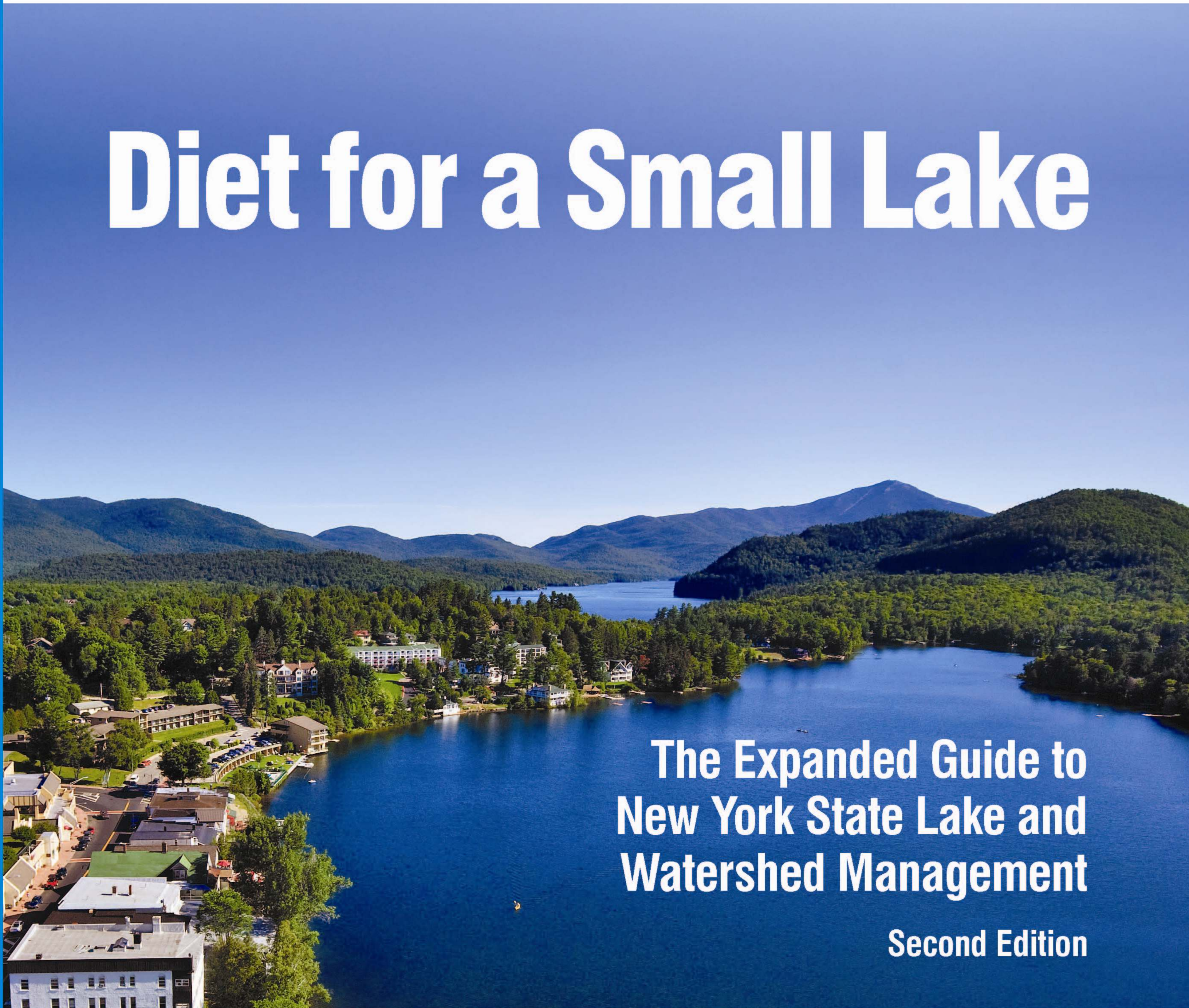
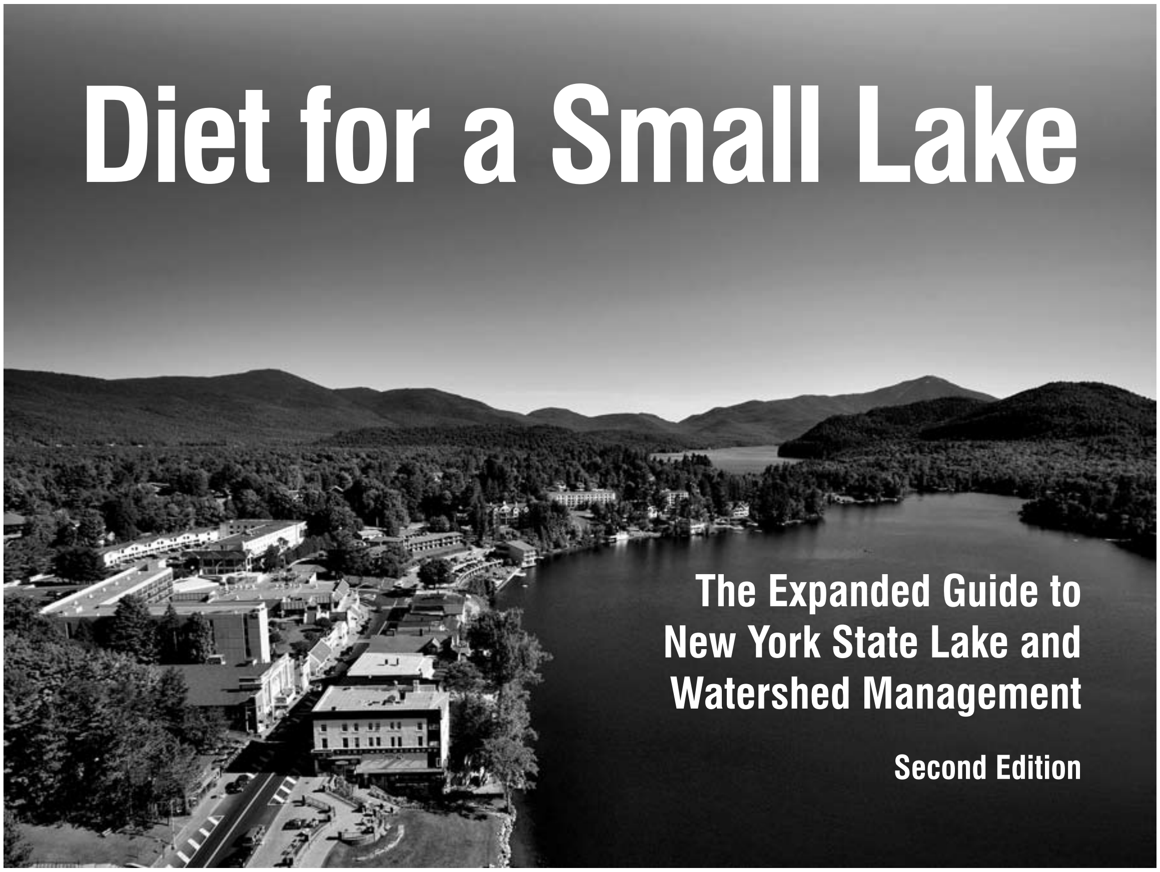
Diet for a Small Lake



The Expanded Guide to New York State Lake and Watershed Management

Second Edition

Prepared by the New York State Federation of Lake Associations, Inc.
in cooperation with the New York State Department of Environmental Conservation



PHOTOGRAPH BY CARL HEILMAN II / WILD VISIONS, INC.

Prepared by the New York State Federation of Lake Associations, Inc.
in cooperation with the New York State Department of Environmental Conservation

Diet for a Small Lake

The Expanded Guide to New York State Lake and Watershed Management

Second Edition, 2009

Citation: NYSFOLA. 2009. *Diet for a Small Lake: The Expanded Guide to New York State Lake and Watershed Management*. New York State Federation of Lake Associations, Inc.

CONTRIBUTORS
Scott Kishbaugh
Sharon K. Anderson
Rebecca Schneider
Lyle Raymond
John Foster
Jim Cunningham

EDITORIAL CONTROL
Sharon K. Anderson
Nancy Craft
Scott Kishbaugh
Nancy Mueller
George C. Kelley

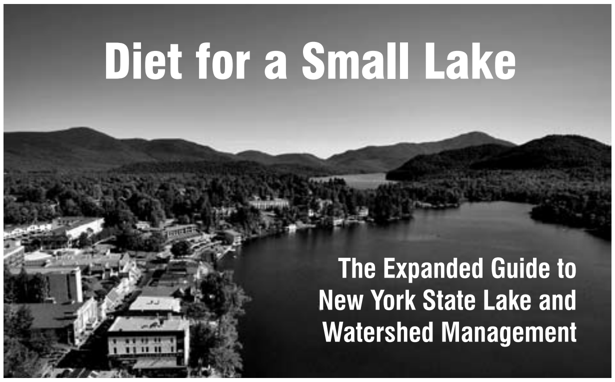
Cover photograph copyright Carl Heilman II / Wild Visions, Inc., used with permission.
Book design and typesetting by Roy Reehil, The Forager Press, LLC.
Printed in the USA on recycled paper.
See Preface Two for more details, including artists and others.

Cataloging Data

New York Federation of Lake Associations, Inc.
Diet for a small lake: the expanded guide to New York State lake and watershed management. 2d ed. / NYSFOLA in cooperation with the New York State Department of Environmental Conservation: NYSFOLA: 2009.
xv, 352 p. : ill. ; 27 cm.
Includes index, bibliographical and internet references.
ISBN 978-0-9823547-0-4 (Hard cover)
ISBN 978-0-9823547-1-1 (Soft cover)
1. Lakes—Management. 2. Watershed management. 3. Lake ecology. 4. Fishery management. I. New York (State) Department of Environmental Conservation. II. Title.

Copies of this book are available from New York State Federation of Lake Associations, Inc.
Phone/Fax: 1-800-796-3652 • www.nysfola.org

Contents



Photograph by Carl Heilman II / Wild Visions, Inc.

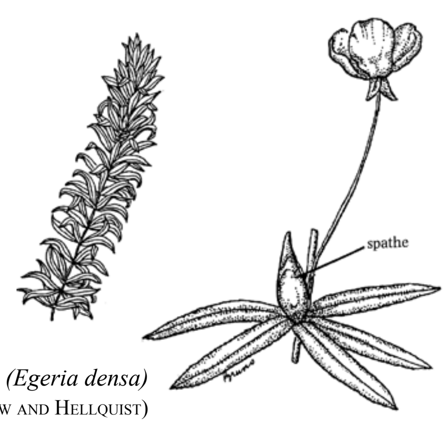
4 Problem Diagnosis: Seeing Beyond the Symptoms

5 Fisheries Management: Matching Expectations to Reality

6 Aquatic Plants: Not Just Weeds

7 Algae and Other Undesirables: Getting Rid of Yuck

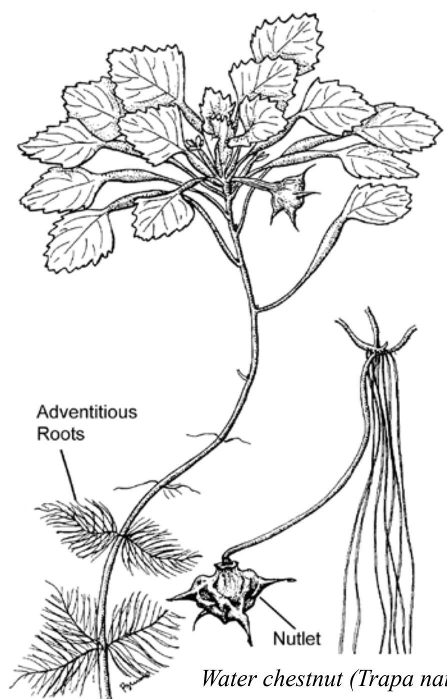
Fanwort (Cabomba caroliniana)
(CREDIT: CROW AND HELLQUIST)



Brazilian elodea (Egeria densa)
(CREDIT: CROW AND HELLQUIST)

Zebra mussels (Dreissena polymorpha)
Top: Single zebra mussel. Bottom: Colony of zebra mussels attached to a hard surface (clam).
(Credit: Wendy Skinner)

Appendices



Water chestnut (Trapa natans)
(CREDIT: CROW AND HELLQUIST)

Preface to the Second Edition

Since its inception in 1983, the goal of the New York State Federation of Lake Associations, Inc. (NYSFOLA) has been to provide a source of dependable information and resources to the diverse lake associations across New York State. The first edition of *Diet for a Small Lake,* published in 1990, was intended for a growing group of lakefront property owners who had a wide-ranging level of understanding about lakes, streams and watersheds. This expanded and updated version of *Diet for a Small Lake* was prompted by questions from NYSFOLA members as well as new developments in watershed management techniques.

The first *Diet for a Small Lake* was a high-water mark in the cooperation between New York State Department of Environmental Conservation (DEC) personnel and the NYSFOLA staff and members. The book benefited both the people and the state. This cooperation has continued with both organizations working together to monitor and improve the lakes in New York State.

When the NYSFOLA Board of Directors authorized the revised and updated second edition of *Diet for a Small Lake, s*everal officers and directors agreed to assist, and Scott Kishbaugh from DEC joined them again. Committee members met regularly, traveling in all seasons to review and critique the developing chapters, suggest additional information for inclusion, and work on organizational procedures for the revision.

- Sharon Anderson, a former NYSFOLA Director, served as chair. In addition to contributing to the writing, she arranged numerous details with DEC and kept the rest of us on track, even though very busy with her job as Watershed Steward at the Cayuga Lake Watershed Network.
- Nancy Craft, retired librarian from Tompkins Cortland Community College, contributed ideas, indexing and editing, and worked tirelessly to maintain consistency in format and style.
- James Cunningham, New Water Technologies, Inc., shared his extensive knowledge of septic and wastewater management systems for Chapter nine, shared some of his image collection, and assisted with the mechanics of publication.
- George Kelley, NYSFOLA Past President and geologist retired from Syracuse University and Onondaga Community College, contributed ideas, this preface, and information about the glacial geology involved in lake formation and change.
- Scott Kishbaugh, DEC Division of Water and CSLAP Program Coordinator, stayed awake many nights writing and editing, and drove many miles to contribute from his professional background and his extensive experience assisting lake associations in New York State.
- Nancy Mueller, NYSFOLA Manager and CSLAP Assistant Program Coordinator, was one of the people who realized the need for a revised edition since she is the focal point for questions from the membership. She kept us in touch with the true needs of the reader, edited text and assisted with images and graphics.
- Lyle Raymond, retired Water Resources Specialist from Cornell University, shared his extensive knowledge in Chapter ten and his experience working with water laws, regulations agencies and local governments to remind us of the roles that policy and people play in protecting lakes.

- Rebecca Schneider, Cornell University professor and NYSFOLA Director, shared her knowledge regarding watersheds for Chapter nine. She also shared her perceptive assessments of how to best present complex materials, and inspired the re-ordering of the content of several chapters.

- Dr. John Foster of SUNY Cobleskill is thanked for sharing his extensive knowledge in authoring Chapter five, “Fisheries Management: Matching Expectations to Reality.” Except for Figures 5–3, 5–6, and 5–8 through 5–19, illustrations are from his collection and any copyright remains his.

Other contributors deserve acknowledgement and <u>they retain their individual copyrights</u>.

- The cover photograph (which is also used on the title page and in the table of contents) is courtesy of Carl Heilman II / Wild Visions, Inc., Brant Lake, NY and the copyright remains his. (www.carlheilman.com)

- David Wright, Esq. of Yorktown gave permission to use the legal information he has drafted (2004).

- Garrett Crow and Barre Hellquist gave permission to use their line drawings of invasive plants (Crow and Hellquist, 2000).

- North American Lake Management Society (NALMS) granted permission to use images from their book *Managing Lakes and Reservoirs*. (Holdren et al, 2001) (www.nalms.org)

- Roy Reehil of The Forager Press, LLC gave permission to use his photographs. The copyrights remains his. (theforagerpress.com)

- The Iowa Department of Natural Resources gave permission for the spiny water flea picture in Chapter three. (www.iowadnr.com)

- Eric Engbretson, U.S. Fish and Wildlife Service, Bugwood.org is the photographer and gave permission for the grass carp image in Chapter six. (www.forestryimages.org)

- The University of Florida Center for Aquatic and Invasive Plants gave permission to use their line drawings of plants for Chapter six. (www.aquat1.ifas.edu)

- Wayne Wurtsbaugh, Utah State University; David F. Brakke, James Madison University; and American Society of Limnology and Oceanography, gave permission for a couple of pictures. (www.aslo.org)

- Original cartoons were provided by Mark Wilson, a member of the Shore Owners’ Association of Lake Placid, and copyright remains his (www.EmpireWire.com).

- Some images were used with permission from various government agencies (see Appendix F, “Internet resources”).

- Artists Wendy Skinner and Chris Cooley improved the presentation of information through their excellent illustrations (© NYSFOLA).

We appreciate the cooperation of individuals in DEC who helped us maneuver around bumps along the way to completion of the new book. DEC also provided funds to support the editing of this document, and provided staff time for the development of Chapters three and six in support of on-going changes in the state aquatic plant management program. Fish images were originally prepared by Ellen Edmonson and Hugh Chrisp as part of *1927-1940 New York Biological Survey*, and are used with permission. Tim Sinnott provided information regarding invasive fish species.

The members of the committee dedicate this book to the people, present and future, who use, appreciate and protect the waterways of New York State.

Preface to the First Edition

Several years ago, the Federation of Lake Associations of New York (FOLA), in response to requests from its membership, saw the need for a publication that would describe lake management activities to the public. Although several excellent publications were available that covered the topics of lake ecology and lake restoration techniques, we felt that none of the publications adequately met this need. It was at this time that I began discussions with Dan Barolo, the Director of the Division of Water of the New York State Department of Environmental Conservation (NYSDEC). Dan agreed with the necessity of such a publication and assigned his staff to work on the manual. Thus, the publication *Diet for a Small Lake: A New Yorker's Guide to lake Management* was engendered.

The 7,500 lakes ponds and reservoirs of New York State need our help. It is often thought that the role of managing our water resources is best left to the "experts" in academia, private industry and government. How will these experts communicate with members of the public? Each individual citizen has his or her own personal beliefs based on education and life experiences. Do these citizens have a minimum knowledge about the ecological and societal aspects of lakes? This manual, and other similar publications used in an integral fashion, are designed to raise the level of understanding for members of the public who are genuinely interested in protecting and preserving out lakes.

The manual is a joint publication of the Federation and DEC. Its title page shows no authorship, but this "oversight" is related to the dilemma of trying to give credit to the spectrum of individuals who contributed to its genesis. The primary authors of the publication were Scott Kishbaugh and Jay Bloomfield of DEC and Ann Saltman of the Federation. Elizabeth Smith of DEC did much of the editing, and without her contribution the manual would probably still be a few faded ideas and a pile of papers in a box. The following NYSDEC employees contributed greatly to the preparation of individual chapters: Jim Sutherland, Sue Benjamin, Mike Rafferty, Jim Swart, Pat Longabucco, Ed Woltmann and Bill Morton.

Finally, my deep gratitude is extended to Italo Carcich, Dan Barolo and Sal Pagano from the Division of Water in NYSDEC for providing the leadership required to complete the manual, particularly when there were equally pressing demands on their staff's time o protect New York State's waters. I also am grateful to Commissioner Tom Jorling of NYSDEC for his strong support of lake management activities in the face of current budgetary constraints. Lastly, I would like to express my appreciation to the 50,000 or so members of the State's lake property owners associations, which make up the Federation. Without their commitment to cleaner lakes, the preparation of this manual would not have been possible.

John Colgan. M.D.
President, NY Federation of Lake Associations
Rochester, New York
June 1990

About NYSFOLA

The Federation of Lake Associations, Inc. was founded in 1983 by a small consortium of lake associations concerned about a variety of problems facing their lakes. Water quality was of concern to nearly all of the lakes, and little information was available on methods to combat the increasing presence of aquatic invasive species. In 1995, the name was changed to the New York State Federation of Lake Associations, Inc. (NYSFOLA) in recognition of the geographic area it served.

With the assistance of the New York State Department of Environmental Conservation (DEC), NYSFOLA spearheaded the development of the Citizens Statewide Lake Assessment Program (CSLAP). This nationally-recognized water testing program, detailed in the Appendix A, "Citizens Statewide Lake Assessment Program," trains and uses citizen volunteers to monitor the health of their lakes. This statewide lake monitoring program remains an important part of NYSFOLA's mission:

> To protect the water resources of New York State by assisting local organizations and individuals through public dialogue, education, information exchange and collaborative efforts.

Since its founding, membership has grown to more than 200 lakes throughout the state, as well as many individual members. Members are invited each May to attend a conference that brings together lake managers from government, academia and the corporate sector to share new technologies and case studies in lake and watershed management.

In 1990, NYSFOLA and DEC collaborated to collect the best lake management information in a single publication. Since its publication, *Diet for a Small Lake: A New Yorker's Guide to Lake Management* has been shipped all over the world and has been used by lake associations, colleges and professional lake managers.

In 1993, the organization became the New York State Chapter of the North American Lake Management Society. This brought the organization into a broader spectrum of lake-related issues and made its members' voices heard at the national level.

In the late 1990's NYSFOLA and DEC again collaborated to study how to develop watershed management plans. Six member lakes worked on the pilot project. The lessons and conclusions from that project are contained in *A Primer for Developing a Successful Watershed Management Program.* Information developed during this and other projects has been incorporated into this manual.

The organization continues to be actively involved in emerging lake management issues. Members of its Board of Directors serve with a number of lake-related advisory groups, including the Northeast Aquatic Nuisance Species Panel, The New York State Invasive Species Task Force, the New York State Water Management Advisory Committee, and the North American Management Society Board of Directors.

Introduction: Designing a Health Plan for a Lake

Welcome

Diet for a Small Lake is a combined effort by the New York State Federation of Lake Associations (NYSFOLA) and New York State Department of Environmental Conservation (DEC). It is designed to motivate private citizens who may not have knowledge or experience in the field of lake and watershed management. Examples from within New York State are provided to illustrate the topics. References to state laws and government structure are specific to New York State, making this book a valuable reference for professionals in the field of water resources management. The information will build the knowledge and confidence required to delve deeper into lake management. Appendices F, G and H contain internet resources, references cited, and additional readings for those who seek more information.

This manual focuses on New York State and refers to common situations faced by lake associations and lakeshore residents. *Diet for a Small Lake* is a practical source to help address immediate problems. The goal is to demonstrate the importance of a management plan as the best tool for long-term reduction and prevention of problems. A comprehensive management plan is the key to the long-term health of a lake and its watershed. A management plan describes the activities that can be undertaken by lake associations, government, the private sector and individuals. It empowers local residents, and helps to balance conflicting interests.

Experience has reinforced the belief that management plans are the best method to ensure optimum use of the lake and surrounding land. Beginning in 1996, NYSFOLA and DEC worked with six lake associations and created several management plans. The results can be found in *A Primer for Developing a Successful Watershed Management Program* (NYSFOLA, 2001), available on the NYSFOLA website (see Appendix F, "Internet resources" and Appendix G, "References cited"). The participating associations represented a wide breadth of lake ecology found in New York. Their experiences, the lessons shared at annual conferences, and countless conversations and emails have been combined with DEC input to create this expanded second edition of *Diet for a Small Lake.*

App's Landing on Oneida Lake's North Shore at dawn.
(Credit: Roy Reehil)

The ideal lake

Ask any audience of lake enthusiasts to imagine the ideal lake and each person will have a slightly different picture. A composite description of an ideal lake might include a completely forested watershed, a beautiful home with a large veranda, tennis courts, a pleasure boat and canoe in the boathouse, and no noise except the songs of birds. The water is clear enough to see the bottom in 20 feet of water. A few blocks away are well-supplied shops and entertainment. Public utilities are reliable, cell phone reception is exceptional, and cable and internet access are affordable. There are no messy weeds in the lake, no troublesome neighbors, and taxes never seem to increase.

Is all this possible? Even spectacular lakes such as Lake George and Upper Saranac don't come close to this fantasy. Many of the features listed conflict with each other. Crystal clear water, a sandy bottom and weed-free lake may provide great swimming but will not provide what a fishery needs to flourish. Nearby stores, municipal water and sewers only come to an area when there are a sufficient number of people to support them. Conflicts typically arise, however, as the sound of powerboats break through the peace that others cherish. Remember the natural limitations that exist. A lake cannot be all things to all people.

Lake management

Lake management is an art, informed by science, of balancing the demands of various users of the land and water. To keep lakes healthy, it is no longer possible to expect nature to take care of problems. Human activities combine with naturally occurring processes to create pollution and disturbances that exceed the natural capability of waters to dilute and purify. Managing a lake means accounting for the needs of fish, plants, wildlife and people.

Lake management is the responsibility of the users of the lake and its watershed and not solely a government function or a job for professors or private consultants. Lake and watershed property owners must understand natural processes, limitations of science, tradeoffs, and even how to work with people. A management plan pulls together all of these factors and then recommends a systematic approach to protecting and enhancing water resources. Lake associations can play a powerful role in motivating, cajoling and supporting governments and professional lake managers who work to draft and implement a management plan.

The resulting document may be called a Lake Management Plan or a Watershed Management Plan. Both terms are used in this publication as applicable to a particular discussion. Lake and watershed management is only possible when the ideas from the entire watershed and all interested parties are taken into consideration. Shoreline property owners, for example, may find a way to get rid of excess water weeds using a process that must be repeated every few weeks. Longer relief, however, means recognizing that the weeds are really a symptom and the cause may be soil and fertilizer washed off their shoreline lawns as well as from farms miles away from the lake.

Accept what you cannot change and manage the rest

Property owners, lake users, and municipalities must be realistic about to what extent a lake and its watershed can be controlled. Disagreements at this fundamental level are among the challenges involved in developing a realistic management plan.

A blend of human and natural laws influences water and watersheds. A reservoir is an example of a system designed by humans and generally conforming to natural laws. An engineer designs the dam, including size, structure and material, based on "natural laws", such as the existence of water pressure. As time passes, human-influenced factors will change how dams are built due to the availability of new building materials, better understanding of technical options and amended regulations. Nature's "laws," however, will always exist.

Another challenge is the limitations of existing knowledge. The best scientists and engineers can do is study the system using observations, models and experiments. It may not be comforting to the reader, but most scientists who study lakes (limnologists) believe that they understand only a fraction of what could be known about lake ecosystems. A lake watershed management plan needs to remember that science is not always black and white, and that the different values of people greatly influence decision-making. To design effective ways for resolving lake problems, lakeshore property owners must join with other watershed residents and with government officials to make decisions that are crucial to creating and implementing a management plan.

How to use this manual

See Preface two for full information on contributors to this publication and the names of the people and organizations who gave permission for use of their copyrighted images. The image owners, organizations and government agencies are also listed more fully in Appendix F, "Internet resources". The copyright for those images remain with the originators; they do not come to NYSFOLA. The artist-created images are © NYSFOLA.

Conventions used include:

- Important terms appear in boldface where they are defined within the context of the paragraph. Refer to the Index of Terms for a listing of the page on which a word is first used and defined.
- Units are given in their standard English versions (gallons, feet, Fahrenheit) except for scientific reporting where the convention is to use metric units (liters, meters, Celsius).

The book is organized to be read from start to finish. A chapter may be selected that addresses an urgent concern, but the reader may need to refer back to previous chapters for background information. This manual attempts to:

- Help the reader understand the overall workings of a lake and how activities on the surrounding land affect it;
- Familiarize the reader with how lakes differ across New York State;
- Explain the most common lake problems and possible solutions;
- Introduce the legal framework that allows for the management of lakes; and
- Walk through the steps for creating a lake management plan.

The NYSFOLA website posts significant new regulations, permitting procedures, and supplemental information as they become available (see Appendix F, "Internet resources").

Summing it up

The best "treatment" for a lake will resemble a health plan rather than a bandage. An effective lake management plan will include immediate actions as well as long-range watershed approaches and will combine both preventive and remedial options. A comprehensive management plan charts a course to identify causes and sources of problems, and a course to plan and implement solutions to the problems. A management plan must be revisited on a regular basis to keep it viable as the lake conditions and people's expectations change. The success of the plan is measured by the degree to which people and actions work together to solve conflicts, protect the lake, and prevent future problems.

1 Lake Ecology: Getting Your Feet Wet

Introduction

To understand how to manage a lake, you must know something about the lake itself. This is not easy because lakes are complex, dynamic biological systems that both influence and are influenced by their environment. Countless examples can be found of how lakes and their environments interact. Just ask the people who live in the western Adirondacks or Central New York and must contend with lake effect snowstorms that form over the Great Lakes each winter. In short, lakes are more complex than the simple concept of big fish eating little fish. While this is a prominent feature of lake environments, and a microcosm of the complex interactions that govern lake ecology, it is much too simplified.

The study of freshwater systems, including lakes, is known as **limnology.** A subset, the study of how plants and animals coexist in a freshwater system, is referred to as **ecology**. Lake ecology encompasses chemistry, geology, biology, geomorphology, and even meteorology. Ecologists seek to understand interactions among individual organisms, populations and communities, how these living components interact with their non-living surroundings, and how these relationships change over time. Chemical and biological components change constantly and create a dynamic balance. A change in one part of an ecosystem, such as increased water clarity or algae density, may cause an alteration in other parts of the system, such as fish populations. These changes may cause re-equilibration, creating a new "steady state," or they may create a dynamic response. This has important implications in lake management, for it is difficult to predict whether an intended management action, such as biomanipulation or drawdown, will lead to an unintended consequence, such as an algal bloom or the loss of a valued fish species.

Limnologists and lake ecologists keep striving to learn more about how lakes function, such as how pollutants move through lakes, why exotic plants thrive in some lakes but not others, how quickly some lakes will fill in, and other dynamics. Even as this trove of lake knowledge builds, however, there continue to be many unanswered questions. This chapter provides an introduction to what is currently understood about how New York State lakes function.

A lake by any other name

The term "lake" will be used throughout this manual as the general term encompassing ponds and reservoirs as well as true lakes. While everyone has some idea of the differences among these ponded waters, and while some legal distinctions are unique to each, no hard and fast boundaries separate ponds from lakes from reservoirs in New York State. All ponded waters serve as the lowest point of a watershed, the recipient of all surface and groundwater flow (and the pollutants they bear). The general definitions, however, bear mentioning.

A lake is usually larger than ten acres in area and ten feet in maximum depth. It may be quite large and deep, with an abundance of cold water at the bottom. It may also exhibit areas of rocky, wave-impacted shoreline because of exposure to prevailing winds. It is important to remember that a lake is usually part of a larger river system with water flowing both into and out of it.

The term **reservoir** is commonly used to describe an artificial lake. It probably has a dam that impounds the water for the purpose of flood protection, power generation, drinking water supply, or to maintain canal water levels. A reservoir may also be used for recreation, but that is generally not its primary function, at least in New York State.

A pond is usually described as a shallow body of water that is smaller than a lake. Typically, a pond has uniform water temperature from top to bottom, little wave action, and often an abundance of aquatic plants. Pond waters are generally supplied from a very small area. The term "pond" also refers to small but permanent waterbodies that are water-filled depressions in the earth, whether created by natural contours, by beaver dams, or by people looking for a steady supply of water for fire protection, livestock or attracting wildlife. **Vernal ponds,** also called vernal pools**,** are ephemeral, forming after spring thaw or large storm events, but dissipating before attaining any degree of permanence. In many ways, vernal pools are the transition between lakes and wetlands.

Wetlands are unique habitats that form the transition between the lake and the surrounding land. Wetlands have several common characteristics:

- the dominance of plants that require a wet habitat in order to live;
- soils that have characteristics associated with flooded or saturated conditions, such as a gray color; and
- evidence of predictable annual flooding.

Flooding may only last several days or weeks, and it sometimes occurs only below ground level. Flooding creates **anaerobic** (without oxygen) soil conditions in which only uniquely adapted plants can survive, grow and reproduce. Flooded conditions also slow down the rate of decomposition of leaves and other organic matter, leading to the build-up of a black, rich organic soil. The combination of plants, soils and microbial communities found in wetlands provides important benefits to lakeshore owners, including flood reduction, filtering of contaminants from groundwater before they enter the lake, and nursery areas for fish and other wildlife. **Groundwater** is freshwater found beneath the earth's surface and is often connected to surface waters, meaning lakes, streams and wetlands. Information on regulations and legal issues related to wetlands is included in Chapter 10, "Legal Framework."

In the beginning…

How a lake was originally formed has great influence over many of its characteristics. Most lakes in New York State are the result of the presence and retreat of glaciers. These glacially carved lakes are deep and have inlets and an outlet, reducing the time that nutrients and the resulting algal blooms stay in the lake. Artificially created lakes typically act as wide rivers or streams. Nutrients are flushed out thereby reducing algal blooms. A special kind of glacial lake, called a kettle lake, is frequently dominated by groundwater seepage. Without a significant outlet or inlet, they are repositories of nutrients that allow algae to thrive.

The power of glaciers

Several continental glaciers formed and retreated over the northern hemisphere for more than a million years. The last Laurentian **glaciation** ended with melting and marginal retreat between approximately 22,000 and 8,000 years ago. Most of the northern third of the United States was affected by four major glaciations and minor advances, each followed by warmer periods similar to conditions today. The major effect of these glaciations was erosion and deposition, responsible for the modifications of New York State topography from earlier networks of stream channels to the rounded hills and valleys that dominate today's landscape.

A large ice lobe extended southwest along the St. Lawrence River Valley north of the Adirondacks into the Ontario and Erie basins, eroding and deepening them. A smaller lobe extended into the Champlain-Hudson River Valley, modifying the region east of the

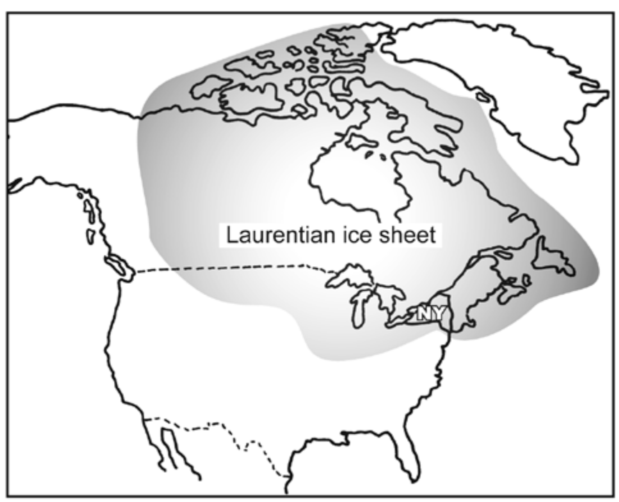


Fig. 1–1. Areas of North America covered by the last of a series of ice sheets. (CREDIT: WENDY SKINNER)

Adirondacks and Catskills. Ice continued to thicken, eventually overtopping the Adirondack and Catskill mountains. The thickening ice over the Ontario and Erie basins expanded onto the lake plain, Appalachian Highlands, and southward into northern Pennsylvania. Ice also extended westward into the Mohawk Valley from the Hudson Valley, and eastward from the Oneida Lake basin.

As the glaciers moved southward and oozed around higher upland areas, erosion of older stream channels was caused by water freezing in bedrock cracks and by debris plucked from its original location to become part of the moving glacial ice base. Continued sliding of the ice caused this entrained debris to act as tools that scraped, gouged and sanded the land surfaces under the ice. These processes are enhanced by thicker ice, so valleys were eroded more deeply than the adjacent uplands. As a result, several of the Finger Lakes and Great Lakes basins are quite deep and some have basins that descend below sea level.

The **glacial margin** is a zone of near equilibrium where the rate of ice melting is balanced by new ice moving into the zone. Water from the melting ice flushes rock debris, ranging from fine clays to large boulders, beyond the ice margin. This develops a **terminal moraine** marking the glacier's maximum advance**.**

Once the melting exceeded the rate of advancing ice, the forward margin of the ice receded during several hundred years, gradually shifting the glacial margin northward. Occasional brief periods of ice-margin equilibrium formed additional **recessional moraine ridges,** and **outwash plains**, or **valley trains** beyond the actual front of the ice. The retreating ice blocked water drainage northward creating temporary glacial lakes in the valleys between the Appalachian Highlands and the ice margin. As the ice continued to melt, waters along the margin eventually drained eastward across lower hills and under the ice into the Mohawk River Valley. Further recession of the ice margin eventually re-established the St. Lawrence drainage north of the Adirondacks. The Lake Ontario and Erie basins were filled with water, and several of the deeper valleys to the south became large lakes**.** The Finger Lakes were formed after glaciers gouged

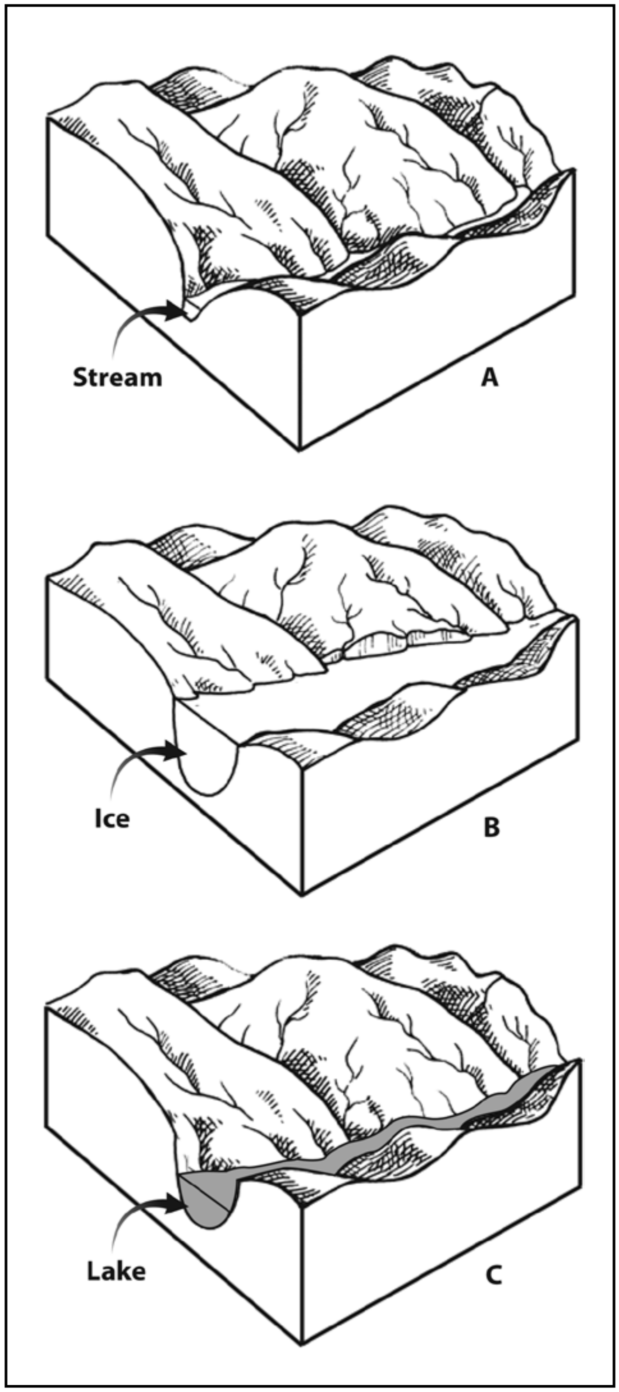


Fig. 1–2. Landscape evolution under glaciation.

A. *Preglacial topography formed by stream erosion.*
B. *Stage of glaciation.*
C. *Postglacial landscape showing U-shaped valley and lake typical of the Finger Lakes region.*

(CREDIT: A & B - WENDY SKINNER;
C - WENDY SKINNER, ADAPTED BY CHRIS COOLEY)

out old river drainage systems that once flowed south. The jumbled mass of terminal moraine rocks blocked the valleys, damming up the old river channels and forming lakes that drained to the north.

The weight of a large mass of ice was sufficient to make the earth's crust bow downward, much like a child walking across a trampoline. As with the trampoline, the earth rebounds upward when the weight is removed. However, the earth's crust responds very slowly. New York State is still adjusting, particularly in the north where the ice was the thickest. This response to loading and unloading of weight on the earth is called **isostatic adjustment**.

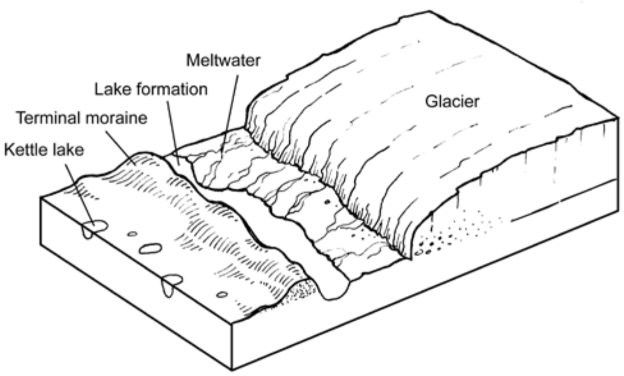


Fig. 1–3. Typical features that develop near the front of a receding glacial ice margin. (CREDIT: WENDY SKINNER)

Erosion-resistant rocks are found near the surface in the northern part of the Finger Lakes, and a series of recessional moraines are found nearly parallel to these rocks. The rocks, recessional moraines, and isostatic adjustment combined to cause a sluggish northward drainage from the water-filled glacial valleys occupied by some Finger Lakes. The slow flow of the Seneca River through the Montezuma Swamp is an example of this restricted drainage. The river cannot keep up with the water volume from springtime rains and snow melt flowing out of Cayuga and Seneca lakes. This causes flooding as the slow-moving Seneca River drains east to the Oswego River.

Smaller **kettle lakes** are found in the outwash materials deposited just beyond the terminal and recessional moraines (see Fig. 1–3). As the glacier melts, ice breaks into various sized blocks that become isolated and later buried under subsequent outwash debris flushing from the melting glacier. These buried, insulated blocks eventually melt, dropping their thin cover of outwash into a depression that fills with groundwater. The numerous kettle lakes in New York State include the Tully chain of lakes south of Syracuse.

Glaciers strongly influenced the terrain from the Great Lakes to Long Island. The area around the Allegany State Park in western New York alone escaped the power of the glaciers, although lake formation throughout the state was also the handiwork of other forces.

Human hands shape the land

Superimposed on this landscape are changes to the topography caused by human activities, such as redirecting streams and creating lakes where none existed before. For example, the Leland Ponds in Madison County previously flowed southward to the Susquehanna River via the Chenango River. With construction of the Erie Canal system, their drainage was redirected to feed the Mohawk and Hudson Rivers.

More commonly, humans create impoundments where water is confined and collected in a reservoir or farm pond. Usually, this is done by damming streams and rivers in order to provide potable water, power, flood control, or recreational opportunities. Farmers create small impoundments of water for animals, irrigation and fire protection. Several of the upland reservoirs in the central area of the state were created as water supplies for the Erie Canal system, although they are now used primarily for recreation.

Water colors

What many of us notice first about a lake is not the geological clues to its origin, but its color. Impurities and suspended particles found in lake water influence its color and clarity. The term color merits further explanation since there is a distinct difference between the color of the lake when viewed from the shore or a boat, and the color of lake water in a bottle.

The color of the lake is related to the uneven absorption of different colors or wavelengths of sunlight. Blue light will penetrate the deepest into pure water and red light will penetrate the least, causing deep, clear lakes to appear blue-green to dark blue in color. A clear, blue sky often intensifies this effect.

The biological palette of water colors, enjoyed by the visually creative but cursed by the lake user, is usually the result of different kinds of algae. **Chlorophyll** is the major pigment in the microscopic plants known as **algae** or phytoplankton that float in lake water. Chlorophyll is green, causing lakes with large amounts of algae to appear green. While chlorophyll is the major pigment, it is not the only pigment present in these tiny plants. Most major groups of algae, such as golden-brown algae *(Chrysophyta)*, green algae *(Chlorophyta)* and yellow-green algae *(Heterokontae)* can be sketched with a mostly full box of crayons. Blue-green algae, which are more correctly identified as bacteria and given the name *Cyanobacteria,* are also adorned with many colors. The most common coloration looks like blue-green paint spilled on the lake. Shades of red can be found in some species of *Oscillatoria* algae, and the less common *Rhodophycaea*, or red algae. Other species of *Oscillatoria*, some species of *Microcystis*, and many types of diatoms (silica-based algae) can be brown, as well as streaked with green and blue-green.

Color in a lake can also come from minerals and organic matter. Brown water may be the result of mineral particles or suspended silt. Some wetlands give off naturally occurring organic compounds called **humic matter**. Humics result from the breakdown of wood and other organic matter by decomposers such as bacteria and fungi. The resulting brownness ranges in color from weak tea to very strong tea. **Hard water** lakes, high in calcium and magnesium compounds, will sometimes appear whitish in color for short periods during the summer. This **whiting** phenomenon is caused by calcium carbonate condensing from solution due to photosynthetic activity in the lake.

The apparent color of the lake is usually related to the color of the water. If you took a bottle of water from a deep clear lake that appeared blue and held it up to a light source, the water would be clear, not blue. Lake water with humic matter will appear clear with a yellowish-brown tint. A bottle of lake water with algae in it will appear cloudy, with remnants of green, red, brown, or whatever other color the algae is. Water containing silt or other mineral particles will appear cloudy and brown. In short, the color of water gives you a good indication of what is in it, or at least of the natural conditions that cause it to be that color.

The water cycle

Each type of waterbody is influenced by its watershed. A **watershed** is the area of land that contributes water to that waterbody. Water may enter a lake from a watershed through streams and rivers, overland sheet flows, or through the ground as shoreline or underwater springs. A watershed may be large or small when compared to the area of a lake. The term watershed is used interchangeably with **catchment basin**, **lake basin** or **drainage basin.** The ridges and hills that divide or direct water movement into one drainage basin or another define the boundaries of a watershed.

Fig. 1–4. A watershed is the area defined by upland ridges that direct waters to a specific waterbody. (CREDIT: WENDY SKINNER)

When water falls from the atmosphere as either rain or snow within a watershed, only a small portion falls directly on the lake. The water that falls on the watershed may move over the surface, seep into the soil or evaporate and re-enter the atmosphere. The term **runoff** refers to moving water on the surface of the ground. It might be a small trickle or a major torrent. When runoff flows in a well-defined channel, it is called a stream or a river. Some streams flow all year; some are intermittent and dry up during the summer and fall. Of the water that seeps into the ground, some is taken up by plants. The rest moves

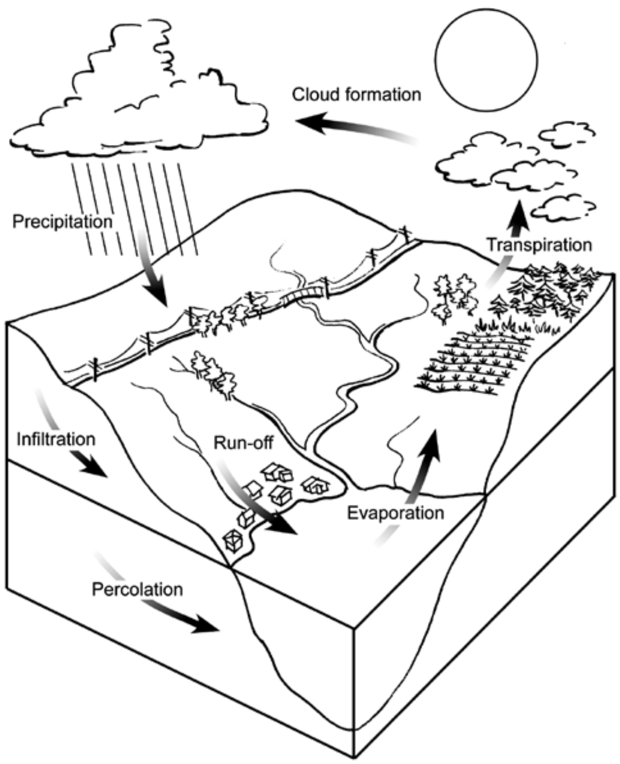


Fig. 1–5. The hydrologic cycle shows that precipitation may seep into the soil as infiltration, move over land as runoff, and then move back into the atmosphere as evaporation or due to the transpiration or respiration activity of plants and animals. (CREDIT: WENDY SKINNER)

below the surface in the pore spaces between the soil particles until it is drawn up from a well or until it re-emerges on the land's surface as springs or streams. Water gets back into the atmosphere by evaporation and the respiration activity of plants and animals, and then falls again as precipitation. This continuous movement and recycling of water is known as the **water cycle** or **hydrologic cycle.** The hydrologic cycle is a closed cycle, since water is neither added to nor removed from it. There is roughly the same amount of water on the planet now as there was millions of years ago.

At each stage in the hydrologic cycle, water can pick up dissolved substances and particles and carry them into a lake. Some of these substances can be **pollutants** that can impair the use of the water by humans, aquatic life or both. A pollutant carried to a lake by water does not necessarily leave a lake the way water does. It may settle to the bottom and be trapped in sediment, or it may stay in a lake when its water evaporates.

How long a pollutant stays in a lake before being flushed out through the outlet can be one factor in the amount of harm it causes. Since it is impossible to know how long any drop of water, or pollutant, remains in a lake, limnologists work with a calculated measurement known as the **hydraulic retention time.** This term represents the time that it would take to fill the lake if it was drained completely, assuming normal precipitation and runoff and no outflow. A shallow pond with a large watershed, and most impoundments, will have a short retention time, often only a few days. A deep mountain lake, such as Lake George, or small rural lake with a small watershed, such as many of the state's kettle lakes, may have a retention time of five to ten years or more. Lakes with long retention times are, in general, better equipped to resist the onslaught of pollution than lakes with short retention times. Lakes with shorter retention times are more susceptible to high nutrient loading. Fortunately, lakes with shorter retention times can improve dramatically if pollutants are artificially flushed out of the lake.

What's so special about water?

Water possesses many unique properties that serve as the foundation for life and are fundamental to the way a lake behaves. The previous hydrologic cycle discussion introduced a few of the special characteristics of water.

Water does such a good job of picking up and transporting pollutants because it is considered "the universal solvent." It will dissolve more substances than any other liquid. This includes many things that are not pollutants, such as the atmospheric gases oxygen, nitrogen and carbon dioxide. Cold water will hold more dissolved gas (such as oxygen) than warm water, while warm water will dissolve many chemicals and minerals.

The precipitation part of the hydrologic cycle can be influenced by water's remarkable ability to store heat energy. Water warms and cools more slowly than the surrounding air. The deeper and bigger the lake, the slower its temperature will change. This high capacity for retaining heat moderates the climate along the shore of large bodies of water such as the Finger Lakes. The air is generally warmer in the winter and colder in the summer when compared to areas far from the shore. Regions with large lakes also tend to be more humid and produce more rain and snow. Good examples in New York State are the areas to the south and east of Lakes Erie and Ontario, where so-called **lake effect storms** are common. The larger Finger Lakes also produce localized lake effect storms.

Through the hydrologic cycle, we can experience water in all three states of matter. On a hot day sweat and water evaporates. In New York State, precipitation condenses and falls as rain, snow, sleet, and sometimes as hail. At normal atmospheric temperature and pressure, water is a liquid rather than a gas or vapor. Quite simply, this cycle allows lakes to form.

Temperature variations too small to change the state of water will still change its density. The density of water is greatest at 39° F (Fahrenheit) (see Fig. 1–6). It is fortunate that water is neither like most other liquids that get denser as they get colder nor like other substances that are densest in their solid state. Surface waters become denser as they lose heat to the colder fall air and sink to the lake bottom. This continues until the lake water column is a uniform 39ºF. Waters cooling below 39ºF become less dense and remain at the surface. When surface waters cool to 32ºF, ice begins to form. If the coldest water were the densest, lakes would freeze from the bottom up, which would obliterate all aquatic life each winter in shallow waterbodies. Instead, the water just below the ice is 32° F and the densest water at 39ºF is at the bottom of the lake. This temperature demonstrates both a divine sense of humor (why 39?) and the unique qualities of water.

The differing densities of water are important during the warmer months of the year as well. Starting in the spring and early summer, most New York State lakes deeper than about 15 to 20 feet form distinct temperature layers, with the top layer warmer than the bottom layer. During the summer, the top layer gets warmer, while the bottom layer stays pretty cold. This upper layer is called the **epilimnion** (literally *over* [French] the *open water* [Greek]). It is separated

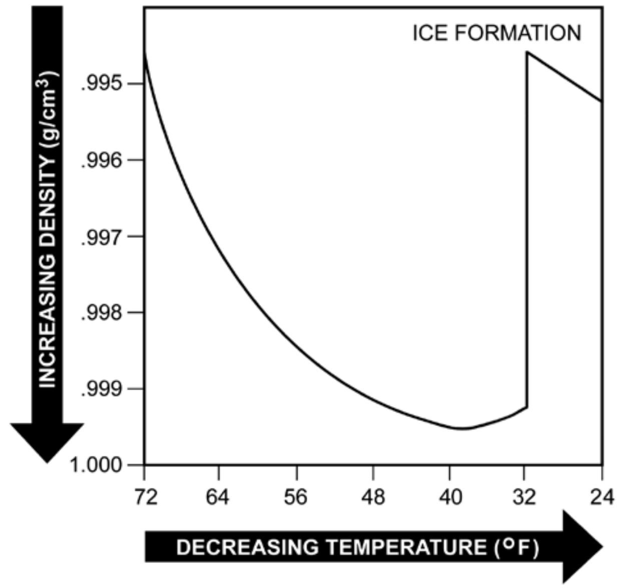


Fig. 1–6. As water cools, it becomes denser until it reaches 39ºF. It becomes lighter as it continues to cool. When water cools to 32ºF and becomes ice, it reaches maximum lightness, causing it to float.
(Credit: Wendy Skinner)

from the lower layer, called the **hypolimnion** *(under water* [Greek]*)* by a very thin layer called the **metalimnion** *(among* or *within* [Greek]*)*. Within the metalimnion, the temperature changes rapidly over a very short vertical distance with the most rapid change occurring at the **thermocline**.

The thermocline creates a thermal barrier to the mixing of surface and bottom waters because different densities created by temperature differences resist mixing. These layers remain until fall air temperatures decrease, causing the water temperature and resulting density differences to decrease sufficiently to allow complete lake mixing.

A similar but less dramatic situation occurs under the ice, when less dense, slightly colder water overlies a dense 39°F bottom layer. This persists until warmer spring air melts the ice and warms the less dense water. As the temperature of the less dense, cold water warms to closer to 39°F, differences in density are again reduced allowing complete lake mixing. In most relatively deep New York State lakes, complete lake mixing occurs in the fall and spring. A **dimictic lake** is one in which this complete lake mixing occurs twice a year. A schematic of these processes is shown in Fig. 1–7.

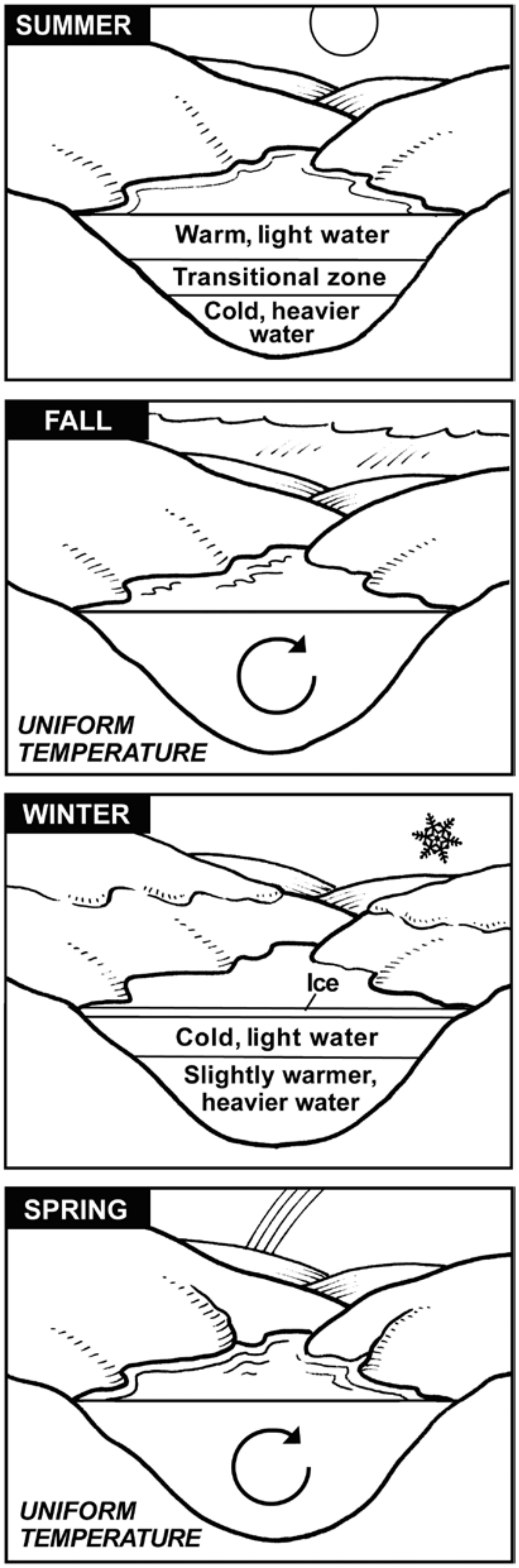


Fig. 1–7. Waters in dimictic lakes in New York State either stratify or mix depending on the season. (Credit: Wendy Skinner)

The process by which thermal layers break down and the lake mixes again is usually called **turnover**, during which time the lake is often referred to as "working." If accelerated by cold, windy weather it can occur rapidly, completing the turnover within a few days. If delayed by calm, warm days, it can occur in stages over a long period.

The depth of the thermocline generally is related to the **transparency** or clarity of the lake water and how exposed the lake is to the wind. Sun penetrates more deeply into a clear lake, resulting in a deeper thermocline than in a turbid lake. A wind-exposed lake will have a deeper thermocline than a protected lake. If the lake is very windy and clear, or very shallow, it may not even have a thermocline. A few deep New York State lakes, such as Green and Round Lakes near Syracuse, never mix due to very steep slopes and small surface areas. This is also related to very high mineral contents in the bottom waters that result in chemical stratification. These unique lakes without thermocline are referred to as **meromictic** lakes.

At the base of the ecosystem

> "If you dig a pond anywhere . . . you will soon have not only waterfowl, reptiles, and fishes in it, but also the usual water plants, as lilies and so on. You will no sooner have got your pond dug than Nature will begin to stock it. Though you may not see how or when the seed gets there, Nature sees to it. She directs all the energies of her Patent Office upon it, and the seeds begin to arrive." (Thoreau, 1854)

What Thoreau noted for Walden Pond applies to most New York State lakes and ponds. We enjoy lakes not just for their water content, but also for the richness of life they support. The origin of life in lakes may appear to be a mix of magic and alchemy, but the fundamentals are readily understood. The lake and watershed ecosystem can be viewed as a machine that converts one form of energy to another. Although there are exceptions, most energy enters the ecosystem as sunlight. Green plants store the energy from sunlight by **photosynthesis,** the process by which sunlight, carbon dioxide and water are used to produce oxygenated organic compounds, such as sugars. **Respiration** is the process that releases this stored energy. It is always occurring, but it becomes critical at night. In the dark, the green plants use oxygen to convert the organic compounds produced during the day. Carbon dioxide and water are byproducts of respiration.

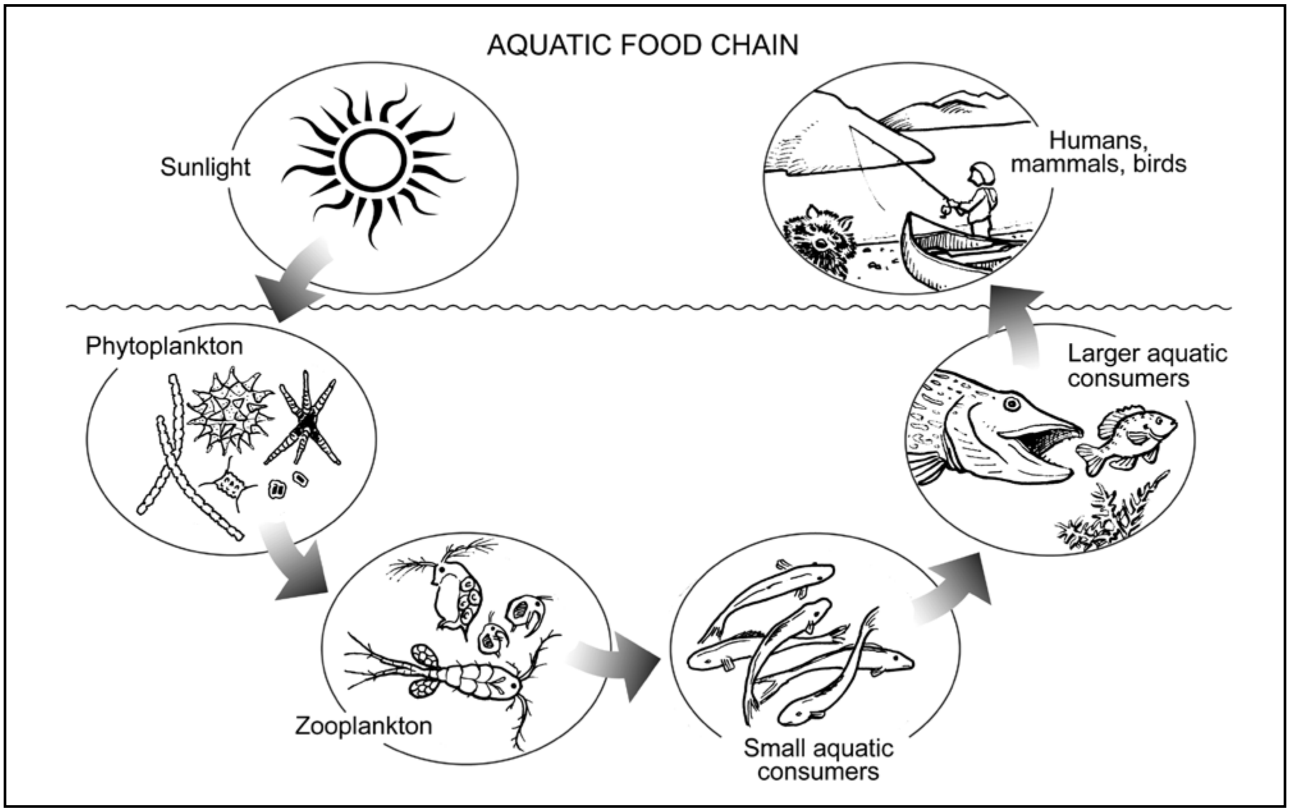


Fig. 1–8. Plants are considered the base of the aquatic food chain since they capture energy from the sun. That energy is passed along to animals in subsequent links in the food chain. (CREDIT: WENDY SKINNER)

Understanding the consequences of photosynthesis and respiration are vital to understanding the ecology of lakes. Oxygen levels in the lake increase during the day and decline during the night. The change can be drastic in lakes that have large quantities of algae and rooted plants.

Surface waters of a lake have higher concentrations of oxygen than the rest of the lake for two main reasons. Most light is available at the surface, allowing for more photosynthesis and greater production of oxygen. Significant amounts of oxygen from the atmosphere are added to the water when it is windy and some oxygen is added even during calm conditions. In contrast, at the bottom of a deep lake there is little or no photosynthesis and only respiration.

When a thermocline exists, it acts as a barrier that prevents mixing of the upper, oxygen-rich layer with the lower oxygen-poor layer. This barrier effectively defines the area where photosynthesis occurs, known as the **photic** zone. The **euphotic zone** is the portion of the photic zone near the surface where light is bright enough for photosynthesis to occur. Below the thermocline, only respiration occurs, resulting in a net consumption of oxygen. As the summer progresses, bottom waters can lose most, or even all, of their oxygen. This **anoxic** condition can trigger a series of chemical reactions that can result in the creation of hydrogen sulfide (rotten egg odor), conversion of some forms of nitrogen to ammonia, and the release of phosphorus and other pollutants from bottom sediments. Oxygen levels can also decline during the winter if the lake surface has a thick layer of ice covered by deep snow. In this condition, little oxygen and light can penetrate into the lake water, and aquatic organisms can use up all of the available oxygen.

Larger animals, such as fish, avoid water with low oxygen levels. If fish cannot find a refuge that has sufficient oxyge-n to sustain life, there will be a large die-off or **fishkill**. This oxygen deficit can also trigger chemical reactions that release nutrients from bottom sediments. Low oxygen levels are exacerbated if there is a rapid dieback of either algae or rooted plants. Bacteria that promote the decay of dead plant material consume large quantities of oxygen. If the oxygen is completely used up, only anaerobic bacteria (living without oxygen) can survive.

Photosynthesis is affected by water's **pH,** which is a measure of its acidity or alkalinity. The term pH refers to the concentrations of hydrogen ions (more literally powers of hydrogen, or pH) on a scale of 1 (many hydrogen ions, very acidic) to 14 (few hydrogen ions, very alkaline, or basic). Pure water is neutral, which is a pH of 7. The pH scale is logarithmic rather than linear. This means that pH 6 is 10 times more acidic than pH 7, and pH 5 is 100 times more acidic than pH 7. Rainfall with a pH below 5.0 is called **acid rain.** Acid rain, caused by the interaction of rain with the emissions of air pollutants, can be 400 times more acidic than rainfall without contaminants, which naturally has a pH of 5.6. In New York State, rain has been measured with pH as low as 3.

Plant photosynthesis removes carbon dioxide from water and adds oxygen. As carbon dioxide molecules are removed from water, an equivalent amount of hydrogen ions are also lost, resulting in an increase in pH. Rapid plant photosynthesis on a sunny summer day, can drive the pH up to 9 or 10. Thus, when you see a lake with a pH of 8.8 to 9.2, as commonly occurs in New York State, it usually means that large amounts of green plants are actively photosynthesizing.

When pH is too high or too low, some aquatic plants and animals die. Approximately 20 percent of lakes in the Adirondacks are so acidic that they cannot support fish life. Many species of fish and plants will die at pH 5.5, although some will survive at pH 5. The upper range for the majority of plants and animals is pH 10.

In most lakes, pH is controlled by the interplay of dissolved substances that impart acidity, including sulfates, nitrates, organic acids to a lesser extent, and dissolved carbon dioxide. Acidifying substances are counteracted by alkaline substances such as the carbonates associated with calcium and magnesium. Carbonates contribute to the **alkalinity** or buffering capacity of water, allowing some lakes to absorb acids without much pH change. Lakes in the Adirondack

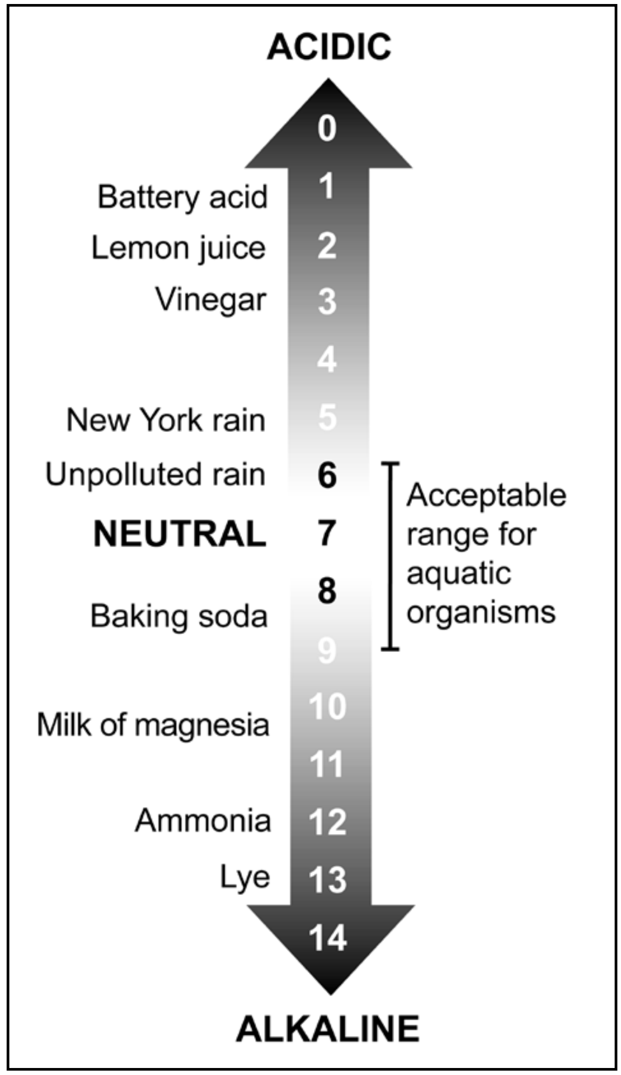


Fig. 1–9. Acidic-to-alkaline pH ranges, comparing the acidity of common items to the pH ranges acceptable for aquatic organisms. (CREDIT: WENDY SKINNER)

and Catskill regions have low alkalinity, and thus are susceptible to the strong pH changes caused by acid rain.

The cycles of the elements

In addition to sunlight, plants need **nutrients** to grow. On land, the raw materials for new roots, flowers and leaves are absorbed from the soil. For some aquatic plants, such as algae and weakly rooted plants, key raw materials are obtained from the water, but most rooted aquatic plants ("weeds") derive their nutrition from the sediment that supports their roots.

The hydrologic cycle is the key cycle affecting a lake, but it is not the only important one. The building blocks of all matter are the elements. Living organisms are made mostly of carbon, hydrogen, oxygen, nitrogen and phosphorus, with smaller amounts of sodium, calcium, chloride, iron and trace levels of several other elements. In a lake ecosystem, these elements are neither created nor destroyed, they merely move from one place to another. The movement of a specific element is called a **biogeochemical cycle**. This adjective is used to denote that the cycle consists of specific mechanisms that may, or may not, involve living organisms. As a broad generalization, the cycles of carbon, hydrogen and oxygen are of minimal interest to lake managers since those elements are rarely in short supply for the organisms of the lake. The availability of nitrogen and phosphorus in the water, however, can take up much of a lake manager's attention.

The rate of photosynthesis determines how much life can exist in the lake, since most energy enters the lake via the sunlight that plants use. The element that is in the shortest supply for photosynthesis limits the amount of photosynthesis that can occur. To understand this, imagine a barrel with vertical staves. The level of water in the barrel can only rise to the height of the lowest stave. To translate this image to plant growth, think of each stave as representing a different nutrient needed for photosynthesis such as sunlight, carbon, hydrogen, and nitrogen. The water in the barrel represents algae. The lowest stave controls the water level, the amount of the element that is in the shortest supply controls the amount of algae. This is called the **limiting factor** because the element in short supply limits the ability of plants to use any of the other elements. If more of the element that is the limiting factor becomes available, more photosynthesis can take place and there is more algal growth. This behavior is referred to as **Liebig's Law of the Minimum**, in honor of the scientist who first proposed it as a mechanism.

A number of factors can serve as the limiting factor for the production of algae. In some lakes, light transmission is limited by water clarity or dissolved organic matter making light the limiting factor. In New York State lakes, nutrients are most commonly the limiting factor for plant growth. Phosphorus is frequently the limiting nutrient because it is rare in the water in New York state lakes. Nitrogen may be the limiting factor in some lakes, particularly those with saltwater influences, or lakes dominated by green algae. Limiting factors for rooted plants are more complex, and in New York State lakes these factors are typically light, space, sediment type, and biological competition rather than nutrients. This will be discussed later.

Since the biological functioning of lakes depend heavily on phosphorus and nitrogen, these two nutrients tend to be a focus for lake and watershed management and monitoring plans. There are many other elements required for a healthy ecological balance. For any given lake, any of the trace elements found in the soils or water may be important. The discussion of lake problems in Chapter three, "Lake problems," discusses some of these "lesser" water-quality indicators in greater detail.

Food webs

The algae and rooted aquatic plants (**macrophytes**) are the **primary producers** for a lake ecosystem because they are the organisms that initially capture the sun's energy. Since photosynthesis provides the energy for the lake ecosystem, algae and rooted plants essentially drive the ecosystem. They make up the largest biomass or weight of biological organisms, about 85 percent in a lake or pond. Animals and microorganisms, such as bacteria, cannot photosynthesize. They can only respire, living off the organic matter produced by other living organisms. Without sufficient plants, animals and smaller organisms would soon run out of energy.

All animals are consumers. Primary consumers eat the producers and make up about 10 percent of the biomass. Second-order consumers and beyond eat the primary consumers, and, together with the decomposers, make up less than five percent of the total biomass. Decomposers are bacteria and other microorganisms that break down the waste products and remains of plants and animals. In the process, they make available to themselves and other organisms the nutrients needed for growth. Typically, a well-defined community of plants and animals interacts with and are dependent upon each other. Their interactions are referred to as a **food web**.

Little green dots and other green stuff

As producers, algae and macrophytes have much in common. It is worthwhile to consider them separately, however, since they also have important differences. Hundreds of species of algae are found in New York State lakes, from little green dots, to bubbling masses, to stringy filaments that look a lot like weeds. Algae can be classified by growth habitat. **Phytoplankton** are the free-floating forms (the little green dots). **Periphyton** attach to surfaces, such as stones, dock pilings and macrophytes. Periphytons that attach to macrophytes are referred to as **epiphytes**. In highly productive lakes, stringy masses of **filamentous algae** attach to boats and submerged objects.

Within these main categories, there are many different varieties of algae. There is a general progression from one type of algae to another through the seasons. Three major varieties dominate most New York State lakes: diatoms, green algae, and blue-green algae. The rapid growth of algae on the surface of lakes, streams, or ponds, which is generally stimulated by nutrient enrichment, is referred to as an **algal bloom**.

Lakes that are clear with few algae generally have diatoms, and these are seldom found at nuisance levels in most New York lakes. **Diatoms** are symmetrical, silica-based, mostly unicellular algae that are literally as fragile as glass, although their cell walls can remain intact in sediments for thousands of years. They form a significant portion of diatomaceous earth and the "skeletal" base of fossil fuels. Their persistence in sediments can be used to construct a historical record indicating when a lake started suffering excessive algal blooms. In New York State lakes, diatoms tend to be found primarily during the spring, due to their ability to survive somewhat colder conditions, and to extract silica from the water column at a time of the year when it is abundant in higher spring precipitation and runoff. When diatoms lose their competitive advantage, they tend to be replaced by green algae.

Green algae *(Chlorophyta)* is the most common and abundant form of algae. This group includes plants as well as mobile animals that contain chlorophyll, flagella (whip-like structures used for locomotion) and even eyespots! Green algae thrive where there are elevated nitrogen levels. Excess nitrogen can come from spring runoff due to the import of nitrate-rich water from acid rain and winter field fertilization. It can come from soils that are naturally nitrogen rich, typical for much of central New York and Long Island. It can also come from long-term use of fertilizers. These algal blooms are occasionally associated with taste and odor problems. The green algae tend to be replaced by blue-green algae in the late summer or early fall in many lakes, particularly those that have high lake productivity.

Blue-green algae are more correctly identified as bacteria and given the name *Cyanobacteria*. Although referred to as blue-green, they are also capable of turning water brown or red. *Cyanobacteria* are most often the cause of taste and odor problems, as well as nuisance conditions in lakes and ponds. *Cyanobacteria* maintain a competitive advantage over other algae. They have the ability to extract nitrogen from the atmosphere in a process called nitrogen fixing, allowing them to thrive as phosphorus levels increase in the water. They can avoid predation by producing gas vacuoles to regulate their position in the water. Some species produce toxins or slimy coats that are unpalatable for zooplankton and zebra mussels *(Dreissena polymorpha)*, and they form masses too large to be ingested.

The algae species listed above are usually the cause of algal blooms in the lakes and ponds throughout the northeastern United States. In some New York State lakes, however, other algae and microorganisms may also comprise a significant part of the planktonic community.

Weeding through the larger plants

The larger rooted plants that inhabit lakes, referred to as macrophytes, resemble the plants that grow on land since they usually have roots, stems, leaves, flowers and seeds. A few species of macrophytes found in New York State lack true roots, such as coontail

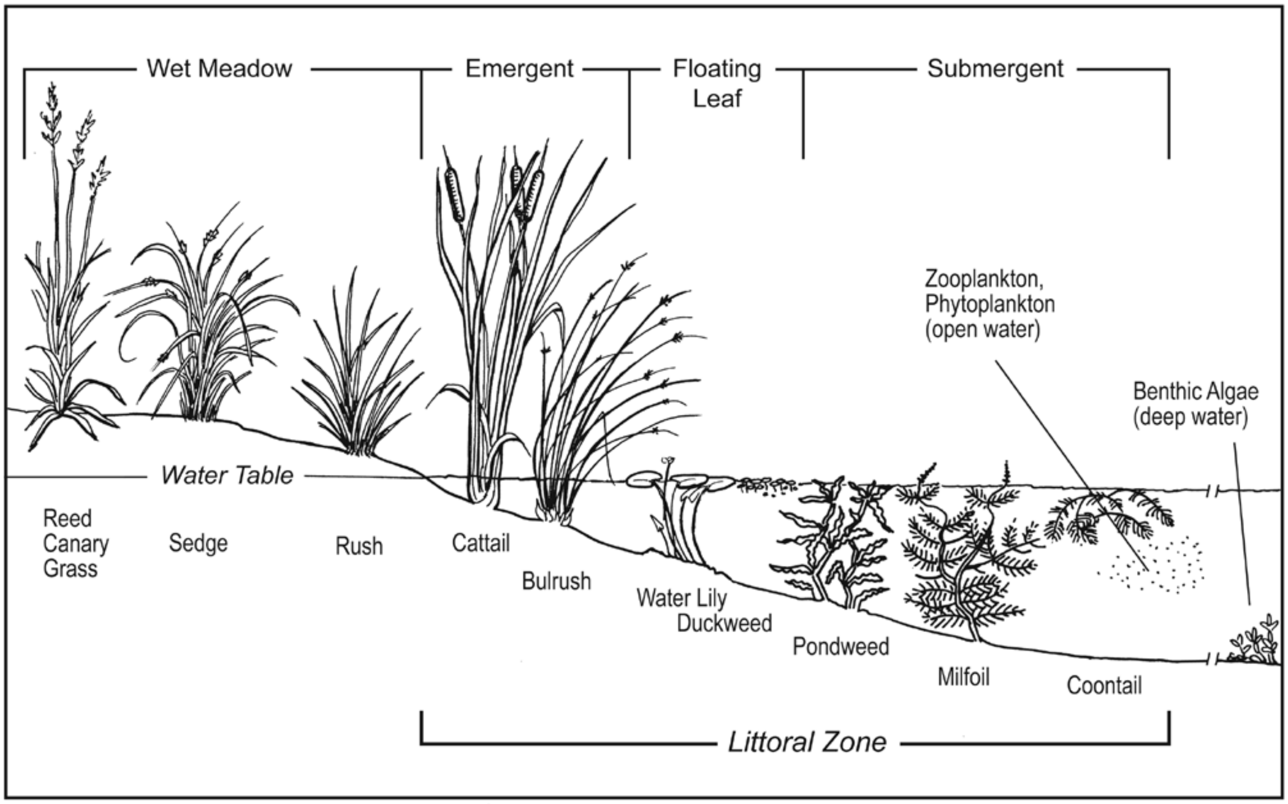


Fig. 1–10. Typical shoreline zone of a lake, pond or marsh showing the transition from upland plants to submerged macrophytes to algae. (CREDIT: WENDY SKINNER)

(Ceratophyllum spp.*)* and bladderwort *(Utricularia* spp*)*. Macrophytes are either **bryophytes,** primarily mosses and liverworts, or vascular plants that transport nutrients and water through their stems. Bryophytes are found in many New York State lakes, but they are generally inconspicuous. Most of the visible macrophytes are vascular plants.

Aquatic plants may be most noticeable to lake users when they are problematic, but functions served by aquatic plants are extensive and impressive. They harbor aquatic insects that serve as the food for fish, as well as providing a launching pad for these insects from the water to the air. They provide cover, nurseries and spawning areas for amphibians, fish and **zooplankton,** the microscopic animals found in every drop of water. They supply food for waterfowl and other creatures of the wild. They hold sediment in place, dampen wave action and otherwise control flow patterns, thereby reducing erosion and the transit of turbidity and nutrients into open waters. They create oxygen and aid in the water purification process by providing habitat for microbial degradation and converting toxic compounds to useful raw materials. Many of these macrophytes are quite beautiful, from the colorful flowers of pickerelweed or water lilies, to the delicate but dangerous nets cast by the carnivorous bladderwort, to the fern-like simplicity of Robbins pondweed. In short, aquatic plants are absolutely essential to the proper maintenance and function of a healthy and attractive lake or pond.

Macrophytes are commonly grouped by their location in the lake. Some emerge from the water, some float on the water, and some are submerged below the water surface. Most macrophytes can be classified into one of these groups, though some macrophytes exhibit characteristics of several of these categories such as having a floating leaf with most of the plant mass below the water.

Emergent plants grow out of the water at the water's edge, in the boundary between dry land or wetlands and the shallow open-water area known as the littoral zone. These plants are rooted in less than one to two feet of water and have the majority of their stems and leaves above the water. The root and stem structures in these plants are robust to withstand the highly variable water level, desiccation and scouring from ice and sediment found near the shoreline.

A large number of emergent plant species are found throughout New York State. Grasses, sedges and rushes are the most abundant, although cattails and non-native plants such as purple loosestrife and phragmites are perhaps the most prominent. The latter are considered **invasive plants** because they can disrupt the natural ecological diversity. An invasive **exotic plant or animal** is one that is not native to the area but has been introduced by animal or human activity.

Floating-leaf plants, such as water lilies, watershield, and more delicate free-floating plants such as duckweed and watermeal can be found just beyond the emergent plants. These plants grow in water ranging from a few inches to as much as six to eight feet deep. Duckweed and watermeal, growing in shallow water, look like surface algae from a distance. Although floating-leaf plants tend to grow in the most heavily used parts of lakes and ponds, they are usually not associated with nuisance conditions. Like emergent plants, they are rooted under the water (sometimes with thick rootstocks called rhizomes), but the floating leaves usually constitute the bulk of the plant mass. The exotic water chestnut, for example, is considered a floating-leaf plant, despite some underwater architecture. The floating leaves shield light from penetrating to the plant below, reducing the amount of underwater plant growth.

The plants that cause the most nuisance problems are generally **submergent plants**, which are plants with the majority of their mass below the water's surface. These are perhaps the most diverse of the aquatic plants, ranging in size from tiny grass-like plants 20 feet under water that barely peek above the sediment layer, to very tall, conspicuous leafy plants that look a little like redwoods when viewed from the lake bottom. Although the bulk of the plant resides under the water surface, some of these plants sprout a floating leaf or rosette of leaves, and even a spike of flowers above the surface, reminding us that the definitions of submergent and floating-leaf are somewhat arbitrary and confusing. Other plants grow to the lake surface and then spread laterally, forming a dense canopy that ultimately prevents other plants from growing in their shade. Several of the most problematic exotic plants, such as Eurasian watermilfoil *(Myriophyllum spicatum)*, curly-leafed pondweed *(Potamogeton crispus)*, and fanwort *(Cabomba caroliniana)* are submergent plants. In addition to annoying humans, many exotic invasive plants don't fill the important function of providing food for the next rung of the food web, the primary consumers.

Primary consumers

Primary consumers, also known as first-order consumers**,** feed on the primary producers. Algae are food for the small invertebrates such as snails, worms, immature insects and zooplankton. The activities of the smaller lake animals may go completely unnoticed by the casual lake user, yet they have an important role in controlling the levels of algae and influencing the kinds and numbers of fish in the lake. For example, in the early 1980s, alewives, a member of the herring family, were introduced into Conesus Lake, one of the Finger Lakes. The alewives grazed voraciously on *Daphnia*, a type of zooplankton. When *Daphnia* populations plummeted, algae grew largely unchecked and water clarity suffered. The increase in algae occurred despite continuing decreases in nutrient concentrations. Without the disruption to the primary consumers *(Daphnia)*, a decrease in algae levels and increase in water transparency would have been anticipated as nutrient levels declined. In contrast, the water clarity of several other Finger Lakes has increased because of an increase in a primary consumer, the zebra mussel *(Dreissena polymorpha)***.** Populations of this exotic bivalve spread to the Finger Lakes and beyond after its accidental introduction into the Great Lakes in the early 1980s. Zebra mussels have filtered out large quantities of algae resulting in a substantial increase in water clarity. Zebra mussels further alter the ecology of a lake by not consuming blue-green algae, which they avoid due to the algae's gelatinous coating.

Size does not determine placement within the food web. While most of the primary consumers are inconspicuous, primary consumers also include clams, sponges, several fish species, wood ducks, muskrats, and moose. Some of the smallest animals in a lake or pond, including the zooplankton, may eat the primary consumers and are therefore known as secondary or second-order consumers. Many animals, including some fish, are less selective **omnivores**, consuming both primary producers and primary consumers. The majority of fish are primarily **planktivores** (zooplankton-eating) or **piscivores** (fish-eating), but most also include algae within their diet. So while the big fish usually do eat the little fish, the size of an organism does not always dictate their culinary habits.

Second-order consumers and beyond

Second-order consumers feed on primary consumers. Second-order consumers include conspicuous members of the lake community, such as planktivorous fish, most turtles and amphibians, as well as the smaller backswimmers, water striders and *Hydra,* which are common in the shallow waters of ponds and crowded college biology and mythology classes. Second-order consumers are eaten by **third-order consumers**, and so on. This pecking order is not always sequential. Sometimes, tertiary or third-order consumers will eat primary as well as secondary consumers. Third-order consumers include some of the large animals found in the marginal or shoreline habitat including raccoons, herons and snapping turtles. As the consumer order increases, the number of species and the abundance of individuals within the species tend to decrease so there are fewer top predators. Consumers, in turn, are fed on after death by scavengers such as leeches, flatworms, waterboatmen and crayfish.

All of these organisms become food for the **decomposers,** the bacteria and fungi that break down all living things and are invisible to the naked eye. Decomposers convert large quantities of organic matter back to carbon dioxide and nutrients, the basic elements needed to support photosynthetic organisms. The process is called **nutrient recycling.** Not only does this prevent the accumulation of thick layers of organic material, it also renews the food web necessary for the maintenance of the entire lake ecosystem. Oxygen is used in the decomposition process, which reduces the amount of oxygen in bottom waters. When oxygen is depleted, noxious or even poisonous chemicals are produced in large quantities. The result is "rotten egg gas" (hydrogen sulfide), and "swamp gas" (methane and ammonia). Some decomposers are pathogenic, and will be discussed in more detail in Chapter four, "Problem Diagnosis."

The vanishing Common Loon: Harbinger of trouble in the food chain

There is probably no better symbol of the Adirondacks than the loon. Furtive and mysterious, its haunting call beckons those longing for a simple yet rugged life. Nearly 1,000 loons are in New York State, mostly found in remote Adirondack lakes from spring to late fall. Although four loon species are found in North America, the common loon is the only one that breeds in New York. While not an endangered species, the common loon is a species of special concern due to low numbers and to their symbolic importance.

The common loon, like the secluded Adirondack Lake, is threatened by increasing residential and recreational demands. Loons are considered excellent environmental beacons, since they live 20-30 years as second-order consumers often returning to the same lakes each year. Loons are affected by environmental stressors when they ingest mercury-tainted fish and lead sinkers, and when acid rain causes fish populations to plummet. Many organizations are concerned about environmental factors causing a decline in the health and reproductive success of loons. The Adirondack Cooperative Loon Program studies these magnificent birds and the effect of mercury contamination on reproductive success of loons in the Adirondacks. Their work is coordinated with similar research throughout northeastern North America, according to their website (see Appendix F, "Internet resources").

Lake habitats

To help make sense of the richness of life within water bodies, biologists have identified discrete regions of lakes called **habitats**. A habitat is a zone where environmental conditions are rather uniform spatially. Each habitat will support a food web made up of certain types of plants and animals. In most lakes, there are several important habitats: the near shore, **littoral zone,** the open-water, **limnetic zone**, and the deeper, bottom water of the **profundal zone**. The littoral zone is generally found within the epilimnion, while the profundal zone is within the hypolimnion. In each habitat, there is a well-defined community of plants and animals and their interactions are referred to as a food web. The composite of the food webs in the three different habitats makes up a larger food web for the whole lake. In a shallow lake, the bottom and littoral organisms dominate the lake's food web. In a deep lake, the open-water zone is more important than the littoral and deep-water zones.

Some simple physical factors determine the amount and kinds of plants and animals that will be present in the food web. If the slope of the bottom is very steep or the water is very turbid, the littoral zone will be very narrow since the water's depth and clarity limit how much light reaches the bottom. If the littoral zone is exposed to the continuous pounding of wave action, plants may be scarce. In a windy location, the bottom may be sand, gravel or large boulders, limiting the accessible soil needed by many rooted plants.

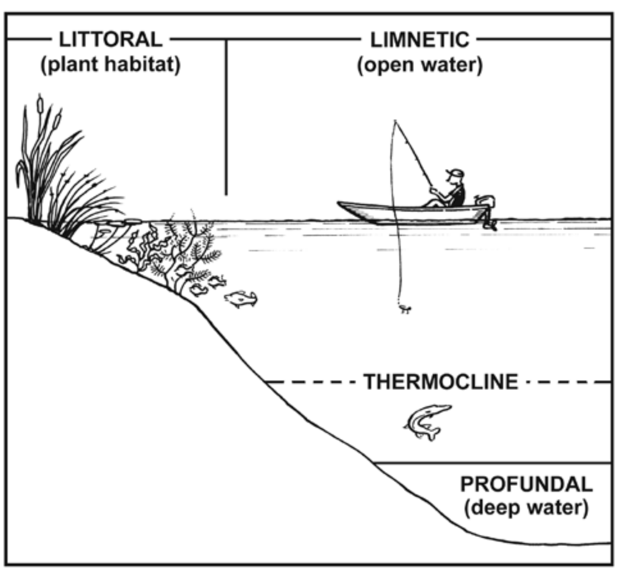


Fig. 1–11. Biologists divide lakes into habitat zones. Each zone—littoral, limnetic and profundal—supports a different aquatic community. (CREDIT: WENDY SKINNER)

The littoral zone extends from the water's edge and includes the area containing macrophytes or rooted plants. Some of these plants are discussed in much greater detail in Chapter six "Aquatic Plants." The littoral zone is ecologically similar to terrestrial habitats. It is very productive and rich in diversity, meaning it has many kinds of plants and animals. Many larger animals, such as fish, frogs, birds and turtles find food and refuge among the plants. The aquatic plant beds serve as a nursery area for young of the warmwater fish that occupy the littoral zone. A wide variety of algae, crustaceans, insects, worms, snails, clams and microscopic animals inhabit this zone.

In the open-water limnetic zone, algae (phytoplankton) and small animals (zooplankton) form the base of the food web. Phytoplankton move at the whim of water movements and gravity, although some can regulate their buoyancy. Zooplankton slowly propel themselves up and down in the water column, which allows them to graze on the phytoplankton and avoid predators. Zooplankton include **crustaceans** and other small animals without backbones (**invertebrates**). Crustaceans are the freshwater relatives of shrimp and lobsters and under the microscope look quite similar to their larger marine cousins. The zooplankton are food for larger invertebrates and most fish, at least at some developmental stage.

At night, the open water may also contain bottom-dwelling animals, such as immature forms of insects (**larvae**) that migrate from the bottom to the lake's surface. They may hatch and fly away, or feed and then return to the bottom before daylight. The open water is also home to some free-floating fungi and bacteria. Larger animals such as fish, fish-eating birds and turtles may be found in this zone occasionally.

The profundal zone has still, cold water, and little sunlight. The plankton that sinks to the bottom of the lake provides the energy and raw materials that fuels the decomposers, such as bacteria and fungi that dominate the bottom region. If there is sufficient dissolved oxygen, there are also some invertebrates and large predatory fish, such as lake trout, that are attracted to the cold bottom waters during the summer months.

In extremely clear lakes, the bottom may be colonized by microscopic or macroscopic algae. The colonial forms may attain heights of several feet and even look like the more complex plants that grow along the shore. These forms are termed **benthic algae** and sometimes are confused with rooted vascular plants. Two common types are brittlewort *(Nitella)* and muskgrass *(Chara)*.

Lake eutrophication and the succession of lakes

> "Lakes are so ephemeral that they are seldom developed in the geologic record. They are places where rivers bulge, as a temporary consequence of topography. Lakes fill in, drain themselves, or just evaporate and disappear. They don't last." (McPhee, 1986)

Although lakes seem permanent in our human time perspective, they are temporary in geologic time, changing more slowly than we can perceive. Lakes act as sediment traps, and it is natural for them to gradually fill in with sand, silt and organic matter. Natural lake aging is the process of nutrient enrichment and basin filling. It moves lake **trophic levels** from a nutrient-poor (**oligotrophic**) condition to an intermediate (**mesotrophic**) stage of nutrient availability and biological productivity, and finally to a nutrient-rich or highly productive (**eutrophic**) state.

It should be understood that this is an inevitable natural process, just as human aging is inevitable. However, the lifespan of lakes, or at least entities that we recognize as lakes or ponds, occur over hundreds to thousands of years unless eutrophication is greatly accelerated by disruptions to a watershed.

Trophic conditions in lakes are relative, not absolute. There is no definitive line between oligotrophic and mesotrophic, or between mesotrophic and eutrophic. Each trophic state, however, has characteristic conditions. Oligotrophic lakes have little organic productivity, clear water and low nutrient levels. These lakes area often characterized by deep water

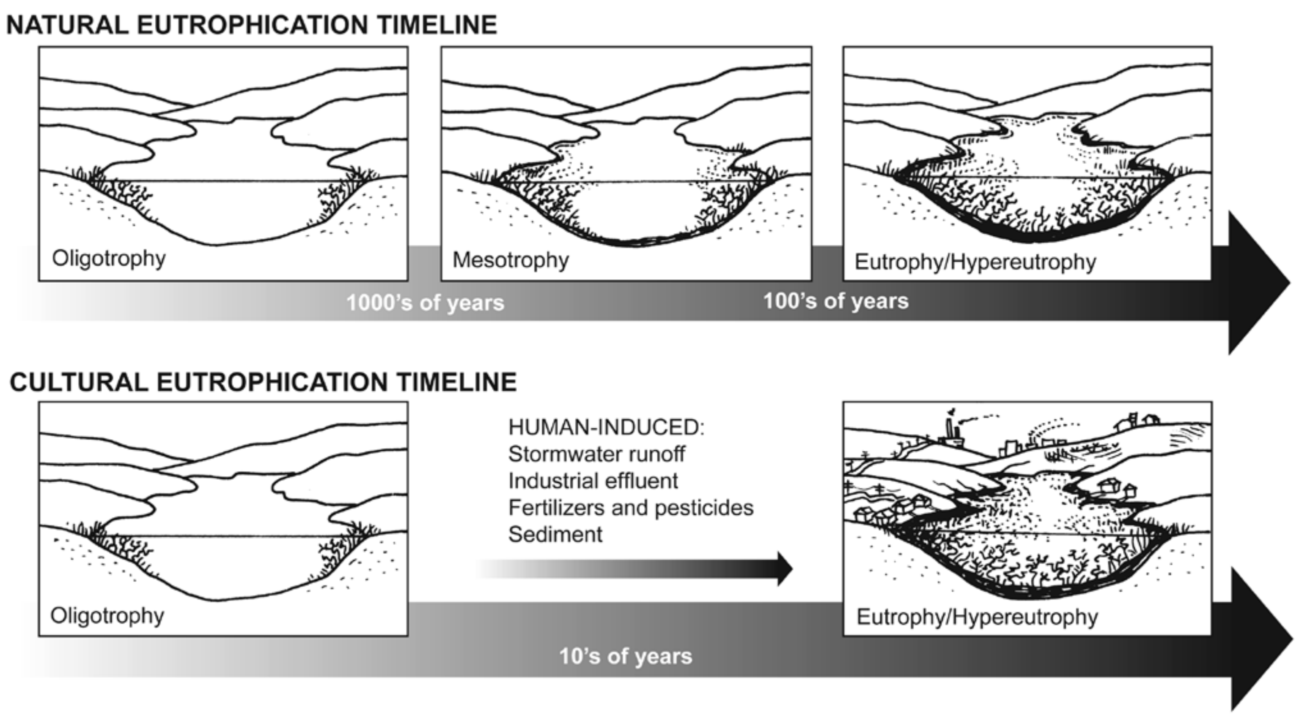


Fig. 1–12. Lakes naturally and slowly progress towards eutrophic conditions. When human activities accelerate the process, it is called cultural eutrophication. (CREDIT: WENDY SKINNER)

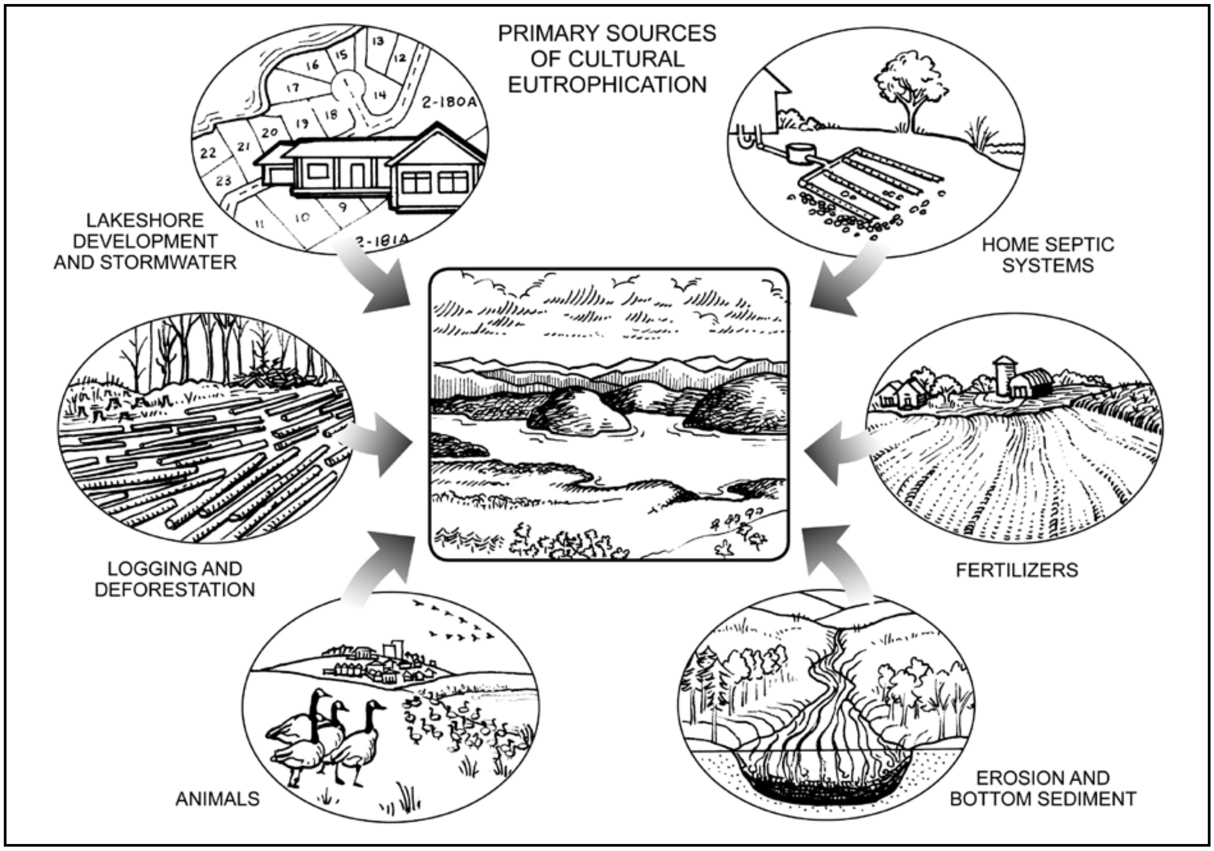


Fig. 1–13. Primary sources of cultural eutrophication. Human activities such as housing, logging, and farming accelerate the rate of natural eutrophication. (CREDIT: WENDY SKINNER)

and steep basin walls. Water in mesotrophic lakes contains a moderate supply of nutrients and organic production. Eutrophic lakes are characterized by a very high level of nutrients that cause a significant increase in the rate of plant growth, usually algae, but sometimes rooted plants as well. Water clarity is greatly reduced, and oxygen depletion is common during the summer months as that organic matter decomposes. Eutrophic lakes tend to be shallow and, typically, have elevated water temperatures.

Lake ecologists may inherently view high productivity in a very different way than an economist. In lakes, high productivity is often thought of as bad. However, these trophic states do not necessarily indicate the existence or even threat of water-quality problems. Some lakes are naturally more productive than others, due to underlying geological influences, slopes and other geomorphic characteristics. **Geomorphology** relates to the geology and shape of the lake basin. The ecosystem and water-quality conditions associated with these lakes have evolved over time to support certain flora and fauna that represent "natural" conditions for the lake. Different species of organisms, from algae to plants, and from insects to fish, inhabit lakes with different trophic conditions. Some naturally more productive lakes, such as Oneida Lake, support healthy warmwater fisheries. Other less productive, oligotrophic lakes, such as some remote and/or acidic lakes in the Adirondacks, may not support warmwater fisheries or may be too cold during much of the summer to promote swimming. So oligotrophic is not necessarily synonymous with healthy, and eutrophic does not necessarily mean unhealthy. However, a shift in trophic condition away from "normal" for a particular lake will often signify underlying water-quality problems and result in use impairments.

Human activities that increase nutrient and sediment loadings to a lake are termed **cultural eutrophication** and include forest clearing, road building and maintenance, farming, construction and

wastewater discharges. If appropriate precautions are taken, damages from these necessary activities can be minimal. Without precautions, these activities can greatly accelerate the natural aging process of lakes; cause successional changes in plant and animal life within the lake, shoreline and surrounding watershed; and impair the water quality and value of a lake. They may ultimately extend aquatic plants and emergent vegetation throughout the lake, resulting in the transformation of the lake into a marsh, prairie, and forest. The influence of cultural eutrophication in the short term may be seen in reduced water depth, decreasing water clarity or more frequent algal blooms. The period of time for such changes to be seen can sometimes be as short as several decades, although it is important to remember that fluctuations in water transparency, algae levels, and other measures of eutrophication also occur naturally from year to year.

Really big picture stuff

While a watershed profoundly affects a lake, there are even larger systems at work. As in localized cultural eutrophication, human activities can accelerate changes in the larger systems of atmosphere and climate. Greenhouse gases, including carbon dioxide and other air pollution, collecting in the atmosphere, trap the sun's heat and cause the planet to warm up. Most scientists believe this global trend, referred to as global climate change, or **global warming**, is dramatically affecting the ecological balance of the planet and is likely to increase severe weather conditions, including more hurricanes, flooding and droughts. Most of the climate change research has not been conducted at a sufficiently detailed scale to evaluate how it affects the small lakes and ponds in New York State. The normal changes from year to year make it difficult to sort out which are caused by global climate change, but some patterns are emerging.

An evaluation of more than 150 years of ice-in/ice-out data from about 40 lakes around the world, including Oneida, Otsego, Schroon, and Cazenovia lakes in New York State, demonstrated that the period of ice cover decreased in about 95 percent of these lakes over this period. For the first 100 years, until about 1950, the duration of ice cover decreased about 12 days, starting about six days later and ending about six days earlier. Since 1950, ice-in started about nine days later and ice-out ended about 10 days earlier, although on average the decrease in the duration of ice coverage in the four New York State lakes was about half the worldwide average. While there was some evidence that this followed a nearly 400-year-old trend, based on sediment core analyses, it appears that the warming trend escalated in the last 150 years.

Changes in water temperatures could impact coldwater fisheries habitats, forcing some fish to relocate. Half of the coldwater habitat in the New York portions of Lake Ontario and Lake Erie could be lost. If temperature and oxygen mixing patterns change, significant reductions in phytoplankton and zooplankton, the base of the food chain, could result. The migration and establishment of historically southern-climate exotic species in the northern temperate climate New England and Mid Atlantic states can be attributed at least in part to global climate change. And it may not be coincidental that increasing occurrences of harmful algal blooms and toxic algae in recent years has been coincident with these warming trends.

The effect of global climate change on lake ecology will continue to be studied in great detail. As this research progresses, however, the effects from global climate change may still not approach the way local actions influence all components of small lake systems in New York State.

Summing it up

This basic introduction to lake ecology is fundamental to understanding the subsequent chapters including how to address the many problems that plague lake users. It was not intended to be a primer on lake ecology. Entire textbooks, college courses, and endless sunrise debates between waiting fishermen have been dedicated to some of these topics. The reader is encouraged to seek out additional resources related to the management activities for the lake he or she loves. Biomanipulation and drawdown are examples of strategies discussed later in this manual that call for a more focused knowledge of the interactions of the biology, physical and chemical aspects of a lake.

2 Lake Montauk to Lake Erie: 7,850 New York State Lakes

Introduction

Famous Lake George, Queen of American Lakes, and beautiful Skaneateles Lake stand in contrast to infamous Onondaga Lake, referred to as the nation's most polluted lake. These extremes exemplify the wide range of lakes within New York State. Lakes can be found in the middle of large metropolitan areas where they are seen daily by millions and in secluded forests accessible only by bumpy dirt roads or narrow hiking trails. Our lakes also come in a wide variety of sizes, shapes, and even colors. This chapter explores the similarities and great variety of lakes in New York State, and provides insights into regional characteristics to help develop informed lake management programs.

Water, water, everywhere

No standard definitions of what constitutes a lake or pond exist in New York State. By the most commonly accepted definitions, however, New York State has about 7,850 lakes and ponds, including its reservoirs. Until the state adopts standard definitions, the unofficial estimate remains at 7,850. That places New York State sixth on the national Most Lakes List, behind Wisconsin, Maine, Michigan, and Minnesota. Alaska leads the list with a nearly unbelievable one million lakes. The lakes of New York State occupy a surface area of nearly 4 million acres, or more than 10 percent of the state. About 80 percent of this watery area is dominated by Lake Ontario and Lake Erie, the two Great Lakes that New York State shares with Canada and other states. Due to their enormous size, these two lakes are usually excluded from standard water resources statistics for New York State, such as volume of water, surface area, and number of shorefront residents. Even without Lake Ontario and Lake Erie, however, other New York State lakes still occupy a substantial part of the surface area of the state, and lakes are an important part of the lifeblood of New Yorkers.

What's in a name?

The names of New York lakes are as idyllic as Journeys End Lake, as peaceful as Whippoorwill Lake, as simple as G Lake, as ominous as Big Bad Luck Pond, and as evocative as Teakettle Spout Lake. The name of a lake may give clues to its character, as with the 34 round, oval and oblong lakes that are named Round and the large number aptly named Green Lake. The colors of the rainbow are well represented. There are lakes named Red, Yellow, Blue, Green, Orange, Brown, Black, White, and even Clear. There is no Purple Lake; one can only speculate whether this was due to its infrequency in nature or in verse. There are at least 23 Silver Lakes or Ponds, some of which are often quite green. One Silver Lake, an acidic Adirondack Lake, may be the clearest lake in the state. About 3,050 lakes, ponds and reservoirs have been officially assigned names and are listed in the *Gazetteer of New York State Lakes, Ponds, and Reservoirs* (NYSDEC, 1987). That list contains the vast majority of New York State lakes considered "significant." Another 500 or so unnamed larger ponds, and 4,300 unofficially named and unnamed smaller lakes and ponds, are often known only by the name of a present or historical landowner.

Lake classifications and characteristics

Best intentions

All waterbodies in New York State are classified by New York State Department of Environmental Conservation (DEC) for their best intended use, such as drinking water, recreation or wastewater disposal. In this system, lakes used for drinking water are considered Class AA or Class A lakes, the distinction corresponding to the amount of treatment required to render the water safe for drinking. As an added distinction, some lakes in the Lake George area are Class

AA-S (S=special), which means that no wastewater, whether treated or untreated, can be discharged directly into them. Consequently, their waters can be used as a drinking water source with only minimal treatment. Similar rules apply to lakes Erie and Ontario, which are also designated as Class A-S.

Lakes used primarily for contact recreation, such as swimming, are designated as Class B. These lakes are not classified for drinking water, have somewhat less stringent water-quality standards, and can accept discharge of treated wastewater, although direct discharges to small lakes are not common in New York State. Class C lakes are used primarily for non-contact recreation, such as fishing and boating.

While Class D lakes were originally designated to accept wastewater, this designation has been phased out. All lakes must now meet the federal goal of "swimmable, fishable" conditions, so Class D lakes have been reclassified to reflect more appropriate uses. Class N lakes are found within the New York State Forest Preserve, and are not classified for human uses, although they do serve many ecological functions within the forest ecosystems. The classification system is described in detail in the Appendix B, "New York State water quality classifications." (6 NYCRR Part 701)

The assignment of lakes into these categories reflects the convergence of several factors:

- historical precedent (how it was used);
- water quality information, is it adequate to support a particular use; and
- caution, without sufficient information, a "lesser" use is assumed.

Water-quality parameters

There are general correlations between best intended use and water-quality conditions, as seen in the Table 2–1 (NYSDEC, 2004a), but there are also some odd results. Heavy recreational use has degraded some lakes classified for drinking water and they may not fully support the best-intended use of the lake. At the other end of the spectrum, many lakes classified for non-contact recreation (Class C) have long been adequate to support contact recreation or even potability. However, because they have seen

(Continued on page 24)

A tale of two lakes

To paraphrase Garrison Keillor, most lakes in New York State, like the men of Lake Wobegon, are above average, at least compared to most United States lakes. That said, there are also too many lakes that don't quite approach average. New York State has a legitimate claim to have both the "best" and "worst" lakes in the country. Fortunately, there are many contenders for the title of best lake, with Lake George, Lake Placid, and countless smaller and obscure lakes and ponds vying for the crown. Skaneateles Lake, the jewel of the Finger Lakes and one of the most pristine lakes in the country, is almost visible from the tallest waste beds along the shoreline of the worst lake in New York State. Onondaga Lake holds the dubious distinction of "most polluted" lake, with its shoreline wastebeds, and contaminated water and sediments. These two opposites, only a few miles from each other, are really oceans apart.

Troubled waters

Onondaga Lake is a 3,000-acre lake in the city of Syracuse and its adjacent urban communities. It is one of the largest urban lakes in the country, enjoys a rich history, and is considered hallowed ground as the site of the founding of the Iroquois Confederacy. In the 19th century, the lake supported a thriving resort industry; a coldwater fishery comprised of Atlantic salmon, lake sturgeon, and whitefish; and served as an important recreational and commercial way station for many residents and visitors. For most of the 19th century, the lake was also a leading domestic source of salt in the United States, and was a large factor in the development and success of the Erie Canal.

Unfortunately, the lake has also been the recipient of a century of industrial contamination and municipal wastewater, byproducts of an age in which urban development was often insensitive to the degrading effects on spectacular natural resources. The resulting ruination prompted Daniel Patrick Moynihan, then a New York State Senator, to give Onondaga Lake the title of "the most polluted lake in the world."

The downward spiral began in the late 19th century. The Solvay Process Company established a factory on Onondaga Lake that produced nearly 80,000 tons of soda ash in 1890. This output grew to nearly 1 million tons annually by the mid 1960s, which resulted in about 2 million tons of calcium chloride and sodium chloride waste. This waste was discharged directly into the lake, or pumped to wastebeds along the lake shore. In-lake waste deposits measured up to 45 feet deep and wastebeds along the shore rose to 65 feet tall along a third of the shoreline. The company became Allied Chemical and eventually Honeywell International. From the middle of the 1910s until the late 1980s, the various companies discharged to the lake a brew of organic compounds, including benzene, toluene, hydrochloric acid, mercury, polychlorinated biphenol (PCB), and other carcinogens.

In addition, undertreated wastewater and untreated stormwater also flowed into the lake. Starting in the 1920's, municipal wastewater from the Metropolitan Syracuse Wastewater Treatment Plant discharged directly in the lake at the south shore. The effluent comprised roughly 20 percent of the water entering the lake, perhaps the largest percentage for any lake in the country. Advanced wastewater treatment was not utilized until the late 1970's, similar to most other wastewater treatment plants in the country. All of this led to the U.S. Environmental Protection Agency (EPA) declaring Onondaga Lake as a hazardous waste site in 1994.

This steady attack of pollutants took its toll. The coldwater fisheries disappeared in the 1920's. Swimming was prohibited by the 1940's. Fishing was banned in 1972, although a catch-and-release program was allowed by 1986, and limited consumption of some fish species was restored in 1999. A significant lake restoration plan has been proposed for the lake, highlighted by a $451 million-dollar settlement with Honeywell International in 2006. Remediation methods include capping, dredging and barrier walls sited along much of the lake bottom, shoreline and within the groundwater zone. Advanced wastewater treatment improvements, and a significant reduction of combined stormwater-wastewater sewer overflows will require a similar expenditure. (Landers, 2006). There is some evidence of recent improvements in nutrient levels in the lake.

Beautiful waters

Skaneateles Lake's rich, blue water is as clean as Onondaga's is dirty. William Henry Seward, world traveler and the Secretary of State under Abraham Lincoln, called Skaneateles Lake "the most beautiful body of water in the world." This Finger Lake is a primary water supply for the city of Syracuse. It spans a length of 17 miles, is 300 feet deep and covers 8,700 acres. It is among the clearest lakes in the country, with water transparency readings occasionally exceeding 50 feet (15 meters), rivaling the water clarity normally found only in sterile, highly acidic lakes. The nutrient and algae levels are very low, while oxygen levels remain high from top to bottom. The lake supports healthy warmwater and coldwater fisheries, including perch, smallmouth bass, lake trout, rainbow trout and landlocked salmon. It has a long history of boating, with the first steamboats using the lake in the 1830's, and it hosts a number of national and international sailing events. These attributes add to the tourism appeal of the quaint village that inherited the name of the lake.

Added credence was bestowed on the purity of Skaneateles Lake when the EPA affirmed that the city of Syracuse could distribute the water from Skaneateles Lake to its users without filtration. This Filtration Avoidance Determination is rare. While awarded to the New York City reservoirs (see "Snapshot of the New York City Reservoirs" case study in the Downstate lakes section of this chapter), this designation has not been granted to Lake Superior and most other pristine lakes. This designation came with a high level of responsibility to keep pollutants out of the lake, which created a number of innovative programs. The Skaneateles Lake Watershed Agriculture Program (SLWAP) involved partnerships between Cornell Cooperative Extension offices, several government agencies, the City of Syracuse, and farmers. Twenty-six farms in the watershed adopted whole-farm plans devised to reduce contaminants exiting the farms. SLWAP resulted in agricultural pollutant management of more than 90 percent of the farmland in the watershed. This reduced soil erosion by more than 2,700 tons per year, and annually saves farmers more than $1,000 in fertilizer costs.

The Skaneateles Lake Watershed Land Protection Program (SLWLPP) is a pollution prevention initiative with extensive educational and outreach programs. It is a partnership between the City of Syracuse and Skaneateles Lake watershed residents. Information is available throughout the watershed on septic management, water-testing and treatment, well management, erosion control and conservation easements for landowners. Municipal regulations have zoning, wastewater and chemical disposal and agricultural activities. In addition, Article 17-1709 of state Environmental Conservation Law (ECL) prohibits point-source discharges within the Skaneateles Lake watershed.

little organized use historically, particularly in remote and inaccessible regions such as the Adirondacks, they have been classified C to fit their best intended use. The aggregate of Class C lakes has lower water clarity than their phosphorus levels might predict because the water in so many of these lakes has a natural brown color that limits light transparency.

Even though similar amounts of pollution often enter both shallow and deep lakes, deep lakes generally have greater water volume and, therefore, a better chance for diluting the pollution. Although the maxim "dilution is the solution to pollution" mostly reflects the use of streams and rivers to dilute wastewater, it also applies to lakes. Table 2–2 shows the relationship between water depth and water quality. (NYSDEC, 2004a)

Water Quality Classification	% of NYS Lakes	Typical Water Clarity (meters)	Typical Phosphorus Levels (ppb)	Typical Water Color*	Typical pH Classification+
Class AAspecial	1%	4–5	10	Faint	Slightly basic
Class AA	7%	3–4	10	Faint	Slightly basic
Class A	10%	3	10–15	Faint	Slightly basic
Class B	23%	2–3	15–20	Not visible	Basic
Class C	46%	2–3	10–15	Moderate	Slightly acidic
Class N	13%	2–3	10–15	Moderate	Acidic

Table 2–1. Correlation between water-quality classification (best intended use) and actual water quality.
**Refers to "natural" brown color. +Neutral pH = 6.8 to 7.2; Slightly basic = 7.2 to 7.5; Basic = greater than 7.5; Slighty acidic = 6.5 to 6.8; Acidic = less than 6.5.*

Lake Type	Typical Water Clarity (meters)	Typical Phosphorus Levels (ppb)	Typical Water Color*	Typical pH Classification+
Very Deep Lakes (>100 feet deep)	4–5	5–10	Faint	Slightly basic
Stratified Lakes (> 20 feet deep)	3–4	10–15	Faint	Basic
Shallow Lakes (< 20 feet deep)	2–3	20	Moderate	Slightly acidic

Table 2–2. Correlation between lake depth and water-quality parameters.
**Refers to "natural" brown color. +Neutral pH = 6.8 to 7.2; Slightly basic = 7.2 to 7.5; Basic = greater than 7.5; Slighty acidic = 6.5 to 6.8; Acidic = less than 6.5.*

There is often a water-quality distinction between deep and shallow lakes in New York State that is not coincidental. The amount of pollutants entering lakes is controlled by a number of factors associated with the perimeter of the lake, including the:

- extent of shoreline development;
- age and viability of septic systems, and frequency of pumping; and
- greenness of surrounding lawns, which indicates how many lawn-care chemicals may be washing into the lake.

What's the dirt on New York State lakes?

Geography and geology influenced when and how land was colonized, and they also dictated the number and kind of lakes that formed. The lands of New York State can be characterized by more than 70 unique categories of soil types, and a similarly large number of categories of near-surface soils and bedrock

soil types. Some of these geologic features leave a significant imprint on the type and quality of lakes within the state. For example, the thin soils and lack of limestone within areas of the Adirondacks leaves many lakes sorely lacking in alkalinity or **buffering capacity**, which renders them susceptible to acidic deposition, commonly called acid rain. The same geologic fingerprint results in many lakes becoming naturally acidified. They have amber-brown coloration and **soft water**, both of which significantly affect their flora and fauna.

Bureaucratic tags

Both DEC and EPA identify ecological regions where common soil and geological features, land use patterns, and other shared factors result in common ecology and lake conditions.

Ecozones and ecoregions

Ecozone is defined as a large area that contains a geographically distinct assemblage of natural communities sharing a large majority of their environmental conditions, species and ecological dynamics. Some ecozones are named for their governing geographic feature, such as the Mohawk Valley, Hudson Valley, Appalachian Plateau, and Manhattan Hills. Other names, such as the Coastal Lowlands (referring to Long Island) are not as descriptive. To add to the confusion, lakes in some of ecozones exhibit few differences from those in others. The ecozone concept, therefore, has limitations for classifying New York State lakes.

EPA has promoted the development of **ecoregions,** dividing the nation into 14 distinct areas based on the "natural" nutrient conditions of an area and not limited by state or local political boundaries. EPA nutrient ecoregions within New York State are shown in Figure 2–1 (EPA, 2007). Water-quality conditions vary within each of these ecoregions, based on surface and bedrock geology, soil types, land uses, and the extent and duration of human usage of these lakes as shown in Table 2–3. (NYSDEC, 1987; 2004a)

These classifications ultimately may be useful for developing regionally based water-quality standards.

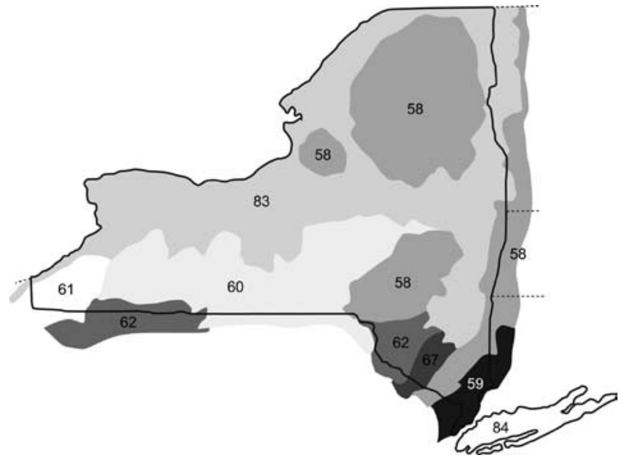


Fig. 2–1. EPA Level III ecoregions in New York State. Areas defined by EPA based on existing nutrient conditions.

USEPA Ecoregions in NYS	Name	% of NYS Lakes	Typical Water Clarity (meters)	Typical Phosphorus Readings (ppb)	Typical Algae Levels (ppb)*
58	Northeastern Highlands	45	2–3	15	1–5
59	Northeastern Coastal Zone	7	3	15–20	5
60	Northern Appalachian Plateau and Uplands	14	3	10–15	5
61	Erie Drift Plain	2	1–2	30–35	20–25
62	North Central Appalachians	7	3–4	10	1–5
83	Eastern Great Lakes and Hudson Lowlands	25	2–3	15–20	5–10
84	Atlantic Coast Plain Barrens	1	1–2	1–20	5–10

*Table 2–3. Water-quality conditions in EPA ecoregions in New York State. Variations are based on surface and bedrock geology, soil types, land uses and extent and duration of human usage. *Measured as chlorophyll a.*

These nutrient-based delineations may have important ramifications for both local and regional lake management. Much of what constitutes lake management in New York State revolves around nutrient control, and is discussed in Chapter four, "Problem diagnosis" and Chapter five, "Fisheries management.

Hydrologic Unit Codes

As if the terms ecozone and ecoregion weren't confusing enough, the state has also been divided into large and small drainage basins. These nested watersheds have been given even more confusing designations called **Hydrologic Unit Codes** (HUC). For New York State lakes, the most significant designations are the "HUC 6" codes, which essentially divide the state into the 14 major drainage basins as pictured in Figure 2–2. (NYSDEC, 2007). HUC

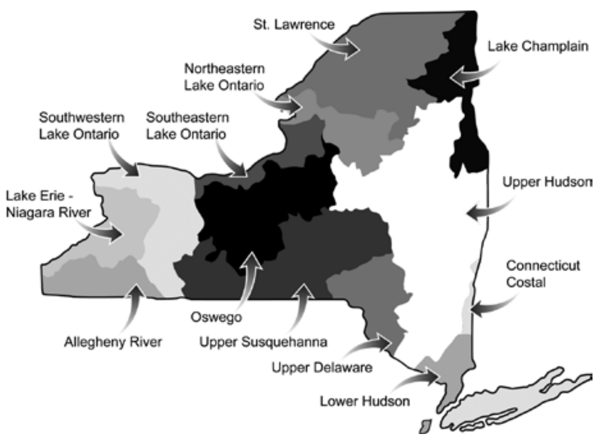


Fig. 2–2. New York State major drainage basins.
The major watersheds designated as Hydrologic Unit Codes 6.

numbers are required on some grant proposals, and these designations serve a number of government purposes. A variety of EPA and state government sources provide information on the HUC codes for specific waterbodies and more information on this nested system.

