2024 Aquatic Ecology

STUDY RESOURCES

2024 NCF-ENVIROTHON
NEW YORK

Aquatic Ecology

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NCf-Envirothon 2024 New York

Aquatic Ecology Study Resources

Key Topic #1: Hydrology and Aquatic Environments

1. Describe the Water Cycle and explain each component in detail.
2. Differentiate between the various types of water bodies, including wetlands, lakes, rivers, and streams, and describe the characteristics of each.
3. Identify major New York State and Great Lakes watersheds and describe their watershed dynamics.

Study Resources

Resource Title	Source	Located on
Diet for a Small Lake, Chapter 1	*New York State Department of Environmental Conservation and New York State Federation of Lake Associations, 2009*	Pages 4-22
Why are Wetlands Important?	*National Park Service, 2016*	Pages 23-25
Types of Wetlands	*United States Environmental Protection Agency, 2021*	Pages 26-27
Selections from: Introduction to Watershed Ecology	*United States Environmental Protection Agency, 2024*	Pages 28-38
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New York State Department of Environmental Conservation and New York State Federation of Lake Associations, 2009

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

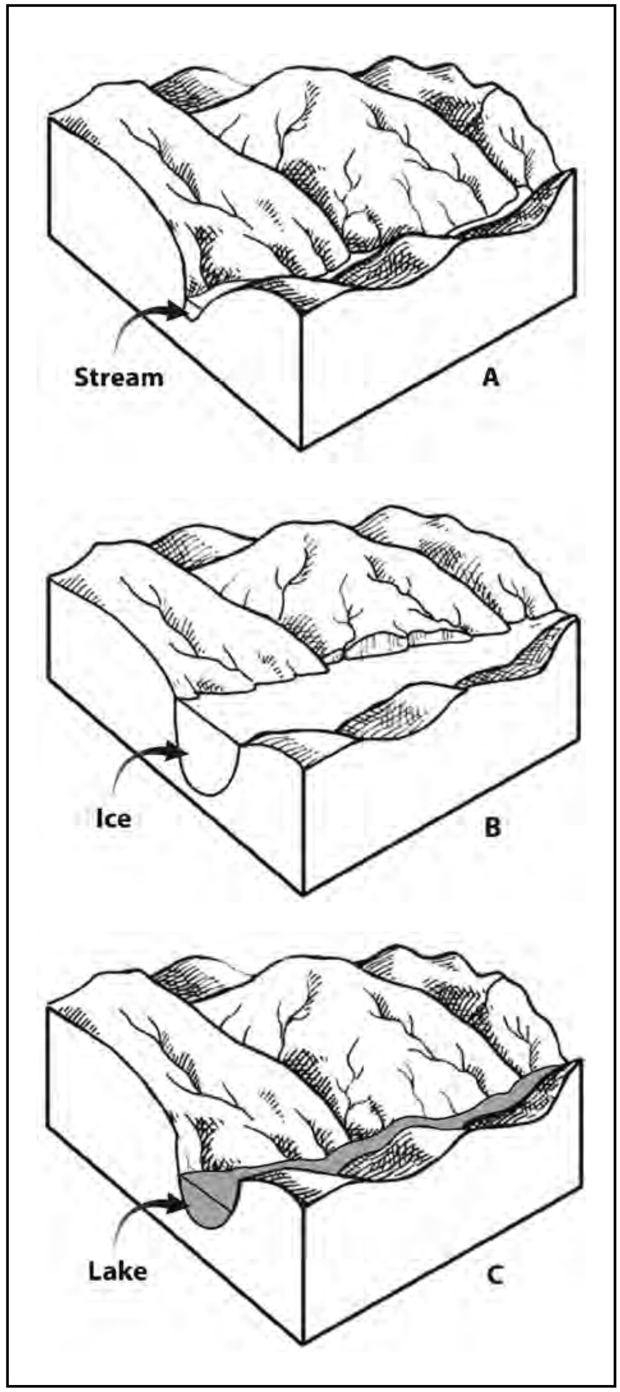


Fig. 1–2. Landscape evolution under glaciation.

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**.

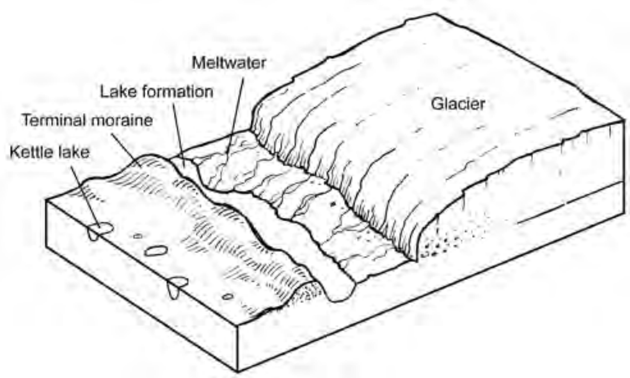


Fig. 1–3. Typical features that develop near the front of a receding glacial ice margin. (CREDIT: WENDY SKINNER)

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

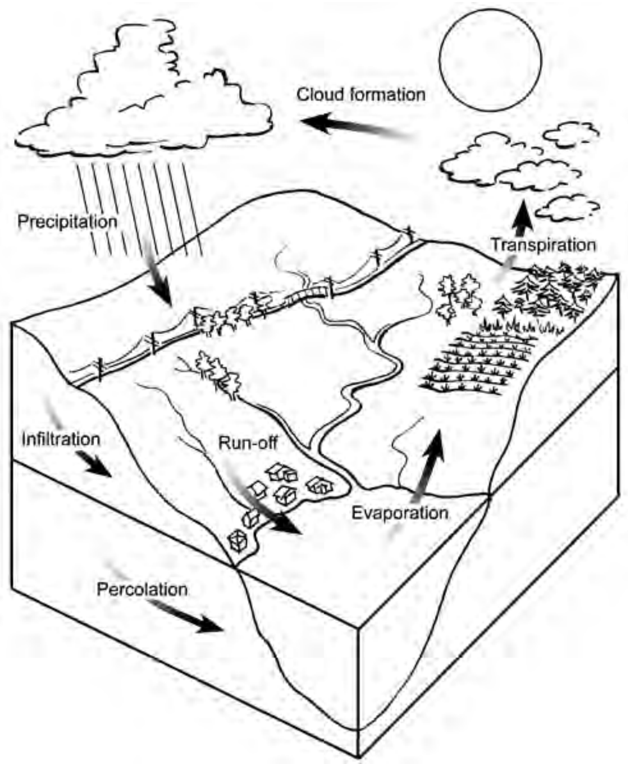


Fig. 1–5. The hydrologic cycle shows that precipitation may seep into the soil as infiltration, move over land as runoff, and then move back into the atmosphere as evaporation or due to the transpiration or respiration activity of plants and animals. (Credit: Wendy Skinner)

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

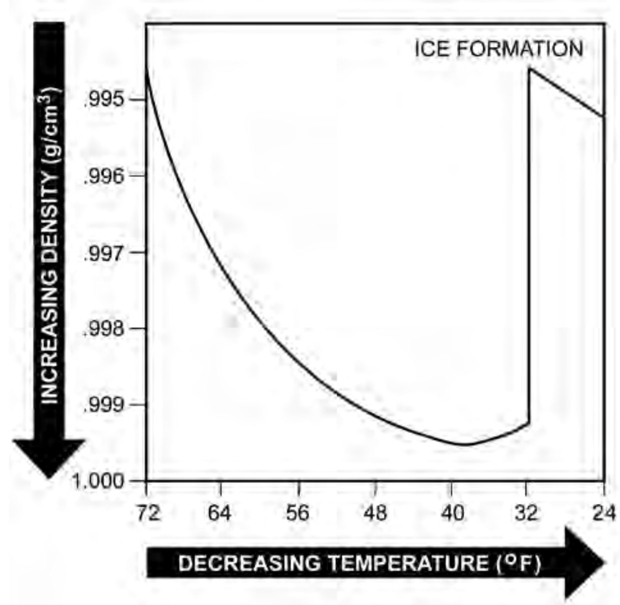


Fig. 1–6. As water cools, it becomes denser until it reaches 39ºF. It becomes lighter as it continues to cool. When water cools to 32ºF and becomes ice, it reaches maximum lightness, causing it to float.
(CREDIT: WENDY SKINNER)

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.

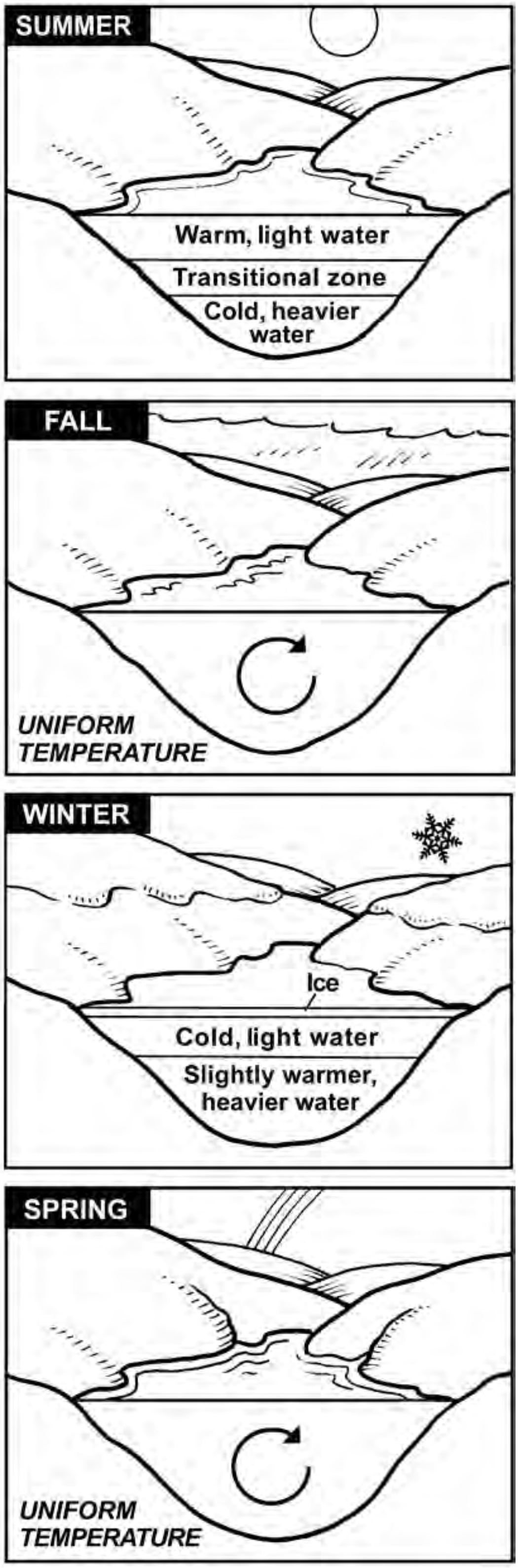


Fig. 1–7. Waters in dimictic lakes in New York State either stratify or mix depending on the season. (CREDIT: WENDY SKINNER)

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.

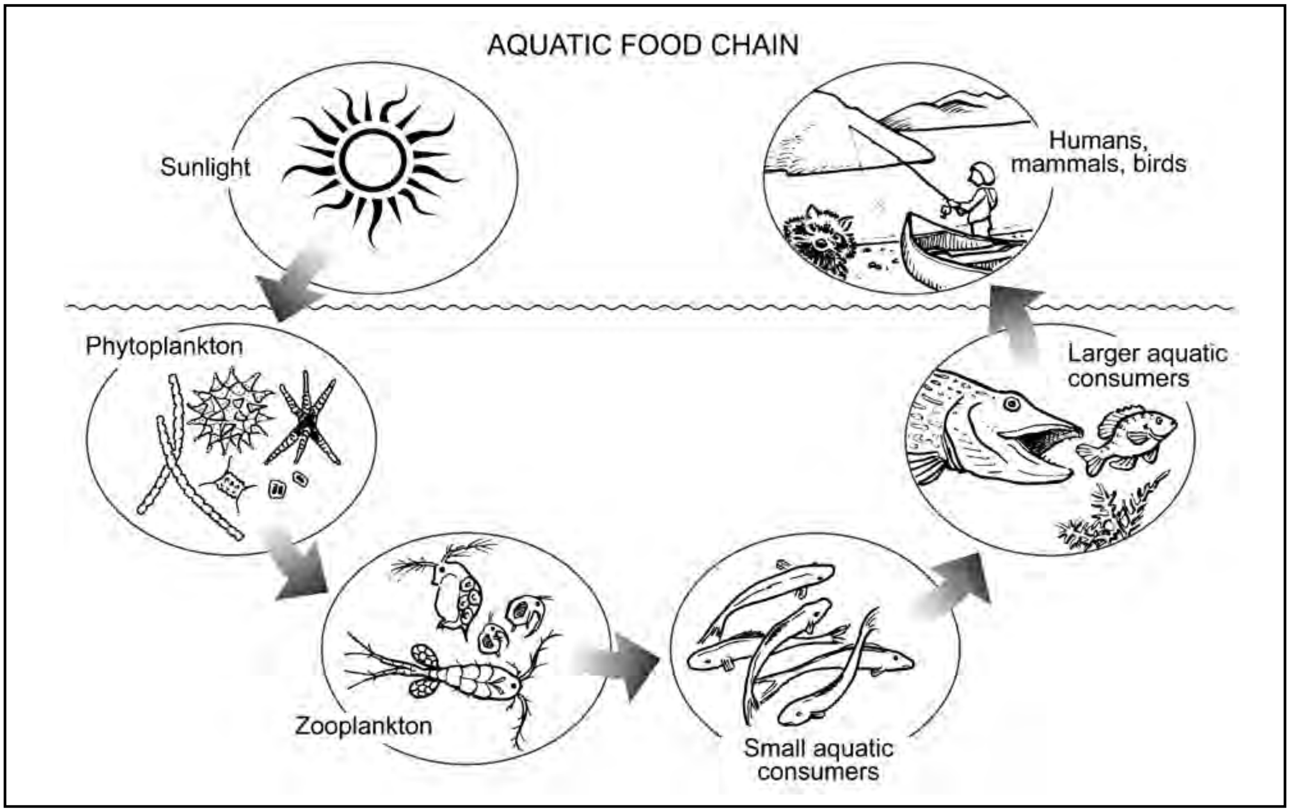


Fig. 1–8. Plants are considered the base of the aquatic food chain since they capture energy from the sun. That energy is passed along to animals in subsequent links in the food chain. (CREDIT: WENDY SKINNER)

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

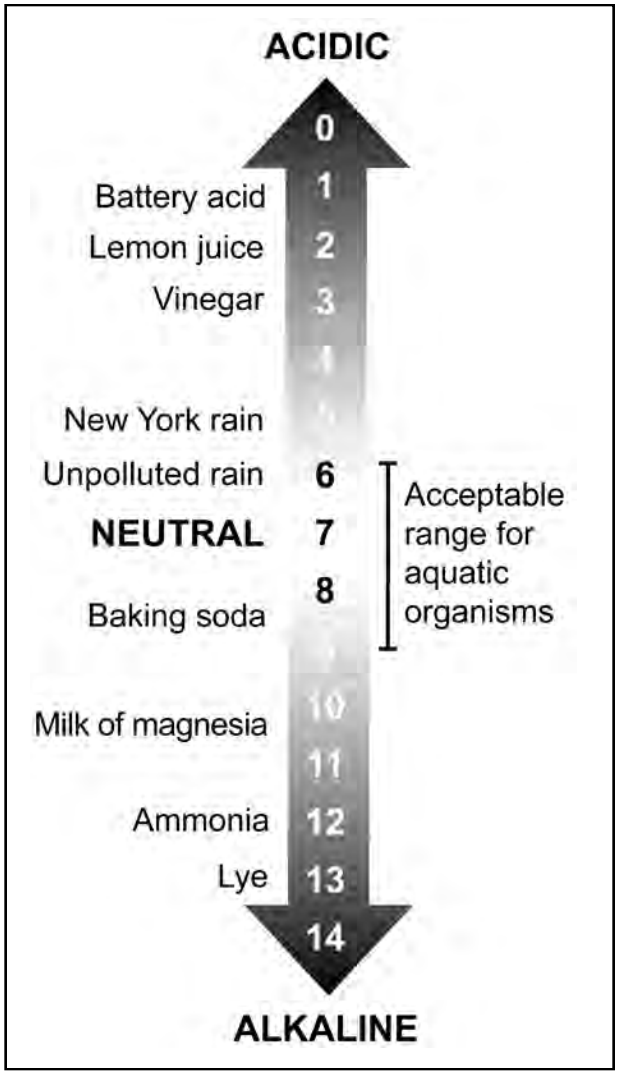


Fig. 1–9. Acidic-to-alkaline pH ranges, comparing the acidity of common items to the pH ranges acceptable for aquatic organisms. (CREDIT: WENDY SKINNER)

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

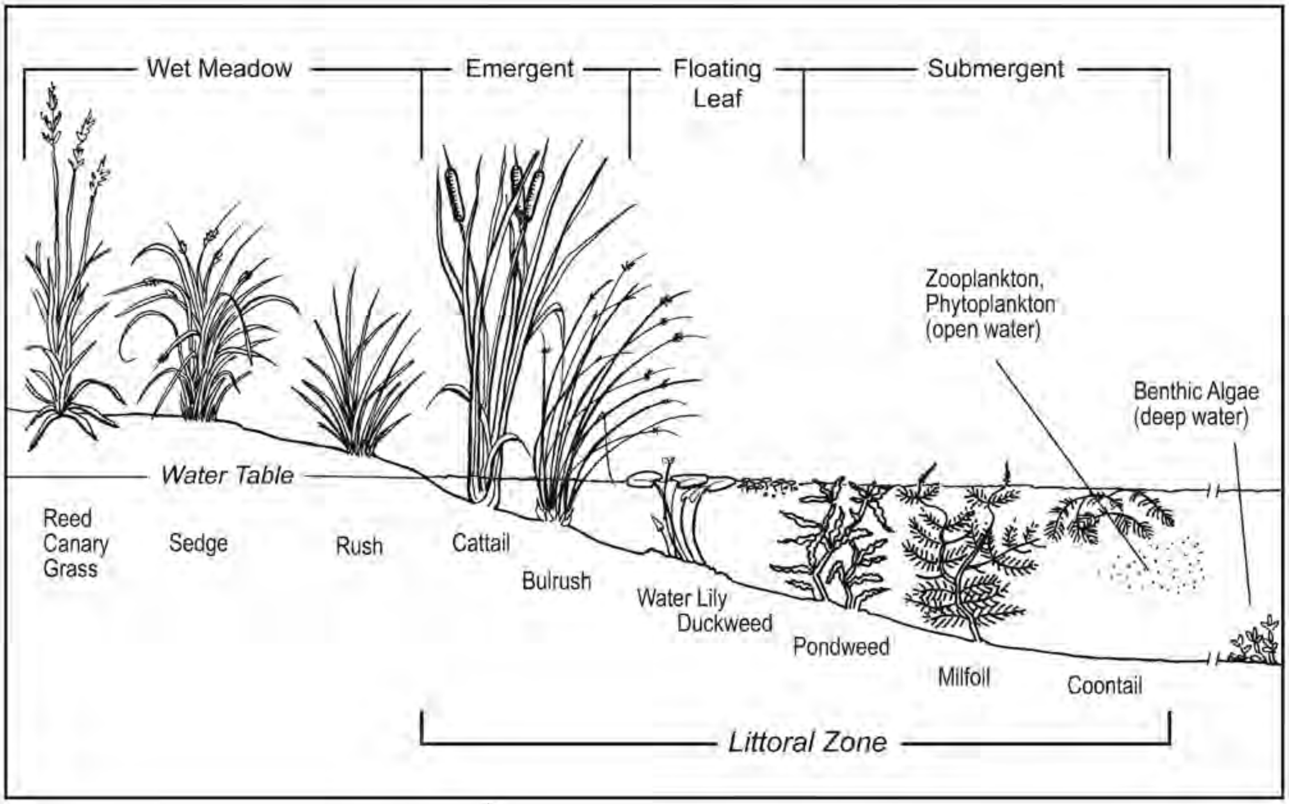


Fig. 1–10. Typical shoreline zone of a lake, pond or marsh showing the transition from upland plants to submerged macrophytes to algae. (CREDIT: WENDY SKINNER)

(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.

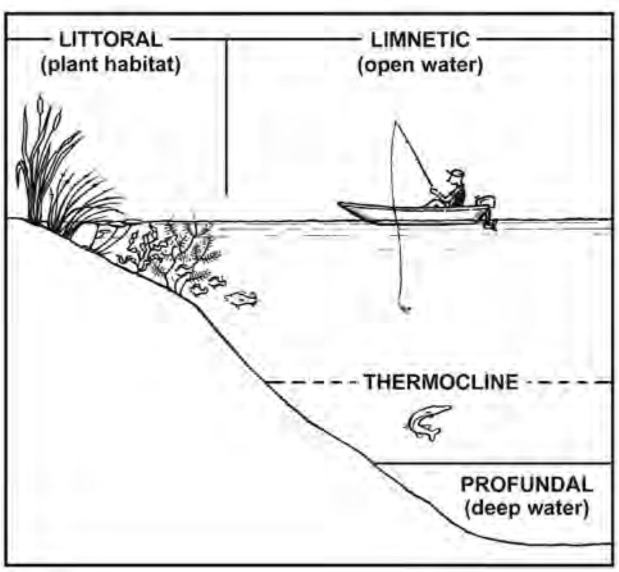


Fig. 1–11. Biologists divide lakes into habitat zones. Each zone—littoral, limnetic and profundal—supports a different aquatic community. (CREDIT: WENDY SKINNER)

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

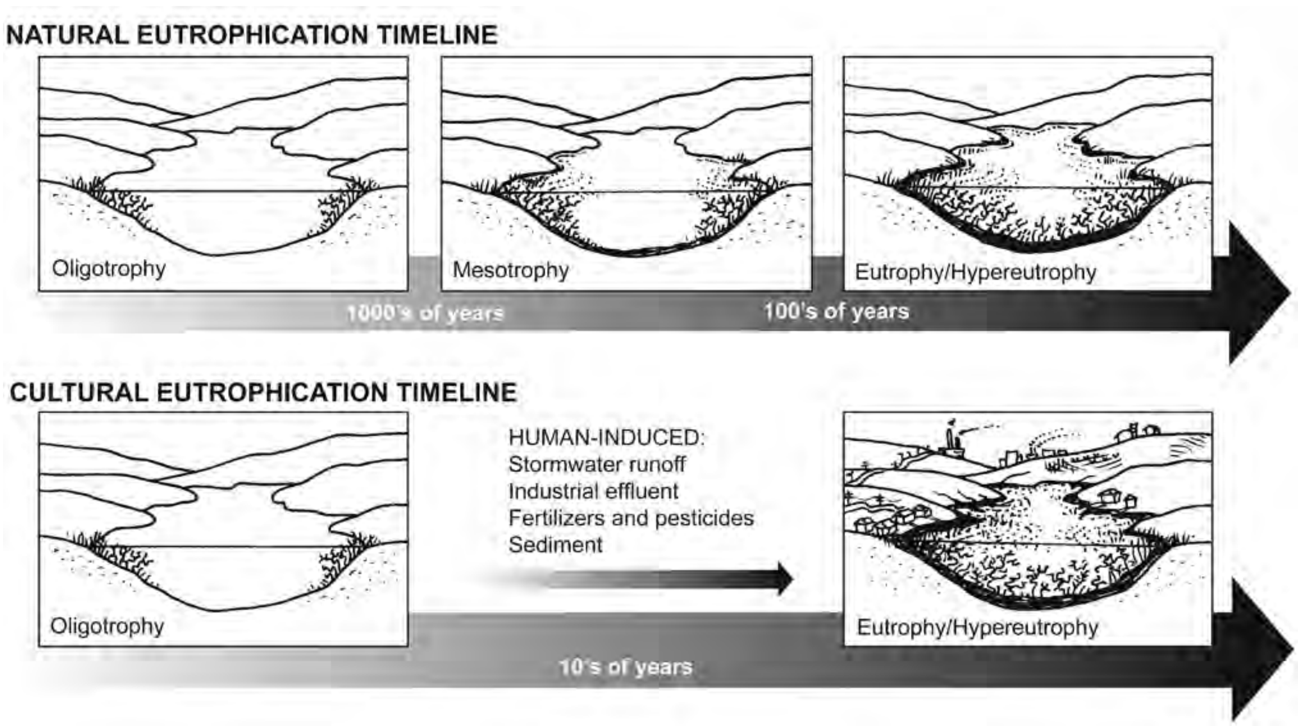


Fig. 1–12. Lakes naturally and slowly progress towards eutrophic conditions. When human activities accelerate the process, it is called cultural eutrophication. (CREDIT: WENDY SKINNER)

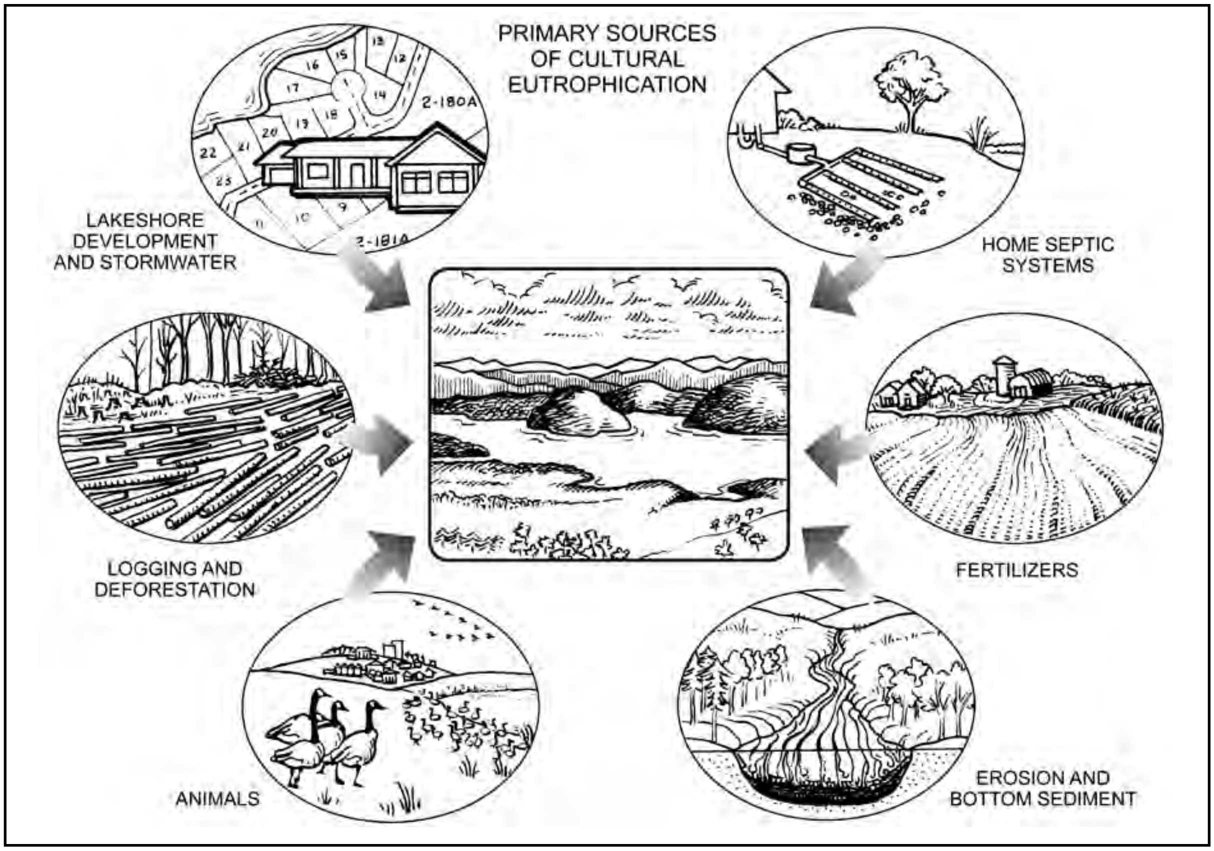


Fig. 1–13. Primary sources of cultural eutrophication. Human activities such as housing, logging, and farming accelerate the rate of natural eutrophication. (CREDIT: WENDY SKINNER)

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.

