The Jefferson Essays

The Lurking Threat

Harmful Algae Blooms Pose Local, Global Hazard

By
Judith Lynch, Ph.D.
Jefferson Educational Society Decadian Scholar

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BE AWARE

Foreward

Dear Reader:

In the following pages you will find the Jefferson Educational Society's new essay titled "The Lurking Threat: Harmful Algae Blooms Pose Local, Global Threat." This essay is the result of research, writing, and analysis by its author, Judith Lynch, Ph.D., the Jefferson's Decadian Scholar, as well as the guidance and support of several others, including the Jefferson Essays Editorial Board.

This latest essay, the Jefferson's seventh, explores a critical issue facing the Erie region: How to properly define the threat posed by Harmful Algae Blooms and other threats to Lake Erie's water quality. It looks at causes and possible solutions while trying to accurately depict the real threats to our environment and economy.

The Jefferson essays are published in hopes of sparking open, constructive dialogue in the spirit of community progress. We hope readers agree that our essays, written by local scholars under the review of an editorial board, should be read not as the last word on any topic, but as the starting point of an important conversation.

Finally, we hope you receive this essay with our compliments and acknowledgment that you have been identified as a person interested in civic issues discussed often at the Jefferson. If you are not already a Jefferson member, we hope you will consider joining. In addition to Jefferson member support, our essays are made possible by the JES and grant support to the Jefferson Alliance for Community Progress from the Erie County Gaming Revenue Authority's Multi-Municipal Collaborative Grant. If you wish to support our essay publication efforts with a membership or donation, please call 814.459.8000; visit www.JESErie.org; or write to the Jefferson Educational Society at 3207 State St., Erie, PA 16508.

We welcome your comments, criticism, suggestions, and support on our latest essay and look forward to seeing you at our Fall Term and Global Summit X events.

Yours in friendship,

F. Ferati

Ferki Ferati, Ed.D.,
Jefferson President

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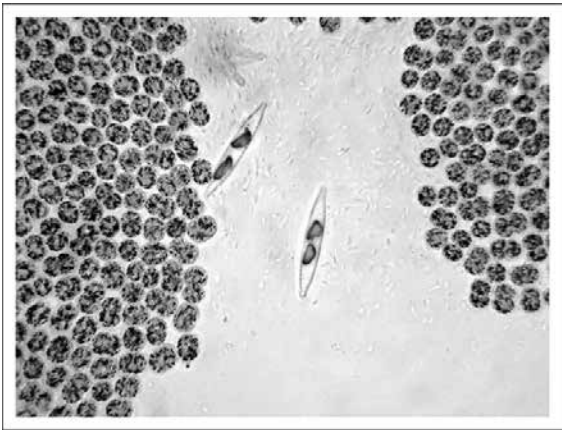
Introduction: Erie's Locational Advantage is Threatened

Erie's origins and rapid growth into a major urban center were not accidental. Situated on the southern shore of Lake Erie with one of the few natural harbors on the Great Lakes, almost equidistant from Cleveland and Buffalo and central to the largest American market, Erie had the potential to be prime real estate in every era. By the mid-19th century, Erie's location and natural harbor made it a commercial center for steamships that plied the waters picking up and delivering goods, some of which made their way south to Pittsburgh. After the Civil War, Erie's transportation network grew to include a railroad web that connected it to every market in the U.S. and Canada. Erie's location made it an alluring place for the site of major industries such as General Electric, which shipped its products worldwide.

Erie is still capitalizing on its location. Today it is the tourist industry that is embedded in Erie's location. Tourism generates about $1 billion a year to the Erie economy. Employment in tourism in the peak summer season is approximately 16,500, with year-round employment of 12,500 *(John Oliver, Visit Erie, 3/26/18)*. Central to Erie's tourist economy is Presque Isle State Park, which receives annually about 4 million visitors.

Erie's ideal locational advantage, however, is now threatened. Many are fearful that the growth of Harmful Algae Blooms (HABs) could make Presque Isle Bay and the waters off Presque Isle State Park unswimmable, its fish unsafe to eat, and attractions such as the U.S. Brig Niagara and Maritime Museum of little interest. Even nearby inland areas like Chautauqua Lake, N.Y., and Edinboro Lake are being adversely affected. Economically, HABs could bring an end to the tourism industry and the locational advantages that the proximity to Lake Erie has historically provided.



Microscopic image showing sheets of *Microsystis* spp. organisms plus two diatoms.
Source: Microscopic photo taken by E.H. Decker - X400 magnification

The Science of Harmful Algae Blooms

So what are Harmful Algae Blooms? They are really not algae. They are bacteria that come in many different forms. The most common type of bacteria producing HABs found in Erie County is called cyanobacteria, which produces toxins called cyanotoxins. The term "cyano" comes from the Greek name for blue, alluding to the blue-green color of the bacteria, often referred to as blue-green algae.

Cyanobacteria exist in every body of water on Earth. They are an ancient form of life that have existed for more than 3 billion years and are believed to be the first organisms to evolve photosynthesis. Their proliferation and release of oxygen are believed to have changed the chemical makeup of the Earth's atmosphere allowing life as we know it to develop *(Environmental Health Perspective,* 2/17, A35*)*.

MONITORING FOR HARMFUL ALGAE AND BACTERIA IN ERIE COUNTY

The **Regional Science Consortium (RSC)** at the Tom Ridge Environmental Center has analyzed water samples for cyanotoxins since 2014, even though testing for cyanotoxins or cyanobacteria is not mandated for recreational waters.

The RSC:

1. Tests for the cyanotoxin: microcystin
    a. Once per week from June through October, taking samples at more than 30 locations along the PA coast line of Lake Erie (Elk Creek to Freeport), Presque Isle swimming beaches, and the perimeter of Presque Isle Bay.
    b. During the 2017 season, the lab analyzed more than 2,370 samples.
    c. More than 420 exceeded some threshold of cyanotoxin, usually the threshold for dogs safely being able to recreate in the water, or the lowest concentration threshold.
    d. When a test exceeds the threshold, the proper signage is installed to inform the public.
2. Conducts research on HABs, including using flow cytometry for cell counts and ecological population dynamics

Research collaborators include: U.S. Geological Survey, Gannon University, Mercyhurst University, and Wilkes University

Source: Dr. Jeanette Schnars, Dir. Regional Science Consortium

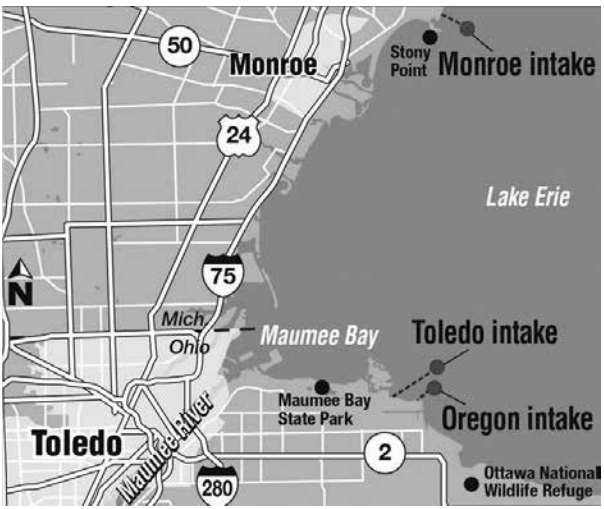
Mycrocystis, a cyanobacteria that can make up HABs, produces at least 80 different varieties of toxins that can cause serious illness or death in humans, pets, wildlife, and livestock. Microcystis clusters release different levels of toxicity depending on environmental conditions. Lower levels may cause only mild distress in humans but can produce more threatening symptoms in dogs, such as vomiting, drooling, diarrhea, muscle tremors, seizures, labored breathing, yellow gums, and difficulty in moving. Higher levels of toxin can cause paralysis and death in both humans and animals.

Cladophora (muck) bloom Anna McCartney

The most recent highly publicized incidence of mycrocystis occurred in August 2014 when HABs shut down the public water system of Toledo, Ohio. Nearly 500,000 residents were without drinkable water for three days when HABs flowed from Maumee Bay along the Ohio shoreline and over the water intake for the city of Toledo, making the drinking water too toxic to ingest.

Toxins not only result from cyanobacteria, but also from myriad other micro aquatic organisms. HABs include red tides that occur in Florida off the Gulf of Mexico and other bodies of water throughout the world. Red Tide is caused by Karenia brevis, a HAB that originates from a dinoflagellate, a one-cell marine organism that produces brevetoxin, the neurotoxin responsible for neurotoxic shellfish poisoning. Other HABs originate from Pseudo-nitzschia, a diatom or microalgae known to produce domoic acid, the neurotoxin also responsible for shellfish poisoning. HABs that produce the toxin microcystin are found in the Great Lakes and inland waters throughout the 50 states and world-wide in fresh, brackish, and salt water.

Cladophora, classified as a nuisance algae bloom and not a HAB, is a green algae that grows into thick mats that quickly become decaying matter. Although this form of algae does not produce toxins, it does result in "muck" zones that harbor bacteria that can close beaches and interfere with the fishing industry. When the mats wash ashore and decay, the odor can be obnoxious and the rotting material can reduce shoreline property values. Cladophora blooms are world-wide. While some of the most disturbing pictures have come from China, the Cladophora blooms have become prolific events along the Pennsylvania shores of Lake Erie and its inland lakes.



The HAB threat to public and animal health has been duly noted by public bodies and officials. In 1998, Congress, with the backing of the Clinton Administration, passed the Harmful Algal Bloom and Hypoxia Research and Control Act. In 2013, under the Obama Administration, the Act was reauthorized with nearly unanimous consent in the House and unanimous consent in the Senate. The Act contained an annual appropriation of $20.5 million through 2018 for the National Oceanic and Atmospheric Administration (NOAA), which was charged with mitigating the harmful effects of algal blooms and hypoxia. This widespread political support came as a result of a report by NOAA and U.S. Sen. Rob Portman of Ohio indicating that the American seafood and tourism industries suffer annual losses of $1 billion due to economic impacts of HABs *(https://lakeimprovement.com/senator-portman)*.