These delineations of ecozones, ecoregions, and HUC drainage areas can be very useful. They are related to lake geography, topography, hydrology, and geology, and other -ographies and -ologies," but they are not really intuitive. For example, the Adirondacks are part of the "Nutrient Poor Largely Glaciated Upper Midwest and Northeast" ecoregion. This ecoregional title does not elicit strong images of a lonely loon call on a peaceful summer morn. Most people would think of "Manhattan Hills" as a New York City address rather than an ecozone. While these geographical fractions of the state are close to valid and easily understood, an even simpler system is possible.

Location, location, location

As in real estate, the most important factors that affect the "value" of a lake are location, location and location. A more intuitive separation of the state uses broad geographic areas that correlate to broad lake characteristics. Although the broad geographical regions used below may share some characteristics with nearby neighbors, each region is unique enough to warrant a separate category, despite the long-standing impression of many New York City and Long Island residents that anything north of Westchester County can be generically called "Upstate." The character of each region is described as it relates to the lakes within its confines. Tables in this section use either metric or standard units in keeping with the original data source.

Long Island and New York City lakes

Fig. 2–3 Location of Long Island and New York City lakes.

This region of the state is characterized by very high population density, and by geology that is unique among New York State regions, which dramatically influences the type of lakes present. The densest population occurs in the western areas including New York City, decreasing to moderate and sparse population densities further east on Long Island. Since this region has the highest population density and smallest percentage of landscape covered by lakes (see Table 2–4), human pressure and its effect on lakes in this region is great. (NYSDEC, 1987; U.S. Census Bureau, 2000)

Region*	Population Density	% of Region Occupied by Lakes
Long Island/NYC	> 6000 /sq. mile	<1%
Downstate	350 /sq. mile	1%
Central NY	100 /sq. mile	1%
Adirondacks	20 /sq. mile	4%
Finger Lakes Region	200 /sq. mile	3%
Western NY	240 /sq. mile	1%

*Table 2–4. Population density of each New York State region and the percentage covered by lakes in each region. *Figures do not include area encompassed by Lake Ontario and Lake Erie.*

The surface geology is primarily gravel with some sand, underlain by thick deposits of unconsolidated sediments. Coarser grained soils dominate the primarily flat or low-elevation terrain, heavily occupied by both fresh and tidal wetlands and plains.

There are not a large number of lakes in this region. A typical lake in Long Island and New York City tends to be small, shallow, and kettle in origin. The lakes are highly productive, with relatively low water clarity and high levels of nutrients and algae. Less than 10 percent of the lakes are larger than 100 acres. The largest is the 500-acre Lake Montauk. More than 30 percent of the named lakes are between 6 and 10 acres.

The western, urbanized portion of this area has small numbers of waterfowl inhabiting "pocket" ponds that fill slight depressions in a dense network of buildings, roads and pavements. The eastern section of this region is characterized by a landscape of oak/pine bush and agriculture, proximity to tidal influences, and the temperature-moderating influences of the Atlantic Ocean and Long Island Sound. There are many small, shallow, moderately colored, fresh to moderately saline, sandy bottomed ponds that are either very weedy or highly turbid. Many of these lakes are classified for shell fishing. Due to the mix of fresh and saline waters, the fisheries communities can be dominated by both freshwater and saltwater fish.

Long Island and New York City lakes are used for aesthetic enjoyment, fishing, and boating that is limited to non-power craft. Unlike other parts of the state, most of these lakes do not suffer the user conflicts among residents, swimmers, anglers, power boaters and canoeists, although birds and humans often compete for the same close spaces.

Fanwort *(Cabomba caroliniana)* is the most significant invasive aquatic plant in this region. The exotic weed is rare in most other parts of the state. Relatively new invaders such as variable watermilfoil *(Myriophyllum heterophyllum)* and Brazilian elodea *(Egeria densa)* are also clogging Long Island waterways. In contrast, Eurasian watermilfoil *(Myriophyllum spicatum)* and water chestnut *(Trapa natans)*, the exotic plants most common to the rest of the state, have only recently been found in this region. Hydrilla *(Hydrilla verticillatum)* was also first found in Long Island in 2008. This region is highly susceptible to invasions from exotic plants and animals due to climate and the proximity to domestic and international shipping routes. Long Island and New York City may be a major gateway through which many exotic organisms enter the waterways of New York State. These lakes and ponds, however, also contain many rare and threatened plant species, some of which are unique to the Pine Barrens on eastern Long Island.

Lake management issues tend to focus on the invasive aquatic plants that are common in many of the shallow lakes in this region. There are algal blooms triggered by nutrients from urban runoff and groundwater, waterfowl contributions, and lake users, and an increasing number of lakes and ponds with blue-green algae producing toxins. There is fish contamination due to pesticides, organic compounds, and heavy metal. As a result, an inordinately high percentage of lakes in this region are on the federal

Region	% of NYS Lakes	% of 303d Lakes Listed for Fish Consumption Advisories
Long Island/NYC	5	20
Downstate	18	10
Central NY	12	15
Adirondacks	58	40
Finger Lakes Region	5	10
Western NY	2	5

Table 2–5. Percentage of lakes in each New York State region, and the percentage of lakes by region that are on the Federal 303d list for fish consumption advisory.

303d list of impaired waters (see Table 2–5) (NYSDEC, 1987; 2004b). The federal 303d list and other state and federal lake assessments are described in greater detail in chapter four, "Problem Diagnosis."

Most lakes in this region are found within a city or county park. Lake management is frequently the responsibility of:

- municipalities including the New York City Department of Environmental Protection and Parks Department;
- county government agencies include parks departments, Environmental Management Councils, and Soil and Water Conservation Districts; and
- larger government including the DEC regions 1 and 2 Division of Fish and Wildlife offices, and the Department of State through their Coastal Zone Program.

An unusual exception to this standard management pattern is the lakes within the town of Southampton. Under many circumstances, they are governed by the original charter granted to the town, superseding the jurisdiction of state or county government in regulatory authority (subject to legal interpretation).

Downstate lakes

Fig. 2–4. Location of Downstate lakes.

This region encompasses the area on both sides of the Hudson River north of the Long Island and New York City region and south of the Catskills. The influence of "The City" is heavily felt by these lakes in this area. The region's large concentration of waterbodies, both natural and constructed, serves the immense thirst of New York City for potable water and recreational opportunities. The region contains a relatively large number of lakes classified for use as a drinking water supply, especially in the northwest and southeast portions of the region. Twenty-two of the twenty-five largest lakes in the region are used for drinking water, the waterbodies within the New York City reservoir system. An even larger number of lakes are classified for contact recreation as shown in Table 2–6 (NYSDEC, 1987).

Region	% of Lakes in Region Classified for Drinking Water	% of Lakes in Region Classified for Bathing
Long Island/NYC	10%	35%
Downstate	25%	60%
Central NY	20%	30%
Adirondacks	20%	10%
Finger Lakes Region	15%	25%
Western NY	25%	30%

Table 2–6. Percentage of New York State lakes classified by intended use.

In colonial times, this region was the first in New York State to experience rapid development. Lakes here have some of the longest history of documented uses. As an apparent result, this region has about half of the New York State lakes named "Lake ___," probably mirroring the European convention of "Loch___."

Currently, population density in this region is high, but lower than in the western Long Island/New York City area. The densest population occurs in the southern areas of the region, where the suburbs of New York City are located, decreasing to moderate and sparse population densities further north, east and west. The primary land uses in the southern areas are urban and suburban residential and commercial development, with limited industrial activity. The northern area is dominated by forested land. The western portion of the region contains agricultural land.

The surface geology is dominated by silt and some bedrock. The underlying bedrock geology includes limestone, shale, sandstone, and siltstone, particularly along the northwestern edge of the region. There is some granitic terrain near the Catskills, which geologically and limnologically resembles the Adirondacks more than the lowland downstate areas. Mountainous terrain and "ancient" hills, including the Catskills and the Shawangunks, dominate the northern portions of the region.

The southeastern and southwestern portions of the region, on both sides of the Hudson River, have a high density of ponded waters, but otherwise the downstate region is not particularly rich in lakes. The lakes tend to be small, soft water kettle lakes of various depths.

About 10 percent of the lakes are greater than 100 acres. The larger lakes generally are less productive with greater water clarity and lower nutrient and algae levels than the smaller lakes. A large number of sizeable, power-generating reservoirs were created along the western side of this region, primarily in the southern portion of the Delaware River basin. Other large reservoirs provide drinking water for New York City and suburban communities, and are not used for recreation. Waterbodies not used for potable water have a variety of other activities, including swimming, boating and fishing. User conflicts are common, largely due to the high population densities.

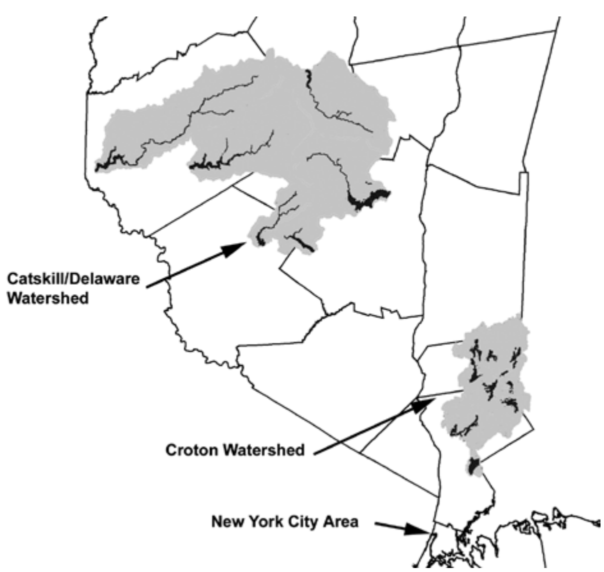


Fig. 2–5. New York City reservoir watershed map.

Snapshot of the New York City Reservoirs

By the early 1800's, the thirst of a growing city, soon to be the largest and most famous in the world, was only partially quenched by an inadequate source of uncontaminated water controlled by the city. Through the foresight of city planners and engineers, and the sweat of thousands of workers, one of the largest public works projects in history began with the construction of the Croton Aqueduct and Reservoir in 1837. Over many years, New York City gradually built a network of reservoirs, constructing dams, conduits, connecting roadways, and underground pressure tunnels criss-crossing tremendous tracts of land occupied by downstate farms, local businesses, and small housing communities. Much of this land was consumed by the city through eminent domain, uprooting thousands of neighbors and scores of neighborhoods, although the huge numbers of workers formed their own temporary communities, and these relocations resulted in some of the first planned communities in the country. By the late 1800s, much of the Croton system of reservoirs had been developed, but it was still not enough as the needs of the city and its expanding suburbs grew. In the early 1900s, the state legislature approved the expansion of the reservoir network into the Catskills, starting with the Ashokan Reservoir, linked to the Kensico Reservoir on the eastern side of the Hudson River through the Catskill Aqueduct. The latter runs between mountain ranges and anywhere from several feet to more than a thousand feet beneath the Hudson River. This system expanded into the Delaware River region in the 1930s, and by 1967 had 18 collecting reservoirs, 6 balancing and distributing reservoirs, 3 lakes, 3 underground aqueducts, and 8 connecting tunnels. This enormous collecting, storage, and delivery system carries more than 1 billion gallons of water as far as 120 miles by gravity. This water is fed into more than 6,000 miles of water distribution lines underneath the city, serving more than 9 million residents of New York City and its northern suburbs, not to mention countless more visitors (See Fig. 2–5) (Galusha, 2002; NYCDEP).

The fisheries communities are dominated by **warm-water fish** that prefer water at or exceeding 50ºF and tend to be tolerant of fluctuations in temperature and oxygen content. This category includes bass, perch, walleye, northern pike, pickerel, muskellunge, sunfish, bluegill and carp.

Many lakes in this region suffer from excessive algae growth and invasive exotic plants, particularly in the more developed southern portion of the region. Eurasian watermilfoil *(Myriophyllum spicatum)* is a problem, although most other exotic plants including water chestnut *(Trapa natans)* have migrated from upstate and Brazilian elodea *(Egeria densa)* and fanwort *(Cabomba caroliniana)* have probably travelled from warmer regions. Like Long Island and New York City, the downstate area is highly susceptible to invasions from exotic plants and animals due to the proximity to multi-state and international boat traffic and to its relatively mild climate. The first New York state finding of Hydrilla *(hydrilla verticillatum)* was in this region, either due to migration from a neighboring state or as an aquaria introduction. At present, the region appears to have less invasive problems than anticipated, although the number of "hot spots" noted on statewide inventories may be artificially low because survey work has been less comprehensive in the southern portions of New York State (see Table 2–7) (NYSDEC, 1987; Eichler, 2004).

Region	% of NYS Lakes	% of NYS Lakes with One or More Species of Exotic Submergent Weeds
Long Island/NYC	5	5
Downstate	18	15
Central NY	12	40
Adirondacks	53	20
Finger Lakes Region	5	10
Western NY	2	10

Table 2–7. Percentage of lakes in each region of New York State compared to the percentage of lakes in that region with exotic, submergent weeds.

**As of 2004, list includes Myriophyllum spicatum, Trapa natans, Potamogeton crispus, Cabomba caroliniana.*

Lake management issues tend to focus on the invasive aquatic plants common in many of the shallow lakes in this region; algal blooms triggered by urban and suburban runoff, lawn fertilization and waterfowl; failing septic systems; water-supply issues; and user conflicts. The high percentage of lakes suffering from exotic weed growth has resulted in a large number of aquatic herbicide treatments and grass carp stockings in this area, perhaps also due to fewer permitting issues associated with the use of these plant management tools. Algae control through the use of copper products (**algacides**) has also been much more common in this part of the state.

Lake management is conducted by:

- residents as individual citizens, or through lake associations and property-owner groups;
- municipalities, including the New York City Department of Environmental Protection, and towns through park districts;
- county governments, primarily Soil and Water Conservation Districts; and
- state agencies, including DEC regions 3 and 4, Division of Water and Division of Fish and Wildlife.

Central New York lakes

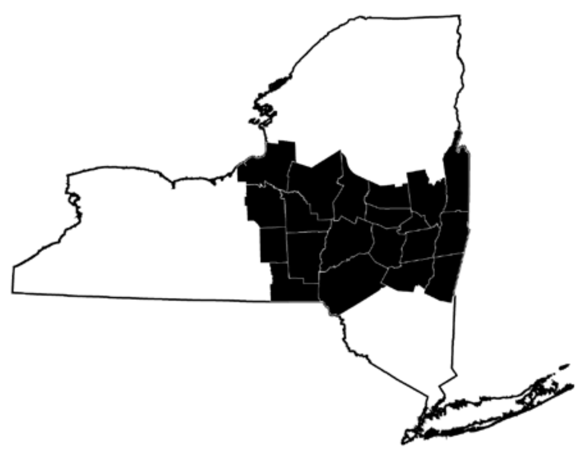


Fig. 2–6. Location of Central New York lakes.

Central New York is a region originally defined by a vast, ancient inland sea that served as the progenitor of the Great Lakes system. It is probably the most disparate of the regions identified here. It encompasses areas known as the Capital District and the Leatherstocking Region. This region stretches from

Downstate to the Adirondacks, from the eastern edge of the Finger Lakes to the Massachusetts and Connecticut borders. It can also be thought of as the eastern Susquehanna River basin, the northern Delaware River basin, and the southern Mohawk River basin. For more than 150 years, the region has been affected by the Erie-Barge Canal system. In short, this potpourri of geographical benchmarks is perhaps the most difficult region to characterize.

The surface geology is dominated by silt, with some bedrock, particularly along the eastern edge of this region. The bedrock geology includes shale, sandstone, siltstone, and some limestone. The terrain is rolling and somewhat irregular.

This region is neither lake-rich nor people-rich. It has the lowest population density of all the regions except the Adirondack region. The primary land uses are suburban or agricultural, with limited commercial and industrial development. The majority of the human activity and densest population is concentrated along the eastern and western edges. The agricultural land is found in interior portions of this region.

The density of lakes is similar to other regions of the state, with the western portion having the highest density. There is great variety in the size of Central New York lakes. Nearly 20 percent of the named lakes are between 6 and 10 acres. More than 20 percent of the lakes are greater than 100 acres. Having so many lakes at each size extreme makes this region unique.

The primary uses for the lakes include fishing, swimming and other forms of contact recreation, and some potable water use. Although many of the lakes have formal boat launch areas to support multiple uses, public access is generally low on the eastern portion of this area, particularly in the Capital Region. The percentage of lakes used for potable water (Class A) or for contact recreation (Class B) is neither high nor low compared to the other lake regions. Only 10 of the largest 25 lakes in the region are used for potable water. Most of the large drinking water reservoirs have use restrictions.

There are also a large number of waterbodies between Syracuse and Utica that are feeder lakes to the Erie-Barge Canal system. These are used to control water level and optimize navigability of the canal. The canal system includes about 40 percent of the freshwater resources in New York State, not including the Great Lakes, although much of it is in the Finger Lakes region.

The Central New York region has many small kettle lakes of various depths. Comparison of all the lakes sampled from each region shows that Central New York lakes have the highest water clarity and lowest nutrient (phosphorus) levels (see Tables 2–8 and 2–9) (NYSDEC, 2004a). The lake water is moderately soft with low to moderate levels of productivity. There is little variation in water transparency and nutrients readings between small and large lakes in the Central New York. (µmho = a measurement of electrical conductivity)

Excessive algae growth is found in some lakes in the more urbanized and agricultural areas of the region. More lakes, however, have plant problems due to invasive exotic plants such as Eurasian watermilfoil *(Myriophyllum spicatum)*. Excessive growth of water chestnut *(Trapa natans)* is locally problematic in the major river systems of the eastern Mohawk and Hudson Rivers and in peripheral small lakes.

Region	Typical Water Clarity (meters)	Typical Phosphorus Levels (ppm)	Typical Water Color	Typical pH	Typical Hardness
Long Island/NYC	1–2	30–35	Faint	Basic	Hardwater
Downstate	2–3	20–25	Faint	Slightly basic	Intermediate
Central NY	3	10–15	Faint	Neutral	Softwater
Adirondacks	2–3	10–15	Moderate	Acidic	Softwater
Finger Lakes Region	2–3	10–15	Not visible	Basic	Hardwater
Western NY	2	30–35	Not visible	Basic	Intermediate

Table 2–8. Comparison of phosphorus (productivity) in all sizes of lakes.

Hardness definitions: Soft water = Conductivitiy < 100 µmho/cm; Hard water = Conductivity > 250 µmho/cm; Intermediate = 100-250.

	Lakes Greater Than 250 acres			Lakes Less Than 250 acres		
Region	**Typical Water Clarity (meters)**	**Typical Phosphorus Levels (ppm)**	**Typical Water Color**	**Typical Water Clarity (meters)**	**Typical Phosphorus Levels (ppm)**	**Typical Water Color**
Central NY	2–3	10–15	Not visible	3	10–15	Faint
Adirondacks	3–4	5–10	Faint	2–3	15	Moderate
Finger Lakes Region	3–4	10–15	Not visible	2	15–20	Not visible

Table 2–9. Comparison of phosphorus (productivity) if lakes are subdivided by size.

Zebra mussels *(Dreissena polymorpha)* have also been found in some of the waterbodies in this region, although their densities are much higher in western regions of the state (see also Chapter three, "Lake problems"). The fisheries communities in the lakes are dominated by warmwater fish. Some of the deeper waterbodies, and the headwaters of larger stream and lake systems, however, do support **coldwater fish**. Coldwater fish require water that is 60ºF or colder with oxygen content exceeding 5 parts-per-million (ppm). Coldwater supports salmonids, including trout and salmon.

Lake management issues tend to focus on user conflicts; invasive aquatic plants common in both shallow and deeper lakes; algal blooms associated with failing septic systems, lawn and agricultural land fertilization, and waterfowl; and development pressures, including an increasing percentage of cottage conversions to full-time residences.

The lake management permitting process is neither significantly more nor less restrictive than in other regions of the state. Lake associations in this region are actively involved in the formal development of lake management plans, perhaps reflecting the increasing use of these lakes. Lake management is conducted by:

- residents as individual citizens, and through lake associations, property-owner groups, and fish and game clubs;
- municipalities and county governments, including planning departments; and Soil and Water Conservation Districts; and
- state agencies, including DEC regions 3, 4 and 7; Division of Water and Division of Fish and Wildlife

Adirondack lakes

Fig. 2–7. Location of Adirondack lakes.

The Adirondack Region is broadly defined here as the large area bounded by the St. Lawrence River, Lake Champlain, and the Mohawk River. It is actually a slightly smaller area, defined by "The Blue Line" that officially designates the Adirondack Park, encompassing more than 6 million acres. In 1892, the New York State Legislature created the Adirondack Park and designated it "forever wild". Scattered parcels of private lands within the park make up more than 60 percent of its area, a situation more common in Europe than in the United States. The park covers more than 20 percent of the state, is nearly three times the area of Yellowstone National Park, and is the largest state park in the nation.

The Adirondacks are highly regarded by the people of New York State, and has the largest number of pristine lakes in the state. Many of the lakes are surrounded by craggy mountains and have conditions inhospitable to all but the most hardy swimmers—steep slopes, rocky bottoms, and COLD water.

The entire park is comprised of a mix of rugged peaks, rolling hills, expansive wetlands, and deep and extensive valleys. The terrain along the eastern side consists of ancient, weathered mountain peaks. Although nowhere near their original size, more than 40 mountain peaks still exceed 4,000 feet. The northern portions of this region consist of flatter plains.

The surface geology is dominated by gravel and sand, with many bedrock exposures. The bedrock geology is metamorphic sedimentary and igneous rocks. It is largely devoid of limestone (calcium carbonate), which severely limits the buffering capacity of the lakes embedded within it.

This region includes the largest assemblage of old-growth forests east of the Mississippi River. Primary land uses are those associated with forested land (silviculture, wildlife habitat and outdoor recreation), with limited residential and commercial uses. Population centers are small and far between. They are found on the edges of large lakes such as Lake George, Lake Placid, Saranac Lake, and along the Fulton Chain of Lakes. This is by far the least populated region of the state. Hamilton County in the interior Adirondacks is among the least populated counties east of the Mississippi River.

Regardless of the depth and breadth of the topographic relief, this is consistently a very water-rich and lake-rich terrain. The diversity of lake types is breathtaking, from mirror-like alpine blue lakes to wide wetlands to tea-colored ponds perpetually bathed in fog and calm. As such, the lakes are perhaps the most difficult to definitively characterize.

There is no "typical" lake in the Adirondacks. Landscapes in nearly all areas have small kettle lakes of various depths, mostly hard water, and mostly with low to moderate levels of productivity. Within the northwestern portion of the park many of these lakes are naturally tea-colored. In contrast, most of the larger lakes tend to be clearwater (low natural color). Most of the large, deeper lakes are among the clearest in New York State.

Lakes at lower elevation that are large and deep tend to have moderate to poor buffering capacity, while many of the smaller and higher elevation lakes have little or no buffering capacity remaining. As a result, many of these lakes have become acidified (Table 2–10) (NYSDEC, 1987; 2004b). Some acidification occurs naturally through weak organic acids inherent in the soils and vegetation indigenous to the region. More often, the culprit is inorganic acids emitted from power plants outside of the region and state. While "acid lakes" are perhaps the most prominent label attached to Adirondack lakes, it is but one of many that could accurately characterize literally thousands of lakes within the park.

Region	% of NYS Lakes	Number of Lakes on the Federal 303d List	% of 303d Listings Due to Acid Rain
Long Island/NYC	5	21	0
Downstate	18	14	0
Central NY	12	10	0
Adirondacks	58	412	95
Finger Lakes Region	5	8	0
Western NY	2	3	0

Table 2–10. Percentage of lakes in each New York State region compared to the number of lakes in each region on the 303d list and the percentage of those affected by acid rain.

With nearly 3,000 lakes, the lake density is very high even though there are 6 million acres of land in this region. All areas support a wide density of lake sizes and depths, although lake densities are lowest in the northeast and western edges of the area.

Compared to the other lake regions, the percentage of lakes used for potable water (Class A) is relatively high, but the percentage classified for contact recreation (Class B) is quite low. This is largely due to two factors. It reflects historically low uses of these lakes for recreation due to much smaller population bases, and limited access to many interior regions of the park prior to the construction of the Adirondack Northway in 1967. There is also little available water-quality information needed to identify the best use of these lakes. Bathing and other forms of contact recreation, however, are usually well supported throughout the park, or at least would be if the water weren't so cold for much of the summer! The primary lake uses are fishing, bathing and contact recreation, and potable water use. In the southern and western portions of the region, some lakes are also used for power generation.

Many lakes within the Adirondack Park are relatively inaccessible, due to the small number of paved roads. In addition, many lakes are found within the Forest Preserve or other highly restrictive land use categories, which limits public access and use. Many of the larger lakes are accessible by major roadways, no doubt originally built to gain access to these valuable resources.

Few lakes in this region have excessive algae growth, although this problem is steadily growing as more housing developments and the humans they hold raise nutrient levels. Sewage effluent can exacerbate algae problems if conversion of lakefront properties from seasonal cottages into year-round residences fails to include septic system upgrades. Increased recreational usage can lead to more nutrient enrichment for algae and can hasten the spread of invasive species, such as Eurasian watermilfoil *(Myriophyllum spicatum)*, and zebra mussels *(Dreissena polymorpha)*. The fisheries communities in the lakes are dominated by a mix of warmwater fish in the open and wooded lowlands, and coldwater salmonids in the mountain districts and wilderness areas

As public access and lake usage increases, conflicts among user groups increasingly dominate local management efforts. Lake management issues tend to focus on user conflicts associated with:

- motor versus non-motor boat uses, including no-wake zone, speed limits and use of personal watercraft;
- introduction and control of exotic plants and animals;
- water level; and on a national level,
- lake acidification.

The regulatory process is significantly more complex in this region than in other parts of the state due to overlapping regulatory authorities. It is also due to more fundamental disagreements over the role of some management options such as aquatic herbicides in a "forever wild" area. These factors have led to a substantially lower rate of lake-wide management activities in the lakes in this region. It is likely, however, that lakeshore property owners manage weed problems along their own shoreline as often here as in other parts of the state.

The lake management permitting process is neither more nor less restrictive than in other regions of the state. Lake associations in this region are actively involved in the formal development of lake management plans, perhaps reflecting the increasing use of these lakes. Lake management is conducted by:

- residents as individual citizens, lake associations and property-owner groups, and members of public advocacy groups, such as the Adirondack Council and the Residents Committee to Protect the Adirondacks;
- academic institutions, such as Rensselaer Polytechnic Institute and Paul Smiths College, among others;
- quasi-governmental agencies, such as Cornell Cooperative Extension and the Finger Lakes-Lake Ontario Watershed Protection Alliance (FL-LOWPA) in the western portion of the Adirondacks;
- municipal and county governments, primarily Soil and Water Conservation Districts;
- local or regional government entities like the Adirondack Park Agency, the Black River-Hudson River Regulating Authority; the Lake George Park Commission and others; and
- state agencies, including DEC regions 5 and 6, Division of Water and Division of Fish and Wildlife.

Finger Lakes region lakes

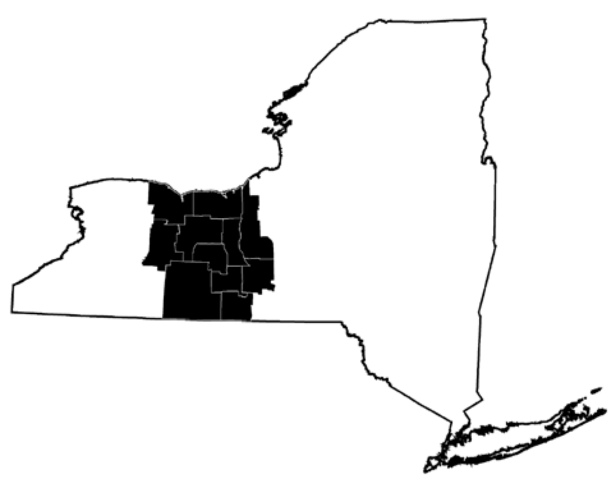


Fig. 2–8. Location of Finger Lakes region lakes.

After Long Island, the Finger Lakes Region can perhaps be more clearly defined, both geographically and in common vernacular, than any of the other lake regions. The Finger Lakes are 11 north-south oriented, mostly very deep glacial lakes found in mid-western New York. The region is generally just south of a line running between Rochester and Syracuse. These long lakes both define the region and are the underpinnings of its cultural, economic and commercial makeup. While there are other lakes in this region, some of which are locally or ecologically important, the Finger Lakes are the most dominant feature.

The surface geology is dominated by silt. The bedrock geology is primarily shale, although limestone outcrops occur in some areas. The terrain is rolling and is controlled by the valleys that were initially formed by rivers and streams and later modified and enlarged by glacial erosion. There is some overlap with the Great Lakes plains on the northern part of the region, and the Appalachian plateau along the southern part.

The population density is smaller than in most other regions. Many of the largest cities, such as Syracuse, Watkins Glen, Ithaca, Geneva and Skaneateles are located at the major inlet or outlet of their lakes. The primary land uses are residential; agricultural with local emphasis on fruits and viticulture; commerce with light industry; and limited heavy industry in the larger cities. Tourism is economically important.

Compared to other lake regions, the percentage of lakes used for potable water (Class A) is fairly low, although nearly all of the Finger Lakes are multi-use drinking water sources. The primary lake uses are fishing, swimming and other forms of contact recreation, and some potable water use. Most of the lake shorelines are occupied by houses that range from small cabins to large mansions, farms, some marinas, and some city or state parks. Use of lake water for irrigation is higher in this region than in most others.

The density of lakes is much smaller than in most other regions of the state, with the combination of rolling hills and deep valleys resulting in most water draining into the very large, deep Finger Lakes. Although the number of lakes is small, the surface area occupied by lakes is the largest outside of the Adirondacks.

Typical lakes in this region are in large, deep, glacial troughs. The largest of the Finger Lakes are among the deepest lakes in the state as shown in Table 2–11. (NYSDEC, 1982; 1987) Due to the underlying limestone, most of the lakes in the region are clear and hard water, with low to moderate levels of productivity.

Region	% of NYS Lakes	% NYS Lakes > 100ft Deep	% NYS Lakes > 1000 Acres
Long Island/NYC	5	0	1
Downstate	18	35	14
Central NY	12	10	12
Adirondacks	58	30	44
Finger Lakes Region	5	20	26
Western NY	2	5	4

Table 2–11. Percentage of lakes in each New York State region compared to the percentage of deep lakes and the percentage of large lakes in each region.

The deeper lakes in this region do not generally suffer from excessive algae growth. Algal blooms are more common in shallower lakes, as in most regions of the state, with the number of blooms steadily growing as increasing developmental pressure causes excess nutrient loading. Evidence points to the Finger Lakes as the threshold through which Eurasian watermilfoil *(Myriophyllum spicatum)* first colonized New York State lakes. Zebra mussels *(Dreissena polymorpha)* first entered this region from the Great Lakes. Most of the largest lakes in this region suffer from one or both of these invasive exotics, due at least in part to the extensive public access available. Successful examples of natural or induced biological controls have occurred in the Finger Lakes regions, however, due to its long history of exotics infestation. The fisheries communities in the lakes are dominated by a mix of warmwater and coldwater fish.

Lake management issues tend to focus on invasive species, water level, fish consumption advisories, pesticides and heavy metals, drinking (source) water protection, and user conflicts. Management plans have been developed for most of the Finger Lakes through the cooperative efforts of local government, environmental organizations, and lake associations. The primary aquatic plant management strategies in this region have been water-level drawdown and mechanical harvesting, with the latter largely funded by the Finger Lakes-Lake Ontario Watershed Protection Alliance (FL-LOWPA). This region has also seen a variety of pioneering and innovative research and experimental projects developed to address a variety of local lake problems.

Lake management is conducted by:

- residents as individual citizens, lake and watershed associations and property-owner groups;
- international research institutions and academic institutions, such as state universities, Cornell University, the Finger Lakes Institute at Hobart-William Smith Colleges, and community colleges, among others;
- quasi-governmental agencies, such as Cornell Cooperative Extension and
- FL-LOWPA;
- municipalities and county governments; and
- state agencies, including DEC regions 7 and 8, Division of Water and Division of Fish and Wildlife, and the State Canal Corporation, which influences lake levels.

Western New York lakes

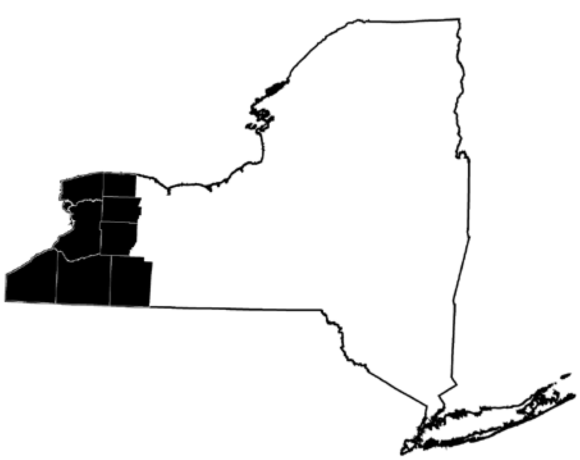


Fig. 2–9. Location of Western New York lakes.

Western New York is the portion of the state west of the Finger Lakes region, bounded by Pennsylvania on the west and south, and by Great Lakes Ontario and Erie to the north and northwest. Lakes of the western region share many characteristics with those in the Finger Lakes region. The majority of the water in this region drains northward to the Great Lakes either directly or through tributaries. A minority of waters drain southwest to the Allegheny River, or due west via the Erie Canal. The construction of the Erie Canal in 1825 drastically altered the interior portions of this region. There is a paucity of other ponded waters, and the density of lakes is smaller than in most other regions of the state.

The surface geology is dominated by silt, with some clay in the western portions of this region. The bedrock geology is dominated by shale, siltstone and sandstone, with some limestone in the north. The terrain is a mix of flat plains and rolling hills.

The primary land uses are agricultural, residential and commercial, with some heavy industry in the larger, older cities such as Buffalo. The population density is larger than in most other regions, and is concentrated in the Buffalo and Rochester metropolitan areas

With the exception of the two Great Lakes, most of the lakes in the region are relatively small and shallow, due to both drainage patterns and lack of significant relief in the terrain. Some lakes fall within watershed divides associated with wetlands, resulting in occasionally variable flow patterns. Most of the small lakes in this region are highly productive with high nutrient and algae levels and low water clarity. By nature, most of these lakes tend to be clearwater. Their intermediate hardness results in sufficient alkalinity or buffering capacity to keep pH levels relatively high, although acid rain falls in this region as in all other regions of the state.

Compared to other regions, the percentage of lakes used for potable water (Class A) is fairly high. Many small reservoirs, built in the center of this region, are used exclusively for drinking water, and public access is generally scarce. The percentage of lakes classified for contact recreation (Class B) is typical of most other regions, supporting fishing, swimming and other forms of recreation. Although the western New York State regions comprises only a small portion of the state's lakes, Lake Ontario, Lake Erie, and Chautauqua Lake provide a relatively large percentage of the lake shoreline in the state, as shown in Table 2–12, and have multiple public access points. (NYSDEC, 1987)

Region	% of NYS Lakes	% of NYS Lake Shoreline
Long Island/NYC	5	2
Downstate	18	11
Central NY	12	16
Adirondacks	58	53
Finger Lakes Area	5	7
Western NY	2	11

Table 2–12. Percentage of lakes in each New York State region compared to the percentage of lake shoreline in that region. Although the western region has very few lakes, it has a significant amount of the New York State lake shoreline.

A large number of western region lakes have excessive algal growth, especially in the agricultural areas. An increasing number of lakes are showing growth of invasive exotic plants such as Eurasian watermilfoil *(Myriophyllum spicatum)* and curly-leafed pondweed *(Potamogeton crispus)*. Recent surveys have found Eurasian watermilfoil is widespread throughout the region. To date, water chestnut *(Trapa natans)* and fanwort *(Camomba caroliniana)* have not been found in this region, although starry stonewort *(Nitellopsis obtusa)*, an exotic macroalga, was first found here. The future colonization of water chestnut is probable since this floating pest is spreading within the state canal system. Some waterbodies have escaped the scourge of zebra mussels *(Dreissena polymorpha)*, although inventories of invasive species in this region are not always up-to-date due to a lack of monitoring programs. The fisheries communities in the small lakes are dominated by warmwater fish. The cool lakes and large rivers support some of the state's best muskellunge populations.

Lake management issues tend to focus on fisheries management, algal blooms, and conflicts between the agricultural community and other lake users. The lake-management permitting process is neither significantly more nor less restrictive than in other regions of the state

Lake management is conducted by:

- residents as individual citizens, and through lake and watershed associations, and property-owner groups;
- FL-LOWPA;
- municipal and county governments, especially the planning departments; and
- state agencies, including DEC regions 8 and 9, and Division of Fish and Wildlife.

Summing It Up

It is very important to consider the setting of a lake when pondering the conditions and problems of that lake. All waterbodies in a northern temperate climate have obvious similarities; most lakes are wet in the summer and hard in the winter. Despite this, many lake characteristics are less homogenous. The geology, topography and use differences help answer why Adirondack lakes look and behave quite differently from the Finger Lakes, or the lakes on Long Island. The savvy lake resident or manager blends knowledge of the natural conditions with the differing expectations of users and local politics in order to determine the possibilities and limitations for a particular lake. Keep the regional differences in mind when reading the next chapter that discusses the problems facing New York State lakes, and later chapters that discuss how these problems can be managed.

3 Lake Problems: Acid Rain to Zebra Mussels

Introduction

This chapter will discuss the most common and significant problems encountered in many New York State lakes. In subsequent chapters we will cover strategies to address these problems, including complex solutions that go beyond relieving the symptoms to addressing the root causes. To set the stage, we revisit in more detail the mythical lake first glimpsed in this book's introduction.

> The lake is surrounded by old growth forest. The sun is shining through the clouds with a light refreshing wind. A solitary, beautiful mansion with a large veranda and a swimming pool graces the shore. A powerful motorboat, a sailboat, and a canoe are moored in the boathouse. The temperature of the clear, blue water is about 80ºF with only slight waves lapping on the sandy beach. The fishing pier allows one to conveniently catch all kinds of plentiful fish that are visible to depths of 20 feet. Virtually no rooted aquatic plants to snag fishing lines or get caught on a motor can be seen. There are no snakes, just enough waterfowl and deer to be picturesque but not a nuisance, and plenty of other wildlife. The lake is completely private, with the dreamer, friends and guests as the sole users. A tennis court and wilderness mountain trails provide for more strenuous recreation. The house is served by public water and sewers, reliable underground electricity and natural gas, cable TV and high-speed Internet access. A short drive away is a major shopping mall and an interstate highway. A nearby resort features golf, a movie theater and excellent restaurants. At night, stars fill the sky to the accompaniment of crickets and spring peepers. Each winter, the lake freezes solid for a few weeks to allow ice skating and snowmobiling, and the snowy mountains offer world class downhill and cross-country skiing.

Though some people would find fault with this scenario, for many lake users this description would be close to paradise, with any deviation from the ideal labeled as a problem. Unfortunately, even the most pristine and user-friendly lake could never measure up to this description since many features of the mythical lake are mutually exclusive. Crystal clear water resting on a sandy, weed-free bottom will not support a good fish habitat. The dearth of people that leads to solitude is contrary to what is needed to support sewers, public water lines, malls and classy restaurants.

Although not able to live up to this mythical standard, many New York State lakes are healthy. They have water clear enough to read a newspaper resting on the lake bottom. They support a wide variety of warmwater and coldwater fish that are pleasing to the eye and palate. They serve as an abundant and refreshing source of drinking and irrigation water, and a playground for swimmers, boaters, and those seeking a quiet stroll along the shoreline. Many rest peacefully in the shadow of towering peaks, and are serenaded at night by singing loons and bellowing bullfrogs.

Regrettably, many other New York State lakes have problems that go beyond being an annoyance or inconvenience. Degraded water quality, aquatic plant problems, and the use impairments associated with these problems are quite often the very reason for developing a lake management plan (and purchasing this book). Lake problems can mean the disruption of the ecological integrity of the system, community-wide expense, and health consequences. Lake problems can reduce property values, discourage tourism, and make swimmers sick.

Problems, problems, problems…

New York State lakes are plagued by a suite of problems ranging from weeds thick enough to walk on, to a mucky lake bottom no swimmer would want to touch, and from slimes that turn a lake too green, to acid rain that turns a lake too clear. Swimmers itch can distress waders, and sediment transported from fields and ditches can make the bottom climb closer to the surface.

While every lake has a unique set of conditions and problems, there is a core group of water-quality or use-impairment problems. Responses of 1,000 lake residents to a statewide survey completed in the late 1980's listed the following problems, ranked by frequency of occurrence (NYSDEC, 2004):

1. rooted aquatic plants
2. excessive boat speed
3. algal blooms
4. too many boats
5. poor bottom conditions for swimming
6. overcrowded conditions
7. poor fishing
8. lake level too high or low

A slightly different list results from reviewing the state **Priority Waterbody List and Waterbody Inventory (PWL-WI),** a compendium of water-quality and use-impairment problems identified through inventories of water-quality databases, government assessments, and public input. The problems are ranked according to the number of lakes affected (NYSDEC, 2002):

1. acid rain/pH
2. rooted aquatic plants
3. algal blooms
4. bacteria/swimmers itch
5. toxics/organics (mostly as they affect fishing)
6. oxygen deficits
7. lake level too high or low
8. turbidity

Part of the discrepancy between these lists reflects the difference between use impairment (as evaluated by lake residents) and ecosystem impacts or water-quality standards violations (as evaluated by government assessments). The PWL list reflects those stressors that can be measured in monitoring programs, whether those programs are designed to identify problems or to evaluate the effectiveness of a management strategy.

In contrast, problems that appear on the lake residents list, but are missing from the PWL list, involve more subjective issues, including excessive boat speed, too many boats, poor bottom conditions for swimming, overcrowded conditions and poor fishing. Except for poor fishing they can be lumped together as "people problems." These and other people problems are generally absent from traditional monitoring programs, yet they are no less important and are frequently the impetus for developing a lake management plan. Chapter eight, "User conflicts," explores these problems, since they require different information and tools to address than the more ecological problems that are the focus of Chapters three through seven.

Many of the water-quality problems discussed below are directly related to the accelerated eutrophication of lakes. Eutrophication is part of the natural succession from lake to prairie, usually taking place over a time frame ranging from centuries to millennia (see Chapter one, "Lake ecology".) Many naturally eutrophic or high-nutrient lakes support a wide variety of activities, but uses may be limited on some oligotrophic or low-nutrient lakes. High-nutrient levels in a lake, however, will increase the growth of algae and rooted plants. An increased level of productivity inevitably leads to a high rate of organic matter decomposition that can deplete the oxygen supply in the hypolimnion during the summer months. This anoxic condition restricts the usable habitat of certain fish and other animals, altering the delicate balance of the aquatic food web.

This chapter focuses on concerns from both the above lists, as well as on concerns reported to the New York Federation of Lake Associations (NYSFOLA).

1. Rooted aquatic plants
2. Algae
3. Invasive animals
4. Pathogens
5. Toxic substances
6. Pharmaceuticals and personal care products
7. Taste problems in drinking water
8. Sediment
9. Curiosities
10. Poor fishing
11. People problems

Invasive species:
A new focus for a growing problem

Invasive species is a broad term that refers to non-native organisms such as rooted aquatic plants, algae, invasive animals, bacteria, viruses, and insects that can harm humans or the environment. This term is often synonymous with the term "nuisance species" since most of the nuisances in New York State lake environments are invasive species. The phrase is not necessarily interchangeable with "exotic species". More than one-third of the plants in New York State are not native to the state, and many of these are important food crops, landscaping and nursery plants, or at least do not cause any environmental harm. However, the first three problems listed above—rooted aquatic plants, algae, and invasive animals—are derived in large part from invasive species, and some of the nuisance plants and animals are exotic.

As the threat from invasive organisms accelerates, lake residents, managers, and government officials are taking notice. Governor George Pataki created an Invasive Species Task Force in 2003 to "explore the invasive species issue and to provide recommendations to the Governor and Legislature by November 2005". The Task Force was comprised of 17 state agencies and non-government organizations (NGOs). It was coordinated by New York State Department of Environmental Conservation (DEC) and New York State Department of Agriculture and Markets (DAM). A final report (NYSDEC/NYSDAM, 2005) summarizing the work of the Task Force is available on the DEC website (see Appendix F, "Internet resources"). One of the recommendations by the Task Force was to establish a "permanent leadership structure to coordinate invasive species efforts." This led to the creation of the Office of Invasive Species within the DEC in late 2007. Funding was also provided for the creation of Partnerships for Regional Invasive Species Management (**PRISMS**). Using education, early detection and rapid response, the PRISMS are to promote cooperative efforts to manage invasive organisms through an integrated approach of protecting or restoring desired native communities at the watershed level. They utilized some existing management entities, such as the Adirondack Park Invasive Plant Program and the Long Island Weed Management Area, and also formed new regional partnerships. These efforts reflect a growing national interest in addressing the 6,500-plus non-indigenous species already found in this country.

Nuisance plants:
Aquatic plants gone wild

The presence of rooted aquatic plants (macrophytes) in lake environments can be summarized in the statement **"**If light reaches the bottom, plants will grow."

Of course, it is not quite as simple as that. Aquatic plant populations are governed by a complex interaction of physical, chemical, and biological factors. These vary from lake to lake, from one part of a lake to another and from one time of year to another. Even though limnologists and knowledgeable lakefront residents recognize that in most parts of the state "phosphorus plus lake equals algae," no grand unification theory exists for describing the growth of aquatic plants in New York State lakes. What we do know, however, is that certain factors do contribute to the spread of aquatic plants. They include sediment type; light transmission; water and sediment chemistry; growing space; and the presence of invasive plants. We also know that the entire ecological web is critically dependent on photosynthesizing organisms native to lakes and that aquatic plants "belong" in lakes, but to what end?

Most lake residents and users recognize the importance of aquatic plants, although grudgingly at times. They also recognize that too many of the wrong type of aquatic plants in the wrong place at the wrong time are not beneficial. They are weeds! While weeds are not restricted to any one category of plant, most of the aquatic plant problems are caused by submergent and exotic plants**.** Submergent plants grow mostly under the water, although some upper leaves may reach the lake surface. Exotic plants are those neither native to a particular lake nor to the region or the state as a whole. Only a small number of exotic plant species are problematic, with a select few causing the majority of invasive plant problems. These plants tend to grow invasively in the absence of natural competitors or predators. When these invasive populations inhibit the uses of lakes, these plants become a nuisance and the target of active lake management.

The problems resulting from excessive weed growth range from annoying to dangerous:

- thick weeds dominated by one plant reduces biodiversity, thereby reducing the number of dependent species (primary and secondary consumers) supported by the lake ecosystem;
- surface blooms and mats deplete oxygen when they decay, resulting in noxious odors and an unsightly appearance;
- canopies of weeds can clog propellers, reduce water circulation, and trap filamentous algae, surface debris, fishing hooks and swimmers limbs;
- high weed densities often change a fish community from larger game fish to pan fish; and
- the scratchy surfaces of some weeds, and the spiked nutlets of others, can make swimming uncomfortable and even painful.

New York State lakes are threatened by a growing number of invasive plants. These plants typically enter through two pathways, both involving the transport of vegetation by boats. States to the not too distant south of New York have longer growing seasons and access to tropical species, which breeds a larger mix of aquatic invaders that can cling to migratory boats. To the north, international commerce from Eurasia across the Atlantic frequently brings more than its intended cargo in ballast water. This commerce, and invasive plants and animals in the ballast water and residual sediments, enter through the St. Lawrence Seaway and into rivers flowing from the Great Lakes, through the Hudson harbor, and then within the state through the Erie and Champlain canals, Hudson River, and other large aquatic highways.

A summary of the worst invaders attacking New York State waterways can be found in the following invasive aquatics Most Wanted List. The term "exotic" is generally used to refer to species that have arrived in this area since Colonial times. The following information on the most problematic aquatic weeds is provided courtesy of a pamphlet entitled "*Common Nuisance Aquatic Plants in New York State*" (McSpirit, 1997). The line drawings are provided by Crow and Hellquist (2000.)

Fig. 3–1. Invasive species can hitchhike their way to new locations if boats are not thoroughly cleaned before launching. (Credit: Mark Wilson)

Eurasian watermilfoil *(Myriophyllum spicatum)* was introduced into New York State in the 1940s, probably in the Finger Lakes region, and has since spread to every region of the state. It is characterized by dense canopies that spread laterally across the surface of lakes, and propagates primarily by fragmentation in pieces as small as one inch. Like most invasive exotic plants, it grows opportunistically in a wide variety of depths, water-quality conditions, and sediment types, although it is commonly found in sandy to mucky soils in depths ranging from 3 to 12 feet. It is the most invasive, submergent aquatic plant in New York State, and is basically impossible to truly eradicate once established in lakes.

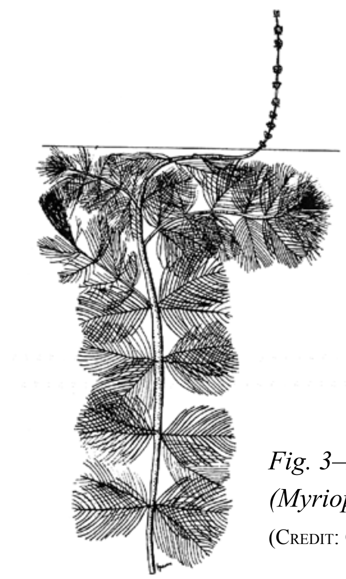


Fig. 3–2. Eurasian watermilfoil (Myriophyllum spicatum) (CREDIT: CROW AND HELLQUIST)

Water chestnut (*Trapa natans*) was introduced in North America and New York State in Collins Lake, Scotia, NY, in 1882, although it was found a few years earlier in a herbarium in Massachusetts. From this "epicenter," it has migrated along the Lake Champlain, Mohawk River, and Hudson River systems. Problems associated with water chestnut are mostly restricted to these areas, although it has increasingly been found in small lakes and ponds. It is not related to the familiar Chinese water chestnut (*Eleocharis tuberosus or E. dulcis*), a rush-like sedge that produces an edible tuber. The water chestnut *(Trapa natans)* forms a conspicuous floating rosette of leaves and a woody, spiked nutlet that serves as a seed for future generations of the plant. The seed remains viable in bottom sediments for several years to decades. Water chestnut grows primarily in sluggish, shallow water with mucky sediments. This is the only submergent plant that the state Environmental Conservation Law (ECL) outlaws. Section 11-509 of ECL states: "No person shall plant, transport, transplant, or traffic plants of the water chestnut, or the seeds or nuts thereof, nor in any manner cause the spread or growth of such plants."

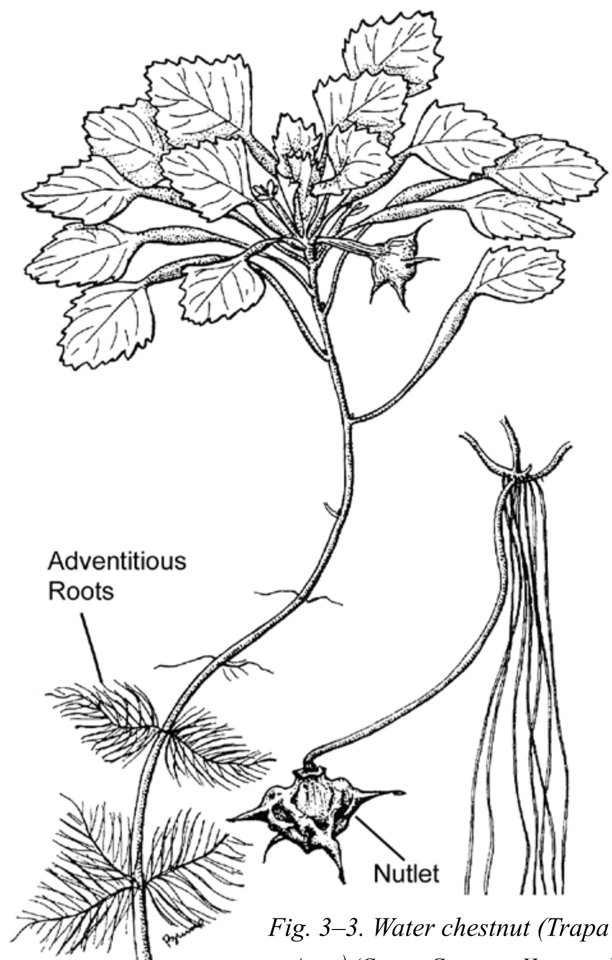


Fig. 3–3. Water chestnut (Trapa natans) (CREDIT: CROW AND HELLQUIST)

Fig. 3–4. Curly-leafed pondweed (Potamogeton crispus)
(CREDIT: CROW AND HELLQUIST)

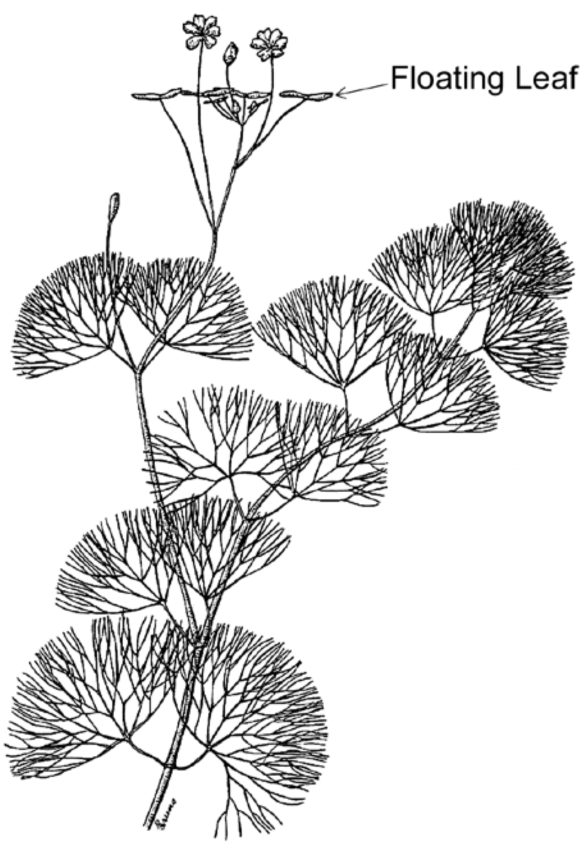


Fig. 3–5. Fanwort (Cabomba caroliniana)
(CREDIT: CROW AND HELLQUIST)

Curly-leafed pondweed (*Potamogeton crispus*) was probably introduced in the mid-1800s in the northeastern United States. It is characterized by a lasagna-like curled leaf and a very early growing season. It is found sporadically throughout New York State. The plants usually begin growing while there is still ice cover and they die back by late June to early July, although there is some evidence that the growing season for these plants has extended into mid-summer due to warming associated with global climate change. Plants then start to grow from overwintering buds or turions, which usually becomes waterlogged in the late summer or fall and drop into the sediment. Curly-leafed pondweed grows in a variety of settings, but generally grows best in relatively shallow water. Control strategies are most often employed in the eastern and southern portions of the state.

Fanwort (*Cabomba caroliniana*) is native to the southern states but not to New York or other northeastern states. It has historically been limited to Long Island, although the first sightings in New York State may have occurred in Orange County in the early 1930s. It prefers shallow water, but, in recent years, it has been found in deep waters of isolated lakes in the southeastern Adirondacks, and on both sides of the southern-to-mid Lower Hudson River basin. It has thread-like leaves that fan out from opposite sides of the stem. It probably spreads by both seeds and fragmentation, although fragmentation seems to be its primary method in the northeastern United States. The white or pink flowers of the fanwort are occasionally seen in New York State lakes. For the most part, fanwort control has been attempted only on Long Island.

Some exotic species once thought to exist peacefully within native plant communities or thought to be limited to isolated waterbodies have been implicated in a growing number of weed problems. They include as some of the non-native watermilfoils such as variable watermilfoil (*Myriophyllum heterophyllum*), Brazilian elodea (*Egeria densa*) and brittle naiad (*Najas minor*). Other plants found recently in New York State, particularly hydrilla (*Hydrilla verticillatum*), will no doubt soon reap havoc on lakes and ponds. These next generations of exotic plants that are starting to expand into the rest of the state are briefly described below:

Variable watermilfoil (*Myriophyllum heterophyllum*) is native to the United States, but it is not yet known if this invasive plant is indigenous to New York. It is characterized by very dense surface canopies of thick brown to dark red stems that can make an unfortunate lake look like a forest floor. It can also co-exist peacefully with other plants, occasionally visible as thick greenish-brown funnels poking out of the lake bottom. Both situations commonly occur in New York State lakes, although invasive weed growth is becoming more commonplace. It is generally found in lakes with soft water and often competes with fanwort.

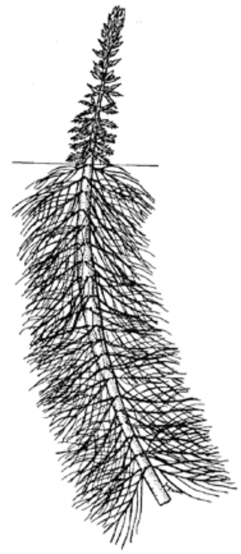


Fig. 3–6. Variable watermilfoil (Myriophyllum heterophyllum)
(CREDIT: CROW AND HELLQUIST)

Unlike many exotic plants, the origin of **Brazilian elodea** (*Egeria densa*) in both New York State and the United States can be traced precisely, to Millneck, Long Island, in 1893. It is a common aquaria plant, often sold under the name *Anacharis*, which can look very similar to both the American elodea (*Elodea canadensis*) and the invasive hydrilla (*Hydrilla verticillatum*). The Brazilian elodea grows very densely in waterways in the southern United States, and has spread beyond Long Island, particularly in the last decade.

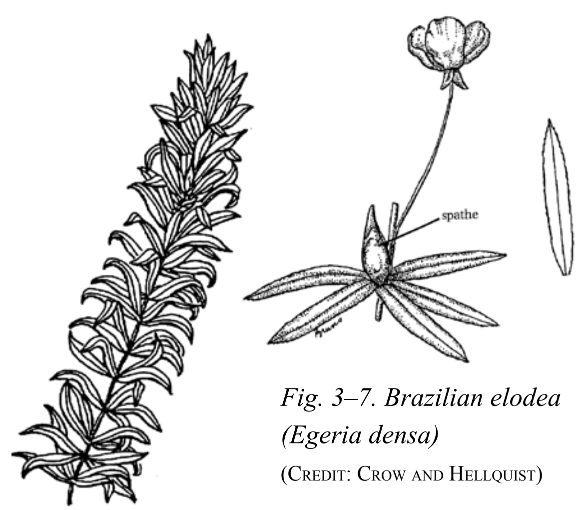


Fig. 3–7. Brazilian elodea (Egeria densa)
(CREDIT: CROW AND HELLQUIST)

Brittle naiad (*Najas minor*) is an exotic plant of European origin that is increasingly found in lakes previously managed for a different exotic plant. Brittle naiad is often the first invader after a large-scale herbicide treatment or drawdown. It has the ability to reproduce from seeds that resist many herbicides and the freezing and desiccating conditions associated with drawdown. The dense bushes of brittle naiad can cause a very scratchy swimming experience, and have required management in some parts of the state.

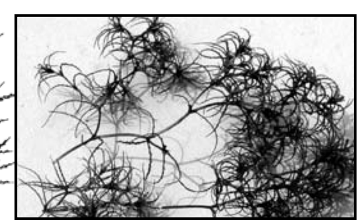


Fig. 3–8. Brittle naiad (Najas minor). The photo shows the curved leaves that are typical of brittle naiad found in New York State.
(CREDIT: CROW AND HELLQUIST)

Fig. 3–9. Hydrilla (Hydrilla verticillatum)
(CREDIT: CROW AND HELLQUIST)

The most invasive of all North American aquatic plants, **hydrilla** (*Hydrilla verticillatum*) was first found in New York State in 2008, although it is suspected that it lurked undetected for many years. It is a relatively new exotic plant from Eurasia, initially discovered in 1980 in the southern United States. In less than 25 years it has spread to all regions of the country, and is growing explosively in many lakes. The state of Florida alone is spending tens of millions of dollars attempting to manage this plant, largely surrendering the fight to eradicate or even control hydrilla.

A few native plant species occasionally grow to nuisance levels. Large-leaf pondweed (*Potamogeton amplifolius*), coontail (*Ceratophyllum demersum*), and bladderworts (*Utricularia* spp.) can be culprits. Dense congregations of floating-leafed plants (primarily waterlilies, watershield, duckweed, and watermeal) at times draw the ire and management efforts of lake residents. Benign native plants that coexist peacefully in a healthy, diverse plant community in some lakes can grow invasively in others. Management tools for these native plants are discussed in Chapter six, "Aquatic plants."

Problems with nuisance weeds vary from one part of the state to another, resulting in highly variable management approaches and regulatory issues. Most of the lakes and ponds on Long Island are so shallow that invasive plant growth occurs with many native plant species. Nuisance-level infestations of exotics are largely lacking, except for fanwort (*Cabomba caronliniana*), which is widespread and can grow invasively. Many other exotics, such as Brazilian elodea (*Egeria densa*) and variable watermilfoil (*Myriophyllum heterophyllum*), are more isolated but grow aggressively in some locations. In the Adirondack Park, isolated lakes and ponds located away from the perimeter and major travel corridors have been spared nuisance-level infestations. Fewer lakes in the interior Adirondacks have recreational uses affected by excessive weed growth than elsewhere in the state. The Central New York region has the highest incidences of known weed problems. This reflects, however, a higher percentage of lakes reporting these problems because they have active lake associations, strong local involvement in state and county reporting mechanisms, and active lake monitoring programs.

Nuisance weed problems in other regions of the state tend to be focused on more heavily used lakes near large roadways. This is probably due to a combination of factors that include greater exposure to boats and trailers transmitting these exotic plants; the ease of public access to these lakes; and more frequent reporting by communities on these high-profile lakes.

Nuisance algae: It's not easy being green

Except for nuisance weeds, excessive algae growth is the most common complaint reported by New York State lake residents and users. Algae takes many forms and can look like a green paint spill, bubbling mats coating the water's surface, strings suspended in the water, green dots adhering to weeds, or an algae tumbleweed or bottom cover in isolated clear areas. All of these can be referred to as algal blooms. As discussed in Chapter one, "Lake ecology," algae suspended in water are referred to as phytoplankton, while algae attached to structures are referred to as periphyton. Between these, there are thousands of varieties of freshwater algae. Nearly all of these can only be differentiated by a phycologist or botanist spending many hours gazing into a microscope.

Algal blooms can occur in many colors and at any time of year, even under ice, but they most often occur in August or September, staining the water bright green or blue. Noxious algae can be found among all major algae species. The blue-green algae species known as Annie, Fannie, and Mike (more formally, *Anabaena, Aphanizomenon,* and *Microcystis*) are most commonly associated with taste, odor, and toxin problems. Other blue-green algae, such as *Oscillatoria* (Ozzie) and *Nostoc,* can also create significant problems.

Water-quality problems associated with algal blooms include the following:

- Quantities of phytoplankton may impart tastes and odors to lake water, rendering it unusable for swimming or drinking. Algae also have a tendency to stick to boats, docks and rocks, leaving a greenish film and rendering them unsightly and slippery.
- The chlorination of water filled with algae or other organic matter can result in the formation of **disinfection byproducts (DBPs),** which are carcinogenic compounds when found at high concentrations. High levels of DBPs have been found in treated water withdrawn from some New York State lakes, particularly productive lakes with high levels of algae and organic material.
- Toxic chemicals emitted by some blue-green algae have caused the death of cattle, dogs and cats that consumed water containing the algae, with incidences in New York State occurring in Lake Champlain and Lake Neatahwanta. The threat to people is often considered slight, since basic water purification technology removes most algae from water, and since most people are quite sensitive to the bad taste and odor that often accompanies toxic algae. However, the threat of illness or worse from exposure to algal toxins, and the risk to children and domestic pets have been great enough to cause some lakes to be quarantined until the toxic blooms have dissipated (see Craine Lake case study). These toxins can also affect the taste of fish. Problems with algal toxins have also escalated in recent years, perhaps as a consequence of global climate change (warmer water, longer growing seasons, and more runoff) and increased monitoring, surveillance, and awareness.
- Oxygen depletion, when bacteria break down large quantities of dying algae, results in deficits for oxygen-sensitive organisms.
- Severe algal blooms can block so much light that rooted aquatic plants cannot grow. While this would not be considered a "problem" by many lake users, it is a mixed blessing. The lack of rooted plants would severely alter the lake ecology and make the lake resemble an aquatic wasteland.

Algal blooms occur throughout New York State, but are most significant in the southern and western lakes. It is likely that algae problems are more prominent there because the region's dense populations contribute high nutrient loading to predominately shallow lakes with small watersheds. Other factors include a slightly more moderate climate and longer growing season. The use of copper sulfate as an algae management tool is common in downstate lakes and in small ponds throughout the state, averaging more than 300 treatments per year.

Exotic but not rare animals

Exotic plants are not the only alien invaders to reap havoc on New York State lakes. The most economically devastating invasive animal is the **zebra mussel** (*Dreissena polymorpha*), named for the zebra-like black and white stripes on their shells. Zebra mussels were found in 1988 in Lake St. Clair near Detroit. They were introduced into the Great Lakes region from bilge water from large commercial barges from Europe, where these mussels are native. They have since spread to lakes throughout the Barge Canal system, to some feeder lakes, including the Finger Lakes,

Case study: Algal toxins in Craine Lake

Lake setting: Craine Lake is 26 acre, weakly stratified, private lake in southern Madison County, in the central (Leatherstocking) region of New York State.

The Problem: Blue-green algal blooms persisted during much of the summer of 2007, creating green clouds and streaks throughout the lake. While the lake historically had exhibited some problems with turbidity due to colloidal materials washing in from the watershed, this was the first documented case of blue-green algal blooms in the county, according to the County Health Department. (Ingmire, 2007) Craine Lake was also among the few mesotrophic lakes (those with few instances of algae problems) that suffer from algal blooms comprised of blue-green algae.

Response: Samples were collected by the County Health Department and were analyzed by researchers at the State University of New York College of Environmental Sciences and Forestry. The algae was determined to be *Microcystis aerginosa*, a blue-green algae species associated with gastrointestinal illness and (in extreme cases) liver damage and mortality. More than 800 µg/l (micrograms-per-liter) of *Microcystin* were measured from within the bloom. Measurement from a composite water sample was 4 µg/l. The World Health Organization (WHO) guidance value for drinking water is 1 µg/l. (Coin, 2007)

In response, county health officials instructed 35 lake homeowners to keep swimmers and pets out of the lake until the bloom passed and *Microcystin* measurements fell below the WHO guidance. Nutrient data indicated elevated hypolimnetic phosphorus and ammonia readings, suggesting persistent deepwater anoxia. It is likely that migration of deepwater phosphorus to surface waters triggered extensive uptake and growth by these phosphorus-limited organisms. The source of these nutrients and the cause of the deepwater anoxia had not been determined at the time of publication of this book, although studies in 2008 suggest that the incidences of algal toxins have decreased or at least exhibit cyclical patterns. There is also some evidence that the recent colonization and heavy expansion of zebra mussels (*Dreissena polymorpha*) may have altered the phytoplankton balance in the lake by selective removal of "beneficial" algae to the advantage of the unpalatable blue-greens (Kishbaugh, 2008; and Coin, 2008).

Lake Champlain, Lake George, and to smaller lakes near the Hudson and Mohawk Rivers. They attach to any hard surface such as rocks, boats, buoys, mooring lines, intake pipes, clams, or even other zebra mussels. Eventually they even attach to less hard surfaces such as aquatic plants like eelgrass. Female zebra mussels can produce up to one million eggs per year, which develop into free-floating larvae (veligers) that rapidly grow shells and seek a place to anchor. Zebra mussels need at least 15 to 20 parts-per-million (ppm) calcium in the water in order to grow shells. Even if lake-wide calcium levels are below this threshold, as they are in many Adirondack lakes, sufficient calcium levels can be found near inlets or shorelines with concrete structures. Zebra mussels have been found at the southern end of Lake George, where calcium levels average 10-15 ppm. Calcium levels exceed 40 ppm in some nearshore areas, however, caused by stormwater runoff, concrete boardwalk construction, and reduced lake dilution due to silt curtains used to reduce turbidity movement into the lake (Cohen and Weinstein, 2001).

The initial impact of zebra mussels is often perceived favorably. They are voracious filter feeders,

Fig. 3–10. Zebra mussels (Dreissena polymorpha) Top: Single zebra mussel. Bottom: Colony of zebra mussels attached to a hard surface (clam). (CREDIT: WENDY SKINNER)

clearing the algae from about one quart of water per mussel each day, resulting in substantial increases in water transparency. Trouble is brewing, however. In several large Midwestern cities, these mussels have clogged water intake pipes, causing millions of dollars in damage and in resulting treatment costs. Many infested bays in New York State lakes are completely covered by zebra mussels, displacing the native mussels. The effects on swimming are also severe. The shells of mussels are quite sharp and the smell of decaying mussels is quite offensive. Zebra mussels have also been indicted as the cause of dissolved oxygen deficits in the Oswego River downstream from Onondaga Lake.

The **quagga mussel** (*Dreissena bugensis*) is a similar freshwater mussel introduced to North America in the late 1980s. It prefers colder water, so it is not as common in New York State lakes as the zebra mussel. It has been found in deep lakes such as Lake Erie, Lake Ontario, Seneca Lake and Cayuga Lake.

Sea lampreys (*Petromyzon marinu*) were introduced to the Great Lakes and Lake Champlain by the creation of canals that circumvented natural barriers to their migration. Their arrival in these lakes nearly decimated the salmonid populations, particularly lake trout. The lamprey has a sucking mouth with as many as 125 teeth. Reminiscent of a creature from a bad horror movie, the lamprey sucks a hole in the side of its victims, draining vital body fluids. Lampricides, which very selectively target the young lampreys (called ammocetes), have reduced the population enough to rescue salmonid populations.

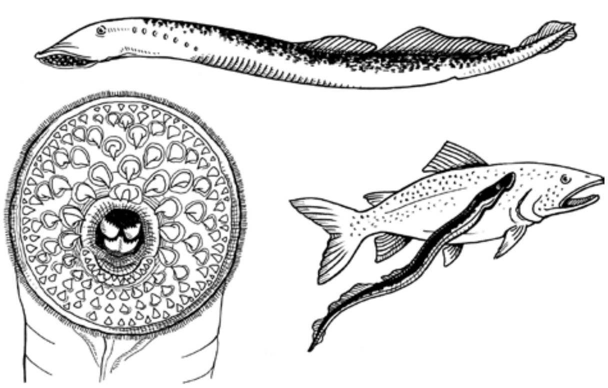


Fig. 3–11. Sea lamprey (Petromyzon marina) Top: Sea lamprey. Left: Lamprey mouth showing rows of teeth. Right: Lamprey attached to a trout victim.
(Credit: Wendy Skinner)

The **spiny water flea** *(Bythotrephes cederstroemi*) is known to many anglers who complain about the bristly gobs of jelly gumming up fishing tackle. This villain (Fig. 3–11) is actually a tiny crustacean with a long, sharp, barbed tail spine and a large eye filled with black pigment. A native of Great Britain and northern Europe, this pest was first found in the Great Lakes in 1984. Unfortunately, they don't make good fish food. The sharp spine, which comprises over 70 percent of the animal's total length, makes it hard for small fish to eat them, and their relatively small size makes them unappealing to large fish. Since spiny water fleas eat zooplankton, thus depriving juvenile fish of an important food source, they disrupt the aquatic food web and may have long-term, harmful effects on fisheries. Adults and eggs of this alien are most likely spread via bilge water, bait buckets, livewells, fishing lines, and downriggers.

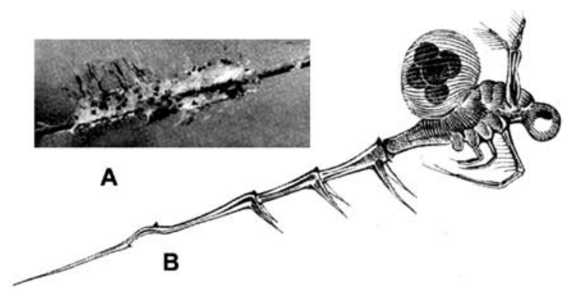


Fig. 3–12. Spiny water flea (Bythotrephes cederstroemi) A. Spiny water fleas look like gobs of jelly with black spots and bristles on a fishing line. B. The spiny water flea is less than one-half inch long. (Credit: Iowa Dept. Nat. Res.)

Many more invasive exotic plants and animals can be found in New York State lakes and saline waters. Some have exotic names, such as banded mystery snail, red eared slider, dead man's finger, and European frog-bit. Some newcomers, such as the round goby (*Neogobius melanostomus*), have already caused some ecological damage. Others, such as the inconspicuous freshwater jellyfish, have been in New York State waters since the 1930s. Some invasive exotics may have locally significant effects on the ecology of a lake. Many of these effects may be masked by other phenomena, or are largely hidden from the watchful eyes of most lake users, and have not been the focus of significant lake management efforts. Chapter five, "Fisheries management," discusses Invasive fish in more detail.

Another exotic organism of increasing importance is the parasite *Myxobolus cerebralis,* a spore more commonly known as *"***whirling disease***."* This parasite causes infected fish to swim in circles, as if chasing their tails, inhibiting their ability to feed or escape predation. Both wild and hatchery-raised trout within New York State have been infected, although the problem is not nearly as prevalent as it is in several western states.

The **northern snakehead** (*Channa argus*) is an aggressive, predatory invasive fish native to China, Russia and Korea. New York State prohibits the importation, possession, sale and live transport of snakehead fish and their viable eggs. Northern snakeheads are highly efficient predators, capable of growing to at least three feet long. They can breathe air and are capable of surviving for days out of water in damp conditions, and they can traverse land to access lakes and streams. Female snakeheads can release tens of thousands of eggs during several spawning seasons each year.

In 2008, large populations of northern snakehead were reported in southern New York State. The discovery triggered the development and implementation of a rapid response protocol by DEC. This protocol included the removal of 1400 fish to temporary holding tanks and the use of Rotenone to eliminate more than 200 northern snakehead that were rapidly reproducing in Ridgeway Lake and surrounding waterbodies in Orange County. Rotenone is a broad-spectrum insecticide, piscicide, and pesticide derived from the roots and stems of several plants. More than 8 tons of fish, mostly common carp, were also sacrificed during the attempt to eliminate the population. The loss was deemed necessary, however, to prevent much larger fish loss and degradation of fisheries in the lake and connected waterways, and particularly to prevent the spread of this invasive fish outside of this lake system (NYSDEC, 2008). Similar rapid response protocols will likely be developed to deal with new and highly aggressive invaders, using the snakehead and hydrilla rapid responses in 2008 as models.

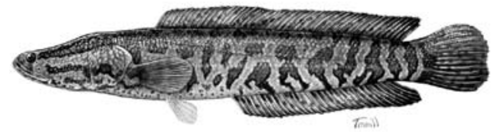


Fig. 3–13. Northern snakehead (Channa argus), an aggressive and predatory invasive fish that is rapidly spreading in the eastern United States. (CREDIT: DEC)

Pathogens: Itching swimmers and water fowlers

Swimmers itch, also known as duck itch, is caused by a parasitic flatworm that lives in the bloodstream of birds, muskrats, and mice. Flatworm eggs enter a lake through feces, and hatch into larvae, usually in late spring to early summer. The larvae then enter certain types of snails (*Physidae* or *Limnaeidae*), and develop into *cerceriae*. After about five weeks, the *cerceriae* are about one millimeter in size, generally too small to be seen by the naked eye. Each adult snail releases up to 2,000 *cerceriae* per day, usually between mid-morning and mid-afternoon. They enter the water searching for warmblooded hosts to begin the cycle again. The *cerceriae* cannot travel long distances, and live only about 24 hours. Although they cannot survive in humans, they will penetrate human skin and die, often inducing a tingling sensation that turns into a rash in 30 to 40 percent of the exposures. In more sensitive or allergic swimmers, intense itching may last a week, several days longer than it lasts in most people. As with other allergens, reactions can become worse with each exposure, and, in the most severe cases, may ultimately require medical treatment.

Waterfowl are also associated with outbreaks of swimmers itch, algal blooms and other problems. Since waterfowl feces are a significant source of the adult flatworm, it is not surprising that the most significant outbreaks occur where water is turbid or weedy near locations where waterfowl congregate. The fecal matter of waterfowl can also bring elevated levels of bacteria into lakes and cause beach closures. These birds frequently assemble at lakes with relatively flat and accessible shorelines. They like lawns or beaches that expand directly to the lakefront, large spaces with open water, and friendly lake residents who like feeding the birds.

Lake pathogens, such as bacteria and viruses, are too small to detect with the naked eye, but can create a host of problems for swimmers and those who use the water for drinking. Problems caused by pathogens range from gastrointestinal distress to death. Bacterial outbreaks occur in all parts of New York State wherever wastewater, stormwater and septic waste from humans and animals enter lakes.

When bacterial contamination is sufficient to cause a water-quality standard violation, the most common result is a beach closure. There were more than 1,500 days of beach closures in New York State in 2004, almost 150 percent more than in 2003. Most of these were marine beaches on Long Island and in New York City, and the increase from 2003 to 2004 was largely attributed to wetter weather and a greater frequency of monitoring. There have also been beach closures at freshwater lake beaches, particularly on the Great Lakes and some of the Finger Lakes state parks. There were about 600 days of freshwater beach closures in 2004. The vast majority of these beach closures have been attributed to bacterial

Case study: Effects of waterfowl on Collins Lake

Lake setting: Collins Lake is a 60-acre urban lake in the village of Scotia in the Capital District region of New York.

The problem: Bird surveys conducted by the Mohawk Valley Bird Club since the 1930s show that the lake has been used extensively by waterfowl for many years. Through the early 1980s, the waterfowl population was dominated by migratory birds, primarily gulls. Canada geese (*Branta canadensis*) sightings at the lake were uncommon. In 1988, only seven Canada geese sightings (recorded as "bird-days") were noted. Just two years later, however, that number exceeded 500 and by 1996 Canada geese bird-days reached nearly 5000.

Year	Canada Geese Bird Sightings (bird-days)	% of All Bird Sightings That Were Canada Geese
1988	7	3
1990	556	41
1994	2108	73
1996	4809	74

Table 3–1. Canada Geese bird sightings.

Response: Water-quality monitoring of the lake was conducted as part of a federal Clean Lakes project from the late 1970s through the late 1980s, and by Union College and DEC throughout the 1990s. Monitoring was conducted in the spring and fall, corresponding to the primary migratory periods for most of the waterfowl using the lake.

Results: The studies showed that spring trophic conditions (nutrient and algae levels) were comparable or even slightly less productive after Canada geese became significant visitors to Collins Lake. In contrast, fall nutrient and algae levels increased substantially but without evidence of significant changes in water clarity or fecal coliform levels. No significant changes in land use or other sources of nutrient loading were observed. While internal nutrient loading was not well documented, the temporal and spatial extent of deepwater anoxia did not change over this period. The density of Eurasian watermilfoil (*Myriophyllum spicatum*) increased slightly. Reductions in daily swimmer counts appeared tied to an increase in user fees for non-residents rather than degradation in water conditions.

Lessons learned: It appears that at least a significant portion of the fall nutrient and algae levels resulted from the major increase in the number of Canada geese using the lake. (Tobissen and Wheat, 2000).

Year	Spring Water Clarity (m)	Fall Water Clarity (m)	Spring Chl.a (ug/l)	Fall Chl.a (ug/l)	Spring Total Phosphorus (ppb)	Fall Total Phosphorus (ppb)
1978-1988	2.0	1.2	11	29	28	36
1989-1997	1.9	1.1	8	37	18	59

Table 3–2. Collins Lake water studies. Chl a *= chlorophyll* a*, an indication of algae density. Ppb = parts-per-billion. µg/l = micrograms-per-liter.*

contamination from stormwater, although some were pre-emptive closures. Chapter eight, “User conflicts,” provides additional information about lake pathogens.

Water-borne organisms other then bacteria can also cause human illness. *Giardia* (also known as beaver fever) and *Cryptosporidium* are two pathogenic protozoans. *Cryptosporidium* is associated with widespread illnesses from contaminated drinking water supplies, although these have not been common or well documented in New York State. *Cryptosporidium* contamination at a water park in central New York State caused numerous people to become ill in 2005.

The type E version of **botulism** (*Clostridium butyricam*) is becoming a more significant problem in the Great Lakes, and perhaps other New York State lakes. The toxins associated with this bacterium have infected lake sturgeon, small-mouth bass, and other fish species. It causes them to swim erratically near the surface of the lake, which exposes them to greater predation. As these infected fish are consumed by fish-eating birds, the toxin has spread upward into these secondary predators, resulting in the death of thousands of aquatic birds. The toxins are prevalent in the high-nutrient, low-oxygen conditions caused by the decay of fish and birds killed by the toxins, further exacerbating the problem. Humans may be susceptible if affected fish or birds are consumed, since cooking does not always neutralize the toxins.

Acid raining, mercury rising, and other toxic troubles

Acid rain illustrates a universal truth: “Lakes are the sink for pollutants that are discharged both upwind and upstream.” Some lakes serve as way-stations for sediment, nutrients and other pollutants as they slowly migrate from mountain streams to the ocean. Other lakes, however, are the final destinations for slowly settling pollutants because they are the first place where the flow of water is sufficiently reduced to allow these materials to settle out. Heavy metals and other organic compounds are deposited and ultimately buried in the sediments of lakes. Once buried in these sediments, they move only when violently disrupted by human dredging or other earth-moving activities, or by a greater natural force such as hurricanes.

More than 400 lakes in New York State are fishless because of acid rain. Acid rain has fallen on lakes throughout the northeastern United States for many decades. Most lakes in New York State have limestone deposits or other acidic buffers that neutralize the weakly acidic rainfall or watershed runoff, allowing these lakes to maintain neutral to basic pH. Small lakes at elevations greater than 2,000 feet within the Adirondack and Catskill mountains, however, do not have this buffering capacity. Over the last few decades, the pH of these lakes has slowly dropped to critically low levels. For the most sensitive aquatic organisms, such as striped bass and fathead minnows, reproductive capacity is affected at a pH of 6.5. At a pH of 6.0, these fish may be nearly eliminated, while lake trout and walleye begin to suffer reproductive effects. These latter species, as well as smallmouth bass and rainbow trout, are lost once pH drops to 5.5. As pH plummets to 4.5, even the few acid-insensitive species, such as yellow perch and large-mouth bass, begin to die off. Although some acid rain impacts have diminished in recent years, due to state and federal Clean Air legislation, sulfur and nitrogen compounds continue to fall and thwart recovery efforts. This is discussed in more detail in Chapter seven, “Algae and other undesirables.” Numerous studies and books have been published in the last 20 years about acid rain and its ecological and cultural significance. Readers are encouraged to seek these publications at their local library for additional information about the effects of acid rain in the Adirondacks and Catskills.

The mechanism for these effects is related to both the hydrogen ion associated with acid rain, and the forms of aluminum (the most abundant metal in the earths crust) that become more soluble as pH drops. As concentrations of hydrogen and aluminum ions increase, fish lose their ability to regulate ion exchange and cannot control the loss of sodium chloride from their gills. There is increasing evidence that aquatic plants, such as spadderdock (*Nuphar sp.)*, and other vegetation along the shoreline and within the watershed are also adversely affected by acid rain. Direct harm to frogs, toads, salamanders, and other fauna, and the cascading effects within the rest of the food web, can be devastating.

Other compounds found in acid rain also endanger lakes. The most significant is **mercury**, a trace contaminant released in the burning of coal and other fossil fuels and waste incineration. Mercury has been found in lakes throughout the state. This liquid metal is passed up the food chain and accumulates in the tissue of some susceptible organisms in a process called bioaccumulation. Over time, small amounts of a toxin such as mercury builds up because it accumulates more quickly than it can be broken down or excreted. This is a problem with secondary predators such as yellow perch (*Perca flavescens*) and largemouth bass near the top of the food chain. Mercury can be further concentrated, enough to be toxic when consumed by even higher-level predators, including humans. This is also true with some other bioaccumulative compounds, such as PCBs (polychlorinated biphenyl).

For most contaminated lakes, the mercury comes from acid rain, not from a local landfill or other nearby sources. The most sensitive lakes appear to be those with moderate levels of organic matter that forms compounds with the mercury. Large numbers of older, top-level predators, such as yellow perch, are susceptible to increased levels of bioaccumulation when they live for a long time. Yellow perch can live up to 11 years

In addition to these pervasive airborne pollutants, local upstream sources for metals and organic compounds can affect human health as well as cause problems when infected fish are consumed. Much attention has been dedicated to the PCB problem in the Hudson River, but there are many lakes throughout the state, particularly on Long Island, with elevated levels of **PCBs** or dense heavy metals generated from local sources. These compounds, generated by industrial processes, often escape from landfills or poorly contained industrial sites, and ultimately are deposited in lakes and ponds. Ongoing research by DEC into **organochlorine** effects on waterfowl found high uptake levels for some birds that had only limited exposure time to these contaminants. Organochlorine contaminants are organic compounds generated through interactions of organic material and chlorine.

As a result of these toxic compounds and other pollutants, the New York State Department of Health (DOH) has issued a statewide recommendation to limit fish consumption to no more than one-half pound per week for all freshwater fish. Site-specific fish advisories have also been issued for more than 70 lakes in New York State, including many of the largest lakes in the state, primarily due to the presence of PCBs and mercury.

Some inorganic compounds can create human health or ecological impacts. Elevated arsenic levels have been identified in some lakes, particularly near the bottom of some oxygen-depleted lakes, including some lakes used for potable water intake. The effect of arsenic on humans has been well documented. Arsenic was a common pesticide for many years, and was used as chromated copper arsenicals for pressure treating wood products. This carcinogen is slowly being phased out by federal regulation.

High ammonia levels are occasionally associated with lakes suffering from persistent oxygen depletion or high nitrogen loading from inadequately treated wastewater (Effler et al., 2001). Ammonia is a corrosive substance that is dangerous at high concentrations and toxic to fish at levels sometimes encountered near the bottom of some anoxic lakes.

Lead poisoning, due to the ingestion of weighted sinkers affixed to fishing line or of weighted lures, has accounted for about 30 percent of loon mortality documented in New York State. Loons (*Gavia immer*) may mistake sinkers for the small stones they regularly ingest to help grind fish bones and mollusk shells, or the sinkers and lures may resemble minnows or other loon prey. Examination of dead waterfowl from the Finger Lakes during an outbreak of duck viral enteritis in 1994 revealed that nearly half of the redhead ducks had ingested lead weights. As a result, New York State has banned the sale of lead sinkers weighing less than half of an ounce (NYSDEC, 2005).

The emerging frontier: From the pharmacy and laboratory

Homes commonly contain a myriad of personal, health and home care products that can have water-quality implications. After the chemicals associated with these products are applied or ingested, they often end up in septic systems and stormwater drains, slowly traveling into streams and lakes. Some of these compounds, such as boron from detergents and caffeine, are so ubiquitous that they serve as tracers of human use. They present a means to evaluate how much water used by humans enters hydrological pathways.

Researchers have identified more than 60 different **pharmaceuticals and personal care product (PPCPs)** in water sources throughout the world, many of which are resistant to traditional wastewater treatment processes in septic tanks or municipal treatment systems. The effects of aspirin, ibuprofen, estrogens, bezafibrate (a cholesterol regulator), and carbamazepine (an anticonvulsant) on Great Lakes fish populations are being studied, because in the laboratory these compounds feminize male fish and disrupt the development of the circulatory system, eyes and bladder. The long-term outcome of humans ingesting sub-therapeutic doses of numerous drugs continues to be closely studied (Potera, 2000). Of particular interest are endocrine disruptors and antibiotic resistant microorganisms, which have been documented in waterbodies that are the recipient of both treated and untreated wastewater and stormwater. Endocrine disruptors are synthetic compounds, such as PCBs, dioxin, and some pesticides, that disrupt hormone production and regulation. Antibiotic resistant microbes result from the overuse of antibiotics to treat a variety of non-bacterial infections. Present water and wastewater systems have not been engineered to adequately treat these products, so they often are returned to humans in their water supplies. However, while these PPCPs have been well researched, these compounds have not been the subject of many lake monitoring programs.

Tastes bad

Too much algae not only looks bad, it also tastes or smells bad. Some algae species can impart taste and odor to water that is very noticeable both in drinking water and in fish flesh. The most offending of these algae species tend to be the blue-green algae, such as *Anabaena*, *Aphanizomenon*, *Microcystis* and *Oscillatoria*. Additional offenders may include, but are not limited to, some green algae such as *Spirogyra*, golden-brown algae such as *Dinobryon*, and diatoms such as *Asterionella*.

Other chemicals can also contribute offensive taste and odor to water. Excessive levels of iron and manganese are often associated with taste and odor problems in drinking water supplies. This is usually due to the reduction of these metals by chemical reaction in the absence of oxygen. Substantial efforts are often required from water providers to remove pollutants from lakes that serve as domestic water supplies. Water supply problems are further exacerbated by poorly oxygenated conditions at the lake bottom. If water intakes are within the hypolimnion, reduced iron, manganese, hydrogen sulfide, and methane can be sucked into water intake pipes, offending the senses of those using lakes for potable water.

Case of the disappearing lake

Many lake residents complain that their lake is filling in, particularly small lakes or ponds that are simply wide portions of streams. They are absolutely correct, because that is what lakes do. As discussed earlier, however, this process is accelerated by cultural eutrophication (see Chapter one, “Lake ecology”). It shouldn’t happen in a few years or even over a generation and it shouldn’t be noticeable to even the most perceptive complainer. Accelerated infilling is usually due to the deposition of highly erodible material. It may have washed down from:

- an unstable upstream site, such as land recently cleared for streamside housing;
- a road construction or improperly maintained roadside ditches; or
- poorly tilled agricultural land.

This material often results in a fundamental change to the characteristics of the depositional zone, where the stuff lands in the lake. The new deposits create favorable conditions for colonization by invasive and exotic plants, which often thrive in disturbed environments.

Excessive weed and algae growth can also result in loss of water depth. Large stands of rooted plants will cause decreased water movement, allowing sediment particles to drop closer to the shore. As weed and algal blooms die off, they drop to the lake bottom, forming an organic layer that contributes to the sediment base. This promotes the growth of additional weeds and algae if the nutrients associated with this sediment are regularly resuspended, which feeds the creation of more sediment, and the cycle continues.

Deposition of erosion materials and decaying plant matter results in a thick, "mucky" layer that causes swimmers and waders to sink to an uncomfortable depth. This can create dangerous conditions for young swimmers and unpleasant experiences for others. This layer is loose and can easily become resuspended on windy days or with heavy boat traffic, causing short-term turbidity problems.

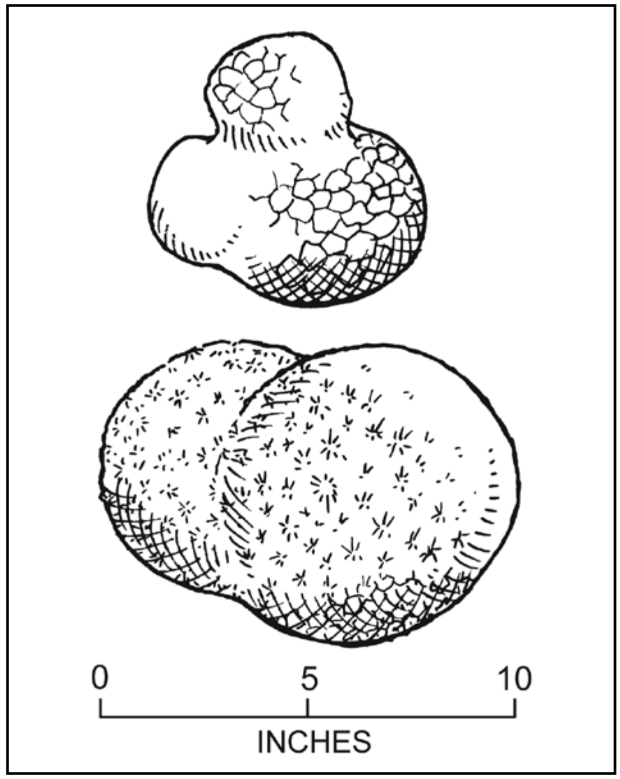


Fig. 3–14 Bryozoans (Pectinatella magnifica) are freshwater animals that form gelatinous colonies with circular or horseshoe-shaped ridges.
(CREDIT: WENDY SKINNER)

Curiosities

There are unusual water creatures and common surface pollutants that are more curious or irritating than problematic. One is the primitive **bryozoans** *(Pectinatella mangifica)*, a colonial animal that looks like gelatinous brains with interspersed dots. Another creature is freshwater sponge, which look like toast or greenish marshmallows on downed tree limbs or lake bottoms.

Tree pollen frequently deposits a yellow dust on the surface of lakes and ponds in spring and early summer. Pollen grains are released from the male flowers of plants. The type of pollen is largely dependent on the local variation in tree species. Eventually, pollen becomes water-logged and settles into the bottom of the lake, although it may also deposit on shoreline rocks when the water level drops.

Foam is a common phenomenon in lakes and ponds. It is formed when air is mixed with organic material, and is enhanced when a surfactant or surface-active compound is also present. It most commonly occurs in the fall, when organic matter from the degradation of plants is reintroduced into the lake, although foam can be induced at any time with the introduction of detergents. Foam has also been attributed to zebra mussel *(Dreissena polymorpha)* infestation, probably due to the excretion of large amounts of organic matter. A quick but largely simplified distinction between "natural" and "unnatural" foam is in the appearance and odor. Natural foam is white to beige in color and has no odor or only a slight earthy or fishy smell. Man-induced foaming can be white to slightly pink and has a perfume odor. Large streaks of foam often occur in larger lakes, caused by water circulation patterns referred to as Langmuir streaks (or windrows). The streaks are generally parallel to the wind direction, and spread further apart with increasing wind.

Oily sheens can shimmer with all the colors of the rainbow. Pretty as they are, however, oil and water do not mix in a healthy lake. A gallon of oil can coat the entire surface of a four-acre lake. Oily sheens may also be associated with iron bacteria, the breakdown of organic matter, or the decomposition of molted insect skins, which can occur when large numbers of mayflies or stoneflies leave the water to become flying adults. An easy way to tell the difference between natural and unnatural sheens is to poke a stick into the "oil slick." A petroleum-based sheen will immediately re-coalesce, while a natural sheen will remain apart.

Poor fishing

There are many reasons why fishing may be poor in a lake. Poor reproduction and over-fishing, the presence of toxins or disease, and lack of conditions that support a sustainable population of fish are all factors that can affect fishing.

Poor reproduction can keep populations of prized fish species down. This can be due to unsuitable habitat related to a lack, or overabundance of aquatic plants or other cover, water-quality conditions, poor temperatures, and other phenomena. It can also be due to competition among fish species for food, or to loss of a food source due to these same factors.

Fish populations may be reduced due to over-fishing or health problems related to toxins, viruses or other diseases. Significant viral outbreaks have occurred in New York State lakes. The *Koi virus* killed thousands of carp in Chautauqua Lake in 2005 (Chautauqua Lake Association, 2005). Less conspicuous infections have been identified in many other lakes, and this can have devastating effects on lakes that support only marginal fisheries.

A particular lake may not support a sustainable population of fish due to a lack of habitat, or food, and water-quality conditions required for a particular game species. Many New York State lakes do not support coldwater fisheries, for example, due to a combination of water that is too warm or oxygen levels that are too low at critical depths and seasons. This is true of lakes without a consistent supply of cold springs. Stocking trout or other salmonids in these lakes may provide temporary fishing opportunities if these fish are stocked in the fall or spring when oxygen and temperature levels are adequate. If not

Case study: Responding to an emergency— Koi Herpes virus

Lake setting: Chautauqua Lake is a 13,000 acre, 17-mile long lake in western New York State. The northern lake basin is deeper and colder than the southern basin. The lake is a popular recreation site for residents and tourists.

The problem: A large number of dead and dying carp were found in the lake in June 2005. Due to prevailing winds and currents, the majority of the carp were located in the southern basin. The New York State Department of Environmental Conservation (DEC) and Cornell University determined that the die-off was caused by Koi Herpes Virus (KHV) disease. This viral disease does not affect humans, but it can cause significant sickness and mortality in common carp (*Cyprinus carpio.*) Over 30,000 dead carp, weighing as much as 10 to 20 pounds each, washed up on the shores of Chautauqua Lake, posing a massive clean-up challenge.

Response: Working closely with local and state agencies, the Chautauqua Lake Association (CLA) led the clean-up efforts. Trucks and barges were used to remove the carp and transport them to the county landfill where, with DEC approval, they were buried in an isolated area. The CLA office became an emergency response center. Association members handled phone calls from the press and property owners six day per week. CLA volunteers worked in 90ºF temperatures removing the carcasses from the shores of the lake. It is estimated that the cost of the clean-up exceeded $80,000. (Chautauqua Lake Association, 2005)

Results: CLA was able to complete the clean-up in about three weeks, and the worst areas were finished before the busy Fourth of July holiday. The disaster showed that lake associations may face unexpected emergencies and need to be prepared to work closely with media and government agencies.

fished out, these fish will perish when water-quality conditions alter naturally with the changing seasons. Poor fishing habitat can also mean too few weeds, or at least the lack of margins created at the end of dense weed beds. While successful anglers may not need such an obvious edge, the lack of weed beds can often be the basis for complaints about fishing.

Poor fishing may also be due to increased populations of the wrong kind of fish, at least from the perspective of the angler. As algal productivity increases, populations of bottom feeders also increase, and growth patterns change for some pan fish. At the other extreme, lakes with too little algae from heavy predation by zooplankton, or acidification, often suffer a lack of game fish. An extreme example of this occurs in the Adirondacks and other high-elevation regions of New York State. Even in lakes with pH adequate to support fish populations, the shift away from more sensitive game fish to less sensitive species can render the angling experience much less palatable for many who venture into these less-traveled lakes. See Chapter five, "Fisheries management," for more discussion of these topics.

People problems

Many of the people problems in lakes can be summarized in two words, "too much." Complaints include too much boat traffic, too much competition for too little space, and too much boating horsepower. User surveys show that these impediments to lake use are among the most important problems facing lake users, and they are often both the main focus and bane of a lake management plan. Yet these "too much" problems are usually poorly documented and quantified. Since the discussion of the origin and resolution of these people problems are so intimately connected, they are discussed together in Chapter eight, "User conflict."

Summing it up

New York State lakes experience a wide variety of lake problems, ranging from traditional water-quality problems caused by excessive nutrient levels and congregation of waterfowl, to nuisance weed growth, acid rain, and toxic contamination. While some of these problems affect the ecological balance of the lake, most have consequences for humans. Use impacts include recreational or aesthetic impairments, human health effects from contaminated drinking water or fish, and the economic effects on the value of lakefront property. Solutions to these problems must often be tailored to the specific circumstances. Some aquatic plant control measures work well on some plants, but not on others, and may actually result in enhanced growth of unwanted plants. It is critical that these problems are correctly diagnosed and sufficiently understood to develop appropriate responses. Chapter four, "Problem Diagnosis," discusses the diagnosis and monitoring strategies necessary to identify and implement the lake and watershed management strategies discussed in later chapters.

4 Problem Diagnosis: Seeing Beyond the Symptoms

Introduction

When problems arise, it is human nature to try to fix what is obviously wrong. A quick fix may be a logical first step, but it is rarely enough and it may take resources away from a better long-term solution.

An example of this is algal blooms. Solving the problem of these smelly, noxious films that can look like paint spills is not simply a matter of poisoning or mopping up the algae, although that goes a long way toward making the lake look nicer. Controlling these blooms requires understanding factors that trigger them, which in turn should focus attention on those actions or sources that contribute to the blooms. Permanent solutions to these problems often require a long-term change in habits rather than an immediate fix.

Controlling algal blooms requires understanding factors that trigger excessive plant growth, such as an abundance of nutrients. Once a cause such as too much phosphorus is determined, the sources of the phosphorus can be identified and a plan made to reduce its input into the lake. The actions needed are different if the source of the phosphorus is lawn fertilizer rather than phosphorus attached to soil particles eroded from upland areas of the watershed. Addressing either of these underlying causes requires changes that go beyond an immediate fix, and involves far more people than those who are experiencing the algae and weed problem.

An analogy may be instructive. When a patient arrives at a doctor's office with a fever, the doctor does not simply prescribe something to relieve the fever. In fact, since fevers are part of the body's defense system, controlling a fever may actually interfere with these defense mechanisms. If a fever is too high, however, it prevents a body from functioning normally, and should be controlled. In addition to bringing a high fever down, the doctor will seek to understand and then treat the cause of the fever, such as controlling a bacterial infection with antibiotics, and educating the patient to reduce the chance of future infection.

Although not a perfect analogy, native plants are like low fevers. Increased native plant growth may be a lake's response to an increasing nutrient and sediment load. It may be a defense mechanism protecting the lake from other more significant responses such as algal blooms or high turbidity. Merely cutting the weeds, like lowering the fever, will do little to solve the real problem.

Connecting symptoms to causes to sources that point to remedial actions, is often crucial to building

Concentration versus load

Water samples collected from a stream are sent to a laboratory to identify the quantities of certain contaminants that may be present. The result of one test may tell how much phosphorus is in a particular amount of water, such as 0.02 micrograms of phosphorus in one liter of water (μg/l).

While concentrations provide useful information about exposure to a pollutant, they do not quantify how much phosphorus a stream is transporting to a lake. To determine the total quantity of a pollutant a stream is contributing, water-flow data are needed. Once the amount of water flowing into a stream at the time of sampling is known, the amount of phosphorus moving through the stream can be determined. A calculation using both the concentration value and the water-flow data gives the amount of phosphorus loading in the stream.

To illustrate it another way, if a one-ounce piece of chocolate has one gram of fat, then the concentration of fat in each piece of chocolate is known. This information alone is not enough. Knowing how many pieces of chocolate are consumed determines the total fat loading from the chocolate. For the health of waterbodies, as for people, loading information can be very informative.

a useful lake and watershed management plan. This is an important model to understand, even if it does not apply to all types of lake problems. Water-quality and lake-use problems may have begun to develop, but have not yet resulted in obvious symptoms or use impairments. An important symptom, such as the loss of a rare plant, may even have gone unnoticed.

Determining the causes of lake problems requires time and effort. It does little to provide short-term relief for those tired of swimming through weeds or suffering from clogged propellers. Comprehensive lake management often provides temporary bandages to cover the wound while long-term healing is taking place. Lake managers, municipal officials, lakefront residents, and taxpayers will continue to debate how much effort and resources should be invested in bandages. Everyone recognizes that bandages are sometimes necessary to allow the wound to stay clean. They also recognize that people are more likely to continue supporting long-term control strategies if those bearing the burden of reducing the flow of nutrients are shown some short-term successes.

This chapter provides tools for systematically diagnosing the underlying causes of common lake problems to develop solutions with long-term benefits.

Monitoring

Monitoring, sampling or testing refers to collecting information, usually from water samples, to evaluate the condition of a lake. Monitoring can reveal water-quality patterns and relationships among water-quality indicators that point to the cause, and sometimes the source, of a problem.

Current data must be collected, using methods that are accurate and reproducible, in order to develop management strategies that address lake problems. It is not enough to have one number indicating, for example, the amount of phosphorus. Where and how often samples are taken, and the type of phosphorus found will affect the usefulness of the information. To analyze and evaluate these data, additional information is required, including weather conditions, lake-bottom contours, watershed activities, and any other factors affecting water quality. The various facets of designing and using monitoring data are broken down into Why?, Who?, What?, Where?, When?, and How?

Why?

This is the first and most important question to answer. Any monitoring program devised without a clear understanding of this question is not likely to generate an acceptable answer to Why? Programs developed with clearly articulated objectives can usually provide easy answers to the Who?, What?, Where?, and When?. The "Why?" of monitoring programs can change or expand once the initial questions are answered, but most of the "Why's" can be summarized as follows:

- *Is the lake safe (for drinking, swimming, eating the fish, etc.)?* Will lake users get sick after consuming the water or fish, or will a wader be injured walking along the lake bottom? It might also relate to whether the lake is safe for the health of the fish and other organisms that share the water.
- *Does the lake support its intended uses?* Chapter two, "From Montauk to Erie," discussed how each of the lakes in New York State is classified for its best intended use, whether it is for drinking water, swimming, fishing, or support of aquatic life. A lake management and monitoring plan should be designed to collect the data require to meet the desired goals.
- *What is the quality of the water?* This includes factors such as the taste or odor of the water, or whether lake users would be offended by excessive algae or weeds, or would enjoy swimming, angling, boating, or looking at the lake. Future water-quality problems, or those not directly related to human use, may also be addressed by this question.
- *What is the condition of the lake?* Many government monitoring programs evaluate general conditions, conduct inventories for water-quality conditions, identify aquatic flora and fauna, identify regional or statewide patterns in lake

use, and characterize lake conditions. These programs are frequently developed to meet government reporting or permitting requirements and to identify locations for more intensive or more targeted monitoring.

- *Is the lake condition getting better or worse?* Long-term monitoring programs often identify water-quality trends, which may aid in evaluating patterns.
- *Did we solve the problem?* Many lake monitoring programs are developed after a lake management technique has already been employed, whether it was an activity to improve water-quality conditions or to enhance lake use. These tend to be reactive monitoring programs, rather than proactive, and usually suffer from a lack of pre-management data.
- *What is the relationship between A and B?* Many of the lake-monitoring programs conducted in New York State have been associated with research studies. Academic research is usually less concerned about conditions in specific lakes than with exploring relationships among lake indicators.
- *Is there enough water to support all lake uses and to protect downstream users?* Water-quantity data, such as lake level, tributary and outlet flow, and water-intake quantities, are often collected to evaluate whether specific lake demands are being met.

Who?

This is the easiest question to answer. Anyone can monitor their lake. Many water-quality indicators, however, need to be sampled using specialized equipment and techniques, and the costs to analyze some water-quality parameters may be too expensive for the typical lakefront resident. Monitoring is not rocket science; citizens, students, and laypeople as well as pointy-headed scientists throughout New York State already collect good quality data.

Individual lake associations have for years designed formal and informal water-quality testing programs for their lakes. Some require long-term monitoring and use water-sample data collected during several years to determine general water-quality characteristics and how they have changed through time. Other programs investigate specific problems, and are usually short-term, intensive studies. Both types of programs can be useful.

In addition, government agencies, drinking water suppliers, scientists and researchers may have already collected water-quality data useful for developing a lake management plan, or for answering a specific question about the condition of a lake. Information and old reports can be found at the local library, or in the files of the lake association secretary, town clerk, county agency staff, or state government official. The U.S. Environmental Protection Agency's (EPA) electronic repository for water-quality data, called STORET (STOrage and RETrieval), holds more than 200 million water sample observations from about 700,000 sampling sites for both surface and ground water. Much of the STORET information is accessible through the EPA website. (See Appendix F, "Internet resources")

Long, long ago…1926 to 1980

It is helpful to know the history of lake monitoring to effectively search for previously collected data. The New York State Conservation Department, now the New York State Department of Environmental Conservation (DEC), conducted a biological survey of each of the major drainage basins in New York State from 1926 to 1934, focusing on fisheries resources and stocking. These studies also evaluated lake and stream water quality related to temperature, oxygen and clarity, invertebrates, plankton, aquatic vegetation, and even aquatic parasites. Dozens of small to large lakes were sampled within each basin. Usually only a single sampling session was conducted at each lake, but the samples provided an invaluable snapshot of conditions at that time. These studies can be found at DEC regional offices and selected libraries across the state.

In 1972 EPA conducted a national eutrophication study of 26 lakes in New York State to "investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs." These studies used lake and stream monitoring to look at nutrient loading in lakes, and evaluated other traditional water-quality indicators and plankton levels. The study results are available through STORET.

Recently defunct programs… 1980 to 2000

The Eastern Lake Survey, conducted in 1984 and 1986, was part of a long-term effort by the EPA known as the National Surface Water Survey. It identified the acidity of surface waters in the United States in areas susceptible to the effects of acid rain. The effort was conducted in support of the National Acid Precipitation Assessment Program. It involved about 1,700 lakes throughout the United States, including 220 lakes in New York State, and these data are available through STORET.

In the 1990s the EPA developed a similar program called the Environmental Monitoring and Assessment Program (EMAP). EMAP was a research program designed to develop the tools necessary to monitor and assess the status and trends of national ecological resources. They planned to sample at four-year intervals a group of lakes within the northeastern United States to determine water-quality changes and trends of a core group of ecological indicators. After about 130 lakes in New York had been sampled from 1991 to 1993, however, the lakes portion of this program shifted to a different region of the country. These data are available through STORET. In recent years this program has changed into a national survey program conducted by EPA in recent years and is described below.

The federal Clean Lakes Program (under Section 314 of the *Clean Water Act*) provided resources to government agencies and others to diagnose water-quality problems (Phase I projects), and to implement water-quality improvement projects (Phase II projects). Water-quality monitoring was conducted from the late 1970s to the mid-1990s on about 25 New York State lakes as part of this program. This program has largely been folded into other federal programs, and the emphasis on water-quality monitoring merged into broader, statewide monitoring efforts. Information about individual lakes surveyed or managed as part of this program is available from DEC's Division of Water (see Appendix F, "Internet resources")

Ongoing programs

The New York City Department of Environmental Protection (NYCDEP) conducts systematic monitoring at each of the 19 reservoirs that supply drinking water to the nearly 10 million residents of the greater New York City area. Summaries of the water-quality results from this monitoring can be found at the NYCDEP's website. (See Appendix F, "Internet resources")

By a cooperative agreement in 1984, the Empire State Electric Energy Research Corporation and DEC established the Adirondack Lakes Survey Corporation to determine the extent and magnitude of acidification of Adirondack lakes and ponds. From 1984 to 1987, the not-for-profit organization conducted an extensive baseline survey of nearly 1,500 lakes within the Adirondacks and high-elevation lakes downstate. In 1992, a long-term monitoring project on a subset of 52 of these lakes began. These data are available through the Adirondack Lakes Survey Corporation website. (See Appendix F, "Internet resources)

The Adirondack Effects Assessment Program is a multi-institutional effort to survey the biological community structure in Adirondack lakes. Institutions involved include Rensselaer Polytechnic Institute, DEC, the U.S. Geological Survey (USGS), and other organizations. The goal is to determine if chemical and biological changes have occurred, and provide baseline information for assessing recovery in the future. These studies began in 1994 and focus on the biological community structure in 30 lakes located in the highly impacted southwest corner of the Adirondacks.

DEC conducts an ambient lake monitoring program on lakes and ponds throughout the state. This program, originally called the Lake Classification and Inventory Survey, sampled lakes in the mid-1970s, and then from 1982 through 1991, and has continued annually since 1996. The program evaluates the trophic condition of previously unmonitored lakes and compares contemporary conditions in lakes with use impairments listed on the state Priority Waterbody List (PWL). It is now part of the Rotating Intensive Basin Surveys (RIBS), the state's ambient surface water-quality monitoring network that each year samples waterbodies within two or three different drainage basins. Approximately 200 lakes have been sampled as part of this program, which was funded from portions of the federal Clean Lakes Program and from ongoing DEC monitoring efforts. Nutrient data collected within this program prior to 2000 are available through the EPA nutrient database from the EPA Office of Water website. Other data are available through the DEC Division of Water. (See Appendix F, "Internet resources")

The DEC Division of Water has also engaged in a long-term monitoring project on the Finger Lakes. Results from this project can be found by searching for, "Water Quality Study of the Finger Lakes" on the DEC website. This project has been taken over by the Upstate Freshwater Institute in Syracuse.

Fisheries staffs at regional DEC offices have been sampling lakes for many years in support of fish stocking and habitat protection activities. Water-quality sampling results, fisheries surveys, fish tissue analyses, and habitat assessments can be obtained by contacting the appropriate DEC Regional Fisheries office. These include special studies of Lake Ontario, the Finger Lakes, and specific contaminant studies such as mercury, PCBs, and other toxins.

Lakes and reservoirs are among the more than 1450 surface water supplies serving more than 15,000 New Yorkers. The New York State Department of Health (DOH) issues an annual water quality report called the DOH Source Water Assessment Program (SWAP). It provides information to

- determine the potable water source;
- inventory potential sources of contamination that may impact public drinking water sources; and
- assess the likelihood of a source water area becoming contaminated.

The DOH Source Water Protection Program works with municipalities and other agencies to monitor and assess pathogenic threats to water supplies, and conducts studies of harmful algal blooms (HABs) in lakes and reservoirs throughout New York state.

A survey of about 900 of the nation's lakes was conducted by EPA in 2007 as part of a continuing series of national surveys. Survey sites were randomly chosen by EPA and sampled by state agencies, consultants, and academicians throughout the country. The DEC surveyed the 12 New York State lakes chosen as part of this survey for a wide variety of physical, chemical, and biological indicators. It is anticipated that these surveys will be repeated in five-year increments, most likely with a different set of lakes.

Academic, local government, and private monitors

State or federal governments or their partners have conducted the majority of the large-scale, multi-lake or multi-year studies of lakes in New York State. County and local governments, academic institutions, consulting firms, and private citizens have managed many smaller studies and monitoring projects.

A number of counties within the watersheds of Lake Ontario and the Finger Lakes have conducted water-quality monitoring on lakes and streams using state funds allocated to them from the Finger Lakes-Lake Ontario Watershed Protection Alliance (FL-LOWPA). Some counties have used these funds to sponsor volunteer water-quality monitoring projects. Others have conducted monitoring programs to evaluate impacts of nonpoint source pollution on lake water quality. Individual programs are discussed in detail at the FL-LOWPA website. (See Appendix F, "Internet resources")

All municipal water supplies are required to monitor the quality of their raw, untreated water supply and issue reports summarizing the results. This includes the multi-use reservoirs found in many parts of the state. Many of these reports can be found on municipality websites. All municipalities with water supplies serving more than 100,000 residents are required to post these reports online. These reports generally contain useful information, even though most of the parameters of interest for lake water quality are not sampled in these drinking-water programs.

The local departments of public works also conduct monitoring of discharges from municipal wastewater-treatment plants, and maintain records associated with the disposal of municipal wastes. This information can provide insights about potential pollutants entering lakes and could be included in lake-monitoring programs.

Many colleges and universities in New York State have been actively involved in water-quality monitoring that complements their educational efforts, supports academic research, and facilitates community relations. Some of these academic institutes or researchers, their research topics, and the waterbodies being studied, are:

- Cornell University: Water quality, aquatic vegetation, fisheries, and ecosystem research in the Finger Lakes, Onondaga Lake, Lake Ontario, Chautauqua Lake, Waneta Lake, Lamoka Lake, and several Madison County lakes.
- Syracuse University: Acid rain and mercury pollution in the Adirondacks.
- Rensselaer Polytechnic Institute: Water quality, aquatic vegetation, and ecosystem research on Lake George, Onondaga Lake, and Adirondack lakes.
- Paul Smiths College: Water quality and paleolimnology studies of Upper Saranac Lake, St. Regis Chain of Lakes, and other Adirondack lakes.
- Colgate University: Water quality and ecosystem research in Central New York lakes.
- Clarkson University: Ecosystem research on Lake Ontario and the Cascade Lakes.
- Finger Lakes Institute: Water quality and ecosystem research and environmental education on the Finger Lakes.
- Hobart and William Smith College (home of the Finger Lakes Institute): Aquatic research on the Finger Lakes, particularly Seneca Lake, and comparisons across the Finger Lakes.
- Institute for Ecosystem Studies: Ecosystem research on Adirondack lakes.
- Keuka College: Water-quality studies of Keuka Lake.
- Southampton College: Water-quality studies of Trout Pond in Southampton and evaluation of algal toxins in freshwater ponds in Long Island.
- SUNY Binghamton: Aquatic vegetation studies of Adirondack lakes and Central New York lakes.
- SUNY Brockport: Aquatic vegetation, fisheries, and ecosystem research on the Great Lakes and Finger Lakes.
- SUNY Buffalo: Water quality and ecosystem studies of the Great Lakes and Finger Lakes.
- SUNY College of Environmental Science and Forestry: Phytoplankton and ecosystem research on the Finger Lakes, Great Lakes, and select Adirondack lakes; algal toxin research throughout the state.
- SUNY Cortland: Water quality in small ponds in Central New York.
- SUNY Fredonia: Water quality, aquatic vegetation, and fisheries studies of Lake Erie, Chautauqua Lake, Cassadaga Lakes, Bear Lake, and Findley Lake.
- SUNY Plattsburgh: Water quality work on Lake Champlain.
- Union College: Water quality, paleolimnology, and ecosystem studies of Ballston Lake, Collins Lake, and select Adirondack lakes.
- Upstate Freshwater Institute: Water quality and paleolimnology studies of Onondaga Lake, the New York City Reservoir systems, several Adirondack lakes, the Finger Lakes, and Central New York lakes.
- Wells College: Water-quality studies of Cayuga Lake.

Several colleges and universities maintain field stations on larger New York State lakes that allow for long-term research and provide a training facility for students and visiting researchers. These include:

- Cornell Biological Field Station at Shackelton Point on Oneida Lake.
- Darrin Freshwater Institute, Rensselaer Polytechnic Institute, on Lake George.
- Huyck Preserve and Biological Field Station at Lake Myosotis.
- SUNY College of Environmental Science and Forestry: Thousand Islands Biological Field Station in the St. Lawrence River; Cranberry Lake Biological Field Station, and the Adirondack Ecological Center on Arbitus and Rich lakes.
- SUNY Oneonta Biological Field Station on Otsego Lake.
- SUNY Oswego Biological Field Station on Rice Creek, Lake Ontario.

Environmental organizations have also been involved in lake monitoring for many years. The Nature Conservancy (TNC) is perhaps the most prominent of these organizations. TNC conducts a number of monitoring programs throughout the state on contract with the DEC through the Natural Heritage Program. They focus on loons in Adirondack lakes, invasive plants on Long Island and in the Adirondacks, and protected plant species throughout the state.

Volunteer monitoring and CSLAP

Volunteer monitoring dates back to the late 1800s with the network of weather watchers assisting the professionals at the National Weather Service to identify long-term weather patterns. In fact, volunteer-staffed stations outnumber professionally staffed stations by more than 40 to 1! Volunteers have also provided a national network of observations on bird populations through the National Audubon Society's Christmas Bird Count, started in 1900, and the U.S. Fish and Wildlife Service's Bird Banding Program, started in 1920.

Volunteer water- and lake-monitoring programs evolved after from the passage of the *Clean Water Act* in 1972. Pioneering lake-monitoring programs formed in Michigan and Maine, and volunteer stream-monitoring programs began in Maryland and through the Izaak Walton League, a nonprofit conservation organization. As state and federal dollars available for government-run monitoring programs continue to decline, or are dedicated to other environmental concerns, large-scale lake monitoring programs have been reduced. In their place, volunteer monitoring programs have played a more prominent role in gathering baseline data for lake managers and lakefront residents.

Individuals interested in lake monitoring will benefit from involvement in an established program rather than working alone. Monitoring programs usually have standardized sampling equipment, materials and testing procedures designed for specific monitoring objectives. Standardization facilitates comparison between lakes and lends validity to the process when sharing data with municipalities or agencies. It may cost more per sample to join a program, but the extra cost may be balanced by access to equipment, expertise in interpreting results, and special arrangements with laboratories and shipping vendors that give bulk-rate discounts to program participants.

There are currently at least ten volunteer lake-monitoring programs in New York State. A much larger number of less formal organizations are dedicated to monitoring a particular parameter such as bacteria levels, invasive plants, and zebra mussels. Others are using monitoring as an educational tool through floating classrooms, lake associations, and other venues. Some monitoring programs are regional. The Adirondack Park Invasive Plant Program (APIPP) is a joint partnership between TNC, the Adirondack Park Agency (APA), DEC, the New York State Department of Transportation (DOT) and others. It trains volunteers to search for exotic plants and works with the DEC and the Darrin Freshwater Institute (DFI) on Lake George to build an inventory of exotic plants found within the Adirondacks and throughout the state. More information can be obtained from the APIPP website. The site also contains lists of related organizations, like the Residents Committee to Protect the Adirondacks, which works with volunteers to evaluate water-quality conditions in about 60 lakes through the Adirondack Lake Assessment Program at Paul Smith's College. (See Appendix F, "Internet resources")

The largest and most extensive volunteer lake-monitoring program is the New York Citizens Statewide Lake Assessment Program (**CSLAP**), a cooperative effort between the New York State Federation of Lake Associations (NYSFOLA), DEC, and lay-volunteer monitors throughout the state. CSLAP was founded in 1986 to collect water-quality data for sound decision-making, identify water-quality problems, and educate lake residents, municipal officials and lake managers. CSLAP volunteers from NYSFOLA member lakes are trained by professional staff to collect water samples, perform field tests, and provide standardized observations about lake conditions and use impairments. DEC provides CSLAP volunteers with equipment and field guides to conduct bi-weekly sampling from May through October. Samples are collected from the deepest part of the lake, and from the bottom of thermally stratified lakes (warm on the top, cold on the bottom). Samples are analyzed at a state certified laboratory (Upstate Freshwater Institute) that has an expertise in lake monitoring and analyses. Aquatic plant samples are also collected and identified for lake associations concerned about invasive plants, rare and endangered species, or other discoveries at their lakes.

More than 225 lake associations and 1,200 volunteers have participated in CSLAP since its inception, collecting more than 18,000 samples. At the end of each sampling season, DEC provides a report for each lake association summarizing water-quality results from previous sampling seasons, including information about management implications for the measured conditions in the lake. Information about participating in CSLAP, and electronic copies of individual lake reports, can be obtained from NYSFOLA and DEC.

What?

In a world where equipment and funds for analytical interpretations were unlimited, a lake monitor could collect a barrel of water and bring it to a laboratory with instructions to "Analyze it for everything." Resources for water sampling are limited and, thankfully, such detailed monitoring is rarely necessary. The results from such an exhaustive investigation would show no detectable levels for the vast majority of lake water-quality indicators.

Most water-quality monitoring projects focus on analyses of a few key indicators that provide the most useful information to answer a defined question. Investigative studies to pinpoint the exact location and cause of a specific problem may employ a sampling protocol with many different parameters. Long-term baseline monitoring to discern how water quality is changing over time may involve only a few parameters tested regularly over a span of years.

While no one set of analyses are appropriate for all water-quality investigations, a core group of limnology procedures and water-quality parameters form the basis of most monitoring programs. Some of these analytical tests, such as Secchi disk transparency, water temperature, algae levels, color and turbidity, are directly related to the symptoms of a problem. Other tests, such as dissolved oxygen, nutrients, and pH levels, can provide significant information about the causes of a problem. In many situations, other water-quality analyses, such as extensive macrophyte surveys, sediment sampling, zooplankton and phytoplankton species identification, or chemical parameters, are needed to gain a greater understanding of the linkage between a symptom and a cause in any particular lake. The results from any given test may determine the direction of future investigations. Many of these water-quality analyses and parameters will provide a good starting point for developing an appropriate monitoring program or testing regime.