Wetlands

Why are Wetlands Important?

Wetlands are highly productive and biologically diverse systems that enhance water quality, control erosion, maintain stream flows, sequester carbon, and provide a home to at least one third of all threatened and endangered species.

Wetlands are important because they:

- improve water quality
- provide wildlife habitat
- maintain ecosystem productivity
- reduce coastal storm damage
- provide recreational opportunities
- improve the water supply
- provide opportunities for education

Why Are Wetlands Important?

In the not too distant past, wetlands were regarded as wastelands. Most people felt that they were places to be avoided, and it was common practice to drain them, fill them or treat them as dumping grounds. A study published by the U.S. Fish and Wildlife Service in 1990 revealed a startling fact: more than half of the 221 million acres of wetlands that existed in the lower 48 states in the late 1700s have been destroyed.

Today, we know that wetlands provide many important services to the environment and to the public. They offer critical habitat for fish, waterfowl and other wildlife, they purify polluted waters, and they help check the destructive power of floods and storms. They also provide a wide variety of recreational opportunities such as fishing, hunting, photography, and wildlife observation. As these and many other wetland functions and values described below have become more widely known, wetlands are increasingly seen as productive and valuable resources worthy of protection and restoration.

- Water Quality: Wetlands act as natural water purifiers, filtering sediment and absorbing many pollutants in surface waters. In some wetland systems, this cleansing function also enhances the quality of groundwater supplies.

- Reduction of Coastal Storm Damage: Coastal wetlands help to blunt the force of major storms. For example, mangrove forests in south Florida and salt marshes along the Atlantic and Gulf Coasts reduce flooding, coastal erosion, and property damage during major storms.

- Flood Control and Streamflow Maintenance: Wetlands along rivers and streams absorb energy and store water during storms, which reduces downstream flood damage and lessens the risk of flash floods. The slow release of this stored water over time can help keep streams flowing during periods of drought.

- Streambank Stabilization and Erosion Control:Wetland vegetation binds the soil on streambanks and riparian wetlands, preventing excessive erosion and sedimentation downstream.

- Wildlife Habitat: Wetlands provide habitat for many species of amphibians, reptiles, birds and mammals that are uniquely adapted to aquatic environments. Upland wildlife like deer, elk and bears commonly use wetlands for food and shelter. Wetlands are particularly vital to many migratory bird species. For example, wood ducks, mallards, and sandhill cranes winter in flooded bottomland forests and marshes in the southern U.S., and prairie potholes provide breeding grounds for over 50% of North American waterfowl.

- Fish and Shellfish Habitat: Freshwater and marine life including trout, striped bass, pike, sunfish, crappie, crab, and shrimp rely on wetlands for food, cover, spawning, and nursery grounds. Between 60% and 90% of U.S. commercial fisheries depend on wetlands.

- Habitat for Threatened and Endangered Species: About one-third of all plants and animals listed as threatened or endangered species in the United States depend on wetlands for their survival, including whooping cranes, American crocodiles, the dwarf lake iris and several orchid species.

- Specialized Plant Habitat: Nearly 7000 plant species live in U.S. wetlands, many of which can only survive in these wet environments.

- **Ecosystem Productivity:** Some wetland types are among the most productive ecosystems on earth. A stand of cordgrass in a salt marsh can produce more plant material and store more energy per acre than any agricultural crop except cultivated sugar cane. Nutrients and plant material flushed from some wetland systems during storms provide essential food for plants, fish, and wildlife in estuaries and other downstream ecosystems.

- **Recreational Opportunities:** Many wetlands contain a diversity of plants, animals and water features that provide beautiful places for sightseeing, hiking, fishing, hunting, boating, bird watching, and photography.

- **Water Supply:** Some wetlands help provide clean, plentiful water supplies. For example, wetlands in Florida's Everglades help recharge the Biscayne Aquifer, the sole source of drinking water for the Miami metropolitan area.

Least Bittern
Photo by Thom Curdts

- **Education:** Ecological, cultural, and historic resources run abundant in our nation's wetlands, and provide countless opportunities for environmental education and public awareness programs.

A staff member at Channel Islands National Park describes a wetlands restoration project to visitors and the media.

Last updated: May 5, 2016

United States Environmental Protection Agency
Office of Water Office of Wetlands, Oceans and Watersheds (4502T)
EPA 843-F-01-002b September 2001

Types of Wetlands

Do you think all wetlands are the same? Think again. Each wetland differs due to variations in soils, landscape, climate, water regime and chemistry, vegetation, and human disturbance. Below are brief descriptions of the major types of wetlands found in the United States organized into four general categories: marshes, swamps, bogs, and fens.

MARSHES are periodically saturated, flooded, or ponded with water and characterized by herbaceous (non-woody) vegetation adapted to wet soil conditions. Marshes are further characterized as tidal marshes and non-tidal marshes.

Tidal (coastal) marshes occur along coastlines and are influenced by tides and often by freshwater from runoff, rivers, or ground water. Salt marshes are the most prevalent types of tidal marshes and are characterized by salt-tolerant plants such as smooth cordgrass, saltgrass, and glasswort. Salt marshes have one of the highest rates of primary productivity associated with wetland ecosystems because of the inflow of nutrients and organics from surface and/or tidal water. Tidal freshwater marshes are located upstream of estuaries. Tides influence water levels but the water is fresh. The lack of salt stress allows a greater diversity of plants to thrive. Cattail, wild rice, pickerelweed, and arrowhead are common and help support a large and diverse range of bird and fish species, among other wildlife.

Nontidal (inland) marshes are dominated by herbaceous plants and frequently occur in poorly drained depressions, floodplains, and shallow water areas along the edges of lakes and rivers. Major regions of the United States that support inland marshes include the Great Lakes coastal marshes, the prairie pothole region, and the Florida Everglades.

The Vernal Pool Association

Many vernal pools fill with water in fall or spring.

Leigh Dunkelberger

Freshwater marshes, like this one in Sequoia National Park, are dependent on rainfall, runoff, and seasonal flooding for their water supplies.

Dave Davis

Farmland surrounds these prairie potholes in Nebraska.

- ***Freshwater marshes*** are characterized by periodic or permanent shallow water, little or no peat deposition, and mineral soils. They typically derive most of their water from surface waters, including floodwater and runoff, but do receive ground water inputs.
- ***Wet meadows*** commonly occur in poorly drained areas such as shallow lake basins, low-lying depressions, and the land between shallow marshes and upland areas. Precipitation serves as their primary water supply, so they are often dry in the summer.
- ***Wet prairies*** are similar to wet meadows but remain saturated longer. Wet prairies may receive water from intermittent streams as well as ground water and precipitation.
- ***Prairie potholes*** develop when snowmelt and rain fill the pockmarks left on the landscape by glaciers. Ground water input is also important.
- ***Playas*** are small basins that collect rainfall and runoff from the surrounding land. These low-lying areas are found in the Southern High Plains of the United States.
- ***Vernal pools*** have either bedrock or a hard clay layer in the soil that helps keep water in the pool. They are covered by shallow water for variable periods from winter to spring, but may be completely dry for most of the summer and fall.

U.S. Army Corps of Engineers

Trees found in swamps are sometimes buttressed at the base, which helps anchor them in the saturated soils.

Forested swamps serve a critical role in the watershed by reducing the risk and severity of flooding to downstream areas.

SWAMPS are fed primarily by surface water inputs and are dominated by trees and shrubs. Swamps occur in either freshwater or saltwater floodplains. They are characterized by very wet soils during the growing season and standing water during certain times of the year. Well-known swamps include Georgia's Okefenokee Swamp and Virginia's Great Dismal Swamp. Swamps are classified as forested, shrub, or mangrove.

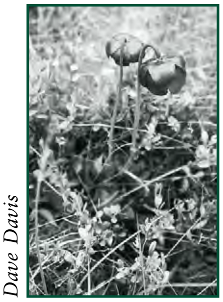
Forested swamps are found in broad floodplains of the northeast, southeast, and south-central United States and receive floodwater from nearby rivers and streams. Common deciduous trees found in these areas include bald cypress, water tupelo, swamp white oak, and red maple.

Shrub swamps are similar to forested swamps except that shrubby species like buttonbush and swamp rose dominate.

Mangrove swamps are coastal wetlands characterized by salt-tolerant trees, shrubs, and other plants growing in brackish to saline tidal waters. These tropical and subtropical systems have a North American range that extends from the southern tip of Florida along the Gulf Coast to Texas.

BOGS are freshwater wetlands characterized by spongy peat deposits, a growth of evergreen trees and shrubs, and a floor covered by a thick carpet of sphagnum moss. These systems, whose only water source is rainwater, are usually found in glaciated areas of the northern United States. One type of bog, called a pocosin, is found only in the Southeastern Coastal Plain.

FENS are ground water-fed peat-forming wetlands covered by grasses, sedges, reeds, and wildflowers. Willow and birch are also common. Fens, like bogs, tend to occur in glaciated areas of the northern United States.



Dave Davis

Bog ecosystems support cranberries, blueberries, and carnivorous plants like the pitcher plant.

The Wetland Fact Sheet Series

Wetlands Overview
Types of Wetlands
Functions & Values of Wetlands
Threats to Wetlands
Wetland Restoration
Funding Wetland Projects
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For more information, visit www.epa.gov/owow/wetlands.

Wetland Resources

On the Internet

EPA's Wetland Home Page contains information and pictures on several types of wetlands .... www.epa.gov/owow/wetlands/types

Types of Wetlands and Their Roles in the Watershed, part of North Carolina State University's WATERSHEDSS h2osparc.wq.ncsu.edu/info/wetlands/types3.html

Wetlands of the United States from the USGS Northern Prairie Wildlife Research Center www.npwrc.usgs.gov/resource/1998/uswetlan/types.htm

Prairie Potholes www.greatplains.org/resource/1999/ppjv/ppjv.htm

In Print

Wetlands. 3rd Edition. W.J. Mitsch, and J.G. Gosselink. 2000. John Wiley & Sons, Inc. New York, NY.

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Adopting a Wetland—A Northwest Guide. S. Yates. 1989.

Introduction

This training module introduces watershed ecology. Understanding watershed structure and natural processes is crucial to grasping how human activities can degrade or improve the condition of a watershed, including its water quality, its fish and wildlife, its forests and other vegetation, and the quality of community life for people who live there. Knowing these watershed structural and functional characteristics and how people can affect them sets the stage for effective watershed management.

After completing this training, the participant should know the basic biotic and abiotic components of watersheds, the basic natural processes and interrelationships occurring in watersheds, and how watershed structure and functions may vary in time and space. Some background in the life sciences is helpful for comprehending this material, but not required.

Goals

The aims of this unit are to:

1. Introduce terms and concepts associated with watershed ecology.
2. Describe typical watershed structure and how watersheds work, at different geographic scales and through time.
3. Provide related examples of contemporary issues in watershed ecology.

Definitions

Watershed. An area of land that drains water, sediment and dissolved materials to a common receiving body or outlet. The term is not restricted to surface water runoff and includes interactions with subsurface water. Watersheds vary from the largest river basins to just acres or less in size.

Watershed Ecology. The study of watersheds as ecosystems, primarily the analysis of interacting biotic and abiotic components within a watershed’s boundaries.

Ecosystem. A functioning natural unit with interacting biotic and abiotic components in a system whose boundaries are determined by the cycles and flux of energy, materials and organisms. It is valid to describe different ecosystems with different, overlapping sets of boundaries in the same geographic area (e.g. forest ecosystems, watershed ecosystems and wetland ecosystems). A watershed is just one of many types of ecosystems.

Watershed ecology is essential knowledge for watershed managers because it teaches us that watersheds have structural and functional characteristics that can influence how human and natural communities coexist within them. The gross structure of a watershed -- its headwaters area, side slopes, valley floor, and water body, as well as its soils, minerals, native plants and animals -- are, in one sense, raw material for all the human activities that may potentially occur there. The watershed’s natural processes -- rainfall runoff, groundwater recharge, sediment transport, plant succession, and many others -- provide beneficial services when functioning properly, but may cause disasters when misunderstood and disrupted.

Watershed Structure

Now that you have reviewed the physical and biological components of watersheds and considered that together they comprise organized, functional systems, the discussion now will briefly cover **watershed structure** (Figure 19). Basically, this includes structure of **flowing waters** (mainly rivers and streams with associated riverine wetlands and riparian zones), **still waters** (lakes and associated basin-type wetlands and shorelands), and **upland areas** of watersheds.

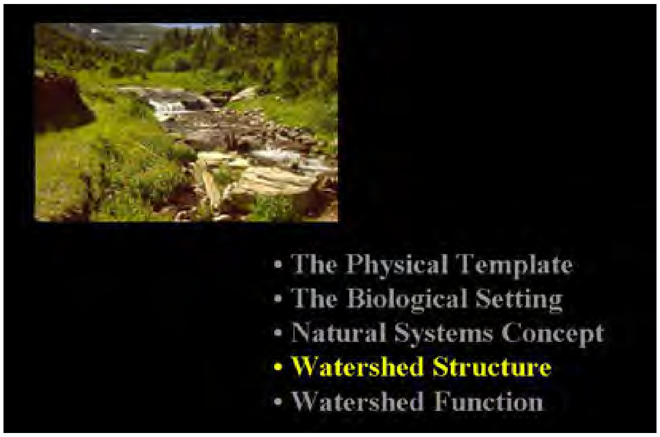


Figure 19. Watershed structure

Flowing (Lotic) Systems

The US has more than 3.5 million miles of flowing water systems, which include springs and seeps, rivers, streams, creeks, brooks and side channels.

The Four-Dimensional Concept (Figure 20) recognizes that lotic systems' structure exists in a four-dimensional framework, as below:

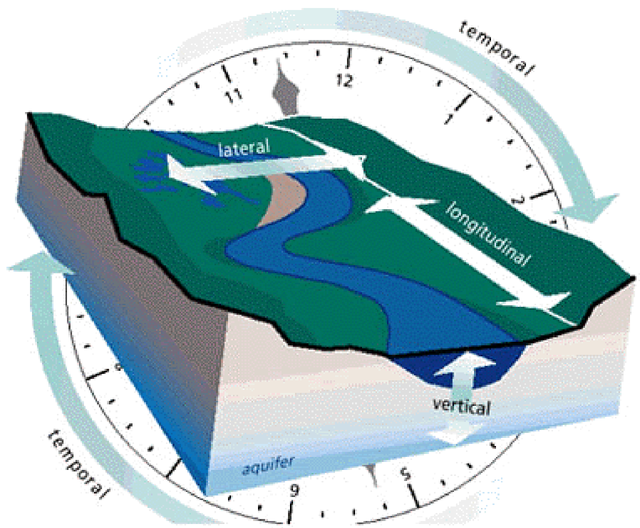


Figure 20. A four-dimensional concept of watershed structure (after Ward, 1989)

Longitudinal (in an upstream and downstream direction) - Flowing water systems commonly go through structural changes en route from their source to mouth. Three zones are usually recognized – **headwaters**, where flow is usually lowest of any where along the system, slope is often steepest, and erosion is greater than sediment deposition; **transfer zone**, the middle range of the stream where slope usually flattens somewhat, more flow appears, and deposition and erosion are both significant processes; and the downstream end's **depositional zone**, where flow is highest but slope is minimal and deposition of sediment significantly exceeds erosion most of the time.

Lateral (across the channel, floodplains and hillslopes) - Again, significant variation occurs among stream types, but a common pattern includes the channel, the deepest part of which is called the **thalweg**; **low floodplains** that a re flooded frequently, and higher floodplains (e.g., the 100-year or 500-year) that are rarely inundated; **terraces**, which are former floodplains that a downcutting stream no longer floods; and **hillslopes** or other upland areas extending up-gradient to the watershed boundary.

Vertical (surface waters, ground water and their interactions) - It is always important to recognize that water bodies are not purely surface features; rivers and streams constantly interact with groundwater aquifers and exchange water, chemicals, and even organisms. Over its entire length, a stream often varies between influent reaches where surface water leaks downward into the aquifer, and effluent reaches where the stream receives additional water from the aquifer.

Temporal (through time, from temporary response to evolutionary change) - The dimension of time is important because rivers and streams are perpetually changing. Structure as described in the other three dimensions above should never be considered permanent, and watershed managers should always think of structure not just as what is there now, but in terms of the structural changes in progress and their rates of occurrence.

Recognition of different types of streams and rivers is mostly reliant on channel form and function. For more on stream and river categories see the Stream Channel Classification box below.

Stream Channel Classification

Classification schemes for lotic systems are based on form and function. Different classifications have different advantages or disadvantages as most were designed for specific applications. The concept of stream order – a numbering system where the number increases with the addition of more tributaries -- is one of the simplest and most widely-used classification schemes. Other classification methods are based on the geomorphology of the channel bed (e.g. bedrock, alluvial), channel patterns and processes (e.g. straight, meandering), or hierarchical classification (e.g. geomorphic province, watershed, valley, segment, channel reach, channel unit). (see Rosgen 1993 and 1996, Montgomery and Buffington 1998).

"Still" (Lentic) Waters

Lentic systems generally include lakes and ponds. A lake's structure has a significant impact on its biological, chemical, and physical features. Some lentic systems may be fresh water bodies, while others have varying levels of salinity (e.g., Great Salt Lake). Most basin-type wetlands are also generally grouped within lentic systems; these are areas of constant soil saturation or inundation with distinct vegetative and faunal communities. Lakes and ponds are almost always connected with streams in the same watershed, but the reverse is not nearly as often true.

The method of lake formation is the basis for classifying different lake types (a list of lake types can be found on the following page). Natural processes of formation most commonly include glacial, volcanic, and tectonic forces while human constructed lakes are created by dams or excavation of basins. In his classic review of lake types, Hutchinson (1957) describes 76 different types of lakes. Of the processes that form these lakes, glacial activity has been the most important mechanism for their formation in North America (Figure 21, next page). Although on human time scales we may think of lakes as permanent, they are ephemeral features on the landscape. They are found in depressions in the earth's surface in regions where water is available to fill the basin. Over time, lakes fill with sediments and organic material while outlets tend to erode the lake rim away.

Areas referred to as lake districts contain lakes created by similar processes. While the individual lakes in a lake district often share similar geologic features, the lakes themselves are often quite unique. In Northern Wisconsin and Minnesota for example many of the lakes were formed by the same glacial processes, but the individual biological, chemical, and physical characteristics of lakes even just a few miles apart can be dramatically different. In these lakes, landscape position of the basin, characteristics of the watershed, and morphometry of the basin are usually more important than method of basin formation for describing the biological features of a lake.

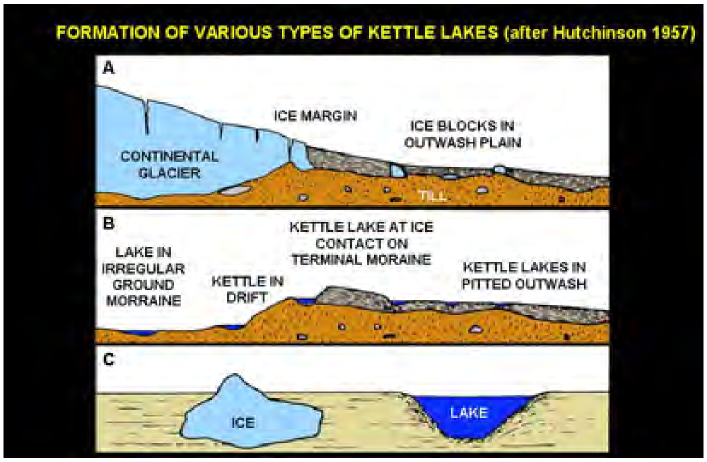


Figure 21. Lake types and formation

Lake Types

Glacial Lakes. Most of North America's lakes including the Great Lakes were formed during the most recent cycle of glacial activity (approx. 10,000 to 20,000). Although glaciers can form lakes through several unique processes, most basins are carved out by the glacier's weight and movement, or created when glacial debris forms dams. Glacial moraine dams are responsible for a number of lakes in North America (e.g., Lake Mendota in Wisconsin). Melting ice blocks left by retreating glaciers create kettle lakes (e.g. Walden Pond in Massachusetts).

Tectonic Basins. These basins form or are exposed due to movements of the earth's crust. This can result from uplifting as when irregular marine surfaces that collect freshwater after elevation (e.g. Lake Okeechobee in Florida), and tilting or folding to create depressions that form lake basins (e.g. Lake Champlain along the New York Vermont border). Lakes also form along faults (e.g. several lakes in California).

Other processes of lake formation are generally less common, but responsible for the wide variety of lakes that we see across North America. Examples include:

Volcanic Lakes. Several different volcanic processes can form lake basins. Craters form natural basins (Crater Lake in Oregon) well-known for their clear waters and lava dams can create basins in valleys.

Landslides. Rockfalls or mudslides that dam streams or rivers can form lakes for periods as short as a year to several centuries (e.g. several lakes in the Warner Range of northeastern California).

Solution Lakes. These lakes can be found in areas characterized by significant limestone deposits where percolating water creates cavities. These lakes are particularly common in Florida.

Plunge pools. Although somewhat rare, these lakes were formed when ancient waterfalls scoured out deep pools. They are often associated with glacial activity that diverted river flow (examples are Falls Lake in Washington and Green Lake in New York)

Oxbow Lakes. Where rivers or streams have meandered across low gradients, oxbows can often form in areas where the former channel has become isolated from the rest of the river. Several examples can be found along the Mississippi River and other large rivers.

Beaver-made and Human-made Lakes. Both humans and beavers create lakes when they dam rivers and streams. Lake Mead and Lake Powell are two of the more dramatic examples of human-made lakes along the course of the Colorado River. In addition to the many large dams, there are upwards of one million small dams impounding lakes and ponds across the lower 48 states.

Basic Functional Differences Between Streams and Lakes

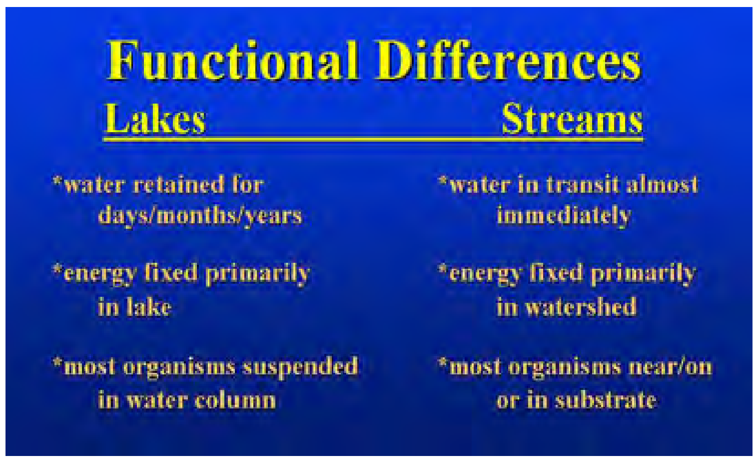


Figure 22. Important stream and lake differences

Differences between lake and stream dynamics are largely the result of differences in the location of energy fixation and the water residence time. Streams are primarily heterotrophic systems with energy fixed in the terrestrial environment rather than the stream itself and they are much more dependent on their watershed. Energy fixation and decomposition are spatially separated from each other. Although lakes are also dependent on their watersheds largely as the source of nutrients, most of the activity occurs in the water. In a lake, energy fixation and utilization of that energy by other organisms are not as spatially separated. Organisms in lakes and streams also tend to differ, due to the fact that stream organisms experience flowing water currents. The majority of primary producers and consumers in streams are benthic organisms that spend much of their time closely associated with the substrate. Because many lakes stratify, and have bottom waters that are limited in light and nutrients, the main challenge for organisms in many lakes is to remain suspended in the water column (Figure 22).

Structure in Upland Areas of Watersheds

The physical form of the uplands in watersheds can vary greatly, in ways beyond the scope of this discussion. Here we focus only on the distribution of and variations in vegetation and land use, which together create the element of watershed structure called **landscape pattern** (Figure 23). Vegetation and land use patterns in watersheds are known to have many significant influences on the condition of the water bodies they drain into; this topic is explored in greater detail in the Academy 2000 module on Watershed Change (http://www.epa.gov/watertrain/agents).

Figure 23. Aerial views reveal the complexity of landscape pattern, which implies many traits of a watershed's ecological functions.

Landscape patterns. Landscape ecology offers a simple set of concepts and terms for identifying basic landscape patterns: **matrix**, **patch**, and **mosaic** (Figure 24). The ecological term **matrix** refers to the dominant (> 60 percent) land cover, while a **patch** is a non-linear area that is less abundant and different from the matrix. A **mosaic** is a collection of different patches comprising an area where there is no dominant matrix. Various patch types have been described in the Examples of Different Patch Types box below. Basically, the most obvious landscape patterns are formed by combinations of native vegetation communities, unvegetated areas, and land use patterns.

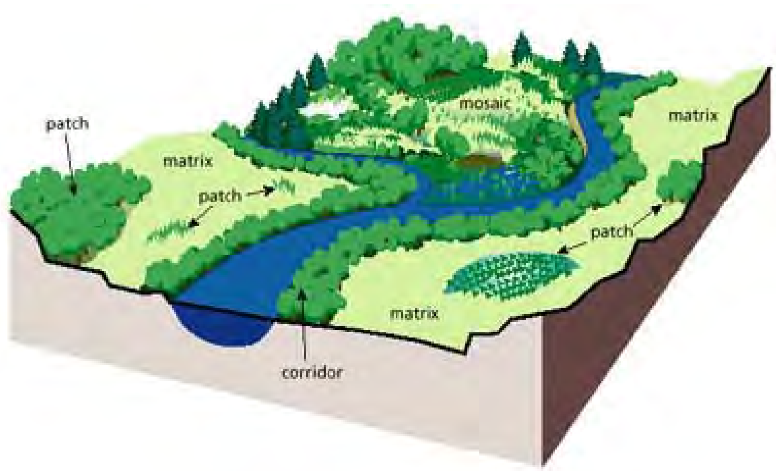


Figure 24. Useful units for describing landscape structure and pattern

Landscape pattern change. The individual patches in a landscape can change, and so can the entire landscape change in pattern and/or composition. Disturbances and various landscape processes maintain a constant dynamic, referred to as a shifting mosaic. Some landscapes remain in a "dynamic equilibrium" and, although changing steadily from place to place, retain an important quality called **mosaic stability**. A well-managed forestry operation, for example, would exhibit over the long term a constantly shifting set of locations where mature forest occurred, but at the same time sustains the relative proportions of forested and nonforested land in the area. Or, a landscape may evolve toward a new type of pattern and composition (e.g., via timber clearcutting, suburban sprawl, abandonment and succession of agricultural lands back to forest, or landscape change due to disease, fire, or global warming). It is always important, when analyzing landscape pattern and landscape change, to remain aw are that the spatial resolution of your information (how small a landscape feature you can detect) **may or may not be sufficient** to detect all the landscape changes of possible significance that may be occurring.