In November 2017, Ohio Congresswoman Marcy Kaptur, co-chairwoman of the House Great Lakes Task Force; Ohio Congressman David Joyce; and a bipartisan group of 53 lawmakers sent a letter to Office of Management and Budget Director Mick Mulvaney urging robust funding in President Trump's fiscal year 2019 budget for programs that address HABs. "We write to respectfully request that you allocate robust funding in the President's Fiscal Year 2019 budget request for programs that address a widespread and ever-increasing problem affecting every state and territory in the nation: toxic algae blooms, also called harmful algal blooms (HABs)," it read.

"Toxic blooms (threaten) human health and cause several billion dollars in economic losses each year. While we have made significant advances in our understanding of where, when and why blooms occur, we must improve our ability to mitigate their impacts on our communities. We strongly support investment in science, research, and management to increase our capacity to forecast, detect, and prevent HABs, as well as to lessen their impacts on human health and economies across the country.

"To make the necessary progress toward understanding and addressing the significant and expanding threats that toxic algae pose to human health and our national economy, we ask that you prioritize a strong and coordinated federal response in this year's budget request with robust funding allocated for HAB-related work."

Despite persistent lobbying and the creation of Great Lakes Day, President Trump remained opposed to full funding. On March 9, 2018, more than 100 advocates for the Great Lakes were in Washington, D.C., lobbying Congress to continue its bipartisan support on issues affecting the health of the Great Lakes. They were asking that the Great Lakes Restoration Initiative receive full funding – $300 million a year. Trump's budget proposal cut that number to $30 million. However, when the budget was passed, the full amount for the Great Lakes was restored. The restoration came as groups representing Great Lakes businesses, industry, environmentalists, cities, states, and Native American tribes lobbied Congress for support.

Recent examples of HABs in United States and Elsewhere

The states in which HABs have become a concern contribute additional state funds to address the problem. In the first years of the 21st century, many states became increasingly alarmed at the annual virulent outbreaks of HABs.

Utah Lake Algea Bloom | CTSY: Utah Dept. of Environmental Quality

In November 2015, the California Department of Public Health, after an outbreak of algae blooms along the Pacific Coast, advised residents to avoid consumption of certain species of crabs because of potential toxicity. Washington state shut down fisheries that sold Razor clams, one of the most sought-after shellfish in the state. The fisheries remained closed throughout summer 2015 because of HABs. In this instance, the HAB was made up of pseudo-nitzschia algae, a form of microalgae, which produces the toxin domoic acid.

In July 2016, at the peak of the tourist season, Utah Public health officials closed Utah Lake because of a large HAB that posed serious health risks to the public and animals.

In fall 2017, the Utah Department of Environmental Quality posted warnings in both Jordanelle State Park and Rockport State Park after HABs were discovered in the water. Field tests conducted in both reservoirs indicated elevated levels of cyanotoxins high enough to threaten the health of animals and people.

The following warning was issued to visitors:

- Do not swim or water ski
- Do not drink the water
- Keep pets and livestock away
- Clean fish well and discard guts
- Avoid areas of scum when boating

In September 2017, the Maine Department of Marine Resources issued a recall of mussels harvested near Mount Desert Island. Thousands of pounds of Maine shellfish from five Maine shellfish dealers were recalled because of concerns they were tainted with a marine neurotoxin. This was the second recall on record and came after a similar algae bloom in 2016. The Maine Department of Marine Resources posted the following health warning:

> Those who eat tainted shellfish generally develop gastrointestinal symptoms within the first 24 hours, such as nausea, vomiting, abdominal cramping, and diarrhea. Some people develop permanent neurological symptoms, particularly dementia. Although rare, the neurotoxin can be fatal, especially among the elderly and children with illnesses such as diabetes, chronic renal disease, and hypertension.

The Mount Desert Island recall of mussels came a day after the department's public health agency closed part of the Down East coast to shellfish harvesting after detecting elevated levels of domoic acid. Shellfish, such as mussels, clams, and oysters, eat phytoplankton and store toxins in their flesh.

While pseudo-nitzschia is common in the Gulf of Maine, the first recorded toxic bloom occurred in fall 2017 and caught state officials and the shellfish industry by surprise, even though a similar recall had occurred in Maine a year before when five tons of shellfish were recalled. Some product got as far as Missouri and Utah before it was returned. Approximately 96 percent of the product was recalled, but about 430 pounds were unaccounted for.

Worldwide Impact

HABs are not just a United States problem. They occur worldwide and are universally recognized as a grave threat. The International Conference on Harmful Algae (ICHA) was formed in 2000 by the French Research Institute for Exploitation of the Sea (IFREMER) and meets annually.

Forthcoming Events

First announcement of the 11th International Conference on Toxic Cyanobacteria (ICTC)

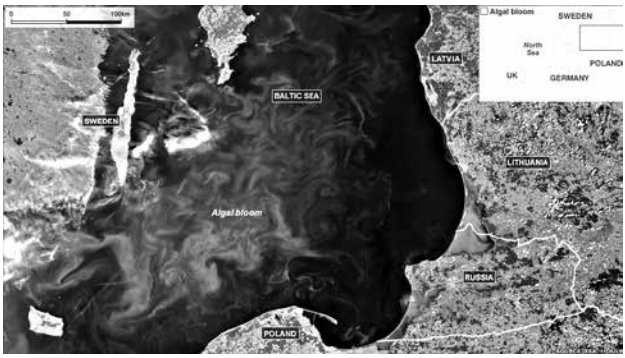
We are pleased to disseminate the first announcement of the *11th International Conference on Toxic Cyanobacteria* (ICTC) that will be held in Krakow, Poland from May 5 – 10, 2019. The ICTC is a periodic scientific meeting that includes members of the international community and focuses on the science and study of cyanotoxins and toxic cyanobacteria. The theme of the ICTC 11 is: "*Learning from the past to predict the future*". Please mark your calendars and make plans to join us in Krakow during May, 2019! Conference website: *http://ictc11.org/*

It deals with all types of HABs and gathers scientific experts and concerned persons to evaluate the latest scientific research and developments concerning HABs. The 2016 ICHA conference was held in Brazil, the 2017 in France, and the 20th annual conference in October 2018 also will be held in France.

Another international body, the International Conference on Toxic Cyanobacteria Harmful Algae Blooms, focuses on cyanobacteria, the algae blooms that produce microcystin. In May 2019, its 11th annual conference will be held in Krakow, Poland. The ICTC was created to respond to worldwide outbreaks of microcytis in the early 21st century, some of which are still evident off the coast of Poland in the Baltic Sea.

Any body of water, whether fresh, brackish or salt, is subject to HAB growth. The only bodies of water not receptive to Harmful Algae Blooms are fast flowing streams and rivers. Inland lakes such as Chautauqua Lake in New York and Lake Baikal in Russia, the largest lake in the world, have both had HABs. On July 17, 2017, the *Chautauqua Daily*, the Institution's newspaper, posted a photo with the following warning:

> Residents should avoid contact with any surface scums or heavily discolored water even if a harmful bloom hasn't been reported in the area. The blooms can cause symptoms such as rashes, abdominal cramps, diarrhea or liver problems depending on the severity of contact, said Jessica Wuerstle, public health sanitarian for the Chautauqua County Department of Health and Human Services (Meyer, *Chautauqua Daily*, 7/19/17).



Harmful Algae Blooms in the Baltic Sea

ALGAE ACROSS THE WORLD

Harmful algal blooms, known as HABs, are on the rise throughout the world. Shown below are some of the worst-hit lakes and reservoirs; not shown are how nearly all of the world's marine coastal areas are affected. Lake Taihu (No. 20) is water-stressed China's third-largest lake. The lake has 40 million people in its watershed, 10 million of whom depend on it for drinking water. In 2007, 2 million of them experienced an event similar to Toledo's 2014 water crisis: Winds drove a massive microcystis bloom deep under Lake Taihu near the city of Wuxi, smothering a water-treatment plant's intake with algae.

1. Klamath Lake
2. Great Salt Lake
3. Rocky Mtn. Lakes
4. Midwest Lakes*
5. Lake Erie
6. Lake Winnipeg and Lake 227**
7. Lake Okeechobee
8. Lake Atitlan
9. Lake Valencia
10. Orinoco Floodplain Lakes
11. Lake Titicaca
12. Coastal Lagoons (Brazil)
13. Lake District (U.K.)
14. Lake Erken
15. Lakes (N. Germany)
16. Lake Balaton
17. Lake Peipsi
18. Lake Victoria
19. Lake Dianchi
20. Lake Taihu
21. Murray-Darling System
22. Lake Taupo/Lake Okaro

*Minnesota, Wisconsin, Michigan, Ohio, North Dakota, and Iowa
**Part of the Experimental Lakes Area in Ontario, a collection of 58 lakes north of Minnesota

SOURCE: Hans Paerl, University of North Carolina-Chapel Hill, and other scientists. THE BLADE

The *Chautauqua Daily* went on to provide assurance from Doug Conroe, executive director of the Chautauqua Lake Association, to those who live and visit Chautauqua Institution:

> Chautauquans should be less concerned about encountering algae on Chautauqua Institution's shoreline than elsewhere on the lake, Conroe said. The CLA performs extra maintenance near the Institution ... which reduces the occurrence of blooms because it keeps water flowing instead of stagnating (Meyer, Chautauqua Daily, 7/19/17).

Clearly, Doug Conroe recognized the potential economic impact of Harmful Algae Blooms to Chautauqua's water quality and bottom line.

Lake Baikal, a world away from Chautauqua, is in eastern Russia. It is the world's deepest and largest freshwater lake. Baikal holds 20 percent of the planet's unfrozen freshwater and is also dealing with HAB outbreaks, according to the Nov. 14, 2016, *New York Times* article titled "Vast and Pristine, Russia's

Lake Baikal Is Invaded by Harmful Algae." The article notes that Lake Baikal has often been described as the world's cleanest lake. Lake Baikal is a World Heritage site, home to more than 3,700 species, more than half found nowhere else. As a World Heritage site, it has become a mecca for visitors. However, the pristine nature of Lake Baikal has changed and alarming Harmful Algae Blooms have been appearing every summer in recent years.