Secchi disk transparency

The **Secchi disk** is a 20 cm (centimeter), steel or heavy plastic disk quartered into alternating sections of black and white. It is attached to a measured rope or cable and lowered over the shaded side of a sampling boat to measure the transparency of the lake. Water transparency is the average of two depths: the depth at which the disk first disappears from sight as it is lowered, and the depth at which it re-appears at it is slowly raised. It is an utterly unsophisticated

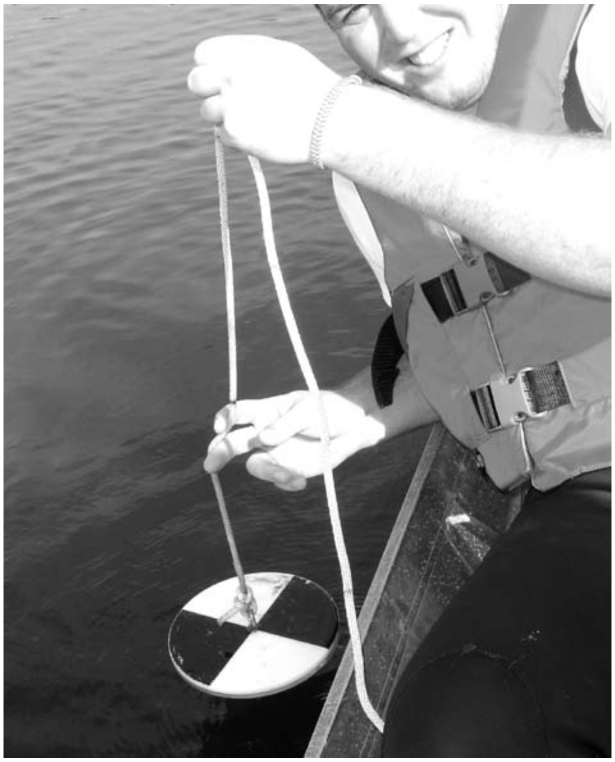


Fig. 4–1. A Secchi disk is a 20 cm disk, quartered into sections, and used for measuring water transparency. (CREDIT: JOHN FOSTER)

but eminently useful tool that dates back to the mid-1860s, when papal cartographer Angelo Pietro Secchi designed it to help him predict circulation patterns in the Mediterranean.

Secchi disk transparency is influenced by concentrations of phytoplankton, suspended inorganic material, such as silt or calcium carbonate ($CaCO_3$), and dissolved organic substances. Each of these substances imparts a color to lake water, ultimately influencing the extent to which light can pass through it. The perceived transparency is also influenced by cloud cover, glare and angle of the sun, wave action, rooted aquatic vegetation, reflection from the lake floor and in extreme cases the vision of the sampler. These interferences can cause a discrepancy between actual and perceived transparency. Despite these interferences, Secchi disk transparency often serves as a surrogate measurement of algae levels in clear lakes with only limited biological productivity (little humic material or other dissolved organic matter), which in turn often provides insights about nutrient levels in the lake.

Temperature and dissolved oxygen profiles

Temperature and oxygen profiles determine the degree of stratification, and the potential for depletion of oxygen, adversely affecting fish and other aquatic organisms. **Dissolved oxygen** is affected by temperature, time of day, and pollution. As water temperature decreases, increasing amounts of oxygen can dissolve in water. During the day, photosynthetic plants create oxygen, and use it at night. Aerobic bacteria and other organisms require oxygen for the consumption of wastes.

Fish and other aquatic organisms require a minimum of four to five milligrams-per-liter (mg/l) of oxygen. The most accurate way to measure oxygen levels is to use a wet-chemistry titration. Reagents are added to a water sample causing a color change when titrated with other reagents. This method, however, is very time-consuming, and requires some pretty nasty chemicals.

Many elaborate lake monitoring programs use electronic meters that utilize miniaturized versions of laboratory tests to collect in-situ ("in place") measurements of an increasing number of water-quality indicators. Temperature and dissolved oxygen meters constituted the first version of these meters, allowing discrete measurements to be taken from lake surface to lake floor, usually in one-meter intervals. Many of these meters, now referred to as multi-parameter probes, can detect an increasing number of water-quality indicators at various degrees of accuracy and reliability. Since electronic meters are expensive, however, most volunteer monitoring programs seldom use them.

Simple dissolved-oxygen test kits are relatively inexpensive at less than \$1.00 per test, and are accurate enough for rough evaluations of oxygenation and **hypoxic** (low-level of dissolved oxygen) or anoxic (insufficient supply of oxygen) conditions. Their use is time-consuming, however, especially for constructing full-depth profiles.

Precipitation and lake level monitoring

Precipitation can greatly affect the overall hydraulic or water budget for lakes, especially in lakes with negligible groundwater, or water that flows from springs. Precipitation can also affect the water level in a lake, resulting in potential recreational and pollution problems by affecting boating and drinking water access, the degree of shore erosion, vegetation levels, or ecosystem dynamics.

Precipitation is accurately measured at more than 100 New York State sites with U.S. National Oceanographic and Atmospheric Agency, National Weather Service (NOAA) gauging stations. It can be measured at a local level by a simple rain gauge installed near the lake surface. Simple rain gauges are not as accurate as those used by NOAA, but provide a more accurate local rainfall measure if the NOAA weather station is a few miles away where weather patterns might be very different.

Lake level can be determined by attaching a staff gauge, calibrated in small increments, to a permanent structure. Frequent measurements, often daily, can determine precipitation totals and water level. Measured simultaneously, precipitation and water-level gauging can determine the influence of direct rainfall on the overall hydraulic budget.

Macrophyte surveys and mapping

Vegetation surveys usually involve some combination of measures or estimates of plant quantities and locations within a lake, which can have a significant affect on recreational access, quality of fisheries, and the overall aesthetic appeal of a lake. This information can provide an understanding of the water quality and use impairments in a lake. The full spectrum of aquatic vegetation surveys, from the simplest to the most sophisticated, is described in a report authored by Madsen and Bloomfield (1993), available through the North American Lake Management Society (NALMS) website. (See Appendix F, "Internet resources") The sophisticated version of a vegetation survey requires the placement of transect lines throughout the lake, running perpendicular from the shoreline to just beyond the maximum depth of aquatic plant growth, to measure plant densities and identify species populations in quadrants placed at regular intervals along the line. Quadrants can range in size from 0.1 square meter (approximately one foot by one foot), to one square meter (a little more than three feet by three feet). They can be examined frequently to determine change in plant densities and coverage. Extensive macrophyte vegetation surveys can be extremely expensive, and may require the time and expertise of qualified specialists, including divers. Individual plant species must be positively identified and their identifications verified to completely address the relationship between macrophyte communities, lake water quality, and use impairment. At the other extreme, simple surface maps can be drawn showing macrophyte coverage areas without regard to plant types.

The most common survey methods fall between the extremes. They involve techniques for collecting plants from the surface, usually using rakes with attached ropes, or observations of plant communities using swimmers or identifications from boats. Rake tosses or other forms of observation can occur at various depths in the weediest areas. Results are more standardized and reproducible if sampling is done using the **point-intercept** method. This technique divides the lake into a series of points, taken from the center or at the intersection points of a grid. These points are then sampled randomly. Recent surveys indicate a strong connection between biomass (the dry weight of plants) and semi-quantitative assessments derived from point-intercept measurements. Point-intercept measurements can generate coverage maps that provide a readily understandable snapshot of plant conditions in a lake (Fig. 4–2). If used in conjunction with the methods described below, the measurements can serve as a surrogate for detailed biomass survey maps.

Vegetation is frequently expressed as a percentage of coverage, or as a qualitative assessment of density, using labels such as rare/trace, scarce/sparse, moderate/medium/common, and dense/abundant.

Cornell University researchers have developed simple, semi-quantitative metrics to evaluate density using easily understood labels such as those shown in Table 4–1 (Lord et al, 2005).

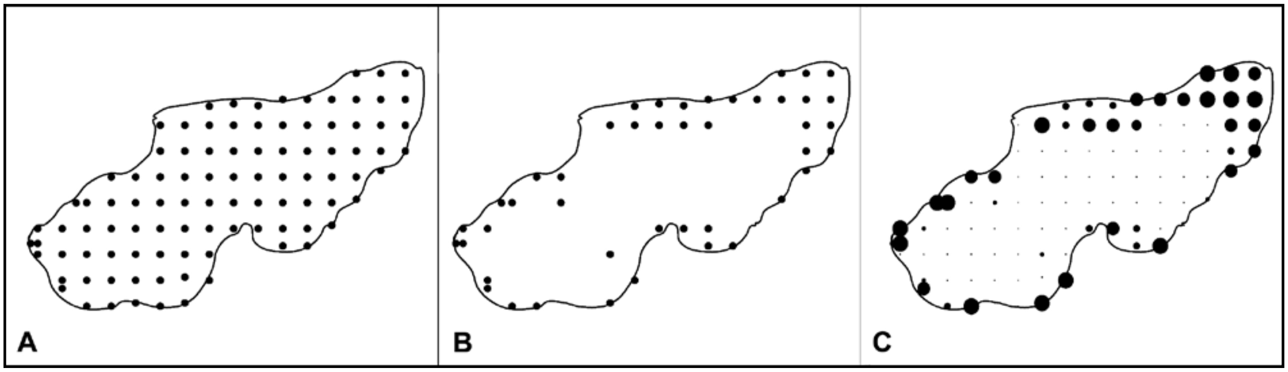


Fig. 4–2. Point-intercept method used to map aquatic plants.

A. Once the point-intercept grid is overlain on a map, the points can be sampled randomly to reduce bias, or specific points within the littoral zone can be sampled during a period of time to evaluate trends.

B. As a result of sampling, one of two types of maps can be created. The middle figure shows the presence/absence distribution map.

C. Alternatively, sampling data can be mapped to show the relative abundance of aquatic plants. Larger circles mean greater plant density.

Density Category	Average Quantity from 2–3 Rake Tosses	Approximate Biomass
No plants	Nothing	0 g/m2
Trace	Fingerful (of plants)	up to 0.1 g/m2
Sparse	Handful	0.1 to 20 g/m2
Medium	Rakeful	20 to 100 g/m2
Dense	Can't Bring in Boat	100 to 400 g/m2

Table 4–1. Estimation of plant density using the rake-toss method. (g/m² = grams-per-square-meter) (CREDIT: LORD ET AL)

In lieu of an extensive macrophyte survey, vegetative cover can be mapped over the course of a year, usually during late spring to early summer and again in the fall. This simple survey can be taken using aerial photographs or on-site inspections by lake residents, preferably those who can view the lake from their rooftops! The most common maps indicate the major plant species in each part of the lake, with little differentiation between thick beds and scattered plants. An example can be seen in Fig. 4–3.

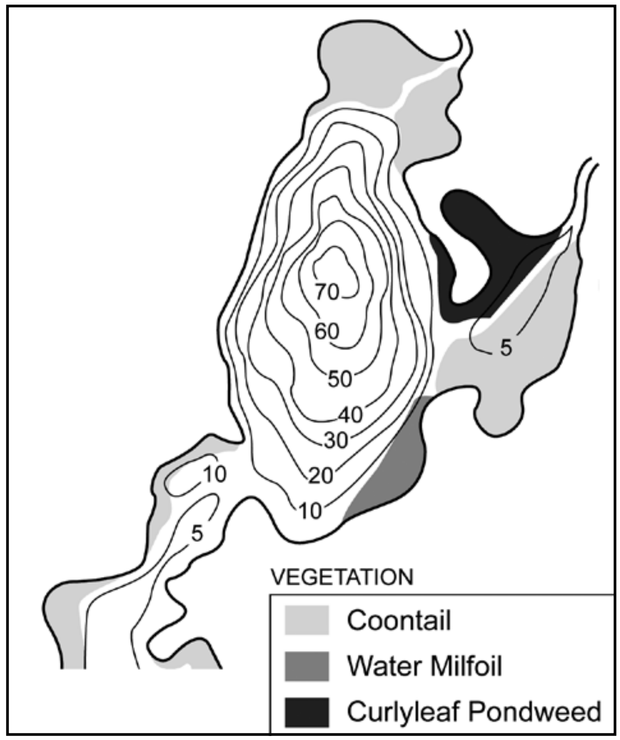


Fig. 4–3. Map indicating location of major plant species within a lake. (CREDIT: CHRIS COOLEY)

Water chemistry parameters

Water samples can be collected for the analysis of specific chemical parameters depending on the nature of the investigation. Eutrophication studies related to algal blooms are often concerned with clarity, dissolved oxygen and temperature, nutrients, organic carbon, turbidity, and algae levels. Acidification studies might look at pH, alkalinity, conductivity, dissolved organic carbon, and several inorganic ions.

Investigations of specific water-quality problems or use impairments are driven by a list of existing symptoms. For any particular set of symptoms some subset of the following common parameters are likely to be selected for testing.

Sampling techniques

The specific type of water-quality sample to be collected, and the **sampling technique** to be used, will depend on the nature of the use impairment and perceived water-quality problem. Many perceived lake problems involve degradation of surface water quality, while other problems develop from degradation of water near the lake bottom. Samples collected from either surface or bottom waters alone, can be characterized as "grab samples." A single sample with both surface and sub-surface waters mixed together is called an "integrated sample." Unless noted specifically, most of the parameters discussed below are collected in grab samples or integrated samples, with only limited processing required. Some of the parameters require filtration or acidification in the field, using bottles, preservatives (usually acid) and filters provided by the laboratory or program directors.

Grab samples constitute the majority of lake water samples. Grab samples can be collected by manually submerging a sterilized collection bottle to elbow depth (approximately 0.5 meters), or with specialized collection devices. Using these devices minimizes surface-layer contamination and maximizes reproducibility. The devices also allow samples to be collected at any point in the water column from the surface to the lake bottom. Sampling by hand may be most appropriate for near-surface samples in very shallow water, or for streams or tributaries entering the lake. Hand sampling may be adequate for inexpensive monitoring projects for which the water-quality indicator is not particularly sensitive to potential contamination from the sampler.

Integrated samples can be collected from the water surface to the lake bottom. Most integrated sampling methods use a hose or tubing system with a vacuum pump. The hose is lowered to the bottom and samples throughout the water column are pumped to the surface. This allows for the changing water-quality characteristics of each horizontal layer of the water column to be considered in each sample. Since the potential for contamination or unbalanced distribution of layers is great, integrated sampling has not normally been performed in most lake diagnostic studies. For biological studies, integrated sampling can offset the problem of "patchy" growth of algae, bacteria and other biological indicators.

A plankton net is used to collect integrated samples for zooplankton and phytoplankton analyses. It is usually lowered to the depth of the thermocline. As it is raised, plankton are trapped and deposited in a small canister at the bottom of the net.

Sediment samples, or **core samples**, can also be considered integrated samples. They integrate discrete layers of sediment deposited over a period of time. Grab-sediment samples usually combine the upper layers of sediment into a single mixed sample. Core samples are collected by trapping a metal or PVC pipe submerged into the sediment, retaining a column of discrete layers that can be analyzed as needed.

Nutrients

Algae have certain nutritional requirements, consisting of both micronutrients (required and available only in small amounts) and macronutrients (required and available in larger amounts). Most nutrients are present in lakes through natural processes such as precipitation, groundwater input, and biological sources in sufficient quantities to meet algae growth requirements. "Limiting nutrients" restrict or limit algal growth. Either phosphorus or nitrogen serves as the limiting nutrient in most lakes. Excessive algal growth can result in significant use impairment when levels of these limiting nutrients are increased through watershed activities such as agriculture, lawn and garden fertilizers, urban runoff, erosion, septic system failures, and sewage effluents. Measuring the levels of phosphorus and nitrogen can help predict the potential for algal growth.

Phosphorus is most frequently the limiting nutrient in lakes, and thus serves as the focus of most nutrient abatement strategies. It is analyzed in most lakes as total phosphorus or soluble, dissolved phosphorus. Total phosphorus levels of greater than 20-30 µg/l are often found in lakes with significant algae growth. (µg/l = micrograms-per-liter; also referred to as ppb, parts-per-billion)

Unlike phosphorus, **nitrogen** can be supplied as a gas through atmospheric contact and it is less frequently the limiting nutrient. It is usually analyzed as total nitrogen, nitrate-nitrogen, or ammonia. The latter two are common inorganic forms of nitrogen. Like phosphorus, nitrogen levels can vary seasonally.

Nitrogen concentrations are usually less than 1 mg/l in most lakes. (mg/l = milligrams-per-liter, or ppm, parts-per-million). Several forms of nitrogen are measured with the use of multi-parameter probes.

It is also important to verify that samples are analyzed by laboratories that have demonstrated proficiency in the testing procedures associated with these lake indicators. Certification of laboratories is the responsibility of the New York State Department of Health (DOH) under section 502 of the Public Health Law. They established the Environmental Laboratory Approval Process (ELAP) to assure certification and adequate quality control. State certified laboratories are listed on the DOH website (see Appendix F, "Internet resources"). While the certification process identifies laboratories capable of analyzing phosphorus, however, few laboratories in New York State are capable of accurately measuring the small concentrations of phosphorus found in most New York State lakes. Even productive, nutrient-rich lakes have phosphorus readings in the ppb range. Most laboratories that analyze nutrients are set up to evaluate samples from wastewater-treatment effluent, stormwater, and other media that have nutrient levels often measured in the ppm range. The analytical methods and materials useful for detecting higher phosphorus concentrations are not capable of measuring the more diluted concentrations in lake water samples. This greatly limits the number of laboratories that should be used for phosphorus testing on lakes.

Chlorophyll a

The best way to measure algae is to count algal cells visible through a microscope. This process often involves graduate students or others who quickly tire of the eyestrain and monotony. A more practical alternative in most monitoring programs is to approximate the amount of algae by measuring **chlorophyll *a*,** the primary photosynthetic pigment found in all algae and most photosynthetic organisms. It constitutes approximately 1.5 percent by dry weight of algal biomass. Chlorophyll *a* levels greater than 10 µg/l often indicate lakes with excessive algae. This parameter usually requires filtering a water sample in the field and adding a preservative to the filter, which is later analyzed for chlorophyll *a*, although this indicator is also available in some multi-parameter probes. Measures of total phosphorus, chlorophyll *a*, and Secchi disk transparency often strongly correlate.

Plankton

Sampling **plankton** provides useful information about the composition of the microscopic plant and animal communities within a lake. While the chlorophyll *a* test can provide a rough estimate of algal densities, it provides little information about the population dynamics of plankton species. Phytoplankton samples are often collected from raw integrated water samples. Algae are usually abundant in patches throughout the upper waters of a lake, and integrating these samples (either by mixing grab samples or collecting a vertical column of water) allows a representative assessment of the lake. Water samples can also be analyzed for the presence of algal toxins. *Microcystins* are liver toxins (hepatotoxins) produced by a number of *cyanobacteria*, particularly *Microcystis*, that are perhaps the most significant and widespread algal toxins found in New York State lakes. These tests are highly specialized and can be performed only by a small number of research laboratories, but the sample collection and processing procedures are not difficult.

Zooplankton samples are not concentrated enough in grab samples to generate population estimates. They frequently move from depth to depth, so are concentrated for analysis by reeling in a net from the lake bottom to the top of the lake. Zooplankton trapped in the net are rinsed to a collection barrel hooked to the bottom of the net, and prepared for analysis. Both techniques require field preservation and inspection of plankton species through a microscope. These analyses are very time-consuming, and thus are often limited to specialized studies, particularly those related to fisheries management.

Conductivity

Conductivity measures the electrical current that passes through a solution. Since electrical current is carried by charged particles (ions), this is an indirect measure of the number of ions in solution, mostly as inorganic substances**.** Soft water lakes have few dissolved ions, resulting in a specific electrical conductivity of less than 100 µmho/cm (conductivity-per-centimeter).

Hard water lakes often have a conductivity exceeding 300 µmho/cm. Since ions frequently impart hardness to water, conductivity is also a rough indicator of hardness. Conductivity should remain fairly constant for a given lake throughout the year. Any significant changes over a short period of time may indicate a significant amount of precipitation or erosion that may impact water quality. Conductivity testing is best done using field conductivity bridges or electronic multi-parameter meters, but can be closely estimated through laboratory analysis. Conductivity is expressed as specific conductance and referenced to a specific temperature, usually 25°C (Celsius).

Dissolved organic carbon

Although the quantity of organic matter relative to inorganic matter in lakes is small, it can have a significant effect on the chemical and biological processes that determine water quality. Organic matter is primarily in dissolved form, and is best defined by measurement of **dissolved organic carbon** (DOC). High organic carbon levels are not necessarily indicative of poor water quality, and are often characteristic of naturally eutrophic or naturally colored lakes. This test also requires filtering in the field.

Color

All lake water possesses at least some **color**. The apparent or perceived color can be caused by both suspended particles such as algae and silt, and by dissolved matter that is usually organic. The true color, most commonly measured in water-quality studies, measures only the dissolved portion of the color, requiring filtering immediately after sample collection. Color units are measured in comparison to a scaled series of platinum-cobalt color standards. High levels of true color can also be well correlated with dissolved organic carbon values. As a result, color frequently serves as a surrogate for the more expensive DOC analysis. Lakes with waters that measure greater than 30 color units generally are sufficiently colored to be perceived by the human eye. The natural color in these lakes often reduces transparency.

Turbidity

Turbidity is caused by suspended materials that scatter and absorb light instead of transmitting it in straight lines through water. Suspended materials such as clay, silt, algae, and other materials have a major influence on Secchi disk transparency readings and, therefore, on the clarity of water. Turbidity, combined with data for chlorophyll *a*, dissolved organic carbon, and color measurements, can explain low or high lake water transparency. It is particularly important for drinking water-supply sources, since turbidity is often related to substances that impart tastes or odors to water, or clog filters and rapidly increase the cost of water treatment. When lake water is disinfected, high concentrations of these turbidity substances can also create carcinogenic compounds. This can be measured from water samples or via multi-parameter probes.

Alkalinity and pH

Pure water consists of an equal number of hydrogen (H^+) and hydroxide (OH^-) ions. pH is a measure of the number of hydrogen ions in solution. At a pH of 7.0, the number of hydrogen and hydroxide ions are equal. At a pH below 7.0, the number of hydrogen ions exceeds the number of hydroxide ions and the lake is "acidic." At a pH above 7.0, the lake is "basic" or "alkaline." A difference in one pH unit corresponds to a ten-fold difference in the number of hydrogen (and hydroxide) ions (Fig. 4–4).

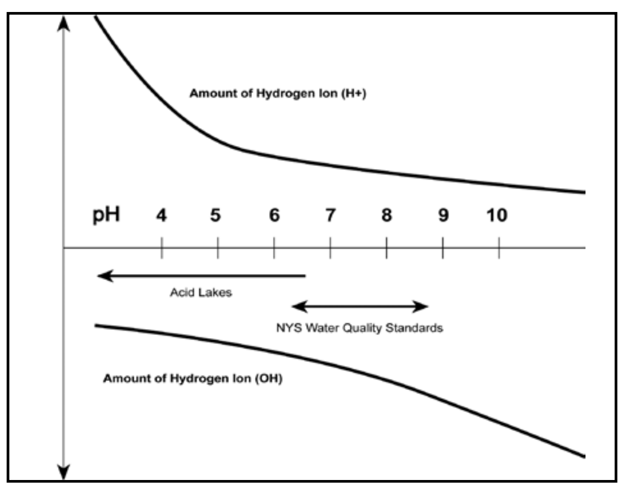


Fig. 4–4. Differences in pH result from changes in the concentration of hydrogen and hydroxide ions.

Most lakes fall within a pH range of 6 to 9, an acceptable range for most aquatic organisms. Pure rainwater has a pH of about 5.6 due to the atmospheric contact with carbon dioxide that forms a weak acid. Acidic precipitation can have a pH as low as 4, nearly 40 times more acidic than normal rainfall, and 1,000 times more acidic than neutral pH 7.0. Low pH is a significant issue for many high-elevation Adirondack lakes. This was discussed in more detail in Chapter one, "Lake ecology."

Alkalinity is the capacity of a lake to neutralize acidic inputs. Lakes overlying limestone deposits often have high alkalinity, and usually have a fairly constant pH in the 6 to 9 range. These are often hard water lakes. Lakes in granitic areas often don't possess this buffering capacity, and may be highly susceptible to acidic inputs. In many Adirondack lake studies, this is more commonly measured as acid neutralizing capacity (ANC), a more accurate measure of buffering capacity in soft water lakes susceptible to acidic inputs.

Alkalinity and pH are best tested in the field. Electronic meters can accurately measure pH, and alkalinity requires titrating water samples to a known pH. Both tests can be done, although less accurately, as lab tests. While the laboratory methodology is more accurate, these indicators can change significantly from field to lab. Lab readings of low pH or alkalinity should be followed with more accurate measures in the field.

Metals, tracers and organic compounds

An increasing number of lakes are being tested for organic compounds and metals. Organic compounds can come from terrestrial pesticides, landfill waste and industrial waste. Metal contamination can be from leaking landfills. It can also enter lakes from atmospheric sources such as mercury as a byproduct of fossil fuel combustion. Calcium, magnesium and other metals that collectively are estimated by conductivity or hardness, may be important indicators of susceptibility to zebra mussel infestation (calcium), taste and odor problems (iron and manganese), or other water-quality problems. Calcium, sodium, and magnesium are often associated with anions, such as chloride, which may indicate problems with road-salting operations. Anions are negatively charged atoms that may serve as tracers for water-quality modeling, since they do not undergo biological or chemical degradation. Other tracers include caffeine, boron, and other compounds generated exclusively from human activities.

Some special study monitoring has looked for the presence of MTBE (methyl tertiary butyl ester), a carcinogenic compound, as an indicator of spent boat fuel in navigable lakes and rivers. This is of even greater concern in lakes in which older, two stroke engines are still used extensively. This compound can only be found at very low levels in most waterbodies, due to the rapid transit, volatility and complex structure of these chemicals. New York State and other states have utilized innovative sampling devices to detect these compounds. PISCES (passive, in-situ concentration/extraction samplers) are temporal or time-composited samplers that possess membranes to allow selective migration of specific pollutants into a collection chamber. These compounds are then concentrated in a hexane solvent over a two-week period. While these samplers don't yield quantitative results, they can be used to compare the relative MTBE levels through time and space. These devices are also used to detect other organic compounds.

Metals and organics must be analyzed at a certified laboratory to accurately evaluate the water quality in a lake. Many of the hazardous organic compounds associated with industrial or landfill waste, such as PCBs and mercury, require specialized collection, laboratory equipment, and advanced laboratory methods. Information from nearby wastewater-treatment plants and local waste-disposal records help identify specific pollutants that may end up in the water, sediments, or fish in a downstream lake. Another effective screening tool is to scan total volatile organics, chemical compounds that vaporize and enter the atmosphere, although they can also enter water and soils. These scans can allow a lake manager to focus on specific pollutants. The very high costs associated with these analyses often limit their use to studies of highly susceptible lakes.

Microbial analyses

When sewage contamination is suspected, a water sample should be sent to a certified laboratory to analyze for **coliform** bacteria. The test is a relatively simple, quick and inexpensive way of determining the risk of waterborne diseases. It requires sterile collection equipment and must be analyzed quickly by a laboratory. The test detects only the contamination level at the time of sampling. The extent of bacterial contamination in a lake can fluctuate from hour to hour, influenced by weather conditions, currents, in-lake cycling, and the degree of bacterial degradation.

Coliform bacteria serve as indicator organisms, meaning they do not pose a health danger themselves, but their presence indicates the likely presence of pathogenic or disease-causing organisms that are more difficult to measure. A high level of coliform bacteria in a lake water sample can indicate sewage contamination and the likelihood that organisms pathogenic to humans may be present, but it does not identify the pathogens. Less common microbiological tests are also available. *Salmonella, cryptosporidium*, enteric viruses, and other pathogenic organisms can be detected in lake water samples, but tests for them are usually quite complicated and typically available at only a few water laboratories.

The large variety of coliform bacteria present in natural waters makes them excellent biological indicators for pathogenic bacteria. Fecal coliform and total coliform are the two tests commonly performed. **Fecal coliform** bacteria grow in the intestinal tracts of warm-blooded animals, including humans, and are present in fecal wastes. The number of bacteria in human feces is estimated to be between 100 billion and 10 trillion per-person-per-day. Positive fecal coliform test results suggest the presence of pathogens that are more dangerous and more difficult to detect. The test for fecal coliform involves growing bacterial cultures from the water samples so a technician can count the number of bacteria.

Total coliform are naturally occurring bacteria that can originate from decaying matter in a lake as well as from feces. Total coliform bacteria are quite diverse and ubiquitous in a lake environment and commonly exist in many places at all times. High total coliform bacteria counts are not necessarily indicative of contaminated waters.

The majority of water testing in New York State lakes has involved either total or fecal coliform testing, consistent with the existing state water-quality standards. Alternative bacteriological tests may provide better indications of human health impacts and the source of bacterial contamination. At the time of this publication, state water-quality standards are in the process of shifting from these more traditional indicators to other bacteriological standards. ***E.coli*** *(Escherichia coli)* is a single species within the fecal coliform group, as shown in Fig. 4–5, adapted from the Tompkins County Department of Health. As with the larger fecal coliform group, *E.coli* are indicators of contamination and are generally not pathogenic. The strain *E. coli 0157:H7,* which has been in the news as causing severe illness, is not a water-quality concern since it is primarily transmitted through food. In some monitoring programs, *E. coli* is the organism of choice to monitor because of its association with intestinal illnesses. The EPA recommends using *E. coli* over fecal coliform as a bacterial indicator, and New York State has adopted federal *E. coli* standards for freshwater systems.

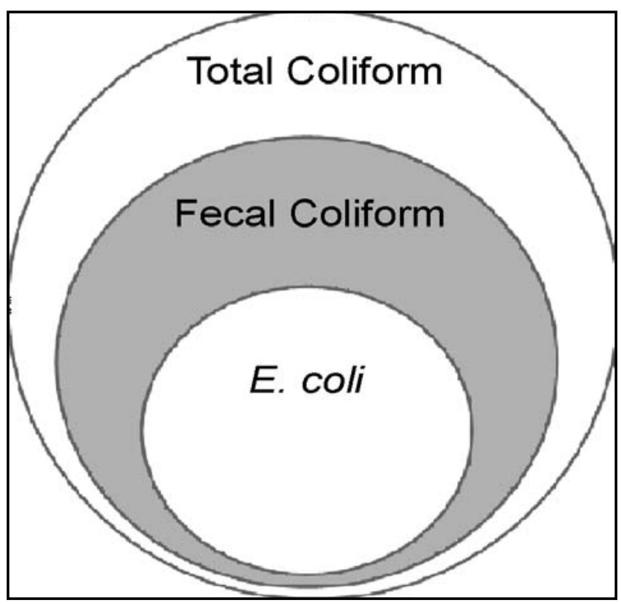


Fig. 4–5. E.coli (Escherichia coli) is a type of fecal coliform, which in turn is a subset of total coliform.
(ADAPTED FROM: TOMPKINS COUNTY DEPT. OF HEALTH)

There are many strains of *E. coli* and they are continually mutating by acquiring new genes. Slight differences in the genetic material of *E. coli* strains show adaptation to different hosts, such as geese, humans and dogs. Comparing the microbe characteristics to a library of microbes from known sources can indicate the type of animal from whose gut it came. This and other processes used to identify the probable source of bacteria or viruses are collectively called Microbial Source Tracking. It is still a new science and somewhat experimental, but one that has been used by Cayuga County to identify the sources of fecal coliform bacteria that have affected Owasco Lake.

Other bacterial tests have also been used. ***Fecal streptococci*** are found in the feces of humans and other warm-blooded animals, especially chickens. Some varieties of fecal streptococci can be attributed to a specific "host" source, while other varieties are short-lived and indicate only recent pollution. The fecal streptococcus test should not be used without other fecal indicators. The ratio of fecal streptococcus to fecal coliform has historically been used to determine the influence of a specific bacterial source relative to the overall bacterial contamination. In recent years, however, this method for evaluating the source of the contamination has fallen out of favor.

Enterococci are a subgroup of fecal streptococcus. The EPA has suggested testing for *enterococci* in salt waters. Their survival there better imitates many pathogens and they are believed to have a higher correlation to human pathogens than *E. coli*.

Sediments hold clues

Water sampling can reveal information about many present-day conditions, but also examining sediments can help develop a fuller understanding of the condition of a lake. Some pollutants, such as heavy metals, may not stay in the water column long enough to be captured in most monitoring programs. Sediment influences rooted aquatic plants more than the water column since the roots take up nutrients and contaminants from the sediments. Sediments can provide historical information about past lake conditions. If fish are found to be contaminated by a heavy metal or hazardous compound, sediment sampling will help to determine the degree to which the concentration of the pollutant is either increasing or decreasing. The sedimentary record can show if a lake ever "naturally" supported a desired condition such as a high degree of water clarity.

Most sediment sampling is conducted from the deepest part of the lake, since sediments tend to focus and migrate toward the deep hole through which most lake water passes. Thus, the deepest part tends to have the most representative conditions. Sediment samples can be obtained by grab samples or by cores using specialized equipment. The suite of tests conducted on a sediment grab or core sample is dictated by the objective of the monitoring. Estimating the extent of sedimentation often requires a paleolimnology investigation of a lake.

When a sediment core is taken, individual slices can be analyzed to look for changes. The rate of eutrophication of a lake can be estimated by looking at diatoms in cores because diatoms remain fairly intact within sediment. The core is studied to determine where the diatom-dominated algae communities shifted to green and blue-green algae-dominated communities. This change often signals a trend toward a higher eutrophic level. A detailed evaluation of the biological communities in the sediment (macroinvertebrates and other benthic organisms) can provide clues about long-term influences on the lake, similar to the use of stream benthic organisms to assess stream-water quality. Changes in chironomid communities (an aquatic midge sensitive to changes in dissolved oxygen), for example, can provide insights about whether deepwater oxygen levels in the lake are naturally low.

The date of changes can be estimated by looking at the levels of lead and cesium in the core. For cores that are at least 150 years old, lead-210 can be used to establish the age of a core because lead-210 is a naturally occurring radionuclide that "ages" at a measurable rate. For younger deposits, layers can be dated using cesium-137, a byproduct of atmospheric testing of nuclear weapons. Its levels will be highest for 1963, corresponding to the peak of the atmospheric testing.

While these tests provide excellent information about the age and aging patterns of lakes, they are also very expensive and can be adequately conducted only by paleolimnologists and other highly trained specialists. They are not, therefore, a standard part of most monitoring programs.

What other information should be collected?

Environmental and socioeconomic patterns within the watershed also influence the lake. Information about these can be gathered by inventorying the natural resources, land and water uses and referring to base maps, land-use surveys, and tax records to help track the sources of water-quality problems. On-lake and watershed cultural and recreational activities may provide some insight into observed changes in water quality. Records from the testing of septic tanks and other on-site waste-disposal systems are useful when trying to determine the sources of excessive nutrients or bacteria, or for educating lake residents about how they may be affecting or protecting their lake. Descriptive information about a lake problem, such as newspaper articles, serves to pinpoint the symptoms associated with most common use impairments.

Some or all of the inventory work may have been done already. A good starting point is to check with county agencies such as the Planning Department, Water Quality Coordinating Committee (WQCC) and Environmental Management Council (EMC). Other sources may include the applicable DEC regional office, or local planning boards. Rather than duplicating an existing study or inventory, lake association members can invest their time in updating or supplementing previous work.

These authorities should also be consulted to see what, if any, monitoring or lake management techniques are currently being used in a lake or watershed. If there is long-range water-quality or watershed monitoring program already underway, the lake association could use the existing data or help supplement the monitoring projects by collecting additional data. It is a waste of time and resources to duplicate monitoring efforts.

Environmental setting

A base map or series of maps can be developed from U.S. Geological Survey (USGS) topographic series maps. Watershed boundaries, areas ill-suited for development, wetlands and critical wildlife habitats can be identified from the maps. The choice of maps should be sufficiently large to encompass the entire watershed, while maintaining sufficient detail to delineate boundaries between specific land types. Some maps are available at a 1:24,000 scale (1 inch equals 2,000 feet). Topographic maps (usually called "topo" maps) can be found at the local planning office, libraries, Soil and Water Conservation District offices, sporting goods stores and bookstores. While some of the existing maps date back to surveys done in the 1950s, many maps have been updated or reworked in the last few years. The most recently updated map should be used whenever possible.

In recent years, much geographic-based information found on topographic maps, soil maps, bathymetric maps, and other maps has been converted into digital data layers. These data layers are a fundamental part of the **geographic information systems** (GIS) developed by government agencies, consulting firms, and others. The New York State GIS Clearinghouse is an excellent, free source of map information available in electronic format. GIS affords an opportunity to develop electronic base maps with digital layers or overlays that contain the information described below. Some of these data are also available through the Environmental Resource Mapper on the DEC website (see Appendix F, "Internet resources"). Maps generated through this on-line program display waterbodies, wetlands, protected plant and animal species, and significant natural communities.

Land uses within the watershed boundary will greatly influence lake water quality. Agricultural land, residential land, commercial land, forested land, park land, or open areas all have different effects. They can change the permeability of the underlying land, and affect the quantity and nature of runoff and nutrient inputs to a lake. Areas of dense development will create hard surfaces impervious to water that will quickly divert contaminants to a water body. Undeveloped areas can act as nutrient traps and provide some buffering of pollution inputs. The high absorption capacity of wetland soils and the vegetated corridors along streams provide a buffer against rising lake levels and flooding during periods of spring runoff or heavy rainfall. Critical wildlife habitats, such as wetlands, nature preserves, and forested corridors are integral to the ecosystem balance and should be identified on the maps so a lake and watershed management plan can aid in their protection. Municipal and industrial point source pollution inputs should also be located on these maps. Land uses may be already delineated on soil surveys available through Soil and Water Conservation Districts (SWCD), or may have been compiled by the local or county planning board or EMC.

An accurate assessment of existing land uses can be used to generate a nutrient or hydraulic budget for the lake. These budgets can be used to determine the expected sources and influence of nutrient and water inputs and outputs. This information can be used to determine a priority list for managing pollution sources, and may help to estimate the effects of any proposed watershed activities on overall water quality. These calculations can be done using computer programs in a process known as modeling that is discussed later in this chapter.

Soil types, underlying bedrock and land slopes also influence water quality. Geological features, such as exposed limestone, can provide buffering against water-quality pollutants, such as high nutrient loads and acid rain. Areas with steep slopes may have the potential for high erosion and sedimentation rates. Considerations of soil erodibility, and the suitability of soils for leach-field placement affect the decision about whether an area is appropriate for development. If soils near a lake shoreline are composed mostly of impervious clays, then construction should be discouraged, because of the high risk of poor permeability and high potential for erosion and runoff. If soil permeability is good, however, controlled development could be permitted, assuming that there are no other limitations and that septic systems are properly installed. Soil surveys, compiled by the U.S. Department of Agriculture's Soil Conservation Service (now called Natural Resources Conservation Service or NRC) are available for many counties. In addition, the New York State Geological Survey (NYSGS) has prepared soil maps for the state (see Appendix F, "Internet resources"). These soil surveys also contain information on geology, topography, erosion potential, depth to bedrock, climate, temperature, precipitation and land use.

Morphological characteristics, such as a lake's depth and shape, influence its original water quality, and may ultimately limit how much water quality can be changed. Shallow lakes may be warmer and naturally eutrophic, so developing a fishery that requires clear, cool water is not feasible. Morphometric maps use the bottom contours of the lake to show the depth and topography, and are commonly used by anglers and lake managers. Maps for several New York State lakes are available online through the DEC Fish and Wildlife website. Planning boards, lake association members, or local anglers may also have constructed maps, or can easily do so by taking depth readings along several transects across a lake. This has become substantially easier with the advent of boat-mounted or handheld electronic depth finders and inexpensive Global Positioning Systems (GPS).

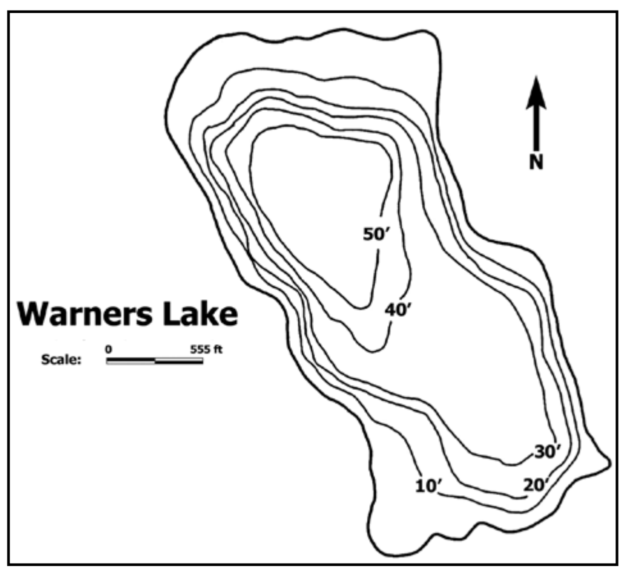


Fig. 4–6. Morphometric map showing lake depths and bottom contours.

(CREDIT: DEC)

Following the flow

It is important to understand where water comes from and where it goes. Many of the pollutants in lakes are carried by rainfall, an incoming stream, direct runoff from nearby land, or seepage from groundwater. The movement of water can be evaluated in a number of ways.

USGS has been gauging large rivers and streams for many years to determine water flow. If a lake association is fortunate enough to have one of these streams entering their lake, they can easily obtain gauging data from the USGS office or online. Gauging information has not been collected, however, for most streams and tributaries in New York State.

Simple staff gauges that measure the height of water can estimate the water coming into the lake through streams and tributaries once the relationship between flow and height is established. This relationship is referred to as a rating curve. Regular or even daily measurements of stream height can be compared to actual flow measurements. Stream flow can be measured accurately with the use of **gauging equipment** that measures stream velocity at specified depths at regular intervals along a cross-section of the stream. An even more simple estimate of stream velocity, though somewhat less accurate, is the use of a float, such as an orange, that can be timed as it passes between two points.

These methods can be used to estimate water flowing out of a lake as well as measuring the water coming into a lake. If the lake is a reservoir or has other regulated withdrawal, records of outflow may be maintained by municipalities, private water companies, utilities, or those who maintain control over water withdrawal or water level.

Accurate measure of groundwater flow is usually done with a series of wells, seepage meters, piezometers (a device that measures water pressure), or other expensive specialized devices. No simple monitoring equipment and techniques have been developed. For many lakes, groundwater flow is mathematically estimated using information about surface flow in and out of a lake, evaporation, and water uptake from domestic intake pipes and other users. This usually results in a "best available," but not very accurate, estimate of net flow, which includes contributions from septic tank discharges.

Dye testing

While fecal coliform analyses can be used to determine the bacteriological condition of a lake, the test cannot be easily used to pinpoint the source of the bacterial contamination. **Dye testing** is a common method for detecting major problems with leaking septic systems. Dye tablets usually come in different colors, such as iridescent red or fluorescent yellow-green, and are usually flushed down the toilet. Another tablet is washed down the kitchen sink if there are separate drainage areas for sewage and for **graywater** from kitchen or non-toilet bathroom uses. After a period of time, usually between fifteen and thirty minutes, the colored dye may be observed in the lake water in front of the home if the septic system is not working properly. This method more effectively focuses on failed leach fields and tanks that have been subject to heavy use, rather than on poorly operating systems. In other words, if the dye is visible that quickly, the septic system is not properly treating the wastewater, but if no dye is visible, the septic system still may not be working correctly. A failed on-site disposal system needs to be upgraded or replaced promptly. NYSFOLA has a protocol available for lake associations interested in instituting a small-scale, voluntary, dye-testing program.

Dam inspection

For lakes originating or expanded through the construction of a **dam**, the status of the dam may be a critical piece of the lake-management puzzle. "High hazard" is the descriptor given to dams when their failure could result in loss of life, serious property or environmental damage, or significant economic loss. Traditionally, the 380 high-hazard dams in New York State are inspected by DEC every two years. Inspections occur every four years for "intermediate hazard" dams, where breaching could damage the environment or property, or affect public utilities or transportation. At the time of this publication, DEC is in the process of revising its dam safety regulations. The proposed changes would make dam owners responsible for operation, maintenance, inspection, repair and emergency planning related to their dam. (See the Text box in Chapter ten, “Legal framework” and the DEC website in Appendix F)

Cultural context

Information concerning human influences, through year-round, seasonal or temporary land-use and recreational interests should be collected and identified on the base map. The local planning office or the county clerk’s tax maps can provide assistance in compiling data on population and human settlements, local economy, industrial and commercial development, and agricultural regions. This information can help to identify potential sources of pollution and help lake managers determine specific land-use trends.

The base map should also show public and private lands that are connected to water-based recreation, along with any associated in-lake structures. Yacht clubs, marinas, beaches, restaurants and hotels all should be considered as lake users. The owners and operators of these enterprises have a vital economic interest in the health of the lake. They can be very helpful participants in lake and watershed management planning and implementation.

Other types of research can also yield useful information. Review of municipal records and discussions with the town historian and with long-term residents can reveal past land uses around the lake, such as farming, logging, old mills, landfills and manufacturing plants. Such information helps to identify some of the current problems affecting lake water quality. Knowing that a tannery operated on the main tributary to a lake from 1853 to 1937 might explain why there are surprisingly high levels of cadmium in lake sediments.

Surveys for qualitative information

This chapter has focused on objectively measured data and information, referred to as quantitative. It is now important to gather subjective or qualitative information. The two forms complement each other. Determinations of many use impairments and the severity of the symptoms are based on qualitative information, while the causes and sources of these lake problems are verified by quantitative information. An angler, for example, may perceive lake conditions as improving when the presence of native aquatic plants improves fishing. In contrast, another lake user views the increase in aquatic plants as a decline in water quality because the weeds are a nuisance for boaters and swimmers. Measurements can determine the amount of increase in weed cover, but it is a subjective decision about whether the existing conditions are acceptable or not.

Interviews, anecdotes, newspaper editorials and user surveys are examples of sources for qualitative information. As seen in the weed example above, different people have different perceptions of the same situation. A survey of lake users is one way to get a large enough sample of opinions that is representative of all users. To provide accurate information, surveys must be carefully worded and distributed. NYSFOLA has sample user surveys and libraries have many books on how to design a good survey.

A survey of lake users is a valuable tool for obtaining their impressions of, and perceptions about, lake conditions. Do they share common concerns about the problems? Are they basing their assumptions on accurate information? Do they agree on the cause and severity of lake problems? What is the trend of problem conditions in their opinion? How has their use of the lake changed? When did they first notice conditions changing? Do they agree about the best course of action? How much are they willing to pay, and should some pay more than others?

The information gathered with user surveys serves many purposes. It can provide information to a lake manager about use impairment and perceived water-quality conditions throughout the lake and watershed. It can help identify important user groups and recreational interests. The acceptability of proposed management strategies can be determined. Surveys can uncover information about the satisfaction of residents with the management and government infrastructure that has previously attempted to restore or preserve lake conditions. User surveys can be used to evaluate and adjust an existing lake-management plan, can pinpoint where a plan is working, and more importantly where a plan has not been adequately addressing use impairments and complaints.

User surveys can help distinguish the difference between perceived and measured water-quality conditions. Some control strategies may provide satisfaction to lake users much like a medical placebo provides relief. This effect may cause a lake association to continue using a lake treatment that cannot easily be verified quantitatively, such as the use of copper sulfate to reduce algae concentrations. Identifying the difference between perceived and measured water-quality conditions may provide guidance in choosing a more appropriate control strategy. It should include planning for actions that brings immediate reduction in symptoms as well as long-term actions to address causes. Incorrect perceptions may point to the need for educational workshops as part of a management plan, recognizing that even misinformed perceptions often have some basis in reality. User perception may indicate that the major sources of pollution are the wastewater-treatment plant and agriculture, while the quantitative evidence actually points to urban runoff, failing septic systems or other nonpoint pollution as the main sources.

Identifying gaps and collecting additional information

Lake and watershed data collection and analysis are lengthy processes. Information gathered about the lake and its watershed, however, is well worth the effort. Both the lake and the broader community will benefit from accurate data when it comes to management planning, applications for funding requests, and securing community support.

As part of the data-gathering process, it is important to evaluate the quality of the data and to identify gaps. Since the overall objective for gathering information is to adequately identify and address each component of the symptoms-causes-sources relationship, it is important to backtrack to see if the questions about each component have been answered. This should be balanced with the knowledge that lake managers may never be able to obtain all the data they desire. While it is important to base recommendations and decisions on sound information, it is not wise to use lack of data as an excuse for not working towards a management plan. It may initially require developing a management plan built solely on available data to gain the support and funds needed to collect the necessary additional data. Generalized statewide or national trends may have to be sufficient for developing and understanding the symptoms, causes, and actions related to a specific lake problem.

Lake managers also need to verify the validity of information gathered from outside sources, such as water-quality data or anecdotes. Water-quality monitoring programs should address **Quality Assurance and Quality Control (QA/QC)**. Any data or information used for generating management plans should come with an assurance that the information accurately represents conditions related to the lake problems. QA/QC programs may involve duplicate sampling, control studies, or other methods used to verify the accuracy of the collecting methods, sample analyses, and study results. Data from outside studies that do not implement an acceptable QA/QC program must be verified, or used only with great discretion.

Once it is determined that there is sufficient data and information and that it is valid and reliable, the data collection process is complete. It will need to be updated periodically, however, to keep the management plan up-to-date as lake and watershed conditions change.

Back to square one

As exhaustingly described above, many indicators, measurements and tests say something about a lake. Such an extensive shopping list can be overwhelming and imposing to someone hungry for more knowledge, but uncertain about where to begin. When the cost and expertise required for some of the analyses are factored in, the natural response of many intimidated lake residents is to do nothing. It doesn't have to be that way since volunteer monitoring programs, such as CSLAP, make lake sampling affordable and relatively pain free. For lake residents not involved in a formal monitoring program, a reasonable starting point could be the following activities:

- *See clearly:* The water transparency of a lake says a lot about its condition. Greenness (algae) and brownness (suspended material or dissolved organic matter) may indicate a lower susceptibility to weeds, but a greater sensitivity to invasive weeds, as well as an indication of where they may grow. Water transparency also says a lot about the safety and palatability of the water for swimming, and how the lake looks. Evaluating water clarity is a surrogate for more expensive water-quality tests. The frequency of water clarity readings less than two meters deep, for example, is often very similar to the frequency of phosphorus readings greater that 20 ppb, which corresponds to the state water-quality standard. Water-clarity tests should be done weekly to detect seasonal trends and impacts of heavy wind and rain.
- *Smell:* Take a whiff of water collected from near the bottom of the lake, whether it has been withdrawn from the bottom of a dam or by using a collection device. If it smells musty, there may be a deepwater oxygen problem. If it smells like a rotten egg, and looks gray to black, there is an oxygen problem. If it stinks in early summer, there is a major oxygen problem.
- *Drop a brick:* Tie a rope to a brick and drop it in the water for a few weeks. It may become a home for zebra mussels (*Dreissena polymorpha*) that were hidden from view before.
- *Feel the foam:* If the foam caused by wave action is perfumy and slick, it may be unnatural. If it smells fishy and looks brownish, it may belong there.
- *Grab a bottom (sample):* If the bottom sediment is sandy, it is less likely to support many invasive species such as water chestnut, or some native plants like lilies, although it may exclude most other plants to the delight of Eurasian watermilfoil (*Myriophyllum spicatum*). Thicker sediments may also support "swimmers-itch" schistosomes, but may not house zebra mussels.
- *Watch the weeds:* Water shield, bladderworts, fanwort, and many of the brown-stemmed milfoils are much more likely to be found in slightly acidic lakes. Ribbon-leafed plants and coontail with an encrusted lime layer indicate harder water and a greater susceptibility to invasion from Eurasian watermilfoil and calcium-limited exotics such as zebra mussels.

Where?

The "where" of lake sampling is largely dictated by the purpose of the monitoring program. An important component of where to sample is the number of sampling locations. Studies designed to investigate a specific problem often warrant multiple sampling sites. A larger number of sampling sites may be required if the problem is isolated, such as multiple weed beds or sites for invasive species, or if the sampling parameter grows or migrates sporadically, such as bacteria. Fewer sampling sites may be adequate if general or lake-wide assessments of water quality are the primary objective. Several sampling locations and depths, however, may be necessary to assure results that are representative of the lake.

Secondary factors that determine where to sample include the lake size, shape, and the configuration of the shoreline and bottom contours. In general, small, geometrically uniform, round lakes may require only a single sampling site at the deepest part of the lake. Larger lakes may require a second site approximately equidistant from both the shoreline and the first site. Lakes with several discrete bays, or several different water sources, may require sites corresponding to each discrete area (Fig. 4–7). Each bay should be sampled at its deepest point to evaluate general water-quality conditions, while samples collected to determine the influence of tributaries should be sampled close to where the tributaries enter the lake.

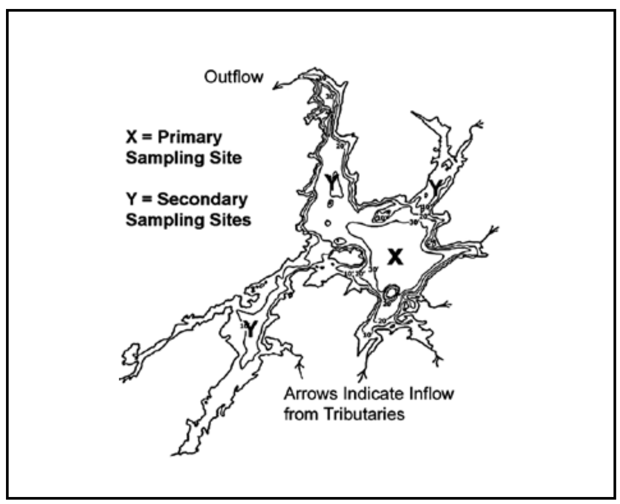


Fig. 4–7. Examples of sampling sites in a lake with discrete bays and different water sources. (CREDIT: DEC)

Open water "surface samples" should be collected at a depth of 0.5 to 2.0 meters to reduce any surface or bottom effects. Deep-water, or "depth," samples should be collected between the thermocline and the lake bottom. Water-sample depth may depend on the type of analysis to be conducted. Temperature or dissolved oxygen readings are usually taken every meter from the surface to the bottom. Some variables, such as phosphorus or color, are often analyzed in both surface and depth samples.

Sampling for aquatic plants or bacteria should focus on areas where those organisms are most likely to be found, or are creating problems. For plants, this is probably within the littoral (near shore) zone. Lake surveys seeking evidence of new invasive or exotic plants are most likely to find these invaders near launch sites, in high traffic areas, and at inlets and outlets. Bacteria monitoring should focus near swimming areas and water intakes, but could also be directed to areas of suspected septic leaching, stormwater runoff, congregations of waterfowl, or places where dye testing has identified potential hot spots.

When?

Sampling frequency is a function of the nature and degree of the water-quality problem. Long-term, baseline studies may involve sampling on a biweekly or even monthly basis. Samples collected to pinpoint short-term, immediate water-quality changes may require daily or weekly collection. Bacterial monitoring requires at least five samples per month to compare to the state water-quality standards. Evaluating changes in nutrient levels in tributaries during storm events may require hourly sampling. Some studies will be dependent upon the frequency or duration of an event such as a storm or holidays causing heavy use of the lake.

For some projects, single samples are desired to identify conditions representing a snapshot in time. If the purpose of the monitoring is to determine whether a particular invasive species has been found, a single positive identification may be adequate. The lack of a positive identification, however, does not necessarily indicate the absence of this species. This snapshot approach can also be extrapolated into a crude method for assessing trends. If these snapshot samples are repeated weekly, monthly, annually, or at other regular intervals, they can be useful in evaluating changes in the indicators being measured. This is most effective if the intervals are closely spaced, assuring minimal change between snapshots, or if the duration of the project is long enough to minimize the impact from any single snapshot that might not be representative of a long-term trend. This is essentially the approach the EPA uses in developing EMAP, their long-term monitoring program, and the national survey approach built out of EMAP in recent years (see Appendix F, "Internet resources").

How do we use all these data?

Trophic state

Secchi disk transparency, total phosphorus, and chlorophyll *a* measurements are often used to determine the trophic level or degree of eutrophication of a lake. Trophic status is based on the assumption that changes in nutrient levels (measured as total phosphorus) result in changes in levels of algae (measured as chlorophyll *a*) and other plants and animals, causing changes in lake clarity (measured as Secchi disk transparency). Average summer values for these three indicators can be used to determine an approximate trophic state.

Dr. Robert Carlson of Kent State University devised a Trophic State Index (TSI) to compare the determinations of the three indicators. Carlson (1977) uses formulas based on empirical relationships between total phosphorus, chlorophyll *a*, and Secchi disk transparency to assign a single TSI. TSI is used primarily to compare lakes within a given region, and assess changes in the degree of eutrophication after the implementation of a lake management plan.

The TSI formulas are as follows:

$TSI_{SD} = 60 - 14.41 \ln SD$

$TSI_{Chl} = 9.81 \ln Chl + 30.6$

$TSI_{TP} = 14.42 \ln TP + 4.15$

where

ln = natural logarithm = log10 x 2.30

Chl = chlorophyll a, measured in μg/l

TP = total phosphorus, measured in μg/l

SD = Secchi disk transparency, measured in meters

A TSI computed from any of the above parameters can be used to determine a general trophic status for a lake. TSI values in most lakes range from zero to 100. A TSI of zero corresponds to the lowest productivity, highest transparency and lowest values for total phosphorus and chlorophyll *a*. A TSI of 100 corresponds to the highest productivity, lowest transparency, and highest phosphorus and chlorophyll *a*. Lakes can be compared to each other by comparing their numerical TSI values for each of the measured parameters.

Using the equations shown above, either chlorophyll *a* concentrations, or Secchi disk transparency can be predicted by knowing phosphorus concentrations. This can be particularly useful when a lake or watershed management plan focuses on the reduction of phosphorus levels. Expected changes in levels of phosphorus due to the implementation of a management plan can be used to determine expected changes in algae levels and lake clarity. The relationship between phosphorus and chlorophyll *a* or Secchi disk transparency can be derived from the TSI equations:

$$\ln Chl = 1.449 \ln TP - 2.442$$
$$\ln SD = 3.876 - 0.98 \ln TP$$

The actual trophic state of given lake may not be well predicted by using TSI. Any two lakes within 10 TSI values probably have the same level of biological productivity. Ranking lakes by their TSI, therefore, can be somewhat misleading. The variation of any one parameter, such as chlorophyll *a,* may be large enough to cause significant variation in the TSI. It is likely that only ranges of TSI values can be used to adequately assess the trophic condition of a lake.

Many lake managers have divided ranges of TSI values into trophic state classifications. Reference values using the formulas above were generated from lakes in the mid-western United States. They indicate that mesotrophic, or moderately productive lakes, have TSI values between 37 and 51. Lakes with TSI values greater than 51 are classified as eutrophic, or highly productive. Lakes with a TSI less than 37 have low productivity and are classified as oligotrophic. Each productivity classification can support a different set of uses. Eutrophic lakes often support excellent warmwater fisheries, while oligotrophic lakes often provide an excellent drinking-water supply. Since TSI formulas were computed for lakes in a different region of the country, however, they have been rounded to the nearest whole number to provide trophic estimates for New York State lakes (Table 4–2).

Parameter	Trophic State		
	Oligotrophic	Mesotrophic	Eutrophic
Total phosphorus	< 10 μg/l	10–20 μg/l	> 20 μg/l
Chlorophyll a	< 2 μg/l	2–8 μg/l	> 8 μg/l
Secchi disk transparency	> 5 meters	2–5 meters	< 2 meters

Table 4–2. Criteria used to designate different trophic state classifications for New York State lakes.

Trophic State indices and classifications can be useful in determining the extent of eutrophication in any given lake but the results cannot be used alone without considering other factors. Since the equations represent the averages for many lakes, any one specific lake may not follow the exact relationships described in the equations. While most lakes will adhere to the general relationships described by the equations, occasionally a lake will not be precisely represented. There is also a tendency to attribute far greater weight than is warranted to changes in TSI. While large changes in TSI for any lake may be important, small changes are probably normal. In addition, each TSI parameter can be affected by other factors. Secchi disk transparency can be influenced by non-algal turbidity, highly colored water, and bottom growth and conditions. To account for some of these interferences, these TSI classifications are valid only for lakes with color-unit values less than 30.

These TSI classifications do not consider how macrophyte levels, dissolved-oxygen concentrations, and other factors influence the degree of eutrophication. They should be used only as part of a larger classification scheme using additional water chemistry and watershed analyses. They should not be used as the sole indicator of either present conditions, or trends in eutrophication or water quality of a lake.

Ratios

The type and growth of algae in a lake is governed by a variety of factors. In highly colored (dystrophic) lakes, algae growth can be limited by poor transmission of light through the water. Lakes filled with poorly rooted plants may have less-than-expected algae growth if these macrophytes outcompete the algae for available nutrients. As discussed in Chapter one, "Lake ecology," some algae cannot grow due to limitations from silica or other micronutrients. In most New York State lakes, however, summer algae growth is limited by either nitrogen or phosphorus. A detailed analysis of water-quality characteristics and of the type of algae in a lake can identify which nutrient limits algal growth. A lake manager who assumes algal growth in a New York State is limited by phosphorus will probably be right most of the time. Nitrogen-to-phosphorus ratios, however, can provide better information. Very high nitrogen-to-phosphorus ratios (usually greater than 30:1) indicate that phosphorus may be in short supply. Very low ratios (usually less than 5:1) suggest that nitrogen may limit algal growth, and may, therefore, cause blue-green algae to be much more common since they can secure nitrogen from the atmosphere as nitrogen gas**.**

Meeting the standards

Most guides for developing lake management plans omit water-quality standards, which is unfortunate. Lake water-quality standards are developed by federal or state governments to confer a degree of protection on lake uses, whether they be recreational or aesthetic uses, human consumption of fish and water, or protection of the lake residents themselves.

Water-quality standards exist for most of the indicators measured in a typical lake monitoring program. It has become clear, however, that the existing standards for most eutrophication indicators are insufficient to prevent highly eutrophic conditions from occurring. For many of these indicators, the lack of an adequate water-quality standard has resulted in state agencies developing **water-quality guidance values**, or criteria that provide thresholds for conditions likely to result in problems, but without all of the regulatory muscle associated with standards (see Table 4.3). Some criteria are narrative rather than numeric, such as "none in amounts that will … impair the water for its best usage." They are still enforceable, however, with the same rigor as numeric standards. For other water-quality indicators, standards and guidance values are inadequate to identify a threshold of concern. Calcium levels exceeding 15 to 20 mg/l, for example, are probably sufficient to support zebra mussel shell growth, yet this number is not reflected in the existing standards. For the most part though, standards and guidance values are critical for evaluating water-quality impacts (See Table 4–3) (NYSDEC, 1999).

Water-quality standards are calibrated for the most sensitive lake use. Aquatic life, primarily fish, is the most sensitive lake use for some water-quality indicators. Extensive toxicology testing conducted for many years has shown that aquatic life will be affected by low-levels of a particular indicator.

For other indicators, drinking water is the most sensitive use. In all cases, a violation of a water-quality standard usually means that a problem either has or will occur. Lake management should focus, therefore, on reducing the incidences of standards violations.

Water-quality results are not graded on a curve. A given lake still gets a failing grade when it does not meet the standard, even if its water quality is better than that of any other nearby lake. When a water-quality standard is not met, a problem exists that could result in use impairments or serious threats to the health of some user group, whether that group be humans or fish.

So what happens when a standards violation occurs? DEC is charged with assessing water resources throughout the state on a regular basis, including water-quality conditions in lakes. EPA and DEC have agreed upon numerical criteria for evaluating water-quality conditions and use impairments in New York State waterbodies. This agreement is referred to as the Consolidated Assessment and Listing Methodology (CALM). The "Listing" part of this phrase refers to the federal *Clean Water Act* requirements, sections **305(b)** and **303(d),** for assessing and listing the

Parameter	Type	Value	Uses Protected	Description
Water clarity	Criteria	4 feet	Swimming	To site new swimming beach (for safety, not to protect water quality)
Dissolved oxygen	Standard	4 ppm	All	To protect aquatic life
Dissolved oxygen	Standard	5 ppm	Coldwater fish (Class T)	To protect fish survival
Dissolved oxygen	Standard	6 ppm	Coldwater fish (Class TS)	To protect fish spawning
Temperature	Standard	Narrative	All	Related to thermal discharges
Total phosphorus	Guidance Value	20 ppb*	Swimming	To evaluate whether tertiary treatment is required for wastewater discharged to lake
Phosphorus, Nitrogen	Standard	Narrative	All	"None in amounts that will result in the growths of algae, weeds and slimes that will impair the waters for their best usages"
Nitrate	Standard	10 ppm	Drinking water	To prevent methamaglobanemia (blue baby disease)
Ammonia	Standard	2 ppm	Drinking water	Separate standard for ammonium only
Color	Narrative	Narrative	All	"None in amounts that will adversely affect the color or impair the waters for their best usages"
pH	Standard	$< 6.5; > 8.5$	All	Developed for regulating wastewater discharge to streams and lakes
Metals	Standard	various	All	Unique standard for each metal
Organic compounds	Standard	50 ppb	All	General standard for all organic compounds without specific standards
Turbidity	Standard	Narrative	All	"No increase that will cause a substantial visible contrast to natural conditions"
DOC, Alkalinity, Conductance, Chlorophyll a	None			
Fecal coliforms	Standard	1 colony / 100mL	Drinking water	Average of minimum of 5 measurements in one month
Fecal coliforms	Standard	200 colonies / 100mL	Swimming	Average of minimum of 5 measurements in one month
Total coliforms	Standard	2400 colonies / 100mL	All	Average of minimum of 5 measurements in one month
E.coli	US Standard	126 colonies / 100mL	All	

Table 4–3. New York State has identified thresholds for water-quality parameters that are likely to result in problems. Legal definitions appear in quotation marks.

**Site-specific phosphorus guidance values exist for Onondaga Lake, the Great Lakes, the New York City reservoirs, and various parts of Lake Champlain.*

condition of waterbodies. The general summary of waterbodies in each state is usually called the "305b Report," and the list of impaired waterbodies is called the "303d List" (NYSDEC). New York State also maintains a separate, in-state assessment referred to as the state Priority Waterbody List (PWL), in which all of the waterbodies in the state are identified as one of the following (NYSDEC, 2002):

- Precluded: The intended uses of the lake, based on its water-quality classification, cannot be realized at an acceptable frequency.
- Impaired: Lake use is severely compromised, although the lake can be used at an acceptable frequency.
- Stressed: Lake-use impacts occur, although they are not significant.
- Threatened: No lake-use impacts occur, although conditions exist that might lead to impacts in the near future.
- Not Impacted: No lake-use impacts occur, and no threats to lake use have been identified.
- Unassessed: Lake-use impacts and/or water-quality conditions have not been evaluated.

Due to the recent addition of non-impacted and unassessed waterbodies to this list, the PWL is perhaps better described as a Waterbody Inventory (WI), so the more cumbersome acronym PWL-WI is more frequently used. Numerical thresholds linked to water-quality standards, guidance values, and criteria have been attached to each of these classifications. A high frequency of violations of these standards usually results in listing a water body as "Impaired," although other evidence may also be required. Other evidence includes beach closures or fish-consumption advisories, signs of "impairments" such as the need for regular algae or weed control, or complaints about water quality. EPA and DEC frequently apply the "10-25 rule." Standards violations greater than 25 percent of the time frequently lead to "impaired" listings; between 10 percent and 25 percent result in "stressed" listings; and up to 10 percent result in "threatened" listings.

Lakes identified as "impaired" or "precluded" are usually placed on the federal 303d list of impaired waterbodies. A 303d listing requires the development of a strategy for determining the sources and acceptable levels of the pollutants that triggered the listing. This is usually called the **TMDL** process, which references the **Total Maximum Daily Load** of a pollutant allowable to maintain the designated uses.

Most of the New York State lakes identified as "precluded" are on this list due to acid rain impacts on aquatic life, particularly fish propagation or fish survival. Several lakes have fish consumption advisories due to organic compounds such as PCBs, or due to metals, particularly atmospheric deposition of mercury as a byproduct of burning of coal in mid-western power plants. Many of the "impaired" lakes found in all parts of the state are due to eutrophication.

Budgets for water, nutrients and other pollutants

Most people think of budgets as an inventory of debits and credits leading to a monetary bottom line. Budgets can also track water or pollutants as they enter and leave a lake.

Water budgets are a way to evaluate the transport of pollutants into a lake as well as the flow of more pristine water that may dilute pollutants. Water budgets can either serve as crosschecks to make sure that all pollution vectors are included within monitoring programs, or they can be used to determine which vectors, if any, can be adequately assessed through previous studies. Water budgets can be calculated for an entire lake, or for a portion of a larger lake that may be subject to a detailed evaluation to isolate the symptoms-causes-sources relationship in a problem spot.

To calculate a water budget, information on water entering and leaving the lake is collected. As noted earlier, many rivers and streams have been gauged by USGS. A lake manager can often obtain estimates of stream flow from nearby gauged rivers or streams if long-term local flow data is not available. Precipitation can be measured by rain gauges or nearby weather stations. Estimates of evapotranspiration for most regions of the state are readily available from NOAA. Water intake or withdrawal through water pipes and dams are often documented or can be estimated by municipalities. Reasonable estimates of domestic water use and discharge from septic systems per watershed resident have also been developed. Groundwater flow tends to be the most difficult to estimate, but is still often calculated to balance the hydrologic ins and outs of the lake. Determining the water budget lays the foundation for looking at the movement and budgets of pollutants, such as nutrients and solids.

Excess phosphorus, quantified by a phosphorus budget, is a concern for many lakes. A nitrogen budget may also be important, if nitrogen limits the growth of algae or rooted plants. Interest in some other element, such as mercury, can lead to the development of a lake's mercury budget, and so on. The phosphorus budget may be limited to the lake, or extend to include both the lake and its watershed. It may be a budget for one year or for a shorter period, such as for the ice-free season.

The amount of pollutants coming into the lake from outside sources is the "external load." This can come from precipitation, stream inflow, and direct runoff not entering the lake through permanent streams. It can also come from groundwater discharge, including the effluent from septic leach fields, or any direct discharges to the lake, such as from wastewater-treatment or industrial facilities. Particulate material, such as waterfowl feces and dry fallout, including dust, pollen and leaves, are other sources of pollution. These are the primary external sources for most "conservative pollutants," meaning those that do not undergo significant chemical or biological change. Conservative pollutants include some solids, total phosphorus, and chloride (often used as a "tracer" in water-quality studies).

Water-quality monitoring of the output from hydrologic sources, such as the mouth of tributaries, can help determine the extent to which each of these sources contribute to the pollutant loading in a lake during a designated time period. The most accurate way to estimate stream loading into a lake is to collect large amounts of stormwater and dry-flow data and build an extensive database for the major tributaries entering a lake.

Accounting for the entire external load can be challenging. For at least some pollutants, rainfall, water quality, and groundwater-flow data may already have been collected. If not available for a given lake, data from nearby lakes can provide an estimate. The biggest missing piece of a nutrient budget tends to be direct runoff and stream inflow data. Nutrient loading from direct runoff to a lake is usually estimated from the loading calculated for other typical land-use activities. Estimates can be extrapolated from data collected for tributaries within a lake watershed, or from values found in literature of samplings collected as close as possible to a specific lake.

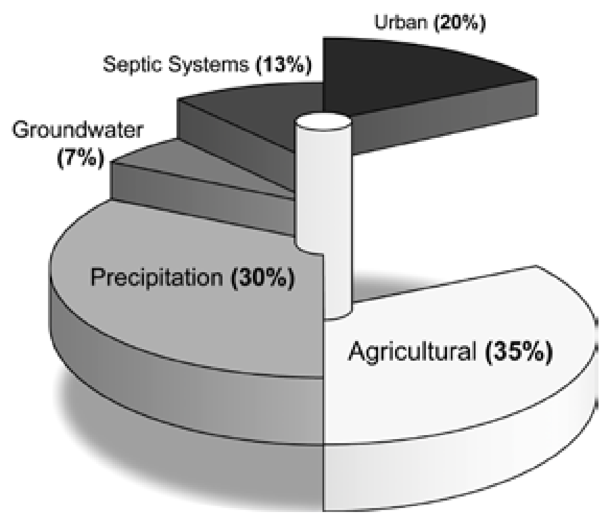


Fig.4–8. Example of a nutrient budget, showing sources of pollutants entering a lake. (CREDIT: CHRIS COOLEY)

Researchers have attempted for years to estimate nutrient export coefficients that show the typical level of nutrient loading derived from specific land uses. Many simple models use nutrient export coefficients to provide an estimate of nutrient loading from land-use activities when local data are not available. These coefficients are only general guides, since they are usually listed as wide ranges and have been developed for groups of many lakes throughout the country. Some coefficients have been specifically developed for lakes within the northern temperate climate, although few exist for land-use activities specific to New York State. Direct measurement of nutrient concentrations in tributaries with a variety of flow regimes can help determine if literature values for these export coefficients are reasonable for a particular lake. The different flow regimes include snowpack melt, storm flow during spring runoff, dry flow, and storm flow during dry periods.

Some pollutants, such as phosphorus, also have internal sources. Phosphorus can be released into the water column from sediment under anoxic conditions, primarily in thermally stratified lakes. Nutrient release from sediments also occurs under highly oxygenated conditions, but it is generally assumed that this is a short-lived phenomenon. During the summer, as the difference between air and bottom-water temperature widens, the thermocline is found at a greater depth. This can allow some bottom nutrients to become entrapped, and eventually mix with upper layers of lake water during lake turnover. See Chapter one, "Lake Ecology," for a more thorough explanation of lake stratification and mixing.

Internal and external sources constitute nutrient loading to a lake. The picture of nutrients in a lake is not complete, however, without accounting for the amount of pollutants leaving through water withdrawal, groundwater outflow, and surface outflow. The calculation of loading to a lake minus what leaves a lake is called net loading**.** Net loading exerts a greater influence on the concentrations of pollutants in a lake than loading alone. As discussed in Chapter one, "Lake ecology," a study of the hydrologic cycle serves as a reminder of how some materials can enter and leave a lake.

To make things even more complicated, many lake studies focus on the concentration of phosphorus in the upper waters of a lake, particularly in a thermally stratified lake. It is in this portion of a lake (epilimnion) that high nutrient levels can trigger algal blooms, and for which water-quality standards are most often written. In addition to net loading, therefore, the migration of pollutants from the upper to lower layers of a lake by settling and other phenomena also needs to be considered.

While all this can seem rather imposing, simple nutrient budgets can be generated with small amounts of water-quality data and water-budget information. Armed with a nutrient budget, a lake manager can identify the primary sources of nutrients to a lake and direct the focus of management efforts to reduce overall nutrient loading.

Taking advantage of relationships and interconnections

Based on individual water-quality indicators, the results from water-quality monitoring studies are often used to either evaluate the present condition of a waterbody, or evaluate whether conditions have changed through time. The relationship between these indicators can also yield other important information about a lake. The correlation between phosphorus and chlorophyll *a*, whether through calculations of TSI, N to P ratios, or plotted against each other, helps to evaluate whether algae are limited by a lack of phosphorus. This also serves as a predictive tool to project what amount of decrease in phosphorus loading to a lake will result in significant decrease in algae densities. A similar correlation between chlorophyll *a* and Secchi disk transparency, or some other measure of turbidity, will help to translate changes in algal density to increases in water clarity. Survey data collected over a wide variety of conditions in a lake can be used to generate projections about improved public perception and improved recreational opportunities. Comparing the trophic indicators to each other and to assessments of lake condition provides a tool for linking water-quality improvement strategies (such as reducing nutrient loading) to lake management objectives (such as improving recreational suitability of the lake).

Individual water-quality indicator linkages have been identified for lakes throughout the country and within New York State as part of the nutrient criteria development process pioneered by a cooperative effort between the DEC, EPA and the states of Minnesota and Vermont. These studies have determined that lakes in common ecoregions often display similar correlations, even if the correlations for individual lakes may ultimately be different from those identified for larger groups of lakes. For lakes in the Adirondacks, for example, people seem to have a common standard for how clear the water must be for swimming. It takes less loss of water clarity in the Adirondacks than in other regions of the state before people complain of reduced recreational conditions related to swimming. This is due in large part to the local perception that high clarity is normal and, therefore, expected within the Adirondacks. Perceived recreational impacts as a result of reduced water clarity tend to occur at Secchi disk transparency readings that are fairly similar throughout the Adirondack Park. This perception of "normal" is so strongly ingrained in the public acceptance of lake water-quality conditions that it can be used as a benchmark, which ultimately affects the management of these lakes.

The correlation among trophic indicators can be used to determine if management objectives are unlikely to be achieved by a particular water-quality improvement strategy. For instance, dissolved organic matter naturally colors some lakes. If that coloration limits water transparency, reducing phosphorus levels will probably not result in a substantial increase in water clarity, although it may still reduce the number of algal blooms. In these lakes, improving water clarity is probably not an achievable management objective because the natural condition for these lakes accounts for much of the lack of transparency. In lakes in which phosphorus and chlorophyll *a* are not well correlated, such as those with very high flushing rates, phosphorus control is unlikely to substantially reduce algal blooms. These scenarios are uncommon in New York State lakes.

More common are lakes where poor water clarity limits light transmission enough to limit weed densities. If a management objective is to improve conditions for swimming by reducing algae to increase water clarity, there may be some unintended consequences. Reducing algae allows more light to penetrate to the bottom of the littoral zone, promoting weed growth that could harm swimming in the future. This phenomenon has occurred in many New York State lakes, including Saratoga Lake. For these lakes, weeds may exert a more substantial impact on recreation than algal blooms. The ancillary benefits of reduced algal blooms, such as better drinking-water quality, and fewer incidences of algal toxins or oxygen deficits, may ultimately make the effort worthwhile. This example illustrates the importance of evaluating the interconnected values of multiple water-quality and lake-use indicators.

Interconnectedness of other water-quality indicators can also be explored. Some studies indicate an apparent correlation between trophic indicators and deepwater oxygen levels. This relationship can be used to identify whether a lake is likely to support salmonids or other coldwater fish that require a balance of cold water and high oxygen levels. Another correlation to examine is the connection between water quality and rainfall or runoff for identifying the relative influence of different sources of external loading. Health officials, for example, have consistently linked heavy rainfall with high bacteria levels at a swimming beach on Owasco Lake, pointing to stormwater runoff rather than waterfowl as a prime source of the contamination. This realization readily made the symptom-causes-sources connections that led to effective management.

Modeling

All water-quality data collected can be entered into water-quality **models**, which are essentially tools to predict changes in lake conditions. These models can be very simple, with input information limited to just a few key water-quality indicators, or very complex, requiring substantial data for a variety of indicators collected frequently during a long period of time. Models will attempt to diagnose a problem in a lake based on the existing relationships among water-quality factors, or to predict future water quality. Many complex models build both diagnostic and predictive capabilities into their processes. Some models focus only on in-lake activities, while others are watershed models that focus on inputs to lakes. While both lake and watershed models can operate independently, the best models combine equations describing the watershed with equations describing the lake.

Lake and watershed models are based on mathematical formulas or equations quantifying cause and effect relationships that trigger specific lake responses. A lake model will include equations that describe the relationship between the average depth of a lake and its phosphorus loading to its trophic condition. The figure below demonstrates this relationship, and is often referred to as a Vollenweider Plot (1975), named for the Canadian limnologist Richard Vollenweider. The relationship between the conditions of a lake, its phosphorus loading, and its depth can be used to show that shallower lakes are more susceptible to phosphorus loading than deep lakes. This is discussed in more detail in Chapter two, "From Montauk to Erie", as it relates to New York State lakes.

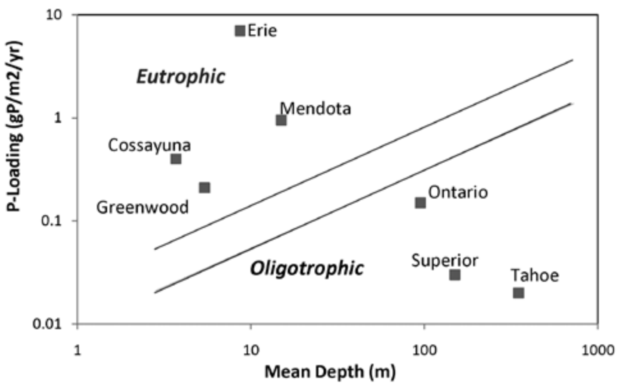


Fig.4–9. Vollenweider Plot showing the relationship between a lake's depth, phosphorus loading, and trophic state. (Adapted from Vollenweider, 1975)

The Vollenweider Plot can also be used to predict the future condition of a lake based on its nutrient loading and depth. The accuracy of the prediction can be increased by making the calculations more complex within the models. Additional information is factored into the equations such as:

- lake-flushing rate, or how quickly water moves through the lake;
- lake volume;
- sedimentation rate, or how quickly material falls through a lake from the surface to the bottom;
- outflow rate, and
- other physical characteristics.

Models developed by Dillon and Rigler (1974) and by Vollenweider (1976) continue to be useful for relatively simple estimates of either phosphorus concentrations within the lake or nutrient loading to the lake. When combined with simple watershed models that use nutrient export coefficients to estimate nutrient loading from various land uses within a watershed, simple nutrient budgets can be developed to identify potential hot spot locations for focusing management efforts.

There are increasingly complex, computer-based versions of these models. EUTROMOD is a lake-input response model available through the NALMS website. BATHTUB is a U.S. Army Corps of Engineers model that evaluates lake eutrophication response to various nutrient loads. Two examples of loading models are BASINS, "Better Assessment Science Integrating Point and Nonpoint Sources," an EPA model, and SWAT, "Soil and Water Assessment Tool," a U.S. Department of Agriculture (USDA) public-domain model. (See Appendix F, "Internet resources") These models use a combination of information, such as site-specific data collected from the lake, historical data collected in similar lakes, and general estimate data for lakes or lake watersheds in the particular region, or other parts of the country. Some of these models predict long-term, lake-wide average conditions, while others predict short-term conditions, local water-quality conditions, and changes through time. For all of these models, larger and more complex data sets collected for the lake and watershed in question enhance the accuracy of the model.

The general public can use many of the simple lake models, but as the models increase in complexity, they require complicated computer software and extensive data not readily available for most lakes. The more complex models tend to be employed by researchers, government agencies, and lake-management professionals involved in intensive management or restoration of high profile waterbodies. Such models can take many years to develop and master. While the diagnostic and predictive powers of these models are very high, they are often not required for the breadth of management likely to be undertaken by lakefront property owners, lake users, and most municipalities.

How much will it cost?

This can literally be the million-dollar question. The cost of monitoring ranges from no-cost and relatively inexpensive volunteer monitoring programs, to studies costly in terms of human resources and equipment, to Cadillac programs conducted on very high-profile lakes.

The only clear generalization that can be made regarding the cost of a monitoring program is that it should be dictated by the objective of the monitoring. Long-term monitoring programs involving water-quality indicators, such as metals or organic compounds, will generally cost more than simple evaluations of contemporary lake conditions. The extent of monitoring and related costs may be very high if the monitoring requires high precision and legally defensible results. There may be little leeway in containing costs if the study is part of litigation or compliance, such as pollutant discharge limits imposed on wastewater treatment. For most lake associations, cost and effort should ultimately be governed by the needs of the data user.

As this book goes to publication, water-quality parameters such as color, pH, turbidity and conductivity tend to cost about $10 per sample or less. Nutrients, chlorophyll *a,* and bacteria tend to cost between $10 and $50 per sample. Metals, organic compounds, and microbiological identifications for phytoplankton, zooplankton and bacteria species tend to cost more than $50 per sample, although many of these analyses provide data for multiple parameters. While metals samples can be expensive, for example, the analytical methodology usually provides results for several metals types, since these are analyzed simultaneously.

Water-sampling equipment costs are quite variable. High-end electronic sampling devices tend to cost up to $10,000, particularly those with data loggers that record data for multiple water-quality indicators. Most of these devices collect instantaneous temperature, oxygen, pH and conductivity readings. Some of the more expensive units also measure some nutrients, chlorophyll *a*, and other water-quality indicators. Electronic meters that only measure temperature and oxygen cost less than $1,500 and tend to be a little less temperamental than more expensive units. Water-sampling devices for collecting grab samples at a variety of depths usually cost about $500, mostly owing to the need for a reliable tripping device. As with the aforementioned electronic devices, however, less expensive versions have also been developed. Integrated samples are usually collected with weighted hoses attached to calibrated lines. These samplers can also be made of materials as diverse as reinforced tubing or simple garden hoses, to PVC pipes with stop valves, to peristaltic pumps. Sediment samplers can range in cost from less than $500 for simple grab samplers, to more than $10,000 for piston-driven corers. Secchi disks can be made inexpensively using instructions readily available on the Internet, but can also be purchased for under $50 from several vendors.

The lake looks bad

Collecting and synthesizing all this information may seem daunting, but it is imperative that the symptoms-causes-sources relationship be adequately investigated and documented. The process of objectively understanding the basis of a water-quality complaint is critical to successful lake and watershed management. Based on the complaint "The lake looks bad," the following illustrates how to determine the symptoms-causes-sources relationship discussed in this chapter.

Symptoms determination

- Determine the number of residents "offended" by aesthetics, through surveys or questionnaires and categorize responses by groups of lake users.
- Determine if all user groups share this opinion, or if it is limited to a single group, and other groups believe that lake conditions have improved for their uses.
- Determine whether this is a recent and/or seasonal problem.
- Identify whether the whole lake or just isolated areas look bad.
- Determine if the complaint is associated with "normal" conditions in the lake or if this represents a change in lake condition.
- Identify any other use impairments that occur as a result of this condition.
- Determine if similar complaints occurred when lake conditions were different. For example, did "the lake look bad" when clarity was high and weeds were high, or when clarity was low and weeds were low?

Causes determination

- Collect water-quality data to determine if the aesthetic problem is related to water-quality problems, particularly those related to trophic indicators. Make sure that the indicators evaluated relate to the use of the lake for swimming, drinking, and fishing.
- Compare contemporary water-quality data to any historical data to determine if changes have occurred and, if so, whether these changes have been sudden or gradual.
- Identify any correlations among water-quality indicators, to evaluate triggers that resulted in impacts, including relationships between weather and these indicators.
- Determine if conditions are different in the area that “looks bad,” particularly if the complaint does not represent a lake-wide problem.
- Determine the extent of rooted plant growth in the lake, both within the offending area and in other parts of the lake. This would include identification of dominant plant species throughout the lake, and how their community structure and densities change during the recreational season.
- Compare plant coverage maps to historical information, when possible, to determine if changes in plant densities or plant community composition (species) have occurred.
- Determine the level of understanding the residential community has about weed growth, particularly in regards to the specific weed(s) of concern. Are their concerns driven by the mere presence of weeds, or just the specific types and densities in the lake?
- Determine sediment types throughout the lake to see if they are conducive to uncontrolled growth of the “feared” weed, and investigate whether the offending plants grow invasively in lakes that are similar with regard to water quality, sediment types, slope, climate, etc.
- Determine if any control mechanisms have been previously attempted or are currently in progress to address the algae or weed problem. If there are, determine the results of those control programs.

Sources determination and actions

- Collect present day and historical records of land-use surveys to determine whether watershed activities are bringing sources of nutrients or sediment into the nearshore and shallow areas, including any swimming areas or fishing corridors.
- Conduct septic dye testing to determine the number of leaking and failing septic tanks and other on-site wastewater disposal systems, and relate the results of that testing to the influx of plant nutrients.
- Determine if the effluent from any wastewater-treatment facilities within the watershed is discharging directly to the lake by surface flow or groundwater.
- Conduct stream, precipitation, and lake-level gauging to determine the percentage of watershed nutrient and sediment sources contributing to the lake water and nutrient budgets. Determine whether the use impairments are directly attributable to changes in water and nutrient levels from watershed or atmospheric sources.
- Collect information on lawn fertilizer use in the watershed. Determine the location of fertilizer and failing septic tank “hot spots” relative to excessive algae or weed growth.
- Investigate development and subdivision records to determine the relationship between changes in residential use or density and changes in vegetation levels and use impairment.
- Survey public boat launch areas, such as boat ramps, roadside launch points, beaches and inlets, to determine if aquatic plants can easily enter the lake through these sites. Inspect the near shore area and the shoreline in the vicinity

of launch sites to determine if weed infestations are more significant, or if there is evidence that plant fragments may be entering the lake from trailers or boat props.

- Determine if waterfowl use the lake, and if lake residents feed or otherwise encourage the waterfowl to congregate.
- Use nutrient and source information to construct a simple nutrient budget for the lake. If it is determined that sediment composition has changed, particularly in weed-infested areas, identify the most likely source of sediment for the lake or for weed-affected hot spots.

Each component of the symptoms-causes-sources relationship listed above may provide the key pathway for a successful lake and watershed management plan. Development of each component may force the development of other components, and direct the collection process toward previously unexplored questions. Information collection cannot be completed without addressing each of these components.

Why?

After all the bottles of water have been collected and all of the maps drawn, it is time to stand back and again ask “Why?’. If the data is not sufficient to answer all of the questions posed in this chapter, then a lake manager’s work is not done.

If the management plan is built around supporting and protecting lake fisheries, for both the fish and the anglers, were anglers surveyed about the quality of the fisheries? Has funding sources to support stocking been secured? Were enough data collected about the native fish to be assured that the stocked fish will not create cascading ecological problems? Is the water-quality data collected specific to fish survival and propagation, including dissolved oxygen, temperature, pH, metals, chlorophyll *a*, phytoplankton identification, zooplankton counts, benthic communities, and macrophyte coverage? Are there aquatic plant coverage maps to aid anglers in identifying prime fishing locations? Is there secured lake access or regulated access for non-resident anglers? Is there a consistent message to lakefront residents to assure they are not recklessly removing all weeds? Is there a boat inspection program to prevent the introduction of zebra mussels and other exotics? While some of these questions are outside the realm of monitoring and problem diagnoses, they all point to the need to revisit data collecting and management planning goals to assure the plan is moving in the right direction. Data collection is a time-consuming and expensive process and should always be undertaken with specific objectives in mind. Purposeless data is bad data.

Summing it up

While it is natural to want to solve an in-lake problem with an immediate solution, such quick fixes are not enough. The cause of the problem must be analyzed and understood before a lake/watershed management plan can be designed to try to solve it. Collecting the necessary information requires asking the questions: Why?, Who?, What?, Where?, When? How? and then Why? again. Sampling methods to answer the questions can range from simple observation and weed identification to the use of very expensive equipment and laboratory testing.

If additional sampling is warranted, it should be integrated with the wealth of information already collected by government-sponsored programs as well as ongoing academic, private and volunteer programs. At the end of the process, there should be confidence that sufficient data has been collected and evaluated to determine the likely cause(s) of the initial complaint, and that the most significant source(s) of the problem has been identified.

The next chapter will take an in-depth look at the health of fisheries, an area with specialized assessment methods and management options.

5 Fisheries Management: Matching Expectations to Reality

Introduction

Anglers love to tell stories, and a lake's reputation is often based on a few experiences by a limited number of anglers. Unfortunately, anecdotal evidence and casual observations by a few anglers do not give an accurate picture of a fishery's status. If a boat load of friends went fishing and were skunked, does that mean that the lake is empty of fish? A bad day of fishing could be due to bad luck, poor site selection, or poor technique, and have nothing to do with fish abundance. Scientific surveys to determine the status of a fishery are necessary to develop an accurate picture of the current state of a lake's **fishery** and to develop and evaluate fishery management plans. Without scientific surveys, fisheries management deteriorates to intuition and guesswork.

Fig. 5–1. Great expectations!
Some anglers have unrealistic expectations about the size and availability of fish for harvest in small lakes. Acre-for-acre comparisons, however, show that small lakes produce more fish than large lakes. (Credit: John Foster)

This chapter introduces fisheries ecology, data-gathering tools and management strategies for managing the fish, their habitat, and anglers.

Gathering fisheries information

The New York State Department of Environmental Conservation (DEC) is responsible for managing fisheries in New York State. As DEC conducts its own scientific surveys on most lakes, their staff may also gather information in partnership with other groups such as universities, conservation organizations, lake associations, and rod and gun clubs. With guidance from a professional fisheries biologist, citizens can gather very accurate fisheries data on their lake. Ideally, lakes should be surveyed every three to five years. Lakes with high socio-economic importance are more frequently surveyed. Small lakes are surveyed infrequently, however, because of limited state resources.

The environmental surveys discussed in Chapter four, "Problem diagnosis," provide an initial step toward identifying the physical, chemical and biological factors affecting fisheries. This information is important for understanding how best to manage a fishery since lake ecology has a tremendous influence on fish populations and the health of fisheries.

When environmental survey information is combined with fish, angler and habitat survey information, a fisheries management plan can be developed, or an existing plan evaluated. Fish, angler and habitat surveys, discussed later in this chapter, give a good indication of how much harvest a lake can support and the level of angling pressure it receives. It will indicate where habitat improvement or stocking can enhance fish populations and angling opportunities. Before delving into these important data-gathering tools, it helps to understand some basic principles of fish habitat.

Habitat limiting factors and critical parameters

Each fish species, and life stages within the same species, require different habitats to carry out critical life functions, such as feeding, resting, hiding from predators, and spawning. The physical, chemical and biological components of the habitat affect the population dynamics of each species. Each of the species will have an optimal range and a tolerance range for every habitat component. Optimal temperature for brook trout, for example, is around 60ºF (Fahrenheit) although their range of tolerance is from 32ºF to 74ºF. As temperature deviates from optimum, however, it begins to limit brook trout survival, growth, and production and population size. Many fisheries are limited by a few obvious habitat parameters, but fisheries are more often limited by a combination or interaction of factors.

Habitat analyses focus on determining the primary limiting factor for a particular game fish. Fisheries biology and public interest can result in a lake being designated for brown-trout production. The management plan would then focus on improving the factors of brown-trout habitat that limit production. Physical limiting factors include habitat, temperature, light, elevation, substrate, depth, structure, shoreline curves, turbidity, and water clarity or transparency. The two most common factors limiting fish production are temperature and nutrient availability.

The temperature regime is the primary factor determining what species of fish a lake can support. Lakes are classified by their dominant fish habitat into three broad categories, optimal temperature of 59ºF (15ºCelsius) for coldwater fish, 68ºF (20ºC) for coolwater fish, and 77ºF (25ºC) for warmwater fish. Most trout stop feeding, for example, at 36º F (2.5ºC), have optimum growth and survival at 59ºF (15ºC), and are stressed at temperatures above 68ºF (20ºC).

Overlap of fish communities can occur in the same lake. Temperature optimums differ among life stages within the same species. Many deep lakes can support coldwater, coolwater and warmwater species in the same lake. In deep lakes, however, available habitat will best support one particular fish community. Understanding the ecological relationships between the temperature regime of a lake and the temperature requirements of fish provides insight into the possible development of a particular fishery.

Lake fertility is the primary factor determining the number and biomass of fish. The more fertile the lake, the more fish-per-acre it will produce. Higher nutrient levels increase phytoplankton and zooplankton production. Predation transfers this energy and biomass through the food chain, resulting in increased fish production and their potential harvest.

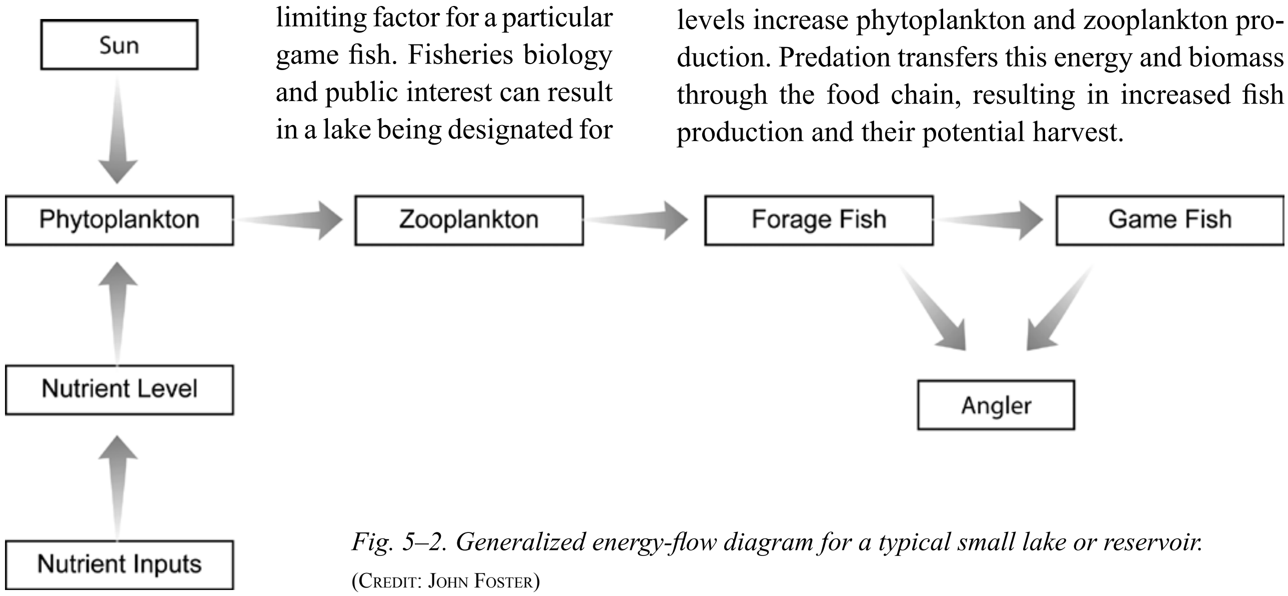


Fig. 5–2. Generalized energy-flow diagram for a typical small lake or reservoir.
(CREDIT: JOHN FOSTER)

Many anglers believe that the clear, cold, Adirondack lakes provide the best fisheries in New York State. Actually, the green, warm, downstate lakes contain and produce the most fish-per-acre. The higher altitude Adirondack lakes have shorter summer with a shorter growing season, but the main difference between these crystal-clear mountain lakes and their murkier southern counterparts is fertility.

Lake fertility is frequently used by aquatic ecologists to classify lakes. High elevation and northern lakes in New York State tend to be either relatively infertile oligotrophic lakes or **dystrophic** lakes with rocky shores and few nutrients. Oligotrophic lakes have scanty nourishment. Dystrophic lakes tend to be shallow, tea-colored, and high in humic matter, with acidic waters and few plants. Oligotrophic lakes are usually so deep and dystrophic lakes so stained with tannic acid that sunlight penetrates only the surface waters. Lowland lakes of central and southern New York State tend to be extremely fertile, nutrient-rich, eutrophic lakes, surrounded by rich farmland. They are usually shallow, and plant growth is supported because sunlight penetrates throughout the water column. Between these two extremes are moderately nourished mesotrophic lakes.

Fertility or nutrient level can be used to accurately predict the yield or standing crop biomass of fish in a lake. Lake fertility determines fish abundance and the type of fish species in a lake. Fisheries biologists measure fertility by conductivity, a measure of how well electricity is conducted through water, or by **Total Dissolved Solids** (TDS) a measure of the level of dissolved particles in the water. Optimal conductivity ranges from 100 to 300 **µmhos. (**Electrical conductivity, µmho, is the opposite of electrical resistance, ohm. Conductivity is resistance spelled backwards and preceded by the Greek letter µ.)

The morphoedaphic index is used by fisheries biologists use to predict fish yield per-acre-per-year. It is used to estimate the pounds of fish available for harvest and is calculated by multiplying the yield-per-acre by the surface area of the lake. This widely used index is derived by dividing a lake's TDS mg/l (milligrams per liter), by its mean or average depth in meters. The mean depth of a lake can be derived by dividing the lake's volume by its surface area. Mean depth is an indicator of the extent of a lake's euphotic-littoral productive zone.

TDS provides a crude measure of a lake's limiting nutrients such as phosphorus or nitrogen. Shallow lakes are more productive than deep lakes. Phosphorus is the most limiting nutrient in standing waters, so it is also used to measure fertility. The optimal range is from .01 to 3.0 parts per million (ppm.)

Physical limiting factors

Temperature and nutrients are critically important, but there are many other factors that also limit a lake's fishery. Fish require adequate space, or habitat, to live. Steep-sided lakes provide very limited littoral-zone habitat, and thus very limited space for fish such as pickerel, bass, or bullheads that require a shallow, inshore, weedy habitat. Other physical limiting factors include light, elevation, substrate, depth, structures, shoreline curves, turbidity and water clarity.

Light is required for primary production and ultimately affects fish productivity of all fish in the lake. Fish generally are more comfortable in dim light, but too little light reduces productivity. Fish production is significantly reduced in areas of prolonged cloud cover, such as the eastern side of the Great Lakes,

Elevation can be correlated with a number of limiting factors. In central New York State, trout usually do not occur in shallow lakes less than 1,500 feet above sea level because of the correlation between altitude and temperature. High-elevation lakes have a shorter growing season and are fed by rain water which is low in nutrients. High-elevation lakes, therefore, have low productivity due to colder water, a shorter growing season, low pH and low nutrients.

Substrate has multiple effects on the distribution and production of fish. The availability and amount of spawning gravel often limits trout production. Fine sediments such as sand and silt provide habitat for bullheads. Coarse sediments such as cobbles and boulders are favored by sculpins, rock bass and smallmouth bass.

Depth can be a limiting factor, since many aquatic organisms are only found at specific depths. Sunfish and pickerel are only found in shallow water. In general, as depth increases, biomass and productivity decreases. In the northeast, however, shallow lakes less than 10 feet deep are often subjected to winter-kill, reducing both plant biomass and fish productivity.

Structures such as shoals and artificial reefs provide substrate for algae and invertebrates whose presence increases food available to fish populations. Rocky shoals also provide shelter for structure-loving fish such as rock bass and smallmouth bass.

Shoreline curves increase the ecotone or transition zone effect and, therefore, increase productivity. Round lakes are less productive than lakes with multiple embayments and shoreline curves.

Turbidity is a measure of particulates suspended in the water column. High turbidity reduces water clarity or transparency, reducing photosynthesis, and making it difficult for fish and other aquatic animals to find food and oxygen. Optimal turbidity for standing waters is 0 to 2 Nephelometric Turbidity Units (NTU), the standard unit for measuring turbidity. (NTU replaces JTU, Jackson, and FTU, Formazin, as turbidity measurement units.)

Water clarity is the opposite of turbidity. It is measured by lowering and retrieving a round, black-and-white plate called a Secchi disk into the lake (see Fig. 4-1, Chapter four "Problem diagnosis"). Water clarity or transparency is measured by calculating the average depth at which the Secchi disk disappears and then reappears in the water column. This depth provides a crude measure of the zone where plant photosynthesis equals respiration. In lakes with low levels of inorganic suspended solids, it provides a relative measure of the density of phytoplankton.

Chemical limiting factors

Chemical limiting factors include fertility, oxygen, carbon dioxide, pH, ammonia, hydrogen sulfide, heavy metals, alkalinity and hardness. See also the discussion in Chapter four, "Problem diagnosis."

Oxygen is required for respiration and metabolism. While some species can survive at very low levels of oxygen, production for most fish begins to drop when oxygen levels fall below five ppm.

Carbon dioxide is optimal at levels from 5 to 10 ppm, but becomes limiting at levels above 10 ppm. High carbon-dioxide levels can occur in the deeper waters of highly productive lakes.

pH is a measure of hydrogen ion concentration. Optimal pH for most aquatic organisms is from 6.5 to 8.5. Brief exposure to higher and lower pH may not be limiting.

Alkalinity is a measure of carbonate and bicarbonate ions, which buffer the changes in pH. Optimal alkalinity is from 50 to 400 ppm. Levels below 50 ppm often result in rapid fluctuations in pH levels that are detrimental to most aquatic organisms.

Hardness is a measure of magnesium and calcium ions in the water. Optimal levels of hardness are from 50 to 400 ppm; levels below 50 ppm are limiting. A low calcium level is often a limiting factor in dystrophic lakes.

Ammonia is toxic to fish and other aquatic organisms. In water, it occurs in two forms, the toxic deionized form (NH_3) and the non-toxic ionized form (NH_4^+). The amount of ammonia in the toxic form is greater at higher temperatures and pH. Total ammonia starts to become limiting around one ppm. High levels of ammonia can occur in the deeper waters of highly productive lakes in late winter or summer.

Hydrogen sulfide is very toxic to aquatic organisms, and continuous exposure to levels as low as .002 ppm is lethal to most fish. Hydrogen sulfide is more toxic at low temperatures and pH. High levels of hydrogen sulfide can occur in the deeper waters of highly productive lakes, also in late winter or summer.

Heavy metals such as cadmium, copper, lead, mercury and zinc become toxic at levels as low as .002 ppm. Acidic lakes leach heavy metals from their substrates.

Biological limiting factors

Biological limiting factors include benthic invertebrate production, zooplankton, the fish community, woody debris, submergent rooted vegetation, and shoreline vegetation.

Benthic, or bottom-dwelling, invertebrate production is consumed by benthic (or demersal) fish such as lake trout, whitefish, sculpins, suckers, bullheads and carp, which are allfree-swimming species living close to the bottom. The size and diversity of the benthic community has a strong influence on the fish community. A large biomass of benthic invertebrates does not necessarily result in a large biomass of fish. Zebra mussels *(Dreissena polymorpha)* can have a tremendous biomass, but relatively little of it is converted into fish biomass. Zebra mussels strain plankton out of the water column, reducing the food available for planktivorous fish, thus reducing the overall fish production of lakes they invade. A survey of benthic invertebrates should focus on standing crop biomass and species diversity. The presence of an **indicator species,** such as blood worms and tubificid, or tube worms, is indicative of past episodes of oxygen depletion that could be limiting the biomass of benthic fish.

Zooplankton are the main source of food for the fry stage of virtually all fish. The fry stage extends from yolk absorption by the larva to the fish reaching approximately one gram in weight. Zooplankton also feed many juvenile and adult fish. The size and species diversity of the zooplankton community influence survival, growth and abundance of the early life stages of most lake fish. Dystrophic lakes produce relatively few large zooplankton species, thus limiting the food base for planktivorous fish.

The fish community limits the production of some species through predation, competition or interference. Alewives *(Alosa sapidissima)* can limit walleye production by predation on larval walleye *(Sander vitreus)*. They can also limit production of ciscoes by out-competing them for food. Large populations of carp and bullheads uproot aquatic vegetation and cloud the water, reducing the size of the littoral zone and interfering with littoral-zone fish.

Woody debris or deadfalls provide shelter and feeding stations for many fish species. The presence and density of many pan fish (sunfish, rock bass, bullheads and yellow perch) and game fish (pike and smallmouth bass) are highly dependent upon the amount of deadfalls in a lake. Deadfalls also provide substrate for algae and invertebrates, which increases overall lake productivity. In spite of these positive attributes, deadfalls are the most frequent thing people remove on "lake clean-up days."

Fig. 5–3. Deadfalls and woody debris attract fish by providing structure and substrate for their food, but they are often removed during shoreline development.
(CREDIT: WAYNE WURTSBAUGH)

Submergent rooted vegetation delineates the littoral zone of a lake, the most productive of the three lake zones. Submergent rooted vegetation provides habitat for littoral zone fish and food for aquatic invertebrates and fish. When the size of the littoral zone is limited, species, population sizes and the production of the lake will also be limited.

*Shoreline vegetation***,** such as bulrushes, provide habitat for aquatic invertebrates that fish eat, nesting areas for crappies, sunfish and bass, and spawning habitat for northern pike. Emergent, or above the surface vegetation also protects windswept shorelines from erosion by waves and boat wakes. Shoreline wetlands can provide a significant source of decaying organic material to fuel the food chain of a lake.

A tremendous amount of environmental data can be collected during one or two sample dates, but some limiting factors might be missed. Additional data and carefully selected sampling dates and times may be necessary to gain a more complete picture.

Seasonally, late summer and late winter are more likely to have limiting conditions such as dissolved oxygen, ammonia, hydrogen sulfide and temperature. During the day, early morning is likely to have low pH and dissolved oxygen problems, while late afternoon may have temperature problems.

Critical environmental conditions happen sporadically. Hot dry summers and severe winters may occur infrequently. When a fishkill is the result of a transient event, conditions can be back to normal before a sampling team can isolate the problem. It is important to remember, however, that although fish abundance, survival and productivity can be limited by transient events, physical, chemical and biological conditions support fish 99.9 percent of the time.

Fig. 5–4. Late-winter water-quality sampling may indicate limiting factors, such as low oxygen levels, that will reduce fish survival and production. The device shown can collect samples at various depths beneath the ice. (CREDIT: JOHN FOSTER)

Scientific techniques for conducting fisheries surveys

Successfully managing a fishery requires knowing the habitat needs of the fish. Scientific surveys are needed to determine existing fish populations, fishing activity and fish habitat. Information from these surveys is then used in the three major management approaches: managing the fish, the habitat, and the angler.

Fish surveys

During fish surveys, fisheries biologists capture, identify, weigh, measure, and remove scales to check for age and growth determinations. These measurements provide valuable information about fish population dynamics including population size, community structure, age/size structure, reproductive success, and growth. Information on habitat utilization and movement patterns can also be gathered.

Fish-survey techniques are adapted to different species and sizes. Fish in lakes are most often surveyed with gill nets, trap nets, seine nets and electro-fishing, although towed nets and angling are sometimes used.

Gill nets used in fish surveys are usually 300 feet long, and consist of six, 50-foot panels of different-sized mesh. Most fish are vulnerable to gill nets, and they are highly effective in both deep and shallow water. Gill nets should be used sparingly since the mortality of captured fish is high. Live fish can be released after workers take measurements and scale samples that are analyzed later to determine fish age and growth. Fish that die in the net can still be used for analysis of their reproductive condition, stomach contents and parasites.

Trap nets are most effective for fish that live in shallow water at particular times of the year. Fish that migrate along the shore are vulnerable to trap nets. These nets are very gentle on the captured fish and most can be released unharmed.

Fig. 5–5. Gill nets are used sparingly by professional fisheries biologists to sample fish populations throughout a lake. (CREDIT: JOHN FOSTER)

Seine nets are typically small-meshed nets that are used to capture young fish, and are only effective when used close to shore.

Electro-fishing is done from a boat using equipment that sends a non-lethal electrical charge into the water, temporarily stunning fish so they can be easily netted at the surface. Electro-fishers work best in water less than six feet deep and, therefore, are most effective on shallow-water species such as bass and sunfish. Boat electro-fishers are often used at night since many fish move to the surface after dark.

Towed nets can be used to sample fish eggs and larvae. Trawls can be used to survey small or young-of-the-year fish on the bottom or in the water column of the lake. Towed nets in small lakes typically use fine-mesh sizes.

Angling or fishing with a hook and line is an effective method of surveying a wide range of species. It can be used at any depth and can target specific species. It is most effective in sampling adult or sub-adult fish. For many species, angling is the most effective way of capturing fish for stomach analysis.

Fish surveys should be extended to lake tributary streams if the species of interest uses streams as part of their life cycle. Walleye and many trout species, for example, use streams for spawning and nursery areas.

Angler surveys

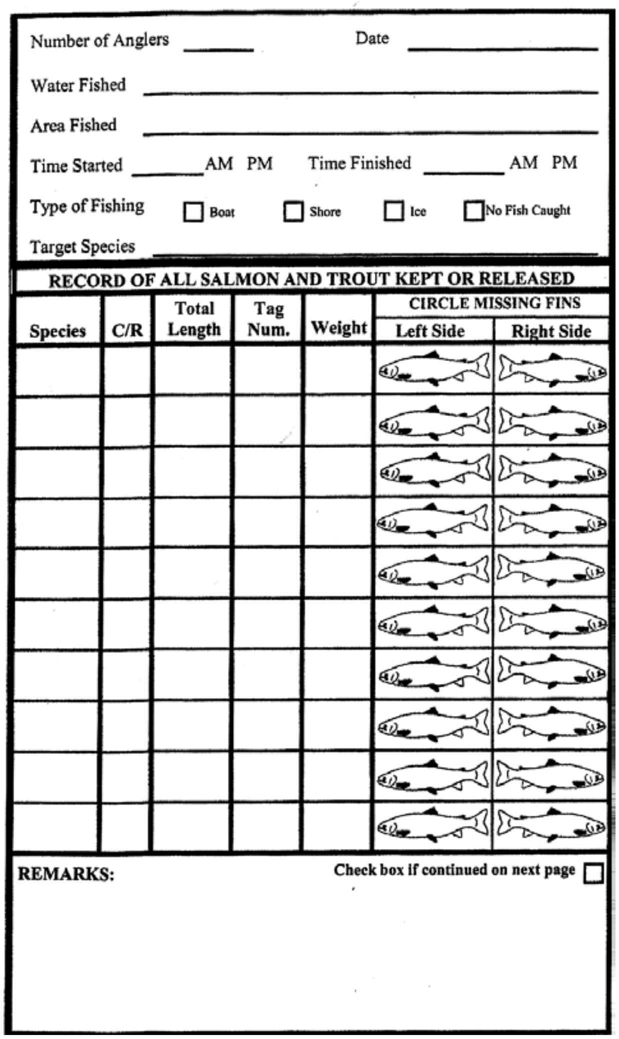
The goal of an angler survey is to collect information about the fishery from the angler's perspective. To be effective, angler surveys must be conducted throughout the fishing season. Five to ten percent of the available fishing days in the season should be covered, including both weekdays and weekends. A good survey of anglers will include an angler census, creel surveys, and angler interviews.

Angler censuses are usually conducted without direct contact. Small lakes can be surveyed from a lookout point, by boating around the lake, or at a boat launch if lake access is restricted. The purpose of the census is to develop counts of how many anglers are fishing the lake each day and whether they are shore fishing, trolling, or still-fishing. The census should also note boat size, angler age, and whether the angler is with other adults, families with children or is alone.

Creel surveys focus on the fish harvested by surveying the angler's creel or basket used to hold the day's catch as a measure of angler success. The species, number, and length of fish harvested, and the number kept or released are recorded. During a creel survey, fish are examined for fin clips and disease, and scales are often removed to determine age. Anglers are often asked the length of time they have been fishing, and the equipment and techniques they employed. Fishing success is defined as catch-per-unit-effort, or the number of fish caught per hour of fishing. Data collected during creel surveys can be used to monitor fish populations, fishing techniques, and the effectiveness of management regulations.

Angler interviews assess the socio-economic aspects of a fishery. The focus of the interview is to assess the angler's preferences. Data collected include the origin of the angler, the money spent in pursuit of fish in the fishery, and the species being sought. Anglers are also asked to rate the fishery and management techniques or regulations.

The combination of the above components of a good angler survey will provide significant information on the state of the fishery. Important data on fishing pressure, the size and total number of fish harvested, and the recreational value of the fishery can only be determined by combining the three different data sets. Survey information can be used to determine the effectiveness of **fish stocking** using data from fin clips, whether regulations are effective or necessary, and how anglers are impacting fish populations. Follow-up surveys measure whether the management plan is working or if it should be modified.


Number of Anglers ______ Date ______
Water Fished ______
Area Fished ______
Time Started ______ AM PM Time Finished ______ AM PM
Type of Fishing ☐ Boat ☐ Shore ☐ Ice ☐ No Fish Caught
Target Species ______

RECORD OF ALL SALMON AND TROUT KEPT OR RELEASED

Species	C/R	Total Length	Tag Num.	Weight	CIRCLE MISSING FINS: Left Side	Right Side

REMARKS: Check box if continued on next page ☐

Fig. 5–6. The DEC Angler Diary is a useful tool for monitoring fisheries. (CREDIT: DEC)

A bias may be inadvertently introduced into the survey data if special interest groups conduct the angler surveys. To evaluate the surveys, professional fishery biologists independently check the fishery by making a site visit to observe the fishery and perhaps do some experimental fishing as a first-hand assessment of fishing success.

Another approach to conducting angler surveys and monitoring a fishery is the Angler Diary Program conducted annually by DEC. Anglers are asked to record the date, where they were fishing, and number and type of fish caught in a diary. This approach is loosely based on the observation that 20 percent of anglers catch 80 percent of the fish. By asking the expert angler and the major users of a fisheries resource to maintain a diary of their activities, DEC fisheries biologists can efficiently monitor the fishery. The diary is mailed to DEC at the end of the fishing season, and is a useful method of monitoring the fisheries of small lakes that are infrequently surveyed.

Habitat surveys

The goal of habitat surveys is to characterize the physical, chemical and biological environment of the lake as they relate to fish production. Most game fish have critical habitat requirements that are essential for their existence and well-being. Periodic habitat surveys, coupled with fish surveys, indicate whether changing water chemistry or habitat conditions are causing changes in fish populations.

Many aspects of habitat surveys can be conducted at any time of year, but some surveys are better conducted at specific times. Physical and biological surveys are usually done during the summer. Water-chemistry surveys are generally conducted at the end of summer and in the late winter, when environmental conditions such as dissolved oxygen, ammonia, hydrogen sulfide and temperature are limiting factors. Water chemistry is discussed in more detail in Chapter four, "Problem diagnosis."

Physical habitat surveys are focused on measures of size, depth, temperature and turbidity or suspended solids. Other measures of the physical environment include flushing rate, water clarity, and substrate type. Initial habitat surveys involve the development of a **hydrographic map.** This will assist in determining the extent of the littoral, limnetic and profundal zones in a lake, and help classify whether a lake is best suited for a warmwater, coolwater or coldwater fishery.

Water-chemistry surveys are conducted to determine whether water-quality parameters are limiting fish populations. Common limiting factors are dissolved oxygen, pH, alkalinity, hardness, and fertility or available food supply. While professional fisheries biologists rely on electronic meters to make these measurements, relatively inexpensive and accurate chemical test kits can also be used to conduct water-chemistry surveys.

Biological habitat surveys focus in three areas: aquatic plants, benthic or bottom-dwelling invertebrates, and plankton. Fisheries biologists survey the biological environment to determine if adequate resources are available to support the fishery. Biological surveys of lower trophic levels can also be used to assess the relative abundance of fish. The size and species of plankton, for example, are a good indication of the relative abundance of planktivorous species such as alewife, compared to predatory species such as lake trout.

Analysis of fish populations

Surveys provide a tremendous amount of data defining the state of the fish population. Fish community structure and population dynamics are important components of these data, which are then analyzed by professional fisheries biologists.

Analysis of community structure provides an overall assessment of the lake's fish population, but most fisheries biologists and anglers focus on collecting data about game-fish populations. Common measures of game fish include population size, and physical size or age structure, as well as measures of population well being, including diet, condition and growth.

Fish community structure

The first step in characterizing the fish community of a lake is to conduct a survey on the relative abundance of the different species living in the lake. The next step is to characterize and group the fish species by their habitat, niche and value to the fishery. Habitat describes where in the lake the fish is found (residence), and niche describes what it does there (occupation) or its role in lake ecology, such as planktivore. The value to the fishery is assessed in terms of whether a fish is a game fish**,** pan fish, or forage fish. Forage fish, such as minnows, darters and sculpins are preyed upon by game fish, pan fish, or other competitors.

Fisheries biologists seek specific data to analyze the fish fauna in a lake. Do warmwater, coolwater or coldwater fish predominate? Is there a good balance between species of the littoral zone with weedy inshore species, and species that can feed on plankton in open water such as yellow perch, crappie and golden shiner? Are benthic feeders such as bullheads, suckers, or whitefish in low density? What percentage of the fish community consists of species of interest to anglers?

What constitutes a good fish community structure is often open to interpretation. Fisheries biologists and anglers are usually focused on filling most niches with fishable species. In a coldwater lake, for example, is it better to have alewives or ciscoes as the forage species for lake trout? Alewives appear to support larger populations of lake trout, but are themselves not a fishable species. Ciscoes, on the other hand, are quite tasty, and can support their own fishery. With ciscoes and lake trout, therefore, there is a fishery for both species, but with alewives and lake trout there is only one fishable species.

Data required to analyze community structure are often difficult to collect in complex lakes. Surveys usually require the use of seines, experimental gill nets, trap nets and electro-fishing.

Relative fish abundance is the most widely used measure of community structure, comparing the proportional representation of each species in the fish community and providing an overall view of community structure. Relative abundance data indicate the "type" of fish community. If bass, sunfish and bullheads dominate the fish community, the lake is probably eutrophic and best as a warmwater fishery. Relative abundance data also permit calculations on the proportion of fishable species to game species. Relative abundance data also indicate the relative balance of the fish community, and whether all niches are filled.

The *ratio of predators to available prey* is another way to measure the balance within a fish community. Predators are carnivores that feed on other fish. Prey fish, also called forage fish, can be divided into carnivores that feed on invertebrates and zooplankton and herbivores that feed on plants and detritus. **Predator-to-prey ratio** is calculated by dividing the combined weight of all prey by the combined weight of all predators in a lake. The ratio can be determined by comparison of predators and prey in a sample collected during an electro-fishing survey. Fish production is most efficient when there exists a proper balance between predator and prey. The most desirable predator-to-prey ratio is 1:4-6 by weight. For each pound of predator, there should be four to six pounds of prey.

Relative balance of the fish community in a lake is another measure of community structure. The amount of game fish in most well-managed small lakes typically represents 15 to 25 percent of the fish community. This measure is very similar to the predator-to-prey ratio since game species, such as bass, walleye and musky, are predators. There are some predatory fish such as gar and bowfin, however, that are not considered game species, and thus are not considered desirable predators by fisheries managers.

Diversity and richness are other measures of the fish community that are used when an aquatic ecologist surveys a lake. Aquatic ecologists do not have the bias towards fishable species that fisherman and fisheries biologists do. Ecologists value all fish equally, while fisheries biologists consider game fish and pan fish to be more valuable than other fish.

Diversity measures the number of fish species in a lake and their proportional representation in the fish community. Diversity increases either by having more species or by having species numbers in balance. Having large numbers of species, without a dominant species, indicates a more diverse fish community. Fish diversity is often strongly correlated with habitat diversity. Many aquatic ecologists use the Shannon-Wiener Diversity Index as one of several measures of fish biodiversity. The fish community of most small lakes would have an expected diversity in the range of one to four species.

Richness is a similar, but much simpler measure of diversity. It is a measure of the number of species in a lake or community. Current theory is that lakes with a larger number of species have a more stable fish community than lakes with fewer species.

Population structure

Fish population structure describes the different sizes or ages of fish that make up a specific species. An accurate assessment of the population structure would require length or age measurements of a random sample of at least 100 fish. Care should be taken that the sampling gear is not overly selective for either smaller or larger fish. Electro-fishing gear, for example, is selective for larger fish, but a trap net is not size-selective.

Length-to-frequency distributions plot the number of fish in a particular species into different length groups. These distributions reflect an interaction of rates of reproduction, growth, and mortality of the age groups present. The length-to-frequency distribution is used to assess fisheries-ecology interactions, and can be used to identify problems such as year-class strength failure, high fishing pressure, habitat or life-stage bottlenecks, low recruitment, and stunting or slow growth.

