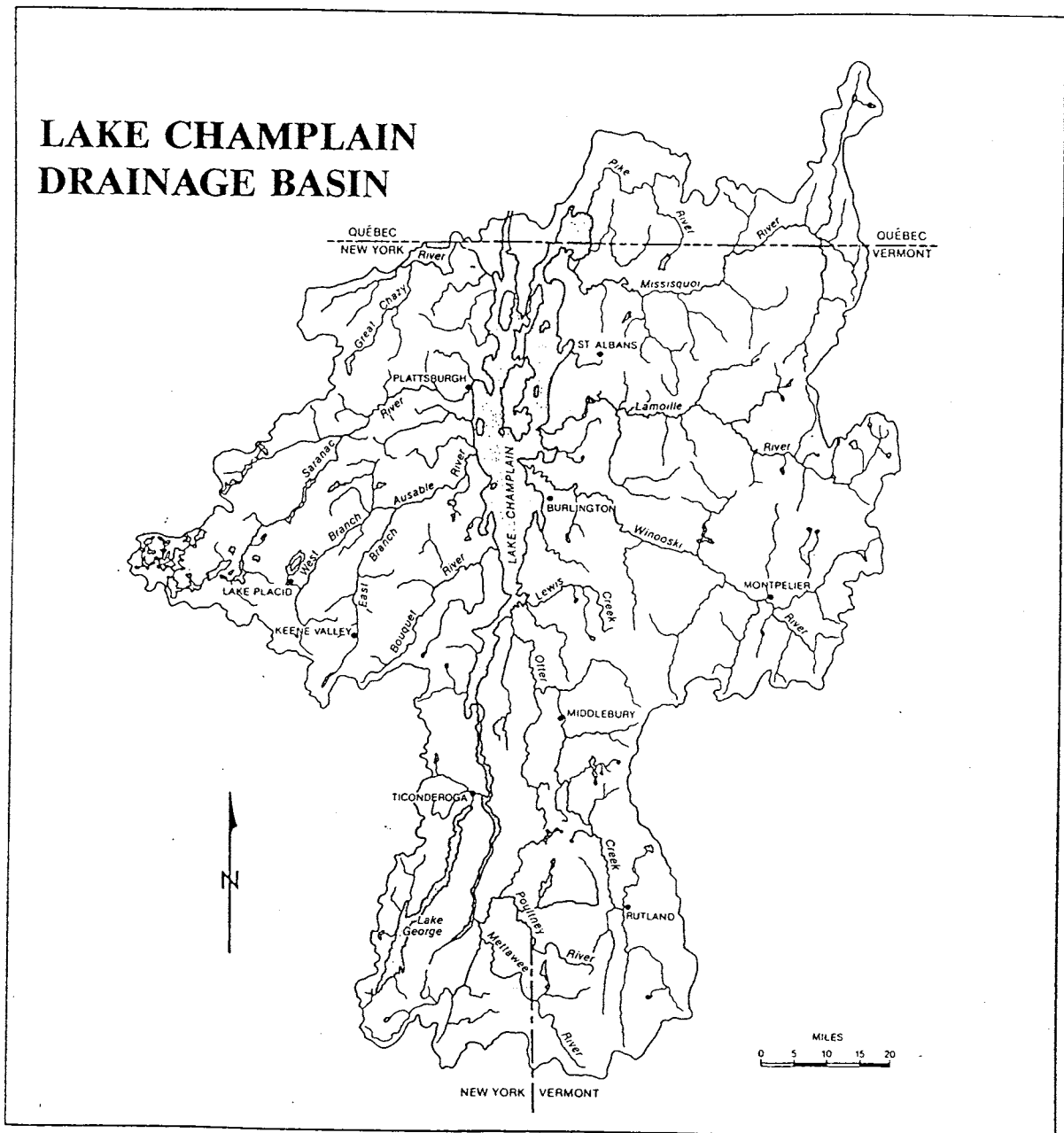


Figure 1. The Lake Champlain drainage basin, including portions of New York, Vermont, and the Canadian Province of Quebec (source: Lake Champlain Committee).

The Lake Champlain Basin has a rich and varied past. It is named after Samuel de Champlain, a Frenchman, who first explored the lake for the Europeans in 1609; but long before that the lake was a focal point for the region's Iroquois and Mohawk Indians. For the 150 years following French exploration, the lake served as a major transportation corridor under French colonial rule. Lake Champlain also held center stage for several critical battles during the American Revolutionary War and the War of 1812 (Hill 1976).

As the young United States of America burgeoned during 19th century, Lake Champlain became a vital corridor for commercial transportation. For a time, it harbored the third busiest lumber port in the country. Although the Lake served a vital role in the transportation network, it was never developed as an industrial center. Only about 3% of the shoreline was developed. In part because of this, much of the archaeological and older architectural evidence of human history remains (Hill 1976).

In the last few decades, however, there has been a rapid increase in the human population in the basin. The numbers of year-round homes, condominiums, and urban development around Burlington and Plattsburgh have dramatically increased. The numbers and sizes of powerboats and sailboats using the lake have increased. On busy summer weekends, the lake in developed areas like Mallets Bay positively teems with boats. Increasing numbers of conflicts are occurring between large power boaters and canoeists, row boaters, and swimmers. In a recent state survey of Vermont residents, about 70% regarded crowding of boats on lakes and ponds as a problem.

The human pressures on the lake's fish and wildlife species have also increased substantially. In 1980, over \$32 million were spent on durable and nondurable goods for duck hunting and fishing in Grand Isle, Franklin, Chittenden, and Addison Counties (Gilbert 1985). This is an enormously important part of the local economy. But all is not well. Fishing success is down and some very large fish of a few species are contaminated with chemicals and are not safe to eat.

Private shoreline development is restricting public access and damaging critical habitat for fish and wildlife. Rapid growth is behind most critical land-use issues in the Lake Champlain Basin. But most communities and the states welcome growth as a sure sign of economic health.

In order to protect our priceless cultural heritage, ensure diverse recreational opportunities for our citizens and visitors, and protect the long-term economic health of our communities, we need sound social science data on human use patterns and desires, the impacts of development on the shoreline environment and the lake, and the economic underpinnings

of the basin. We face some tough decisions -- it is important to know what the implications of each potential option are.

Physical Processes

In order to understand the physical processes in the lake, we must first look at the physical setting of the lake. The lake is divided geologically into five distinct basins, each with individual characteristics (Figure 2).

1. South Lake - from the mouth of the Poultney River to Crown Point - is narrow and shallow, much like a river.
2. Main Lake (Broad Lake) - Crown Point north to Rouses Point - contains 81% of the volume of the entire lake, including the deepest, coldest water.
3. Malletts Bay - lies to the southeast of Grand Isle - because of the causeways to the southwest and north, it has the most restricted circulation of any of the basins.
4. Inland Sea (Northeast Arm) - lies to the east of the Vermont islands, but also including the narrow passage between North Hero and the Alburg Peninsula.
5. Missisquoi Bay - receives the drainage of the Missisquoi and Pike Rivers. Water flow is to the south to the Inland Sea. Very shallow (maximum depth 13 ft), warm.

The general, long term pattern of mass transport is to the north, as shown in Figure 3. Water retention times are longest in the Main Lake -- about 3 years, and shortest in the South Lake -- less than 2 months (Myer and Gruendling 1979).

Because mass transport is to the north does not necessarily mean that the current flow is always to the north. The current speed and direction at any particular point in the lake will be affected over the short term by wind conditions, lake stratification, and the internal seiche.

Wind patterns, or atmospheric forcing, are the primary determinant of surface water flows in Lake Champlain. Although intuitively and theoretically we know this, we do not understand in any quantitative way how wind events translate into water movement patterns.

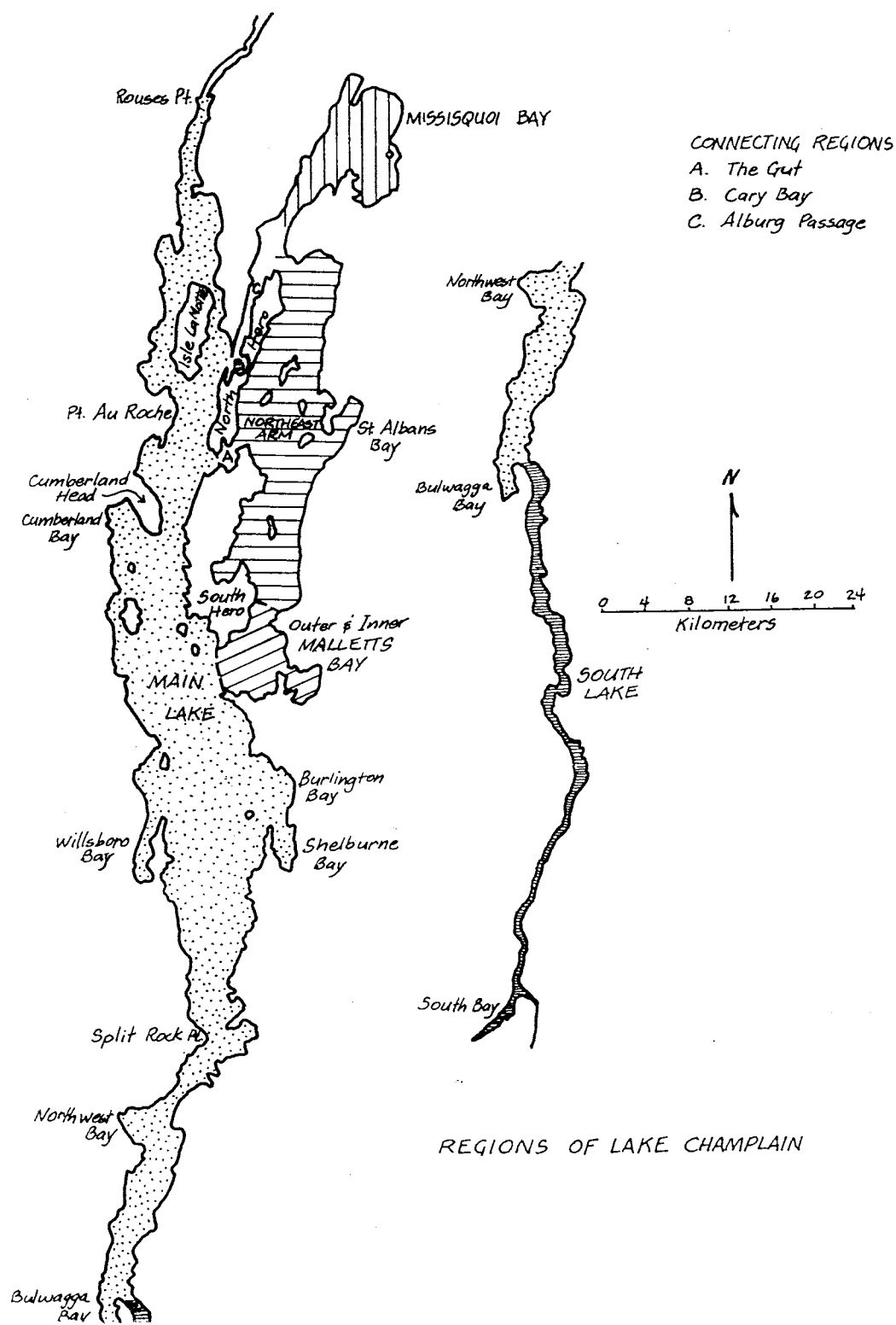


Figure 2. The five major basins of Lake Champlain (from Myer and Gruendling 1979)

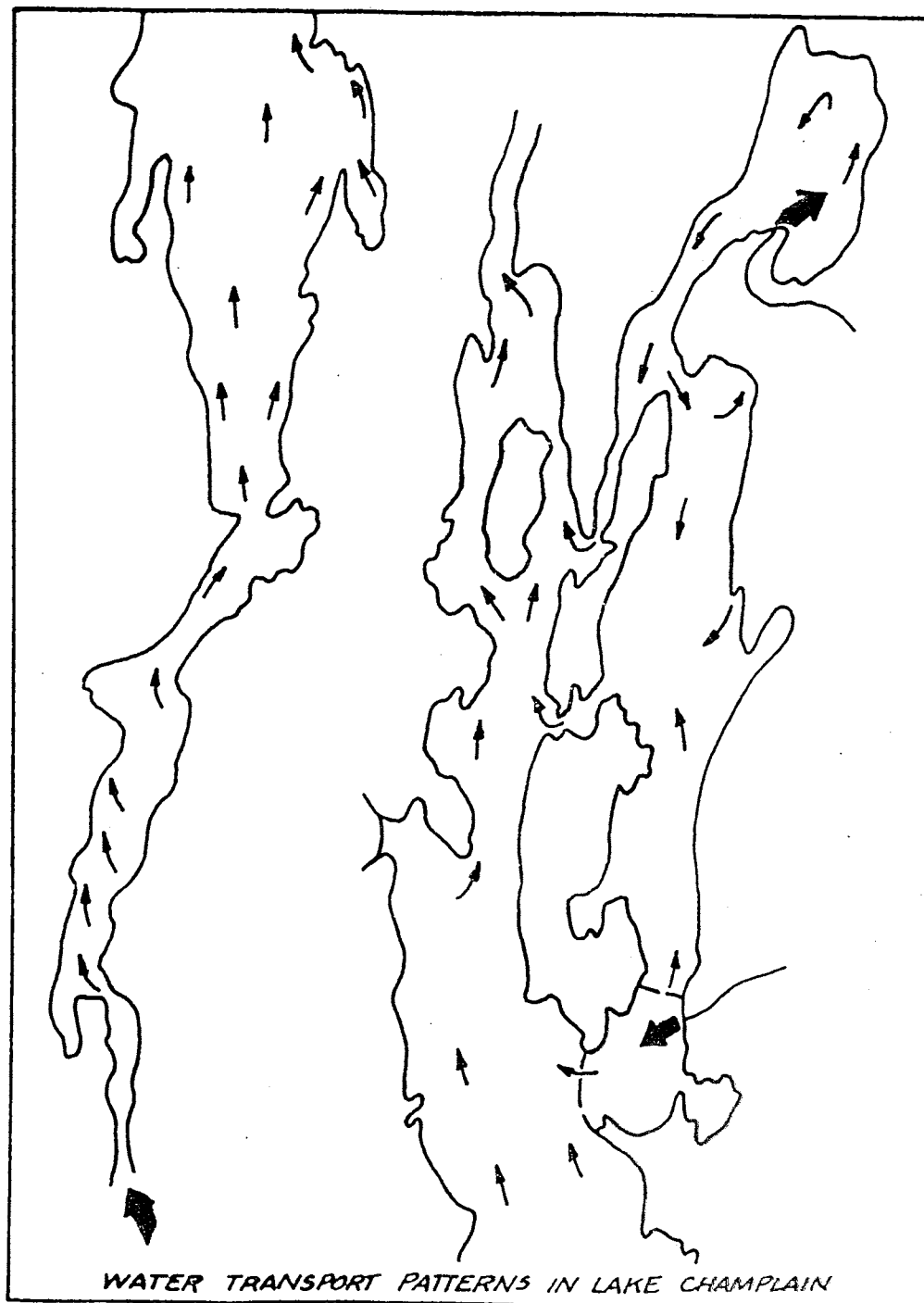


Figure 3. Generalized water transport patterns in Lake Champlain (from Myer and Gruendling 1979).

There have been a number of drift studies of surface water flow that show generally northerly or northwesterly drift associated with the dominant wind direction from the south or southwest in the summer. But there is considerable variation, and some studies have shown evidence of circular gyres, flow reversals and cross-lake drift. In the summer, in the deepest portions of the lake, current direction can be opposite of what it is at the surface because of thermal stratification and the internal seiche.

Because the Main Lake is so deep, it predictably stratifies in the spring and summer. In the spring, the sun warms the surface layers of the water column. This warmer water is less dense than the colder, deeper water, where the sun's rays do not penetrate, so it floats on the surface and without external stirring, does not mix with the colder water below. Figure 4 shows the typical thermal structure of the Main Lake in the summertime. Notice the warm epilimnion, the sharp zone of temperature change (thermocline), and the deeper cold water in the hypolimnion.

Once this thermal structure is established, the prevailing southerly winds set up the internal seiche. A few days of consistent winds from the south gradually pile up the warm surface waters in north end of the lake, depressing the thermocline to greater and greater depths. This pushes the colder deep water to the south and the thermocline gradually rises in the south. When the wind stops, the lake water moves to equilibrate, setting up a sloshing motion back and forth, or the internal seiche. The predictable on and off south winds of the summer provide just enough forcing to keep the seiche going until fall, when the thermocline breaks down as the surface waters cool.

Glenn Myer (SUNY, Plattsburgh) and others have measured the amplitude of the internal seiche at 15 meters. An internal wave of this magnitude can result in considerable turbulent mixing and transport of water. The primary seiche in the Main Lake has a period of about 4 days, but there also appear to be other smaller seiches operating with different periods and different nodal characteristics.

Vertical differences in current flow patterns at the surface and at depth for a section of the Main Lake in the summer are illustrated in Figure 5. Notice that current flow directions at the surface and at depth at many points in the lake are not the same. This probably indicates the effects of the internal seiche.

The Inland Sea is much smaller than the Main Lake and shallower. Because of this, the strong pattern of thermal stratification can be modified by wind stress and bottom topography. The currents tend to vary considerably. There are also apparently at least 2

Typical Summer Stratification

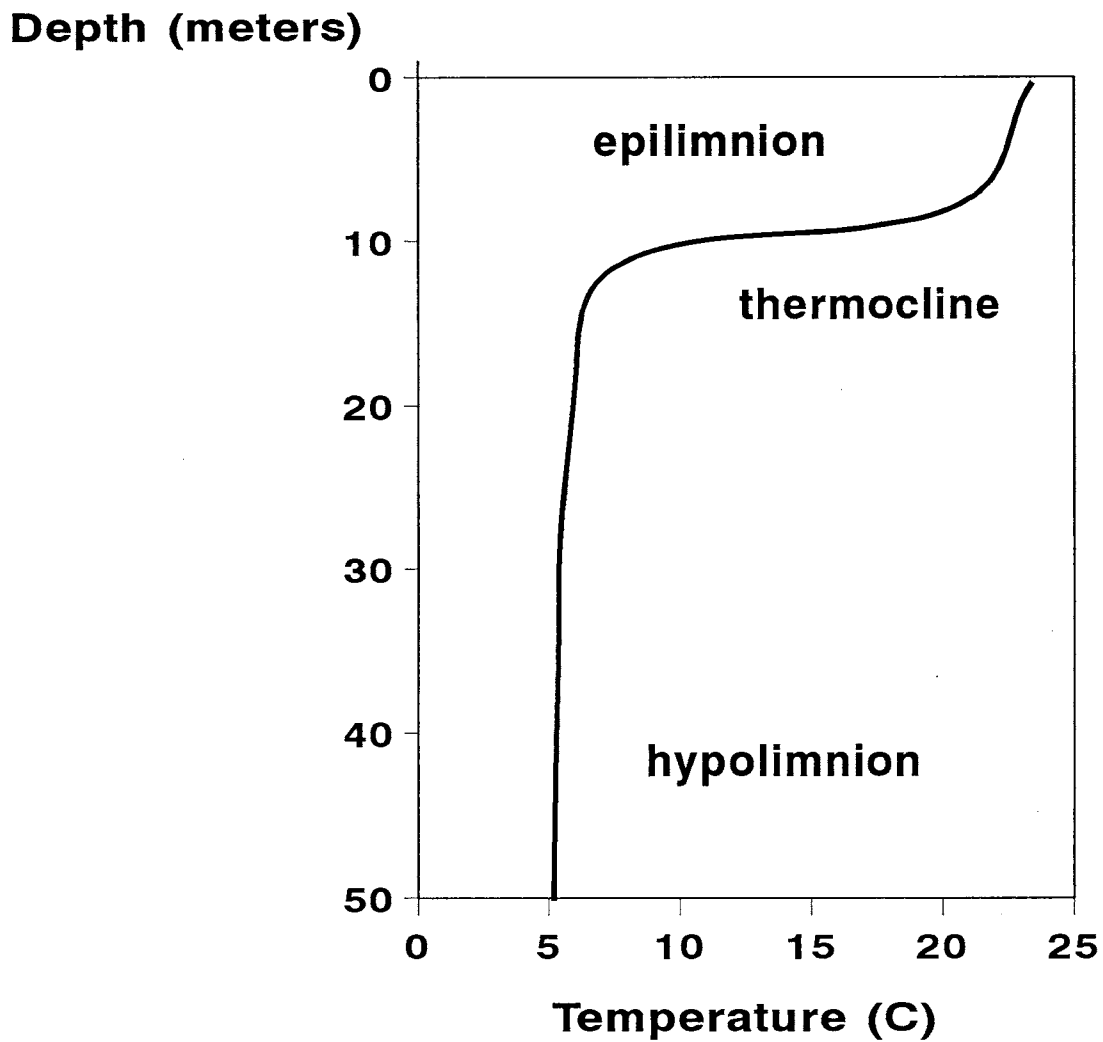


Figure 4. Typical thermal structure in the Main Lake in summer. The thermocline is the sharp zone of temperature change between the warm epilimnion at the surface and the cold hypolimnion at depth.

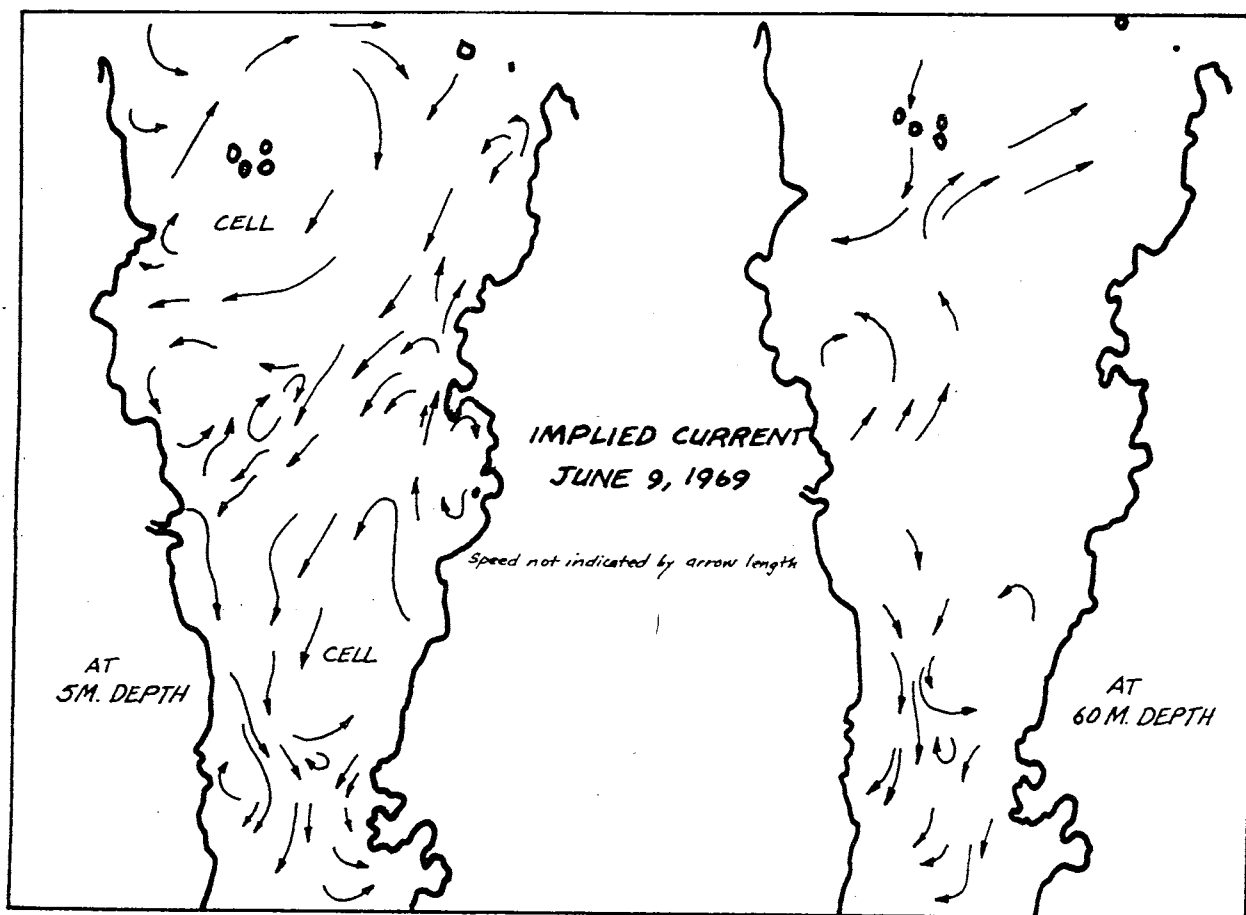


Figure 5. Implied currents at two depths in the Main Lake between Willsboro Point and Thompson's Point (from Myer and Gruendling 1979).

internal seiches with periods of about 3.6 days and 2.4 days. The amplitude of the seiche is lower, on the order of about 10 meters. The currents in the shallow regions of the Inland Sea respond to local shoreline configuration and bottom topography.

Current patterns in Inner and Outer Malletts Bay, Missisquoi Bay, and other isolated bays such as Cumberland, Shelburne, and Burlington Harbor do not show the same degree of thermal stratification because they are shallower and turbulent mixing can break down the stratification. Flow patterns have been studied to greater degrees in Cumberland Bay and Burlington Harbor because of the discharges located there. Circular flow patterns, influenced by the shoreline are common. There are also apparently strong directional flows away from the shoreline in Burlington Bay. In the South Lake, the flow is generally northward.

A complete understanding the hydrodynamics of the lake is absolutely essential to understanding the distribution and fate of sediments, nutrients, and toxins in the Lake. In order to understand and eventually model the dynamics of the lake in any sort of reliable way, we must assess:

1. atmospheric forcing,
2. inflows, outflows, and throughflows from all five lake basins,
3. inflows from the watershed to the lake,
4. the thermal structure of the lake, and how wind events and stratification act to set up seiches of varying magnitude and period,
5. shoreline geometry and bathymetry,
6. groundwater flows into the lake, and
7. precipitation/evaporation.

With only a handful of meteorological stations on the lake, we know very little about atmospheric forcing. We have very limited empirical information on inflows, outflows and throughflows in any of the 5 basins. We do have a relatively good handle on inflows from the watershed and will have an even better one with the recent Management Conference funding for stream gauging stations. We have a very rudimentary understanding of seiche characteristics, and essentially no data on groundwater inflows to the lake.

Pat and Tom Manley (Middlebury College) have two current meter and thermistor moorings in the Main Lake. To understand exchange rates between the basins, at a minimum additional moorings should be established at the passages at The Gut, Carry Bay, Alburg Passage, and the Richelieu River. Limited dynamic models of lake transport have been

developed for portions of the lake by Jeff Laible (University of Vermont) and others, but a whole-lake dynamic model does not exist and is needed if we want to be able to predict the fate and effects of sediments, nutrients, and toxins in the lake.

Water Quality

Not only is good water quality a prerequisite for the organisms that live in the lake, but it is also essential for Lake Champlain's economic, recreational, and cultural well-being. More than 150,000 people get their drinking water from municipal systems that draw from the lake and thousands more draw individually from the lake. If people can't swim in the water, or navigate their boats through the aquatic weeds, they will not recreate on the lake. The Lake Champlain Committee reports that the economies of 46 of 50 lakeshore communities in the basin depend on summer residents and tourists for their livelihood (Lake Champlain Committee 1990).

To understand lake water quality, we must first go back and consider the five major basins of the lake. Each has a distinct chemistry--in fact, their ionic concentrations appear almost as 5 individual, interconnected lakes. Within the Main Lake and South Lake, cation, alkalinity, and conductivity long term average values decrease from south to north (Myer and Gruendling 1979). This chemical gradient is strikingly different from most lakes, which tend to pick up cations as the water flows through the basin. The chemical characteristics of the water will affect living organisms and the behavior of toxic substances in the lake.

I would like to discuss briefly our understanding in three major water quality arenas: pathogenic organisms, nutrients, and toxic substances. First, pathogens.

Pathogens are bacteria, viruses, and other disease-causing microorganisms that enter the lake primarily from human and animal waste. Sources of these materials include leaky septic fields, municipal sewer overflows, boat holding tank discharges, and runoff from agricultural areas (carrying animal waste) and urban and suburban paved surfaces. Lake public beaches suffer periodic closures due to these pathogens and lake residents risk gastrointestinal ailments.

Nutrients are those elements critical for life. The primary nutrients needed by algae and other aquatic plants are nitrogen and phosphorus. In Lake Champlain, like most freshwater lakes, phosphorus is the nutrient that limits plant growth. When phosphorus concentrations exceed 10-20 $\mu\text{g/l}$, algal populations in the lake bloom. Concentrations exceeding 20 $\mu\text{g/l}$ are generally considered eutrophic.