HABs' Effects in Lake Erie

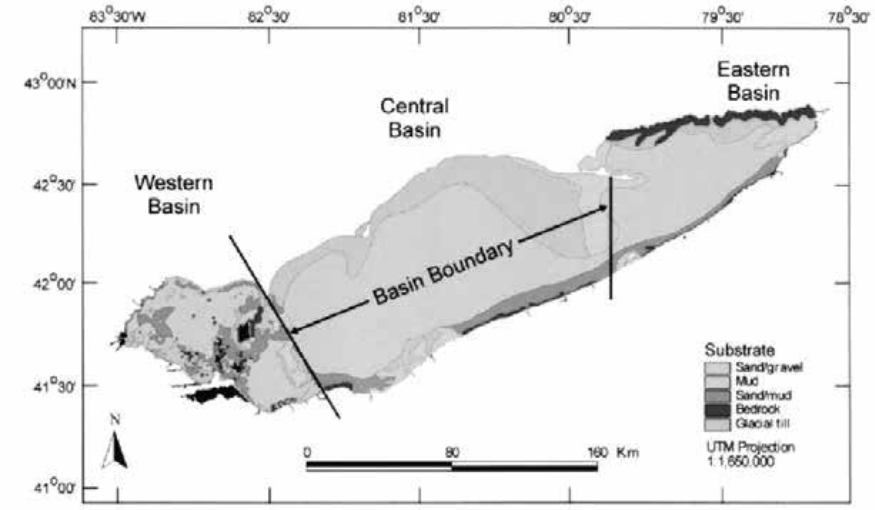
Clearly, HABs are a global problem, but what about Lake Erie? Lake Erie is the smallest, shallowest, and warmest of the Great Lakes, a group of interconnected bodies of freshwater on the United States-Canada border. The Great Lakes, consisting of Lakes Superior, Michigan, Huron, Erie, and Ontario, flow from west to east and eventually empty into the Atlantic Ocean through the St. Lawrence River. Collectively, the lakes are referred to as the Great Lakes Basin and contain about the same amount of freshwater as the world'slargest single lake, Lake Baikal.

The Great Lakes can be best understood as a river, as they receive many tributaries, including rivers and streams. However, the largest single source of water in the Great Lakes is precipitation. Lake Erie annual rainfall averages 27 to 33 inches, and total water replacement of Lake Erie takes approximately 2.7 years, the time it takes for one drop of water to flow from the farthest west point to the farthest east.

More importantly to the health of the Great Lakes is the watershed, the area where water drains into the Great Lakes. An Army Corps of Engineers map highlights in chartreuse green the drainage basin or watershed of the Great Lakes.

Lake Erie is thus part of a much larger system—one that includes all of the Great Lakes and their drainage basins. As a result, what happens in one area of the Great Lakes is likely to affect other areas, particularly to their east, and this is especially true of Harmful Algae Blooms.

Scientists who study Lake Erie have divided the lake into three distinct areas, the Western Basin, Central Basin, and Eastern Basin. The most aggressive and prolific outbreaks of Harmful Algae Blooms have occurred in the Western Basin. The Central Basin, which includes Erie



and Presque Isle, also includes Huron/Vermillion-Cleveland and eastern Ohio. The Central Basin ends at the New York border, marking the beginning of the Eastern Basin. Since water in Lake Erie flows eastwardly, the Western Basin eventually affects the Central and Eastern Basins of Lake Erie.

The Western Basin is the shallowest, most southern and warmest of the Lake Erie Basins. These factors contribute to its outlier status in terms of HABs. Most importantly, the Detroit River and four other rivers, the Maumee River, the Portage River, the Sandusky River and River Raisin drain large agricultural areas, emptying agricultural sediment into the Western Basin of Lake Erie. The Maumee River is the largest tributary to Lake Erie with a watershed of 6,500 square miles, but the effects of pollution generated from the Detroit River are viewed by most scientists as the primary cause of HABs in Lake Erie.

In Lake Erie, the HAB culprit is microcystis. The question is what causes microcystis to bloom, produce toxins, and die? Scientists and public policy officials have uniformly fixed much of the blame on phosphorous.

Although the most notable outbreak of microcystis was in August 2014 when a toxic algae bloom clogged the Toledo public water intake, HABs have been plaguing the Western Basin for decades. The data show the frequency of HABs has increased significantly since the mid-1990s. The *U.S. Action Plan* for Lake Erie identifies the cause as the increased use of phosphorus in the agricultural area delivered by the rivers bringing spring runoff into the Western Basin (*U.S. Action Plan*, 1). In February 2018, with the apparent agreement among environmentalists that phosphorous runoff was the primary problem, Canada and four states – Ohio, Michigan, Indiana, and Pennsylvania – formally adopted new phosphorus reduction targets for the Western and Central Basins. These became part of the Great Lakes Water Quality Agreement.

An Old Problem Rages Anew

The Microcystis cyanobacteria bloom on September 23 was concentrated in the western basin of Lake Erie. This image was obtained from the Copernicus Sentinel-3 satellite. The bright green images indicate surface scum. (Photograph courtesy of the National Oceanic and Atmospheric Administration) September 2017

The war against phosphorus in the Great Lakes is not a new one, dating to the 1960s. By 1969, there was so much direct release of industrial and human waste into Lake Erie that it was declared a dead body of water. In that year, the Cuyahoga River near its mouth in Cleveland caught fire and made international news. It also created a nation-wide civic response, including the Nixon Administration's decision to create the federal Environmental Protection Agency, the Clean Water Act, and local commitment to clean up Lake Erie. By the 1980s, many sewage plants had been modernized and a ban on phosphate detergents, combined with phosphorus removal programs at wastewater treatment plants, had been adopted. These actions reduced the Lake Erie phosphorus load and brought a dramatic improvement in Lake Erie's water quality. "In the late 1980s and early 1990s, HABs faded as a threat and populations of walleye and other game fish rebounded (*Environmental Health Perspective*, DOI:10.1289/ehp.125-A34).

HABs, however, are back. Since the 1980s there have been a number of factors that have caused the reemergence of concern about the condition of Lake Erie water. According to a Nov. 20, 2013 article in the *Toledo Blade*, Illinois-Indiana Sea Grant program extension climatologist

Molly Woloszyn noted that weather records showed that Lake Erie was warming. Data also showed an increased frequency of thunderstorms and fewer days of light showers since the 1970s in both Sandusky and Erie (*The Blade*, 11/20/13). Then on Aug. 4, 2014, Toledo's Collins Park water plant was shut

The Great Lakes Water Quality Agreement was originally adopted in 1972, with updates in 1978, 1983, 1987, and 2012.

The Agreement included 10 Annexes of which one was Annex 4: Nutrients.

Annex 4 set initial total phosphorous concentration and loading criteria and established lake ecosystem objectives specifically for Lake Erie.

An Objectives and Targets Task Team was created in September 2013 with 25 binational members.

The task team concluded that non-point runoff from the Maumee River during the spring period of March 1 to July 31 each year was the best predictor of cyanobacteria bloom severity.

The task force then concentrated on reducing phosphorous emanating from the Maumee River.

Source: Annex 4 Objectives and Target Task Team Report to the Nutrients Annex Subcommittee, 5/11/15

down. Schools and businesses closed. Residents were warned not to drink or bathe with city water because the microcystin levels in the water were almost three times higher than allowable.

Even before the Toledo HAB outbreak, Canada, the U.S., and states that border the Great Lakes acknowledged an increasingly serious HAB problem. Consequently, they adopted in 2013 the U.S.-Canada Great Lakes Water Quality Agreement Annex 4, finalized in February 2018. It established a phosphorous reduction goal of 40 percent.

In conjunction with Annex 4, the EPA's Great Lakes National Program Office and a number of environmental organizations adopted an action plan for phosphorous reduction in Lake Erie. It contains partners' commitments for the 40 percent phosphorus reduction and a strategy for accomplishing the goal.

New technology, such as satellite monitoring, is now being used to forecast HABs. On July 13, 2017, using satellite data, the National Oceanic and Atmospheric Administration (NOAA), predicted that western Lake Erie would experience significant HABs, potentially reaching levels experienced in 2013 and 2014, but less than the record bloom of 2015. Predictions were on target.

On November 7, 2017, the *Cleveland Plain Dealer* announced that the Harmful Algae Blooms in Lake Erie in summer 2017 were the third-largest on record. Scientists from NOAA and Ohio Sea Grant theorized that the HABs were fed by high concentrations of phosphorus flushed from farm fields in the Maumee River watershed due to heavy rains in May and June.

NOAA estimates that the Western Basin receives about 61 percent of Lake Erie's total phosphorous load. The Detroit, Maumee, and Sandusky rivers have been identified as the chief contributors of this phosphorous content to the Western Basin. The phosphorus originates from many different sources, but

scientists agree that the primary source is runoff of fertilizer and manure used to spur growth in agricultural fields. The phosphorus is picked up by spring rains and snowmelt, flows into tributaries, and then empties into Lake Erie. The U.S. Action Plan for Lake Erie indicates that these nonpoint sources contribute upwards to 89 percent of the annual total phosphorus load in the Western Basin.

The U.S. Action Plan for reducing phosphorous in the Western Basin calls for agricultural producers to adopt best management practices of nutrient stewardship. Farmers were counseled to apply fertilizer at the

- Right time
- Right place
- Right rate
- Right source.

The goal of the U.S. Action Plan is to have 80 percent of the farmed acres in the Basin under 4R certified management by 2020.

