Chapter 6

Lake Science

Lake Science - Limnology

Fresh water is essential for human life. People use fresh water, such as that found in lakes, for drinking, recreation, growing crops, commerce and industry. People also value lakes for their fundamental ecological function as habitat for fish and wildlife.

People often think of a lake as a uniform mass of water, almost like a bathtub that is evenly mixed. In reality, lakes are extremely patchy and constantly changing. The characteristics of lakes can be divided into three broad categories: physical, chemical and biological. The study of these three categories within lakes and other inland waters – saline and fresh, natural and manmade – is called limnology. Scientists study limnology in the hope of increasing our understanding of how lakes function.

Physical Characteristics

Physical characteristics of lakes include their shape (also called morphology), light levels, temperature, water movement and water levels.

Lake Erie was formed about 15,000 years ago by the Wisconsin glaciation. Lake Erie is the smallest of the Great Lakes in volume. It is longer east to west than north to south, and is relatively shallow for a Great Lake. Because of this morphology, it warms rapidly in the spring and summer and frequently freezes in winter.

The interactions of light, temperature and mixing are the most fundamental physical processes affecting Lake Erie. Light is absorbed by the water resulting in an increase in surface water temperature. In winter, when air and water temperatures drop, ice forms on Lake Erie.

The water in Lake Erie is rarely still. Wind action, temperature changes and even a small tidal effect keep the waters of the lake in a constant state of movement from wave action, both on and below the surface.

Few characteristics of Lake Erie are as widely discussed as the water level. Water levels fluctuate, sometimes greatly, from day to day, season to season, year to year and over longer periods. For seasonal fluctuations, water levels are highest in the spring due to snowmelt and spring rains, and lowest in the winter due to increased evaporation in late summer and fall until the lake freezes.

Chemical Characteristics

Lakes' chemical characteristics are very complex and include oxygen, nutrient levels and pollutants.

The most important chemicals used by animals and plants living in the lake are oxygen and nutrients. Algae, plants and organisms found in lakes function similarly to plants and people found on the land—requiring either carbon dioxide or oxygen to survive. Algae and lake plants use carbon dioxide in the water to make oxygen. In turn, lake organisms get their required oxygen from the water.

Scientists are interested in the oxygen levels in the lake waters because oxygen levels measure the activities of both plants and animals. Areas of low oxygen are sometimes referred to as "dead zones," implying that nothing can survive there.

Algae and aquatic plants also need nutrients in order to grow. On land, people grow plants by adding nutrients to the soil as fertilizers. These same nutrients, particularly nitrogen and phosphorus, are used by the plants in the lake waters. Nutrients are necessary for the life in the lake, but excessive levels can cause increases in the numbers of undesirable species. Thus, the introduction of too many nutrients can disrupt ecological balance and is considered pollution.

Pollutants are chemicals that have been added to the lake that interfere with desirable functions of the lake such as its use by fish and wildlife, or by people for drinking water and recreation. Pollution enters the lake through both point and non-point sources. Point sources of water pollution are stationary locations such as sewage treatment plants, factories and ships. As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States.

Nonpoint source (NPS) pollution comes from many sources in both urban and rural areas.

NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters and even our underground sources of drinking water. These pollutants include excess fertilizers, herbicides and insecticides from agricultural lands and residential areas; oil, grease and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands and eroding streambanks; salt from irrigation and road de-icing practices; acid drainage from abandoned mines; bacteria and nutrients from livestock, pet wastes and faulty septic systems; and atmospheric deposition.

Biological Characteristics

The amount of biological activity (also called productivity), where the organisms live and the interactions they have with each other and with the environment determines the biological characteristics of lakes.

Depending on water chemistry, particularly nutrient levels, lakes may have low productivity (low biological activity) or high productivity (high biological activity). Lake Erie has relatively high productivity, meaning there are high levels of algae and plants in the lake and also large amounts of fish and other organisms.

Algae, plants and animals have different habitat needs and therefore live in different parts of the lake. In order to help study these different communities of organisms, scientists divide the lake into several zones. These include the littoral zone, pelagic zone, euphotic zone, profundal zone and benthic zone, all of which will be explored later in this chapter.

Biological communities are also linked through food webs, the cycle by which the energy from food moves through different organisms. The main source of this energy is from the sun. Energy from the sun, combined with nutrients in the water, is used by algae and plants to make simple sugars. Algae are eaten by small animals called zooplankton. Zooplankton are an important food source for juvenile and small fish. Fish are in turn eaten by other fish, birds and mammals, including people. At each stage, some organisms die and fall to the bottom of the lake where they decompose into nutrients that are used to begin the cycle again.

Some of the greatest impacts to biological lake communities can come from invasive species that have undesirable impacts on the aquatic food web. For example, zebra mussels, and their close cousins the quagga mussels, eat algae making this food source less available for juvenile fish. Since most fish, regardless of size, do not eat zebra mussels, most of the mussels die and decompose without contributing to the food web.

In this chapter, the physical, chemical and biological characteristics of Lake Erie, including the "Dead Zone" and invasive species will be explored.

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Mayflies

They are called many things: Canadian soldiers, June bugs, shadflies and even a nuisance. The prolific and sometimes pesky family of aquatic insects known as mayflies may be the most denounced creatures in Lake Erie; but they are also clean-water barometers for our lakes and streams. Bottom-dwelling insects for the first year or so of their lives, mayflies could never emerge in adulthood without clean, oxygen-rich sediments in Lake Erie and adjacent streams that they call home. About an inch in length, the mayfly can be identified by its elongated body and delicate, transparent wings. These harmless and attractive water lovers are found in nearly every major body of fresh water in the state, but perhaps most closely associated with Lake Erie's Western Basin. Mayflies all but disappeared nearly 50 years ago but began reappearing in swarms in 1995.

Along Ohio's North Coast, the genus of mayflies called *Hexagenia* are both a bane to coastal residents and a boon to sport anglers who frequently try to emulate the fanciful bugs when tying artificial fishing lures. Mayflies are a favorite delicacy for hungry Lake Erie fish, including the prized walleye, smallmouth bass and yellow perch. Mayflies convert vegetation into palatable tidbits for fish and birds. Biologists say there is a direct connection between water quality improvements, the return of the mayfly after a 50-year absence and the resurgence in Lake Erie's walleye fishery. Along with bald eagles and walleyes, mayflies are a key indication of Lake Erie's improving health.

Mayfly nymphs live under water, breathing through gills located in their abdomens. During this aquatic phase, mayflies shed their skin several times to accommodate their growing bodies. Each summer (usually mid-May through June) millions of adult mayflies swarm from the lake's shallow waters and move inland. Mayflies mate in flight, after which the female flies back over the water and deposits as many as 8,000 eggs. There, her eggs sink into the sediment at the lake's bottom. The entire process – from the time the mayfly nymph emerges from the water to molt, mate and die – takes only 24 to 72 hours.

While their annual reproduction ritual is a nuisance for locals who must scrape swarming mayflies from windshields and shovel them off porches and roadways, it is a life-affirming sign for biologists who understand the insects' important role in Lake Erie's intricate food chain.