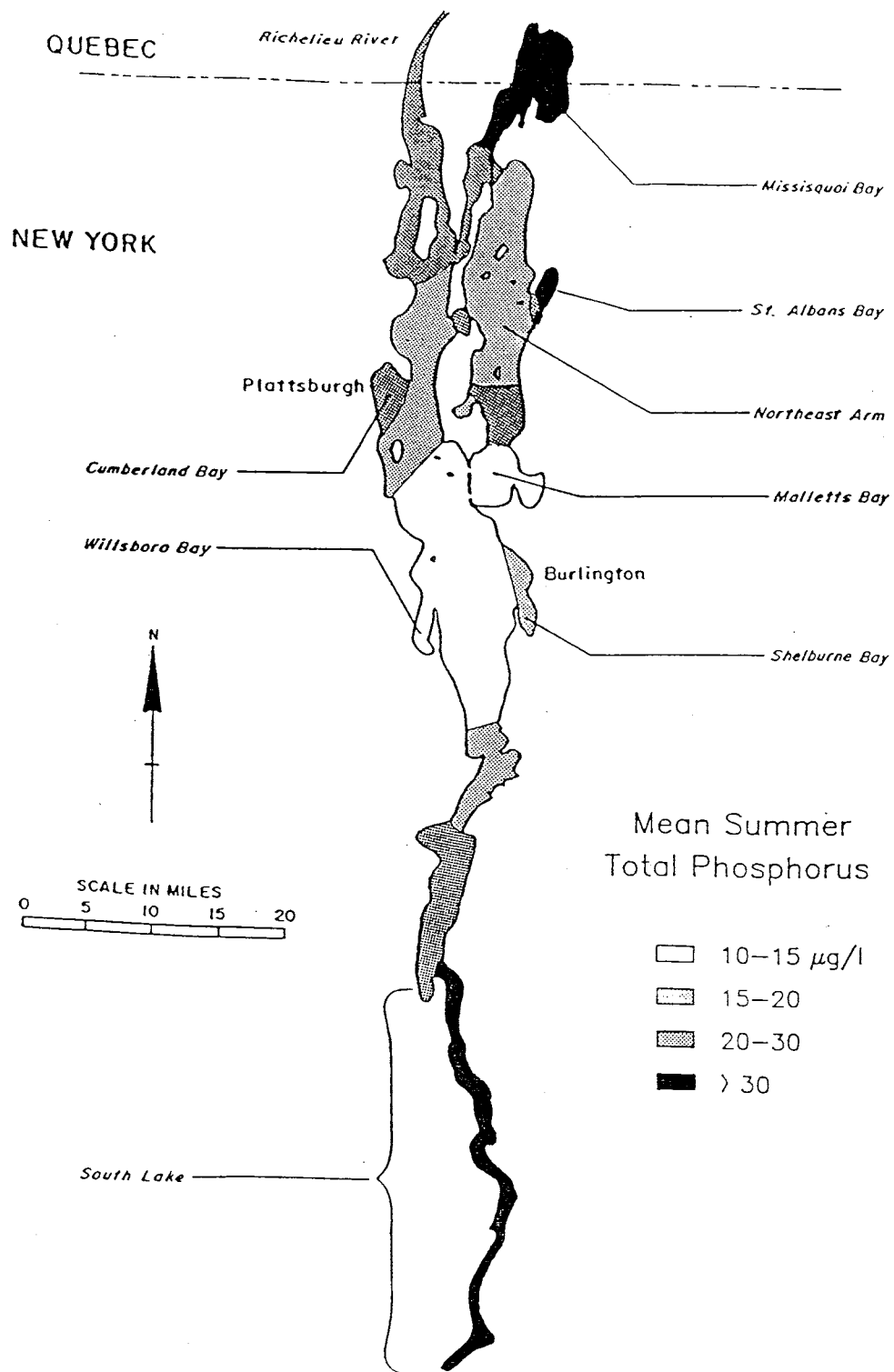


Figure 6. Mean summer phosphorus levels in Lake Champlain over the period 1979-1988 (from Smeltzer 1989).

Figure 6 shows mean summer phosphorus concentrations in Lake Champlain for the 10 year period between 1979-1988. This data comes from the monitoring programs carried out by the States of Vermont and New York. The following paper by Alan McIntosh (this volume) contains more information about that program. The high phosphorus concentrations in the bay areas and in the South Lake lead to serious algal nuisance conditions and considerable use impairment. Even in areas where the average phosphorus concentration is below 15 $\mu\text{g/l}$, phosphorus concentrations vary considerably and occasional high concentrations lead to periodic blooms. Shoreline areas across the length of the lake show eutrophication problems, probably from localized inputs of phosphorus from soil erosion, septic field seepage, and/or runoff.

Concern about phosphorus in Lake Champlain is not new. The Lake Champlain Basin study of 1979 identified it as a problem and recommended phosphorus reductions through continuation of phosphorus-detergent bans, construction of phosphorus removal facilities for selected wastewater treatment plants, and agricultural nonpoint source management practices (New England River Basins Commission 1979). All of these recommendations have been pursued, at least in part, and an admittedly crude analysis of trends shows no significant increase in phosphorus since that time -- but no decrease either. Phosphorus management may have prevented the increase, but we still have a problem. In fact, if you compare phosphorus levels in Lake Champlain to those in the Great Lakes before aggressive management in those areas (Figure 7), you will notice that the phosphorus-rich areas of Lake Champlain are comparable to the most notoriously eutrophic areas of the Great Lakes more than 15 years ago -- namely, western Lake Erie and Saginaw Bay in Lake Huron (Smeltzer 1989; DePinto *et al.* 1986).

Where is the phosphorus coming from? If you look geographically (Figure 8), about 60% comes from Vermont, 35% from New York, and 5% from Quebec (Myer and Gruendling 1979; Smeltzer 1989). Using preliminary data collected as part of the New York-Vermont Phosphorus Study, Eric Smeltzer (Vermont Agency of Natural Resources) estimates that between 2 and 42% of the phosphorus loading in five Vermont tributaries is from point sources and 58-98% from nonpoint sources (Figure 9).

The sources of nonpoint source phosphorus include animal waste and agricultural runoff, urban and suburban stormwater runoff, septic field seepage, and runoff from golf courses, forested landscapes and other areas. The relative contribution of each of these sources is unknown.

The University of Vermont and the Soil Conservation Service studied nonpoint source pollution in two watersheds, the St. Albans and the LaPlatte, for 10 years, from about 1979-1989 (Meals 1990; Vermont Rural Clean Water Program Coordinating Committee 1991).

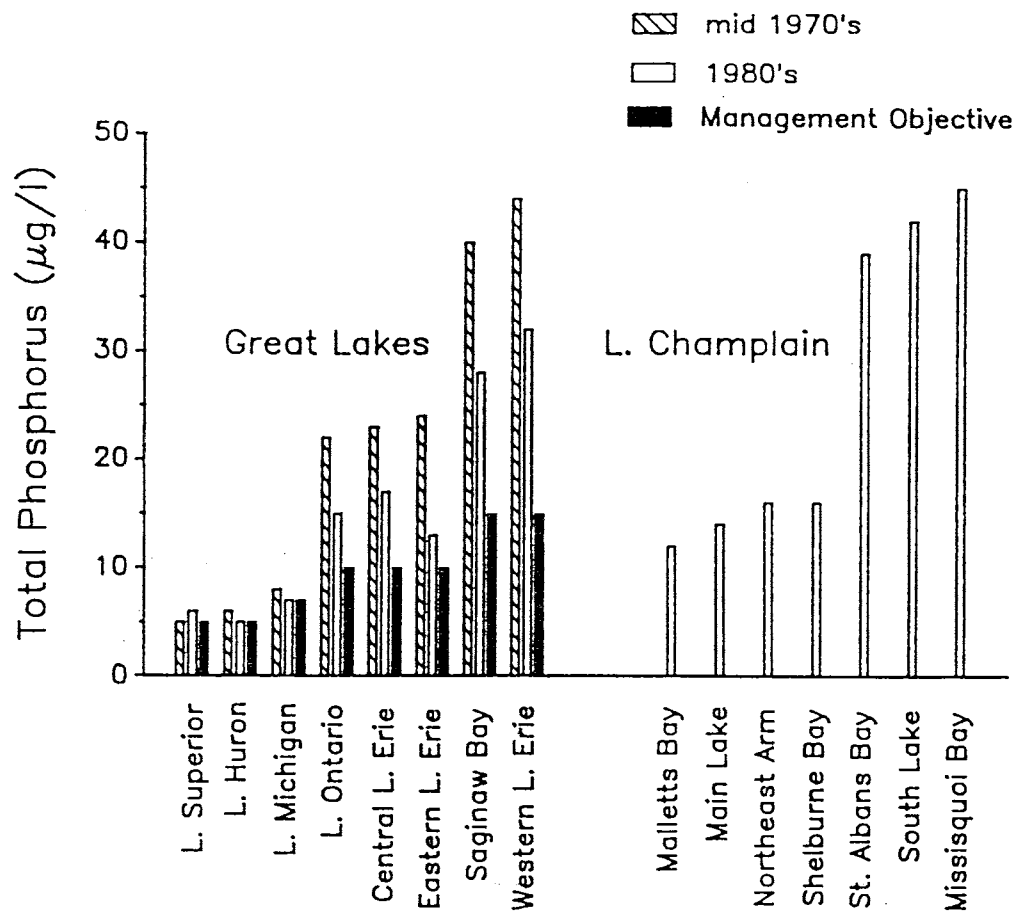


Figure 7. Comparison of phosphorus levels and management objectives in the Great Lakes and Lake Champlain. Great Lakes data from DePinto, et al. 1986 (from Smeltzer 1989).

Phosphorus Loading

From New York, Vermont, and Quebec

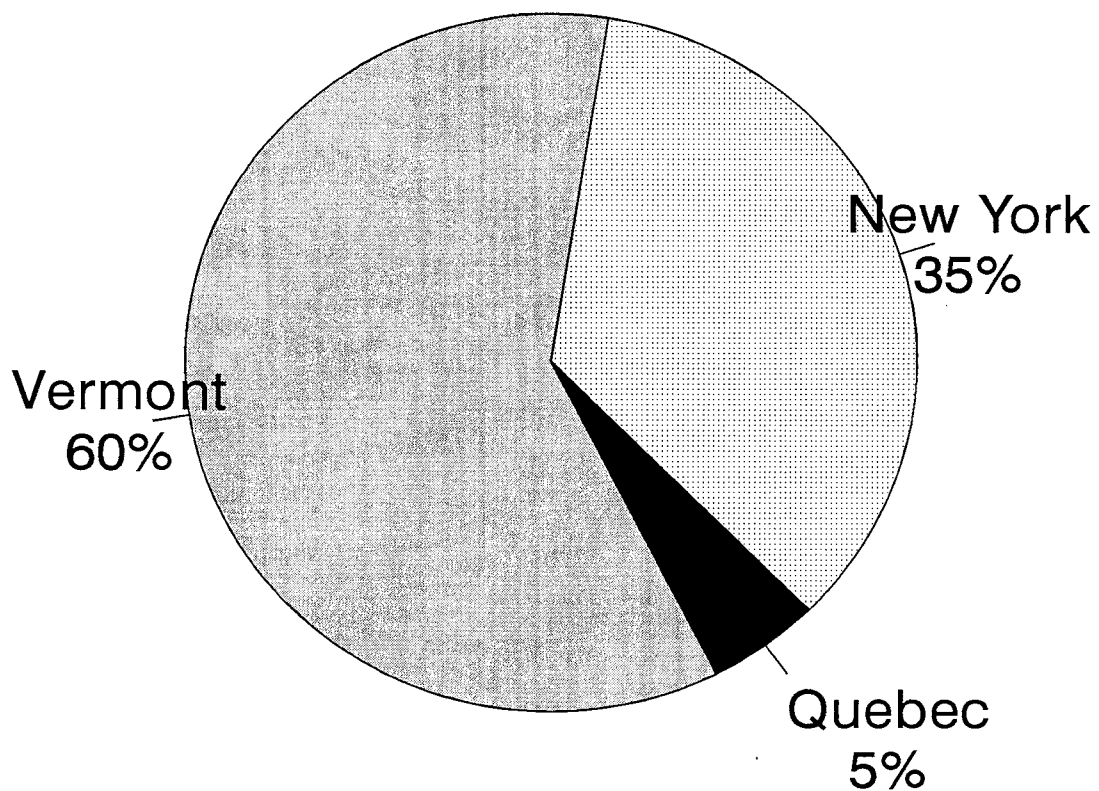


Figure 8. Percent phosphorus inputs to Lake Champlain from New York, Vermont, and the Canadian Province of Quebec.

1990 Phosphorus Loading

(metric tons per year)

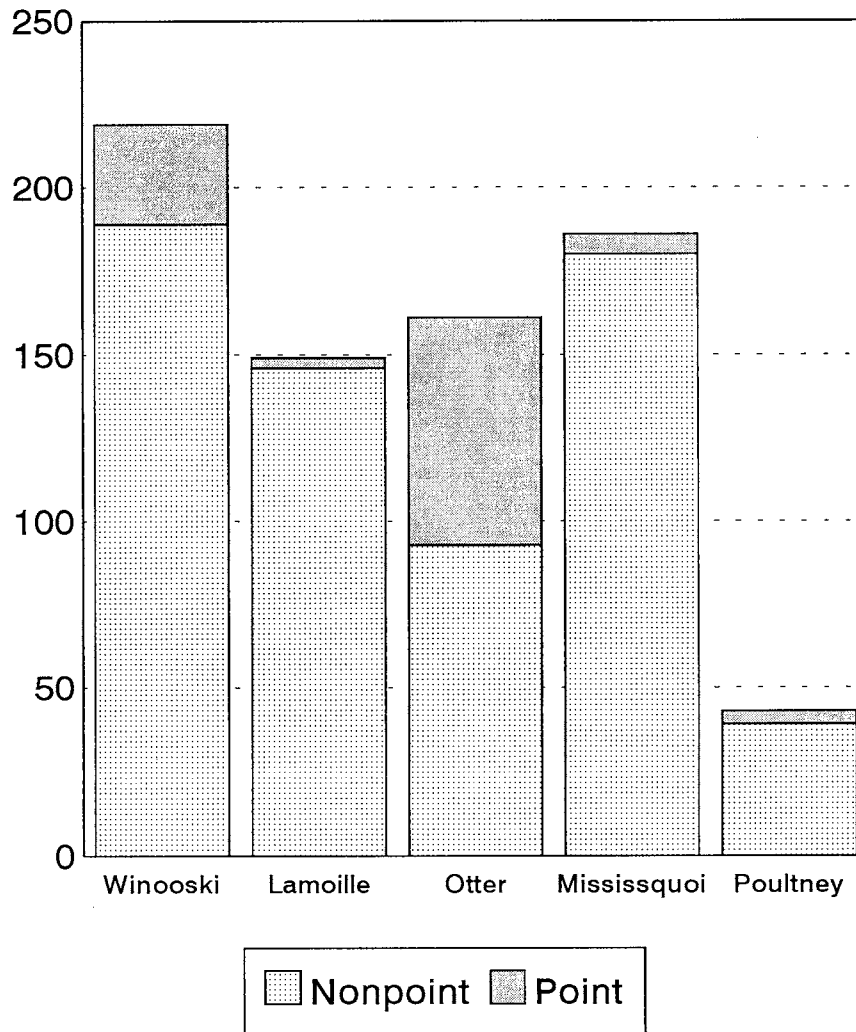


Figure 9. Point and nonpoint source loadings of phosphorus from five Vermont tributaries to Lake Champlain (1990 preliminary data from the New York-Vermont Lake Champlain Diagnostic-Feasibility Study, courtesy Vermont Department of Environmental Conservation).

They looked at phosphorus in the water at the edge of agricultural fields and downstream in the watershed before and after animal waste management was initiated. They found that manure management significantly decreased the amount of phosphorus in streams adjacent to farms, but were unable to see changes downstream in the watershed. It is not clear why, but it may be that the experimental methods were simply not adequate to detect changes in phosphorus.

The States of New York and Vermont are working to develop a lake-wide phosphorus model that can be used to evaluate lake water quality responses to reductions in phosphorus loading. The State of Vermont has recently established phosphorus standards for various sections of Lake Champlain. The goal of phosphorus reduction in the lake is to reduce algal productivity, therefore we must understand in what quantities, and under what conditions, the phosphorus is biologically available. The various phosphorus monitoring programs measure total soluble phosphorus -- it is unclear how much of this is biologically available. We also must understand how phosphorus is transported and transformed in streams on the way to the lake and how phosphorus moves between the sediment and the overlying water column in the lake.

Under low oxygen conditions, phosphorus is liberated from the sediment. Studies by Jack Drake and others (Ackerly 1983; Hyde 1991) in Malletts and St. Albans Bays have shown that when oxygen concentrations in the hypolimnion are low, phosphorus concentrations increase. In shallow water areas, wind-generated water turbulence resuspends sediments and probably increases soluble phosphorus. This increased phosphorus loading may be part of the cause for high phosphorus concentrations in the shallow South Lake, Missisquoi Bay, and St. Albans Bay.

In order to predict what magnitude of loadings reductions will result in lower phosphorus concentrations in the lake itself, much additional research is needed, including research on:

1. in-stream transport, attenuation, and transformation of phosphorus,
2. in-lake sediment contributions to the phosphorus load, and
3. speciation of phosphorus, in order to identify the relationships between total phosphorus and bioavailable forms.

Toxic substances are the third component of water quality. Much of the ongoing concern about toxic substances in Lake Champlain results from health advisories for consumption of large fish from Lake Champlain because of mercury and polychlorinated biphenyl (PCB) contamination. Toxic materials can also be a concern for those who draw their drinking water from the lake.

Toxic materials can cause a number of health problems for people, including cancer, neurological disorders, birth defects, headaches, nausea, and other problems. A study of women in the midwest who ate fish from Lake Michigan contaminated with PCBs showed that their babies weighed less at birth, had smaller heads, and were less able to recognize objects at the age of seven months than babies born to mothers who did not eat these fish. Follow up studies have shown that mothers who nurse their babies continue to transfer fat-soluble toxins such as PCBs to their babies (Environment Canada 1991).

Toxic effects on Lake Champlain's biota have not been investigated, but in the Great Lakes system, chemical contamination results in increased invertebrate and fish mortality, and numerous abnormalities. Eleven wildlife species in the Great Lakes Basin have also been shown to experience reproductive and other problems attributable to chemical contaminants (Environment Canada 1991). All are long-lived fish-eating species and most also occur in the Champlain basin. These individual species effects can translate into unanticipated community changes.

The information base on toxic materials in Lake Champlain is extremely limited. There is a general consensus in both the management agencies and the research community that there is insufficient information on toxic substances in the lake to make sound management decisions. We must characterize the sources of toxic materials in the lake and its watershed; document the current concentrations of priority pollutants in lake water, sediments, air, and biota; and uncover the transport pathways and fate of toxic materials in the lake system. Once we know which materials are present and where, we must understand the effects of those materials on the Lake Champlain ecosystem. Let's take these one at a time.

Toxic materials enter the basin and the lake from both point and nonpoint sources. In 1987, there were 7 direct industrial discharges, 66 sewage treatment plant discharges, 34 hazardous waste sites, and 95 landfills (30 inactive) in the basin that are actual or potential point sources of toxic materials (Bean and McIntosh 1987). Nonpoint sources include surface runoff, groundwater inputs, and atmospheric transport. Some information is currently collected as permit requirements on the materials in point source discharges. Additional information on these sources will be gathered through Management Conference funding.

It is much more difficult to collect information on nonpoint source inputs, but to control toxic substances, we must know where they are coming from. Stream monitoring programs could be established to measure inputs of pesticides, PAHs and other materials from surface runoff. Atmospheric monitoring stations will be necessary to begin to understand airborne routes of entry.

In the Great Lakes, recent studies have shown that a large percentage of the chemical contaminants in the lakes have an atmospheric source (International Joint Commission 1988). Table 1 shows the percentage of annual PCB inputs to the Great Lakes that come from atmospheric sources. Notice that as much as 90% of the direct inputs of PCB into Lake Superior is from the atmosphere (direct is atmospheric deposition on the lake surface, indirect is PCB that falls out on land and then is carried through the watershed to the lake). Table 2 shows the percent lead attributable to the atmosphere--notice again for the upper Great Lakes, over 90% comes from the atmosphere. Atmospheric contributions in the lower Great Lakes (Erie and Ontario) are much smaller.

The differences in the importance of the atmospheric route in the upper and lower Great Lakes is related to the larger surface area and longer residence times of the upper Great Lakes and the relative lack of point sources of PCBs in the upper lakes (Eisenreich, Looney, and Thorton 1981; Baker and Eisenreich 1990).

For Lake Champlain, it is difficult to predict whether it may be receiving the same high percentages of inputs from the atmosphere as the upper Great Lakes or not. We know that the surface area of Lake Champlain is considerably less than the Great Lakes, and its drainage area is generally larger than those of the Great Lakes. Point source inputs of PCB are unknown, but probably small.

Table 3 compares the ratio of land in the drainage basin to water and the retention times of the Great Lakes and Lake Champlain. Notice that the Lake Champlain Basin has a much higher ratio of land to water, but a shorter residence time than the upper Great Lakes. Since we know so little about the behavior of PCB as it moves from the land surface through the watershed to the lake, it is difficult to predict what this different morphometry means--clearly an area for research.

Our second charge is to document concentrations of toxics in lake water, sediment, air, and biota. Some data are available here. Hunt (1975), Zuegg (1991), and McIntosh (University of Vermont) and colleagues currently are documenting metal concentrations in lake sediments at selected sites. McIntosh is also documenting organic toxin concentrations. These preliminary data suggests that some toxic materials are elevated in lake sediments.

The particular sites where toxins accumulate are controlled by source locations, circulation patterns in the lake, and sediment characteristics. Considerable additional information on the latter two factors is needed.

Table 1. Annual PCB inputs to the Great Lakes and the fractions attributable to atmospheric pathways. Direct is atmospheric deposition on the lake surface, indirect is deposition on the land that is then carried through the watershed to the lake (from International Joint Commission 1988).

Lake	<u>Total Inputs</u>	<u>% Atmospheric</u>	
	kg/yr	Direct	Indirect
Lake Superior	606	90	0
Lake Michigan	685	58	0
Lake Huron	636	63	15
Lake Erie	2520	7	6
Lake Ontario	2540	6	1

Table 2. Annual lead inputs to the Great Lakes and the fractions attributable to atmospheric pathways. Direct is atmospheric deposition on the lake surface, indirect is deposition on the land that is then carried through the watershed to the lake (from International Joint Commission 1988).

Lake	<u>Total Inputs</u>	<u>% Atmospheric</u>	
	kg/yr	Direct	Indirect
Lake Superior	241	97	0
Lake Michigan	543	99	0
Lake Huron	430	94	4
Lake Erie	567	39	7
Lake Ontario	426	50	23

Table 3. Land to water ratios and retention times in the Great Lakes and Lake Champlain.

	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario	Lake Champlain
Ratio of drainage basin to water surface	1.6	2.0	2.3	3.0	3.4	18.9
Retention time (years)	191	90	22	2.6	6	3

Vermont and New York state monitoring data indicate elevated levels of PCBs in large lake trout throughout the lake, and in eels and bullheads in Cumberland Bay. Mercury levels are elevated in walleye. We know nothing about how these contaminants affect the growth, reproduction, and survival of these fishes. Epidemiological data suggest that eating large quantities of these large fish, which most anglers and others do not generally do, could pose health threats to people. But risk assessments, to quantify the risks of exposure from eating Lake Champlain fish in varying amounts, have not been conducted.

Except for very limited laboratory single species toxicity test data, we know almost nothing about the effects of the toxins that are present on the living resources in Lake Champlain. As soon as we know which materials are a problem, we must move rapidly into experimental studies of the effects of those materials on the Lake Champlain ecosystem.

Living Resources

The living resources in Lake Champlain are tremendously diverse. If the management goal for Lake Champlain is to maintain this diversity we probably need much additional information about how the lake's habitats and communities are structured and maintained. I would like to begin by discussing the lake's critical habitats and then present some of what we know and need to know about particular fish and wildlife species and aquatic communities.

One of the most important critical habitats in the basin are the wetlands. These wetlands include marshes in the tributary mouths and lowlands around the perimeter of the lake; and bogs, fens and swamps in other portions of the basin. About 40% of Vermont's wetlands exist in the four northeastern lake counties. These are also the four counties where population growth is the greatest (Borre 1989).

Wetlands in the Champlain Basin serve a variety of important functions. They include:

- important spawning and nursery areas for lake fishes, such as northern pike,
- feeding, nesting, resting, and stopover habitat for waterfowl and other waterbirds, and
- essential habitat for endangered and threatened species, including about 1/3 of the listed plants and 1/2 the listed animals in Vermont.

They also provide flood water control, water quality improvement, and shoreline erosion and protection functions.

Many unvegetated shallow water areas around the lake are also critical habitat for waterbird, fish, wildlife, and a variety of lesser known aquatic species, but which areas are most important has not been delineated. These habitats have also been invaded in many portions of the lake by two exotic, or introduced, aquatic plants, Eurasian water milfoil and water chestnut. Both these aquatic weeds thrive under high phosphorus concentrations and in other lakes, have been shown to have a variety of negative impacts on water quality and, native aquatic plants. Milfoil has also been shown to have some positive impacts on survival of small fish such as yellow perch which use the weed beds as nurseries.

Specific data on the effects of exotic aquatic plants on water quality and living resources in Lake Champlain have not been collected. Because these nuisance plants probably contribute to the degradation of water quality and significantly impair human uses of the lake, mechanical control by harvesters and by hand is practiced, primarily in the South Lake. Research is currently underway at Middlebury College (Sallie Sheldon and colleagues) to examine biological control of milfoil by a small herbivorous aquatic weevil.

There are a variety of wildlife species that use the Lake Champlain Basin including large and growing populations of snow geese, blue herons, cormorants, gulls, and terns that use the islands and wetlands in and around the lake. The Missisquoi National Wildlife Refuge provides highly productive breeding habitat for waterfowl and also serves as a key concentration area during fall migration. Surveys on the refuge indicate that waterfowl use exceeded 1.3 million use-days in 1990 -- about 75% by ducks and 25% by geese (U.S. Fish and Wildlife Service, unpublished data). Additional surveys of migratory birds and the basin habitats they use are needed.

The lake's pelagic community is a diverse assemblage of organisms including phytoplankton, zooplankton, forage fish and top predators. Phytoplankton, or small plants that drift in the water column, show a typical seasonal pattern of population blooms in the spring and fall (Myer and Gruendling 1979). This pattern is related to physical parameters in the lake -- light intensity, nutrient availability, mixing depth in the water column, and the grazing rate of the zooplankton. The annual zooplankton cycle is offset from the phytoplankton cycle, with zooplankton numbers increasing after the phytoplankton have bloomed.

Fish populations in the lake have been in a state of considerable flux for most of this century. Data on fish populations in the lake are available from New York and Vermont state surveys and fisheries research conducted primarily at the University of Vermont. Changes in fish populations result from fishing pressures, stocking by fisheries managers,

habitat alteration, the effects of the introduced parasitic sea lamprey, and interactions between species in the lake.

A simplistic view of the pelagic food web in the lake is shown in Figure 10. Let us start at the top and talk about the components of this crude model. Lake trout (*Salvelinus namaycush*) and other salmonids are stocked in Lake Champlain by the U.S. Fish and Wildlife Service and the States of New York and Vermont. In 1991, about 115,000 fish were put into the lake (Vermont Fish and Wildlife Department, unpublished data). Although these stocked fish grow well in Lake Champlain, there is very little evidence to suggest that they are reproducing naturally (Plosila and Anderson 1985). The excellent growth of lake trout is probably attributable to an abundant forage base, including zooplankton (especially mysid shrimp), smelt, and sculpin.

Sea lamprey are clearly a cause of significant mortality for lake trout. In surveys conducted by the U.S. Fish and Wildlife Service and the States of Vermont and New York, about 80% of these fish show evidence of lamprey attack (scars). Even one attack probably has serious negative impacts on the fish. Although in Lake Champlain, limited data suggest that growth rates are not significantly reduced by lamprey attack, data from the Great Lakes clearly suggests that one lamprey attack significantly increases the chances of early mortality. It is not clear what percentage of lake trout die after a first, or subsequent, attack, but it is clearly substantial. Annual mortality of lake trout from all causes is about 48% of the population (Vermont Fish and Wildlife Department, unpublished data).

Rainbow smelt (*Osmerus mordax*) are probably the primary forage fish in Lake Champlain. Other forage fishes include sculpin, cisco, yellow perch, and the introduced white perch in the South Lake. Lake trout, walleye, and other predatory fish probably feed extensively on smelt.

Assuming that the sea lamprey control program initiated in 1990 by the U.S. Fish and Wildlife Service and the 2 states will result in a significant increase in survival of lake trout, it seems important to begin to understand the food chain relationships between lake trout and smelt. Preliminary energetic analyses by George LaBar (University of Vermont) suggest that if the mortality of lake trout is reduced from 48% to 35-40% after lamprey control, the consumption rate of smelt will double. We simply do not know if smelt productivity can keep up with this predation rate. Some of the pressure on smelt could be relieved if lake trout will switch to alternate forage fish such as perch. Smelt population sizes can fluctuate dramatically as a function of both abiotic factors and the availability of their food, the zooplankton.