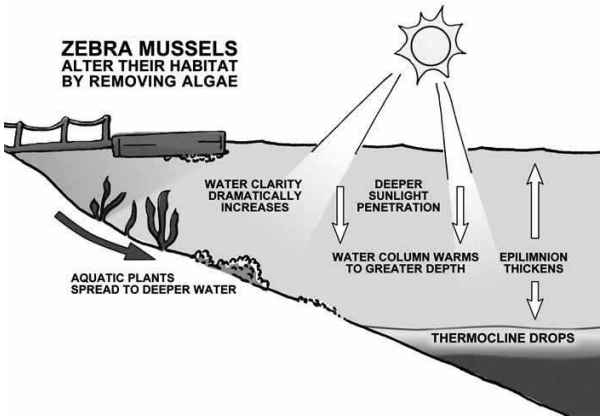
One of the agricultural practices that initially increased the phosphorous load was "no-till" cultivation. This is the application of manure and chemical fertilizers directly onto the land's surface, instead of working them into the soil. While an advance in farming practice, using no-till planting to apply seeds and fertilizer leaves fertilizer full of phosphorous susceptible to runoff in spring storms. Storms carry nitrogen and phosphorus directly into streams that feed rivers (Smith et al. *Journal of Soil and Water Conservation*, March-April 2015, 27A). Farmers today are being advised to use a cover crop to secure the fertilizer. Iowa researchers found that no-till practices that include a permanent grass cover, such as switchgrass, corn, and soybean, have the least amount of run-off phosphorus (Mallarino, Antonio, Iowa University, PhysOrg.com). Suburban and urban residents in the Western Basin, and in the Lake Erie Basin as a whole, are also adding phosphorous to the lake. Lawn fertilizers, phosphorous-rich dishwasher liquids, construction runoff and faulty drainage systems eventually bring phosphorus into Lake Erie. Many manufacturers desiring to have an ecofriendly product to market have eliminated phosphorous in their products.

However, reducing the total phosphorous load by 40 percent is more complicated than just persuading suburbanites to use less or different types

of fertilizers and asking farmers to carefully calibrate the amount and time of fertilizer application and use a cover crop with no-till farming. Some of the phosphorous brought by nonpoint sources into Lake Erie's Western Basin is classified as legacy phosphorous. In other words, it is phosphorous that is embedded in the soil, perhaps originating from fertilizers applied years ago. In the Maumee River watershed alone, an estimated 4 million tons of phosphorous are contained in its top 8 inches of soil and more in the streambeds that feed the Maumee River. Researchers surmise that strong rains can wash imbedded phosphorous, as well as newly applied phosphorous, into the tributaries of rivers emptying into Lake Erie (*Nature Geoscience*, 2016; DOI: 10.1038/ngeo2693).

Other Complicating Issues

Other aspects of change that add complications to reducing total phosphorous content are the invasive species of Quagga and Zebra mussels. These invasive species were brought from Eastern Europe to the Great Lakes in the ballast of lake freighters in the late 1980s. They are ubiquitous and insideous. There are now billions, perhaps mega trillions, of Zebra and Quagga mussels that live in Lake Erie. Quagga and Zebra mussels compete for algae, micro-nutrients, and plankton, with Lake Erie's small fish population, causing a reduction in the overall fish population. The vast numbers of Quagga and Zebra mussels devour so much algae that the normal shading within the lake waters disappears allowing more sunlight to filter to the bottom of the lake, propelling the growth of HABs.

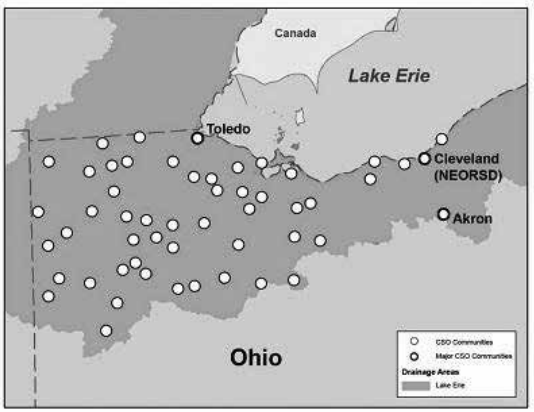


While the Quagga and Zebra mussels eat algae, they are discriminating eaters and spit out the blue-green algae or cyanobacteria that contain toxins, leaving it to fester into Harmful Algae Blooms. Further, the mussels concentrate phosphorus in their feces, which is deposited on the lake's bottom and subjected to direct sunlight. That process increases the growth of HABs. These phosphorous deposits can be stirred up during storms, adding to the lake's phosphorous levels and making reduction of phosphorous more difficult. In addition, there appears to be few predators of Quagga and Zebra mussels. They are not recommended as a food for humans because of the likelihood that they contain toxins; however, it has been discovered that some Lake Erie fish and

waterfowl have adapted to eating the mussels.

Phosphorous, whether from the excrement of Quagga and Zebra mussels or from agricultural runoff, or embedded sediments, adds to the chemical richness of Lake Erie, causing an overdose of nutrients particularly in the deeper waters of Lake Erie. The resulting explosion of phosphorous-eating algae eventually die, burning up much of the oxygen in the water and which then can suffocate other aquatic life. This is called hypoxia or eutrophication. Webster's defines eutrophication as "the process by which a body of water becomes enriched in dissolved nutrients (such as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen." The water, overdosed by phosphorous and inundated by dying algae, can turn into a bog and then a dead zone, though it occurs only in summer. The Lake Erie dead zone has been growing significantly and is now estimated to cover as much as 10,000 square miles. Most of it lies in the Central Basin but also now includes the area around Sandusky in the Western Basin (Greenwald, Newest Lake Erie "dead zone" brings horror story for fish near Sandusky, *The Blade*, July 19, 2005).

It is not just the run-off from agricultural areas, or phosphorous legacy deposits, or Zebra and Quagga mussel feces that are causing the high phosphorous content. It is also point pollution – a single identifiable source of pollution. One single point-source is man-made drainage. A large portion of the Western Lake Erie watershed was originally the Great Black Swamp. Beginning in the early 1900s, tile drainage ditches were installed in order to make the land usable for agriculture. These drains were buried beneath fields to help lower the water table and collect surface water after it filtered through a few feet of soil, thus diverting it away from the fields to avoid standing water. Over the years, phosphorous drained into the tiles, where it could remain for years, until a violent storm swept the phosphorous into Lake Erie.



Point sources not only include drainage tiles but also sewage treatment plants. On January 19, 2015, Karen Kaczala of the *Toledo Press* reported the following:

> Each year, wastewater is released into Lake Erie from outdated combined storm water and sanitary sewer systems. These systems collect rainwater runoff, domestic sewage and industrial wastewater in the same pipe that handles wastewater disposal and storm water drainage. Following heavy rains, due to combined sewer overflows, raw sewage and storm water are transported into the lake, bypassing municipal sewage treatment plants. The phosphorus from the waste contributes to the development of harmful algal blooms. It is estimated that combined sewer overflows (CSOs) contribute up to 1.5 percent of the total phosphorus load into Lake Erie, according to the Ohio Environmental Protection Agency.

CSO Issue

Combined sewer overflows are a collection of pipes and tunnels that are designed to catch surface runoff from storms and carry the effluent into the sanitary system. In older cities heavy storms often overload the CSO and as a result there is a back-wash that includes sewage as well as the surface runoff that spills into streets and nearby streams and lakes. In the Lake Erie Ohio basin there are 62 identified CSO communities. CSOs are considered the second-most significant contributor of phosphorous to the Lake Erie Basin, after agricultural runoff, according to the Ohio Lake Erie Phosphorus Task Force II. CSOs are no longer used in newer constructed areas. Current preferred design separates storm sewers from sanitary sewers; however, many older cities continue to operate combined sewers. The following CSOs have permits to discharge waste into Lake Erie:

MUNICIPALITY	FINAL DISCHARGE	DISCHARGE FROM
Akron	Lake Erie	Cuyahoga River
Avon Lake	Lake Erie	Lake Erie
Bluffton	Lake Erie	Riley Creek
Bowling Green	Lake Erie	Poe Ditch
Bucyrus	Lake Erie	Sandusky River
Clyde	Lake Erie	Raccoon Creek
Columbus Grove	Lake Erie	Plum Creek
Crestline	Lake Erie	Westerly Creek
Defiance	Lake Erie	Maumee River
Delphos	Lake Erie	Jennings Creek
Delta	Lake Erie	Bad Creek
Deshler	Lake Erie	Brush Creek
Dunkirk	Lake Erie	Shallow Run Ditch
Elyria	Lake Erie	Black River
Euclid	Lake Erie	Lake Erie
Fayette	Lake Erie	Unnamed stream to Deer Creek
Findlay	Lake Erie	Blanchard River
Forest	Lake Erie	Forest Simpson Ditch to Blanchard River
Fostoria	Lake Erie	Portage River, East Branch

Fremont	Lake Erie	Sandusky River
Gibsonburg	Lake Erie	Hurlbut & SR 300 Ditch (to Portage River)
Green Springs	Lake Erie	Flag Run Creek
Greenwich	Lake Erie	SW Branch of Vermillion River
Hamler	Lake Erie	South Turkey Foot Creek
Hicksville	Lake Erie	Mill Creek
Lakewood	Lake Erie	Lake Erie
Leipsic	Lake Erie	Little Yellow Creek
Lima	Lake Erie	Ottawa River
Luckey	Lake Erie	Toussiant Creek
McComb	Lake Erie	Algire Creek
Metamora	Lake Erie	Ten Mile Creek
Monroeville	Lake Erie	West Branch Huron River
Montpelier	Lake Erie	St. Joseph River
Napoleon	Lake Erie	Maumee River
NEOSRD	Lake Erie	Lake Erie
North Baltimore	Lake Erie	Rocky Ford Creek
Norwalk	Lake Erie	Rattlesnake Creek
Oak Harbor	Lake Erie	Portage River
Ohio City	Lake Erie	Long Prairie Creek
Pandora	Lake Erie	Riley Creek
Paulding	Lake Erie	Flat Rock Creek
Payne	Lake Erie	Flat Rock Creek
Perrysburg	Lake Erie	Maumee River
Port Clinton	Lake Erie	Portage River
Sandusky	Lake Erie	Sandusky Bay
Swanton	Lake Erie	Al Creek
Tiffin	Lake Erie	Sandusky River
Toledo	Lake Erie	Maumee River
Upper Sandusky	Lake Erie	Sandusky River
VanWert	Lake Erie	Town Creek
Wapakoneta	Lake Erie	Auglaize River
Warren	Lake Erie	Mahoning River
Wauseon	Lake Erie	North Turkeyfoot Creek
Willard	Lake Erie	Jacobs Creek
Woodville	Lake Erie	Portage River

Source: Appendix A of the Report to Congress: Combined Sewer Overflows into the Great Lakes Basin

Many of the communities listed in this table are in the Western Basin, but some of the Ohio municipalities, such as the Northeast Ohio Regional Sewer District and Akron, are in the Central Basin, which includes part of eastern Ohio and Pennsylvania. The only Pennsylvania municipality that operates a CSO and has a permit to empty some of its effluent into Lake Erie is the city of Erie.