Vegetational patterns. Upland vegetation structure varies spatially, following various biogeographical patterns based on climate, physiography, soils, disturbance regimes, and their interactions (Figure 25). **Vegetation communities** are areas where a few species of plants dominate and establish a characteristic form or structure, within which a potentially large number of less abundant organisms also exist. Nationwide, there are hundreds of vegetation community types; the Society of American Foresters recognizes over 80 forest types alone (SAF, 1980). As a first step in analyzing vegetational patterns, it is easier to recognize a few generalized upland vegetation types based on their growth form, including:

- Forests (deciduous, evergreen and mixed)
- Shrublands
- Grasslands
- Forbs (broad-leaved herbs)

Examples of Different Patch Types
Disturbance patch. A patch which results from an alteration or disturbance.
Remnant patch. A patch which survives disturbance for some extended period of time.
Environmental patch. A patch which exists due to the natural variation of the environment (such as a soil type).
Regenerated patch. This type of patch resembles a remnant patch, except that it has regrown on a previously disturbed site.
Introduced patch. This type of patch is created by a human process (e.g., a clearcut, or a stand of planted trees).
Corridor. a uniquely important type of patch that links other patches in the matrix (e.g., a river channel, riparian or buffer zone).

These categories are commonly found on land cover maps likely to be available in the GIS data for most watersheds, and can be consulted to give a general sense of vegetation patterns in the watershed.

Human activity has carved up and fragmented many of the natural vegetation patterns that formerly covered our watersheds. Without human influence, however, vegetation patterns would not be uniform due to

Figure 25. Examples of matrix, patch, and corridor

different vegetation communities arising from different environmental conditions (e.g. variations in moisture and temperature due to slope and aspect) and events (e.g., fire, pest outbreak). In the West, the "rain shadow" is a common, basic example of how vegetation varies with physical position.

***Example:* Southern Sierra**
As moisture-laden air is pushed east, it begins to slowly rise as it reaches the gradually-sloping foothills of the southern Sierra. As the air rises, pressure increases, and moisture in the air begins to condense. As the air continues eastward, it continues upward to the crest of the range, and moisture within the air is seemingly wrung-out, much like a sponge. The eastern slope of the Sierra is quite dramatic, topographically. Indeed, Mt. Whitney, the highest point in the coterminous United States, is just a matter of miles from North America's lowest point (Death Valley, CA). Much of the eastern slope is quite dry, since the air is now deprived of much of its moisture.

Land-use patterns. Increasingly, the landscape structure and pattern we see is the result of widespread human activity. In all fields of environmental management including watershed management, analysis of land use types, patterns, and trends is commonplace. Because multiple uses occur in many locations and some land uses are not in themselves a visible landscape feature, mappers often use term **land cover** to describe the delineation of landscape structure and pattern formed by the dominant land uses and remaining vegetation communities. Some common land cover categories (indicating land uses within the areas) include:

- urban land (residential, commercial, industrial, mixed)
- agriculture (row crops, field crops, pasture)
- transportation (roads, railroads, airports)
- rangelands
- silviculture
- mining/extractive areas

Like vegetation patterns, the land use patterns in a watershed can be studied through GIS data or maps. Human-dominated landscapes, just as natural landscapes, are shifting mosaics that often progress through a series of changes in what is dominant.

***Example:* Rural Upstate New York**
Pre-settlement landscapes in upstate New York were probably almost entirely forested. By the mid to late 19th century, clear-cutting had removed the forest from most areas. In the first part of the 20th century, cropland and pasture became widespread and dominated 70% or more of the landscape, with remnant scattered forest patches, wetlands and lakes. By the second half of this century, a trend in migration into cities and towns led to an assorted pattern of landscapes, including urban/suburban-dominated areas with forest and agricultural patches, heavily agricultural landscapes, and transitional rural lands with decreasing agriculture and increasing forest regrowth.

Watershed Functions

Most of this training module has been spent describing the basic building blocks of watersheds, their structure and pattern. Now, the module concludes with a discussion of a few of the essential functions that occur in most healthy watersheds (Figure 26). These include:

- Transport and storage
- Cycling and transformation
- Ecological succession

Figure 26. Watershed function

As this module has gradually added layers upon layers of information about watersheds, this final category is the most complex. As you follow these materials, recall the elements of the physical template, the biological setting, the characteristics of natural systems, and the discussion of watershed structure – and appreciate why watersheds as natural systems are capable of performing many complex functions.

Transport and storage (of water, energy, organisms, sediments, and other materials)

Because a watershed is an area that drains to a common body of water, one of its main functions is to temporarily store and transport water from the land surface to the water body and ultimately (for most watersheds) onward to the ocean. But, in addition to moving the water, watersheds and their water bodies also transport sediment and other materials (including pollutants), energy, and many types of organisms. It is important when recognizing the **transport** function to also recognize temporary retention or **storage** at different locations in the watershed (Figure 27).

Figure 27. Sediment transport and deposition

Transport and Storage. As matter physically moves through the watershed, there are a number of terms which arise relative to various stages of cycling. ***Availability*** refers not just to the presence of an element in a system, but also speaks to the usability of a given agent. For instance, nitrogen gas may be plentiful in and around dam spillways, but N2 is not a usable form for most aquatic organisms, and thus the availability of nitrogen is compromised. ***Detachment*** refers to the release of matter from an anchoring point, and its subsequent movement. ***Transport***, a process most evident in stream channels, involves the movement of a material through a system. ***Deposition*** refers to a given endpoint within a cycle. ***Integration*** refers to the assimilation of matter into a site or organism following depositional processes (see Naiman and Bilby 1998). An example using these terms is included below.

Example: **Seston**
Seston (suspended particulate matter) is an important food source for a few key aquatic organisms. In the context of the above continuum, seston's availability within a given stream system may refer to the source. In a hypothetical example, nitrogen and phosphorus, both limiting in many freshwater ecosystems, are made available to a stream during a period of elevated discharge. Attached algae (periphyton) begins to grow on rocks and submerged surfaces (***availability***). During growth and maturation, algal cells begin to slough off from the rocks and logs (***detachment***) and the current carries these cells, rich in chlorophyll, downstream (***transport***). *Hydropsychid* caddisfly larvae, which feed on seston, spin elaborate nets (much like a spider's web), anchoring these nets on cobble substrates or other submerged features. These nets catch the suspended particulates as they drift with the current (***deposition***). The caddisfly larvae then feed off particles captured in the net (***assimilation***); algal cells represent high quality food for these organisms and they may, as a population, exert an influence over the relative abundance of various particle-types.

Transport and storage of water. One can view a watershed as an enormous precipitation collecting and routing device, but transportation and storage of water actually involves a complicated mix of many smaller processes (which are **bolded** in the following text). Even before **precipitation** reaches the ground (Figure 28), it interacts with vegetation. Trees and other vegetation are responsible for **interception** and **detention** of some of the rainfall, leading to some **evaporation** and also slowing the amount reaching the ground via **throughfall** and giving it time for better **infiltration** to groundwater (one form of **storage**). **Saturation** of soils, occurring when precipitation exceeds infiltration, leads to **overland flow** and, over longer time frames, **drainage network development** (Figure 29). The consistent flow of water in channels affects and shapes **channel development and morphology** in ways that seek dynamic equilibrium with the job to be done (moving water downstream). Recall also this module's earlier discussion of the **longitudinal profile development** of rivers and streams, and how upper, middle and lower zones of streams generally have very different forms to handle very different sets of functions, many related to transport and storage of water.

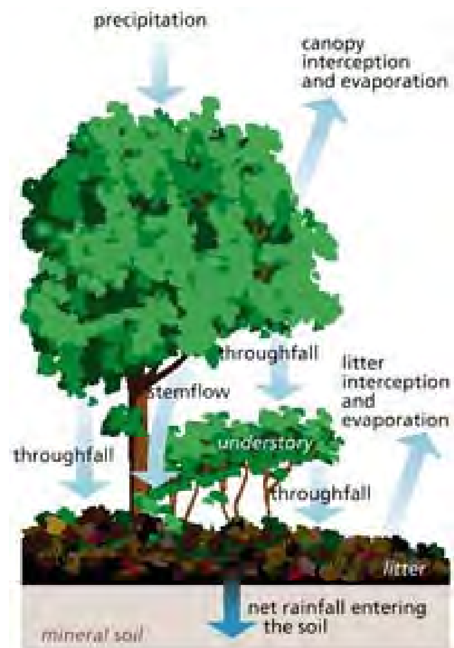


Figure 28. Dynamics of precipitation

Transport and storage of sediments. Watersheds also collect and transport sediments as a major function. Sediment transport and storage is a complex network of smaller watershed processes, like the water processes described above, and actually is inseparable from water transport and storage. Sediment related processes mostly involve **erosion** and **deposition**, but sediment transport and storage also play a longer-term role in **soil development**.

The **drainage network development** and **channel development** (Figure 30) discussed above appears to be dominated by erosion at first glance, but the redeposition of sediments on floodplains is an important function that rejuvenates soils and influences the productivity and diversity of stream corridor ecosystems.

Cycling and Transformation.

Cycling and transformation are another broad class of natural functions in watersheds. Various elements and materials (including water) are in constant cycle through watersheds, and their interactions drive countless other watershed functions. Figure 31, for example (overleaf), illustrates interactions of the carbon and nitrogen cycles with stream biota and the resulting influence on dissolved oxygen. Elements like carbon, nitrogen, and phosphorus comprise the watershed's most important biogeochemical cycles. Cycling involves an element of interest's transport and storage, change in form, chemical transformation and adsorption.

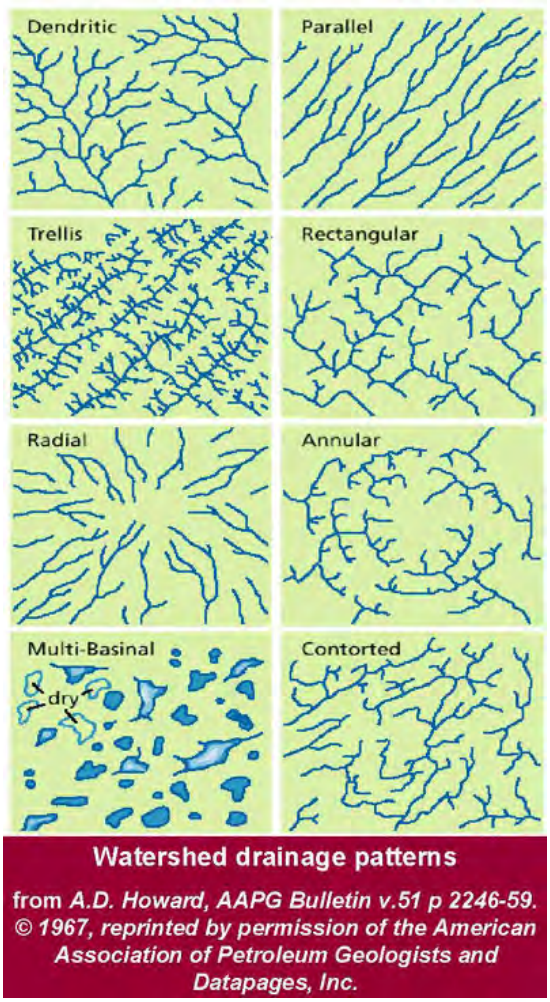


Figure 29. Common drainage patterns

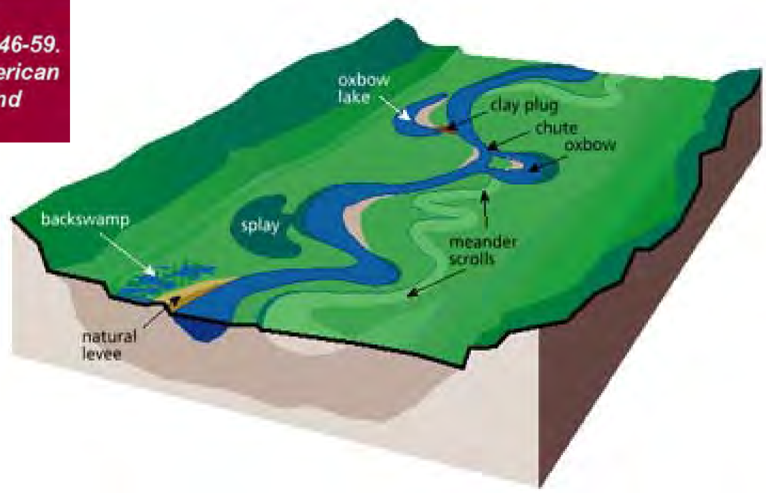


Figure 30. Common channel and near-channel features

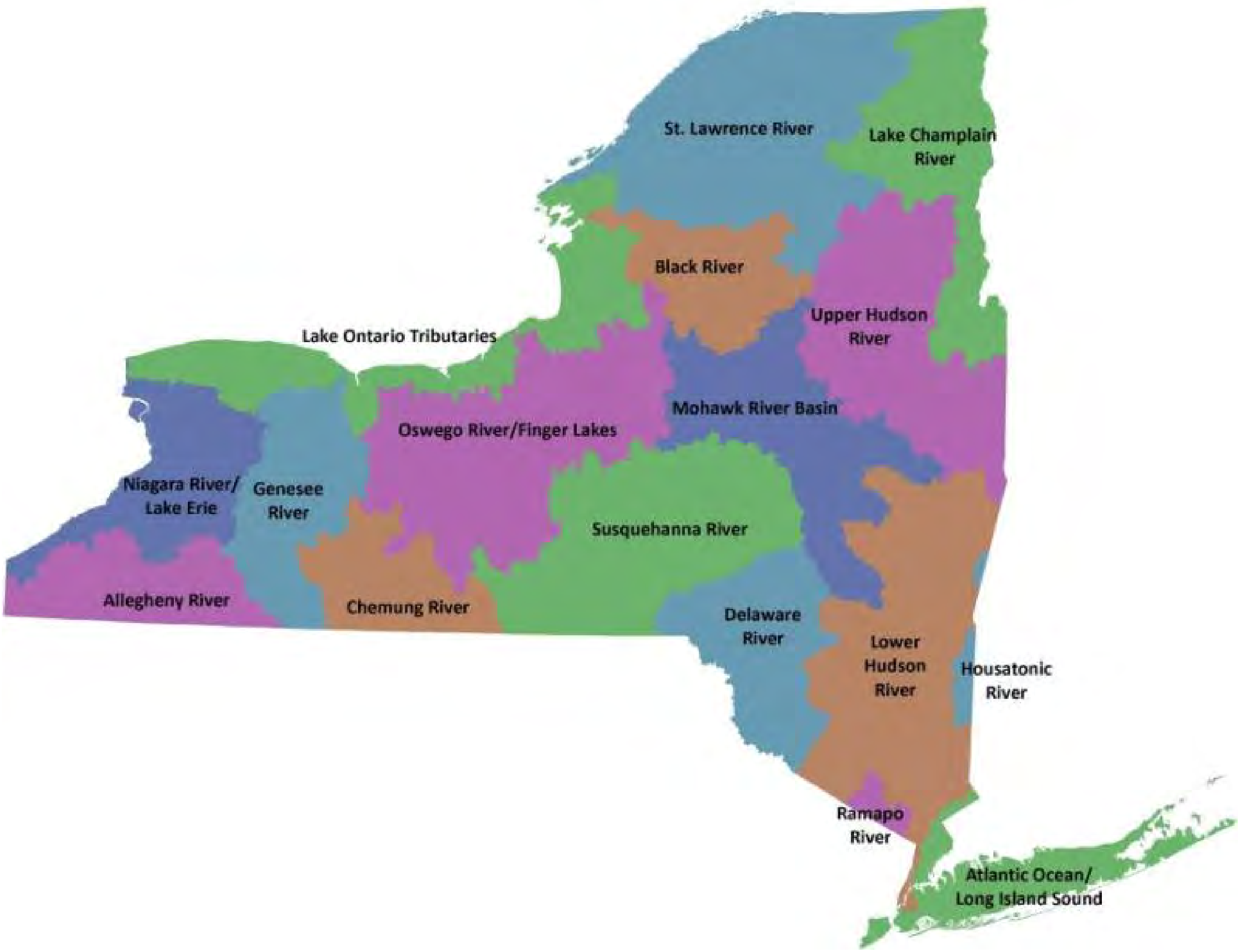
Great Lakes Basin Poster

New York State Watersheds

New York State Department of Environmental Conservation

Watersheds

New York's waters (lakes, rivers and streams) fall within one of 17 major watersheds, or drainage basins. A watershed is an area of land that drains water into a specific body of water. Watersheds include networks of rivers, streams, and lakes and the land area surrounding them. Watersheds are separated by high elevation geographic features (mountains, hills, ridges)



NCF-Envirothon 2024 New York

Aquatic Ecology Study Resources

Key Topic #2: Aquatic Species and Ecology

4. Identify the biotic and abiotic components of aquatic ecosystems and describe the processes by which these interact.
5. Describe the role of native freshwater fish, macroinvertebrates, aquatic plants, and wetland mammals common to New York State in freshwater ecosystems.
6. Describe the impact of New York State aquatic invasive species on native species and freshwater ecosystems.
7. Describe the role of cyanobacteria in aquatic ecosystems and their role in the development of harmful algal blooms (HABs).
8. Explain the role of aquatic ecosystems in biogeochemical cycles such as the carbon, nitrogen, and phosphorus cycles.

Study Resources

<u>Study Resources begin on the next page!</u> ➡

Estuaries: Where The Ocean Meets Fresh Water

Estuaries are biomes that occur where a source of fresh water, such as a river, meets the ocean. Therefore, both fresh water and salt water are found in the same vicinity; mixing results in a diluted (brackish) saltwater. Estuaries form protected areas where many of the young offspring of crustaceans, mollusks, and fish begin their lives. Salinity is a very important factor that influences the organisms and the adaptations of the organisms found in estuaries. The salinity of estuaries varies and is based on the rate of flow of its freshwater sources. Once or twice a day, high tides bring salt water into the estuary. Low tides occurring at the same frequency reverse the current of salt water.

The short-term and rapid variation in salinity due to the mixing of fresh water and salt water is a difficult physiological challenge for the plants and animals that inhabit estuaries. Many estuarine plant species are **halophytes**: plants that can tolerate salty conditions. Halophytic plants are adapted to deal with the salinity resulting from saltwater on their roots or from sea spray. In some halophytes, filters in the roots remove the salt from the water that the plant absorbs. Other plants are able to pump oxygen into their roots. Animals, such as mussels and clams (phylum Mollusca), have developed behavioral adaptations that expend a lot of energy to function in this rapidly changing environment. When these animals are exposed to low salinity, they stop feeding, close their shells, and switch from aerobic respiration (in which they use gills) to anaerobic respiration (a process that does not require oxygen). When high tide returns to the estuary, the salinity and oxygen content of the water increases, and these animals open their shells, begin feeding, and return to aerobic respiration.

Freshwater Biomes

Freshwater biomes include lakes and ponds (standing water) as well as rivers and streams (flowing water). They also include wetlands, which will be discussed later. Humans rely on freshwater biomes to provide aquatic resources for drinking water, crop irrigation, sanitation, and industry. These various roles and human benefits are referred to as ecosystem services. Lakes and ponds are found in terrestrial landscapes and are, therefore, connected with abiotic and biotic factors influencing these terrestrial biomes.

Lakes and Ponds

Lakes and ponds can range in area from a few square meters to thousands of square kilometers. Temperature is an important abiotic factor affecting living things found in lakes and ponds. In the summer, thermal stratification of lakes and ponds occurs when the upper layer of water is warmed by the sun and does not mix with deeper, cooler water. Light can penetrate within the photic zone of the lake or pond. **Phytoplankton** (small photosynthetic organisms such as algae and cyanobacteria that float in the water) are found here and carry out photosynthesis, providing the base of the food web of lakes and ponds. **Zooplankton** (very small animals that float in the water), such as rotifers and small crustaceans, consume these phytoplankton. At the bottom of lakes and ponds, bacteria in the aphotic zone break down dead organisms that sink to the bottom.

Nitrogen and phosphorus are important limiting nutrients in lakes and ponds. Because of this, they are determining factors in the amount of phytoplankton growth in lakes and ponds. When there is a large input of nitrogen and phosphorus (from sewage and runoff from fertilized lawns and farms, for example), the growth of algae skyrockets, resulting in a large accumulation of algae called an **algal bloom**. Algal blooms (Figure 4) can become so extensive that they reduce light penetration in water. As a result, the lake or pond becomes aphotic and photosynthetic plants rooted in the lake bottom cannot survive. When the algae die and decompose, severe oxygen depletion of the water occurs. Fishes and other organisms that require oxygen are then more likely to die, and resulting dead zones are found across the globe. Lake Erie and the Gulf of Mexico represent freshwater and marine habitats where phosphorus control and storm water runoff pose significant environmental challenges.

Figure 4. The uncontrolled growth of algae in this lake has resulted in an algal bloom. (credit: Jeremy Nettleton)

Rivers and Streams

Rivers and streams are continuously moving bodies of water that carry large amounts of water from the source, or headwater, to a lake or ocean. The largest rivers include the Nile River in Africa, the Amazon River in South America, and the Mississippi River in North America.

Abiotic features of rivers and streams vary along the length of the river or stream. Streams begin at a point of origin referred to as source water. The source water is usually cold, low in nutrients, and clear. The channel (the width of the river or stream) is narrower than at any other place along the length of the river or stream. Because of this, the current is often faster here than at any other point of the river or stream.

The fast-moving water results in minimal silt accumulation at the bottom of the river or stream, therefore the water is clear. Photosynthesis here is mostly attributed to algae that are growing on rocks; the swift current inhibits the growth of phytoplankton. An additional input of energy can come from leaves or other organic material that falls into the river or stream from trees and other plants that border the water. When the leaves decompose, the organic material and nutrients in the leaves are returned to the water. Plants and animals have adapted to this fast-moving water. For instance, leeches (phylum Annelida) have elongated bodies and suckers on both ends. These suckers attach to the substrate, keeping the leech anchored in place. Freshwater trout species (phylum Chordata) are an important predator in these fast-moving rivers and streams.

As the river or stream flows away from the source, the width of the channel gradually widens and the current slows. This slow-moving water, caused by the gradient decrease and the volume increase as tributaries unite, has more sedimentation. Phytoplankton can also be suspended in slow-moving water. Therefore, the water will not be as clear as it is near the source. The water is also warmer. Worms (phylum Annelida) and insects (phylum Arthropoda) can be found burrowing into the mud. The higher order predator vertebrates (phylum Chordata) include waterfowl, frogs, and fishes. These predators must find food in these slow moving, sometimes murky, waters and, unlike the trout in the waters at the source, these vertebrates may not be able to use vision as their primary sense to find food. Instead, they are more likely to use taste or chemical cues to find prey.

Wetlands

Wetlands are environments in which the soil is either permanently or periodically saturated with water. Wetlands are different from lakes because wetlands are shallow bodies of water that may periodically dry out. Emergent vegetation consists of wetland plants that are rooted in the soil but have portions of leaves, stems, and flowers extending above the water's surface. There are several types of wetlands including marshes, swamps, bogs, mudflats, and salt marshes (Figure 5).

Figure 5. Located in southern Florida, Everglades National Park is vast array of wetland environments, including sawgrass marshes, cypress swamps, and estuarine mangrove forests. Here, a great egret walks among cypress trees. (credit: NPS)

Healthy aquatic ecosystems have a wide variety of plant species and different species of insects, fish, amphibians and other animals. Unhealthy aquatic ecosystems have very few species. You have already learned about the different types of fish found in New York waters. Here are some of the other common plants and animals, from the smallest to the largest, that you might find when you fish these waters.

WATCHING AQUATIC LIFE

A perfect time to look for aquatic life is when you're fishing. Besides telling you what the fish you're after might be eating, watching aquatic life can help pass the time when the fish aren't biting. Look around. What can you see while you're out fishing?

MICROSCOPIC ANIMALS (ZOOPLANKTON)

These tiny animals float or "swim" in the water and seeing them usually requires a microscope. Along with microscopic plants (algae), they form the base of the food web (page 57) that all other organisms directly or indirectly depend upon.


Copepod

Hydra

LEECHES

These are often found in warmwater lakes, ponds and rivers. They like weedy areas with soft bottoms. They attach to fish and other animals and feed on blood.


Leech

AQUATIC INSECTS

These are an important source of food for many fish species. Insects, such as mayflies, stoneflies and caddis flies, are an important food for trout. Fly fisherman tie flies to look like various aquatic insects.

Insects that Spend Most of Their Lives In or On the Water

Water Strider

Water Boatman

Backswimmer

Whirligig Beetles

Diving Beetle

Insects that Spend Some or All of Their Adult Lives Out of Water


Mayfly (nymph)


Mayfly (adult)


Stonefly (nymph)


Stonefly (adult)

Blackfly


Caddisfly (nymph)


Caddisfly (adult)


Dragonfly


Damselfly

Mosquito

Insects such as mayflies are only found in high-quality waters. Most kinds of mayflies are sensitive to pollution. Usually the presence of mayflies is an indication of good water quality.

MOLLUSKS (SNAILS, CLAMS AND MUSSELS)

These soft bodied animals are usually covered by a hard shell. Although saltwater clams and mussels are popular foods, freshwater species are not typically good to eat. Mussels and clams feed by filtering algae out of the water, while snails usually eat plants. Some mollusks move by a slimy foot that sticks out of their shell, while others attach themselves to hard surfaces, like rocks and docks, and do not move.

Pond Snail


Freshwater Mussel

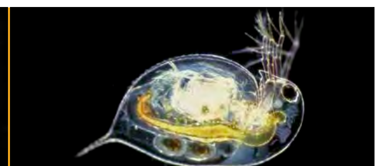
Fingernail Clam

CRUSTACEA

This very large group of animals includes crabs, lobsters and shrimp. Almost all are found in water. Crayfish, a relative of the saltwater lobster, are one of the more obvious crustaceans found in freshwater. They usually live in burrows or under rocks during the day and feed at night. Other freshwater crustaceans, such as the water flea and scud, are much smaller in size and seeing them may require a microscope.


Crayfish

Scud


Water Flea

REPTILES

Unlike amphibians, reptiles do not lay their eggs in water and do not have a phase of life where they live entirely in water. Their young hatch out of eggs on land and look like smaller versions of the adult. Turtles and some species of snakes prefer watery habitats. Note that although New York's water-snake species look dangerous and may bite if handled, they are not poisonous.

Snapping Turtle

Painted Turtle


Northern Water Snake

AMPHIBIANS

Unlike reptiles that can be found far from a lake or pond, amphibians require that their skin remain moist, so they are always found near water. Their eggs are laid in water, and young amphibians have gills and spend their early lives in water. Hellbenders and mudpuppies, two of New York's larger amphibians, spend their entire lives in water.


