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 80°F 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.

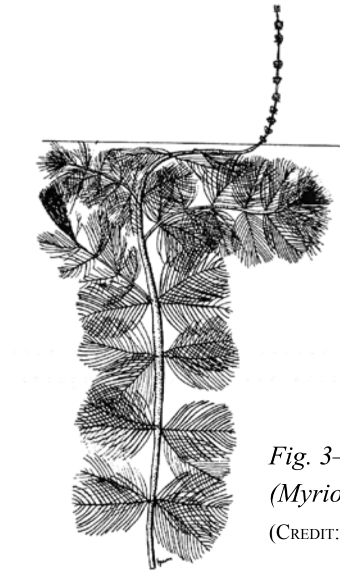

Fig. 3–2. Eurasian watermilfoil (Myriophyllum spicatum) (CREDIT: CROW AND HELLQUIST)

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."

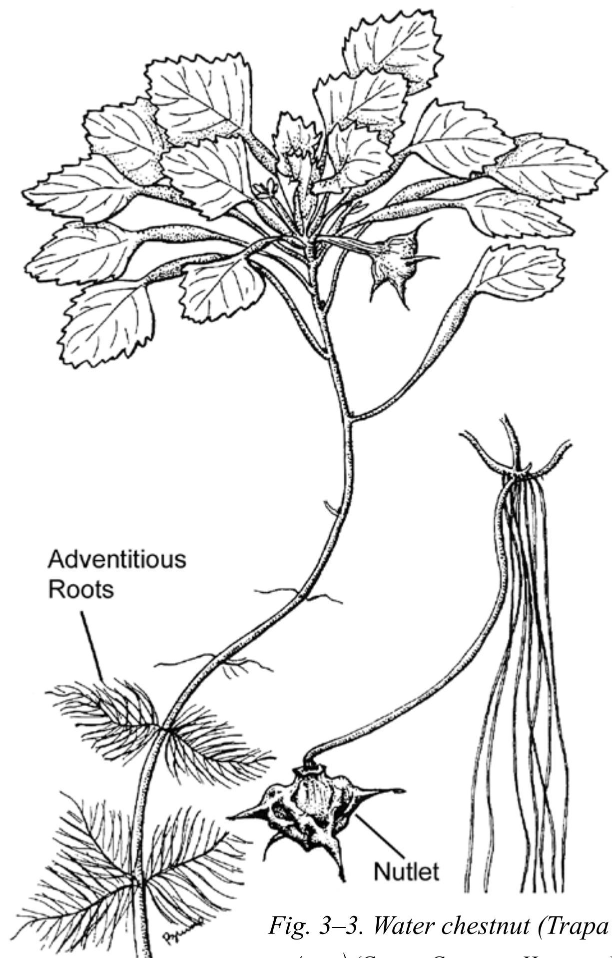

Fig. 3–3. Water chestnut (Trapa natans) (CREDIT: CROW AND HELLQUIST)