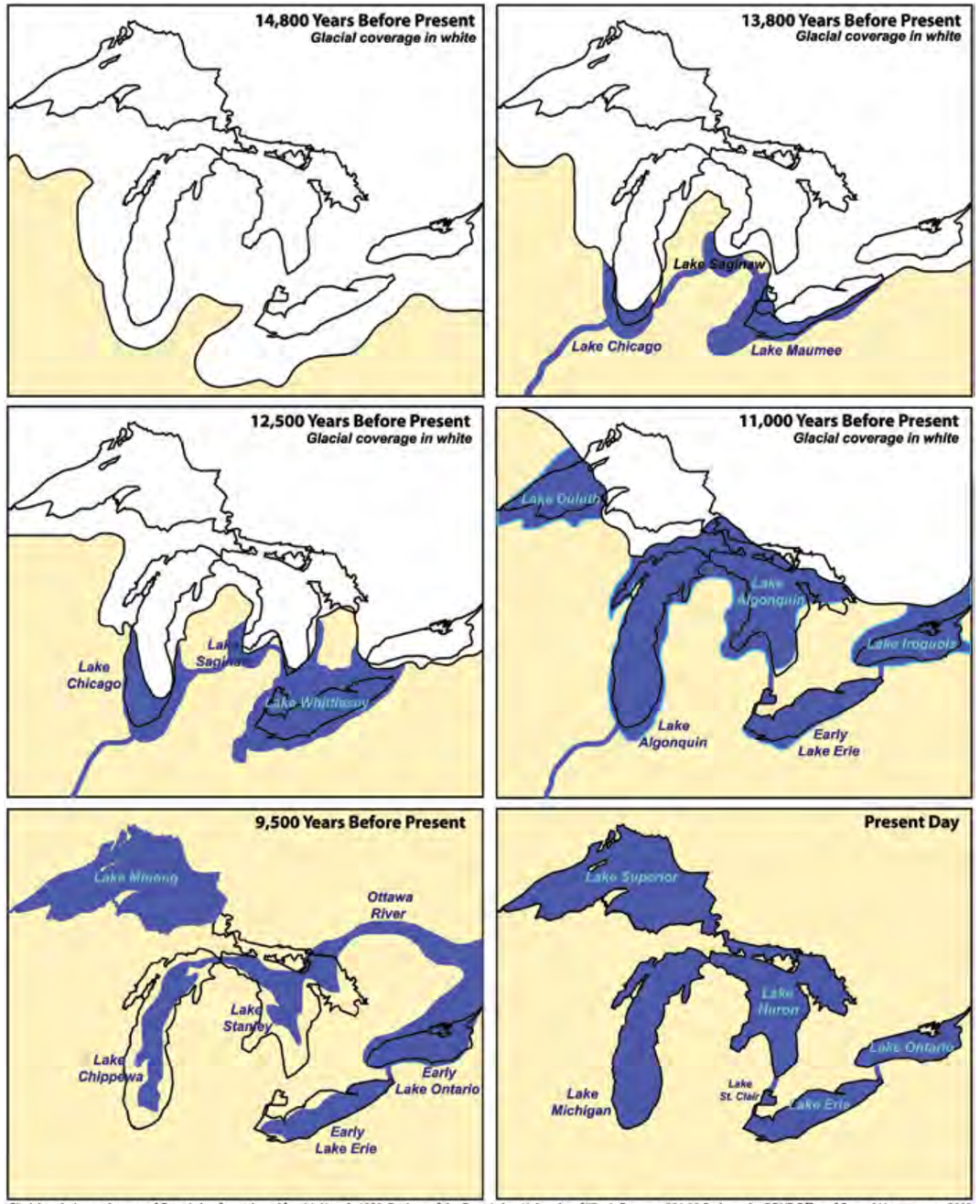
Background photo: Canada geese

Ice forming on lake near the Huron River mouth, Erie County

Middle Bass Island glacial grooves, Ottawa County

Ice fishing in the Lake Erie islands region
Photo by Ohio Sea Grant

Canada Geese



Glacial evolution and stages of Great Lakes formation - After J. L. Hough, 1958, Geology of the Great Lakes. University of Illinois Press. pp. 284-96. Redrawn by ODNR Office of Coastal Management, 2005

Lake Formation and Morphology

Most lakes in the US are relatively young, geologically speaking, being less than 15,000 years old. There are two reasons for this. First, a large number of the lakes (including Lake Erie) were formed by the Wisconsin glaciation, which occurred at about that time. Second, lakes serve as sediment traps. Because particles settle readily in calm waters, lakes begin filling with sediment immediately upon formation. The particles may come from the air and land near the lake, or from within the lake itself (organic particulates from photosynthesis, or mineral precipitation from the water chemistry). Sediments eventually fill the lake over long periods of time.

In North America, glaciation extended south to about the Ohio River. There are no glacial lakes south of the Ohio River, and in fact there are very few natural lakes of any origin south of the Ohio River.

For additional Lake Erie information, see Chapter 2: Coastal Awareness and the lake formation informtion in Chapter 10: Geology.

Light, Heat, Stratification

The interactions of light, temperature and mixing are the most fundamental physical processes affecting Lake Erie. Light is absorbed by water, which results in an increase in the temperature of surface waters. As light passes through water, its intensity is attenuated (or decreased). The rate at which the penetration of light decreases with depth depends on the number of suspended particles in water. The level of light determines the maximum depth at which algae and plants can grow. This depth has been determined to be the point where available light is reduced to 0.5 to 1 percent of the amount of light available on the surface. Above this water column level, there is enough light for photosynthesis to occur. Photosynthesis is the creation of complex organic molecules (simple carbohydrate sugars) by plants and algae from the energy supplied by light. Photosynthesis also releases oxygen into the water as a by-product of the process.

In early spring, the waters of Lake Erie are cold and the temperature is nearly the same throughout the water column. For a while, winds stir the waters of the lake and cause mixing throughout the water column. As sunlight becomes more intense and air temperatures increase, the upper layers of the water become warmer. Because light intensity decreases with the depth of the water, the water temperature decreases gradually with increasing depth. Additionally, cooler water is denser than warmer water and the cooler water drops to the lake floor. Eventually, the warmer water at the surface ceases to mix with the cooler water below. This results in the formation of thermal stratification of the lake. Between the warmer water on the surface and the cooler water below, a relatively short transition zone occurs where the rate of change of temperature is rapid. The point at which this change is the greatest is called the thermocline.

In the winter, when air and water temperatures drop, ice forms on the surface of Lake Erie. Ice cover is of great interest to those who use the lake. Boaters must remove their boats in the fall to prevent winter ice damage, and ice fishing is very popular on the Great Lakes when conditions permit. Ice conditions can vary dramatically from year to year, depending on the winter conditions. Ice cover usually begins forming in the Western Basin of the lake around the last two weeks in December. By January, ice cover is nearly complete

Physical Characteristics

in the Western Basin, and ice formation accelerates in the Central Basin. Ice formation continues through January, with maximum ice cover of the entire lake usually achieved in the early part of February. In late winter and early spring, as temperatures begin to increase again, the ice in the Western Basin begins to break up. By mid-March, much of the western part of Lake Erie is again ice-free, with the ice breakup proceeding east in March and early April. By the end of April, Lake Erie is largely free of ice cover, although ice rafting at the Niagara River outlet sometimes lasts into May.

Water movement (seiches, waves, currents)

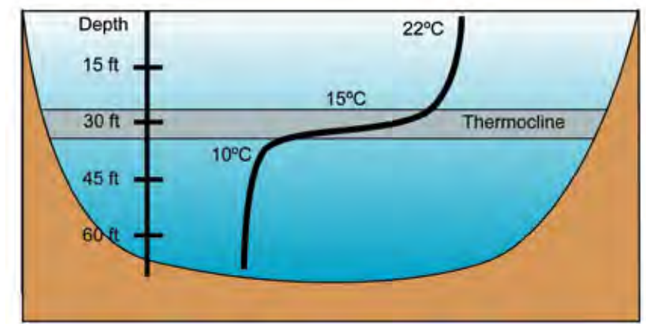
A seiche (pronounced say'sh) is an oscillating wave in a lake. In the Great Lakes, seiches are caused by wind blowing across the surface of the water. When the winds die down, the water accumulated along the downwind coast flows back across the lake and begins sloshing back and forth. In similar fashion to what occurs if you splash water in one direction in your bathtub, the sloshing causes rising and falling water levels on both sides of the lake. With each circuit, the seiche diminishes in height eventually damping out. Like the striking of a bell, it takes only one disturbance event to begin the wave action of a seiche. Once begun, a seiche can continue for days after the forces that created it cease.

Lake Erie is particularly prone to seiches because it is shallow and elongated in the direction of the prevailing winds. Seiches in Lake Erie are typically very small, about a foot, although large, noticeable differences in shoreline depths may occur under sustained wind conditions. While 2 to 6 foot displacements in water levels are not uncommon on an annual basis, seiches of up to 15 feet can occur during unusually large storms, and rare events have been recorded with seiches of higher than 20 feet. A seiche is not a tidal event. Tides are driven by gravitational forces, and in the Great Lakes, the largest true tide is not more than two inches.