Year-class strength is a measure of the proportion of a fish population born in a particular year, the interaction between birth rate and survival. Year-class failure, therefore, could be due to either a high mortality rate or a reproductive failure rate.

Fishing pressure is a measure of the percentage of fish population removed. High-fishing pressure is illustrated in a length-to-frequency distribution as a precipitous drop in abundance for fish reaching a fishable size.

Habitat or life-stage bottlenecks are illustrated by a drop in abundance when fish reach a certain life stage or move into a particular habitat.

Recruitment is a measure of the addition of new members into the population being fished. Low recruitment in a length-to-frequency distribution is illustrated by the abundance of fish in the size-classes immediately below the fishable size.

Stunting or slow-growth in a length-to-frequency distribution is illustrated by an abundance of fish in a particular size-class, with relatively fewer fish in smaller and larger size-classes.

Fish population size

Proportional stock density (PSD) is an index of the size structure of a fish population used to assess the quality of a fishery. It divides the number of fish caught of a particular species into designated sizes and then determines the percentage of fish in each size-class.

Bass anglers, for example, are likely to catch fish down to 8 inches (stock size); are allowed to keep bass with a minimum size of 12 inches (quality size); and would prefer bass larger than 15 inches (preferred size).

A balanced fishery for warmwater game fish, such as bass and pickerel, will have a PSD around 50 percent, with a range from 40 to 60 percent. For every two fish captured, one is a keeper! In a balanced population, about 10 to 25 percent of the bass captured should be greater than 15 inches. Similarly, if a pan fishery is balanced, 20 to 60 percent of fish larger than stock size should be in the quality, or keeper size range.

An accurate assessment of game-fish populations using PSD as a tool requires that a minimum of 20 stock-size fish be captured. As stated above, the method of sampling can affect results. Electro-fishing is selective for large fish, while anglers tend to catch more small fish. Using an angling survey alone, therefore, would most likely indicate that small fish dominate the fishery.

	Stock	Quality	Preferred	Memorable
Warmwater Fish				
Largemouth Bass	8	12	15	20
Smallmouth Bass	7	11	14	17
Pumpkinseed	3	6	8	10
Bluegill	3	6	8	10
Crappie	5	8	10	12
Bullhead	6	10	12	15
Channel Catfish	11	16	24	28
Chain Pickerel	10	15	20	25
Coolwater Fish				
Walleye	10	15	20	25
Muskellunge	20	30	38	42
Northern Pike	14	21	28	34
White Perch	5	8	10	12
Rockbass	4	7	9	11
Yellow Perch	5	8	10	12
Coldwater Fish				
Lake Trout	12	20	26	31
Rainbow Trout	10	16	20	26
Brook Trout	8	13		
Burbot	8	15	21	26

Table 5–1. Length-size designations, in inches, for various species of fish. (Credit: John Foster)

Estimates of fish population size are usually conducted on game fish, except in cases of pest species. It often requires considerable effort to estimate the number of a specific species of fish in a lake. The two common measures of fish population size are catch-per-unit-effort and mark-and-recapture.

Catch-per-unit-effort data are strongly correlated with fish-population size whether collected by angling, electro-fishing or netting. Fisheries biologists can make an approximate measure of population size simply by comparing catch-per-unit-effort survey data from different lakes. Catch-per-unit-effort data, collected by anglers, also provide a measure of relative population size for year-to-year comparisons. If the average catch of bass-per-hour during the first week of bass fishing season was 25 percent lower than last season, for example, then the population of fishable bass in the lake this year was approximately 25 percent lower than last year.

Data collected by anglers are an accurate way to estimate population size of game fish. Records are kept on the number of fish captured per hour (catch-per-unit-effort), and the total number of fish removed from the fishery (creeled fish). Catch-per-unit-effort is then plotted against the cumulative catch of game fish to provide an estimate of game-fish population size.

Mark-and-recapture is the most common method of determining population size of fish in small lakes. A substantial number of fish are captured and marked by clipping the fin. Clipped fish are returned to the lake and given time to disperse. A second sample is then collected, and the ratio of marked-to-unmarked fish is multiplied by the original number of fish marked to estimate the total population of fish in the lake.

Population well being

Fish diet analysis provides a short-term measure of population well being by indicating the proportion of empty stomachs and the proportion of predators eating their preferred prey. An analysis of fish stomach contents can be used to determine predator-to-prey relationships. Stomach analysis can also indicate the availability of food, by determining if all niches are filled, or if niches are available for the introduction of new species. Fish diet analysis will also indicate which species are competing for the same prey.

To conduct an accurate diet analysis, fish must be captured using a quick, non-stressful technique. Angled fish provide good subjects for stomach analysis. Simple techniques are also available to collect stomach contents from live fish so they can be returned to the lake unharmed. To determine if fish are feeding selectively or opportunistically requires a measure of the percentage of prey available in the habitat versus the percentage of prey items in the stomach.

Fish condition is a measurement of fish well-being that indicates how well a fish has been feeding over the last few weeks. Fat fish are considered to be in good condition and skinny fish are considered to be in poor condition. If fish condition is poor, fish are not getting enough food, indicating a problem in the food supply or in feeding relationships. If fish condition is good, food supply is not limiting and fish are not having much effect in controlling prey populations.

To measure condition, fish are captured, measured and weighed. Condition is then calculated by multiplying each fish's weight in grams by 100, then dividing that product by the cube of its length in centimeters.

$$\text{Condition} = (\text{Weight in grams x 100}) / (\text{length in cm}^3)$$

Fish-condition data on most types of fish, in tables of mean-length versus mean-weight, are found in reference works such as the Shannon-Weiner Diversity Index. To evaluate fish condition in a lake, data from the lake are compared to the reference data. Average condition for largemouth bass, for example, is 1.35 and average condition for brook trout is 1.10. If the average condition of largemouth bass in a lake is 1.25, and the average condition of brook trout is 1.20, then largemouth bass in that lake are in worse condition and brook trout are in better condition than average.

Growth provides a long-term measure of population well-being. Slow growth indicates poor food, a limited growing season, or a population under stress due to poor water quality. A very high rate of growth and a falling population usually indicates over-fishing. Growth data are vital for determining how long it takes for fish to attain legal size or sexual maturity. Fisheries managers strive to maximize growth. Many of the issues faced in fish management of small lakes is devoted to correcting problems caused by minimal growth or stunting.

Length-at-age is the most common fisheries technique for analyzing the growth rate of individual fish species. Length-at-age analysis uses the **annuli** (growth rings) on a fish's scale to determine its length for each year of growth. Scale growth is proportional to body growth. Fish do not grow more scales as they get bigger, their individual scales must grow to keep the body covered, and this growth creates marks similar to annual tree-ring marks. After determining

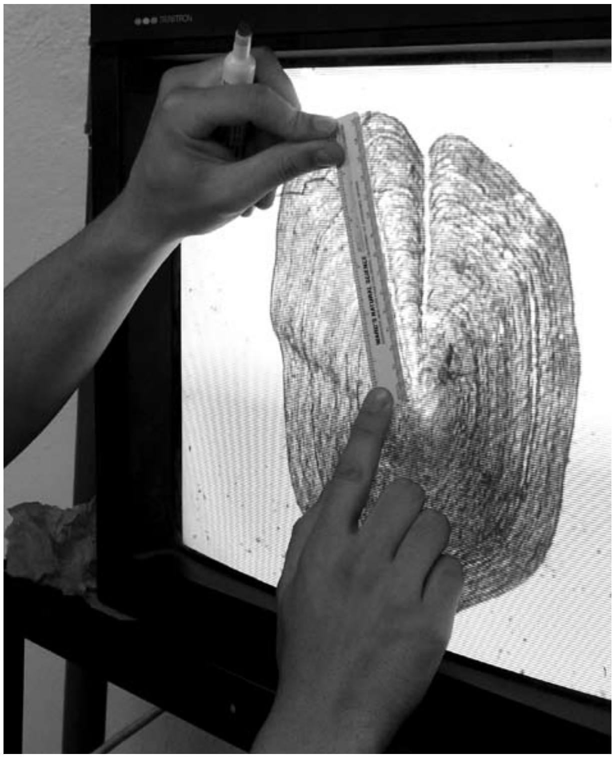


Fig. 5–7. Age-frequency distribution, growth, condition, and other fisheries measures are determined from analysis of growth rings on scales. (CREDIT: JOHN FOSTER)

how well fish within a species have grown throughout their lifetime, comparisons can be made with average growth rates for that region.

Table 5–2 shows average sizes at different ages for natural populations of fish growing in New York State. This table can be used to determine if fish in a particular lake are growing better or worse than average. It can also be used to determine how long it takes a particular fish species to attain legal size. Largemouth bass, for example, average four years to attain the legal size of 12 inches in New York State. The table can also be used to determine if growth in a particular lake is slow during certain life stages or ages.

Managing fish populations

Relatively few choices are available for direct management of fish populations compared to the number of choices available to manage fish habitat or to manage the angler. Two choices, population manipulation and lake rehabilitation, have been used extensively in the past, but are not used as frequently today. Stocking is now the most frequently used

	Age in Years										
	0	1	2	3	4	5	6	7	8	9	10
Warmwater Fish											
Largemouth Bass	.0	.5	9.0	11.0	12.0	13.0	14.5	15.5	17.0	18.0	19.0
Smallmouth Bass	2.0	4.5	7.0	10.5	12.0	13.5	14.5	15.5	17.0	17.5	19.0
Rockbass	1.5	3.0	4.5	6.5	7.0	7.5	8.0	8.5	9.0		
Bluegill	2.0	3.0	5.0	5.5	6.0	6.5	7.0	8.0			
Black Crappie	.5	3.0	7.0	7.5	8.5	9.0					
Coolwater Fish											
Walleye	5.5	8.5	12.0	15.0	17.0	19.0	20.0	21.0	22.0	23.5	25.0
Yellow Perch	1.9	2.8	3.4	4.9	5.6	6.7	8.4				
Whitesucker	2.0	4.0	5.5	7.5	9.0	11.0	12.0	13.5	14.0	16.5	18.0
Coldwater Fish											
Lake Trout	2.0	6.0	9.5	12.0	15.0	18.0	20.0	23.5	24.0	26.0	28.0
Brook Trout	2.5	4.0	5.5	7.0	9.0	12.0					
Rainbow Trout	3.0	5.5	7.5	10.0	19.0	21.5					

Table 5–2. Average sizes at different ages for natural populations of fish in New York State. (CREDIT: JOHN FOSTER)

Fig. 5–8. Common carp (Cyprinius carpio)
(CREDIT: DEC)

Fig. 5–9. Northern pike (Esox lucius)
(CREDIT: DEC)

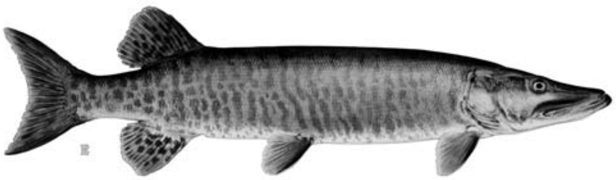


Fig. 5–10. Tiger muskellunge
(Esoc lucius cross Esox masquinongy) (CREDIT: DEC)

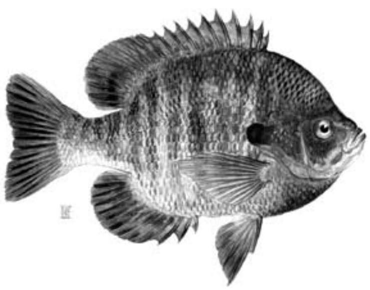


Fig. 5–11. Pumpkinseed sunfish (Lepomis gibbosus)
(CREDIT: DEC)

Fig. 5–12. Bluegill (Lepomi macrochirus)
(CREDIT: DEC)

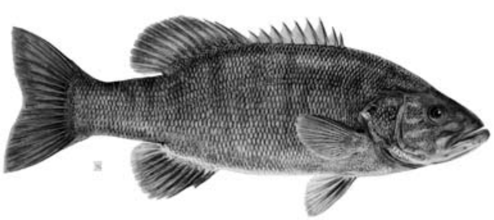


Fig. 5–13. Smallmouth bass (Micropterus dolomeiui)
(CREDIT: DEC)

method for managing fish populations. Financial support for fish hatcheries and stocking programs in most states accounts for more than half of the monies spent on fisheries management.

Fish population manipulation involves removal of undesirable species or sizes. Stunted sunfish, for example, can be netted and removed from a lake. This approach to fisheries management is often labor intensive and not cost effective. Fish culling can also be accomplished by having a fishing derby or bow-fishing tournament in which an undesirable species, such as carp, is targeted. Similar results can be accomplished by manipulating the habitat so that undesirable fish have difficulty spawning or surviving.

Lake rehabilitation is focused on killing all fish in a lake, and then restocking with desirable game fish and pan fish. Fish are poisoned with rotenone, a natural chemical that will break down into carbon dioxide and water in a few weeks. Rotenone suffocates fish and gilled invertebrates by preventing their use of dissolved oxygen. It is harmless to other aquatic organisms and to wildlife that eat the dead fish.

Lake rehabilitation may be suitable for restoring the ecological balance in very small, cut-off lakes that lack tributary streams and a surface outlet, but it seldom results in a long-term solution. Game fish are easily poisoned but some undesirable fish, such as carp and bullheads, are extremely hard to eliminate completely. Significant populations of the targeted fish often return within ten years.

Fish stocking in New York State has improved fishing and enhanced fisheries in hundreds of lakes. Stocking has helped restore brook trout, Atlantic salmon, lake trout and walleye to lakes where they had been eliminated. It has also been used to create fisheries, such as tiger musky and tiger trout that would not otherwise exist.

Most state hatchery systems are focused on rearing game fish for stocking, but forage fish or invertebrates may also be stocked to improve the forage base for game fish. The species of fish present in a small lake is generally due to chance, so adjustments to the fish community by professional fisheries biologists can improve the fishery. Opossum shrimp (*Mysis relicta*) is often stocked because it provides a good forage base for many game species such as lake trout, Atlantic salmon, walleye and musky. In coldwater lakes, ciscoes and rainbow smelt are often stocked to support Atlantic salmon populations, while sculpins, alewives and whitefish have been stocked as forage for lake trout.

Stocking can be used to control stunted fish populations. Many small lakes have limited fishing opportunities, but support a large forage base of stunted pan fish such as bullheads, sunfish and yellow perch. This situation may develop when game fish are over-fished, but pan fish are ignored. Stocking the appropriate predator species, such as walleye, largemouth bass, lake trout or salmon, can restore the ecological balance between predator and prey. Predation by these game fish will reduce the pan-fish population, thus making more food available to the remaining pan fish and increasing their growth and size.

Fish production is defined as the increase or decrease of fish biomass through time. It is usually measured in pounds-per-acre-per-year. Using stocking to increase production in a lake is tricky, since a lake can only support a certain biomass of fish. This level, called the lake's **carrying capacity**, is based primarily on its size, depth and fertility. There is no practical means of making a lake hold more fish. Stocking more fish than the carrying capacity of the lake allows will simply overpopulate some segment of the fish community and there won't be enough food to sustain growth.

Fisheries surveys and stomach analysis can indicate that there are empty niches available. If a lake has an area of rocky substrate and shoals, but no shoal-living fish, then stocking smallmouth bass and rock bass will not only increase production but will also create new fisheries. Rock bass and smallmouth bass will prey on crayfish and aquatic insects that had not been adequately preyed on before.

Stocking can only increase production if the stocked fish fills an empty niche, and there is enough habitat, food and shelter to support them. Otherwise, stocking a new fish species will displace an existing fish species and its population will decline. If the stocked fish supports a fishery and the displaced fish did not, some folks would call that progress.

Fig. 5–14. Largemouth bass (Micropterus salmoides)
(Credit: DEC)

Fig. 5–15. Yellow perch (Perca flavescens)
(Credit: DEC)

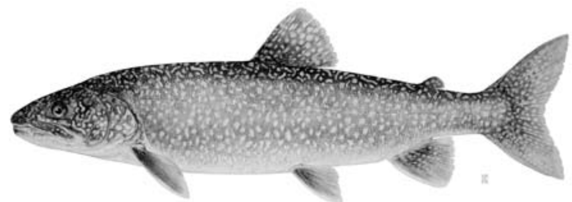


Fig. 5–16. Lake trout (Slavelinus namaycush)
(Credit: DEC)

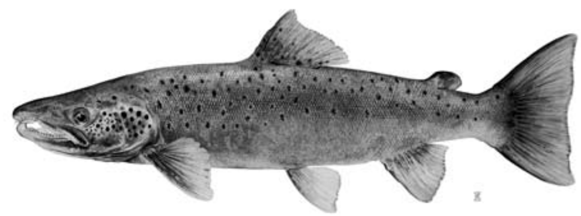


Fig. 5–17. Atlantic salmon (Salmon salar)
(Credit: DEC)

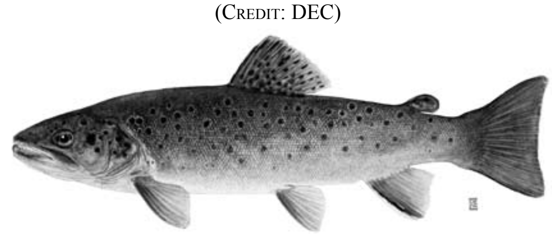


Fig. 5–18. Brown trout (Salmo trutta)
(Credit: DEC)

Fig. 5–19. Walleye (Sander vitreus)
(Credit: DEC)

Stocking can enhance an existing fishery. The single most important factor affecting the size of game-fish populations is *year-class* strength. The number of fish in a year-class usually depends on the number of spawners and environmental conditions in the spawning and nursery habitat. In some lakes, catastrophic winter- or summer-kills could also be a determining factor in survival or failure of some year-classes.

A new *year-class* or generation is born each year. After four or five years, fish from a given year-class will have grown to a size to enter the fishery. Fishing will be fantastic if these fish were part of a strong year-class. It will even be better if two or three strong year-classes occur consecutively. Conversely, fishing will be lousy if several weak year-classes entered the fishery consecutively. Lakes that have strong natural reproduction produce the most successful year-classes and thus maintain a large enough population of catchable fish to offset a few weak year-classes. In lakes where reproduction is spotty, however, stocking can be used to even out year-class variability and maintain or enhance a fishery.

Requests to DEC from anglers, clubs and associations are the greatest single factor in determining whether a lake will be considered for stocking. After receiving such a request, a fisheries biologist will survey the lake and determine if it is suited for the kind of stocking requested. If the lake in question is shallow and eutrophic, it would be futile to stock coldwater trout, even if that is what the public requests. Another important factor that will be evaluated is the forage base. Yellow perch, for example, is the best forage base for walleye. If a large population of yellow perch exists, stocking of walleye would be supported.

After a stocking plan has been devised and implemented, the fisheries biologist must periodically re-evaluate the effect of stocking to see where it might be improved. The critical question is whether stocking is improving the fishery. If stocking is not benefiting anglers, than it will probably be discontinued. Another reason to discontinue stocking occurs when natural reproduction of the stocked species reaches a level that is self-sustaining.

Fisheries biologists initially use standard rates for determining how many fish should be stocked in a lake. Standard rates for stocking are based on the size or surface acreage of a lake, lake productivity and the amount of available prey. Follow-up surveys will evaluate the success of the stocking. Data are collected on the growth and survival of the stocked fish, its effect on the forage base, and the amount of natural reproduction. Based on the survey information, stocking levels will be increased, decreased or eliminated altogether.

Fish can be stocked as eggs, fry, fingerlings or adults. Stocking of juvenile fry and fingerling are most popular. Stocking of adults occurs in some put-and-take trout fisheries, where it is expected that fish will be caught and removed before food conditions in the lake deteriorate. Stocking fry has some significant advantages. It is cheap and more likely to result in self-reproducing fish populations, but fry are very vulnerable to predation. If a lake contains alewives, stocking tiny three-day old walleye fry in May would simply feed the alewives. Stocking two-inch pond fingerlings in July, however, lets the walleye avoid predation by adult alewives, and at the same time provides the walleye with abundant alewife fry to feed on.

Managing fish habitat

Fisheries management has traditionally focused on the top of the food chain, dealing primarily with anglers and game species. Management plans are aimed at stocking a specific game species or regulating the angler. Many fisheries problems, however, are best solved through habitat management. If the lake trout fishery is collapsing because of summer die-offs due to oxygen depletion in the profundal zone, stocking more lake trout or reducing the catch will not do much to protect the fishery. The only sure, long-term management of this coldwater fishery is managing the coldwater habitat. This entails watershed or shoreline management to reduce nutrient input, or aeration to add oxygen to the habitat.

The absence of critical habitat, such as trout-spawning habitat, can be overcome by stocking. Usually, however, habitat improvements are cheaper in the long run than continued stocking. Habitat protection and restoration efforts are the best solution to the gradual loss of important habitat. For more detailed information on watershed management, see Chapter nine, "Watershed management." Small lakes are especially vulnerable to fish habitat loss. As lakeshore development increases, naturally vegetated lakeshores are dredged for docks, covered with stones to prevent erosion, and converted into lawns and sand beaches. The water gradually becomes murkier from the increased nutrient input of septic systems, fertilizer runoff, shoreline erosion and boat traffic. Fish production is reduced because inshore places for fish to hide, feed and grow are gone due to the removal of emergent bulrushes and woody debris, and the lack of sunlight to submergent plants caused by murkier water. The great fishery and recreation that first drew families to the lake gradually deteriorates with continued growth, use and development.

The first step in reversing habitat deterioration is realizing that altering the lakeshore habitat will cause alterations in fish populations. Lakeshore owners seldom realize that the aquatic "weeds" and deadfalls they remove are essential for maintaining healthy fish populations. Fewer still are willing to give up their lawns. Fish habitat cannot be managed without understanding aquatic ecology. A simple rule is that lakes with the best fisheries have the healthiest fish habitat.

State, university or private fisheries biologists, working with local fishing clubs or lake associations, can develop a management plan to improve and protect fish habitat. They can review proposed shoreline development plans to insure that no damage is done to lake fisheries. Fisheries biologists can provide suggestions to developers and landowners for plan revisions to reduce the damage to fish habitat and populations. It is easier to protect fish habitat beforehand than it is to restore it after the damage is done.

Methods of improving fish habitat and fishing need not be expensive. Construction of artificial reefs and cover, planting lakeshore buffer strips, stabilizing shorelines, or transplanting aquatic plants to reduce erosive wave action can be easily carried out by individual lakeshore owners, conservation clubs, or public service groups such as scouts. Restoration of native lakeshore vegetation and the corresponding reduction of lakeside lawns and beaches can have significant benefits to a landowner, such as cutting maintenance costs, attracting wildlife, and improving fish habitat. See also Chapter nine, "Watershed management."

Winter-kills are massive fish die-offs that occur periodically in many small lakes. When thick ice and snow prevent light from reaching underwater plants, they stop producing oxygen and eventually die. As the dead plants decompose and surviving plants continue to respire in the absence of sunlight, dissolved oxygen in the water is depleted and fish die. The largest fish are often the most vulnerable to winter-kill. It may take four years or more for the surviving young-of-the-year to grow to a size that will restore the fishery. Winter-kills are most common in highly fertile lakes and the solution is to add oxygen via an **aeration** system. Aeration prevents ice from forming, lets in light, facilitates gas exchange, adds oxygen, mixes the water column and cools the lake. Fisheries biologists can make recommendations to lake associations or conservation clubs on the placement and types of systems that would work best for a particular lake.

A high nutrient level does not always translate into high fish production. Lakes can actually be too fertile to support good populations of game fish. The phytoplankton and plants fertilized by nutrients, which usually provide food and oxygen to the lake, consume oxygen on sunless days or when they die and decompose. Decomposing plankton and plants in deep lakes can eliminate production of coldwater fish such as lake trout, whitefish and salmon. Very fertile, shallow lakes can have massive fishkills when plant respiration depletes oxygen on cloudy, windless summer days.

Excessive nutrients fuel massive algal blooms, which deplete oxygen needed by fish and aquatic invertebrates. The best long-term solution is identify nutrient sources and then to control nutrient input. Common nutrient sources are eroding lake or stream banks, runoff from lawns and farms, and leakage from septic systems.

Some fish species such as carp and bullheads aggravate habitat degradation by stirring up deposited sediment loaded with nutrients. While control of these fish can result in a short-term fix, the long-term solution to improving fishing in lakes with excessive nutrients is the reduction of nutrient inputs to the lake. Frequently, reducing these inputs requires a watershed-wide approach. Definitions and testing techniques for nutrients are discussed in Chapter four, "Problem diagnosis." Input control is discussed in Chapter nine, "Watershed management."

Maintaining brushy, tree-lined stream banks can help filter out sediments and reduce nutrients. The added benefit of shade to keep the water cold is essential to maintaining brook-trout or brown-trout populations in most small lakes. The addition of **riparian** or shoreline vegetation, woody debris and boulders will reduce streambank erosion and siltation and the deepening and scouring of streambeds, and will provide shelter for spawning fish and fry.

Turbidity interferes directly with sight-feeding fish, clogs their gills and smothers their eggs. It also limits the habitat available to littoral-zone fish by reducing the depth at which submergent plants can occur. Turbidity reduces water clarity, blocks sunlight, and limits the production of plankton and submergent plants, reducing the production of invertebrates and fish. If the source of the turbidity is tributary streams, improvement in water clarity can only be accomplished by developing and implementing a watershed management plan. If the source of turbidity is lakeshore erosion, then planting riparian and emergent lakeshore plants has been shown to be the best solution.

Increased shoreline development, and waves from wind and boat traffic also causes shoreline erosion. If banks are steep, construction equipment can be used to create a gentle slope before planting trees and shrubs. Boulders and rip-rap stones can be placed at the base of an eroding bank to anchor the soil until plantings can become established. Planting emergent vegetation along the edge of the lake can also help stabilize eroding banks, and buffer strips of trees help filter out nutrients as well as hold soil in place.

Moderate levels of aquatic vegetation are essential to most fish communities. Aquatic vegetation shelters young fish and provides food and substrate for prey organisms. Excessive vegetation, however, interferes with fishing, upsets predator-to-prey balance, and causes dissolved oxygen problems. Aquatic plants can be controlled by stocking herbivorous organisms such as grass carp, snails and crayfish. Carp and bullheads uproot plants and increase turbidity, thus reducing plant growth. Other solutions include herbicides, water-level manipulation, or cutting and harvesting. See Chapter six, "Aquatic plants" for detailed information on aquatic vegetation management.

Most forage species use inshore weedy areas as spawning and nursery habitat. Some unwanted species such as carp, also spawn in shallow water. Dropping lake water levels during spawning of carp or sunfish in early summer can expose their eggs and reduce their reproductive success. Dropping water levels in the early fall can force forage fish from cover, increasing their vulnerability to predation by game species such as walleye and bass.

Most small lakes have limited spawning habitat, and reproduction for important game fish because of the size or quality of the available habitat. If lake trout and walleye spawning habitat is limited, adding gravel on a shallow offshore shoal may be all that is needed. Emergent wetlands are the spawning and nursery habitat for pickerel, pike and muskies. Emergent wetlands are also critical to the survival of forage species such as killifish. The addition of bulrushes may be all that is needed to increase production of these species.

Tributary streams provide spawning habitat to trout, smelt, walleye and other lake species. If dams, and culverts obstruct access to the spawning habitat, inexpensive fish ladders can be installed to provide safe fish passage.

Fish habitat can be limited by a lack of oxygen in deep waters. If deep waters become anoxic, or oxygen-depleted, destratification or aeration will significantly increase fish habitat. Enlarging the profundal zone area with sufficient dissolved oxygen increases the available habitat for deep-water species. This process can bring bottom nutrients to the surface where they can be utilized by phytoplankton and rooted plants, which also encourages fish production.

The critical habitat requirement for shoal-living fish, such as rock bass and smallmouth bass, is structure or cover. Many other fish, such as walleye, yellow perch and largemouth bass, are also attracted to these habitats. They can easily be constructed or restored in the winter by piling field stones or boulders on the ice above 10 to 15 feet of water. Sunken trees also restore natural structure. Periphyton (aufwuchs) will grow on these artificial reefs increasing production of food for fish, and provide habitat for fish and invertebrates. The term *aufwuchs* refers to the fuzzy-looking, slimy, green coating of algae, diatoms, protozoans, bacteria, and fungi seen on underwater objects.

Managing the angler

A major approach to fisheries management is to manage the angler. This usually takes the form of education and regulation. Education about the fisheries ecology of a particular lake can be provided by state, academic and private fisheries biologists. This is best accomplished through formal reviews and question and answer sessions at meetings of local lake, angler or conservation associations. State fisheries management agencies, such as DEC, have a range of angler management regulations that can be offered to local anglers, or conservation and lake associations seeking ways to improve fishing.

Education to adjust expectations

Anglers, lakeside property owners, and other stakeholders often have their own, very different expectations of a fishery. Anglers prefer deep, coldwater lakes containing game fish, such as trout and salmon, and pan fish, such as ciscoes and whitefish that require considerable equipment and expertise to catch. In many deep, coldwater lakes, however, most property owners would simply like to take their family out for a few hours of fishing, or to catch dinner. A shallow, productive, warmwater lake would be better suited to this expectation. Through knowledge of the ecology of the fishery, stakeholders can better match their expectations to the reality of the basic ecology of their lake.

The expectations of the typical angler also need to be adjusted to the local fishery. Some anglers get grumpy when they don't catch their limit of game fish, when the fact is that their expectations are too high. On a typical day of fishing, few anglers will even catch a game fish. When interviewed, the majority will indicate that fishing was poor. In most cases, fishing is not poor. Most game fish are simply more difficult to catch and fewer in number than pan fish. That is the nature of fishing.

Otsego Lake, for example, has one of the top ice fisheries in Central New York for lake trout. On any given day, however, 95 percent of lake-trout anglers do not catch their two-fish limit, and 75 percent do not even catch a lake trout. This might be annoying to many ice anglers, but from a broader perspective, it is not a negative outcome. There simply aren't enough fish for everyone to catch their limit. If every ice angler caught their limit on a typical weekend, the entire population of keeper-sized lake trout in Otsego Lake could be wiped out!

Ecology

Anglers seldom understand their role in maintaining the ecosystem balance of a small lake. As fishing increases and anglers remove more game fish, the number of predatory fish, such as lake trout decrease. As lake trout decreases, zooplankton-eating prey fish such as alewives increase, because fewer lake trout are feeding on them. As zooplankton-eating fish increase, zooplankton decrease. As zooplankton decrease, phytoplankton increase and the lake turns greener and greener. Lake water can also turn green from imbalances that start at the bottom of the ecosystem. If nutrient input from runoff increases, nutrient levels in the lake increase. This provides food for phytoplankton, increasing their population, and turning the water green.

Fisheries programs often become very focused on game fish, disrupting the ecosystem balance of small lakes. We know that changes in one part of a food chain will affect other parts. If only bass are removed from a small warmwater lake, bass populations decrease, while sunfish populations increase because of reduced predation. Sunfish populations overrun their food supply, their growth stunts, and they become so numerous that they successfully prey on bass eggs and fry. To maintain ecosystem balance, fisheries biologists have determined that anglers should harvest four to five pounds of sunfish for every pound of bass harvested.

Fisheries regulations

Fisheries regulations focus on the major areas of seasonal access, types of fishing gear allowed, and species harvest limits. Regulating fishing seasons is the most commonly used method for limiting access, and enables fisheries managers to limit access when fish are most vulnerable. Protection during spawning seasons is the most common use of this type of regulation. Season regulation can also be used to protect fish during migrations, or when water temperature is stressful to fish. One example is prohibition of trout fishing in the Beaver Kill, from Iron Bridge at Horton downstream to the first Route17 overpass from July 1st through August 31st when trout are under stress during the hottest part of the summer and vulnerable to over-fishing. For a similar reason, a no-ice-fishing regulation eliminates access to this same fishery during the winter. Both regulations protect trout at times of the year when they are most in danger from over-fishing.

Access to small lakes is often regulated by the surrounding property owners who are able to limit physical access. A common example is a boat-launch facility owned by a marina or lake association that will only allow member boats, or only allow a daily limit of transient boats on the lake. If access is too restricted, however, DEC could decide that the lake is no longer "public" and no longer warrants expenditure of public funds for surveys and stocking.

A *no-boats regulation* may confine the fishery to shore fishing, which limits access to offshore habitats that then become a refuge for the fish. This type of regulation also protects the lake from the introduction of exotic species such as zebra mussels and plants that often hitch a ride on boats and trailers.

A *no-motor regulation* confines the fishery to inshore waters and reduces access to offshore areas, and portions of the lake far from the boat launch. This regulation also eliminates troll fishing and provides some protection to walleye and salmon stocks.

Regulating gear is another tool for managing the angler. While it is not readily obvious, all fisheries are subject to gear limits. Public fisheries are limited to angling with a specified number of hooks except for collecting bait, and some are for specialized fisheries such as smelt (see Fig. 10-1).

Fly-fishing-only is the most restrictive regulation in terms of allowable fishing gear. The intent of this regulation is to protect fish where pressure is heavy, to spread the harvest over a longer period of time, and to allow more fish to grow to a larger size. Fly-fishing-only regulations are sometimes placed on a body of water for aesthetic reasons. This type of regulation is also used on lakes where the philosophy of catch-and-release is encouraged but not required.

Baitfish use or possession is prohibited in some lakes, such as Trout Pond and Huggins Lake, Town of Colchester, Delaware County. Baitfish regulations were recently upgraded by DEC. They include a list of approved "green" baitfish, the only species that can be purchased or used in New York State. The regulations also include a number of restrictions and prohibitions concerning the possession, use and transportation of prohibited baitfish (DEC, 2008. See also Appendix F, "Internet resources"). This type of regulation protects the lake from bait-bucket introductions of non-native or invasive species of fish, plants or diseases.

Harvest regulations

Harvest limits are the focus of the vast majority of fishery regulations. A multitude of regulations govern the harvest of fish, but only the most common are described below:

Catch-and-release regulation allows recreational fishing, but eliminates the harvest of fish. It protects targeted fish species. In the case of health advisories, it also protects the angler.

Bag or daily-limit regulation restricts the number of fish an individual can possess both on and off the water. The public perception of these regulations is that they serve to prevent over-harvesting. This would only be the case if most anglers could catch their limit each trip. Since relatively few anglers catch their limit on a given trip, bag limits generally do little to protect fish populations from over-harvesting. The primary purpose of bag limits is to distribute the catch among anglers, and to prevent a few anglers from commercially fishing a game species.

Minimum-size limit regulation insures that fish smaller than a particular length will be released. The statewide minimum size limit for largemouth bass is 12 inches. This means that, except under special conditions, you may only creel bass 12 inches or longer. This regulation allows fish to mature and spawn at least once before becoming part of the fishery. It is only effective when applied to slow-maturing species.

One-over-limit regulation allows an angler to keep only one fish over a set length. The limit in Otsego Lake, for example, is two lake trout 21 inches or longer, but no more than one lake trout longer than 27 inches. This regulation limits the harvest of trophy fish and spreads the catch of large fish among anglers.

Protected-slot-limit regulation protects fish within a size range or slot. In Lake Ontario, for example, lake trout greater than 25 inches and less than 30 inches must be released. There are two purposes for having a protected-slot limit. It allows fish within that slot to grow to a larger size that might be preferred by anglers. It also protects the most successful spawners in those species where medium-sized fish produce the most offspring.

Fishery regulations can be used to develop a trophy bass or walleye fishery. Fishing pressure can be very heavy on popular small lakes near population centers. These lakes often have bass and walleye populations made up of large numbers of sub-legal fish, since fish are removed from the population as soon as they become legal size. Lakes can only produce a fixed number of pounds of fish per year and anglers may decide to impose regulations that would shift the bass or walleye populations toward larger fish. These regulations reduce the quantity of fish harvested, but can improve the quality of the fishery. Protected-slot-limit, one-over-limit, or minimum-size limit regulations that protect or reduce the harvest of midsize fish will increase the number of larger fish available for harvest in a few years.

Summing it up

New York State is blessed with many small lakes that provide convenient angling opportunities for millions of anglers of all ages. Poor fishing in some of these lakes generally results from a lack of understanding of basic fish management concepts and an unwillingness to alter practices that degrade fish habitat. Because of their size, it is unrealistic to expect small lakes to be all things to all people. The desires of local anglers and property owners must be matched with the ecology and production capabilities of the lake and its surrounding watershed to establish a realistic management plan for the fisheries.

With proper management, small lakes can provide annual crops of harvest-sized fish commensurate with their fertility and ecology. Several useful options are available to fisheries biologists, lake associations and anglers for implementing management procedures designed to achieve this result. Successful angling opportunities can be provided in small lakes with minimal effect on other uses provided the lake is properly stocked and managed.

6 Aquatic Plants: Not Just Weeds

Introduction

For a frustrated lake resident, rooted aquatic plants may all be called seaweeds, while a scientist may call them macrophytes and extol their virtues. Still others hold each name in shrouded reverence, marveling at the gentle swell of the purple bladderwort or the primitive majesty of the horsetail. Yet although each person may view the plant kingdom with unequal parts idolatry and contempt, all those who spend time around lakes share a core set of reasons for understanding aquatic plants.

This chapter focuses on strategies to minimize the impacts of excessive aquatic plants. The term "minimize" is appropriate because eradicating water weeds is neither practical nor wise. Aquatic plants will grow wherever light reaches the lake bottom. Most have reproductive structures (seeds, roots, rhizomes, etc.) that cannot be fully exterminated. The goal of management is to minimize the impacts of invasive plant populations, and the impacts of nuisance growth.

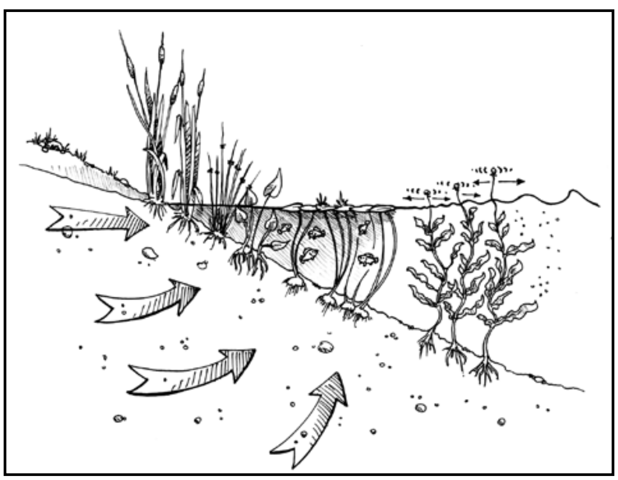


Fig. 6–1. Rooted aquatic plants, called macrophytes, reduce erosion by dampening wave action, sheltering young fish, supplying food for ducks and providing homes for creatures at the base of the food chain.
(Credit: Chris Cooley)

Aquatic plants in the ecosystem

All aquatic plants should not be removed, even if that were possible. They play an essential role in a healthy lake ecosystem. Boaters with clogged props may consider all aquatic plants to be "weeds" and curse their existence, but lakes devoid of aquatic plants might as well be swimming pools. They may be recreationally pleasing, but functionally and aesthetically they are bleak. Wetland and aquatic plants provide many benefits and ecosystem services:

- forests of plant stems and leaves provide protective nursery areas for small fish, tadpoles and other aquatic organisms;
- networks of roots help bind the sediment and prevent erosion;
- leaves shade and help cool the water;
- plant stems absorb the energy of waves, translating it into movement of stems and leaves, and reduce erosive power at the shoreline;
- roots throughout the shoreline sediments intercept groundwater flowing from upland areas and filter out nutrients and other contaminants; and
- plants produce oxygen which keeps the water healthy for fish and other animals.

Removal of plants may have undesirable consequences. Some uses of the lake, such as fishing, require a healthy population of plants. Weed-free lakes may not support potable water usage since aquatic plants filter pollutants out of the water. Efforts to drastically reduce plant populations frequently cause conflicts among lake users, even when anglers, swimmers and property owners all agree there are too many weeds. Part of plant management consists of balancing differing needs.

Preparing for action

Developing a plan

An aquatic plant management plan first defines the goals and the steps required to achieve those goals. Ideally, it is set within the context of broader lake management planning, including water-quality improvement, fisheries management, and a multitude of other objectives. In many New York State lakes, nuisance aquatic plant growth is often the trigger for the development of a lake and watershed management plan (see Chapter eleven, "Management plan development").

Aquatic plant management plans can be developed in different ways. Some lake groups consult experts to properly identify the offending plant(s), present strategies to effectively control them, and lay out a process for implementation. Other lake groups take on these tasks from within, sometimes assigning the task to a single (very unlucky) person.

Regardless of the means to the end, experience demonstrates that all affected parties need to be actively involved. Building consensus about "How much is too much?" is an important step in setting aquatic plant-management goals and choosing strategies. Though not always easy, building consensus for a plan of action is crucial for success. Consensus building is not necessarily about getting everyone to agree. It is about getting everyone to work together toward a common goal despite strongly varying opinions about how to get there.

Aquatic plant identification

To manage plants, it important to know what plants are there. Identification is critical because many strategies for controlling nuisance weeds only work for specific aquatic plants. The seed banks of naiads and some varieties of pondweeds (*Potamogeton sp.)* can tolerate the arid and icy conditions associated with winter water-level drawdown. The populations of these plants may actually increase after a drawdown at the expense of other plants that reproduce vegetatively. Grass carp *(Ctenopharyngodon idella)* like the taste and texture of some plants but not

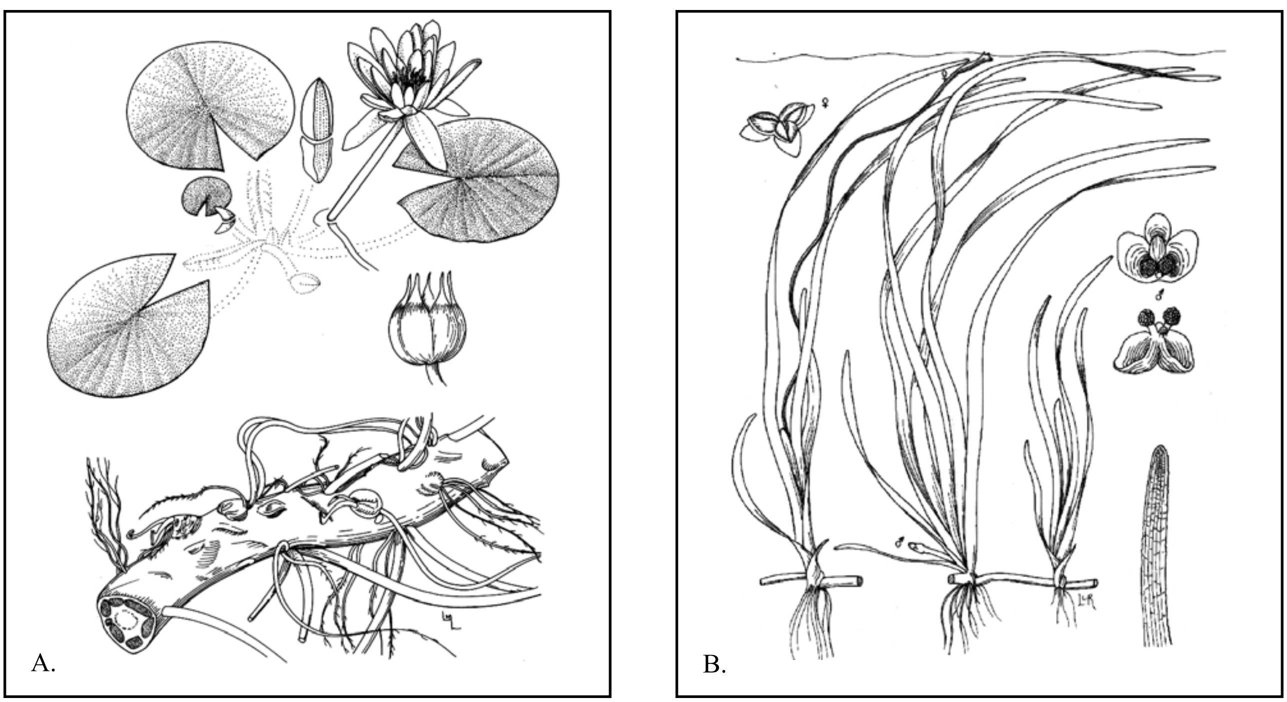


Fig. 6–2. Different plants require different management strategies. A. Water lilies (Nymphaea sp.) and other plants with extensive root systems are not easily removed by hand harvesting. B. Eel grass (Vallisneria sp.) is an example of a plant with weak roots that can easily be removed. (CREDIT: UNIV. OF FLORIDA)

others, and their preferences are unpredictable and inconsistent. Plants that are strongly rooted, such as water lilies (*Nymphaea sp.)* and hardy Eurasian watermilfoil *(Myriophyllum spicatum)*, derive the majority of their nutrition from the bottom sediments, and respond to treatments differently than plants such as coontail, bladderwort and eel grass that are weakly rooted and absorb nutrients from the surrounding water. These examples illustrate the importance of carefully identifying the nuisance plants so that appropriate management strategies can be selected. Plant identification skills are also needed to conduct an aquatic plant survey of the lake, a topic discussed in Chapter four, "Problem diagnosis."

Who's in charge?

It is important to identify the regulatory oversight and to recognize the regional variability that occurs in both regulation and environmental sensitivity to different plant management strategies. Don't waste time selecting plant control techniques that are not likely to be permitted.

The New York State Department of Environmental Conservation (DEC) maintains responsibility in most of the state for regulating aquatic plant management under various articles within the state Environmental Conservation Law (ECL). Permits obtained through DEC are required for some, but not all aquatic plant-management tools and situations. Some tools also require the evaluation of potential environmental impact. A permit is likely to be required if a portion of a lake is classified as a wetland under ECL Article 24. The DEC regional offices can assist in determining if any portion of a lake is classified as a regulated wetland. If it is, most activities in water less than two meters (m) deep are regulated and require a permit.

Aquatic plant-management permit applications are evaluated on a case-by-case basis in each region of the state. Some regional patterns have emerged, because regulatory requirements and environmental constraints dictate some variation within the review process. This is especially true for proposals involving aquatic herbicides and herbivorous fish (grass carp). By statutory law, aquatic herbicides can be legally used on lakes within the Adirondack Park, for example, but to date no permits have been issued. This is partially due to the stronger regulatory framework protecting wetlands within the Park. On Long Island, aquatic herbicide use is also very limited, though not due to regulatory restrictions. Both regions have historically had lower incidences of aquatic plant problems and have experienced stronger public opposition to aquatic herbicide use than other regions of the state. Permit approval for grass carp also varies widely by region. Grass carp are often stocked in Long Island lakes, but less so in the Adirondack Park where wetlands protection has greater significance.

Restrictions on use of aquatic herbicides and grass carp exist in other regions as well. This includes the large number of wetland lakes in the eastern portion of Central New York, the relatively short retention, time lakes or wide rivers in the southwestern Adirondacks, and water-supply reservoirs throughout the state. In contrast, a very large number of both aquatic herbicide and grass carp permits are issued downstate. This can be attributed to the large number of weed-infested lakes and the large population base affected by excessive weed growth. In most other regions of the state, the proclivity toward issuing permits for aquatic herbicides and grass carp is neither high nor low.

Some lakes have oversight by additional agencies. For lakes where the bottom is owned by the state of New York, plant-management activities that might significantly impact the lake bottom are administered by the Office of General Services (OGS). (see Appendix C, "Who owns New York State lakes?") The Adirondack Park Agency (APA) maintains regulating authority on waterbodies within the Adirondack Park, primarily authorized under wetland regulations (specifically 9 NYCRR 578.3(n)(2)(ii) and ECL Article 24) that govern the APA and activities that could affect the region's water resources. The regulatory definition of a wetland in the Adirondack Park differs from state and federal wetland definitions. Within the Adirondacks, the shallow portion of all lakes that have emergent, submergent, floating leaf or deep-water marsh wetland plant communities in less than two meters of water are classified as wetlands. Any activity that could substantially impair the functions served by, or the benefits derived from, freshwater wetlands is a regulated activity and requires a permit from the APA. This basically encompasses all shallow-water plant-management activities on lakes within the Adirondack Park. In deeper waters, APA jurisdiction is much more limited.

Other entities may have authority over some aquatic plant-management activities. Authorities that regulate water level in the state, such as the New York State Canal Corporation and the Hudson River-Black River Regulating District, may dictate whether water level in feeders to the canals or larger river systems can be manipulated for aquatic plant management. Such authorities have control of water levels in many New York State lakes. Other government agencies that possess regulating authority include the:

- U.S. Army Corps of Engineers for "navigable" waters, and for the upstate reservoirs designated as feeder lakes for the Erie/Barge Canal;
- New York State Department of State for "wetland" lakes with direct connections to designated coastal areas;
- Lake George Park Commission, Saratoga Lake Protection and Improvement District, and local government agencies with delegated responsibilities from DEC for regulating wetlands;
- New York State Office of Parks, Recreation, and Historic Preservation (OPRHP) for those lakes and ponds that have state park land; and
- Departments of Health (statewide and county) often provide input on permit applications for projects that may affect potable water, such as some aquatic herbicides.

The local or regional office of these agencies should always be contacted to determine whether they have regulatory authority over a proposed lake-management activity and whether a permit is required.

An ounce of prevention

There remain many unanswered questions about how, why, and where aquatic plants will grow, but it is quite clear that exotic plant problems start from a single plant, seed or fragment from a distant plant bed. The best control strategy for non-native nuisance plants is prevention. If the plant isn't in a lake, there is no need to develop control methods. Even in lakes that are already weed-infested, the arrival of new or hardier exotic plant species might cause worse problems.

New introductions of plants are often found near boat launch sites. Propellers, hitches, and trailers frequently get entangled with weeds and weed fragments. Boats not cleared of exotic fragments after leaving a lake may introduce plants to another lake. Bilge or bait-bucket water may contain traces of exotic plants or animals. They should always be emptied and washed before moving from one lake to another. Bait buckets should be emptied in the trash, not in the lake.

Boater education and inspection programs are useful and have been utilized at boat-launch sites in several locations in the state. Lake associations provide handouts to boaters about the link between boats and the movement of invasive exotic plants. Signs posted at boat launches by DEC and advocacy groups encourage boaters to do self-inspections and remove any hitchhikers. These signs provide pictures of the most significant invaders, most often water chestnuts, zebra mussels, and Eurasian watermilfoil. They also highlight hot spots on boat props and trailers where straggling plants may cling, and the proper methods for removing and disposing of them. Volunteers may be trained to conduct inspections of boats and trailers entering or leaving the lake to make sure all plant fragments are removed. Lake stewards have been posted at boat launch sites in Lake Champlain, Lake George, Lake Placid and at several locations through stewardship programs led by Paul Smiths College and the Adirondack Student Conservation Association (SCA).The most extensive programs add boat-wash stations, ranging from simple hoses to pressurized hot washes, to remove both nuisance plants and **veligers**, the larval stage of the zebra mussel.

Invasive species can be introduced in other ways. Ducks and other waterfowl often unwittingly transport plants from lake to lake. Since they more often encounter canopy-forming plants such as watermilfoil and water chestnut, the fragments and seeds from these exotic plants are common hitchhikers. So feeding the ducks can effectively feed invasive plants to the lake. Many exotic plant species can be readily purchased for household fish tanks or water gardens. Prevention depends on education programs, in the absence of stricter federal or state laws that ban or restrict the sale of these plants. At present, only the planting or transit of water chestnut *(Trapa natans)* plants and seeds is prohibited within New York State. The New York Invasive Species Council, however, is developing a four-tier classification list of exotic plants and animals that will ultimately provide a framework for prohibiting or restricting the introduction of potentially invasive organisms, including those provided through the nursery trade.

Fig. 6–3. Informational signs about exotic invasive plants can be posted at boat launches to educate boaters. It is important for boats, trailers and equipment to be inspected and cleaned before launching. (Credit: DEC)

Rapid response

The best chance for control of exotic plants is when they are first detected and then removed before becoming established. Complete eradication is rarely possible even when the plant exists as a small isolated patch. Once the population is extensive, limiting its expansion becomes more difficult. Where invaders have thrived for decades, nuisance plant communities will probably remain forever, and will require ongoing management. But in some lakes, and even in a few regions of the state, some invasive species have not yet established footholds. The early detection and rapid response to pioneering invasions of exotic aquatic plants can prevent the unwanted spread of these plants and the ecological and recreational problems associated with their domineering presence.

Early-detection networks of trained volunteers can be very effective in identifying newly introduced aquatic plants and implementing a rapid response plan to remove the offenders. Early detection and rapid response works best in areas where invasive species have not yet established firm footholds. Many lakes in the interior of the Adirondack Park, for example, remain free from invasive exotic plants, and neither Eurasian watermilfoil *(Myriophyllum spicatum)* nor water chestnut *(Trapa natans)* have established a significant presence in Long Island. Water chestnut is mostly restricted to the corridors associated with the Hudson and Mohawk Rivers and Lake Champlain.

Accurate plant identification is critical for effective early detection and rapid response. Some invasive plants, such as water chestnut, can be readily identified with minimal training. Some invasive plants are more difficult to identify in their early stages. Some plants, such as curly-leafed pondweed *(Potamogeton crispus)*, have early growing seasons that do not correspond to the recreational season in New York State, or the plants grow in deepwater habitats and are less readily detected. Eurasian watermilfoil is notoriously difficult to correctly identify due to its similarity to several other plants. It is often first observed in beds rather than as isolated plants. Even this pernicious invader, however, can be identified through careful early-detection networks.

There are problems associated with using rapid response to control plants in New York State lakes. Some management techniques simply do not work rapidly. Regulatory requirements often dictate a permitting timetable measured in months or even years, rather than days or weeks. Other techniques require significant capital expenditures. When new exotic animals such as snakehead are introduced into New York, the DEC holds statutory authority to intervene in rapid response control efforts, even in private waterbodies. This authority may not exist for exotic plants, impeding the use of state funds or enacting the emergency provisions of the State Environmental Quality Review (SEQR) Act to streamline the regulatory process. It is anticipated that a rapid response protocol will eventually be established for pioneering introductions of at least some invasive exotic plants, particularly those new to or not yet established in the state.

The discussion of each aquatic plant-management technique presented in this chapter outlines the expected implementation timetables for securing permits and grants, other necessary actions, and the best timing for the treatment to be effective. When all of these tools are considered, the "simplest" strategies, such as hand harvesting, tend to be the most effective rapid-response tools in the plant-management toolbox. Model rapid response plans have been developed to dispatch new invasions in the Adirondacks and within Lake Champlain as part of the Adirondack Aquatic Nuisance Species (ANS) plan.

Plant management techniques: What works?

Weed problems have plagued New York State lakes for decades. During that time much has been learned from successes and failures, but no silver bullet has been developed. Every management strategy has some risks associated with its use in the dynamic and unpredictable biological settings of lakes. "Management" sometimes even makes the problem worse.

When choosing the most effective management techniques, the plant manager must keep in mind the factors that most influence weed growth. First and foremost, exotic species cannot grow in a lake unless they are introduced. Aquatic plants have physical requirements, including the proper sediment characteristics and water depth, adequate light transmission, and space. Some plants do not grow well in certain bottom substrates. Water depth and clarity are important because plants cannot grow if sunlight is inadequate. Management actions that decrease water depth or increase water clarity allow plants to grow in areas where they did not grow before. Management actions that increase water depth or decrease water clarity may select for plants that are light insensitive.

Space is needed since plants cannot grow on top of other plants. Some invasive species gain more space by forming dense canopies that out-compete native plants by blocking sunlight. Invasive plants then take over the vacant areas no longer occupied by their predecessors. Perhaps most importantly, invasive plants grow very well in "disturbed" environments where the sediment characteristics have been altered for a variety of reasons.

All plants, aquatic and terrestrial, need nutrients for vigorous growth. These nutrients are generally obtained from the sediments rather than the water column. Increased nutrient concentrations in the water, through leaching septic systems, fertilizer, stormwater, and other sources, will influence weed growth only when they are deposited in the sediments. Prior to sediment deposition, however, nutrients are often absorbed by algae, resulting in reduced water clarity. This gives an edge to invasive plants such as Eurasian watermilfoil and water chestnut that thrive in more turbid water. The connection between nutrients and algae is far stronger than the connection between nutrients and macrophytes. Most rooted aquatic plants are nitrogen limited; their growth may be limited by shortages of nitrogen. Algae are usually phosphorus-limited in New York State lakes. While both nutrients are provided by many pollution sources, such as stormwater or soil erosion, watershed management actions focusing on phosphorus control are more likely to reduce excessive algae than control nuisance weeds.

The core group of aquatic plant-management strategies that have been used in New York State lakes can be categorized by their mode of action:

- *physical* control strategies that impact the physical growth patterns of the weeds by disturbing the sediment, altering light transmission through the water or to the plants, or water-level manipulation;
- *mechanical* control strategies that remove the plants and root systems, such as cutting, harvesting, and rotovating;
- c*hemical* control strategies, such as herbicides that are toxic to all or selected aquatic plants; and
- *biological* control strategies, such as herbivorous fish and insects that are predators consuming enough plant matter to reduce growth below nuisance levels.

Alternatively, plant-management control strategies can be categorized as "local" or "lakewide." Local strategies can be used by an individual lakefront owner. Lakewide strategies impact most or all of a lake. Lakewide strategies require a greater consensus among lake residents and are more likely to require a permit. These categories are used to organize the remainder of this chapter, since weed sufferers are likely to find this distinction valuable in selecting a mode of action. Other factors described for each aquatic plant-management technique include the advantages and disadvantages of each method and its cost. Because prices vary with place, time and circumstance, the cost listings are relative at the time of publication of this book.

Local strategies are discussed first, because anyone can use them without a consultant, an army of permit writers, and a truckload of cash. The chapter then discusses the high tech, multi-permit, big ticket items such as mechanical, biological or chemical strategies. These more complex management activities are briefly introduced because they should only be attempted after extensive research. Unexpected consequences are noted under each management technique, at least as much as the unexpected can be predicted.

The techniques described are not specifically endorsed by New York State Federation of Lake Associations (NYSFOLA) or by regulatory agencies. This is simply a list of recognized methods for addressing specific aquatic plant problems. Additional information about each of these techniques can be found from a variety of sources, including Holdren et al., (2001); Cooke et al. (1993); and Baker et al. (1993). (see Appendix G, "References cited" and Appendix H, "Additional readings")

Local management activities

Hand harvesting

Principle

Hand harvesting is the most common plant-management technique used to control nuisance weeds in New York State. It is the only strategy that generally requires no permits in most parts of the state, no significant expertise, and little risk of side effects. It is used first, before the harvester is overwhelmed by the work, or used last after permits cannot be secured or consensus can't be reached for larger scale techniques. It is used as an interim measure until a consensus of tired arms and sore backs supports the use of large-scale techniques. It is perhaps most effective when used in concert with whole-lake control strategies, as a follow-up to prevent re-infestation or re-establishment of large beds of weeds. It is ineffective for plants with extensive root systems, such as water lilies.

Anyone can hand harvest, although only the cautious can do it well. It is comparable to weeding a garden. The entire root system must be removed by grasping the plant material from under the roots of the plant as close as possible to the sediment layer. Digging into the sediment may be needed to grasp the root crown and free the intact plant from the sediment. Side-effects, such as fragmentation, turbidity and bottom disturbance, are reduced by pulling plants slowly, and harvesting while the plants are still robust. Plants and roots should be deposited away from the shore to minimize re-infestation of the lake.

Advantages and disadvantages

Hand harvesting is an effective rapid-response tool, particularly for controlling exotic plant species such as water chestnut or Eurasian watermilfoil. It is also a useful way to prevent re-infestations following a large-scale plant-management strategy. In both situations, it is most effective when combined with a vigilant surveillance program. For target plants that do not reproduce vegetatively, hand harvesting can provide long-term control if the plants are removed prior to the formation and fall of seeds.

Hand harvesting can be conducted on a single plant or a small bed at a minimal expense, if not minimal labor. In theory, only time, patience and the amount of available elbow grease limit the area cleared by hand harvesting. In reality, it is restricted to small areas because it is so labor intensive. It is difficult to hand pull large or deep beds of plants, and inconvenient to hand pull scattered plants, although this may be the best way to prevent the expansion of single plants into small beds.

Efforts to rush the process often result in fragmentation, incomplete plant removal, and bottom

Insider's guide to hand harvesting weeds

So you wanna pick some weeds? How hard can that be? Well, if collecting a bouquet of picturesque aquatic plants, it may be very similar to gathering wildflowers from an endless meadow. If trying to prevent these pesky plants from returning or spreading, however, the process is not quite so simple. Here are some tricks of the trade that have proven successful in effectively controlling the propagation and re-growth of Eurasian watermilfoil and water chestnut, perhaps the two most heavily plucked plants.

For Eurasian watermilfoil *(Myriophyllum spicatum)* (Martin and Stiles, 2005 and Eichler, 2005):

- Each sediment type creates unique challenges for hand harvesters. Muckier sediments are easily disturbed, resulting in turbidity that can inhibit divers abilities to locate plants. Harder sediments can be rough on the divers hands.
- Beds are generally best harvested by working in from the outside edge, usually moving from greater to lesser depth to minimize disturbance of milfoil beds by boats (assuming they migrate to the harvesting site from the open water.)
- Plant stems should be removed by prying the root crown out of the sediments, rather than pulling or tugging on the stems. Divers should insert their fingers into the sediments around the root crown, which may be the size of a tennis ball for mature milfoil plants, and should exert a steady pull. It has been described as similar to pulling an onion out of the soil, although the milfoil plants have more fine roots.

For Water Chestnut *(Trapa natans)* (Samuels, 2005)

- Water chestnuts reproduce from the nutlets. The nutlets are very sharp so wear old shoes and gloves when harvesting.
- The best window for removing water chestnuts is between mid-June and mid-August.
- Plants should be flipped upside down once picked to prevent seeds from dropping. If nutlets are removed before they drop, the plants will be eliminated as a seed base for future growth. The nutlets can survive in sediments for up to 20 years so any dropped in previous years are likely to be viable. Do not remove the plants too early; new plants may crop up and produce seeds, unless re-harvested. If plants are removed later than August, some nutlets may drop off during the harvesting process since they are loosely attached to the plant by late summer.
- Since infestations spread outward from the edge of the plant beds, start removing plants from the outside and work into the center of the beds.
- Kayaks are effective for removing chestnuts due to their maneuverability through dense beds, but canoes carry more chestnut cargo.
- Plastic laundry baskets work well for holding chestnuts in kayaks. Leaf tip (self-standing) bags work well for transporting plants out of canoes or pontoons.
- Dispose of the plant in the trash or by composting on land away from shore (but watch out for the nutlets!)

disturbance resulting in high turbidity. Harvesting can create significant fragmentation and a surface "bloom" of cut plants that can migrate around the lake. Unless rapidly removed, these plant masses will migrate to the shoreline of an unappreciative downwind neighbor.

Even when performed properly, hand harvesting frequently results in the release of some plant fragments, roots or seed. These drift back down to the lake bottom and become the vegetative stock for new generations of plants. Since many nuisance plants spread vegetatively through runners and rhizomes, the inability to remove these parts can result in rapid re-infestation from beds outside the shallow range of hand harvesting. This is not an effective way to remove plants that have extensive root systems, such as water lilies.

The hand harvesters are also responsible for disposal of the weeds. Large piles of water weeds will create an unseemly, smelly mess as they decay, although deposited mounds of plants will dry into much smaller piles. Composting is a common disposal strategy, although aquatic plants are usually nitrogen poor and are not particularly beneficial gardening supplements.

Target and non-target plants

Hand-harvesting is the ultimate selective plant-management technique. It removes plants one at a time, and removes only those plants that are identified as exotic, invasive, or otherwise contributing to nuisance conditions.

Costs

The advantage to hand harvesting is that it can be done at minimal or no cost. If someone is hired to hand pull, however, the cost can exceed $1,000 per acre.

Regulatory issues

Hand harvesting is not a regulated activity in most regions of the state, although some DEC Regional Offices may require permits or approval to perform large-scale hand-harvesting. This would take the form of a Protection of Waters permit governed under ECL Article 15.

An ECL Article 24 wetland permit may be required for lakes outside of the Adirondack Park and partially or wholly encompassed within wetlands. Large-scale hand-harvesting operations within the Adirondack Park require an APA permit. A wetlands permit is not required if the hand harvesting:

- is conducted only on an individual's property, or with the permission of the property owner, or is done by individual shore land owners adjacent to their shoreline;
- is conducted by hand in open water;
- leaves at least 200 square feet (ft^2) of contiguous, indigenous wetland vegetation in the immediate vicinity of the owners shoreline;
- does not involve more than 1000 ft^2 of native freshwater wetland plants;
- does not involve rare or endangered species;
- involves no **pesticides** or any other form of aquatic plant management, including mechanical plant harvesting methods or benthic barriers;
- involves no dredging, removal of stumps or rocks, or other disturbance to the bed and banks of the water body; and
- the activities are not a part of a lakewide harvesting program by individuals or groups.

History and case studies in New York State

Hand harvesting has a long history of use in New York State. It is likely that nearly every lakefront resident has performed hand harvesting, though not necessarily with the care and thoroughness needed to be effective. Hand harvesting has successfully controlled small patches of Eurasian watermilfoil in Lake George, Mountain Lake, Indian Lake and Lake Colby. Studies conducted in Chautauqua Lake have shown a long-term reduction in Eurasian watermilfoil beds in small areas after uprooting of plants through hand harvesting. Small beds of water chestnut have been controlled by Boy Scout groups and private citizens in Oneida Lake and Sodus Bay. Most of these efforts have successfully controlled the targeted plants, but continued efforts have been necessary to prevent re-infestation.

Diver harvesting

Principle

Scuba divers will be required for hand harvesting large plant beds, or for plants growing in water greater than a few feet deep. As with all hand harvesting, divers also need to pull out the roots. When done properly, this should not significantly disturb the substrate. If done incorrectly, it can create sediment clouds and cause water-quality problems.

In the simplest situations, diver-harvested plant materials are placed in mesh bags and taken away from the lake. More extensive diver harvesting uses a suction hose in a process referred to as **suction harvesting** or **diver dredging.** A barge with a large engine powers a dredge hose that sucks the diver-pulled and fed plant materials, rather than using the hose like a vacuum cleaner to ingest plants and sediment. The dislodged plants go into a spoils-collection basket on the barge. The basket traps the plant matter, allowing water to drain back into the lake.

Diver harvesting collects a much smaller biomass than does the large-scale mechanical harvesting operations discussed later. Only small targeted areas are harvested, and only the nuisance plants are removed. Plants can be disposed of at a site away from the lake, or dried and used for mulch or fertilizers. Disposal may be confined to small, individual sites.

Advantages and disadvantages

Divers can remove plants from between docks, in shallow water or in open water, even when a suction hose is used since the diver, and not the barge,

(Continued on page 128)

**Case study:
Hand harvesting by divers
in Upper Saranac Lake**

Lake setting: Upper Saranac Lake is a 5,200-acre lake with more than 44 miles of shoreline found near the northern edge of the Adirondack Park.

The problem: Eurasian watermilfoil *(Myriophyllum spicatum)* was first discovered in 1996, and local residents and lake users have been concerned that it may invade large portions of the lake.

Response: A privately funded control effort using benthic mats and suction harvesting with four divers was initiated in 1998 by a partnership of organizations, including the:

- Upper Saranac Lake Foundation (USLF);
- Adirondack Aquatic Institute (AAI), and Adirondack Watershed Institute (AWI) at Paul Smith's College; and
- Cedar Eden Environmental, LLC.

This three-year effort achieved local control of large Eurasian watermilfoil beds primarily in front of state lands, which comprise nearly 50 percent of the lake shoreline. It resulted in the annual removal of about 50 acres of Eurasian watermilfoil across three to four miles of shoreline, at an annual cost of about $60,000. This level of effort was insufficient to prevent the spread or re-establishment of the plant. The benthic barriers and harvesting kept plant densities from being high enough to consider other control options for managing extensive Eurasian watermilfoil beds. In addition, political considerations prevented the use of some techniques, such as aquatic herbicides.

A more extensive, three-year harvesting and benthic matting program was initiated by USLF in May of 2004 to reduce Eurasian watermilfoil to acceptable levels, although additional work continued into at least 2008. Benthic barriers were placed on the lake bottom in the middle of May. Based on the experience of other large-scale, diver-assisted harvesting programs in other New York State lakes, a crew of 20 divers was assembled two divers for approximately every 500 acres of lake area. All were experienced and certified divers who were trained in a one-day session involving plant identification and safety. Additional in-water training covered advanced Eurasian watermilfoil identification and removal techniques. Divers were divided into four teams, each with an experienced dive leader to coordinate diving operations. Day-to-day direction and decision making was conducted by Crew Chief Tim LaDue, with additional volunteer resources provided by the Upper Saranac Lake Association and USLF. Additional resources used to support this hand-harvesting effort included 10 "top-water" team members, four dive platforms boats, two tank dive boats, dinghies, kayaks, and a patrol boat.

Divers harvested Eurasian watermilfoil plants five days a week for 55 days, starting on June 1st and ending August 15th. The divers hand-pulled plants in a systematic path based on wind direction, traffic patterns, existing growth and anticipated flow and control of fragments. Team members tracked locations with global positioning system (GPS) units, recorded detailed survey information about the presence and density of Eurasian watermilfoil and native plants, and transported bagged Eurasian watermilfoil to a remote location.

The project costs for 2004 were approximately $535,000, or approximately $200-per-acre of infestation. Labor costs were about $1,000 per hour, and constituted about 75 percent of the overall project cost. The project managers devised a unique compressed air-distribution system. It was used to reduce the extensive financial and logistic overhead cost associated with supplying and replenishing air tanks to such a large team of divers. This also provided a more effective means for mass plant removal in large beds. Conventional diving operations, using scuba tanks, provided greater mobility to access and remove smaller or more remote beds.

Future costs will likely be reduced since the capital costs for purchases of boats and other equipment will be lowered. It is difficult to compare these numbers to costs of other management activities, since the low to moderate density of plants targeted in hand harvesting was different than those encountered in other plant management efforts. Based on the number of divers, quantity of harvested plants and project costs, this is the most extensive hand-harvesting project to date in New York State.

Results: A three-year evaluation was completed by the Adirondack Watershed Institute at Paul Smiths College. (Martin and Stiles, 2005) Results from 13 transects surveyed around the lake in late 2004 demonstrated re Eurasian watermilfoil removal ranging from 27 percent to 100 percent of the pre-harvest plants. The majority of the sites exhibited greater than 60 percent removal. Removal rates were not closely related to either the plant densities or the number of times an area was hand harvested. Eurasian watermilfoil plants remaining at the end of the growing season resulted from either incomplete hand harvests or regrowth within the growing season. Most of this regrowth occurred in water depths between 8 and 12 feet. By 2008, the average Eurasian milfoil plant densities were less than 20 stems per acre in 15 surveyed areas, compared to densities exceeding 400 stems per acre in some parts of the lake prior to hand harvesting. August milfoil densities increased from about 120 to more than 500 stems per acre from 2007 to 2008 in an unmanaged area of the lake.

Lessons learned: This project demonstrates that hand harvesting can be effective for controlling even large-scale, Eurasian watermilfoil infestations, but control in large or heavily infested lakes requires significant resources and a well-devised plan of attack with consistent year-to-year follow up.

controls the operation. The main limit to suction harvesting is the length of the dredge hose and the length of any barge-attached surface air and safety lines for the divers.

Suction harvesting can have significant, although usually temporary, side effects. High turbidity, reduced clarity, and algal blooms can result from either the disturbance of bottom sediments, or the release of sediment slurry from the on-barge collection basket. This may reduce dissolved oxygen and impact the lake ecosystem. Sediment disturbance or removal, therefore, should be very minimal. Some less discriminating harvesters use the suction hoses to remove plants and roots by scouring the bottom, blurring the practical distinction between suction harvesting and dredging, despite the significant regulatory differences between the two techniques.

Disruption of the bottom sediments can have a deleterious effect on the animals living in the sediments and on the non-target plants living in the vicinity of the harvested area. Sediments may also contain heavy metals or other potentially hazardous materials that can be released into the water if proper precautions are not taken.

Lakeshore owner dissatisfaction may result from a slow rate of diver harvesting that fails to control their weed beds during the first year. This dissatisfaction may result in funding shortfall during subsequent years, since some of the operating funds for diver harvesting will probably come from these same lakeshore residents. They may prefer faster or less costly methods that may have more significant ecological side effects.

Target and non-target plants

Diver harvesting can achieve selective control, although some nearby non-target plants and sediment may be removed. Some heavily rooted plants with extensive root systems, such as water lilies, are difficult to control with this method.

Costs

Diver harvesting, without the added suction dredge, is among the most labor-intensive plant management techniques available. Plants can be hand harvested by professional, experienced scuba divers at a rate of about 90 plants per hour (per diver) for an area's first harvest, and about 40 plants per hour for a re-harvested area. This includes diving time, finding and removing only targeted plants, bagging, and disposal. The entire operation costs about $0.25 to $1.00 per plant, or upwards of $400 to $1,000 per acre, based on a "typical" density of aquatic plants in a lake.

The cost greatly increases when suction harvesting equipment is added, since the machinery costs about $20,000 to $30,000. The most significant cost is labor due to the slow rate at which diver dredges operate and the skilled labor required. Suction harvesting often requires at least three experienced specialists; one barge operator and at least two scuba divers. This adds an additional $500 to $1,000 per-person-per-day to the cost of the operation. Depending on the plant density, a one-acre site could take from 2 to 40 days to dredge or from $1,000 to $25,000 per acre, exclusive of the equipment costs.

Regulatory issues

Permits are not required for small-scale hand harvesting by divers working without a suction dredge. If suction is used only for plants and not sediment, some DEC regions will not require permits. Suction harvesting involving sediment is considered dredging projects and is discussed elsewhere in this chapter. The regulations that cover suction harvesting are similar to those encountered when proposing a lakewide dredging project. A permit must be obtained from the DEC and from the U.S. Army Corps of Engineers if the lake is a "navigable" waterway. Within the Adirondack Park, the APA may also require a permit.

The process for obtaining permits can be extensive and difficult. Projects often require a public notification period. If the local community does not completely support the project, it can be delayed or even terminated. While suction harvesting does not usually command the same attention as the large-scale sediment removal dredging projects, the potential for public disagreement must still be considered.

History and case studies in New York State

Suction harvesting projects have occurred with some success in Lake George, East Caroga Lake, and Saratoga Lake. The higher cost and more significant permit issues encountered in many regions of the state, as well as the need for highly trained personnel to operate the hoses and the boat, have precluded the extensive use of this technique in other parts of the state. The largest example of hand harvesting by divers without the use of suction equipment is Upper Saranac Lake (see case study page 126).

Benthic barriers

Principle

Benthic barriers, sometimes called benthic screens or bottom barriers, prevent plant growth by blocking the light required for growth. The barriers also provide a physical barrier to growth by reducing the space available for expansion and by preventing plants from germinating. Most aquatic plants under these barriers will be controlled if they are deprived of light for at least 30 days.

Barriers should be installed during low-growth periods, usually in early spring after ice-out, since dense plant growth can make installation difficult. During the summer, barriers can be applied after physical removal of the plants. Barriers are most often used around docks, in swimming areas, or to open and maintain boat-access channels.

Benthic barriers can be commercially purchased or homemade. They are usually made of materials that are heavier than water and are permeable to gases produced during the degradation of plant material. Commercial benthic barriers are made of plastic, fiberglass, nylon, or other non-toxic materials. Typical barriers from commercial vendors in New York State cover between 150 and 250 square feet. The narrow dimension ranges from 7 to 12 feet for installation in small spaces such as between docks. Homemade barriers can be opaque garden tarps with PVC pipe frames constructed to hold them in place. Barriers should be securely fastened to the bottom

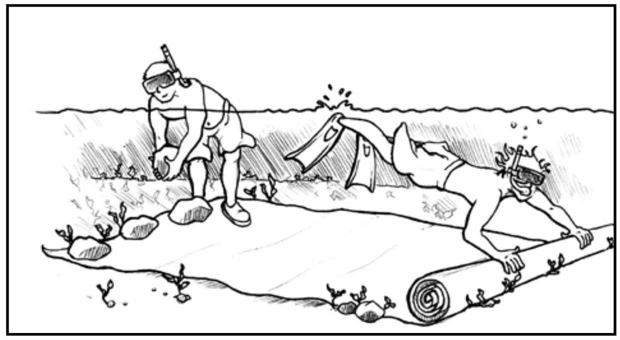


Fig. 6–4. Benthic barriers clear small areas by blocking sunlight and eliminating space where weeds can grow. (Credit: Chris Cooley)

with stakes or anchors. Rocks can be used as weights to hold the tarps down, and steel reinforcing rebar rod can be used to stake the mat in place. Wide areas can be controlled if barriers are overlapped by four to six inches.

Barriers can be installed from the shore in shallow water by two or four people. The roll can also be placed on a small boat and unwound as the boat is rowed away from shore. Scuba divers are often required to install and secure the barriers in water depths greater than six feet. Plots with steep slopes, natural obstructions, or heavy plant growth may require additional assistance.

The screening materials and anchors should be removed at the end of the growing season so they can be cleaned off and protected against ice damage during the winter. Some lake residents keep the barriers permanently anchored. In these situations, or in deeper water areas, the barriers should be periodically cleaned to remove organic material. This will prevent new plants from growing on top of the barriers. With proper maintenance, the screening materials can last several seasons.

Advantages and disadvantages

Benthic barriers can be among the safest and least detrimental in-lake physical control technique and often afford the greatest public satisfaction. They have been effectively used for many varieties of nuisance vegetation and in a wide variety of lake conditions. They can be used in any portion of the lake where rooted weeds can grow. Benthic barriers do not introduce toxic or hazardous chemicals and do not involve extensive machinery. Some materials are said to photodegrade in ultraviolet light, but the degradation products are usually innocuous.

Barriers may eliminate some species of benthic invertebrates, especially if the barriers are permanently installed on the lake bottom. It is possible that they also interfere with some warmwater fish spawning. Most other components of the food web are not adversely affected, and the ecological side-effects are insignificant outside of the treated areas, but long-term ecological impacts from benthic barriers have not been well studied.

Benthic barriers are cumbersome to place and anchor, but can be sited by laypeople almost as well as professionals. Installation and maintenance will require significant thought and time. The materials may be heavier than water, but currents and the natural buoyancy of the covered vegetation can cause the screening material to move or deteriorate. Should these barriers drift to the surface, they can be difficult to replace. Any large application will probably require additional anchoring and reinforcement. This is especially important when the screens rest on steep slopes, uneven terrain, or thick plant cover.

Buoyancy due to gas formation from degrading plants must be prevented to avoid ballooning or screen movement. These problems can be avoided by cutting small slits in the materials, large enough to allow gas escape, but not large enough to allow plant growth through the holes.

Maintenance is critical to minimizing plant regrowth due to sediment or silt deposits on top of the screens. Materials used in some benthic barriers allow root structures from deposited plant fragments to take hold. Some manufacturers claim that any new growths can be easily removed from the screen surface. Removing individual plants fragments from the barriers underwater, however, can be very tedious and will almost certainly require the use of scuba divers in deeper water. Other manufacturers recommend that their materials be removed and cleaned annually. This is not practical for large applications because of the potential for tearing, the weight of the water and sediment on the barriers, and the difficulty of re-installation. Even for small applications this can be tedious, since barriers are difficult to remove once they accumulate sediment, falling debris, newly rooted plants and any zebra mussels present in the waterbody.

The benefits of benthic barriers are thus counterbalanced by the difficulty of installation and maintenance and the overall cost. These considerations usually limit the use of benthic barriers to areas of either intensive recreational activities or strong aesthetic concern. For large areas, permitting issues may become more significant.

Target and non-target plants

It is possible to site benthic barriers to provide selective control over **monoculture,** or single-species beds of exotic or nuisance plants. If carefully sited, they can be effective for selectively suppressing an area of undesirable plants and maintaining native and controlled plant communities. Without proper use, however, this is a non-selective control strategy. If target plants are intermixed with desirable native plants, it is difficult to achieve selective plant control. Blocking sunlight and photosynthesis will kill all of the plants beneath the barriers, not just the nuisance plants.

Costs

For professional installation, the cost of benthic barriers ranges from $10,000 to $20,000 per-acre, depending on the choice of screening material. The price can vary depending on whether the application involves an initial or repeat installation. The ability to reuse the materials for several years will help to amortize these costs. Unfortunately, many lake associations cannot afford the cost of professional materials and installation, except perhaps on the most critical weed beds. Control, therefore, should be limited to small areas with nuisance vegetation, although less expensive alternatives are commonly used by non-professionals.

An insider's guide to benthic barriers

Before Installation Tips:

- When possible, plan ahead for a spring installation.
- Map areas where barriers will be installed, including dimensions of beds, bottom conditions, and slope.
- Take a photograph just in case, but DEC does not currently require permits for benthic barriers.

Construction Tips:

- Newer systems use a breathable, webbed tarp that allows gases to escape, usually available in 6 foot x 30 foot rolls. Alternatively, landscape fabrics or geotextiles are suitable for blocking sunlight and venting gases. Burlap will deteriorate more rapidly. Tarps should be vented with one inch cuts in regular intervals.
- Tarps are held to the bottom by a frame made of sun-resistant PVC pipe that has been slotted lengthwise and concrete-reinforcing rebar.
- A loop of the tarp is inserted into the slot in the PVC pipe and is held in place with the inserted rebar. The PVC pipe is then closed at both ends with glued-on caps. These bars are placed 18 or 20 inches apart, making the system quite heavy even in water.
- Alternatively, the PVC-rebar pipes can be made separately and simply laid as weights on top of the breathable tarp material.
- Wooden frames (2x2 inch boards) are another method, provided the wood is not pressure treated. Frames can be constructed 12x12 inches square, made of 2x2 inch boards. Plywood triangles are screwed to each corner and to a center brace. (Fig. 6–6) Once the tarp is stapled to the frame, another set of plywood triangles are screwed in the corners to create a sandwich that secures the tarp to the wood frame.
- For larger areas, construct multiple 12x12 inch frames that can be installed adjacent to one another. Larger frames are too difficult to install and maneuver.

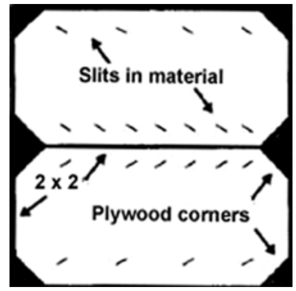


Fig. 6–5. Homemade 12x12 inch square benthic barrier constructed of 2x2 inch, non-pressure-treated wood. (Adapted from Cornell Cooperative Extension Onondaga County)

Installation Tips:

- Barriers should be installed as soon as possible after spring spawning and removed in four to six weeks, but no later than Labor Day.
- Barriers should not be installed within 50 feet of any public or private water intakes.
- Any sticks or large stones should be removed from the barrier site prior to installation.
- It takes four strong people to place these mats in position over the weeds. Bags of stone may also be needed to submerge the barrier frames during installation.
- Wood-frame barriers should be anchored with native lake cobbles placed in polypropylene sand bags. Ropes should be used to tie the bags shut and attach them to the frame.
- A diver may be needed to position tarp and weight bags over the center brace.
- Barriers installed in less than six feet of water should be marked with buoys to protect boaters, swimmers and weed harvesters.
- Warning signs should be posted in areas with heavy boat traffic to keep boaters and their anchors away from the barrier site.

Post-installation tips:

- The barrier materials and frame should be periodically inspected and maintained to prevent the barriers from becoming a navigation hazard.
- The tarp needs to be "burped" with additional vent cuts if there is any evidence of air bubbles underneath it.
- Mats can be relocated to a new area after two or three weeks to extend the area of weed-growth suppression. Weeds in the original area will grow back slowly, similar to their start-up growth in the spring. (Somerlot, 2005)

Regulatory issues

In most regions of the state, the use of benthic barriers has not been a regulated activity. There are situations, however, where approval or permits may be necessary. The U.S. Army Corps of Engineers considers benthic barriers to be “fill”, and thus require permits on navigable waters. DEC has increasingly required permits if the barriers are not removed at the end of the growing season. Regional DEC offices may require permits for benthic barriers if boulders or gravel are used and when they are placed as contiguous barriers by multiple neighbors. When a large portion of the lake bottom will be covered, approval or permits may be required to prevent disruption of fisheries habitat. The regulatory framework for this permit would be a Protection of Waters permit issued under Article 15 of the ECL.

Outside the Adirondack Park, benthic barriers are considered regulated activities within 100 feet of wetlands and adjacent areas under Article 24 of the ECL. Within the Adirondack Park, a wetland permit is required by the APA to “smother” aquatic habitats, and by extension the overlying plants (9 NYCRR Part 578 Special Provisions Relating to Freshwater Wetlands).

History and case studies in New York State

Benthic barriers have been commonly used throughout the state for many years. Most applications have been by individual lakefront residents and are frequently not documented. The application of benthic barriers in Conesus Lake has been summarized by the Conesus Lake Association (2002). The recolonization of aquatic plants following the removal of benthic barriers in Lake George is discussed in the Journal of Aquatic Plant Management (Eichler et al, 1995). In both lakes, benthic barriers have effectively controlled nuisance plants, although in relatively small areas. Other New York State lakes that have been “treated” with benthic barriers include Brant Lake, Schroon Lake, Eagle Lake, Upper Saranac Lake, and Skaneateles Lake. This technique is no doubt used in many more lakes.

Rotovating / Hydroraking

Principle

Rotovating or rototilling is a relatively new form of mechanical control for aquatic vegetation. It uses a rototilling machine to cut aquatic plant roots from the sediment and remove them from the lake. **Hydroraking** is essentially the same technique, but it uses a mechanical rake to collect and remove some of the cut material. Neither is common in New York State, although this technique has been used more frequently in recent years.

Rotovating is primarily used for vegetation control around docks and swimming areas. The machine is usually mounted on a barge and has a large rotating head. Protruding tines churn up the sediment and dislodge the roots and plants. The rotating head can be easily positioned with a hydraulic boom winch and winch cable. This is also true for hydroraking. Plants are brought up on the rotator and disposed of on shore, or the floating vegetation is raked up for proper disposal.

In areas inaccessible to the rototiller barge, the rototiller boom may be maneuvered between docks and other shallow areas. The height of the rototiller boom and winch cable determines the maximum depth for rotovating.

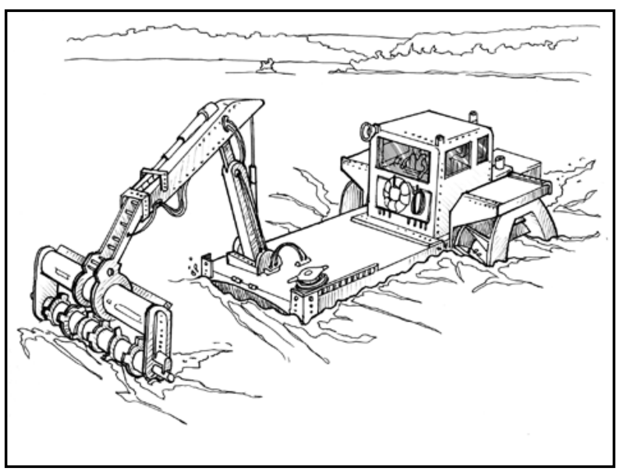


Fig. 6–6. Rotovating equipment uses large cutters to remove aquatic plants and their roots from lake sediments.

(CREDIT: CHRIS COOLEY)

Advantages and disadvantages

Rotovating and hydroraking have the potential to be more effective than mechanical harvesting. Both techniques can provide immediate relief and tend to work faster than mechanical harvesting. Since the roots, as well as the plant, are removed they provide a longer duration control strategy than mechanical harvesting.

This technique has controlled Eurasian watermilfoil *(Myriophyllum spicatum)* for as long as two years, but the introduction of plants from uncut areas may reduce this longevity. Hydroraking is more effective at controlling very strongly rooted plants, such as water lilies, and it can also remove small stumps common to artificial lakes.

These techniques usually need to be performed several times per year, depending on the density of weed beds, growth rates, and types of vegetation. New plant growth can easily occur if root stock is not completely macerated or if seeds are dispersed. There is less regrowth after rotovating than after hydroraking because of the greater removal or disturbance of root systems.

Side effects described under hand or mechanical harvesting apply to rotovating, but are greatly magnified. Provisions must be made to minimize turbidity and to remove the floating cut plants before they are dispersed downstream**.** Significant lake sediment disturbance can destroy the invertebrate and benthic habitats, and may result in localized turbidity and water-transparency problems. Freshly disturbed sediment provides an ideal habitat for colonization by fast-growing exotic species, and can skew the plant community towards invasives that actually make plant problems worse. Rotovating churns up a brew of root masses, vegetation, and other organic debris that decay in the lake. Under windy conditions or strong currents, plant fragments can spread beyond the treatment area unless they are collected immediately. This increases the potential for re-infestation of the plant species that reproduce vegetatively.

Negatives aspects associated with mechanical control of vegetation, such as heavy machinery, potentially high cost, and slow results, will contribute to potential public dissatisfaction. Floating weeds and high turbidity may be more noticeable than with other techniques. Unless the cut weeds are removed quickly, the public may perceive rotovating as a management technique that detracts from the aesthetic appeal of the lake. Even if this distraction is only temporary, it may be either untimely or be embedded in the memories of lake residents whose support is critical for the success of any lake-management strategy.

Hydroraking has many of the advantages of rotovating without as many of the drawbacks. The disturbances of bottom sediments are less significant, since the method involves less intense cutting and removal of the plants. Problems with excessive fragmentation, bottom disturbance, and impacts to bottom fauna may be less common, but still occur.

Target and non-target plants

Rotovating and hydroraking are essentially non-selective since the machinery cannot be easily maneuvered to cut individual plants. The blades cut all plants and their root material within beds of diverse plant species. These techniques have been used in New York State primarily to control dense beds of Eurasian watermilfoil where other plants are not likely to exist.

Costs

The capital costs for a rotovating operation $100,000 to $200,000. Operating costs range from $200 to $300 per-acre. One to three acres can be rotovated each day. If hydroraking or rotovating services are contracted out, the cost is approximately $1,000 per-acre. This operating cost is slightly lower than for mechanical harvesting, but the operation can take twice as long. These costs and time estimates do not consider retrieval and disposal of cut plants.

Regulatory issues

Due to the disruption of the bottom sediments during operation, the use of a rotovator or hydrorake requires an ECL Article 15 permit issued by the local DEC office. Few permits have been obtained in New York State, although it is likely that much small scale rotovating occurs under the regulatory radar screen. This may be because lake residents, and perhaps rotovator and hydrorake operators, have not always been aware of permit requirements, or they may have been negligent in applying for necessary permits. Use of these techniques is brought to the attention of regulatory agencies only through the vigilance of concerned neighbors. The APA considers rotovating to be a regulated activity if the activity could substantially impair the functions served by or the benefits derived from freshwater wetlands.

History and case studies in New York State

Rotovating and hydroraking have a limited history in New York State, and specific examples have not been documented. Rotovating is being used at an increasing frequency in small areas of much larger lakes, particularly in the Finger Lakes region and in western New York State. As these actions become more widespread and "supervised" within a regulatory context, case studies will no doubt be better documented.

Lakewide or whole lake management activities

Mechanical harvesting

Principle

Mechanical harvesting physically removes the upper portion of rooted aquatic plants, using a machine to cut and transport the vegetation to shore for proper disposal. It is often described as underwater lawn mowing. This common method of aquatic vegetation control can be used for clearing boat channels, launch sites, swimming areas, and other high use areas where weeds pose the greatest nuisance. It is often done to improve recreational use, which can be resumed immediately after harvesting. Harvesting also removes the nutrients, primarily phosphorus, stored in the plant structure, thus controlling one contributor that causes excessive rooted vegetation growth.

The two different types of mechanical harvesting operations are single-stage harvesting and multistage harvesting. A single-stage mechanical harvester cuts a swath of aquatic plants from six to eight feet in depth and from six to ten feet in width. Cut vegetation is transported by conveyer belt and stored on the harvester. The maximum capacity of the harvesting barge is usually between 6,000 to 8,000 pounds wet weight of aquatic plants. The harvester transports the plants to shore where they are unloaded to a truck for disposal.

The multistage harvester refers to two or more specialized pieces of equipment. The first machine cuts the vegetation and utilizes the plant's natural buoyancy to bring it to the surface. The cutting capabilities for the multistage harvester are usually greater than for the single-stage harvester. The cutting depth can extend as far as 10 feet, and the cutting width can be up to 12 feet. A second machine follows the cutter and rakes up the floating cut fragments for disposal.

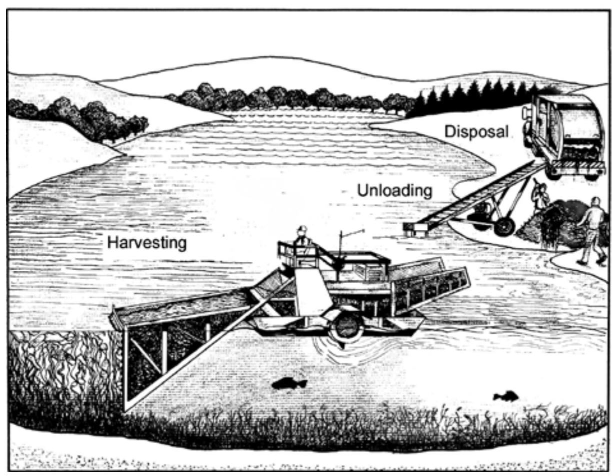


Fig. 6–7. Mechanical harvesting removes the cut weeds from the lake. Some harvesters dump the collected weeds on the shore where they are manually loaded into a dump truck. Newer, larger harvesters can offload weeds directly into a dump truck. (CREDIT: DEC)

Advantages and disadvantages

Harvesting provides immediate relief by removing the surface canopies of the dense, underwater, rooted plants that most interfere with recreational uses. Public support for harvesting can be strong because the plant canopy is the most conspicuous feature of nuisance plants and often defines the need for management.

The growing leaves, nutlets and flowering parts of strongly rooted plants are removed when the tops of the aquatic plants are cut. Weakly rooted plants may be completely uprooted. For aquatic plants that propagate primarily from seed banks or nutlets, such as water chestnut, removing the top of the plant prior to the maturation of the seeds can eliminate their growth the following year. Multiple years of harvesting may gradually deplete the bank of seeds in the sediments. Harvesting does not remove the lower portion of standing aquatic plants, which continue to provide cover and habitat for fish and other aquatic life.

Harvesting removes the nutrients stored within the plant material. It has been estimated that this may comprise as much as 50 percent of the internal (sediment-bound) load of nutrients that might otherwise become available for plant growth. In most lakes the macrophyte-bound portion of the sediment nutrient load is probably much lower.

The most significant side effect of mechanical harvesting is plant fragmentation. Plant fragments that are not picked up and removed from the lake can spread to other parts of the lake or to downstream waterbodies. The result is increased propagation of plants that spread primarily from fragments, such as Eurasian watermilfoil.

Plant communities may be altered by harvesting. If both native and fast-growing exotic plants are cut equally, the exotic plants may grow back faster and dominate the plant community. This is especially true for plants that propagate by fragmentation, and these are usually the plants originally targeted for removal. Stressed plant communities often favor the selective growth of exotic plants. As with the backyard lawn, cut plants often rebound with more luxuriant growth.

There may be negative environmental consequences of an improperly designed or executed harvest. Small, slow-moving fish can be trapped in the cutting blades or removed by the conveyer belt. If all cut vegetation is not removed, its decay may cause oxygen levels to temporarily fall, nutrient levels to rise, and short-term turbidity to occur. Even well-designed harvesting plans impact macroinvertebrates and other benthic organisms and may remove herbivorous insects that might otherwise help control aquatic plants.

The logistics of harvesting can frustrate lakefront property owners. Mechanical harvesters cannot be operated in shallow areas near docks and shorelines, but these are the very areas most residents want cleared of vegetation. Due to the slow cutting rates and relatively narrow cutting band, the harvester may need to be on the lake during most daylight hours throughout the summer. The perpetual presence of the machine is objectionable to some residents and may be an obstacle to jet skiers and water skiers.

Suitable launch sites for the harvester, or locations to park the conveyor, can be hard to locate in very shallow lakes or lakes with steep banks. If the conveyor is located away from the areas to be harvested, time is wasted traveling between the sites. Time is also lost loading and unloading the conveyer, especially when shoreline conditions prevent it from being close to the harvested area. The slowness of getting weed beds harvested can be exacerbated by unfavorable weather conditions, and mechanical breakdowns.

Many lake scientists, and an increasing number of lakeshore residents, believe that harvesters are simply very large riding mowers. Neither harvesting nor mowing will prevent re-growth, or even provide any significant long-term control. Harvesting is used to provide cosmetic control of excessive growth and to sustain popular recreational uses. The long-term benefits derived from harvesting do not approach the benefits of other cause-, or source-based management strategies. Harvesters can spread invasive weeds to places not yet colonized and create problems where none previously existed.

Harvesting remains the plant management tool of choice in many very large New York State lakes even though there are significant drawbacks. It is one of the few large-scale options for controlling weeds in lakes where herbicides are taboo, drawdown and dredging are heavily regulated, and other options are too costly.

Target and non-target plants

These techniques are generally non-selective since the mechanical harvesters cut nearly all of the plants contacting the cutting bar. The machines cannot be easily maneuvered to selectively remove target plant species within diverse beds, and they cannot be operated in very shallow water. Selectivity is limited to targeting only plant beds comprised of a single plant species.

Costs

Both capital and operating costs can be quite high due to the large equipment expenditures and the technical expertise necessary to run or repair the machinery. The purchase cost for a harvester and shore conveyor averages between $100,000 and $200,000. Some single-stage harvesters can be purchased for closer to $50,000. Leasing a harvester can reduce the overall costs unless frequent harvesting is needed, in which case, leasing costs quickly overtake purchasing cost. A typical leasing price in New York State is approximately $150 to $300 per hour. Additional set-up, transport, and sitting fees of about $300 are usually added.

A harvester can cut approximately one acre of aquatic plants every four to eight hours depending on the size of the harvester and the type and density of the plants. Acceptable control of aquatic plants may require two or more harvests during the recreational season. This increases the costs and can create scheduling challenges when outside contractors are involved.

Regulatory issues

The regulations governing mechanical harvesting vary within the State. APA requires a permit for any activity in the Adirondack Park that disrupts the plant community in a wetland, including the area within a lake that supports the growth of plants. This includes mechanical harvesting. Outside of the Adirondack Park, harvesting is not regulated except where it is conducted within or adjacent to classified wetlands. In these circumstances, an ECL Article 24 permit from the local DEC regional office is usually necessary. Certain areas should be restricted from harvesting because they are important as a fishery or because they receive little or no use. The Environmental Permits staff at the local DEC office should be contacted for further information.

History and case studies in New York State

The use of harvesters in New York State dates back at least to the 1950s. Historically a wide range of native plants, from submergent plant species such as large-leafed pondweed (*Potamogeton amplifolius*), and floating leaf plants such as water lilies, have been the target of harvesting efforts. Recently, however, most mechanical harvesting operations in New York State have targeted Eurasian watermilfoil *(Myriophyllum spicatum)*.

Fig. 6–8. Large-leafed pondweed (Potamogeton amplifolius) is a native plant once commonly targeted by harvesting operations. (Credit: Crow and Hellquist)

Case study: Mechanical harvesting in Saratoga Lake

Lake setting: Saratoga Lake is a 4,000 acre, heavily used recreational lake in Saratoga County in the foothills of the Adirondack Park.

The problem: Increased development pressure and recreational use in the 1960s and 1970s resulted in degraded water quality and impaired use of the lake for most recreational activities. More than 50 percent of the recreational users objected to the algae levels and water clarity. (Kooyoomjian and Clesari, 1973) In 1932, water clarity was about 5 meters and the lake was fully oxygenated throughout. By 1967, water clarity had dropped to about 1.5 meters and oxygen deficits began at a depth of about 6 meters. One of the inflows was locally called "Gas Brook" due to the persistent sewage smell.

In the 1970s, water-quality improvements resulted from the diversion of municipal wastewater out of the watershed, nutrient inactivation and the implementation of nonpoint source control measures on agricultural lands. These activities were funded in part by a federal Clean Lakes Project. (Hardt, et al, 1983) In response to the increased water clarity, nuisance growth of Eurasian watermilfoil *(Myriophyllum spicatum)* and curly-leafed pondweed *(Potamogeton crispus)* dominated the littoral zone to a depth of about four meters. This resulted in a shift from algae- to macrophyte-dominated system, without significant improvement in recreational conditions. However, 75 percent of the lake residents indicated that the lake was "somewhat" to "much" clearer. Water clarity did improve from about 1.5 meters in 1967 to more than 3 meters by the mid-1990s.

Response: The Saratoga Lake Protection and Improvement District (SLPID), a local management and taxing authority, oversaw the use of two mechanical weed harvesters purchased in 1984 that cut from 500 to 750 acres of nuisance vegetation per year. They operated daily from May through September. The biomass of the major macrophyte species in the lake did not experience significant change between 1982 and 1994, when an aquatic-plant survey was conducted by Darrin Freshwater Institute (DFI). (Boylen, et al, 1995) Some species were more abundant in 1982, while others were more abundant in 1994. (Table 6–1) Eurasian watermilfoil populations were substantially reduced in water depths less than about one meter but this was probably due to the winter drawdown that was regularly conducted each year.

By the early 1990s, in the midst of the harvesting program and supplemental work in shallower areas with a suction harvester, more than 90 percent of the lake residents identified rooted aquatic plants as a minor problem. This included effects due to weed decomposition and floating weeds cut by boats or harvesters. This problem was identified as significant by 40 percent of residents. About 60 percent viewed the harvesting program as successful, versus about 70 percent who viewed the sewering and drawdown conducted through the Clean Lakes Program as successful.

Plant Species	Range of Biomass, 1982	Range of Biomass, 1994
Eurasian watermilfoil	40-1000 g/m2	0-700 g/m2
Curly-leafed pondweed	0-170 g/m2	0-250 g/m2
Southern naiad	10-400 g/m2	0-450 g/m2
Eelgrass	0-40 g/m2	0-600 g/m2
Water stargrass	0-140 g/m2	0-30 g/m2

Table 6–1. Biomass of plant species in Saratoga Lake in 1982 and 1994.

The harvesters were replaced by larger, more efficient machines in the late 1990s. SLPID has been investigating an integrated approach to aquatic plant management. They have been conducting small-scale experiments since 2000 on the use of aquatic herbicides and herbivorous insects, while continuing the use of the mechanical harvesters. By 2007, large scale aquatic herbicide use was adopted as the management tool of choice.

Lessons learned: Mechanical harvesting may not result in a significant reduction in aquatic plant density or coverage, but it may be viewed favorably by many lake residents, particularly in light of what may be perceived as less desirable alternatives. For a lake this size, however, it is expensive.

In the late 1980s, the advent of the Aquatic Vegetation Control Program in the Finger Lakes region enabled many counties to purchase mechanical weed harvesters or harvesting services for use on the Finger Lakes, embayments to Lake Ontario, and some smaller waterbodies. Outside of the Finger Lakes region, harvesting has been conducted on Lake Champlain and Oneida Lake to remove water chestnut, and on Saratoga Lake, Greenwood Lake and many smaller lakes to remove Eurasian watermilfoil. (see Case study) A statewide inventory of lakes that utilize mechanical harvesters has not been compiled, largely due to the lack of regulatory oversight in most parts of the state, and therefore no paper trail of permits exists.

Dredging

Principle

Dredging removes the top layer of sediments that hold biologically available nutrients involved in exchanges and interactions with the water column. Sediment removal may improve the overall water quality in lakes where nutrient loading from sediments is a major factor affecting nuisance weed and algae growth. When the top layer of sediment is removed, so are the plants, plant roots, the nutrients they contain, and at least some of the accumulated seed bank. Dredging also serves to reduce rooted vegetation growth by increasing the lake depth, thereby reducing the amount of sunlight that reaches the bottom.

There are two basic dredging methods, drawdown excavation and in-lake dredging. During drawdown excavation, water is pumped or drained from the lake basin. The exposed mud is then dewatered (dried) sufficiently to accommodate the heavy earth-moving equipment that does the dredging.

In-lake dredging is used where it is difficult or impossible to drain a lake. Cutterhead hydraulic pipeline dredges are most commonly used. These dredges can operate anywhere on the lake, cutting to a depth of 60 feet. When the cutterhead is lowered to the lake bottom and moved from side-to-side, the rotating blades loosen the sediments, which are then transported by a dredge pump through a pipeline for discharge at the disposal site. The discharge is slurry that is 10 to 20 percent sediment and 80 to 90 percent water. The slurry requires a relatively large disposal site, designed to allow adequate residence time for the water to evaporate.

The other common type of in-lake dredge uses a grab-type bucket instead of a cutterhead. They are commonly used around docks, marinas and shoreline areas. Bucket-dredge performance is not hampered by stumps and other debris that may impede cutterhead dredges. They can be easily transported to different areas within a lake. This method removes sediment that is drier rather than as slurry. The sediment must be dumped within the radius of the crane arm, however, onto a barge or into a truck on shore. Sediment resuspension, and its associated ecological impacts, can be minimized by the proper selection of specialized dredges. Equipment selection is important because it influences the environmental impacts.

Advantages and disadvantages

Dredging has proven to be an effective control technique for many lakes to increase water depth, reduce excessive vegetation levels, and control nutrient release from sediments. It has been used for small lakes, or for only a small portion of a basin in large lakes.

Dredging is one of the few multi-purpose aquatic plant-control strategies. Sediment removal deepens a lake for recreational and navigational purposes. It can reduce hazardous substances such as heavy metals and other toxic materials in bottom sediments and ultimately in the overlying water. It can also reduce the number of organisms living in the sediment and water.

Although the benefits of dredging can persist for a relatively long time, it is probably the most difficult lake restoration technique to successfully complete. Most lake communities have not been willing to endure the extensive environmental review and permitting process. If plant management is the primary goal, other strategies should be considered first, but other feasible management alternatives for increasing the lake depth may not exist.

Dredging can have profound effects on the entire lake ecosystem. Some of these effects are temporary or predictable, but many are not. Results depend on specific lake conditions, which make it extremely difficult to predict whether this is the correct treatment for a lake. If dredging is not done properly, it can actually make lake conditions worse by causing excessive turbidity, fishkills and algal blooms. Dredging projects should be accompanied by an extensive water-quality and sediment-toxicity monitoring program.

Dredging can harm fish, not only by causing turbidity but also by eliminating the benthic organisms upon which they feed. After a lake has been dredged, it can take two or three years for benthic fauna to re-establish. It is advisable, therefore, to dredge only a portion of a lake and leave a portion in its natural state.

Disposal areas for dredged sediments spoils should be selected carefully. Disposal is not suitable in woodlands, floodplains or wetlands because the muck will blanket and kill terrestrial vegetation. A carefully engineered and diked upland area may be the best option. Disposal sites should be fenced to keep out people and animals.

Public perception of dredging is often unfavorable because it is such a drastic control technique. It is critical to involve the lake community early in the planning process. Residents who feel removed from or ignored in the design phase may turn public opinion against the project, prompt reduced cooperation from officials and cause project delays.

Target and non-target plants

Dredging removes all plants in the dredged area. Some selectivity can be achieved by limiting the depth of material to be removed, the type of sediment and the area of the lake to be dredged.

Costs

Dredging costs depend on site conditions, desired depth of excavation, available access, nature of the spoils, and disposal, transport and monitoring requirements. Treatment costs per acre of surface area cut to

Case study: Dredging in Collins Lake

Lake setting: Collins Lake is a 70-acre urban lake, in the village of Scotia within the Capital District of New York State. It is used primarily for swimming and passive recreation by village residents.

The problem: Collins Lake is considered to be the first in North America with a confirmed identification of the exotic macrophyte, water chestnut *(Trapa natans)*. The plant covered most of the lake surface in the early 1970s. Hand pulling and the use of aquatic herbicides shifted plant dominance to curly-leafed pondweed *(Potamogeton crsipus)*, another exotic plant species. The macrophyte beds eventually covered about 60 percent of the lake surface to a depth of about 10 feet. The significant recreational impacts to swimming and boating and the high sedimentation rate of one centimeter-per-year (cm/year) triggered the need to dredge the lake to the 10-foot depth of the littoral zone.

After nearly 10 years of permitting issues, the lake was hydraulically dredged intermittently from 1977 to 1994 to control nuisance levels of curly-leafed pondweed as part of a federal Clean Lakes project. Ten percent of the lake bottom was dredged, yielding over 50,000 cubic meters (m^3) of sediment.

Results: Prior to dredging, curly-leafed pondweed densities were approximately 170 stems per-square-meter (m^2) during the peak of the growing season in mid-May. Dredging reduced pondweed densities to less than one stem per m^2 in 1979. Densities were still less than six stems per m^2 by 1988. In the portions of the lake not dredged, plant densities by 1988 were about 150 stems per m^2, similar to those measured prior to dredging. By the early 1990s, Eurasian watermilfoil dominated the aquatic plant communities. (Tobiessen and Benjamin, 1992)

Lessons learned: While the dredging was successful in dramatically reducing existing plant populations, this ultimately resulted in a shift from curly-leafed pondweed to the deeper-dwelling Eurasian watermilfoil *(Myriophyllum spicatum)*. This is one of many examples of how unintended and often undesired consequences result from even well-designed projects. Lakefront residents and recreational users should be aware of the potential for a shift from one type of plant (or algae) to another in response to active management. This also shows that in-lake management, without active watershed management, may limit the effectiveness of the control measures.

Case study: Dredging in Ann Lee Pond

Lake setting: Ann Lee Pond, once known as Saw Mill Pond, is a 10-acre pond near Albany. In the late 1700s, it was used by America's first Shaker settlement for agricultural and commercial operations. In recent years, it has been used solely for non-contact recreational purposes, including fishing, ice skating, nature walks and wildlife observation.

The problem: By the early 1970s, the lake was highly productive. It had a dense surface coverage of submergent, floating, and emergent aquatic plants, including water lilies (white and yellow), curly-leafed pondweed, coontail, and common waterweed. The lake was also characterized by algal blooms and an accelerating sedimentation rate. After evaluating a number of aquatic plant management alternatives, the Albany County Environmental Management Council (EMC) authorized a hydraulic dredging project to be supplemented by a mechanical harvesting program after the dredging was completed.

Immediately prior to dredging, the typical water depth of the lake was about 0.7 meters. In 1980, about 16,500 cubic meters (m^3) of mostly organic sediment was removed from about seven acres of the lake. This increased the average depth of the lake to around two meters.

Results: Water-quality changes in Ann Lee Pond were not significant during or after the dredging operation. Dissolved oxygen levels increased, due to the removal of oxygen demand from decaying organic materials in the sediment. The density and aerial extent of water lilies decreased, but the common submergent plants became re-established after the dredging operation was completed in the fall of 1980. Curly-leaf pondweed *(Potamogeton crispus)* recolonized at levels comparable to those measured before the dredging. Coontail *(Ceratophyllum demersum)* densities decreased significantly, and common waterweed *(Elodea canadensis)* levels increased in abundance.

Lessons learned: Dredging is not likely to reduce the extent of submergent aquatic plant coverage unless the final water depth prevents sunlight from reaching large portions of the lake bottom. Dredging may shift the kinds of plants growing in a lake by reducing the density of plants, such as water lilies, that are limited by greater water depth. (Enviromed, 1982)

the typical depth of about three feet range from about $1,000 to $40,000. The latter figure represents a situation in which sediment spoils must be transported out of the area, which may be required for lakes in heavily developed areas.

Regulatory issues

The permitting process is usually lengthy and detailed. The DEC Regional Permit Administrator should be contacted as early as possible when a dredging project is contemplated. Often, the process results in the denial of a dredging permit for a variety of reasons.

Any dredging requires at least an ECL Article 15 Protection of Waters permit from the regional DEC office. APA requires a freshwater wetland permit within the Adirondack Park. Outside of the Park, the project could require additional permits if part of the dredged lake is classified as a wetland, or if sediment testing uncovers hazardous materials. In general, the permitting process under ECL Article 24 is somewhat simpler if the project removes less than 400 cubic meters of sediment. U.S. Army Corps of Engineers permits may also be required if the project takes place in a "navigable" waterway.

History and case studies in New York State

There have been a few dredging projects conducted for aquatic plant control, including Belmont Lake in Long Island for the control of fanwort *(Cabomba caroliniana)* in the early 1970s, and more recently Collins Lake in the Capital District for controlling curly-leafed pondweed *(Potamogeton crispus)* (see case study). A dredging project on Glen Lake was designed to improve water quality rather than for weed control. In river systems and shallow portions of lakes, it is most common to dredge to simultaneously clean up contaminants and improve navigation, as was done in the Great Lakes and in Cumberland Bay in Lake Champlain. Many of the original Clean Lakes projects in New York State in the 1970s involved dredging, but few of these were implemented to reduce weed populations.

Water-level drawdown

Principle

Drawdown involves winter manipulation of lake level to expose rooted aquatic vegetation and sediments to the freezing and drying action of cold air. The water level must be lowered at least three feet and the sediment must freeze to a depth of at least four inches. Snow cover may insulate the sediment and prevent freezing in mild winters. Freezing can help control weeds by loosening roots and loose organic material on the exposed lake bottom. Drawdown usually occurs between December and April in New York State.

Some species of rooted plants can be severely damaged or killed after four weeks of lowered lake levels. Some plant species are resistant to freezing and others may actually be enhanced by this technique (see Table 6–2). In general, plants that reproduce by seeds, such as naiads and many pondweeds, are less susceptible to drawdown than those plants that reproduce by rhizomes and other vegetation means. The latter includes Eurasian watermilfoil *(Myriophyllum spicatum)* and fanwort *(Cabomba caroliniana)*. Drawdown should be used every other year or twice every three years to discourage the establishment of resistant plant species. These resistant species are often the non-native or exotic plants that originally caused the nuisance conditions.

Substrate drying can limit the availability of nutrients, particularly under low oxygen conditions. Compaction of the loose, upper layer of sediment provides weed control by reducing the potential for re-suspension of the sediment and the nutrients adhering to it.

Advantages and disadvantages

Water-level manipulation is one of the most common lake management techniques. It is used not only for the control of nuisance aquatic vegetation but also for repairing dams and docks, maintaining retaining walls and erosion control structures, cleaning up the shoreline, altering downstream flow, and as part of dredging and benthic barrier techniques. Drawdown

Decrease After Drawdown	No Change or Variable	Increase After Drawdown
Brazilian elodea *(Egeria densa)*	Bladderworts *(Utricularia sp.)*	Duckweed *(Lemna minor)*
Coontail *(Ceratophyllum demersum)*	Cattail *(Typha latifolia)*	Naiads *(Najas sp.)*
Fanwort *(Cabomba caroliniana)*	Common waterweed *(Elodea canadensis)*	Pondweeds *(Potamogeton sp.)*
Hydrilla *(Hydrilla verticillatum)*	Eelgrass *(Vallisneria americanum)*	Water bulrush *(Scripus sp.)*
Milfoils *(Myriophyllum sp.)*	Muskgrass *(Chara vulgaris)*	
Robbins pondweed *(Potamogeton robbinsii)*	Water chestnut *(Trapa natans)*	
Southern naiad *(Najas quadalupensis)*	White water lily *(Nymphaea sp.)*	
Water shield *(Brasenia schreberi)*		
Yellow waterlily *(Nuphar sp.)*		

Table 6–2. An incomplete list of common submergent aquatic plants in New York State and the response of their populations to winter drawdown. (ADAPTED FROM HOLDREN, ET AL, 2001)

is a fairly simple management strategy for relatively small lakes for which water levels can be fully controlled. Public response is generally favorable due to the low cost and the winter timing that does not interfere with summer recreation.

Drawdown creates an unfavorable environment for many nuisance aquatic plant species, such as Eurasian watermilfoil and fanwort, and encourages beneficial plants. Most nuisance vegetation problems occur in the shallow littoral zone. Depending on the slope of the lake and the depth of the littoral zone, drawdown only impacts the near-shore area while maintaining sufficient volume of water to support fish and wildlife. Since no chemicals or significant mechanical equipment is used, once water levels return to normal there may be no visible changes in the lake besides the changes in vegetation densities and plant community structure.

Drawdown can negatively affect adjacent wetlands or other areas with desirable vegetation. This impact is greater on lakes with large littoral zones. The impact of drawdown on many traditional wetland plant species is variable.

The potential impacts to benthic communities can be substantial since drawdown essentially shifts their habitat temporarily from aquatic to terrestrial. While some water-level variability occurs naturally within many lakes, anthropogenic manipulation of this marginal habitat can exert significant stress on frogs, turtles and other winter mud-dwellers. For this reason, proposals for water-level drawdown will often be closely evaluated by DEC, particularly in those lakes classified as wetlands, or those that possess sensitive or highly valued shoreline or marginal habitat. Removal of shallow water vegetation used for fish spawning or shelter may affect some fish species. See Chapter eight, "User conflicts," for other potential negative effects on flora and fauna when water level is altered.

The removal of sediment-anchoring macrophytes along the shoreline has the potential to increase turbidity caused by waves, wind-induced erosion or re-suspension of sediments. Lakes with complete drawdown sometimes experience algal blooms after refilling. Sometimes new, or previously unnoticed plant species emerge that are unaffected, or even enhanced, by drawdown. Without competing species, non-native plants can flourish to the point of preventing the re-growth of native plants.

Winter drawdown can deplete oxygen, and fishkills may result, if a lake is shallow, and the sediments and inflow have a high oxygen demand. Nutrient release can also be enhanced and cause algal blooms. Hypolimnetic aeration may be necessary to mitigate these impacts.

If too much water is removed, or drawdown is followed by a period of drought, water levels may take a long time to return to normal levels. Domestic or fire-protection water-intake pipes may be exposed to the elements resulting in frozen pipes, or water levels below the intake levels. If the lake level does not recover sufficiently, recreational use of the lake could be limited for much of the summer. This can reduce both residents' acceptance of drawdown and summer revenues from recreation and tourism. When devising a drawdown schedule, it is critical to prepare for the possibility of a low-precipitation summer. Conversely, the potential side effects of drawdown may be overridden in periods of normal or high precipitation. Heavy groundwater inflow in lakes near low water tables, such as those commonly found in Long Island and in wetlands within the Adirondacks and western New York, may prevent the winter desiccation needed to impact rhizomes and other plant reproductive structures.

Concerns over water level will often dominate lake association meetings, and any discussions regarding lowering the lake level may be hotly debated. With a well-conceived plan, and some luck from Mother Nature, lake users can be rewarded by decreased weed growth and restored water levels.

Target and non-target plants

Seed producing plants are usually not as severely affected as those that reproduce vegetatively since seeds generally remain viable after freezing and thawing. Plants that reproduce by seeds sometimes increase in density or coverage after the drawdown. The effects of drawdown on specific plant species common to New York lakes is summarized in Table 6–2.

Costs

If a lake has a dam or controllable spillway, drawdown costs are negligible. If pumping is needed to further reduce the lake level, or other impact mitigation is necessary, costs will increase. The costs for initially building a dam or water-level control structure are not factored in, since such activity is not generally undertaken primarily for weed control.

Regulatory issues

ECL Article 15, Title 8 defines regulations relating to the volume, timing, and rate of change of reservoir releases. Title 8 also specifies other requirements such as monitoring, inspection, and maintenance of records. It is under this authority that the DEC issues permits for drawdown. When drawdown significantly affects navigability of a waterbody, the New York State *Navigation Law* may also apply. In addition, wetlands regulations require an ECL Article 24 permit for the use of this technology because drawdown often impacts adjacent wetlands.

Drawdown is a regulated activity in lakes within the Adirondack Park. It requires a permit from the APA if it could substantially impair the functions served by or the benefits derived from freshwater wetlands.

History and case studies in New York State

Drawdown has been commonly used on many New York State lakes, often for reasons unrelated to aquatic plant control. Drawdown for the purpose of controlling Eurasian watermilfoil has been undertaken at Galway and Saratoga Lakes in Saratoga County, Greenwood Lake on the New Jersey/New York border, and some Adirondack lakes in the Fulton Chain of Lakes. Forest Lake, in the southern Adirondacks, was drawn down to control common waterweed and native pondweeds. Lake levels in Minerva Lake, also in the southern Adirondacks, were lowered for the control of native plants. Most of these have been fairly successful, although immediate effects included colonization by a different mix of invasive plants that dominated the aquatic plant community for a few years. The dominant plants in Robinson Pond in Columbia County, for example, shifted from Eurasian watermilfoil *(Myriophyllum spicatum)* to brittle naiad *(Najas minor)* after the lake was drawn down for the benefit of fisheries habitat downstream. The shift in plant dominance reversed several years later.

Biological control

Herbivorous insects

Principle

In the early 1990s, the populations of Eurasian watermilfoil crashed in the northern end of Cayuga Lake, the longest Finger Lake. Plant community structure dramatically shifted from invasives to desirable native plants (see case study). Researchers at Cornell University determined that the Eurasian watermilfoil populations were being significantly preyed upon by an herbivorous milfoil moth, *Acentria ephemerella.* The moth is considered a **naturalized** organism, one introduced some time ago that has adapted to New York State lakes. Similar damage is inflicted on Eurasian watermilfoil plants by a native herbivorous milfoil weevil, *Euhrychiopsis lecontei,* which is present in many New York State lakes. At least 25 herbivorous insect species have been found that feed on Eurasian watermilfoil including chironomid larvae (*Cricotopus* sp.) and a genus of caddisflies (*Triaenodes tarda*). The milfoil moth and the milfoil weevil are the most studied, and perhaps the most promising, for induced Eurasian watermilfoil control in New York State.

The mode of action of these various herbivores varies somewhat. The milfoil moth lays its eggs on the Eurasian watermilfoil plants near its base. When the caterpillars hatch, they crawl up the plant and feed on the growing tips (meristems). Research suggests that one moth per stem of Eurasian watermilfoil is necessary to significantly impact plant populations. The adult moth life stage lasts a mere two days, during which the males mate with the mostly wingless females. The female then swims down to lay her eggs on the lower plant leaflets. Two life cycles are

Case study: Herbivorous insects— Natural control in Cayuga Lake

Lake setting: The 43,000 acre Cayuga Lake is one of the largest lakes in the state and is the largest Finger Lake by surface area.

The problem: Eurasian watermilfoil *(Myriophyllum spicatum)* was first reported in the lake in the 1960s, grew abundantly after Hurricane Agnes in 1972, and dominated the aquatic plant community until the early 1990s.