SIMPLE LAKE CHAMPLAIN FOOD WEB

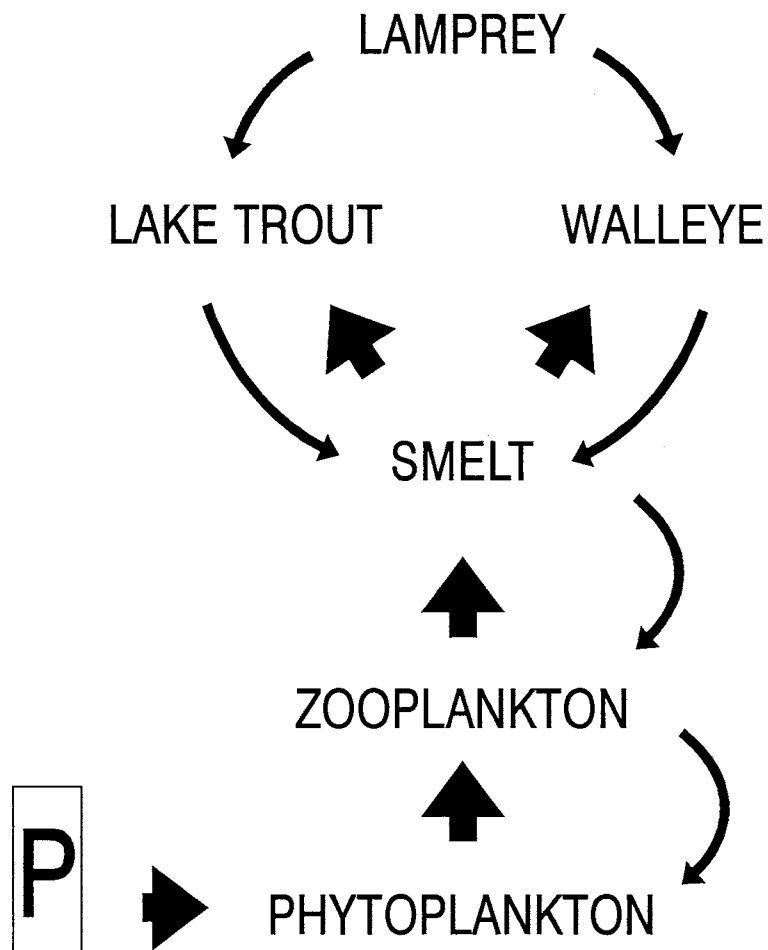


Figure 10. A simple food web representing the pelagic community in Lake Champlain.

Zooplankton population densities are strongly influenced by the population sizes and the species composition of the phytoplankton. Phytoplankton productivity and species composition respond to the concentration of nutrients, especially phosphorus, in the water column. While we can predict that total phytoplankton production will decrease as phosphorus concentrations decrease, clearly a goal for lake management, we don't know by how much and we cannot predict how the community composition of the phytoplankton may vary with changes in nutrient loading. Changes will depend on how the competitive balances between phytoplankton species shift. Studies in other lakes indicate that most zooplankton are specific in either the size or species of phytoplankton they consume. If the preferred food populations change, there will be implications for the zooplankton.

Knowledge of the phytoplankton and zooplankton communities in Lake Champlain is limited. Monitoring efforts are reviewed in the following paper; studies of how plankton respond to varying nutrient concentrations and studies of species interactions are almost totally absent. In my opinion, effective management of the lake's fish populations requires this information.

I couldn't conclude this discussion of the fish resources without saying a few words about walleye and yellow perch. Walleye (*Stizostedion vitreum vitreum*) populations in Lake Champlain have been declining for a number of years (Vermont Fish and Wildlife Department, unpublished data), and it is not clear why. Lamprey depredation is probably one cause, but survey data from both states suggest that not many young fish are surviving in the lake. We don't know the cause of this recruitment problem, or even if it is occurring at the egg, larval, or juvenile stage. It is possible that spawning habitat degradation, or mercury body burdens in adult fish, or a variety of other factors could be reducing reproductive fitness.

We also don't know how increased lake trout stocking or salmonid survival might affect walleye recruitment. Larger populations of salmonids might consume young walleye as they come into the lake. Because lake trout consumption rates are generally higher than walleye consumption rates, lake trout may more effectively exploit a limited forage base. If we want walleye in the lake, perhaps in the future we will have to think about stocking fewer lake trout.

Yellow perch (*Perca flavescens*) supports the largest fishery in Lake Champlain (Vermont Fish and Wildlife Department 1991). Data collected by the State of Vermont clearly show that the average size of these fish has been declining in the northern lake basins (Figure 11). There is considerable public concern about this decline in the state. The cause is unknown, but it might be related to overfishing or a variety of other factors. For example, the decline in the predatory gamefish, lake trout and walleye, may have allowed yellow perch

Yellow Perch Length Distribution

Lake Champlain Harvest Zone 5

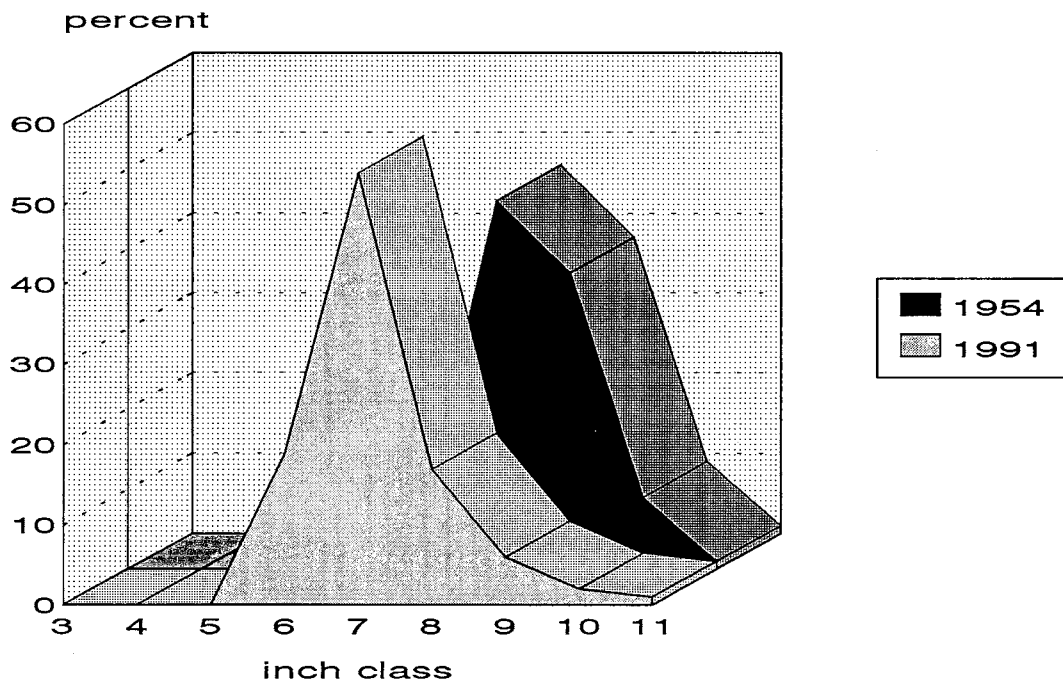


Figure 11. The length distribution of yellow perch in Lake Champlain Zone 5 (northern lake). Data from the Vermont Department of Fish and Wildlife.

populations to increase to the point where their food, benthic invertebrates and zooplankton, is limiting, causing lower growth rates. Better survival of larval fish, because of the cover provided by water milfoil, may also contribute to this problem.

Best management of the fisheries in Lake Champlain clearly demands an integrated approach. And we clearly must know a lot more about the complex interactions among the lake's organisms.

Finally, a few words about zebra mussels. The arrival of this small bivalve into Lake Champlain, is imminent. We must prepare by designing an appropriate monitoring program to watch for it and an appropriate research program to understand and control its impacts.

I'd like to conclude with a message of hope. Our knowledge of Lake Champlain is incomplete, but at least we are aware of some of the areas that need attention. It will take time to get the answers we need, but I believe that we, the assembled technical expertise, can begin to provide the information we need to manage the lake most effectively.

Literature Cited

- Ackerly, S.C. 1983. Sediment-phosphorus relationships, St. Albans Bay, Lake Champlain. MS Thesis, University of Vermont, Burlington, Vermont. 265 pp.
- Baker, J.E. and S.J. Eisenreich. 1990. Concentrations and fluxes of polycyclic aromatic hydrocarbons and polychlorinated biphenols across the air-water interface of Lake Superior. *Environ. Sci. Technol.* 24(3): 342-352.
- Bean, R. and A. McIntosh. 1987. An approach for managing priority pollutants in the Lake Champlain basin. Vermont Water Resources Research Center, University of Vermont, Burlington, Vermont. 97 pp.
- Borre, A.L. 1989. Threats to wetlands in the Lake Champlain region of Vermont: the need for further protection. U.S. Environmental Protection Agency, Region 1, Boston, Massachusetts. 51 pp and appendixes.
- DePinto, J.V., T.C. Young, and L.M. McIlroy. 1986. Great Lakes water quality improvement. *Environ. Sci. Technol.* 20: 752-759.
- Eisenreich, S.J., B.B. Looney, and J.D. Thorton. 1981. Airborne organic contaminants in the Great Lakes ecosystem. *Environ. Sci. Technol.* 15(1): 30-38.

- Environment Canada. 1991. Toxic Chemicals in the Great Lakes. Volume II - Effects. Environment Canada, Toronto. 755 pp.
- Gilbert, A.H. 1985. Resident and nonresident hunting and fishing expenditures in Vermont, 1980. Vt. Agr. Exp. Sta. RR 44. University of Vermont, Burlington, Vermont 50 pp.
- Hill, R.N. 1976. Lake Champlain, key to liberty. The Countryman Press, Woodstock, Vermont. 296 pp.
- Hunt, A.S. 1975. Sediment properties, Lake Champlain: 1971-1975. Completion report to Office of Water Resources Research, U.S. Geological Survey, Department of the Interior. 85 pp.
- Hyde, K.M. 1991. Internal cycling of phosphorus in Malletts Bay, Lake Champlain. MS Thesis, University of Vermont, Burlington, Vermont. 139 pp.
- International Joint Commission. 1988. Summary--A plan for assessing atmospheric deposition to the Great Lakes by the Atmospheric Deposition Monitoring Task Force of the Surveillance Work Group. A Report to the Great Lakes Water Quality Board. International Joint Commission, Great Lakes Regional Office, Windsor, Ontario.
- Lake Champlain Committee. 1990. State of the Lake: A Lake Champlain advisory. Lake Champlain Committee, Burlington, Vermont. 21 pp.
- Meals, D.W. 1990. LaPlatte River Watershed water quality monitoring and analysis program. Program report 12: Comprehensive final report 1979-1989. Vermont Water Resources Research Center, University of Vermont, Burlington, Vermont. 345 pp.
- Myer, G.E. and G.K. Gruendling. 1979. Limnology of Lake Champlain. New England River Basins Commission, Boston, Massachusetts. 408 pp.
- New England River Basins Commission. 1979. Lake Champlain basin study, shaping the future of Lake Champlain. New England River Basins Commission, Boston, Massachusetts.
- Plosila, D.S. and J. Anderson. 1985. Lake Champlain salmonid assessment report. Vermont Department of Fish and Wildlife, Waterbury, Vermont and New York Department of Environmental Conservation, Albany, New York. 126 pp.

- Smeltzer, E. 1989. Current Lake Champlain water quality. Pages 16-26 in: Proceedings of a symposium on Lake Champlain, Basin Harbor Yacht Club, October 2, 1989, A. McIntosh, ed. Vermont Water Resources Research Center, University of Vermont, Burlington, Vermont.
- Vermont Rural Clean Water Program Coordinating Committee. 1991. St. Albans Bay Rural Clean Water Program 1980-1990, Final Report 1991. Vermont Water Resources Research Center, University of Vermont, Burlington, Vermont. 508 pp.
- Vermont Fish and Wildlife Department. 1991. A report of the yellow perch task force to the Fish and Wildlife Board. Vermont Fish and Wildlife Department, Waterbury, Vermont. 24 pp.
- Zuegg, P.H. 1991. Near-surface trace metal diagenesis in sediments from Shelburne Bay and Cumberland Bay, Lake Champlain. MS Thesis, University of Vermont, Burlington, Vermont. 140 pp.

MONITORING IN THE LAKE CHAMPLAIN BASIN

Summary of Address
December 17, 1991

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My task is to review with you historic and on-going monitoring activities in the Lake Champlain Basin. In preparing my comments, I have maintained a very broad perspective, focusing on all aspects of the basin, including air, land and water, to the extent possible. I have done this primarily because any activity anywhere within the basin may ultimately affect the lake.

Obviously, when addressing monitoring in an 8,234 square mile drainage basin, it is critical to organize one's comments in some logical manner. For this presentation, I will consider the various types of monitoring presently in use, and, for each, will discuss the following: (1) background for each type of monitoring; (2) status, both from an historic and current perspective, within the Lake Champlain Basin; and (3) my views on the outlook for the future.

First, however, there are several relevant issues which must be addressed prior to any discussion of monitoring in the basin.

Issues in Monitoring

Diversity. As Mary Watzin so ably points out, the Lake Champlain Basin is extremely diverse, both in terms of its biota and its physical properties. There are five sub-basins, each with distinctive characteristics. For example, while the South Lake, in many ways, mimics a river and shallow Missisquoi Bay rarely, if ever, stratifies, the Main Lake displays a thermal regime characteristic of a large, deep lake.

Such varied properties lead to profound differences in how pollutants behave in the sub-basins. For example, while wind-driven resuspension of sediment-associated nutrients or toxic substances may be a real concern in Missisquoi Bay, it is not an issue in the deeper parts of the basin. Conversely, Lake Champlain's internal seiche may affect transport of pollutants in the Main Lake but not in shallower areas.

Biological diversity is important to consider as well, with many forms of life found in Lake Champlain. Consider that there are more than 80 species of fish in the lake. Distribution of these organisms varies between basins. Hence, any program focused on these biota must be based on an understanding of where organisms exist.

A practical implication of Lake Champlain's complexity is that any monitoring program purporting to be comprehensive clearly must incorporate the sampling of many different parts of the lake. A water sample from Mallett's Bay will tell you very little about the quality of the lake near the mouth of the Poultney River. Finding a species of plankton in Missisquoi Bay doesn't guarantee that one will also find it in the South Lake. Thus, comprehensive monitoring programs for Lake Champlain will, by definition, be costly and time-consuming.

Temporal Influences. For many parameters, wide seasonal fluctuations may be the rule. For example, pulses in phytoplankton populations may be sudden and dramatic. Likewise, the behavior of pollutants like phosphorus or various toxic substances may be strongly influenced by changing meteorological conditions. When designing lake-wide monitoring programs, it is imperative to include all aspects of the lake's annual cycle. Also, great care must be taken to avoid extrapolating data from any one season or period to other times of the year.

Duration of monitoring is a key issue. Educated judgments about changes in the condition of a lake like Champlain must be based on long-term trends. The literature is replete with examples of erroneous conclusions based on data collected over a brief period of time.

Auxiliary Data. Frequently, to facilitate the interpretation of monitoring data, it is important to include additional information. For example, concentrations of trace elements in lake sediments are known to be strongly affected by such factors as organic content and per cent sand, silt and clay. Inclusion of information regarding such parameters is critical to those evaluating trace contaminant data. Unfortunately, in too many cases, this additional information is missing.

Data Evaluation. An important part of any monitoring program is the Quality Assurance/Quality Control (QA/QC) program, which allows the validity of the data generated to be evaluated. There is historic information from Lake Champlain; an important consideration when reviewing these data is whether or not they have been appropriately collected and analyzed. Unfortunately, in many cases, there is simply not enough information presented to make a judgment.

Data Base Coordination. Many of us are collecting some type of data from Lake Champlain. This information sits in filing cabinets, or on shelves or computer disks. It is imperative that we begin to coordinate better data management activities for the lake. I urge members of the Lake Champlain Research Consortium and various state and federal agencies to redouble their efforts in this area.

I also strongly advocate the release of summaries of monitoring data to lay audiences. I believe that it is important that we continue to inform all interested parties about lake issues. Clearly written, concise descriptions can be an effective vehicle for this. The states have done this for their diagnostic study, and we will be releasing results of our 1991 biomonitoring program this spring.

Funding. Long-term monitoring is critical. It is also time-consuming and expensive. We must explore ways to pay for such activities. More on this follows.

There are many different types of monitoring routinely carried out within watersheds. By definition, "monitoring" implies an on-going activity, one that is repeated on some regular basis. Hence, for the most part, I shall exclude from my comments those cases where a survey or assessment was intended to be a single event.

Let's explore, then, the various types of monitoring that have occurred or are occurring within the basin. I'll consider the following categories:

Baseline Monitoring

The collection of physical, chemical and biological data from the air, land and water is critical to our long-term understanding of the Lake Champlain ecosystem. In short, we cannot hope to know this lake and predict how it is changing over time, both as a result of natural processes and anthropogenic stresses, unless we collect information about the ecosystem on a long-term and continuing basis. How, for example, can we hope to detect the loss of vital organisms from the lake when we're not even certain what species exist there in the first place?

Table 1. Current monitoring and research projects in the Vermont Monitoring Cooperative.

CURRENT MONITORING PROJECTS

Forest Health Monitoring:

North American Maple Decline Program, VT Hardwood Health Survey
National Forest Health Monitoring Program, etc.

Animal Biodiversity:

Insects, birds, amphibians

Surface Waters:

Stream chemistry, macroinvertebrates, fish populations

Meteorology:

Basic meteorology in both open field and within forest

Precipitation Chemistry:

NADP/NTN, UAPSP, VT Acid Precipitation Monitoring Program

Atmospheric Chemistry:

Ozone, Aerosols, Fine Particulate, Visibility

CURRENT RESEARCH PROJECTS

Multi-disciplinary data visualization and evaluation.

Pollutant and micro-meteorology gradients in a forest canopy.

Assessment of variability in tree health sampling methods.

Biogeography and environmental tolerance of balsam fir.

Maple foliage surface structure and chemical exchange mechanisms.

Impacts of climate change on forest productivity along elevational gradients.

Winter forest microclimatology.

Air/Land. Historically, there has been relatively little routine collection of data in this area. Past provisions of the Clean Air Act have incorporated monitoring of traditional air pollutants, but such data are of limited value in our discussion of Lake Champlain. Of significance is the formation of the Vermont Monitoring Cooperative (VMC) by the University of Vermont (UVM) and the Vermont Agency for Natural Resources (ANR). While the focus of the VMC will primarily be on forest ecosystem health (Table 1), the movement of pollutants such as PCBs and arsenic (Figure 1) from the atmosphere through the terrestrial ecosystem into tributary streams and rivers, and ultimately the lake, will be considered by the VMC.

Additional data on the significance of the atmosphere in overall pollutant loading to Lake Champlain will come from activities funded by the Management Conference. For example, monies have been allocated to the states to enhance the routine monitoring of toxic substances in air at various locations within the Champlain basin. In addition, funds from National Oceanic and Atmospheric Administration will probably help develop the data base necessary to access the contribution of pollutants from the atmosphere.

Water. There have been a number of programs dedicated to the routine monitoring of water quality variables in streams and rivers; for example, for many years the U.S. Geological Survey has maintained a station in its NASQAN program on the northern end of Lake Champlain. In addition to flow data, information on water chemistry has been generated.

Collection of baseline data by others has occurred sporadically over time. Much of the early information is summarized in the Limnology of Lake Champlain (Myer and Gruendling 1979). For example, ten-year mean values reported by Potash and Henson for such variables as calcium and alkalinity determined at points throughout the lake (Table 2) clearly demonstrate a gradient of increasing values from north to south.

Similarly, historic data on lake biota have clearly established patterns of seasonal change in major groups of algae in particular areas of the lake (Figure 2). In general, however, there has been little or no attempt to link changes in lake plankton populations to alterations in the food web or water chemistry. This type of food web assessment awaits.

The past decade has seen a distinct decline in the collection of baseline data from the lake. For example, no one, to my knowledge, has been routinely monitoring water chemistry of the broad lake during the past 10 years. There are, however, several new initiatives of note. The Manleys and others at Middlebury College have begun to collect hydrographic and side-

Nescaum Fine Arsenic Concentration on 2/18/89

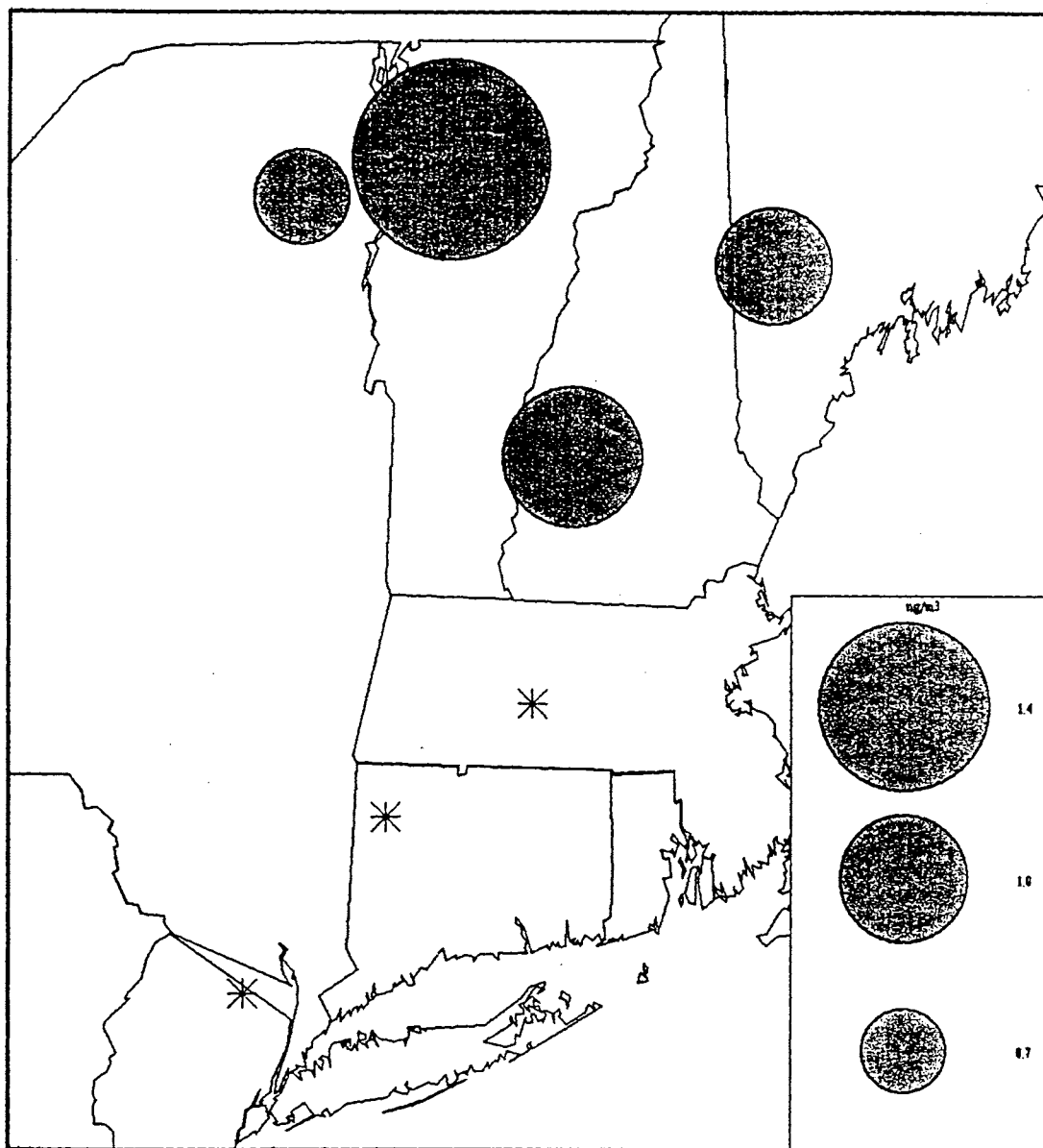


Figure 1. Example of air quality data from Vermont Monitoring Cooperative.

Table 2. Ten-year mean values calculated from samples taken at major reference stations along the length of the Lake (data from Potash & Henson, as presented in Myer and Gruendling 1979).

Station	Number of Samples	pH	Cond. mhos.	Alk.	Na	K Mg/liter	Ca	Mg
1. Whitehall (South Lake)	13	7.85	234	71.9	4.50	1.46	27.62	6.11
2. Five-Mile Point (South Lake)	59	7.87	217	67.1	6.33	1.31	25.22	5.29
3. Crown Point	53	7.90	183	50.7	4.66	1.29	19.63	4.45
4. Thompson's Point	71	7.79	162	43.9	4.24	1.20	16.94	4.17
5. Lake Reference (Main Lake)	331	7.67	155	42.4	4.11	1.22	16.57	3.85
6. Cumberland Head (Main Lake)	57	7.87	151	40.7	3.87	1.12	16.11	3.68
7. Rouses Point (Main Lake)	36	7.87	143	39.3	3.77	1.09	15.65	3.51
8. Malletts Bay	198	7.39	114	27.9	3.11	0.99	11.97	2.42
9. Inland Sea (Northeast Arm)	36	7.75	128	32.8	3.23	1.33	14.47	3.25
10. Missisquoi Bay	<u>28</u>	7.72	110	27.4	2.97	1.12	12.10	2.73
TOTAL	882							

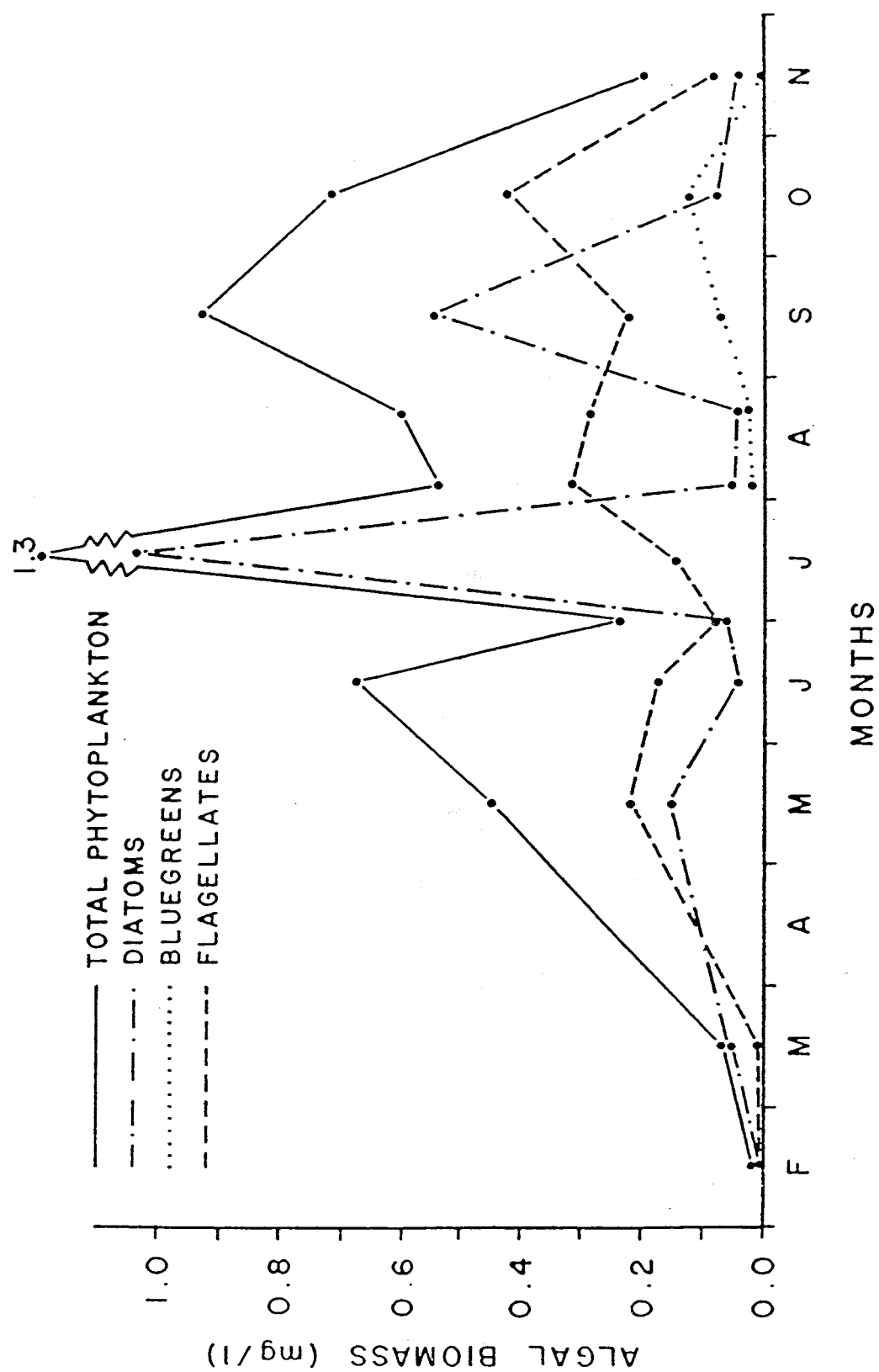


Figure 2. Seasonal dynamics of phytoplankton populations in Malletts Bay. (taken from Myer and Gruendling, 1979).

scan survey data from several sites in the lake (Figure 3). Such efforts will provide vital information on basic flow and transport capabilities of the lake, thereby enhancing studies of nutrient enrichment and pollution by toxic contaminants.