The Nitrogen Factor

The picture becomes even more complicated. Research scientists recently found that nitrogen is also important in the growth of Harmful Algae Blooms. In February 2017, Sharon Levy in *Environmental Health Perspectives* underscored the contribution that nitrogen furnishes to a HAB eruption. She states that a

proper strategy for reduction of blooms must include reduction of nitrogen and notes that researchers who are updating the Great Lakes Water Quality Agreement are including the need to understand nitrogen pollution and to control its impact as well as phosphorus:

> New insights into microcystis ecology challenge long-standing ideas about how best to control ... blooms. Researchers now understand that an excess of another nutrient, nitrogen, shifts the balance in favor of microcystis rather than other HAB forming cyanobacteria, diatoms, or green algae. "Microcystis relies on nitrogen from the watershed," says Hans Paerl, a microbial ecologist at the University of North Carolina. "Many lakes that have microcystis blooms are receiving increasing loads of nitrogen from synthetic fertilizers, urban runoff, and atmospheric pollution. Nitrogen is the new part of the story." (Levy, Microsystis Rising; Why phosphorous reduction is not enough to stop CyanoHABs, *Environmental Health Perspectives*, vol. 125, 2/17)

King, et al., in "Urea Release by Intermittently Saturated Sediments from a Coastal Agricultural Landscape," published in the *Journal of Environmental Quality*, March 17, 2017, linked the growth of Harmful Algae Blooms to Urea-N, nitrogen that comes from organic fertilizers. Their research found that Urea-N was exported from fields during storms and drained into ditches, producing Harmful Algae Blooms. The HABs are then transported downstream to rivers and lakes and continue to mature despite the dilution effect. They found that concentrations of Urea-N in shallow waters were higher during warm summer months. It is interesting that many of the soybean farmers in Erie County have turned to using organic fertilizers such as chicken litter, containing high levels of nitrogen.

Similar to phosphorous, there is legacy nitrogen. At the University of Calgary, scientists have determined that nitrogen fertilizer has the capacity to linger in the soil. Synthetic nitrogen fertilizer was first applied to crops in 1982 and these researchers have found that about 15 percent of that fertilizer still remains in the soil. Eventually this nitrogen either seeps through the soil or is evacuated by torrential storms and enters the groundwater. This means that nitrate reduction targets could take longer than previously thought to accomplish. Reducing nitrate contamination in aquifers may be as problematic as the reduction of phosphorous (Sebilo et al., "Long-term fate of nitrate fertilizer in agricultural soils," Proceedings of the National Academy of Sciences, 2013; DOI).

As noted, the Western Basin contains four major rivers: the Detroit, Maumee, Sandusky, and the River Raisin, while the Central Basin contains only two, both in Ohio: the Cuyahoga River and the Grand River. Except for the Detroit, the rivers of the Western Basin drain mainly agricultural areas. Both the Detroit in the Western Basin and the Cuyahoga River in the Central Basin drain primarily urban areas. While all of the rivers of the Western Basin have been designated by the International Joint Commission as Areas of Concern, only the Cuyahoga

River in the Central Basin River has been so designated.

The U.S. and Canada entered into the Great Lakes Water Quality Agreement Annex 1 in 2012. It establishes and defines Areas of Concern (AOCs) as "geographic areas designated by the parties where significant impairment of beneficial uses has occurred as a result of human activities at the local level." An AOC is a location that has experienced environmental degradation, and 28 have been designated in the Great Lakes Basin. Only one, Presque Isle Bay, has met its identified targets and was delisted in February 2013. The AOC for Presque Isle pertained only to Presque Isle Bay. The AOC named two Beneficial Use Impairments (BUI): fish tumors and other deformities and dredging activities.

What is being done?

In March 2018, Ohio officially designated the entire western end of Lake Erie as an impaired waterway because of toxic algae growth that consistently covers much of the lake. The designated impairment area is about 60 miles long and stretches from Toledo to Marblehead. The Ohio EPA, working with university researchers, has produced measurement standards for phosphorous, considered the main culprit in the algae bloom growth. Despite the fact there is also a federal plan for phosphorous reduction, the targets are primarily voluntary and have been slow in coming. Environmental groups are frustrated by the slow progress in phosphorous reduction in the Western Basin and are demanding tougher and enforceable regulations throughout the Western Basin. These advocates are now joined by Ohio Governor John Kasich, who indicates that the voluntary steps farmers have taken to control the amount of fertilizers feeding Lake Erie's massive algae blooms aren't working fast enough. Therefore, the Kasich administration has announced new steps to reduce the algae blooms, but both agriculture and wastewater plants are fighting back.

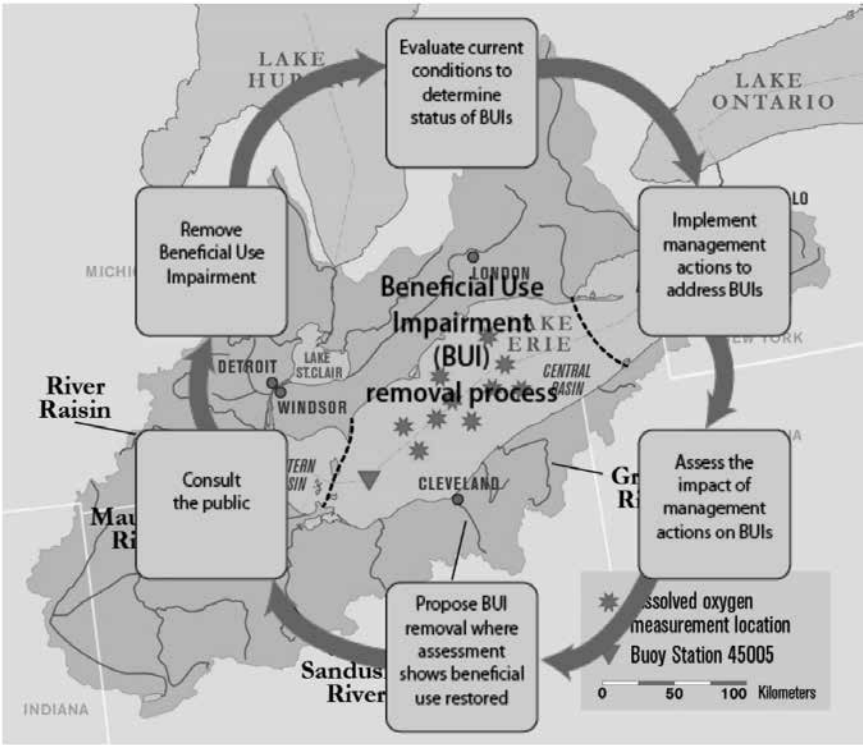
EPA data point to agriculture as the biggest polluter and wastewater treatment plants as the second-largest algae-feeding polluter of Lake Erie. While Ohio has already banned spreading manure and fertilizer on frozen or soggy fields, the Kasich plan, if adopted, would impose new limits on nearly all of Ohio's wastewater plants, requiring them to remove more than 2 million pounds of phosphorus that they dump into the state's rivers, streams, and lakes each year.

The new Ohio regulations must obtain legislative approval before they can be implemented. Meanwhile, the federal government has announced new targets in an effort to meet their treaty responsibility of reducing phosphorous by 40 percent. These targets are directed at the agricultural community. They are all voluntary. In a release from environmental groups, including the National Wildlife Federation, the Alliance for the Great Lakes, and the Michigan League of Conservation Voters, environmentalists say they are disappointed with the plan's reliance on voluntary efforts to reduce nutrient runoff.

Algae blooms in the Central Basin have been less evident and of less concern, except for the Cuyahoga River that drains the Cleveland area. Though the Cuyahoga River rebounded after it caught fire in 1969, actual improvements of its water quality have been slow in coming. In 1987, the International Joint Commission (established in 1909 by the governments of the United States and Canada under the Boundary Waters Treaty and expanded with the signing of the Great Lakes Water Quality Agreement of 1978, amended in 1987 and 2012) designated the Cuyahoga River an Area of Concern (AOC) under the Great Lakes Water Quality Agreement.

The Cuyahoga River was the first area of the Great Lakes to receive an AOC listing. In 1988, the Ohio Environmental Protection Agency appointed a 33-member planning committee to create the Remedial Action Plan, which was completed in 1992. Since then, with the help of governmental grants, the 33-member planning committee has been actively pursuing the goals stipulated in the remedial action plan.

The Cuyahoga River is the only tributary emptying into Lake Erie's Central Basin that has been designated an AOC. In the Western Basin, by comparison, most of the major tributaries including the Maumee and Black rivers, have been designated an AOC with specific beneficial impairment infringements identified.