Lake levels

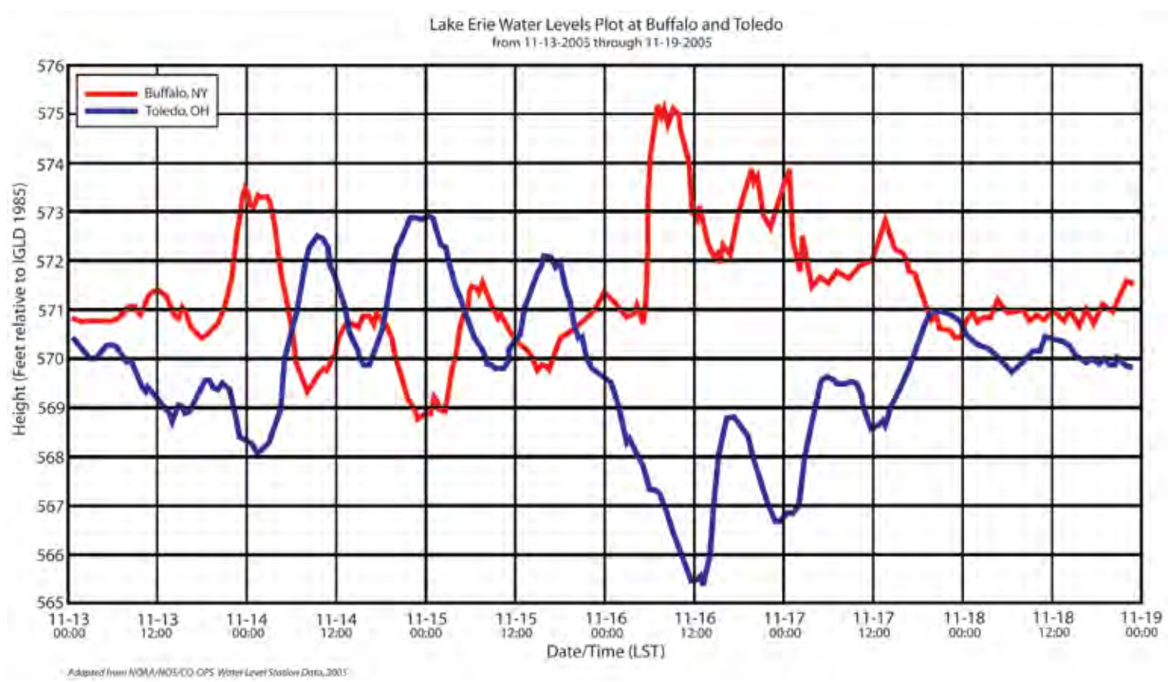
Water levels fluctuate, sometimes greatly, from year to year, season to season and over longer periods. During annual fluctuations, water levels are highest in the spring with the combination of snowmelt and spring rains, and lowest in the early winter due to evaporation. High water levels tend to be good for boaters, but may reduce the area of beach available to beachgoers and for plant growth. Low water levels can create problems for boaters, but may increase the amount of beach and shoreline habitats. Changes in water levels can also cause changes in erosion patterns, which may be particularly troublesome at times of high water levels when wave action can reach farther inland and higher on bluff faces.

Lake Erie water levels have been recorded since the 1860s. The annual average water level of Lake Erie over the period of record is about 571.3 feet IGLD85. The highest monthly average water level for Lake Erie occurred in June 1986 and was 574.28 feet IGLD85. The lowest recorded monthly average water level for Lake Erie of 568.18 feet IGLD85, occurred in February 1936 during the dustbowl of the Great Depression. Two commonly referenced water levels on Lake Erie are the Ordinary High Water Mark of 573.4 feet IGLD85 and Chart Datum (or Low Water Datum) of 569.2 feet IGLD85.



Typical temperature - Depth relationship in the Lake Erie Central Basin in July

High water and low water seiche effects at the Columbus Street boat slip in Sandusky



Glacial grooves at Kelleys Island, Erie County

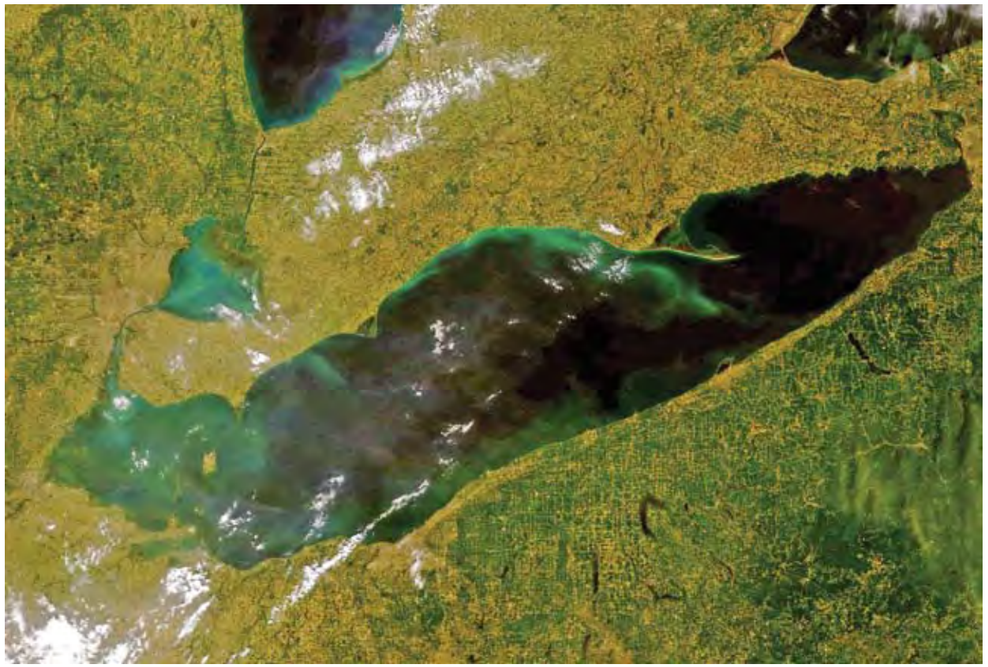
Chemical Characteristics

Water sampling at Stone Lab, Gibraltar Island, Ottawa County

Water sampling Photo by Fred Snyder

Chemical analysis, Stone Lab
Photo by Ohio Sea Grant

Algae identification in the lab
Photo by Fred Snyder



Satellite imagery of Lake Erie. Concentrations of green indicate algal bloom sites. Imagery source – NOAA/University of Wisconsin-Madison, 2005

Dissolved Oxygen (DO)

The amount of dissolved oxygen present in lake water is important for and affected primarily by biological activity. In the spring and summer, when photosynthesis is occurring at its highest rate, dissolved oxygen in the warm, well-lit parts of the lake is present at relatively high levels. In deeper waters where there is less light, dissolved oxygen is used by biological organisms as they undergo metabolic processes. Scientists call this "biological oxygen demand" or BOD. In deeper areas, biological oxygen demand may cause dissolved oxygen levels to drop.

Nutrient Cycling

Algae and aquatic plants are like terrestrial plants in that they need nutrients in order to grow and photosynthesize. On land, farmers grow more crops and people grow lusher lawns by adding nutrients to the soil as fertilizers. These same nutrients, particularly nitrogen and phosphorus, are used by plants in lake waters. When lots of nutrients are present, large numbers of plants can grow in the lake. When there are fewer nutrients present, algae and plant growth are said to be limited.

Cold, deep blue lakes such as Lake Superior and some mountain lakes are very low in nutrients and have very low numbers of algae and plants, which accounts for the greater water clarity. Among the Great Lakes, Erie has relatively high nutrient levels. As a result, algae become very abundant in the upper parts of the lake where there is sufficient light. Algae's presence causes the lake water to look somewhat green and cloudy.

As algae and plants die, they sink to the bottom of the lake. If there is sufficient oxygen at the bottom and the lake waters are well mixed, the algae and plants rot and release the nutrients they have stored in their bodies back into the lake waters. These nutrients are available for a new generation of algae and plants to use. If the lake is deep and dark, and the waters are not well mixed, there might be a lack of oxygen at the bottom of the lake. When this happens, nutrients become trapped in lake sediments and high concentrations accumulate in the bottom waters of the lake. These nutrients are unavailable to grow more algae and plants until the lake waters mix again.

Point and non-point source pollution

Nutrient Enrichment

There are several reasons for the higher nutrient levels in Lake Erie. One reason is the lake is relatively shallow and well-mixed, especially in the Western Basin. This keeps nutrients circulating in the water, making them more available for plants to use. Fertilizer runoff from agricultural and residential lands near Lake Erie is another reason Lake Erie has high nutrient levels.

Bacterial Contamination

Escherichia coli (E. coli for short) is a common bacterium that lives in human and animal intestines, where it is present in large numbers. There are hundreds of E. coli strains and most are relatively harmless, causing illnesses such as traveler's diarrhea only when consumed in exceedingly high numbers. The Ohio Department of Health monitors Lake Erie beaches during the swimming season, using E. coli as the indicator species for contamination. If beach water quality fails to meet the standards set for E. coli, the Ohio Department of Health recommends the beach be posted to advise against swimming. Higher bacteria counts are associated with rainfall events (non-point source run-off), high winds that stir up lake sediments and long calm periods with high temperatures. Contamination occurrences can be reduced by eliminating combined sewer overflows, adjusting sewage treatment methods, and providing better supervision of agricultural run-off.

Algae sampling in the Lake Erie islands region Photo by Fred Snyder

Sediment sampling Photo by Fred Snyder

Biological Characteristics

Trophic Levels

"Trophic" means nutrition or growth. Thus, the trophic level of a lake means the amount of biological activity it can support. Depending on water chemistry, particularly nutrient levels, lakes may have low productivity (low biological activity) or high productivity (high biological activity). There are three main factors that influence the trophic status of a lake: rate of nutrient supply, climate and basin morphology.