In the biological arena, UVM scientists, with the aid of a three-year grant from the Lintilhac Foundation, have begun to collect data on zoo- and phytoplankton populations at 22 sites throughout the lake (Figure 4); data from the fall of 1990 (Figure 5) show the distribution of copepods and cladocera at the 22 sites. In addition, sediment samples for the enumeration of benthic macroinvertebrates will be collected at nine sites over the next several years. Among the interesting findings of this year's work is the discovery by Alan Duchovnay (University of Vermont) of a species of copepod (*Thermocyclops crassus*) never before reported in North America. Sampling has revealed the existence of this new species in Missisquoi Bay.

Underlying all efforts to protect and enhance the quality of Lake Champlain must be an understanding of how the lake functions and which types of aquatic life it supports. Important as well is the response of the lake to changes within its watershed. Without the routine collection of biological, chemical and physical data such as those described above, this basic understanding will be, at best, incomplete. Background data collection must be a priority, and, I suggest, we need to search for innovative ways to support such work. For example, an equitable system of user fees may be appropriate, since good water quality is a prerequisite for most recreational and consumptive uses of the lake.

Issue Oriented Monitoring

Certain problems are recognized to be of such importance that they merit special attention. Obvious examples include eutrophication and pollution by toxic substances. The ultimate solution to these problems requires that pollutant inputs to the system be reduced or eliminated. Before such actions can be taken, however, monitoring is often required to identify sources of these pollutants, to understand how they are transported within the basin and to determine their impacts on the ecosystem.

Eutrophication. There is a long history of concern about nutrient enrichment of Lake Champlain, with most interest focusing on the acknowledged limiting factor, phosphorus. During the 1970s, for example, rough estimates of tributary loading of phosphorus to the lake were made (Table 3). These estimates should be regarded with caution, as comparatively few measurements were available.

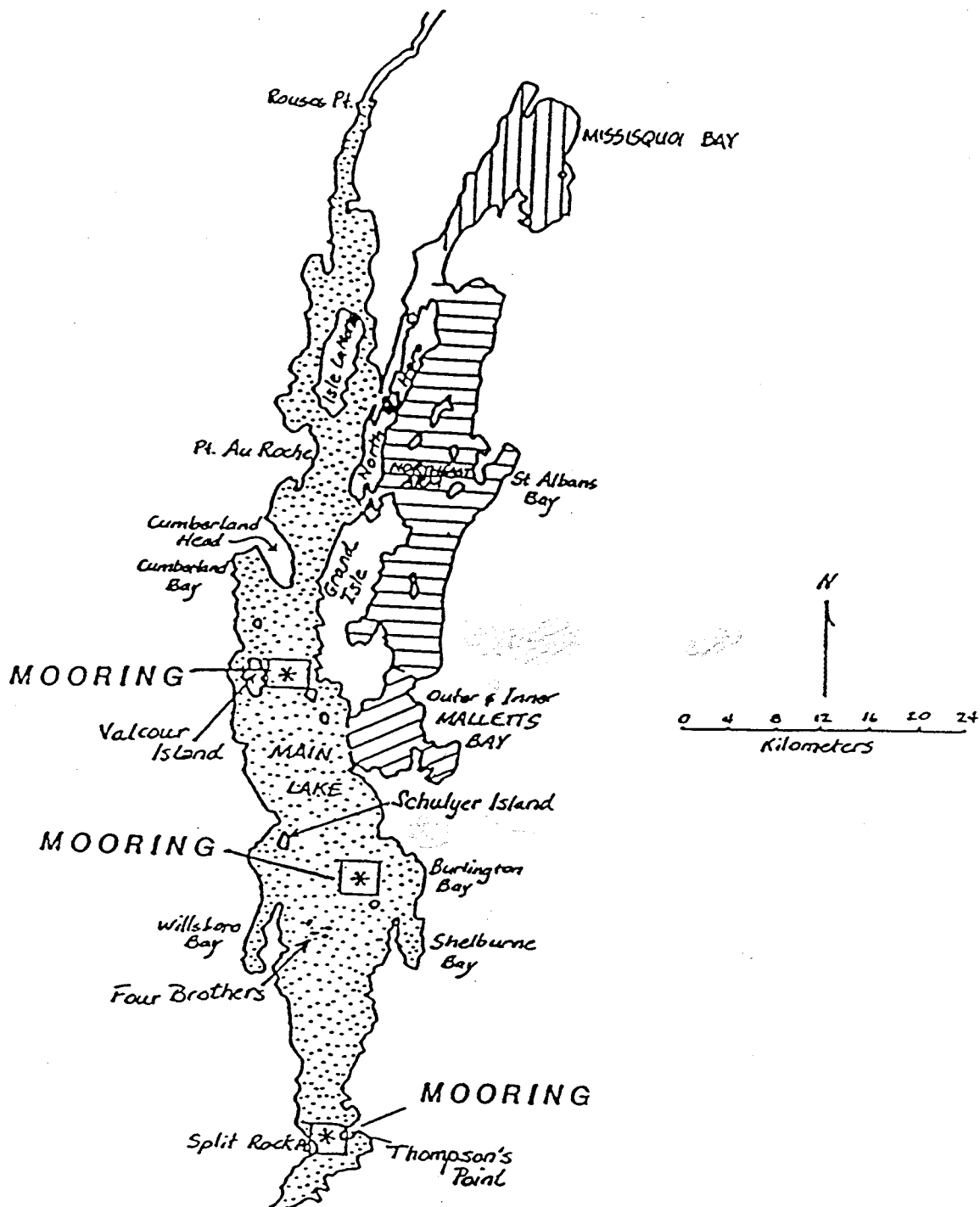


Figure 3. Mooring sites in Lake Champlain (Source: P. and T. Manley, Middlebury College).

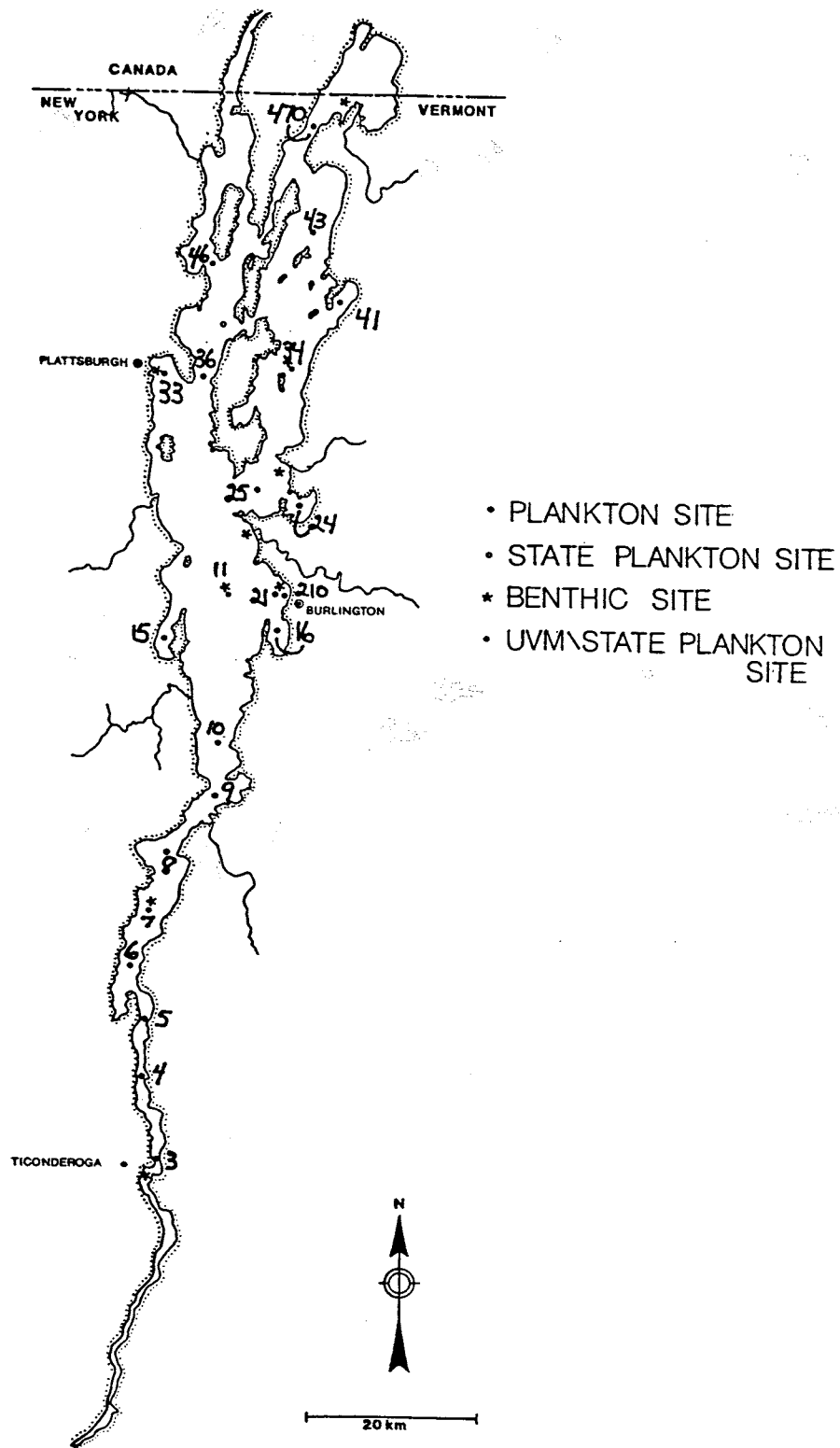


Figure 4. Location of biomonitoring sites on Lake Champlain.

LAKE CHAMPLAIN ZOOPLANKTON

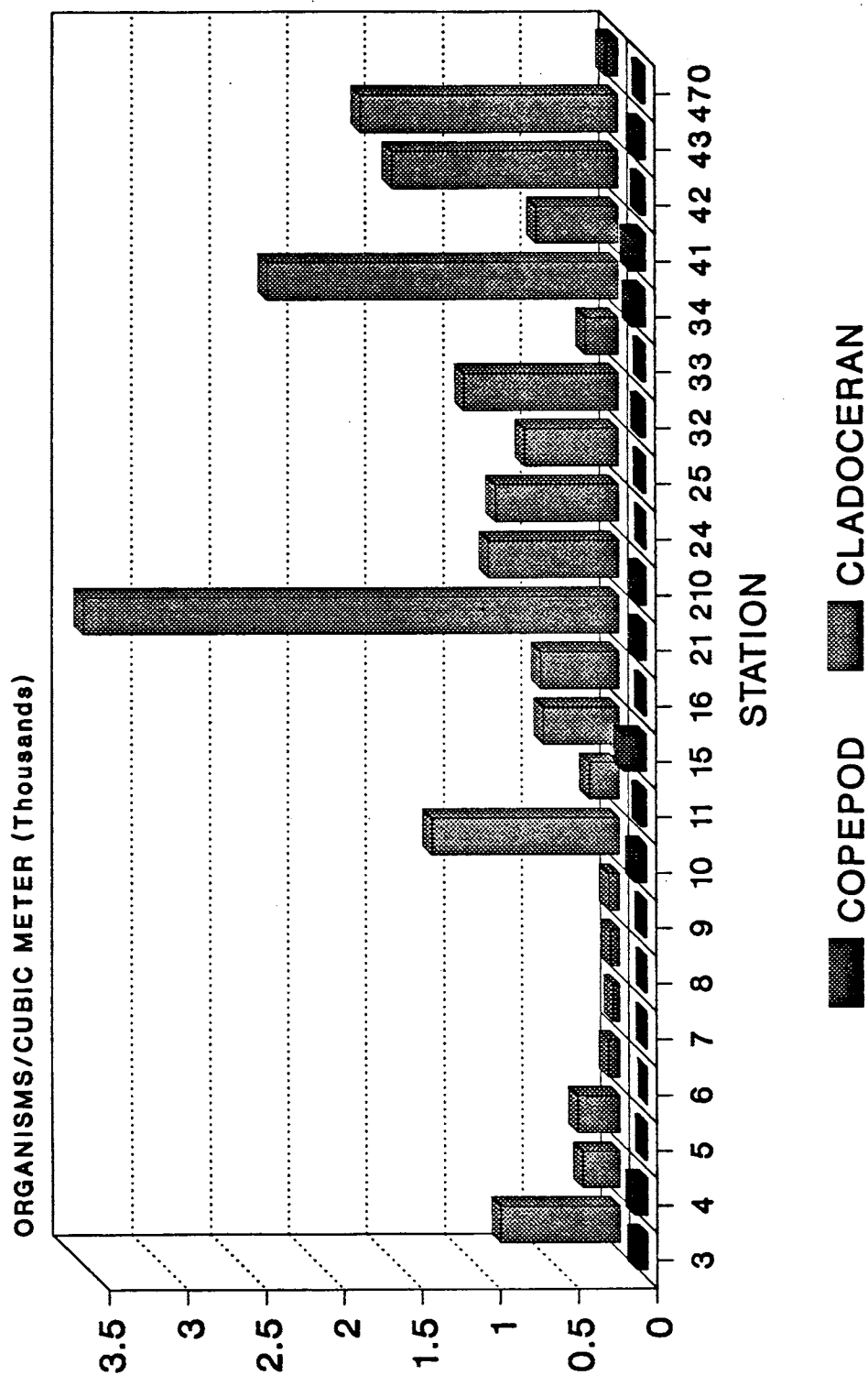


Figure 5. Numbers of zooplankton in Fall, 1990 samples.

Table 3. Various estimates of point-source loadings of total phosphorus to tributaries within the drainage districts of Lake Champlain (data from Bogdan, as cited in Myer and Gruendling 1979).

District	B-1 ¹	B-2 ²	kg TP/y	EPA ³	H-G ⁴
A	34,200	34,700		23,500	20,600
B	25,660	25,000		10,300	11,500
C	16,800	13,700		12,900	14,500
D	85,200	82,500		81,400	104,700
E	0	0		0	0
F	40,000	41,200		39,300	53,400
H	0	0		0	0
J	800	1,400		1,800	5,000
K	32,800	46,500		70,800	79,900
L	0	0		0	1,000
M	1,300	2,000		3,600	5,900
S	<u>17,800</u>	<u>21,000</u>		<u>22,700</u>	<u>30,800</u>
SUM	254,568	268,000		266,300	327,300

¹ Level B-1 loadings based on 0.56 (1.12) kg TP/C/y for primary and secondary plants in NY (PQ, VT) and 0.70 (1.4) kg TP/C/y for no treatment in NY (PQ, VT).

² Level B-2 loading based on effluent and flow data for plants with adequate data and extrapolated per capita data for plants with no data.

³ Table 14, EPA (1974).

⁴ Appendix E, classes b, c and d with no attenuation of TP with distance, Henson-Gruendling (1977).

Beginning in the 1970s, Vermont instituted a lay monitoring program to measure total phosphorus, summer chlorophyll and transparency in inland Vermont lakes (Table 4). Lay monitoring data for Lake Champlain (Figure 6) demonstrate trends in summer phosphorus over the past decade; despite increasing reductions from point sources, levels of phosphorus have remained fairly constant over time.

A more intensive program, the Lake Champlain Diagnostic-Feasibility Study, is now underway. This joint project undertaken by the Vermont ANR, New York Department of Environmental Conservation (DEC), U.S. Geological Survey, and U.S. Environmental Protection Agency has gauged and is sampling all significant tributaries to the lake to estimate phosphorus loading. In addition, 52 stations in the lake itself (Figure 7) are being monitored for chlorophyll a and total phosphorus. Ultimately a whole-lake model will be developed and phosphorus loading allocations for sub-basins will be implemented in an effort to achieve in-lake standards.

Toxic Substances. Less attention has been paid to the routine monitoring of toxic contaminants in Lake Champlain. Some of the earliest work was performed by the Quebec Ministere de l'Environnement. A survey of several stations in the Richelieu and Pike Rivers in 1978 revealed the presence of pesticides and polychlorinated biphenyls (PCBs) in mollusks and fish. A second survey in 1983 measured levels of mercury and organics at sites in the Richelieu (Figure 8), while a final one in 1986 revealed that levels of DDT, PCBs and mercury were below guidelines for sediments and fish, with the exception of mercury in pike.

The New York DEC has included four tributaries entering Lake Champlain in its Rotating Intensive Basin Studies (RIBS). The survey, most recently conducted during 1987-1988, focused on toxic substances in the water column and bottom sediments and on the condition of the macroinvertebrate community at the mouths of the Bouquet and Saranac Rivers and in Ticonderoga Creek and the Richelieu River. Results show significant levels of cadmium, copper, and lead but that water quality at three of the four locations was considered good (Table 5).

Currently, an assessment of toxic substances in Lake Champlain sediments is being carried out by several scientists, including Al Hunt at UVM, Bob Fuller at SUNY-Plattsburgh and John King of the University of Rhode Island under the auspices of the EPA and the Management Conference. Data generated on toxic contaminants in sediments (Figure 9) at 30 sites throughout the lake will hopefully represent the first of an on-going series of measurements to track trends in the accumulation of toxic substances in the lake over time.

Table 4. Water quality variables measured in Vermont Lay Monitoring Program (Source: Vermont Agency of Natural Resources).

<u>Number of Years Sampled</u>	<u>Number of Lakes</u>		
	<u>Spring Phosphorus</u>	<u>Summer Chlorophyll</u>	<u>Summer Transparency</u>
1 or more	195	55	56
2 or more	125	52	53
3 or more	106	48	47
4 or more	84	45	43
5 or more	66	39	40
6 or more	57	28	31
7 or more	46	16	27
8 or more	37	10	23
9 or more	36	5	15
10 or more	36	0	0
11	20	0	0

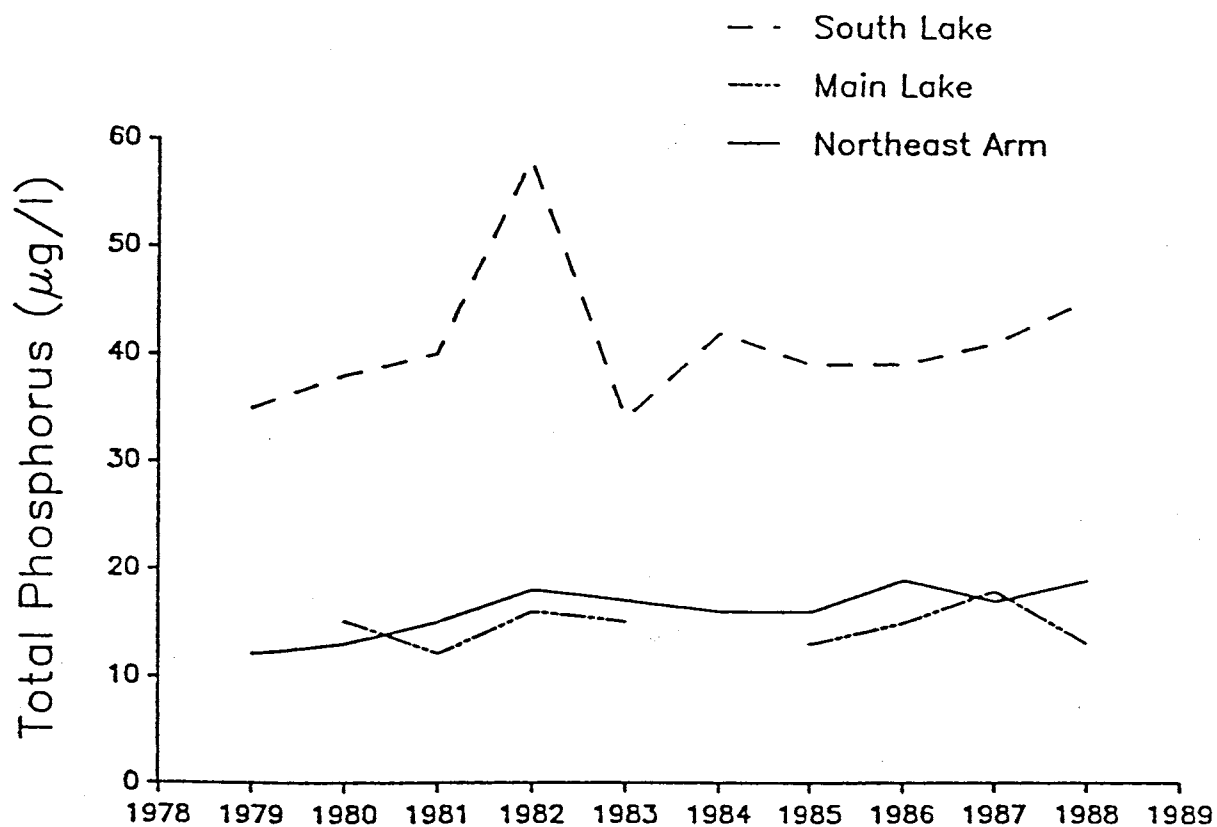


Figure 6. Phosphorus trends during 1979-1988 at three monitoring stations in Lake Champlain (Source: VT Agency of Natural Resources).

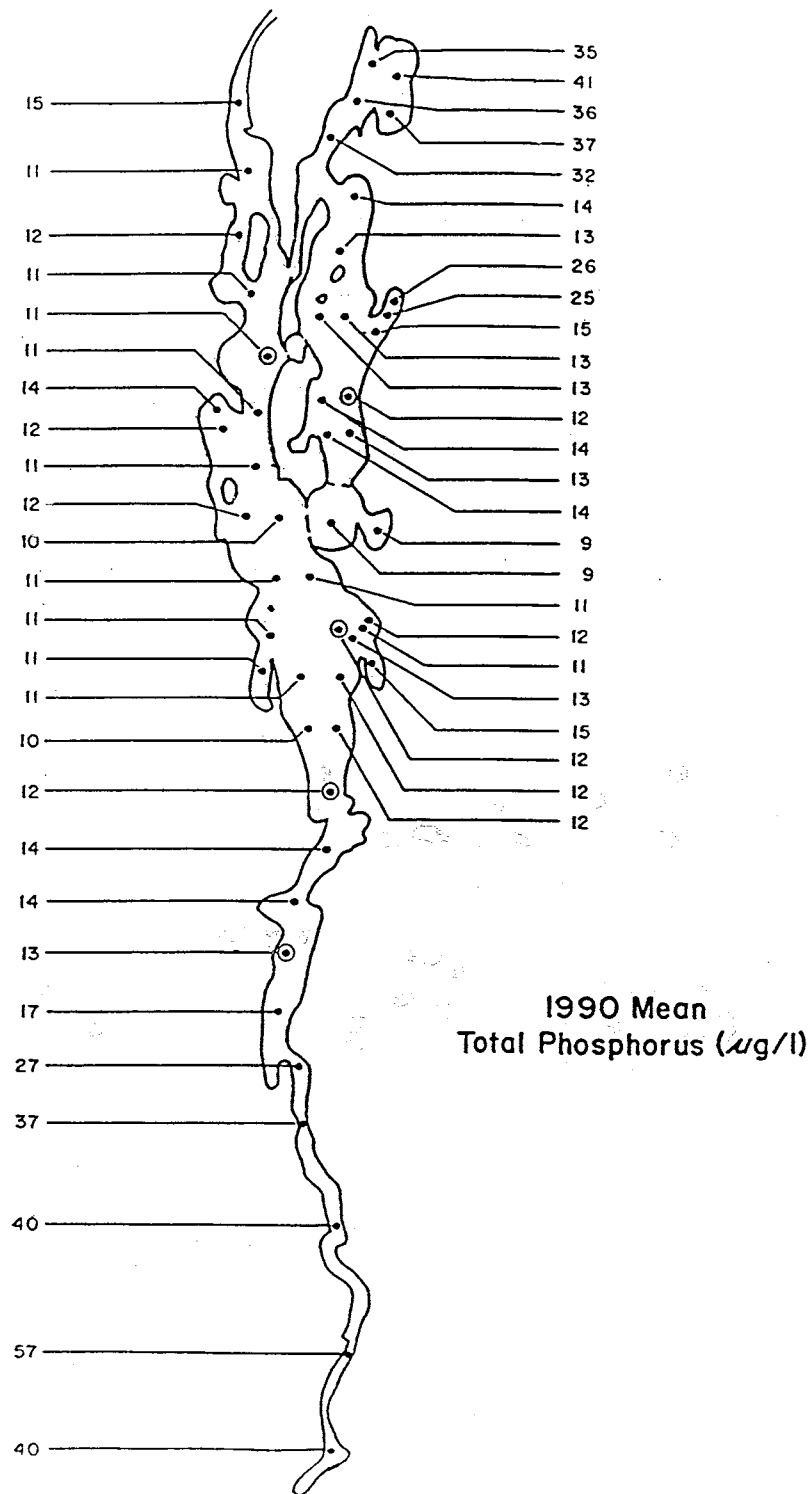
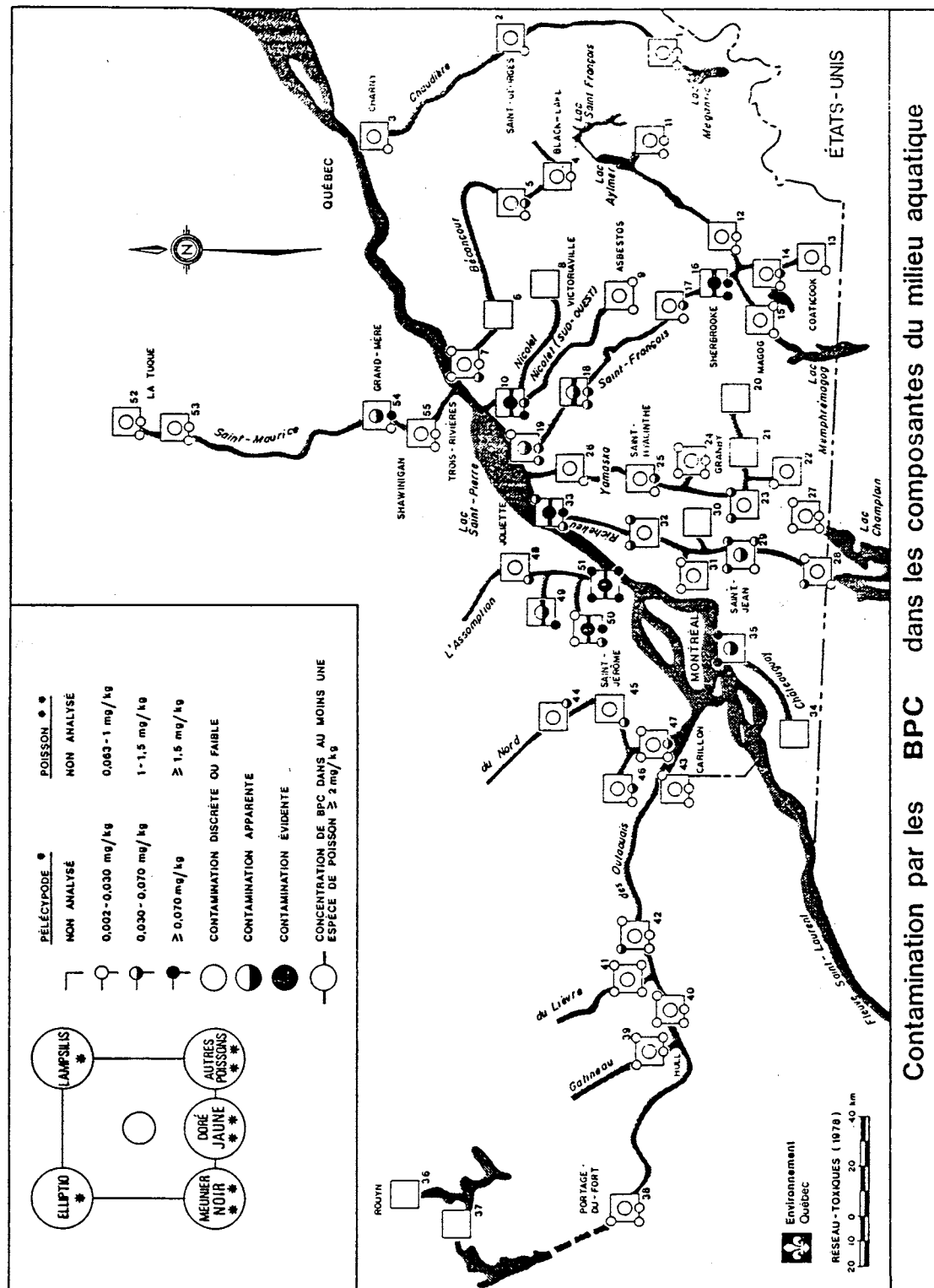


Figure 7. The 1990 mean total phosphorus concentrations in Lake Champlain ($\mu\text{g/l}$) (Source: VT Agency of Natural Resources).