Mudpuppy


Juvenile Red Spotted Newt

Hellbender


Green Frog

Bullfrog

BIRDS THAT LIVE NEAR WATER

Abundant plant and animal life around lakes, ponds, rivers and streams attracts many birds to live near water.

Waterfowl (ducks, geese and swans)

Ducks, geese, and swans love to feed on the aquatic plants that grow in freshwater. Diving ducks, like mergansers, are excellent swimmers and divers, chasing down the fish they eat.

Canada Goose

Mallard Duck (Male and Female)

Common Merganser

Wood Duck (Male and Female)

Black Duck

Wading Birds

Herons and egrets are specially adapted with long legs for wading and pointed beaks for feeding on fish in shallow water.

Great Blue Heron

Green Heron

Snowy Egret

Other Birds that Live Near Water

The osprey, or fish hawk as it is sometimes called, is a large raptor often seen hovering over water bodies searching for fish to dive on and catch in the sharp talons on their feet. Belted kingfishers look for prey from branches overhanging the water, diving to catch small fish in their large beaks. Red-winged blackbirds are insect eaters that nest in cattails and other marsh grasses. Cormorants are large, voracious, fish-eating birds whose abundance sometimes becomes a nuisance.

Osprey

Kingfisher

Red-winged Blackbird

Double-crested Cormorant

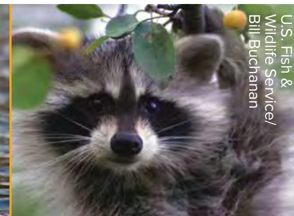
MAMMALS

Muskrat, beaver and otter spend most of their lives in and around water. Other animals, like raccoon and mink, frequent shoreline areas, feeding on crayfish, frogs and insects. Bats can often be seen swooping after insects at dusk above a lake or river.

Muskrat

Beaver


River Otter



Raccoon


Bat

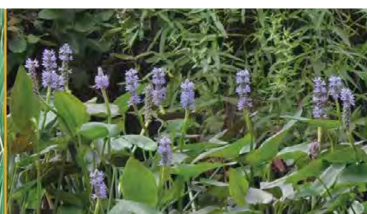
AQUATIC PLANTS

Except for the microscopic plants called algae, aquatic plants are classified as floating, emergent or submergent. See definitions and examples below. Aquatic plants are an important food source for many aquatic animals and provide habitat for insects that are an important food for fish. Ducks and many other aquatic birds nest among aquatic plants and many also eat them.

Emergent Plants

Plants like cattail, pickerelweed and bulrush have sturdy stalks that emerge above the water's surface.


Cattail


Pickerelweed

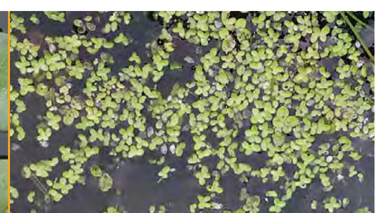

Bulrush

Floating Plants

Plants like white water lily, yellow water lily and duckweed have leaves that float on the water's surface.

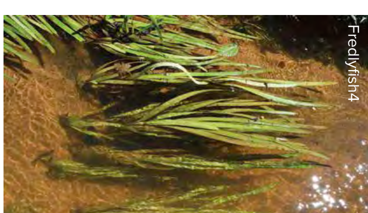

White Water Lily


Yellow Water Lily

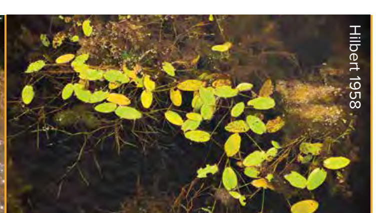

Duckweed

Submergent Plants

Plants like pondweed, water-milfoil and coontail grow completely below the water's surface.



Eel Grass



Pondweed

Coontail

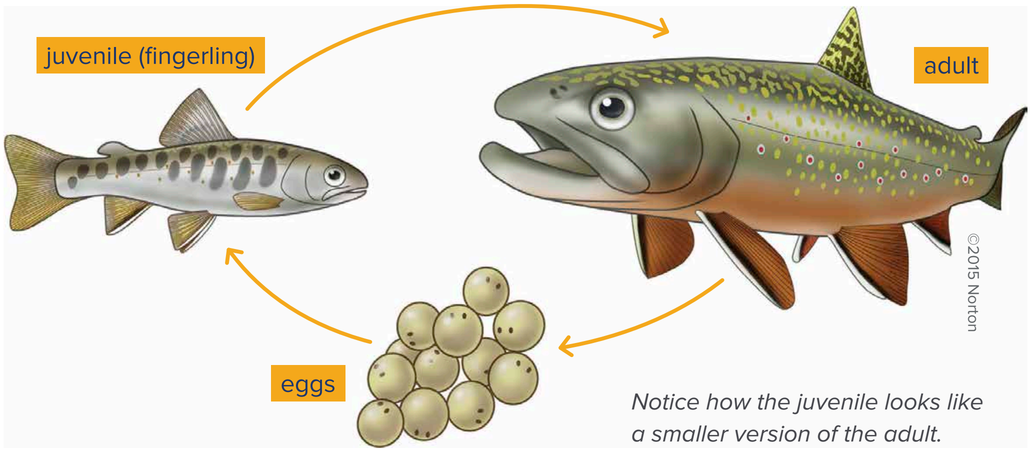
THE CYCLE OF LIFE

A life cycle is the series of changes, or stages, in the life of an animal. Most animals, including mammals, fish, reptiles and birds have simple life cycles with three life stages: before birth, young and adult. The young typically look similar to the adults, only smaller. Humans have a simple life cycle.

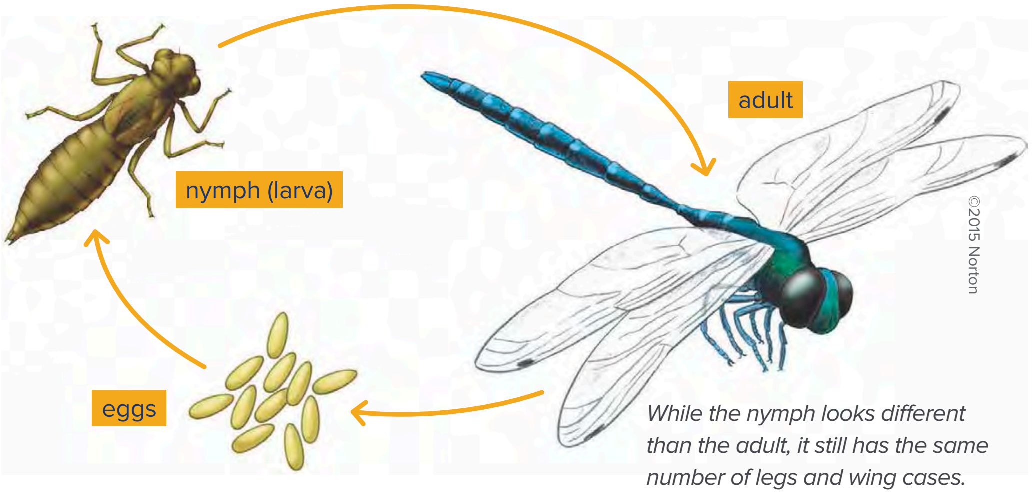
Some animals, such as amphibians, go through a more complex life cycle called metamorphosis. They completely change as they develop into adults. The adult can often live in different environments than the young. The change of a tadpole into a frog is an example of metamorphosis. The tadpole lives entirely in water, while the adult can live in both water and on land.

Look at me now!

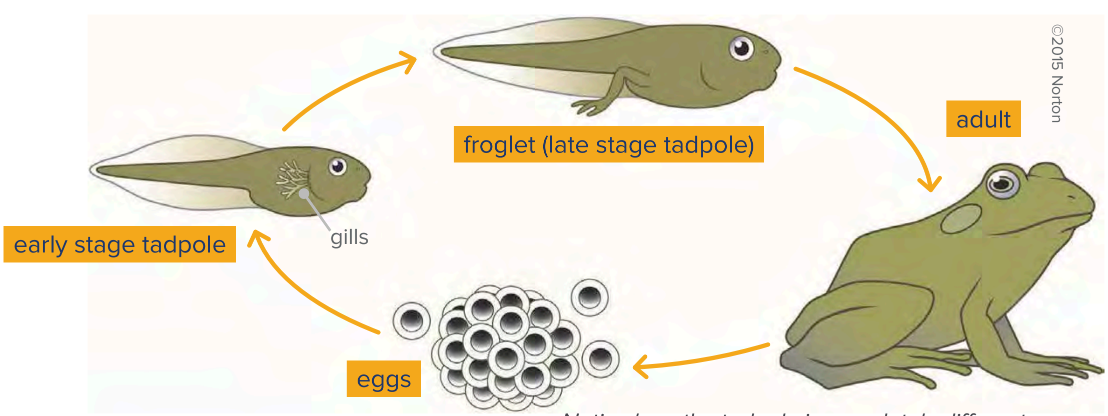
The early development stages of aquatic organisms can look similar or very different from the adult stage! At right are three examples of aquatic organism life cycles that illustrate this:



TROUT (SIMPLE LIFE CYCLE) – Egg to juvenile to adult



DRAGONFLY (INCOMPLETE METAMORPHOSIS) – Egg to nymph to adult

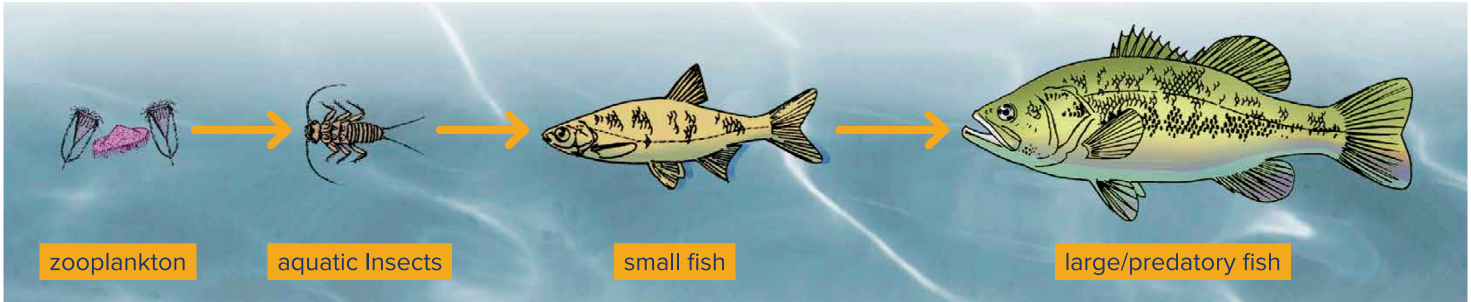


Notice how the tadpole is completely different than the adult. It has a tail where the frog has legs.

FROG (METAMORPHOSIS) – Egg to tadpole to froglet to adult

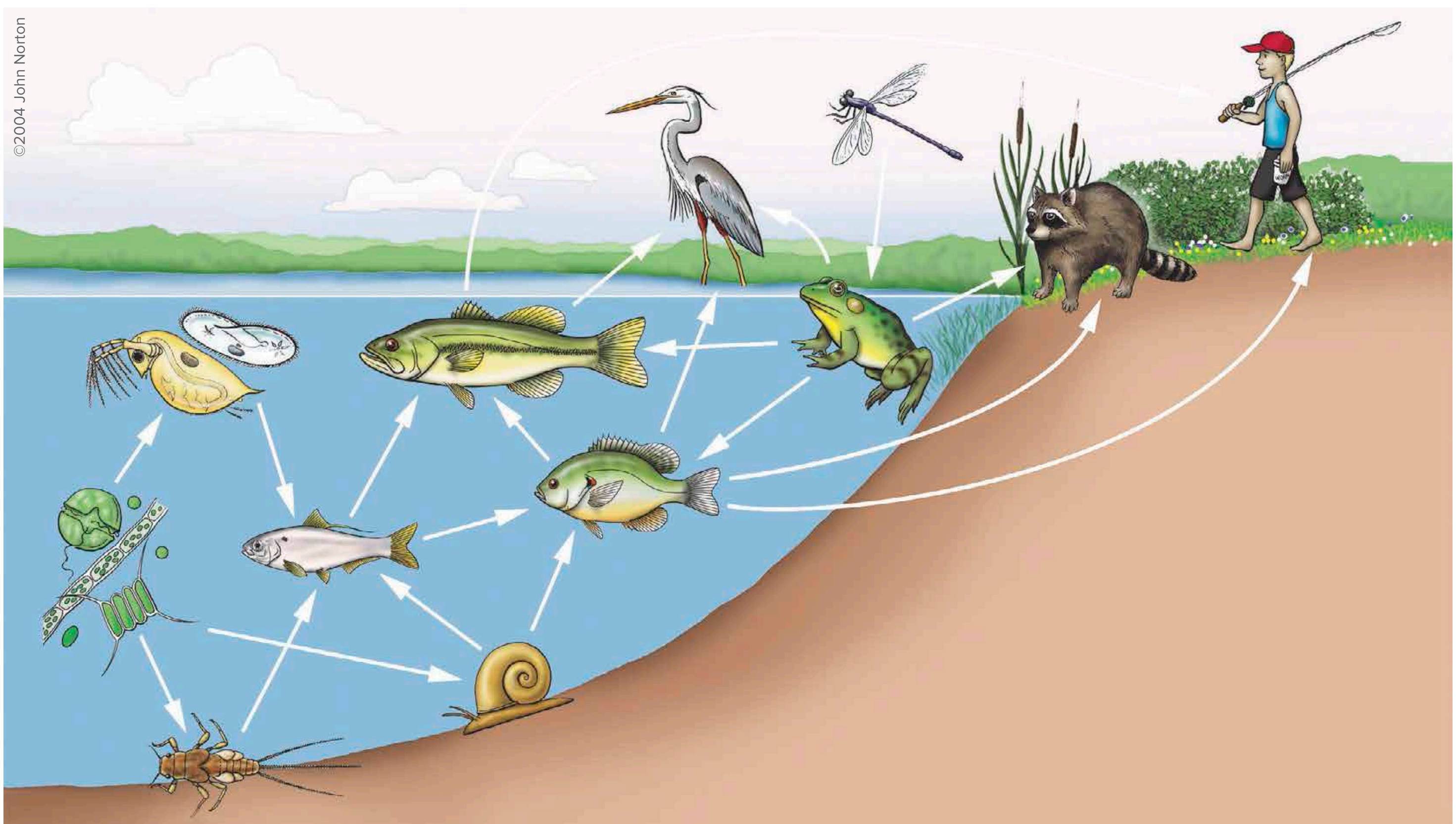
THE WEB OF LIFE

All life is connected to each other in one way or another. The simplest way to think about this is a food chain. In a food chain each group of plants and animals is used as food by the group above it. For example, the sun gives energy to algae (tiny plants), which feed zooplankton (tiny animals), which feed aquatic insects, which feed minnows and other small fish, which feed bass and other large fish.



Aquatic Food Chain

In any ecosystem, a series of food chains connect to each other. When you draw all the connections, you get something that looks more like a web than a chain. This more complicated "food web" shows how living things are connected to each other.



Aquatic Food Web

REFERENCES

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Websites

- DEC Animals, Plants and Aquatic Life Publications www.dec.ny.gov/pubs/4799.html
- Freshwater Macroinvertebrates of NY www.dec.ny.gov/animals/35772.html

The Great Lakes Basin: Invasive Species

New York Sea Grant

INVASIVE SPECIES

From the spread of the sea lamprey with the opening of the Erie and Welland Canals in the early 1980's, invasive species have impacted the environment of the Great Lakes. Today, more than 180 invasive species, from the alewife to zebra mussels, make their home in the Great Lakes. The invaders compete for food and habitat, alter food webs and have caused the extinction of some native species.

Zebra and quagga mussels have had a profound impact on the Great Lakes since their arrival in ships' ballast water in the late 1980s. The original zebra mussel (Dreissena polymorpha) and the related quagga mussel (Dreissena rostriformis bugensis) that arrived a few years later, are responsible for changes in the food web. They filter out plankton and other particles from the water, reducing the available food for other species. Both species of mussels are prolific breeders and their numbers grew rapidly. Quagga mussels are found in colder, deeper areas of the Great Lakes, often covering the substrate hundreds of feet below the surface. The filtering activity of zebra and quagga mussels has increased water transparency in the Great Lakes. The increased light penetration allows for more algal and plant growth in the water. This water clarity often results in people believing the mussels have "cleaned-up" the Great Lakes, but in actuality they have only made the water clearer. In fact, as mussels filter water close to the bottom of the lakes, they can actually take up pollutants, contaminants and bacteria that can become part of the food web when mussels are consumed by bottom-dwelling fish like round gobies.

Like zebra and quagga mussels, the **Round Goby** (Neogobius melanostomus) was introduced in ballast water from ships coming from the Black and Caspian Seas in Europe. These aggressive fish feed actively on the eggs of many Great Lakes fish like lake trout, bass and whitefish. They also compete with other benthic (bottom-dwelling) fish like sculpin and darters, reducing their numbers. Gobies are easily identified by their suction cup-shaped, fused pelvic fins. No other Great Lakes fish has this suction disk on its belly. Round gobies have highly developed sensory systems that allow them to avoid predators and detect prey. They are also capable of multiple spawnings (up to 6 times per year), allowing them to quickly increase and maintain the size of their populations.

The **sea lamprey** (Petromyzon marinus) is referred to as the "vampire" of the Great Lakes since it is a parasitic fish that feeds on the blood and body fluids of other fishes. Originally from the Atlantic Ocean, sea lamprey made their way to Lake Ontario through the St. Lawrence River and moved through the other Great Lakes with the opening of the Erie and Welland Canals. Sea lampreys have a sucker-like mouth ringed with sharp teeth that they use to attach to fish. Once firmly anchored, sea lampreys use a rasping tongue to break through the slime and scales before feeding. Special enzymes are released by the lamprey that prevent the fish's blood from clotting, allowing the lamprey to continue its meal. Sea lampreys take a toll on the fishes of the Great Lakes, often targeting fish with small scales like whitefish, lake trout and salmon. The Great Lakes Fishery Commission is charged with controlling sea lamprey populations and they use a variety of techniques including Lampricides (pesticides to target lampreys), traps and barriers.

People are encouraged to help reduce the spread of invasive species by cleaning their boats and trailers before moving them to other areas, draining live-wells, properly disposing of bait and to taking other steps. Visit http://www.protectyourwaters.net/ to learn more about the Stop Aquatic Hitchhikers! campaign and what you can do to slow the spread of aquatic invasive species.

Although many aquatic invasive species (AIS) have spread through the Great Lakes by ballast water, bait bucket dumping and hitchhiking on recreational boats and trailers, these are not the only means of introductions. Recently, efforts have been made to prevent the introduction or spread of AIS through the aquarium organisms in and nursery trades and classroom release. These pathways provide a significant threat to the health of trade (OIT) the Great Lakes. The release or escape of aquarium fish, reptiles, amphibians and invertebrates, as well as the spread of nonnative plants have the potential to alter ecosystems and impact food webs. Notorious examples such as the northern snakehead (Channa argus) fish, red swamp crayfish (Procambarus clarkii), goldfish (Carassius auratus), and plants, like Eurasian watermilfoil (Myriophyllum spicatum) and hydrilla (Hydrilla verticillata) have been released or escaped from aquaria, backyard ponds or water gardens. The habitatude campaign focuses on protecting the environment by teaching people about not releasing unwanted plants and animals.

Sea Grant
New York

New York Sea Grant
229 Jarvis Hall
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Buffalo, NY 14260-4400 Tel: 716.645.3610 www.nyseagrant.org
New York's Sea Grant Extension Program provides Equal Program and Equal Employment Opportunities in association with Cornell Cooperative Extension, U.S. Department of Agriculture and U.S. Department of Commerce and cooperating County Cooperative Extension Associations.

Invasive Mussels: Zebra Mussel (*Dreissena polymorpha*) and Quagga Mussel (*Dreissena rostriformis bugensis*), 2016

(Source: https://www.usgs.gov/communications-and-publishing/news/earthword-quagga-mussel)

Round Goby

The round goby is a small, soft-bodied fish with a distinctive black spot on the first dorsal fin. Photo by Dave Jude, Univ. of Michigan

Common Name: Round goby
Scientific Name: *Neogobius melanostomus*
Origin: Eurasia

Description

The round goby is a small, soft-bodied fish with a distinctive black spot on the first dorsal fin. They have large, protruding eyes and range in length from 4″ to 10″. While juveniles are grey, adult round gobies have grey, black, brown, and olive green markings.

Habitat

Round gobies inhabit both fresh and saltwater. They are a bottom dwelling species, preferring sandy or rocky shelves with low silting. They have spread throughout the Great Lakes and into the interior of the U.S.

Threat

The round goby is an aggressive fish that outcompetes natives for food, shelter, and nesting sites. They prey heavily on eggs, including those of many popular sport fish. They consume large amounts of invasive mussels containing toxins, posing the risk of bioaccumulation further up the food chain. They can survive in degraded ecosystems and serve as a host to many parasites.

Management

While native predatory fish have begun to prey on round gobies, their populations still reach high numbers as a result of their rapid reproduction. Management includes the use of fish pesticides, physical barriers, and bioacoustic and pheromone traps.

Sea lampreys in a tank

January 30, 2024

(Source: https://www.usgs.gov/media/images/sea-lampreys-a-tank-0)

Harmful Algal Blooms (HABs)

Background

Harmful algal blooms (HABs) in freshwater (lakes, ponds, rivers, and streams) generally consist of visible patches of cyanobacteria, also called blue-green algae. Cyanobacteria are naturally present in low numbers in most aquatic (freshwater and/or marine) systems. Under certain conditions, including adequate nutrient (e.g., phosphorus) availability, warm temperatures, and calm winds, cyanobacteria may multiply rapidly and form blooms that are visible on the surface of the affected waterbody. Several types of cyanobacteria can produce toxins and other harmful compounds that can pose health risks to people and animals through ingestion, skin contact, or inhalation.

DEC has routinely documented the occurrence of HABs in New York State since 2012 and has produced resources to inform the public of the occurrence of HABs and strategies to avoid them. In addition, through data collection, development of lake and river surveillance programs, and research, the DEC is working to identify the primary factors triggering HAB events and facilitate decision-making to minimize the frequency, intensity, and duration of HABs as well as the effects that HABs have on both people and aquatic life which rely on clean water.

Be Prepared

Before you go in the water, check which waterbodies have blooms or have had them in the past.

Know it, Avoid it, Report it!

Because it is hard to tell a HAB from non-harmful algal blooms, it is best to avoid swimming, boating, otherwise recreating in, or drinking water with a bloom.

Know it

Most algae are harmless and are an important part of the food web. Certain types of algae can grow quickly and form blooms, which can cover all or portions of a lake. Even large blooms are not necessarily harmful. However some species of algae can produce toxins that can be harmful to people and animals. Blooms of algal species that can produce toxins are referred to as harmful algal blooms (HABs).

HABs are likely triggered by a combination of water and environmental conditions such as:

- excess nutrients (phosphorus and nitrogen);
- lots of sunlight;
- low-water or low-flow conditions;
- calm water; and
- warm temperatures.

Depending on the weather and the characteristics of the lake, HABs may be short-lived (appearing and disappearing in hours) or long-lived (persisting for several weeks or more).

Avoid it

- People, pets, and livestock should **avoid contact** with any floating mats, scums, or discolored water. Colors can include shades of green, blue-green, yellow, brown or red.
- **Never drink, prepare food, cook, or make ice with untreated surface water**, whether or not algae blooms are present. In addition to toxins, untreated surface water may contain bacteria, parasites, or viruses that could cause illness if consumed.
- People not on public water supplies **should not drink surface water during an algal bloom**, even if it is treated, because in-home treatments such as boiling, disinfecting water with chlorine or ultraviolet (UV), and water filtration units do not protect people from HABs toxins.

Report it

- If you suspect that you have seen a HAB, please report the HAB to DEC. Fill out and submit a Suspicious Algal Bloom Report Form.
    - If possible, attach digital photos (close-up and landscape to show extent and location) of the suspected HAB in the web form.
    - Email HABsInfo@dec.ny.gov if you are not able to complete the form.
- Please report any health symptoms to NYS Health Department at harmfulalgae@health.ny.gov and your local health department.

HABs may look like parallel streaks, usually green, on the water surface.

Green algae can look like floating rafts on the water, but do not produce harmful toxins.

If contact occurs:

Rinse thoroughly with clean water to remove algae. Stop using water and **seek medical attention immediately** if symptoms such as vomiting, nausea, diarrhea, skin, eye or throat irritation, allergic reactions, or breathing difficulties occur after drinking or having contact with blooms or untreated surface water.

You should inform your physician and you local health department if you were exposed to an algal bloom, both to help determine the proper course of treatment and to determine if others should also be notified of this potential risk.

People vary in their sensitivity to HABs exposure, in the way some people are more sensitive to poison ivy and other environmental allergens and irritants. Cyanobacteria can release toxins and other harmful compounds that affect people through skin exposure or ingestion. Gastrointestinal symptoms including nausea, vomiting, and diarrhea are possible. Skin or throat irritation, allergic reactions, or asthma-like breathing difficulties are also symptoms of exposure.

Staying Safe Around HABs

Swimming, Wading, and General Recreation

Don't let children or pets wade, drink the water, or walk in beach debris if you suspect an algae bloom is present. The best advice is "Know it, Avoid it, Report it." Following this advice will greatly reduce the likelihood of exposure to HABs.

People recreating in and on the water should be aware of the potential for HABs in any waterbody they consider using (check the HABs Notifications page for a list of waterbodies with bloom reports or OPEN NY for past listings). The risk for exposure while swimming is greater when blooms cover a large part of a waterbody or when water sample results show a bloom is present in the open water (i.e., the deeper portions of a waterbody).

More information about these symptoms can be found on the Department of Health (DOH) Blue-green Algae webpage.

Swimming at regulated beaches will greatly reduce your risk of exposure to HABs, since beaches are closely monitored by professionals for the presence of blooms. Beach closures of health officials are conducted to protect swimmers from potentially harmful events, including HABs.

If you plan on swimming outside of a regulated swimming beach, learn how to help you reduce your risk of exposure to potential hazards. It is your responsibility to decide if the risks associated with swimming in a waterbody are acceptable. People and pets should avoid swimming in heavily discolored water or surface scums and should not handle algae material.

Animal Exposure

People, Pets, and livestock should avoid contact with any floating mats, scums, or discolored water. Colors can include shades of green, blue-green, yellow, brown or red.

HABs cells can stick to animal fur and become concentrated when the animal cleans itself. Rinse your pet or livestock with clean water and seek veterinarian medical assistance should your animal show any signs of distress after a potential HABs exposure. HABs may release a fast-acting nerve toxin that can be dangerous for pets, particularly dogs that swim within blooms. Symptoms of HABs exposure for dogs include:

- Stumbling, seizures, convulsions, paralysis.
- Excessive salivation or drooling.
- Disorientation, inactivity, or depression.
- Elevated heart rate and difficulty breathing.

If you see or suspect any of these symptoms, particularly within 30 minutes to a few hours after exposure to a HAB, seek immediate veterinarian care.