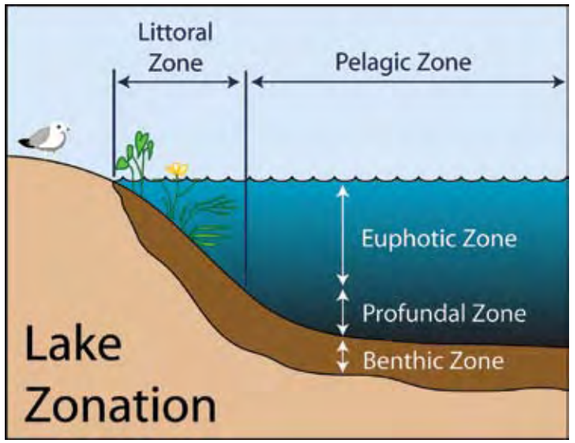
Lakes with higher nutrient supplies tend to be more productive, particularly if they are also located in lower latitudes where there is more sunlight and it is warmer for long periods of the year. Shallow lakes tend to keep nutrients in circulation, and therefore also tend to be more productive.

Oligotrophic lakes are the least productive. They have low nutrient levels, low numbers of plants and algae, and low levels of photosynthesis.

Mesotrophic lakes have moderate productivity, somewhere in between oligotrophic and eutrophic lakes.

Eutrophic lakes are the most productive. They have high nutrient levels, usually large amounts of algae and other plants, and high rates of photosynthesis. Lake Erie is considered to be eutrophic, although all of the other Great Lakes are mesotrophic or oligotrophic.

leopard frog



LAKE ZONATION

Lakes typically have different zones of biological communities, related to the physical properties of the lake.

Euphotic Zone: The vertical zone in the upper part of the lake where light is able to penetrate. In an oligotrophic lake, the euphotic zone may extend down 65 feet or more. In Lake Erie's Western and Central basins, the euphotic zone is usually less than 10 feet deep.

Profundal Zone: The vertical zone in the deeper part of the lake where light does not penetrate and the waters are dark.

Benthic Zone: Lake sediments from their surface to the deepest point of biological activity. Organisms normally found in the benthic zone include invertebrates such as insect larvae, worms and crustaceans.

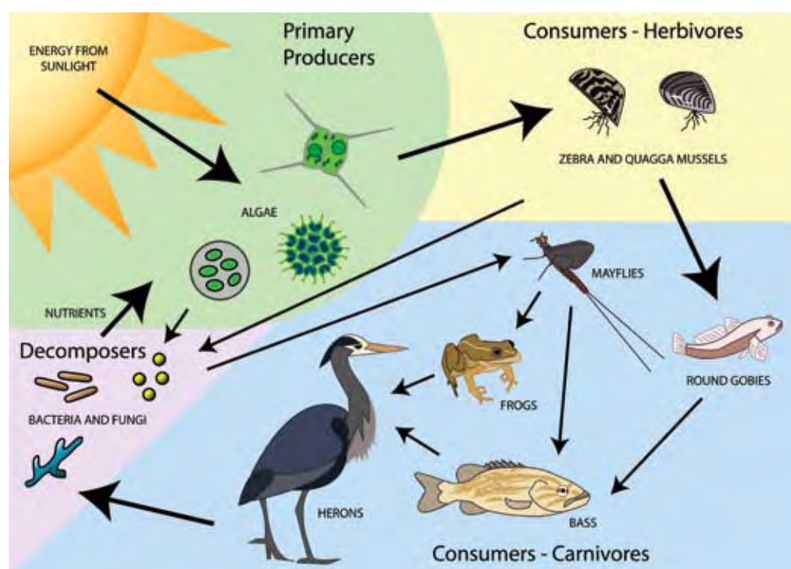
Littoral Zone: The area of the lake where the sunlight penetrates all the way to the sediments, making it possible for rooted aquatic plants to grow. This zone is at the intersection of the euphotic zone with the area of shallow water, and is usually found around the edge of the lake.

Pelagic Zone: The central open water area in the lake where light penetrates the upper waters, but does not penetrate all the way to the sediments. Plants are not able to grow rooted in the sediments, but there may be algae in the upper waters. This zone includes both the euphotic zone and the profundal zone down to the surface of the sediments.

AQUATIC FOOD WEBS

A food web shows what each group of fish, animals and organisms eats. The complexity of food webs may help to ensure survival in nature. If one organism in a chain becomes scarce, another may be able to fill its role. Food webs also show how energy is passed from one group to another. The food web begins with the introduction of energy from sunlight.

Primary Producers: Plants are called primary producers because they make their own food by converting sunlight, nutrients and water into carbohydrates that can be used as food by the plant or other organisms. In Lake Erie, most primary producers are microscopic floating plants. An example is green algae. There are many different kinds of green algae. There are also other kinds of algae, like blue-green algae, that are not as edible for other organisms in the food web.



Aquatic food web

Consumers (Herbivores and Carnivores): The next level in the food web consists of herbivorous consumers, or organisms that eat food produced by plants. Examples of primary consumers include zooplankton. Carnivorous consumers make up the next level of the food web. Examples of carnivores include gizzard shad, juvenile fish and frogs. Top predators are carnivores at the end of the aquatic food web and include fish such as walleye and bass and birds such as herons. Humans are also at the end of the food web.

Decomposers: When organisms in the food web die, many of them fall to the bottom of the lake. Organisms such as bacteria and fungi live in the lake bottom and convert the dead organisms back into nutrients that can be used again by primary producers.

Changes in a Food Web: Because a food web is a series of connections, it is sensitive to change. Changes at one point in the food web will almost always result in changes somewhere else. An example of this might be the introduction of a new herbivore such as the zebra and quagga mussels. When these mussels were introduced, other herbivores had less food and their numbers decreased. This reduced the food available for carnivores that fed on the "other" herbivores, and ultimately for the top predators. Thus, while the numbers of mussels may increase, there will be fewer of the "other" organisms in the food web.

Littoral zone fish sampling
Photo by Fred Snyder

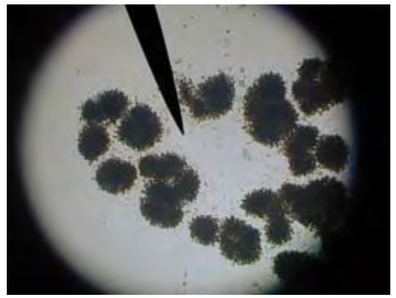
Littoral macroinvertabrate sampling
Photo by Ohio Sea Grant