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

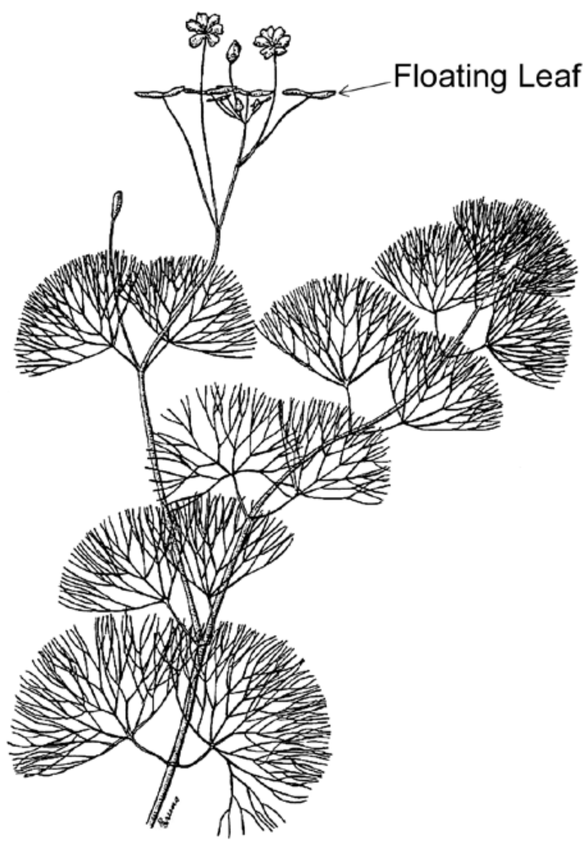

Fig. 3–5. Fanwort (Cabomba caroliniana)
(CREDIT: CROW AND HELLQUIST)

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 north-eastern 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.

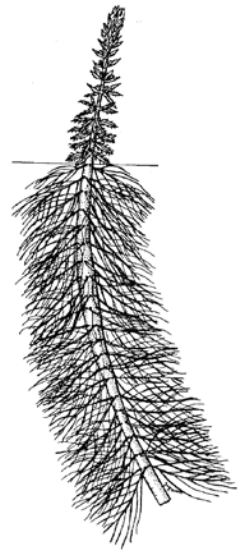

Fig. 3–6. Variable watermilfoil (Myriophyllum heterophyllum)
(CREDIT: CROW AND HELLQUIST)

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.

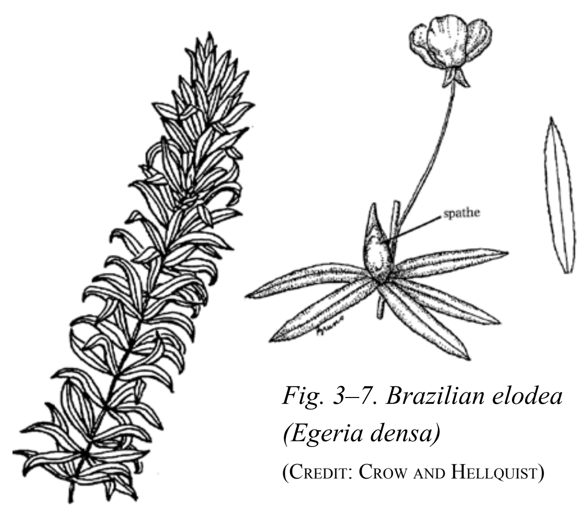

Fig. 3–7. Brazilian elodea (Egeria densa)
(CREDIT: CROW AND HELLQUIST)

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.

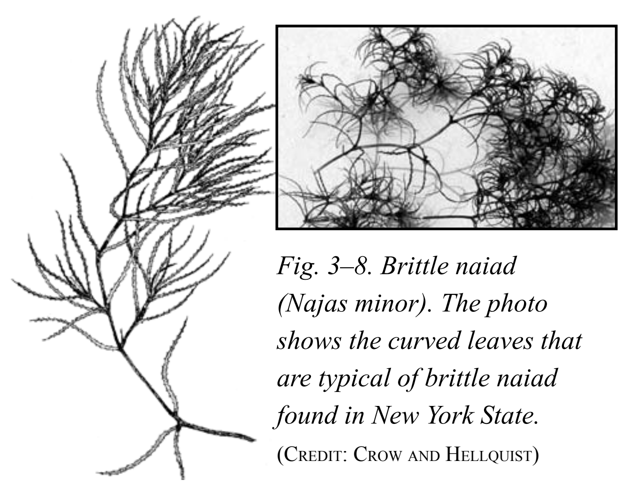

Fig. 3–8. Brittle naiad (Najas minor). The photo shows the curved leaves that are typical of brittle naiad found in New York State.
(CREDIT: CROW AND HELLQUIST)

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.