When an area becomes a designated AOC, it is given a beneficial use impairment listing, which identifies the specific change in the chemical, physical, or biological integrity of the Great Lakes system that has occurred. The International Joint Commission has identified 14 possible impairments:

1. Restrictions on fish and wildlife consumption
2. Tainting of fish and wildlife flavor
3. Degraded fish and wildlife populations
4. Fish tumors or other deformities
5. Bird or animal deformities or reproductive problems
6. Degradation of benthos - flora and fauna on lake bottom
7. Restrictions on dredging activities
8. Eutrophication or undesirable algae
9. Restrictions on drinking water consumption or taste and odor problems
10. Beach closings
11. Degradation of aesthetics
12. Added costs to agriculture or industry
13. Degradation of phytoplankton and zooplankton populations
14. Loss of fish and wildlife habitat

In order to redress the BUI designation and delist the area, the state and local advisory group must meet restoration targets specified in a remedial plan that relate to each BUI infraction. In order to delist an area, the local public advisory council, the state, and the International Joint Commission must agree that the BUI removal criteria have been met.

The Cuyahoga River remains one area that has a BUI listing of Number 8: "Eutrophication or Undesirable Algae." Since 2010, more than $13 million from the Great Lakes Restoration Initiative has been used to fund more than 40 projects to address these problems in the Cuyahoga River Basin. The local planning committee indicates that BUI delisting will occur when the Trophic Index, a tool for measuring toxicity included in Ohio's Nutrient Reduction Strategy, indicates that conditions are not impaired as a result of excessive algal growth due to sources of nutrients. Delisting can also occur if the Trophic Index is not available and there is no evidence of persistent nuisance growth of algae, such as filamentous Cladophora,

Regional Science Consortium HAB Monitoring Sites

Beach 1
Beach 2
Beach 6
Mill Road Beach
Beach 9
Beach 11
Scott Run
Vista 3
Sturgeon Bay
Ferry Slip
Marina
Niagara Boat Launch
Horseshoe Pond
Boater's Beach
Perry Monument
Erie Yacht Club
Garrison Run
South Pier
Dobbins Landing
Liberty Park
Cascade Creek
Lake Cliff Boat Launch
Shades Beach
Freeport Beach
Elk Creek
Avonia Beach/Trout Run
Walnut Creek

Regional Science Consortium Full Members

Allegheny College
California Univ. of PA
Edinboro Univ. of PA
Gannon University
Grove City College
Iroquois School District
LECOM
Mercyhurst University
Millcreek Township School District
Penn State Erie
Penn State University
Pennsylvania Sea Grant
PA DCNR at Presque Isle
PA DEP
PA Fish and Boat Commission
U.S. Geological Survey
Slippery Rock Univ. of PA

or blooms of blue-green algae within the last three years due to nutrient sources within the AOC (http://www.cuyahogaaoc.org/bui-8-eutrophication-or-undesirable-algae.html).

Lake Erie Harmful Algae Bloom Bulletin 23 issued for September 28, 2017, indicated that the microcystis cyanobacteria bloom continues in the Western Basin along the Michigan and Ohio coasts from the Maumee River east through the islands, and northeast of the Ontario coast. The Bulletin indicated that measured toxin concentrations were below recreational thresholds throughout most of the bloom extent, but concentrations exceeded the threshold in the Maumee Bay and in the Western Basin extending towards the Ontario coast where the bloom is most dense.

The Lake Erie algae bloom in 2017 reached its maximum size in August, then shrunk, but reappeared in September at which time it grew to 1,000 square miles, stretching from Toledo to the Ontario shore. The extent of the HAB was sufficient to do damage to the tourist business. It appears that charter fishing was particularly impacted. Captain Dave Spangler of Dr. Bugs Charters in Oak Harbor, Ohio, west of Sandusky, reported that the bloom resulted in approximately 20 percent to 25 percent reduction of the fishing business (Cleveland *Plain-Dealer*, 11/07/17).

Although HABs have occurred near and around Presque Isle State Park, unlike the Ohio portion of the Central Basin, there are no areas in Pennsylvania that are currently listed as an Area of Concerm. Nevertheless, with the algae events occurring in the Western Basin and the algae bloom reaching the Cuyahoga River area in the Central Basin, there is a recognized potential of HABs spreading eastward to Pennsylvania. In 2014, in response to this risk and to address more localized smaller bloom events, the Lake Erie Harmful Algae Bloom Monitoring and Response Strategy was created by Pennsylvania-based environmental organizations to provide a coordinated response to this potential threat.

The organizations that are part of the Monitoring and Response Strategy are the Pennsylvania Department of Conservation of Natural Resources, Pennsylvania Department of Environmental Protection's Office of Great Lakes, Erie County Department of Health, Pennsylvania Sea Grant, Regional Science Consortium and the Citizen Science Volunteers. In May 2014, this group of agencies adopted

a strategy to eliminate HABs and revised the strategy in July 2017. The member organizations have taken on the responsibility for informing the public and water resource managers of HAB outbreaks and for educating the public and posting public advisories in the event blooms are detected.

Assessing the Local Threat

To accomplish their mission, the Task Force, principally through the Regional Science Consortium, conducts regular monitoring activities by staff and volunteers. In addition, the Regional Science Consortium coordinated with other educational outreach and research projects for Lake Erie and the Upper Allegheny Ohio River Basin.

Obey posted signs to protect your pets. While HABs can have blue, green or brown foam, scum or mats, the water can look perfectly clear.

On July 11, 2017, Presque Isle State Park lifeguards reported seeing algae blooms off several beaches. This coincided with a similar outbreak in the Western Basin. At Presque Isle, the park posted signs and prohibited swimming at Beaches 6, 7, 9, and Barracks Beach until tests on the following day showed that the water was safe for humans. Nevertheless, some of the results came back with toxic levels sufficient to harm dogs, so the initial all-purpose warning signs were replaced with signs that indicated that the water was unsafe for dogs. Testing throughout August 2017 continued to show the existence of HABs in Presque Isle Bay and also along the Pennsylvania shore of Lake Erie.

Tests confirmed that there were more Harmful Algae Blooms in the bay than at Presque Isle State Park or along the lakeshore. This is understandable since bay waters are less turbid, and turbidity is one of the conditions that make water less susceptible to growth of HABs.

> Scientists believe that around the year 1800, (about) 3,000 tons of phosphorous flushed annually into Lake Erie. It seeped off the land from rocks, soils, and decaying plant and animal life. It also fell from the sky in raindrops. … By the 1930s, the lake's annual phosphorus load had climbed to 10,000 tons. By the late 1960s, about 24,000 tons of phosphorus flowed into the lake annually.
>
> [Today] Lake Erie's annual average phosphorus load remains about 9,000 tons, well under its 11,000-ton target set in the 1970s and far below the 24,000 tons common in the late 1960s.
>
> Source: Egan, *The Death and Life of the Great Lakes*, p. 220 & 227.

In 2018, lake quality problems have persisted with a number of algae blooms being detected and drawing keen observation. In addition, Presque Isle beaches have been "plagued with swimming restrictions and advisories because of high E. coli bacteria counts, making it unsafe for swimming at times," and

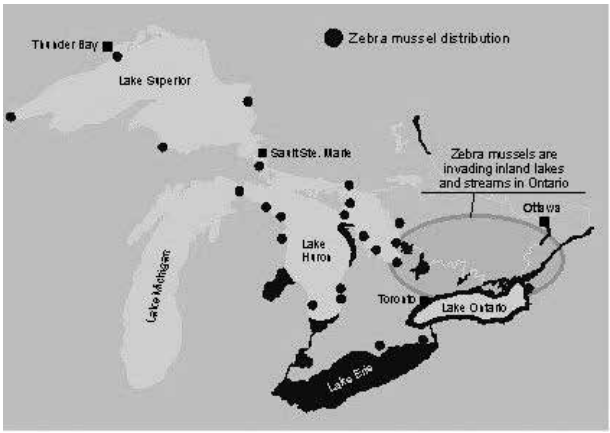
dangerous for pets, the *Erie Times-News* reported (Aug. 13, 2018).

Erie, as noted previously, falls within the Central Basin. In December 2016, *The Science of the Total Environment* published an article titled "Internal Loading of Phosphate in Lake Erie Central Basin," by Adina Paytan, Kathryn Roberts, Sue Watson, Sara Peek, Pei-Chuan Chuang, Delphine Defforey, and Carol Kendal. The authors point out that reduction of phosphorous during the 1980s in the Western Basin initially resulted in higher water quality for the Central Basin of Lake Erie as well as the Western Basin. However, in the 21st century there has been a decline in ecosystem health, despite the fact that external phosphorous loads are still meeting goals. This fact sparked the research group to undertake a renewed effort to understand phosphorous cycling in the Central Basin of Lake Erie. Their examination led them to the conclusion that sediment, rich in phosphorous, is responsible for the poorer quality of water and not the phosphorous run-off that infuses the Western Basin and then spreads eastward.

These researchers note that by 2005 the amount of phosphorous in the Central Basin and the extent of the oxygen-depleted zone began to increase. They point to research studies that show that internal loading from sediments, rather than nonpoint sources, such as agricultural runoff, may be responsible for the increased phosphorous in the deep water of Lake Erie. They argue that if the phosphorous in Lake Erie is largely derived from historic loading of fertilizers and detergents, then it can be expected that phosphorous will decrease over time with appropriate management actions to reduce the external inputs that Annex 4 of the bi-national treaty establishes (Paytan et al., Internal Loading of Phosphate in Lake Erie Central Basin, *Science of the Total Environment*, 12/4/16).

The existence of Quagga and Zebra mussels may complicate this optimistic view. The researchers do not address any connection of sediment phosphorous to the widespread existence of Zebra and Quagga mussels which may be a contributing factor in understanding how the sediment in Presque Isle Bay and in and around Presque Isle State Park can be adding to the growth of Harmful Algae Blooms.

Zebra and Quagga mussels excrete large amounts of phosphorous and these mussels are pervasive throughout Presque Isle Bay and Park. Further, the Central Basin has a multitude of submerged shipwrecks and associated debris. This debris is covered with Zebra and Quagga mussels. Additionally,



the 55 breakwaters on the lake side of the peninsula harbor millions of Zebra and Quagga mussels, providing a rich environment for sediment phosphorous.