Lake Erie water snake Photo by Ohio Sea Grant

Hungry heron

Lake Erie Oxygen Depletion

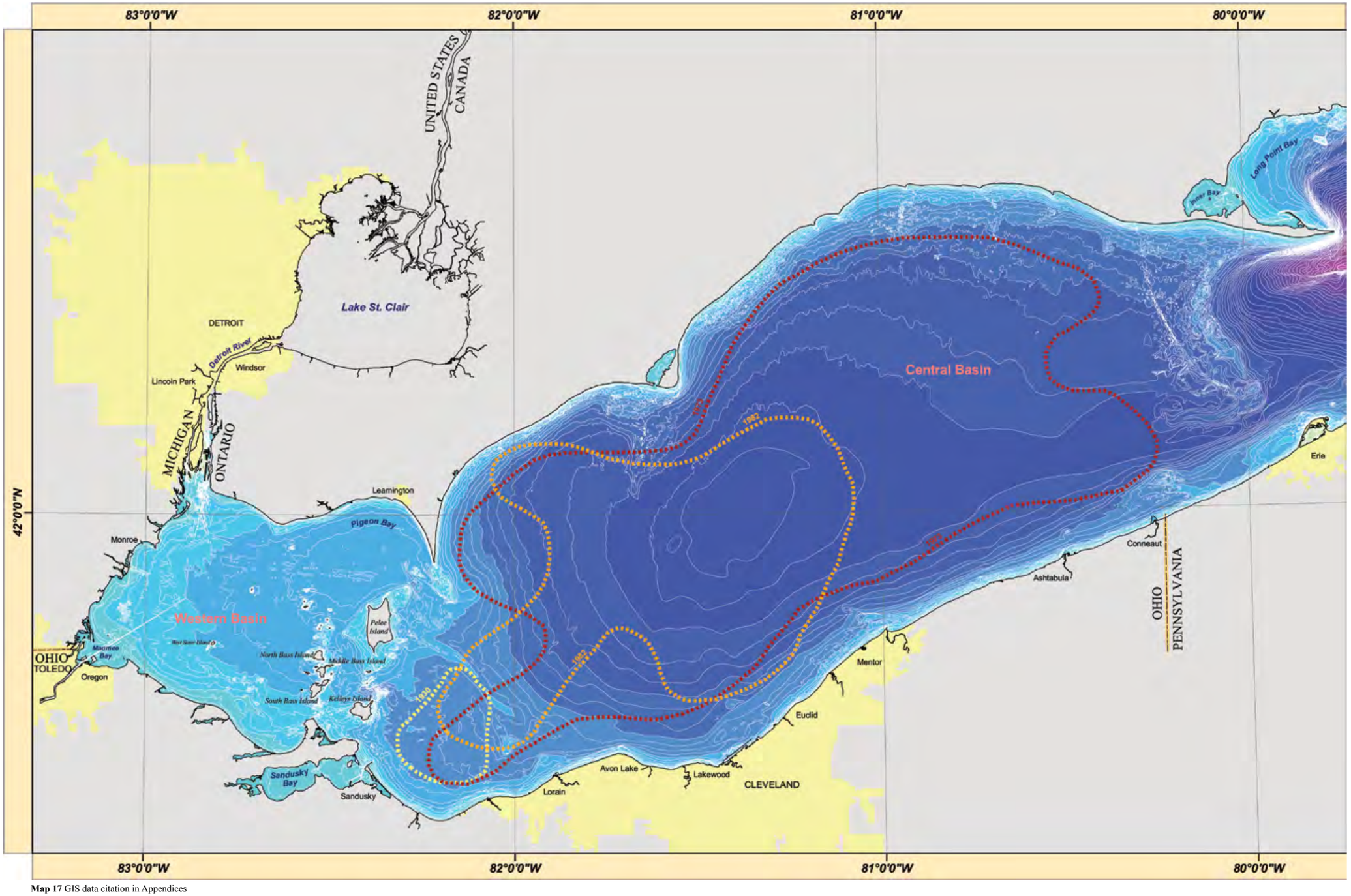
Smallmouth Bass



Microcystis Photo by Fred Snyder

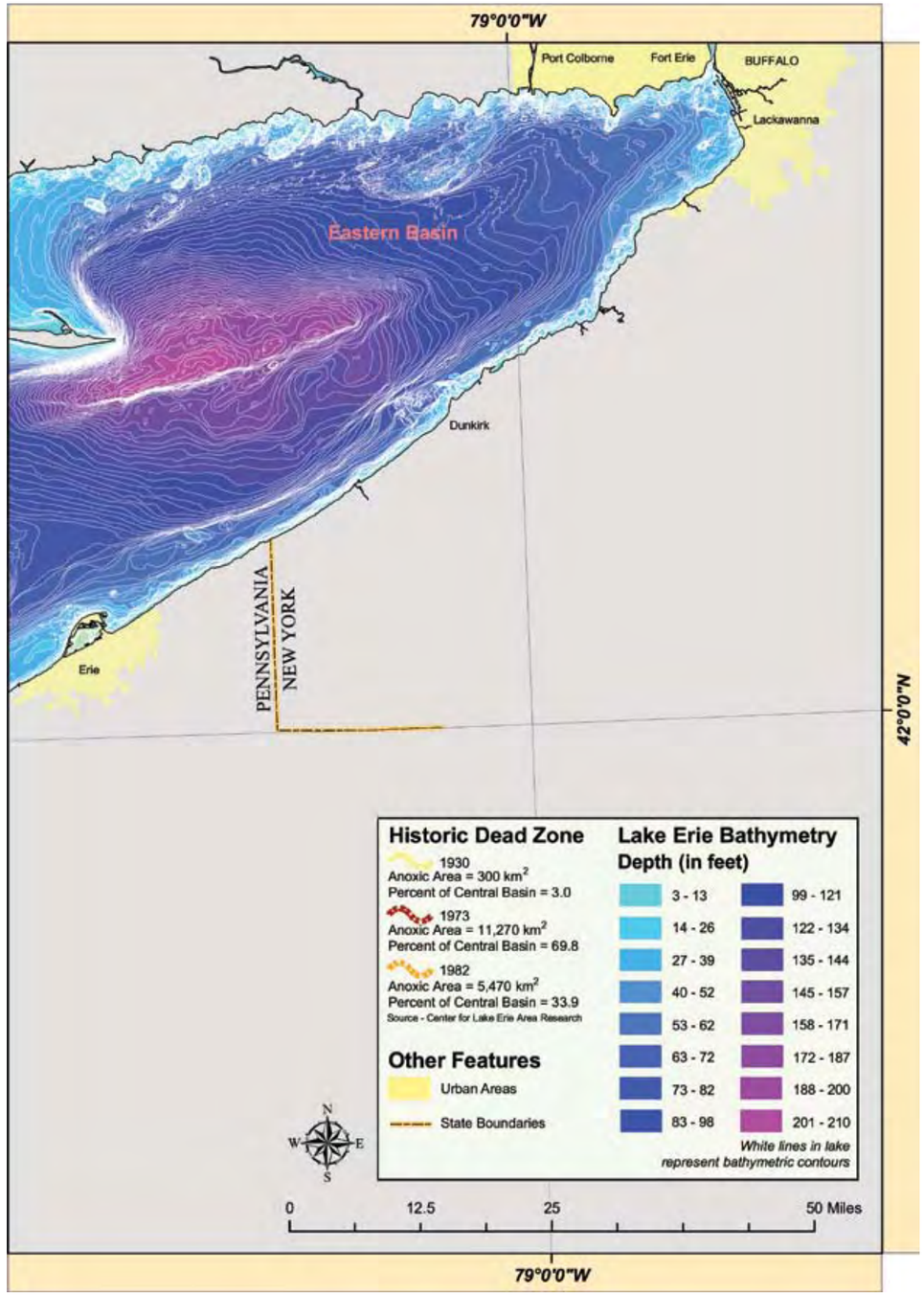
Midge larvae

Yellow perch



Map 17 GIS data citation in Appendices

Lake Erie Oxygen Depletion



Map 17 GIS data citation in Appendices

Lake Erie Oxygen Depletion (Central Basin "Dead Zone")

The bottom waters in the Central Basin of Lake Erie are prone to becoming anoxic (without oxygen) in late summer. This layer of cold water at the bottom of the Central Basin that has little or no dissolved oxygen in it is commonly referred to as the "Dead Zone." The configuration of Erie's Central Basin is partly responsible for the problem, but too many nutrients (especially phosphorus) from human activities are also a major factor.

Layers of Water

As water warms in the Central Basin, located from about Huron, Ohio to Erie, Pa., it forms three specific layers. The warm surface and upper layer (epilimnion) is where warm water mixes with oxygen from the air, and supports plenty of plant and animal life. The second layer (thermocline) is a small, relatively thin layer of water where rapid temperature change and loss of some oxygen occurs. The bottom layer (hypolimnion) is cold, has low to moderate oxygen, no sunlight or algae activity, and decomposition by bacteria occurs here. The separation of water into these three layers can come about in most offshore waters deeper than 49 to 60 feet, to the bottom of the lake. Hot weather, precipitation and wave action all dictate the onset and length of oxygen depletion. The severity of oxygen depletion varies from year-to-year, depending on water temperature and the thickness of the bottom layer.

The separation of water into distinctive layers takes place every summer from mid- to late-July through early September. In the fall, this zone breaks down when lake waters mix and all become one temperature in an event called a "turnover."

Why Oxygen Depletion Occurs

The "Dead Zone" occurs because bacteria in the hypolimnion use oxygen as they decompose dead algae and other materials that have sunk to the bottom. As bacteria consume oxygen, no new oxygen is created to replace it because the temperature and water density gradient do not allow for plant growth. Growth of plants releases oxygen into the water. The Central Basin is unique in that the cold hypolimnion layer at the bottom is relatively small and all or nearly all of the oxygen may be used up seasonally by bacteria in the decomposition process.

Lake Erie's Western Basin is too shallow for a cold water layer to form. Therefore plants and algae can live throughout the water column and decomposition continues at the lake bottom throughout the summer without consuming all the oxygen. The Eastern Basin of the lake is much deeper, so bacteria have a greater volume of cold, well-oxygenated water to use in the short time period when conditions are right for an anoxic layer of water to occur.

The shape of the Central Basin and its many sources of nutrient inputs create an environment in which an anoxic condition can occur, or has occurred, seasonally each year. In fact, research has shown that these periods of low oxygen in the Central Basin hypolimnion have been recorded for centuries. This condition is made worse by heavy nutrient inputs such as phosphorous and nitrogen, via rivers and other man-made sources. These nutrients give rise to large blooms of both green (good) algae and blue-green (toxic) algae. Water quality agreements made in the 1970s helped reduce nutrient inputs into the lake, but increasing development pressures have added to problems with combined-sewer overflows and non-point source pollution from agriculture and development. These human-induced effects have made the problem of low oxygen levels in the Central Basin worse during late summer.