Response: Aquatic vegetation surveying conducted from 1987 to the late 1990s identified a crash of Eurasian watermilfoil populations in the early 1990s. While mechanical harvesting supported by the state-funded Aquatic Vegetation Control Program occurred in several locations in the lake during this time, the Eurasian watermilfoil decline was attributed to herbivory caused by the milfoil moth, *Acentria ephemerella*. Native plant populations in the lake increased dramatically over the same period. No measurable change in overall aquatic plant biomass resulted after the onset of milfoil moth herbivory. After the insects arrived, the total biomass dropped in the northwest end of the lake to 70 percent of the original biomass, but tripled in the southwest end. Overall plant populations were found at a greater density in the southwest end, and a lower density in the northwest end of the lake. (Table 6–3)

Eurasian watermilfoil populations steadily decreased in the northwest end of the lake and stabilized at very low densities (less than 0.5 grams per square meter) after 1995. Eurasian watermilfoil populations in the southwest end of the lake rebounded slightly by the late 1990s, but biomass remained less than 10 percent of the overall aquatic plant community throughout this “recovery” period.

Lessons learned: This case demonstrates the potential for control of Eurasian watermilfoil by these insects. (Johnson, et al, 2000)

generally completed during the summer. The caterpillars over-winter on plants near the lake bottom and begin actively feeding the next May.

The milfoil weevil feeds on more of the plant than the meristem. Adult weevils swim and climb from plant to plant, feeding on leaflets and stem material. Females lay two eggs per day, depositing each on a different Eurasian watermilfoil meristem. Once hatched, the larvae first feed on the growing tip. They then mine down into the stem of the plant and consume internal stem tissue. Weevils pupate inside the stem, and adults emerge from the pupal chamber to mate and lay eggs. Adults travel to the shore in autumn where they over-winter on land. The weevils generally spawn two to four generations-per-year, and two to four weevils per stem are required to significantly damage the Eurasian watermilfoil plants.

There are differences between the effects caused by milfoil weevils and moths. Weevils appear to start controlling plants in early summer. They reduce the height of plants in the manner of a mechanical harvester. Plants often return after the weevils depart the lake in the fall for wintering sites along the shoreline. Moths appear to produce a more permanent control, but may be more susceptible to predation or competition from weevils. The most critical period for lake residents concerned about invasive weed growth is the three-month window between Memorial Day and Labor Day. This corresponds to peak recreational use and the most active period for insect **herbivory** (consumption of plants) by both weevils and moths. Both milfoil weevils and moths, therefore, could prove to be effective in New York State.

Plant Species	% Plant Community Before Onset of Herbivory*	% Plant Community After Onset of Herbivory*
Eurasian watermilfoil	58-95%	Less than 1-11%
Eelgrass	24% (NW end)	54% (NW end)
Common waterweed	3% (SW end)	50% (SW end)
Total Plant Biomass	100%	70% (NW end) to 300% (SW end)

Table 6–3. Percentage of plant community in Cayuga Lake before and after onset of the herbivory.

**Herbivory first reported as significant about 1991.*

In recent years, a number of researchers and commercial interests have reared these two herbivorous insects in the laboratory and have introduced them through controlled stocking projects. The insects are attached to small bundles of Eurasian watermilfoil and placed in a small plot of targeted plant beds. Stocked areas are often quarantined from the rest of the lake by buoys and signs to minimize disturbance from boat traffic. It is believed that the insects migrate from the bundled plants to nearby beds to continue their growth and reproductive cycles. In lakes stocked to date, insects have not spread or controlled Eurasian watermilfoil beyond the limited stocking area.

Advantages and disadvantages

Many aspects of herbivorous insects make them ideal control agents. Both the milfoil weevil and moth damage the growth of Eurasian watermilfoil and cause only minimal damage to native plants. Plant biomass is reduced slowly, which minimizes the risk of inducing significant oxygen loss due to microbial breakdown of the decaying plant matter.

No impacts to other parts of the aquatic ecosystem have been observed. Since these insects are either native or naturalized in New York State, large-scale stockings or planned introductions are unlikely to create significant disruptions. That makes this plant-management strategy unique among all the control methods discussed here. The aquatic insects are living organisms that may have the ability to adapt to small changes in the natural environment, such as shifts in water quality or temperature. They are more immune to lake changes that are disadvantageous to other management techniques, such as high flow that flushes out chemicals.

Use of herbivorous insects is a very "low maintenance" and unobtrusive control strategy. Once the insects are stocked, and buoys or signage are sited to minimize disturbance, the insects do their work without the need for other assistance. They are inconspicuous, differing from noisy and ungainly machines, plant killing chemicals, or other clear signs of the intensive efforts that often accompany the battle against invasive weeds.

Are these insects the perfect weed control, a silver bullet? Unfortunately not. Some New York State lakes with naturally high levels of these insects are still overwhelmed with Eurasian watermilfoil. None of the stocking projects in New York State have resulted in control that can be completely attributed to the stocking. This is true even in lakes where control stocking augmented indigenous insect populations. Obviously, something other than a large insect population is needed to control Eurasian watermilfoil growth. It is not yet known if poor results are due to inadequate stocking rates, predation on stocked insects by native fish, or premature evaluation of the results. Research conducted by Cornell University and SUNY Oneonta in several Madison County lakes suggests that bluegills *(Lepomis macrochirus)* or pumpkinseed sunfish *(Lepomis gibbosus)* may be feeding on milfoil weevils, preventing herbivorous activity and keeping Eurasian watermilfoil densities high (Lord, 2004). This suggests that a top-down biocontrol approach may be preferred. One such approach would be to stock walleye or other top predators to feed on the fish that prevent milfoil weevils or moths from mowing down the Eurasian watermilfoil.

There is some evidence that the stocking method plays an important role in the success of a program. Stocking adult insects at a moderately low density, on widely separated bundled stems, often results in greater reproductive success for the next generation of eggs and larvae. This improves the migration of herbivores from bundled stems to peripheral plants and beyond. Such "selective" stocking, however, is very difficult to make commercially viable. It is anticipated that continued research, larger scale stocking projects, and continued evaluation of existing projects will bring reports of successful stockings.

There are other difficulties that make herbivorous insects at best a glimmer of hope rather than an on-going success story. The logistical difficulties associated with producing and distributing the very large quantities of insects have yet to be overcome. Part of this problem has to do with scale. Lakes that have experienced successful Eurasian watermilfoil control by indigenous milfoil moths or weevils have upwards of two insects-per-plant. This can be extrapolated to literally millions of these insects per lake. It is several orders of magnitude larger than what has been "produced" in all of the labs and commercial operations in the business. Even if the insects could be more readily mass-produced, they might not be affordable to some lake communities. Other lake environments are simply not hospitable to large insect populations.

Another disadvantage to biological control is that the life cycle of the insects does not always correlate with the needs of lake users. Eurasian watermilfoil that has been stressed by weevils often rebounds in the fall when the predation from the weevils is diminished. In the spring, it takes the weevils awhile to knock back the fall regrowth, sometimes extending into the early part of the recreational season. This may be less of an issue with the aquatic moth and other herbivores such as caddisflies and midges, although widespread effects from the latter have not yet been demonstrated in New York lakes.

Other lake management techniques can negatively impact biological control. Herbivory is greatly affected by harvesting because both insects and their habitat can be removed. Since weevils over-winter along the shoreline, the lack of shoreline substrate (vegetation, leaf litter, etc.), or the use of management techniques that alter either the water level (drawdown) or the makeup of the shoreline (benthic barriers, dredging), threatens their long-term survival.

Herbivorous insect stockings remain a promising, but thus far elusive aquatic plant control strategy. In theory, this should be identified as a lakewide control strategy, but insect use in New York State lakes has so far yielded only limited control of plants, in small beds, close to the insect release areas. The potential benefits are substantial, and the promise of a "natural" control method with very minimal side effects, remains very high. It cannot be stated with any certainty, however, that this promise will ultimately translate into a viable control strategy. The limited on-going research has not achieved any significant breakthroughs in recent years. It is hoped that greater attention dedicated to invasive plant problems and management will translate into more research and funding for the methodology, followed by greater success. Until then, herbivorous insect stocking remains at best a glimmer of hope rather than an on-going success story.

Target and non-target plants

The milfoil moth and weevil are very selective in their feeding preferences. The milfoil moth inflicts significant damage only on Eurasian watermilfoil. The leaves of some other submergent aquatic plants may have superficial teeth marks from the moth, but the plants are otherwise unaffected by the munching. The milfoil weevil uses Eurasian watermilfoil as its sole host. Research in British Columbia indicates that the weevil previously utilized northern watermilfoil (*Myriophyllum sibericum*) as its host and adapted or evolved to use Eurasian watermilfoil *(Myriophyllum spicatum)* (Kangasniemi, 1993). On-going research at Cornell University is looking at herbivory and potential use of several species of leaf beetle (*Galerucella sp*.) on water chestnut *(Trapa natans)* and several native plant species, including water lilies.

Costs

The costs for whole-lake plant management using insects cannot be easily determined. As a general rule, stocking costs have been approximately $1 per milfoil weevil or moth. About 1,000 insects have been stocked per-acre of Eurasian watermilfoil, translating to about $1,000 per acre.

Regulatory issues

Stocking herbivorous insects requires a Fish and Wildlife ECL Article 11 permit from the DEC. To date, a single annual permit is issued to the stocking entity, such as academic researchers or a commercial firm. Each lake to be stocked is identified on the permit. At the present time, there is no permitting distinction between stocking native insects (such as the milfoil weevil) and non-native insects (such as the milfoil moth). In the future, there could be some regulatory differences. Insect stockings also require a Freshwater Wetlands Permit (ECL Article 24) by the APA for lakes within the Adirondack Park.

History and case studies in New York State

Both the milfoil weevil and moth are found in most of the New York State lakes surveyed, but the history of herbivorous insect stockings in New York State lakes dates only from the late 1990s. Milfoil weevils have been stocked in small areas in several small New York State lakes, including Lake Moraine in Madison County, Sepasco Lake in Dutchess County, Findley Lake in Chautauqua County, Lake Bonaparte in Lewis County, and Millsite Lake in Jefferson County. An experimental stocking was also performed in Saratoga Lake. Each of these projects has exhibited limited successes, since neither insect migration from the treatment plots nor long-term reduction of Eurasian watermilfoil has been observed. A more significant research project involved the stocking of the aquatic moth in Lincoln Pond in Essex County (see case study). This has been closely monitored for several years. Long-term success has not been shown.

Case study: Herbivorous insects—Active management

Lake setting: Lincoln Pond is a 600-acre lake in Essex County, along the eastern edge of the Adirondack Park.

The problem: Like many Adirondack lakes, Lincoln Pond enjoyed highly favorable water-quality conditions for many years. In the late 1980s, Eurasian watermilfoil *(Myriophyllum spicatum)* was introduced into the lake at one of the public launch sites. By 1999, detailed surveys of the lake showed that Eurasian watermilfoil grew densely (400 to 1,200 grams per m^2) on 120 acres in waters up to 15 feet deep, which limited recreational use of the lake. Comparison with historical plant community data suggested that Eurasian watermilfoil was colonizing the lake at a rate of about 20 acres per year. It had the potential to infest another 300 acres of the littoral zone. Surveys also found native or naturalized populations of the milfoil weevil (*Euhrychiopsis lecontei*) and the milfoil moth (*Acentria ephemerella*). Both generally averaged less then 0.2 insects per stem, an insufficient number to significantly influence Eurasian watermilfoil populations.

Response: The Lincoln Pond Association expressed strong interest in using biological control to manage the Eurasian watermilfoil problem. In the spring of 2000, The lake association, the Natural Resources Department at Cornell University, Cornell Cooperative Extension in Essex County, the Lake Champlain Basin Program and other partners collaborated on a project. Approximately 20,000 second and third instar moth caterpillars were stocked at a rate of two caterpillars per stem. An instar is the immature insect between molts, or shedding of the outer shell

Prior to the caterpillar stocking, moth populations increased at some sites in the lake (although not in the stocked areas), to as high as 0.4 moths per stem, but they had largely disappeared by the end of 2000. The same pattern was observed in 2001. On the other hand, weevil populations, which were very low prior to the stocking, increased substantially. Populations rose to 0.8 weevils per stem in several locations in both 2000 and 2001. It is believed that the weevils were naturally present in higher densities than previously believed, and that they occupied and affected the Eurasian watermilfoil stems prior to the augmentation of the moths. This prevented the moths from propagating on the Eurasian watermilfoil host. There also appeared to be some difficulties in the moths surviving and "evolving" after the augmentation, perhaps due to problems in transit to the lake bottom. Other research, conducted by Cornell University, suggests that predation by pumpkinseed fish may have impacted future generations of the moths. (Lincoln Pond Study Group, 2002)

Lessons learned: We still have a lot to learn about augmented biological control. Continued research will ultimately improve the application of this promising lake management tool.

Grass carp

Principle

Grass carp (*Ctenopharyngodon idella),* also known as white amur, remove vegetation in a lake by consuming it at a rate of 20 to 100 percent of their body weight each day. This physical removal of vegetation is a type of **biomanipulation,** altering the food web in order to change lake conditions or give advantage to a desired species. Use of grass carp is one of the few biomanipulation tools shown to control excess levels of nuisance aquatic plants. More uses of biomanipulation are discussed in Chapter seven, "Algae and other undesirables."

Fig. 6–9. Grass carp (Ctenopharyngodon idella) eat vegetation at a rate of 20 to 100 percent of their body weight each day. (CREDIT: ERIC ENGBRETSON)

The grass carp is the most extensively studied and most frequently stocked fish used for aquatic plant management in North America. They were originally imported to Arkansas and Alabama from Malaysia in 1962. The common carp, rudd, tilapia, and silver dollar fish are other fish that feed on or disturb aquatic plants, but these haven't been stocked to manage nuisance plants.

Only sterile **grass carp**, called **triploid carp**, are presently allowed for stocking in New York State. The fish have been stocked at a rate of about 10 to 40 per acre of lake surface, with lower rates more acceptable in recent years. Fish used for stocking are approximately two feet in length, too large to be preyed on by largemouth bass. When stocked, they weigh less than one pound, but they can increase by up to six pounds per year. They can achieve several hundred pounds, although this is rare in northern temperate climates.

In most states that allow their use, grass carp are restricted to lakes with no permanent outflow. This reduces the possibility of escape and maximizes the control of vegetation within the target lake. New York State allows stocking in larger lakes with an outflow only when migration out of the lake can be prevented.

Advantages and disadvantages

There is a great deal of interest in using these fish to control nuisance aquatic plants. Grass carp are perceived as a "natural" plant control agent even if they are not native. This technique gains some of its public support because it appears to be devoid of the more conspicuous, disruptive or controversial aspects of other control strategies.

Biological control methods are relatively new and not well understood. They have not been widely studied in the field, and have not been applied to a wide variety of lake conditions. The results from biological manipulation experiments, either in theory or in laboratory studies, are not easily reproduced in actual lakes. Since lakes are both dynamic and fragile, a change in one component of a lake ecosystem can have dramatic effects on other components. The potential side-effects of a particular technique may outweigh the benefits for many lakes.

While these eating machines may be an excellent option in some situations, the use of grass carp is not a panacea. One undesirable side-effect that has been observed is an increase rather than decrease in the plant species being targeted. Grass carp are reported to favor particular plant species, but these preferences may be a function of the conditions in individual lakes. While carp will selectively feed on particular types of plants, their choice of plants is not predictable and varies from lake to lake. Once the preferred plants have been removed, less palatable plants can grow explosively, or grass carp can completely eradicate all aquatic vegetation. This may be bad for the plant community and the entire ecosystem in a lake, but may be acceptable in small, self-contained ponds. It is unrealistic to expect that these fish will remove weeds from a specific part of a lake, such as by an individual dock or swimming area since fish have access to the entire lake.

Grass carp do not meet the criteria for an "ideal" candidate to be introduced into an aquatic system, due to the potential eradication of the entire plant community and the associated repercussions. The absence of aquatic plants will have significant effects on the aquatic animals whose habitat has been destroyed. Subsequent declines in fish populations could ripple down the food chain, affecting zooplankton and phytoplankton abundance. Grass carp do not co-adapt with other aquatic species, do not have a narrow niche, are not easily controlled if they escape, and are not free from exotic diseases and parasites.

Grass carp can also enhance eutrophic conditions. More than 50 percent of the nutrients in the ingested plant material could be reintroduced to the lake system through carp excretion. This nutrient recycling could stimulate algal blooms and oxygen depletion. The removal of rooted plants by the carp may mean less competition for available nutrients, further feeding algal blooms, although this may be limited to lakes with poorly rooted plant communities such as those dominated by coontail or bladderwort.

The risk of ecosystem disruption makes the containment of grass carp imperative. They have a propensity for flowing water and can escape unless inlets and outlets are screened. Escaped carp may destroy desirable aquatic plants in tributaries and outflow streams. The escaped fish also equal a lost investment as nuisance weeds remain in the lake.

Though grass carp have voracious appetites, in New York State most permitted stocking rates are not high enough to result in significant first-season control. Many of the less successful experiments with grass carp have resulted from not waiting long enough for the carp to effectively control excessive weed growth. This is particularly true in lakes where

High	High to Moderate	Moderate	Moderate to Low	Low
Brazilian elodea *(Egeria densa)*	Curly-leafed pondweed *(Potamogeton crispus)*	Bladderwort *(Utricularia sp.)*	Eelgrass *(Vallisneria americanum)*	Cattail *(Typha sp.)*
Common waterweed *(Elodea canadensis)*	Duckweed *(Lemna sp.)*	Coontail *(Ceratophyllum demersum)*	Floating leaf pondweed *(Potamogeton natans)*	Common reed *(Phragmites australis)*
Hydrilla *(Hydrilla verticillatum)*	Fanwort *(Cabomba caroliniana)*	Filamentous algae	Slender spikerush *(Eleocharis acicularis)*	European frog-bit *(Hydrocharis morsus-ranae)*
Large-leaf pondweed *(Potamogeton amplifolius)*	Illinois pondweed *(Potamogeton illinoensis)*	Pondweed (most) *(Potamogeton sp.)*	Watermilfoils (most) *(Myriophyllum sp.)*	Variable watermilfoil *(Myriophyllum heterophyllum)*
Musk grass *(Chara sp.)*	Naiads (most) *(Najas sp.)*	Stonewort *(Nitella sp.)*	Water primrose *(Ludwigia sp.)*	Water chestnut *(Trapa natans)*
Southern naiad *(Najas quadalupensis)*	Sago pondweed *(Stuckenia pectinatus)*	Watermeal *(Wolffia sp.)*		Water lily *(Nuphar sp. & Nymphaea sp.)*
				Water shield *(Brasenia schreberi)*

Table 6–4. Grass carp (Ctenopharyngodon idella) feeding preferences for common nuisance aquatic plants.

stocking rates were kept fairly low to prevent eradication of all plants. Grass carp can live 10 to 12 years, providing multiple years of plant control, although most stocking projects require substantial restocking in narrower intervals of four to six years due to loss by predation and other factors. Due to the sterilization required for fish stocked in New York State, the number of fish does not increase.

Target and non-target plants

Using grass carp to remove Eurasian watermilfoil or water chestnut is akin to using children to reduce the world's supply of brussel sprouts. Though grass carp are most often stocked in New York State lakes to control Eurasian watermilfoil, grass carp generally prefer softer or more ribbon-leafed pondweeds, coontail, naiads, common waterweed and some filamentous algae. Two increasingly common exotic plants, Brazilian elodea *(Egeria densa)* and hydrilla *(Hydrila verticillatum),* are highly favored by these herbivorous fish. Grass carp palates are somewhat unpredictable, and can change with water hardness, the age and lake-specific texture of the plants and even the proximity of target plants to heavily used shorelines, since these fish also avoid contact with humans. Unusually hungry grass carp have been observed feeding on grass clippings and low hanging tree leaves. In the absence of their preferred food, the grass carp will consume the less desired, problem plant species. Preferential munching on a non-target plant species can reduce plant competition, allowing more aggressive plants to dominate the plant community.

Costs

Grass carp offer one of the least expensive, lake-wide techniques for controlling nuisance aquatic vegetation. Prices range from $50 to $100 per acre, based on a "standard" allowable New York State stocking rate of about 10 to 15 fish-per-vegetated-acre. These costs can be amortized, since the carp live for 10 to 20 years, although restocking rates of up to 35-50 percent may be required every four to six years.

Regulatory issues

DEC regulates the stocking of grass carp through ECL Article 11. Stocking of sterile grass carp is only approved after a complete and thorough State Environmental Quality Review (SEQR) process.

Any proposed plans for using grass carp should be discussed with the DEC Regional Fisheries Manager. The manager is responsible for issuing the stocking permit and may be able to advise lake residents about any major obstacles. Grass carp stocking that requires any modifications to a dam, such as screening to prevent escape, will also require a permit from the DEC Dam Safety Unit. For lakes within the Adirondack Park, the APA requires a wetland permit for the stocking of grass carp. For these projects, the DEC and APA cooperate on a coordinated review of proposals.

New York State's present policy indicates the following:

- No person or organization shall possess or introduce any grass carp into waters of the state without having obtained a stocking permit from DEC.
- Only sterile, triploid grass carp will be considered for introduction into the waters of the state. All fish must be certified as triploids by competent taxonomists retained by the applicant before being released.
- All proposed introductions of sterile, triploid grass carp into New York State must be supported by a complete Environmental Impact Statement (EIS). Within the EIS review process, DEC could deny a permit to stock grass carp.
- In New York, DEC policy is to limit stocking rates to no more than 15 fish per surface acre for those ponds of five acres or less.

When the lake/pond is contained wholly within the boundaries of land privately owned or leased by the applicant, the following conditions must be met:

- Aquatic plants must significantly impair the intended use of the pond;

- No endangered, threatened or species of special concern shall be present in the proposed stocking area;
- The lake/pond is not contiguous to part of a New York State regulated wetland;
- The lake/pond is not a natural or manmade impoundment on a permanent stream as shown on USGS topographic maps; and
- At least two years have elapsed from the date of the last stocking unless it is demonstrated that previous stocking had high fish mortality.

History and case studies in New York State

Since 1991, there have been thousands of permits issued by DEC for the use of grass carp. The vast majority of these are for less-than-one-acre "farm" ponds with no inlet or outlet and a single landowner. Most of the permits have been issued in the Finger Lakes, western New York, and the Downstate region. The effectiveness of these stockings has not been well documented. Some experimental stockings have been evaluated by the DEC Division of Fish and Wildlife, but most information is anecdotal.

Case study: Grass carp *(Ctenopharyngodon idella)* in Lake Mahopac and Lake Carmel

Lake setting: Lake Mahopac is a 560-acre lake in Putnam County, north of New York City. Lake Carmel is a 200-acre lake in the same area. Both lakes are heavily used for swimming and other recreational activities

The problem: Lake Mahopac had dense, homogenous beds of Eurasian watermilfoil *(Myriophyllum spicatum)* inhabiting most of the lake shoreline to depths of 12 to15 feet. Lake Carmel suffered water-quality problems related to excessive nutrient and algae levels and poor water clarity for many years. By the early 1990s, nuisance weed growth, primarily common waterweed and coontail, also plagued Lake Carmel. The lake was dredged in the late1980s, and mechanical plant harvesting after 1986 achieved some success. Residents of the town served by Lake Carmel were opposed to the use of aquatic herbicides. By the mid-1990s, surveys of plant biomass reported 150 to 400 grams-per-square-meter (g/m$^{2)}$ for about 100 acres of lake bottom.

Response: In October, 1994, 2565 triploid grass carp were privately stocked in Lake Mahopac at a rate of 15 fish per-vegetated-acre. The objective of the treatment was to provide 70 percent control of the vegetation. In 1999, 10 grass carp per-vegetated-acre were stocked in Lake Carmel. At the time of stocking, water clarity was about 3.5 feet, historically typical for this lake.

Results: *Lake Mahopac*: A private consulting biologist monitored the results of the treatment. By 1995, he reported that the biomass of aquatic vegetation, including filamentous algae, had been reduced by 73 percent from pre-stocking levels. By 1996, vegetation had been reduced by 86 percent from baseline levels. Reports through the New York Citizens Statewide Lake Assessment Program (CSLAP) indicated that aquatic plant coverage had dropped from "dense" at the lake surface in the mid-1990s to "not visible" from the lake surface. This continued through at least 2001.

DEC fisheries surveys of the lake in the late 1990s revealed virtually no submergent rooted aquatic vegetation. Catch rates for largemouth bass *(Micopterus salmoides*), the lake's principal gamefish, were high compared to most neighboring lakes before and after treatment, although by 1999 there was a decline of almost 50 percent for bass over 15 inches. It is not known if this decline can be attributed to the grass carp, but many local anglers blame the decline on the loss of aquatic vegetation. (NYSDEC, 2000)

Lake Carmel: By 2002, plant biomass dropped under 50 g/m^2 in the northeast cove (which had less pre-treatment biomass) and under 100 g/m^2 in the southern cove. Water clarity dropped to about 2.5 feet, due to more frequent blue-green algal blooms. Although large-mouth bass continued to be the dominant fish species, only about 15 percent of the fish were greater than 6 inches long. (Grim, 2003) This suggests that the loss of refuge habitat for the young fish may affect future age-classes of the fish. (See Chapter five, "Fisheries management" for discussion about age-classes)

Lessons learned: Moderate stocking rates of 10 to 15 fish per-vegetated-acre can be effective at removing nuisance vegetation. At the higher end of this range, near total eradication of plants can occur. Water-quality changes and fisheries impacts may also occur, although studies to date have not been adequate to attribute observed changes solely to the use of grass carp.

Case Study: Anecdotal reports regarding the use of grass carp *(Ctenopharyngodon idella)* in Plymouth Reservoir

The effectiveness of any lake management activity is best evaluated through a well-designed scientific study. Unfortunately, this is rarely done since design of controls and data collection takes away from already precious funds. While this is understandable, given the high costs of lake-management tools, quantification of their effectiveness would help the next generation of lake managers make informed decisions.

Simple surveys can provide some of the information needed to evaluate the success or failure of a particular management strategy. In 1994, homeowners on Plymouth Reservoir, an 80-acre impoundment in Chenango County, used a survey to evaluate the use of grass carp the previous year. In 2004 the survey was repeated with the same respondents. A summary of the survey answers are reported below as A1994 and A2004 respectively. (Doing, 2005)

Q. Did the carp adapt to their settings?

A1994. The carp seem to have adapted to their surroundings. Only one to two dead fish were found.

A2004. The carp seem to be well adapted. Fish approximately 3 feet in length have been observed feeding along the shorelines.

Q. Did you notice a preference for any food type (plant), and was this the target species?

A1994. In areas where curly and floating pondweed had been abundant, the weeds were not as concentrated. Previously the weed growth had been dense and floating on the surface. In sections of the lake where Eurasian watermilfoil had been dense, there was an obvious decrease. Grasses were found floating that appeared to have been pulled out by the roots.

A2004. There appears to be a decrease in pondweed (various species), eel grass and elodea.

Q. Was the physical condition of the lake…notably clearer, about the same, or not as clear…?

A1994. The physical condition of the lake was about the same as in previous summers.

A2004. The lake was not clear, with considerable more brownness. Our lake has a natural brown color. The increased amount of rain and snow the past two years may have contributed to this. We have had a problem with an excessive amount of nutrient flow into the lake since the 1998 tornado destroyed 1,000 plus acres of state forest adjacent to our lake.

Q. Were the (overall) aquatic plant populations, in the areas where people swim and boat … denser, about the same, or less dense?

A1994. Aquatic plant populations in these areas were noticeably less dense and thick.

A2004. The weeds are noticeably less dense and thick. It is hoped this is due to our weed control efforts, but we have had heavier snowfalls in recent years. Also the darker color and particulates in the lake may be diminishing the amount of sunlight filtering through to the plants.

Q. Was the recreational condition of the lake… improved, unchanged, or degraded?

A1994. Overall, the ability to use the lake improved… Fishing and boating were greatly improved.

A2004. In 2003 and 2004 the lake did not improve or degrade.

Q. In retrospect, was there any unanticipated lake effect from the stocking, and were they positive or negative?

A1994. Too early to make any determinations, but we were pleased with the water quality and aesthetics of our lake.

A2004. The general consensus has been the carp have had a positive impact on the lake. We have maintained moderate stocking of the carp. It is difficult to determine the number remaining in the lake.

Q. Would you say the carp provide effective control, provide no noticeable control, make the problem worse, or it is too early to gauge effectiveness?

A1994. Too early to gauge effectiveness.

A2004. We feel the carp have provided effective control.

The experiences with grass carp in New York State have been somewhat variable. When stocking rates are high, grass carp effectively remove submergent aquatic plants. In many instances, long-term eradication of nearly all plant material has occurred. This poses a threat to the long-term integrity of the aquatic ecosystem since plants provide habitat for fish spawning and survival, as well as other benefits. In some lakes, short-term water-quality impairment, including increased turbidity, has also resulted.

Walton Lake is an example of poor results from use of grass carp. The initial stocking of 10 fish-per-vegetative-acre had only limited effect on plant densities. A higher stocking rate two years later of 15 to 19 fish-per-vegetative-acre resulted in removal of about 30 percent of the plants. The carp selectively removed every plant species except Eurasian watermilfoil, which actually increased in some areas. Subsequent higher stocking rates of 20 to 27 fish-per-acre removed the Eurasian watermilfoil, leaving a scarcity of plants throughout the lake. No measurable impact on water clarity occurred, but fish catch rates declined as plant populations were reduced.

Aquatic herbicides

Principle

Aquatic **herbicides** are chemicals that kill macrophytes or inhibit their normal growth through direct toxic reactions or by hampering their photosynthetic ability. Some chemicals are species-specific and others affect a broad spectrum of plants. The herbicide is usually applied to the water directly above the nuisance weed bed and the plants are left to die and degrade within the lake.

Herbicide applications must be properly timed to correlate with lake conditions, plant life cycles and recreational uses of a lake. To be most effective, herbicides should be applied between the onset of thermal stratification (usually late spring) and the onset of fish spawning and native plant uptake (usually early summer), although some fall treatments take advantage of selective plant growth by some invasive exotic plants.

Most herbicides contain toxic chemicals designed to kill plants. Through a registration process overseen by DEC and the U.S. Environmental Protection Agency (EPA), half a dozen aquatic herbicides can be used in New York State. Several other aquatic herbicides are also registered for use by the EPA and can be used in other states, but New York is among the few states that has a separate registration process. This provides both enhanced environmental protection and regulatory oversight, an additional regulatory layer applauded by some and unwanted by others. Only licensed professionals can legally apply herbicides in lakes, except in very small, private waterbodies, as discussed in the *Regulatory Issues* section below. Applicators are licensed by the State of New York. A list of licensed applicators is available from the DEC Bureau of Pesticides in Albany (see Appendix F, "Internet resources").

Nearly all of the aquatic herbicides registered for use in New York State carry at least one water-use restriction for a time period after the application. Use restriction range from 24-hour restrictions on bathing to 30-day prohibition of the use of the lake water for irrigation of established row crops. Certain herbicides may be restricted in lakes that are used for domestic drinking-water supplies. Restrictions are clearly identified on the labels governing the use of the products.

There are two main classes of aquatic herbicides. Contact herbicides are toxic to only those parts of the plant contacted by the herbicide. The treatments tend to work quickly and will usually be effective from several weeks to several months. Effectiveness is usually limited to a single growing season because seeds and roots are not normally affected. Once the chemicals have degraded or flushed out of the system, plant growth will resume, and reapplication may be necessary.

Systemic herbicides affect the plant's metabolic or growing processes. Systemic herbicides often move from the application site to the root system and affect the entire plant. A treatment usually takes from three to eight weeks to be effective, but plant control with these herbicides can last for several years. With some systemic herbicides, plant die off may not occur until early- to mid-summer. The benefits of herbicide application, therefore, might be delayed until much of the recreational season has passed.

Approved herbicides are available in either liquid or granular form. Most granular herbicides are activated through **photodegradation.** When the granules sink to the lake bottom and out of the photic zone, photodegradation ceases, and the chemical is no longer effective. For some other herbicides, residuals sink to the lake sediment and may provide some additional, temporary vegetation control through uptake by plant roots.

Advantages and disadvantages

No documented cases exist of an herbicide treatment gone awry in New York State, but few lake issues cause as much heated discussion as the planned use of chemical control. There will inevitably be two factions in lake associations and the community. The first group will claim that there are absolutely no conditions or situations that justify chemical treatment. The other group will insist that if herbicides are not immediately applied the weeds will invade the entire lake, destroy all recreational enjoyment and cause property values to plummet. They are not likely to listen to each other, and both groups are convinced that the other could ruin the lake. The decision whether or not to use chemical treatment often rests on these human dynamics rather than ecological factors.

Concerns about the use of herbicides should be balanced against the ecological damage caused when invasive plants spread through a lake ecosystem, creating "biological pollution" and drastically altering the ecological balance. Aquatic herbicides can provide at least temporary control of Eurasian watermilfoil *(Myriophyllum spicatum).* This pernicious, exotic weed has not been consistently controlled by any other whole-lake strategies.

To facilitate a decision, as much information as possible should be obtained about the nuisance plant, proposed herbicide, existing water chemistry of the lake, and all the pros and cons of using a particular herbicide on a particular lake. Discretion is vital when extrapolating information from one lake to the conditions of another. Differing weather conditions, recreational uses, water chemistry, and vegetation types could yield dramatically different. The DEC regional office can provide assistance in obtaining necessary information.

Chemically treated lakes may experience some significant side effects. When herbicides are applied in a lake environment, the affected plants drop to the bottom of the lake, die, and decompose. The resulting depletion of dissolved oxygen and release of nutrients can have detrimental effects on the health or survival of fish and other aquatic life, particularly in small, shallow lakes and ponds.

The toxicity of the herbicide to non-target plants can be of great concern. Data are very limited on the effect of specific herbicides on plant species in New York State lakes. It is unclear whether target-plant species listed on herbicide labels can be completely controlled without adversely affecting non-target species in a given lake. If a wide variety of plant species are eradicated by an herbicide treatment, fast-growing, opportunistic exotics may re-colonize the treatment area. Lake residents may find that beds of the original nuisance plant are even greater than before.

Short-term effects of aquatic herbicides have been fairly well studied for most aquatic organisms and their surrounding environment. Studies to date indicate that humans and most animals have high tolerance to the short-term toxic effects of currently approved aquatic herbicides. This is especially true of "newer generation" herbicides that are formulated to disrupt the metabolic processes specific to chlorophyll-producing plants. Any negative impacts have been deemed to be an "acceptable risk" if the herbicide is applied in the appropriate manner.

The long-term effect of herbicides on humans and other organisms is not well studied. High herbicide dosages can elicit toxic response for the applicator, and protective gear must be worn. The pesticide labels and permitted conditions are designed to protect applicators and others using treated lakes.

Newer formulations and greater experience by applicators will continue to improve the effectiveness of this management strategy. Recent herbicide treatments have effectively controlled the target plant, sometimes for many years. An herbicide treatment might be ineffective due to poorly timed application, unusual weather conditions, eradication of non-target plants, re-infestation by exotic species, or by simply using the wrong herbicide to control a particular species.

Target and non-target plants

At the dosage rates allowed in New York State lakes, most aquatic herbicides are not truly selective, although some herbicides are partially selective when applied at the proper time and dosage rate. If applied when plants are actively growing, these chemicals will remove most plants within the treatment zone. Selectivity can be increased by choosing the proper herbicide, correlating the application to the growth period of target plants and by lowering dosage rates to protect non-target plants. For example, 2,4-D and triclopyr can selectively control dicots (flowering plants with opposite seed leaves), while fluridone can be both selective or broad spectrum depending on concentration, exposure time and the plant species.

In New York State, the most frequently used aquatic herbicides are diquat, 2,4-D, endothol, glyphosate, fluridone, and triclopyr. Table 6–5 lists the susceptibility of common New York State submergent, floating, or emergent plants to these most common herbicides.

Diquat is a contact herbicide that controls emergent species such as cattail; floating species such as duckweed; and submerged species such as coontail, milfoil, nitella and some varieties of pondweed. It must be applied in water less than six feet deep or closer than 200 feet from shore, whichever provides the greater distance from shore, and maybe limited in lakes with stressed bass, walleye, or muskellunge populations.

2,4-D is a systemic herbicide used for controlling a wide variety of emergent, floating and submerged species, primarily Eurasian watermilfoil, water chestnut, coontail, and water hyacinth. It remains in the sediment for several months and cannot be used in waters used for potable water supplies when the concentrations of the chemical exceed 70 ppb.

Endothol is a contact herbicide often used to control coontail, Eurasian milfoil, and most pondweeds. It stays in the water column longer than either diquat or 2,4-D, but its breakdown products (carbon, hydrogen and oxygen) are of less concern than those from these other herbicides. The Aquathol® K formulation is preferred in New York state lakes to minimize toxicity.

Glyphosate is a systemic herbicide used almost exclusively on emergent and floating plants, notably cattail and water lily. It has not been commonly used for submergent plant control in New York State, and requires significant setbacks from potable water intakes.

Fluridone is a systemic herbicide. In New York State it is used extensively for the control of Eurasian watermilfoil and curly-leafed pondweed. It has been used at low dosage rates to attempt to manage target plants while preserving non-target plants.

Triclopyr was registered for use in New York State in 2007. It is a systemic herbicide that targets Eurasian watermilfoil and purple loosestrife *(Lythrum salicaria).* Data from other states, and initial data from New York State in 2008, indicate that this is a fairly selective herbicide that can be applied at higher dosage rates than fluridone.

Copper-based herbicides have been registered for rooted plant control in New York State, but since they can affect some aquatic organisms at the label application rate, they require extensive review and environmental assessment by the DEC. Copper-herbicide mixtures are commonly used when both algae and rooted plant control is desired. The dosage rate of copper required to control most macrophytes is much higher than would normally be allowed for algae control. Copper may be applicable in those rare instances in which a macroalgae, such as *Chara,* inhibits lake use. *Chara*, also known as muskgrass, is a weakly rooted algae that superficially resembles larger aquatic plants. Copper is a common algacide and is discussed in greater detail in Chapter seven, "Algae and other undesirables."

Herbicide:	Diquat	2,4-D	Endothal	Glyphosate	Fluridone	Triclopyr
Emergent Plants						
Arrowhead *(Sagittaria sp.)*	Low	High	Low	High	Low	Medium
Cattail *(Typha sp.)*	Medium	Medium	Low	High	Medium	Low
Pickerelweed *(Pontederia cordata)*	Low	Medium	Low	Medium	Low	High
Purple loosestrife *(Lythrum salicaria)*	Low	Low	Low	High	Low	High
Reed grass *(Phragmites sp.)*	Low	Low	Medium	High	Low	Medium
Water bulrush *(Scirpus sp.)*	Medium	High	Low	High	Low	Low
Floating Leaf Plants						
Duckweed *(Lemna sp.)*	High	Medium	Medium	Low	High	Low
Water chestnut *(Trapa natans)*	Low	Medium	Low	Medium (foliar only)	Low	Medium
Water shield *(Brasenia schreberi)*	Medium	Medium	Medium	Low	Medium	Medium
White water lily *(Nymphaea sp.)*	Low	Medium	Medium	High	Medium	Medium
Yellow water lily *(Nuphar sp.)*	Low	Medium	Medium	High	Medium	Medium
Submergent Plants						
Bladderwort *(Utricularia sp.)*	High	Medium	Low	Low	Medium	Low
Brazilian elodea *(Egeria densa)*	High	Low	Low	Low	High	Low
Bushy pondweed *(Najas flexilis)*	High	Medium	High	Low	Medium	Low
Common waterweed *(Elodea canadensis)*	High	Medium	Low	Low	High	Low
Coontail *(Ceratophyllum demersum)*	High	Medium	High	Low	High	Low
Curly-leafed pondweed *(Potamogeton crispus)*	High	Low	High	Low	High	Low
Eelgrass, tapegrass *(Vallisneria americanum)*	Low	Low	Medium	Low	Medium	Low
Eurasian watermilfoil *(Myriophyllum spicatum)*	High	High	High	Low	High	High
Fanwort *(Cabomba caroliniana)*	Medium	Medium	High	Low	High	Low
Hydrilla *(Hydrilla verticillatum)*	High	Low	High	Medium	High	Medium
Large-leaf pondweed *(Potamogeton amplifolius)*	Low	Low	Medium	Low	Medium	Low
Muskgrass *(Chara sp.)*	Low	Low	Low	Low	Low	Low
Robbins pondweed *(Potamogeton robbinsii)*	Low	Low	Medium	Low	High	Low
Sago pondweed *(Stuckenia pectinatus)*	High	Low	Medium	Low	Medium	Low
Variable watermilfoil *(Myriophyllum heterophyllum)*	Medium	High	Medium	Low	Medium	High
Water stargrass *(Zosterella dubia)*	High	High	Medium	Low	Medium	Medium

Table 6–5. Impact of New York State registered herbicides on common aquatic plants.

(ADAPTED FROM HOLDREN ET AL, 2001)

Costs

Aquatic herbicide treatments are generally less expensive than other large-scale plant-control methods except for very large areas. Typical costs range from $200 to $1500 per-acre of treated area per-application. Some treatments will have to be repeated on a regular basis. Most of the cost is associated with the chemical itself. Costs will vary with the chemical brand and form (liquid or granular), required dose rate, frequency of application and applicator fees. The costs have generally been lower when local applicators were used.

Regulatory issues

Herbicide use in New York State requires a permit from the DEC regional Environmental Permits office, in compliance with ECL Article 15 and Part 326 of the NYCRR. If all or part of the lake contains a regulated wetland, an additional wetland permit will be required. If the outlet flow needs to be controlled with the use of sandbags to assure herbicide contact time or keep the chemical out of downstream waterbodies, dam safety permits may be required. For some lakes, the generic EIS prepared by the manufacturers of these herbicides will be deemed insufficient to address all of the permitting issues. In this case, a site-specific EIS may be required. Additionally, aquatic plant monitoring and the development of a plant-management plan is required by DEC for most of the state's "high profile" lakes. A list of the waterbodies for which these requirements exist is available on the DEC website. The Adirondack Park Agency requires a separate permit for herbicide use within the boundaries of the Park, under the purview of the aquatic wetland program. A compelling public benefit needs to be demonstrated to allow the use of herbicides in most wetlands, since there are stringent regulations governing activities within wetlands, particularly within the Adirondack Park.

No aquatic herbicide permits have been issued in some regions of the state, such as the Adirondacks. Reasons include the overlapping regulatory authority of DEC and the APA, strong sentiments about the use of herbicides, the presence of and concern for protecting rare and endangered species, the abundance of pesticides alternatives, and the lack of historical precedent for the use of many aquatic plant-control strategies. Few permits are issued in other regions of the state where lakes are used for potable water intake or encompass wetland areas, due to a more rigorous permitting process for these waterbodies. Pesticide use in Suffolk County (Long Island) has also been restricted by legislative initiative to protect groundwater.

Aquatic herbicides can be applied by a homeowner, after securing a purchase permit from the DEC, for lakes and ponds smaller than one acre, solely on private land and with no outlet leaving the property. This permit is valid for a year and involves a fairly simple application form to be submitted to regional DEC pesticides offices.

History and case studies in New York State

Federal regulation of herbicides began in the early 1900s. "Modern" pesticide regulations developed from the passage of the **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** in 1947. Both federal and state attention to pesticides, including aquatic herbicides, was greatly increased by the publication of *Silent Spring* by Rachael Carson (1962).

Aquatic herbicides have been used in New York State for many years. In fact, nearly 500 permits are issued annually, not including purchase permits for small farm ponds. Aquatic herbicides permits have been issued in nearly every part of New York State. Most lakes treated with aquatic herbicides have not been closely studied either before or after treatment. The most thoroughly monitored lakes have been Waneta and Lamoka Lakes in Schuyler County and Snyders Lake in Rensselaer County (see case studies and Fig. 6–10).

Case study: Aquatic herbicides in Waneta and Lamoka Lakes

Lake setting: Waneta Lake is an 800-acre lake that is part of a two-lake chain with its downstream, similarly-sized southern neighbor Lamoka Lake. They are located in the western Finger Lakes region. The Waneta-Lamoka Lakes Association was formed in 1938 to address a variety of lake management issues. The lake is a valued local fishery for largemouth bass *(Micropterus salmoides)* and smallmouth-bass *(Micropterus dolomieui*), and a secondary source for muskellunge *(Esox lucius cross Esoc masquinongy)* brood stock throughout the state. The lake fisheries, therefore, have enjoyed a high level of protection.

The problem: Waneta Lake has a long history of recreational use impacts associated with both nuisance algae and weeds. Weed problems have been exacerbated by the introduction and spread of Eurasian watermilfoil *(Myriophyllum spicatum)* throughout both Waneta and Lamoka Lakes since the mid-1980s. By the late 1990s, Eurasian watermilfoil comprised just over 50 percent of the biomass of aquatic plants in Waneta Lake, and was identified at 80 sites in the lake during 2000. Mechanical weed harvesting was conducted during the mid-1980s, with funds provided through the Aquatic Vegetation Control Program, the predecessor to the Finger Lakes-Lake Ontario Watershed Protection Alliance (FL-LOWPA). This was marginally successful, but the funds for this activity were not maintained.

Response: The lake association proposed the use of fluridone to reduce the coverage and density of Eurasian watermilfoil, while maintaining sufficient cover of native plants to protect the valuable fisheries resource in both Lakes. (ENSR, 2001) Funding was provided through the creation of a special taxing district. After much discussion, the DEC issued a permit only for Waneta Lake for the whole-lake application of fluridone at an initial concentration of 12–14 parts-per-billion (ppb) in the summer of 2003, with provisions for a bump application as needed to restore fluridone residuals back up to 6 ppb within 60 days. There was very low dilution, probably due to relatively low inflow and low photodegradation. Fluridone residuals remained above 6 ppb for more than 60 days, without supplemental applications. Fluridone remained above 3 ppb for nearly 175 days.

Performance standards were developed and adopted to evaluate herbicidal impacts to Waneta Lake. Recovery of native and exotic plants was monitored as part of an extensive survey program conducted by Cornell University. Results were evaluated by the lake consultant and DEC to determine if "sufficient" recovery existed to maintain cover and fish refuge if treatment was permitted in the downstream Lamoka Lake. The performance standards required less than 25 percent loss of native plant cover and overall aquatic plant biomass, and greater than 90 percent Eurasian watermilfoil removal within the year of treatment, and return to pre-treatment native plant densities the following year. (Lord, Johnson and Miller, 2004)

Results: As a result of the herbicide treatment, Eurasian watermilfoil disappeared from Waneta Lake, and there was no evidence of it anywhere in the lake through the summer of 2004. Eurasian watermilfoil first returned in 2005, and began regrowing extensively along the northern and southern shores of the lake in 2006. Prior to treatment, traces of native plants were found in 54 of the 64 survey sites in 2003. Post-treatment, native plants were found in 50 sites during 2004, and in 37 sites during 2005. After treatment, native plant biomass was initially reduced to about five percent of the pre-treatment biomass. No significant water-quality changes or fisheries impacts were reported or attributable to the herbicide treatment. Large-scale treatment of Lamoka Lake was not approved, however, due to delays in the plant recovery in Waneta Lake. An experimental control of a small part of Lamoka Lake was allowed in 2005. By 2008, Eurasian watermilfoil was sufficiently re-established to justify partial lake treatments of both Waneta and Lamoka Lakes with triclopyr, with additional treatments in other parts of both lakes contingent upon both target plant loss and native plant survival or recovery to protect the lake fisheries. The strategies developed to evaluate the Waneta Lake treatment have been used in assessing the positive and negative impacts of other herbicide treatments throughout the state.

Lessons learned: The controversies over the proposed treatment in Waneta Lake are a microcosm of the issues surrounding the use of aquatic herbicides in New York State. It is unlikely that all parties involved will agree that the process and the results were adequate. The dialogue accompanying the application process, however, was insightful and open, and the compromise reached by the advocates for, the opponents of, and the mediators in the permitting and evaluation process may serve as a template for future contentious aquatic plant-management proposals. It is also hoped that the results from the well-designed monitoring plan will provide sorely needed answers to continuing questions about the use of aquatic herbicides in New York State lakes. (Lord, Johnson and Wagner, 2005)

Case study: Aquatic herbicides in Snyders Lake

Lake setting: Snyders Lake is a 110-acre lake in the Capital District region of New York State. It is used primarily by local residents for recreation.

The problem: For many years, water-quality issues dominated lake management discussions. Resident complained about increased turbidity attributed to nearby development, and about blooms of the red alga *Oscillatoria rubescens* in winter and spring. Weeds were not dense enough to warrant active management until the late 1980s. Biological surveys, conducted on the lake from the 1930s through the late 1980s, reported that plants covered about 20 percent of the lake bottom. By the late 1990s, dense aquatic plant beds existed throughout the littoral zone and were dominated by Eurasian watermilfoil *(Myriophyllum spicatum)*.

Response: After significant public debate, the Lake Association of Snyders Lake voted to conduct a whole-lake application of fluridone in the spring of 1998. A combination of private funds and state grants were used to offset the approximately $25,000 treatment cost.

Fluridone was applied at a rate of approximately 11 to13 ppb. Herbicide levels were tracked by the lake association at several locations and depths for about 5 months. Fluridone residuals remained above 6 ppb for at least 55 days, above 4 ppb for more than 115 days, and were still above 2 ppb for at least 155 days. This greater-than-expected longevity was caused by less dilution due to dry conditions and an inactive outlet for the duration of the treatment.

Results: By the end of summer 1998, there were no observable submergent aquatic plants in the lake. Scattered submergent plant growth returned the following summer, but this was limited primarily to macroalgae (*Chara* spp.) and isolated single stems of Eurasian watermilfoil. In 2000 and 2001, however, extensive beds of brittle naiad (*Najas minor*) were found in areas where sediment was thick and organic-rich. Isolated, small quantities of other native plants (large-leaf pondweed, leafy pondweed, macroalgae) were found throughout the littoral zone. Eurasian watermilfoil was largely limited to small patches in thinner sediments. Aquatic plants survey maps drawn prior to the fluridone treatment and again in 2000 look very similar except that brittle naiad *(Najas minor)* largely replaced Eurasian watermilfoil. (Fig. 6–10)

After 2001, Eurasian watermilfoil recolonized large patches of the littoral zone. It was less dominant due to the well-established brittle naiad beds, but it spread to some areas not previously "weed free." The coverage and density of the Eurasian watermilfoil/brittle naiad beds prompted a spot treatment with endothal in the summer of 2004 in a small portion of the lake.

Anecdotal information indicated a general satisfaction with the results of the initial treatment. Most lake residents were satisfied with the transition from Eurasian watermilfoil to brittle naiad, although the latter is also an exotic, invasive species. Although Eurasian watermilfoil returned to the lake, the densities in most regions of the lake were significantly lower than prior to treatment and for at least ten years after treatment. There were few reported complaints from anglers. Water-quality conditions were relatively stable throughout the treatment and subsequent response period. Reports of blue-green algal blooms or other water-quality complaints were less frequent than in most previous five-year periods. Annual aquatic plant monitoring continues to track the extent of exotic and native plants in the lake.

Lessons learned: Aquatic plants have the ability to recover, or to be re-introduced after an herbicide treatment. Native plants may be the initial re-colonizers if the dosage rate is high enough to control root systems, <u>and</u> if new invasive plants are not re-introduced,. Too high a dosage, however, can render a lake susceptible to invasive re-infestation or ecological impacts from a barren lake bottom. (Kishbaugh, 2002)

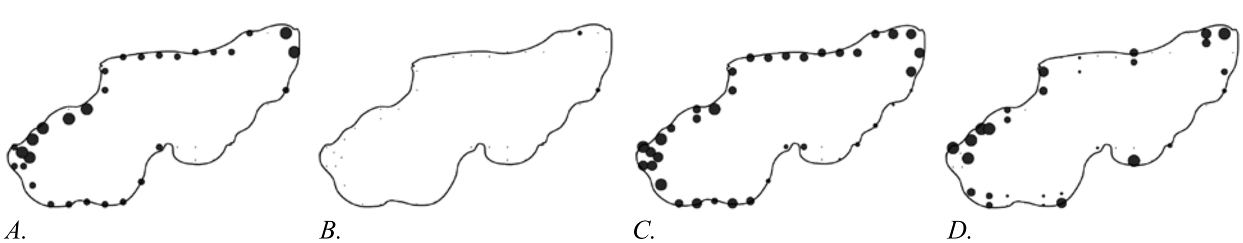


Fig. 6–10. Plant communities in Snyder Lake: A. Pre-treatment B. 1998 C. 2000 D. 2003

Shading

Principle

Shading involves the use of non-toxic, vegetable dyes to inhibit light penetration throughout the water column. This limits the growth of nuisance aquatic vegetation in water depths greater than two to four feet. The dye absorbs certain wavelengths of light, which further limits plant photosynthesis. Shading is used to treat an entire waterbody and is most often used in farm ponds. It is rarely used on large lakes, due in large part to cost considerations (see case study "Multiple strategies for invasive species control in Adirondack Lake").

The treatment duration is a function of water-retention time. When applied to lakes with significant inflow or outflow, dyes will quickly dilute or be flushed downstream. These dyes may persist throughout much of the recreational season, depending on the flushing rate of the lake.

The use of shading dye is prohibited in potable water supplies, but there are no restrictions associated with the immediate use of dye-treated water, although most lake residents will be deterred from swimming in a lake so artificially colored. The dyes impart a rather unnatural color to the water, despite efforts by dye manufacturers to mimic the natural appearance of lake water.

The most common chemical dye used in shading is Aquashade®, an inert, blue liquid, vegetable dye. Many shading products that are registered as having herbicidal impacts are combined with copper formulations to enhance algae control. In recent years, many similar products have been advertised as "landscaping tools" or "colorants" that improve the "aesthetic quality" of the water. This marketing technique steers clear of any claim of herbicidal impact and is done to avoid regulatory restrictions outlined in FIFRA.

Advantages and disadvantages

Lake dyes are non-toxic to humans and most aquatic organisms. Disruption of lake ecology can occur, since the non-selective reduction of the plant community can influence fish habitat. Dyes can frequently and rapidly wash out of a lake. Repeated applications are needed in lakes with very low residence times, or after spring runoff or storm events.

This control strategy is less expensive than others, and may result in some limited success in controlling nuisance vegetation with only minor side effects. Nonetheless, the public may perceive the technique to be another "toxic chemical." Anyone proposing to use chemical dyes should enlist public support prior to application.

Target and non-target plants

Shading dyes have been shown to be somewhat effective for several nuisance plants including common waterweed (*Elodea*), pondweeds (*Potamogeton*), naiad (*Najas*), watermilfoil (*Myriophyllum*) and some filamentous algae. Since dyes reduce the transmission of light through the water column of a lake, however, all submergent plants are affected. Specific lake areas or individual weed beds cannot be isolated for treatment unless water flow is somehow restricted

Costs

Shading dyes are relatively inexpensive for small lake and pond applications, but costs can become prohibitive for large-scale treatments. The cost of the chemical dyes is about $50-per-gallon. Applied at the recommended concentration of one part per million (ppm) each gallon will treat four acre-feet of water (one acre of surface area at a depth of one foot).

Regulatory issues

The use of herbicidal agents is governed under FIFRA. If the label on the dye promotes plant control, use of the chemical requires a pesticides permit from the DEC. This applies to lakes or ponds greater than one acre in size, waterbodies owned by multiple residents, or those that drain beyond the property lines of a single landowner. Permits are not required for products that make only "landscaping" or "colorant" claims. The DEC Regional Office should be consulted, however, prior the use of any shading agent.

The use of chemical dyes or other shading agents in lakes within the Adirondack Park is a regulated activity. It requires a permit from the APA if the activity could substantially impair the functions served by or the benefits derived from freshwater wetlands.

History and case studies in New York State

Shading has been commonly used on ponds, particularly golf course and ornamental ponds, for many years. There is little historical information on the use of shading agents in larger New York State lakes. Field research on the dyes has been rather sparse, though one large-lake experiment took place in Adirondack Lake in the late 1980s (see case study).

Integrated plant management (IPM)

Integrated Pest Management, commonly known as IPM, is the process of using multiple management actions to achieve long-term control of pests. This approach improves effectiveness by extending the benefits of each technique. This concept can also apply to plants. **Integrated plant management**, a form of IPM, points to the need for plant managers to avoid focusing on only a single management tool.

In general, IPM involves the use of a whole-lake control strategy, such as an aquatic herbicide, in concert with at least one other control strategy, such as hand harvesting. This is comparable to painting a room using both a roller and a brush. The roller is best for the broad expanses of wall and the paint

Case study: Multiple strategies for invasive species control in Adirondack Lake

Lake setting: Adirondack Lake is a 200-acre lake in the town of Indian Lake in the middle of the Adirondack Park. It was formed by a stone dam originally built in 1910 to create a recreational lake, and was rebuilt by the Civilian Conservation Corps (CCC) in the 1930s. The lake is characterized by a group of floating peat bogs, which have historically been managed by a variety of strategies, and are currently corralled by a log boom. The lake flushes, completely exchanges the volume of water in the lake, about every 10 months.

The problem: Rooted aquatic plant growth has been the subject of complaints from the late 1960s to early 1970s. By the late 1970s, the aquatic plant populations in the lake were dominated by beds of large-leafed pondweed, although other native species were well represented.

Response: The Adirondack Lake Association utilized a number of lake-management tools during the late 1970s and early 1980s. They included water-level drawdown from three to nine feet, mechanical harvesting, and the aquatic herbicide 2,4-D. In 1984, 500 gallons of Aquashade® were applied at a rate of one part-per-million (ppm). In combination with a relatively deep lake drawdown, 90 percent of the aquatic plant beds were cleared from the lake for two years, with aquatic plant growth limited to shallow water by early 1986. By later that year, however, the APA estimated aquatic plant growth to be "moderate" to "abundant". By 1987, after another deep winter drawdown, Aquashade® was applied again, primarily to control large-leafed pondweed beds covering 80 percentage of the shallow, shoreline areas to a depth of seven feet. Aquatic plant communities shifted from large-leafed pondweed to brittle naiads (*Najas minor*) and common waterweed (*Elodea canadensis*) by 1988. By 1990, after a year of no control, e large-leafed pondweed returned in abundance. As aquatic plant growth increased, Aquashade® was applied a third time in 1991, again after a deep winter drawdown, and a fourth time in 1994. Total cost for the four treatments was approximately $54,000.

Result: It was believed that the repeated Aquashade® treatments reduced plant populations in the deeper water, but had less impact in the shallow water. By 1996, the lake association shifted the agent of control from Aquashade® to grass carp *((Ctenopharyngodon idella)*, in part due to the lower costs. There was an expected cost of $35,000 for a 10-year grass-carp control versus about $54,000 for 10 years of shading agents. (Grim, 1996)

Lessons learned: In a relatively large lake, even without a rapid flushing rate, the benefits from an application of shading dye can be relatively short-lived. The alteration in the plant community demonstrated that these agents may be less effective in shallow water portions of lakes where plant growth is limited by factors other than light transmission. (Kishbaugh, 2004)

Case study: Integrated Plant Management Techniques in Lake George

Lake setting: Lake George is a 28,000 acre lake located in the southeast corner of the Adirondack Park.

The problem: Eurasian watermilfoil *(Myriophyllum spicatum)* was first identified at three locations in 1985. By 1998, the plant had spread to 127 known sites, 31 of which contained dense growth. Preventing additional spread of the Eurasian watermilfoil, and controlling existing beds, has been the focus of considerable local efforts for many years.

Response: A consortium of state and local agencies, and the Darrin Freshwater Institute (DFI) used lakewide aquatic plant surveys and selected experimental control strategies from 1987 to1992. (Darrin Freshwater Institute, 1991) In 1995, physical management efforts were incorporated into an Integrated Aquatic Plant Management Program under the auspices of the DFI. In 2002, Lycott Environmental, Inc. and the Lake George Park Commission implemented the program on Lake George. (Eichler and Boylen, 2002)

Results: As of 2005, a total of 149 Eurasian watermilfoil sites were identified throughout the lake. Since 2002, most of the new infestations have been identified by volunteers. A combination of management techniques has cleared 72 of them. An additional 43 sites were found cleared by the end of 2004. "Cleared" refers to no visible Eurasian watermilfoil remaining. Six more sites are used by DFI for research purposes and have not been actively managed. The number of known Eurasian watermilfoil sites increased by an average of eight sites per-year from 1987 through 2001, with a total of 141 sites identified. From 2002 through 2004, there was an increase of only two to three sites per year. It is not clear whether this represents reduced Eurasian watermilfoil dispersal rate in Lake George or a limitation in the progress to locate new invasion sites. Approximately 40 percent of previously managed sites remained free of Eurasian watermilfoil. The annual cost for the management program is about $150,000. (Lycott, 2006)

Between 2002 and 2005, 7,000 to 16,400 Eurasian watermilfoil plants were removed by hand each year from 64 to76 locations. About 40,000 square feet of Palco® pond liner, in 7 foot x 50 foot sections, was installed in both 2004 and 2005. 1,500 square feet of pond liner was also reclaimed and relocated in 2004 from a site managed in 2003. In addition, 45 to 50, 30-gallon barrels of Eurasian watermilfoil were removed by suction harvesting in 2002 and 2003 at a single site at the rate of approximately 35,000 plants each year. In 2004, no suction harvesting took place, since it was decided that the possible negative impacts and efficiency of suction harvesting, relative to barrier methods, was not cost effective. Hand harvesting efficiency, as estimated by repeat harvesting, exceeded 85 percent in all years, and 97 percent in some years. (Lyman and Eichler, 2005)

Lessons learned: Benthic barriers can be an effective management strategy, particularly when plant densities are low. When integrated with hand harvesting, these efforts can clear significant portions of the lake bottom. Active annual maintenance is necessary to prevent recolonization of Eurasian watermilfoil in these areas. While these methods have been successful under certain circumstances, there are many considerations for implementation including water clarity, substrate conditions, species and density of the aquatic plant growth, and depth of the plant growth.

brush best for the corners and details. The herbicide broadly controls most plants, while hand harvesting removes any remaining solitary plants. Mechanical harvesting used in tandem with benthic barriers is a similar useful pairing. Harvesting controls plants in deeper water and benthic barriers control the shoreline plants. The installation of benthic barriers can also be expedited using drawdown, adding another management tool. Not all techniques can be paired. Mechanical harvesting and herbivorous insects, for example, are an unsuccessful pair, since harvesting removes the tips of the plants where the insects thrive.

In any plant-management program, preventive measures should always be coupled with any in-lake, aquatic plant-management actions. Strategies include preventing the introduction of invasive plants, and keeping excess nutrients and sediments from entering the lake. This is discussed in greater detail in Chapter nine, "Watershed management."

Other management activities

There are other techniques that are experimental, part of the folklore of weed management, or used in other regions of the country. The most common ones are noted below.

Surface covers are light-inhibiting agents that are usually constructed from the same material as benthic barriers. They float on the water instead of being anchored on the lake bottom. Surface covers interfere with recreation and safe boating, and can be aesthetically unpleasing. They have not been regularly used in New York State lakes.

Weed rollers and sweepers are patented devices that are connected to docks and travel across plant beds in an arc centered at the dock edge. The devices typically use a roller to compress plants or a sweep a bar that dangles chains over the top of plants. Both contraptions weaken plants over a period of several days to weeks, causing the plants to dislodge and degrade. Some DEC regional offices have determined that permits are required if lake sediments are disturbed and some regions have limited their use to post-fish spawning periods. These devices are not widely used, but there are vendors in New York State.

Use of plant pathogens, such as fungi, as a possible aquatic weed control has been researched for many years. In Maryland, pathogens referred to as "Northern Disease" were implicated in a Eurasian watermilfoil *(Myriophyllum spicatum)* population crash. This led to significant laboratory research on the plant pathogen *Mycoleptodiscus terrestris* by the U.S. Army Corps of Engineers and the Republic of China, where Eurasian watermilfoil is indigenous. This has not evolved into a viable plant management technique.

Altering sediment chemistry to affect nutrient uptake in rooted aquatic plants has shown limited success in other parts of the country. The work is still very experimental and none of the substances under investigation are presently registered as aquatic herbicides in New York State. Their full impacts are unknown, and they cannot be legally applied for aquatic plant control in New York State lakes.

Scattering corn on lake bottoms is recommended by some lake residents to attract common carp (*Cyprinus carpio*). These bottom-scouring fish then supposedly disturb the lake bottom and disrupt the growth of rooted plants. No corn-chumming projects have been documented in a New York State waterbody, although some officials residing at bays along Lake Ontario have pushed for this rather than many of the techniques described above. It is not known how many fish it would take to roil up the bottom enough to dislodge plants, not to mention the turbidity and spectacle of such rubble-rousing.

The use of *ultrasonic devices* is discussed in detail in chapter seven, "Algae and other desirables" as a means for controlling nuisance algae. Some limited experimental ultrasonic treatments of water chestnut *(Trapa natans)* in Lake Champlain in 2005 demonstrated water chestnut mortality without any apparent effects on fish after 10 seconds of 20 kHz ultrasound waves. On-going research is focused on scaling up the procedure to treating one acre plots per day, at a cost under $1000 per acre. Additional data will be required to determine if this is a safe and viable control option (Wu and Wu, 2007).

Decision trees for controlling Eurasian watermilfoil and water chestnut

Management does not start with the choice of a particular control method but rather with the problem plants. Eurasian watermilfoil and water chestnut are currently the most significant invasive plant species found in New York State. A decision tree for each of these species is provided to help determine the most appropriate management techniques for a particular typical lake (see Figs. 6–11 and 6–12). If different plants are the object of concern, lake associations may want to make their own customized decision tree to aid in making choices and communicating those choices.

Putting it all together: The art of aquatic plant management

This chapter has described many methods used to combat nuisance aquatic plants. None is a panacea for weed problems, however, and aquatic plant management remains extremely complex. There are many considerations that make plant management as much an art as a science.

The convergence of timing, longevity, and public perception

Each management strategy has its own timetable of effectiveness and longevity. There are also other milestones during a project that can impact public perceptions and expectations. Immediately after a mechanical harvester cuts a swath of nuisance Eurasian watermilfoil, for example, plant fragments and turbidity clouds may follow the harvester much as the rats followed the Pied Piper. This is often a temporary phenomenon, but this detritus may make people unhappy when it ultimately lands on their shoreline. Some herbicides cause marginally susceptible plants to temporarily turn a white or pinkish color. Mats of filamentous algae may form on the tips of plants treated with a systemic aquatic herbicide, and the rooted plants themselves may become increasingly denuded ("poodled") prior to falling out of the water column. Such unsightly consequences can cause a public perception that these side-effects are worse than the weeds.

Sacrificing the wrong plants

Some plant control methods remove beneficial native plants along with the target nuisance species. Aquatic herbicide permits have been denied in New York for this reason, especially when the beneficial plants support fish habitat. Drawdown has some effect on unwanted Eurasian watermilfoil *(Myriophyllum spicatum*), but it can also kill native plants. This gives the more aggressive Eurasian watermilfoil an extra niche to fill upon its recovery. There are also a large number of protected plants identified as rare, threatened, or endangered in New York State, and there are nearly 600 federally protected terrestrial and aquatic species. Many of the techniques described in this chapter can also affect these protected plants, so the state permitting process involves a level of review necessary to afford adequate protection to them. The more than 6500 non-indigenous species in the country, however, are among the greatest threats to these protected plants, so managing nuisance plants in lakes with protected species becomes a necessary balancing act. This provides yet another reason for identifying and controlling exotic plants before they turn into an invasion.

All are equal, but some are more equal

Although New York State regulatory agencies permit the use of each of the aquatic plant-management techniques discussed in this chapter, some techniques are more favored than others. Some of this bias originates in the funding sources used to pay for aquatic plant control. Historically, some grant programs have not included certain management techniques. In some regions of the state, such as Long Island and the Adirondacks, aquatic herbicide treatments are uncommon to non-existent. Some of this is due to strict regulations governing land use, water quality, and

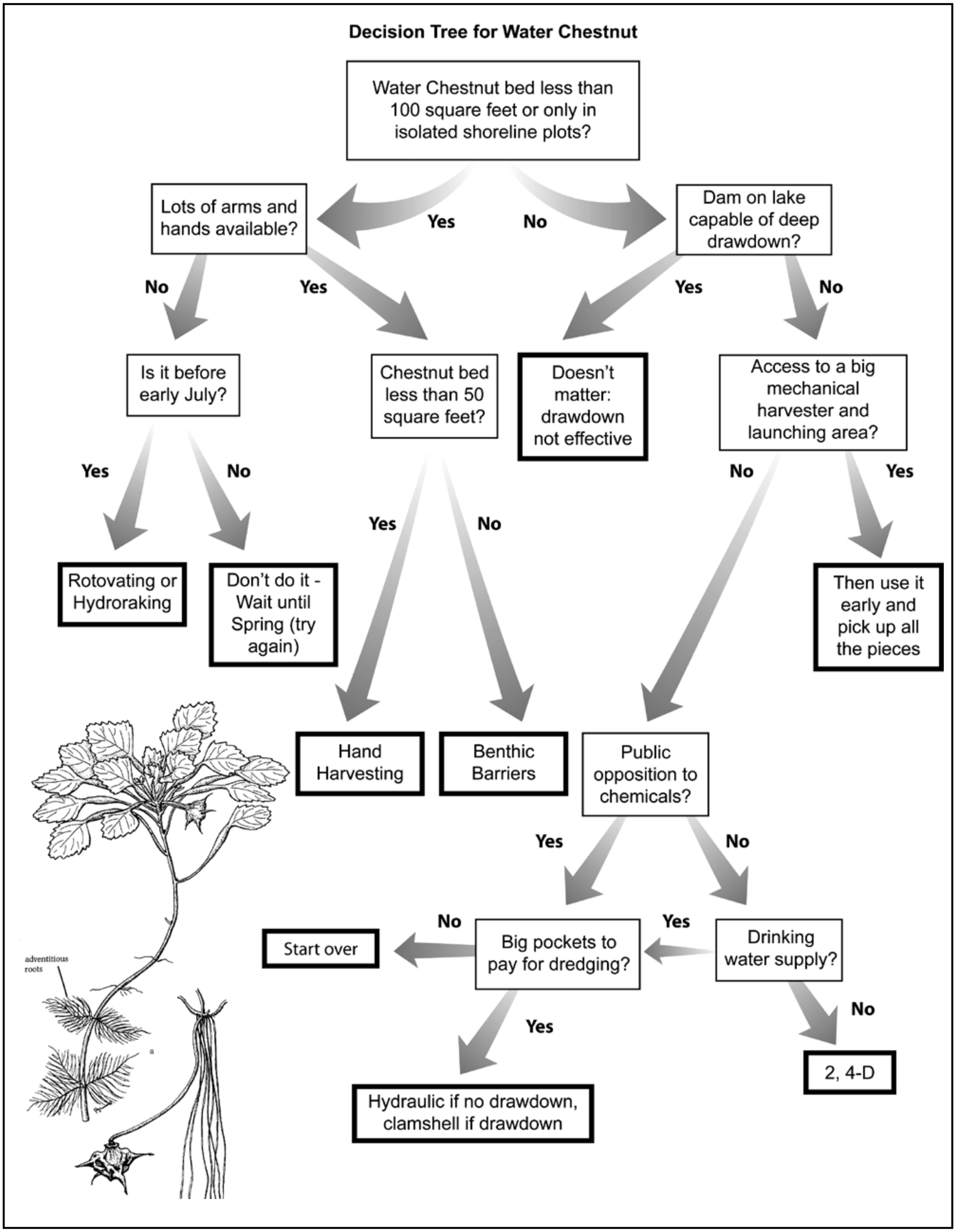


Fig. 6–12. Decision tree for controlling Water chestnut (Trapa natans).

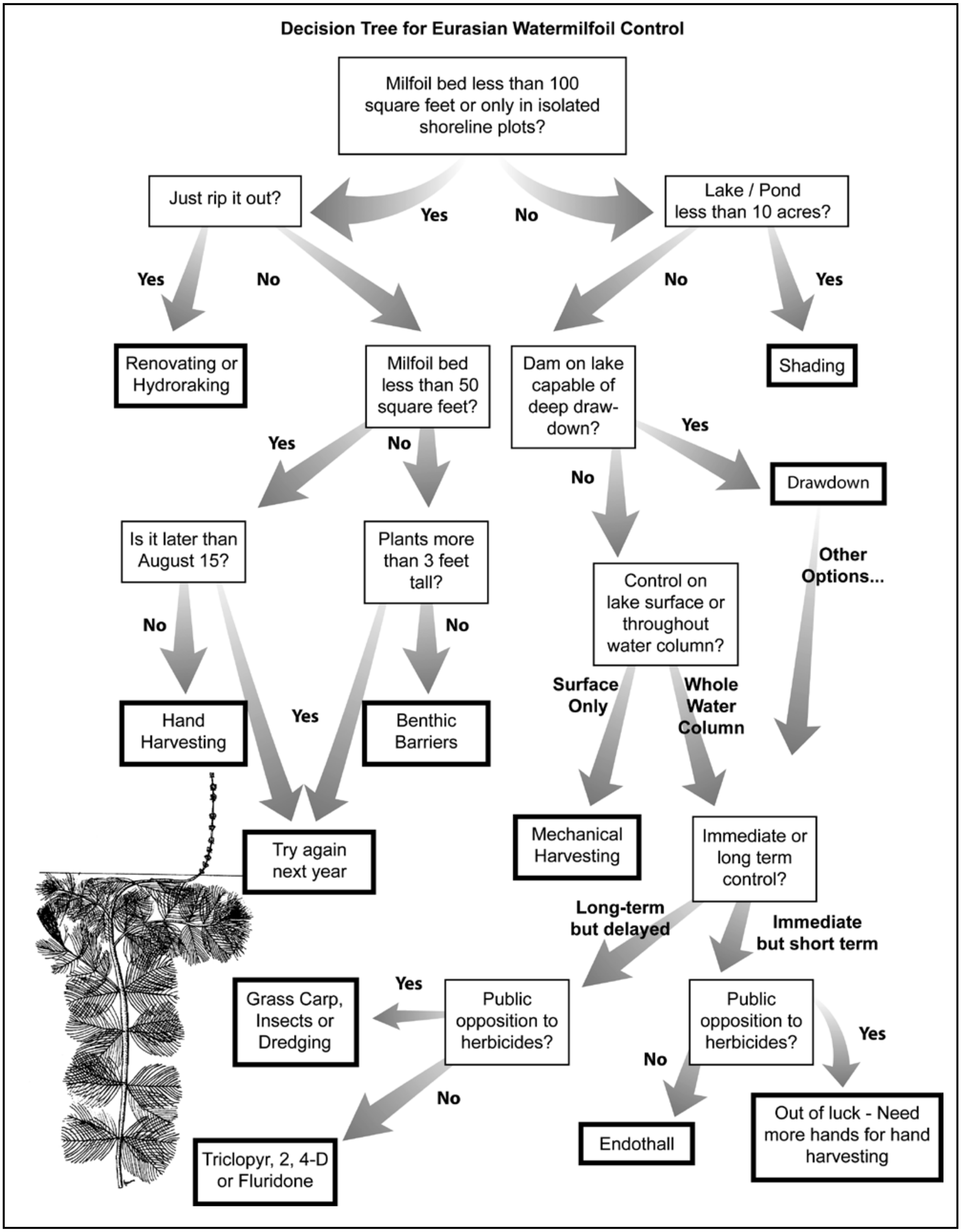


Fig. 6–12. Decision tree for controlling Eurasian watermilfoil (Myriophyllum spicatum).

especially wetlands in these regions. It is important to remember that the primary role of the permitting agencies is environmental protection. Invasive or exotic plants have only recently been recognized as biological pollution capable of causing great ecological harm. Surrendering expanses of beneficial native plants for the sake of invasive plant removal has met regulatory skepticism. Some of this partiality is philosophical, since the political and social environment in some regions of the state strongly influences management decisions. Sociopolitical influences are likely to change as circumstances change, but for now, most aquatic plant-management activities will continue to be closely scrutinized within the Adirondacks and on Long Island. It is also worth noting that regulatory agencies evaluate the actions for invasive exotic plant control much more favorably than they evaluate actions for native plant control.

There is no such thing as eradication

Eradication of invasive exotic plants is a prime goal of plant-management actions, but in reality, eradication is but an illusory dream. No method completely removes all nuisance plants or their means of reproduction. Drawdown rarely exposes plants lurking in the deepest part of the lake. Some aquatic plants are developing resistance to the few herbicides capable of controlling them. Hand harvesting does not always remove the entire root system. If a plant appears to have been exterminated from a lake, new plants or their means of reproduction can be introduced to become the next generation of invaders. The good news is that water chestnut *(Trapa natans)* can be controlled and perhaps even extirpated from a lake. The bad news is that if there is a reservoir of nutlets skulking in the lake sediments, these seeds can remain viable for up to twenty years. Water chestnut is unique among invasive exotic plants in that it is:

- visible and apparent very early in its colonization;
- a seed producer, and thus controllable if removed prior to seed formation; and is
- easily distinguishable among aquatic plants found in New York State.

Other seedy invaders, if so easily bulls-eyed, could also be candidates for eradication, but it must be stated that a reasonable goal for aquatic plant management is not eradication. For lakes with a monoculture of a single exotic plant species, a targeted control project will essentially eliminate all plants in the lake, rendering the lake susceptible to re-invasion from either the same or a different invasive exotic plant. For lakes with a mix of exotic and native plants, even a successfully selective removal of just the exotic plants may still leave some lake residents unhappy with the remaining lush plant growth, despite the better residual ecological balance. Successful plant management must be accompanied by reasonable expectations.

Summing it up

Plant management starts with the identification of the nuisance plant and progresses to the most appropriate control method for that particular plant in a given New York State lake. The most important lesson is that there is no magic bullet, no single tool that will work on all aquatic plant problems in all New York State lakes. Aquatic plant control, like the larger goal of lake and watershed management, involves the delicate process of choosing the right management tools, building consensus toward the use of those tools, and sometimes getting lucky when it works right.

While nuisance weeds are usually the most prominent part of a lake-management plan, they are not the only plague on a lake. Chapter seven, "Algae and other undesirables", and Chapter eight, "User conflicts" will discuss the most common strategies for dealing with the myriad of other lake and watershed management issues confronted by those who live for the beauty and protection of New York State lakes.

7 Algae and Other Undesirables: Getting Rid of Yuck

Introduction

Aquatic macrophytes, or rooted aquatic plants vex many New York State lake users, but they are not the only significant in-lake problem. Algal blooms, nuisance species, and poor water quality may be nearly as, or more, troublesome than macrophytes. This chapter describes immediate and sometimes short-term techniques for coping with these three common concerns.

The in-lake management strategies presented in this chapter and in Chapter six, "Aquatic plants," are the primary mechanisms for correcting the most prevalent water-quality problems. Those solutions may alleviate the symptoms but do not solve the underlying cause. Approaches that deal with the underlying problem will lead to solutions that last longer than those that only address symptoms. Chapter nine, "Watershed management," will discuss the long-term, watershed-based strategies that are the best way to address the real cause of in-lake problems. Dealing with "the big picture," however, requires much effort and time. The interim methods for dealing with the symptoms usually keeps lake users happy while longer-term solutions are being developed.

Algae control by physical means

Algal blooms are among the most significant and common lake problems encountered in New York State lakes and, therefore, algae management is discussed first. Techniques are grouped by physical, chemical and biological control.

The three management techniques that control most algae through physical means all involve lake stratification. Lakes in New York State may stratify in summer and winter. When a lake is stratified, colder, heavier water sinks to the bottom and lighter, warmer water rises to the top. This creates distinct layers that do not mix easily. In relatively deep lakes, these layers become less distinct during the spring and fall months and mix together in the process known as destratification or turnover. See Chapter one, "Lake ecology" for a full discussion of stratification and related terms. Figure 1-7 illustrates stratification and turnover.

During stratification, the bottom water, or hypolimnion, receives little or no exposure to the atmosphere, which can lead to oxygen depletion. This is usually much more severe in the summer stratification, during the four warmest months of the year. The hypolimnion is the location for reactions with the sediment, degradation of organic materials that have settled out of the water column, and significant biological activity. This combination of oxygen depletion and chemical reactions can lead to deoxygenated, high-nutrient conditions.

Artificial circulation

Principle

Artificial circulation is the process which injects compressed air from a pipe or ceramic diffuser into the hypolimnion. With some circulators, water is moved through the use of solar-powered impellors. Either method can eliminate thermal stratification and improve the flow and movement of water within a lake. This may improve fisheries and reduce taste and odor problems associated with ammonia, iron and manganese by changing them to a reduced state. It may also lower algae levels by inhibiting the release of phosphorus from oxygen-depleted bottom sediments. A reduced state is the opposite of an oxidized state, changing the oxidation state of an atom by gaining electrons.

There are several ways that artificial circulation can correct algae problems. Lake sediments may release bound phosphorus under low-oxygen conditions, which encourages algal blooms when the lake turns over in the fall. Increased circulation will restore sufficient oxygen to bottom waters and minimize this nutrient release. In a lake with light-limited algae, mixing that extends to the lake bottom will decrease the time that individual algae cells are exposed to light, thus restricting their growth. This is referred to as the "critical depth" concept. Circulation may improve zooplankton survival and increase predation, which can reduce algae levels. Algae species may shift from blue-green to less noxious green algae from the increased surface water contact with the atmosphere, a lowering of the pH and incorporation of carbon dioxide-rich bottom waters.

The rising column of bubbles from the aerator, if sufficiently powered, will produce lake-wide mixing that eliminates temperature differences and results in a constant temperature throughout the water column. The disintegration of the thermal layers allows mixing that exposes bottom waters to the atmosphere. When the temperature and density differences between upper and lower layers are nearly eliminated, wind and other natural mixing mechanisms will assist in maintaining well-mixed conditions.

Advantages and disadvantages

Artificial circulation can be used in most lakes that exhibit summer thermal stratification and have a distinct epilimnion and hypolimnion. Artificial circulation is a popular technique since it is best used alone. Many of the benefits in algae control, such as light-limitation and lower pH, are not easily achieved by other restoration techniques.

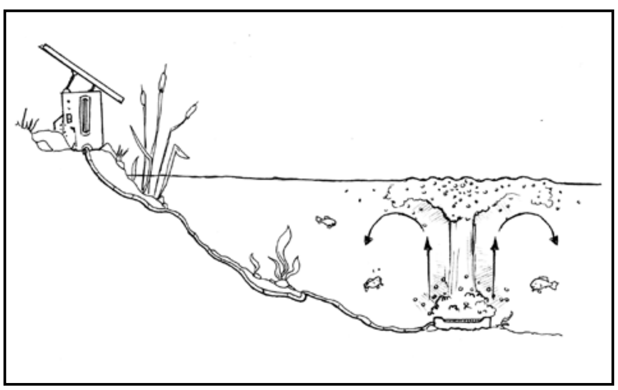


Fig. 7–1. Artificial circulation using solar power, showing compressor on the shore and pipe and hose to diffusers sitting on the lake bottom.
(CREDIT: CHRIS COOLEY)

Complete mixing by artificial circulation will increase the temperature in the hypolimnion as much as 15ºF to 20ºF. This could have disastrous effects, however, on the cold-water fish species that thrive in the hypolimnion.

Artificial circulation may adversely affect lakes that are not thermally stratified. Its use, therefore, should be limited to stratified lakes. Portions of the lake, such as shallow coves or bays, are not good candidates for this treatment if they are separated from mixing with the stratified layers in the rest of the lake; if there is a significant littoral zone; and if the algae growth is nutrient-limited.

In stratified lakes where algae are nutrient-limited in the epilimnion, artificial circulation may increase the phosphorus levels in the upper layers, promoting increased algae growth. This would decrease transparency, and perhaps raise the pH, shifting the dominant algae from green to blue-green. The same scenario may occur when only partial destratification is achieved, especially in lakes that do not possess a distinct epilimnion and hypolimnion. These effects may be temporary since migration of nutrients from sediment to hypolimnion to epilimnion may be reduced once deepwater oxygen levels rise.

Failure to achieve the desired objective with artificial circulation may be caused by lake chemistry, insufficient design, or equipment failure. Correct air flow pressure, system sizing, flow rate, and depth of air release depend on the site conditions, and must be properly designed to maximize success. Even when artificial circulation is successful, the perceived benefits are usually delayed.

Costs

Costs for artificial circulation are low, relative to other management techniques. The primary costs are for the compressor and installation of pipes and air diffusers. The cost for artificial circulation is approximately $150 per acre of surface area.

Regulatory issues

Circulators generally do not require permits, but the local New York State Department of Environmental Conservation (DEC) Regional Office should be consulted to determine if wetland or other site-specific permits may be needed.

History and case studies in New York State

Artificial circulation was originally employed to reduce winter fishkills caused by oxygen depletion, but is now commonly used to control eutrophication problems in small ponds and reservoirs. It has been rarely used in large New York State lakes, although the frequency of use in recent years has increased. These projects have not been well documented.

Hypolimnion aeration

Principle

Hypolimnion aeration is used to increase oxygen circulation within a lake and increase oxygen content of the deep waters without causing enough turbulence to disrupt the stratified layers. Aeration of the lake bottom waters uses an air-lift device to pump or lift the deep, stagnant water layer for exposure to the atmosphere. This results in aeration and the loss of some gases such as carbon dioxide and methane. Then the water sinks back to the hypolimnion. Hypolimnetic aeration may also be accomplished by injecting pure oxygen or air into the bottom waters or by using an air-lift device along with injection.

When the hypolimnion has sufficient oxygen, release of phosphorus from oxygen-depleted bottom sediments will be minimized, and this may result in decreased algae levels. Aeration also allows the lake to maintain sufficient oxygen levels for coldwater fish such as trout, without adversely increasing the water temperature or destratifying the lake. It can also reduce taste or odor problems associated with ammonia, iron and manganese, an important consideration if deep water is being withdrawn for drinking water purposes. Aeration may also improve the quality of hypolimnetic water discharged downstream.

Case study: Artificial circulation in East Sidney Reservoir

Lake setting: East Sidney Reservoir is a 210-acre impoundment in the north branch of the Susquehanna River in south-central New York State.

The problem: High nutrient (phosphorus) concentrations resulted in excessive algal blooms, reduced water clarity, and hypolimnetic anoxia. Runoff from a largely cattle and agricultural watershed increased nutrient loading in the lake.

Response: An artificial circulation system was installed in 1989 to prevent anoxia in the bottom waters. The system consisted of a 15-horsepower compressor, 122 meters (m) of galvanized pipe, 305m of flexible hose, and eight 331m PVC pipe diffusers. The diffusers were joined, and a manifold and valve system controlled airflow to each section. The diffusers were sited at a depth of about 9m from 1990 through 1992. The system was generally operated for 23 hours-per-day from late May through mid-October. Airflow ranged from 0.3 to 1.1 cubic meters per minute during this period.

Results: Deepwater oxygen levels in the reservoir increased during the course of the study, resulting in lower phosphorus and metals concentrations in the bottom waters of the reservoir. Maximum total phosphorus levels in the hypolimnion ranged from 130 to 170 parts-per-billion (ppb) before and after the study, but only reached about 50 ppb during most of the study. Surface phosphorus readings were actually higher in 1991. Average deepwater phosphorus readings also dropped from about 70 ppb before the artificial circulation to about 40 ppb during the study. Similar reductions occurred in manganese and iron concentrations. Summer water clarity and chlorophyll a readings were essentially unchanged as a result of the artificial circulation, and weak thermal stratification still occurred, resulting in intermittent dips in dissolved oxygen levels and occasional nutrient and metals release from bottom sediments.

Lessons learned: Artificial circulation systems can be successful for minimizing some water-quality effects associated with deepwater anoxia, but these systems must be carefully designed to assure full circulation and to assure destratified conditions during the peak stratification period of late spring through mid-fall (Barbiero et al, 1996).

Advantages and disadvantages

Hypolimnetic aeration is appropriate when lakes are stratified and have a large hypolimnion. Aeration systems are generally used only during summer stratification and not used during winter stratification due to the decreased biological activity and higher solubility of oxygen in cold waters.

The use of hypolimnetic aeration in shallow lakes and reservoirs with only partial stratification should be considered with great caution. Shallow lakes without hypolimnion do not benefit from summer aeration. Some type of winter aeration might be beneficial in preventing fishkills in the most productive shallow lakes and ponds because ice cover that lasts for months can prevent natural aeration.

Although the stratified layers are usually maintained during deep-water aeration, nutrients may diffuse from the hypolimnion to the epilimnion during the process. This may increase the algae levels in the epilimnion and the thermocline.

Another potential disadvantage to hypolimnetic aeration is the supersaturation of bottom waters with nitrogen gas, which can lead to "gas-bubble disease" in fish. Since the nitrogen-rich gas cannot be dissipated through exposure to the atmosphere, nitrogen build-up can be significant in lakes that remain stratified for several months.

Costs

Costs of aeration are dictated by the amount of compressed air required to fully aerate the hypolimnion. This is a function of the lake's hypolimnetic area, the rate at which oxygen is used up, and the extent to which the lake is stratified.

Aeration projects can be extremely expensive. Typical operating costs for six months of operations are estimated to be at least $2,500 per acre of surface area. The capital cost for the equipment tends to be very high, and the operating costs increase proportionally to the size of the lake. Most hypolimnetic aeration projects are funded by a research institute or corporation. The funds necessary to carry out an aeration project are usually well beyond the means of most lake associations.

Regulatory issues

Permits to install and operate an aerator are required by DEC under Article 15 of the Environmental Conservation Law (ECL), and by the Adirondack Park Agency (APA) if the lake is within the boundaries of the Adirondack Park.

History and case studies in New York State

There have been very few attempts to aerate the hypolimnion of lakes in New York State. The only major project was Lake Waccabuc in Westchester County (see Case study on aeration). This project was somewhat successful at increasing oxygen levels at the sediment-water interface and reducing the migration of pollutants out of the lake sediment, but these benefits were neither sustained nor extended higher in the water column.

Case study: Aeration in Lake Waccabuc

Lake setting: Lake Waccabuc is a 140 acre lake in Westchester County, just north of New York City.

The problem: The lake experiences water-quality problems and invasive plant growth typical of eutrophic lakes with high nutrient loads entering the lake through stormwater drains and other sources. The lake thermally stratifies in the spring, and exhibits anoxic conditions throughout the hypolimnion during much of the summer, resulting in an internal phosphorus loading that represents nearly half of the overall nutrient loading to the lake (Martin, 2004).

Response: The Three Lakes Council represents Lake Waccubuc, Lake Oscaleta, and Lake Rippowam. In the early 1970's, the Council and Union Carbide utilized local interest in protecting water quality and their desire to conduct an aeration study to develop a project in these three lakes. In 1972 two hypolimnetic aerators were installed at a depth of 45 feet on the bottom of Lake Waccabuc. Lake Oscaleta and Lake Rippowam were untreated in order to serve as control studies.

Results: The study conducted by Union Carbide reported the following (Three Lakes Council, 2001):

- a decrease in the in-lake nutrient concentrations which otherwise would have been available for algae production;
- an improvement in water-quality conditions by eliminating or decreasing hydrogen sulfide, iron and manganese levels; and
- creation of a suitable environment which can support a coldwater (trout) fishery.

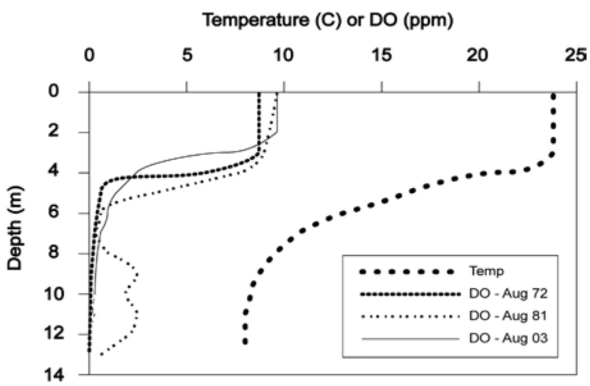


Fig. 7–2. Temperature / Oxygen profiles in Lake Waccabuc August of 1972, 1982, and 2003.

It is not clear from an evaluation of these data (Fig. 7–2) that coldwater fisheries could thrive as a result of aeration. In-lake nutrients, such as deepwater phosphorus, hydrogen, sulfide, iron and manganese levels may have dropped due to the elimination of anoxia near the lake bottom. It also appears that by 2003, these aerators were not functioning as efficiently as they had in the 1970's and early 1980's.

Once the two-year experiment was completed, Union Carbide funded the operation of the aerators by the lake association for several years, after which local contributions covered the $15,000 per year cost of the system. The lake association and local community also engaged in septic and stormwater management activities to reduce external nutrient sources to the lake. They developed multiple water-quality monitoring programs to evaluate long-term changes in the lake. In 2004, the aerators operated at a cost of about $9,000 annually. In 2005, the Three Lakes Council planned to conduct an additional feasibility study for upgrading the aeration system.

Lessons learned: It is not clear from this study if aeration would be successful in other lakes in oxygenating all of the hypolimnion, and if it would be adequate to support the stocking of coldwater fish. These data do indicate that some of the problems associated with an anoxic hypolimnion will be reduced, mostly those related to formation of hydrogen sulfide and related compounds.

Hypolimnetic withdrawal

Principle

Hypolimnetic withdrawal is most often accomplished through the installation of a pipe or siphon along the bottom of the lake, usually at the outlet. Water flows out of the hypolimnion by gravity, past the outlet to the receiving waters. If there is insufficient elevation for gravity flow, an auxiliary pump can be installed.

The benefits from hypolimnetic withdrawal should be greatest during the months of significant stratification and nutrient release, usually June through August. Summertime hypolimnetic withdrawal serves to remove the high-nutrient waters, thus reducing the potential for algal blooms when the epilimnion and hypolimnion mix during fall turnover. Some coldwater algae species common to New York State lakes, including some species of *Oscillatoria* and other blue-green algae capable of regulating their buoyancy, may also be selectively removed with this strategy.

The withdrawal serves to decrease oxygen deficits and elevated nutrient (phosphorus) concentrations in the hypolimnetic waters of lakes. In time, the oxygen and nutrient conditions in the bottom waters significantly improve, and the supply of nutrients available for release from the sediments may be ultimately exhausted. The hypolimnetic withdrawal takes advantage of the higher solubility of oxygen in cooler water to help restore oxygenated conditions to the lake bottom. It may also help preserve the coldwater fisheries that may exist, or allow restoration of one that historically existed in the bottom waters.

Hypolimnetic withdrawal can be used in stratified lakes or small reservoirs with oxygen-poor or nutrient-rich bottom waters. It has been particularly effective for lakes where reductions in external nutrient loading have been made but internal lake loading has not been addressed.

Advantages and disadvantages

This is a relatively passive lake management tool. Withdrawal valves and water flow are mostly inconspicuous and can achieve oxygenation and algae control without the use of algae-killing chemicals or large, artificial circulation or aeration equipment.

The most significant adverse effects of hypolimnetic withdrawal involve the discharge waters. Important fishery streams below the lake outlet are particularly susceptible. Hypolimnetic waters with low oxygen and high nutrient content can cause oxygen depletion, algal blooms, and taste or odor problems in receiving waters. There may be noxious odors in the discharge waters due to the production of hydrogen sulfide in the hypolimnion, rendering the mixture aesthetically unpleasant for downstream residents. Hypolimnetic waters may also contain elevated levels of ammonia, arsenic, or other dangerous compounds. The downstream side-effects generally occur if the receiving waters are nutrient-limited, or if the flow from the discharge constitutes a large percentage of the receiving waters. The flow associated with the discharge, like that from a surface discharge, may need to be sufficiently large to meet downstream flow and water-quality needs. This may dictate the sizing of the pipes and valves used to regulate this discharge.

Conversely, there may be some benefits for downstream waters, such as coldwater conditions to support fish propagation, but the additional need for high water quality may require treatment of the discharge. As more hypolimnetic waters are released from the lake, the water quality of the discharges should improve as oxygen conditions in the hypolimnion improve.

Hypolimnetic withdrawal can also produce thermal instability and possibly destratification. This introduces nutrient-rich anoxic water to the epilimnion, causing algal blooms, odor and taste problems, and recreational and aesthetic impairments. If withdrawal rates are greater than inflow rates, withdrawal may cause an unintended lake drawdown. This is less of an issue when using surface withdrawals, since these are often self-regulated by the height of the boards, depth of the weir, or physical constraints of the control structures.

Costs

For lakes with sufficient elevation to generate gravity flow (head), hypolimnetic withdrawal can be one of the least expensive lake restoration techniques available. For lakes with poor gravity flow, it may be necessary to install pumps and a piping system, which significantly increases the costs. The costs can be low to moderate even with the cost of the pumps and associated plumbing. Typical installation, maintenance, and operation costs for a pumped and pipe withdrawal system has run from $35,000 to $130,000 capital costs, and about $10,000 per year operating cost.

Regulatory issues

The DEC requires a State Pollution Discharge and Elimination System (SPDES) permit for hypolimnetic discharges. Special attention is given to preserving the quality of the receiving waters. Freshwater wetland permits would also be required by the APA for lakes within the Adirondack Park.

History and case studies in New York State

The use of hypolimnetic withdrawal as an in-lake management tool has not been attempted in any New York State lake, although it has been proposed for several large lakes. Galway Lake in Saratoga County has used a controllable gate about 20 feet below the surface of the lake to reduce overall phosphorus concentrations in the lake. The gate is opened from two to eight inches during the summer for intervals of up to two weeks.

Hypolimnetic withdrawal is occasionally used in New York State lakes and reservoirs for other objectives, such as supporting trout populations in downstream rivers and streams. Bottom water from the Ashokan Reservoir in the Catskills, for instance, is released to support trout fisheries in Esopus Creek.

One of the few well-documented instances of a hypolimnetic withdrawal in a New York State lake is an innovative project by Cornell University. Cold, hypolimnetic water from Cayuga Lake acts as a heat sink and provides air conditioning and refrigeration to portions of the Cornell Universitiy campus. This is not a lake-management strategy since the benefits associated with the project are not conferred to the lake itself. Environmental benefit associated with the utility heat exchange comes from the reduction of contributions to global warming, since the alternative would be the continued burning of fossil fuels for campus cooling. Cornell benefits from reduced energy costs. Questions remain regarding potential impacts to the lake with respect to:

- Increased primary productivity associated with the introduction of nutrient-enriched hypolimnetic waters into the shallow, southern end of the lake; and

- Aquatic ecosystem concerns related to damage to small crustaceans (*mysids*) at the intake (Callinan, 2004).

Algae control with chemicals

Algacides

Principle

Algacides are generally copper-based chemicals used to kill algae cells, and to reduce the use impairments associated with excessive algal growth. The copper inhibits the photosynthetic ability of the algae cells, and may affect the way nitrogen compounds are metabolized within the cell. Copper is sometimes combined with some herbicides to reduce standing populations of rooted plants as well as algae.

Copper sulfate is the most common algacide and one of the most popular algae control techniques. Copper sulfate is usually applied in granular form, often dragged in burlap bags behind an applicator boat to ensure slow release. Liquid forms of copper sulfate can be applied where other copper formulations might bind with suspended particles, dissolved organic matter, or carbonate ions, rendering them ineffective for algae control. Copper sulfate can be used to control algal blooms, and in extreme situations, to control excessive rooted plant growth.

Some formulations of algacides use chelated copper, which consists of copper combined with other agents to prevent staining. Compared to copper sulfate, chelated copper tends to be less toxic, takes longer to work and persists in the water longer.

Not all algacides are copper based. Non-copper algacides, usually involving an oxidizing agent, are use to remove algae from the water and from hard surfaces such as boats and docks. Chlorine can serve as an algacide in controlling flagellated algae that move with the use of a whip-like tail, including dinoflagellates species common to many New York State lakes. In very small ponds, non-copper algacides may be used to oxidize algae cells, but will generate hydrogen peroxide when the active ingredient reacts with water. Algacides using sodium carbonate peroxyhydrate have been registered for use in New York State.

Advantage and disadvantages

Algacides are one of the few algae control strategies that work very quickly. These can be useful in providing short-term relief while management plans are developed for the long-term problem of controlling nutrient in-flow. The quick action and low cost of algacides accounts for its popularity. Copper sulfate could, theoretically, be effective on any lake with a flushing time greater than a few weeks since the contact time to destroy algae using copper is very low. Copper sulfate has been used in a wide variety of lakes, from small swimming ponds and lakes to the swimming beaches of very large lakes.

The use of algacides is also a multi-use control strategy. It can be applied to waters used for recreation and it can even help control swimmers itch. Some of the copper compounds have been approved for use in drinking-water supplies, and may help to reduce algae populations that can produce toxins or taste and odor compounds. This advantage may become more prominent as municipalities become increasingly aware that chlorinating water supplies with heavy algae concentrations produces trihalomethanes and other carcinogens. Use of algacides may be limited in lakes supplying drinking water since copper can impart an unpleasant taste. Oxidizing algacides, such as those using sodium carbonate peroxyhydrate, cannot be used in treated drinking-water reservoirs.

Copper sulfate application may be restricted to particular sites within a lake. This is due to the mixing capabilities of the treatment lake, the dose rate, and the proximity to the treatment site of any significant recreational sites, inflow-outflow streams and water-intake pipes.

There are only limited data on the toxicological effects of copper on either humans or aquatic organisms. Nearly all of these data consider only the acute or short-term toxicity effects. Non-target organisms may be adversely affected by copper sulfate treatments. Some fish species and amphibians are particularly sensitive to even moderate copper levels. Copper levels as low as five ppb may have adverse effects on some aquatic organisms. Copper sulfate will also kill zooplankton, the microscopic animals that feed on algae. Snails are susceptible to copper, and this has been exploited as a means for addressing swimmers itch problems as discussed later in this chapter.

Studies in New York State and Vermont have shown conflicting results about the effect of copper on benthic organisms. The DEC study of lakes treated with copper sulfate found elevated copper levels in the sediments, and some effect on the macroinvertebrate diversity, particularly mayflies. These effects could not be definitively tied to sediment toxicity, since lakes requiring copper treatments may suffer loss of diversity due to the effects from eutrophication.

It is not clear that copper sulfate is acting as anything but a placebo even if the side effects after copper sulfate treatment were either overestimated or mistakenly tied to the treatment. Water-quality data collected from several lakes that have been treated with algacides have not shown any significant changes in either water transparency or algae levels after treatment (NYSDEC, 2004). The residents of the communities surrounding these lakes, however, believe that the copper sulfate improved water quality in their lakes. It is unclear whether the same changes would have been perceived after the application of other control techniques or after no action at all. The effectiveness of any control technique should be verified by both quantitative methods, through water-quality testing and measurements and qualitative measures, through resident surveys and an assessment of changes in recreational uses of the lake.

Algae usually grow faster than zooplankton. Copper sulfate treatment may cause a "rebound" effect shortly after application when algae levels increase faster than zooplankton levels. For many lakes, multiple treatments may be required to keep algae levels in check through the growing season and the summer recreational season. Due to the potentially significant ecological side effects and limited effectiveness of the treatment, however, it is likely that is has achieved its popularity as an algacide primarily due to its immediate control and low cost.

While copper can have a detrimental effect on target and non-target organisms, certain species of blue-green algae may be tolerant to copper, including the noxious species *Aphanizomenon, Oscillatoria,* and *Anabaena.* This may result in blue-green algae concentrations greater than those that occurred before treatment.

Many of the potentially observable changes within the ecosystem after copper application may be masked by other water-quality changes. Many lakes experiencing algal blooms are also affected by other problems that previously altered the ecosystem. The potential side effect associated with algacides may not be easily detectable.

Algacides have been called "a temporary poison for a permanent problem: (Stewart, 1986). It is "temporary" due to the resiliency and fast growth rate of algae. It is "poison" due to the potentially toxic effects of copper on several organisms within the food web. Copper serves as a micronutrient in the human diet, and is toxic to humans only at very large doses. It is a "permanent problem" because only the symptoms are addressed by copper sulfate treatments, not the causes or sources of excessive algae. While copper has an immediate effect on existing algae concentrations, the effect is usually temporary. Since this control strategy does not address the problem of excessive nutrient levels, or reduce internal or external nutrient cycling, algae may return to pre-treatment levels within a short time. Some lake communities may find it necessary to apply copper several times over the course of a summer.

Case study: Algacides in Ballston and Kinderhook Lakes

Lake setting: Ballston Lake is a nearly 300-acre lake in Saratoga County, just south of the southeast portion of the Adirondack Park. Kinderhook Lake is a 350-acre, 12-meters deep impoundment of the Valatie Kill just south of the Capital District region of New York.

The problem: Ballston Lake suffers from frequent algal blooms, and the lake has relatively high phosphorus concentrations of about 25-30 ppb. Secchi disk transparency readings are typically about 2 meters, indicating low-water clarity. Like Ballston Lake, Kinderhook Lake has a long history of copper sulfate treatments, with regular and multi-year treatments since 1960. The lake association became concerned over long-term loading of copper in the lake and sediments, and conducted an experimental study of the use of alum.

Response: Copper sulfate has been regularly used to control excessive algae levels in Ballston Lake since at least the early 1960s. There were whole-lake treatments after 1973, although treatments have not occurred since 1999. Typically, 1200 pounds of copper sulfate were applied in late June or early July, resulting in application rates of about 0.3 parts-per-million.

Results: The range of water-clarity readings in Ballston Lake in the late 1970s was from 1.7m to 2.4m, slightly more compressed but approximately equivalent to the same range found from the late 1980s through the present day. Phosphorus and algae levels were in the same range. A DEC study of the lake in the mid-1990s found that sediment copper levels of 175 milligrams per kilogram (mg/kg) were above copper levels in untreated lakes (10–20 mg/kg), and above the state sediment standard expected to result in "contaminated" sediment. Although these readings frequently result in toxicity for many benthic macroinvertebrates, this was not found to be true in Ballston Lake. It was found in many copper-treated New York State lakes evaluated in this study, including Kinderhook Lake.

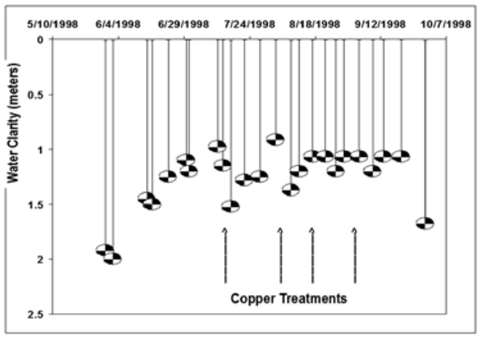


Fig. 7–3a. Effect of copper treatments on Kinderhook Lake clarity.

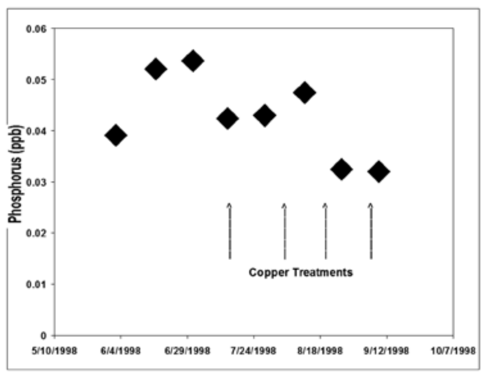


Fig. 7–3b. Effect of copper treatments on Kinderhook Lake total phosphorus.

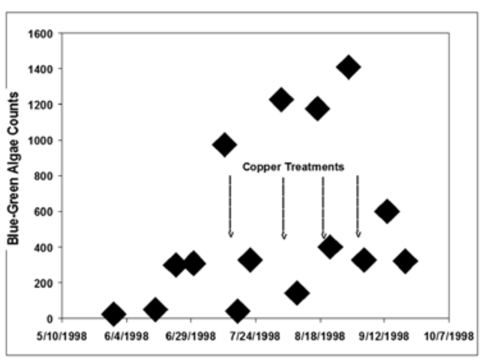


Fig. 7–3c. Effect of copper treatments on Kinderhook Lake blue-green algae.

In a typical year in Kinderhook Lake, copper was applied to the lake in two-week intervals during the peak recreational season, resulting in four copper treatments. The impact on blue-green algae levels and water clarity can be seen in the following plots for copper treatments in 1998. (Collins, 2004; NYSDEC, 2004)

The results from the water-quality monitoring indicate that blue-green algae levels dropped immediately after the treatments. This resulted in an increase of about one foot in water clarity. Within a week, clarity readings dropped again and blue-green algae levels increased. By the time of the next treatment, both water-clarity and blue-green algae readings returned to the levels they had prior to the treatment.

Lessons learned: Copper treatments in both Ballston Lake and Kinderhook Lake have not resulted in long-term decreases in algae levels, and increase in water clarity appeared to be short-lived. Sediment toxicity did not appear to occur in either lake. While the residents of Kinderhook Lake have experimented with the use of other methods for reducing algae levels, copper continues to be used extensively in many New York State lakes, including Ballston Lake.

Costs

Copper sulfate is one of the least expensive control techniques. Costs consist of chemicals and fees required by the licensed applicators. Chemical costs area \$5 to \$25 per **acre-foot** (one acre of surface area to a depth of one foot). The applicator costs usually are not substantial. Costs for controlling snail populations should be comparable to algae control costs.

Regulatory issues

Copper sulfate use is governed by both state law (6NYCRR Part 327) and approved pesticides labels. Permits and licensed applicators are required for treatment of public lakes with copper sulfate or other algacides. Purchase permits suffice for ponds of less than one acre with no outlet. Purchase permits allow for the use of copper sulfate by the general public, rather than a licensed applicator, provided that the label instructions are followed. When copper sulfate is to be used for treatment of snails or macroinvertebrates, permits have not always been required, although that is currently under review by regulatory agencies.

Treatments are generally restricted to the time period from May to September. Treatments after Labor Day require special authorization by DEC. Repeat treatments are not allowed at intervals of less than two weeks, and use of the lake for bathing and livestock watering is prohibited for at least 24 hours following a treatment. Dosages are not to exceed 0.3 ppm copper sulfate or 0.2 ppm for chelated copper in the upper six feet in ponds or lakes with over two acres of surface area. For lakes with low alkalinity, lower dosage rates are computed based on alkalinity measurements, and product labels indicate that it should not be used if carbonate hardness of the water is less than 50 ppm. It must be applied as a liquid (spray) or solid (with burlap bags), not by direct broadcasting of the crystalline form.

Non-copper algacides are restricted-use pesticides. They are available for use only by licensed applicators, not by the general public, and thus are subject to the same regulations as copper products.

History and case studies in New York State

Copper sulfate has been used for many decades in New York State lakes, some on a biweekly to annual basis. It is used yearly on more than 300 lakes and ponds throughout the state, mostly on small ponds of less than three acres. Most of these small-pond treatments have not been well document. Case studies from Ballston Lake and Kinderhook Lake are typical of copper treatments (see Case study on algacides).

Nutrient precipitation and inactivation

Principle

Nutrient precipitation uses a chemical agent, such as alum, to remove phosphorus from the water column. Nutrient deactivation works by sealing the bottom sediments to prevent the release of phosphorus to the overlying water with low oxygen concentrations. These two actions reduce nutrient concentrations in the water and often result in decreased algae levels and increased water clarity. Phosphorus precipitation and inactivation are used primarily on lakes with significant internal nutrient loading and where the external nutrient loads have been reduced as much as possible. This method is also commonly used on small swimming ponds and lakes that are plagued by nuisance algal blooms.

In a process called flocculation, the chemical agent binds to phosphorus, causing it to form heavier aggregates that precipitate out of the water column. Aluminum and, less frequently iron salts are used to flocculate due to their high affinity for phosphorus. Aluminum sulfate, or **alum**, the most commonly used binding agent, can be used in either granular or liquid form.

Alum added at small dose rates can achieve phosphorus precipitation but may not be sufficient to provide inactivation. Alum applied at a large dose can provide long-term inactivation that includes sealing the bottom sediments. This minimizes the release of biologically available phosphorus from the lake sediments when oxygen is depleted from the hypolimnion. Larger doses are often added directly to the hypolimnion to reduce the exposure of near-shore organisms to the toxic effects of aluminum. Hypolimnetic addition may reduce the potential for phosphorus precipitation from the upper waters as bound in algae cells. The application rates are dependent on the initial pH and buffering capacity (alkalinity) of the water. Large doses must neither compromise environmental safety nor exceed acceptable levels of aluminum and acidity. Whole-lake treatments should consider the relative depth, volume and alkalinity of each section of the lake to avoid overdosing or underdosing any given section.

Incoming streams and other inlets can also be treated with aluminum or iron salts to reduce the concentrations of phosphorus. This may require sedimentation basins to improve the time available for the precipitation reactions to occur. This treatment may be limited to lakes with one or two very large surface inlets and little, if any, spring or groundwater flow.

Advantages and disadvantages

Alum has a long history of use in the municipal drinking water treatment process, and may not have the same stigma that often accompanies other chemicals applied to lakes. This is particularly true in the context of removing pollutants, such as toxin-producing algae that might otherwise affect lake users. The ability of alum and other coagulants to purge particles from the water column is a significant advantage as both a short-term and long-term strategy for reducing suspended material in the lake.

For many New York State lakes, this technique may be a reasonable alternative to either algacides, which are often ineffective, or sediment removal, which is expensive and public acceptance is difficult to obtain. Compared with other alternatives, such as whole-lake dredging, phosphorus precipitation and inactivation can be extremely cost-effective and equally long-lasting. Depending on the alum dose rate, the quantity of nutrients bound within the sediments, and the existence and success of external nutrient control, phosphorus precipitation and inactivation may be effective for many years. Data suggest that alum may effectively seal lake nutrients for 10 years in unstratified lakes, and 20 years in stratified lakes.

Like algacides, alum can work very quickly, often within an hour. Unlike algacides and other less expensive treatments, alum addition goes beyond cosmetic repair. Alum addition may be ineffective if external nutrient sources are not "turned off," just as aquatic plant controls are less effective if the targeted nuisance species continue to re-infest the lake.

Adding alum may also dramatically increase transparency by precipitating the suspended phosphorus and reducing the algal turbidity. While this is normally an advantage, clearer water may result in a substantial increase in rooted aquatic vegetation, particularly in lakes where deeper weed growth is currently limited by poor light transmission.

The most serious disadvantage of using alum is the potential for elevated aluminum levels and low pH. The toxic effects of dissolved aluminum on non-algal, aquatic organisms and humans are not well documented. Dissolved concentrations of free aluminum above 100 ppb can be toxic to many fish species, while other species may show acute or chronic toxicity symptoms at concentrations as low as 50 ppb. Large doses of alum can potentially increase the levels of free aluminum, and lower pH to levels that could be dangerous for many animal species. Free aluminum is the most biologically available form of aluminum. The addition of aluminum salts to a lake serves to lower the pH. At pH levels near 5, dissolved aluminum is toxic to fish. Most professional lake consultants will check the buffering capacity of a lake before applying alum. Pre-buffered alum is also commercially available to minimize this concern.

Many of the concerns about aluminum toxicity may not be warranted. In highly productive, well-buffered, hard water lakes, which are the usual recipients of alum treatment, alum addition sufficient to provide adequate phosphorus inactivation and binding will not drop the pH to dangerous levels. In these lakes, most aluminum quickly drops out of the water column, and remains bound in the sediment, unavailable to aquatic organisms. Poorly buffered lakes, including many lakes within the Adirondack Park, may not be good candidates for alum addition.

Some species of pathogenic bacteria can survive for short periods during flocculation but prior to precipitation. These pathogens could be ingested when the water is used for drinking or recreational purposes. This danger may warrant a period of restricted use immediately following application of alum.

Costs

Phosphorus precipitation or inactivation will have a high initial cost for labor and equipment. The cost ranges from $100 to more than $500 per acre, depending on whether the primary goal of the treatment is phosphorus precipitation or inactivation. Phosphorus inactivation is a long-term treatment. Its initial cost can be amortized over several years, so alum can be among the least expensive algae control techniques.

Regulatory issues

As a general rule, Environmental Impact Statements (EIS) will need to be completed and accepted for the use of alum in most New York State lakes. Beyond that, at the time of this publication, there remains uncertainty about the regulatory status of alum.

The New York City Department of Environmental Protection (NYCDEP) has determined that alum additions to the tunnels of some of the upstate drinking-water reservoirs will not have a significant negative effect on the environment. The DEC has ruled that alum discharges from the reservoir tunnels would violate the narrative water-quality standard for settleable solids and result in the deposition of an environmentally harmful quantity of accumulated particulate matter on the reservoir bottom. Some DEC offices have determined the SPDES permits would be required. Others maintain that permits issued through other program would be adequate, such as wetland permits issued through Article 24 of the ECL.

Alum may serve to reduce algae or even weed growth by binding phosphorus otherwise available to these plants, but it is not registered for use as an aquatic pesticide in New York State. Aquatic herbicide permits under Article 15 of the ECL, therefore, cannot be issued for alum, and alum treatments intended to control algae and other aquatic plants, or potentially even the nutrients that specifically cause algae growth, cannot be approved since they would require the use of an illegal, unregistered herbicide.

The DEC may eventually identify conditions under which alum can be used without applying for permits through one of three programs. Consistent statewide regulations for the use of alum are likely to be implemented in the near future. Until that time, DEC regional offices must be consulted when alum additions are considered.

The use of alum in lakes within the Adirondack Park is a regulated activity, requiring a permit from the APA if the activity could substantially impair the functions served by or the benefits derived from freshwater wetlands. It is not clear if APA jurisdiction applies if alum is injected directly and solely to the deepwater region of a lake with greater than two meters depth, although shallower treatments clearly require wetland permits.

The regulatory uncertainty of this treatment in New York State may significantly curtail its use as a lake-management tool, at least in the near future. Regulators faced with controversial decisions may not be inclined to issue permits or entertain proposals for the use of this management strategy within the realm of existing regulatory structures, such as SPDES. The only permits issued in recent years have been through the wetlands permitting program. Until government regulators determine the most appropriate permitting mechanisms for alum, and outline the procedures for these permits, it is unlikely that alum will be used extensively as a lake-management tool in New York State. Even if these thorny regulatory questions are resolved, heightened awareness of the issues associated with alum treatments will result in much greater scrutiny than for other physical control strategies that operate under similar principles.

History and cases studies in New York State

Saratoga Lake and Irondequoit Bay have been treated with alum in an experimental manner to determine its effectiveness in phosphorus inactivation. Irondequoit Bay in Rochester was treated during the summer of 1987. It showed an increase in water clarity, reduced surface algae levels and lower phosphorus readings within the hypolimnetic waters. This lasted

Case study: Nutrient inactivation (alum) in Kinderhook Lake

Lake setting: Kinderhook Lake is a 350-acre, 12-meter deep impoundment of the Valatie Kill just south of the Capital District region of New York State.

The problem: Copper sulfate had been regularly used since at least the 1960s to manage blue-green algal blooms common to the lake. Sampling was conducted by the Kinderhook Lake Corporation through the Citizens Statewide Lake Assessment Program (CSLAP), and DEC monitoring through the Lake Classification and Inventory (LCI). These surveys concluded that blooms were triggered by excessive loading of phosphorus in the lake. As much as half of this loading may have been due to internal sources caused by phosphorus released from bottom sediments under anoxic conditions. Although surface phosphorus concentrations generally were below 50 to 60 ppb, deepwater phosphorus levels at times exceeded 800 ppb.

Response: The Corporation was issued a DEC wetlands permit for the application, since the lake is classified as a DEC Article 24 wetland. It conducted an experimental low-level alum treatment of the lake beginning in 2001, hoping to reduce the perpetual need for copper additions, and to protect the lake from significant zooplankton toxicity and dangerous drops in pH. Alum was added in 1000-1500 pound (lb) doses in regular intervals from late May through late August. Alum dose rates were devised to increase water clarity to no greater than four to five feet to prevent the transformation of the lake from an algae-dominated to a macrophyte-dominated system. Excessive growth of Eurasian watermilfoil, water chestnut, curly-leafed pondweed, bushy naiad, and Sago pondweed has regularly occurred when water clarity is "too high". Throughout the experiment, they documented changes in nutrient concentrations, water clarity, algae levels, and speciation. The goals for surface and deepwater nutrient levels were originally 20ppb and 1000ppb respectively. Alum treatments were modified after 2002 in an attempt to lower deepwater phosphorus levels, surface water nutrient concentrations, and to increase water clarity.

Results: The following results were obtained from the experimental alum treatment of Kinderhook Lake (Collins, 2007):

Treatment strategies were modified each year after analyzing the water quality and microscopic results from the previous year. Alum was injected directly into the hypolimnion in 2002, and more extensively in 2003, in an attempt to reduce deepwater phosphorus concentrations. Alum was added to the Valatie Kill in 2004 in hopes of reducing external nutrient loading to the lake. Overall, surface and deepwater phosphorus levels decreased, while algae community dominance shifted from blue-green algae to green algae. Continued use of this promising management technique is caught in the uncertainty over the permitting and evaluation of alum projects.

Lessons learned: Public perceptions of the treatments were generally favorable, and the lake association was considering coupling alum treatments with low-level copper treatments when blue-green algae counts exceeded 100. They were also considering installation of aerators to increase deepwater oxygen levels in a portion of the lake with high organic sediments that reduce the effectiveness of the alum treatment.

Year	Alum Added (lbs/yr)	Copper Added (lbs/yr)	% Surf TP Samples Exceeding 20ppb	% Surf Samples Exceeding 40 ppb	Max. Hypo TP (ppb)	% Water Clarity Readings < 4ft	Max. Blue-Green Algae Counts
1998	none		100%	100%	800 ppb	60%	1400
1999	none		100%	40%	NA	60%	2600
2001	25,000		80%	20%	550 ppb	70%	700
2002	24,400+ 20,000#		75%	13%	800 ppb	45%	600
2003	12,000+ 43,050#		Not measured	Not measured	200 ppb	30%	350
2004	15,000+ 20,500# 8,000@	1,000	Not measured	Not measured	175 ppb	35%	550
2005	9,000+ 10,500#	1,000	Not reported	Not reported	500 ppb	35%	550
2006	10,000+ 15,000# 1,700@	1,000	100%	33%	250 ppb	45%	600
2007	1,500+ 20,500#	180 gallons	Not reported	Not reported	275 ppb	25%	450
2008	none	5,850	Not reported	Not reported	400 ppb	8%	200

+ alum added to the surface waters, # alum added directly at a depth below 10 feet
@ alum added to the inlet stream and shoreline runoff areas

Table 7–1. Effect of alum treatment in Kinderhook Lake from 1998 through 2007.

for many years. In Saratoga Lake, there was no appreciable improvement in water quality as a result of the alum application due to the small treatment area and low application rates.

An experimental, low-level alum treatment, in which alum essentially replaced copper sulfate, was conducted in Kinderhook Lake. Surface phosphorus and algae levels were lowered to some degree. Drastic algae reductions were not desired due to the potential for increases in rooted aquatic plants as a result of higher water clarity. Deepwater nutrient levels proved more difficult to control (see Case study on nutrient inactivation).

Algae control through biology

Biomanipulation and fish stocking

Principle

Biomanipulation is a broad term that describes any biological introduction to an ecosystem for the purpose of shifting ecological conditions to the advantage of a desired species of lake condition, or to enhance recreational conditions. It is used primarily to alter the ecosystem dynamics for the purpose of controlling specific fish populations and reducing algae levels. Aquatic plant management by stocking herbivorous insects and fish is also a form of biomanipulation, as discussed in Chapter six, "Aquatic plants." Gamefish stocking is utilized to enhance the population of fish species prized by anglers, but is not done with the intent of biomanipulattion, though it may have biomanipulation consequences. Desired sports fish have been stocked for many decades, as discussed in Chapter three, "Lake problems." Its use as a water-quality management tool dates only from the mid-1970s.