Long-term exposure to algal liver toxins may lead to symptoms such as repeated vomiting (green liquid), diarrhea or tarry (bloody) stool, loss of appetite, anorexia, jaundice (yellowing of eye whites or gums), abdominal swelling tender to the touch, cyanosis (bluish coloration) of skin, dark urine, or reduced urine output. Consult your veterinarian if you have concerns. Any information you can provide to the veterinarian about the potential duration of algae exposure will help to determine the appropriate course of action.

New York Sea Grant published a Dogs and Harmful Algal Blooms (HABs) brochure. The brochure includes descriptions of common symptoms and what to do, information about toxins and how dogs are exposed, how to reduce your dog's risk of exposure, and how to report suspected blooms.

Fishing

Whether or not HABS toxins accumulate in fish flesh is still being studied. There have been no reports of people becoming sick from eating fish caught during a HAB. Some states have provided some precautionary advice about limiting consumption of fish fat, skin, and organs and recommend rinsing/cleaning fillets with fresh water before cooking or freezing. The New York Freshwater Fishing Guide advises anglers to avoid eating fish caught from areas that have the thick paint-like or pea soup-like coloration characteristics of HABs.

Drinking Water/Consumption

Never drink, prepare food, cook, or make ice with untreated surface water, whether or not any bloom is present. People not on public water supplies should avoid drinking surface water during an algal bloom, even if it is treated, because in-home treatments such as boiling, disinfecting water with chlorine or ultraviolet (UV), and water filtration units do not protect people from HABs toxins.

If washing dishes in untreated surface water is unavoidable, rinse with bottled water to reduce possible residues. While we don't know if water containing low levels of HABs toxins could leave residues on dishes, taking this precaution may help reduce possible risk.

If you are not on public water and use surface water for drinking, preparing food, cooking, or making ice, you may be at risk of exposure to HABs, cyanotoxins, and other common drinking water contaminants. Please contact your local health department. More information can be found on the Department of Health Blue Green Algae webpage.

Nutrient Spiraling. The flow of energy and nutrients in ecosystems are cyclic, but open-ended. True systems, in both an environmental and energetic context, are either "open" (meaning that there is some external input and/or output to the cyclic loop) or "closed" (meaning that the system is self-contained). In watersheds, streams and rivers represent an open-system situation where energy and matter cycles, but due to the unidirectional flow, the matter does not return to the spot from whence it came. Also, nutrients "spiral" back and forth among the water column, the bodies of terrestrial and aquatic organisms, and the soil in the stream corridor en route downstream. Hence, the concept of nutrient "spiraling" implies both movement downstream and multiple exchanges between terrestrial and aquatic environment, as well as between biotic and abiotic components of the watershed.

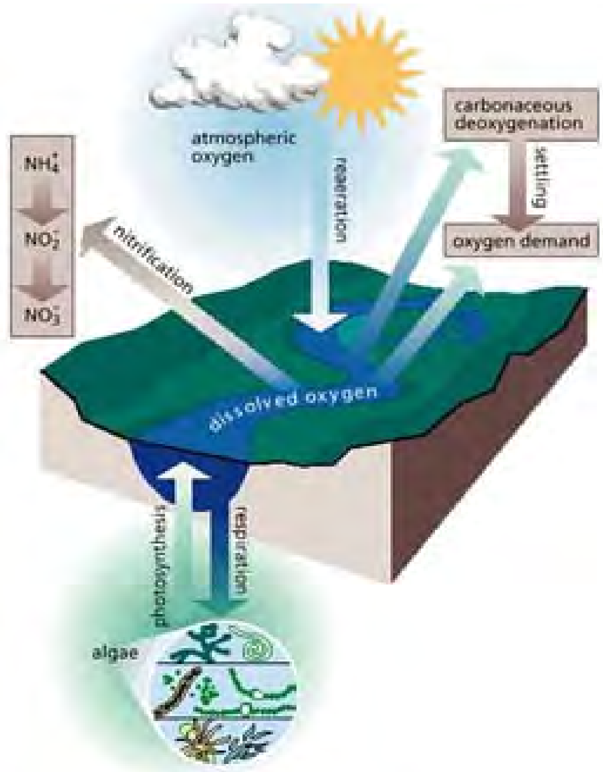


Figure 31. Carbon and nitrogen cycles affect stream biota

The Cycling of Carbon and Energy. In food webs, carbon and the subsequent synthesized energy is cycled through trophic (food web) levels. Energy transfer is considered inefficient, with less than 1 percent of the usable solar radiation reaching a green plant being typically synthesized by consumers, and a mere 10 percent of energy being typically converted from trophic level to trophic level by consumers.

Nitrogen (N) (Figure 32, next page). N_2 (gaseous state) is not usable by plants and most algae. N-fixing bacteria or blue-green algae transform it into nitrite (NO_2) or ammonia (NH_4). N-fixation, precipitation, surface water runoff, and groundwater are all sources of nitrogen. Under aerobic conditions, NH_4^+ is oxidized to NO_3^- (nitrate) in the *nitrification* process. Losses of N occur with stream outflow, denitrification of nitrate (NO_3) to N_2 by bacteria, and deposition in sediments. Unlike P, inorganic N ions are highly soluble in water and readily leach out of soils into streams. NH_4^+ (ammonium) is the primary end-product of decomposition.

Phosphorus (P). Phosphorus in unpolluted watersheds is imported through dust in precipitation, or via the weathering of rock. Phosphorus is normally present in watersheds in extremely small amounts; usually existing dissolved as inorganic orthophosphate, suspended as organic colloids, adsorbed onto particulate organic and inorganic sediment, or contained in organic water. Soluble reactive phosphorus (consisting of ionic orthophosphates) is the only significant form available to plants and algae and constitutes less than 5 percent of the total phosphorus in most natural waters. Phosphorus tends to exist in waters of a pH of 6-7. At a low pH (<6), P tends to combine readily with manganese, aluminum, and iron. At a higher pH (>7), P becomes associated with calcium as apatite and phosphate minerals. It is normally retained in aquatic systems by algae, bacteria and fungi.

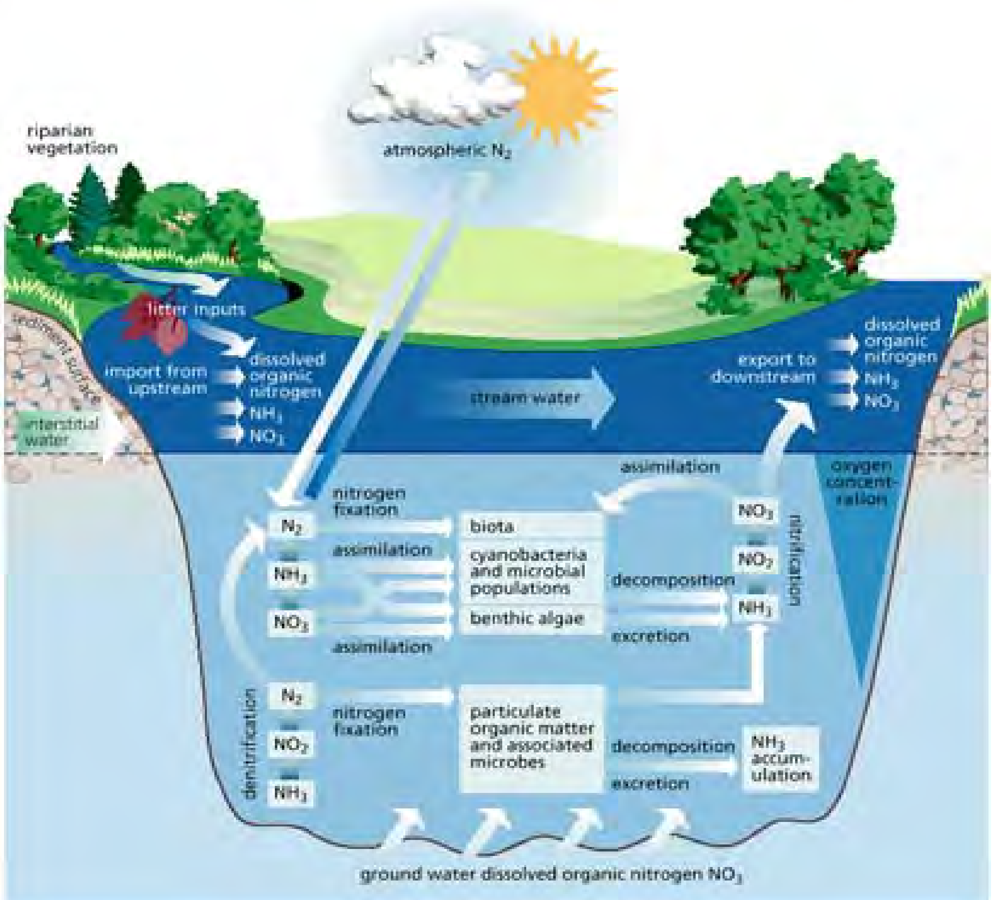


Figure 32. The nitrogen cycle

Nitrogen and Phosphorus limitation. Most watershed systems (both the aquatic and terrestrial realms) are either N or P limited, in that these are the required elements which are at the lowest availability. As a general rule, the N:P ratio should be 15:1. A lower ratio would indicate that N is limiting, a higher ratio places P in that role. Commonly P is the limiting factor. Often, the slightest increase in P can trigger growth, as in algal blooms in an aquatic setting. In N and P limited systems, an input of either element above and beyond normal, “natural” levels may lead to eutrophication.

The stream corridor is often a mediator of upland-terrestrial nutrient exchanges. As N and P move down through subsurface flow, riparian root systems often filter and utilize N and P, leaving less to reach the stream. This has a positive influence on those already nutrient-overloaded bodies of water, but would not necessarily be a positive influence on organisms struggling to find food in very clean, nutrient-limited headwaters streams. Microbes also denitrify significant amounts of N to the atmosphere . Still, N-fixers, like alder, may serve as sources of N for the stream channel, and groundwater pathways between the stream and the streamside forest may provide significant quantities of nitrogen.

Decomposition (Figure 33). Decomposition involves the reduction of energy-rich organic matter (detritus), mostly by microorganisms (fungi, bacteria, and protozoa) to CO2, H2O and inorganic nutrients. Through this process they both release nutrients available for other organisms and transform organic material into energy usable by other organisms. In lakes, much of the decomposition occurs in the waters prior to sedimentation. In the headwater reaches of streams, external sources of carbon from upland forests are a particularly important source of organic material for organisms and decomposition of microscopic particles occurs very rapidly. The bacteria and fungi modify the organic material through decomposition and make it an important food source for invertebrate and vertebrate detritivores, thereby reinserting these nutrients and materials into the watershed's aquatic and terrestrial food webs.

Decomposition is influenced by moisture, temperature, exposure, type of microbial substrate, vegetation, etc. Specifically, temperature and moisture affect the metabolic activity on the decomposing substrate. Nutritional value (as well as palatability) of the decomposing structure will also affect the time involved in complete breakdown and mineralization. Decomposition involves the following processes:

- The leaching of soluble compounds from dead organic matter
- Fragmentation
- Bacterial and fungal breakdown
- Consumption of bacterial and fungal organisms by animals
- Excretion of organic and inorganic compounds by animals
- Clustering of colloidal organic matter into larger particles

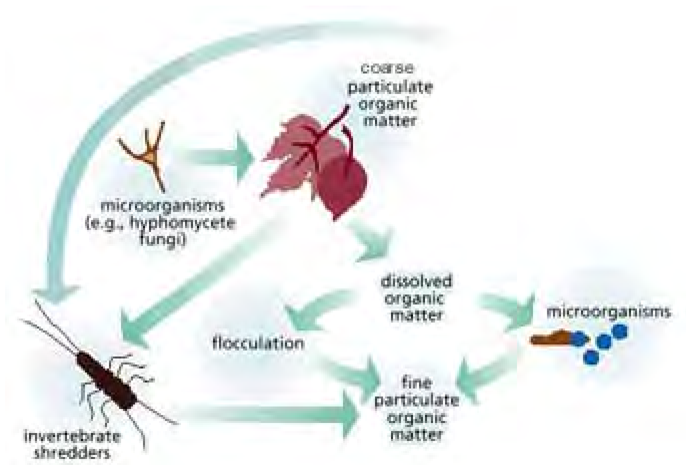


Figure 33. A simplified decomposition process

The process of death and consumption, along with the leaching of soluble nutrients from the decomposing substrate, release minerals contained in the microbial and detrital biomass. This process is known as mineralization.

NCF-Envirothon 2024 New York

Aquatic Ecology Study Resources

Key Topic #3: Watershed Health and Management

9. Identify threats to aquatic ecosystems, such as point and non-point source pollution, biomagnification of toxins, erosion, development, invasive species, and excess nutrients.
10. Describe the impact of changes in climate on water quality and water resources.
11. Assess natural and human impacts on river and stream health, and formulate recommendations for best management practices to reduce/mitigate negative impacts.
12. Explain why it is important to take the entire watershed/catchment area into account when planning for protecting water quality.

Study Resources

Resource Title	Source	Located on
Protecting Water Quality from Urban Runoff	*United States Environmental Protection Agency, 2003*	Pages 65-66
Nonpoint Source Pollution (DEC)	*New York State Department of Environmental Conservation, 2024*	Pages 67-68
Selections from Stormwater Toolkit	*Honeoye Lake Watershed, 2024*	Page 69-72
Climate Change Impacts on Freshwater Resources	*United States Environmental Protection Agency, 2024*	Pages 73-77
Selections from Homeowner's Guide to Lake Friendly Living: Working Together to Protect Honeoye Lake	*Honeoye Valley Association, 2024*	Pages 78-86

<u>Study Resources begin on the next page!</u> ➡

United States Environmental Protection Agency
EPA 841-F-03-003

Protecting Water Quality *from* URBAN RUNOFF

Clean Water Is Everybody's Business

In urban and suburban areas, much of the land surface is covered by buildings and pavement, which do not allow rain and snowmelt to soak into the ground. Instead, most developed areas rely on storm drains to carry large amounts of runoff from roofs and paved areas to nearby waterways. The stormwater runoff carries pollutants such as oil, dirt, chemicals, and lawn fertilizers directly to streams and rivers, where they seriously harm water quality. To protect surface water quality and groundwater resources, development should be designed and built to minimize increases in runoff.

The most recent National Water Quality Inventory reports that runoff from urbanized areas is the leading source of water quality impairments to surveyed estuaries and the third-largest source of impairments to surveyed lakes.

Did you know that because of impervious surfaces like pavement and rooftops, a typical city block generates more than 5 times more runoff than a woodland area of the same size?

How Urbanized Areas Affect Water Quality

Increased Runoff

The porous and varied terrain of natural landscapes like forests, wetlands, and grasslands traps rainwater and snowmelt and allows them to filter slowly into the ground. In contrast, impervious (nonporous) surfaces like roads, parking lots, and rooftops prevent rain and snowmelt from infiltrating, or soaking, into the ground. Most of the rainfall and snowmelt remains above the surface, where it runs off rapidly in unnaturally large amounts.

Storm sewer systems concentrate runoff into smooth, straight conduits. This runoff gathers speed and erosional power as it travels underground. When this runoff leaves the storm drains and empties into a stream, its excessive volume and power blast out streambanks, damaging streamside vegetation and wiping out aquatic habitat. These increased storm flows carry sediment loads from construction sites and other denuded surfaces and eroded streambanks. They often carry higher water temperatures from streets, roof tops, and parking lots, which are harmful to the health and reproduction of aquatic life.

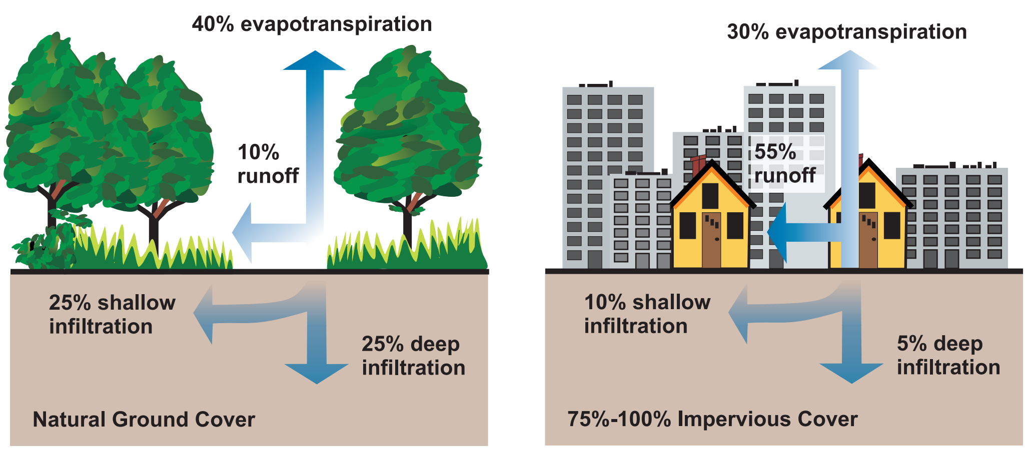
The loss of infiltration from urbanization may also cause profound groundwater changes. Although urbanization leads to great increases in flooding during and immediately after wet weather, in many instances it results in lower stream flows during dry weather. Many native fish and other aquatic life cannot survive when these conditions prevail.

Increased Pollutant Loads

Urbanization increases the variety and amount of pollutants carried into streams, rivers, and lakes. The pollutants include:

- Sediment
- Oil, grease, and toxic chemicals from motor vehicles
- Pesticides and nutrients from lawns and gardens
- Viruses, bacteria, and nutrients from pet waste and failing septic systems
- Road salts
- Heavy metals from roof shingles, motor vehicles, and other sources
- Thermal pollution from dark impervious surfaces such as streets and rooftops

These pollutants can harm fish and wildlife populations, kill native vegetation, foul drinking water supplies, and make recreational areas unsafe and unpleasant.



Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface ruunoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.

Managing Urban Runoff

What Homeowners Can Do

To decrease polluted runoff from paved surfaces, households can develop alternatives to areas traditionally covered by impervious surfaces. Porous pavement materials are available for driveways and sidewalks, and native vegetation and mulch can replace high maintenance grass lawns. Homeowners can use fertilizers sparingly and sweep driveways, sidewalks, and roads instead of using a hose. Instead of disposing of yard waste, they can use the materials to start a compost pile. And homeowners can learn to use Integrated Pest Management (IPM) to reduce dependence on harmful pesticides.

In addition, households can prevent polluted runoff by picking up after pets and using, storing, and disposing of chemicals properly. Drivers should check their cars for leaks and recycle their motor oil and antifreeze when these fluids are changed. Drivers can also avoid impacts from car wash runoff (e.g., detergents, grime, etc.) by using car wash facilities that do not generate runoff. Households served by septic systems should have them professionally inspected and pumped every 3 to 5 years. They should also practice water conservation measures to extend the life of their septic systems.

Controlling Impacts from New Development

Developers and city planners should attempt to control the volume of runoff from new development by using low impact development, structural controls, and pollution prevention strategies. Low impact development includes measures that conserve natural areas (particularly sensitive hydrologic areas like riparian buffers and infiltrable soils); reduce development impacts; and reduce site runoff rates by maximizing surface roughness, infiltration opportunities, and flow paths.

Controlling Impacts from Existing Development

Controlling runoff from existing urban areas is often more costly than controlling runoff from new developments. Economic efficiencies are often realized through approaches that target "hot spots" of runoff pollution or have multiple benefits, such as high-efficiency street sweeping (which addresses aesthetics, road safety, and water quality). Urban planners and others responsible for managing urban and suburban areas can first identify and implement pollution prevention strategies and examine source control opportunities. They should seek out priority pollutant reduction opportunities, then protect natural areas that help control runoff, and finally begin ecological restoration and retrofit activities to clean up degraded water bodies. Local governments are encouraged to take lead roles in public education efforts through public signage, storm drain marking, pollution prevention outreach campaigns, and partnerships with citizen groups and businesses. Citizens can help prioritize the clean-up strategies, volunteer to become involved in restoration efforts, and mark storm drains with approved "don't dump" messages.

Related Publications

Turn Your Home into a Stormwater Pollution Solution!
www.epa.gov/nps

This web site links to an EPA homeowner's guide to healthy habits for clean water that provides tips for better vehicle and garage care, lawn and garden techniques, home improvement, pet care, and more.

National Management Measures to Control Nonpoint Source Pollution from Urban Areas
www.epa.gov/owow/nps/urbanmm

This technical guidance and reference document is useful to local, state, and tribal managers in implementing management programs for polluted runoff. Contains information on the best available, economically achievable means of reducing pollution of surface waters and groundwater from urban areas.

Onsite Wastewater Treatment System Resources
www.epa.gov/owm/onsite

This web site contains the latest brochures and other resources from EPA for managing onsite wastewater treatment systems (OWTS) such as conventional septic systems and alternative decentralized systems. These resources provide basic information to help individual homeowners, as well as detailed, up-to-date technical guidance of interest to local and state health departments.

Low Impact Development Center
www.lowimpactdevelopment.org

This center provides information on protecting the environment and water resources through integrated site design techniques that are intended to replicate preexisting hydrologic site conditions.

Stormwater Manager's Resource Center (SMRC)
www.stormwatercenter.net

Created and maintained by the Center for Watershed Protection, this resource center is designed specifically for stormwater practitioners, local government officials, and others that need technical assistance on stormwater management issues.

Strategies: Community Responses to Runoff Pollution
www.nrdc.org/water/pollution/storm/stoinx.asp

The Natural Resources Defense Council developed this interactive web document to explore some of the most effective strategies that communities are using around the nation to control urban runoff pollution. The document is also available in print form and as an interactive CD-ROM.

For More Information

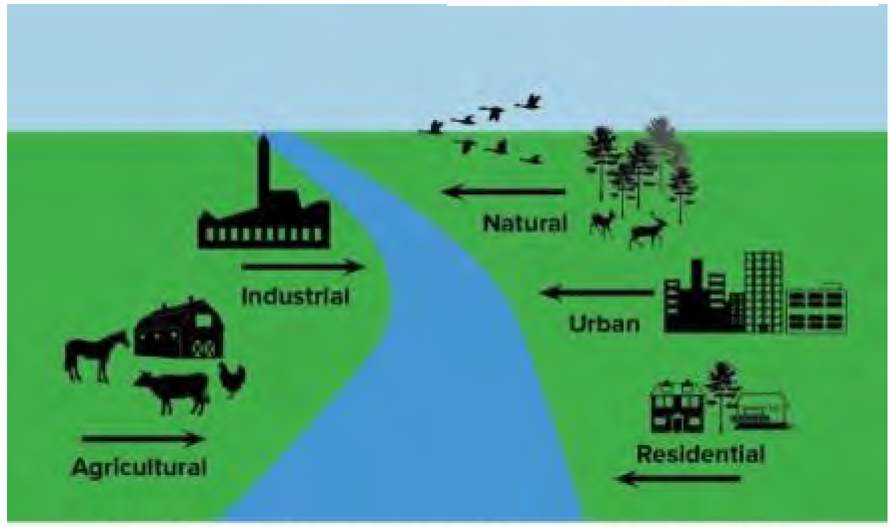
U.S. Environmental Protection Agency
Nonpoint Source Control Branch (4503T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460
www.epa.gov/nps

February 2003

Nonpoint Source Pollution

What is nonpoint source pollution?

Traditional images of pollution are often of a pipe conveying water into a river or stream. Nonpoint source pollution comes from many sources and is caused by rainfall or snowmelt moving over and through the ground that picks up and carries away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, coastal waters, and ground waters.



There are many possible sources of pollution in a watershed.

Examples of NPS pollution

- Excess fertilizer nutrients (nitrogen, phosphorus) from agricultural lands and residential areas
- Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks
- Sediment from physical alterations of stream banks and channels, for example, straightening streams, constructing/removing dams or levees
- Pathogens and nutrients from livestock, pet wastes and faulty septic systems
- Oil, grease, toxic chemicals, and salts from urban runoff
- Pesticides from agricultural lands and residential areas
- Atmospheric deposition of nutrients and other pollutants

Nonpoint Source Program Goal

The goals of the Nonpoint Source (NPS) Program are to control pollution from nonpoint sources to the waters of the state and to protect, maintain and restore waters of the state that are vulnerable to, or are impaired by nonpoint source pollution. NY's NPS Pollution Program was updated and approved by EPA in 2020, Nonpoint Source Management Program (PDF).

Nonpoint Source Program Objectives

Develop Watershed Plans

Numerous watershed plans have been developed throughout New York to characterize and identify watershed impairments and to provide recommendations and strategies to address water quality concerns. The most comprehensive watershed plans are consistent with EPA's nine key elements. These plans are similar to total maximum daily load (TMDL) plans to improve water quality, both plans: identify and quantify pollution sources, estimate pollutant reductions needed to achieve water quality targets and recommend best management practices (BMP) to be implemented. Nine Element Watershed Plans are approved by NYSDEC.

Implement Watershed Projects

Watershed projects are implemented to reduce nonpoint source pollution through a combination of state, local or federal assistance. DEC supports the implementation of watershed projects through the NYS Environmental Protection Fund and other funding opportunities. DEC tracks agricultural and non-agricultural NPS state-funded watershed projects (including pollutant load reduction estimates) through the Grant Reporting Tracking System (GRTS).

Monitor Water Quality

New York evaluates water quality issues related to nonpoint sources within the context of its Statewide Waters Monitoring and Assessment Program (SWMP). DEC also supports nonpoint source-related water quality assessment activities undertaken by county, municipal, watershed coalition, and citizen volunteer programs.

Protect and Restore Waters

By controlling and abating new and existing sources of nonpoint source pollution, DEC conserves and protects from nonpoint source pollution all waters of the state, including surface and ground waters, for all public beneficial uses. By supporting the strategic implementation of watershed projects, impaired waters, as identified in the NYS Waterbody Inventory/Priority Waterbodies List (WI/PWL) and the federal Section 303(d) list of impaired waters, are restored and/or partially restored, leading to their removal from these lists.

Integrate NPS Management into Other State and Local Programs

DEC promotes integration of NPS Program priorities into other applicable state, local and federal programs by participating in advisory committees with partner agencies and integrating NPS program priorities into regulatory programs.

Provide Guidance and Technical Assistance

DEC supports revisions to the nonpoint management practices catalog, development of nonpoint source related standards and guidance by the USDA-NRCS, and other NPS-related guidance.

Best Management Practices to Address NPS Pollution

Best Management Practices (BMPs) are measures determined to be efficient, practical, and cost-effective to guide a particular implementation activity to address sources of nonpoint pollution. Nonpoint source BMPs are specific practices or activities used to reduce or control impacts to waters from nonpoint sources, by reducing the loading of pollutants from such sources through storm water runoff and infiltration into surface and ground waters.

BMP Examples

- Riparian buffers
- Stream bank stabilization
- Soil health (conservation tillage, cover crops on agricultural lands)
- Rain gardens
- Green roofs
- Bioswales

Soil Erosion and Sedimentation Control

Help protect water quality and the health and safety of a community by using best management practices (BMPs) to prevent uncontrolled drainage and runoff associated with land development.

If disturbing soils, removing existing vegetation, or changing topography, use best management practices. These may include a gravel construction entrance, properly installed silt fence, maintenance of an undisturbed buffer along ditches and streams, and reestablishment of ground cover as soon as possible after development.