Enhancing the problem

Exotic species like zebra and quagga mussels change the way nutrients are cycled and the timing of nutrient availability. Zebra mussels, and particularly quagga mussels, filter out nutrients and green algae early in the year and release fecal pellets (nutrients) late into the summer. They also do not consume the blue green (toxic) algae. This process causes more demand for decomposition and also decreases the amount of green algae (phytoplankton) that would normally be available to zooplankton, which are in turn a good source of food for juvenile and other small fish. Concentrations of blue-green algae can lead to taste and odor problems with drinking water from the lake. The loss of oxygen in the lower layer of the lake will force aquatic life to move out of that area of water to places that will be less than ideal for them, but they will generally still survive. However, if strong winds blow the cold layer of water to shore, a rapid water temperature change and a rapid loss of dissolved oxygen can cause a large fish kill.

Correcting problems, finding solutions

Actions we can take as coastal residents and local decision makers to decrease the anoxic zone include supporting legislation that aims to stop the spread of exotic aquatic nuisance species, supporting funding for improved treatment facilities that reduce combined-sewer overflow input, acting responsibly by not spreading exotic species, utilizing smart land use practices that protect or improve watersheds and wetlands, minimizing shore and streamside development, and reducing nutrient inputs and runoff. These practices include protecting vegetation along streams, streamside setbacks of at least 50 feet, reducing and improving timing of fertilizer applications, reducing harbor and nearshore hard structures like seawalls and jetties, maintaining thickly vegetated buffer strips and retention basins adjacent to developed areas, not overly clear-cutting areas for development and monoculture planting and recycling.

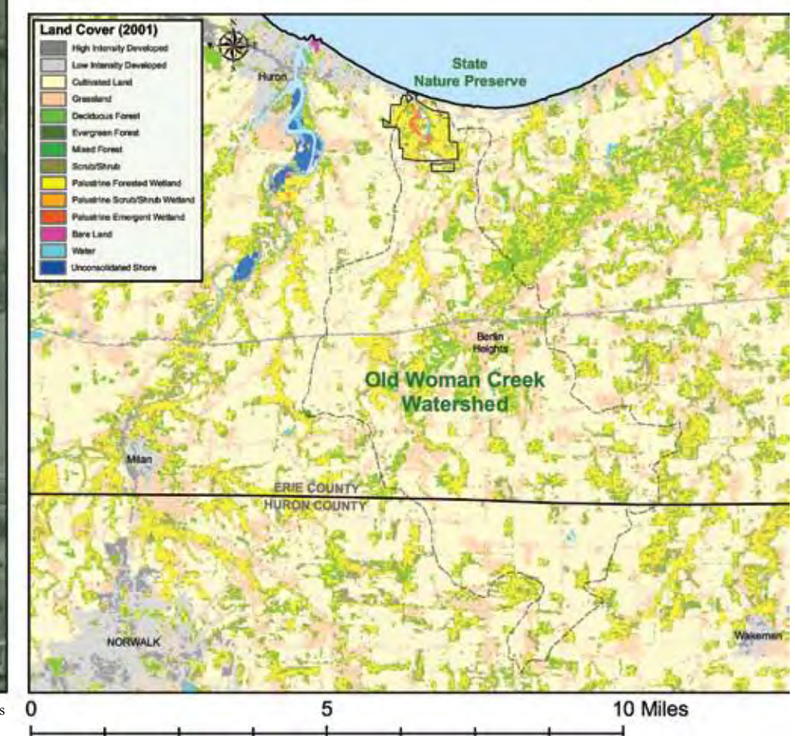
Mouth of estuary

View of Old Woman Creek estuary

Old Woman Creek estuary

Old Woman Creek Visitor and Research Center

FOCUS AREA



Map 18 GIS data citation in Appendices

Old Woman Creek

Old Woman Creek

Every river or creek in northern Ohio that flows directly into Lake Erie has an area near its mouth where lake water and stream water meet and mix. This mixing area is called an estuary. Freshwater estuarine areas are critical to the health of Lake Erie, serving as the lake's last line of defense by filtering out sediment and pollutants. Estuaries protect wildlife, fish and migratory birds, and buffer land from storms and flooding.

Estimates indicate that more than 90 percent of Ohio's historical wetland acreage has been lost to other land uses. Virtually all the estuaries along the Ohio shore have been impacted by human development. By comparison, the Old Woman Creek estuary is relatively natural. A portion of this area and its surrounding uplands have been protected as a State Nature Preserve to ensure that it retains its natural character.

In a partnership between the Ohio Department of Natural Resources and the National Oceanic and Atmospheric Administration, Old Woman Creek has been designated as a National Estuarine Research Reserve (NERR).

The NERR System is a network of federal, state and community partnerships. The Reserve System promotes informed management of our nation's estuarine and coastal habitats through stewardship, public education and scientific understanding. Old Woman Creek is operated as a Research Reserve by the ODNR Division of Wildlife. The National Oceanic and Atmospheric Administration administers the Reserve System at the federal level and provides much of Old Woman Creek's operational funding.

Of the 26 Research Reserve sites around the country, Old Woman Creek is the only in the Great Lakes. This site is the best example of a natural estuary remaining along the Ohio's Lake Erie shore. During the past 25 years, Reserve staff have created a program that integrates long-term scientific research and monitoring, public outreach and education and coordination of coast-wide management initiatives.

Since establishment of the Old Woman Creek National Estuarine Research Reserve, Old Woman Creek has welcomed visitors from 50 states and 24 foreign countries, provided more than 2,300 programs, guided tours and estuarine ecology workshops for schools, universities and members of the public, and published 210 scientific papers on research conducted at Old Woman Creek by university affiliated scientists and Old Woman Creek research staff. Research at Old Woman Creek enhances our understanding of the role these critical areas play in the Ohio coastal area and within the Great Lakes at large.

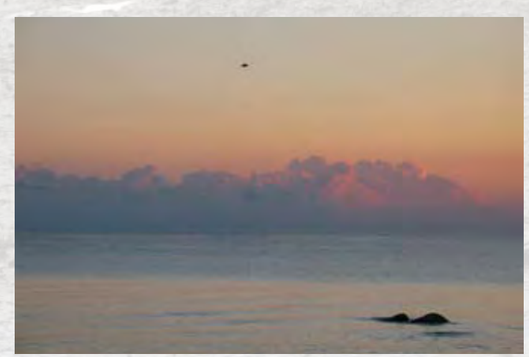
Old Woman Creek has a variety of habitats that the first Firelands settlers would have observed: wetlands and open water areas of the estuary, swamp forests, upland habitats, creek, barrier beach and nearshore Lake Erie.

The specific plant and animal habitats supported by estuaries like Old Woman Creek are determined by conditions in the estuarine drainage basin and in Lake Erie. The rate at which fresh water enters the estuary, the amount and type of waterborne and bottom sediments, the degree of lake water flushing, water depth (and hence temperature and degree of sunlight), all combine to produce habitat and food at interwoven small and large scales. Different combinations of these factors can produce several distinct habitats within a single estuary. A significant physical change, such as reduced Lake Erie water levels, can trigger dramatic changes in the estuarine biologic community, greatly enlarging or reducing various species' populations.

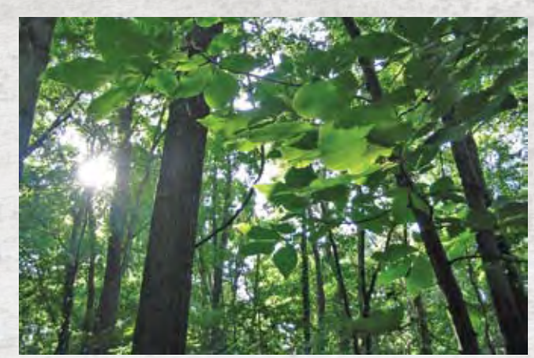
The Old Woman Creek estuary attracts many waterfowl and wading birds, including ducks, geese, herons, egrets, kingfishers and shorebirds. Several rare plants and animals, including the American bald eagle, thrive within the area. For some creatures, including waterfowl and several types of fish, reproduction and growth depend entirely on the availability of functioning estuarine wetlands. Meanwhile, other species spend their entire life cycle in estuaries like Old Woman Creek.

Within the open water areas of the wetland, Old Woman Creek is rich in floating plankton. These tiny plants and animals provide food for large populations of immature and adult fish and other species. The nutrient rich waters support large stands of water lotus, cattails, sedges and grasses. The blades of submerged aquatic plants are homes for algae, snails and other food for larger animals. The vegetation provide habitat for fish, insects, reptiles and amphibians.