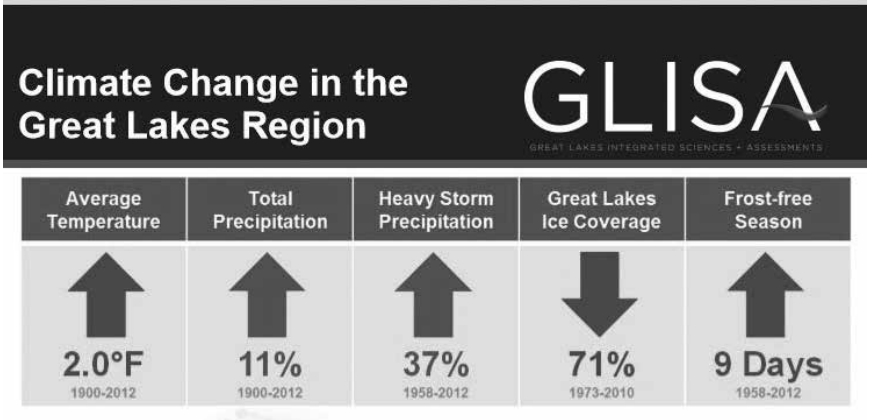
The growth of the Quagga and Zebra mussels seems to be related to climate change. The Federal Environmental Protection Agency notes in its publication "Nutrient Pollution, Climate Change and Harmful Algal Blooms" (https://www.epa.gov/nutrientpollution/harmful-algal-blooms) that all algae need carbon dioxide to survive. Higher levels of carbon dioxide in the air produced by the warming of Earth's waters and land lead to rapid growth of algae, especially toxic blue-green algae that can float to the surface of the water. Further climate change is expected to produce extreme storms followed by periods of drought. These higher-intensity storms can cause more nutrient runoff and sediment dislodgement adding additional phosphorous to the bay and lake.

In the U.S. coastal areas, the rising of seawater as a result of climate change is expected to result in more shallow and stable coastal water, conditions that are perfect for the growth of algae. The water is also rising in the Great Lakes and, according to "Rising Waters," (*Erie Times-News*, March 29, 2018) Lake Erie, for the first in many years, had frozen. The snowmelt from the record 2017-18 snowfall and subsequent rain are raising the water table. The colder temperature is good news for those concerned with Harmful Algae Blooms. However, the higher water table may not be, especially if we have violent spring-summer storms that stir up long-held phosphorous sediment in the bay and lake.

Karl Havens and Hans Paerl, in an article in *Environmental Science & Technology* titled "Climate Change at a Crossroad for Control of Harmful Algal Blooms," note the following:

> A climate-driven change in water temperature, including both a general warming and more extremes, can modify the phytoplankton community by favoring bloom-forming cyanobacteria, which are able to take advantage of warmer conditions and increasing hydrologic extremes.

These authors maintain that time is of the essence for Lake Erie and that nutrient reduction strategies may be overwhelmed by climate change (Havens & Paerl, Climate Change at a Crossroad for Control of Harmful Algal Blooms,



Environmental Science & Technology, 10/14/15). The sense of urgency is corroborated by the *Great Lakes Integrated Sciences Assessment* done by NOAA. The study notes that the average air temperature in the Great Lakes region has risen by 2 degrees C since 1900 and, in recent years, Great Lakes waters have warmed faster than the surrounding air temperature, with Lake Superior warming twice as fast as the air since 1980. The study notes that there can be no doubt now that with the continuation of the current practices and the warming of lake waters, Harmful Algae Blooms will increase, killing fish and wildlife, threatening human health and diminishing water quality, and threatening the economic benefits that Lake Erie has historically provided.

In his beloved tale, *The Lorax*, Dr. Seuss instructs youngsters about the importance of safeguarding the environment. In 1992, when informed of the improvements to Lake Erie, Dr. Seuss removed the reference to Lake Erie in the next edition of *The Lorax*. Perhaps if he were alive today, he would reinsert the description of "smeary Lake Erie."

"You're glumping the pond where the Humming-Fish hummed! No more can they hum, for their gills are all gummed. So I'm sending them off. Oh, their future is dreary. They'll walk on their fins and get woefully weary in search of some water that isn't so smeary. I hear things are just as bad up in Lake Erie."

A Generational Challenge

Clearly, Pennsylvania's part of Lake Erie exhibits eutrophication – excessive nutrients causing a dense growth of plant life, and death of animal life from lack of oxygen. Controlling the growth of Harmful Algae Blooms is the

challenge of this generation. The problem is both complex and threatening. It is one that must engage scientists, activists, citizens, and elected officials alike.

Plastics pollution is a huge, global problem. Could part of the solution be turning to environmentally friendly, biodegradable plastics? French company Algopack, based in Brittany, has made a business out of turning brown algae into plastic.

Remy Lucas, Ecology/Natural Resources,
March 10, 2016

While the Pennsylvania environmental organizations based in Erie were mounting a gallant defense against the growing threat of Harmful Algae Blooms, New York state was also on the march organizing its response to the rising concern of HABs, particularly to inland waters. In New York, it was Gov. Andrew Cuomo who led the charge. In 2018, Cuomo scheduled a series of four summits to address the threat of Harmful Algae Blooms in upstate lakes and waterways to be held in New Platz, Syracuse, Rochester, and Ticonderoga. The summits gathered area environmental and health scientists together to address the community about the challenges posed by the growth of HABs. Cuomo set the tone by noting that the HAB threat in New York was growing at a frightening rate proposing a $65 million initiative to battle them. While much of the HAB problem is centered on inland lakes and waterways, such as Chautauqua Lake and Findley Lake, part of the environmental package called for a new sewage plant for Niagara Falls (Carola, Chris, *Associated Press*, 2/27/18).

In 2016, Niagara Falls Mayor Paul Dyster warned residents about harmful blue-green algae blooms when he issued a "bloom notice" for the area. The algae were found in a northeast portion of Hyde Park Lake near Gill Creek. Dyster, in issuing the "bloom notice," warned that people and pets should avoid contact with the affected water. In July 2017, U.S. Congressman Brian Higgins, of New York, urged that more federal funds be allocated to address toxic algae blooms that threaten the health of Lake Erie.

A Call to Action

What can the Erie region area do? Perhaps our concerned citizens could persuade the Governor and Pennsylvania's other elected officials to join the battle in more demonstrative ways, sound the alarm and trumpet the need to combat Harmful Algae Blooms.

We need a comprehensive strategy. On the local level, sewage treatment facilities and in-ground septic systems should be monitored, and any possible contamination

I set up a workshop in my garage where I started analyzing the makeup of different algaes. Then I used the tools common in plastics manufacturing to transform them. I ended up patenting my invention and starting a company.

Remy Lucas, Ecology/Natural Resources,
March 10, 2016

of phosphorous and nitrate into Lake Erie eliminated. Farmers should be informed of their responsibility to employ best practices, such as linking the application of the right amount of fertilizer to the right time to fertilize. Farmers should be instructed to use cover crops. Winter cover crops should also be employed and fertilizer should not be applied to frozen ground. Homeowners should choose phosphorus-free dishwasher detergent, dishwashing soap, and lawn fertilizer. We all can be more conscious of our individual impact on the Lake Erie environment.

There may be something else that could be done. All over the world scientists and entrepreneurs are experimenting with algae. In 2010, several Caribbean islands were invaded by sargassum, a "brown algae" that has a nauseating odor when it decomposes on beaches. Granted, cyanobacteria is not an algae; nevertheless, the story about sargassum is worth noting.

Innovative Solutions

Scientist and entrepreneur Rémy Lucas looked at the epidemic of sargassum, the brown algae, and saw an opportunity. Lucas is a promoter of green chemistry, a branch of chemistry that focuses on sustainable product design that minimizes the use and generation of hazardous substances. Lucas believed that sustainable science could provide an answer to the sargassum invasion. He began to experiment with turning the brown algae into plastics. Today his newly formed company sells granules called Algopack to about 20 different plastics manufacturers, who use them to make different products, including USB drives, toys, glasses frames, key chains, road signs, food packaging and lamps, to give a few examples. Lucas notes that these objects are biodegradable. If they are in the ground, they will decompose in 12 weeks. They are also compostable.

After three years of research into algae with Wageningen University, Salga Seaweeds, Avans Biobased Lab in Breda, and other institutions, Klarenbeek and Dros were invited to establish an open research and algae production lab at the Luma Foundation in Arles.

Source: Morris, *Dezeen*, 'Dutch Designers convert algae into bioplastic for 3D printers.' Dec. 4, 2017

In 2016, Dutch designers Eric Klarenbeek and Maartje Dros announced the development of a bioplastic made from algae. Klarenbeek and Dros cultivated various kinds of algae, including cladophora, in vats. They then dried and processed the algae into a material that they used in 3D printers to make plastic housewares. They believe that the plastic produced from algae could completely replace oil-based plastics over time. The chemistry is relatively basic. Algae undergo photosynthesis and use sunlight to turn carbon dioxide gas and water into food. Some of that food is in the form of starch. The starch is a polymer and is made up of smaller repeating molecules

strung together. They are the main components of plastics. The resulting bioplastic doesn't contain harmful chemicals and breaks down in the environment. The benefits are three-fold: the process removes carbon dioxide from the air; it creates a substitute for the petroleum-based plastic; and, it is biodegradable.

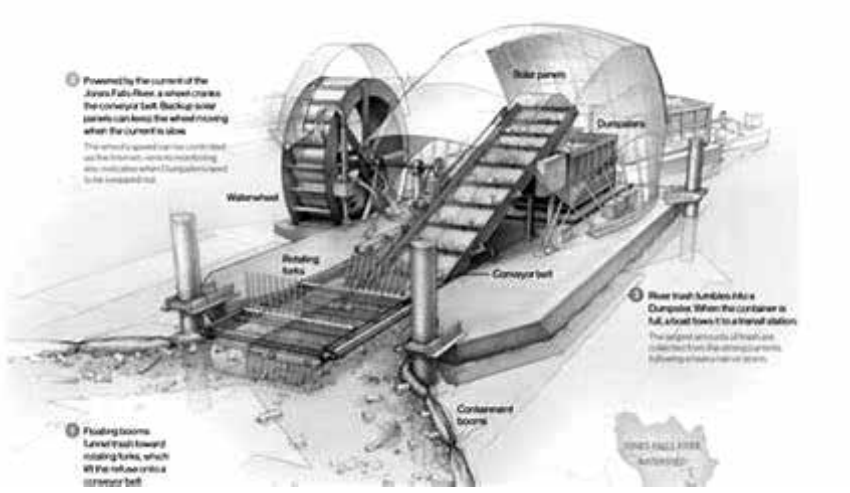
Baltimore's solar-powered water wheel can devour 50,000 pounds of harbor trash every day.