Biomanipulation can generally be divided into two categories:

- stocking specific organisms, usually fish, to enhance zooplankton grazing, which will reduce algae populations; and
- removal of specific organisms, usually bottom-dwelling fish, to enhance water clarity.

Fish stocking to reduce algae usually involves piscivorous (fish-eating) fish that outcompete or prey on planktivorous (plankton-eating) fish that consume large zooplankton. Examples include stocking piscivorous large-mouth bass, lake trout and walleye that target the planktivorous bluegills and alewives. The reduction of planktivores populations tends to increase the size and abundance of zooplankton, such as *Daphnia*, that feed on algae populations. The result is increased water clarity. This is often referred to as "top-down" management of the food web since it involves manipulating the top of the web, the largest secondary consumers. This is achieved in a number of ways:

- increasing piscivores populations by stocking new or existing species;
- restricting fishing access or angler removal of piscivores; and
- improving piscivores habitat to increase populations.

Fish removal is used to control bottom-feeding fish that often cause turbidity and increase nutrient concentrations by their disturbance and consumption of organic material near the lake bottom. Carp are the most prevalent bottom-feeding species, but brown bullhead, suckers, and other bottom-dwellers are also found in New York State lakes. These are removed by a number of mechanisms, including fish poisoning, water-level manipulations, and targeted catches. Rotenone, a natural substance found in tropical plants that inhibits the ability of fish to use oxygen, has been used more than 150 times in New York State since the 1940s to control undesirable species. Concentrations of rotenone cannot exceed 1 ppm. Other piscicide fish poisons, such as **TFM (trifluoromethl-nitrophenol)**, have been used to control lamprey in Lake Champlain.

Several million fish are stocked by DEC in more than 1,200 waterbodies throughout the state. Sports fish such as brook, brown and rainbow trout, walleye, salmon, bass, perch and muskellunge are stocked in lakes and ponds to enhance the fishing experience, not as a means to manipulate water-quality conditions. Stocking programs are conducted on heavily used lakes and streams with public access to enhance sports fisheries and to restore native fish species to the full extent of their historical range. Fingerlings, young fish three to five inches long, are generally stocked in the summer or fall. Yearlings, older fish six to nine inches long, are stocked in the spring. These fish are raised in one of the twelve DEC fish hatcheries around the state. Each hatchery typically specializes in one or more of the stocked species. Private fish and game clubs, lake associations, local governments, and individuals interested in promoting or enhancing sports fisheries also stock fish in New York State lakes, frequently using fish raised at one of about 50 private or out-of-state hatcheries permitted by DEC.

Advantages and disadvantages

This top-down approach may be as effective as the bottom-up approaches that utilize nutrient controls to reduce algae levels. Biomanipulation may serve to achieve multiple water-quality objectives, while at the same time increasing the population of desired fish species and removing "trash" fish. The longevity of biomanipulation may be greater than other in-lake algae control strategies, such as algacides. It is most effective if the stocked fish survive and propagate, if removed species are prevented from re-entering the lake by fish barriers, and if selective fishing pressures prevent the removed species from becoming re-established as a dominant species. Stocking must be balanced by maintaining low fishing pressure on the stocked species.

Stocking policies intended primarily to enhance sports fisheries could also potentially benefit a larger lake user group. It can help to restore lake fisheries impacted by temporary or transient problems. Those problems include an unusual winter fishkill, chemical reclamation such as using rotenone, or after another lake problem have been "solved" such as using lime to neutralize a fishless acidic lake. Fish can also be introduced into a newly created pond or otherwise fishless lake.

The concept of biomanipulation is a nice theory, and will sometimes work in practice. Like all biological introductions or manipulations, however, the results are not easily predictable. Stocking fish that are not naturally found at sufficiently high concentration levels to meet the stocking objectives may cause unexpected side effects. Insufficient concentrations of a desired fish species, or abundance of "trash fish," may be associated with water-quality conditions, existing fishing practices or policies, or plankton communities controlled by something other than predator-prey relationships, such as toxins or micronutrient levels. The increase in zooplankton grazing as a result of piscivores stocking may selectively control more palatable algae, such as diatoms, and leave less edible plankton, such as blue-greens. Blue-green algae are often the most dominant algae in highly productive lakes, making them among the most likely candidates for biomanipulation. These algae may be found in long filaments and large colony size, or may exude toxins or gelatinous coatings that render them inedible to zooplankton. There is some evidence that large, benthic invertebrate predators and insects will also benefit from reduction in planktivorous fish, and this may have a negative effect on the zooplankton. This will serve to increase algae levels, since these invertebrate predators do not include algae within their prey.

Selective removal of brown bullhead *(Istalurus nebulosus)* and carp *(Cyprinus carpio)* can be very difficult. These fish are prolific and often spawn in areas not subject to disturbance during drawdown. Although drawdown is not always effective, the use of rotenone or other fish poisons can be very controversial unless the target is an exotic or invasive fish. Several desirable fish species, such as walleye and rainbow trout, are more sensitive to rotenone than are many of the potential target species, such as carp. Brown bullhead, in particular, may also be considered a desirable species by some anglers.

Fish stocking can introduce non-native fish into a "natural" fish community, or may introduce pathogens or illnesses associated with the hatchery-raised stocked fish. Genetic diversity is affected when large quantities of hatchery-raised, genetically homogeneous species are introduced. Some desired sports fish, such as alewives, can exert a negative biomanipulation effect on a lake system by selectively removing zooplankton or other algal grazers. Biomanipulation to increase water clarity and light penetration can also result in increased macrophyte growth.

For lakes with existing native populations of stocked piscivores, biomanipulation is more likely to be considered a natural control strategy. Even without a pre-existing population, biological control is perceived to be more "natural" then algacides, and more inconspicuous than physical controls. Biomanipulation, therefore, does not always result in the controversies that surround other control strategies. Biomanipulation remains an experimental procedure, however, with regard to water quality enhancement. Similar to other biological control mechanisms, the introduction of a new element into the predator-prey relationships that may otherwise be stable can bring unexpected and unpredictable results. It can create controversy about fish removal with the use of fish poisons, or through large-scale fishing tournaments that create user conflicts or lake overcrowding. These effects can complicate the process of building cooperation among lake user groups and others contributing to the holistic management of the lake. While fish stocking may enhance the recreational use of the lake for lake residents, it often makes the lake a more desirable destination for visitors on lakes with public access, and this can be a double-edged sword. While it can bring economic benefits to a region, it also has the potential for triggering water-quality problems through increased use of the lake. As such, biomanipulation and stocking should be evaluated and utilized with great caution, and must have the early involvement of all parties, including lake users, residents, and regulatory agencies (see Case study on biomanipulation).

Costs

The typical price of the fish associated with fish stocking is $100 to $200 per hundred fish, with a minimum order required. Stocking rates of anywhere from 100 to 1,000 fish per acre have been recommended for biomanipulation. The broad range accounts for highly variable water-quality conditions, plankton levels, existing fish populations and stocked species. For sports fishery stocking, a standard rate is about 500 trout fingerlings per acre, about 100 bass fingerlings per acre, and about 500 bluegill fingerlings per acre. Lower stocking rates are used for older fish. DEC recommends stocking older walleye at a rate of 20 per acre. The cost for removing fish is about $500 to $1,000 per acre. The cost for rotenone control is about $20 per acre-foot of lake volume.

Regulatory issues

Article 11 of the ECL (ECL 11-0507) states: "Fish or fish eggs shall not be placed in any waters of the state unless a permit is first obtained from the [New York State] Department [of Environmental Conservation]" This even applies to private farm ponds. Stocking permits can be obtained through DEC Regional Fisheries offices. They have also been folded into the Farm Fish Pond License, a free, five-year license, also required by DEC to take fish from these ponds. The use of rotenone requires a licensed New York State pesticide applicator and a permit from DEC. A freshwater wetlands permit is also required from the APA for waters within the Adirondack Park.

History and case studies in New York State

Although biomanipulation has been commonly used in New York State as a fisheries-management tool, it has not been regularly utilized or documented as a lake-management activity to restore or enhance water-quality conditions. A small-scale biomanipulation project suggested for highly eutrophic Lake Neatahwanta involves stocking predator fish, such as largemouth bass and northern pike, to feed on zooplanktivorous fish such as yellow perch and rudd. Among the more controversial proposals for the lake is a suggestion to stock the lake with zebra mussels to reduce algae populations. Walleye and other top predator fish have been stocked at high rates in several Madison County lakes to feed on bluegills and pumpkinseed that consume milfoil weevils, as discussed in Chapter six "Aquatic plants."

An evaluation of 44 published reports in which piscivorous fish were stocked in waterbodies to improve trophic status found that planktivorous fish declined, although less so in lakes with lower productivity. In nearly 75 percent of these studies, zooplankton size and density increased, but this led

Case study: Biomanipulaton in Moe Pond

Lake setting: Moe Pond is a 38-acre impoundment created in 1939 in the Central New York Leatherstocking Region of the state.

The problem: Although it was probably naturally acidic, the lake has exhibited high nutrient and algae levels since at least 1970. It was dominated by blue-green algal blooms. These blooms resulted from high nutrients and a reduction in acidity as a result of the introduction of 50 metric tons of crushed limestone in 1966 and 1967 to irrigate a downstream golf course. In the early 1970's, phosphorus concentrations in the pond ranged from 40 to 70 ppb. By 1994, while phosphorus levels had dropped slightly (to 37 ppb), algae levels (37 ppb) and water clarity readings (0.9m) were typical of lakes suffering from extensive algal blooms. This 1994 survey determined that the fish community was composed of only brown bullhead (*Ictalurus nebulous*) and golden shiner (*Notemigonus crysolucas*). The latter is a planktivorous fish thought to be responsible for the lack of large zooplankton, which in turn allowed for high algal densities. It was suggested that if predators of golden shiner were introduced, the zooplankton would proliferate and algal grazing would increase, thereby increasing water transparency.

Response: Although a biomanipulation stocking project was planned, it was discovered that an unauthorized stocking of piscivorous fish had occurred by the spring of 1999. It contained both largemouth bass (Micropterous slmoides) and smallmouth bass (Micropterous dolomiem). The pond is so remote that it is likely that the fish were transported to the pond in buckets, and thus were probably limited in number. Subsequent monitoring by SUNY Oneonta focused on water quality and biological changes to the pond. Water-quality indicators related to eutrophication were evaluated, when available, before and after the fish stocking.

Results: It appears that water clarity increased significantly, triggered by a decrease in algae levels (chlorophyll a) and phosphorus concentrations in the pond. The decrease in algae levels was also triggered by an increase in zooplankton, particularly rotifers and Copepods, which in turn increased due to the drop in planktivorous fish.

The decrease in phosphorus concentrations, along with the increase in water clarity may have triggered a shift from algae dominance to macrophyte dominance. Prior to 2000, the presence of a common waterweed (*Elodea canadensis*) was not noted in the lake. These plants were first observed by 2000. By 2003 they were found in dense stands reaching the surface of nearly the entire pond, growing from a depth of as much as two meters.

Lessons learned: Biomanipulation projects can work, although it is unlikely the future poorly planned projects will be as successful, at least from the perspective of water quality rather than nuisance weed growth (Albright et al, 2004).

	1972	1994	1999	2000	2001	2002
Secchi Depth (m)	-	0.9	-	1.2	1.1	>2.2
Total Phosphorus (ppb)	40-70	37	-	-	-	26
Nitrite+Nitrate-N (ppm)	-	<0.05	-	-	-	0.14
Chlorophyll a (ppb)	-	37	-	27	20	12
Rotifers (# per L)	-	-	673	425	1251	2842
Cladocera (# per L)	-	-	378	785	234	1307
Copepods (# per L)	-	-	370	276	174	838
Golden Shiners (# per L)	-	8,142	3,210	1,040	1,708	
L.Mouth Bass (# per L)	-	0	1,588	811	3,724	
S.Mouth Bass (# per L)	-	0	958	576	504	

Table 7–2. Effects of biomanipulation in Moe Pond from 1972 through 2002.

to lower algae levels and higher water clarity in only about 20 percent of the studies (DeMelo, 1992). In a separate review of 41 eutrophic lakes in which piscivores stocking was the only management action pursued, only about 30 percent exhibited some water-quality improvement (Drenner, 1999).

Rotenone has been used within the Adirondacks to restore native brook trout by removing other fish that compete with the brook trout, but this was not intended to improve water quality. Biomanipulation has been limited to either accidental introductions of exotic species, such as zebra mussels or Eurasian watermilfoil, or unintended results from the introduction of fish, such as the alewives introduced into Conesus Lake.

Barley straw

Principle

Barley straw has been used to reduce algae levels in ponds and lakes, resulting in clearer water and few incidences of algal blooms. This treatment was first utilized by farmers in England in the early 1990s (Holz, 2000). Barley straw research results are available through the Center for Aquatic Plant Management in England (CAPM) (see Appendix F, ”Internet resources”).

How barley straw affects algae is not understood, but most of the research suggests one or more of the following:

- Barley straw or the fungi that decompose it in the water, releases hydrogen peroxide or organic compounds (oxidized polyphenolics) that inhibit the growth of new algae.
- Rotifers released from the barley straw decompose algae cells.
- Algae cells or phosphorus attach to the straw, or the organic materials released from the straw, and are decomposed by bacteria.
- Bacteria utilize carbon from decomposing barley straw, resulting in expansive bacterial growth that may outcompete algae cells for nutrients.

There has not been a very consistent track record on the use of barley straw. Some studies have found good control of most types of algae. Others have found that barley straw does not work very well, and still others have found that filamentous (mat-forming) algae may actually increase. Algae control may be delayed if the water temperature is too cold and the period for degradation of the straw is delayed. The decay of high doses of straw, and the resulting algae loss, may trigger delayed algal blooms and oxygen deficits, but this usually requires very higher dose rates. Some evidence indicates that barley straw is less effective in controlling nuisance algae in lakes and ponds with a retention time of less than 50 days.

Dried straw should be used, rather than barley hay or fresh barley. The barley straw must be loosely netted to allow air and water contact across a large surface area to maximize oxygen exchange within the straw. Netting that holds Christmas trees or even large onion bags are often used. Typical application rates are two to five bales per acre (100 to 250 pounds), with higher rates used for lakes with a history of algae problems. The application rate does not appear to be dependent upon water depth. Effective control is less likely when algae are growing at depths that exceed four feet. Anchored floats are used to keep the netted straw properly located in the upper three to four feet of water. This enhances exposure of straw to areas of most intense algae growth and associated use impairments.

The straw is more effective at controlling new algae growth than it is at removing pre-existing algae. The straw, therefore, should be put in place when water temperature is high enough to support decomposition but before dense algae stands have developed. Algae control, if achieved, will usually occur shortly after straw decomposition begins. Decomposition takes about two months in the spring versus about two weeks in early summer. The effect will last until the decomposition is complete, usually in 30 to 90 days. Second doses are sometimes applied if algae levels increase again. This generally corresponds to the remainder of the growing season in New York State lakes.

Advantages and disadvantages

Barley straw appears to be one of the few algae control mechanisms that actually reduces the amount of algae rather than controlling the nutrients that trigger the blooms. Unlike copper sulfate or other chemical means of algae control, barley straw does not control algae through toxicity or chemical algacidal effects. It is less likely to trigger public complaints because it is more likely to be perceived as "natural." It is also one of the few lake management activities that anyone can do. It doesn't require a license and is easily employed by anyone, without extensive training or expertise. Loading the bales into the lake, however, and especially removing water-logged bales from the lake may not be for the weak of arm!

Barley straw can be effective in controlling either planktonic (green dots) or filamentous (long green strands) algae, although the latter may require a dose rate as high as 400 to 600 pounds per acre. Oxygen deficits associated with rapid bacterial degradation of the decaying algal cells are minimized because the rate of algae decrease appears to be gradual.

Given the quantity of straw required to control algal blooms, particularly filamentous algae, and the work required assembling the bags, this may not be a practical strategy for algae control in lakes or ponds larger than 100 acres. It might be effective in managing algae isolated bays of larger lakes. Bale removal can also be very taxing since "spent" bales weigh about 150 pounds.

In many ways, barley straw, like herbivorous insects, represents the future of lake management. Both embody innovative biological control mechanisms that rely on "natural" interactions to address excessive "unnatural" vegetation growth. Yet both are largely replete with greater parts of promise and potential than achievement for neither has yet translated into viable and reproducible management strategies. Their proponents often claim success when none can yet be verified, and continued interest in these tools is often buoyed more by hope than by progress. Both have worked, in some cases, though perhaps more often through observations of what happened naturally than what was induced by intent or aspiration.

The future of barley straw as a management tool in New York State is likely to be dictated by regulatory constraints. Federal and state governments have yet to make a determination about the appropriate marketability of this product, and the permitting structure governing the use of these produces in "public" waterbodies is unclear. Until these uncertainties are resolved, many lake residents and especially lake associations may be unable to apply barley straw to lakes. Even then, it may still ultimately be more of a pond management tool than a lake restoration technique.

Costs

The use of barley straw is among the least expensive lake management strategies. Farmers capable of growing barley straw, or lake residents fortunate enough to befriend such a farmer can utilize this technique at little cost. For those without such connections, the cost of the straw depends on the quantity required. Several vendors within New York State sell quantities for use in small farm ponds, usually in 30-pound bales, at a cost of $150 to $400 per acre. Lower prices might be available through county agencies working cooperatively with local farmers to investigate the use of this control strategy. Barley straw has been offered by several Soil and Water Conservation Districts (SWCD) at a cost of about $6 to $10 per bale. In the Midwestern states, where barley straw has been more commonly used, farmers charge about $5 per bale, or about $20 to $50 per acre.

Regulatory issues

The regulatory structure that governs the use of barley straw appears to be a moving target that is taking a lot of left turns. The U.S. Environmental Protection Agency (EPA) and DEC require that barley straw be regulated as a pesticide under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) if the product claims herbicidal benefits. Since it has not been registered for use as a pesticide, however, it cannot be applied by commercial applicators or others in the business of managing lakes. Neither can it be sold for the purpose of algae control, explicitly or implicitly for any waterbody, large or small, by garden shops or nurseries.

Landowners with private ponds on their property may be able to purchase barley straw for landscaping purposes or as a "home remedy" for clarifying or conditioning water. New York State has not yet determined a statewide policy about whether it would be allowable to use barley straw on "public" waterbodies for purposes other than algae control. Given these regulatory uncertainties, it is not clear if the conditions by which barley straw is produced for, marketed, or applied in New York State lakes will change dramatically in the near future.

The use of barley straw in lakes within the Adirondack Park is a regulated activity, requiring a permit from the APA if the activity could substantially impair the functions served by or the benefits derived from freshwater wetlands.

History and case studies in New York State

Because of its relative novelty and the uncertain regulatory framework of this management tool, it is not surprising that barley straw has not been used extensively in New York State. Several county agencies, particularly in the western part of the state, have partnered with farmers and individual landowners to promote the use of barley straw. Some experimental work has been conducted through Cornell University, but these treatments have not been well documented. No lake-size treatments have been reported in the literature, although it is anticipated that increased documentation will surface when this technique moves from anecdote to history.

Other in-lake problems

The earlier parts of this chapter, and Chapter six, "Aquatic plants," have discussed management techniques used to control nuisance weeds and algae. While these are two of the most common lake problems, they are not the only ones. Techniques to manage nuisance species and the water-quality problems of acid rain, unpleasant taste and undesirable odors are the next topics to be discussed. Many of the other lake problems discussed in Chapter four, "Problem diagnosis," are either too new for innovative lake managers to have developed any in-lake management tools, or are much better addressed through source-management strategies discussed in Chapter nine, "Watershed management."

Nuisance species management

For some lake residents, a nuisance species includes anything that doesn't call the lake home, and some of the ones that do. Generally "nuisance species" refers to exotic or non-native plants or animals, and some very abundant home-grown pests. Nuisance species may upset not only the ecological balance of the lake, but also the recreational or aesthetic uses of the lake. Chapter six, "Aquatic plants," discusses control of nuisance aquatic plants. There are a number of other lake invaders that are as unwelcome and sometimes as difficult to control. These include aquatic pests such as zebra or quagga mussels, sea lamprey, leeches and waterfowl that trigger problems such as swimmers itch and other bacterial outbreaks.

Waterfowl control strategies

The sight of swans sailing across the Pine Barrens of Long island, or the sound of honking Canada Geese *(Branta canadensis)* streaming above New York State lakes and ponds can be as fundamental to the pastoral outdoor experience as the bellow of the bullfrog or the changing of the leaves. For many lake residents, however, these sights and sounds are stark reminders of the problems that plague many lakes. Canada Geese are perhaps the most prominent example, leaving pellet reminders of their affinity for lakefront flatlands, pathogenic evidence of their congregations, and perhaps even mocking calls in their status as a protected species. (See the Case study on waterfowl) Migratory Canada Geese using New York State waterways as aquatic landing strips in transit are protected by the U.S. Fish and Wildlife Service under the Migratory Bird Treaty Act of 1918 and the Migratory Bird Conservation Act of 1927. There are questions about whether these birds have become non-migratory and recognition that they have moved to nuisance status during the last 25 years. The U.S. Fish and Wildlife Service and several state wildlife agencies now allow limited hunting and control of Canada Geese from September 1st through March 10th, and are now being allowed to establish August hunting seasons.

The most effective deterrent is to discourage the geese from visiting the lake and partaking in crusty bread provided by otherwise well-meaning lake residents and unsuspecting visitors. "Don't feed the ducks" is the single most effective waterfowl management strategy available, particularly on small, crowded lakes. This may be in conflict with the desires of the younger crowd who enjoy throwing bread crumbs and stale heels to geese, swans and other feathered friends. Waterfowl feeding should be strongly discouraged to protect water quality and to keep the wildlife wild. The end of handouts might also prevent the birds from becoming too comfortable around people, and may encourage them to migrate to warmer climates with better winter dining.

A second defense is to modify their habitat. This can be achieved by discouraging grazing and eliminating easy pathways for goslings to migrate from water to land. Physical barriers at least 6 to 30 inches above the ground will provide roadblocks for many geese. Landowners can make a simple fence of string, with attached hanging aluminum strips or shiny tape, supported 6 to 12 inches above the ground at the water's

Case study: Waterfowl control on Collins Lake

Lake setting: Collins Lake is a 70-acre urban lake in the village of Scotia, just west of the Capital District region of New York State.

The problem: Canada Geese *(Branta canadensis)* discovered the lake in the late 1980s and apparently told all their friends. The change in waterfowl populations was discussed in Chapter three, "Lake problems." The beach at Collins Lake was increasingly blanketed by goose droppings, and this contributed to increasing concerns about bacterial contamination and other health issues.

Response: In 2000, the Village of Scotia initiated an aggressive waterfowl control program that included fencing the beach, and addling the eggs (puncturing with a metal skewer). Trustees from the Village elected not to euthanize the geese due to public opposition to hunting and trapping the birds. From 2000 to 2005, about 200 eggs were addled annually under a permit issued by the U.S. Fish and Wildlife Service. An orange plastic fence was erected along the perimeter of the beach shoreline to prevent the geese and goslings from walking onto the beach. Park staff also raked and removed droppings from the beach on a daily basis during the summer recreational season (Marx, 2007).

Results: After steady increases in resident goose populations from 1988 to 2000, populations stabilized at about 115. Bacterial levels stayed well below state water-quality standards. Bacterial counts rose sharply in 2005, coincident with heavy spring and midsummer heat and rainfall, with substantial increases in goose droppings on the surrounding park lands. It is believed that the egg-addling program initially controlled local geese, but the populations were greatly augmented by transient geese. Local geese ultimately utilized the nearby Mohawk River for nesting and sustenance. By 2005, this resulted in a rise in transient populations to about 180. As a result of the elevated bacterial levels, the Village and the Schenectady County Health Department agreed to close the beach for the most of summer 2005. In 2006, local environmental groups "gently" harassed the geese, keeping them out of the lake and surrounding park land. Trained border collies were enlisted in 2007. This reduced the goose population and eliminated the need for the village to start a goose extermination plan. The Village improved lake circulation by installing aerators, and by controlling nuisance curly-leaf pondweed and Eurasian milfoil populations with herbicides. The fecal coliform levels dropped substantially by midsummer, allowing the swimming beach to reopen in August (Martialay, 2005). Fecal coliform readings were close to drinking-water standards in 2007, and the beach remained open for the entire year.

Lessons learned: Canada Geese control can be achieved with significant and consistent efforts from the affected community. It appears, however, that the populations adapted and found nearby contiguous habitat that still impacted the lake through major runoff events. Vigilant efforts were required to remove the geese and improve water-quality conditions.

edge. Goslings cannot cross these fences, and the adults will not cross if it means leaving the goslings behind. Some lake communities install temporary fencing, removable during recreational hours, along swimming beaches and adjacent to large manicured lawns or other tempting buffet plots. The same objectives can also be achieved by planting dense shrubbery along the shoreline and walkways. Many native shrubs, such as ivy and juniper, are not palatable to geese and also serve to minimize shoreline erosion, providing an added benefit to the lake. Alas, many New York State lake residents report less than stellar results using these habitat modification methods.

Modifying human habitat can be equally effective at reducing human-waterfowl conflicts. Exposure to bacteria or pathogens found in the fecal matter of the waterfowl can be minimized by avoiding flat areas with heavy concentrations of waterfowl, and by minimizing ingestion of lake water potentially contaminated with pathogens.

The next level of goose control involves actions to offend their senses. Some people have tried Mylar tape that reflects sunlight and produces a humming noise in the wind. Noisemakers and pyrotechnics work best before geese are established in an area rather than after nesting pairs are oblivious to all but the beating of their hearts. These noisemakers can take the form of starting pistols, sirens, and explosive devices. Many of these require special permits. Some people have treated waterfront lawns with grape-flavored spray (*methyl anthranilate)* that the geese supposedly avoid. Only one such product (ReJeXIT©) can be used in New York State, and it requires a DEC permit. Other grape juice substitutes are no doubt used in other places.

Perhaps the most effective deterrents have been the use of trained dogs, usually border collies, to chase away the offending birds. Once established as a goose menace, usually through several chases every day for several weeks, the dogs can control the goose populations with less frequent romps. In most cases, the geese do not become acclimated to the situation. This method has been very successful on Collins Lake (see Case study on Collins Lake).

The most controversial control measures have involved destroying the eggs or the geese themselves. Several lake communities have undertaken egg-addling projects, puncturing, shaking or oiling the eggs to prevent hatching or to allow bacterial contamination to enter the egg. This has been effective, but only when utilized for many years throughout a large geographic area surrounding the lake. For most lake communities, these draconian measures should constitute the last resort given the volatile brew of spicy emotions and half-baked truths that often pepper the accompanying public dialogue.

The capture or killing of geese, like disrupting eggs or nests, requires state and federal permits. Permits are only issued when other measures have been deemed ineffective. Given the uncertainty of their status as a protected species, permits are usually required from DEC for the trapping or lethal control of Canada Geese. Rules promulgated in 2006 by the U.S. Fish and Wildlife Service allow public health officials and municipalities to remove nests and eggs, and to round up birds, after securing federal permits if they can demonstrate a threat to public health.

Swimmers itch

Nothing ruins the fine memory of a nice day at the beach more than an outbreak of swimmers itch. Copper sulfate, used as an algacide, is also used to kill snails, the intermediate carrier for this topical bacterial infection that may result in rashes and external itching. Copper sulfate has been extensively used to break the duck-snail-flatworm cycle (see Fig. 7–4 and Chapter three, “Lake problems”). It is applied at a rate of about 10 pounds of copper sulfate per acre-foot of water. Chemical costs of copper for snail control are similar to costs for algae control, $5 to $25 per acre-foot.

More drastic measures have included inoculating geese to prevent the production of the schistisome flatworm, either by injections or by treating their food sources. This has been effective only for resident geese populations that have caused persistent problems. It was utilized as a control measure in Lake Pleasant and Sacandaga Lake in the central Adirondacks.

Pumpkinseed sunfish *(Lepomis gibbosus)* and freshwater drum *(Aplodinotus grunniens)* are sometimes stocked in small ponds because they feed on the snails that are part of the infection cycle. Management strategies for waterfowl control discussed above can assist with long-term strategies for dealing with swimmers itch. Outbreaks of swimmers itch are localized since the *cerceriae,* the microscopic flatworm juvenile stage that causes the itch, only live 24 hours, and only travel short distances.

The most common strategies for dealing with swimmers itch have ranged from preventing the flatworm from penetrating the skin, to using topical steroids to reduce the symptoms of the irritation. The *cerceriae* will penetrate the skin after the water evaporates from the swimmers. By rigorously drying with a rough towel before the water evaporates, swimmers can break the *cerceriae* loose from the skin. The rash and itching tend to be focused on the lower extremities, but any body part expose to the water can be affected. The entire body should be vigorously rubbed.

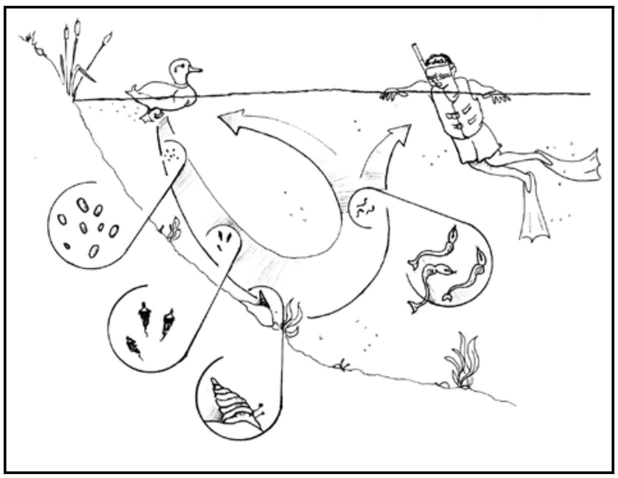


Fig. 7–4. Life cycle of cerceriae that cause swimmers itch. Flatworms in waterfowl feces burrow into the skin of unsuspecting swimmers. (not drawn to scale)
(CREDIT: CHRIS COOLEY)

Muscling out the zebra (and quagga) mussels

The shells of both zebra and quagga mussels have the black-and-white stripes of their equine namesakes, but they are much less well received. Quagga mussels *(Dreissena rostriformis bugensis)* are one of the new exotic invaders. They are beginning to outnumber zebra mussels *(Dreissena polymorpha)* in some of the western Great Lakes, although they presently are far less common in New York State lakes. Management of these invasive bivalves is similar to the strategies listed below for controlling zebra mussels.

The most effective control measures for zebra mussels involve preventing them from entering the lake in the first place. This is achieved by inspecting boat hulls, trailers and especially the bilge water in powerboat engines. The mussels are very hardy, but are ultimately susceptible to drying periods of at least three days, and to rinsing with high-pressure hot water.

Large-scale infestations in lakes are impossible to eradicate. Ecological and substrate modifications associated with zebra mussel infestation can rarely be reversed. There are, however, some measures that have been taken to remove or repel the mussels.

- *Pluckin' the shells* is a technique only effective for very small infestations, particularly in areas where the opportunities for re-infestation are limited by substrate or water chemistry. The zebra mussel populations in Lake George appear to have been well managed by this technique, but it is a very labor-intensive control strategy (see Case study on invasive species).

- *Dose 'em with chemicals.* Chlorine and copper have been used by municipalities to control zebra mussels, particularly in water-intake pipes. Exposure time is too low, however, to effectively control these animals in most large waterbodies. The higher doses and contact time required to control zebra mussels in larger waterbodies would also have significant environmental repercussions.

- *Unpleasant tastes* from chemical repellents that are added to paints used on boat hulls and other hard surfaces have been shown to repel the mussels.

- *Noise and vibration* can be effective at reducing zebra mussel populations. Studies by Cornell University on Oneida Lake found that ultrasonic waves below 200Hz were effective.

- *Predatory control* research continues on the use of diving ducks, freshwater drums, viral agents and other organisms that feed on zebra mussels. These methods have not been developed to a degree useful for commercial applications.
- *Changes all around them. C*ontrolling zebra mussels by altering the physical environment in which they thrive. This concept includes winter drawdown, utilized in the Niagara River, as well as research on modifying temperature and humidity during air exposure.
- *Biocontrol*. The New York State Museum recently identified a bacterium (*Pseudomonas fluorescens)* lethal to zebra mussels when ingested, even as dead cells, suggesting that mortality is due to a natural toxin rather than infection. They have developed a commercial product that may be available for use in managing zebra mussels in controlled settings, such as the end of pipes or fish hatcheries, as early as 2009 (Foss, 2008) This biopesticide is not practical, however, for use in open systems such as lakes or reservoirs. (See Appendix F, "Internet resources.")

Leeches

These predatory, worm-like creatures may have been prized by medieval barbers and alternative medicine practitioners, but they are not welcome guests at a swimming beach. Leeches are usually found in shallow, protected waters, concealed among aquatic plants or under stones, logs and other debris, at least until encountered by an unsuspecting toe. They are attracted to water disturbances that occur near docks and swimming areas and are most active in summer.

Leech control can be achieved most easily using bait buckets or small, coffee-can sized metal containers with a closable lid that has been punctured with small holes that are approximately the size of

Case study: Invasive species control in Lake George

Lake setting: Lake George is a 28,000-acre lake located in the southeast corner of the Adirondack Park.

The problem: Like many Adirondack lakes, Lake George was considered to be immune to infestation by zebra mussels *(Dreissena polymorpha)* due to substrate and water chemistry limitations. Calcium levels are too low in the lake to support shell generation. Local sources of calcium from inflow streams and concrete structures near the shore, however, contribute to microenvironments capable of supporting zebra mussels. The first two zebra mussel shells were found in 1999 growing on a bottle along the southwestern side of the lake. Subsequent surveys found a much larger population of mussels confined to a 15,000 square-foot area about 50 feet from shore, corresponding to a zone where calcium levels were four times greater than in the main lake. The majority of the lake was still considered inhospitable to colonization by zebra mussels.

Response: The Darrin Freshwater Institute (DFI) conducted an extensive hand-harvesting program to remove zebra mussels from Lake George. Divers worked for more than 250 hours in April of 2000, before the water temperature rose to more than the 55ºF that allows mussels to multiply. They removed nearly 20,000 adult mussels attached to hard surfaces primarily along the lake bottom. An additional 300 mussels were removed during one of the four survey sweeps of the lake later that summer (Yusco, 2000; Cappiello, 2000). The Lake George Association (LGA) also initiated a "Drop a Brick on Zebra Mussels" program, utilizing volunteers and lake residents to site bricks to which zebra mussels could attach. The intention was to identify other locations in the lake that could support the growth and proliferation of these mussels (Lake George Association, 2003).

Results: Most scientists involved in zebra mussel research do not believe that all of the mussels were removed from the lake, although water-quality monitoring conducted by DFI did not find any evidence of zebra veligers (mobile juveniles) anywhere in the lake.

Lessons learned: The intensive zebra mussel hand-harvesting activities on Lake George demonstrated that these invasive animals can be kept under control. It is successful, however, only when zebra mussels are confined by chemistry or substrate to manageable portions of the lake, or in very small ponds or lakes, and only with extreme vigilance and effort.

leeches. Raw meat in the bottom of the can attracts the leeches, which feed and then cannot escape through the jagged side of the holes. The can should be placed in shady water since leeches do not like direct sunlight.

Other control methods for nuisance leech populations in small ponds include winter drawdown. Water levels must be lowered below the frost line to freeze the overwintering leeches in the bottom muds. Ducks prey on leeches, but duck stocking programs create their own problems. Copper sulfate pentahydrate, applied at a rate of about five ppm, about the same dosage rate as for snail control, may also kill non-swimming species of leeches.

Sea lamprey

These jawless fish are usually associated with the marine environment, but have significantly affected fisheries in the Great lakes and Lake Champlain in recent years. The most common control strategy for sea lampreys is the use of TFM (*trifluoromethyl-nitrophenol)* to destroy the larval stage of the lamprey. This has been used in more than 175 streams tributary to the Great Lakes. Barriers have also been used to block upstream movement of the lamprey, including velocity generators that can be effective against these poor-swimming fish. Adjustable height barriers have also been used to block the lampreys, but allow the movement of other fish during their critical migratory seasons. Sterilized males have been introduced to affect species spawning success, and trapping has also been utilized.

Just skimmin' the surface

A lot of junk can wash up or float on the surface of lakes. This can be three-dimensional foam, bubbling surface mats of filamentous algae, detached weeds and garbage; or other stuff like duckweed, pollen and oil slicks. The appropriate management of plant cuttings and surface algal blooms is discussed in Chapter six, "Aquatic plants," and earlier in this chapter. For the other surface irritants, prevention remains the best cure.

While foaming events are often natural, they can be exacerbated or even caused by introducing surfactants (bubbling agents) to lakes. While New York State and other lands sharing the Great Lakes have made progress in reducing foam by banning phosphorus in laundry detergents, most dishwasher detergents still contain phosphorus, and phosphorus-laden laundry products can still be purchased from non-Great Lakes states. Algae, macrophytes, and zebra mussels appear to be very efficient at creating the organic material necessary to agitate the water into an unpleasant froth. It may not be worth the effort to control this flotsam when it is localized. This is particularly true for small surface foam or oil deposits.

Larger or more concentrated debris can often be removed with netting or screens. Rolls of fiberglass window screening attached to wooden dowels can be used to skim surface flotsam. Most filamentous algae do not stick to nets and screens, so they can be easily cleaned. Algae can be very dense and heavy.

Water-quality problems

Mitigating acid rain effects through liming

Principle

Lime, calcium carbonate, is used to increase pH in acidified lakes and to provide alkalinity to buffer future acidic inputs. The ultimate goal is to improve the habitat required to support fish and other aquatic life. In New York State, those lakes acidified by acid rain are those most often scheduled for liming. Until this acidic precipitation is prevented, liming will provide only temporary neutralization of lake waters. Liming may have some very limited applicability in precipitating phosphorus within the water column (see Case study on lake neutralization). Liming may also benefit some lakes that have become acidified due to the application of copper sulfate or alum, although existing regulations governing the use of these produces are unlikely to result in lake acidification.

Case study: Lake pH neutralization in Wolf Pond

Lake setting: Wolf Pond is a 50-acre kettle pond in the northeastern corner of the Adirondack Park.

The problem: Like many of its neighboring small, high-elevation Adirondack lakes, Wolf Pond became culturally acidified before the early 1970s. The pH of the lake was measured at 4.9 by the DEC in 1973, and the lake was neutralized by adding approximately 50 tons of hydrated lime by November of that same year. While there may have been a temporary improvement in pH, trout stocked by the DEC in the lake after the neutralization had disappeared by 1980, when the pH of the lake had fallen back to 4.5.

Response: A research study was conducted by Cornell University and the Church and Dwight Company, parent company for Arm & Hammer. Wolf Pond was neutralized with 14 tons of USP grade sodium bicarbonate (baking soda, $NaHCO_3$), in August of 1984 (Kishbaugh, 1985).

Results: The experimental neutralization of Wolf Pond with sodium bicarbonate brought the pH of the lake up to 6.8 at two months post-treatment, with aluminum levels dropping by half. By August of 1985, the pH had dropped back to 6.5, and by the following year it had slowly dropped back to highly acidic readings. The lake was again neutralized with 20 tons of sodium bicarbonate in July 1987, bringing the pH up to approximately 7.5. By the following summer, however, pH had dropped back to 6.6, following the same pattern found with the initial neutralization. With pH above 6 during the majority of this period, however, brook trout stocked after the neutralization survived well, and the pond was heavily fished by the local fish and game club.

Lessons learned: Neutralization, whether with lime, sodium bicarbonate, or other alkaline agents, can be effective for temporarily restoring pH to normal levels in even dilute, acidic Adirondack lakes. The effects are short-lived, however, and will largely be erased by continued exposure of these sensitive ecosystems to continuing acidic rainfall and runoff (Bisogni and Arroyo, 1991).

Neutralization liming involves application of a basic agent to either the lake water or the surrounding watershed. Both techniques involve the use of calcium-based neutralizing agents, usually crushed lime [$Ca(OH)_2$], hydrated lime, or limestone ($CaCO_3$). These agents restore the alkalinity of lakes by increasing the quantity of carbonate (CO_3^{2-}) and hydroxide (OH^-), the basic anions that neutralize acidic inputs. This helps maintain pH at a sufficiently high and stable level to provide a suitable habitat for most aquatic organisms. It also brings the pH, alkalinity and calcium to a level where dissolved aluminum toxicity is less of a threat to aquatic organisms.

Other sodium-based neutralizing agents, such as sodium bicarbonate (baking soda, $NaHCO_3$) and soda ash (Na_2CO_3) can eliminate some of the problems associated with lime-based agents, such as pH "hot spots", organic alkalinity precipitation, and the insolubility of lime agents. These agents can be used in direct lake application, or injection into sediments to react with the acidic cations in the overlying water, and may be more appropriate for lakes with higher flushing rates. Sodium compounds cannot be added directly to watersheds, due to sodium-soil interactions that may damage the soils.

Neutralizing agents are transported to the lake by truck or by air, depending on the available access to the lake, or the proximity of the lake to the chemical supplier. The most common applications are by airplane, by hand or mechanical application at several locations throughout the lake, or injection into the lake sediment. Direct lake application can be done along the roadside with the lime added to the water. Watershed applications are usually along the shoreline or into feeder streams.

Dose rates depend on the degree of acidification, size of the lake, flushing rate, and neutralizing agent. Typical applications are from 0.2 to 2 tons per acre for direct lake application. For application in the watershed, the dose rate is 2 to 4 tons per acre of lake surface. Slightly overdosing allows settling to the lake bottom, providing greater longevity to the treatment. A large portion of the neutralizing agent may sink to the bottom of the lake, and ultimately may be covered with deposited materials. In general, lime requires a smaller dose rate than limestone, due to the greater solubility of lime.

Advantages and disadvantages

Liming works! It has been shown to effectively restore pH and alkalinity in lake systems. Liming and biomanipulation techniques can be combined to alter the chemical and biological makeup of a lake, usually to the benefit of a prized or once naturally occurring fish species.

Liming is not a one-time solution. Lake neutralization efforts will always be hampered by the continual acidic rainfall, and will achieve long-term successes only in lakes where the acidic input is low relative to the volume of the lake. Liming may provide at least a stopgap measure for improving acidified conditions to restore recreational uses, and to improve the habitat for fish and other aquatic organisms. Some believe, however, that the use of lime may prevent politicians from making difficult decisions about long-term control of the sources of acid rain.

Neutralization success has been limited to lakes with long flushing times. Lakes with a flushing rate of greater than one year are usually approved for neutralization in New York State. Even lakes with long flushing times may re-acidify within several months, depending on weather conditions, type of neutralizing agent, and the thickness and acidity of the ice pack within the watershed. This pulse of acidity occurring in the weeks after ice-out may have the most significant influence on re-acidification. As a general rule, the effects of liming last about twice as long as the retention time of the lake. Retention time is the time required to replace all of the water in the lake.

Lime also serves as a settling agent. It will combine with phosphorus and algae cells to reduce both the algae densities and the potential for future growth. Liming could be considered for use in alkaline lakes suffering from high phosphorus or algae levels. Most lakes that are candidates for neutralization liming are unlikely to suffer from algal blooms or excessive phosphorus concentrations.

The most significant ecological effects may be from aluminum toxicity. Lake neutralization usually brings the pH back to 7.0 or above. The pH change from 4.4 to 5.4 corresponds to the range of greatest aluminum toxicity. Fish and other aquatic organisms may be killed from exposure to these aluminum levels during neutralization, and are also susceptible if the pH drops to that level during re-acidification. The calcium lime product precipitates any organic matter present in the water column, and removes some organic alkalinity in the lake. Lime precipitation and buried sediments may increase the susceptibility of the lake to re-acidification.

Since liming has a long history in the agricultural industry, the use of limestone has been well studied in the terrestrial environment, and it is available at a relatively low cost. Some water companies also use lime to prevent acid corrosion of water-intake pipes, a testament to its non-toxic qualities. As with most other chemical treatments, liming introduces an element to lakes that has potentially large side effects. Although lime is not toxic at the dose rates required for lake neutralization, it is a strong base, and over-neutralization with hydrated lime can result in pH "hot spots" or elevated pH levels at the treatment site. In these locations, pH could rise to greater than 9 or 10, and this could be as dangerous as low pH levels.

The long-term effects of neutralization are not well understood. Lakes which have undergone multiple neutralizations may have experienced permanent changes in the ecosystem structure of the lake, with organisms that can tolerate sharp pH changes dominating other species. Plant communities which are the recipients of deposited, inactivated lime or limestone may have been altered by the changing pH in the sediment. Neutralized lakes will frequently become more biologically productive, by providing a more suitable habitat for many links in the food web. While this might ultimately represent a restoration of historical levels of lake productivity, the resulting decrease in water transparency and increase in algae levels may create some ecological stress or limited recreational effects.

Costs

Costs will vary widely with choices about the neutralizing agent, dose rate, distance from the chemical distributor to the lake, and treatment method. Lime treatment at easily accessible lakes will vary in cost from about $25 to $100 per acre of surface area, including chemicals and applications costs. Sodium-based compounds are as much as 10 times more expensive. Cost of treatment at less accessible lakes could increase tenfold. Stream or watershed applications should approximate the costs of direct lake application for easily accessible lakes.

It has been estimated that neutralizing and restocking each of the verified acidic lakes within the Adirondack Park would cost more than $20 million.

Regulatory issues

Liming and other neutralization efforts on public waters require permits from DEC, issued through the lake liming program summarized below, and from the APA on all lakes within the Adirondack Park. The use of lime as a precipitant has not been evaluated as a general management tool, so regulatory frameworks have not yet been enacted.

History and case studies in New York State

The DEC began neutralizing certain acidic waters with agricultural limestone in 1959 as a management tool to help restore or protect valuable fisheries. In recent years, the DEC liming program has included 32 waterbodies, all located within the Adirondack Park. The program has worked cooperatively with researchers and other government agencies, including the U.S. Army Environmental Center at Fort Drum. Some of these lakes have been restocked with trout or other native fish species after the neutralization. As another alternative to mitigate the harmful effects of high acidity, the EPA's Lake Acidification Mitigation Project (LAMP) conducted research on watershed liming to determine the effects of liming the entire ecosystem on the water chemistry, terrestrial vegetation and soil biota (see Case study on large scale management).

Despite the media attention devoted to acid rain, most of the lakes in New York State have not yet been acidified. Acid precipitation has affected lakes in only a few regions of the state, primarily in the higher elevation areas in the Adirondack Mountains, and some portions of the Catskills. Figure 7–5 shows the regions in the Adirondacks where acidic lakes (pH <5.5) have been found.

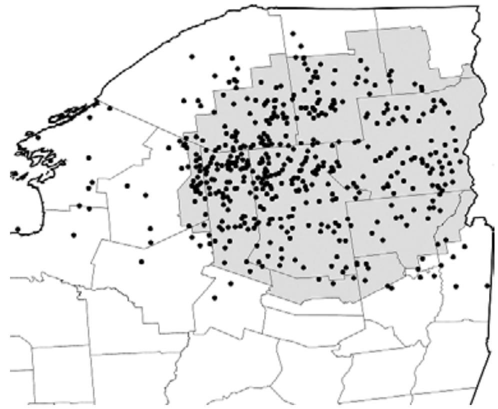


Fig. 7–5. Distribution of acidic lakes in New York State with pH <5.5. (CREDIT: DEC, 2008)

While rainfall remains acidic throughout New York State, liming or other methods of lake neutralization need not be considered by most lake residents at this time. Acidified lakes in New York State tend to be up in the clouds, in remote locations, with slopes and soils (mostly granitic) that do not support septic systems and road networks. These tend to be lakes that are only sparsely developed.

Unlike many other lake problems, long-term solutions to acidification are not presently available to the individual resident or lake association. The only effective solution to acid precipitation is controlling the sources of air pollution, primarily nitrous and sulfur oxides that combine with water vapor to form acids. Mitigating these sources is a scientific and political process that is beyond the scope of any one lake association. Control must be done at the origin of the pollutants, including emissions from fossil fuel combustion of factories, industrial facilities, power plants, automobiles, and others. Through cap and trade programs initiated in 2005, there have been some significant strides in this direction. Federal *Clean Air Act* legislation has reduced the acid rain precursors, sulfur and nitrogen compounds, as well as mercury, in recent years. These cap and trade programs led to a 50 percent reduction of nitrous oxides (NO_x) and 33 percent reduction in sulfur dioxide (SO_2) emissions from 2003 to 2006. With litigation against electric generators, SO_2 emission reductions have exceeded 80 percent since 1990. This has resulted in chemical and limited biological improvements in some Adirondack lakes. New York State has proposed cutting mercury emissions by 50 percent (capping releases at about 800 pounds per year) by 2010 and 95 percent by 2015, more stringent than the 70 percent cut proposed by the federal government for 2018.

Taste and odor problems

Not so clear

In most New York State lakes, turbidity equals algae, and the most common measures for controlling algae have already been discussed. There are some lakes, however, in which turbidity is associated with suspended sediments, inorganic compounds and other small particulate matter such as clay. Maintaining a

**Case study: Large scale management—
Lake pH neutralization with lime**

The DEC began liming acidified lakes in 1959. Prior to that, systematic lake management programs conducted in the state consisted of fish stocking programs begun as early as the 1930s. More than 100 lakes and ponds with surface pH readings below 5.7, and retention times greater than two years, were neutralized with agricultural limestone or hydrated lime. Liming of 30 to 50 lakes has been done on a more regular basis since 1990 to provide recreational fishing opportunities not otherwise available. These liming activities were not intended, however, to be an alternative to improving the emission controls necessary to promote long-term restoration of these lakes.

Cornell University also conducted an Extensive Liming Study (ELS) to evaluate changes in water chemistry, and stocked brook trout populations in response to liming. The pH of Mountain Pond rose from 4.7 to 7.0 within a few days after aerial application of agricultural limestone in late October 1983. Although the limestone dissolved less than 10 percent initially, and was still dissolving after two years, the pH had dropped to pre-neutralization levels within four months due to the rapid flushing time of the lake. In the spring, pH rose slightly as more limestone dissolved, resulting in several more months of circumneutral (near neutral) pH readings. By March 1985, pH levels were lower than prior to neutralization.

The Lake Acidification Mitigation Project (LAMP) in the 1980s was conducted by a consortium of Cornell, Syracuse and Indiana Universities, Clarkson College, and U.S. Geological Survey (USGS). It involved the use of finely ground calcium carbonate sprayed by helicopter. Two lakes included in this liming program were Woods Lake and Cranberry Pond, with respective flushing rates of 2.1 and 5.9 times per year. Both lakes were limed in May 1985 with agricultural limestone, restoring the pH over a period of several days from approximately 4.5 to greater than 9.0. Woods Lake pH readings remained nearly neutral at 7.0 for about six months, but were below 5.5 within a year. The lake was limed again the following year with 38 tons of calcium carbonate, applied to penetrate the bottom waters and sediments of the lake. Cranberry Pond pH readings dropped below 7.0 in less than four months. At seven months, pH levels top to bottom in the lake had dropped below 5.0. The deeper waters in both lakes remained acidic after neutralization. Both lakes were fishless prior to the neutralization, even though Woods Lake had been stocked the year before. Stocked brook trout survived well following the liming, and were limited more by lack of suitable spawning substrate than by water chemistry. Diatom and phytoplankton (algae) populations also increased after the neutralization. Liming did not appear to adversely affect the zooplankton levels in the lake (NYSDEC, 1990).

healthy balance of aquatic and semi-aquatic plants along the shore can prevent significant turbidity by keeping soil attached to a rigid network of roots.

Turbidity in a drinking-water supply is often addressed at the water-treatment plant through filtration, coagulation, or other standard water-treatment operations (see Chapter nine, "Watershed management"). In-lake management of turbidity in large lakes is usually not cost effective, but a number of measures have been employed in small ponds. One method is to use gypsum (hydrous calcium sulfate, plaster of Paris), to precipitate the suspended particulates at a rate of about one pound per 750 gallons of water. Aeration can be used when the turbidity is associated with a reduced form of chemical compounds, such as iron and manganese.

I'm not gonna drink that!

Most taste and odor problems associated with the use of raw lake water for household purposes can be solved, or at least addressed, by water treatment. Lakefront property owners or municipal water suppliers can remove pollutants or odoriferous compounds through the use of activated carbon, activated charcoal, filtration, or potassium permanganate. Most offending compounds tend to be reduced forms of iron, sulfur, manganese or certain types of algae. These can all be exacerbated by the low-oxygen levels commonly found in the bottom of lakes, which is where intake pipes are occasionally located.

Taste and odor issues can be addressed in the long term by instituting watershed management actions such as reducing nutrient loading through septic, stormwater, and fertilizer management, and implementing in-lake management actions to increase deepwater oxygen levels. Some treated water may have a chlorine taste imparted to the water in the disinfection process. A chloride taste may also occur naturally due to conditions such as the breakdown of chloride salts and runoff from road-salting operations. Many of these methods are discussed in Chapter nine, "Watershed management."

Some water providers modify the depth of the water intake rather than institute management actions to reduce pollutants triggering the production of these various compounds. This usually requires a balancing act. Intakes too close to the lake surface can suck in the algae that congregate in the warm, well-lighted surface waters. Intakes near the lake bottom are more likely to suck in poorly oxygenated, poorly circulating water, and the chemically reduced pollutants found in deeper waters. Potable water issues may be resolved by switching from lake water to well water. Drilled wells, however, can be expensive and may encounter a new cascade of problems associated with groundwater quality or quantity.

Other in-lake management solutions for water-quality problems and why they are given short shrift here

Dilution and flushing

Lake management texts describe how high-quality water can be used to dilute pollutants or flush them out of lake systems. In most New York State lake watersheds, the quality of nearby surface water sources is similar to the water in the lake, so flushing or dilution are not likely to result in significant improvements. High-quality groundwater can be used to dilute and flush small ponds if adequate quantities are available, but this management technique has been used in only a few small lakes and ponds in New York State. More information about this tool is provided in other references listed in Appendix G, "References cited" and Appendix H, "Additional readings".

Fungi, bacteria, and viral pathogens

Each of these biological control agents has been used experimentally on at least one lake in the New York Downstate region as a means to attack algae or the biochemical oxygen demand exerted by other organic compounds. Bacillus spores, microorganisms, and enzymes have been marketed as a "natural" means to clean bottom muck, clear the water, and reduce odors. They were originally developed for use in hatcheries to clean up uneaten fish food and waste. Like other means of biomanipulation, these are largely experimental, and the permit structure governing their use is uncertain. At present, the permitting situation is similar to that for barley straw. Permits may not be required if the products claim to clarify the water, not act as algacides or pesticides. Bacterial agents may have some applicability in small ponds, since they are similar to the microbial cleansers added to septic systems, but have only limited utility. They have not been well studied in New York State lakes as a control agent for larger lakes.

Sediment oxidation

Sediment oxidation is accomplished by injecting calcium nitrate into sediments to break down organic matter, and injecting ferric chloride to bind available phosphorus released from the sediments. Sediment oxidation has not been used as a lake management technique in New York State. Given the uncharted regulatory territory and scientific complexity of the technique, it is unlikely to be utilized in the near future, although some lake consultants have used these techniques in other states.

Nutrient addition

Nutrient control is often the foundation for developing lake management plans. Research suggests, however, that adding nitrogen may shift algae dynamics to favor algae that are either more palatable to zooplankton, or are less likely to trigger use impairments, or may free iron to bind with phosphorus (Kortmann and Rich, 1994; Tilman, 1982). No applications of this technology have been reported in New York State. Increased nutrient additions in surface waters could enhance the warmwater fisheries of a lake, and has been discussed in the context of fisheries management in Lake Ontario. The addition of a perceived pollutant to the water, such as nitrogen, would be inconceivable to most lake communities.

Can't stand the noise

One of the newest strategies for dealing with excessive algae growth is to emit ultrasonic sound waves in the water to destroy the vacuoles of the algal cell walls that provide buoyancy. This is similar to one of the techniques used to control zebra mussels. The commercially marketed sonic devices use transducers of less than 50 watts, and are reported to be applicable for small ponds of up to three acres per sonic unit. The use of ultrasonic devices was also discussed briefly in Chapter six, "Aquatic Plants". This management treatment has not been used, or at least well-documented, in any New York State lakes, and thus cannot be evaluated at this time.

Summing it up

Historically, lake management was often equated with algae control and many of the management techniques described in this chapter have a long history. Some have been improved in recent years to reflect advances in delivery systems. Others, such as biomanipulation, are riding a wave of renewed interest in biological control. Barley straw, one of the newest management techniques, perhaps reflects just one old farmer's simple method for dealing with an age-old pond problem.

In recent years, nuisance weed control has become the focus of an increasing number of lake management plans. The age of wastewater treatment shifted the focus of water-pollution control to control of stormwater and toxic materials. The slow resolution of algae, aquatic weed and water-quality problems may ultimately shift attention to conflicts about how these improving water resources can be used. Once the lake is clear and the surface is weed free, competition for the use of the lake demands increasing attention. Chapter eight discusses "People problems" on New York State lakes, and some techniques that can be used to address these concerns.

8 User Conflicts: Learning to Share

Introduction

Ecologist Garrett Hardin (1968) spoke of the "*Tragedy of the Commons"* as a paradigm for the struggle of allocating limited resources in a world suffering from near limitless need. In many ways, the conflict among the various user groups for the allotment of lake-water resources can be described as a similar struggle, if not a tragedy. These struggles have not spared the lakes, ponds, and reservoirs of New York State. As the demands on limited resources exceed the carrying capacity of lakes, user conflicts need to be addressed and resolved. This problem will become increasingly important as population pressures continue to grow. The solutions invariably require that users share the lake resource and be willing to compromise on their demands without compromising the underlying health of the lake ecosystem. Lake associations can play a key leadership role in conflict resolution.

User conflicts include some of the most contentious issues for New York State lake residents and recreational lake users. Some of these detract from the recreational and aesthetic enjoyment of lakes, while others create situations where safety or human health can be compromised. People problems related to lakes often fall into the categories of incompatible uses, water-level issues and public access issues.

Fig. 8–1. Over 1,100 canoes and kayaks converged on Fourth Lake in July, 2008 during a charity event called "One Square Mile of Hope." (Credit: Roy Reehil)

Incompatible uses

- *Water supply versus recreational use.* Water for swimming and recreation may seem a secondary concern compared to fulfilling the basic human needs of drinking water and hygiene or even irrigating crops. A plentiful supply of water and lakes in New York State allows recreation to take a higher priority than in many other states. Allocation of water from the Great Lakes, for instance, will become the focus for enormous conflict in coming years as drought-stricken states and countries look for alternative water sources. (See Appendix E, "Interstate River Basin Commissions.")
- *Excitement versus serenity*. People are universally drawn to a lake for escape and relaxation, but their methods for achieving this can differ dramatically. Some seek the excitement of speed, while others seek solitude. This dichotomy translates into conflicts between those who want noise and speed controls on a lake versus power boats and personal watercraft.
- *Pristine settings versus economic development*. Considerable disagreement can arise between people interested in maintaining scenic vistas such as forested "viewsheds," and those desiring to increase lake development and local tax bases.
- *Moldy bread versus moldy lake*. Conflicts can arise between the pleasure of feeding waterfowl and the pleasure of a lake free of pathogens and algae.

Water-level issues

Power generation versus the interests of downstream water uses. Current practices for hydroelectric generation maximize power generation and minimize costs through dam operations by rapidly changing flows, alternating high flows and zero-flow periods and complete drawdowns on a daily basis. Such operations create conflict because they seriously impact anglers and their fish, boaters and other downstream users.

- *Internal lake association conflicts*. Some lakeshore owners desire a low water level to control weeds, repair docks and reduce erosion, while others want water level high enough to assure boat access and protect submerged water lines. These conflicts can occur throughout the year but are often exacerbated in the fall.
- *Ownership issues.* Who owns the keys to the dam, and who is responsible for maintaining or repairing the dam? Do we need more than Hans and his thumb? Who is responsible for protecting vulnerable downstream river uses and the value of lakefront properties? Most important, who is liable and accountable for any catastrophic tragedies in the event of a dam breach or failure?

Public access issues

- "*Outsiders" versus "Insiders*." Non-residents who use New York State lakes through boat launches, marinas and other means of public or semi-private access are frequently pitted against lakefront or local residents who are opposed to opening the lake to non-residents. State and municipal governments try to strike a balance between providing residents and taxpayers access to waterfront recreation while protecting municipal water supplies, lakefront property values, and environmental stewardship.

- *Local anglers and lake users versus competitors at fishing tournaments and derbies*. A battle between two groups for big fish, which do not necessarily cooperate with either group trying to lure them.

Many management tools can be used to address user conflicts, but they can all be summed up in one word, "COMMUNICATION." The development of bottom-up, holistic, lake-management plans requires interaction, cooperation and compromise among user groups. Most New York State lakes are multiple-use resources. Some uses may ultimately be incompatible, but there is usually enough water or water surface in New York State to go around. Several management tools have been developed to address user conflicts if communication does not lead to compromise or if a management structure is needed to create a compromise.

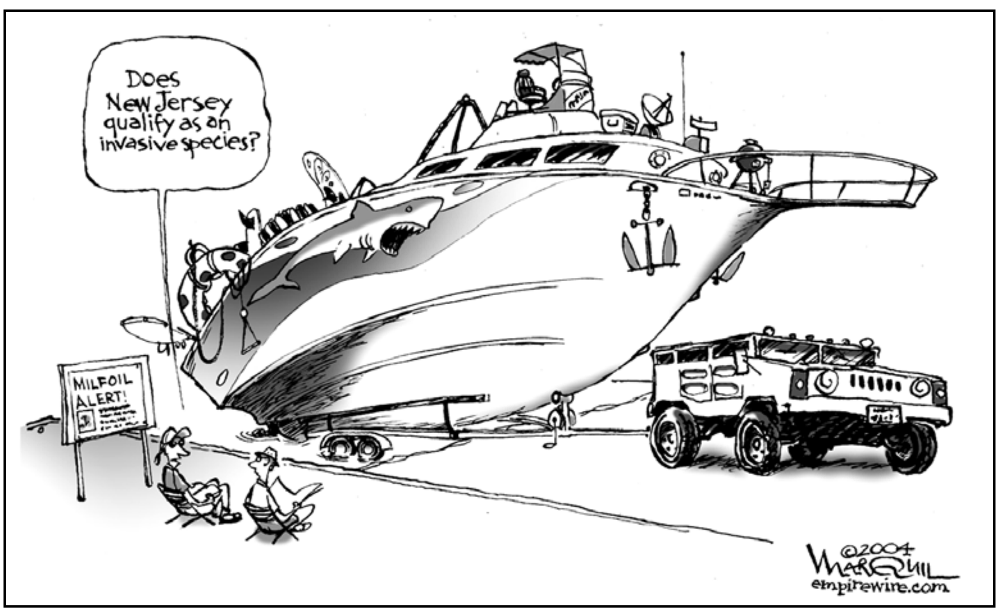


Fig. 8–2. Conflict can arise when residents have to share the lake with "outsiders."
(CREDIT: MARK WILSON)

Incompatible uses: Use and user conflicts

Use restrictions

Applying restrictions by imposing limits or outright bans on a particular use of a lake can help to address conflicts among lake users. **Speed limits** are the most obvious and universally applied restriction. No overriding state law covers boat speed on New York State lakes as long as boaters operate in a "careful and prudent manner." The New York State *Navigation Law*, however, does impose speed limits on specific New York State lakes, usually not exceeding 45mph during daytime hours and 25mph during nighttime hours. The navigation law names specific lakes or counties where more sweeping regulations have been enacted. These include Saratoga, Warren, Suffolk and Nassau counties. The law also authorizes several counties and towns to enact their own speed limits or **no-wake zones**.

The navigation law also provides no-wake zones within 100 feet of the lake shore on all navigable waters. It allows municipalities to govern the use of personal watercraft and jetskis provided that regulations do not restrict access to federally maintained navigational channels. Municipalities can regulate anchoring or mooring of vessels within 1,500 feet of the shore within their jurisdiction.

At the local level, ordinances are occasionally passed to restrict lake uses, particularly boat speed and certain watercraft (by size or type). Some lake associations have restricted motor size to less than 10 horsepower (hp), and others have banned power boating altogether. Many lake associations address the problem of excessive boating speed through limitations of motor size or by extending the state's no-wake zone. Many of these ordinances are difficult to enforce, particularly if the enforcing authority that has jurisdiction over the lake is at a "higher level" than those passing the ordinance. Boat speed limits included in deed restrictions or passed through a lake-association referendum may not be readily enforced if the association does not have the jurisdiction or resources to provide law enforcement. Local ordinances may not

Case study: Speed limits on the Erie Canalway

Setting: The 524-mile Erie Canalway National Heritage Corridor includes the Mohawk River and portions of the Hudson River, several branch canals and many lakes, including Oneida Lake, Onondaga Lake, Cayuga Lake and Seneca Lake.

The problem: No speed limits existed throughout the corridor. Boat speed in the canal-run rivers was self-imposed and dictated by traffic, weather and river conditions. This prompted complaints about reckless watercraft, shoreline damage and excessive noise and affected paddlers, crew teams, lake and river-front residents and other recreational users.

Response: In 2005, the New York State Canal Corporation, which has regulatory responsibility over the use of the state canal, established speed limits for the entire Erie Canalway (Gurnet, 2005). Speed was restricted to 10 miles per hour (mph) in created sections of the canal, 45 mph in river segments within the Canal Run and the lakes within the corridor, and 5 mph within 100 feet of a dock, moored vessel or bridge. The 5 mph limit is consistent with the state no-wake-zone regulations on lakes. These limits were enacted for the state canal season, running from May 1 through November 15. New speed-limit signs were installed along the corridor, and educational flyers were provided.

Results: It is too early to determine whether speed limits have reduced user conflicts within the corridor. Enforcement is problematic due to limited staffing in the State Police Marine Patrol, the agency authorized to enforce these speed limits.

In 2005, canal usage increased by 7 percent despite substantially higher fuel prices (Allen, 2005). In 2006, Governor Pataki proposed eliminating tolls on the system in a one-year pilot program to promote as much as a 25 percent increase in recreational use of the canal (Azzopardi, 2006). This was later extended through 2007, but tolls were reinstated for the 2008 season. Studies had shown that boat traffic on the canal dropped 15 percent when fees were first imposed. Tolls ranged from $5 to $100, depending on the size of the vessel, and generated about $200,000 annually.

Case study: Access permits for the New York City Reservoir System

Setting: The New York City Reservoir System encompasses 18 collecting reservoirs, 6 balancing and distributing reservoirs, 3 lakes, 3 underground aqueducts and 8 connecting tunnels in the east and west side of the Hudson River.

The problem: The New York City Department of Environmental Protection (NYCDEP) is charged with protecting potable water sources for residents of New York City. It strives to identify sources of contaminants to the water supply, whether they are water-quality impurities, invasive species, chemical or biological pollutants. The large area encompassed by the New York City reservoirs exerts pressure to keep these reservoirs open to the public. There is continued effort to provide New Yorkers with recreational access to these resources, particularly residents from communities upended by the formation of these reservoirs during many decades. This desire is further compromised by increased security needs in light of the terrorist attacks in 2001.

Response: NYCDEP instituted fishing and boating permit program for each of the New York City Reservoirs. Permits are issued for what are referred to as "Fishing Properties." All boats must be approved and registered with NYCDEP. Only rowboats between 11'6" and 16' can be issued permits, valid from April 1 or ice-out until December 1. Anglers must store their fishing boats at designated storage areas. Some of the more than 240 boat-storage areas are occasionally restricted due to overcrowding. Each time a boat is brought into storage, it must be steam cleaned and registered with NYCDEP. Boats are not allowed within 500 feet of dams, dikes, tunnels, bridges or other structures on New York City property. In addition, boats are not allowed within 200 feet downstream of some spillways or at any distance from other spillways. Swimming or other forms of contact recreation are not allowed in any of these reservoirs.

be effective if policing is the responsibility of understaffed county sheriffs or state police. There are specific lake-use regulations enacted just for Lake George (6 NYCRR Part 646) and other individual lakes.

Use restrictions can be also be applied to individual properties. Restrictions may be defined in property deeds and affect the ability or inability of the owner to subdivide the land. Deed restrictions may be imposed on lake uses by the original owner of the land. These may include restrictions on dock size or construction materials, lake access, use or size of power boats and fishing limits. Some of these deed restrictions are implemented by a group of lake residents interested in promoting a particular use "philosophy," and new residents are often attracted to lake communities sharing this philosophy. Some of these restrictions, however, have been resisted or legally challenged by other residents. Legal interpretations of use restrictions have been variable. Some have been affirmed by judges, while others have been overturned, usually as too outdated or too vague to be enforced. Lake associations interested in the regulatory approach to boating restrictions should elicit the help of a knowledgeable attorney to determine which laws may apply to their lake.

Lake zoning

The term "**zoning**" usually refers to regulation of space on the land. Lake zoning, however, is the process by which the use of the lake surface is rationed among the recreational users by local residents or ordinances. Restrictions may be mandated by the physical characteristics of the lake. Waterskiing may not be allowed in some areas due to water depth. Narrowness of a channel may also restrict waterskiing because the New York State *Navigation Law* requires no-wake zones within 100 feet of shore. In most cases, lake zoning is an extremely valuable lake-management strategy. It forces equity, or at least a valiant effort at equity, for what might otherwise be an inherently selfish grab of resources.

Area zoning allocates lake uses to specific areas of the lake. Recreational use of the open water beyond 500 feet from the shoreline, for instance, can be limited to power boating, operating personal watercraft, and sailing. Shoreline areas to a distance of 500 feet can be limited to non power-boating even though the navigation law may allow low-speed or no-wake power boating closer to the shore. Boat traffic may be allowed transit through the non-power-boating zone only to access the open water and may be directed with navigational channel buoys from the boat launch. Swimming may be restricted to beaches at the opposite end of the boat-launch site or within 100 feet of individual docks. All boat traffic may be banned from a buffer zone around a community water-intake pipe in order to protect a band of rare and endangered aquatic plants or to prevent fragmentation of a population of invasive plant species that would facilitate its dispersal. Fishing may be allowed from shorelines, docks or boats, but anchoring may be restricted to outside the swimming zones.

Time zoning allocates lake uses to specific times of the day. To avoid complaints about noise, power boating or personal watercraft could be restricted to the hours between 10 AM and 7 PM. Swimmers could be limited to the hours between noon and 6 PM, generally corresponding to the time when lifeguards are available and on duty. Passive boating could be restricted to early morning or evening when wave action is generally reduced and conflicts with powerboats may be minimal.

Swimming prohibited

Beach closures are often a last resort for dealing with lake pathogens although state law requires that beaches be closed if they violate water-quality standards. At the time of publication of this book, New York State is in transition from coliform-based standards to standards based on *Escherichia coli* or those based on *Enterococci*. State code currently allows counties to choose from either a total-coliform or fecal-coliform standard based on instantaneous or geometric mean numbers as discussed in Chapter four, "Problem diagnosis."

There is a time lag between public exposure, sample collection and analyses. A few state regulatory agencies, therefore, have adopted pre-emptive standards to minimize public exposure to high levels of pathogenic organisms (Table 8–1).

Agency	Pre-Emptive Standard for Closure
State Office of Parks and Recreation	> 0.5 inches of rain in a 24 hour period. Applied as guidance only to selected beaches
Cayuga County Department of Health and Human Services	Secchi disk transparency of < 4 feet and presence of chemical substances capable of toxic reactions or skin/membrane irritation

Table 8–1. Regulatory agencies pre-emptive standards for beach closures.

Role of lake associations

Lake associations, and the meetings they hold, offer a rare opportunity for public discussions and a forum for building a common base of information and consensus. The associations also provide a mechanism for conducting user surveys, soliciting the opinion of experts and independent advisors, and distilling divergent opinions into a common, integrated management plan. In short, lake associations are an ideal agent for fostering constructive communication as a foundation for resolving, or at least compromising incompatible uses.

Water-level issues

Water-level control

Water levels change naturally in lakes and ponds by several feet or more each year. New York State lakes typically exhibit highest levels during spring snow melt; drop to their lowest levels from July through September when hot temperatures and plant growth drive evapo-transpiration rates up; and rise again with autumn rains.

Water levels have been managed for a variety of purposes since early European settlement including preventing flooding of shoreline property, preventing ice damage to docks and shorelines, maintaining sufficient water for fish or dam operations or providing a buffer for spring runoff. Conflicts over how to manage water levels can often resemble the fight between the Hatfields and McCoys. Someone removes a weir board or three or opens the valve allowing the water level to drop. Sometimes this involves vandals or unimaginative thrill seekers, but it can also be the handiwork of a disgruntled lake resident with a perpetually flooded basement. Alternatively, someone puts in a weir board or three or closes the valve, and the lake fills to capacity. This is almost certainly a different lake resident whose lakefront property is harmed by receding water levels. These events repeat, usually as midnight or otherwise clandestine operations and cause the water level to yo-yo up and down.

The resolution of water-level control issues requires knowing who owns the dam. Many low-hazard ("A" level) dams are owned by individual landowners, while moderate-hazard ("B" level) dams are usually owned by municipalities, and the highest-hazard ("C" level) dams are owned by government or utilities. The New York State Code of Rules and Regulations (6NYCRR Part 608) and Environmental Conservation Law (ECL Article 15-0517) states that any person who "owns, erects, reconstructs, repairs, maintains, operates, or uses" a dam signifies ownership and, therefore, responsibility for the dam. The definition of ownership, or at least responsibility, may change shortly after this book is published. The Dam Safety section of the New York State Department of Environmental Conservation (DEC) should be consulted to determine the "practical" status of dam ownership (see Appendix F, "Internet resources").

The decision about appropriate water level may be made diplomatically, at least at first. It is often made by a committee of lake residents, a municipality or some regulating authority such as DEC or one of the many state water-level-regulating districts. A few key elements should be part of the decision-making process whatever method a lake community uses to arrive at a decision about water level. First, it should be understood that drastically changing the natural pattern of water-level fluctuations will probably have negative impacts on shoreline plant communities and, therefore, on the associated aquatic organisms such as fish. Studies now indicate that most shoreline aquatic and wetland plants are adapted to and dependent upon the frequency, duration, magnitude and rate of change of flooding or drawdown periods. Without these events, the plants either die or cannot reproduce. Unfortunately, fish species such as northern pike depend on the same flood events to access wetlands for spawning and, therefore, will also decline if the natural pattern is altered. Mimicking the natural pattern of lake-level fluctuations may be an important starting point for planning.

Equally important, the goals of the lake community and its residents must be articulated. These goals might include assurances that sufficient water exists to guarantee boat access, water intake and other "high-water" needs. At the same time, there may be a goal to maintain a sufficiently low water level to prevent flooding, allow aquatic plant control, maintain water movement and flow, and support downstream water needs.

Water-level manipulation may be dictated by or require permits from DEC or the Adirondack Park Agency (APA) (see Chapter six, "Aquatic plants"). Manipulation may be restricted by regulatory requirements associated with downstream flow and aquatic habitats. At least in small lakes, the ultimate decision about the most appropriate water level may be less important than consistency in water-level management. Great variations in water level in small lakes may create significant ecological disruption and render the lake susceptible to erosion and infestation by exotic and invasive plants.

Fixing the dam

Most readers are trying to manage existing lakes and ponds, not create a lake by building a dam from scratch. Details concerning the construction of ponds or of dams to create lakes are beyond the scope of this publication. Excellent publications from the U.S. Department of Agriculture (1982) or DEC (1989) already exist. Dam repair and maintenance, however, are common concerns for New York State lake residents and are often a fundamental part of lake-management plans.

DEC and dam owners each have specific roles and responsibilities when dams are constructed, reconstructed or rehabilitated. DEC issues dam safety permits for the construction, reconstruction or rehabilitation of dams, not for the dams themselves. The permitting program involves review of dam design, oversight of construction or repair and inspections before the reservoir can be filled. The owner of a dam is responsible for making sure the dam is maintained and operated in a safe condition at all times. If reconstruction or rehabilitation of a dam is necessary, the owner hires a licensed professional engineer to develop an appropriate design for the dam work and to apply for all local, state and federal permits needed to carry out the project.

Dam repair, whether instituted as a means to better control water level or to minimize the threat of catastrophic failure, requires a permit from DEC if the dam has a height equal to or greater than 15 feet and a maximum impoundment capacity equal to or greater than one million gallons.

Reconstruction or repair of any impoundment with a capacity exceeding three million gallons also requires a permit regardless of the height of the structure.

Dock management

A **dock** may be the pathway from a home to the lake, but it is not always the path of least resistance. Dock construction can be a very contentious issue whether due to their prominence on an otherwise undisturbed shoreline or their sheer size. New York State *Municipal Law* Section 46A allows communities to regulate out to 1,500 feet from the shoreline, including the design and size of docks. This provides municipalities with the authority to regulate dock density, the size and length of docks and docking fees. Dock density refers to the number of docks per linear foot of shoreline, usually one dock per parcel.

Regulating authority also rests in some state agencies, with distinctions between state-owned lakes and navigable waters. The State Office of General Services (OGS) issues permits for actions, such as installing permanent docks and floats, when the state owns the lake bottom (See Appendix C, "Who Owns New York State Lakes?"). The list includes many of the large lakes in the state, including the Great Lakes, Lake Champlain, Lake George, Oneida Lake and the nine multi-use Finger Lakes. It also contains some smaller lakes in the state, usually up to the mean high-water mark. OGS can be contacted to determine the "ownership" status of any lake in the state (see Appendix F, "Internet resources"). The state also owns the bottom of feeder lakes for the state canal and lakes and ponds residing on state land such as those in the Forest Preserve and state parks and management areas administered by DEC or the State Offices of Parks, Recreation, and Historic Preservation (OPRHP).

Most residential docks are exempt from permit requirements on state-owned lakes because they are within the riparian rights of the upland owner. These exemptions, outlined in *Public Lands Law*, Section 75, include non-commercial docks in existence prior to June 17, 1992 with a surface area of less than 5,000 square feet and docking capacity of no more than 7 boats up to 30 feet long. For docks constructed later, exemptions are limited to structures with a surface area of less than 4,000 square feet that do not exceed 15 feet in height above mean high water. To qualify for this exemption, however, docking facilities must have a capacity of 5 or fewer boats, and mooring facilities must have a capacity of fewer than 10 boats.

A Protection of Waters permit (ECL Article 15) from DEC is required for constructing, reconstructing or repairing docks or platforms and installing moorings on "navigable waters" in the state. As with the exemptions for "state-owned" lakes, however, there are also exceptions to the permit requirement under Protection of Waters. These include docks with a surface area of less than 4,000 square feet, mooring areas for fewer than 10 boats, temporary anchoring sites, docks approved prior to May 4, 1993, relocation or rearrangement of existing facilities and normal maintenance and repair of less than 50 percent of existing structures.

For those waterbodies not regulated by OGS, OPRHP administers the portions of the *Navigation Law* related to docks. The Lake George Park Commission, the U.S. Army Corps of Engineers, the APA and some counties also have jurisdiction in some waterbodies, and the Coast Guard may have some jurisdiction in navigable federal waterways.

The New York Planning Federation recommends no more than one dock per 125 feet of lakefront, extending up to 100 feet from the mean high-water mark. Dock regulations should also consider the surrounding ecological habitat, the use of best management practices to control erosion and the potential for interference with navigation (Clothier, 2005).

Boat houses are tightly regulated through NYCRR 570.3, which defines a boathouse as a single-storied, covered structure without heat or kitchen, bath or sleeping facilities. The APA further clarified these definitions in 2002 and also the definitions associated with regulated "structures." These refinements were adopted in part to address questions about regulatory authority over motorized floating cabins, which more closely resemble houseboats than boat houses and multi-level heated residences that realtors could market as year-round cabins.

While dock repair is usually more of a lakefront-property issue than a lake-management issue, the use of **de-icers** is a dock-repair strategy that dips into the realm of lake management. Also known as **ice bubblers** or ice eaters, de-icers have been used to prevent ice damage around boats, docks and breakwalls in areas where temperatures occasionally become cold enough to freeze lakes, rivers and brackish waters.

De-icers push deep, warmer waters upward, causing continuous water movement. A ½-hp motor will keep a 50-foot-diameter area clear of ice in quiet waters, while a 3/4-hp motor will keep a 75-foot-diameter area open.

Effective use of de-icers along log cribbing on Lake George and other Adirondack lakes seems to be reducing ice-push damage. De-icers or ice-eaters can be obtained through most marine equipment suppliers.

A "bubbler" does not generally require a DEC permit around a private dock and breakwall. Safety issues must be considered, however, since the affected area can be widespread. Small bubblers may only thin and weaken the surrounding ice, posing an invisible danger to people using the lake ice for winter recreation. Use of such devices near public access areas may be restricted by community and park authorities. It is wise to contact local officials, the regional DEC office, and the APA if the lake is within the Adirondack Park before installing such a device.

Case study: Dock management using de-icers.

Lake setting: DeRuyter Reservoir is a 600-acre, multi-use impoundment in Central New York.

The problem: Lake-ice expansion extending more than 10 feet toward the shoreline caused docks anchored as deep as 10 feet to buckle and rotate. A camp owner installed a "permanent" dock using water-well casing with welded steel reinforcing bars. **Ice push** or expansion during the following winter bent and tilted the dock to about a 30-degree angle.

Response: After much work and new welds, the dock was restored to usable condition the next summer, and a de-icer was installed to prevent further ice push. The location of the de-icer took advantage of a slow water drift toward the outlet and the dam.

Results: The winter after installation, an area about 200 square feet around the dock was kept ice free. Slow water movement toward the dam outlet created an ice-free zone along the shore extending approximately 200 yards from the bubbler, allowing open-water winter fishing on this portion of the lake (Kelley, 2005).

There has been a long-standing concern about the use of pressure-treated lumber for docks on lakes, particularly on lakes serving as drinking-water sources. Cypress is perhaps the ideal choice for dock construction, though it may not be available at many lumberyards. Redwood, black locust and eastern red or northern white cedar are all excellent choices for their durability and weathering capability but can be rather expensive. Compressed sawdust composites or aluminum have been used in recent years for the same purpose. Other materials such as steel, plastic or concrete may have applications for support posts, but these non-wood alternatives may be expensive. Concrete may leach calcium into the surrounding waters, making a lake more susceptible to zebra mussel *(Dreissena polymorpha)* infestations.

Role of lake associations

Water-level decisions for moderate- to low-hazard dams are often the domain of lake associations. There are some dams in New York, such as a group of dams in Rensselaer County, which were originally owned by a private company that once needed a steady supply of water but were later sold to a lake association. This relieved the company of responsibility in water-level conflicts and the significant risk of litigation in the event of a dispute or catastrophic failure. Lake associations are also more likely to exert some influence on decisions by elected officials or municipal officers about water level and the timing and extent of drawdown. Disputes about the ownership of a dam are also more easily investigated by lake associations, particularly those with access to legal advice, time and a willingness to search through deeds and historical records. Lake associations may be needed to raise funds required to comply with changing regulations about what is deemed a "safe" dam, from hiring design engineers to interpreting new or updated laws. See DEC Dam Safety section, Appendix F, "Internet resources."

Public-access issues

The access to environmental resources, whether for recreational use, commerce, or to quench thirst, can be viewed as inherently a legal issue. The legal use of and access to lakes is discussed in greater detail in Chapter ten, "Legal framework." The intricacies of this issue are far too dynamic and changeable to fully address in this book, but several important issues are discussed below.

Guarding the keys to the lake

Many lake residents complain about overcrowding. Implicit in the complaint is the concern that non-residents get unfettered access to "their" lake through boat ramps, roadside points that serve as unofficial launches, other public waterways and even overly accommodating lake residents who allow access through their property. Increased **public access** is a stated goal of municipalities from the local to the federal level and is often a requirement for fish stocking and for receiving government grants for lake-management programs. This allows recreational opportunities for more people, including those taxpayers who do not own lakefront property, but it often results in user conflicts as a result of the increased noise and activity levels and competition for fish.

One way to reduce conflict is to limit access. Some towns or counties restrict access to only lake residents through the issuance or sale of local boat-registration stickers or beach tags. It is presumed that invited visitors of residents exert minimal impact on the lake, particularly if they are not launching "alien" boats.

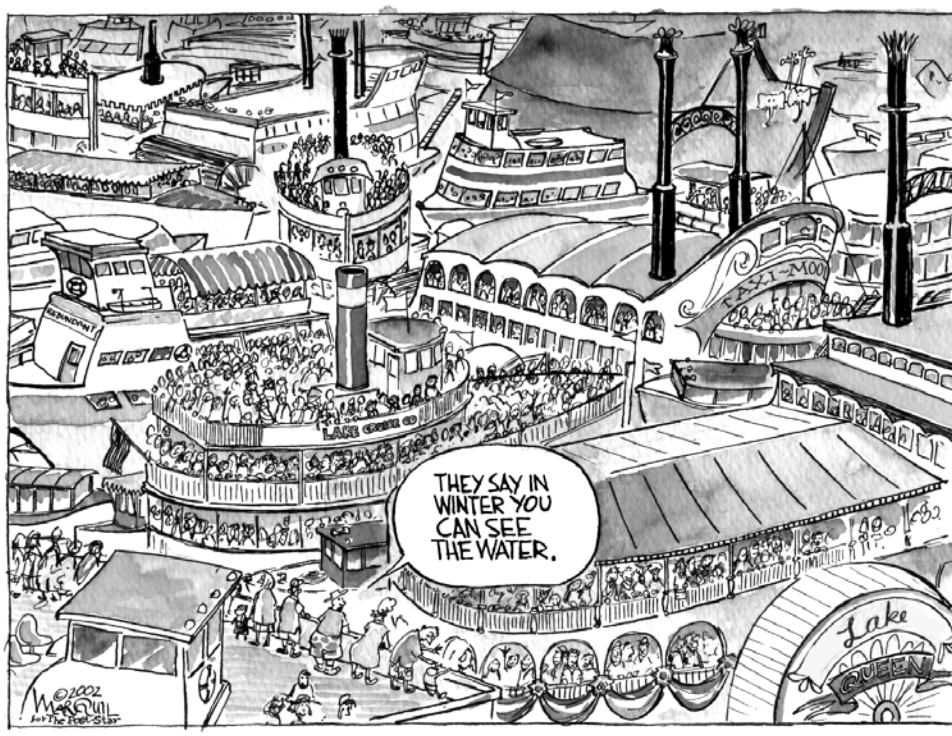


Fig. 8–3. Lake residents may fear that increased public access will result in overcrowding. (Credit: Mark Wilson)

Access points may be gated or otherwise blocked, with keys provided only to local residents. Entry through launch sites, whether town, county or state, may be further restricted after a certain “carrying capacity” is reached on fine summer days. Parking space may be limited in the lots associated with launch sites. In extreme cases, access sites can be removed, although this is usually contrary to the broader objectives of municipalities and the taxpayers they serve.

Increasing lake access could also be addressed by making all beaches public, as is done in Hawaii, although the liability issues may be problematic. Additional “passive” access could be provided through partnership with the town or county to promote non-power boating, picnicking and hiking trails along the lake.

User fees and licenses

In lieu of voluntary or regulated restrictions on lake use, user fees can be imposed to effectively restrict the use of and access to lakes. Launching fees are charged at some launch facilities. Licenses are required for boats registered in New York State and for the right to fish the waters of the state. Local licenses, issued by town or county recreation departments, may also be required for access to waterbodies or local parks associated with these waterbodies otherwise prohibited for recreational use. These generally take the form of boating licenses and fishing permits although boathouse registration, dock and mooring fees may also be charged. Some of these, such as fees charged by the Lake George Park Commission for the use of Lake George, are determined by New York State, while others are at the discretion of local authorities.

Private marinas charge fees for the use of dock slips, boat rentals, launching or other activities that ultimately “regulate” lake use. User fees may also be built into the costs associated with hotel rentals when these are served by private beaches with life guards.

Utility bills charged by municipalities may serve to restrict or otherwise regulate the use of lake water for a variety of drinking water, irrigation, domestic or industrial purposes. Municipal wastewater treatment costs passed along to sewered customers may effectively reflect user fees if the effluent from the wastewater plant is discharged into a nearby lake. Receipt of wastewater can be considered a viable lake use because lake residents “use” the lake to dilute wastewater to save the cost of piping the effluent to a distant river. Several large lakes in New York State do receive wastewater. The use of a lake as a receptacle for wastewater, however, is usually incompatible with nearly all other lake uses.

Life’s a beach

There will always be debates about the merits of sailing versus power boating or warmwater versus coldwater fishing, but there is little question that everyone likes to swim where there’s a sandy beach. Unfortunately, naturally sandy beaches are not found at many New York State lakes, and many lake residents would like a pile of sand to “happen” on their shoreline. There is no doubt that some shoreline improvement projects are completed surreptitiously under the sparkle of moonlight, usually with help from a muscular friend with a dump truck and a load of clean white sand. The “Psst, Buddy” school of lake management was founded in part due to frustration with a seemingly endless list of shoreline regulations. Under ECL Article 15, however, bottom “improvement” materials are regulated as fill in “navigable waters” or nearby wetlands, and building a beach at a lake through alteration of the lake bottom requires a permit from DEC.

Role of lake associations

Lake associations usually cannot take on access issues, particularly those related to denying access, without consulting state and municipal officials and individual landowners. Many lake associations at private lakes, however, control access to members, lakefront residents and guests at beaches and launch sites. Lake associations also promote signage and other informational tools to minimize the introduction of exotic species at less formal launch sites, such as gaps between guard rails, flat spots near roadside parking sites and at parking lots of shoreline businesses.

Summing it up

These last three chapters have examined the lake-management toolbox for issues of aquatic plant control, algae control and management of user conflicts. While the management tools in each of these categories may be neatly tucked into separate compartments, there is much overlap. Many of these tools can be used to fix multiple problems, and the compartments really don't need to be separated. Lake management really involves integrating the various management tools. Some are highly specialized and expensive, others are hand crafted, and still others are cobbled together with duct tape into a single, comprehensive management approach to optimize lake uses and water-quality conditions. Even a skilled lake craftsperson will get frustrated fixing the same problems repeatedly. A truly comprehensive lake-management plan does not focus only on dealing with the symptoms but also directs attention to the causes of problems. See Chapter nine, "Watershed management" and Chapter eleven, "Management plant development" for further information.

Many in-lake management tools or strategies for modifying behaviors discussed in Chapters six through eight are really lake-management "band-aids." They address either the symptoms of the problem (such as algae bloom) or the cause of the problem (oxygen deficit triggering nutrient release from bottom sediments). They do not, however, address the source of the problems, such as failing septic systems, stormwater runoff, eroding soils from a poorly contained construction site or multiple public-access points. Without long-term strategies for managing the sources of problems or the actions that lead to the problems, lake managers will spend a lot of time and resources on band-aids. Chapter nine, "Watershed management," discusses the role of a lake watershed as the foundation for lake problems and the management strategies that can be utilized to develop long-term control of the most common lake problems in New York State lakes.

9 Watershed Management: The Big Picture

Introduction

Our attention is drawn to water in lakes and streams. Houses line the shore, with windows facing outward to the water, drawing our eyes away from the surrounding hillslopes. The uplands surrounding each lake, however, are part of the lake's watershed. They are the source of water to the lake and cannot be ignored. Upland activities play an integral role in the health and sustainability of a lake. It is critical to understand the links between a lake and its watershed to help manage the watershed wisely and to protect the lake.

A watershed is defined as all land that contributes rainfall to a body of water. The watershed functions like a bowl, and water runs downhill to the bottom where the lake is located. The **watershed divide**, created by hills, ridges or mountains in the landscape, is equivalent to the lip of the bowl, and its location determines where rainfall will go. The watershed divide, therefore, determines the limits of water sources that enter each watershed. See Chapter one, "Lake ecology," Figure 1–4.

Watersheds vary in size, with the smallest catchment basins containing only a few square miles, nested within larger watersheds, which are embedded in the largest drainage basins, such as the Mississippi, Nile or Amazon rivers. These major basins may include tens of thousands of square miles. Traditionally, there has been no distinction in the naming of watersheds based on size, and the terms watershed, drainage area, river basin and catchment are generally used interchangeably. Major drainage basins have been identified within New York State. See Chapter two, "From Montauk to Erie," Figure 2–2.

These basins contribute significantly to the major waterbodies in the eastern United States. They drain to the four main points of the compass:

- North to Lake Ontario and the St. Lawrence River;
- West to the Ohio and Mississippi rivers;
- South to the Delaware River, Delaware Bay and the Susquehanna River--the major tributary of the Chesapeake Bay; and
- East to the Hudson River and the Atlantic Ocean

Natural water flowpaths

Despite enormous variability in watershed sizes, the processes controlling movement, availability and quality of water are similar. Understanding the flowpath of water moving through the watershed and the phases of the hydrologic cycle by which water is affected (Fig. 9–1), is critical for understanding and managing the landscape for sustainable water.

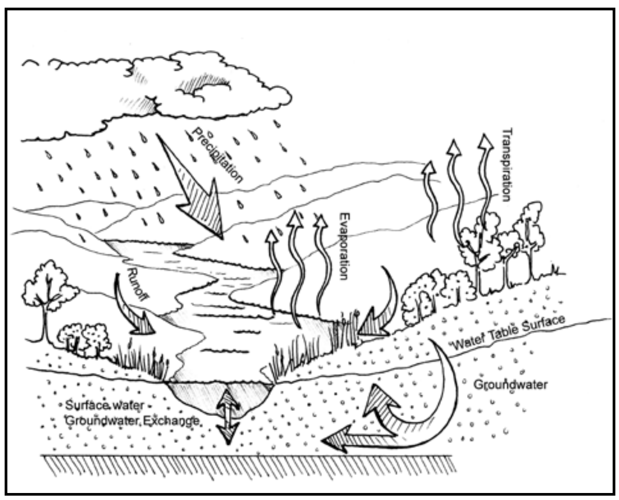


Fig. 9–1. Cross-section of a watershed showing the three major flowpaths of water after it enters the basin as rain or snow. (CREDIT: CHRIS COOLEY)

Prior to human occupation, mixed hardwood forests covered much of the landscape of the northeastern United States and had become well established following the recession of the glaciers about 10,000 years ago. Within forests, most rainfall and snow are first intercepted by the vegetative canopies of dense, leafy treetops as well as shrubs and herbaceous or grassy meadows. These plant canopies take the full force of the falling rain and slow the impact of raindrops before they hit the soil surface, reducing their power to dislodge soil particles. Extensive networks of plant roots also help bind the soil and hold it in place.

In a forested landscape, most precipitation infiltrates into the soils instead of moving as overland runoff (Fig. 9–2). The amount of direct runoff depends in part on the duration and intensity of a precipitation event. This flowing water moves downhill following natural depressions in the land surface to form little creeks, which intercept other creeks and coalesce to form bigger streams and rivers. This interconnected system is the stream-channel network that drains water naturally from the watershed. The smallest creeks, roughly about three feet wide, are known as **headwaters** and cumulatively account for one-half to three-quarters of the total stream-channel length. These inconspicuous creeks intertwine throughout each watershed and provide a tight connection between the land and water.

Under dense, continuous vegetation, only a little water actually runs across the ground surface. Plant roots, soil clumps, earthworm holes and animal tunnels combine to create microscopic channels by which water moves downward. Surface layers of rich, black, loamy, organic matter also absorb water like a sponge. This organic matter can be very deep, derived from centuries of accumulation of decomposing leaf litter. Some accounts from pioneering explorers who first visited western New York describe the soil of the lowlands as having a rich, organic-matter layer from 8 to 12 inches deep. Such deep organic soils are hard to find today.

Water penetrates the soil surface until it meets bedrock or another impermeable surface and then begins to fill the pore spaces between the soil particles. This saturated zone is called groundwater, and the top

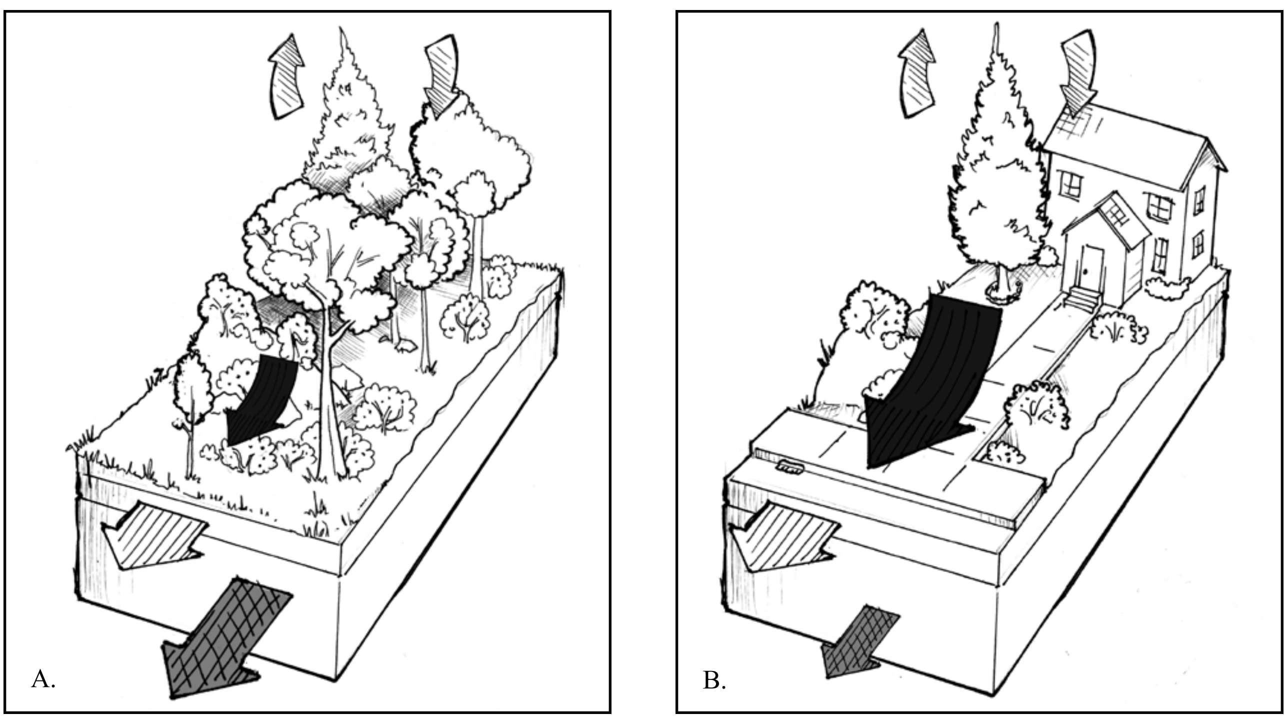


Fig. 9–2. Schematic showing how rainfall is distributed between runoff and infiltration to groundwater. A. Highly vegetated landscape. B. Landscape altered by impervious surfaces.

(CREDIT: CHRIS COOLEY MODIFIED FROM *RAPID WATERSHED PLANNING HANDBOOK*, 1998) is called the **groundwater table**. Some groundwater moves laterally along shallow flowpaths less than six feet deep below ground and makes its way into creeks. This shallow flow, plus direct overland runoff, occurs within minutes to hours of a rainfall event and is responsible for the visible rise in creek levels that occurs in response to an intense storm (Fig. 9–3). Much of the sediment movement in streams occurs during this initial rising water level, a phenomenon called "first flush." Snowmelt each spring also results in a high and prolonged rise in water level in most northern streams. Deeper groundwater, however, moves much more slowly. Groundwater continues to contribute to flow in the stream for days, weeks and even months after the precipitation event. This is called **baseflow** and is critical for maintaining life in streams and for providing aquatic habitats for fish, insects and other organisms. A nationwide study by the U.S. Geological Survey (USGS) in 1998 determined that roughly one-half of all water flowing in streams comes from groundwater (Winter et al, 1998).

Groundwater contributes significantly to the surface water of our lakes. Coastal-plain ponds of Long Island and other kettle lakes are actually a surface outcropping of the underlying groundwater table and usually have no evidence of stream inflows or outflows. Their water levels simply fluctuate with the natural rise and fall of the larger groundwater system.

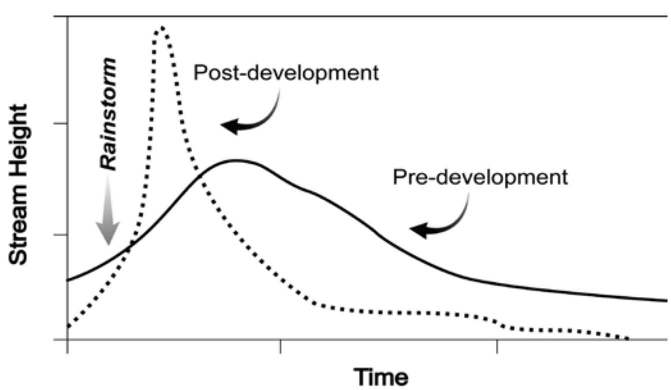


Fig. 9–3. Plot of stream level rise, called a hydrograph, during the course of a storm event both in the forested pre-development landscape and in a post-development landscape with lots of impervious surfaces.

(CREDIT: CHRIS COOLEY)

Groundwater is also a contributing source of deeper lake waters. The groundwater moves rapidly as shallow flow from near-shore areas and discharges directly into the lake along the shorelines. Deeper groundwater flowpaths, originating farther away in the watershed, also contribute to lakes but at slower rates. This invisible shoreline seepage is a common phenomenon in many lakes. Groundwater discharges from the sediment for distances of 30 to 40 feet from the lake's edge. On a hot summer day, swimmers can feel cooler groundwater seeping around their feet.

The water cycle is completed through the process of evapo-transpiration. This includes evaporation of water from lake and land surfaces and transpiration of water through stems and leaves of trees and other plants. Solar energy from the sun converts water from the liquid to the vapor form. Ultimately the water vapor condenses to clouds that start the process of precipitation again.

Human effects on watersheds

Humans have altered watersheds, and these changes have affected the quantity and quality of water that enter rivers and lakes. Humans have cleared forests, replacing them with buildings for residential, industrial and commercial development, with agricultural fields and lawns and with networks of roads. This means fewer forest canopies to intercept rainfall and fewer roots to bind and hold soil. Raindrops impact the soil, splashing and dislodging soil particles which are easily carried away by surface runoff.

Many soil properties that influence water retention have also been degraded. The sponge-like properties of soil depend on the amount of organic matter or decomposing leaf litter present. This organic matter, however, has largely been oxidized by exposure to the sun and washed away by rain. Annual harvesting of crops, without leaving leaves or stems behind, reduces organic matter buildup in fields. Repeated lawn mowing, with removal of grass clippings, has the same result. Most recently, exotic earthworms have invaded our landscapes as escapees from bait buckets or compost piles. These invasive species consume organic matter at high rates and have contributed to the decline in soil organic matter content.

Soil is also more compacted, with fewer air spaces or pores for water to move through. Tilling with heavy equipment and vehicle traffic causes clay particles to stick together, decreasing the soil's porosity when the soil is wet.

When rainfall occurs, less infiltration takes place due to these changes, and more overland runoff occurs. This overland flow is increased because we have replaced our natural soils with the impenetrable surfaces of asphalt roads, building rooftops and parking lots. Rainfall runs from these impervious surfaces and is captured by the network of drainage ditches and storm sewers that have been engineered to prevent road flooding. The network of ditches captures the runoff and rapidly transports it directly to the streams!

Consequently, the movement of water into creek channels becomes much more rapid as water from each part of the watershed races into the **stream channel** at about the same time. Stems and leaves of healthy vegetated streamsides would normally slow rising flood waters (Fig. 9–4). Curving meandering streams also would slow down the flow rate. In many places, however, streamside plants have been cleared and replaced with housing developments or fields. Stream channels have been straightened and shorelines hardened, creating perfect sluiceways to carry water downslope. Water levels rise faster and higher than before. Floods result, as has been clearly demonstrated along the Mississippi River in the United States and in recent floods and mudslides on deforested slopes elsewhere around the world. Studies now clearly document that the magnitude and frequency of floods has increased due to human development in watersheds.

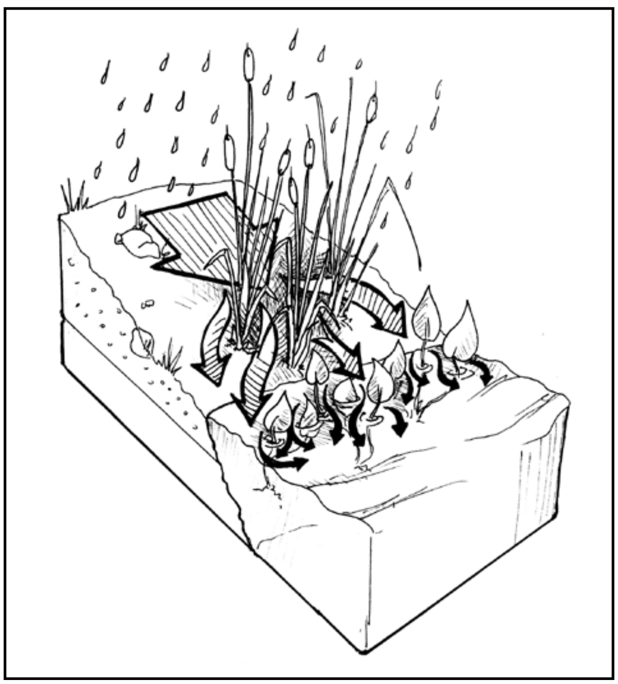


Fig. 9–4. Schematic showing how wetland plants intercept and slow down flowing water during storms. (CREDIT: CHRIS COOLEY)

It is necessary to reexamine the events in the hydrologic cycle to understand how flood frequency can be increasing, even when drought frequency is also increasing! Each watershed receives only a finite amount of precipitation. It can move across the surface as runoff, infiltrate the ground to contribute to groundwater or evaporate into the atmosphere. When runoff is increased, less water is available to recharge the groundwater, and the groundwater table drops in elevation. The groundwater drop is further exacerbated by withdrawal of water from wells for irrigation and drinking water. Society is increasingly turning to groundwater as a dependable, clean source of fresh water, and new wells are being drilled daily. While normal precipitation may have occurred in a watershed, losses from overland flow and increased pumping reduces the groundwater aquifer below a level needed to maintain streams, wells and vegetation. Humans perceive these conditions as a drought. Streams dry out, leaving fish and other aquatic organisms stranded. Wells run dry because the water table drops below the bottom of wells. Crops and garden plants die because they can no longer use deep roots to access moist soils and groundwater.

The increases in runoff due to poor watershed management are being exacerbated by changes in the patterns of timing and intensity of precipitation resulting from global climate change. Studies have clearly demonstrated an increase in the intensity of storm events in New York and parts of the Northeast over the past century. Results of model predictions by the Union of Concerned Scientists (Hayhoe, et al, 2007) suggest this trend will continue over the next several decades.

Human effects on water quality

It is not just the quantity of water that has been affected by changes in our watersheds. Water quality is also deteriorating. Contaminants enter above ground by surface flow in tributary creeks and below ground in groundwater. Contamination from clearly identified individual sources is called **point source pollution**. These sources include regulated operations such as industrial discharge, sewage-treatment plants or known groundwater pollutant sources such as landfills. Federal and state governments established a comprehensive program for addressing point source pollution with the passage of the *Clean Water Act* of 1972 and its subsequent amendments. Water pollution can also be due to an accumulation of contaminants from multiple smaller sources across the landscape, and this is called diffuse or nonpoint source pollution.

Nonpoint source pollution is difficult to control because it involves many small sources distributed across a broad area. Sediments eroding from cleared lands are a major problem, turning lake water brown and cloudy after every rainfall event. Runoff from parking lots and roads carries trace metals, aromatic hydrocarbons and other contaminants associated with vehicles. Pesticides and fertilizers are transported rapidly with runoff from suburban lawns and from croplands. At critical concentrations, all these chemicals can harm fish and other aquatic organisms. They also make the water unhealthy for swimming and drinking by humans.

Phosphorus is important for the growth of algae and plants. Under natural conditions it has limited availability in freshwater systems. Phosphorus contamination, however, is a concern because excess amounts cause algal blooms and lake eutrophication. Phosphorus from fertilizers and from livestock and human wastes is transported into fresh water whenever there is erosion from construction sites, croplands or lawns because it binds readily to sediment particles,

Some contaminants enter our lakes below ground, carried by groundwater from upslope septic systems, agricultural fields, livestock facilities, leaking fuel tanks, automotive or industrial spills. Wastes from livestock or septic systems create a different type of risk because they are a source of bacteria, viruses and other disease organisms that can threaten water quality and human health. Many of these **pathogens** persist for days or weeks in water and soil, and some have dormant stages that can last for years. These pathogens are transported easily in above-ground runoff but can also move in groundwater.

Healthy, vegetated wetlands and streamsides can help to eliminate many contaminants from groundwater before they enter surface waterbodies. Both wetlands and streamsides are the natural filter systems that interface between our terrestrial and aquatic habitats and remove contaminants using a variety of processes (Fig. 9–5).

- Growing plants take up phosphorus and other nutrients and transform them into leaves, roots and other tissues.
- Sponge-like organic matter in the soil binds to phosphorus and trace metals and stores these contaminants in the soil profile.
- Microbial organisms residing in the wetland soils can transform some chemical contaminants. In particular, nitrate (NO_3-), a component of fertilizers and animal wastes, is transformed into gaseous nitrogen (N_2) by denitrifying micro-bacteria and then released into the large atmospheric pool of nitrogen gas. Thus it is efficiently and inexpensively removed from groundwater.
- Bacteria and viruses also are removed during the transit through wetland soils, consumed in microbial food webs or bound to clays and organic matter.

These processes provide valuable ecosystem functions that have been lost in many places**.** More than half of the nation's wetlands have been drained and replaced with housing developments or croplands during the past 100 years. Streamside vegetation has been cleared and stream banks reinforced to make way for railways, roadways, crops and buildings. There are ongoing initiatives to restore legally recognized wetlands. There is no comprehensive federal or state protection, however, for most stream-side habitats, and much work is needed to reestablish wetlands nationally.

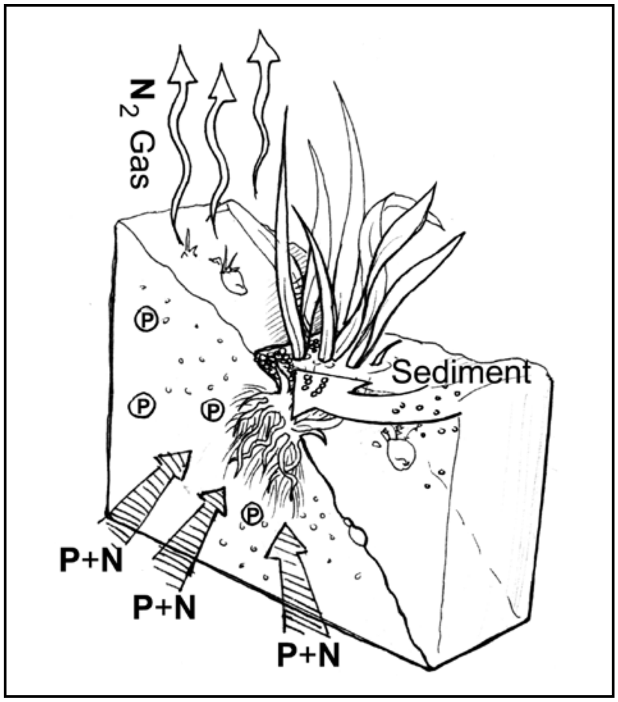


Fig. 9–5. Schematic showing how wetland plants remove contaminants from groundwater by plant uptake.
(Credit: Chris Cooley)

What can you do?

Cumulative changes affect the quality and quantity of our water. It is important to manage the watershed to maintain a healthy lake. Traditional approaches to managing water resources have been nonintegrated and usually have competing management strategies designed to address single, narrow purposes. Typically, a river-lake system is managed simultaneously for waste disposal, flood control, recreational fishing and irrigation or public water supply by independent government agencies, without public input and without consideration of the cumulative effects on the long-term health of the water itself. In the last two decades, however, awareness of the cumulative environmental effects resulting from this approach has been recognized. There have been some radical changes to management strategies that include all stakeholders and particularly public citizens in the following activities:

- Discussion of how a water resource is used;
- Consideration of the watershed as the comprehensive unit of management; and
- Incorporation of mechanisms for monitoring success and providing feedback so that management strategies can be changed if stakeholders are dissatisfied or water quality deteriorates.

The immediate need of dealing with one site-specific pollution episode after another often demands attention and consumes the efforts of lake managers. Such ongoing, recognizable threats to water quality can continually dominate the focus of management and prevent development of long-term approaches for sustainable protection of a lake and its watershed. It is imperative, however, to build a proactive, comprehensive watershed plan. Information about legal requirements is developed in Chapter ten, "Legal framework." Chapters eleven, "Management Plan Development" and twelve "Implementation and Evaluation," discuss in detail the process of watershed management planning and implementation.

General strategies for watershed management

Techniques available for improving water quality and quantity are as numerous as the list of land-use practices that may occur in a watershed. Specific problems and the typical recommended practices to solve them are described below. It is important to realize that different types of strategies may be relevant in dealing with any given issue. Three broad types of strategies in use are regulation, stakeholder outreach and education, and financial incentives.

Regulation

People generally assume that the only way to stop a problem is to create an ordinance or other regulation that makes an activity illegal. An example of an ordinance would be establishment of stream-side buffer requirements and prevention of vegetation clearing (see the sample ordinance.) Such legislative-based deterrents do play an important role. To be effective, however, they require resources for detection, policing and enforcement-processes that can require tremendous amounts of effort and time. Often towns have a direct opportunity to enforce such regulations only when landowners apply for a construction permit or variance. As a result, it is valuable to consider the advantages of two other strategies:

- stakeholder education; and
- financial incentives.

When used in the proper combinations, these strategies provide powerful tools for improving watershed management. As they are being implemented, it is important to provide mechanisms for monitoring and for incorporating feedback into the decision-making process.

Sample Ordinance: Streamside protection setback

The setting: Town of Ulysses, Tompkins County, NY Zoning Ordinance

The problem: As a result of the implementation of the U.S. Environmental Protection Agency (EPA) Phase II Stormwater Regulations in 2003, portions of the Town of Ulysses that adjoin Cayuga Lake were identified as constituting an MS4 community and, therefore, subject to Phase II regulations. Within this area, steep slopes are subject to increasing development pressure, and numerous small tributaries are sources of sediment and runoff into Cayuga Lake.

Response: Considering the broader issue of erosion control as a town-wide issue of importance, the town adopted a zoning ordinance designed to protect streamsides by requiring vegetated buffers adjacent to all streams. The zoning ordinance states:

> "USGS topographic maps will be used to classify impermanent and permanent streams. Impermanent, also known as seasonal, streams require a minimum of twenty-five (25) feet of setback on each side of the stream, extending from the stream bank towards the uplands. Permanent streams are required to have a minimum fifty (50) feet of buffer on each side of the stream, extending from the stream bank toward the upland."

Results: Existence of this ordinance in the town zoning law has facilitated the review of construction permits by board members and reduced ambiguity about required protection practices. Although in place for only one year, the ordinance provided valuable guidance for town planners and developers dealing with site plan design and approval.

Stakeholder outreach and education

Inappropriate landscape practices often arise from lack of information on the part of watershed residents. Most landowners have a natural sense of stewardship, and they want to take care of the land and water. Few people, however, are aware of the connection between activities on their property and the effects on a lake or stream that may be several miles away. Educating landowners about their actions and how they can affect downstream waters can be a powerful tool. This educational outreach includes holding workshops, developing and distributing fact sheets, home visits, billboards, radio or television advertising and a host of other strategies. Education is generally directed toward adults. Research suggests that long-lasting changes in behavior are best achieved by engaging youth through school or other activities. Children can often reach their parents with an educational message more effectively than agency professionals.

Financial incentives

Increasing awareness of good practices is an important first step for changing landowner behaviors and improving the lake watershed. Sometimes changing a land-use practice requires new equipment, labor or other resources that have costs beyond the scope of the individual landowner. Landowners also may not be able to afford the long-term maintenance costs of a given practice. Farmers tend to be supportive of replacing crops with natural woody vegetation along a stream's edge, but few can afford to do the actual streamside restoration or to absorb the annual loss of profit resulting from taking that land out of cultivation. Successful adoption of this practice by farmers is more likely if financial resources are made available in conjunction with an outreach program. It may be enough to provide planting supplies, loan earth-moving equipment or assist with labor during construction. Alternatively, it may be necessary to provide annual tax relief after the project is in place to augment a farmer's agricultural income.

Comprehensive watershed planning

The next step in planning is to take a comprehensive, big-picture look at the watershed. This holistic approach is needed to thoughtfully plan for the types, locations and amounts of future development that can potentially place negative pressure on the lake and its surroundings. This level of comprehensive planning is particularly useful where river or lake flooding or summer droughts have already become a problem.

The first focus will be to protect those areas of the watershed that directly influence lake water quantity and quality. Such critical areas should include the following:

- Groundwater recharge areas;
- Steep slopes which could be a source of erosion and runoff;
- Lake shorelines where vegetated buffers would help to filter water, buffer wave energy and reduce erosion;
- Wetlands of all kinds;
- Areas with sensitive soils, such as sands, which drain rapidly without attenuation of contaminants; and
- Vegetated buffers along all tributary streamsides, including headwater streams.

Comprehensive planning should also take into account biologically critical habitats in upland areas that provide important resources at different stages in the life cycle of desirable aquatic organisms. Herons and wading birds, for example, feed along the shallow water edge but use nearby woods for roosting and nesting. Certain types of lake fish migrate up tributary streams for spawning. Both amphibians and reptiles, typically viewed as purely aquatic organisms, incorporate the surrounding terrestrial landscape into critical parts of their life cycles. Snapping, painted and spotted turtles all have shelled eggs that must remain oxygenated during incubation. Female turtles will leave a lake and travel up to 500 feet or more into surrounding terrestrial uplands until they find appropriate habitat to dig their nests (Fig. 9–6). In contrast, salamanders, frogs and other amphibians lay their gelatinous eggs within the water, floating freely or attached to strands of vegetation. Once the juveniles have metamorphosed into their adult forms, many species of frogs and salamanders leave the water and migrate into the surrounding uplands for distances of 50 to 200 feet, where they may spend several years living under the litter, in the soil or on the vegetation. It is critical to protect all these outside-lake habitats to maintain the populations of such organisms for the long term.

These biologically critical areas should be included as lands are identified for protection. In addition, it may be important to identify and protect a buffer zone immediately outside the critical area where development and other activities are minimized. This buffer zone should consist of a naturally vegetated transition area that can provide a visual screen, a noise-reduction buffer and a first filtering system for trash and other wastes. Native plantings appropriate to the specific region of the state should be used.

Planning is also important outside of these critical areas. If flooding and summer droughts are becoming a problem, it will also be useful to take a fresh look at land uses across the watershed that accelerate runoff

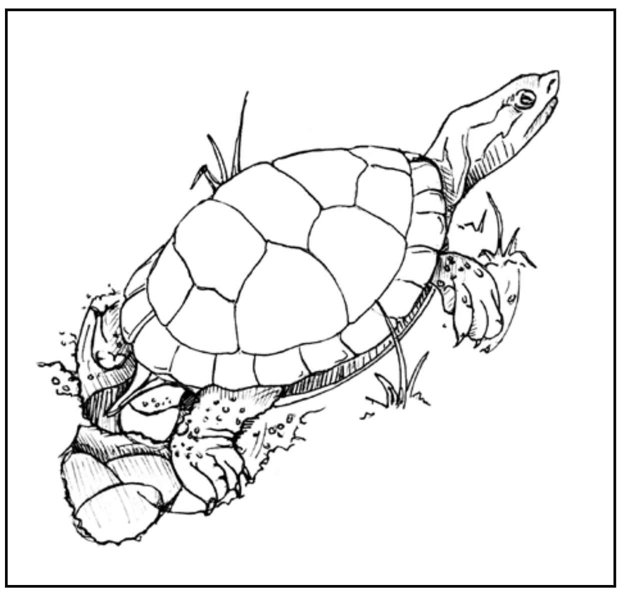


Fig. 9–6. Female turtle building nest in upland soil.
(CREDIT: CHRIS COOLEY)

and decrease groundwater infiltration during storms. Impervious surfaces of rooftops, roads and parking lots are a primary culprit. A rule of thumb is that watersheds having more than 10 to 15 percent coverage by impervious surfaces will exhibit clear signs of altered stream-flow patterns, increased magnitude and frequency of flooding and reduced baseflow between storms, erosion, habitat collapse and loss of aquatic species. Numerous other types of land practices also will contribute to these problems:

- Loss of former wetlands that have been drained and ditched or filled to support railroads, agriculture, insect control or housing development;
- Streams that are straightened and dredged or have armored banks that rapidly convey water downstream;
- Extensive networks of roadside ditches that drain runoff directly into streams; and
- Fields left uncropped and exposed during storms and spring snowmelt.

Protection of steep slopes, reestablishment of green spaces or restoration of wetlands and stream channels are solutions that will help to alleviate these problems.

Management of growth

It may be desirable to limit the amount of development allowed to take place. Development can be valuable with benefits such as increased services or tax revenue available to the overall community. Higher density development, however, will also produce increased water use, waste generation and habitat loss. Certain types of businesses and industries have risks associated with the chemical wastes they produce. Once established, it is very difficult to remove buildings or families that have become "rooted" and view themselves as part of the community. Careful planning can allow development to proceed only to appropriate levels. Engagement of the community during this process is critical to avoid contention associated with the use of taking by eminent domain.

Various strategies are available. For most of these, however, the lake association will need to work collaboratively with the various local governments that exist within the watershed. Local governments in New York State play a major role in determining land use within their town, village or county jurisdictions. Watersheds rarely follow political boundaries. It will take some effort and patience to help the different town boards understand that they need to become part of a larger, more integrated group with common goals. A lake association can work collaboratively with local town boards to develop a long-term plan that meets the goals of both the towns and the lake association.

Local governments have the authority to prepare and adopt comprehensive plans, zoning and subdivision regulations. They frequently are in a position to decide what land-use issues will be addressed and what standards will be used. Ideally, each local government should have a current, comprehensive plan or master plan outlining the use of land resources within the area of its jurisdiction. This plan should be somewhat flexible because goals and objectives will change as the community grows and develops. The following is a list of strategies available for carrying out control of the development set forth in such a plan.