It is the cumulative impact of many construction projects on the landscape that can negatively affect our waterways. Erosion and sediment control are important for every project, big or small!

Construction projects may require a permit.

Over 500 SF of disturbance: Apply for a municipal Erosion and Sediment Control (ESC) Permit (Town Code Officer at Richmond, Canadice, Bristol, Naples or South Bristol). A permit is required before digging.

Over 10,000 SF of disturbance: Develop an Erosion Control Plan for municipal approval and ESC Permit (Town Code Officer at Richmond, Canadice, Bristol, Naples or South Bristol). All permits and approved Erosion Control Plan are required before digging.

Over 1 acre of disturbance: Obtain coverage under NYS Department of Environmental Conservation SPDES (State Pollutant Discharge Elimination System) General Permit for Stormwater Discharges are from Construction Activity - before digging. See NYSDEC Construction Stormwater Toolbox at: https://www.dec.ny.gov/chemical/8694.html

The goal of BMPs is to prevent soil from leaving a property and entering waterways.

Erosion and Sediment Control Actions Include:

- Construction of a gravel construction entrance
- Installation of silt fence at lower edge of disturbance
- Establishment of ground cover
- Avoidance of areas near ditches, streams, and wetlands
- Assessing construction sites at the end of each day
- Complete projects in a timely manner

DO THIS

Effective Installation

Stabilized Construction Entrance

- Create a gravel construction entrance that is at least 6in deep and 12ft wide.
- Use loose, big stone (2-3in) to scrape and collect mud from construction vehicles and keep adjoining roadways clean.

Silt Fence

- A silt fence prevents erosion because it allows water to filter through but not soil.
- Effective installation includes placing the fence in the proper location, partially burying (trenching), and staking for adequate reinforcement.

Ground Cover

- Seeding disturbed areas after construction is complete will reduce runoff and erosion.
- Any disturbed areas that are at final grade or will remain idle for an extended period of time should be seeded and mulched within days of completion.

Buffers

- Sites near water (ditches, streams, wetlands, and lakes) require extra protection from erosion and sediment control.
- Maintaining vegetated buffers that are as wide as the project will protect water quality by filtering runoff.

NOT THIS

Ineffective Installation

Construction Entrance

- A poorly constructed gravel drive is less than 6in deep and uses small and rounded stones.
- Sediment tracked into roadways is a potential safety issue and results in pollution of our waterways.

Silt Fence

- Ineffective installation of a silt fence or poor placement will result in erosion and runoff into waterways.
- Placement of a silt fence in an area of concentrated flow without proper trenching and staking are common mistakes.

Ground Cover

- Bare ground us highly susceptible to erosion during rain events.
- Establishing ground cover by seeding and mulching immediately after construction will largely eliminate erosion.
- Don't skip the mulch.

Buffers

- Disturbance adjacent to water may result in negative impacts to water quality.
- Disturbance may also be a violation of local, state, and federal law.
- Maintaining a vegetative buffer zone will protect water quality.

Agriculture Best Management Practices

Protecting the beauty and health of our landscape also protects the beauty and water quality of our Lake. Best management practices (BMPs) provide effective ways to make the most of our natural resources while minimizing unintended effects on our lands and waters.

Agriculture Best Management Practices for Water Quality:

No-till farming

- Conservation Tillage (No-till) - leaving plant material from past harvest on the soil will keep nutrients and pesticides on the field, reduce runoff and erosion, and improve soil, water, and air quality.
- Cover Crops - growing annual plants when fields are fallow will control erosion, allowing uptake of excess nutrients, and weed suppression.
- Critical Area Planting - planting grass, shrubs, and trees will protect areas vulnerable to erosion including steep slopes, swales and along waterways, and heavy use areas (livestock and equipment).

Wetland Exclusion Fencing

- Filter Strips - planting strips of grass at the lower edges of fields will trap runoff containing sediment, nutrients, and pesticides before it enters waterways.

Riparian buffers

- Fencing - using fencing to guide animal movement out of streams or into divided pastures decreases erosion, improves water quality, and distributes nutrients.
- Riparian Buffers - planting and maintaining 20+ feet of vegetated buffer (grass, shrubs, trees) next to drainage ditches, streams, and rivers will help filter runoff, protect soil from erosion, improve water quality and support wildlife.
- Grassed Waterways - utilizing natural vegetation to conduct water downslope helps to prevent soil loss and improve water quality.
- Water Management - developing a watering facility to provide livestock with water from a well, spring, pond or other source is an alternative to direct access to surface water.

Cover Crops

Grassed waterway

- Pest Management - keeping crop pests at manageable levels will help protect soil, water, and air.
- Conservation Buffers - establishing a vegetated buffer (grass, shrubs and/or trees) between fields and waterways will protect surface waters
- Nutrient Management - applying the correct amount and form of nutrients for crop yield goals will help minimize loss into surface waters and groundwater.

References and Resources:

- Ontario County Soil & Water Conservation District (www.ontswcd.com) (585) 396-1450
- United State Department of Agriculture Natural Resources Conservation Service (nrcs.usda.gov) (585) 394-0525

Forestry Best Management Practices

Protecting the beauty and health of our landscape also protects the beauty and water quality of our Lake. Best management practices (BMPs) provide effective ways to have an economically viable timber harvest while minimizing unintended effects on our lands and waters. Most towns within the watershed have regulations governing timber harvesting activities.

Forestry Best Management Practices for Water Quality:


Culvert


Log Landing

Skid trail


Stream Crossing

- Pre-harvest Planning - planning in advance with the help of a forestry professional will be more economical and effective and allow proper application of BMPs to protect soil, water, and remaining timber.
- Critical Areas - protect water quality by avoiding critical areas which include streams, streamside management zones, floodplains, wetlands, water bodies, steep slopes (30% or greater), and unstable soils.
- Log Landings - locate landings at least 200 feet away from water. Use straw bales or silt fencing to minimize erosion. Buffer landings from roads and use coarse gravel to filter mud before vehicle enter public roads.
- Forest Roads and Skid Trails - plan location to minimize the amount of cut and fill and to minimize the number of water crossings. Avoid water bodies and/or provide buffer strips. Avoid steep slopes. Identify and utilize appropriate stabilization, drainage, and erosion control measures. Engage a forestry professional for design of forest roads.
- Stream Crossings - minimize stream crossings. Place unavoidable crossings where there are low, stable banks and a firm stream bottom. Install culverts or bridges during low flow and stabilize soils immediately after installation. Be sure culverts are not too small. Engage a forestry professional for design of stream crossings. Crossings may require a state or federal permit.
- Disturbed Soils - smooth soils and seed and mulch all disturbed areas including roads, skid trails, and landings as soon as possible to minimize erosion.
- Wetlands - avoid wetlands. If avoidance is not possible, use clean fill to construct roads, ensure ditches do not drain the wetland, and employ erosion control techniques such as silt fencing and straw bales. Disturbance to wetlands may require a state or federal permit.
- Erosion and Sediment Control - apply erosion control techniques including water diversion features (water bars, deflectors, turn up, diversion ditch), silt fence or straw bales to protect waterbodies, filter strips, soil stabilization and gravel at culvert intake and outfalls.
- Permits - several state and federal regulations are in place to protect wetlands, streams, and water quality during timber harvest. Contact regulatory staff to determine if your harvest plan requires a permit.

References and Resources:

- NYS Forestry BMPs for Water Quality: https://www.dec.ny.gov/docs/lands_forests_pdf/forestrybmp.pdf
- Do I need a NYSDEC Protection of Waters Permit?: http://www.dec.ny.gov/permits/6335.html
- Do I need a NYSDEC Freshwater Wetland Permit?: http://www.dec.ny.gov/permits/6279.html


Ford Crossing

Climate Change Impacts on Freshwater Resources

Clean freshwater, comprising both groundwater and surface waters, is essential to life on Earth. People need water for drinking and sanitation, and all plants and animals need water to survive. Water also supports agriculture, energy production, navigation, manufacturing, and many other uses. In addition, freshwater supports many ecosystems and provides habitat and breeding grounds for animals.

Less water for drinking. *Climate change is likely to increase people's demands on water while also decreasing water supplies in some parts of the country.*

Increased runoff and harmful algal blooms. *In the summer, algae develop on Lake Erie due to excess agricultural runoff and warm water temperatures.[36] As a result, a dead zone forms at the bottom of the lake that cannot support wildlife. Water bodies like Lake Erie may become more stressed as more frequent and intense rain events lead to more runoff.*

Less water for agriculture. The Midwest produces many high-value "specialty" crops, such as apples, cherries, and pumpkins.[31] These crops are particularly sensitive to drought and other climate stressors that can decrease water supplies for agriculture.[32]

Groundwater depletion. *The use of groundwater for crop irrigation has increased significantly over the past century.*[33] *Irrigation accounts for 70% of all groundwater withdrawals nationwide.*[34]

Climate change affects where, when, and how much water is available. These effects vary by region and can harm the health of people and ecosystems. For example, rising temperatures, drought, and reduced snowfall are putting more pressure on water supplies in the Southwest.[1] In contrast, the Northeast and Southeast may experience more extreme storms and heavy rains, which can put aging water infrastructure (such as dams, sewers, and water treatment facilities) at risk.[2]

To help reduce climate risks, many water utilities are considering potential impacts to their systems and taking steps to build resilience. Government agencies are supporting many resilience projects specifically focused on water resources. Individuals can also take steps to use water efficiently and help keep water bodies clean.

More infrastructure failures. As the climate changes, more frequent and intense rainfall can threaten dams in some regions of the country. In fact, more than 15,000 dams in the United States have been identified as "high risk" for potential failure.[35]

Top Climate Impacts on Freshwater Resources

Climate change may disrupt the stability of water resources at local, regional, and national scales. Three key impacts are described in this section.

1. Reduced Water Supplies

A lack of snowmelt combined with drought caused low water levels in Shasta Lake, California, in 2021.7

In many areas of the country, climate change is likely to increase people's demand for water while also shrinking water supplies. In mountainous and cold-weather regions, many people depend on snowpack for drinking water, agriculture, and other uses. "Snowpack" refers to the layers of snow that accumulate over long periods of cold weather. As it melts, snowpack feeds into streams and becomes an important freshwater resource.

In the West, warmer temperatures and changes in precipitation are reducing snowpack.[3] In some areas, less snow is falling, as more precipitation is falling as rain rather than snow.[4, 5] Higher temperatures are also causing snowpack to melt earlier.[6] All of these changes affect when and how much water is available.

Even without the impacts of climate change, the United States' water supply has begun to diminish.[8] Much of our water supply comes from groundwater held in underground formations called aquifers. In some parts of the nation, increased demand for water has led to pumping groundwater from aquifers faster than they can be naturally refilled. Persistent droughts in some areas are accelerating this decline.[9] Warming temperatures from climate change may increase the chance of droughts, especially in the West.[10]

2. Impaired Water Quality

Climate change is expected to harm water quality. For example, increased rainfall can lead to more runoff of sediments, nutrients, pathogens, and other substances into water bodies. Increases in nutrient runoff, along with warming water temperatures, can also lead to harmful algal blooms. These algal blooms can kill fish, shellfish, and other animals. They can also make drinking and recreational water sources unsafe for people and pets.

Climate change threatens to increase the salinity of water bodies and groundwater through saltwater intrusion.[11] Rising sea level and increased drought can enable saline water to advance farther upstream and inland in estuaries, wetlands, and aquifers. Higher salinity can contaminate freshwater supplies and harm aquatic plants and animals. These impacts are especially likely to happen in low-lying areas such as Louisiana, Florida, and portions of California and the mid-Atlantic.

3. Stress on Water Infrastructure

As much of the U.S. water infrastructure nears the end of its planned life, climate change impacts, such as more extreme weather events, will further strain its ability to operate well.[12] Heavy rainfall events can cause dams and levees to fail.[13] In addition, climate impacts on other parts of society may have indirect effects on water utilities.[14] For example, storms that damage power generation or distribution might shut down water and wastewater plants.[15] In other cases, there may be competing needs from surface reservoirs, which face demands as a drinking water supply as well as a source for generating electricity.

For more specific examples of climate change impacts in your region, please see the National Climate Assessment.

Freshwater Resources and the Economy

The United States uses water to grow crops, raise livestock, produce energy, manufacture and distribute goods, and support many other parts of the economy. Nationwide, healthy watersheds also provide millions of jobs as well as revenues in tourism, recreation, fishing, and other industries.[16]

In addition, watersheds provide a host of ecosystem services. These beneficial services are the free work that communities do not have to do, or pay for, themselves. While it can be hard to put a dollar value on these services, they provide tremendous benefits to society. Among these benefits are water filtration and storage, soil formation, carbon storage, flood control, erosion control, and recreation. Watersheds also function as critical wildlife corridors, providing passage for animals during their life cycles.

Clean water is also essential to human health. Water utilities spend more than $109 billion each year to provide safe drinking water and wastewater services in the communities they serve.[17] Nonetheless, more than 7 million people get sick from diseases spread through water each year.[18] These illnesses cost the U.S. health care system more than $3 billion annually, and climate impacts are expected to increase risk of exposure to water-borne pathogens and water-treatment expenses.[19, 20, 21]

Environmental Justice and Equity

Certain groups of people in the United States, including Indigenous communities, low-income communities, communities on the U.S.-Mexico border, migrant farm workers, and others lack access to clean water and sanitation services. Climate impacts will compound this situation.

For example, many rural residents currently depend on community or private wells where water is treated minimally or not at all. Some small and rural water utilities also struggle to provide safe and affordable drinking water and wastewater services. Barriers to providing these services can include limited resources, extreme climate, or remote locations.

Many Indigenous communities lack access to water for drinking, agriculture, fisheries, and other uses.[25] Climate stressors can worsen this problem. For example, decreasing snowpack, decreasing streamflow, and warmer water temperatures are harming salmon populations in the Northwest. Salmon loss affects Indigenous peoples' economies and cultural identities.[26] In Alaska, traditional hunting and subsistence practices have been disrupted by ice melting due to rising temperatures.[27]

Outside of some U.S.–Mexico border cities, unincorporated communities called "colonias" lack both water and wastewater services.[28] Some border cities also face stormwater and pollutant runoff problems.[29] These areas are often prone to flooding and increases in heavy rains caused by climate change are expected to worsen.[30]

Related Climate Indicators

Learn more about some of the key indicators of climate change related to this sector from EPA's Climate Change Indicators:

- Temperature
- Heavy Precipitation
- River Flooding
- Drought
- Streamflow
- Snowpack
- Snowfall

What We Can Do

We can reduce climate change's impact on water resources in many ways, including the following:

- **Create resilient water utilities.** EPA's Creating Water Resilient Utilities provides tools, training, and assistance to help utilities assess climate risks to their systems and increase resilience.
- **Build sustainable water infrastructure.** Communities can maintain and renew aging water systems with planning tools, financing help, best practices, and new technologies.
- **Use water wisely.** People can reduce water use in their homes and yards by repairing leaks, choosing WaterSense-labeled products, planting native or drought resistant vegetation, and many other actions.
- **Reduce runoff.** Individuals can help reduce nutrient pollution. For example, use fertilizers on yards only when necessary and clean up pet waste.
- **Work with nature.** Communities can use nature-based solutions to help restore aquatic habitats and promote the resilience of freshwater resources.
- **Learn about local water quality.** Use EPA's How's My Waterway tool to find out the condition of water bodies in your area.

Related Resources

- Fifth National Climate Assessment, Chapter 4: "Water."
- Ground Water and Drinking Water. Provides information about public water systems and EPA standards to protect water quality.
- Municipal Wastewater. Provides information about wastewater collection and treatment and EPA standards to protect waters.
- EPA: U.S.–Mexico Border Water Infrastructure Grant Program. Funds projects to improve wastewater services in the border region.
- Small and Rural Water System Resources. Provides funding, tools, and resources to help small and rural communities improve wastewater treatment services. The U.S. Department of Agriculture also provides loans and technical assistance for water programs in rural areas.
- Centers for Disease Control and Prevention: Healthy Water. Provides education and resources about ensuring healthy water for drinking, agriculture, recreation, industry, and more.
- EPA: Report on Seasonality and Climate Change. Summarizes the state of the science on observed changes relating to seasonality in the United States, including observed impacts on the water resources.

Working together to protect Honeoye Lake

Honeoye Lake's beauty has made it a popular destination. Traditional summer camps are giving way to year-round homes, as more and more people want to enjoy the beauty and tranquility of lakeside living. The landscape is dramatically changing as lots are cleared and driveways paved, and trees are removed to make way for fertilized lawns. The cumulative effects from such drastic changes to the landscape mean big changes to the health of the lake. By changing the natural environment to a suburban landscape, the lake ecosystem can no longer function properly.

Leaving the natural topography and vegetation of the forest floor around your house protects the lake.

15 simple strategies for sustainable lakeshores & landscapes to protect Honeoye Lake

1. Reduce Impermeable Surfaces
2. Limit Lawn Size
3. Use Water Wisely

4. Minimize Erosion
5. Be Smart About Lawn Care
6. Use Phosphorus-Free Fertilizer
7. Maintain Your Septic System
8. Don't Flush Your Drugs
9. Maintain Your Vehicles
10. Conserve Water
11. Reduce Household Hazardous Wastes

12. Install a Vegetative Buffer
13. Plant a Rain Garden
14. Go Native

15. Join the HVA Today!

Simple Step #1
Reduce Impermeable Surfaces

Permeable surfaces allow water to infiltrate and soak into the ground. Impermeable surfaces do just the opposite. When water hits this kind of surface, instead of soaking in, it runs off. This is what creates stormwater runoff. The larger the area of impermeable surface, the greater the volume of stormwater runoff.

Ways to lessen your impermeable footprint:

• Keep paved driveways as small as possible. Use permeable surfaces for driveways and overflow parking areas that aren't needed on a regular basis. While gravel driveways may start off permeable, over time the compaction makes them nearly as impermeable as regular asphalt.

• Rooftops are impermeable too - so keep your home a modest size and build up - not out - on lakeshore lots.

• Use stone pathways or stepping stones across your lawn instead of poured concrete or asphalt paths.

•Try one of the newer permeable pavement technologies. There are permeable paver systems, asphalt, and concrete - so you can get just about any look you want. Prices vary - and while all options are generally more expensive than traditional pavements, it is definitely money well spent.

Below: Permeable pavers being installed.

Simple Step #3
Use Water Wisely

Using water wisely around the yard helps prevent pollution from stormwater runoff.

If you have an irrigation system:

• Water your lawn and garden in the morning or evening when temperatures are cooler to minimize evaporation.

• Adjust sprinklers so only your lawn is watered and not the house, sidewalk, or street.

• Install a rain sensor on your irrigation controller so your system won't run when it's raining.

• Choose shrubs and groundcovers instead of turf for hard-to-water areas such as steep slopes and isolated strips.

• Spread a layer of organic mulch around plants to retain moisture and save water, time and money.

• Use drip irrigation for shrubs and trees to apply water directly to the roots where it's needed.

Or better yet, landscape with native plants that won't need irrigation once they are established. This will save water and save you the cost of the installation and maintenance of an irrigation system!

Barren strawberry is a great native groundcover that is drought resistant.

Other ways to prevent runoff from your property:

• Install a rain barrel to collect runoff from your roof and to use for watering your garden.

• Direct your downspouts onto your lawn or into a rain garden, away from your driveway and other impermeable surfaces.

• Install covers on pools and spas and check for leaks around pumps.

• Check for leaking outdoor faucets.

• Use a broom instead of a hose to clean driveways and sidewalks.

• Patios provide space that doesn't ever need to be watered. These useful "outdoor rooms" can also add value to your property. Just be sure to keep it permeable!

Simple Step #5
Be Smart about Lawn Care

Fertilizers, leaves, grass clippings, animal waste, and eroded soil are all sources of phosphorus. When they are swept or washed into the street or nearest storm drain, they end up in a nearby stream or the lake. Follow these tips for smart lawn care with water quality in mind.

• Apply fertilizer at the recommended rate. Fall is the best time. Don't fertilize before a storm. Never apply to frozen ground. Or better yet, skip the fertilizer all together!

• Yard waste can contribute significant amounts of phosphorus to water ways. Keep soil, leaves, and lawn clippings out of the street, ditches, storm drains, and streams by bagging them, composting them, or leaving them right on the lawn as a natural fertilizer.

• Mow higher. Keep grass length to 2½ – 3 inches. It is healthier for your lawn - and means you can mow less often!

Mow Your Way to Clean Water. Lawn care practices can have a big impact on water quality and the environment.

• Pick up pet waste. Pet waste can contain harmful bacteria as well as phosphorus. Flush it in the toilet or place it in the garbage.

• Build healthy soil using compost and other natural amendments. Healthy soils are more resistant to disease and insect problems.

• Learn about Integrated Pest Management (IPM) and use pesticides sparingly and only when really needed. Do not apply pesticides as part of a 'routine maintenance plan'. When use is needed, be sure to follow the label. Often the timing of the application is critical to its success. There are many organic products available at stores - try these first - and only use chemicals as a last resort.

Simple Step #6
Use Phosphorus-Free Fertilizer

What do I look for?

The three numbers in fertilizer bags show the N-P-K nutrient analysis. The middle number is the phosphate (phosphorus) content. A "zero" in the middle means it is phosphorus-free.

Will phosphorus-free fertilizer keep my lawn green & healthy?

Yes! Soils in most parts of New York already have an adequate amount of phosphorus to grow a healthy lawn. In these instances, adding more phosphorus with fertilizer is not needed and will not benefit your lawn.

How do I find out what my soil needs?

If you are concerned that your lawn may need phosphorus, you can have your soil tested. Soil testing is available through your local Cornell Cooperative Extension office for a reasonable fee.

Besides being lake-friendly - It is now the Law!

As of January 1, 2012, New York State law prohibits:

• the use of phosphorus-containing lawn fertilizer unless you are establishing a new lawn or a soil test shows that your lawn does not have enough phosphorus,

• the application of lawn fertilizer on impervious surfaces, (Picking up fertilizer applied or spilled onto impervious surfaces is required.)

• the application of lawn fertilizer within 20 feet of any surface water except: where there is a vegetative buffer of at least 10 feet; or where the fertilizer is applied by a device with a spreader guard, deflector shield or drop spreader and is applied at least three feet from surface water,

• the application of any lawn fertilizer between December 1 and April 1.

The law also requires retailers to display phosphorus-containing fertilizers separately from non-phosphorus fertilizers and to post an educational sign where the phosphorus-containing fertilizers are displayed.

The law does not apply to agricultural fertilizer or fertilizer for gardens.

Simple Step #7
Maintain Your Septic System

Maintaining your onsite wastewater treatment system (OWTS) - or septic system - not only protects Honeoye Lake and nearby groundwaters from being contaminated, but also protects your health and your investment in your home. Typical pollutants found in household wastewater include nitrogen, phosphorus, and disease-causing bacteria and viruses. A properly designed, constructed, and maintained system can provide long-term, effective treatment of household wastewater. If not properly maintained, a failing system can cost tens of thousands of dollars to replace.

Know the signs of a failed system:

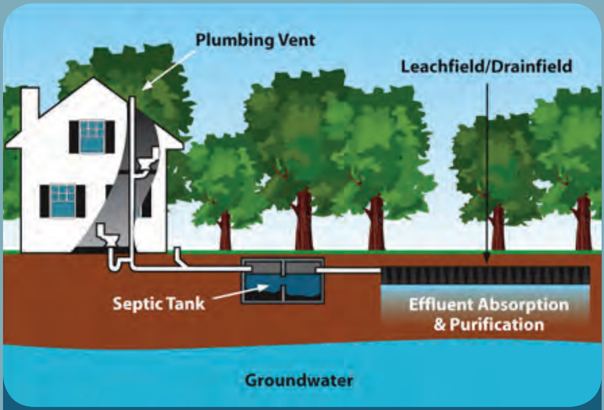
• Pooling water or muddy soil around the tank or drainfield or in your basement.

• Bad smell coming from area of tank.

• Toilet or sink backs up when you flush or do laundry.

• Bright green grass over the drainfield.

If you notice any of these signs - call a professional to have your system looked at right away.



A typical septic system has 4 main parts:

• a pipe from the home that carries the wastewater into the tank;
• a tank that holds the water long enough for the solids to settle out to the bottom and the oil and grease to float to the surface;
• a drainfield where the water from the tank is discharged;
• the soil where the microbes provide the final treatment.

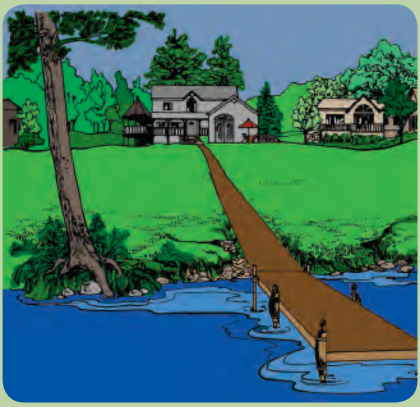
Alternative Systems

Due to unsuitable soils, high bedrock or groundwater, or small lot size you may have a hard time making a traditional septic system work on your property.

There are alternative systems now available that use new technologies to improve treatment processes, many of which need less space to function. Such systems use sand, peat or plastic media instead of soil to treat the wastewater. Some of these systems are already being used on Honeoye Lake. *Photo at left is a Puraflo system that uses peat moss as a filter.*

Simple Step #12
Install a Vegetative Buffer

More and more people are building year-round or second homes on Honeoye Lake. They often bring their idea of a conventional yard with them, leading to a grass lawn down to the lakeshore.



Traditional lawns on a lakeshore can cause:

- Excessive plant and algal growth,
- Shoreline erosion and sedimentation,
- Loss of wildlife habitat,
- An increase in nuisance animals,
- Loss of leisure time.

A naturally landscaped yard adds value to your property and can also benefit Honeoye Lake's water quality and overall health.

What is a vegetative buffer?

A vegetative buffer, or buffer zone, is a strip of natural vegetation along the shoreline of a lake or waterbody.

Ideally, the vegetation should cover at least 50-75% of the property's lake frontage.

By restoring the shoreline with native plants, you restore the ecological functions of the lakeshore. The benefits of buffers include:

- Food and shelter for local wildlife,
- Stabilized soil and reduced erosion,
- Filtration of pollutants and sediments,
- Absorption of nutrients,
- Deterrence of nuisance species,
- Privacy from lake users,
- Save time and money in maintenance.

Got geese?

Canada geese love short, tender grass and avoid tall grass where predators can hide. A shoreline buffer will send the geese packing.