SOURCE: QUEBEC MINISTÈRE DE L'ENVIRONNEMENT

Figure 8. Monitoring sites for PCBs in Quebec surface waters (Source: Quebec Ministère de L'Environnement).

Table 5. Rotating Intensive Basin Studies (RIBS) data for four New York rivers in the Lake Champlain Basin (Source: New York Department of Environmental Conservation).

Waterbody	Monitoring Location	Water Column Parameters of Concern	Community Assessment	Tissue Analysis Parameters Above Background	Toxicity Test # Toxic/# Test	Bottom Sediment Parameters Above Background	Fish Advisory	Water Quality Assessment
Richelieu River	Rouses Point	Cadmium, Copper	Non-Impacted	Not Collected	1/8	None	Limited Advisory (PCB, Chlordane, Mercury)	Fair
Saranac River	Plattsburgh	Cadmium, Copper, Iron, Lead	Non-Impacted	None	0/6	Lead	None*	Good
Bouquet River	Willsboro	Cadmium, Copper, Iron	Non-Impacted	Titanium	1/6	None	None*	Good
Ticonderoga Creek	Ticonderoga	Copper	Slightly Impacted	None	1/6	None	None*	Good

* The Lake Champlain limited advisory would be applicable up to the first barrier impassible by fish.

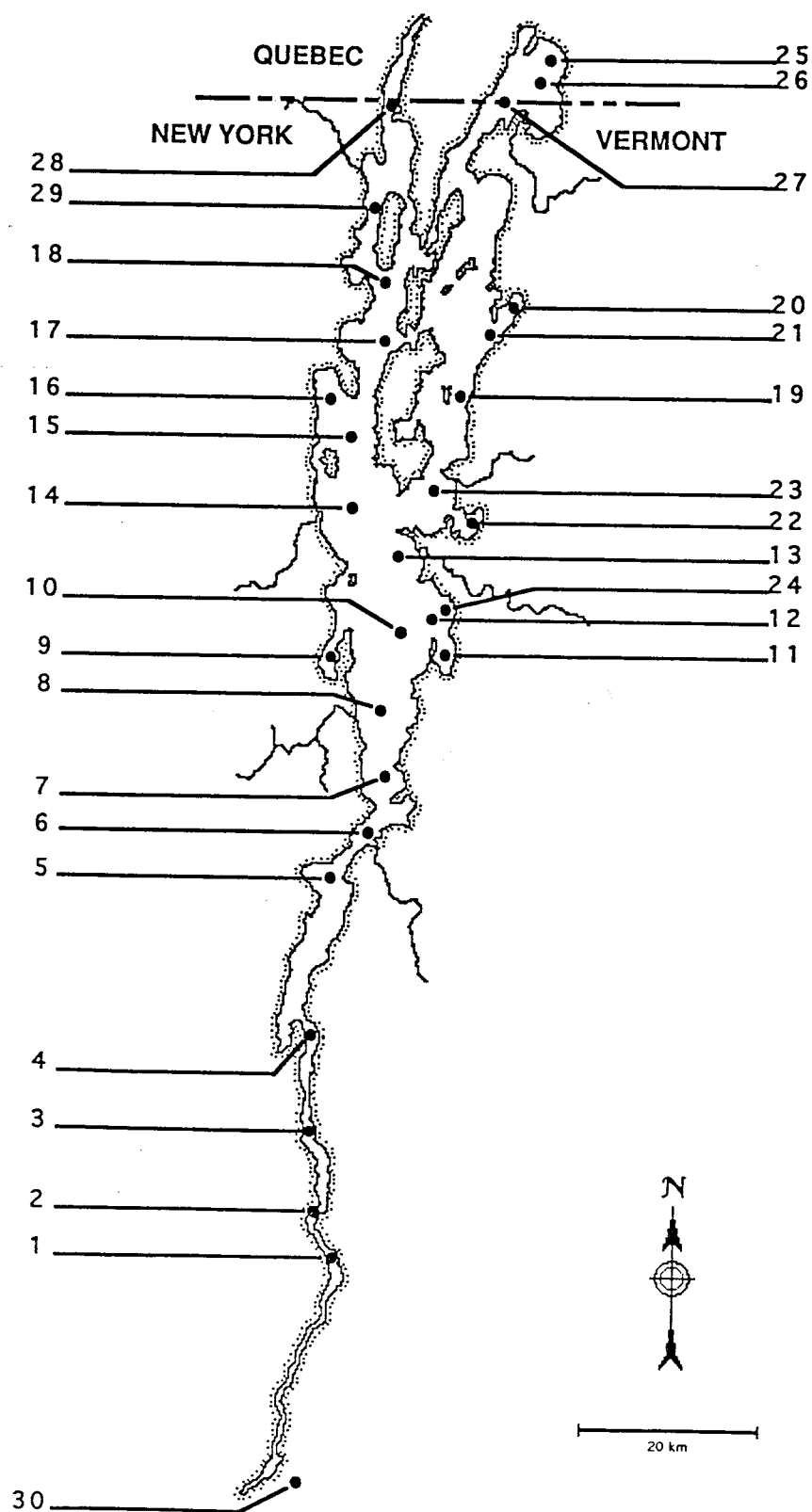


Figure 9. Lake Champlain sediment toxics sampling locations.

Outlook for Issue Oriented Monitoring. In the case of phosphorus, we are in the midst of an intensive monitoring and assessment program. Such efforts must be continued and expanded as necessary, particularly where complicating factors such as the release of phosphorus from sediments is a concern. In the realm of toxics, we are just beginning. In those areas of the lake where toxics are clearly elevated, we should develop comprehensive programs similar to those used in the Great Lakes. Likewise, we should implement more general programs designed to monitor the impacts of exposure to toxic contaminants on lake biota.

Source-Oriented Monitoring

When there are known significant sources of pollutants within a watershed, they may be the target of specific monitoring efforts. Some of these programs, such as the National Pollutant Discharge Elimination System (NPDES), which focus on the quality of point source discharges, are mandated by federal law. In other cases, the monitoring programs take the form of specific projects dedicated to a particular problem. For instance, a Soil Conservation Service-funded decade-long study at UVM has assessed the impact of agricultural Best Management Practices (BMPs) on water quality in two Vermont drainage basins.

While source-oriented monitoring typically focuses on existing facilities, it may also include pre-operation measurements at proposed point sources, such as the monitoring efforts of Aquatec at the site of the new fish hatchery at Grand Isle.

Point Sources. All major point sources in the basin are subject to some form of routine monitoring; state and NPDES permits require measurement of standard water quality parameters and some toxic substances. The New York DEC, as part of its permitting process, has required routine analysis of point source discharges for priority pollutants, and, in January, 1991, the Vermont ANR initiated a preliminary screening program to assess toxic pollutants being discharged by sewage treatment plants throughout the state (Table 6).

As it is mandated by federal law, monitoring of point sources will continue. It is encouraging to note that toxicity testing is increasingly being incorporated into point source discharge monitoring. With funding from the Management Conference, a toxicity screening program at discharges throughout the basin is being initiated.

Nonpoint Sources. Prime concerns in this category include agricultural runoff. The previously noted SCS-funded project on BMPs by Don Meals and his coworkers found that these practices were effective in reducing bacterial contamination of streams entering the lake.

Table 6. Occurrence of detectable levels of priority pollutants in 15 publicly owned treatment works (Source: VT Agency of Natural Resources).

<u>Metals</u>	<u>N/15</u>
Silver	4
Barium	12
Copper	15
Zinc	14
Iron	15
Lead	1
 <u>Organic Compounds</u>	 <u>N/15</u>
Chloroform	6
Trichloroethane	1
Bromodichloromethane	2
Methylene Chloride	5
Diethylphthalate	1
Dimethylphthalate	1
Tetrachloroethane	2
Acetone	2
Toluene	2
Ethylbenzene	1
Xylene	1
4-Methylphenol	1

Other examples in this category include monitoring for toxic contaminants around hazardous waste sites such as the Pine Street Barge Canal in Burlington and the mouth of the Saranac River in New York.

Major questions remain regarding the role of agricultural activities in the nonpoint source pollution of Lake Champlain; plans now underway to develop a basin-wide comprehensive agricultural monitoring network promise to extend the existing information base to agricultural sources throughout the basin.

Other nonpoint issues demand attention as well. For example, we have, unfortunately, almost totally neglected the role that atmospheric deposition and urban runoff play within the basin. Hopefully, future programs dedicated to preserving the lake will incorporate efforts to monitor these and other nonpoint sources within the basin as needed.

Site-Specific Monitoring

Frequently, nearshore areas of lakes come under particular stress. The introduction of substantial point source discharges, runoff from urban and agricultural areas and intense recreational usage may raise substantive concerns about the quality of these areas. In these cases, a site-specific program may be designed. In the Great Lakes, there are now at least 42 "Areas of Concern" (AOCs), where pollution is so extensive that specially designed assessment and monitoring programs have been established. The focus in the AOCs is broad, covering all negative impacts on the resource and suggesting controls for any significant source of pollution within the basin.

There are few cases of comprehensive site-specific monitoring within the basin. Perhaps the best example we have is the Pike River in Canada, where a broad range of measurements of routine water chemistry parameters and toxic substances has been related to untreated waste discharges and agricultural runoff in the river's drainage basin. Similar, but less comprehensive monitoring has been done in Mallett's Bay in response to concerns about over-enrichment of the bay.

The concept of AOCs in Lake Champlain is an appealing one. We clearly have regions within the lake where point and nonpoint sources of pollution have led to degradation of the resource. Two examples could be Burlington Harbor and Cumberland Bay. I suggest that it is time that we institute monitoring and assessment programs to identify such AOCs in Lake Champlain and address the following: (1) use impairment occurring at these sites, (2) sources of pollution, and (3) available control strategies.

Human Use

To ensure that the various human uses of surface waters are maintained, various monitoring programs have been implemented. Examples include routine monitoring of fish flesh for the presence of toxic substances and of bacterial quality in swimming areas.

As with discharge permits, there are federal mandates ensuring that our potable water supplies are routinely monitored for bacterial and chemical quality. In fact, new provisions of the Safe Drinking Water Act will require more stringent sampling and analysis of organic contaminants in our water supplies.

As everyone who swims at one of Burlington's public beaches knows, monitoring for bacterial quality is a routine occurrence; there have been a number of times in recent years where coliform counts have exceeded existing standards at various Lake Champlain beaches. Dr. Robert Sjogren of UVM has amassed a data set describing the bacterial quality at various points in the lake.

There have, for a number of years, been efforts to monitor the level of contamination of edible tissues of Lake Champlain sport fish. One obvious result of this monitoring has been current restrictions on the consumption of large lake trout and walleye. New York and Vermont have begun to coordinate routine collection of fish for analysis of a variety of trace contaminants. The sites and chemicals monitored are indicated in Figure 10 and Table 7.

While these efforts will undoubtedly continue, other initiatives should be considered as well. For instance, if degraded conditions occur in near-shore waters of the lake, early life stages of fish such as walleye may be adversely affected. Assessing the viability of populations in these areas may be a logical extension of current efforts. Likewise, if new toxic substances of concern are identified in the lake, fish tissue monitoring should be expanded to include such contaminants.

Sentinels

Because certain biota are capable of concentrating toxic contaminants to high levels, they may be used as sentinels to identify areas of high contamination. For years this concept has been put into practice by such programs as NOAA's Mussel Watch along our ocean coastlines. While examples in freshwater are less common, this type of monitoring, usually using mollusks, has been occurring in recent years in the Great Lakes.

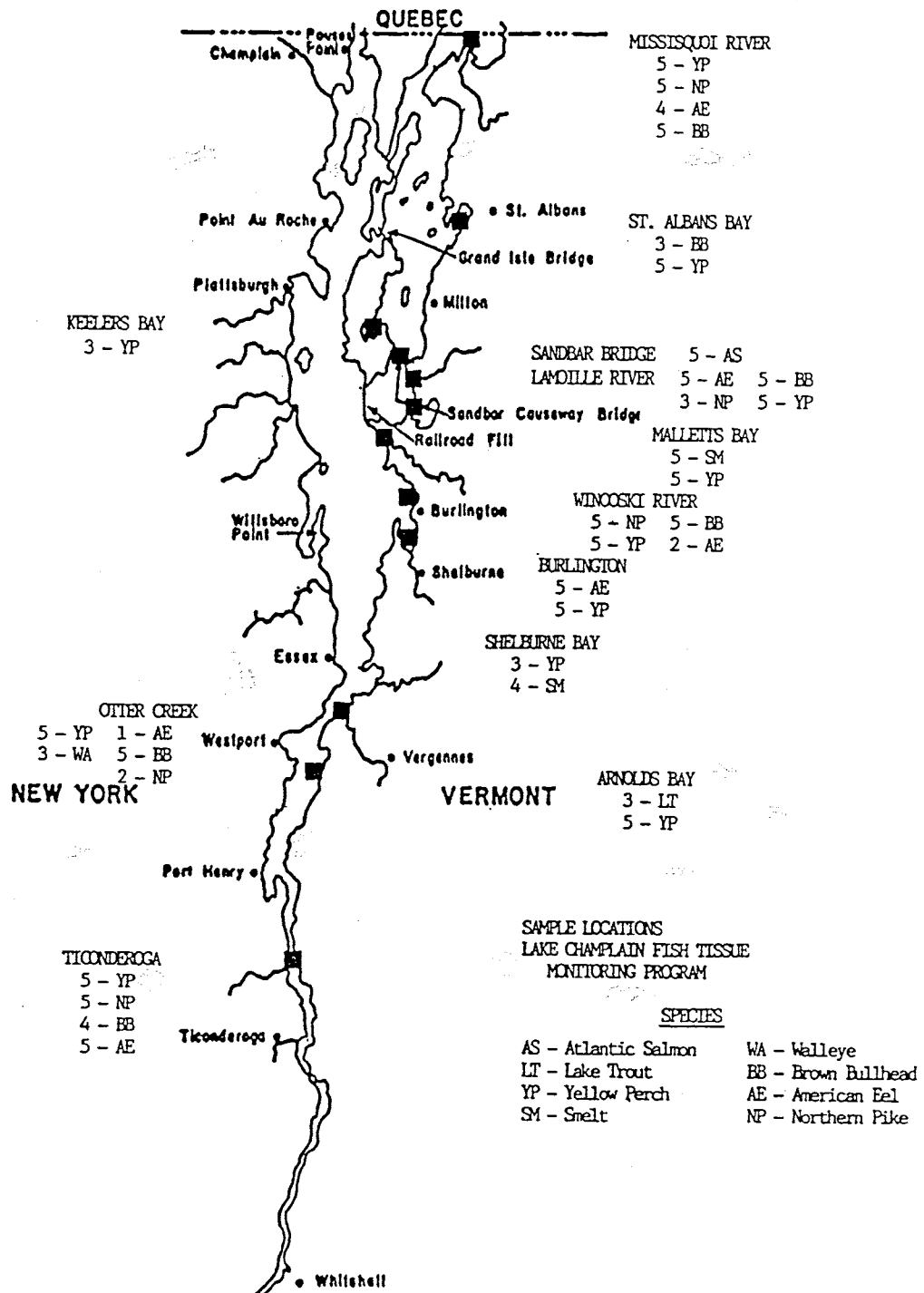


Figure 10. Location of fish collection sites in Lake Champlain for Polychlorinated Biphenyls (PCB) and chlorinated pesticide analysis (Source: VT Agency of Natural Resources).

Table 7. Contaminants analyzed by the States of New York and Vermont in fish tissue
(Source: VT Agency of Natural Resources).

DDE	Heptachlor
DDD	Heptachlor epoxide
DDT	Endrin
Dieldrin	Mirex
Alpha BHC	Toxaphene
Beta BHC	Aldrin
Gamma BHC	Methoxychlor
Delta BHC	PCB-arochlors 1016, 1221, 1232, 1242, 1248
Hexachlorobenzene	1254, 1260, 1262, 1268

Contaminants found in one or more of the fish samples:

PCB (arochlors 1254 and 1260 only)
 Total DDT (includes DDD, DDE & DDT)
 Dieldrin
 Alpha BHC
 Hexachlorobenzene (HCB)

No detectable levels were found of:

Beta BHC	Endrin
Delta BHC	Heptachlor
Lindane	Heptachlor oxide
Aldrin	Mirex
Chlordane	Methoxychlor
Toxaphene	PCB Arochlors 1016, 1232, 1242, 1248, 1262, 1268

To date, the only known example of this approach within the basin has been the effort in Quebec to identify levels of organic and inorganic contaminants in tissues of several mollusks, including *Elliptio* and *Lampsilis* species. Among the findings was the occurrence of elevated levels of PCBs in mollusks from the Richelieu River.

The Management Conference has committed funding to initiate use of sentinels at river mouths to assess the availability of key toxic contaminants in Lake Champlain. Results of this program should help direct future efforts to identify and control sources of these pollutants within the basin.

The use of sentinels may be a reliable method for tracking toxic contaminants within Lake Champlain over time, particularly as efforts to control specific sources of these pollutants increase. Coordination between New York, Vermont and Quebec on such programs is vital.

Ecosystem Health

Perhaps the newest type of monitoring is the use of routine measurements to track the status or condition of an aquatic ecosystem. Measures currently in use elsewhere are quite diverse, including assessment of microbial populations in lake sediments, identification of changes in phytoplankton community structure, and calculation of population turnover rates of zooplankton. Underlying all these proposed approaches is the desire to find a rapid, relatively easy way to predict when an ecosystem is under stress.

Nationally, there are several on-going efforts based on the ecosystem approach. In streams and rivers, the EPA's Rapid Bioassessment Program uses data on the nature of benthic communities to determine the overall quality of lotic habitats. A new EPA program, Environmental Monitoring and Assessment Program (EMAP), is focusing on a variety of ecosystem measures in lakes around the nation.

Within the lake itself, the only known example of on-going ecosystem health monitoring is being conducted on the Richelieu River in Quebec. Two sites have been included in a province-wide effort to assess the quality of surface waters by monitoring the status of benthic communities.

The application of ecosystem health measures to Lake Champlain should be a priority. With a combination of measures made at different levels of the ecosystem, this monitoring is an effective way to determine when conditions within the lake are improving or deteriorating. Because such changes may be expected to vary considerably in the different sub-basins of the lake, ecosystem health measures would likely be tailored to specific areas.

For example, assessment of the status of walleye populations might be appropriate for areas like the Northeast Arm, while in areas of the South Lake, the presence of immature forms of the mayfly *Hexagenia* might be a feature of an ecosystem health approach.

Conclusions and Recommendations

1. In the past, there have been efforts to monitor various aspects of the Lake Champlain ecosystem. By and large, however, particularly in recent years, monitoring programs have not been sufficiently intensive to characterize the lake. Hence, substantial data gaps exist in all aspects of the lake's biology, chemistry and hydrology.
2. The various types of monitoring described above all have applications in the Lake Champlain basin. In particular, there seems to be a great need for basin-wide programs in which physical/chemical and biological data are collected and correlated. Identification of appropriate measures of ecosystem health should be commenced forthwith and a program initiated as soon as practicable. Finally, I advocate the use of an "Areas of Concern" approach for certain parts of Lake Champlain.
3. While some monitoring is mandated by federal law, other programs must rely on nontraditional sources of funding. Serious consideration must be given to the identification of appropriate funding avenues for the support of relevant monitoring in the Lake Champlain ecosystem.
4. As is the case in many large ecosystems, there has been too little coordination of effort among those interested in or performing monitoring in the Lake Champlain ecosystem. It is suggested that appropriate state and federal personnel work cooperatively with the Lake Champlain Research Consortium and the Vermont Monitoring Cooperative to enhance the efficiency of future monitoring programs.
5. Data collection, storage, evaluation and accessibility are key issues that need to be more effectively confronted if on-going and future monitoring programs are to be cost effective and of the greatest utility.

Literature Cited

- Myer, G. and G. Gruendling. 1979. Limnology of Lake Champlain. Lake Champlain Basin Study, New England River Basin Commission. 407 pp.

RECREATION MANAGEMENT

Introduction

Lake Champlain is a significant natural resource offering diverse recreational opportunities. A multitude of residents and visitors utilize the lake each year. Increased recreational visitation has led to numerous problems, including overuse in some areas, lack of boat storage, lack of access and user conflicts. Although these issues have been brought to the attention of state and local managers in the past, implementation of plans to resolve them has been delayed or nonexistent due to lack of funding and personnel. Recently, staff from Vermont and New York decided to make the development of a cooperative recreation management plan a priority. Both states are committed to addressing the lake as a whole resource, and to using a broad-based consensus of public interests to develop management strategies.

Vermont and New York sponsored a workshop in March, 1991 to bring together the recreation community to provide input on the most pressing recreation issues and information/data needs. Issues identified at this workshop included:

Lack of recreation management and planning: An overall management vision, goals and strategies are needed for Lake Champlain. There is a lack of basic information on many aspects of recreation use, facilities and carrying capacities for the various areas of the lake. A consistent funding source for research and planning, as well as for implementation and maintenance, is needed.

Need for protection and enhancement of natural and cultural resources, water quality, and fisheries: Protection and enhancement of the environment and cultural resources of Lake Champlain is essential for recreation. Resources perceived as extremely important are water quality, fisheries, critical habitats, and ecosystem health.

Lack of access: Access, especially for handicapped and low to moderate income users, is severely limited.

Recreational conflicts: There is a need to document carrying capacities and amounts and types of conflicts, and to identify potential conflict solutions.

Need for education and enforcement: Some issues and situations could be alleviated, at least in part, by increased educational efforts in such areas as stewardship, ethics, appropriate uses, and boating safety. Education was seen as an important component of enforcement activities.

Need for shoreland protection and development controls: Increasing shoreland development carries with it water quality problems and other issues, such as public trust doctrine ramifications, aesthetic losses, loss of access, loss of historic, cultural, and archaeological sites, and lack of consistent planning.

The results of the March 1991 Recreation Workshop were used to draft a preliminary workplan and implementation strategy for the development of a Lake Champlain Recreation Management Plan. The National Park Service has provided funding in 1991 and 1992 to the two states to begin recreation planning.

Approach and Discussion

The results of the March, 1991 workshop and the draft workplan for developing a recreation plan for Lake Champlain served as the framework to guide the discussions of this working group. The session began with a review of previous efforts and a discussion of the draft workplan. The group as a whole endorsed the need for a Recreation Management Plan and the draft workplan as the outline to develop it. Discussions about the research and information needed to develop this plan followed.

Highest Priority Research and Monitoring Needs

The highest priority need for recreation management in the Lake Champlain Basin is development of a comprehensive, long-term recreation management plan. The need for such a plan has been a recurring emphasis of reports on Lake Champlain over the past decade. The working group endorses the development of a recreation management plan for

Lake Champlain based on refinements to the existing draft workplan and implementation strategy. The research and information needed to develop this plan include:

1. Conduct an inventory of recreation resources on Lake Champlain and its immediate environs. This inventory should focus on recreational, natural and cultural resources, and should be computerized using a GIS approach.
2. Determine recreational use patterns on Lake Champlain. This study should include the types of boats, their relative numbers, and their use patterns; a similar examination of non-boating use; and an analysis of current and projected demand for recreation on Lake Champlain.
3. Identify potential recreation opportunities. This process should identify high priority opportunities, including access to the lake, marinas, trails/greenways, islands, and utility corridors.
4. Develop use capacity guidelines for Lake Champlain. These guidelines should specify appropriate amounts and types of recreation on Lake Champlain. A management zone approach should be taken which is based on normative standards and compatibility of lake uses.
5. Determine the economic impact of Lake Champlain-based recreation. This study should determine the expenditure patterns of lake users so that economically informed decisions can be made about recreation management on Lake Champlain.
6. Determine the interrelationships between water quality, other environmental resources in Lake Champlain, and recreation uses. For example, this study should examine the extent to which boat-based recreation on Lake Champlain impacts water quality and the extent to which degraded water quality impacts the quality of the recreation experience.
7. Throughout the data and information gathering steps described above, efforts to synthesize and formulate the recreation management plan for Lake Champlain should be ongoing. Emphasis should be placed on extensive public involvement and implementation through demonstration projects.

Other Needs (Demonstration Projects)

Demonstration projects and public information and education programs should be an active and important part of the Lake Champlain Management Conference work on recreation issues. Recreation-related demonstration projects have high public value and visibility. High priority demonstration projects are as follows:

1. Develop key public lake access sites.
2. Develop lake-oriented trails which accommodate multiple recreation uses.
3. Develop lake-oriented public education and information programs for lake access sites, school curriculums, and general public workshops, forums, and lectures.
4. Develop junior sailing programs and other youth awareness programs on the lake.
5. Convert railroad rights-of-way to recreation uses along the lake.

Public involvement should occur through appropriate study of lake user groups and through advisory groups, public meetings, and other techniques appropriate to the plan formulation process.

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CULTURAL RESOURCES

Introduction

The cultural resources of the Lake Champlain Basin represent an irreplaceable and increasingly threatened historic record of the activities of the people who have lived here. Nearly 12,000 years of human inhabitation have resulted in a high density of cultural resources both along the lake's shoreline and submerged in its waters. Because of early Native American settlements, the lake's role in the French and Indian War, the American Revolutionary War, and the War of 1812, and its position as a major transportation corridor in the 19th century, the lake has become a repository of important artifacts chronicling these times. Depth and cold have preserved submerged sites remarkably well and, until recently at least, a relative lack of shoreline development has left many of the land-based resources undisturbed, creating a wealth of opportunities for research, education and recreation.

The recent increase in the human population in the Lake Champlain Basin has threatened its cultural resources with deterioration and destruction. Effective management of these resources will require new information and a higher awareness of the issues pertaining to their protection and preservation.

Approach and Discussion

The session began with an overview of the present state of affairs regarding the cultural resources in the Lake Champlain Basin, including positive changes in public and political attitudes toward cultural resources in general and the economic implications of preserving them. More historic sites are discovered each year and many more are expected to be found and explored as new technologies become available. Participants agreed that effective management of all sites is essential in order to balance protection and accessibility. Management techniques such as preserve formation were reviewed and the need for a general inventory of cultural sites was emphasized.

The group then formulated a statement that all participants agreed captured the common view of the values of and threats to cultural resources in the basin. This position statement follows:

"The cultural resources of the Lake Champlain Basin represent an endangered, nonrenewable resource having the potential to improve the quality of life of basin residents and visitors. The unique, multicultural history of the basin, represented by Native American, French, British, and early American architectural, archaeological, and historic sites and watercraft, presents potentially the best national opportunity to develop a bistate/international program of cultural resource management.

Research into cultural patterns and analysis of historic lake uses can provide insight into current environmental issues. The development of appropriate mechanisms for public interpretation and access provides a timely opportunity for enhanced economic and recreational uses and community pride. Responsible stewardship through enhanced interdisciplinary research, management, and public education would produce preservation, public awareness, and increased public access to these resources."

This statement was used to direct and focus all subsequent discussions of research and monitoring needs. Broad areas of action were identified first and then more specific needs were prioritized.

Highest Priority Research and Monitoring Needs

The group agreed on six highest priority information needs.

1. Develop a plan for research, inventory, and management of basin cultural resources. This process could begin immediately by convening a Cultural Resources Planning Symposium, coordinated between Vermont, New York, and Quebec.
2. Inventory submerged and land-based resources in the basin. Collaborate with the National Oceanic and Atmospheric Administration, the National Park Service, and others as appropriate. For each site, information should include the immediate environmental condition of the site and its contents, its significance, and the threats to its preservation.
3. Increase public education and publications programs concerning cultural heritage.

4. Conduct historical research into Native American, military, early settlement, and industrial sites.
5. Use inventory data and historical research to increase public access through a "land trails" system, underwater sites program, and roadside markers.
6. Develop a plan to secure increased funding for implementation and staffing.

Other Research and Monitoring Needs

The following other information needs were also identified. They are listed in no particular order.

1. Investigate and document existing archaeological collections and make the information available to the public.
2. Identify existing conditions that pose threats to cultural resources.
3. Analyze the issues relating to public versus private ownership of cultural resources.
4. Establish a landowner cultural resource registry program.
5. Promote nonmonetary public incentives to private landowners for stewardship to protect historic resources.
6. Develop mechanisms for public participation stewardship and interpretation.
7. Identify organizations to develop and carry out heritage tourism.
8. Strengthen law enforcement and compliance with cultural resources protection laws and regulations.
9. Establish a curatorial facility in the Lake Champlain Basin.
10. Enter all cultural resource site information into a Geographic Information System.
11. Promote a more holistic understanding among all concerns.

12. Find a balance between increased public interpretation and access and limiting access to sensitive sites.
13. Identify opportunities for joint ventures.