Zoning

Zoning is a method by which local governments can protect natural resources using regulations to control land-use activities. The area in the town's jurisdiction is divided into districts. The local government then establishes laws which govern the use of land within each district. Zoning can protect water resources directly by identifying protection districts for physical or biologically critical areas, such as watersheds, wetlands and aquifer recharge areas. Through zoning laws for a given district, community development around a lake can be controlled by restrictions which define minimum setback distances from the lake's edge, percentage of a lot that can be occupied and minimum lot size. Some additional zoning regulations that help to protect lake water resources include the following:

- Restrictions on slopes greater than eight percent to reduce housing density;
- Preventing erosion and runoff by restricting maximum house size, percentage of land cleared, on-site stormwater runoff management, impervious surface coverage;
- Restrictions on type, location or maintenance operations of residential on-site waste-disposal systems to prevent pollution of lake water;
- Requiring minimum widths of vegetated buffer strips along stream edges and lakeshores to maximize water filtration and erosion control;
- Building code requirements with limits on height to prevent obstruction of views, design requirements to reduce flood vulnerability, use of permeable walkways and driveways and a requirement for on-site retention of all stormwater runoff; and
- Development density controls, including cluster zoning to concentrate human usage and allow for greater expanses of green space or requiring large minimum lot sizes to minimize the percentage of impervious surface coverage.

Zoning variances

A **zoning variance** is an exception granted by the zoning board of appeals to a landowner removing all or some zoning restrictions. Zoning variances can be developed in some areas to protect unusual landscape features, such as steep hillsides, scenic vistas, erosive sites and natural drainage which may restrict development. Special zoning provisions can be established such as "incentive zoning," which allows for cooperative arrangements between an individual property owner and the community.

Reality check on the power of zoning controls

Zoning laws are a critical first step because they provide the authority for controlling development. See Chapter ten, "Legal framework" for discussion about developing a town zoning ordinance. Without an ordinance in place that requires protection of vegetated streamside buffers, the majority of developers and landowners will not understand the need for setting aside land that could be cleared and used for other purposes. Having a regulation in place, however, is not sufficient by itself, and the laws do not necessarily reflect the reality of the process. Implementing and enforcing regulations is critical. The power for implementation is determined by the members of the town board, who are responsible for creating the zoning law; by members of the planning board, who determine how stringently new development permits are reviewed, and by members of the zoning board of appeals, who determine when the regulations can be set aside. In small communities, the composition of all three of these boards plays a big part in how development proceeds. Town board members are elected by the public, but members of the other two boards are appointed by the town board. The self-interests, political motivations, financial concerns or environmental attitudes of these individuals frequently influence how zoning is translated into practice.

Land acquisition

Land acquisition is a way to plan for the preservation of natural resources, open spaces and to provide areas for public recreation. Land acquisition is frequently accomplished by state, county or local governments or by a private non-profit organization such as The Nature Conservancy. Conservation easements and land trusts are the two methods of land acquisition most frequently used in New York State. Potential revenue sources for land-acquisition projects include state appropriations, county and local property taxes, county sales tax, local improvement districts, motel-hotel tax, transfer tax and user fees, as well as state and other local bond acts.

A **conservation easement** is a legal document which restricts the type and amount of development that may take place on a parcel of land. The most distinctive aspect of protecting land through granting a conservation easement is that the property remains in private ownership, yet its current and future use is regulated by a legal agreement which is stronger than local zoning or land-use laws. Conservation easements are often developed for open-space preservation, historic preservation, protection of natural habitats, and preservation of areas for public recreation or education**.** Additional details on easements are described in Chapter ten, "Legal framework."

A land trust established in the Thousand Islands handles conservation easements for almost 1,000 acres on Grindstone Island. These easements will prevent further development of the land and will preserve some of the island's scenic vistas. In addition, the easements will provide protection for one of the two remaining muskellunge spawning grounds by prohibiting cultivation, timbering and construction within 100 feet of the mean high-water mark.

Point source pollution control

The smelly, offensive discharge from an industrial pipe into a stream can easily be recognized as the source of a downstream fishkill. In the early years of water management, such pollution was considered synonymous with point source pollution. The first targeted national effort to clean up our waters was to eliminate these situations. The federal government established the *Clean Water Act* in 1972, empowering states to control these discharges. The act and its subsequent amendments identified a set of standards for acceptable drinking-water levels. It set standards for allowable maximum concentrations or allowable chronic exposures for designated periods at lower concentrations for many different pollutants. These standards are based on research studies that quantify the effects of contaminants on the health of humans, fish and other organisms, as well as the smell, appearance and other properties of water. New research may periodically indicate the need for tightening the standard for a specific pollutant. The *Clean Water Act*, now in place for almost four decades, has been highly effective at improving the quality of the nation's waters.

With the enabling legislation of the *Clean Water Act*, New York State created the State Pollution Discharge Elimination System (SPDES) which requires that a Department of Environmental Conservation (DEC) permit be obtained for "constructing or using an outlet or discharge pipe that discharges wastewater into surface waters or groundwaters of the state, or constructing or operating a disposal system such as a sewage treatment system."

The SPDES system designs permits to meet the water-quality standards established by the EPA. SPDES permits are in effect for five years and then require a renewal application. Transfer of ownership requires a reevaluation of the permit, as does any modification to the discharge. Additional details concerning the SPDES permit system are included in Chapter ten, "Legal framework."

Point-source discharges generally have been less problematic for lakes than for rivers in New York State because more discharges go into flowing waters or groundwater than directly into lakes. This is due in part to two old adages. "Out of sight, out of mind" dictates pushing wastewater quickly and as far away from lakefront or riverfront communities as possible, while minimizing the cost of piping wastewater deep into the bowels of a lake. "Dilution is the solution to pollution" utilizes the cleansing capacity of rivers and very large lakes. There remain, however, many lakes in New York State, particularly large lakes such as the Great Lakes, Oneida Lake and the Finger Lakes, that are used in part to assimilate wastewater. A greater number of lakes are downstream of wastewater-treatment plants.

The effectiveness of the SPDES approach is based on a system of regular monitoring of the quality and quantity of the permit-holder's outflow. The permit holder is required to monitor the outflow and report on a monthly basis or, at minimum, on an annual basis. DEC complements the self-monitoring with periodic sampling. Violations to the permit requirements, such as excessive eliminations, inadequate controls or insufficient reporting, can be subject to civil or criminal court action, fines or shutdowns. SPDES has proven to be an effective system for reducing water pollution. The weakness in the system is its dependence on self-monitoring, which necessitates that permit holders be honest, competent and willing to comply with permit requirements. Without such cooperation, small violations such as periodic dumping of larger pollutant quantities may pass through the monitoring process undetected.

Wastewater treatment facilities

The most common SPDES permits relate to **wastewater treatment facilities**. This type of permit deserves special consideration because wastewaters from these facilities often are discharged directly to watercourses, usually streams, rivers and lakes. Up to 95 percent of wastewater discharged from industrial and municipal treatment facilities consists of pure water. The balance consists of suspended materials, dissolved organic matter, microbiological pathogens such as bacteria, and nutrients such as phosphorus and nitrogen. The actual content of the wastewater depends on the source of the water. Industrial wastes can contribute a diverse and more toxic suite of contaminants, including trace metals and organic compounds. Each SPDES permit issued by DEC evaluates the specific chemicals used in the industry and sets limits on discharge concentrations to control environmental damage.

Wastewater treatment plants are designed to remove the bulk of these contaminants to protect downstream aquatic systems. The completeness of removal is dependent on the type of wastewater treatment system used.

Modern wastewater treatment technologies are capable of converting wastewater to drinking-water quality. Numerous municipalities around the world turn sewage into public drinking water, especially where water is in limited supply. Most of our southern states recycle water for irrigation or groundwater recharge. Industrial and municipal wastewater plants typically discharge into rivers, streams and lakes, only to have downstream municipalities withdraw water from that same waterbody for public drinking-water supplies. It might sound disgusting, but water leaving the space station's purification system is cleaner than the water most of us drink on earth. Wastewater from urine, oral hygiene, hand washing and condensation is reclaimed from the space shuttle's fuel cells. Even on earth, people might be consuming tomorrow what is flushed today because all the water on the earth is recycled.

Why not treat all wastewater to pollution-free levels? The simple truth is the cost involved. The higher level of treatment efficiency a system has, the greater the capital construction costs and the expenses for long-term operation and maintenance. Small, on-site systems, such as septic tanks and leach fields, are relatively simple, inexpensive systems that require little maintenance. They are not, however, very efficient at removing all pollutants humans dump down the drain and ultimately into our lakes and streams. Today there are ever-increasing numbers of on-site systems that use a wide range of technologies previously tested and used in full-scale wastewater-treatment systems.

Large-scale municipal wastewater treatment systems

Sewage collection systems convey wastewater from homes and businesses to a treatment facility. There are three types of gravity sewers: sanitary, storm and combined sewers that simultaneously carry both sanitary wastes and stormwater runoff. Unfortunately, many municipalities with regulated combined sewers often experience overflows during major rain events. When this happens, the combined flow exceeds the capacity of the wastewater-treatment plant, and untreated effluent is discharged directly into the stream or lake.

Throughout the nation, **sanitary sewer overflow systems (SSO)** and **combined sewer overflow systems (CSO)** lead to unregulated discharges. The Wet Weather Water Quality Act of 2000 addressed these problems through the Capacity, Management, Operations and Maintenance Program (CMOM). CMOM helps local municipalities develop capital improvements and maintenance plans for their collection systems. There are many methods for evaluating and testing collection systems for rehabilitation. Smoke testing, flow isolation, internal television inspection, dye tracing and hydraulic modeling are all methods for assessing what needs to be fixed. There are also many new trenchless technologies compared to dig-and-replace methods of repair. The EPA publishes guidance documents for CSO control, and these can be found by contacting the EPA's Office of Water Resources Center (see Appendix F, "Internet Resources").

Pump stations are used when sewers are located at too great a depth or on too steep an incline for gravity movement. Many communities in hilly areas may have numerous pump stations. Lake homes are often placed near the water and have to use a pump station to lift their wastewater up to a gravity-collection system if one is available. Pump stations are mechanical devices that rely on a constant power supply and maintenance. Homeowner systems do not normally have the advantage of duplicate equipment and standby generators that are available to larger municipal systems.

Preliminary treatment

Preliminary treatment is the first step in the process once the collection system conveys the wastewater to the treatment plant. Large screens remove large objects that can plug the pumps and then sand and stones that can fill up process tanks are removed.

Primary treatment

Primary treatment is a physical process of settling solids that have a specific gravity greater than water and flotation of particles that have a specific gravity less than water. Material such as plastics and grease are removed from the surface of the primary tanks. Heavy solids sink to the bottom and are removed daily before they become anaerobic and produce methane gas. These solids are then pumped to the solids-handling units, where they go through digestion or dewatering. The residual sludge may be used as compost or spread on agricultural fields, although there are some concerns about the long-term effects of the associated chemicals and pathogens on soil and groundwater. The liquid, dissolved-solids product of primary treatment flows on to secondary treatment.

Secondary treatment

Some plants skip the primary treatment process, allowing wastewater to flow directly into the secondary process from the preliminary treatment process. There are many secondary processes, but they all have the goal of removing non-settleable solids and of converting soluble material into material that will settle for ultimate removal and separation from the liquid. The majority of secondary processes today use biological microorganisms that consume soluble organics in wastewater and convert them into biological cells which have specific gravity greater than water. These cells will settle to the bottom of a secondary clarifier, a large, low-velocity tank, and are later removed and processed in solids handling. Generally, there are two types of microorganisms used:

- Attached-growth microbes are found in processes such as trickling filters and rotating biological contactors. They attach to a media, and wastewater is introduced to them. These processes rely on a sufficient amount of food (wastewater), oxygen (ambient air) and a wide range of microorganisms (bacteria and protozoans) to convert wastewater into a growing biomat attached to the media. Eventually, the microbes detach from the media and flow into a downstream tank for removal. New attached microbes grow in their place, and the cycle starts again.
- Suspended-growth microbes live in a suspension of water, food and other microbes within a tank that has aeration (ambient air) introduced at the bottom to mix microbes with wastewater and supply oxygen for their respiration. This process is called activated sludge, and there are many variations of the process. Some are designed specifically to remove carbonaceous materials, and some are designed to remove nitrogen and phosphorus. As with the attached-growth process, there is a secondary clarifier that settles the microbes for removal to solids processing or reuse back into the aeration tank.

Tertiary treatment

Tertiary treatment provides additional treatment beyond typical secondary levels. A variety of processes available include using microbes under aerobic and anoxic conditions, chemical precipitation, sand filtration, microfiltration, membrane filtration, activated carbon, reverse-osmosis, constructed wetlands and other processes specific for nearly anything desired to be removed. These cutting-edge technologies can be specially tailored but are expensive to construct and operate. Many are being widely used, however, in sensitive watersheds that require very low levels of nitrogen and phosphorus discharges.

Post treatment

The treated water is conditioned to make it more suitable for aquatic life in the receiving water prior to discharge into a stream or lake. Some wastewaters may need post treatment to adjust the pH to an acceptable range or adjustments may be needed to add dissolved oxygen. Some industrial facilities also adjust the temperature of the water being discharged. Almost all municipal systems are required to disinfect their treated water prior to discharge to remove any possible pathogenic microorganisms that might make it through the treatment processes. Most facilities use chlorination because of its low cost and ease of use, but it interacts with organics to form chlorine-produced disinfection by-products (DBPs). As an alternative, many plants are using ultraviolet (UV) light technology to radiate microorganisms and prevent their replication.

Solids-handling systems

Solids-handling systems include a variety of processes that stabilize the solids produced in the treatment facility. Treatment facilities have used anaerobic digestion for more than 100 years to produce methane gas and a stabilized, solid by-product. Some plants use an aeration process establishing aerobic digestion. Incineration of undigested solids, which requires a stringent air permit to operate, can be found at some facilities. A variety of composting processes are used that help recycle wastewater solids for many uses, including the local golf course. Ultimately, solids removed from the plants go into farmland and landfills or are sold at the local garden store as bagged compost. Everyone agrees that recycling is the green thing to do, as long as it does not end up in our waterways and cause greening up of our streams and lakes.

Phosphorus and nitrogen removal

In an effort to control aquatic plant growth, phosphorus removal is being required to lower effluent levels. Many new technologies have been employed to achieve levels below 0.2 milligrams per liter (mg/l) total phosphorus. The lower Potomac River basin and the New York City watershed are good examples of municipal wastewater facilities that have achieved phosphorus levels below 0.2 mg/l.

Phosphorus removal is achieved both biologically and with physical-chemical methods. Biological phosphorus removal requires a modification of conventional activated-sludge treatment systems, including the addition of an anaerobic phase that results in the growth of a microbial population with higher cellular phosphorus content. Plant operators can vary the time and level of anaerobic and aerobic zones to create a stressed environment, resulting in phosphorus uptake and phosphorus release.

Chemical removal of phosphorus involves the addition of metal salts, such as aluminum sulfate, and sodium aluminate or lime to form insoluble phosphate precipitates. Iron salts typically used are ferric chloride, ferrous chloride and ferrous sulfate that can be used in dry or liquid form. The physical process of tertiary filtration is used in wastewater facilities to remove phosphorus that is attached to solid particles. The New York City watershed wastewater facilities use both chemical and microfiltration processes to significantly reduce phosphorus levels for direct discharge into numerous reservoirs that supply unfiltered drinking water to the city. Some of these facilities are producing treated wastewater with phosphorus levels of less than 0.05 mg/l.

The use of biological phosphorus removal, chemical precipitation and microfiltration are difficult for homeowners to manage in small, on-site systems. Many new attached-growth and suspended-growth on-site systems are available to homeowners who have limited site conditions and requirements for higher levels of performance than a typical septic system and soil adsorption field can provide.

There is also an increasing trend toward removal of nitrogen. Regulations may require removal of all forms of nitrogen or just ammonia ($NH4+$) to prevent lake eutrophication or to reduce ammonia toxicity for freshwater aquatic organisms. Some New York State wastewater facilities are required to provide treatment that can achieve ammonia levels of less than 0.5 miligrams per liter (mg/l). This uses a biological treatment process called nitrification, where the ammonia form is oxidized to nitrite and then to nitrate. Two microorganisms, *Nitrosomonas* and *Nitrobactor,* are responsible for the two-step process. Many factors affect nitrification, such as temperature, alkalinity, and adequate numbers of healthy microorganisms.

Many municipal and industrial wastewater-treatment systems extend nitrification one more step. Denitrification is the biological conversion of nitrate-nitrogen to more reduced forms. A variety of nitrification and denitrification processes include suspended-growth and attached-growth microorganisms, such as activated sludge, trickling filters and rotating biological contactors.

Small, on-site, homeowner-managed systems have been designed in the last decade to improve wastewater treatment efficiencies for nitrogen and phosphorus by using proven technologies employed in municipal wastewater facilities. Which of the many advanced new systems on the market work the best? Studies around New York State lakes are working to validate whether these systems can achieve lower levels of nitrogen and phosphorus to protect water quality. The Skaneateles National Community Decentralized Wastewater Demonstration Project is evaluating alternative, on-site systems around Skaneateles Lake, which provides unfiltered drinking water for the City of Syracuse.

The Environmental Technology Verification (ETV) Program was created by the EPA to facilitate the use of innovative environmental technologies through performance verification. It seeks to provide high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase and use of environmental technologies. All ETV evaluations are conducted in accordance with rigorous quality-assurance protocols to ensure that the data generated and the results are defensible. National Sanitation Foundation International (NSF), in cooperation with the EPA, operates the water-quality protection centers (WQPC). NSF Standard 40 pertains to residential wastewater-treatment systems. Lake homeowners who are interested in nitrogen reductions will find that NSF Standard 245 has useful information about advanced nitrogen removal (see Appendix F, "Internet Resources").

The Buzzards Bay Massachusetts Alternative Septic System Test Center is another ETV partner that has been validating the performance of on-site treatment technologies. These testing centers operate various on-site systems under a wide range of conditions, including normal loading, spike loading, cold temperatures, warm temperatures and what happens when the homeowner goes on vacation and there is little or no flow entering the system. Systems are tested for efficient removal of pollutants and also are evaluated for electrical use, chemical use, noise, odors, mechanical components and electrical/instrumentation components. They are also studied to determine how difficult the systems are to operate and maintain, how much sludge they produce and how often the homeowner needs to remove the sludge that has accumulated. The ETV program has illustrated that some manufactured systems do not live up to their performance claims and can be difficult to maintain. Alternative treatment units were once banned in Texas because of the lack of maintenance and the failures that resulted. NSF standards 40 and 245 now require vendors of certified systems to provide a two-year initial service policy, including four site visits. They also:

- must extend the policy if the homeowner desires additional service;
- must have standby parts in stock; and
- must be able to provide service within 48 hours.

NSF will withdraw their certification if vendors are not compliant.

This publication could not begin to review all the new systems available, so before purchasing an expensive new system, check the EPA's ETV reports, as well as the work by the Massachusetts Alternative Septic System Test Center (see Appendix F, "Internet Resources").

Role of lake associations

Within the context of watershed protection, it would be useful to identify and locate all SPDES permit holders in the watershed. This list is public information and can be obtained directly from the DEC website. The type and location of discharge at each site can be added to your map system. It is not appropriate for a watershed group to actually monitor or sample outflows, at least if the intent of the monitoring is to litigate discharge violations. Good self-monitoring and increased vigilance against violations of SPDES discharges, however, may be a benefit resulting from increased community interest in permitted discharges.

Associations may gain the greatest benefit from working cooperatively with SPDES permit holders. Citizen volunteers may be able to assist in the monitoring program or provide public praise for effective efforts to protect water quality.

Because sewage treatment plants are the most prevalent sources of discharge, there is value in learning about current treatment levels, the types of contaminants moving through the system, and whether the treatment plant is part of a CSO. If the lake association decides that greater protection is needed, they can promote cost-effective solutions. A common solution is to upgrade to secondary or tertiary treatment. Another option is to separate industrial from residential wastes to remove specific toxic substances. It is also worthwhile to educate homeowners about limiting their use of toxic household substances and disposing of them appropriately instead of into the sewer or septic-system network.

One option for a CSO is to create separate systems for stormwater and sanitary flows. However, the cost of separation is usually high. An association will have to do its homework to convince the local municipality that such upgrading or retrofitting is justified. Valid arguments include:

- Linking phosphorus removal in the treatment plant to phosphorus levels in the lake;
- Cost of phosphorus removal from other sources;
- Connection among nutrients, algae, clarity and lakeshore owner perception;
- Percent of tax base associated with lake residents versus per-resident cost of upgrade; and
- Expense of in-lake management methods associated with excessive phosphorus, such as copper sulfate, alum and water-treatment costs.

Nonpoint source pollution controls

Nonpoint source pollution includes a broad and complicated array of contaminants such as sediments, nutrients, pesticides, pathogens and a mixed cocktail of pharmaceuticals and personal health-care products. These pollutants are introduced from a multiplicity of small sources, not from well-defined individual sources. Controlling nonpoint source pollution is not as simple as "turning off the faucet," for it often occurs within a large land area. This pollution moves through complex transport and delivery mechanisms within the lake watershed and enters watercourses at many locations. Management is based on sources, in the context of the major land use and associated contributing stakeholder groups.

Best Management Practices

A lake association or other local resident groups have a number of options available to reduce nonpoint source pollution coming from the watershed and affecting the lake. A **Best Management Practice (BMP)** is any procedure that prevents or reduces the availability, detachment or transport of pollutants. Control of any one of these phases can reduce pollutants delivered to waterbodies. Pollutants that can be controlled through the use of management practices include sediments, nutrients, pesticides, pathogens and pharmaceuticals. Public education is a BMP that can directly affect nonpoint source pollutants entering waterways (see "Pollution control guidelines for lakeshore homeowners").

A lake association must assess the types of pollutants and the conditions associated with various land uses in the watershed and identify which uses may be potential sources of nonpoint pollution. The goal is to increase the adoption of management practices appropriate to that land use, through a combination of vigilant monitoring, outreach, ongoing education, incentives and enforcement of legislative deterrents.

Pollution control guidelines for lakeshore homeowners

Never wash anything directly in the lake. Using soap or a cleaning agent to wash dishes, pets or people contributes pollutants to the water. Avoid washing boats or cars near the lake where detergent and oil may pollute the water.

Never discard branches, leaves, grass clippings or any dead plant material from the yard into the lake, drainage ditches or on flood-control lands. They can clog the shoreline, and will add extra nutrients during decomposition. Branches and stumps can foul fishing lines.

Never throw the ashes from a wood stove, fireplace or campsite into the lake. Ashes contain phosphorus, nitrogen and carbon which fertilize aquatic plants. Spreading the ashes on your garden or lawn is a more sensible use and provides an alternative to commercial fertilizers.

Minimize your use of fertilizers, and never fertilize the strip directly along the shoreline.

A good practice is to plant a strip of trees or shrubs along the shoreline. The plant roots reduce erosion, and the vegetation can absorb fertilizer runoff before it reaches the lake. It also has scenic benefits and discourages geese trespassing.

For lawn and garden care, consider the same suggestions that are used by farmers to reduce fertilizer use and waste. See “Agricultural sources” in the “Nutrients and pathogens” section below.

BMPs are selected to address specific pollution problems appropriate to a site’s characteristics, operation considerations and budget. Agricultural practices, for example, have been developed for cropland, pastures, barnyard or manure management and pesticide control. Urban practices have been designed to keep city streets and roadsides clean, while construction practices have been developed for erosion and runoff control. Forestry practices have been developed for activities such as road construction in timberlands, timber harvest techniques, regeneration of forests cut or killed by disease or fire and the use of pesticides.

Management practices were seldom designed with water-quality protection as the primary goal, but rather to maintain productivity on the land, reduce costs of pesticides and fertilizers or prevent lawsuits because of mudslides or flooding on neighboring properties. Regardless of their original intent, many of these practices are useful in lake-restoration projects. Managers of lakes and streams generally use management practices to control erosion and sediment, nutrient and pesticide runoff. These processes are often interrelated. Reducing the delivery of sediment to a waterbody, for example, will also reduce nutrients or pesticides bound to sediment particles. The reader is encouraged to see Appendix G, “References Cited” and Appendix H, “Additional Readings” to explore BMP practices in more detail.

The remainder of this chapter gives an overview of major nonpoint source pollutants, key sources and the Best Management Practices for reducing or eliminating the contaminants.

Erosion and stormwater runoff

A watershed land surface intercepts rain events, and a large portion of the rainfall moves across the surface to lakes and streams as runoff. Increased volume and intensity of **stormwater** contributes to an increase in the magnitude and frequency of floods, increased erosion and degraded stream and lake systems. Equally important, however, are the large quantities of contaminants which are transported along the way, including suspended sediments and attached or dissolved nutrients such as phosphorus, trace metals, petroleum hydrocarbons and de-icers from roadways. EPA Phase II stormwater regulations involve two programs to control construction activities and municipal separate storm sewer systems (MS4s). These regulations were initiated to help reduce stormwater runoff from these sources and require that small towns of applicable densities or that discharge into critical water bodies develop plans for reducing stormwater runoff from their jurisdictions. New York State Stormwater Phase II is administered by DEC. Some of the required activities are the development of pollution prevention protocols, drainage-use ordinances, GIS mapping, outfall inspections, outreach activities and watershed vulnerability analysis.

Agricultural sources

Erosion of sediments from unvegetated farm fields has traditionally been identified as one of the leading sources of sediments. The use of BMPs is being fostered through education awareness programs, tax relief and a multitude of federally funded initiatives such as the Conservation Reserve Program. These BMPs include the following:

- Maintenance of a cover crop during winter months;
- Use of mulch and silage to protect the soil;
- Tilling and crop planting parallel to topographic contours to slow water flow and trap sediment;
- Use of a filter strip along field edges or a riparian buffer along stream banks to trap and slow runoff;

Case study: Agricultural Best Management Practices

Lake setting: Cannonsville Reservoir, a 4,800-acre potable impoundment in Delaware County in the Catskill Region, is the third-largest reservoir the New York City reservoir system.

The problem: The New York City Department of Environmental Protection (NYCDEP) has developed a comprehensive management program to address point and nonpoint source pollutant loading to the New York City reservoir system in hopes of avoiding expensive water filtration of its surface water supplies as required by the federal Safe Drinking Water Act. As part of their filtration avoidance agreement with the EPA, the city partnered with the local farm community to establish a voluntary, incentive-based watershed agriculture program (WAP) that funds the design and implementation of individual farm plans. More than 85 percent of the farms within the New York City watershed system are currently participating in the WAP. At the onset of the program in 1993, DEC, with funding from WAP, launched a long-term paired watershed study designed to quantify the water-quality effects of agricultural BMPs implemented under the WAP on a single upland dairy farm located in a sub-watershed of Cannonsville Reservoir.

Response: A variety of agricultural BMPs were implemented on a 160-hectare, third-generation dairy farm with 80 milking cows and 35 heifers. These included a storage lagoon for manure and milkhouse washwater, stream corridor and silage-storage relocation, diversion ditches, contour strip cropping, improved crop rotation and manure-spreading schedules. Stream flow, nutrient and sediment concentrations were continuously measured during event and baseflow conditions for two years pre-BMPS and nine years post-BMPs in the farm watershed. They also were monitored at a nearby 86-hectare, forested, control watershed basin. Weather and runoff conditions were comparable at the two watersheds during the study period.

Results: Runoff events were shown to be important contributors of phosphorus, delivering an average of 57 percent of soluble phosphorus and 84 percent of particulate phosphorus total annual loads from the farm site. A statistical comparison of the first six years of data from the paired watersheds demonstrated that the blending of farm-management and physical-infrastructure BMPs resulted in seasonal reductions of 35 to 50 percent in the event-loading of soluble phosphorus, and reductions of 15 to 40 percent in the event-loading of the particulate phosphorus. Annual event-load reductions were 43 percent for soluble phosphorus and 29 percent for particulate phosphorus. Load reductions were greatest in winter and summer and occurred despite a slight increase in herd size during the course of the study. Presumably, decreases in stream losses of phosphorus were a consequence of greater retention of phosphorus within the farm watershed, an outcome that could eventually lead to saturation of soil with phosphorus. This saturation likely will result in higher stream losses once again as the soil's capacity to retain phosphorus is exceeded.

Lessons learned: Agricultural BMPs can effectively reduce phosphorus discharge into outflow streams from farmland, but in the absence of efforts to improve the overall mass balance of phosphorus on the farm, they ultimately will increase phosphorus retention within the farm watershed and likely lead to soil saturation. Livestock farms, in particular, need to reduce importation of phosphorus in feed and fertilizer, in addition to applying soil and water BMPs to effect a sustainable improvement in water quality. While the extent of agricultural BMPs in this study may be larger than on the typical New York State dairy farm, most of the practices utilized are commonly recommended for both small and large New York State farms (Bishop, et al, 2005).

- Strip cropping of corn or vegetables alternating with strips of a grain crop to help capture and slow runoff;
- Use of grassed waterways and farm ponds to capture sediment moving from fields;
- Planned, rotational grazing of livestock to help reduce soil erosion;
- Fencing of streams to keep livestock away; and
- Protection of the soil surface by retaining last year's crop residue before and during planting and by reducing tillage and soil turning.

Residential development

Another of the major sources of runoff originates from the spread of urban development across the landscape. It occurs during the construction process when land is being cleared and exposed. Uprooting trees and shrubs disturbs the soil and removes the network of roots that helped to hold the soil in place. Runoff continues after construction from the resulting impervious surfaces of rooftops, roadways and parking lots. Construction strategies for reducing this runoff include the following:

- Reducing the total amount of impermeable surfaces by replacing them with gravel or permeable pavements;
- Replacing expanses of lawn with landscaped patches of trees, shrubs and mulch to capture and hold rain water;
- Disconnecting gutters and other features that transfer rooftop runoff to roadside ditches, which then transmit it straight to streams; and
- Diverting on-site runoff to rain gardens or small depressions where water has time to infiltrate the soil.

It is useful to remember that rainwater contains fewer dissolved ions that make "hard' groundwater so challenging. If possible, consider rain barrels to harvest roof runoff as an alternative source of freshwater for laundry, showers and watering gardens.

Town maintenance

Local governments can play a pivotal role in stormwater management. First, they can develop regulations for housing densities, zoning and the building-permit process. They can mandate the amount of impervious surface in the watershed and encourage or mandate the use of BMPs to treat on-site runoff.

Second, towns designated as municipal separate sewer and stormwater systems (MS4s) are required under EPA Phase II regulations to adopt an ordinance that controls stormwater runoff from construction and post-construction activities. Best Management Practices for stormwater runoff include the following:

- Disturbed area limits are designed to minimize the area affected by construction activity. Where possible, soil disturbance should be phased or restricted to only the parts of the development site that are under active construction.
- Surface roughening can be applied on the exposed soil when vegetation is removed. Construction equipment is used to scarify or groove the soil, following the slope contours. The grooves spread the runoff horizontally and increase the time for water to soak into the ground.
- Non-vegetative soil stabilization includes actions such as covering disturbed areas with mulches, nettings, crushed stone, chemical binders and blankets or mats. This BMP is a temporary measure that should be used only until a long-term vegetative cover is developed.
- Silt fences combined with hay bales have been a common practice to capture sediment transported in runoff and prevent its movement downslope. Proper placement and monitoring are critical to ensure its success.
- Mulching is used to protect constructed slopes and other bare areas. Materials such as grain, straw and hay are applied to critical areas, reducing runoff and evaporation loss and holding seeds, lime and fertilizer in place.

Third, town managers can directly control a major source of stormwater contaminants through the management practices they employ in maintaining town roads. Road salts, such as sodium chloride (NaCl) and calcium chloride (CaCl), are the predominant road de-icers used in the northeastern United States. They have contributed to a significant rise in conductivity in streams. Conductivity is a measure of dissolved ions in water. Modern storage facilities with roofs, cement pads and berms are critical for capturing precipitation and preventing salt-contaminated runoff. Outreach and support from tax-paying stakeholders is needed to encourage the use of alternative de-icers, such as biodegradable, sugar-based products.

Town highway staffs also maintain networks of ditches connecting impervious surfaces to streams. Recommended BMPs to reduce the adverse effects of these ditches on streams include the following:

- Discouraging ditch scraping that leaves bare soil exposed during storm events;
- Encouraging reshaping and widening of ditches as necessary to allow regular mowing. Using good hydroseeding practices, including not seeding before a rain event or late in the fall when seeds will not have time to germinate;
- Installing check-dams to slow water velocities along steep, hillslope ditches; and
- Directing the ditch discharge away from streams and into an infiltration basin, a constructed wetland or a detention pond so that the water can recharge the groundwater slowly.

Finally, town managers should be encouraged to use their influence in decisions concerning the use of combined sewer and stormwater overflow systems. Qualified advisors can be consulted concerning the problems associated with CSOs and the need to decouple these two sources of runoff contaminants.

Nutrients and pathogens

Phosphorus is the key ingredient causing eutrophication of freshwater lakes and streams, and nitrogen is now recognized as the comparable factor causing estuary pollution. Both phosphorus and nitrogen are bound to suspended sediments and also are dissolved in water. A primary source of these contaminants is the fertilizers used for crops and lawn management. Nutrients are also derived from manure wastes associated with livestock, pets on lawns and human wastes inadequately treated by on-site wastewater systems. Animal wastes from all sources host pathogens including bacteria, viruses and protozoans and can be a threat to human health.

Agricultural sources

The agricultural industry has been strongly targeted for nutrient reduction during the past several decades. BMPs are well established and work well where applied and enforced. These include the following recommendations concerning fertilizers:

- Proper storage of fertilizers to avoid spills;
- Soil testing to determine proper application rates;
- Timely application during the growing season to maximize plant uptake and minimize runoff or groundwater contamination during storms and snowmelt;
- Minimizing erosion by integrating nutrient management with the BMPs identified for stormwater runoff control;
- Strategies for wellhead protection, including storing fertilizers more than 100 feet from a well; and
- Crop rotation with legumes to reduce the need for fertilizers.

Manure from pigs, cows and chickens is a major focus for on-farm management and includes the following:

- Testing manure to match application rates to plant-nutrient needs and soil-test data;
- Pasturing livestock at proper densities for soil type, slopes and groundwater depths;
- Requiring permits for concentrated animal feedlots;

- Constructing and managing storage facilities to avoid runoff and leaks, including sewage lagoons, earthen storage ponds, tanks or sheltered concrete-slab areas; and
- Developing a constructed wetland for treatment of wastes.

Urban sources: On-site wastewater treatment systems

New York State lakefronts are vulnerable to contamination from on-site wastewater treatment systems, better known as **septic systems**. Site conditions such as steep slopes, poor soils and small lots can make it difficult to design an effective traditional system. Steep slopes direct wastewater breakouts and surface-water runoff directly into the lake before it can be adequately treated. A system correctly designed for a seasonal-use cottage will be burdened by increased use when the cottage is converted to year-round use. Untreated or partially treated wastewater contains nutrients that contribute to aquatic blooms and degrade water quality. Wastewater may also contain pathogens, disease-causing microorganisms such as bacteria (*E. coli*), viruses and protozoa such as C*ryptosporidium*.

Traditional septic systems

Traditional or conventional systems consist of three main components (See Fig. 9–7).

- A collection system of pipes that convey waste to the septic tank;
- A tank, where solids and floatable materials are collected; and
- A soil-based treatment system, commonly called a leachfield or a drainfield, where most of the wastewater treatment occurs; a distribution box divides and directs flow through the multiple lines of a leachfield.

Septic systems, when properly designed, installed and maintained, are an effective and economical way to treat wastewater. Proper care and regular maintenance prolong the life of the system and are wise and cost-effective investments.

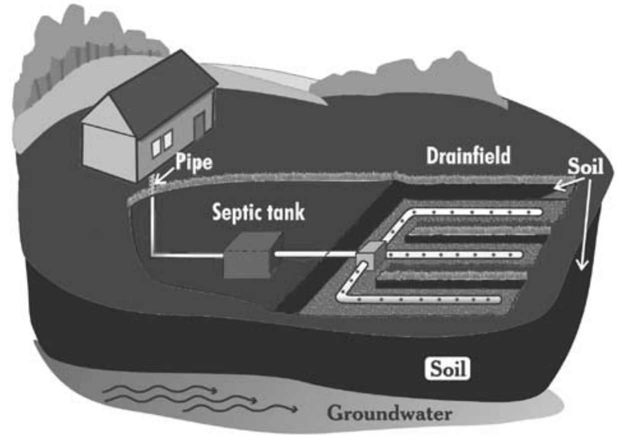


Fig. 9–7. Traditional or conventional systems consist of three main components. (CREDIT: EPA)

Household chemicals, such as paints, wood preservatives or solvents, should never be poured down the toilet or drain. These common household products can destroy the natural bacteria in a septic tank and pollute a lake. Local recycling and household hazardous waste collection programs should be used for these materials. Local recycling coordinators can inform residents about the preferred or required methods for proper disposal of these materials if recycling is not an option. Many communities have annual collection programs for materials that need special handling.

Other suggestions for proper care of an on-site system include avoiding the use of garbage disposals and reducing the amount of water to the system. Garbage disposals add unwanted solids and grease to the septic system and require a larger septic tank. Keep excess water out of and away from the system by conserving water, fixing leaks properly and diverting water from sump pumps and roof gutters away from the drainfield. Excess water saturates the system, reducing its effectiveness. Install low-flow faucets, shower heads and toilets to further conserve water.

For a system to work properly, solids in wastewater must remain in the tank until they are pumped out. If heavy or floatable solids are washed out of the tank, they are carried into the leachfield pipes and can clog the drainage conduits. This can happen because of a structural problem in the tank; too much water or additives that keep solids in suspension.

Septic systems should be inspected each time they are pumped, preferably every two to three years.

A septic tank is different from a holding tank that collects wastewater until it can be professionally pumped out. Holding tanks do not treat wastewater but simply store it to prevent it from entering the ground and eventually the lake. Holding tanks are usually only a temporary option because frequent pumping is expensive and inconvenient. At some lakes, however, they may be the only option for small lots near the water or in ground incapable of successfully operating a leachfield. County health departments have the final decision, and some counties will not permit holding tanks to be used.

Alternatives to traditional septic systems

It is often difficult to remedy failing on-site systems in lakefront environments. Municipal sewers may not be feasible due to expense, especially in areas of low-density population, in locations distant from the treatment plant or where the ground is hilly, rocky or wet. Alternative leachfield designs are often the best solutions for difficult lakeshore properties where soil is unsuitable (such as clays) or where there is insufficient depth to bedrock or groundwater.

All alternative systems must be designed and submitted to the local health department by a system professional. Appendix 75-A of the New York State Public Health Law, 201(1)(1) specifies that all alternative dispersal systems must be preceded by a dual-compartment septic tank or two septic tanks in series and of sufficient volume. Local health departments can answer specific questions.

Three of the most common alternatives include the raised-bed system, the mound system and the sand-filter system. Other alternatives may be allowed by the local health department on a limited experimental basis or for replacement systems on difficult sites.

- The raised-bed system is used where soil is suitable but of insufficient depth. One foot is the minimum required soil depth for a conventional system. An additional amount of suitable soil with a percolation rate of 5 to 30 minutes per inch is trucked onto the site, and a conventional stone and pipe leachfield system is constructed. Sufficient soil must be available to provide

Case study: Septic management and education

River setting: The 1,000 Islands area of the St. Lawrence River is a vital ecological, recreational and economic resource in the northwestern area of New York State.

The problem: Sewage pollution in the busy summer resort region of the 1,000 Islands was perceived to be a major problem, primarily due to many poorly functioning septic disposal systems.

Response: The Save the River organization was formed in the late 1970s to address winter navigational issues within the St. Lawrence River and eventually became involved in other water-quality and ecological issues. The organization implemented an alternative sewage project, funded by the DEC in 1988 under the motto "Save the River—It's Not a Sewer." The project consisted of a public educational campaign focused on extensive distribution of educational brochures outlining sewage problems and booklets highlighting alternative methods of wastewater disposal. Voluntary inspections were conducted, including septic tank inspections, system surveys and dye tests. Homeowners with systems that "passed" the inspection were awarded a handcrafted River Great Blue Heron Clean Water Award statuette. Those failing inspections were provided site-specific recommendations to upgrade their septic system.

Results: More than 500 homes were surveyed, with about half passing the inspections. Many of the failed systems were upgraded, at least in part due to the non-confrontational approach to upgrading systems and to the additional value gained by passing the inspection. Those gains included an improved septic system, reduced impact on river-water quality, and a visible symbol of environmental stewardship, many of which were proudly displayed and observable from the river (Marr, 1991).

one to two feet or more of separation from the original ground surface. Gravity distribution may be used where the imported soil provides a minimum depth of two feet between the trench bottoms and the original ground surface. If that is not possible, dosing or pressure distribution is required using a siphon or pump.

- The mound system is also an above-ground distribution system created with fill material, usually a porous, sandy soil. Although the overall size of the mound is substantially smaller than a raised-bed system, it has more stringent soil characteristics and construction specifications, including required pressure distribution. In both the raised-bed and mound systems, wastewater from the septic tank is allowed to seep through the soil bed or is pumped there for more even distribution. This provides distribution and treatment or additional decomposition of waste materials by soil microbes. The wastewater filters down through the original ground surface to the groundwater table.

- A sand-filter system can also be used where soils are unsuitable for conventional drain fields. Wastewater flows from the septic tank to a pump or siphon tank, which periodically releases the water to a sand filter that is two to three-feet deep. This allows the filter to dry before the next "dose." The filter is lined with clay or plastic to prevent wastewater leakage. The filtrate may be collected and piped to a disinfection unit. Some residential sand filters may require a surface water discharge, but they usually are approved only to correct an existing problem when no other alternative is available. DEC has not allowed surface discharge for new residences since October 1990. Municipal or commercial septic tank sand-filter systems, however, may still be able to use surface discharge.

Sand-filter systems usually are fairly effective and require little maintenance, but the capital cost is high, and filter beds may need frequent replacement. The same considerations of soil and site conditions required for conventional septic tank leach fields are also applicable for raised-bed and mound systems.

Other proprietary alternatives are available, including peat-filter systems and synthetic media filters. If either system is approved, the local health department may require monitoring performance of the systems and a service agreement between the homeowner and the manufacturer or a local service provider.

On very small lots or where water is severely limited, lakeshore owners are adopting waterless toilets for managing human wastes. Incinerator toilets use electricity to burn organic wastes, converting them to dry ash. Dry-composting toilets depend on decomposition of wastes by adding sufficient quantities of sawdust or other carbon sources. These alternative toilets eliminate any potential for leaching of wastes into lakes. Both types of toilets may require special permits from the municipality.

Systems for small communities

In many communities, site conditions may preclude the use of even alternative on-site systems. Where lot sizes or soil and site conditions are not suitable for on-site systems, cluster systems may be appropriate. In cluster systems, wastewater is transported through small-diameter sewers to a drainfield, mound or sand filter which is used by several residences. Cluster systems can be both inexpensive and simple to operate and can work well if management and maintenance of the system is well organized and efficient.

Municipal law in New York State allows the formation of special districts for this purpose. Private maintenance corporations, such as transportation corporations or homeowner associations, are also possible, but most DEC regions prefer municipal ownership. To protect drinking-water supplies, some municipalities have adopted watershed rules and regulations that govern on-site wastewater treatment system design, installation, inspection, management and maintenance. All current watershed rules and regulations are on the New York State Department of Health (DOH) website. See Appendix F, "Internet Resources," and search "Title 10."

Small communities can explore a range of other options. Small-diameter gravity systems, pressure or pump systems and vacuum systems all allow residential septic tanks to be connected to the main municipal sewer system if it has available capacity. Oxidation ponds and ditches, facultative lagoons, trickling filters and overland flow treatment are well suited to small communities. They are less expensive, more energy efficient and easier to run and maintain than conventional centralized wastewater treatment facilities. Both DEC and the EPA publish helpful "standards" manuals that are available on their websites. See Appendix G, "References cited" and Appendix F, "Internet Resources."

Role of lake associations

Lake associations can conduct educational programs on septic-system care, encourage local legislation to require regular septic-system pumping and inspection and promote high professional standards or even certification of contractors that pump and inspect these systems.

The first step is to educate lakeshore owners about the importance of maintaining a functioning wastewater-treatment system. A well-informed lake homeowner should be aware of the location and condition of his or her septic system, how to detect potential problems and the health and water-quality problems that can develop when a system fails. Fact sheets or display booths at an annual fair are a good place to start.

Some lake organizations would like to collect information on how many and which systems are failing. Several methods are being used by different lake associations, and some have partnered with local municipalities to hire trained inspectors to conduct inspections.

One method of detecting septic system leaks is by using a septic leachate detector. This is a hand-held fluorometer that can locate effluent plumes and domestic wastewater in lakes. The probe is submersed in lake water in front of a shoreline home. A response can be noted on the chart recorder if human sewage, detergents and the whiteners found in laundry products are detected. The septic leachate detector (otherwise known as a septic snooper) has proven to be an effective tool for public health officials, water-planning agencies, consultants and engineers. A significant limitation to its widespread use, however, has been its high purchase cost.

Dye tests have been used by some lake communities interested in detecting failed septic tanks. Dye is flushed down a toilet, and its appearance in the lake is seen as evidence of system failure. Unfortunately, the accuracy and value of this simple test is limited. A failing system may not be detected. They do not consistently detect leachfield failures, or wastewater may be short-circuiting to groundwater and never reaching the leachfield.

Lake associations can promote legislation that requires septic-system pumping and inspection when ownership of the property is transferred or at specified time intervals. The time frame is frequently shorter for homes closer to the lake than for those in the uplands. To be effective, those doing the inspections must be properly trained. The New York Onsite Wastewater Treatment Training Network offers a series of state Education Department-accredited workshops that are administered by SUNY-Delhi but are held statewide at locally sponsored sites. Lake associations can sponsor or give scholarships for training. Continuing education credits are offered to professional engineers, code-enforcement officers and wastewater treatment plant operators. Others who have attended include town supervisors, planning and zoning officials, lake association members and property owners, contractors, wastewater-treatment system service providers, engineers and sanitarians.

Pesticides

The United States currently consumes about one billion pounds of pesticides annually. Once applied, they do not disappear from the landscapes. In 2006, the USGS released a survey of 100 pesticides in 51 major river basins nationwide. They detected pesticides in almost every stream studied. Pesticides were found in shallow groundwater beneath both agricultural lands and urban areas. Most frequently detected in agricultural streams were atrazine, metolachlor and cyanazine. Most frequently detected in urban streams were simazine, prometon and tebuthiuron, which typically are used in cities for controlling pests. The pesticides were almost always detected at low concentrations that were unlikely to affect people, but they were detected in most fish. Most waterbodies had more than one pesticide present.

There are several reasons for reducing our dependency on pesticides and reducing their presence in lakes and other aquatic environments. A growing body of evidence is showing that even low concentrations of different pesticides can affect the reproduction, growth and health of frogs and other aquatic organisms. There is also some disturbing evidence that human health is affected as well. In agricultural settings, weeds and insect pests consistently have been shown to develop resistance to pesticides, resulting in a need for more or stronger chemicals to maintain crop yield. Several strategies can be used to reduce both total use of pesticides and the risk of their movement into groundwater and surface waters.

Agricultural uses

The agricultural industry is the primary consumer of pesticides, and its use is well controlled. Regulations exist, and widespread education encourages the following BMPs:

- Good training and certification of applicators to ensure their safety and to protect the health of the environment;
- Proper storage of pesticides to prevent spills;
- Crop monitoring to identify pest outbreaks early so fewer pesticides are needed;
- Use of alternative integrated pest-management approaches, such as tilling for weed control or alternating crops to prevent pest population buildup;
- Following recommendations regarding the application of pesticides by not exceeding the recommended dose rates and by applying pesticides under proper weather conditions so they won't be washed or blown away; and
- Scouting for pests and using spot treatment instead of broadcast application.

Homeowner uses

Homeowners are seldom recognized as major users of pesticides, and, therefore, fewer education programs or strategies have targeted them. Options to reduce such homeowner usage include the following:

- Educating to increase awareness of good pesticide management practices, including proper storage, application and disposal;
- Working with supply vendors to provide smaller package sizes so that unused pesticides will not need disposal, and encouraging homeowners to purchase small packages;
- Considering alternatives to pesticides for pest management, such as using the dryer for clothing and blankets to kill fleas and ticks instead of spraying with pesticides or substituting less hazardous but common household products such as soap and water or borax;
- Minimizing pesticide application rates on lawns or other outdoor areas;
- Encouraging proper disposal of residual waste and packaging instead of dumping them down the drain; and
- Helping to establish hazardous-waste collection days and pick-up sites.

Antibiotics, pharmaceuticals and health-care products

Although identified openly but indecipherably on ingredient labels of bottles and boxes, chemicals have been almost totally overlooked for their effects on water quality and the environment. Thousands of new chemicals have been introduced recently in cosmetic, health care, pharmaceutical and other consumer products. Researchers from USGS (Kolpin, et al, 2002) found traces of these products in 139 rivers in 30 states. Caffeine is now so ubiquitous that it is becoming a signature of sewage contamination in freshwaters. It is a better indicator than *Escheria coli* (*E. coli*) counts because *E. coli* can come from other sources such as farmland runoff.

Triclocarban, a chemical which makes soap "antiseptic" is a good example. In use for nearly 50 years, it gained public appeal and widespread use in handsoaps about a decade ago. Scientists have recently looked at the effects of this chemical. A study by Halden and Paull (2005) found that triclocarban is barely broken down by conventional sewage treatment. Approximately 70 percent is released when treated sludge is spread on farmland. The by-products form an animal carcinogen as the sludge degrades. Its other effects have not yet been investigated. It is ironic that the Federal Drug Administration (FDA) determined in October 2005 that triclocarban does not provide any more benefit than regular soap in reducing the spread of illness.

How are these thousands of chemicals affecting the health of lakes, streams and humans? Drs. Wilson and Smith, of the University of Kansas at Lawrence, and their colleagues investigated the effects of triclosan, a chemical used in acne soaps, and the antibiotic ciprofloxacin, used to treat urinary tract infections. They found that their presence in stream water eliminated one to two species of algae from the stream community (Wilson, et al, 2003). Tergitol, a component of hair dyes and spermicides, reduced the number of algal species present by 50 percent and the volume of algae by 75 percent. Dr. Stuart Levy (2001), of Tufts University in Boston, found that *E. coli* can develop resistance to triclosan. More disturbing are the increasing findings of "intersex" fish in the past few years from both the freshwaters of the eastern United States and marine waters off California. Male fish have been found with ovary, egg-laying tissue in their testes. Small-mouth bass with this abnormality have been collected throughout Maryland's Potomac River. In November 2005, affected sole and turbot were collected off southern California. Scientists hypothesize that the likely causes are contraceptives, as well as endocrine disruptors, estrogen-like chemicals released from plastics and other consumer products that are common in sewage wastewater as well as pulp mill effluents (Solomon, 1998).

Role of lake associations

Education is an important component of the solution to the problems of chemical pollution in lakes and streams. Lake association projects could include distribution of booklets on proper disposal methods and cooperating with community hazardous waste cleanup days. Homeowners should be discouraged from pouring unused chemicals down the drain or into the backyard. They should be encouraged to deal responsibly with household chemical wastes by doing the following:

- Not disposing of paints, automobile fluids and similar chemicals by pouring them down the drain, and by filtering turpentine and brush cleaners for reuse;
- Taking used motor oil and antifreeze to a gas station for recycling;
- Finishing all medications or disposing of them properly; some pharmacies have periodic programs where they will accept leftover medicines for proper disposal;
- Supporting use of organic meats that were not grown with food supplements;
- Reading labels when purchasing chemicals to become familiar with potential hazards;
- Using alternative, less harmful products and biodegradable products whenever possible and never buying more than necessary; and
- Discarding unused products and empty containers safely into the trash to be buried in sanitary landfills but never near a lake or poured into a backyard.

Natural-areas management

Management of the natural areas of forests and streams is everybody's job, not just the job of professional park rangers. Nearly 70 percent of the New York State landscape is currently forested, and the majority of these forests are owned by non-industrial, private landowners. Informed management of these landscapes will have direct benefits to the lakes located downslope and downstream.

Forestry Best Management Practices

Nonpoint source pollution from silviculture activities is a minor contributor to overall sources of pollution, but it can cause severe local damage to streams and lakes. Most degradation is associated with erosion and sedimentation due to:

- clearcut or excessive harvesting;
- the design, location, construction, use, maintenance and abandonment of logging roads, skid trails, log landings; and
- direct disturbance of streams.

Thermal effects on water due to the removal of streambank vegetation may also affect the quality of the fishery.

The Cooperative Forest Management Program and the state Cooperative Forestry Program are administered by DEC and relate to the proper management and harvesting of forest resources in New York State. These programs provide technical advice and assistance to forest landowners and primary wood-using industries. County Soil and Water Conservation Districts (SWCDs) also prepare management plans for agricultural woodlots in cooperation with DEC. The Timber Harvest Guidelines provide the basis for management practices to prevent water-quality impacts from harvesting operations. These guidelines are administered through DEC programs and contracts between the county SWCD and rural landowners and loggers. Some silviculture BMPs includes the following:

- Road and skid trail management involves the appropriate design, location and use of roads and skid trails. These roads and trails should be located away from poorly drained areas and restricted primarily to shallow slopes, except during dry summer logging. They should be at least 150 feet from streams, ponds and marshes. This BMP benefits from water diversion and reseeding of vegetative ground cover after logging.
- Diversion of water, through the use of water bars located at regular intervals along dirt roads, helps prevent gullying and reduces erosion along logging roads. Water bars are small berms constructed of soil that are perpendicular to the road surface to capture water and divert it downhill. Tractors and other logging equipment should not be driven through streams. Instead, bridges should be erected over streams and culverts used to divert the flow. The culvert diameter should be at least 15 inches for maximum possible flow, and should be properly designed to facilitate upstream migration of fish.
- Ground cover maintenance for silviculture activities is similar to vegetative-cover measures used at construction sites. Maintenance of a vegetative cover will help reduce sediment and nutrient runoff from the activity site. Leaving treetops, branches and other logging residue scattered on the ground also reduces erosion. Such coarse debris has been shown to provide refuge and habitat for wildlife and reduce deer herbivory of young tree seedlings. Special precautions should be taken to maintain vegetative cover within 50 feet of any streambanks adjacent to the forestry site.

Streamside erosion control

Streambank erosion is estimated to account for more than 20 percent of the annual soil loss in New York State, nearly 75 tons of soil for each mile of streambank in the state (USDA Soil Conservation Service, 1975). These sediments pose a serious threat to water quality and fish habitat in streams and lakes. The problem of streambank erosion has increased as changes in land use have resulted in greater runoff volumes and peak rates of discharge. Some of these changes include forests cleared for agricultural land and later converted to urban development. Each change has resulted in higher rates of surface-water runoff that causes erosion and widening of streams. Removal of riparian (streambank) vegetation for farming and unlimited access of livestock to streams exacerbates the problem of streambank erosion.

Buffer strips or greenbelts

Buffer strips can be grasses, shrubs or trees planted or allowed to grow at the water's edge to protect streams from land-use activities adjacent to streams or lakes. Depending on the slope, soil and adjacent land uses, the buffer strip can range from 25 to 450-feet wide. Its functions include:

- stabilizing a streambank to minimize erosion;
- filtering out sediment and other substances (nutrients, pesticides, heavy metals);
- maintaining stream integrity by retaining a natural vegetative corridor;
- enhancing recreational stream use;
- preserving trees and shrubs that shade the stream; and
- keeping water cooler (and better) for fish and restoring degraded fish and wildlife habitat.

The U.S. Department of Agriculture (USDA) currently recommends a 100-foot vegetated buffer consisting of three zones to maximize the streamside's functions for flood reduction (Zone 1), nutrient uptake (Zone 2), and filtering of overland runoff (Zone 3).

Streambank and roadbank stabilization and management

This BMP includes the use of hardening or armoring banks and adding vegetative stabilization to reduce erosion along streambanks and roadbanks susceptible to stormwater runoff. Hardening is now being discouraged with the growing recognition of the multiple benefits of vegetated buffer strips. Hardening may be necessary, however, where residences, roads or other existing structures are threatened by eroding streambanks. Several methods are used to harden stream banks.

- **Rip-rap** is rock and stone rubble used as a blanket or liner to prevent erosion in highly susceptible areas. This practice is used to stabilize sites that are subjected to large volumes of water and cannot be stabilized with less expensive vegetative measures. Rip-rap usually is installed with heavy equipment because the stones must be large enough to resist displacement by high water or strong currents.
- **Log cribbing** is effective in reducing streambank erosion, and spaces between the logs can provide an excellent fish habitat. Once the crib has been constructed, usually along the outside bend of a stream, it is filled with rocks to hold it in place. Construction and maintenance costs of log cribbing are expensive.
- Non-vegetative and **vegetative stabilization** reduces soil and streambank erosion by stabilizing exposed soils and slopes with materials such as straw, hay or commercially processed materials. This cover can be temporary, prior to reseeding, or permanent. Vegetative stabilization also can include cover crops or even reforestation. Forested lands normally retain more precipitation than agricultural and urban lands. Reforestation, therefore, reduces both the volume of runoff and peak discharge. Streamflow is reduced, resulting in less flow pressure on embankments, which minimizes channel erosion.

Summing it up

A lake, including both its physical and biological health, is intimately connected with the surrounding landscape. A sustainable, long-term protection program for a lake will be successful only if watershed management is a significant part of the plan. This chapter provided an overview of the process of watershed management, and a framework of diverse strategies available to address both nonpoint and point source pollution. The next chapter provides an in-depth discussion of the legal framework available to implement a regulatory system for lake protection and management.

10 Legal Framework: It Helps to Know the Rules

Introduction

Previous chapters in this book have already taught much about lakes and their associated watersheds, including the multitude of lake uses and of users who often have conflicting interests. Those interests affect lake water quality, water levels, navigation, fisheries, wildlife and the appearance and ambient character of the lake. No lake or pond is "typical." Each has a unique mix of uses, users and environmental characteristics. When problems arise, as they inevitably will, demands for action follow.

This chapter covers the laws at the federal, state and local level that provide authority for regulatory action. It introduces the agencies that may assist in carrying out these laws. Most lake-management decisions are voluntary and do not rely on a regulatory framework. In fact, the impetus for lake management often begins with a citizen's group, and this chapter concludes with a review of organized citizen approaches to accessing governmental programs. The role of lake associations is emphasized, and various ways they may be constituted is discussed.

No one governmental entity, federal, state or local, has absolute power over lake management. This has both benefits and drawbacks. On the plus side, every person, organization and constituency has some say over decisions that affect the lake and its watershed. The structure is disseminated and hence "democratic." On the other hand, it seems that decisions could be made more efficiently if each lake and its watershed were managed by a single agency. Only one lake in New York State has such an agency. The Lake George Park Commission carries out, in cooperation with others, the laws and regulations of the state, Adirondack Park Agency (APA) and local government.

Governmental agencies seem to be quite capable of making decisions on issues when there is little disagreement between the major constituencies. If land developers, anglers, hotel owners, lakeside property owners, and farmers in the watershed, academics and elected officials are all either neutral or on the same side of an issue, the only problem will be how to finance it. When constituencies disagree, however, the governmental decision-making process often breaks down. These disagreements can sometimes be mediated by bringing in "experts" to explain the "facts." If the experts disagree, then look out! The likely outcome will be procrastination or no decision at all. Such non-decisions have the same effect as denying a proposal or project.

Government roles and responsibilities

Federal government

The federal government's executive branch has many departments and agencies that are involved in natural-resource management and regulation. The cabinet level environmental agency is the U.S. Department of the Interior (DOI). It has responsibility for managing the national parks and regulating hunting and recreational fishing, and also contains the Bureau of Indian Affairs (BIA). The U.S. Geological Survey (USGS) is part of the Interior Department. When the USGS is hired to do a water-project study, they may also collect water-quality data. Key types of information available from the USGS include stream-flow data, topographic maps and groundwater data. Their information may also include specific types of water-quality data deemed to be of national concern.

The U.S. Environmental Protection Agency (EPA) is an independent agency responsible for enforcing national environmental laws such as the *Clean Water Act* and *Clean Air Act*. The EPA has jurisdiction over water and air pollution, pesticide usage, solid and hazardous-waste management and related areas. The federal government has delegated many EPA activities to the states, and New York State is among the states that have accepted these responsibilities. The delegation of these responsibilities is sometimes accompanied by federal dollars, which allows for many of the staff in state agencies to be paid through federal grants. The EPA is responsible only for establishing the general direction of the state environmental regulatory program. The New York State Department of Environmental Conservation (DEC) manages day-to-day activities.

The U.S. Department of Agriculture (USDA) directs some additional environmental programs. The U.S. Forest Service manages national forests, the Natural Resources Conservation Service (NRCS) and the Farm Service Agency. These agencies work with farmers to improve the efficiency of agricultural operations and to protect the long-term condition of soil and water resources. Updating county soil maps is the responsibility of NRCS.

There are still other federal agencies involved in natural resource issues. The Army Corps of Engineers is responsible for maintaining navigation in inland and coastal waters and protecting wetlands from development. The National Weather Service, part of the U.S. Department of Commerce, provides weather forecasts and historical climate data. The Federal Energy Regulatory Commission regulates hydroelectric projects.

Congress, the federal legislative branch, passes new federal laws and amends existing laws. The judiciary branch, the federal courts, interprets these laws and how they are applied by federal departments and agencies.

In recent years, the U.S. Department of Homeland Security has played an increasing role in "peripheral" lake-management issues, from protection of raw water supplies to the administration of the Federal Emergency Management Agency (FEMA), which oversees the response to catastrophic environmental events, including dam breaches. As with other federal programs, at least some of these responsibilities have been delegated to the states.

The Public Health Security and Bioterrorism Preparedness and Response Act (better known as the *Bioterrorism Act*) was signed into law in 2002. It includes specific requirements for community drinking-water systems serving more than 3,300 people. These water systems are required to prepare and submit vulnerability assessments. Most of the nation's water systems have met the security requirements of the Bioterrorism Act. Security requirements for smaller systems, serving less than 3,300 people, are voluntary. By the summer of 2005, there were no similar requirements for wastewater utilities.

Federal government and Indian tribes

Federally recognized tribes have sovereign status supported by special legal provisions and federal agency responsibility. The Bureau of Indian Affairs within the Department of the Interior administers and manages land held in trust for American Indians by the United States (see Appendix F "Internet resources").

If watershed planning might affect tribal members or their lands or waters, the federal Bureau of Indian Affairs, a special EPA office and the tribal nonpoint source program should be contacted, as well as officials within affected tribal nations (see Appendix F "Internet resources").

According to the EPA, a partial list of Federally Recognized tribes in New York State includes: Cayuga Nation; Oneida Nation; Onondaga Nation; Saint Regis Mohawk Tribe (formerly the St. Regis Band of the Mohawk Indians); Seneca Nation; Tonawanda Band of Seneca Indians; and the Tuscarora Nation.

EPA has an American Indian Environmental Office (AIEO) that strives to strengthen environmental protection in Indian Country, especially through building the capabilities of tribes to manage their own environmental programs. The AIEO provides contact information for federally recognized tribal governments, maintains a list of tribes that have developed water-quality standards, and provides lists of resources. EPA's Tribal Nonpoint Source Program provides information on training workshops, grant funding for tribes and the Tribal Nonpoint Source Planning Handbook (EPA, 2008).

New York State government

It is not the purpose of this manual to describe the workings of government in New York State in great detail. An excellent book is available on this subject, the *Local Government Handbook*, available from the office of the New York State Secretary of State. The handbook describes the intricate and often puzzling relationships among federal, state and local government entities.

State government is divided into three branches similar to the federal government. The governor heads the executive branch. In this capacity, he appoints the heads of the state agencies that are answerable to the executive branch. The legislative branch passes new laws and amends existing ones. The judicial branch is the court system, with the court of appeals as the supreme body. It is the role of the courts to interpret whether the laws of the state, as passed by the legislature and enforced by the state agencies, are being carried out properly.

The environmental management structure in New York State differs from the federal model. Many of the activities of the U.S. Department of the Interior and the EPA are consolidated into one state agency, the New York State Department of Environmental Conservation (DEC). There are some exceptions. The Department of Health (DOH) has jurisdiction over public water supplies and on-site wastewater systems although DEC also has limited authority in these areas. A summary of key state laws that apply to lake management is presented later in this chapter.

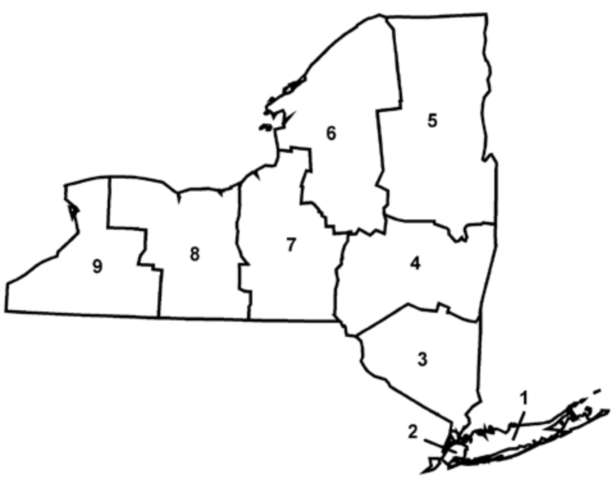


Fig. 10–1. Map of DEC regions. The regional office where a lake is located is the best place to start when there are questions about permits, regulations and natural-resource management. (Credit: DEC)

DEC functions as both an environmental regulatory agency and a natural-resource management agency. It has divided the state into nine regions along county boundaries. Day-to-day activities are directed from regional offices, while the long-term management framework is developed by staff in the Central Office in Albany. DEC is organized along broad program lines such as Air Resources, Fish and Wildlife Management, Water, and Lands and Forests.

The executive department's Office of Parks, Recreation and Historic Preservation (OPRHP) manages state parks outside the Adirondack and Catskill regions. OPRHP also has responsibility for enforcing the navigation laws. Another unit of the executive department, the Adirondack Park Agency (APA), regulates the park land-use policy and administers regulations and policies associated with the management of lakes within the park. DEC manages the public lands within the Adirondack and Catskill parks, including campgrounds at lakes.

Interstate River Basin Commissions

New York State is a member of five Interstate River Basin Commissions. Lake associations located in these river basins may wish to consult the databases and activities of the Commission that includes their lake, especially where the lake drains into a tributary of the river system. (See Appendix E, "Interstate River Basin Commissions")

Local government

New York State laws authorize the formation and operation of local counties, towns, villages and cities. Different units of government have jurisdiction over specific activities. Although local governments have substantial involvement in natural-resource management, their efforts are not as comprehensive as the role of the state agencies.

Localities provide water supply and sewage treatment services, often through special revenue districts. Solid-waste disposal, planning and regulation of land uses by private owners are also the responsibility of local governments, although there are some exceptions. The state is authorized, for example, to regulate private land use in the Adirondack Park, a power bestowed in Article 8 of *New York State Executive Law*. The state also maintains ownership of the beds of most navigable waters in the state (see Appendix C, "Who owns New York State lakes?").

Local government may organize groups of citizens and agency staff to serve in an advisory role on environmental matters. Discussed below are several groups that are logical partners for lake associations because they provide a significant link between local, county and state governments.

County Water Quality Coordinating Committees (WQCC) have been formed in each of the 62 New York State counties to coordinate water-quality management activities among the various county agencies. A staff person from the County Soil and Water Conservation District (SWCD) or planning department may provide leadership for the WQCC. Other local entities that may be involved include the county health department, cooperative extension, the Environmental Management Council, local citizen groups and regional DEC staff. These committees may select a unique name. Two examples from the Finger Lakes region are the Cayuga County Water Quality Management Agency and the Tompkins County Water Resource Council.

Environmental management councils (EMCs) can be established by the county governing body. About half of New York counties have an EMC that serves as an advisory agency and as a county-wide forum for environmental concerns. EMCs often work closely with planning and other agencies and have the authority to advise the county on all matters affecting the preservation, conservation and ecologically suitable use of natural resources of the county. They may engage in advocacy, education and planning activities such as the preparation of a wetland and open-space inventory. They may also prepare annual reports on the state of the environment in the county.

Towns, villages and cities may create *Conservation Advisory Councils* (CACs) and *Conservation Advisory Boards* (CABs) to assist in the protection of the environment and to provide environmentally sound management for the natural resources of a municipality.

CACs are usually created by local law or by resolution of the local governing body. In this context, they have resource-planning and project-review functions. They coordinate with organizations of a similar purpose and with other official municipal bodies active in community planning for that municipality. These bodies also have an educational role within the local community by providing a forum for citizens to address environmental issues. CACs are natural partners for lake associations.

A CAC may be designated to become a CAB by the local legislative body. The principle difference is that a CAB is authorized to review applications that seek approval for the use and development of any open area listed in the open-space index prepared by the CAC. This includes recommendations on appropriate action on each application. The CAB can also function as a CAC if authorized to do so by the local legislative body.

The activities of CACs and CABs also typically include conducting research into critical land areas of the municipality and production of a report and map of local land uses. A representative from each CAC or CAB is entitled to be a member of the county's EMC if one exists.

Statutory authority: *NYS Environmental Conservation Law (ECL), Article 49, Title 3.*
NYS General Municipal Law, Section 247.
Responsible agencies: NYS Agencies; Local Governments; Not-for-Profit Organizations.

Role of private organizations

There are many established organizations with an interest in natural-resources management. See Appendix F, "Internet resources" for contact information. These organizations represent many public interest sectors and are often collectively referred to as "environmental" groups. They include national groups such as the Sierra Club, the Audubon Society, the Natural Resources Defense Council and The Nature Conservancy. Professional societies, such as the Ecological Society of America (ESA) and the North American Lake Management Society (NALMS), are involved in lake-management issues that affect the entire country. They may be able provide expert witnesses to testify in judicial proceedings on local issues with national ramifications.

Many national organizations have chapters, affiliates or equivalent organizations at the state level. The New York State Federation of Lake Associations (NYSFOLA) is the umbrella organization for lake associations in New York State. It is also a chapter of NALMS. NYSFOLA has three major programs, the Citizens Statewide Lake Assessment Program (CSLAP), the Volunteer Pollution Control Program and an annual conference. NYSFOLA also provides technical and educational assistance, publishes the quarterly newsletter *Waterworks*, and maintains a website (see Appendix F "Internet resources"). NYSFOLA also networks with others, provides notice of grant opportunities for lake-management projects and is involved in statewide water-resources policy issues.

There are number of groups that focus on statewide issues, providing information or hosting regional gatherings, but they are rarely drawn into local conflicts. The New York State Conservation Council, for example, represents the interests of sporting groups, such as ducks and fisheries. The New York Rural Water Association (NYRWA) assists in the formation and operation of water and wastewater systems. There are also statewide groups that represent professionals such as civil engineers, geologists, planners and attorneys.

Role of lake associations

Lake associations are the only organizations that routinely become involved with local lake-management issues. The association may have originally been a social club or a fish-and-game group, but, over the years, many have evolved into a more scientifically based environmental group. Most work on small projects, become a partner in a project funded by larger agencies or organizations and help with education and outreach. This limited role in implementation has often led to lake associations finding a niche as an environmental watchdog, calling the attention of local authorities to lake- and watershed-management issues and needs.

At minimum, a lake association should:

- Hold regular meetings and circulate a newsletter to its members.
- Collect available information on the lake and its watershed.
- Educate its members in the areas of lake ecology, restoration and management.
- Conduct educational efforts for the public on lake management or specific issues concerning the lake.
- Develop a working relationship with each local government around the lake, with state agencies, such as DEC, and with state legislators and environmental groups.
- Become an active member in NYSFOLA, attend the NYSFOLA Annual Conference and seek participation in the CSLAP program.
- Maintain a website with links to other appropriate sites.

There are between 150 and 250 lake associations in New York State, depending on the definition of "association." Some are quite active, whereas others have long been dormant and exist only in name. A large or multi-county lake may be represented by more than one association. Most associations have fairly stable membership levels, while others become temporarily larger due to controversy surrounding water-quality issues or major development projects

Water law

Water laws that define the rights of landowners bordering lakes and streams are known as riparian rights. If traced back to their origins, one eventually finds what is known as common law. Common law is derived from a system of unwritten law that was developed in England. Court judges based their decisions on these unwritten customs or the application of reason in the absence of precedents that applied to the circumstances of each case. This system of common laws was adopted from English law by the United States courts and state legislatures at the time of the American Revolution.

Common law is derived from unwritten customs. It differs from statute law, which is an act of a legislative body. Administrative rules and regulations, derived from specific statute laws, are created by appropriate governmental agencies assigned the responsibility of carrying out statute laws. It is helpful to keep in mind that state and federal laws governing the use of lakes and streams, including prohibitions against contamination and destruction of habitat, set limits on a landowner's riparian rights, rather than supplanting them. An example is the federal *Clean Water Act*, which establishes maximum allowable discharges of pollutants into lakes, streams and groundwater.

Riparian water rights apply only to surface waters in lakes and streams. When common-law riparian rights originated, the courts did not have access to factual knowledge about underground waters. Surface waters could be seen. Underground water was called "percolating" water and could not be seen. Consequently, landowners were given almost unlimited rights to pump groundwater from wells on their lands, even when the pumping was so extensive that the water level in adjacent wells, lakes or streams was lowered. The connection between surface and groundwater as comprising one integrated hydrologic system was not well understood. Thus, there exist two bodies of common law, and statute laws have followed suit. One body of laws is for surface or riparian water, and one is for percolating or groundwater.

Application of riparian water rights to wetlands is an open question and remains to be tested in the courts. Current federal and New York State statutory laws take precedence and severely limit what landowners can do with their wetlands. Presumably, wetlands that contain open areas of water throughout the year would also be identified as riparian surface waters under common-law concepts. Federal and New York State wetland laws contain somewhat different definitions of what constitutes a wetland, based on the soils and vegetation suited to a wetland environment.

The interests of riparian landowners are not absolute. The courts have developed the doctrine of reasonable use, under which a riparian owner generally has the right to the use of a stream or lake without a substantial decrease in quality or quantity from the uses of adjacent landowners. Reasonable use is essentially the application of common sense in regard to a lake or stream that is shared in common with other landowners. If a landowner's use predominates to the disadvantage of others, then the landowner's use is usually deemed to be unreasonable. Reasonable use generally depends upon the particulars of each situation, especially the extent of injury to others. The common law doctrine of reasonable use, however, is more applicable to streams than lakes. For example, common law is difficult to apply when boat wakes interfere with the use and enjoyment of others. A statutory law is better suited to control boat wakes.

The question of "Who owns your lake?" is very complex and involves a host of old patents and acts. Much of this is encapsulated in *New York Public Lands Law (*Article 75, 9 NYCRR, Part 270). The New York State Office of General Services (OGS) in Albany maintains a list of the lakes in New York and can indicate whether the state owns a specific lake (see Appendix C, "Who Owns New York State Lakes?") They also maintain deeds and maps going back to the 1600s and will supply copies upon request. As a rule of thumb, lakes smaller than 12 acres are not necessarily owned by the state, but one needs to check with OGS to be sure. "Private ownership" of lakes applies only to the ground beneath some of the water. The people of New York State own all surface and ground water in the state and also the ground under the water of many navigable bodies of water.

A deed of land adjacent to a private lake generally conveys title to the center of the lake. There are several methods of establishing the center of the lake.

This ownership may be illusory if no efforts have been made to exclude the public through the years. If the public has had access to the lake over private property for a continuous period of at least 10 years with the knowledge of the lakefront owner, a prescriptive easement may be acquired. This is often referred to as **squatters' rights**. The courts have

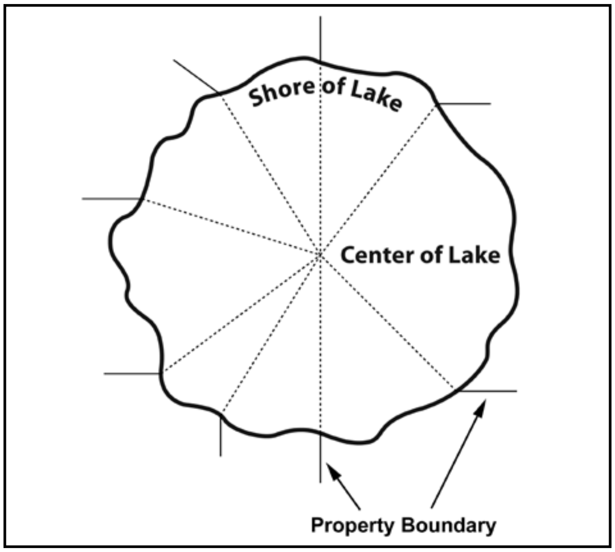


Fig. 10–2. Round lake (pie) method of measuring to the center of a lake. Property boundaries are established by the "pie method," where a point is located at the center of the lake, and property boundaries are extended to this center point, similar to slices of a pie. The method is also used at the ends of long lakes.

(CREDIT: CHRIS COOLEY)

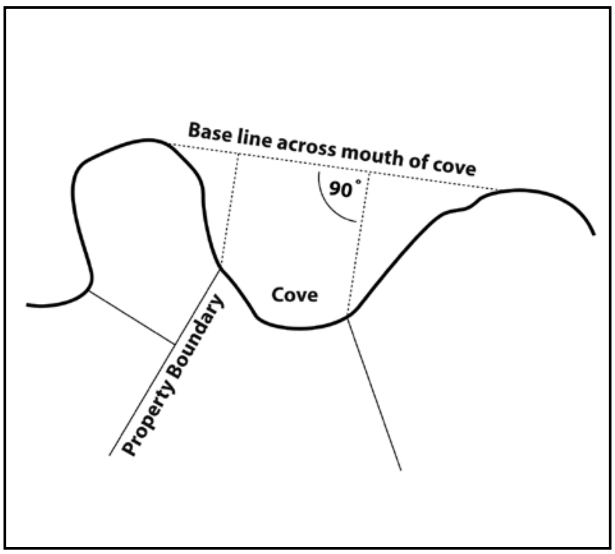


Fig. 10–3. Perpendicular method of measuring to the center of a lake. On a lake with **headlands** *and penetrating coves, a baseline is drawn between the headlands of the cove, and property boundaries are extended perpendicular to the shore to intersect this baseline. A headland is defined as a height of land that juts into a body of water.*

(CREDIT: CHRIS COOLEY)

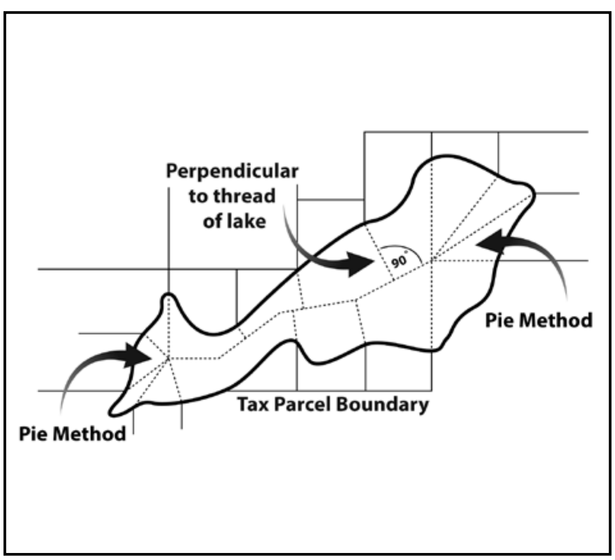


Fig. 10–4. Long lake method of measuring to the center of a lake. On a long, narrow lake, a baseline is established along the midpoints between the shores, and property boundaries are extended to intersect this midpoint baseline at right angles. The round or pie method is used at the ends of the lake.

(CREDIT: CHRIS COOLEY)

held that it was irrelevant that the use was seasonal in nature and not year-round. The courts have held that seasonal public use of Lake Nancy in Saratoga County was sufficient to give non-residents and the public a prescriptive easement for access to the lake. Historically, people who own property one row away from the lakeshore may be able to access the water via prescriptive access or deeded right of way.

Laws and regulations

There ought to be a law! To restrict an activity, there needs to be a federal, state or local law that can be enforced. An activity is not illegal just because it is annoying. This section covers specific federal, state and local laws relating to water-pollution control, wetlands regulations, environmental impact reporting requirements, protection of state waters and public water supply regulations. It also includes empowerment of towns, villages, and counties to create special districts and undertake various planning and zoning actions relative to lake watershed management. Citation for the laws is given after each discussion.

Federal and State Pollution Discharge Elimination System

The *Federal Clean Water Act* was developed primarily to control water pollution. Its principle regulatory program is the *National Pollution Discharge Elimination System* (NPDES), which is administered by EPA. Section 301 of the act prohibits the discharge of any pollutant into the waters of the United States without a permit. Wetlands are covered under Section 404 of the *Clean Water Act*, which empowers the Army Corps of Engineers to regulate discharges of dredge and fill material.

The *Clean Water Act* authorized financial incentives and punitive actions to encourage the development and improvement of pollution controls by wastewater facilities. Section 402 authorizes permits for controlling stormwater runoff from municipal storm sewer systems, from construction sites exceeding one acre in size and from industrial sites.

In New York State, the NPDES program is administered by DEC and is known as the ***State Pollution Discharge Elimination System*** **(SPDES)** pronounced "speedies." A SPDES permit must be obtained before an owner or operator of any large wastewater system can legally discharge sanitary, industrial or commercial wastewater into New York State waters. "Large" is defined as a system discharging 1,000 gallons or more per day. Non-industrial sewage and effluent discharges from private dwellings of less than 1,000 gallons per day do not require a SPDES permit.

On-site wastewater systems of single-family dwellings with an estimated flow not exceeding 500 gallons per day are regulated by the state or county health department under the *New York State Sanitary Code, New York State Public Health Law*. The sanitary code requires a qualified engineer for new wastewater systems. Inspections of new wastewater systems are to be carried out every five years. These inspections have also been removed from the jurisdiction of local code enforcement officers (See also Chapter Four, "Problem Diagnosis").

Compliance and self-monitoring reports are a major part of the SPDES program. DEC conducts surveillance, sampling and facility inspections and enforces penalties and corrective actions where necessary. DEC requires each SPDES permit holder to conduct effluent monitoring to assure that approved discharges meet the limits outlined in the permit, and penalties are imposed for noncompliance. Permits are reviewed and reissued every five years. Additional information on the SPDES process or on specific SPDES permits is available from DEC regional offices. DEC should also be contacted if a problem appears to exist with a local treatment plant discharge.

The permit also specifies the types and quantities of pollutants allowed in discharges, including schedules and conditions under which the discharges are permitted. Owners and operators of wastewater facilities must treat the wastewater to meet the limits listed in their SPDES permit. SPDES permits also require industries discharging into municipal collection systems to pre-treat their wastes if they are considered a Significant Industrial User (SIU).

Surface runoff stormwater that flows during and after land development can result in flooding and soil erosion that causes significant pollution of lakes, streams and rivers. Control of land uses and development is vested in the powers of town, village and city governments. Under Section 404 of the federal *Clean Water Act*, many urbanized areas in New York State are required to establish management programs to control stormwater discharges from separate, municipal storm-sewer systems. This requirement is administered by DEC under the state SPDES program.

This requirement is being applied in phases. The phase most relevant to lake associations is Phase II. The first aspect of Phase II applies to all of New York State. Construction activities that disturb one or more acres, or are in a *Total Maximum Daily Load* (TMDL) watershed, will usually require a permit from DEC and a plan for preventing pollution from stormwater runoff. The second aspect applies only to certain areas of the state that meet population requirements and have sanitary sewers that are separate from stormwater runoff systems. These areas are referred to as municipal separate storm sewer systems (MS4s). In the future, DEC anticipates extending statewide the requirements that are currently required only of MS4s.

In 2003, each MS4 filed a notice of intent to comply with a statewide stormwater permit. This notice detailed activities to be undertaken by 2008 that would significantly reduce the pollutants discharged into water bodies. These activities are grouped into six categories, termed "minimum control measures." They are:

- Public education and outreach on stormwater effects.
- Public participation and involvement.
- Illicit discharge detection and elimination.
- Construction-site stormwater runoff control.
- Post-construction stormwater management.
- Pollution prevention and good housekeeping at municipal operations.

Statutory authority: FEDERAL: *Water Pollution Control Act of 1972,* commonly known as *the Clean Water Act* under subsequent amendments, *Sections 301, 302, 306, 307, 402, 404; National Environmental Policy Act*, Section 42, U.S.C. 4321 et seq., 1969.
STATE: *Environmental Conservation Law* (ECL) Articles 17, Titles 7 and 8. (6NYCRR Parts 652, 700-704, 750-757, 800-94).
Responsible agencies: EPA, DEC, City & County Heath Departments.

State Environmental Quality Review Act

The ***State Environmental Quality Review Act (SEQRA)*** was passed in 1975 and is pronounced "seeker." It requires individuals or groups to determine whether proposed projects they directly undertake, fund or approve may have a significant effect on the environment. SEQRA is most frequently applied to lakes when wetlands are involved.

Actions covered by SEQRA include SPDES discharge permits, dredging, construction activities, well drilling, benthic barriers and shoreline improvement. Applicants may be state or local agencies, local governments, districts, departments, authorities, boards, commissions, public or private corporations or individuals. The SEQR Act helps to facilitate communication between government agencies, project sponsors and the general public to ensure that decisions are made in the preliminary stages of project planning that will avoid or minimize adverse environmental effects. SEQRA requires agencies to act on the information produced in the environmental review.

If a proposed action is determined to have a significant effect on the environment, then an E*nvironmental Impact Statement* (EIS) must be prepared. An EIS is a report containing a description of a proposed action, the environmental setting, potential environmental impacts, ways to minimize the effects, and reasonable alternatives. The EIS also serves as a public disclosure of the record used by an agency in its environmental decision-making process. The SEQR objectives are accomplished through the general review guidelines of DEC. The guidelines are also used as a mechanism for coordinating interagency environmental review of a proposed project.

Two types of action are defined in SEQRA. A Type I action is likely to have a significant effect on the environment, and preparation of an EIS will probably be required. A Type II action is not expected to have a significant effect on the environment, and an EIS will not be required.

A Type I action requires a fully coordinated review, a lead agency and preparation of an *Environmental Assessment Form* (EAF). The EAF is used by the agency to help determine the environmental significance or non-significance of an action. The EAF should contain information to describe the proposed action, its location and purpose, and the potential effects of the action on the environment.

A C*ritical Environmental Area* (CEA) refers to a specific, designated geographic area that has exceptional or unique characteristics that make the area important to the local community. Actions undertaken in a critical environmental area must be treated as a Type I action under SEQRA. There are at least 25 lakes in New York State within CEAs. They range from small ponds such as Magid Pond in Westchester County to large lakes such as Lake George. While DEC is the main agency that designates an area as a CEA, local agencies may make recommendations. A listing of critical environmental areas can be found on the DEC website (see Appendix F, "Internet resources").

Because many different agencies or groups may be involved with a given project, SEQRA requires that a local agency be designated as having primary responsibility for coordinating the environmental review of the proposed action. The lead agency is required by law to determine whether a project will have a significant effect on the environment. If it is determined that the proposed action will not have an adverse effect, then a negative declaration is recorded by the lead agency.

If it is determined that the action may have a significant effect on the environment, a draft environmental impact statement (DEIS) must be prepared. The DEIS is intended to be a source of environmental information used by other involved agencies during the period of preliminary project planning. The DEIS is circulated for public review and comment, and a hearing is held if the lead agency considers it to be necessary.

After the DEIS and possible public hearing are completed, the lead agency must determine whether a final environmental impact statement (EIS) is required. The final EIS should reflect revisions and updating of the information contained in the DEIS with consideration given to agency reviews, comments received and the record of the public hearing if one is held. There are several opportunities for other agencies and the public to provide input throughout the EIS process. Public participation is also necessary to determine whether the project is consistent with community values.

Information sources concerning the status of a proposed project under SEQR are the local newspaper and the *Environmental Notice Bulletin*, available free from the DEC website or by paid subscription for a paper version (See also Chapter Six: "Aquatic Plants"). Additional information concerning specific aspects of SEQR may be found in the *SEQR Cookbook*, a DEC reference manual that provides a step-by-step discussion of the basic SEQR process and is available on the DEC website (see Appendix F, "Internet resources").

Statutory Authority: *Environmental Conservation Law (ECL), Article 8.*
NY Code of Rules & Regulations: 6 NYCRR Part 617.
Responsible agency: DEC.

Wetlands

Freshwater wetlands are recognized for their invaluable benefits for flood control, fish and wildlife habitat, water-pollution treatment, erosion control and esthetic resources. They can serve as sinks (traps) for removal of nutrients in runoff from the surrounding watershed. Wetlands stabilize lake levels by their highly retentive capacity and provide extensive recreational and educational opportunities to the public.

Federal laws and regulations

From the 1800s through the 1960s, wetlands in the United States were regarded as wastelands or a public nuisance. Congress made draining and filling wetlands national policy under the *Swamp Lands Acts* of 1849, 1850 and 1860 in 15 western states. In 1967, the first national regulations to protect wetlands were issued using provisions in the 1899 *Rivers and Harbors Act.*

This act applied only to wetlands below the mean high-water mark on navigable waterways.

Under the *Rivers and Harbors Act*, the U.S. Army Corps of Engineers has jurisdiction over navigable waters. It has jurisdiction over wetlands on inland tributaries under "waters of the United States" as defined in the *Clean Water Act*. This has been interpreted to mean all freshwater wetlands of one acre or more in size. The corps has jurisdiction over wetlands permits as an extension of its role over wetlands associated with navigable waters. Although the corps is the lead agency, wetlands permits are also subject to approval by EPA and review by the Fish and Wildlife Service.

As the result of a Supreme Court case in 1980, the EPA issued final guidelines for evaluating Section 404 permits under the *Clean Water Act*. In 1986, the corps issued a comprehensive set of regulations for issuing permits affecting wetlands (51 Federal Register 41, 206). In 1990, the EPA and the corps completed a Memorandum of Agreement about compensation through mitigation for unavoidable impacts on wetlands.

The federal authority to protect "isolated" wetlands that are not directly connected by surface-water flow to a river, stream or lake remains under contention. The only definitive way to determine whether an area is subject to Corps of Engineers permit jurisdiction is to seek a determination from the appropriate district office. The districts correspond to major stream watersheds. The five Corps of Engineers district offices relevant to watersheds that have part of their drainage in New York State are located in Buffalo, New York City, Pittsburgh, Philadelphia and Baltimore.

Statutory authority: *Clean Water Act, 1972, Section 404, U.S.C. 1344.*
Rivers & Harbors Act, 1899, Section 10, U.S.C. 403.
Responsible agency: U.S. Army Corps of Engineers.

New York State Freshwater Wetlands Act

New York State passed the *Freshwater Wetlands Act* in 1975 to regulate the use and development of the state's freshwater wetland resources and to preserve, protect and conserve wetlands and the benefits derived from them.

The *Freshwater Wetlands Act* provides for the regulation of all freshwater wetlands in the state over 12.4 acres (5 hectares) in size. Maps are available from DEC and local government jurisdictions showing the locations of regulated wetlands in New York State. The act also provides for the regulation of smaller wetland areas if they have been determined by DEC to be of unusual ecological importance and regulates activities in adjacent areas within 100 feet of the vegetative boundary of the wetland.

The DEC Division of Fish and Wildlife plays a leading role in the inventory, mapping and classification of the state's wetland resources. Permits are required, according to best-use classifications, which are designed to regulate draining, dredging, filling or polluting designated wetland areas. Other lake-management activities may require wetland, SEQR or SPDES permits, including many aquatic plant-management actions, benthic barriers and shoreline improvements.

Responsibility for the regulation of wetlands within the Adirondack Park is given to the APA under the *Freshwater Wetlands Act*. Authority is also delegated to local governments for administering certain parts of the permitting program. The APA regulates freshwater wetlands of one acre or more in size, whereas wetlands outside the park are regulated if they are 12.4 acres or larger. Smaller-size wetlands, both within and outside of the park, can be regulated if they have unique characteristics. Under APA regulations, many underwater plant communities are designated as deepwater wetlands even if these came into existence only by invasion of exotic aquatic plants. As in the rest of the state, most normal agricultural activities are exempt from the regulatory requirements.

In addition to administering regulations under the *Freshwater Wetlands Act*, DEC uses a variety of methods to preserve and protect the state's wetlands. These include purchases of significant or vulnerable wetlands, cooperative easements and agreements with landowners and restoration or enhancement of municipally owned wetlands that have already been degraded.

Statutory authority: *Environmental Conservation Law* (ECL) Article 24, Article 7.

NY Code of Rules & Regulations (6 NYCRR Parts 662, 663, 66).
Responsible agency: DEC.

Protection of Waters Program

The New York State Protection of Waters Program is administered by DEC under the *Stream Protection Act* (Title 5, Article 15, ECL). It is designed to prevent undesirable activities on waterbodies by establishing and enforcing regulations that:

- Are compatible with the preservation, protection, land enhancement of the present and potential values of water resources for protecting the health and propagation of fish, wildlife, and waterfowl inhabiting streams;
- Will protect the public health; and
- Will be consistent with reasonable economic and social development of New York State.

Under this Program, all waters in the State, including lakes and their tributary streams, are assigned a class designation based on existing or expected best use. (Also see Appendix B,"New York State Water Quality Classifications")

- Class AA or A is for waters used as a source of drinking water.
- Class B indicates a best usage for swimming and other contact recreation, but not for drinking water.
- Class C is for waters supporting fisheries and is suitable for non-contact activities.
- Class D is for waters meeting none of the above criteria.

Classes A, B and C may have a further "T" added, indicating it may support a trout population, or a "TS" indicating it may support trout spawning. Small ponds or lakes with surface area of 10 acres or less, located within the course of a stream, are usually considered to be part of the stream for classification purposes.

Activities requiring permits under the Protection of Waters Program include:

- Disturbance of the bed or banks of protected streams and other watercourses;
- Construction, reconstruction or repair of dams and other impoundment structures;
- Construction, reconstruction or expansion of docking and mooring facilities;
- Excavation or placement of fill in navigable waters and their adjacent and contiguous wetlands; and
- Water-quality certifications for projects that require a federal permit.

As this book is going to publication, the DEC Dam Safety Office is proposing new rules to amend Dam Safety Regulations. The new rules would apply to dams 15 feet or more in height or with a maximum impoundment capacity of three million gallons or more. Dams are classified as A, B or C depending on how much damage would be caused if they failed. The proposed amendments require more dam inspections, better record keeping, planning for emergencies and heavy financial assurance requirements. See the DEC website for updated information.

Public water supply regulations

State laws require a permitting system to assure the sufficiency and quality of water supplies and to ensure that the withdrawal and use of water does not adversely affect existing supplies and uses, human health or the environment. Responsibility for protecting public water-supply sources is shared by DEC and DOH.

DEC has authority for ensuring that a public water supply is not contaminated, that there is a sufficient quantity for public use, that conservation measures will be used and that environmental effects from withdrawals will not endanger other water supplies or has other undesirable effects. A permit application to DEC is automatically given to DOH, which has regulatory authority for ensuring that the water supply meets sanitary requirements for human consumption under the New York State Sanitary Code.

The DOH is also responsible for the New York State Source Water Assessment Program. This program was mandated by the 1974 federal *Safe Drinking Water Act*, as amended in 1986 and 1996, to provide national standards for drinking water. Drinking-water sources include lakes and reservoirs used for this purpose. The New York State program is not a water-source protection program but is a DEC program to compile and organize information on existing water-protection programs. No new mandates or regulations were imposed by the state program. The DOH Water Assessment Program is also intended to provide guidance in administering existing regulatory programs.

Questions that DEC will consider in processing an application for a new community water-supply source, whether surface or groundwater or for expanding an existing source include:

- Is the proposed project justified by public necessity?
- Have other water-supply sources been adequately considered?
- Will the water supply be adequate to meet the demands of the proposed or existing service area?
- Will there be proper protection of the water supply and watershed?
- Is the proposed project just and equitable for all affected municipalities with regard to present and future needs?
- Has the applicant included a water-conservation plan in accordance with local water resource needs and conditions?

Who owns your dam?

Is your lake created or controlled by a dam? Do you or the members of the lake association own, maintain or use that dam? Do you use or own property on that lake? Does your association have a good liability policy in place? If a municipality owns the dam, does the association have good relationships with them?

As this book goes to publication, the Dam Safety Office of the new York State Department of Environmental Conservation (DEC) is in the process of revising existing regulations "*..to ensure that dam owners provide proper operation, maintenance, inspection, repair and emergency planning...*" The proposed revisions might include stringent requirements based on the size of the lake behind the dam and, in some situations, heavy financial assurance requirements.

The proposed regulations are available from the DEC website (see Appendix F, "Internet resources") or go to www.ny.gov, search for "dam safety" and look for "Part 673—Dam Safety Regulations." Appendix F also includes an internet address where updates are posted.

Dam owners, lake property owners and lake associations are strongly encouraged to remain aware of this issue.

The DOH administers the Watershed Protection Rules and Regulations Program, under which a public water supplier develops rules and regulations to protect the entire watershed upstream from the intake point from unwanted contamination sources. These rules and regulations have been adopted by about 200 water-supply systems in New York State. It is always wise to check whether a specific lake is in one of these protected watersheds and what rules may apply. Many of these watershed regulations are over 40 years old, do not address many of today's contamination threats and are not vigorously enforced, relying instead on a treatment facility at the intake site.

Statutory authority: *Environmental Conservation Law (ECL), Article 15, Title 15.*
NYS Public Health Law, Article 11, Title I.
Responsible agencies: DEC; NYS DOH and county health departments.

Dock and mooring regulations

New York State *Navigation Law* and the *Public Lands Law* require permits for residential or commercial docks and moorings from the Office of General

Services (OGS) for public lakes resting on underwater land owned by the State of New York. In addition, these laws require permits from DEC and, in some cases, the U.S. Army Corps of Engineers and the town or village of residence. The *Public Lands Law* spells out exemptions for some residential docks.

The *Parks and Recreation Law* (Section 13.13) defines the authority to regulate the mooring of boats in waters in parks or reservations within the jurisdiction of the Office of Parks, Recreation and Historic Preservation (OPRHP) or any other state agency. The *Public Lands Law* includes regulations on the size, shape and number of docks. In general, docks may extend no farther than 40 feet offshore and may not exceed a surface area of 700 square feet (sq. ft.).

Statutory authority: *Navigation Law, Public Lands Law, Parks and Recreation Law (Section 13.13)*
Responsible agencies: Office of General Services (public lakes), DEC.

Boating regulations

New York State *Navigation Law* applies to all of the navigable fresh waters of the state and to their tributaries and outlets, even if they are not themselves navigable. The navigation laws are quite detailed and should be checked if there is a question about a specific body of water. Parts of the navigation law are administered by DEC, and parts are administered by the New York State Office of Parks, Recreation and Historic Preservation (OPRHP).

The law deals with the regulation of excessive boating speeds but has specific speed limits for only a few lakes in the state. On Canandaigua or Keuka lakes, for example, boats cannot exceed 45 mph during the day or 25 mph at night. Noise from pleasure boats has also been limited on these lakes.

The law is limited in providing statewide control of boating and other recreational activities. Through local law, towns, villages and counties may have authority to impose speed limits near the shoreline, provided they maintain jurisdiction of the lake and that existing state or federal laws do not impose stricter limits. The number of boats on a lake can be addressed through restrictions of docks, moorings or access (See also Chapter eight: "User Conflicts").

Navigation Law also governs the discharge of wastes from pleasure boats. No discharges are allowed in some lakes, including Lake George, Lake Champlain and Greenwood Lake. Since 1988, the law has also restricted the sale or use of quick-release **tributyltin (TBT)** anti-fouling bottom paint for boats. TBT has been determined to be toxic to aquatic life at very low concentrations.

The P*arks and Recreation Law* provides for other boating restrictions related to recreational water sports, boating speed and mooring for lakes under the jurisdiction of the OPRHP or any other state agency.

Laws dealing with navigation are difficult to pass and even more difficult to enforce. Furthermore, navigation, parks and recreation laws and town, village and county laws are very confusing and difficult to understand. Lake associations interested in the regulatory approach to boating restrictions should elicit the help of a knowledgeable attorney to determine which laws apply to their lake.

Special districts

Special districts provide service to and levy a tax on property owners in a geographically defined area. In New York State, the special districts created by counties or towns and villages are different and are discussed separately.

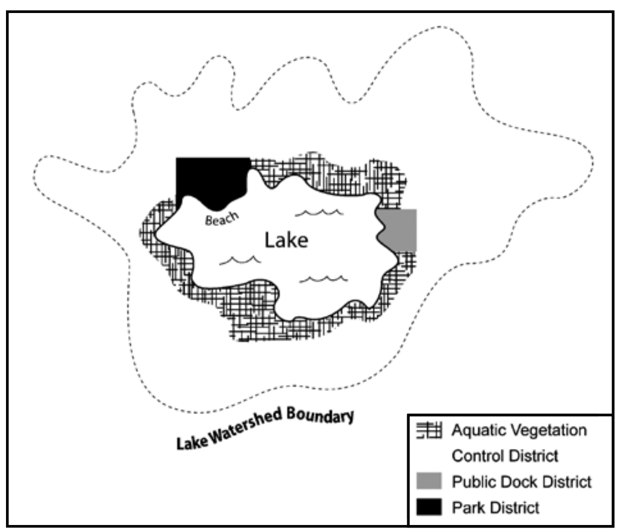


Fig. 10–5. Examples of Special Districts created to provide service to and levy tax on property owners in a geographically defined area. (CREDIT: CHRIS COOLEY)

County

Under articles 5-A, 5-B, and 5-D of county law, counties can establish special districts for water, sewer, drainage, refuse, wastewater management, lake protection and rehabilitation, hurricane protection, flood and shoreline erosion control and small-watershed protection. The responsible agencies are county or regional health departments and DEC. County districts may be created or extended by presenting a petition by the municipality that has at least 25 owners of taxable real property of record located within each proposed district to the county legislative body. The county may also present a petition on its own.

Improvement districts may be established by petition of 50 percent of the residents and owners within a proposed district or simply by a resolution of the board. The petition to set up a district requires description of the geographical boundaries of the proposed district and a statement of the manner of raising the taxes to support it. A public hearing is held, and the resolution is subject to a public referendum. If the vote on the referendum is positive, application for approval is made to the state comptroller and the New York State Department of Audit and Control.

Ad valorem taxation is collected based on assessed valuation of the properties, so more valuable lots pay higher fees. Benefit taxation establishes a fixed-amount unit fee that is then charged per parcel so everyone pays the same amount. Different rates can be set for multi-family properties and for commercial establishments. Tiered-payment taxation charges the highest rate to property owners nearer to the lake and properties with access to the beach or docks.

County small watershed protection districts (SWPDs) are created under Article 5-D of the county law and PL-566 of the federal law administered through USDA and NRCS. SWPDs are established for the purpose of constructing and maintaining projects and improvements for flood prevention and land treatment and for conservation, development, disposal and utilization of water. Where a County Soil and Water Conservation District (SWCD) exists, it serves as the designated agency. DEC, the New York State Soil and Water Conservation Committee and the U.S. Secretary of Agriculture grant assistance toward approval of the project application.

For more information, see *Legal Requirements and Administrative Procedures for Approval of County Districts*, NYS Department of Audit and Control, Division of Municipal Affairs. It includes a guide for the preparation of applications to be submitted to the state comptroller for approval of county districts. Questions relating to Special District formation should be directed to the Department of Audit and Control, Division of Legal Services, Special District Unit. See Appendix F, “Internet resources” for more information.

Town

Subject to a permissive referendum, towns can establish special improvement districts under Article 12 of town law by petition of the people or Article 12-A by motion of the town board. Town districts of interest to lake managers include sewer, water, wastewater disposal, drainage, park, water supply, aquatic plant growth control and water storage and distribution. Harbor improvement, public dock and beach erosion and control districts can be formed in towns bordering upon or containing within their boundaries any navigable waters of New York State.

A town does not need to form a district if the town board chooses to provide sewer, water, drainage or water improvements in the entire area of the town, in an area within the town or outside a village. The responsibility of the town board then involves the management, maintenance, operation and repair of any sewer, drainage or water improvements within the designated area.

If a town board chooses to form a special district, the steps are basically similar to the county process above. The town board adopts a resolution appropriating funding for an engineer to prepare a map, estimate cost and indicate compliance with SEQR procedures. A petition is circulated for signature by 50 percent of the resident owners and owners of 50 percent of the assessed valuation covered by the proposed district. The petition is presented to the board. They act on a resolution that is either approved or denied. Within 10 days of approval, filing is made seeking approval from the state comptroller and the Department of Audit and Control.

Village

A village does not need to form a district in order to provide sewer or water services. The village should have a public hearing, however, if the property owners are to be charged through an assessment for sewer or water improvements. Additional information can be obtained by referring directly to the *New York State Village Law*, Section 22.2200 and Section 14-1416.

District operation

There are three types of improvement districts of special interest to lake associations. A park district may be established to maintain a park area, including a beach or lakefront area. An aquatic vegetation control district is set up to reduce both rooted weeds and algae through managing the lake and its watershed. A lake protection and rehabilitation district may be set up to:

- Coordinate research and surveys for data collection and analysis of the lake, related shorelines and the drainage basin.
- Plan and implement rehabilitation projects.
- Secure the cooperation of local government officials for the purpose of enacting ordinances relating to lake protection.
- Maintain liaison with state and local government officials involved in lake protection and rehabilitation.

Whether or not a special district is needed for maintaining a dam depends upon who has authority to do so and, especially, who is responsible for the maintenance costs. If required, a dam-maintenance special district would be set up under the same rules as for other special districts.

In establishing special districts, there are always people who object because they don't want more taxes or because they do not use the resource or both. Attempts may be made to create a so-called "donut district" by carving out an objecting landowner. The general consensus among town attorneys has always been that you cannot create a donut district because all the properties within the area of the district are benefited by the establishment of the district, and that is that. Recent indications from the comptroller, attorney general, and the New York State Association of Towns, however, are that such donut districts will be allowed. If so, it will make it much easier to create improvement districts.

Special districts are run by towns, which generally rely on a volunteer advisory committee comprised of concerned citizens. The special district advisory committee may supersede a lake association, although it often involves the same people. The committee commonly holds monthly meetings to create a management plan, and to propose a budget used to determine the special district tax. The town board approves final decisions and usually provides staff support to handle all taxes and filings. Most towns also cover the insurance and pass through to the district a fair charge plus five percent for administrative expenses.

Local land-use planning and regulation

Local governments have been authorized under New York State law to establish planning boards and zoning boards of appeal. Municipalities also have the authority to prepare and adopt comprehensive plans, zoning and subdivision regulations. In the process of passing and enforcing these laws, local governments must work cooperatively with both federal and state levels of government that share in the responsibility for the planning and management of land and water resources.

Land-use planning is a voluntary approach, and local governments are frequently in the best position to decide what land-use issues will be addressed and what standards will be used. Ideally, local governments should have a current comprehensive plan or master plan outlining the use of land resources within the area of its jurisdiction. This plan should be somewhat flexible because goals and objectives will change as the community grows and develops or as other changes occur in the makeup of the community.

Land-use programs in a lake community are written to effectively manage growth and development or other changes within the watershed. These programs will vary from one community to the next depending on local needs. Land-use controls offer an excellent opportunity for protecting lakes as well as valuable aquifer-recharge areas. Subdivision regulations, building codes, floodplain management, slope-development restrictions, contractual access to the shoreline, height restrictions, seasonal dwelling conversions, clustering, performance bonding and vegetation-cutting restrictions are just a few examples of existing land-use programs found in New York State.

Zoning is a method by which local governments can protect natural resources by using regulations to control land-use activities. An area is divided into districts through zoning. The local government then establishes laws that govern the use of land within each district. Zoning can protect water resources through protection districts for watersheds, wetlands and aquifer recharge areas. Indirect means include performance zoning, cluster zoning and other techniques. Through zoning laws, community development around a lake can be controlled by provisions such as defining minimum setback distances, percentage of a lot that can be occupied or covered and minimum lot sizes.

Zoning variances can be developed in some areas to facilitate unusual landscape features such as steep hillsides, scenic vistas, erosive sites and natural drainage that may restrict development. To address these environmental limitations, special zoning provisions can be established such as "incentive zoning," which allows for cooperative arrangements between an individual property owner and the community. These same concepts can be applied to recreational activities on lakes (See Chapter Eight, "User Conflicts").

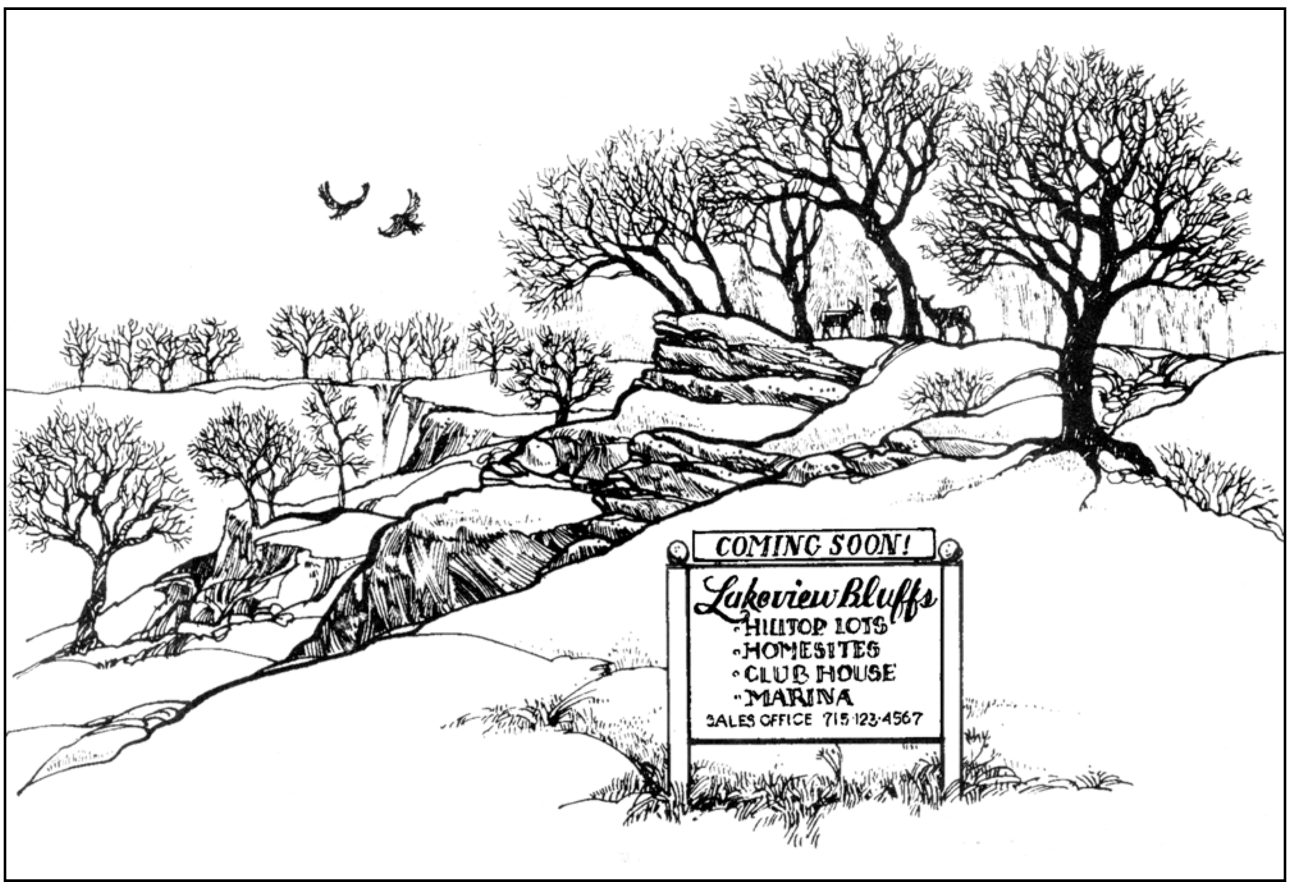


Fig. 10–6. Land-use controls offer an excellent opportunity for protecting lakes as well as valuable aquifer-recharge areas. (CREDIT: HOLDREN ET AL, 2001)

Role of lake associations

A lake association is the most common route for citizens to become involved in protecting a lake. Most lakes in New York State now have a lake association. They range from strong, well-organized associations complete with professional staffs, to loosely organized, largely social groups of interested stakeholders. The stronger organizations have substantial support and operating budgets and are found on the larger lakes. The less well-organized groups are more characteristic of the smaller lakes. Each type has specific advantages and disadvantages.

An unincorporated association is easy to form and is probably the most common type of structure for a lake association. A name is chosen, and a tax ID number obtained. The association can then open a bank account and carry on its operations.

What if the association wants to hire an employee, or rent an office or purchase some office equipment? What if the association gets sued? Under New York State law, an unincorporated association has no legal existence separate from that of its members. To hold the individual members liable, a plaintiff must show that the defendant-member actually authorized the specific acts in advance or ratified those acts after the fact (Martin v. Curran, 303 N.Y. 276, 1951). The plaintiff also has procedural hurdles. A suit must be brought against the association, a judgment taken and proof it cannot be satisfied. A second suit is then brought against the officers or members claimed to be liable for the acts.

This is all very comforting, but it is not difficult for a plaintiff's attorney to claim that members of the association had specific knowledge and authorized the allegedly negligent acts in question. For example, if the association votes to operate a beach, and then someone drowns, a lawyer may be able to show that everyone in the lake association "authorized" the negligent acts that led to the drowning.

The major liability concern of lake associations is being sued for "all they are worth" because of a traumatic accident. The lake association's assets probably are not that large. That is why a lawsuit also names the officers, agents, employees and persons acting for or on behalf of the association. Lake associations may decide to become a not-for-profit corporation to protect the individual members by limiting their liability (see Appendix D, "Incorporating and insuring a lake association").

Although a corporation may have limited liability, anyone on the board of directors or who participates in the management of the corporation will have some exposure. In the past, a one-million dollar general liability **insurance** policy could be purchased for a reasonable sum by even the smallest lake association. Prices have skyrocketed, however, and many New York State lake associations are finding that they cannot obtain general liability insurance at any price. This is particularly true for lake associations that own or maintain dams, swimming beaches, buoys or other "obstacles" in the lake. Some associations are even finding it difficult to obtain affordable directors and officers insurance that previously served as a "second best" alternative to a general liability policy.

A major benefit of having a corporation is the credibility it provides. Unlike the unincorporated lake association, there is a clearer structure for the association with recognized rules. This is especially useful in applying for grants where a not-for-profit corporation has a major advantage. Some grants actually require some form of corporate entity. See Appendix D for information on incorporating and insuring a lake association.

Land protection for lake protection

Land trusts are an effective way to preserve the environmental quality of both land and water resources. A land trust is a private not-for-profit group controlled by local citizens. It acquires land or interests in land for protection of open space, recreation or resource lands, including rare or endangered species, scenic vistas, farm land and unique natural habitats. Some land trusts are small with activities confined to limited areas such as a particular watershed, community or county. Others are larger in scope, such as the Finger Lakes Land Trust. Some are national in scope, such as The Nature Conservancy (see Appendix F, "Internet Resources"). Land trusts have grown in number and expanded the range of their activities in the last 20 years. A land trust may acquire outright ownership of the land or make use of a conservation easement that is negotiated with the landowner.

Conservation easements (CE) provide land-use protection that is stronger than the local zoning or land-use laws, while leaving the land in private ownership. CEs restrict the type and amount of development that can take place on a parcel of land without a land trust or other entity having to purchase the land outright. CEs are often developed for open-space preservation, historic preservation or protection of natural habitats, or are developed for public recreation or educational purposes. Agreements designed for lake-watershed protection vary from "forever wild" easements to those that allow limited residential use, farming or properly managed commercial timber harvesting.

The CE is individually tailored to meet the specifications of the landowner and the recipient organization or agency. A CE clearly defines the limits on the number and location of structures and the types of commercial and industrial activity. They may specify what can be done to the surface of the land and its natural growth. The landowner assigns the right to enforce the restrictions to a qualified conservation recipient such as a public agency or a land trust.

A CE is a legal agreement that is transferred with any future sale of the land. It "runs with the land," not with the owner of the land. This means that the original owner and all subsequent owners are bound by the restrictions of the easement, which are recorded in the county or town records office. The landowner benefits by knowing the land will be protected even when ownership changes. When the CE is donated, its value may be deductible as a charitable contribution on federal and state income taxes. If the local assessor determines the CE has reduced the value of the parcel, the landowner's property taxes may be lowered. They may also result in a reduction in estate taxes, and landowners may receive monetary compensation for the easement itself.

Statutory authority: *Environmental Conservation Law (ECL), Article 49, Title 3.*
General Municipal Law, Section 247.
Responsible agencies: NYS Agencies; local governments; not-for-profit organizations.

Summing it up

No one governmental entity has absolute power over all aspects of a lake or its watershed. Lake management requires shared roles by federal and state agencies, local governments and the local citizens. A lake association needs to understand the principal agencies involved and the laws and regulations that govern their actions (Wright, 2004).

Lake associations are the only organizations that routinely become involved with local lake management issues, often finding a niche as an environmental watchdog, calling attention to watershed management issues, goals and needs. Nongovernmental organizations carry out educational activities and work toward the preservation of critical environmental areas, including lakes and streams.

The federal *Clean Water Act* includes a broad array of water pollution control regulations. Authority to carry out the federal regulations and related state regulations is delegated to DEC. Wetlands are protected under both Section 404 of the federal *Clean Water Act* and New York State *Freshwater Wetlands Act*. Responsibility for protecting public water supplies is shared by DEC and DOH.

Local governments have broad powers to provide services such as water supply, waste disposal, sewage treatment and lake protection and rehabilitation. Towns also regulate land uses through zoning and other means. The formation of special districts is a common device for meeting these needs. Land trusts or conservation easements are other tools that may be useful to protect unique areas or property.

11 Management Plan Development: Putting the Pieces Together

Introduction

Earlier chapters discussed the history of lakes and the problems to which they are susceptible. Now is the time to prioritize the problems and outline the actions needed to remedy them by gathering together all that has been learned in the earlier chapters, from diagnosing lake problems to understanding how activities in the upland affect lake quality. This can best be done through creating a **watershed management plan**. This chapter describes guidelines for writing such a plan, including who might be involved and suggestions about how to involve them. The term “watershed management plan” has been chosen as a reminder that upland activities affect the health of a lake as much as the activities of lakeside property owners and lake users.

The overall goal of a management plan is to maintain or improve the health of the lake so it can continue to provide services and enjoyment. Creating a watershed management plan is more than a bureaucratic exercise; it is a systematic approach to lake management. Often the catalyst for developing a plan is a visible problem, such as weeds. The plan defines the desired results, lists what needs to change, and the steps necessary to get there. It keeps efforts coordinated and focused on the steps most needed to achieve long-range improvement through addressing the true causes of the problems. A good plan considers the social, economic, political and cultural context of the lake and its watershed.

The dialogue created among watershed stakeholders during the process has long-term benefits. Involvement of diverse interests increases knowledge and awareness, which frequently leads to better decisions and increased acceptance when it comes time to take action. A broad base of support usually is needed to affect change since many problems are the result of nonpoint source pollution and cannot be solved by a single individual or governing body. A planning process that balances multiple uses can also reduce conflict among lake users.

There are other tangible benefits to creating a watershed management plan. It provides a rationale when seeking funding and the detailed data required by most grant applications. Some funding sources give preference to projects that are outgrowths of a management plan.

Many of the suggestions in this chapter have been distilled from the management planning experience of lakes in New York State, especially from six lakes that participated in a pilot watershed management project. This project was a joint effort of the New York State Federation of Lake Associations (NYSFOLA) and the New York State Department of Environmental Conservation (DEC). The resulting report, *A Primer for Developing a Successful Watershed Management Program* (NYSFOLA, 2001), is referred to and quoted below. The full text is available on the NYSFOLA website (see Appendix F, “Internet resources”.)

Every lake is unique in terms of the economics, ecology, geology, politics, and values. The six lakes selected for the pilot project reflect that diversity. They included:

- Chateaugay Lake, a rural northern Adirondack lake;
- Cossayuna Lake, a shallow lake located between the Capital District and the Adirondack Park;
- Findley Lake, a western lake that is contained almost entirely within one town;
- Oscawana Lake, located in the populated lower Hudson River Valley;
- Owasco Lake, a relatively large Finger Lake whose watershed spans three counties; and
- Queechy Lake, located south of Capital District near the Massachusetts border.

One of the key lessons learned during the pilot program was that creating a lake or watershed management plan takes time—typically three to six years. It requires considerable patience to identify stakeholder groups, establish a communications network, and attract broad involvement. It can be tedious to accumulate from many sources the scientific information needed to document what is known about a watershed. It requires commitment and persistence to maintain the effort needed to chose strategies that are realistic and acceptable to people with diverse interests and values.

In addition to time, two other basic ingredients are expertise and money. At least one of these three ingredients usually is in short supply. If you have the expertise needed to accomplish a task by a certain deadline, there may not be enough money to complete it properly. Remembering this can reduce frustration and aid in anticipating and addressing any shortfall. Lake associations have found that a surprising amount can be done at no monetary cost to the association. Facilities, equipment, expertise and labor have been obtained through in-kind contributions, pro bono technical assistance, and volunteers. If money is in short supply, it can be worth investing time to cultivate the relationships needed to acquire these resources.

Getting people together for a common purpose

> "Never doubt that a small group of thoughtful, committed citizens can change the world." ® Margaret Mead (used with permission)

Who to include?

The first step is to form a core committee to provide continuity and to shepherd the process from the beginning to completion of the plan. The role of the committee is to oversee the planning process and to keep the broader public informed and involved.

A lake association can be an ideal starting group since it can:

- begin the process;
- become an environmental watchdog;
- educate lake users and property owners on their role in protecting the lake and watershed;
- help to complete small projects; and
- serve as a catalyst to sustain the management plan effort over many years.

If no lake association exits, related conservation groups or a few neighbors might be interested in beginning such a group. Information on forming a lake association is found in Chapter ten, "Legal framework," and in Appendix D, "Incorporating and insuring a lake association." While the actions of an association can be large, its membership alone is not sufficient. Lakeside owners may have full-time jobs, time constraints and are unlikely to have all the expertise or the diverse perspectives necessary to create a successful plan.

For the committee to work well together, it needs a common goal. This can be as simple as maintaining their enjoyment of the lake, or seeking to protect property values. Within that context, individuals bring their personal views based on their knowledge and experience. As they participate, their outlook changes and their knowledge increases as they become involved in matters outside of their initial area of interest. The broader this knowledge becomes, the easier it will be for each person to understand the needs and beliefs of others. Moving from conflict to understanding is a critical requirement for a successful plan. The lake associations in the NYSFOLA pilot program saw this resulting sense of community as the greatest benefit of the management planning process.

Initially it may seem easier to exclude individuals with different opinions. The initial progress may be faster, but all too often the group that feels excluded may block further progress after the committee has invested much time in planning. This can cost more time, money and personal energy than it would have if the disparate views had been included from the beginning. The dialogue that results from broad involvement at early stages continues to pay off, as the group's growing understanding of the interests of others frequently results in better decisions and smoother implementation. Many funding sources favor proposals that show strong collaboration among groups, and these groups may constitute a broad enough base to spur policy changes or other chosen actions.

The core committee should have representation from each group that may be affected by the identified problems or by the potential strategies to address the problems. The committee should include:

- lake users and property owners;
- farmers and other large landowners in the watershed;
- municipal officials;
- conservation agency staff;
- members of local tribes; and
- people with scientific knowledge about lake ecology and lake restoration.