Simple Step #13

Plant a Rain Garden

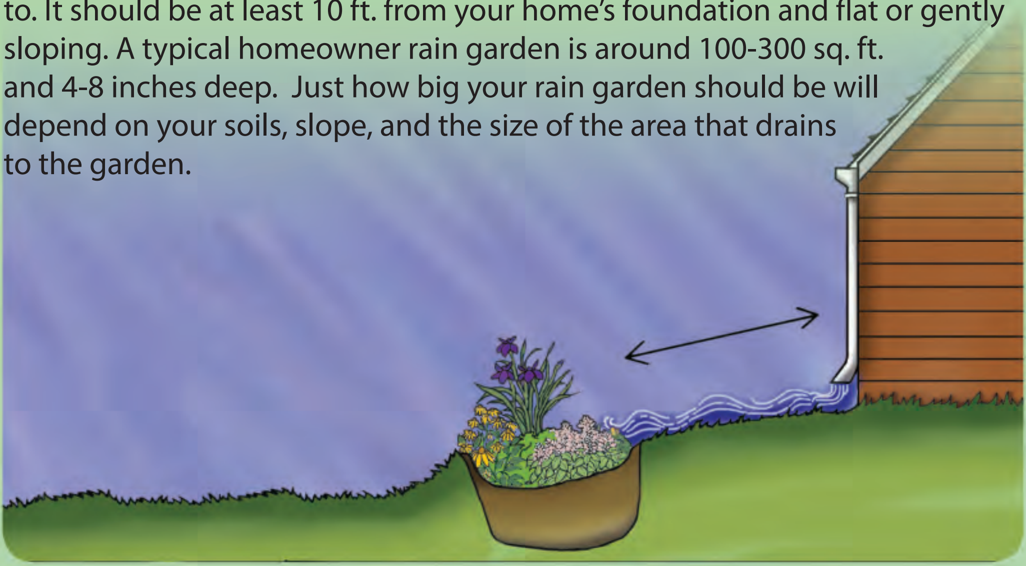
A rain garden is a vegetated depression that collects rainwater. This allows the rain that falls on rooftops, driveways, and patios to infiltrate into the ground instead of becoming stormwater runoff.

Rain gardens are beneficial in many ways:

- Help keep water clean by filtering stormwater runoff before it enters local waterways.
- Help alleviate problems with flooding and drainage.
- Enhance the beauty of yards and communities.
- Provide habitat and food for wildlife like birds and butterflies.
- Reduce the need for expensive stormwater treatment structures in your community.

Getting Started:

The first step is sizing and siting your rain garden. You want to pick a location on your property that you can direct a downspout or other source of runoff to. It should be at least 10 ft. from your home's foundation and flat or gently sloping. A typical homeowner rain garden is around 100-300 sq. ft. and 4-8 inches deep. Just how big your rain garden should be will depend on your soils, slope, and the size of the area that drains to the garden.



The Benefits of Native Species

With all the benefits that native plants provide, you can feel good about enjoying the beautiful landscape all around you.

Native plants:

- Help protect New York's biodiversity by providing food and habitat for birds, butterflies, and other wildlife.
- Save you time and money. Natives have evolved in our environment over many years and are already adapted to survive here; they are low maintenance and don't need lots of fertilizer, pesticides, and watering.
- Help reduce stormwater runoff. The deep roots of natives absorb and filter runoff more effectively than the short roots of many turf grasses and other ornamental plants.

The extensive roots of native plants improve the ability of the soil to infiltrate water and to resist erosion. In fact, native plants often have more biomass below the surface than above. For example, little bluestem, a great bunch grass for the garden, only grows 2-3' tall, but can have roots up to 8 feet deep.

The shallow roots of turf grass are better than bare soil, but pale in comparison to native plants. Kentucky bluegrass is shown in the drawing above.

So many choices...

Native plants come in just about every size, shape, and color. You can design a native plant garden for interest in all 4 seasons, or a theme garden based on form or function. Here are just a few ideas to get you started.

Blue Vervain

Hummingbirds

Cardinal Flower
Wild Columbine
Fireweed
Bee Balm
Beardtongue
Trumpet Honeysuckle

Birds

Dogwoods
Viburnums
Bayberry
Serviceberry
Chokeberry
Cutleaf coneflower

Butterflies

Milkweeds
Joe Pye Weeds
Asters
New York Ironweed
Woodland sunflower
Goldenrods

Deer Resistant

Blue Vervain
Culvers Root
Bergamot
Foamflower
Sensitive Fern
Bugbane

Salt Tolerant

Winterberry
Summersweet
Spicebush
Arrowwood
Elderberry
Witch hazel

NCF Envirothon 2024 New York

Aquatics Study Resources

Key Topic #4: Applied Field Techniques

13. Identify native freshwater fish, macroinvertebrates, aquatic plants, and wetland mammals common to New York State using a field guide.
14. Identify major New York State aquatic invasive species using a field guide.
15. Assess water quality based on macroinvertebrate species surveys.
16. Evaluate local water quality using common water monitoring tools.
17. Delineate a watershed based on topographic maps.
18. Interpret the results of water quality monitoring data from New York State lakes.
19. Analyze existing water quality data to propose aquatic ecosystem restoration strategies.

Study Resources

Resource Title	Source	Located on
Stream Insects & Crustaceans	*Save our Streams, Izaak Walton League of America (undated)*	Pages 88-89
NALMS Student Video Series #1: How to Take a Secchi Depth (video)	*North American Lake Management Society, 2017*	Pages 90
How to Read a Topographic Map and Delineate a Watershed	*United States Department of Agriculture, Natural Resources Conservation Service (undated)*	Pages 91-94
Instructions for Rake Toss Sampling	*NYS Department of Environmental Conservation, 2024*	Page 95
Finger Lakes Invasive Species Field Guide	*Finger Lakes Partnership for Regional Invasive Species Management, 2020*	Pages 96-102
Water Quality Monitoring with the Citizens Statewide Lake Assessment Program (CSLAP)	*New York State Department of Environmental Conservation and New York State Federation of Lake Associations, 2024*	Page 103-104

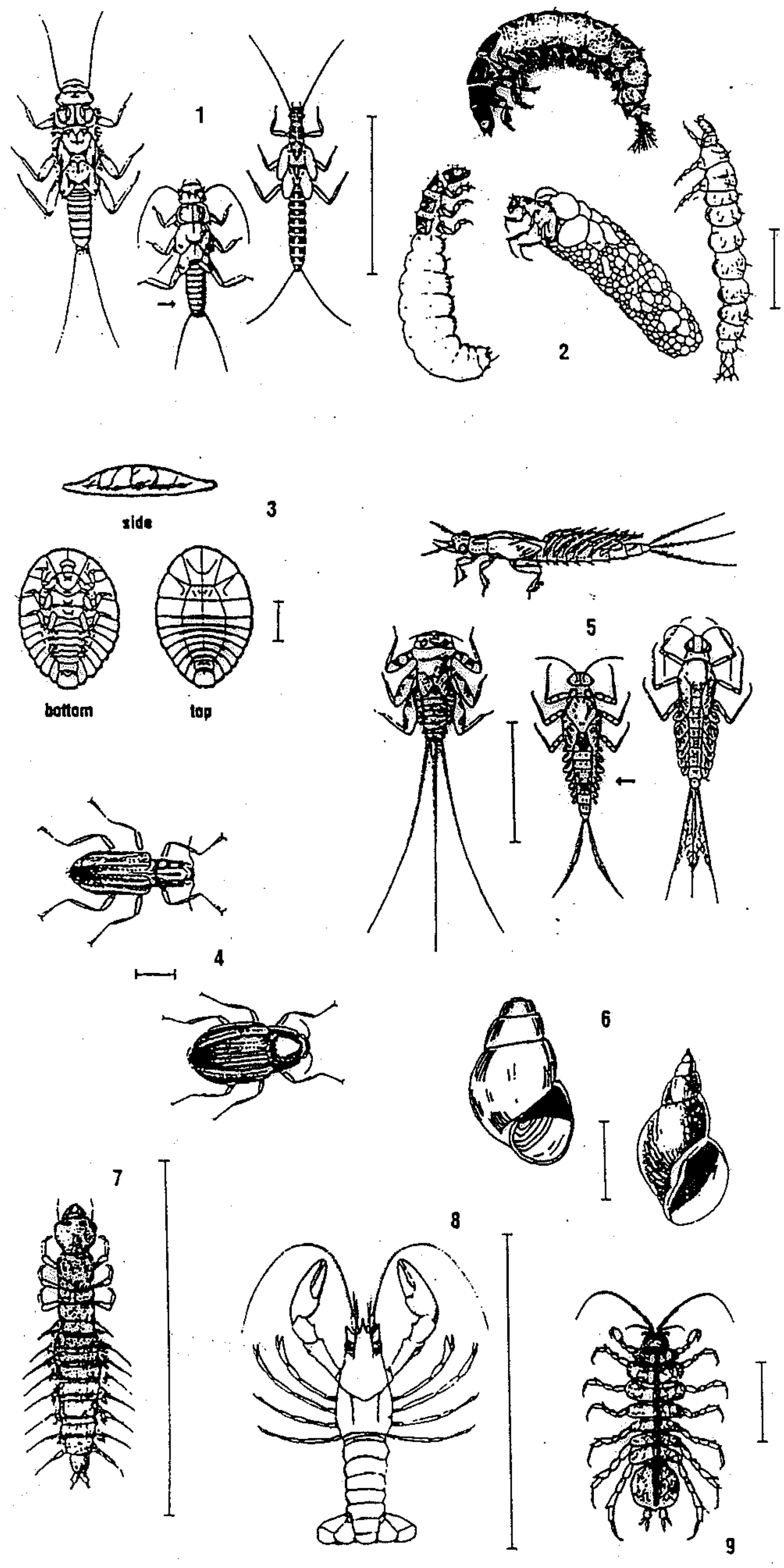
Study Resources begin on the next page! ➡

FingerLakes Community College

Finger Lakes Institute

Finger Lakes PRISM Partnership for Regional Invasive Species Management

Hobart and William Smith Colleges



Bar lines indicate relative size

Stream Insects & Crustaceans

GROUP ONE TAXA

Pollution sensitive organisms found in good quality water.

1 *Stonefly: Order Plecoptera.* 1/2" - 1 1/2", 6 legs with hooked tips, antennae, 2 hair-like tails. Smooth (no gills) on lower half of body. (See arrow.)

2 *Caddisfly: Order Trichoptera.* Up to 1", 6 hooked legs on upper third of body, 2 hooks at back end. May be in a stick, rock or leaf case with its head sticking out. May have fluffy gill tufts on lower half.

3 *Water Penny: Order Coleoptera.* 1/4", flat saucer-shaped body with a raised bump on one side and 6 tiny legs on the other side. Immature beetle. Three views.

4 *Riffle Beetle: Order Coleoptera.* 1/4", oval body covered with tiny hairs, 6 legs, antennae. Walks slowly underwater. Does not swim on surface.

5 *Mayfly: Order Ephemeroptera.* 1/4" - 1", brown, moving, plate-like or feathery gills on sides of lower body (see arrow), 6 large hooked legs, antennae, 2 or 3 long, hair-like tails. Tails may be webbed together.

6 *Gilled Snail: Class Gastropoda.* Shell opening covered by thin plate called operculum. Shell usually opens on right.

7 *Dobsonfly (Hellgrammite): Family Corydalidae.* 3/4" - 4", dark-colored, 6 legs, large pinching jaws, eight pairs feelers on lower half of body with paired cotton-like gill tufts along underside, short antennae, 2 tails and two small hooks hooks at back end.

GROUP TWO TAXA

Somewhat pollution tolerant organisms can be in fair quality water.

8 *Crayfish: Order Decapoda.* Up to 6", 2 large claws, 8 legs, resembles small lobster.

9 *Sowbug: Order Isopoda.* 1/4" - 3/4", gray oblong body wider than it is high, more than 6 legs, long antennae.

Save Our Streams

Izaak Walton League of America
1401 Wilson Blvd. Level B
Arlington, VA 22209

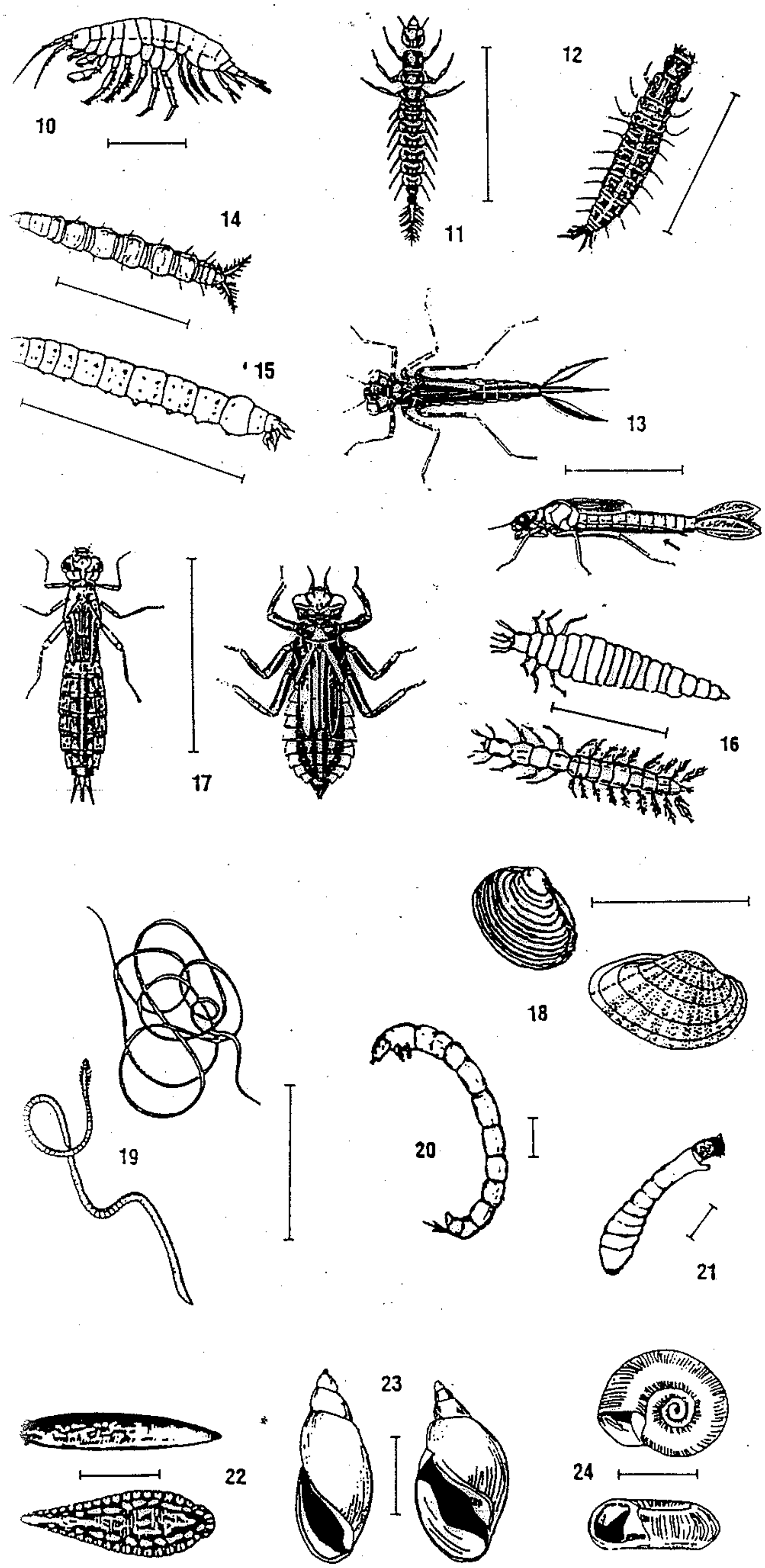
Finger Lakes Regional Stream Monitoring Network

FingerLakes Community College

Finger Lakes Institute

Finger Lakes PRISM — Partnership for Regional Invasive Species Management

Hobart and William Smith Colleges



Bar lines indicate relative size

GROUP TWO TAXA continued

10 *Scud: Order Amphipoda.* 1/4", white to grey, body higher than it is wide, swims sideways, more than 6 legs, resembles small shrimp.

11 *Alderfly larva: Family Sialidae.* 1" long. Looks like small hellgrammite but has 1 long, thin, branched tail at back end. No gill tufts underneath.

12 *Fishfly larva: Family Corydalidae.* Up to 1 1/2" long. Looks like small hellgrammite but often a lighter reddish-tan color, or with yellowish streaks. No gill tufts underneath.

13 *Damselfly: Suborder Zygoptera.* 1/2" - 1", large eyes, 6 thin hooked legs, 3 broad oar-shaped tails, positioned like a tripod. Smooth (no gills) on sides of lower half of body. (See arrow.)

14 *Watersnipe Fly Larva: Family Athericidae (Atherix).* 1/4" - 1", pale to green, tapered body, many caterpillar-like legs, conical head, feathery "horns" at back end.

15 *Crane Fly: Suborder Nematocera.* 1/3" -2", milky, green, or light brown, plump caterpillar-like segmented body, 4 finger-like lobes at back end.

16 *Beetle Larva: Order Coleoptera.* 1/4" 1", light-colored, 6 legs on upper half of body, feelers, antennae.

17 *Dragon Fly: Suborder Anisoptera.* 1/2" - 2", large eyes, 6 hooked legs. Wide oval to round abdomen.

18 *Clam: Class Bivalvia.*

GROUP THREE TAXA

Pollution tolerant organisms can be in poor quality water.

19 *Aquatic Worm: Class Oligochaeta.* 1/4" - 2", can be very tiny; thin worm- like body.

20 *Midge Fly Larva: Suborder Nematocera.* Up to 1/4", dark head, worm-like segmented body, 2 tiny legs on each side.

21 *Blackfly Larva: Family Simulidae.* Up to 1/4", one end of body wider. Black head, suction pad on end.

22 *Leech: Order Hirudinea.* 1/4" - 2", brown, slimy body, ends with suction pads.

23 *Pouch Snail and Pond Snails: Class Gastropoda.* No operculum. Breathe air. Shell usually opens on left.

24 *Other snails: Class Gastropoda.* No operculum. Breath air. Snail shell coils in one plane.

Izaak Walton League — Defenders of Soil, Air, Woods, Waters and Wildlife

NALMS Student Video Series #1: How to Take a Secchi Depth

https://www.nalms.org/secchidipin/monitoring-methods/quick-start-video/

United States Department of Agriculture
NRCS Natural Resources Conservation Service
Federal Building, 2 Madbury Road, Durham, NH 03824-2043 (603) 868-7581 Fax: (603) 868-5301 www.nh.nrcs.usda.gov

How to Read a Topographic Map and Delineate a Watershed

This fact sheet is an excerpt from Appendix E of the *Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire*, 1991. Alan Ammann, PhD and Amanda Lindley Stone. This document and method is commonly called "The New Hampshire Method."

Interpreting Topographic Maps

In order to successfully delineate a watershed boundary, the evaluator will need to visualize the landscape as represented by a topographic map. This is not difficult once the following basic concepts of the topographic maps are understood.

Each contour line on a topographic map represents a ground elevation or vertical distance above a reference point such as sea level. A contour line is level with respect to the earth's surface just like the top of a building foundation. All points along any one contour line are at the same elevation.

The difference in elevation between two adjacent contours is called the contour interval. This is typically given in the map legend. It represents the vertical distance you would need to climb or descend from one contour elevation to the next.

The horizontal distance between contours, on the other hand, is determined by the steepness of the landscape and can vary greatly on a given map. On relatively flat ground, two 20 foot contours can be far apart horizontally.

On a steep cliff face two 20 foot contours might be directly above and below each other. In each case the vertical distance between the contour lines would still be twenty feet.

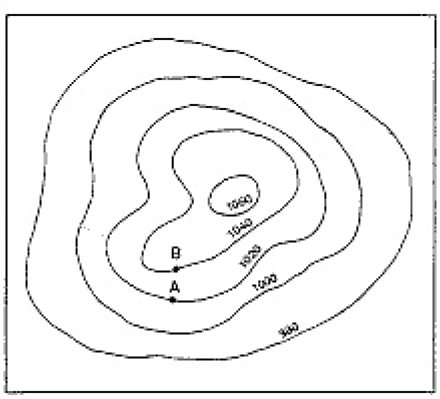


Figure E-1: Isolated Hill

One of the easiest landscapes to visualize on a topographic map is an isolated hill. If this hill is more or less circular the map will show it as a series of more or less concentric circles (Figure E-1). Imagine that a surveyor actually marks these contour lines onto the ground. If two people start walking in opposite directions on the same contour line, beginning at point A, they will eventually meet face to face.

If these same two people start out in opposite directions on different contours, beginning at points A and B respectively, they will pass each other somewhere on the hill and their vertical distance apart would remain 20 feet. Their horizontal distance apart could be great or small depending on the steepness of the hillside where they pass.

A rather more complicated situation is one where two hills are connected by a saddle (Figure E-2). Here each hill is circled by contours but at some point toward the base of the hills, contours begin to circle both hills.

How do contours relate to water flow? A general rule of thumb is that water flow is perpendicular to contour lines. In the case of the isolated hill, water flows down on all sides of the hill. Water flows from the top of the saddle or ridge, down each side in the same way water flows down each side of a garden wall (See arrow on Figure E-2).

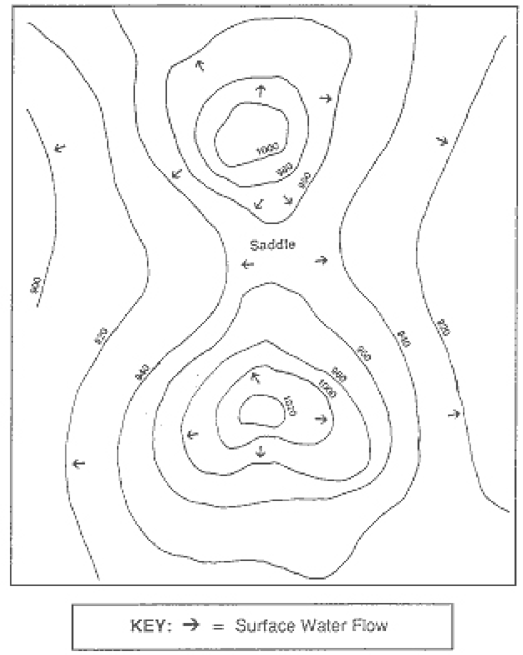


Figure E-2: Saddle

As the water continues downhill it flows into progressively larger watercourses and ultimately into the ocean. Any point on a watercourse can be used to define a watershed. That is, the entire drainage area of a major river like the Merrimack can be considered a watershed, but the drainage areas of each of its tributaries are also watersheds.

Each tributary in turn has tributaries, and each one of these tributaries has a watershed. This process of subdivision can continue until very small, local watersheds are defined which might only drain a few acres, and might not contain a defined watercourse.

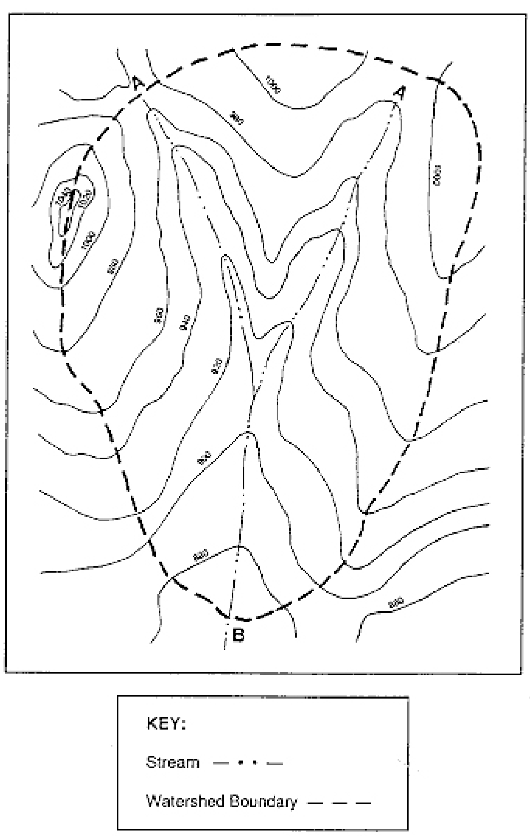


Figure E-3: Idealized Watershed Boundary

Figure E-3 shows an idealized watershed of a small stream. Water always flows downhill perpendicular to the contour lines. As one proceeds upstream, successively higher and higher contour lines first parallel then cross the stream. This is because the floor of a river valley rises as you go upstream. Likewise the valley slopes upward on each side of the stream. A general rule of thumb is that topographic lines always point upstream. With that in mind, it is not difficult to make out drainage patterns and the direction of flow on the landscape even when there is no stream depicted on the map. In Figure E-3, for example, the direction of streamflow is from point A to point B.

Ultimately, you must reach the highest point upstream. This is the head of the watershed, beyond which the land slopes away into another watershed. At each point on the stream the land slopes up on each side to some high point then down into another watershed. If you were to join all of these high points around the stream you would have the watershed boundary. (High points are generally hill tops, ridge lines, or saddles).

Delineating a Watershed

The following procedure and example will help you locate and connect all of the high points around a watershed on a topographic map shown in Figure F-4 below. Visualizing the landscape represented by the topographic map will make the process much easier than simply trying to follow a method by rote.

1. Draw a circle at the outlet or downstream point of the wetland in question (the wetland is the hatched area shown in Figure E-4 to the right)
2. Put small "X's" at the high points along both sides of the watercourse, working your way upstream towards the headwaters of the watershed.
3. Starting at the circle that was made in step one, draw a line connecting the "X's" along one side of the watercourse (Figure E-5, below left). This line should always cross the contours at right angles (i.e. it should be perpendicular to each contour line it crosses).
4. Continue the line until it passes around the head of the watershed and down the opposite side of the watercourse. Eventually it will connect with the circle from which you started.

At this point you have delineated the watershed of the wetland being evaluated.

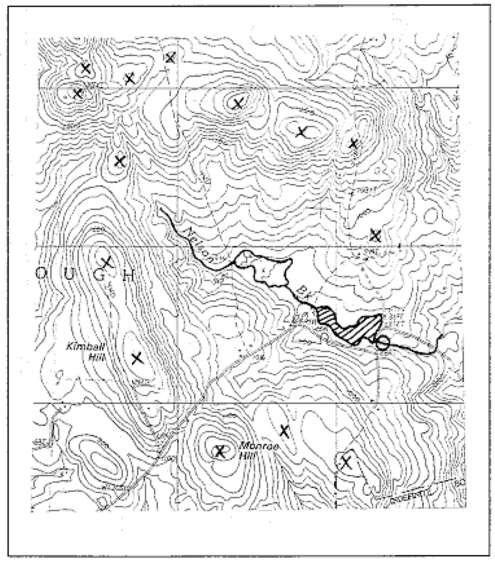


Figure E-4: Delineating a Watershed Boundary - Step 1

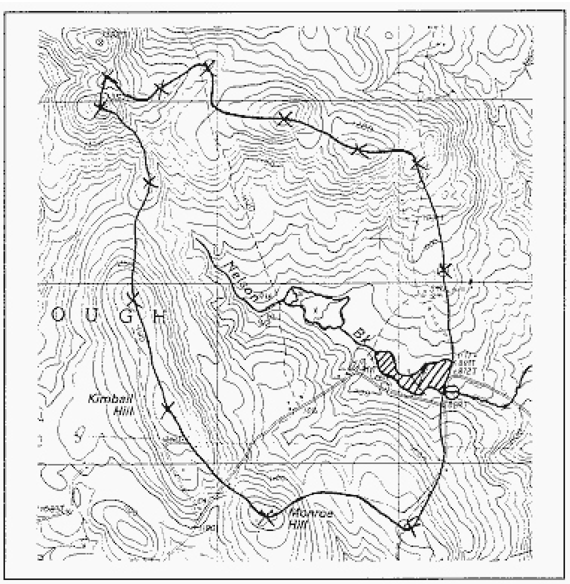


Figure E-5: Delineating a Watershed Boundary - Step 2

The delineation appears as a solid line around the watercourse. Generally, surface water runoff from rain falling anywhere in this area flows into and out of the wetland being evaluated. This means that the wetland has the potential to modify and attenuate sediment and nutrient loads from this watershed as well as to store runoff which might otherwise result in downstream flooding.

a) The dot grid method is a simple technique which does not require any expensive equipment. In this method the user places a sheet of acetate or mylar, which has a series of dots about the size of the period at the end of this sentence printed on it, over the map area to be measured. The user counts the dots which fall within the area to be measured and multiplies by a factor to determine the area. A hand held, mechanical counting device is available to speed up this procedure.

b) The second of these methods involves using a planimeter, which is a small device having a hinged mechanical arm. One end of the arm is fixed to a weighted base while the other end has an attached magnifying lens with a cross hair or other pointer. The user spreads the map with the delineated area on a flat surface. After placing the base of the planimeter in a convenient location the user traces around the area to be measured with the pointer. A dial or other readout registers the area being measured.