Concluding Comments

This session brought together a group of professionals who have all been working towards better management of the basin's cultural resources, but who have rarely met to exchange ideas. One of the greatest intangible benefits of this working group session was to establish a network among cultural resource professionals which can be used in the future to develop a coordinated, basin-wide cultural resources management strategy.

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ECONOMICS

Introduction

The economic interrelationships between and among Lake Champlain, its residents, and its visitors are complex. The lake provides direct economic support to a variety of recreational activities and it also provides indirect support to nearly everyone who lives or works in the basin. The lake is a source of water for drinking and a variety of industrial and commercial uses; it is also the ultimate repository of nearly all wastewater produced within the basin. Much of the environmental damage done to the lake as a result of these uses also has economic consequences. Similarly, rectifying the environmental damages has a variety of economic implications.

The economic issues that should be addressed include not just measuring the impact of the lake on the regions's economic environment, but also quantifying the costs of ameliorating some of the lake's problems, especially its water quality problems. It will be important to assess the costs and benefits of various pollution control strategies and to ensure that pollution abatement is accomplished at the lowest possible overall cost, given the desired outcome.

Approach and Discussion

Because economics is such a broad topic area, the group began by trying to determine which aspects of the basin's economy and economic development should be the focus of Management Conference activities. The group agreed that the primary focus should be on the public, fiscal, and business implications of the Comprehensive Pollution Prevention, Control, and Restoration Plan for Lake Champlain, not on economic development in general. With such a focus, the group discussed the information base needed to promote efficient and least-cost ways of maintaining the environmental quality of the lake and basin. A brainstorming approach was used initially, then the group worked towards general consensus on high priority issues. All needs are listed in relative order of priority.

Highest Priority Research and Monitoring Needs

1. Assemble an economic database to help define Lake Champlain's role in the basin's economy. The particular role of lake-based recreation and fishing should be assessed as part of this survey (this project is already underway, with Management Conference funding).
2. Establish a clearinghouse for economic data. Potential sites discussed include SUNY-Plattsburgh and the Vermont Center for Rural Studies. Some connection with other data management efforts should be maintained.
3. Explore means to incorporate economic cost/benefit analyses into the Request-For-Proposals (RFPs) process for both research and demonstration projects. This might involve consultant services to work with the Technical Advisory Committee over the short term, and the creation of a guide for preparing the economic analysis portion of future RFPs.
4. Investigate the economic implications of water pollution to discover who pays for and who benefits from pollution control strategies in the basin. Explore the mechanisms and alternatives for allocating public and private costs of implementation. Studies should focus on phosphorus first, then move to other pollutants.
5. Examine basin-wide incentives to foster economic efficiencies and cooperation that help to implement the recommendation of the Comprehensive Plan.

Other Research and Monitoring Needs

1. Consider whether town-level resurveys of household economic data are necessary or cost-effective to supplement the national census data.
2. Create a macro-economic model for the basin to evaluate demographic and economic scenarios.
3. Separate in-basin from external economic factors to explain the degree to which the future of the basin is determined within the basin.
4. Identify important distinctions between New York and Vermont economies in tourism, industry, agriculture and other areas.

5. Separate drinking water issues from phosphorus control issues for priority micro-economic analysis.

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LAND AND SHORELINE USE

Introduction

The intensity and pattern of development and human activities on the land and shoreline around Lake Champlain can have important consequences for the water quality of the lake, the fish and wildlife resources that depend on the lake, and human uses and enjoyment of the lake and the basin. The conflict between developing and protecting the natural resources in the basin repeatedly emerges when land use planning decisions must be made.

Because all of the land in the Lake Champlain Basin drains into the lake, human activities anywhere in the basin can affect the quality of the lake water. Nonpoint source pollutants can be delivered to the lake from a number of land uses. Agriculture is a vital component of the basin's economy, but agricultural runoff carries phosphorus and pesticides that can degrade lake water quality. Urban areas are growing and urban runoff, carrying a variety of substances from roads and other impervious surfaces, can also contribute to poor water quality.

With an increase in the number of people living in the basin and the popularity of water-based recreation such as fishing, swimming, boating, and scuba diving, recreational conflicts centering on land and shorelines uses and access have intensified. Limited lake access and a shortage of boat docking and storage space suggest that additional shoreline development might be needed, but too much shoreline development will interfere with other forms of recreational use and may negatively affect fish and wildlife species using critical shoreline habitats.

Clean water, productive wetlands, abundant fish, and natural shoreline are basic requirements for outdoor recreation. If land and shoreline uses are not planned carefully, we risk losing the very resources that are essential to the recreational, aesthetic, and economic fabric of the community.

Approach and Discussion

The group began by considering land and shoreline use issues in each of ten different subject areas, which follow:

- Aesthetics
- Shoreline Flood Control (Lake Level)
- Shoreline Management
- Erosion Control
- Public Trust Doctrine
- Land Use Impacts
- Public Participation
- Financial Incentives
- Institutional Arrangements
- Sustainability

Participants then suggested research and monitoring needs in each of these topic areas. Ideas were consolidated where possible and then ranked across all categories. Ranking was done by vote: each participant voted for his/her six highest priorities.

Highest Priority Research and Monitoring Needs

Highest ranked priorities are listed below in relative rank order.

1. Evaluate the impacts of various types of Lake Champlain shoreline use on the water quality of the lake, including the impacts of:
 - lakeshore septic tank loading,
 - pesticide and fertilizer use on residential, commercial, and agricultural properties,
 - runoff from roads and parking lots,
 - construction activities for beaches, roads, boat launch sites, etc.,
 - dumping and filling, and
 - recreation facilities of all types.
2. Determine the relative contributions of the various land use types in the basin to the pollutants in Lake Champlain. Land uses that should be considered include

agriculture, forestry, construction of all types, and urban and residential development. The full range of pollutants, including sediments, toxic substances and nutrients should be examined.

3. Examine growth trends and alternative future scenarios for Lake Champlain Basin land use and Lake Champlain shoreline use. Develop land use computer simulation models that combine growth trends and contemporary planning information to create a range of future scenarios.
4. Inventory the local protection mechanisms and local zoning regulations that exist to protect the views and viewsheds, floodplains and shoreline of Lake Champlain.
5. Design a public participation program to determine subject areas and issues of importance to localities. Identify local needs and desires for model regulations. Include in the study a survey of the successes and failures of other public participation efforts in the Lake Champlain Basin.
6. Using the concept of sustainability, investigate the feasibility of planning for and managing land use on the basis of Lake Champlain's human carrying capacity.

Other Research and Monitoring Needs

Research and monitoring needs in this category are not in any priority order.

1. Inventory and assess the scenic resources (both from and toward Lake Champlain) and the components of these resources.
2. Evaluate the existing land use management techniques and regulatory controls to determine their effectiveness in addressing water quality.
3. Evaluate the effectiveness of land use buffer zones to protect water quality.
4. Evaluate possible improvements in the public trust doctrine's legal meaning in New York and Vermont and identify the larger legal issue that underlies this doctrine.
5. Identify critical areas for soil erosion and pollutant generation in the basin that are important to Lake Champlain.
6. Complete an economic analysis of various future land use development scenarios.

7. Evaluate the influence of distance and connectivity of pollutant generation in the basin on the delivery of pollutants to Lake Champlain.
8. Identify an institutional arrangement that allows for the ongoing coordination of land use management as it relates to water quality.
9. Inventory existing shoreline land use.
10. Identify existing land use jurisdictions and develop alternative proposals for institutional arrangements.

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NUTRIENT CYCLING AND EUTROPHICATION

Introduction

Eutrophication will certainly be one of the major water quality management issues that the Management Conference must address. Most of Lake Champlain suffers from elevated phosphorus levels (see plenary paper by Watzin, in this volume). The lowest phosphorus levels in the lake occur in Malletts Bay, but even here, the average value is about 11 $\mu\text{g/l}$, which exceeds the conventional oligotrophic criterion of 10 $\mu\text{g/l}$. Most of the lake is either in the mesotrophic (10-20 $\mu\text{g/l}$) or eutrophic (>20 $\mu\text{g/l}$) range. Areas such as the South Lake, Missisquoi Bay, and St. Albans Bay regularly have summer phosphorus concentrations in the 30-50 $\mu\text{g/l}$ range.

The algal blooms and reduced water clarity that high phosphorus levels induce have led to serious impairment of the uses of Lake Champlain, particularly recreational uses. Lake user surveys have shown that serious nuisance conditions and reduced use are a reality in the eutrophic bays and nearshore areas and in the South Lake.

A variety of phosphorus management programs were implemented in the 1970s and 1980s (for example, phosphorus detergent bans and the construction of phosphorus removal facilities at some wastewater treatment plants) and a new generation of point and nonpoint source controls is currently being planned. Phosphorus concentrations in Lake Champlain over the last decade, however, have remained relatively constant. The reasons for this are not immediately apparent and clearly justify continued research in this area.

Approach and Discussion

Workshop participants used the water quality objectives for nutrients drafted by the Plan Formulation Team of the Lake Champlain Management Conference as guidelines for discussion. Three major topics emerged from the discussion and are summarized here.

Water Quality Standards. Ecosystem health should be the major consideration in setting eutrophication-related water quality standards. Measurements, such as chlorophyll a and phosphorus concentrations, Secchi disk depth, and dissolved oxygen concentrations at the lake bottom, should be evaluated for their usefulness in characterizing ecosystem health. Specific, attainable ecosystem objectives should be articulated prior to establishing quantitative criteria.

Nutrient Loading and Monitoring. Nonpoint source loading of phosphorus, and factors affecting that loading, need to be identified and characterized for all watersheds in the Lake Champlain Basin. The bioavailability of various forms of phosphorus and other nutrients is a crucial issue, so both nutrient speciation and total amounts should be measured. Although phosphorus enrichment is the most widely recognized cause of eutrophication, other nutrients such as nitrogen and silica can also be important in the process and should be monitored as well.

Whole-Lake Modeling. Models vary greatly in complexity. A simple initial model can be used to identify data gaps and provide initial direction for management programs. Any whole-lake computer simulation model for phosphorus should be linked to a watershed model. Ideally, a whole-lake and watershed model should include hydrodynamics, nutrient inputs and effects, and toxic substances. Again, nutrients other than phosphorus should be included in the model.

A voting process was used to rank these three major areas. Whole-lake modeling and nonpoint source nutrient loading were the issues of most concern to the group members. Research needs within these categories were identified and ranked through another vote by category.

Highest Priority Research and Monitoring Needs

Whole-Lake Modeling. The group assumed that the total phosphorus model associated with the Diagnostic-Feasibility Study will be completed, so it is not included on the following list. This in no way negates its importance. All participants agreed it will provide useful preliminary management information and aid in the development of a more comprehensive, integrated whole-lake model.

To support the development and implementation of a whole-lake, predictive phosphorus model, the following priority research and monitoring needs were identified.

1. Develop a database on phosphorus and other nutrient concentrations in the lake and the basin with sufficient spatial and temporal coverage to be used in a predictive model.
2. Investigate phosphorus movement across the sediment-water interface.
3. Examine the bioavailability of phosphorus and other nutrients, including both nutrients in the lake and those moving from the watershed to the lake. These studies should also include investigations of phosphorus transport and transformation processes in streams.
4. Investigate the relationships among nutrients, phytoplankton, zooplankton, and benthic communities (including the possible impact of zebra mussels).
5. Couple hydrodynamic modeling to investigations of nutrient transport and utilization.
6. Develop appropriate linkages between modeling activities, monitoring activities, and management activities to ensure best use of information.

Nonpoint Source Nutrient Loadings. To support a better understanding of nonpoint source nutrient loadings on a subwatershed basis, the following studies are needed.

1. Sample tributaries for additional parameters (other than total phosphorus, total dissolved phosphorus, and chloride, which are being collected as part of the Diagnostic-Feasibility Study).
2. Investigate littoral zone and water column recycling of nutrients.
3. Establish relationships between land use activities and total tributary loading, especially with respect to management practices.
4. Evaluate the effectiveness of Best Management Practices, including the relationship between land-use generation and delivery to the lake, with a review-feedback mechanism.
5. Investigate the role of river sediments and suspended solids in transport and delivery of nutrients to the lake.

Other Research and Monitoring Needs

While a number of other research needs surfaced during this group's discussions, none were developed in any detail. Some of these included developing a detailed understanding of the phosphorus-primary productivity linkage, the relationship between eutrophic conditions and oxygen depletion, and the location and rates of sedimentation in the lake.

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FATE AND EFFECTS OF TOXIC SUBSTANCES

Introduction

Toxic substances are an issue of wide public concern in the Lake Champlain Basin. Much of this concern results from health advisories that have been issued in both New York and Vermont concerning consumption of some large fish from Lake Champlain because of elevated levels of mercury and polychlorinated biphenols (PCBs) in their flesh. Toxic substances are also a concern for those who draw their drinking water from the lake.

The information base on toxic substances in Lake Champlain and any potential impacts is summarized in the plenary papers by Watzin and McIntosh earlier in this volume. Potential sources of toxic contaminants in Lake Champlain include municipal and industrial waste discharges, hazardous waste disposal sites, landfills, atmospheric deposition, and runoff from agricultural and urban areas. In all cases, little is known about the magnitude of the loading of toxic substances to the lake, the fate of those substances in the lake, and their ultimate effect on both the lake's ecosystem and human health. Numerous questions remain to be addressed through research and monitoring in order to respond to concerns about toxic substances and to develop appropriate management strategies.

Approach and Discussion

To set the stage for group discussion, Alan McIntosh reported preliminary findings from his EPA-funded Lake Champlain sediment toxic substances assessment. He noted that lake-wide contamination may not be a major concern, but that certain areas, such as Cumberland Bay and Burlington Harbor, contained elevated levels of PCBs, mercury, and other contaminants. John Hassett (SUNY-Syracuse) then spoke briefly about his experiences in modeling the Great Lakes ecosystem. In particular, he spoke of the need to obtain good water column and sediment data to support and test any model, and of the need to be directly involved with chemical analyses to be sure all compounds of interest are included in the analysis. He suggested that focusing on "hot spots" can be valuable, but may mask area-wide concerns. Trefor Reynoldson (Environment Canada) emphasized the efficacy of looking for biological effects first when attempting to uncover toxic problems. He suggested

that top predators are a good group to examine for effects. If effects are documented, then sediment work may be in order.

The group then discussed toxic substances known or suspected to occur in Lake Champlain and various management options that might be employed to deal with these substances. The participants concluded that despite the existence of some historical data on sources of toxic contaminants, there was virtually no information on the impacts of toxic substances on the lake's ecosystem. Much more effort is needed to determine (1) the role of point versus nonpoint sources of persistent toxic pollutants within the basin; (2) the movement of persistent toxic substances like mercury and PCBs into and through the lake; and (3) the effects of these toxic substances on both the lake ecosystem and human health.

After this initial discussion, the group split into two subgroups: one to address research and monitoring needs in the area of fate and transport of toxic substances, and one to address research and monitoring needs in the area of effects of toxic substances. Both groups generated prioritized lists of needs. The subgroups rejoined, and research and monitoring needs were again prioritized from the combined list.

Highest Priority Research and Monitoring Needs

The group identified five highest priority needs to address the broad issue of toxic contaminants in the Lake Champlain ecosystem. They are listed below in priority order.

1. Quantify atmospheric, tributary and direct sources of mercury, PCBs, and other substances as appropriate into the lake and assess the role of in-place contaminated sediments.

Substantial work towards achieving this objective is already underway with funding from the Management Conference (EPA), the U.S. Geological Survey and the National Oceanic and Atmospheric Administration. Management Conference funds are supporting the screening of direct discharges by the states of Vermont and New York. The Conference is also supporting the sediment assessment program underway at the University of Vermont, SUNY - Plattsburgh, and the University of Rhode Island. Both EPA and NOAA are supporting monitoring of atmospheric inputs of selected toxic substances. The USGS is initiating a study of PCBs and trace metals in tributaries and tributary mouths.

2. Survey the status of key lake populations to identify any effects of exposure to toxic contaminants:

- fish (for example, number with tumors, reproductive success)
- birds (for example, reproductive success of terns, cormorants)
- mammals (for example, otter and mink reproduction)
- benthos (for example, community structure)
- miscellaneous (for example, zooplankton, phytoplankton, macrophytes, surface microlayer)

Once the assessment is completed, research and monitoring programs should be developed as appropriate.

Relatively little of this critical work has been initiated. For example, there are no records of fish tumors or reproductive effects of toxic contaminants on mammals or birds. Some very limited work has been done on benthic communities. In general, there is little relevant information concerning the impacts of toxic contaminants on the Lake Champlain ecosystem. The U.S. Fish and Wildlife Service might be encouraged to support efforts on fish, mammals and waterfowl, while investigations of the invertebrate communities might be funded by the EPA.

3. Assess the status of biota in "hot spots" where toxic contaminants have accumulated. Both laboratory and field approaches should be used.

Standard sediment bioassays are being conducted at nine sites identified during the sediment assessment study underway at UVM and elsewhere. Work in this area should be expanded to include assessment of impacts at the population and community level in areas such as Cumberland Bay, Burlington Harbor, and others, as appropriate.

4. Examine watershed and in-lake transport and transformations of lake-wide toxic substances, particularly mercury and PCBs.

Relatively little work in this arena is underway. Mercury speciation will be examined in the lake as part of the sediment assessment study (Fuller, at SUNY - Plattsburgh). The USGS study will look at PCB concentrations in tributaries, but transformation and transport information will be limited. Understanding how key toxic contaminants cycle through the Lake Champlain ecosystem will be critical to designing an effective management strategy, therefore, additional work in these areas should be initiated.

5. Develop and test "early warning systems" to evaluate toxic contaminant sources in the Basin. Implement these protocols to monitor changes in the status of point sources.

No such activity is underway. Once sources within the basin have been identified, implementation of this approach could be used to monitor changes in the status of such sources.

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HUMAN HEALTH

Introduction

The health of the people living in the Lake Champlain Basin and using its resources is an obvious concern of the Management Conference. The most apparent potential problems are associated with pathogens and toxic substances in lake water and fishes. Pathogens enter the lake primarily from human and animal waste. Sources of these materials include leaky septic fields, municipal sewer overflows, boat holding tank discharges, and runoff from agricultural and urban areas. When numbers of pathogens in lake water are high, it is not safe for swimming or for drinking without treatment.

The existing health advisories for consumption of some large fish from Lake Champlain because of mercury and PCB contamination illustrate one concern about toxic substances. Toxic substances can also be a concern for those who draw their drinking water from the lake. Toxic materials can cause a number of health problems for people, including cancer, neurological disorders, birth defects, headaches, and nausea.

Quantification of the health risks associated with pathogens and toxic substances in lake water and fishes is essential in order to design management strategies to reduce human exposure and lower these risks.

Approach and Discussion

The participants in the Human Health working group began by identifying and discussing the potential human health problems resulting from lake use. The group felt that two problems, the presence of toxic substances in fish and the presence of pathogens in lake water, had the highest potential for posing health risks to users of Lake Champlain. Because of the limited information on the nature and extent of pathogens and toxic substances in Lake Champlain, the group did not prioritize between these two issues. A third issue, potential health risks from toxic substances in drinking water from the lake, was considered by the group to be of lesser concern. Priority research and monitoring needs were identified separately for these three major concerns.

Highest Priority Research and Monitoring Needs

Toxic Substances in Fish. The group concluded that the available data on Lake Champlain should be collected, analyzed, and evaluated before recommendations for collection of new data are made. The group outlined a stepwise research plan (including both desk-top and field research) for evaluating the public health risks associated with eating Lake Champlain fish, and recommended that current fish monitoring programs be maintained until additional needs are identified through the process outlined below.

1. Update past inventories of the available data bases, including monitoring data (fish and sediment) and source inventories (industry surveys and discharge permits). Identify the depth and breadth of knowledge in these areas.
2. Analyze available data and identify situations that may pose the highest risk to humans (i.e., use the data to prioritize needs). The following criteria and examples should be used in the prioritization process.

Toxicants of Concern - PCBs, mercury, dioxin, and others as identified.

Areas of Concern - Burlington Bay, Ticonderoga, Cumberland Bay.

Fish Species of Concern - those with high contaminant levels (salmon, lake trout, walleye, eel), and those consumed in large amounts by humans (smelt, bullhead, perch).

3. For high priority situations, perform a generic or screening quantitative risk assessment using best available data.
4. For situations where a potential health risk is identified, determine the data necessary to improve confidence in the risk estimates. Replace generic data or assumptions with data specific to Lake Champlain. For example, two areas where data are critical, but limited, are data on the concentrations of contaminants in fish actually harvested by the basin populations and data on the actual rates of fish consumption by local populations. The collection of data on fish consumption (specific to fish species) was considered a very high research priority by the group.
5. Once data collection has been completed, revise and refine generic risk assessments using data specific to Lake Champlain.

6. Communicate and interpret results of the risk assessment to the public. Begin risk management.

Pathogens in Water. The group developed three research recommendations regarding pathogens in water, but did not feel it was sufficiently knowledgeable to rank them in priority order.

1. Assess the potential for the presence of pathogens other than fecal coliforms (including *Giardia*) at problem beaches.
2. Develop a plan for monitoring problem beaches more comprehensively so than decisions to close a beach are based on good spatial as well as temporal data.
3. Expand the coliform testing program to other areas to determine the magnitude of the problem throughout the basin.

Other Research and Monitoring Needs

Toxic Substances in Drinking Water. Although considerably less time was spent on this issue, the group did identify three research priorities concerning toxic substances and drinking water.

1. Inventory drinking water sources throughout the basin (such a data base may already exist, or would be relatively easy to assemble).
2. Identify chemicals of highest concern. These might include pesticides (especially water-soluble corn herbicides such as atrazine), trihalomethanes, volatile organic chemicals, and lead. Test those water supplies that have a high potential for impact by these chemicals.
3. Although evaluating the potential health risks of groundwater contamination may not be a high priority for the Management Conference, concern over the potential risks associated with nitrates and other contaminants in private, rural wells located near agricultural land was expressed, and a monitoring program to assess the magnitude of the problem was discussed.

Concluding Comments

The number of participants in this working group was quite small. At times, participants felt the group suffered from the lack of a "critical mass," especially during discussions of the health risks associated with pathogens and toxic substances in drinking water. Because of low attendance in this session, the group recommended that a second workshop on health issues be held.

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ATMOSPHERIC PROCESSES AND DEPOSITION

Introduction

Determining the contribution of toxic substances from the atmosphere to the lake is a difficult, yet extremely important, component of an overall assessment of toxic loading to the lake. Studies have shown that a large percentage of the chemical contaminants in the Great Lakes have an atmospheric source; it is not known what the percentage is for Lake Champlain. The surface area of Lake Champlain is considerably less than the Great Lakes, but its drainage area is proportionally much larger than those of the Great Lakes; these differences in morphometry may mean that atmospheric delivery of toxic substances is quite different in the Champlain Basin (see plenary paper by Watzin, earlier in this volume for a more complete discussion).

Concerns about atmospheric pollutants currently focus on mercury and PCBs, in part because of the health advisories for consumption of large fish contaminated with these toxins. The Clean Air Act amendments of 1990 may result in changes in atmospheric pollutant mixtures and deposition patterns in the Lake Champlain Basin; some substances may increase as others decrease. These factors are a major concern to scientists, regulators, and others who are interested in restoring and maintaining the long-term health of the Lake Champlain ecosystem.

Approach and Discussion

The Atmospheric Processes and Deposition working group began by looking afresh at the state of knowledge regarding atmospheric processes and deposition in the Lake Champlain Basin. Group members discussed a series of questions designed to lead from identification of perceived atmospheric problems, through the current state of knowledge, to recommendations for action. The questions posed and the group response to those questions follow.

What are the atmospheric issues of concern for Lake Champlain? Some of the issues identified were:

- a) quantifying atmospheric deposition of toxic substances,
- b) resolving direct (lake) and indirect (watershed) pathways for atmospheric deposition to the lake,
- c) resolving direct atmospheric and indirect (drinking water, fish consumption, etc.) pathways of human exposure to airborne contaminants,
- d) clarifying the role of the lake as a source or sink for certain pollutants,
- e) defining changing deposition gradients and temporal patterns,
- f) improving the resolution of micro- and meso-scale meteorological processes, and
- g) visibility degradation.

For all these issues, the group expressed the critical concern that the knowledge base regarding toxic substance concentrations, flux processes, and meso-scale meteorology in the basin is severely limited.

What are the contaminants of primary concern? Contaminants identified include mercury, other trace metals, nutrients, polynuclear aromatic hydrocarbons (PAHs), and pesticides. Mercury, other trace metals, and nutrients should be measured together, in order to conduct interpretive and source-apportionment studies. Dioxins and PCBs were not considered high priorities for monitoring because of difficulties in quantifying concentration and flux and the low probability of successful management of atmospheric inputs. Conversations with other work groups, however, made it clear that there is a need to provide some information about the behavior of PCBs in the basin.

What are the most appropriate analytical approaches? The science of measuring wet and dry deposition of substances from the atmosphere is quite young. Various approaches for chemical screening, element speciation, and biomonitoring to assess atmospheric exposures, accumulation, and gradients were discussed.

The group agreed that some screening would be helpful in the basin, rather than simply relying on lists of contaminants from other regions. Participants also agreed that decisions about analyses should not be based solely on laboratory capabilities, but also on knowledge about what contaminants might be of concern.

What atmospheric processes are of primary concern? Wet and dry deposition to the lake surface and the land surface in the watershed, fog and cloud deposition, watershed transformation and transport processes, revolatilization, gas and particle phase distribution, source-receptor relationships, and the effects of air quality changes on deposition were all identified as important.

Participants also felt that local efforts should concentrate on processes unique to the Lake Champlain Basin because other federal programs focus on processes common to multiple basins.

What existing regional programs are most relevant?

- a) Adirondack Lakes Survey Corporation Trace Metals Study (ALSCTM): five New York sites including Willsboro (on the lake) for mercury and other trace metals, 1991-1993.
- b) Northeast States for Coordinated Air Use Management (NESAUM) Aerosol Study: nine northeast sites including Whiteface, NY and Underhill, VT for aerosol chemistry, 1988-present.
- c) University of Rhode Island/Vermont Department of Environmental Conservation: elemental analysis of aerosols samples and precipitation at Underhill, VT, 1982-1989.
- d) New York Department of Environmental Conservation volatile organic carbon compounds (VOCs): ten New York sites, including Willsboro, 1990-present.
- e) National Atmospheric Deposition Program/National Trends Network: Underhill, VT and Whiteface, NY, 1984-present, part of the national network for comprehensive precipitation chemistry monitoring.
- f) EPA Operational Evaluation Network Acid Modes Study: Underhill, VT and Whiteface, NY, 1988-1990, comprehensive daily atmospheric and precipitation chemistry analysis.
- g) Vermont Monitoring Cooperative (VMC): intensive ecosystem-level monitoring and research on atmospheric deposition, and forest response, at Mt. Mansfield, VT.

What is the status of current monitoring and research in the region?

- a) Lake Champlain Management Conference - supporting enhancement of New York and NESCAUM programs.
- b) Vermont Monitoring Cooperative - long-term research and monitoring on pollutant deposition mechanisms in forested watersheds.
- c) Interagency Monitoring of Protected Visual Environments (IMPROVE) - Aerosol and visibility monitoring in the Lye Brook Wilderness in southern Vermont.
- d) Environment Canada - Hemmingford, Quebec toxic deposition monitoring site under development (air quality and effects on forests at several elevations).

Other efforts (such as the EPA Clean Air Status and Trends Network) are in the discussion or planning stage, but are not yet a reality.

What are the opportunities for cooperation and coordination? The Departments of Environmental Conservation in New York and Vermont have a good working relationship and have established cooperative monitoring efforts. These involve linking New York's efforts in Willsboro (trace metals, PCBs) with Vermont's aerosol chemistry and additional meteorological measurements. The commitment of additional funds from NOAA may provide other opportunities.

Discussions are underway in the Vermont Monitoring Cooperative to develop a cooperative project on mercury concentration and flux in and above a mixed hardwood forest in the Lake Champlain Basin. These studies would be built into VMC research studies on ozone and micrometeorology in the forest canopy.

Individual researchers also are interested in cooperative work to study trace metals in precipitation and cloud water.

Highest Priority Research and Monitoring Needs

Three broad categories of information needs were identified:

1. Spatial gradients and temporal variation in pollutant concentration and deposition in the basin. Contaminants of primary concern are mercury, trace metals, nutrients, PAHs, pesticides, and PCBs.

2. Meso-scale meteorological processes in the basin (wet and dry deposition, revolatilization, watershed transformation and transport processes).
3. Ecological processes which modify the interception, storage, and release of atmospheric contaminants by the watershed and lake.

Specific recommendations were divided into three categories: general or organizational priorities, priorities for monitoring, and priorities for research. These recommendations are **not** listed in any rank order.