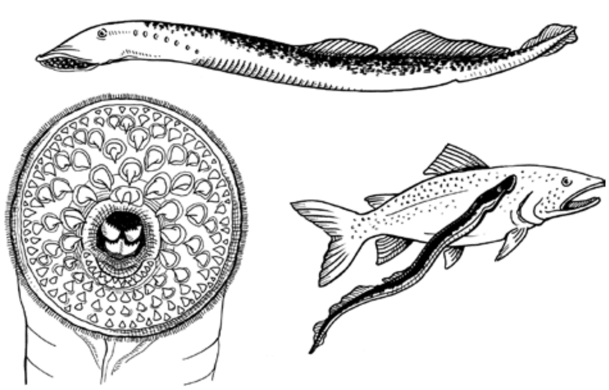

Fig. 3–11. Sea lamprey (Petromyzon marina) Top: Sea lamprey. Left: Lamprey mouth showing rows of teeth. Right: Lamprey attached to a trout victim.
(CREDIT: WENDY SKINNER)

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.

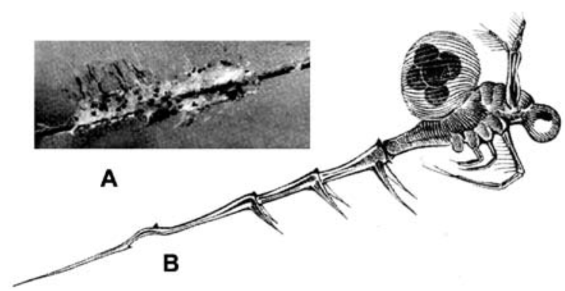

Fig. 3–12. Spiny water flea (Bythotrephes cederstroemi) A. Spiny water fleas look like gobs of jelly with black spots and bristles on a fishing line. B. The spiny water flea is less than one-half inch long. (CREDIT: IOWA DEPT. NAT. RES.)

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.

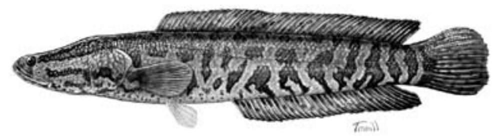

Fig. 3–13. Northern snakehead (Channa argus), an aggressive and predatory invasive fish that is rapidly spreading in the eastern United States. (CREDIT: DEC)

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.

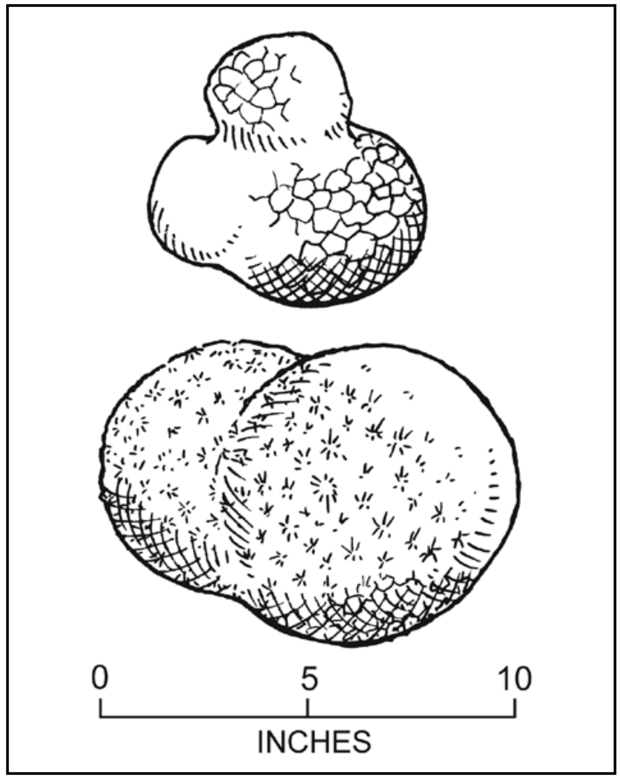

Fig. 3–14 Bryozoans (Pectinatella magnifica) are freshwater animals that form gelatinous colonies with circular or horseshoe-shaped ridges.
(CREDIT: WENDY SKINNER)

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 overfishing 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.