Located approximately three miles east of Huron on U.S. Route 6 in Erie County, the Old Woman Creek National Estuarine Research Reserve (NERR) offers a trail system and visitor center with exhibits pertaining to the ecology, natural and cultural history of Old Woman Creek. The preserve's offices are located in the Ohio Center for Coastal Wetlands Studies, which overlooks the eastern shore of the estuary. The center also provides laboratory facilities for ecological research and serves as a focal point for public visitation and educational programming. In an effort to demonstrate sustainable design products and practices, a recent remodeling of the Old Woman Creek NERR visitor center incorporates many recycled-content products and environmentally friendly building materials and construction techniques. Old Woman Creek NERR is a key partner in the effective administration of the Ohio Coastal Management Program.



View of Lake Erie from the mouth of the estuary



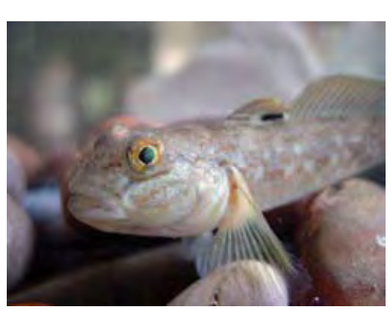
Wooded areas of Old Woman Creek State Nature Preserve

Invasive Species

Phragmites at Mentor Marsh State Nature Preserve, Lake County

Cluster of zebra mussels Photo by Fred Snyder

Purple loosestrife at Pickerel Creek Wildlife Area, Sandusky County



Round Goby Photo by Kristin Stanford

Invasive Species

Invasive species are aggressive non-native invaders that will eventually displace native plant communities. A wetland typically maintains a diverse, native plant community through its "seedbank." That is, seeds are stored in wetland sediments where they may remain for several years without germinating. As environmental conditions change, seeds germinate in response to favorable growing conditions. Invasive or exotic plants are able to out-compete and thus replace the native plant species growing from the seed bank. In time, the seed bank will be dominated by the seeds of these exotic plants.

Invasive plants threaten the integrity of many Lake Erie coastal wetlands, such as the Old Woman Creek estuary near Huron. Invasive or exotic plants can seriously impact the biodiversity and thus the ecological stability (the ability to recover from a disturbance) of coastal wetlands. When fewer plant species are present, there is less diversity in food sources and in cover for the animals living in the wetland. The economic cost as well as the environmental cost, both in direct damages and in restoration, can be extensive.

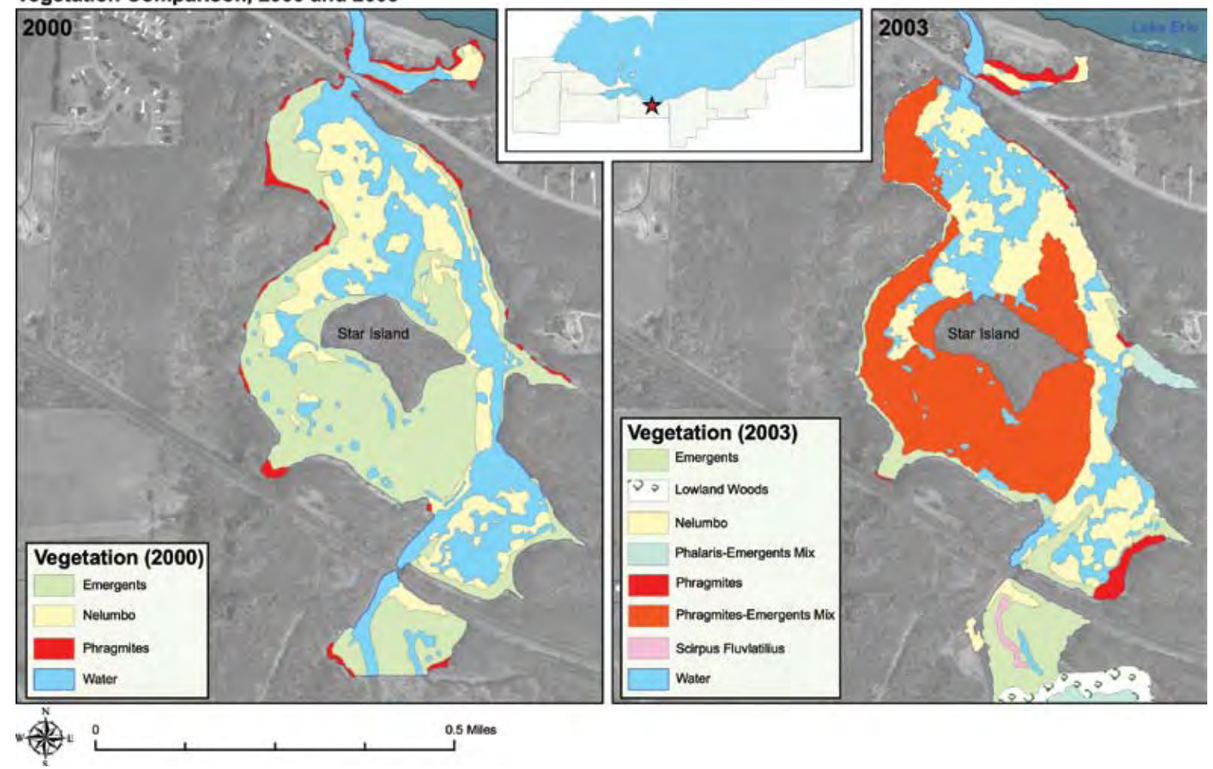
Fluctuations in Lake Erie water levels play an important role in determining the extent and composition of aquatic plants in coastal wetlands. The recent decline in Lake Erie water levels has facilitated the invasion of non-native plants, particularly *Phragmites australis* (Cav.) Trin. ex Steud. in Old Woman Creek.

Although *Phragmites australis* is considered an invasive species today by many natural resource managers, it is actually a native species that has been reported along Lake Erie's shore since the first Europeans set foot in the area. The native strain of this species is not invasive and did not significantly change its distribution from the late 1800s to the late 1900s (Stuckey, 1989). What we see today is an exotic strain of this species, which was accidentally introduced in the eastern part of the United States from Europe. This strain rapidly spread through much of the eastern United States and has become a nuisance species, particularly in wetlands.

With the decline in lake levels in 1999, the Old Woman Creek wetland has experienced a shift from an open-water system to a shallow-water predominately vegetated system. The decline in lake water levels and the resulting exposure of mudflats and nearshore areas in the estuary have provided a foothold for "opportunistic" species, such as *Phragmites.*

The spread of *Phragmites* has been monitored at Old Woman Creek for more than a decade. It was not reported in the Old Woman Creek estuary until the mid-1980s, when it was observed at the barrier beach that separates the estuary from the lake. This suggests that the plant was introduced into the estuary from Lake Erie. From 1993 through 1999, small dense stands were confined to several low relief shoreline floodplain areas (Whyte, 1996, per. comm.) With the advent of lower lake levels in 2000 and 2001, *Phragmites* expanded into the newly exposed mudflats in the wetland (Trexel-Kroll, 2002). By the end of the 2001 growing season, this species was present in scattered beds throughout the estuary. In five separately monitored *Phragmites* beds in the estuary, there was a four-fold increase in the size of the beds during this 2-year period. This expansion was believed to be caused by the rapid spread of rhizomes. A rhizome is an underground plant stem that generally lies horizontally and that is often enlarged in order to store food.

Old Woman Creek National Estuarine Research Reserve and State Nature Preserve Vegetation Comparison, 2000 and 2003



Map 19 GIS data citation in Appendices

Translocation of rhizome fragments was considered to be the cause for the growth of new, non-adjacent beds (Trexel-Kroll). Since 2000, *Phragmites* have continued to expand; by 2004 they accounted for more than three-quarters of the vegetation in the estuary (Whyte, 2005). A management program has been initiated to prevent further expansion of this plant and resulting loss of native species.

Two other exotic aquatic plants have been reported in the estuary since 1980. Purple loosestrife *(Lythrum salicaria L.)* has been found intermittently since the mid-1980s. Since the invasive nature of this plant was recognized when it was first sighted, appropriate management procedures were implemented to prevent its establishment. Eurasian water-milfoil *(Myriophyllum spicatum L.)* was first reported in the estuary in 1992 and intermittently since then. So far, it has not established a reproducing population.

Mapping and Monitoring

At Old Woman Creek, the mapping of aquatic vegetation, including invasive, has been an integral part of the ecological monitoring program for the past ten years. The strategy of the monitoring program at Old Woman Creek, which began in 1980, is based on the premise that physical, chemical and biological aspects of habitats and communities are excellent indicators of the effects of a vast array of environmental factors. Chronic environmental disturbances can be detected through changes in these monitored indicators.

The on-going chemical monitoring program has provided basic chronological information about water quality in the estuary. In 1995, this water monitoring program was expanded to incorporate the system-wide program of the National Estuarine Research Reserve (NERR) system. The System-Wide program has developed a data network among the 26 Research Reserve sites so that national and regional variability and

Invasive Species

trends in estuarine water quality can be detected and monitored. The availability of this monitoring data along with the results of future monitoring efforts will facilitate the management of Old Woman Creek by providing early warning of changes in estuarine resources.