General or Organizational Priorities:

1. Form an Atmospheric Science Advisory Group. While the need for understanding the impacts of atmospheric deposition (especially of toxic substances) on the lake is widely recognized, there is limited expertise in this area within the Lake Champlain Basin research community. The role of this group would be to provide technical expertise and advice for studies related to atmospheric processes in the basin. Members of this workgroup agreed to serve in this capacity. Steps should be taken to formalize this group and develop a working relationship with the Management Conference and the Lake Champlain Research Consortium.
2. Assess the utility and comparability of existing monitoring sites. A formal process of assessment should be undertaken to identify monitoring or research sites, QA/QC procedures, variables, and measurement frequency throughout the Lake Champlain basin.
3. Build on and, if necessary, assure the continuation of the key monitoring and research sites identified above.
4. Work with NOAA to promote meteorological interpretation of monitoring data with a particular emphasis on synoptic and meso-scale pollutant transport.
5. Work with Quebec and Environment Canada to coordinate monitoring and research with their sites in the basin north of the lake.
6. Work with biological effects and watershed groups to agree on priority pollutants for basin studies. An orderly process needs to be developed to coordinate and use information from these groups to help in decision making about which pollutants need monitoring and research attention.

Priorities for Monitoring:

1. Enhance the Vermont and New York monitoring efforts. The Management Conference has authorized preliminary funding to support additional measurements of toxic deposition near the Lake in both states. Other measurements in the basin could be built on these studies.
2. Assess spatial (horizontal, vertical) and temporal (diurnal, seasonal) patterns in pollutant concentrations and deposition, possibly through short-term "screening" assessment using drum samplers and PIXE analysis, biomonitoring, passive samplers, and other low-cost methods.
3. Measure Hazardous Air Pollutants in cloud water and other precipitation at additional sites. Because of the large watershed to lake area ratio in the basin, scavenging of toxic chemicals from clouds by high-elevation forests may be extremely important quantitatively. A few studies have shown chemical concentrations to be highly enriched in cloud water relative to other wet and to dry deposition.
4. Improve understanding of meso-scale meteorological processes through monitoring and modeling. Relatively little is known about variation in meteorological conditions in the basin. Deposition may vary much more than concentration, due to variation in precipitation and other meteorological factors. To examine these factors, additional meteorological stations should be established on the lake and in the basin; additional evaluations of existing meteorological databases should also be undertaken (limited work in the basin has already been started by the VMC).

Priorities for Research:

1. Investigate ecological processing of atmospheric contaminants. Given the basin's large drainage area to lake surface ratio, and likely much greater wet and dry deposition rates away from the lake surface, there is a critical need to understand how various contaminants are collected, processed, stored, and ultimately released from the surrounding forest ecosystem.
2. Quantify source-receptor relationships. Research should be undertaken to determine (1) the ultimate sources of transported pollutants, and (2) the relative importance of the lake as a source or a sink.

3. Determine the relative phase distribution of pollutants. There is considerable uncertainty about whether pollutants are transported and deposited in the particulate, gaseous, or aqueous phase. The relative distribution and interaction among these phases needs to be determined in order to estimate loadings.
4. Begin efforts towards data integration. Integration and modeling of monitoring and research activities and results needs to occur in order to develop ecosystem-scale understanding of the behavior and effects of pollutants in the basin. Methods for this integration include: (1) integrating data across multiple disciplines, such as the VMC meteorological/air quality/effects project started recently; (2) combining monitoring and modeling activities to evaluate model performance, identify critical monitoring needs, and extrapolate site-specific monitoring results to basin-wide spatial scales; and (3) modeling relationships among sources, concentration and flux, meteorology, and accumulation to develop pollutant budgets and to support whole-lake modeling efforts.

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WATERSHED PROCESSES

Introduction

This group focused on the physical processes by which nutrients, sediments, and toxic substances are generated, transformed, and transported through the watershed to Lake Champlain. It is essential to understand these processes in order to manage water quality in the lake effectively. Studies of nutrient loading to the lake, for example, demonstrate that despite point source control of phosphorus through wastewater treatment and agricultural nonpoint source reductions by managing manure on selected farms, there have been no measurable decreases in the total amount of phosphorus reaching the lake. Explanation of this finding requires a better understanding of phosphorus attenuation in soil and water, movement into streams, movement between stream sediment and the overlying water column, and transport over longer distances to the lake.

Many of the same physical processes that influence nutrient delivery to the lake also influence the delivery of toxic substances to the lake. These toxic substances might include pesticides applied to agricultural crops or suburban lawns, leachate from hazardous waste sites and landfills, and petroleum product derivatives washed off paved surfaces. The large surface area of the Lake Champlain drainage basin compared to the surface area of the lake itself makes understanding watershed processes and managing pollution sources in the watershed particularly important.

Knowledge of how phosphorus and other pollutants are transported, transformed, stored and released in stream systems in the watershed will help answer some fundamental questions about how distance from the lake affects pollutant delivery. At present, for example, we do not know how to compare the impact on Lake Champlain of a phosphorus source one mile from the lake with a similar source 50 miles from the lake. Understanding transport and attenuation processes would allow better targeting of point and nonpoint source treatment efforts across the basin.

Evaluation of the effectiveness of nonpoint source treatment is also a critical issue. Achievement of phosphorus loading goals for the lake, for example, relies on the ability to allocate allowable phosphorus discharges effectively among source areas in the basin. Such

allocation in turn rests on our ability to implement nonpoint source controls of known effectiveness and to predict the outcome of tradeoffs among point and nonpoint source controls. Determining the cost effectiveness of treatment programs also rests on knowledge of treatment performance. At present, the actual effectiveness of many practices is essentially unknown at both the edge-of-field level and at the watershed level.

Approach and Discussion

The group began with a brainstorming session in which over one hundred specific research and monitoring needs concerning watershed processes and nonpoint source pollution were generated. This large number of perceived needs reflects not only the large number of participants in this session, but also the numerous gaps in our understanding of the physical processes by which pollutants are generated, transported, transformed, and delivered from the land to the lake. The group condensed this list into 67 topics by combining similar themes and eliminating those deemed inappropriate. These 67 items were then ranked by vote into three categories: high, medium, and low priority.

Most of the discussion about these items centered on transport and transformation of nonpoint source pollutants through the Lake Champlain watershed and delivery of pollutants to the lake. In general, the pollutant groups of concern were nutrients (primarily phosphorus), metals (primarily mercury), other toxic substances, and sediments, in that order. The highest priority items listed below all contribute to the overall goal of achieving sufficient understanding of nonpoint source pollutants in order to predict loading to the lake and to design effective means of pollution prevention, control and reduction. Quantitative assessment of the relative contributions of major nonpoint source types will, for example, allow limited treatment resources to be focused on the most important sources of nutrients, metals, and other toxic substances in the basin.

Three of the highest priority research needs require immediate attention. These are (1) investigating phosphorus transport phenomena in basin streams, including rates of transport, attenuation, transformation, storage and release from aquatic sediments; (2) quantifying pollutant contributions from major land uses in the basin at both the edge-of-field level (areal export rates) and watershed level (total load to the lake); and (3) evaluating Best Management Practices (BMPs) for effectiveness in reducing pollutant delivery and for cost effectiveness, with emphasis on riparian buffer strips and on manure and fertilizer applications to agricultural lands. Other high priority items such as development of a basin-wide data base and long-term watershed monitoring can take place concurrently, but the

utility of such efforts depends on understanding of the first three fundamental questions. Development of a large scale nutrient model for the basin must be based on results of these efforts and will therefore probably be the last step in the progression

Highest Priority Research and Monitoring Needs

The research and monitoring needs which ranked the highest are listed in priority order.

1. Investigate phosphorus transport, transformation, storage, and release processes in streams.
2. Locate high phosphorus loading sources in the watershed. Identify critical subwatersheds within the Lake Champlain drainage basin as a focus for prioritizing land treatment for phosphorus management.
3. Investigate the total (watershed) and areal (edge of field) contributions of nutrients to the lake. Calculate the relative control costs from all major land uses in the basin (such as agriculture, silviculture, urban/suburban, septic).
4. Develop a basin-wide data base on land use, land cover, soils, slope, and hydrography.
5. Investigate the total (watershed) and areal (edge of field) contributions of metals and other toxic substances to the lake. Calculate the relative control costs from all major land uses in the basin and from natural geologic processes.
6. Calculate water and chemical budgets for first order watersheds.
7. Establish additional long-term watershed monitoring sites for phosphorus, to complement current river-mouth stations.
8. Develop a large scale nutrient (phosphorus first) model for transport, delivery, interactions, and mixing.
9. Determine which Best Management Practices are most effective and cost efficient for phosphorus reduction. BMPs for evaluation include riparian zone, timing of manure or fertilizer application, constructed wetlands, urban runoff treatment, livestock exclusion, cover crops, nitrogen versus phosphorus management, grazing management, detention ponds, and infiltration basins.

10. Determine phosphorus and sediment delivery ratios for the Lake Champlain basin.
11. Investigate whether the flow path of water to the lake affects the toxins or other materials delivered to the lake.
12. Evaluate groundwater contributions to lakes and streams and associated water quality issues.

Other Research and Monitoring Needs

Those research and monitoring needs ranked **medium priority** include the following:

1. Conduct a landscape level surface water quality study (nitrogen and phosphorus) and determine the functional interactions of subwatersheds.
2. Determine the effects of acid deposition on leaching of nutrients and heavy metals from watersheds.
3. Conduct a first cut statistical analysis of land use data with respect to the total phosphorus and soluble reactive phosphorus concentrations in each tributary monitored.
4. Assess the amount and fate of atmospheric mercury and PCB deposition.
5. Determine the factors affecting mercury methylation (especially in wetlands).
6. Determine the sources and fates of pathogens in the watershed.
7. Evaluate the effectiveness of urban Best Management Practices such as street cleaning, catch basins, and stormwater treatment for reducing the loading of nutrients and toxic substances.
8. Develop better techniques to assess inputs of pollutants from urban runoff.
9. Characterize soil phosphorus adsorption over time in septic leach fields to determine saturation and breakthrough.
10. Develop methodologies for inventory and evaluation of phosphorus from septic tanks and direct domestic discharge.

11. Establish the correlations between edge-of-field water quality measurements and in-stream water quality standards.
12. Determine whether the forest canopy enhances atmospheric deposition of pollutants.
13. Assess which principles should be used to allocate sampling resources among monitoring networks.
14. Evaluate the toxicity of runoff from corn fields to benthic invertebrates.
15. Determine which phosphorus reactions are most indicative of bioavailability.
16. Establish more precise flow gauging of the lake's major tributaries.
17. Evaluate the effectiveness of agricultural nitrogen management versus phosphorus management.
18. Evaluate pesticide losses (arsenic) from fruit orchards.
19. Determine the importance of landfills and Superfund sites to pollutant loadings.
20. Determine pesticide (corn herbicide) loads in runoff from agricultural lands.
21. Assess the phase distribution and chemical form of PCBs in streams.
22. Determine the precision necessary to quantify nonpoint source phosphorus loads and the implications for sampling design and load estimation.
23. Determine what social barriers exist to prevent lifestyle changes which might reduce nonpoint source pollutants.
24. Evaluate the economics of point source phosphorus control versus equivalent nonpoint source phosphorus control.

Research and monitoring needs that fell into the **low priority** category are those that were brought up in the brainstorming session, but which did not receive much support during the group voting. These needs generally fell into three groups:

- (1) develop an improved understanding of **specific sources**, including airports, earthen manure storage pits, agricultural tile drainage, corn silage storage, household pesticides, hydrocarbons from urban runoff, and sediment from back roads;
- (2) evaluate the effectiveness of **specific treatments**, including detention ponds, grazing management, infiltration, and optimal combinations of treatments for phosphorus and nitrate from agriculture; and
- (3) develop an improved understanding of **basic system phenomena**, including lag time in nutrient losses, slope stability of river banks, and temporal variability in herbicide runoff.

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IN-LAKE PROCESSES -- HYDRODYNAMICS

Introduction

Hydrodynamics can be simply defined as the movement of water. Hydrodynamics, or water flow patterns, are the force behind the transport of sediment, nutrients, and toxic substances in Lake Champlain. Water quality and toxic fate and effects models rely heavily on hydrodynamics as a driving mechanism.

Hydrodynamic studies must define both the advective processes (transport by water current) and diffusive processes (movement caused by concentration gradients and thermal agitation) that carry pollutants throughout the lake. Wind is an important controller of advective processes, so meteorology must be addressed as an important part of hydrodynamic analyses.

This group addressed research and monitoring needs related to hydrodynamics and the role that hydrodynamics plays in transport analysis. It is transport analysis that will ultimately serve as a management tool. Transport analysis and transport models can be used to track the distribution and fate of nutrients, toxins, and other substances in the lake and to evaluate various management scenarios for controlling the distribution of those substances. As such, the reliability of any water quality assessment will be closely linked to the reliability of the hydrodynamic assessment and transport analysis.

Approach and Discussion

There are several means by which hydrodynamic characteristics can be assessed:

- a) direct field measurements of hydrodynamic variables (for example, currents and water temperature),
- b) field measurements of a conservative substance (such as the chloride ion) which can be used with a chemical transport analysis and available inflow-

outflow data to estimate the exchange characteristics of the hydrodynamics, and

- c) classical hydrodynamic modeling based on the physical principles of conservation of fluid mass and momentum.

Much discussion focused on modeling concerns. Hydrodynamic models can be developed to assess whole-lake dynamics including the motion of surface and internal seiches. Initially these models do not have to be highly refined, but they should be designed so that future refinement can be easily accomplished. A whole lake model must include the boundary conditions of the small shallow bays. More finely detailed, site-specific models of nearshore areas can be used to evaluate particular management problems. Such problems might include episodic runoff events, bed shear and resuspension, shoreline erosion, short-term transport of industrial and municipal point source discharges, optimization of outfall and water intake locations, impact of marina expansions, and other management concerns.

The group discussed these three major approaches and then developed a list of research and monitoring priorities by consensus.

General Recommendations

All three approaches outlined above should be used to characterize the hydrology of Lake Champlain. Direct field measurements of currents and temperature are necessary to begin to estimate mass transport, exchange rates between basins, and the magnitude of the internal seiche. The conservative tracer approach might be particularly appropriate for calibrating water quality models. All of the data generated must have the appropriate spatial and temporal resolution for use in hydrodynamic and transport modeling.

Highest Priority Research and Monitoring Needs

Priorities were divided into two general categories: those pertaining to modeling and those pertaining to field data collection. Both avenues should be pursued in tandem. Priorities within each category are presented in relative rank order.

Modeling Priorities

1. Develop a whole lake hydrodynamic model for crude estimation of mass transport and exchange rates between basins.

2. Develop refined, site specific models for evaluation of specific problems.
3. Provide through initial dynamic modeling efforts the transport predictions necessary for a mass balance model for nutrient management.

Field Data Collection Priorities

1. Establish current meter arrays to characterize flows into and out of all five major lake basins.
2. Collect long-term measurements of temperature and currents (especially in the Main Lake) to characterize the internal seiche. Two stations currently exist in a north-south transect in the Main Lake; an additional two stations on an east-west transect are needed.
3. Establish meteorologic stations on the lake at both the north and south end in order to estimate and characterize atmospheric forcing of water currents.
4. Examine sediment resuspension and spatial and temporal patterns of sediment movement in the lake, especially in site-specific problem areas.
5. Assess the quantity and quality of the groundwater contribution to the lake.
6. Monitor stream discharge and lake inflows on a long-term basis.
7. Monitor the extent and duration of ice cover on the lake.
8. Update shoreline and bathymetry data in areas where refined, site-specific models are needed.

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WETLANDS AND OTHER CRITICAL HABITATS

Introduction

Wetlands are clearly one of most important critical habitats in the Lake Champlain Basin. Lake Champlain wetlands include marshes immediately surrounding the lake, and swamps, bogs, and fens in other portions of the basin. Other critical aquatic habitats include the shallow water zones in bays and river mouths, and the islands in the lake.

Wetlands and other critical habitats serve a variety of important functions. They are spawning and nursery areas for lake fishes, feeding and nesting areas for waterfowl and other waterbirds, and essential habitat for many threatened and endangered species (see plenary paper by Watzin, earlier in this volume). Wetlands also store flood waters, improve water quality, and protect the shoreline from erosion.

Threats to wetlands and other critical habitats in the Lake Champlain Basin are real. Almost one half of Vermont's original wetlands have been lost, largely to agricultural conversion and development. These threats continue, as do stresses from pollution, invasion of exotic species such as water chesnut and milfoil, and other sources.

Approach and Discussion

Group members represented a large number of interest groups both public and private, with interests in research, management, and protection of wetlands and other critical habitats in the Lake Champlain Basin. A general brainstorming session was held to identify research and monitoring needs. These needs were classified into major categories and consolidated where possible. The group then voted to identify and rank priorities.

Highest Priority Research and Monitoring Needs

The following research needs are listed in relative order of importance, as identified by the voting process.

1. Compile existing data on wetlands and critical habitats. Determine the most effective inventory methodology and complete inventories for the basin.
2. Conduct surveys of biota found within Lake Champlain Basin wetlands and other critical habitats. Surveys should include endangered and threatened species as well as other birds, reptiles, amphibians, and some invertebrate species such as mussels. Major plant communities should also be included. Characterize species-habitat associations for important groups (for example, waterfowl and colonial waterbirds).
3. Investigate best stewardship methods to protect priority habitats from future degradation.
4. Study the roles of wetlands in water quality improvement, shoreline stabilization, flood control protection, fish and wildlife habitat, and other functions. Factors that might be considered include wetland size, cover type, position in the landscape, and surrounding land use.
5. Identify the economic values of Lake Champlain wetlands, such as the contribution to fisheries resources of wetland-associated spawning grounds and the contribution of wetland habitat to the maintenance of waterfowl resources. Also, examine what effect classification as a wetland or critical habitat has on land value.
6. Assess the effects of non-native nuisance aquatic species such as purple loosestrife, phragmites, Eurasian water milfoil, and water chestnut on Lake Champlain wetland functions and values.
7. Determine the role of natural water level fluctuations in the maintenance and health of Lake Champlain wetlands. Determine the effect on wetlands of modifying or stabilizing natural fluctuations.
8. Assess the potential impacts of zebra mussels on the functions of Lake Champlain wetlands. Specifically, evaluate how waterfowl production and natural communities may be impacted (especially native mussels, rare species, and fish spawning areas).

Other Research and Monitoring Needs

Other information needs that were identified are listed below. They are not listed in ranked order.

1. Examine what methods are available to assess the effects of cumulative losses of wetlands on the Lake Champlain Basin ecosystem. Apply the best method(s) in a cumulative impact assessment that is basinwide.
2. Assess the successes and failures of wetland mitigation projects in the basin, especially examining whether created wetlands provide the equivalent functions and values of natural wetlands.
3. Investigate the use of created wetlands for tertiary treatment of wastewater and water quality improvement.
4. Assess the major causes of wetland loss in the Lake Champlain Basin and examine the trends over time.
5. Assess the effects of toxic substances on wetlands and wetland biota.
6. Examine the design of buffer strips around wetlands for greater protection of functions.
7. Investigate potential financial incentives and tax structure changes that might be implemented to protect wetlands.
8. Examine the current use and effectiveness of local zoning for protection of wetlands and other critical habitats.
9. Assess what regulation changes may be needed to strengthen wetlands protection. Investigate the best ways to enforce regulations and deter illegal activities.
10. Develop a coordinated acquisition strategy for wetlands in the basin on both sides of the lake.
11. Develop a public education program on the functions and values of wetlands.

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FISH AND EXOTIC SPECIES

Introduction

Fish populations in Lake Champlain have changed dramatically over the last century. These changes have resulted from fishing pressures, stocking by fisheries managers, the effects of sea lamprey, invasions by species new to the lake, and interactions between fish species and the other aquatic organisms in the lake. Some of these changes and some of what we know about fishes and other aquatic organisms in Lake Champlain are discussed in the plenary paper by Watzin, which appears in the first section of this report.

Exotic species are those that are not native to Lake Champlain, but have been (or might be) introduced into the lake either intentionally (like rainbow trout) or unintentionally (like sea lamprey). Sea lamprey, which are parasitic as adults on large fish, have had devastating effects on sport fish populations in the lake. If the experience in the Great Lakes can be used as an example, the tiny zebra mussel, which could expand into Lake Champlain in the near future, may also have dramatic effects on natural communities and human uses of the lake.

The fish of Lake Champlain are in constant interaction with other organisms in the lake. These interactions constitute a food web. A food web can be envisioned as a series of pathways for the transfer of energy. Solar energy is used by plants (which may be microscopic) to grow and reproduce. These plants, which in lakes are present as plankton, are eaten by only slightly larger animals, usually invertebrates, which in turn are eaten by fish. In the Lake Champlain ecosystem, the largest fish, such as walleye and lake trout, are at the "top" of the food chain. Every time one organism eats another, some of the energy contained in the organism eaten is lost, so it requires a great deal of energy from the lower levels of the food web to maintain the top predators.

Predation is a powerful force for determining the size of the different trophic groups in a community. If a predator is removed from an ecosystem, the population of its former prey will increase. In turn, this increased prey population will make increased demands on its food resource, leading to a decrease in that resource, and so on for all linkages in the web.

It is impossible to alter the population structure of any component of a food web without having an impact on all connected parts of the web. In the same manner, an increase in primary production, or plant biomass production, as occurs in eutrophic situations, can also have reverberating effects through the food web.

When attempting to understand how human influences affect fish populations in the lake, it is important to remember that the fish are not isolated, but part of a complex, interdependent matrix of species. In the same way, the impact of exotics must be addressed in terms their disturbance of the historic food web dynamics of the lake.

Approach and Discussion

The session began with a discussion of the potential management strategies for fisheries. All participants agreed that over the short term, stocking of important sport fishes (such as lake trout and other salmonids) would likely continue. The consensus of the group was that a reasonable goal for fisheries management on the lake was to restore, protect and manage a productive and diverse fisheries resource. This management goal was an underlying assumption of all other group deliberations.

To begin to address research needs, participants first made individual lists of data needs for fish and exotic species. These individual lists were then consolidated and divided into five major headings: food web dynamics, human impacts, management plans, recruitment, and zebra mussels and other exotic species. Next, priorities were assigned within each subheading by allowing each person to score each item from 1 (very low priority) to 5 (very high priority). Rank was then determined by total score. Priorities across categories were then determined by allowing everyone to score their first priority item with a '3', their second a '2' and their third a '1'. Again, scores were summed for each item and ranks determined.

Highest Priority Research and Monitoring Needs

The four highest ranked research needs follow. The number one priority, understanding food web dynamics, received more than two and one-half times the votes of the next highest priority. In the view of this working group, food web studies are critical to managing Lake Champlain's fish and exotic aquatic resources. Only a slight preference was given to sea lamprey habitat and population studies (2 on the list) over recruitment studies (3 on the list).

For each major item, the specific data needs are identified. The terms "need," "expand," or "continue" are given after each item. "Need" means that the information is not being collected at this time, "expand" means that data collection is now underway but needs to be expanded, and "continue" means that adequate data collection efforts are underway and should continue. The current status of those needs for food web dynamics studies is indicated in Table 1.

1. Understand food web dynamics in Lake Champlain
 - a) Collect data on food habits, abundance, energetics, growth, and mortality of critical pelagic and benthic groups and species.
 - b) Critical groups and species (not listed in ranked order) include lake trout, Atlantic salmon, walleye, rainbow smelt, yellow perch, cisco, trout perch, sculpin, zooplankton, mysids, benthic invertebrates, and phytoplankton.
2. Monitor sea lamprey habitat and populations
 - a) Monitor density of larvae in streams and deltas: expand.
 - b) Monitor production of transformers from streams: expand.
 - c) Monitor scaring and wounding rates for major prey fish species: improve data synthesis and management.
 - d) Determine the age and sex structure of adult lamprey populations: expand.
 - e) Monitor the movement of transformers: need.
 - f) Evaluate the characteristics and quality of lamprey habitat in order to determine why lamprey are present in some streams and not in others: need.
 - g) Monitor the growth rates and patterns of use of adults in the lake: expand.

3. Determine status of recruitment of major sport species, including walleye, Atlantic salmon, and lake trout.

Walleye:

- a) Develop techniques for monitoring the abundances of juveniles: need.
- b) Evaluate the key characteristics and the quality of spawning and nursery habitat: expand.
- c) Assess the genetic variability of stocks: expand.
- d) Evaluate stocking success: expand.
- e) Determine water quality and quantity on spawning grounds: need synthesis of available information.

Atlantic salmon:

- a) Assess the genetic variability of stocks: need.
- b) Monitor the mortality rates of all age classes: continue for adults: need for juveniles.
- c) Determine the important food items in the diet: expand.
- d) Investigate sources of first-year mortality: need.
- e) Determine the rates of cormorant predation: need.
- f) Assess harvest rates: continue.
- g) Evaluate the effects of smolt size and condition on adult population size: expand.
- h) Evaluate the effectiveness of various stocking techniques: expand.

Lake trout:

- a) Investigate water quality, substrate characteristics, and water currents of spawning grounds: need.
 - b) Evaluate egg survival on spawning grounds: expand.
 - c) Locate spawning grounds: expand.
 - d) Investigate rates and causes of egg resorption before spawning: need.
 - e) Evaluate genetic differences between hatchery strains: expand.
4. Conduct pre- and post zebra mussel invasion studies. No studies are currently underway, so all priorities are needs.
- a) Monitor the appearance and distribution of zebra mussels.
 - b) After arrival, examine the effects of zebra mussels on the lake's food webs and on threatened and endangered species (especially native mussels).
 - c) Monitor the diets of potential zebra mussel predators before and after invasion.
 - d) After arrival, determine the effects of zebra mussels on walleye and lake trout spawning grounds.
 - e) Determine the reproductive viability of zebra mussels.

Other Research and Monitoring Needs

These additional research and data needs are not ranked; categories are listed alphabetically.

Food Web Dynamics:

- 1. Expand forage base monitoring.

Table 1. Data existing and needed for critical groups and species of aquatic organisms in Lake Champlain.

<u>Species</u>	<u>Need/Status</u>				
	<u>Diet</u>	<u>Abundance</u>	<u>Energetics</u>	<u>Growth</u>	<u>Mortality</u>
Lake trout	Expand	Continue	Available	Continue	Expand
Atlantic Salmon	Expand	Continue	Need	Continue	Expand
Walleye	Need	Expand	Available	Expand	Expand
Rainbow smelt	Expand	Expand	Available	Expand	Expand
Yellow perch	Need	Need	Available	Expand	Need
Cisco	Need	Need	Available	Need	Need
Trout perch	Need	Need	Need	Need	Need
Sculpin	Need	Need	Need	Need	Need
Zooplankton	Need	Expand	Need	Need	Need
Mysis	Need	Need	Available	Need	Need
Benthos	Need	Need	Need	Need	Need
Phytoplankton	Not needed	Need	Need	Need	Need

2. Develop multispecies management models.
3. Evaluate perch and smelt as predators.
4. Develop a whole "ecosystem" model.
5. Study zooplankton and mysid populations.

Human Impacts:

1. Monitor threatened and endangered species.
2. Determine effect of land use changes on nearshore habitat.
3. Monitor concentrations of toxic substances in fish flesh.
4. Determine the value of fisheries to the public.
5. Identify and monitor indicator species.
6. Determine the effects of fishing tournaments on fish populations.
7. Determine the status and effects of commercial hook and line fishing on yellow perch and other populations.
8. Evaluate user conflicts.

Management Plans:

1. Revise and develop management plans.

Recruitment:

1. Evaluate role of wetlands in recruitment of key species.
2. Investigate natural reproduction of salmonids.

3. Determine and establish most effective fish stocking procedures.

Zebra Mussels and Other Exotic Species:

1. Identify the critical level of sea lamprey control for achieving reasonable sport fisheries populations.
2. Design and conduct zebra mussel education and technical assistance programs.
3. Determine the impact of milfoil on littoral community structure and function.
4. Determine methods for prevention of exotic introductions.
5. Evaluate methods of control of zebra mussels, including those on water intakes.

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WILDLIFE

Introduction

Although fish may be Lake Champlain's most obvious living resource, many other animals depend on the lake for at least some part of their lives. The diversity of birds, mammals, reptiles, and amphibians using the lake contribute to the quality of the lake both as an ecosystem, and as a recreational resource. Human activities have influenced the populations of many of the species of animals, sometimes causing increases in numbers, sometimes decreases.

Human development along the shoreline fragments the habitat of species living in shallow water or at the land-water interface. Introduced species such as Eurasian watermilfoil, *Phragmites*, and water chestnut change the shoreline habitats where they are present, and the impacts of these changes on wildlife are not well known. In other ecosystems, it has been shown that top predators -- often birds or mammals -- are particularly vulnerable to toxic substances such as PCBs, which bioaccumulate through the food chain. It is not clear whether this is a problem in Lake Champlain.