More members can be added to the core committee when new interest groups are identified. Turnover in membership is normal given the long time commitment and new members should be recruited to maintain the breadth of perspectives.

Involvement of the municipal leaders within the watershed is critical to success. The response from municipal leaders can vary from enthusiastic support to grudging recognition that the town needs to be kept informed. The NYSFOLA *Primer* (2001) reports:

> "Local politics, including relationships with the Lake Association and perceptions about the importance of the lake to the town are the key to getting town involvement in lake-management projects. These relationships are extremely variable from one watershed to another, and each must be dealt with according to the perceptions and past relationships between town residents and the lake association."

Scientists with knowledge of lake ecology and lake restoration techniques can help unravel the underlying causes of problems, identify a suite of potential solutions, and insure that the needs of fish and wildlife can also be considered as well as the desires of the stakeholders. The expertise of scientists is especially critical in compiling information about the current lake conditions, including the topics discussed in chapters one through nine. The compilation of their findings is often called a **State of the Lake Report**. It becomes the handy reference for recording trends and patterns, ferreting out the causes of problems, assessing whether there is sufficient data

Building partnerships

Recruit people from groups that have diverse perspectives and expertise for the core committee, or at least to serve in an advisory capacity. Many of these groups are discussed in Chapter ten, "Legal framework." Examples include:

State, federal and tribal groups such as:
- DEC state and regional offices;
- New York State Department of Transportation;
- U.S. Geological Survey;
- New York State Geological Survey;
- Natural Resources Conservation Services in the U.S. Department of Agriculture;
- Regional office of U.S. Environmental Protection Agency EPA;
- Tribal leaders; Bureau of Indian Affairs and EPA's American Indian;
- Adirondack Park Agency, where applicable.

County agencies such as:
- Cooperative Extension;
- Soil and Water Conservation District;
- Health Department;
- Planning Department;
- Chamber of Commerce;
- Environmental Management Council;
- Water Quality Coordinating Committee WQCC.

Informal leaders and interest groups such as:
- Large landowners such as farmers;
- Businesses that depend on the lake;
- Sportsmen and fishing clubs;
- High school or college environmental clubs;
- Conservation organizations and land trusts;
- Professionals such as educators, lawyers, accountants, and people who know how to write grants. Many of these people may already be in the core committee if they own property on the lake.

to draw meaningful conclusions, and providing a scientific justification for decision making. Some scientists or university faculty may own property on the lake and be willing to help. While not the only factor, good science must be at the foundation of evaluating lake health and identifying possible management actions.

If possible include on the core committee one individual who receives regular salary from a government or county office for administrative services. In addition to helping locate data, this individual is important for keeping the process moving, maintaining consistency as volunteers come and go, and serving as a repository for important documentation. Staff members of local Soil and Water Conservation Districts (SWCD) or county planning departments may be willing to serve in this position if local watershed management fits within their regular duties.

Who will lead?

The results of watershed management planning efforts around the state unequivocally show that success hinges on having the right committee leader. The NYSFOLA *Primer* (2001, p. 11) uses the word "team" rather than "committee" and reports that a successful lake management plan (emphasis original):

> "…requires a dedicated leader with good leadership skills. The team leader needs to have the skills necessary to identify who the relevant stakeholder groups are, to define the key issues, and to diplomatically bring these factors into the discussions. Results were best when the leader was locally recognized and accepted. The personality of this team leader is vital.
>
> A major factor in core team success was available time. This project takes a considerable amount of management time. Respondents indicated it often required ten hours or more a week throughout the year to make phone calls, organize meetings, and help organize information. Such a commitment places a heavy burden on volunteers who are also juggling full-time jobs and families. The project becomes a stress instead of a satisfying challenge.
>
> Projects seem to proceed most smoothly when the leadership roles can be included as part of a person's job duties within a relevant agency. Agency affiliation provides a continuity that is lacking with citizen leaders, who are not necessarily engaged in the process for long-term follow-up. It also provides linkages and a professional interest in the outcome on the part of the Project Leader as part of long-term job responsibilities. Agency people also have ready knowledge to help identify relevant groups and stakeholders.
>
> Selection of the right people and agency is, however, not a minor issue. Many citizens feel an "agency" has a "biased agenda" or is a "regulatory threat." This reduces their effectiveness for getting stakeholder involvement. The historical relationship of a particular agency with the particular community is very important."

Who can help?

While the committee provides continuity throughout the process, others may be involved when their expertise is needed. Agency staff may be able to provide services as part of their job. Professionals may donate expertise to a good cause. College students and faculty may be able to help with components such as conducting public opinion surveys, monitoring water, gathering data on flora and fauna, mapping and analysis.

Government agencies have data and knowledge, as well as information on regulations and policies. Relevant information might include soil types, streamflow data, population data, biological information, and water chemistry. Various government agencies have jurisdiction over activities being conducted in the watershed, or within the lake itself, such as construction of docks, shoreline zoning, discharge of wastewater, and the management of wetlands. Some actions may fall within the purview of a county health department, SWCD, or town planning board, and in-kind help or staff assistance may be available from those agencies.

It is important to carefully select the proper agency when seeking help. Citizens often relate stories of how they called some agency and got "the run-around," being transferred to several other phones or getting an employee who doesn't recognize the agency's ability to help. The following tips can help obtain the desired information, whether it is from a governmental agency, professionals, volunteers, or committee members:

- Determine what information or assistance is needed and write it out.
- Talk with others who have experience with different agencies to determine who is most likely to be of help. Start with the town, city or village before going to a county or state agency. Federal agencies often refer requests to state and local agencies.
- Start with the agency's technical staff first, rather than contacting upper-level management.
- Be cordial, no matter how dire the issue may be or how unhelpful a staff person seems. This process is all about building connections.
- Contact your area elected officials for additional advice and support. Describe the information or assistance you need, and the contacts you have already made with government staff.
- Write down who you talked to and a summary of what they said. Seek their opinion on who else might be able to help. Set up a file of notes, correspondence and e-mails.
- Follow up your conversation with a letter that captures key points and expresses appreciation, suggesting a personal meeting after you have reviewed the data.

Enthusiasm and warmth are contagious. Many people are willing to help when approached by someone who is dedicated and passionate about a project or cause. Even someone who is not able to help immediately may become a great contact later in the process.

Public outreach and involvement

Private citizens play a significant role in protecting water quality and aquatic habitat. Surveys conducted in both the Great Lakes (Beldon Russonello & Stewart, 2002) and Chesapeake Bay watersheds (Blankenship, 2002) show that citizens care deeply about water resources but do not understand how their personal choices and actions affect water health. To many, one failing septic system, one person feeding ducks, one person dumping grass clippings into a stream, or one farmer letting his cows use an upland stream may seem unimportant. The cumulative affect of many instances, however, is quite detrimental and this collective, nonpoint source pollution is the greatest threat to most lakes. Because families and individuals will be asked to change their behavior, and possibly accept additional regulation, it is important to keep them involved in the planning process. Ongoing outreach campaigns can influence public perceptions and foster cooperation.

> "Communication with the diverse groups of stakeholders throughout the watersheds was critical to obtaining their perspectives on watershed issues and to building their sense of ownership and involvement. Successful communication needs to increase stakeholder awareness of the project and to get feedback as the critical step of getting the total community to buy into the project and future implementation needs. Communication methods could be divided into two types: those methods conducted to get actual feedback from stakeholders, and those methods largely used to inform stakeholders." (NYSFOLA, 2001)

Fig. 11–1. It is important to include all relevant stakeholders from the very beginning. Lakeshore owners cannot achieve their goals without collaboration and acceptance from those who have a vested interest in the lake. (CREDIT: HOLDREN ET AL, 2001)

The core committee ensures that the broader community is well informed and involved from the very beginning. Outreach may be delegated to a sub-committee of people with a talent for presenting technical information in ways that laypersons can readily understand. Sharing information widely and in a variety of ways increases the likelihood that people will respond to at least one facet of an outreach campaign. Some individuals may pay attention in fear of new regulations, others may be interested in fisheries protection, and others may care about the drinking water supply.

Outreach methods may include:

- Using of newspapers, radio and websites;
- Speaking with key organizations, community leaders, and municipal officials;
- Surveying residents and lake users;
- Holding formal public forums at several points in the process; and
- Using formal and informal community bulletin boards.

Fig. 11–2. Keeping the community involved and informed takes persistence, long-term commitment and the use of multiple methods of distributing information.
(CREDIT: HOLDREN ET AL, 2001)

Techniques for building awareness in the community

1. Develop a logo and standardized look for materials to help people recognize your efforts.
2. Prepare a short informational flyer that introduces the idea of a watershed management plan. Include a map of the watershed with political boundaries, a summary of the purpose and process, and trivia information such as size, wildlife, and history. Include information on how people can get involved.
3. Distribute a press packet that includes the flyer and a couple of articles about the process and key issues. Submit additional articles on a regular basis, including quotes from people and officials.
4. Contact radio and TV stations for their policies regarding public-service announcements and interviews. Remember to include stations at local colleges and public-access cable channels.
5. Attend networking events such as meetings of the Chamber of Commerce, tourism organizations, and other events where one-on-one conversations flourish.
6. Develop a presentation that any committee member could give at a meeting of service clubs such as Kiwanis and Rotary, a church discussion group, a town board meeting or an outdoor recreation club.
7. Create a table-top display that can be set up in libraries, bank lobbies, community centers, county fairs, Earth days and Water Weeks, etc.
8. Host activities that raise interest and awareness such as a lakeshore or stream clean-up days, a fishing derby, a canoe trip, a photography contest, or a water festival. Finding another group to co-sponsor the event is a good way to build partnerships and gain help. Invite local politicians to the events, especially when there are photo opportunities.
9. Set up a website and keep it updated so people will visit often. Ask other groups to set links to your website and offer links to theirs in return. Link the website to the NYSFOLA website.
10. Publish a newsletter from the committee, and submit articles to newsletters from other groups such as the Soil and Water Conservation District, Cooperative Extension, recreation clubs, schools and towns.
11. Create fact sheets on specific topics such as weed management, septic system care, and ecological landscaping. Seek permission to customize existing materials already developed by other watershed groups and government agencies.
12. Host informational meetings on key topics. If the topic is controversial, be sure multiple sides are presented in a balanced way.

Watershed inventory

Problems, both existing and foreseen, are frequently the stimulus for creating a management plan. As discussed in Chapter four, "Problem diagnosis" and Chapter nine "Watershed management," the real cause behind the symptoms may not be obvious, but it must be found if lake management is to be effective. An important step, therefore, is to gather available information and data that are needed to understand the problems. This process also includes analyzing the information, identifying data and information gaps, and setting goals. The preceding chapters of this manual provided guidance for this investigation and facilitated dialogue with people who have needed technical information.

Compiling information in one document, often called a Watershed Inventory or State of the Lake Report, builds the foundation for the management process and results in a valuable long-term resource. It should include detailed information about the biological and physical conditions of the lake and its watershed, demographic characteristics and the input gathered through public surveys and meetings.

The type, amount and sources of information can vary in different watersheds. When vast quantities of information exist, it can be difficult to decide what is relevant and useful. Initial identification of problems and input from stakeholders can guide the investigation and tailor data collection efforts. Once the problems have been identified and defined, general goals can be developed that include both short-term and long-term solutions. These initial solutions will not involve specific recommendations or management alternatives, but they will provide direction for the evaluation process. While this step is important, be careful not to overspend time, energy and money compiling information, thus depleting these resources before finishing the management plan.

Keep good records as information is collected such as the source, contact information, explanations of uncommon terms, and information about when and how data were created. This information is called **metadata**: essentially data about data.

Data that can be included in a State of the Lake Report

The amount of information that can be collected may seem endless. Before you start, think about which types of data are needed for good decision making. Focus your efforts based on concerns and preliminary goals. The following are examples of some of the information and data that can be collected:

- The size and boundaries of the watershed.
- Major tributaries and the larger watersheds of which the lake is part.
- Facts about the lake such as the surface area, length of shoreline, volume of water and hydraulic retention time.
- Location of any dams and their ownership.
- Lake uses and trends.
- Boundaries of all municipalities and tribal lands within the watershed.
- Information on land management such as land-use ordinances and zoning for all the municipalities that govern the watershed.
- Land use, including the location of specific uses, their percentages and whether land is public or protected
- Wetlands and flood plain delineations.
- Weather patterns.
- Geology, terrain and soil types.
- Water-quality monitoring data.
- Documentation of native and invasive flora and fauna.
- Special attributes or areas within the watershed and what could threaten them.
- Stormwater outfall pipes in developed areas.
- Agency reports such as Rotating Intensive Basin Study (RIBS) reports and the Priority Waterbody List/Waterbody Inventory (PWL-WI) from DEC. (See Appendix F, "Internet resources")
- Significant restoration projects already completed or underway.
- Anecdotal and traditional knowledge from long-term residents and tribal members.
- Point-sources of pollution.
- Significant water-quality violations such as chemical spills.
- Aerial, satellite and infrared photographs (together called remote sensing.)
- Demographics and population distribution.
- Social and economic trends.

Biophysical assessment

To understand where lake water is coming from and going to, the first step is to become familiar with the boundaries of the lake's watershed. The Natural Resource Conservation Service (NRCS), SWCD or U.S. Geological Survey (USGS) may have already identified the watershed boundary and the political boundaries of the towns and counties that intersect the watershed.

USGS 1:24,000 topographic maps are excellent aids for delineating the watershed divide, determining surface tributaries that contribute to the lake and the terrain that directs the movement of contaminants (Fig 11–3). Commonly referred to as "topo" maps, they can be obtained from the USGS (see Appendix F, "Internet Resources") and often from local sporting goods stores.

The next step is to identify the different types of land uses and their locations in the watershed using aerial photographs or geographic information systems analysis (GIS) (see Fig. 11–4). GIS is a powerful, computerized mapping tool used to precisely overlay and analyze maps and aerial images. Use these tools to locate residential areas, industrial complexes, livestock facilities and other potential sources of runoff or groundwater contaminants. Both potential point and nonpoint sources of contaminants should be identified. Under the category of potential point-sources, note the presence of gas stations, auto repair shops, stockpiles of road salt and de-icers, dry cleaners and sites of current and former industrial and municipal waste disposal areas.

Consideration must be given to all of these land uses and their potential contaminants relative to their position along the topographic gradients, particularly on steep slopes. This will influence the flowpaths of water that enters the lake. The tributary stream-channel network must be identified and its condition assessed. USGS topographic maps show the main stream-channel system by using dashed or solid lines to indicate whether streams are intermittent or perennial. Such detailed information is not available from large-scale topo maps or most remote sensing data. Data from maps or aerial photographs may be out of date and it may be necessary to walk along streams and roadside ditches to collect detailed information about present conditions. Is there a healthy buffer of natural trees, shrubs and other plants at least 30 to 50 feet wide along every stream? Are there sites of extensive stream bank erosion? How do networks of roadside ditches act to augment stream channels? Take time to map their outflows into streams and note whether the ditches have scraped or exposed substrates that can be a source of erosion sediment during storm events. Where do storm drains discharge into streams? Gathering this information will take time and effort but can provide a valuable source of information about pollutants and how they move into the lake. School classes and youth groups are an excellent resource for the stream walks needed to develop this database. Highway departments may have some of this information already and be grateful for any additional information you can provide them.

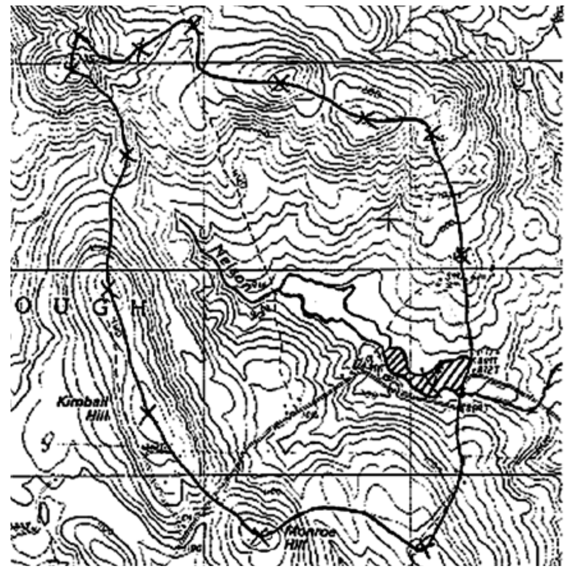


Fig. 11–3. The high points around Nelson Lake and its adjacent wetland (noted with hatch marks) are marked with Xs on a topographic map. The line that results when the Xs are connected across these highest areas represents the boundary of the watershed. (CREDIT: NRCS)

One of the most challenging tasks will be to evaluate the groundwater system contributing to the lake. A useful rule of thumb is that the groundwater table generally parallels the surface topography, with higher water-table heights under hills and lower water-table heights in valleys and lowlands. Groundwater moves

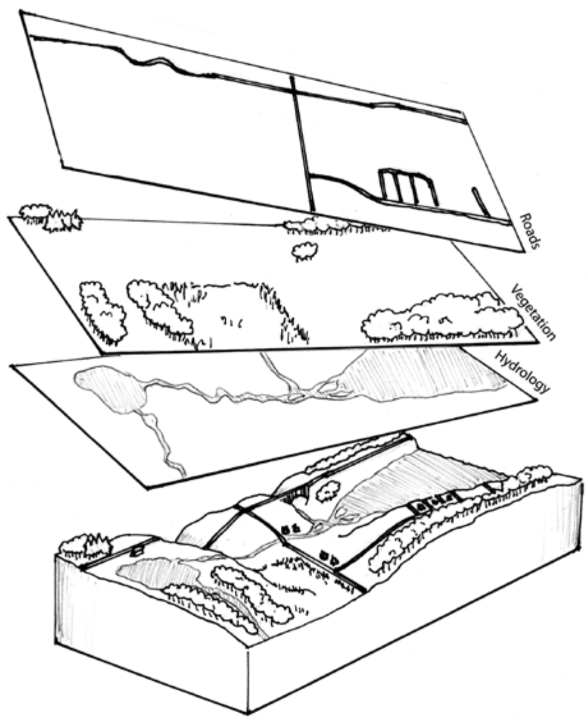


Fig. 11–4. Schematic showing how GIS software overlays different layers of data to show their spatial relationships with each other. The bottom image represents the reality of the landscape. Each additional layer represents one feature of the landscape such as the surface water features (hydrology), vegetation and the network of roads. (CREDIT: CHRIS COOLEY)

downslope from areas where the water table is higher to areas where it is lower.

Information from homeowners about water-table depths in their private wells can provide useful guidance on local variations. Topo maps, augmented with well data, can help to highlight the direction of groundwater flow that can transport a plume of contaminants into the lake or the location of groundwater recharge areas.

Mapping the classification and distribution of different soil types will provide additional insights into factors that affect groundwater. "Light" soils that have a high content of porous sands and gravels provide little filtering capacity and will readily permit contaminants to leach underground. Professionals can help identify soils and their associated land uses that can put groundwater at risk. Check with the local SWCD for soil maps that may already exist.

Finally, it is important to record the presence of other natural features that may be contributing to sustaining the lake's water, such as floodplains, healthy forest patches and wetlands where groundwater recharge can occur or water is filtered before it enters the lake. These features deserve protection.

Assessing trends and public concerns

Decisions are not based solely on physical and biological science. If the priorities and management strategies recommended by the core committee are to be broadly adopted they must be relevant to the broader local community. Economic, political and social trends all influence lake management. Census data, research by social scientists, reports by the Chamber of Commerce and forecasts by planning departments can be helpful sources of information. Planning departments may have projections on the amount and probable location of future development derived from current patterns and land use controls such as zoning. Communities with zoning may find it very instructive to create a map of what the community could look like if all the land were developed to the extent that zoning allows. This is called a **zoning buildout**. During the data analysis phase, this map can be used to investigate implications for the lake, other water resources and natural areas if the buildout became a reality. It may also point to areas of the watershed that can best support new development.

The core committee should do additional investigations to identify the areas of concern to stakeholders. There are many ways to gather stakeholder views such as personal dialogue, small group discussions, phone interviews, surveys on the web, surveys mailed to watershed residents and visitors, and large formal meetings. Plan to use a variety of methods because each has pros and cons related to the number of people reached, the time and money expended, and accuracy of the feedback. Some people lack access to electronic communication, some will not take time to give a written response, and some people are uncomfortable talking in groups. There are many books about how to write surveys. *Mail and telephone surveys* (Dillman, 2000) is a classic text that includes basic information on design and discusses alternatives to a traditional written survey.

The participants in the NYSFOLA watershed project (2001) used surveys to identify watershed issues and to generate public interest. Surveys were viewed as one good way to inform the public about lake issues and the management planning process. Project participants were nearly unanimous in their feeling that public opinion surveys were one of the most successful activities conducted for communicating with stakeholders. The *Primer* continues (op. cit., p. 31):

> "Writing a good survey requires considerable effort and is not a task to be undertaken lightly. The questions must be thoughtfully worded, a [mail] survey needs to be sent out at least twice to get adequate feedback, and follow-up telephoning may be needed."

Whatever information collection method is used, it is important that the process be unbiased. The way a question is phrased can give the appearance of bias, can breed suspicion, skew the answer, and result in erroneous information. The process used must communicate sincere interest in divergent opinions and result in information that is actually used to improve decision making.

Analyzing the data

A core committee which has strong involvement with water resource professionals may be able to analyze and interpret the information collected. Alternatively, forming a separate technical committee can be useful. Professionals not willing to commit to service on the core committee may be willing to be a member of the technical committee where their particular expertise is needed. Water resource professionals should be heavily involved and help guide the process.

- *Identify data gaps*. Amassing available relevant data does not mean all the data necessary for good decision making has been collected. Targeted studies and water monitoring may need to be conducted to move forward. Alternatively, the committee may have to make the best decisions possible with known data, keeping in mind that the plan will be revisited and revised as more information becomes available. The management plan should, therefore, include steps to obtain the desired additional data.
- *Assess the overall water quality* and the variations in conditions. Patterns may be found based on weather, land use, political boundaries or other factors. Political differences in protective ordinances and levels of enforcement are factors that can affect water quality.
- *Quantify the amount of pollution* and its sources based on information available. See the Chapter four, "Problem diagnosis" section on *Budgets for water, nutrients and other pollutants*. A limited number of critical pollution sources will often contribute a disproportionate amount of contaminants. Identifying and targeting these critical sources can provide the greatest return for the resources expended.
- *Compare water quality conditions* to standards, regulations and information on concerns and priorities gathered through public participation.

Data collection and analysis can consume many resources and slow down the process. There is a balance between having strong scientific information for decisions and getting mired in the plethora of fascinating, and often expensive analysis tools. Neither information gathering nor analysis of information is the desired end. These tools, such as monitoring, mapping, and modeling, are a means to an end and the focus should stay on the contribution these tools can make to management decisions. The information collected and related data analysis is compiled into a document that can be shared with stakeholders, used when deciding on management strategies and quoted when writing funding proposals.

Watershed management strategies

A broad or preliminary goal was identified early in the process, such as eliminating beach closures, improving drinking water or reducing aquatic weeds. Subsequent investigations improved knowledge of current conditions, underlying causes and public priorities. This knowledge is now used to further define the desired outcome and to select specific objectives for the level of watershed protection that is appropriate and achievable, and to identify indicators that show measurable progress. The indicators and objectives will guide the selection of management strategies needed to meet the goal. They should be recorded as part of the plan because they provide the rationale and targets for the management strategies.

Indicators and objectives

Data analysis led to improved understanding of the severity of watershed conditions, the likely underlying causes and the critical sources of deleterious contributions, all relating to the health of the lake. Indicators either directly or indirectly quantify the status of a condition, especially a complex condition like “a healthy fishery” or “a polluted lake”. What do these phrases really mean? How will you know if the fishery is healthy or the lake is no longer polluted? If the underlying cause of a poor fishery is low oxygen and excess turbidity, then sufficient dissolved oxygen levels and a reduction of total dissolved solids to a stated level would indicate that the lake can support a healthy fishery.

The indicators selected should measure environmental changes clearly linked to the problem or the desired goal so they will be a valid indicator of progress. A value should be set for each indicator. Total phosphorus, for example, may be chosen as an indicator of eutrophication and a desired value of less than 0.015 mg/l (milligrams per liter) established as the target. Indicators may be regulatory, such as when a Total Maximum Daily Load (TMDL) has been set for the waterbody (see Chapter four “Problem diagnosis”). One indicator generally will not be sufficient; it is better to have a combination of indicators. The additional indicators of chlorophyll *a*, Secchi disk readings and other forms of phosphorus data would provide a better gauge of eutrophic changes. Indicators need to be quantifiable using methods that are affordable, practical and dependable for measuring the magnitude of the problem and the progress toward the established goal.

Indicators can be valuable as a communication tool. The “sneaker index” has gained popularity since 1988 when it was first used in Maryland’s Patuxent River (Clarke, 2002). Each year volunteers wade into the river and measure the depth at which they can no longer see their white sneakers. It is a powerful symbol as well as a meaningful marker toward a goal.

Objectives are tools for achieving the indicator targets. Both the critical sources of contaminants and public priorities are considered when developing objectives. It is important to include all relevant stakeholders in this objective-setting process from the very beginning. The objectives must consider the interests of all relevant stakeholders and the need for sustainable water protection.

Sample objectives include:

- Restoring vegetation along 20 miles of streamsides to prevent erosion and improve filtering.
- Avoiding further loss of wetlands within the watershed.
- Reducing the transport of erosion sediment to the lake by roadside ditches.
- Reducing nutrient runoff from farm fields.
- Repairing or replacing all failing septic systems.
- Minimizing flooding by increasing infiltration of surface water and groundwater recharge.

Once a complete list of objectives and targets is developed, evaluate their feasibility and appropriateness relative to the biophysical condition of the watershed and lake, the costs and public acceptance. Keep refocusing on the end goal rather than individual self interests. Appropriate science-based strategies for improving the watershed that are acceptable to the public can then be identified. When the core committee and involved stakeholders have divergent perspectives, it helps to work on “can you live with it” rather than “do you like it”.

Moving from goals to management: a simplistic example

Goal: The lake is no longer pea-soup green

Data analysis: Phosphorus levels are highest after storm events and at the mouth of two tributaries with residential communities as the predominant land use.

Indicators and targets:

- Total phosphorus to have a monthly average of less than 0.015 mg/l and measurements after storms or snowmelt not to exceed 0.025 mg/l.
- Chlorophyll *a* measured in the water column to have a geometric mean of less than 5 µg/l.
- Secchi disk reading of at least 10 feet on average and 6 feet after storm events.

Objectives:

- Reduce phosphorus contributions from lawn fertilizers.
- Restore a minimum 15-foot buffer strip of woody vegetation along 60 percent of the stream.

Management strategies:

- Educational programs on environmentally-responsible lawn care for homeowners to be given each spring and fall.
- Establish a "lake friendly" certification program for lawn-care companies.
- Train landscape designers and nursery firms on the selection, marketing, and care of attractive woody ornamentals for streamsides.
- Include training and work in lawn care, landscaping and stream-side plantings in the youth summer job program.
- Adopt a local ordinance that prohibits application of fertilizer with phosphorus on established lawns unless a soil test shows the need.
- Strengthen enforcement of the existing stormwater ordinance.
- Install sediment traps in the stormwater collection system to reduce the movement of soil to which phosphorus is attached.
- Preserve undeveloped land by creating conservation incentives and promoting conservation easements.

Choosing management strategies

There are many potential management strategies and they can be divided into two broad categories. Most management plans, including the example to the left, will have items from both of these categories.

- *Structural practices* include physical devices such as vegetated basins that trap sediment, fences that keep livestock out of streams, and porous pavers that increase infiltration of stormwater.
- *Nonstructural practices* include regulations and voluntary changes in behavior such as municipal ordinances, permits, stormwater pollution prevention plans, inspection of septic systems and improved lawn care practices.

The first step is to review the structural and nonstructural practices already in place. Which are most effective? How does the public accept them? Are current practices in critical areas? Acknowledge protective efforts already established, look for modifications that could improve existing practices and programs, and identify gaps that should be filled.

A variety of potential action strategies can then be evaluated for their ability to address the underlying cause of problems, meet objectives and make the most progress toward the established goal. Some management strategies may work in some critical areas and not in others. Other strategies may be effective only if several are combined or done in sequence. Selection criteria should include:

- considerations of short and long-term costs relative to effectiveness;
- current conditions;
- likelihood of success;
- permitting or legal issues including compatibility with existing processes;
- additional benefits derived from the practices (such as increased wildlife habitat);
- unintended consequences or negative side affects; and
- community acceptance.

The committee presents key findings on the state of the lake, objectives, indicators and an early draft of management strategies. These meetings can minimize delays imposed by individuals or interest groups claiming at a later date that they were left out of the decision loop. Public forums are most effective when there has been outreach from the beginning of the planning process, and when feedback is thoughtfully considered and incorporated. Like surveys, these forums double as public education.

The devil is in the details

Before finalizing the plan, more information is needed. Who will accomplish what, in what time frame, and what resources will be needed? Many of the strategies are likely to fit within the core work of agencies such as Soil and Water Conservation Districts, planning and health departments, and Cooperative Extension. Other tasks might be logically addressed by municipalities, the lake association or a county Water Quality Coordinating Committee.

Consider scheduling projects that can be accomplished quickly and provide some "easy wins" and highly visible successes. Be realistic when setting time frames. A strategy might take a short amount of time to carry out but the permitting process, grant proposals or building the necessary collaborations can take a considerable amount of time.

The availability of resources is another important factor when drafting a timeline. Shortages of labor, money and public support can all limit progress, especially if the timeframe to completion is long. Acknowledging the completion of interim steps toward reaching an objective can reduce frustration if progress is slow. Consider defining and setting dates for milestones, such as the completion of a significant task or progress made, as measured by indicators. This level of planning has the added value of defining points where the management strategies can be evaluated.

Each milestone is an opportunity to take advantage of experiences and any new information gained. **Adaptive management** is a type of natural resource management in which decisions are made as part of an ongoing science-based process. Adaptive management

Outline of a typical watershed management plan

Executive Summary

Introduction

Information on the core committee and any subcommittees such as the technical committee.

Public participation efforts

Watershed description
- Physical and natural features
- Land use and land cover
- Demographic characteristics
- Watershed Conditions
- Water quality standards
- Available monitoring and resource data

Pollutant source assessment
- Nonpoint sources of pollution
- Point-sources of pollution
- Hazardous waste sites
- Mines and other pollutant sources
- Historic sites such as an abandoned tannery

Pollution loads and water quality
- An estimate of existing pollutant loads
- Future build-out pollutant load estimates
- Identification of critical areas

Watershed goals
- Management objectives
- Indicators
- Key pollutant load reduction targets

Identification of management strategies
- Existing management strategies to be continued
- Additional strategies needed to achieve goals

Implementation program design
- Schedule of activities
- Interim milestones
- Costs
- Technical assistance and other resources needed
- Informational and educational activities
- Evaluation/adaption process
  (USEPA, 2008)

involves testing, monitoring, and evaluating applied strategies, and incorporating new knowledge into management approaches that are based on scientific findings and the needs of society. Results are used to modify management policy, strategies, and practices (adapted *from Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management, 2000).* The repetitive nature of adaptive management recognizes that protecting natural resources requires coping with uncertainty. Planning that allows for assessing and adjusting goals supports continual improvement.

The management plan

Once details have been settled, the information is gathered into a management plan. The sample outline on the previous page provides a description of the process, as well as showing the common elements of a plan. If the compiled information produces a document that is lengthy, or if the process is taking a long time and a tangible proof of progress is desired, the plan can be broken into two documents—a State of the Lake Report containing the gathered data and a Watershed Management Plan containing the objectives and working plans. Full or summary versions of the plan may be included later in requests for funding or for permits.

The plan may be printed, transferred to compact discs, or posted on a website. It is then made available to those involved in development and implementation, including property owners, governmental bodies and agencies. Presenting the final document is another key time for a public forum and a celebratory party. NYSFOLA would appreciate receiving a copy to be shared with other lakes that are starting their own planning process.

Information and education

Some management strategies will be educational efforts, such as programs on environmentally-responsible lawn care. General education needs to be ongoing in addition to any programs specifically intended to help meet the objectives. Keeping the public informed about progress keeps the plan alive and ensures the continuation of implementation. Strategies such as the adoption of new ordinances or a new tax will take education to build public support (sometimes called political will) and to educate people on how to comply. Education about water science is also helpful. Increasing understanding of the concepts covered in the earlier chapters of this book will support behavioral change, may reduce resistance and conflict, and will build the community's capacity to deal with emerging problems. People become interested and learn in different ways, so use a variety of approaches such as money savings, health implications, improved quality of life, and economic benefits. Use different methods such as websites, pamphlets, events, contests, and press releases.

Summing it up

Creating a watershed management plan is a giant step towards the real goal of implementing actions to protect the lake and its watershed. A plan should not sit on a shelf. It is a "living document" to be revised and reorganized as more information is learned, and the public continues to have input. Leadership and broad involvement are important beginning in the early planning stage. They continue to be important as funds are sought and adaptations are made. Implementation, funding, and evaluation are discussed in the next chapter.

12 Implementation and Evaluation: Don't Stop Now

Introduction

At the party to celebrate its completion, the Watershed Management Plan is proudly displayed with a glossy photo on the cover. The core committee is all smiles because their work is finally done. Reaching this point is cause for celebration, for developing a management plan that is backed with strong support is a great accomplishment, even if there is more work ahead. The real value of a management plan comes from implementing the plan so the goals set forth are met. This chapter provides guidance to continue the momentum through seeking funding, sorting out conflicts and conducting ongoing evaluations that document successes and lead to adjustments that improve management.

Money and services will be needed to carry out the strategies set forth in the management plan. The necessary funds can come from a creative mix of sources, such as grants from federal, state or local government; private foundation grants; donations of labor and services; loans; taxes; sales; fees for services and bonds. Start by seeking resources for a pilot project that is easy to complete, not contentious and can be successful. Successfully obtaining small amounts of funding is important for momentum and to establish a good track record for eventually applying for larger sums. A proposal written for less than $5,000 is more likely to be funded because a funding source can give more awards in this range, and the application process is likely to be simpler than for larger projects. One or two knowledgeable volunteers can write such a small proposal. Proposals asking for larger sums or for longer time periods take serious documentation and planning and usually require involvement of professionals for data gathering and grant writing.

Proposal writing 101

Previous chapters in this publication have helped the committee to identify problems and to gather data. The management plan developed from Chapter eleven has charted a course to identify causes and sources of the problems, and charted a course to plan and implement solutions.

The committee now needs to clearly restate the primary goals and objectives defined in the management plan. There must be a clearly defined purpose before they can identify potential funding sources. What specific objectives have been identified and what is their priority or rank from most significant to least significant? Have potential strategies been identified and are those strategies supported by the available data?

Some common elements are necessary when applying for funds from any source. The first four elements, adapted from the New York State Federation of Lake Association's *Guidelines for Grant Writing* (NYSFOLA, 2000), have been developed through the management planning process.

- *Clearly identify the problem* or issue that needs funding. The State of the Lake report, described in Chapter eleven, will have documentation about what the problem is and the actual or probable causes of the problem.

- *Defend the project* as the best solution to this problem. The management plan will have identified specific strategies to address the problem.

- *Identify appropriate groups or agencies to be included as partners*. The management plan will note the collaborators needed to carry out each strategy. The core committee, public outreach groups, and diverse interest groups will have to build the relationships and knowledge base needed. Including partner groups demonstrates the importance of the project to the broader community and also shows that the expertise needed to accomplish the project is available. If your lake project is perceived as too small for a particular funding source, consider collaborating with groups representing one or two other lakes facing similar problems.

- *Draft a clear scope of the work and a realistic budget*. The management plan will provide a starting point, but the tasks and resources necessary to complete each strategy probably will need to be developed in more detail for a funding proposal. Many funding sources require matching funds or cost sharing. This may be stated as a ratio, such as one-to-one, or a percentage, such as fifty-fifty. If $5,000 was granted, and a one-to-one match required, the applicant must come up with another $5,000 in matching funds. Often the match can consist of in-kind services and volunteer time rather than cash.

Relationships developed early in the management planning process now begin to pay off. Funds from a federal program cannot serve as a match for another federal program, and state funds usually cannot serve as a match for other state funds. State funds and federal funds can sometimes be paired to make a match. This can be tricky, however, because some state money may have initially come from the federal government.

Finding the pot of gold

The last two elements of the proposal-writing process are identifying sources of funding and preparing the proposal. Sources of funding are constantly changing, but some basic information on governmental sources of funding can be helpful. Local sources of current information may include Water Quality Coordinating Committees (WQCC), county planning departments and Soil and Water Conservation Districts (SWCD). See Appendix F "Internet resources" for more information on these and the following sources.

Federal funding sources

The Federal *Clean Water Act* requires the federal government to provide financial assistance for national lake protection and restoration efforts. Prior to the early 1990s, the U.S. Environmental Protection Agency (EPA) fulfilled this mandate with the Clean Lakes Program, as described under Section 314 of the *Clean Water Act*. Since then, Congress has failed to authorize funding for the program. Some states have continued the Clean Lakes Program by using funds authorized under Section 319 of the *Clean Water Act*, usually referred to as the Nonpoint Source Program. Nonpoint Source 319 funds are an example of federal funds that are given to states for distribution. New York State has not used these funds for activities related to the Clean Lakes Program objectives.

Other federal agencies also provide support. The U.S. Department of Agriculture (USDA), through the Farm Service Agency, provides cost-sharing grants to reduce agricultural nonpoint source pollution and streambank erosion, and to protect wetlands and wildlife habitat. The Natural Resources Conservation Service (NRCS) conducts the Rural Clean Water Program. The Farm Home Administration offers guaranteed and insured loans for agricultural pollution controls, including soil conservation, farm-waste treatment and nutrient and fertilizer runoff control. The U.S. Department of the Interior, through the Forest Service and Fish and Wildlife Service, offers research grants and financial assistance for studies on forestry and habitat development, pesticide transport and watershed management practices. The U.S. Geological Survey (USGS) investigates the chemical and physical characteristics of lakes, streams and watersheds through fifty-fifty matching grants, cooperative programs and the state Water Research Institute Program. Other programs and assistance for lake and watershed protection and management may be available through the Office of Education, the Department of Commerce, the Department of Housing and Urban Development and the Office of Mining Reclamation and Enforcement.

New York State funding sources

For many years, New York State has provided funding to support lake monitoring and management projects through the Department of Environmental Conservation (DEC) and Department of State (DOS). State legislators may be able to secure funding for lake restoration projects within their districts, usually as "member items," referring to resources secured by a member of the Legislature. These funds also may be referred to as "pork barrel" items in the state budget. Some lake associations have successfully obtained member items for projects that benefit residents and taxpayers (and voters!) in a specific legislative district.

In New York State, some conservation projects involving land acquisition and facilities development have been funded by bond acts approved by statewide referendum. The 1996 *Clean Air-Clean Water Environmental Bond Act* designated $1.6 billion for a wide variety of environmental projects, including land acquisition, wastewater treatment, toxics, pollution prevention and habitat restoration. These funds were targeted to specific regional areas associated with large management plans, including Lake Champlain, Onondaga Lake, the Great Lakes and the Finger Lakes. While none of these funds were used for specific in-lake restoration activities, many of the projects funded by the 1996 Bond Act used watershed-nutrient and pollutant-control strategies outlined in Chapter nine, "Watershed management." Past Bond Act funds have been administered through DEC.

The Environmental Protection Fund (EPF) is the New York State permanent fund dedicated to addressing a broad range of environmental and community development projects. One aspect is the Local Waterfront Revitalization Program, administered annually by DOS. Current proposal categories include:

- urban waterfront redevelopment;
- preparing or implementing a waterbody management plan;
- coastal education programs;
- development of a waterfront vision and implementation of revitalizing strategies;
- stewardship funds to develop boat launch sites; and
- creating a "blueway trail."

The most significant source of EPF funding for lake improvement projects comes from the Invasive Species Eradication Grant (ISEG). This program provides funding to municipalities or not-for-profit organizations, including lake associations, to eradicate invasive plants or animals. Proposals for invasive species management through this competitive, matching-grants program are reviewed by DEC. Grants are awarded for projects most likely to achieve this eradication. The majority of these funds have been used to control terrestrial and aquatic plants.

Funding also may be available from colleges and universities for research projects and water-quality studies. The New York State Water Resources Institute at Cornell University, through the Legislature and the Department of Agriculture and Markets, can provide grants for research and educational projects for government agencies, educational institutions and not-for-profit organizations in the state. Other research institutes may be interested in funding lake research programs. Some specialized statewide organizations can also fund certain projects. The Conservation Fund, which receives money from sales of fishing and hunting licenses, may fund projects involving protection and management of fish and game populations. Certain stream or lake-improvement projects may qualify for these funds.

Local funding sources

Localities are assuming more of the cost burden for projects associated with lake management as funding from federal and state sources has diminished. Local governments, lake associations and individual lake users are taking more responsibility for generating funds that may pay for a project or may be used to match federal and state dollars.

Many communities have local organizations or foundations that supply funds regionally or to the community. Look for foundations and trusts set up by families with a long history in the area and by large employers. Different regions of the state have community foundations such as the Community Foundation of the Southern Tier. These sources may take an interest in a lake restoration project, related research or education. Instead of supplying funding, corporations may provide goods and services, such as donating older equipment or allowing staff to take a paid day of leave to do volunteer work.

Forming a special district is an equitable way to raise revenues by taxing district residents for improvements (see Chapter ten, "Legal framework"). Some associations charge dues to help cover restoration projects. Chapter eleven, "Management plan development", provides more information about both of these methods.

Some local governments are permitting developers to contribute to a fund for community parks and recreation in lieu of providing recreational land within a subdivision. Other sources of funds include a tax on property transfers and a "bed tax" on hotel and motel receipts. Room charges or "bed taxes" are typically used to support cultural activities and to promote tourism, which may depend on healthy water resources.

Additional funding sources may be found by contacting local planning departments, Environmental Management Councils and county Water Quality Coordinating Committees.

Cruising the information highway

Many funding resources and informational tips are available through the World Wide Web. The following is a sample of some of the resources available at the time of publication of this book. See Appendix F, "Internet resources," for addresses and other information.

- *Federal Grant Notices* coordinates all federal funding opportunities. A free e-mail subscription service provides daily updates on funding.
- *Foundation Center* lists public, corporate and charitable organizations that provide grant monies. Some resources are free, others are by subscription.
- *Grants News* is a monthly publication of the New York State Assembly that lists resources for grants and for training in grant writing.
- *Guidestar* provides electronic versions of IRS 990 tax forms that help with researching the funding history of grantors.
- *Libraries* associated with research facilities and institutions of higher learning may provide searchable online databases of funding sources. If access requires a user affiliation, see whether this can be met by one of the management plan partners.
- *Sea Grant New York* provides links to funding sources.

Proposal preparation

After identifying potential funding sources, the next step is writing the actual proposal. Information documented in the State of the Lake report and management plan will be invaluable in making a strong proposal for a project or program. While there are many books and online sources about writing proposals for funding, some reminders are worth noting.

- *Funding deadlines are usually firm*. Dates may be stated as the day the proposal must be received or the date by which it must be postmarked. An increasing number of applications are being accepted or required to be submitted through the Internet. Allow ample time for computer glitches.

- *Match the application to the funding source*. Use words and phrases in the proposal that make it clear the project is in line with the grantor's selection criteria. If it isn't, it is probably a waste of time to apply. The grantor may receive 200 applications and fund only 10 of them.

- *Follow the format and any guidelines about length or font size*. It may seem silly, but an applicant made the news when their proposal was rejected for having a margin less than the one-inch minimum.

- *With collaborative projects*, and most lake management projects, letters of commitment or support may be needed, with the role of each partner clearly identified. Allow plenty of time to obtain letters (and to write thank-you notes in response).

- *Invest time to think through the proposal* and it will serve as the project work plan. A poorly developed project may be funded, only to have the recipient then worry about how to do what they said they would do. A shoreline restoration projected in central New York, for example, was budgeted to cost $200,000, but grew to cost $600,000. The grant recipients had to be very creative to find the additional funds.

- *Keep in mind that the effort of writing a grant proposal is never wasted*. Once written, it can be altered as required and resubmitted at a moment's notice as different funding opportunities are found. It also provides a template for subsequent projects.

Conflict is normal

The committee has developed a Watershed Management Plan, and has found resources to carry out some of the strategies. Suddenly hesitation and conflict develop. Conflict is normal and will occur even when everyone has good intentions. While the management planning process may have evolved relatively smoothly, hackles may still rise when it comes time for implementation. People may perceive their property rights are at risk, or an agency may feel others are taking over their turf, or different interests may compete aggressively for limited funds for their pet project. Power, values, aesthetic preferences and lack of information can underlie disputes and tear a community apart.

Attempting to avoid all conflict is counterproductive. Initial avoidance may lead to the conflict reemerging with greater intensity and more entrenched positions. Success comes from understanding what underlies the conflict and seeking a constructive resolution. Long-term gains are more likely to be achieved when everyone's concerns have been heard and considered. Progress is a series of small steps forward. Not everything has to get done at the same time. Look for win-win solutions rather than fighting to be a winner while others lose. In this process, ask, "Can I live with this solution?" rather than "Do I like this solution?" It's important that everyone can live with the decision, even if it is not ideal.

The following principles are adapted from *Watershed Conflict Resolution: Some Guiding Principles* (Raymond, 1995). They can help harness conflict to create productive results and creative solutions. A neutral facilitator skilled in conflict resolution or mediation may be helpful.

- *Identify perceived threats* that underlie different positions on an issue.

- *Separate people from the problem*. Try to understand the concerns of others and then discuss underpinnings of a person's position. Don't attack the person or personality.

- *Invent options for mutual gains*. The options first put on the table may not be the full suite of possibilities. Think outside of the box, don't judge prematurely and be open to unexpected solutions.

- *Be alert to internal differences* within interest groups that are critical to their postures in a dispute. Seek to develop trust to uncover those differences.

These thought processes and attitudes do not occur all at once. They evolve throughout the typical stages in a process. It is important to develop an early rapport through communicating openness while looking for solutions that are acceptable to all. Listening is essential as each party's concerns are identified. It is useful to realize that people need to get their concerns or opinions out in the open, after which they are more willing to move forward with a discussion about alternative solutions.

The next step is to articulate the issues, which may be different from the problem as it was first perceived. It may be necessary to equalize power and share or gather information before generating, evaluating and discussing possible solutions. If an option is selected that everyone can live with, it is wise to put the agreement in writing!

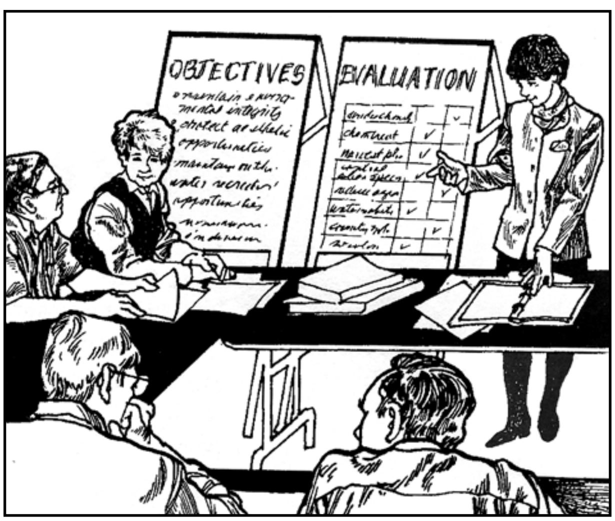


Fig. 12–1. Periodically review progress toward objectives and make adjustments as needed to the management strategies, timetable and responsible party. (CREDIT: HOLDREN ET AL, 2001)

Is the management plan working?

Securing funding and resolving conflicts are definite indications of success. A better indication is being able to report that the lake is healthier as a result of the work everyone accomplished.

Monitoring provided information on the state of the lake, helped with identifying problems and can now be used for evaluation. It still can take the form of measuring water-quality parameters, such as nutrient levels or vegetation growth, or it may expand to include a survey of lake users to assess the effects of the management plan. Monitoring the effectiveness of the management plan requires both money and time, which must be considered in the overall budget for implementing the plan.

Monitoring and evaluation need to be customized to the management goals and objectives. If the overall goals were to reduce the density of aquatic weeds to restore the lake for swimming, boating and drinking water, then macrophyte mapping would be a high priority. If the goals were to reduce soil erosion to restore clarity, then turbidity measurements might be taken as frequently as every other week. See Chapter four, "Problem diagnosis," for more details on monitoring water-quality parameters. If the primary goal was to improve fishing, then water-quality data specific to fish survival and propagation must be the focus of data collection. See Chapter five, "Fisheries management" for more details on this topic.

Some goals and objectives may address more subjective concerns such as poor aesthetics, or impaired swimming, boating or fishing. While water-quality data may provide some answers, an opinion survey of users may be valuable in quantifying perceptions. A change in response from "The lake looks bad" to "It couldn't be nicer" is a satisfying accomplishment. Opinion surveys are increasingly a component in water-quality monitoring programs.

Evaluation also may take the form of regular assessments of the project's administrative aspects. Long-term effectiveness of the management plan may require that each component be implemented on schedule and within the allocated budget. Timetables need to be continuously checked and adjusted if necessary.

Periodic review of the management plan as a whole is also valuable. Plans are sometimes referred to as "living documents" to convey the idea that they should be updated as the results of multiple strategies are monitored, as new challenges arise, as community values evolve and as new technologies or information becomes available.

Summing it up

Much can be gained from developing and implementing a management plan. The most obvious is a lake that is healthier and that brings enjoyment. Equally long-lasting benefits come from improved community awareness, involvement and partnerships. Recent studies show that communities and individuals feel more resilient when disasters occur if they are engaged in tree plantings, water-quality monitoring or other aspects of land and water stewardship. The following bits of wisdom are compiled from *A Primer for Developing a Successful Watershed Management Program* (NYSFOLA, 2001), the experience of 100 watersheds as summarized by EPA (1997), and a nationwide information-gathering effort by the Center for Watershed Protection (Schueler and Holland, 2000).

Leadership matters. A good leader who is congenial and can motivate others is pivotal. A leader who can work on the management plan as part of job duties in a relevant agency can draw more easily on the knowledge of that agency. If responsibility for the plan rests with consultants or technical staff, the result can be a lack of broader ownership and involvement by the community during the planning process and implementation.

Be patient with yourself and collaborators. If the key to real estate is location, the key to watershed management is patience. Problems didn't arise overnight, so finding a solution also will take time. Keep the larger goals in mind, but focus on smaller steps. The project is in trouble if it becomes stressful rather than a satisfying challenge for the project leader and core committee.

A good plan serves as a sound foundation. Implementation may falter if the plan is seen as an end in itself without sufficient attention or understanding of how to implement it. The plan should be realistic about the amount of funding, time and human resources available. Failure to commit the resources and authority to a long-term process can lead to the management plan being shelved in favor of other priorities. Regulatory authority rests with governments, which have influence on many areas of water quality. Management plans have failed when governmental entities were not sufficiently involved in both planning and implementation.

Keep taking small steps forward. The best plans have a clear problem statement, a vision of what is desired and a goal to obtain. Strategies need to stress watershed-management outcomes in relation to changes in behaviors and in land-use practices. Steps to achieve the goal contain specifics of who will do what, when and with what resources.

Be realistic. Plans need to cover a reasonable area and may fail if there are too many sub-watersheds and too many stakeholders. If documents are too long and too complicated, they may be ignored or misunderstood by decision-makers and citizens. A 50-square-mile watershed was once considered a reasonable scale to work with, but some are finding that working at a sub-watershed scale of 10 square miles or less is more effective. Creating plans for each tributary watershed can seem time consuming, but may bring better results.

Be adaptable. Future conditions such as land-use changes in the watershed may have profound effects on a waterbody and potential changes need to be considered during the planning and evaluation processes. Unexpected land-use changes may trigger plan revisions. Changes in standards and regulations may also require adaptation.

Celebrate success. Regardless of how small, celebrate progress as well as major milestones. Progress may include obtaining funding for a project, clearing a small but invasive weed patch, planting trees along the shoreline or a lake association developing greater participation and more enthusiasm. Make each celebration a public photo-opportunity to celebrate partnerships and encourage further participation.

PHOTOGRAPH BY DAVID F. BRAKKE

Enjoy the improvements in the lake and watershed.

ABCs of Lake Management

(Kishbaugh, 2008)

Alliances, even among odd bedfellows
Big books? Management plans don't have to be huge
Committees—not individuals—to do the work
Donated labor and expertise
Everyone has a say, even those who don't say it
Fact finding to determine the issues that focus the plan
Go back to your objectives, again and again
Help!!! Don't be afraid to ask for it
I'm in charge—make sure someone is
Just do it
Keep it local
Lawyers, guns and money—you need at least two of these
Mediation to resolve disputes among lake users
Now what? Plan two steps ahead
Ownership and why a plan fails without it
Plan a lot of time to build a management plan
Question authority (or authorities) if they have they answers
Riparian owners, the focus of many plans
Symptoms connected to causes connected to sources
Timeframes and how to build them right
User conflicts and use impairments
Volunteers to lick stamps, buy donuts, pull weeds…
Why, why, why, why, (why are we doing this)?
Xpect delays, obstacles, problems
Y y y y y y y y y (…it's worth repeating)
Zat's all I can think of

Appendix A

Citizen's Statewide Lake Assessment Program (CSLAP)

New York State contains over 7000 lakes, ponds, and reservoirs, and many of these waters are used by the public for recreation. Management practices must be implemented for individual lakes and ponds if these waters are to be protected from the increasing pressures of cultural eutrophication. Reliable, long-term information on water quality, problem areas, and use impairment is necessary before management practices can be established for ponded waters and surrounding watersheds. The New York State Department of Environmental Conservation (DEC) can gather information from less than five percent of the state's significant lakes on an annual basis, and only a few special study lakes are monitored on a regular basis.

The Citizens Statewide Lake Assessment Program (CSLAP) is a cooperative effort between the DEC and the New York State Federation of Lake Associations, Inc. (NYSFOLA). It is a scientific and educational program in which citizen volunteers are trained to collect information on ponded waters. The water chemistry samples, watershed data, and historical information are used to build long-term information bases, educate lakefront property owners, lake users, and concerned citizens, and develop management strategies specific to each CSLAP Lake.

The program coordinators from DEC and NYSFOLA conduct training for volunteers from NYSFOLA-member lake associations. Participants are tested on concepts and procedures. A sampling protocol manual contains the purpose and objective of the program and sampling instructions. Quality control checks are periodically conducted with on-site visits by the program coordinators or through additional sampling and laboratory analyses.

The program was implemented in 1986 on 25 waterbodies throughout New York State. The number of participating lake associations increased to 53 in 1988 and was at 97 in 2008. The weekly sampling efforts commence in mid-June and continue for 15 consecutive weeks through the end of October. Water-quality data include secchi desk readings for water transparency, and water samples for chemistry. Chemistry parameters analyzed are total phosphorus, nitrate nitrogen, color, pH, specific conductance, and chlorophyll a. Water samples are processed by the volunteers and sent to Upstate Freshwater Institute in Syracuse for analysis. Equipment and supplies necessary to collect and process the water samples are provided by the DEC and NYSFOLA. Each volunteer maintains a field record that is sent with the bi-weekly samples. All data are stored on a computer file at DEC.

Some participants gather additional information during the sampling season, including aquatic vegetation identification, dissolved oxygen profiles, precipitation and lake level gauging, and acidic precipitation analysis.

An annual report includes a summary of historical information and information collected during the sampling season. Additional information is available from DEC and NYSFOLA (see Appendix F, "Internet resources").

Appendix B

New York State Water Quality Classifications

Source: 6 NYCRR Part 701

Class N: Enjoyment of water in its natural condition and where compatible, as source of water for drinking or culinary purposes, bathing, fishing and fish propagation, recreation and any other usages except for the discharge of sewage, industrial wastes or other wastes or any sewage or waste effluent not having filtration resulting from at least 200 feet of lateral travel through unconsolidated earth. These waters should contain no deleterious substances, hydrocarbons or substances that would contribute to eutrophication, nor shall they receive surface runoff containing any such substance.

Class $AA_{special}$: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival, and shall contain no floating solids, settleable solids, oils, sludge deposits, toxic wastes, deleterious substances, colored or other wastes or heated liquids attributable to sewage, industrial wastes or other wastes. There shall be no discharge or disposal of sewage, industrial wastes or other wastes into these waters. These waters shall contain no phosphorus and nitrogen in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages.

Class $A_{special}$: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These international boundary waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes

Class AA: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These waters, if subjected to approved disinfection treatment, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes

Class A: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes

Class B: Suitable for primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival

Class C: Suitable for fishing, and fish propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

Class D: Suitable for fishing. Due to such natural conditions as intermittency of flow, water conditions not conducive to propagation of game fishery, or stream bed conditions, the waters will not support fish propagation. These waters shall be suitable for fish survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

Class (T): Designated for trout survival, defined by the Environmental Conservation Law Article 11 (NYS, 1984b) as brook trout, brown trout, red throat trout, rainbow trout, and splake

Appendix C

Who Owns New York State lakes?

The beds of most navigable bodies of water in the State are State-owned, including the bed of the Atlantic Ocean, Long Island Sound, Great Peconic Bay, Gardiners Bay, Hudson River, Mohawk River, St. Lawrence River, Lake Champlain, Lake Erie, Lake Ontario and the Finger Lakes (see Table C-1). Various activities relating to the use of this land, such as construction of commercial docks, moorings, piers and breakwaters or occupation of previously filled in lands, require permission from the state.

Most residential docks are probably exempt from the requirement to obtain authorization, since they are within the riparian rights of the upland owner. *Public Lands Law, Section 75* contains full information, including the specific exemptions. It is available on the website below.

Full information, applications for permits and an up-to-date list of water bodies are available from:

N.Y.S. Office of General Services
Real Estate Development – Land Management.
Corning Tower, 26th Floor
Empire State Plaza
Albany NY 12242–0001
Phone: 518–474–2195
Fax: 518–474–0011
www.LandUnderWater@ogs.state.ny.us

TABLE C-1 New York State list of state-owned bodies of water August 2006

NAME OF WATERBODY	COUNTY	DEC REGION	SPECIAL DETAIL
ARTHUR KILL RIVER	RICHMOND	2	TIDAL INFLUENCE
ATLANTIC OCEAN		1,2,3	TIDAL INFLUENCE
BARRETTS CREEK	BRONX	2	TIDAL INFLUENCE
BLACK RIVER & BAY	JEFFERSON	6	TOP OF BANK AND MLW
BLOCK ISLAND SOUND	SUFFOLK	1	TIDAL INFLUENCE
BRONX RIVER	BRONX	2	TIDAL INFLUENCE
BUSHWICK INLET	KINGS	2	TIDAL INFLUENCE
BYRUM RIVER	WESTCHESTER	3	TIDAL INFLUENCE
CANADARAGO LAKE	OTSEGO	4	MLW
CANANDAIGUA LAKE	ONTARIO/YATES	8	GRANGER V. CITY OF CAND.
CATSKILL CREEK	GREENE	4	TO FALLS ,TIDAL INFLUENCE
CAYUGA LAKE	CAYUGA	7	MLW, STEWART V. TURNEY
CHADAQUOIN RIVER	CHAUTAUQUA	9	TOP BANK
CHATEAUGAY LAKE	FRANKLIN	5	
CHAUTAUQUA LAKE	CHAUTAUQUA	9	ELEV. 1809' ORIGINAL LAKE ELEV.
CHAZY LAKE	CLINTON	5	CHAP. 289 LAWS OF 1868
CONESUS LAKE	LIVINGSTON	8	MLW
CRANBERRY LAKE	ST. LAWRENCE	6	ACQUIRED
CROSS LAKE	CAYUGA/ONONDAGA	7	WIDE AREA SENECA RIVER
EAST RIVER	NEW YORK	2	TIDAL INFLUENCE

Appendix C

TABLE C-1 New York State list of state-owned bodies of water August 2006 continued

NAME OF WATERBODY	COUNTY	DEC REGION	SPECIAL DETAIL
EASTCHESTER BAY	BRONX/NASSAU	2,3	TIDAL INFLUENCE
FORT POND BAY	SUFFOLK	1	TIDAL INFLUENCE
GARDINERS BAY	SUFFOLK	1	TIDAL INFLUENCE
GENESEE RIVER	MONROE	8	MOUTH OF RIVER
GRAVESEND BAY	KINGS	2	TIDAL INFLUENCE
GREENWOOD LAKE	ORANGE	3	ORIGINAL BED ONLY
HARLEM RIVER	NEW YORK	2	TIDAL INFLUENCE
HONEOYE LAKE	ONTARIO	8	MLW
HUDSON RIVER		VARIOUS	TIDAL INFLUENCE
IRONDEQUOIT BAY	MONROE	8	MLW
KEUKA LAKE	STEUBEN	8	MLW
KILL VAN KULL	RICHMOND	2	TIDAL INFLUENCE
LAKE CHAMPLAIN	ESSEX	5	MLW
LAKE ERIE	ERIE/CHAUTAUQUA	9	MLW
LAKE GEORGE	WARREN	5	REF. ROGERS ROCK ELEV.
LAKE MAHOPAC	PUTNAM	3	RESERVOIR BY DEED
LAKE ONTARIO		6,7,8,9	MAITLAND CASE
LITTLE NECK BAY	SUFFOLK	1	TIDAL INFLUENCE
LITTLE PECONIC BAY	SUFFOLK	1	TIDAL INFLUENCE
LITTLE SODUS BAY	CAYUGA	7	MLW
LONG BEACH BAY	NASSAU	2	TIDAL INFLUENCE
LONG ISLAND SOUND	NASSAU/SUFFOLK	1,2,3	TIDAL INFLUENCE
MAMARONECK HARBOR	WESTCHESTER	3	TIDAL INFLUENCE
MOHAWK RIVER		VARIOUS	OUTSIDE OF CANAL
NEW ROCHELLE CREEK	WESTCHESTER	3	TIDAL INFLUENCE
NEW YORK HARBOR	NEW YORK	2	TIDAL INFLUENCE
NEWTOWN CREEK	KINGS	2	TIDAL INFLUENCE
NIAGARA RIVER	NIAGARA	9	TOP BANK
NISSEQUOGUE RIVER	SUFFOLK	1	TIDAL INFLUENCE
NOYACK BAY	SUFFOLK	1	TIDAL INFLUENCE

Appendix C

TABLE C-1 New York State list of state-owned bodies of water August 2006 continued

NAME OF WATERBODY	COUNTY	DEC REGION	SPECIAL DETAIL
ONEIDA LAKE	ONEIDA	6	CANAL POOL ELEVATION
ONONDAGA CREEK	ONONDAGA	7	OLD BED OF CREEK
ONONDAGA LAKE	ONONDAGA	7	CANAL ELEVATION
ORIENT HARBOR	SUFFOLK	1	TIDAL INFLUENCE
OSWEGATCHIE RIVER	ST. LAWRENCE	6	MLW
OSWEGO RIVER	OSWEGO	7	MLW
OTISCO LAKE	ONONDAGA	7	MLW
OTSEGO LAKE	OTSEGO	4	MLW
OWASCO LAKE	CAYUGA	7	MLW
PECONIC BAY	SUFFOLK	1	TIDAL INFLUENCE
PECONIC RIVER	SUFFOLK	1	TOP BANK
PISECO LAKE	HAMILTON	5	MLW
QUEECHY LAKE	COLUMBIA	4	MLW
RAQUETTE LAKE	HAMILTON	5	MLW-DEC JURISDICTION
REYNOLDS CHANNEL	NASSAU/QUEENS	2	TIDAL INFLUENCE
SCHROON LAKE	WARREN	5	MLW
SENECA LAKE	SENECA	8	MLW
SENECA RIVER	SENECA	8	TOP BANK- SEE CANAL LANDS
SHEEPHEAD BAY	KINGS	2	TIDAL INFLUENCE
SKANEATELES LAKE	ONONDAGA	8	MLW
SMITHTOWN BAY	SUFFOLK	1	TIDAL INFLUENCE
SODUS BAY	WAYNE	8	MLW
ST. LAWRENCE RIVER		6	TOP BANK-PASNY
STONY BROOK HARBOR	SUFFOLK	1	TIDAL INFLUENCE
SUSQUEHANNA RIVER		3,4,7	TOP BANK
TIOGA RIVER		VARIOUS	TOP BANK
UNADILLA RIVER		VARIOUS	TOP BANK
WEST CANADA CREEK	HERKIMER	6	TOP BANK
WHITE LAKE	ONEIDA	6	MLW
WOOD CREEK	ONEIDA	6	TOP BANK ORIGINAL BED

THIS LIST IS NOT ALL INCLUSIVE AND IS TO BE USED ONLY AS A GUIDE

NOTES: M.L.W= MEAN LOW WATER
TIDAL INFLUENCE REFERS TO INLETS AND MEAN HIGH WATER

Appendix D

Incorporating and Insuring a Lake Association

The primary reason for a lake association to incorporate is to limit liability. The major liability concern of lake associations is being sued for "all they are worth" because of a traumatic event. The lake association's assets probably are not significant, which is why a lawsuit also names "all the officers, agents, employees and persons acting for or on behalf of the association."

Contrary to popular belief, a corporation provides very little protection from this type of exposure. This common misconception leads to the proliferation of corporations by people frightened into thinking the corporation will protect them. The only "limited liability" a corporation provides is from contractual claims, such as the corporate lease on the photocopier or other equipment.

Although a corporation may have limited liability, anyone on the Board of Directors, or who participates in the management of the corporation will have some exposure. In the past, a one-million dollar general liability policy could be purchased for a reasonable sum by even the smallest lake association. Prices have risen dramatically, however, and many New York State lake associations are finding that they cannot obtain general liability insurance at any price. This is particularly true for lake associations that own or maintain dams, swimming beaches, buoys or other "obstacles" in the lake. Some associations are even finding it difficult to obtain affordable Directors and Officers insurance that previously served as a "second best" alternative to a general liability policy.

If a plaintiff decides to sue the lake association, a way will be found. The corporate officers who were down at the beach will be sued for being negligent. The corporate personnel who supervised the allegedly negligent personnel will be sued for negligent supervision. The corporate personnel who hired the person who failed to supervise the personnel who failed to supervise will be sued for negligent hiring. Everyone else will be sued for failing to set down proper corporate policies to prevent the tragedy from happening.

A major benefit of being a corporation is the credibility it provides. Unlike the unincorporated lake association, there is a clearer structure for the association and recognized rules. This is especially useful in applying for grants, where a not-for-profit corporation is a major advantage. Some grants actually require some form of corporate entity.

An ordinary not-for-profit corporation is surprisingly simple under New York State law. Most legal offices will do the job for about $300. The nuts and bolts for setting up a not-for-profit corporation include:

1. Pick a name, such as 'Flamingo Lake Association, Inc.'. Look for the name at the New York State Department of State website to see whether it is already in use (see Appendix F, "Internet resources").

2. Locate a legal corporate service or reasonably priced attorney to create the corporation. There will be a form to fill out. Select a type of not-for-profit corporation:

    - Type A: May be formed for any lawful non-business purpose including, but not limited to civic, patriotic, political, social, fraternal, athletic, agricultural, horticultural, animal husbandry, or for a professional, commercial, industrial, trade or service association.

    - Type B: May be formed for one or more of the following non-business purposes: charitable, educational, religious, scientific, literary, cultural or for the prevention of cruelty to children or animals.

    - Type C: May be formed for any lawful business purpose to achieve a lawful public or quasi-public objective.

- Type D: May be formed when such formation is authorized by any other corporate law of this state for any business or non-business, or pecuniary or non-pecuniary, purpose or purposes specified by such other law, whether such purpose or purposes are also within Types A, B, C.

Type A is the easiest and most common type of corporation. A lake association, however, may well be able to incorporate under other types. Use Type B, for example, if charitable donations will be solicited or assets will be owned. Be sure the Purposes Clause includes those statements, and that provision is made for distribution of asses if dissolution becomes necessary. You need to consider if you are going to own any assets. Upon dissolution, the assets may be required to be divested and distributed.

A Purposes Clause is required containing information such as:

> The Corporation is established for the purpose of facilitating the proper maintenance and preservation of Flamingo Lake within the Town of Somewhere through:

1. Studies and planning of issues relating to Flamingo Lake.
2. Civic and community awareness activities.
3. Preparation and submission of applications for grants and loans intended to facilitate proper maintenance and preservation of Flamingo Lake.
4. Retaining contractors, employees, and consultants to assist and advise the corporation.
5. Opening banking and depository accounts and pay expenses incurred.
6. In-lake management programs, watershed improvements, drainage, landscaping, lighting and parking facilities, and the construction of appropriate facilities.
7. Advertising and promotional activities.
8. Advancing and promote an awareness of the importance of maintaining and preserving the scenic and historical beauty of the community and the role of Flamingo Lake.
9. Providing advice and guidance and serve as a resource to persons seeking to locate and/or invest within the community, and serve as a liaison to the municipal agencies responsible for regulating development and construction within the Flamingo Lake community.
10. Fund raising activities to help fund the corporate purposes.
11. Doing all other things necessary and appropriate, directly and indirectly, in the determination of the corporation, to facilitate appropriate activities in order to maintain and preserve Flamingo Lake within the Town of Somewhere.

The incorporation process usually takes five to ten business days. Be sure to ask for the "Black Beauty" kit. This is a handsome corporate kit, with official resolutions, impressive certificates and the corporate seal. Most lawyers do not bother to fill them out unless paid to do so by the client.

An SS-4 form is enclosed with the Black Beauty kit or it can be downloaded from the IRS website (see Appendix F, "Internet resources"). The SS-4 form is faxed to the nearest IRS office, conveniently listed in the directions on the back of the form. A Federal Employment Identification Number will then be issued to the corporation that can be used to open bank accounts and do business for the association. The number is also used if employees are hired, which gets into another whole layer of state and federal paperwork!

A bank usually has its own signature card/corporate resolution procedure to open a bank account. You may also be asked for a copy of the corporate banking resolution. This is included in the Black Beauty corporate kit. You will probably need an attorney, or at least an accountant to fill out this paperwork.

The problem of how to enforce the collection of dues from property owners around a lake is a common one for all types of lake associations. Some property owners may have "easements" or "covenants" in their deeds. For others, there may be implied Prescriptive Access rights based on usage – "squatter's rights" of access to the lake without actually owning property on the lake shore. As a rule of thumb, these easements, covenants and prescriptive rights are generally not enforceable when it comes to collecting association dues.

In 1987, however, New York State's highest court, however, provided other legal grounds for requiring recalcitrant property owners to pay their fair share of community association dues for maintenance and upkeep of community property (Seaview Association of Fire Island v. Williams, 69 N.Y. 2d 987, 517 N.Y.S. 2d 709, 1987). Although this case involved a homeowners association, it will also apply to lake and beach associations. The Court ruled:

> "Where there is knowledge that a private community homeowners' association provides facilities and services for the benefit of community residents, the purchase of property there may manifest acceptance of conditions of ownership, among them payment for the facilities and services offered. The resulting implied-in-fact contract includes the obligation to pay a proportionate share of the full cost of maintaining those facilities and services, not merely the reasonable value of those actually used by any particular resident."

A lake association should take the following steps to maximize the chances of recovering dues payments from property owners:

1. Post signs announcing the association's existence and the fact that it maintains community facilities, such as the lake itself, or whatever role it has in maintaining the lake – "Flamingo Lake (Homeowners) Associations, a Privately-maintained Community…"
2. Insure that the local realty brokers are aware of the group's requirements. Give them a stack of brochures highlighting all the things the Association provides. They will be happy to use it with prospective homebuyers.
3. Insure that the Association's budget is reasonable. A court will need to see it to ascertain that the cost of excessive activities or actions are not included.
4. Adhere to accepted procedure of by-laws.
5. Have regular, publicized meetings.
6. Hold incontestable elections at least annually.

If there is still difficulty in collecting dues payments, action can be taken through Small Claims Court for amounts up to $3000. It should be kept in mind that a lawyer is required to represent a corporation in court. The lawyer's fee may be as much or more than the dues to be collected. Another argument formerly used before the 1987 New York State Court of Appeals decision mentioned above was that the property owner is unjustly enriched, having enhanced property values as a result of the resource being maintained by the Association, even if the property owner does not actually use the lake. This argument requires proof, such as from a real estate broker, that the objector's property values are enhanced through the Association's maintenance of the community resource.

Donations to most not-for-profit corporations <u>cannot</u> be deducted for tax purposes. This should be clearly stated in any fund-raising letter or other publicity. A <u>Foundation</u> can be established, however, for the specific purpose of raising funds to help manage a lake. This was done with great success at Keuka Lake; donations are tax deductible and raising funds is much easier.

There are a number of legal and accounting issues that must be resolved when setting up a Foundation to solicit charitable donations. Clearance must be obtained from the New York State Attorney General's Charities Bureau (see Appendix F, "Internet resources"). Detailed records must be kept of the source of donations and the expenditures and distribution of the funds collected. There are very detailed regulations issued by the Federal IRS to prevent people setting up a foundation, donating money to it, taking a tax deduction, and then distributing the money back to their own private uses.

For most not-for-profit corporations, the New York State Attorney General form is only two pages long with a $25 fee. It allows fund-raising up to $5000 a year if your corporation is otherwise entitled to solicit charitable donations. If you raise more than $5000, approval is needed under Federal IRS Section 501(c)(3), which is available from the IRS website (see Appendix F, "Internet resources").

(Adapted from "Special Districts and Foundations" *in* Wright, David O. Esq. *Lake Law: A Short Overview of the Legal Rights and Obligations of Lake Associations.* Conference: New York State Federation of Lake Associations, Hamilton NY, May 1, 2004. pp. 1–4, 6–9.)

Appendix E

Interstate River Basin Commissions

New York State is a member of five Interstate River Basin Commissions or Compacts. Lake associations located in these river basins may wish to consult the databases and activities of the Commission that includes their lake, especially in those cases in which the lake drains into a tributary of a river system.

These commissions are created by compacts among the member states, and also require approval of the U.S. Congress. They rely primarily on the regulatory programs of the member states to achieve coordinated interstate resolution of water-resource problems that have multi-state effects. The three of the Commissions that include New York State also have been delegated regulatory authority as noted below. This authority is for resolving specific pollution or water-flow problems with multi-state influences when a member state is out of compliance with agreed upon standards. These Commissions also engage in extensive non-regulatory programs and activities that are more likely to be relevant to inland lake associations (see Appendix F, "Internet resources").

The three Interstate River Basin Commissions that include New York State, each with regulatory authority, are:

- Delaware River Basin Commission www.drbc.net;
- Susquehanna River Basin Commission www.srbc.net; and
- Ohio River Valley Sanitation Commission (for Allegheny River in New York State) www.orsanco.org.

The other commissions or compacts are:

- Great Lakes Commission www.wglc.org; and
- New England Interstate Water Pollution Control Commission www.neiwpcc.org.

Example of the extensive non-regulatory programs and activities of Commissions that may be of interest to lake associations include:

- Compile basin-wide water-resource databases.
- Develop comprehensive river-basin plans.
- Promote cooperation and coordination for water-resources protection.
- Research water-resources issues of regional interest.
- Advocate for achieving data management and environmental quality goals.
- Develop education and training programs.
- Set interstate water-pollution control standards.
- Support water-resource monitoring programs, including volunteer programs.
- Coordinate emergency responses to spills with interstate significance.
- Conduct surveys and studies.
- Mitigate flood damages and facilitate flood-warning programs.
- Protect and ensure adequate water-supply and stream flow.
- Develop programs to preserve, protect and enhance aquatic ecosystems.

These are the common types of programs and activities of Interstate River Basin Commissions. Check a specific Commission's website to identify programs or other activities not listed above. Some Commissions, for example, may have targeted funding programs to address water quality, invasive species, or other issues for which a lake association may be eligible.

Great Lakes Basin protection

Eight Great Lakes states have agreed on a Great Lakes-St. Lawrence River Basin Water Resources Compact. It was enacted in 2008 and congressional approval and the president's signature were obtained in September 2008. The Canadian provinces of Ontario and Quebec are nonbinding members. The Compact is designed to implement the purposes of the Great Lakes Charter (1985) and the Great Lakes Charter Annex (2001). The purpose is to "develop an enhanced water-management system that is simple, durable, and efficient, retains and respects authority within the Basin, and most importantly, protects, conserves, restores, and improves the Waters and Water-Dependent natural Resources of the Great Lakes Basin." A driving force for this Compact is to prohibit new or increased diversions of water from the Great Lakes Basin. Updates are available at www.cglg.org.

The 2001 Great Lakes Charter Annex includes directives to:

- Develop a new set of binding agreements;
- Develop a broad-based public participation program;
- Establish a new decision-making standard;
- Project review under the U.S. Water Resources Development Act of 1986; and
- Develop a decision support system that ensures the best available information.

Appendix F

Internet Resources: Government and Private

The following are resources available on the World Wide Web as of the date of this publication. Readers are reminded that URL addresses sometimes change or disappear. If a very specific URL does not work, search the base URL for the department or organization.

New York State Federation of Lakes Association, Inc. (NYSFOLA)
P.O. Box 84, Lafayette, NY 13084–0084 http://www.nysfola.org
CSLAP monitoring program. Annual conference each May. Publications: *Waterworks; Diet for a Small Lake; Guidelines for grant writing; A primer for developing a successful watershed management program.* Individual as well as lake association memberships.

New York State internet resources

New York State Government (NYS)
http://www.state.ny.us/

NYS Department of Environmental Conservation (DEC)
Albany, NY and regional offices http://www.dec.ny.gov
Annual Water Week programs. Sample publications: *Funding Sources and Tips on Grant Applications for Watershed Protection and Restoration; Watershed Planning Tools; WET: Water Education for Teachers*
NYS Section 303(d) List of Impaired Waters
http://www.dec.ny.gov/chemical/31290.html

Rules and regulations that govern DEC activities and programs
http://www.dec.ny.gov/65.html

Environmental Notice Bulletin
http://www.dec.ny.gov/enb/enb.html

Citizens Guide to SEQR
State Environmental Quality Review Cookbook
http://www.dec.ny.gov/permits/357.html

Regulations and proposed changes regarding dams on lakes
http://www.dec.ny.gov/lands/4991.html
http://www.dec.ny.gov/enviromentdec/42014.html

Fish and Wildlife web pages with morphometric maps showing bottom contours for selected New York State lakes.
http://www.dec.ny.gov/outdoor/9920.html

DEC Rotating Intensive Basin Study (RIBS)
http://www.dec.ny.gov/chemical/30951.html

NYS Water Inventory / Priority Waterbody List
http://www.dec.ny.gov/chemical/23846.html

(NYS) Invasive Species Task Force. 2003. Report.
http://www.dec.ny.gov/docs/wildlife_pdf/istfreport1105.pdf

NY State Museum (NYSM)
Cultural Education Center, Albany NY 12230 http://nysm.nysed.gov
Research into biophysical control of zebra mussels.
http://nysm.nysed.gov/press/releases/mdan.cfm

NYS Department of Audit and Control. Division of Municipal Affairs
http://www.osc.state.ny.us/local gov/pubs/liststats.htm

Handbook: *Legal requirements and Administrative Procedures for Approval of County Districts* (and) Division of Legal Services. Special District Unit. Background, trends and issues on town Special Districts in New York State.

NYS Department of Health / Environmental Laboratory (DOH)
http://www.nyhealth.gov/

Among a great deal of other helpful information, this source includes information on Appendix 75a regarding wastewater treatment, watershed rules and septic systems in general. Search specific words, such as wastewater, septic, etc.

Environmental Laboratory Approval Process (ELAP) - List of Approved Labs
http://www.wadsworth.org/labcert/elap/elap.html

NYS Office of General Services (OGS)
http://www.ogs.state.ny.us/

Enter "submerged lands" for general information on regulations for underwater lands, part of the OGS Division of Real Estate Development. However, specific information on riparian rights in lakes and how lines of ownership are drawn in lakes must be requested by writing, phoning, faxing or e-mailing.

The e-mail address is landunderwater@ogs.state.ny.us
Telephone: 518–474–2195.
Mail: NYS Office of General Services,
Division of Real Estate Development, Lands Under Water Program,
Empire State Plaza, Albany, NY 12242

NYS Office of Parks, Recreation and Historic Preservation (OPRHP)

Data on parks and navigation laws. http://nysparks.state.ny.us/

NYS Department of State (DOS)
http://www.dos.state.ny.us/

NYS Attorney General, Charities Bureau
http://www.oag.state.ny.us/bureaus/charities/pdfs/how_to_incorporate.pdf

Select "Public Institutions/Charities," and look for booklets on forming not-for-profit lake associations.

NYS Code of Rules and Regulations (NYCRR)
http://www.dos.state.ny.us/info/nycrr.htm

Guide to NYS Agency Rules and Regulations http://www.gorr.state.ny.us/main_gorr_pages/reg_guide.html

- Part 327 Copper Sulfate Uses
- Part 608 Dam Ownership
- Part 690 Lake George
- Part 701 NYS Water Quality Classification

Local Government Handbook
http://www.dos.state.ny.us/lgss/handbookpage.htm

Division of Local Government, NYS Department of State
Excellent coverage of everything you want to know about the history, structure and operation of NYS towns, villages, cities and counties. Includes special-purpose units (districts, for example), citizen participation, public services, land-use planning and regulations, as well as administration and financing.

NYS GIS Clearinghouse (NYSGIS)

Geographic and cultural data http://www.nysgis.state.ny.us

NYS Geological Survey (NYSGS)
(search word Geological Survey) http://www.ny.gov
Access to water and geologic data; *Empire State Geogram;* list of survey publications, and list of local geology guidebooks from the NYS Geological Association annual programs.
Publications Sales, Rm. 3140, Cultural Education Center, Albany, NY 12230.
(Also see US Geological Survey, http://ny.water.usgs.gov, for data about NYS water).

New York City Department of Environmental Protection (NYCDEP)
http://www.nyc.gov/html/dep/html/home/home.shtml
The Reservoir Watershed Map is at
http://www.ci.nyc.ny.us/html/dep/html/drinking_water/wsmaps_wide.shtml

Other New York internet resources

Adirondack Park Agency (APA)
http://www.apa.state.ny.us

Adirondack Lakes Survey Corporation (AKSC)
Long-term monitoring of 52 APA and high-elevation lakes http://www.adirondacklakessurvey.org/

Cayuga Lake Watershed Network
8408 Main St., P.O. Box 303, Interlaken, NY 14847 PH: 607–532–4104 http://www.cayugalake.org

Darrin Freshwater Institute (DFWI)
http://www.rpi.edu/dept/DFWI/

Finger Lakes-Lake Ontario Watershed Protection Alliance (FL-LOWPA)
Water Resources Board, 309 Lake St., Penn Yan, NY 14527 http://www.fllowpa.org

Finger Lakes Institute (FLI)
http://www.fli.hws.edu
PH: 315–781–4390 at Hobart and William Smith College,
601 Main St., Geneva, NY 14456

Finger Lakes Land Trust (FLLT)
PH: 607–275–9487, 202 East Court Street, Ithaca, NY 14850 http://www.fllt.org

Lake George Park Commission (LGPC)
http://www.lgpc.state.ny.us

New York State Geological Association (NYSGA)
http://www.nysga.net
Ph: 866–843–4449, Staten island NY 10314–6609
Annual conference; local geology guidebooks 1956–present. Also see NYS Geological Survey (above) for guidebooks from 1925–1995.

New York Rural Water Association (NYRWA)
http://www.nyruralwater.org
PH: 518–828–3155, P.O. Box 487, Clavaerack NY
To promote development, improvement, and sound operation of rural water and wastewater systems. Has a program to train for Water Operator certification.

Residents Council to Protect the Adirondacks (RCPA)
http://www.rcpa.org

Skaneateles Lake Watershed Land Protection Program (SLWLPP)
City of Syracuse Watershed Coordinator, PH: 315–473–2634 http://www.SLWLPP.org

Upstate Freshwater Institute (UFI)
P.O. Box 506, Syracuse, NY 13214 http://www.upstatefreshwater.org

Federal internet resources

U.S. Environmental Protection Agency (EPA)
http://www.epa.gov

Entry to the agency's programs, laws rules and regulations. For example, search "stormwater" or "combined sewer overflows" or "Office of Water Resources."

Terms of Environment
http://www.epa.gov/OCEPAterms

Catalog of Federal Funding Sources for Watershed Protection
http://www.epa.gov/OWOW/watershed/academy

(Draft) Handbook for Developing Watershed Plans to Restore and Protect our Waters. #EPA 841–B-05–005. National Service Center for Environmental Publications
PH: 513–489–8190 or 800-490-9198 http://www.epa.gov/ncepihom/

Environmental Technology Verification Program
http://www.epa.gov/etv/

Environmental Monitoring and Assessment Program
http://www.epa.gov/emap

Case Study on Skaneateles Lake Watershed
http://www.epa.gov/ogwdw/protect/csesty/Skaneateles.html

Archive of Water-quality Data
http://www.epa.gov/Storet

EPA Office of Water Resources. BASINS model
http://www.epa.gov/Waterscience/criteria/nutrient/database/index/html

Native Americans in New York State

EPA American Indian Environmental Office
http://www.epa.gov/Indian

EPA Tribal Nonpoint Source Program
http://www.epa.gov/owow/nps/tribal

Contact information for federally recognized tribes, tribal governments, lists of tribes with water-quality standards, and lists of resources.
http://www.epa.gov/tribalportal/index.htm
http://www.epa.gov/tribal portal/whereyoulive/region2.htm

U.S. Department of Agriculture (USDA)
http://www.usda.gov

Agricultural Research Service http://www.ars.usda.gov

(search) *Soil and Water Assessment Tool*

National Invasive Species Information Center http://www.invasivespeciesinfo.gov
Covering federal, state and international sources.
General information page: search Resource Library, then search Invasive Species lists.

U.S. Department of the Interior (USDOI)
http://www.doi.gov

U.S. Geological Survey (USGS)

Environmental and geologic data and publications http://www.usgs.gov

USGS topographical maps http://topomaps.usgs.gov

Government data specific to New York State http://ny.water.usgs.gov

U.S. Forest Service (USFS)
http://www.fs.fed.us

U.S. Natural Resources Conservation Service (NRCS)
http://www.nrcs.usda.gov

U.S. Army Corps of Engineers (USACE)
Eutrophication model (search word BATHTUB; "all Corps sites") http://www.usace.army.mil

U.S. Department of Commerce
http://www.commerce.gov

U.S. National Weather Service (NOAA)
http://www.nws.noaa.gov

U.S. Federal Energy Regulatory Commission (FERC)
http://www.ferc.gov

U.S. Department of Homeland Security (DHS)
http://www.dhs.gov

U.S. Federal Emergency Management Agency (FEMA)
http://www.fema.gov

U.S. Federal Internal Revenue Service (IRS)
http://www.irs.gov

Other internet resources

Interstate River Basin Commissions (and) Great Lakes Basin Compact http://www.glc.org/about/glbc.html

Delaware River Basin Commission http://www.drbc.net

Susquehanna River Basin Commission http://www.srbc.net

Ohio River Valley Sanitation Commission (for Allegheny River in New York State) http://www.orsanco.org

Great Lakes Commission http://www.wglc.org

New England Interstate Water Pollution Control Commission http://www.neiwpcc.org.

Great Lakes-St. Lawrence River Basin Water Resources Compact http://www.cglg.org

Organizations and universities internet resources

North American Lake Management Society (NALMS)
413 Vernon Blvd., Suite 100, Madison, WI 53705–5443 http://www.nalms.org
Annual conference. Publications: *Lakeline; Lake and Reservoir Management; State-by-state List of Lakes and Governmental Organizations Publications Concerning Watershed Management*

Center for Environmental Information (CEI)
55 St. Paul Street, Rochester, NY 14604 PH: 585–262–2870 http://www.ceinfo.org

Center for Watershed Protection (CWP)
8390 Main Street, 2nd floor, Ellicott City, MD 21043 http://www.cwp.org
Stormwater Center http://www.stormwatercenter.net
"Helping others to protect and restore our nation's streams, lakes, rivers and estuaries." Publications catalog

Center for Urban Ecology and Sustainability (CUES)
http://www.entomology.umn.edu/cues/gervais/gervais2.html
Sections on designing and maintaining sustainable shoreland landscaping

Center for Aquatic Plant Management (barley straw research) (CAPM)
CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB, England http://www.capm.org.uk

Aquatic Plant Management
(barley straw research) http://www.btny.purdue.edu/pubs/APM/APM-1–W.pdf

National Sanitation Foundation (NSF)
International food safety, water quality, public health and product testing http://www.nfg.org

Massachusetts Alternative Septic system Testing Center
PH: 508–291–3625 http://www.buzzardsbay.org/eitmain
Testing of on-site septic systems

Minnesota Department of Natural Resources
PH: 1–800-657–3757 http://www.minnesotasbookstore.com
Lakescaping for Wildlife and Water Quality (book)
Restore Your Shore (cd and guide)

University of Minnesota Extension Service http://www.umn.edu
Sustainable urban landscape information series http://www.sustland.umn.edu/design/water3.html
Shoreland landscaping series (four parts) http://www.extension.umn.edu/distribution/natural resources/DD7357.html
Native plants for sustainable landscapes http://www.extension.umn.edu/distribution/horticulture/DG7447.html

University of Wisconsin Extension Service http://www.uwex.edu
Shoreland restoration (Step-by step on website)
A Growing Solution (video)

Audubon Society http://www.audubon.org

Ecological Society of America http://www.esa.org

Izaak Walton League http://www.iwla.org

Natural Resources Defense Council http://www.nrdc.org

The Nature Conservancy http://www.nature.org

New York State Conservation Council http://www.nyscc.com

Sierra Club http://www.sierraclub.org

Grant funding lists and writing training

Federal Grants aid http://www.fedgrants.gov

Foundation Center http://www.fdncenter.org

Grants Action News http://www.assembly.state.ny.us.gan/

Guidestar http://www.guidestar.org

Sea Grant New York http://www.seagrant.sunysb.edu/funding

Internet resources for copyrighted images

In addition to government organizations listed above (such as DEC and EPA), a number of individuals and organizations gave permission to use their copyrighted material as images in various chapters of this publication. The copyright remains with the government agency, individual or organization.

Carl Heilman II / Wild Visions, Inc. http://www.carlheilman.com
Gave permission to use his photograph of Mirror Lake on the cover, the title page and in the table of contents. The copyright remains his.

Garrett Crow and Barre Hellquist Gave permission to use their line drawings of invasive plants (see Appendix G for Crow and Hellquist, 2000).

Roy Reehil, The Forager Press, LLC http://www.theforagerpress.com
Gave permission to use his photographs. The copyrights remain his.

North American Lake Management Society (NALMS) http://www.nalms.org
Gave permission to use images from their book *Managing Lakes and Reservoirs.* (see Appendix G for Holdren et al, 2001)

The Iowa Department of Natural Resources http://www.iowadnr.com
Gave permission for the picture of the spiny water flea in Chapter three.

Eric Engbretson, U.S. Fish and Wildlife Service http://www.bugwood.org
He is the photographer and gave permission for the grass carp image in Chapter six.
http://www.forestryimages.org/browse/detail.cfm?imgnum=5371496

The University of Florida Center for Aquatic and Invasive Plants http://www.aquat1.ifas.edu
Gave permission to use their line drawings of water lilies and eel grass in Chapter six.

American Society of Limnology and Oceanography http://www.aslo.org
Wayne Wurtsbaugh, Utah State University (picture of woody debris in Chapter five)
David F. Brakke, James Madison University (last picture in the book).

Original cartoons were provided by Mark Wilson http://www.EmpireWire.com
He is a member of the Shore Owners' Association of Lake Placid, and the copyright remains his.

Appendix G

References Cited

The following are the resources specifically cited in the various chapters. Also be sure to check resources listed in Appendix F, "Internet resources" and Appendix H, "Additional readings". The New York State Federation of Lake Associations (www.nysfola.org) is a good resource for information and publications, and the North American Lake Management Society (www.nalms.org) has an extensive publications list.

Introduction

NYSFOLA. 2001. *A primer for developing a successful watershed management program.* Lafayette, NY: New York State Federation of Lake Associations in cooperation with New York State Department of Environmental Conservation.

Chapter one

McPhee, John. 1986. *Rising from the Plains*. New York, NY: Farrar, Straus and Giroux.

Thoreau, H.D. 1854. *Walden*. New York, NY: HarperCollins Publishers.

Chapter two

Eichler, L. 2004. "Annual report 2003." *Darrin Freshwater Institute Aquatic Plant Identification Program.* 2004–1. Troy, NY: Rensselaer Polytechnic Institute.

Galusha, D. 2002. "Tunneling into history: building New York City's reservoir system." *The Conservationist*. August 2002, pp. 2–6.

Landers, J. 2006. "New life for Onondaga Lake." *Civil engineering* 76:5 (64–86). May 2006

NYCDEP. *Reservoir watershed map.* New York City Department of Environmental Protection. (http://www.nyc.gov/html/dep/html/drinking_water/wsmaps_wide.shtml)

6 NYCRR Part 701. "New York State Water Quality Classifications." *New York Code of Rules and Regulations.*

NYSDEC. 1982. *Gazetteer of New York State lakes, ponds and reservoirs*. Albany, NY: NYSDEC Division of Water.

NYSDEC. 1987. *Characteristics of New York State Lakes - gazetteer of lakes, ponds, and reservoirs. 3d ed.* Albany, NY: NYSDEC Division of Water.

NYSDEC. 2004a. Unpublished data. Albany, NY: NYSDEC Division of Water.

NYSDEC. 2004b. *New York State Waterbody Inventory / Priority Waterbody List*. Albany, NY: NYSDEC Division of Water. (http://www.dec.ny.gov/chemical/23846.html)

NYSDEC. 2007. Unpublished data. Albany, NY: NYSDEC Division of Water.

U.S. Census Bureau, 2000. *State and County QuickFacts*. Washington, D.C.: U.S. Census Bureau.

U.S. EPA. 2007. *Level III ecoregions in New York State*. Washington, DC: Environmental Protection Agency, Office of Water.

Chapter three

Chautauqua Lake Association. 2005. Unpublished handout. Chautauqua NY.

Cohen, A.N. and A. Weinstein. 2001. *Zebra mussel's calcium threshold and implications for its potential distribution in North America.* San Francisco, CA: San Francisco Estuary Institute.

Coin, G. 2007. "Blue-green algae on Craine Lake tests as toxic." *Syracuse Post- Standard.* September 15, 2007.

Coin, G. 2008. *"Toxic algae expected to return to Craine Lake."* Syracuse, NY: *Syracuse Post-Standard.* May 29, 2008.

Crow, G.E. and C.B. Hellquist. 2000. *Aquatic and wetland plants of northeastern North America.* 2 volumes. Madison, WI: Univ. Wisc. Press.

Effler, S.W., R.K. Gelda, and C. W. Matthews. 2001. "Implications of industrial loads for ammonia pollution in an urban lake". *Water Environ Res*. 2001 Mar-Apr; 73(2):192–203.

Ingmire, S. 2007. Personal communication about Craine Lake. Wampsville, NY: Madison County Department of Health.

Kishbaugh, S.A. 2008. *Personal communications regarding Craine lake.* Albany NY: NYSDEC Division of Water.

McSpirit, K. 1997. *Common nuisance aquatic plants in New York State*. Albany, NY: NYSDEC.

NYSDEC. 2002. *Priority Waterbody List*. Albany, NY: NYSDEC Division of Water. (http://www.dec.ny.gov/chemical/23846.html)

NYSDEC, 2004. Personal communications and unpublished data. Albany, NY: NYSDEC Division of Water.

NYSDEC, 2005. Information from NYSDEC website regarding lead fishing weights and loons. NYSDEC. (available at www.dec.ny.gov/outdoor/7908.html)

NYSDEC. 2008. Information re northern snakehead from NYSDEC website. Albany, NY: NYSDEC. (available at www.dec.ny.gov) (www.dec.ny.gov/animals/45488.html) and (www.dec.ny.gov/animals/45493.html)

NYSDEC and NYSDAM. 2005. *Final report of the New York State Invasive Species Task Force.* Albany, NY: New York State Department of Environmental Conservation (and) New York State Department of Agriculture and Markets.

Potera, C. 2000. "Drugged drinking water." *Environmental Health Perspectives* 108 (10). October, 2000.

Schneider, R. 1998. Personal communictions about acid rain impacts to macrophytes. Ithaca, NY: Department of Natural Resources, Cornell University.

Tobissen, P. and E. Wheat. 2000. "Long and short-term effects on waterfowl on Collins Lake, an urban lake in upstate New York". *Lake and Reserv. Manage*. 16 (4): 340-344.

Chapter four

Carlson, R.E. 1977. "A trophic state index for lakes." *Limnol. Oceanogr*. 22: 361–9

Dillon, P.J. and F.H. Rigler. 1974. "A test of a simple nutrient budget model predicting the phosphorus concentration in lake water." *J. Fish. Res. Board C*an. 31: 1771–8

Lord, P.H., R. L. Johnson and K.Wagner. 2005. "Effective aquatic plant monitoring: data and issues from Waneta Lake." Conference: Northeast Aquatic Plant Management Society, Saratoga Springs, NY.

Madsen, J.D. and J.A. Bloomfield. 1993. "Aquatic vegetation quantification symposium: an overview." *Lake Reservoir Mgmt* 7 (2). Feb. 1993.

NYSDEC, 1999. *Water quality regulations: Surface water and groundwater classifications and standards.* Albany, NY: NYSDEC Division of Water.

NYSDEC. 2002. *Priority Waterbody List*. Albany, NY: NYSDEC Division of Water.

NYSDEC. 2008. *New York State Section 303(d) list of impaired waters*. Albany, NY: NYSDEC Division of Waters.

Vollenweider, R.A. 1975. "Input-output models with special reference to the phosphorous-loading concept in limnology." *Schweiz Z Hydrol 37:* 53–84.

Vollenweider, R.A. 1976. "Advances in defining critical loading levels for phosphorus in lake eutrophication." *Mem. Inst. Ital. Idrobiol*. 33: 53–83.

Chapter five

Foster, John. 2006. Personal communications regarding fisheries management. Cobleskill, NY: SUNY Cobleskill.

NYSDEC. 1941. (Fish images from) *1927–1940 New York Biological survey.* Albany NY: New York State Department of Environmental Conservation.

NYSDEC. 2008. *New York freshwater fishing; 2008–09 official regulations guide.* Albany, NY: New York State Department of Environmental Conservation.

Chapter six

Baker, J.P., H. Olem, C.S. Creager, M.D. Marcus, and B.R. Parkhurst. 1993. *Fish and Fisheries Management in Lakes and Reservoirs*. EPA 841–R-93–002. Washington, DC: Terrene Inst. U.S. Environ. Prot. Agency.

Boylen, C.W., L.W. Eichler, and T.B. Clear. 1995. "An aquatic plant assessment of Saratoga Lake". Troy, NY: Rensselaer Polytechnic Institute.

Carson, Rachel. 1962. *Silent spring.* Boston, MA: Houghton Mifflin. 368 p.

Conesus Lake Association. 2002. *The Conesus Lake dockside/near shore lake weed and algae treatment guide.* Lakeville, NY: The Association.

Cooke, G.D., E.B Welch, S.A. Peterson, and P.R. Newroth. 1993. *Restoration and Management of Lakes and Reservoirs.* Boca Raton, FL: Lewis Publishers.

Darrin Freshwater Institute. 1991. "Hand harvesting Eurasian watermilfoil in Lake George". DFWI Rep. 91–7. Troy, NY: Rensselaer Polytechnic Institute.

Doing, R. 2005. Personal communication. Plymouth Reservoir Lot Owners Association.

Eichler, L.W., R.T. Bombard, J.W. Sutherland, and C.W.Boylen. 1995. “Recolonization of the littoral zone by macrophytes following the removal of benthic barrier material”. *J Aquat Plant Manage*. 33: 51–54

Eichler, L.W. and C.W. Boylen. 2002. *A review of physical aquatic plant management efforts for Lake George, New York in 2002. Technical Report 2002.* Bolton Landing, NY: Darrin Freshwater Institute.

Eichler, L.W. 2005. Personal communication. Bolton Landing, NY: Darrin Freshwater Institute.

ENSR International. 2001. “Draft supplemental environmental impact statement for the control of Eurasian watermilfoil in Lamoka and Waneta Lakes with fluridone”. Document No. 8734–352–03. Willington, CT: ENSR International.

Enviromed Associates, 1982. “Final report: the monitoring of the restorational dredging of Ann Lee Pond, Colonie, New York”. *USEPA Phase II final report*. Scotia, NY: U.S. Environ. Prot. Agency.

Grim, J. 1996. *Supplement to Adirondack Environmental Assessment Form: Environmental Impacts of Stocking Triploid Grass Carp.* Unpublished report, Rhinebeck, NY: Northeastern Biologists.

Grim, J. 2003. Personal communications. Rhinebeck, NY: Northeastern Biologists.

Hardt, F.W., G. Hodgson, and G.F. Mikol. 1983. “Saratoga Lake Phase I Diagnostic-Feasibility Study and Management Plan”. *USEPA Clean Lakes Program*. U.S. Environ. Prot. Agency. 236pp

Holdren, C., W. Jones, and J. Taggart. 2001. *Managing Lakes and Reservoirs*. Madison, WI: N. Am. Lake Manage. Soc. and Terrene Inst., in coop. Office of Water Assessment. Watershed Protection. Division. U.S. Environ. Prot. Agency. Madison, WI.

Johnson, R., P. Van Dusen, J. Toner and N. Hairston Jr. 2000. “Eurasian watermilfoil biomass associated with insect herbivores in New York.” *J. Aquat. Plant Manage. 38: 82–88.*

Kangasniemi, B.J. 1993. “Observations on herbivorous insects that feed on *Myriophyllum spicatum* in British Columbia”. *Lake restoration, protection and management*. EPA 440/5–83–001. Proceedings, 2d annual conference, North American lake Management Society, U.S. Environ. Prot. Agency.

Kishbaugh, S.A. 2002. “Assessment of Eurasian watermilfoil control with Sonar at Snyders Lake, NY: 1998–2001”. Conference: Northeast Aquatic Plant Management Society, Suffern NY.

Kishbaugh, S. 2004. *“Aquatic plant survey of Adirondack Lake”.* Unpublished report submitted to the Hamilton County Soil and Water Conservation District. *Albany, NY.*

Kooyoomjian, K.J. and N.L Clesari. 1973. *Perception of water quality by selected groupings in inland water-based recreational environments. RPI report 73–7.*Troy, NY: Rensselaer Polytechnic Institute

Lincoln Pond Study Group. 2002. Personal communication. Elizabethtown, NY: Essex County Cooperative Extension.

Lord, P.H. 2004. “Biocontrol of Eruasian watermilfoil in central New York.” Occasional paper #38. Oneonta, NY: SUNY Oneonta Biological Field Station.

Lord, P.H., R.L. Johnson and M.E. Miller. 2004. “Waneta Lake 2003 and 2004 plant community structure research subsequent to 2003 fluridone treatment for control of Eurasian watermilfoil”. Ithaca, NY: Cornell University.

Lord, P.H., R. L. Johnson and K.Wagner. 2005. “Effective aquatic plant monitoring: data and issues from Waneta Lake”. Conference: Northeast Aquatic Plant Management Society, Saratoga Springs, NY

Lycott Envrionmental, 2006. *Lake George integrated aquatic plant management program.* Annual report. Southbridge MA.

Lyman, L. and L. Eichler. 2005. “Successes and Limits of Hand Harvesting, Suction Harvesting, and Benthic Barriers in Lake George, NY “. Conference: Northeast Aquatic Plant Management Society, Saratoga Springs NY.

Martin, M.R. and C. Stiles. 2005. “The use of hand-harvesting to control Eurasian milfoil in Upper Saranac Lake, Franklin County, NY”. Conference: Northeast Aquatic Plant Management Society, Saratoga Springs NY.

NYSDEC. 2000. “Warmwater Lakes and Ponds.” *Annual Report, 1999/2000.* NYS. Albany, NY: NYSDEC Bureau of Fisheries.

Samuels, A. 2005. Personal communications. Syracuse, NY: Cornell Cooperative Extension – Onondaga County.

Tobiessen, P., Swart, J. and S. Benjamin. 1992. "Dredging to control curly-leafed pondweed: A decade later". *J. Aquat. Plant Manage*. 30: 71–72.

Wu, M.Y. and J. Wu. 2007. "Can ultrasound eradicate water chestnut?" *Ecol. Restor. 25(1): 64–65.*

Chapter seven

Albright, M.F., W.N. Harman, W. T. Tibbits, M.S. Gray, D.M. Warner and R.J. Hamway. 2004. "Biomanipulation: A classic example in a shallow eutrophic pond." *Lake and Reserv. Manage.* 20(3): 181–187.

Barbiero, R.P., S.L. Ashby, and R.H. Kennedy. 1996. "The effects of artificial circulation on a small northeastern impoundment." *Wat. Res. Bullet.* 32 (3): 575–584.

Bisogni, J.J. and S.L. Arroyo. 1991. "The effect of carbon dioxide equilibrium on pH in dilute lakes." *Water Research,* 25, no.2, 185–190.

Callinan, C. 2004. Personal communication regarding Cornell lake source cooling project at Cornell University. Albany, NY: NYSDEC Division of Water.

Cappiello, D. 2000."Lake George zebra mussels out-muscled." *Albany times Union. Albany NY 8/30/00.*

Collins, J. 2004, 2007. *Report to the NYSDEC on the alum treatment of Kinderhook Lake.* Unpublished report, Niverville, NY

DeMelo, R., R. France and D. J. McQueen. "1992. Biomanipulation: Hit or myth?" *Limnol. Oceanogr*. 37(1):192–207.

Drenner, R. W. and K. D. Hambright. 1999. "Biomanipulation of fish assemblages as a lake restoration technique." *Arch. Hydrobiol*. 146:129–165.

Foss, S. 2008. "Biopesticide may solve zebra mussel problem." Schenectady NY: *The Sunday Gazette.* November 12, 1008.

Holz, J. 2000. "Controlling pond algae with barley straw." Nebr. Coop. Ext. NF400-429.

Kishbaugh, S.A. 1985. *Sediment-water interactions in acidified Adirondack lakes neutralized by sodium bicarbonate.* M.S. thesis. Ithaca, NY: Cornell University.

Kortmann, R. and P.H. Rich. 1994. "Lake ecosystem energetics: The missing management link." *Lake Reserv. Manage*. 8:77–97

Lake George Association Newsletter, May 2003. "Drop a brick on zebra mussels." Lake George, NY: The Association. (http://www.lakegeorgeassociation.org/html/zebra_mussels.htm)

Martialay, M. 2005. "Collins Park set to open on schedule." *The Daily Gazette:* 6/1/05. Schenectady, NY.

Martin, M. 2004. *Diagnostic feasibility study and lake & watershed management plan for Lake Rippowam, Lake Oscaleta, and Lake Waccabuac.* Saranac Lake, NY.

Marx J., 2006. Village of Scotia. Personal communications regarding Collins Lake. Scotia, NY: Village of Scotia Parks Department.

NYSDEC. 1990. *Final general environmental impact statement on the New York State Department of Environmental Conservation program of liming selected acidified waters*. October, 1990, Albany NY: NYSDEC.

NYSDEC, 2004. Unpublished data. Albany, NY: NYSDEC Division of Water.

NYSDEC. 2008. Unpublished data. Albany, NY: NYSDEC Division of Water.

Stewart, K. 1986. Personal communication regarding copper sulfate. Buffalo, NY: SUNY Buffalo Department of Biological Sciences.

Three Lakes Council, Inc. 2001. *Aerators.* Unpublished information. (Available at www.threelakescouncil.org/aerators.htm)

Tilman, D. 1982. *Resource Competition and Community Structure*. Princeton Univ. Press, Princeton, NJ.

Yusco, D. 2000. "Muscle power meets mussel power." *Albany Times Union. Albany NY, 6/18/00.*

Chapter eight

Allen, P. 2005. "More boaters using state canals." *The Daily Gazette,* 10/5/05. Schenectady, NY

Azzopardi, R. 2006. "Canal boaters get toll-free summer." *The Daily Gazette*, 3/23/06. Schenectady, NY

Clothier, T. 2005. "What's up, dock? Local dock and shoreline regulations". Presentation to the New York State Federation of Lake Associations Annual Conference. Hamilton, NY.

Gurnett, K. 2005. "Slow your engines". *Capital Region Times Union,* 5/15/05. Albany, NY

Hardin, Garrett. 1968. "The Tragedy of the commons". *Science* 162:3589 (1243–1248). Dec. 13. 1968.

Kelley, G. 2005. Personal communication about dock maintenance. DeRuyter, NY: Tioghnioga Lake Association.

NYSDEC, 1989. *Guidelines for design of dams*. Albany, NY: NYSDEC Division of Water. 31 pp.

U.S. Department of Agriculture. 1982. *Ponds- planning, design, construction*. Agricultural handbook number 590. Washington, D.C.

6NYCRR, Part 646. Lake George.

6NYCRR, Part 608. Dam ownership

NYS Environmental Conservation Law, Article 15–0517. Dam ownership.

NYS Municipal Law, Section A. Docks.

NYS Navigation Law. Article 4, Part 1. Section 45. Reckless operation of a vessel: speed.

NYS Public Lands Law, Section 75. Dock construction permits

Chapter nine

Bishop, P.L., W.D. Hively, J.R. Stedinger, M.R. Rafferty, J.P. Lojpersberger, and J.A. Bloomfield. 2005. “Multivariate analysis of paired watershed data to evaluate agricultural best management practices effects on stream water phosphorus” *J. Environ. Qual*. 34: 1087–1101.

Halden, R.U. and D.H. Paull. 2005. “Co-occurrence of triclocarban and triclosan in U.S> water resources.” *Environment, Science and Technology* 39: 1420-1426.

Hayhoe, et al. 2006. *Climate change in the U.S. Northeast.* Union of Concerned Scientists. (http://www.climatechoices.org/assets/documents/climatechoices/NECIA_climate_report_final.pdf)

Kolpin, E.W., E.T. Furlong, M.T. Meyer, E.M. Thurman, S.D.Zaugg, L.B. Barry and H.T. Buxton. 2002. “Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999–2000: A national reconnaissance.” *Environment, Science and Technology* 36: 1202–1211.

Levy, S.B. 2001. *Antibacterial household products: cause for concern.* Emerging infectious diseases 7 conference. 3 Supp. Conference Proceedings: 512–515.

Marr, L. 1991. “Save the River! It’s Not a Sewer!” *Waterworks* 7(1). Winter, 1991. Syracuse NY: NYSFOLA.

Rapid watershed planning handbook: A comprehensive guide for managing urbanizing watersheds. 1998. Staff of the Center for Watershed Protection for the U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds (Region V). Ellicott, MD: Center for Watershed Protection.

Solomon, K.R. 1998. “Endocrine-modulating substances in the environment: the wildlife connection.” *International Journal of Toxicology* 17: 159–172.

U.S. Department of Agriculture. 1975. *Erosion and sediment control inventory*. Syracuse, NY: USDA Soil Conservation Service.

Wilson, B.A., V.H. Smith, F. Denoyelles, Jr., and C.K. Larive. 2003. “Effects of three pharmaceutical and personal care products on natural freshwater algal assemblages.” *Environment, Science and Technology* 37: 1713–1719.

Winter, T.C., J.W. Harvey, O.L. Franke, and W.M. Alley. 1998. “Ground water and surface water: a single resource.” U.S. Geological Survey Circular 130. Washington DC: U.S. Geological Survey.

Chapter ten

The chapter was adapted from the 2004 conference presentation of David O. Wright, combined with the working knowledge and experience of committee member Lyle Raymond.

Wright, David O. Esq. 2004. “Lake Law: A Short Overview of the Legal Rights and Obligations of Lake Associations”. Conference: New York State Federation of Lake Associations, Hamilton NY.

Holdren, C., W. Jones, and J. Taggart. 2001. *Managing Lakes and Reservoirs*. Madison, WI: N. Am. Lake Manage. Soc. and Terrene Inst., in coop. Office of Water Assessment. Watershed Protection. Division. U.S. Environ. Prot. Agency. Madison, WI.

U.S. EPA. 2008. *Handbook for developing watershed plans to restore and protect our waters*. EPA 841–B-08–002. Washington DC: U.S. Environmental Protection Agency, Office of Water.

Chapter eleven

Dillman, Don A. 2000. Mail and telephone surveys: The Tailored design method. 2d ed. New York: John Wiley & Sons. 464 p.

Belden Russonello & Stewart. 2002. *Protecting the Great Lakes: Responsibility to awareness to action. Analysis of public opinion in Great Lakes states*. [Prepared] for the Biodiversity Project and the Joyce Foundation. Washington DC: Belden Russosnello & Stewart.

Blankenship, Karl. 2002. “Getting the message out key to restoration, cleanup efforts.”Seven Valleys PAA: *Bay Journal*, published by the Alliance for the Chesapeake Bay. (www.bayjournal.com/article.cfm?article=793)rke, Wendy. 2002.

Clarke, Wendy. 2002. *Window on the Chesapeake: the Bay, its people and places*. Newport News VA: Mariners' Museum; Charlottesville VA: Howell Press. (excerpt about sneaker index is available at www.baygateways.net/sneakerindex.cfm)

Mead, Margaret. Used Courtesy of The Institute for Intercultural Studies, Inc., New York. (institute@interculturalstudies.org)

NYSFOLA. 2001. *A primer for developing a successful watershed management program.* Cortland, NY: New York Federation of Lake Associations (and) New York State Department of Environmental Conservation. 32 p.

Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management. Washington DC: Federal Register 65, no. 202, October 18, 2000, p. 62571. (www.gpoaccess.gov.) Find "Federal Register"; search "page 62571".

U.S. EPA. 2008. *Handbook for developing watershed plans to restore and protect our waters*. EPA 841–B-08–002. Washington DC: U.S. Environmental Protection Agency, Office of Water.

Chapter twelve

Holdren, C., W. Jones, and J. Taggart. 2001. *Managing Lakes and Reservoirs*. Madison, WI: N. Am. Lake Manage. Soc. and Terrene Inst., in coop. Office of Water Assessment. Watershed Protection. Division. U.S. Environ. Prot. Agency. Madison, WI.

Kishbaugh, S. 2007. "ABCs of lake management" *in Diet for a small lake.* 2d ed. Lafayette, NY: New York State Federation of Lake Associations.

NYSFOLA. 2000. *Guidelines for grant writing.* New York State Federation of Lake Associations. Available at www.nysfola.org.

NYSFOLA. 2001. *A primer for developing a successful watershed management program.* Lafayette, NY: New York State Federation of Lake Associations (and) New York State Department of Environmental Conservation. 32 p. Available at www.nysfola.org

Raymond Jr., Lyle S. (1995). *Watershed conflict resolution: Some guiding principles.* Ithaca, NY: Cornell Cooperative Extension, Local Government Program/ Center for the Environment, Cornell University.

Schueler, T. and H. Holland, editors. 2000. *The practice of watershed protection: Techniques for protecting our nation's streams, lakes, rivers, and estuaries.* Ellicott City MD: Center for Watershed Protection. Available at www.cwp.org.

U.S. EPA. 1997. *Top 10 watershed lessons learned.* EPA# 840-F-97–001. Washington DC: Environmental Protection Agency, Office of Water.

Appendix C

Bauder, Alan C. 2006. New York State list of state-owned bodies of water. Albany, NY: Office of General Services, Natural Resources.

Appendix D

Wright, David O. Esq. 2004. "Lake Law: A Short Overview of the Legal Rights and Obligations of Lake Associations". Conference: New York State Federation of Lake Associations, Hamilton NY.

Appendix E

Raymond Jr., Lyle S. 2008. Personal communication regarding the Interstate River Basin Commissions.

Appendix H

Additional Readings

The following are resources which may be helpful in developing lake and watershed management plans. Also check the resources listed in Appendix F, "Internet resources" and Appendix G, "References cited." The New York State Federation of Lake Associations (www.nysfola.org) is a good resource for information and publications, and the North American Lake Management Society (www.nalms.org) has an extensive publications list.

The NYSFOLA 2001 publication, "*A primer for developing a successful watershed management program*" is available from the web (www.nysfola.org). It contains an extensive list of references on watershed management planning tools, grant writing tools, survey writing tools, related organizations, and a sampling of "lake books". Many are available from NYSFOLA and others are available from the organizations listed or from your local library or college.

Anderson, R.O. & R. M. Neumann. 1996. "Length, Weight and Associated Structural Indices". *In* B.R. Murphy and D. W. Willis, editors. *Fisheries techniques*, 2nd edition. Bethesda, Maryland: American Fisheries Society. Pages 447–481.

Bloomfield, J. 1980. *Lakes of New York State*: Volumes I - III. New York, NY: Academic Press, Inc.

Caduto, M. J. 1985. *Pond and brook: a guide to nature in freshwater environments*. Englewood Cliffs, NJ: Prentice Hall Publishers.

Callinan, C. 2001. *Water quality study of the Finger Lakes*. Albany NY: New York State Department of Environmental Conservation, Division of Water. (www.dec.state.ny.us)

Cooke, G.D., E.B. Welch, S.A. Peterson, and P.R. Newroth. 1993. *Restoration and Management of Lakes and Reservoirs.* Boca Raton, FL: Lewis Publishers.

De La Cruz, D. 2006. "Gov't makes it easier to kill Canada geese without permit." Schenectady, NY: The Associated Press reprinted in *The Daily Gazette*. 8/18/06.

Effler, S. W., S. R. Boone, C. A. Siegfried and S. L. Ashby. 1998. "Dynamics of zebra mussel oxygen demand in Seneca River, New York." *Environmental Science and Technology* 32(6):807–812.

Eichler, L. 2004. Annual Report 2003: Darrin Freshwater Institute Aquatic Plant Identification Program. 2004–1. Troy, NY: Rensselaer Polytechnic Institute.

Green, D.L. 1989. *Centrarchid sampling manual*. Bridgeport NY: Cornell Warm Water Fisheries Unit, Cornell Biological Field Station.

Korth, R., S. Borman and J. Temte. 1997. *Through the looking glass: A field guide to aquatic plants.* Madison, WI: University of Wisconsin Press.

Magnuson, J.J., D.M. Robertson, B.J. Benson, R.N. Wynne, D.M. Livingstone, T. Arai, R.A. Assel, R.G. Barry, V. Card, E. Kuusisto, N.G. Granin, T.P. Prowse, K.M. Stewart, and V.S. Vuglinski. 2000. "Historical trends in lake and river cover in the northern hemisphere." *Science* 289: 1743–1746.

McComas, S. 1993. *Lake Smarts: The First Lake Management Handbook*. Washington DC: Terrene Inst. in cooperation. with U.S. Environ. Prot. Agency.

McComas, S. 2003. *Lake and pond management guidebook*, Boca Raton, FL: Lewis Publishers.

NYSDEC. 1985. *Stream corridor management: a basic reference manual*. Albany, NY: New York State Department of Environmental Conservation, Division of Water. (www.dec.ny.gov)

NYSDEC. 1988. "Design Standards for Wastewater Treatment Works: Intermediate-sized Sewerage Facilities." Albany, NY: NYSDEC.

NYSDEC, 2002. *New York State Water Quality 2002*. Albany, NY: New York State Department of Environmental Conservation.

NYSDEC. 2004. *Ten State Standards: Recommended Standards for Wastewater Facilities.* Albany, NY: NYSDEC.

NYSDEC. 2007. *Creating a pond.* Albany, NY: New York State Department of Environmental Conservation. (www.dec.ny.gov/website/dcs/streamprotection/PondBro.pdf)

NYSDEC. 2007. *Citizens guide to SEQR***.** Albany, NY: New York State Department of Environmental Conservation (www.dec.ny.gov) (www.dec.ny.gov/website/dcs/seqr/seqrcitizen)

NYSDEC. 2007. *State Environmental Quality Review act cookbook.* Albany, NY: New York State Department of Environmental Conservation (www.dec.state.ny.us./website/dcs/seqr/cookbook1.pdf)

NYSDEC. 2007. *How to apply for a permit: Applicant's guide to the Uniform Procedures Act.* Albany, NY: New York State Department of Environmental Conservation (www.dec.state.ny.us/website/dcs/upa/applyUPApermit.pdf)

NYSDOH, 2004. Chemicals in sports fish and game. Albany, NY: New York State Department of Health.

Patrick, J. 2005. "Dam failures can take devastating toll". Schenectady, NY: *The Sunday Gazette.* 9/11/05

Raymond, Lyle S. 1996. *Cooperative watershed protection: what makes it work?* Ithaca NY: Cornell Cooperative Extension, Local Government Program/Center for the Environment, Cornell University.

Ruttner, F. 1952. *Fundamentals of limnology*. Toronto, ON: Univ. Toronto Press.

Soil and Water Conservaton Society. 2000. *Integrated watershed management in the global ecosystem.* Edited by Rattan Lal. Based on the proceedings of the Internationals Conference, Toronto, Canada, July 1997. Boca Raton FL: CRC Press.

Sousounis, P. and P. Glick. 2004. "The potential impacts of global climate change on the Great Lakes Region". *First National Assessment of the Potential Consequences of Climate Variability and Change.* (www.climatehotmap.org)

Sutherland, J.W. 1990. *Interim report on the Lake George nuisance aquatic plant management program.* Albany, NY: New York State Department of Environmental Conservation.

Tetra Tech, Inc. 1999. *Getting in step: Engaging and involving stakeholders in your watershed.* Prepared under contract 68–C-99–249 to the U.S. Environmental Protection Agency.

USDA Soil Conservation Service. 1975. *Erosion and Sediment Control Inventory*, Syracuse, NY: U.S. Soil and Conservation Service.

U.S. EPA. 1978. *Innovative and Alternative Technology Assessment Manual* (EPA# 430/9–78–009). Washington DC: Environmental Protection Agency.

U.S. EPA. 2001. *Protecting and restoring America's watersheds; Status, trends and initiatives in watershed management.* (EPA# 840-R-00-001). Washington DC: Environmental Protection Agency, Office of Water.

U.S. EPA. 2002. *Onsite Wastewater Treatment Systems Manual*. Washington DC: Environmental Protection Agency.

Warren County SWCD. 2006. *Detecting failing septic systems on your lake: a cost effective methodology.* Warrensburg, NY: Warren County Soil & Water Conservation District and Adirondack Community College, Queensbury NY; funded by NYSDEC Onsite Wastewater Working Group.

Westerdahl, H.E. and K.D. Getsinger, eds. 1998. *Aquatic plant identification and herbicide use guide. Vol. 2. Aquatic plants and susceptibility to herbicides*. Vicksburg, MS: Waterways Experiment Station. U.S. Army Corps Eng.,

Wetzel, R.G. 1983. *Limnology*. New York: NY: CBS Coll. Pub.

Index of Terms

Page numbers identify the first use and the definition of a given term. Many common terms, however, are also discussed in detail in one or more of the subsequent chapters. Terms such as algae, nutrients, phosphorous and Eurasian watermilfoil, for instance, are discussed frequently throughout the book. The CONTENTS will also help identify terms as they relate to a specific discussion chapter.