Planimeters can be costly depending on the degree sophistication. For the purposes of The New Hampshire Method, a basic model would be sufficient. Dot counting grids are significantly more affordable. Both planimeters and dot grids are available from engineering and forestry supply companies. Users of either of these methods should refer to the instructions packaged with the equipment they purchase.

For more information on The New Hampshire Method, wetlands restoration programs, conservation planning, ecosystem restoration, and other technical references, visit www.nh.nrcs.usda.gov or call (603) 868-7581.

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Instructions for Rake Toss Sampling

1. If possible, identify sampling points in advance, using an overlay GIS grid map or hand drawn map. Otherwise assign sampling sites ("stations") in well defined intervals (every 100 meters) in parallel or perpendicular lines to shore

2. Navigate to first station, toss rake line as far as possible, and slowly bring back into boat.

3. Estimate overall plant abundance using USACE/Cornell abundance scale:

"Zero" = no plants on rake
"Trace" = fingerful of plants on rake
"Sparse" = handful of plants on rake
"Medium" = most to all tines on rake covered with plants
"Dense" = difficult to bring into boat.

4. Remove plants from rake tines and separate into individual piles for each plant type (species), based on unique physical attributes.

5. Estimate plant abundance for each plant type/species using USACE/Cornell abundance scale or percentage abundance, and identify each plant type/species on form by plant species name or assigned number ("Water chestnut", "Unknown #1", etc.).

6. Take one specimen from the pile corresponding to "Unknown 1" (or the first named plant), place in a clean light colored tub with lake or tap water to refloat the plant, and take a digital photograph of the plant. Repeat this with a specimen for each plant. Record digital image number on survey form to link with assigned plant species number.

7. Collect voucher specimen for any unknown, suspected exotic or protected plant (based on comparison to laminated "cheat sheet"), and place in a labeled ziplock bag. Each plant should be placed in a separate bag, labeled with the species name/number. Collect only one specimen for each assigned plant number.

8. Identify next sampling point from GPS coordinates, pre-determined sampling grid, or visual observation, and repeat steps 2-7.

9. After all sites have been sampled, remove first collected plant from bag, shake water off, and place on newspaper, attempting to spread out the plant leaves (newspaper with plant can be submerged in tray to refloat, and paper can be slowly withdrawn while holding plant to set "spread" plant in place). Allow newspaper to dry and cover with second newspaper to help blot excessive water. Repeat with all collected plants on separate paper. Label each plant with name or number of plant, lake name, and date. Keep plants in case specimens are needed by NYSDEC for confirmation and archiving.

ROUND GOBY

Neogobius melanostomus
Origin: Eurasia

Round Gobies are small, brown and black blotched fish with large, frog-like heads. There is a black spot on their front dorsal fin, which is a characteristic of the species. They grow to just under 30 cm in size. Round Gobies can be distinguished from native sculpins (*Cottoidae*) by their fused pelvic fins, or suctorial disc, which helps them attach to surfaces in flowing water.

HABITAT

Round Gobies are bottom dwellers of fresh or brackish water. They can thrive in a wide variety of habitat types, including open sand, dense macrophytes, and rocky substrates.

INVASIVE RANKING, NYS

High

THREAT

Round Gobies are aggressive fish that can outcompete native species for food, shelter, and nesting sites. They also prey on eggs of many native fish species. Round Gobies bioaccumulate many contaminants, which are then passed on to larger game fish and then potentially to humans.

MANAGEMENT STRATEGY

Prevention

MANAGEMENT

Prevention and education are the best management strategies. Clean, drain, and dry all equipment prior to moving between waterbodies, and do not release live bait. Little can be done to eradicate populations once they are established.

DISTRIBUTION

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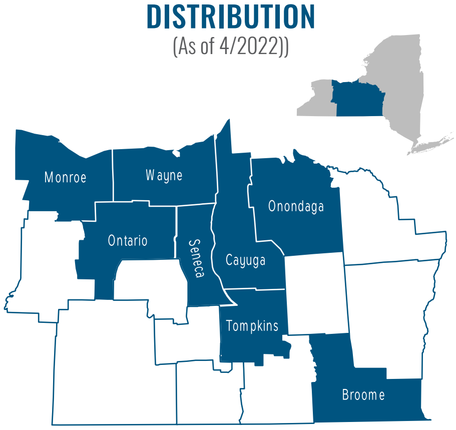

www.fingerlakesinvasives.org

REFERENCE - Invasives Species Awareness Program. (2011). Round Goby. Retrieved from Ontario Invading Species Awareness Program: http://www.invadingspecies.com/invaders/fish/roundgoby/
U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [6/8/2017].

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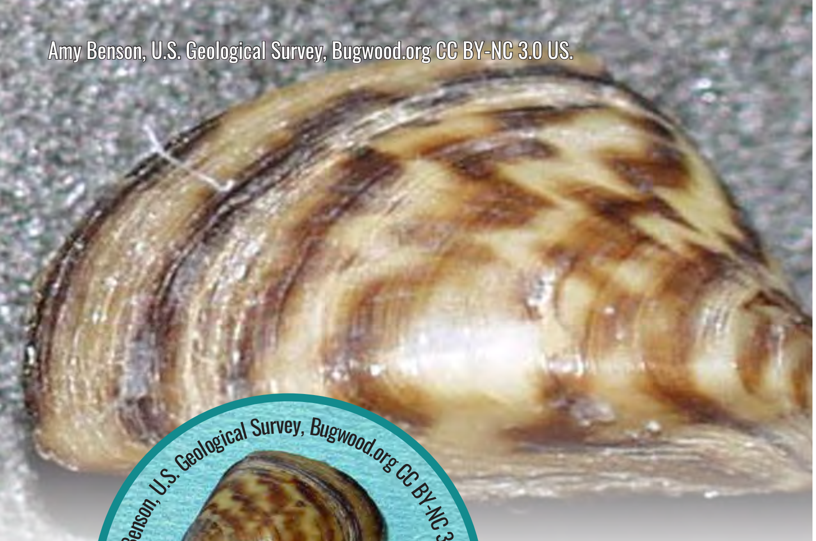

ZEBRA MUSSEL

Dressina polymorpha
Origin: Eurasia

Zebra mussels are filter-feeding, freshwater, bivalve mollusks that attach to most surfaces in aquatic environments. Zebra mussels are small, up to 3 cm long, and D-shaped with light and dark yellow to brown alternating stripes. This species is similar in appearance to the quagga mussel (*Dreissena rostriformis bugensis*), but they can be distinguished by the presence of a flattened underside. When placed on a flat surface, zebra mussels will remain upright.

INVASIVE RANKING, NYS

Very High

MANAGEMENT STRATEGY

Chemical
Mechanical
Physical
Biocontrol
Prevention

DISTRIBUTION

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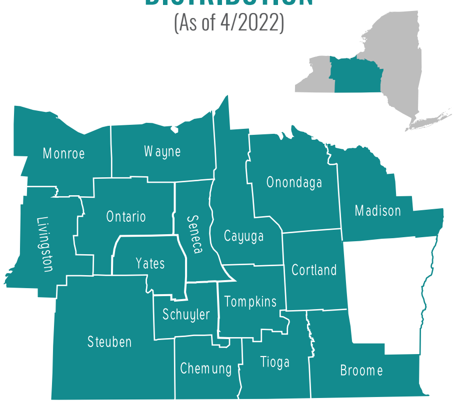

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HABITAT

Zebra mussels inhabit freshwater lakes, rivers, reservoirs, streams, and ponds up to depths of widely varying depths. They attach to any stable substrate including sand, silt, cobbles, macrophytes, concrete, and metal. They do not tolerate salinity or low dissolved oxygen.

THREAT

Zebra mussels can outcompete and displace native species. Although they have some predators, they breed faster than they can be consumed. As filter feeders, they remove particles from the water, affecting the clarity, content, and ultimately the food chain of aquatic ecosystems. They can also attach to and cover many surfaces, which can cause slippery and sharp conditions, and clog intakes or other pipes.

MANAGEMENT

The best management strategy is prevention through education and stewardship. As this species is most commonly spread through fishing and boating equipment, it is important to use precautions such as cleaning, draining, and drying your boat and other aquatic equipment before moving to another water body. Zebra mussels are very difficult to control once established. In closed systems such as water treatment plants, chemical, thermal, electrical, and biological controls may be used.

REFERENCE - U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [6/7/2017].

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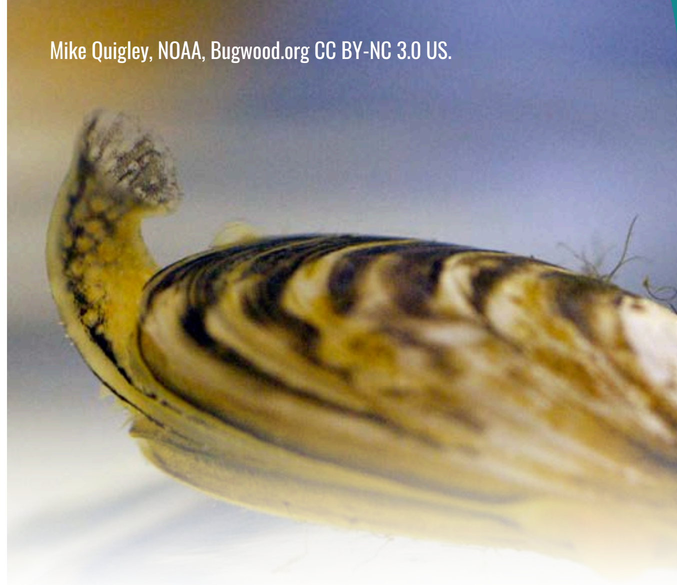
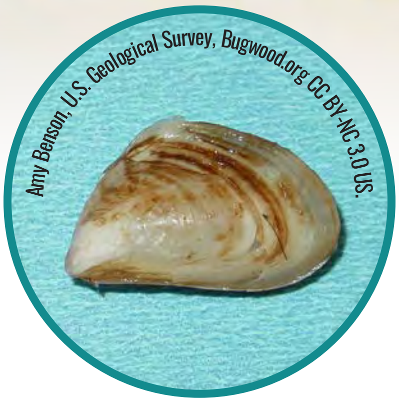
INVERTEBRATES





QUAGGA MUSSEL

Dreissena rostriformis bugensis
Origin: Eurasia

Quagga mussels are filter-feeding, freshwater, bivalve mollusks. Their appearance is variable, but shells usually have dark concentric rings that fade toward the hinge. Shells can grow to about 4 cm and are rounded, with a slightly bowed bottom that causes the mussel to tip over if set on its flattest surface.

HABITAT

Quagga mussels inhabit freshwater at varying depths depending on temperature, where they are sheltered from wave attack. They can live on a wide variety of soft and hard surfaces.

THREAT

Quagga mussels can outcompete and crowd out native species. As filter feeders, they remove particles from the water, which affects water quality and the food chain of aquatic ecosystems. They also cover many surfaces and can be a nuisance to humans due to their sharp shells.

MANAGEMENT

The best management strategy is prevention through education and stewardship. As these species are most commonly spread through fishing and boating equipment, it is important to use precautions such as cleaning, draining, and drying your boat and other aquatic equipment before moving to another water body. Not much can be done once established. Manual removal may be performed on small, accessible populations. In closed systems, such as water treatment plants, other control methods can be used, including chemical, thermal, electrical, and biological controls.

INVASIVE RANKING, NYS

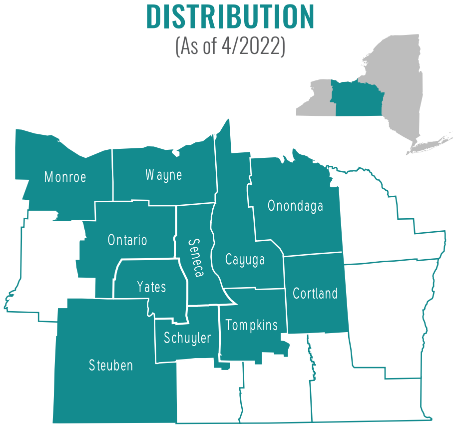
Very High

MANAGEMENT STRATEGY

Chemical
Mechanical
Physical
Biocontrol
Prevention

DISTRIBUTION

(As of 4/2022)



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REFERENCE - U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [6/7/2017].

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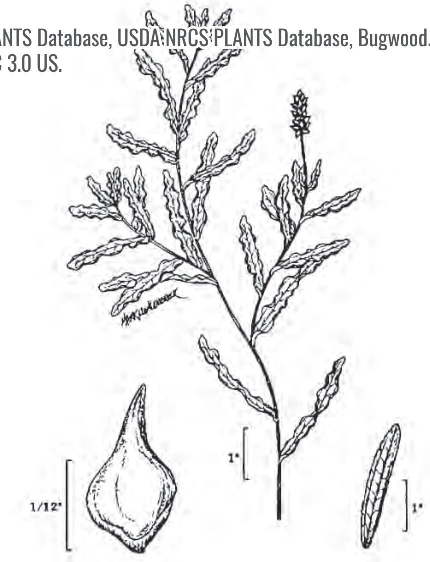

CURLY-LEAVED PONDWEED

Potamogeton crispus
Origin: Europe, Africa, and Australia

Curly-leaved pondweed is a submerged perennial aquatic plant that can grow to about 5 m long. It has rigid, reddish-green, oblong leaves with finely toothed, wavy margins and blunt tips, which grow in an alternate arrangement. This species produces very small greenish-red flowers on a spike above the water surface. It also reproduces using overwintering buds, called turions.

INVASIVE RANKING, NYS

High

MANAGEMENT STRATEGY

Chemical
Mechanical
Physical
Prevention

HABITAT

Curly-leaved pondweed grows in a wide variety of environments, including shallow, deep, still, flowing, slightly brackish, or freshwater water up to a depth of about 6 m.

THREAT

This species is one of the first to grow in the spring and can grow quickly, allowing curly-leaved pondweed to outcompete native plants for light and space thereby reducing the biodiversity and value of aquatic habitat. Curly-leaved pondweed's senescence during midsummer can cause a critical loss of dissolved oxygen. The decomposition process can result in increased levels of phosphorous, which can lead to algal blooms. Dense infestations will also inhibit boating, fishing, swimming, and other recreational activities.

MANAGEMENT

The best management strategy is prevention through education and stewardship. As this species is most commonly spread through fishing and boating equipment, it is important to use precautions such as cleaning, draining, and drying your boat and other aquatic equipment before moving to another water body. This plant may be removed manually, provided all fragments and stem parts are also removed. Herbicides have been effective in controlling infestations.

DISTRIBUTION

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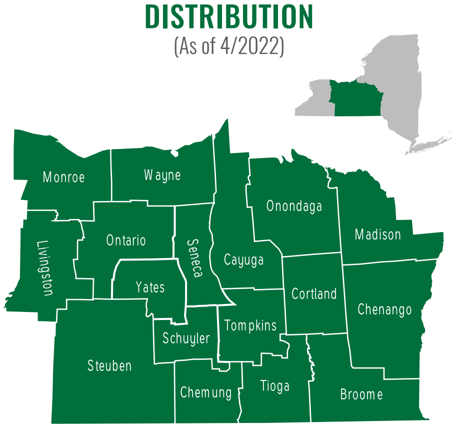

REFERENCE - U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [6/7/2017].

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EURASIAN WATERMILFOIL

Myriophyllum spicatum

Origin: Eurasia

Eurasian watermilfoil is an invasive submerged aquatic plant that can be easily mistaken for several native plants. Each leaf is blunt-tipped and finely divided into at least 12 pairs of leaflets, arranged in whorls of four on brown or green stems. The plant can grow up to 6 m in length. Tiny pink flowers may occur on emergent spikes in mid-June and again in late July. Although each plant can produce 100 seeds in a season, it reproduces more successfully via fragmentation.

INVASIVE RANKING, NYS

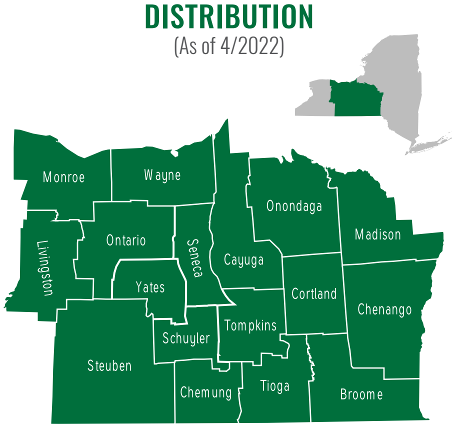
Very High

MANAGEMENT STRATEGY

Chemical
Mechanical
Physical
Biocontrol
Prevention

DISTRIBUTION

(As of 4/2022)



HABITAT

This invasive can be found to depths of 10 m in lakes, ponds, and quieter sections of rivers and streams. It can grow in fresh or brackish water, across a wide range of temperatures, and thrives in disturbed areas with nutrient loading, intense plant management, and/or abundant motorboat use.

THREAT

Eurasian watermilfoil can spread very easily through fragmentation. This species forms dense mats that outcompete and displace native species, degrade habitat, and inhibit recreational activities.

MANAGEMENT

Education about practices such as clean, drain, and dry, as well as timely reporting of sightings is an important management practice to reduce the spread of this species and prevent new infestations. Once Eurasian watermilfoil is established, it is very hard to control. Mechanical control can enhance the spread of an infestation by creating and transporting plant fragments. If extreme care is taken to prevent or remove fragments, small infestations may be mechanically or manually removed. Many herbicides can control milfoil populations. Biocontrol insects or the triploid Grass Carp (*Ctenpharyngodon idella*) may also be options for control.

REFERENCE - https://nas.er.usgs.gov/queries/greatlakes/FactSheet.aspx?SpeciesID=237
U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [6/7/2017].

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HYDRILLA

Hydrilla verticillata
Origin: Asia

Hydrilla is a submerged herbaceous perennial plant with visibly serrated leaves that grow in whorls of three to eight, often five. The undersides of Hydrilla leaves can be spiny and the midrib of each leaf is often reddish. Hydrilla can spread by seeds, tubers (which resemble tiny bulbs in the sediment), plant fragments, and turions (overwintering buds located on the stems). This invasive plant looks similar to American or Canadian waterweed (*Elodea canadensis*), a common native and aquarium aquatic plant, which has smooth leaves usually arranged in whorls of three and no tubers or turions.

INVASIVE RANKING, NYS

Very High

MANAGEMENT STRATEGY

Chemical
Mechanical
Physical
Biocontrol
Prevention

DISTRIBUTION

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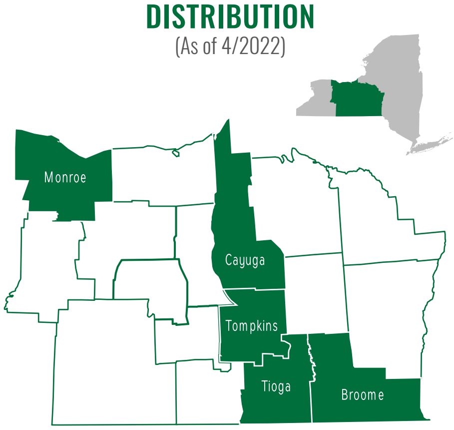

HABITAT

Hydrilla inhabits freshwater lakes, ponds, rivers, impoundments, and canals. Hydrilla is shade-tolerant and can thrive in a wide range of nutrient conditions and depths.

THREAT

Hydrilla spreads quickly, and once established, forms dense stands that crowd out native species and disrupt aquatic habitats. Hydrilla can also clog waterways and restrict water flow, which may damage water control structures and inhibit recreational activities such as swimming, boating, and fishing.

MANAGEMENT

Several techniques have been used to manage Hydrilla. Mechanical removal can be effective only if all parts of the plant are removed including the long-lasting tubers. Herbicides and physical barriers, such as benthic mats, are also effective. Biological agents can also be a successful management strategy, although they are not widely used in NY. The best management strategy is prevention through education and stewardship. As this species is most commonly spread through fishing and boating equipment, it is important to use precautions such as cleaning, draining, and drying your boat and other aquatic equipment before moving to another water body.

REFERENCE - U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [6/7/2017].

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PLANTS

WATER CHESTNUT

Trapa natans
Origin: Eurasia

Water chestnut is a floating-leaved, annual, aquatic plant. Linear, oppositely arranged submersed leaves are replaced by feathery adventitious roots early in the growing season. On the water surface, the plant forms a rosette of green, glossy, triangular floating leaves with toothed edges and inflated petioles. Plant stems are cord-like and can grow up to 5 m. Small, white, four-petaled flowers bloom from the center of the rosette during the summer, eventually producing large, four-spined seeds.

HABITAT

Water chestnut grows best in quiet, shallow, high nutrient water bodies with a soft bottom substrate. They prefer waters with an alkaline or neutral pH.

THREAT

Populations of this species can form very dense mats of interlocking and stacking rosettes. These thick mats completely shade the water column and suppress most other aquatic plant growth in the area. Dense mats also inhibit boating, swimming, and fishing. The seeds are painful when stepped upon.

MANAGEMENT

Small populations can be controlled by hand pulling the plants prior to seed maturation. Large infestations have been controlled by the use of mechanical harvesters or the application of aquatic herbicides. Biocontrol options are in development. As always, the best management strategy is prevention through education and stewardship. As this species is most commonly spread through fishing and boating equipment, it is important to use precautions such as cleaning, draining, and drying your boat and other aquatic equipment before moving to another water body.

INVASIVE RANKING, NYS

Very High

MANAGEMENT STRATEGY

Chemical
Mechanical
Physical
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DISTRIBUTION

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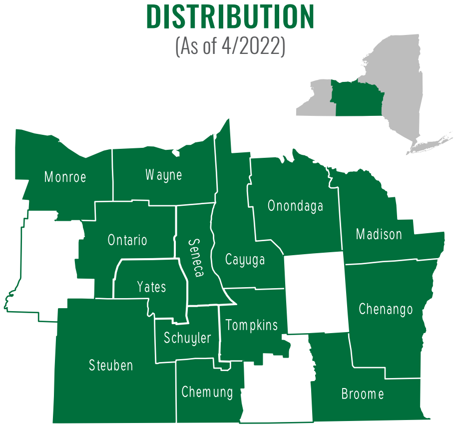

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REFERENCE - U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [6/8/2017].

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Water Quality Monitoring with the Citizens Statewide Lake Assessment Program (CSLAP)

The Citizens Statewide Lake Assessment Program (CSLAP) is a volunteer lake monitoring and education program that is managed cooperatively by DEC and New York State Federation of Lake Associations (NYSFOLA). The program was adapted from successful volunteer monitoring programs in Vermont, Maine, Minnesota, and Illinois. CSLAP is one of the longest running, continuous, volunteer monitoring programs in the nation. Through this program, relationships between lake associations, academic and private research institutions, and local and state entities are built statewide.

Who participates in CSLAP?

The lake associations and volunteers in the CSLAP program are diverse and spread throughout New York State. Trained CSLAP volunteers regularly collect data from more than 150 lakes annually, and over 2,000 volunteers have sampled more than 270 lakes since 1985. Lake associations collect information from public and private lakes ranging in size from small ponds to large lakes.

Participating lake associations and volunteers are concerned citizens dedicated to conserving and protecting water resources and providing data to help develop lake management plans. Volunteers range educational and scientific backgrounds, and include: lake residents and users, teachers, lakefront community, students, and scientists.

Data Collection

Every other week during the summer months, volunteers record lake information on field data sheets and collect water samples at the deepest part of the lake for lab analysis. A comprehensive list of sampling parameters is given in the Lake Parameters table below.

Data collected by CSLAP contribute to management efforts at the state and local level. At the state level they contribute to water quality criteria development, clean water plans, and federal 305b and 303d reports. Data are made publicly available on the DEC Info-Locator and are used directly by lake associations, town and county governments, not-for-profits, and other state agencies.

Regular lake monitoring keeps track of existing problems, detects threats to lakes before they become a problem, and helps to evaluate lake condition patterns throughout NYS. Lake residents and trained volunteers are in a position to observe lake changes and compare them to baseline conditions. In addition to the parameters described below, CSLAP participants help with the early discovery of harmful invasive species and harmful algal blooms.

What does NYSFOLA do?

NYSFOLA is a non-profit group of lake associations, individual citizens, park districts, lake managers, environmental organizations, and consultants dedicated to the preservation and restoration of NYS lakes and watersheds.

The goals and objectives of NYSFOLA are to protect the water resources of New York through public outreach, education, sharing information, and partnerships. NYSFOLA was founded in 1983 to address water quality concerns and invasive species issues for concerned lake associations. The organization expanded following the launch of CSLAP and the program continues to be an important part of their mission.

Below are the CSLAP Lake Monitoring Parameters

CSLAP Lake Monitoring Parameters	
Parameter	**Importance**
Water Temperature (°C)	Water temperature affects the growth of plants and animals, the amount of oxygen in the water, and the length of the recreation season.
Water Clarity (m)	Water clarity is determined with a secchi disk to measure how far down into the water column you can see.
Conductivity (µmho/cm)	Conductivity measurers the amount of dissolved and suspended materials in the water, including salts and organic material. Conductivity may be related to geology or land use practices.
pH	pH means water acidity. A pH value between 6 and 9 supports most types of plant and animal life.
Color (true) (platinum color units)	Water color is affected by organic matter (decaying plants). The color of water can affect water clarity and impact plant growth by limiting the amount of sunlight that can pass through the water.
Phosphorus (total, mg/l)	Phosphorus is an important nutrient for the growth of aquatic plants and animals in lakes. Too much phosphorus can harm aquatic life, water supplies, and recreational uses.
Nitrogen (nitrate, ammonia, and total dissolved, mg/l)	Nitrogen is also an important nutrient for the growth of aquatic plants an animals in lakes. Too much nitrogen can harm aquatic life, water supplies and recreational uses.
Chlorophyll a (µg/l)	Chlorophyll a is the primary pigment in green plants and estimates the amount of algae in a lake. The amount of chlorophyll a may be influenced by phosphorus and can affect the water clarity.
Calcium (mg/l)	Calcium is an important nutrient for most aquatic organisms and is required for mussel shell growth. Calcium enters lakes through natural limestone deposits. Calcium concentration is related to lake conductivity and improves the lake's buffering capacity to acid rain.