The best inventory data for wildlife are for game species and colonial birds. Large numbers of birds use the Lake Champlain islands as nesting grounds, including ring-billed gulls, double-crested cormorants, great blue herons, and other colonial birds. The increase in numbers of ring-billed gulls in the last 50 years has been at least partly responsible for the decline of the common tern, now listed as endangered in Vermont, as the gulls crowd the terns out of their traditional island nest sites. Double-crested cormorants arrived just over 10 years ago and already have more than 1,000 nests on Young and Four Brothers Islands. Migrating waterfowl also use lake habitats, especially the wetland areas, in large numbers each year.

Efforts to monitor nongame species of wildlife lag far behind game species and waterbirds, although some excellent work is underway through the Nongame and Natural Heritage Program and other organizations. Information about the occurrence and distribution of amphibians, reptiles, and small mammals, as well as selected invertebrates, are needed.

An inventory of habitat types and their extent within the Lake Champlain Basin is also important and could provide a more cost-effective basis for monitoring trends of many wildlife species. Such an inventory could easily be combined with the efforts of other working groups (for example, wetlands).

Approach and Discussion

The group began by discussing the state of knowledge about wildlife in the Lake Champlain Basin and then made a comprehensive list of concerns and data needs. The initial list ranged from the need for baseline occurrence data to concerns about management and economics. Chief among management concerns was the threat of development and the loss, fragmentation, and conversion of habitat. Other concerns related to the potential effects of toxic substances on wildlife and to the effects that management for featured species might have on nontarget species (for example, the effects of lamprey control and beaver management on other species). The general lack of knowledge about the population dynamics of most wildlife species was also highlighted.

The group then had a lengthy discussion of each data need on the comprehensive list, allowing all participants to appreciate the justification and scope of each proposed project. By the end of this discussion, most of the group had an adequate appreciation of the state of knowledge about wildlife species and their habitats in the Lake Champlain Basin. Both past and existing sources of inventory data, as well as plans for supplementing these programs, were discussed.

The final step was to examine the items on the master list of priority projects and develop a final ranking of research and data needs. Again, there was considerable convergence on the most important items and little or no disagreement about the final rankings of importance.

Highest Priority Research and Monitoring Needs

Research and monitoring needs for wildlife resources were described and ranked as follows:

1. Document the occurrence and distribution of wildlife species in the Lake Champlain Basin. Emphasize reptiles and amphibians, selected invertebrates, small mammals, and rare species of all taxa.

ECOSYSTEM HEALTH

Introduction

An interest in ecosystem health comes from a desire to restore and maintain the biological integrity of Lake Champlain and its surrounding watershed. In the Great Lakes region and other parts of the country, managers have begun to realize that simply regulating the concentrations of chemicals entering a body of water from discharge pipes is not sufficient to restore and maintain a healthy and diverse ecosystem. It is important to look at the assemblages of organisms living in the system and use information about their health and community structure as a measure of ecosystem function. Further discussion of this idea appears earlier in the report, in the keynote paper by Trefor Reynoldson.

At the national level, the U.S. Clean Water Act calls for restoration and maintenance of "the chemical, physical, and biological integrity of the nation's waters." The EPA is asking the states to adopt measures of biological integrity as part of their water quality standards by 1993. This requirement recognizes that techniques for assessing ecosystem health are still being refined and that a considerable degree of site-specificity is necessary.

In order to assess and monitor the health of the Lake Champlain ecosystem, managers will need to define clearly what constitutes a healthy ecosystem. Then they must assess the available data as a measure the status of the ecosystem, identify the gaps in that data, develop strategies for filling those gaps, and implement those strategies--recognizing the limitations of available time and money.

Approach and Discussion

The session began with comments from Mary Henry (U.S. Fish and Wildlife Service) and Trefor Reynoldson (Environment Canada). Referring to management efforts underway in the Great Lakes Basin, they reported five points they regarded as central to evaluating and managing ecosystem health.

1. Historical data should form the basis for what is normal.

2. Update inventories of land use and habitats in the Lake Champlain Basin. All inventory data should be stored in digital (computer) format.
3. Evaluate the effects of human development on wildlife and wildlife habitat. Although a far-reaching goal, this is a persistent concern.
4. Collect or refine population data on selected wildlife species, including waterfowl, colonial waterbirds, neotropical migrants, raptors, amphibians, and reptiles.
5. Identify wildlife species that serve as indicators of habitat quality and environmental health.
6. Examine the effects of exotic plant and animal species on habitat quality for wildlife.
7. Develop a database of wildlife species-habitat associations.
8. Evaluate the contributions of wildlife, including both game and nongame species, to the economy of the basin.
9. Investigate the relationships and interactions between colonial waterbirds and other wildlife and fish in the lake.
10. Assess the impacts of beavers on habitat for other wetland species.
11. Examine the impacts of toxic substances on wildlife.

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2. In order to restore a system you must know what uses you are attempting to restore it for, and hence what uses are impaired.
3. The fate of indigenous species, particularly natural top predators, is a good indication of the overall health of the system.
4. A model that includes trophic dynamics is necessary for appropriate management.
5. If we can provide for a healthy biota, then de facto, we protect all uses of the lake.

The group then discussed a list of impaired uses from the Great Lakes Basin, and developed a list of impairments for Lake Champlain. These included altered communities of plants and animals, habitat deterioration, reductions in water clarity, algal blooms, elevated levels of contaminants in some fishes, reduced recreation use and enjoyment of the lake, and others. From this list, a list of the elements of ecosystem health was generated. The elements of health were split into four broad categories: community-level factors (for example, species diversity, species richness, resilience, productivity, turnover rates), population-level factors (for example, abundances, age structure, reproductive success, genetic diversity), physical factors (for example, clear water, no toxic contaminants), and cultural factors (for example, beauty, access, management structures, and human use).

This information was used to generate a preliminary definition of ecosystem health for Lake Champlain. In the Great Lakes Basin and other areas, definitions are quite specific concerning particular components of the ecosystem. Because many felt that critical data on populations and communities were lacking for Lake Champlain, this initial definition is quite general.

The following preliminary definition is suggested:

A healthy Lake Champlain ecosystem is one characterized by diverse assemblages of self-reproducing species that are in dynamic equilibrium. Species present should be predominantly natives, and depend on Lake Champlain waters for some portion of their life cycle.

Four conditional statements were viewed as necessary to explain and amplify this definition:

1. The Lake Champlain ecosystem includes its drainage basin, which is a source of major inputs of materials and energy to the Lake. The health of that

ecosystem shall be judged by considering the status of organisms and communities of organisms that are directly dependent on the lake for some portion of their life cycle or daily activities.

2. The ecosystem includes species that depend on Lake Champlain for only a portion of their life cycle or only for certain activities, for example, mink, migratory waterfowl, and American eel.
3. The definition is not meant to exclude stocking to augment sport fisheries populations.
4. Dynamic equilibrium refers to the condition of populations that show neither increasing nor decreasing trends over the long-term, although short-term variations are expected.

The discussion then turned to identifying research needs. Research priorities were identified and articulated for three of the four components of ecosystem health identified earlier: community structure, population dynamics, and physical factors. Cultural factors were not addressed because they were covered in other groups (for example, the Land and Shoreline Use group). To determine top priorities among the needs identified, each person was given four votes that could be applied to the three categories in any combination.

Highest Priority Research and Monitoring Needs

Based on the voting and subsequent discussion, the group identified and amplified four top priorities:

1. Examine Lake Champlain food webs for critical linkages and to provide data for bioenergetics modeling. This would provide a tool for selecting indicator species and the necessary information for production estimates.
2. Determine the species composition of Lake Champlain communities beginning with benthic organisms. Benthic communities are stationary, cost-effective to monitor, provide a large amount of information on habitat characteristics and quality, and there is good background information about them in the literature.

3. Select ecosystem health indicator species for Lake Champlain.
4. Examine the age-class structure, growth, reproduction and recruitment for designated species. These species should include both top predators and lower level species. Stocked or manipulated species should not be used, particularly for reproduction and recruitment studies.

Other Research and Monitoring Needed

Other research and monitoring needs are grouped according to the general categories of ecosystem health information.

Community Structure:

1. Identify important habitats and prioritize habitat types for research and characterization.
2. Identify community responses to nutrient and toxic inputs.
3. Establish long-term monitoring stations for characteristic communities.

Population Dynamics:

1. Perform manipulative field and laboratory studies to establish cause and effect linkages pertaining to food web dynamics and community response to environmental stresses.
2. Determine population characteristics for potential indicator species.
3. Examine the health of individuals; relate individual impairment to ecosystem response.
4. Compile existing data on Lake Champlain populations.
5. Examine populations of fish-eating birds and other wildlife.

Physical Properties:

1. Monitor chemical and contaminant concentrations in lake water and sediments.
2. Examine the physical characteristics of habitats including their hydrology, geology, and chemistry.

Concluding Comments

The results of this session offer two strong and valuable insights. First, the information needed for assessing ecosystem health is the same information needed in many other aspects of living resources management. Research might occur as part of an integrated set of studies needed to address other subject areas as well as ecosystem health.

Second, there is a strong need for a structured approach to refining the definition of ecosystem health. The participants in this working group differed widely in their thinking. Some wished to rely heavily on work in the Great Lakes. Others felt that we needed to develop data specific to Lake Champlain before to going beyond generalities. Still others felt that we already know enough about the lake to develop a more detailed definition, perhaps including selection of indicator species. There is a strong analogy between this situation and the one that surrounded the development of a definition of "species rarity" before the establishment of the International Union for the Conservation of Nature and the Natural Heritage Programs. Perhaps a similar approach to that used by the Natural Heritage Program, but based on measures of ecological structure and function, might be useful in both defining and quantifying ecosystem health.

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ECOSYSTEM MODELING

Introduction

Modeling can be used as a framework to organize information; it can facilitate a more complete understanding of complex interactions in a system; and it can be used as a vehicle to predict the effects of various management scenarios on lake water quality and the composition of the lake's biota. An ecosystem model would simulate the hydrology of the lake, the fate and effects of nutrients in the lake, and the interactions and community composition of the fish and other organisms living in the lake. Such a model would be constructed in parts, beginning with the hydrology, and probably ending with an integrated model of the lake's food webs. It would draw on data collected in most field studies and monitoring programs in existence or initiated under the auspices of the Management Conference.

The development of an integrated model for Lake Champlain must be guided primarily by management questions, with the goal of optimizing short and long-term strategies for achieving management goals. Some examples of the kinds of management questions which might be addressed by modeling include the following:

1. What are the absolute loading rates of selected pollutants from both point and nonpoint sources, including in-place contaminated sediments?
2. Are the concentrations of those pollutants in the water column, sediments, and biota at steady-state with respect to each other and these loadings?
3. What are the relative contributions of each source to the total annual loading of Lake Champlain?
4. What is the optimum design for sampling stations in Lake Champlain for cost-effective temporal and spatial monitoring?
5. Which bays (for example, Missisquoi, Malletts, Cumberland) act as net sources or sinks of contamination to the Main Lake and to what extent?

6. What is the time scale relationship between pollutant loading and accumulation in water, sediment, and biota?
7. How do various management programs affect the goals of other management programs (for example, nutrient control, toxic control, fish stocking, erosion control)?
8. If no remedial action is taken, what are the long-term impacts for Lake Champlain of current pollutant loading rates?
9. What optimum mix of priority pollutant load standards (point and nonpoint) must be implemented to achieve a desired water quality in Lake Champlain and how long will it take?
10. What long-term monitoring is required to verify the future response of the system to remedial actions?

One principal benefit from the modeling effort will be the definition of the relationship between external nutrient and toxic loadings and in-lake eutrophication and toxic chemical exposures and responses. The model will provide estimates of the response of the lake to a variety of potential regulatory and remedial actions with respect to point and nonpoint source inputs of nutrients and toxic chemicals. Specific results and benefits might include:

1. Predictions of long-term hydrodynamic current patterns between local embayments, the Main Lake, the South Lake, Northeast Arm, and outer Mallets Bay.
2. Predictions of potential human health hazards from nuisance algal blooms and bioaccumulation of toxic chemicals in fish.
3. A synthesis of the data generated through most Lake Champlain studies into a comprehensive, system-level understanding of transport and transformation of priority pollutants in Lake Champlain.
4. Development of a model(s) which can be used as a long-term management tool for predicting potential impacts of municipal, industrial, and agricultural development on Lake Champlain water quality.

Approach and Discussion

The working group discussed a systematic modeling approach for Lake Champlain. Model components would be developed in a way that would describe the relationship between inputs of pollutants and in-lake transport, transformation, fate, and effects. To ensure efficiency in model development, scientific credibility, and management utility, the conceptual design must be undertaken in concert with monitoring and other field data collection and with studies of process and mechanism. The constraints imposed by laboratory and field observations will be extremely important in determining the model's operational feasibility.

A significant amount of data will be necessary for model calibration and application to Lake Champlain. In fact, the modeling effort might profitably guide and optimize monitoring efforts. Initial screening models can suggest a scientifically credible spatial and temporal monitoring plan for Lake Champlain, estimating such things as the number of sampling sites, their locations, the number of cruises per season, and other factors. The modeling team should make this evaluation a top priority at the beginning of the model development period.

Highest Priority Research and Monitoring Needs

The modeling effort discussed above will depend on the collection of four general categories of data and information:

1. System-specific physical data - includes extensive morphometric, hydrologic, and water circulation data on the Lake Champlain Basin.
2. External loading and forcing data - includes careful measurement of both point and nonpoint source loading of all materials from all significant sources as well as meteorological data (wind speed and direction, air and water temperature, solar radiation).
3. Process-related data - includes field and laboratory experiments on chemical properties, transport processes, chemical transformation processes, and bioaccumulation processes.
4. Field observations - includes systematic measurement (spatial and temporal coverage consistent with problem specification) of all model state variables

and, whenever possible, measurement of key fluxes and transport rates. These data are essential for calibration and confirmation of the model.

Other Research and Monitoring Needs

A more detailed listing of data needs from various compartments is given in Table 1. These data needs should be considered a general overview to the types of parameters required for modeling purposes and subject to change as research and management agendas develop.

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This was an evening session open to all participants.

Table 1. Generalized description of modeling parameters needed for Lake Champlain.

Parameter/Matrix	Lake Water	Tributary Loads Water	Atmospheric Loads Water	Lake Sediment	Lake Pore Water	Lake Biota
Diss. Priority Toxics	A	A	A			
Part. Priority Toxics	A	A	A			
Total Priority Toxics	S	S	S	A	A	A
Total Phosphorus	A	A	A	A	B	B
Sol. React. Phosphorus	B	B	B	C	B	
Nitrate	B	B	B	C		
Ammonia	B	B	B	C	C	
TKN	B	B	B	C	C	
Diss. Avail. Silica	B	B	B	C	C	
Chloride	A	A	A			
Conductivity	A	A	A			
Temperature	A	A	A			
Suspended Solids	A	A	A			
Size Fractions	B	B				
DOC	A	A			B	
TOC	A	A		A	B	
Chlorophyll-a	A	A				
Hardness	A	A	A		B	
pH	A	A	A	A	A	
Alkalinity	A	A	A			
DO	A	A				
Total Incid. Radiation	A	A	A			
UV Light	A	A	A			
Light Extinction	A	A	A			
Porosity				A		
Grain Size				A		
% Solids				A		
Eh				A	A	
River Flow		A				
Wind Vel. Director	A		A			
Biomass						C
Gut Contents						A
Growth Rate/Age						A
Phytoplankton Major						
Groups/Biomass						A
Lipid						A

Legend

A = First Priority

B = Second Priority

C = Last Priority

S = Sum of Particulate and Dissolved

* = Need to Calculate Wet and Dry Deposition

DATA MANAGEMENT AND GEOGRAPHIC INFORMATION SYSTEMS

Introduction

The Lake Champlain Management Conference will be spending significant amounts of money on data collection over the life of the Lake Champlain Basin Program. If a well-orchestrated data management and quality assurance program is not developed up front, the Conference risks wasting that investment. In the Chesapeake Bay Program, inadequate initial planning for quality control and data management resulted in the collection of unreliable data necessitating recollection of a significant amount of data to compensate for that error. Much of the data was also initially stored in relatively inaccessible formats. The development of a data management policy to assure quality data collection and the future availability of data to all interested parties will ensure that this scenario is not repeated in the Lake Champlain Basin Program.

A Geographic Information System (GIS) is a geographic analysis software tool that requires formal information management practices for using spatially referenced data. Many people confuse "GIS" with the larger arena of data and information resources management. Because much of the data that will be developed as part of the Lake Champlain Management Conference's research, management, and planning efforts will be spatial in nature, GIS has become the umbrella term for everything related to data management and analysis. Any final data management plan, however, must address all data types.

Approach and Discussion

The discussions in this group focused on the need for data management standards, the relative merits of a centralized versus distributed data access system, the need for a function to ensure suitable data documentation and quality control, the need for a staffed data clearinghouse for all projects and a full time database administrator, and the need to underwrite the development of "tools" so that many people can access and utilize the information held in a common repository. After a lively discussion, the group agreed by consensus on a series of recommendations to the Management Conference concerning data management and GIS.

General Recommendation

The Lake Champlain Management Conference should establish a formal, staffed information resources management function. This function should provide GIS data layer management, data tracking, data archiving, data distribution, and GIS product development. All data should be developed and stored in a format that is generally accessible to all future data users.

Highest Priorities for Data Management

Specific priorities for data management follow, in no particular rank order.

1. Adopt standards for data quality control and quality assurance. Guidelines should ensure that appropriate spatial and temporal references are included in all data bases that are developed. Protocols should be geared towards attaining a shareable database (standards for spatial data are currently under development, standards for other types of data should also be addressed). The group noted that standards are critical, but should not limit research.
2. Establish a data clearinghouse for the Lake Champlain Basin Program. The clearinghouse should be staffed with a data administrator and perform the following functions:
 - a) provide a vehicle for data storage, retrieval, and archiving for all new studies,
 - b) provide a review and advising role to the Management Conference's Technical Advisory Committee on all research proposals containing a GIS or data collection component,
 - c) facilitate data coordination and data sharing,
 - d) compile and catalog existing and historic data through the recommended clearinghouse, and
 - e) develop tools to assist access to all data layers and databases.
3. Cooperate, coordinate, and capitalize on other data development efforts in the region, such as the Northern Forest Land Study.

4. Build data partnerships between federal and state agencies, researchers, local government, and citizens. Facilitate the sharing of existing data available at the local government and regional planning commission level.
5. Compile and set priorities for the development of common, basin-wide data layers. Ensure that the needs of the research, management, and planning communities and all considered in this process. The data clearinghouse recommended above could oversee development of these common data layers.

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PUBLIC FORUM

Introduction

In an effort to solicit public input on the research and monitoring needs concerning Lake Champlain, an evening public forum was held. A panel consisting of the following people was present to receive comments and answer questions from the public:

Lisa Borre, Lake Champlain Coordinator, Vermont Agency of Natural Resources
Art Cohn, Vice-chair, Vermont Citizen's Advisory Committee
Jim Connolly, Lake Champlain Coordinator, New York Department of
Environmental Conservation
Alan McIntosh, Director, Vermont Water Resources and Lake Studies Center
at the University of Vermont
Lee Steppacher, Lake Champlain Coordinator, U.S. Environmental Protection
Agency
Mary Watzin, Executive Director of the Lake Champlain Research Consortium

Approach and Discussion

Following a brief introduction to the workshop and the Management Conference, the floor was opened for comments from members of the public. A few people came forward to share their opinions, but comments were limited. Dividing into small discussion groups created a more comfortable atmosphere, and from these small group discussions, a variety of public concerns emerged.

Public Concerns

These concerns are not prioritized, and represent a synthesis of the input from the persons attending the public forum.

Water Quality: Concerns about the quality of Lake Champlain waters was a broad-based; individual issues that were raised included high phosphorus levels and eutrophication problems in the lake, the leaching of raw sewage from faulty septic systems, and toxic contaminants.

Exotic species: Zebra mussels, sea lamprey, and water chestnut were all mentioned as species of public concern. Approaches for enlisting water treatment plant personnel and the general public to help watch for the arrival of zebra mussels were discussed. One suggestion was to work with the state police to pass out information about zebra mussels to boaters. Boaters could then ensure their own activities do not result in introductions and watch for mussels as they travel the lake.

St. Albans Bay: Continuing water quality problems in the bay are of great concern to area residents. Milfoil invasion, the movement of the sludge bed from the sewage treatment plant into beach areas, and the failure of septic systems around the bay were all mentioned as particular concerns.

Fisheries issues: Concerns about the forage base available to larger sport fishes and the effects of sea lamprey control and phosphorus control on fish populations were voiced. Another issue was the public perception that the lake's fishes are contaminated, even when that perception may not be warranted.

Overuse of the lake: The increasing numbers of boaters on the lake was a worry to some. Concern was expressed about maintaining the quality of the recreational experience on Lake Champlain.

Public input: Community groups are available and interested in lake-related issues. The Management Conference should consider tapping into the particular talents and expertise of citizen groups such as conservation commissions, sport fishing groups and others.

Public education: Many people felt that better public education -- about fish contamination, human impacts, new scientific knowledge, and other topics of concern to lake users -- is essential for the development of more responsible and informed lake users. Several ways in which this might be accomplished were discussed, including public seminars or lecture series, publications, and hands-on activities.

Mapping the Lake Champlain Basin: The advantages of a geodetic control system for better spatial data management were presented.

SYNTHESIS OF COMMON HIGHEST PRIORITY RESEARCH NEEDS

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It is clearly evident that elevated concentrations of phosphorus and toxic substances, and the biological manifestations of their presence in the lake, will be a central focus of the Comprehensive Pollution Prevention, Control, and Restoration Plan for Lake Champlain that the Management Conference must develop. Not surprisingly, the single greatest recurring theme across working group sessions is the need to document the extent and effects of water quality impairments on the Lake Champlain ecosystem. Whether it be examining the effects of reduced water quality on recreation activities, understanding the effects of toxic substances on the lake ecosystem, or predicting how water currents might distribute pollutants in the lake, water quality concerns appear paramount in no less than ten of sixteen working group session reports.

Four Common High Priority Needs

Four particular areas deserve primary and immediate attention: phosphorus loading and transport studies, toxic substance investigations, hydrodynamic support studies, and ecosystem health and living resources investigations. Each of these is explained below.

Phosphorus Loading and Transport Studies. In order to plan compliance schedules and management actions to control phosphorus concentrations in the lake, it is necessary to answer two primary questions: (1) how much phosphorus is discharged into the lake and its watershed and from where, and (2) what happens to that phosphorus once it enters the basin. The 3-year Diagnostic and Feasibility Study underway in the states of New York and

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Vermont will provide much of the necessary information on point source loading of phosphorus. The essential next steps are to assess the magnitude of nonpoint source loading and to investigate the transport, fate, and effects of phosphorus entering the basin from any source. These needs appear at the top of the list in both the Nutrient Cycling and Watershed Processes session reports.

In order to estimate nonpoint source loading of phosphorus, information about land cover types and land use activities and about watershed hydrology will be critical. Runoff from agriculture, urban areas, golf courses, forests, and other land use types probably all contribute varying amounts of phosphorus to the watershed. It will be important to know not just the amount of phosphorus leaving each land use category, but also the total amount exported by each watershed within the basin. Management actions might focus on those watersheds that contribute the greatest amount of nonpoint source pollution to the lake.

Predicting what happens to phosphorus once it enters the basin depends on an understanding of water flow patterns in the basin, phosphorus behavior in the water and sediments, and phosphorus availability to and uptake by algae and other plants in streams and in the lake. Phosphorus is transported by water currents and reacts with other substances in the water column, including other chemicals and suspended particles. The chemical form of phosphorus may change and a portion may be stored in stream or lake sediments. Phosphorus can also be released from the sediments under low oxygen conditions and other circumstances.

Management actions ultimately must target those phosphorus sources that are the largest contributors to eutrophication of the lake. Only when we understand how phosphorus is transported through the basin will we be able to do this. Currently, if 100 pounds of phosphorus are discharged 20 miles upstream from the lake, we cannot predict how much of it reaches the lake, on what timetable, or in what form (for example, is it a bioavailable form that will contribute to nuisance algal blooms). Whether by point source or nonpoint source reductions, if management actions are to result in water quality improvements, we must understand how phosphorus inputs anywhere in the watershed translate into phosphorus concentrations and algal blooms in the lake itself.

Toxic Substance Investigations. Concerns about the potential impacts of toxic substances in Lake Champlain water, sediments, and biota are apparent in many session reports, but basic data on concentrations of these substances in the basin are scanty at best. The Management Conference is currently supporting an initial examination of toxic substances in lake sediments. This assessment will begin to provide some of the necessary information, but an ongoing effort in this arena will be critical. Once we know which toxic substances

are present in the basin in significant concentrations, we must identify the sources of those contaminants, document how they are transported and accumulate in the lake system, and examine their effects on living resources and, potentially, human health.

In the Great Lakes Basin, a high percentage of some contaminants seem to have an atmospheric source. Whether this is also the case for the Lake Champlain Basin is unknown. Information on cloud water concentrations and wet and dry deposition of contaminants will be extremely important to fill this information gap. Because the Lake Champlain Basin contains 18 times more surface area in land than in water, it is also important to begin to investigate how substances move through the watershed to the lake.

Studies of the effects of the toxins that are present on living resources in Lake Champlain must begin as soon as information on concentrations is available. Effects can be acute -- an organism dies -- or more subtle, such as reduced growth and reproduction or changes in behavior. Both acute and subtle, but chronic, effects on single species can translate into more widespread effects on the ecosystem as a whole.

Management actions concerning toxic contaminants should focus on those substances that are having detrimental effects on living resources or the health of the human population living in the basin. Individual actions might be aimed at both eliminating toxins at their source and restoring particular habitats and communities in the lake degraded by the presence of contaminants. Until additional data are available, the specific course of action will remain unclear.

Hydrodynamic Support Studies. Understanding and predicting the transport and fate of phosphorus and toxins in the lake require an understanding of hydrodynamics, or water flow patterns. Hydrodynamics is the primary driving mechanism for transport of sediment, nutrients, toxins, and other substances in the lake.

Many groups identified the development of a whole-lake, predictive model as an interim goal for better management. A predictive model could be used as a tool to track the transport and fate of pollutants in the lake and to evaluate various management scenarios. Modeling can also be used as an integrating factor, drawing related, but disconnected information together. It can provide a systematic approach to answering management questions.

Because a model is only as good as the data available to validate and run it, model development activities must proceed hand-in-hand with a strong field monitoring program in hydrodynamics. Hydrodynamic field studies should include measurements of currents, temperature profiles, and water exchange rates between the five major basins in the lake.

Ultimately water quality parameters must also be monitored if the model is to be used for management decisions.

Ecosystem Health and Living Resource Investigations. The living resources in the Lake Champlain Basin exist in a complex ecosystem that includes the open waters of the lake itself, the rivers and streams that drain into the lake, the wetlands and shallow water flats around the perimeter of the lake, the lake islands and other areas. All parts of that ecosystem are affected to varying degrees by water quality impairments, but the greatest concerns about managing living resources now center on those organisms living in the lake itself. This is evident in the Nutrient Cycling, Toxic Substances, Fish and Exotic Species, and Ecosystem Health session reports.

A number of management actions underway and proposed for Lake Champlain may have significant effects on the lake's aquatic communities. The sea lamprey control program and salmonid stocking efforts may increase the numbers of predators feeding on forage fish in the lake. Basin-wide management of phosphorus inputs, by decreasing nutrient concentrations in the lake, will alter the phytoplankton food base available to zooplankton and forage fish. We currently cannot predict how Lake Champlain aquatic communities will respond to these changes. For example, we don't know whether the forage base is sufficient to support increased numbers of lake trout under current levels of stocking of other salmonids. We also don't know how other nongame fishes in the lake may respond to increased populations of lake trout and a decreased forage base. If the experience in the Great Lakes can be used as an example, the tiny zebra mussel, which could expand into Lake Champlain in the near future, may also have dramatic effects on natural communities and human uses of the lake.

Field studies of the structure and function of the lake's aquatic communities are needed in order to predict the response of those communities to management activities. In particular, it will be critically important to begin to understand how species interact in the lake. We must document the linkages in the lake's food web, the rates of consumption at each level in the system, and the patterns of predation and competition among species.

This information is also critical for approaching the notion of "ecosystem health." Those species that might be the best indicators of the health of the ecosystem will also be those species that are critical or pivotal links in the food web, or alternatively, those species that are natural integrators -- those whose survival depends on several other important links lower in the food web.

To the extent that we can identify healthy and degraded portions of the lake, it would also be important to begin to identify characteristic communities in both these conditions. That information could then be used in a predictive sense to assess and monitor the status of those portions of the lake where health is unknown.

Concluding Comments

These proceedings outline an enormous agenda for research and monitoring on Lake Champlain. Other topics not included in the four areas outlined above cannot be ignored if a truly comprehensive management plan is to be developed. However, by targeting the four areas outlined above, some of the most critical and immediate needs will be addressed.

As information begins to come in from early investigations, this agenda will probably need refinement, alteration, and embellishment. It may be prudent to consider a process whereby this agenda is periodically reassessed and modified. The Lake Champlain Research Consortium would welcome the opportunity to continue to work with the Management Conference and its Technical Advisory Committee in these periodic reassessments.

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