Making plastic out of nonpetroleum product is not a new idea. Maize or corn is also being used to generate plastic, though turning maize, or corn, into plastic has considerable problems associated with it. The more corn that is grown, the more fertilizer hits the ground, and the more algae blooms are generated. Further, with a growing world population, using a food source for generating plastics may exacerbate food insecurity.

More momentous is the breakthrough of J. Craig Venter, the scientist who mapped the human genome. In June 2017, Venter and Exxon Mobil Corp. announced the breakthrough that could enable widespread commercialization of algae-based biofuels. In other words, algae not only has the potential to replace oil as the basic component of plastics, but also could replace oil as an energy source.

A common problem experienced by the Dutch and Caribbean efforts and Exxon Mobile operations is obtaining sufficient quantities of algae. Perhaps with a little design change a mechanism developed for Baltimore's Inner Harbor by John Kellett and Daniel Chase of Clearwater Mills could be refashioned as an amphibious harvester of algae and cyanobacteria, which could clear the waters of Lake Erie and inland lakes of unwanted algae, and at the same time collect the raw material for an algae-based plastics industry in Erie County.

The solar powered Baltimore trash collector generates 2,500 watts of electricity a day, which is enough energy to carry on its work. The money for the design



and production of the trash collector came from the Waterfront Partnership, a nonprofit that promotes the Inner Harbor. The Trash Wheel has been so successful that two additional trash wheels have been added to the Baltimore clean-up effort. Kellett is now working with groups around the world to set up similar devices. Interestingly, Findley Lake is currently using a similar machine to gather unwanted cladophora and other seaweeds from its waters. Perhaps if contacted by Erie advocates, Kellett would help design a cyanobacteria/algae-collecting amphibious device that gathers unwanted cyanobacteria and cladophora, hopefully furnishing raw material for an Erie plastics or chemical industry.

We need to underline the fact that cyanobacteria is not an algae and maybe it is not the raw material for a new plastics industry. However, cyanobacteria, according to researchers Nora Lim and Bernard Glick, does have a great deal of potential as a source of fine chemicals, as a biofertilizer, and as a source of renewable fuel. These researchers note that the potential "is being realized as data from research in the areas of the physiology and chemistry of these organisms are gathered and as the knowledge of cyanobacterial genetics and genetic engineering increases." (Lim and Glick, *Biotechnology Advances*, "Biotechnological uses of cyanobacteria," 1985, Pages 195-208). This conclusion was made in 1985. It would be interesting to find out the current estimation of the potential uses of cyanobacteria.

The subject of Harmful Algae Blooms is a big issue and perhaps the gravest threat facing the Erie area. While we need to learn more about HABs, their causes, and their consequences, we cannot escape this serious problem by turning our heads and wishing it away. We live in exciting times in which seemingly impossible things have become possible to solve. Let's think big. Let's work urgently to better understand this threat, all to protect our greatest resource, Lake Erie.

SOURCES

Annex 4 Objectives and Targets Task Team Final Report, "Recommended Phosphorous Loading Targets for Lake Erie," May 11, 2015.

Associated Press, "Algae leads to 'impaired' designation for Lake Erie," *Erie Times-News*, March 23, 2018, B8.

Barrone, Jennifer, "Trash Collector," *Science World*, Scholastic, April 23, 2018, p. 12.

Bertani, Isabella et al., "Tracking cyanobacteria blooms: Do different monitoring approaches tell the same story?" *Science of the Total Environment*, January 2017, Vol. 575, pp. 294-308.

Biello, David, "Deadly Algae Are Everywhere, Thanks to Agriculture," http.// www.scientrifc American.com, August 8, 2014.

Brooks, Bryan et al., "In some places, in some cases, and at some times, harmful algal blooms are the greatest threat to inland water quality," *Environmental Toxicology and Chemistry*, May 2017, Vol. 36, pp. 1125-1127.

Chris, Carola, "Cuomo kicks off effort to combat algal blooms in lakes, Associated Press, February 27, 2018.

Chapman, Peter M., "Harmful algal blooms should be treated as contaminants," *Integrated Environmental Assessment & Management*, October 2015, Vol. 11, pp. 523-524.

Chapra, Stephen et al., Climate Change Impacts on Harmful Algal Blooms in U.S. Freshwaters: A Screening Level Assessment, *Environmental Science and Technology*, August 15, 2017, Vol. 51, pp. 8933-8943.

Ding, Shiming et al., "Internal phosphorus loading from sediments causes seasonal nitrogen limitation for harmful algal blooms, *Science of the Total Environment*, June 2018, Vol. 625, pp. 872-884.

EBSCOhost.com, "Senate passes Great Lakes amendment help fight harmful algal blooms," September 27, 2017.

Egan, Dan, *The Death and Life of the Great Lakes*, W.W. Norton & Co., New York, 2017, pp. 212-247.

"EPA Announces Action Plan to Combat Harmful Algal Blooms in Lake Erie," http://www.waterworld.com, March 9, 2018.

Gimenez Papiol, G., "Climate conditions, and changes, affect microalgae communities ... should we worry?" *Environmental Assessment and Management*, March 2018, Vol. 14, pp. 181-184.

Havens, Karl E. et al., "Climate Change at a Crossroad for Control of Harmful Algal Blooms," *Environmental Science and Technology*, November 3, 2015, Vol. 49, pp. 12605-12606.

Hong, Li et al., "Simultaneous Removal of Harmful Algal Blooms and Microcystins Using Microorganism and Chitosan-Modified Local Soil," Environmental Science and Technology, May 19, 2015, Vol. 49, pp. 6249-6256.

King, Mason D. et al., "Urea Release by Intermittently Saturated Sediments from a Coastal Agricultural Landscape," *Journal of Environmental Quality,* March/ April 2017, Vol. 46, pp. 302-310.

Levy, Sharon, "Microcystis Rising," *Environmental Health Perspectives*, February 2017, Vol. 125, pp. A34-A39.

Lim, Nora and Bernard Glick, *Biotechnology Advances*, "Biotechnological uses of cyanobacteria," 1985, Pages 195-208).

Martinez-Ruiz, Erika, "How do toxic metals affect harmful cyanobacteria? An integrative study with a toxigenic strain of Microcystis aeruginosa exposed to nickel stress," *Ecotoxicology & Environmental Safety*, November 2016, Vol. 133, pp. 36-46.

Medina, Victor et al., "Evaluation of the Destruction of the Harmful Cyanobacteria, MIcrocystis aeruginosa, with a Cavitation and Superoxide Generating Water Treatment Reactor," *Bulletin of Environmental Contamination & Toxicology*, June 2016, Vol. 96, pp. 791-796.

McGowan, John A. et al., "Predicting coastal algal blooms in southern California," Ecology, May 2017, Vol. 98, pp. 1419-1433.

Pa. Dept. of Environmental Protection Office of the Great Lakes et al., "Lake Erie Harmful Algal Bloom Monitoring and Response Strategy for Recreational Waters," July 2017.

Palm-Foster et al., "Farmer preferences for conservation incentives that promote voluntary phosphorus abatement in agricultural watersheds, *Journal of Soil and Water Conservation*, September/October 2017, Vol. 72, pp. 493-505.

Pang, Chengfang et al., "Multi-criteria decision analysis applied to harmful algal bloom management: A case study," *Integrated Environmental Assessment & Management*, July 2017, Vol. 13, pp. 631-639.

Patterson, Brittany, "Massive Toxic Algae Blooms May Prove a Sign of Climate Change to Come," https://www.Scientific American.com.

Paytan, Adina et al., "Internal loading of phosphate in Lake Erie Central Basin" *Science of Total Environment*, February 2017, Vol. 579, pp. 1356-1365.

Smith, Douglas R. et al., "What is causing the harmful algal blooms in Lake Erie?," *Journal of Soil and Water Conservation*, March/April 2015, Vol. 70, pp 27A-29A.

Smith, Douglas R. et al., "Lake Erie, phosphorus, and microcystin: Is it really the farmer's fault?" *Journal of Soil and Water Conservation*, January/February 2018, Vol. 73, pp. 48-57.

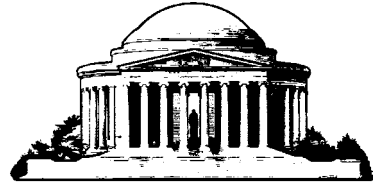
Wines, Michael, "Behind Toledo's Water Crisis, a Long-Troubled Lake Erie," *New York Times*, August 4, 2014.

Wolf, David et al., "Reeling in the Damages; Harmful algal blooms' impact on Lake Erie's recreational fishing industry," *Journal of Environmental Management*, September 2017, Vol. 199, pp. 148-157.

Wolf, David & H. Allen Klaiber, "Bloom and Bust: Toxic Algae's Impact on Nearby Property Values," Presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Mass., July 31-August 2, 2016.

Xinghua,Meng et al., Trash to Treasure: From Harmful Algal Blooms to High-Performance Electrodes for Sodium-ion Batteries, *Environmental Science and Technology*, October 20, 2015, Vol. 49, pp. 12543-12550.

Zhang, Ceci, "Slime Science," *Science World*, Scholastic, April 23, 2018, p. 23.



JEFFERSON
EDUCATIONAL SOCIETY

Erie's Think Tank for Community Progress

3207 STATE STREET
ERIE, PENNSYLVANIA 16508-2821

814-459-8000
www.jeserie.org