Sources:

Stuckey, R.L. 1989. Western Lake Erie aquatic and wetland vascular-plant flora: its origin and change. In: K.A. Krieger (ed.), Lake Erie Estuarine Systems: Issues, Resource, Status, and Management. NOAA Estuary-of-the-Month Seminar Series No. 14, NOAA Estuarine Programs Office, Washington, DC. p.205-256.

Trexel-Kroll, D. 2002. Succession of Floating-Leaf to Emergent Plant Communities following Reduced Water Levels in Old Woman Creek Estuary. M.Sc. Thesis, Miami University, Oxford, OH. 56pp.

Whyte, R.S. 1996. The Vegetation Dynamics of a Freshwater Estuary on Lake Erie: The Old Woman Creek State Nature Preserve and National Estuarine Research Reserve, Huron, Ohio. Ph.D. Dissertation, Miami University, Oxford, OH. 372pp.

Whyte, R.S. 2005. A Floristic Survey of the Estuary. Final report of SWMP Biomonitoring Grant to Old Woman Creek NERR. 18pp + figures.

Zebra Mussels *(Dreissena polymorpha)* Quagga mussels *(Dreissena Bugensis)*

Zebra mussels and quagga mussels are small, fingernail-sized mussels native to Asia's Caspian Sea region. Zebra mussels were discovered in Lake St. Clair near Detroit in 1988. Tolerant of a wide range of environmental conditions, zebra mussels spread to parts of all of the Great Lakes and the Mississippi River and are now showing up in inland lakes. In 1991, another mussel species, quagga mussels, was identified in North America. These species are now found in the St. Lawrence Seaway, lakes Ontario, Erie and Huron, and in Saginaw Bay.

One female zebra mussel can produce as many as 1 million eggs per year. These develop into microscopic, free-living larvae called veligers that begin to form shells. At about three weeks, the sand-grain sized larvae start to settle and attach to any firm surface using "byssal threads." They will cover rock, metal, rubber, wood, docks, boat hulls, native mussels and even aquatic plants, colonize on docks, native mollusks, nets, water intake pipes and valves and clog water systems of power plants, water treatment facilities and irrigation systems. The invasive mussels have also severely reduced and eliminated native mussel species.

Zebra mussels can have great impacts on our economy, and ecosystem. Most significantly, zebra and quagga mussels filter plankton from the surrounding water. Each mussel can filter about one quart of lake water per day, consuming large portions of the microscopic plants and animals which form the base of the food chain. However, not all of what they remove is eaten. What they don't eat is combined with mucus as "pseudofeces" and discharged onto the lake bottom where it accumulates. This material may benefit bottom feeders but reduces the plankton in the food chain for upper water species. Over time, this feeding behavior can affect the lake's entire ecological balance, causing significant shifts in native species populations. Diving ducks, the freshwater drum, and other fish including the invasive round goby, are known to eat zebra and quagga mussels.

Dealing with zebra and quagga mussels

Zebra and quagga mussels frequently attach themselves to boat hulls. To rid boats of mussels, thoroughly clean and scrape the boat's hull or leave the boat out of water for 10 days or more as zebra mussels cannot live long without water. All of the live wells and bilge areas should also be drained and dried. Chlorine bleach added at the rate of one part bleach to 10 parts water is recommended for areas where trapped water remains. A chlorine/water mixture at this recommended dilution will not affect the aquatic environment.

Sources:

Ohio Sea Grant College Program and Purdue University

Round Goby *(Neogobius melanstomus)*

The round goby is a small, bottom-dwelling fish that was first found in the Great Lakes Region in 1990. Originally from the Black and Caspian sea areas of Eastern Europe, it is believed that this exotic species arrived in the ballast water of vessels coming into the Great Lakes. Since their first sighting in the St. Clair River, round gobies have spread to all the Great Lakes, including Lake Erie where they were first found in 1993. Since then, populations of these invasive fish in Erie's Western Basin have grown to an estimated 10 billion in 2002.

The aggressive nature of round gobies and their ability to become abundant quickly may allow them to outcompete some of our native species for food resources and spawning habitat. Round gobies can eat zebra mussels, fish eggs, plankton, fish and benthic invertebrates. Because zebra mussels are filter feeders that accumulate contaminants in their body tissues, round gobies that eat zebra mussels may be consuming a high level of contaminants. When a predatory fish such as a walleye eats a round goby that fed primarily on zebra mussels, the walleye may be getting a much larger load of contaminants than it would from eating other types of prey fish. This change in the food chain could put dangerous concentrations of contaminants into sport-fish at a much faster rate. Gobies have also become a nuisance to fisherman who have difficulty catching larger target sport fish in areas where goby are present

Sources:

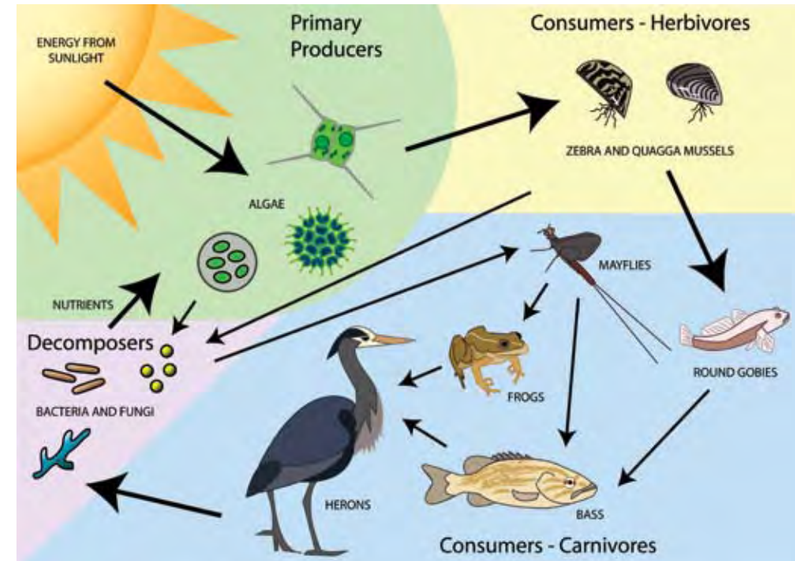
J.Great Lakes Res. 31(1):78-86.
USGS:GLSC Fact Sheet 2000-1

Spiny Water Flea *(Bythotrephes cederstroemi)*

It is difficult to precisely pin down how invasive species enter the Lake Erie ecosystem, but research has shown a link between ship traffic and the introduction of invasive animal and plant species through ballast water. The invasive spiny water flea, was first recorded in Lake Huron in 1984 and in lakes Erie and Ontario the following year. Within several years, it was identified in all the Great Lakes. After an initial large pulse of this invasive species during the late 1980s, its population has declined to very low numbers. The spiny water flea would now be considered only a minor component of the Lake Erie zooplankton. This is not surprising, as the spiny water flea is found most frequently in cold, deep, oligotrophic lakes in its European home range.

Sea Lampreys *(Petromyzon marinus)*

Sea lampreys are primitive jawless fish native to the Atlantic Ocean, but are now found in all five Great Lakes. As adults,



Aquatic food web influenced by invasive species

lampreys act as parasites and attach to fish with a sucking disk-like mouth and sharp teeth. This attachment enables the lampreys to feed on body fluids, often scarring or even killing the host fish. During its 12 to 20 month life, a single sea lamprey may kill 40 or more pounds of fish. In Lake Erie, a native lamprey (silver lamprey) also exists, but the exotic sea lamprey is much larger and more predaceous.

Sea lampreys were first discovered in Lake Erie in 1921, following the construction of the Welland Canal (see Chapter 13: Transportation). Although the invasive lampreys have had an immense impact on fisheries in the upper Great Lakes, they have never been very abundant in Lake Erie. In the spring, sexually mature sea lampreys swim up Central Basin tributaries, such as the Grand River and Conneaut Creek to deposit up to 60,000 eggs in saucer-like depressions in gravel riffles. The adults die after spawning; the eggs hatch into larvae which live 4 to 6 years as filter feeders in burrows constructed in the soft tributary's sediments. Larvae then transform into free-swimming juveniles and move downstream to Lake Erie, where they quickly attach to prey fish.

Proactive control measures reduce the number of lampreys that migrate to Lake Erie. Lampricides, chemicals lethal to lamprey, are used as the primary eradication method. In Ohio, sea lamprey population assessments are periodically conducted in various Lake Erie tributaries by ODNR Division of Wildlife fisheries biologists. Research results determine the need and frequency for applying lampricide in the streams.

Sources:

USGS and ODNR Division of Wildlife