

2018



YEAR 3  
PROJECT UPDATE

# HARMFUL ALGAL BLOOM

RESEARCH INITIATIVE



Track Blooms  
From the Source



Produce Safe  
Drinking Water



Protect  
Public Health



Engage  
Stakeholders





# HARMFUL ALGAL BLOOM

## RESEARCH INITIATIVE

YEAR 3 PROJECT UPDATE | OCTOBER 2018

IN THE SUMMER OF 2014, cyanobacteria, commonly known as blue-green algae, made people near Lake Erie afraid to use their water. After the crisis was over, front-line state agencies in Ohio worked with science teams at Ohio universities to fill in critical gaps in our knowledge—things that were still unknown about tracking and dealing with harmful algal blooms. The newest results are in from this Harmful Algal Bloom Research Initiative (HABRI), and state agencies are now better prepared to prevent and handle water issues from harmful algal blooms.

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#### The University of Toledo

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#### Ohio Sea Grant College Program

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### Key Federal Partners

National Aeronautics and  
Space Administration

National Oceanic and  
Atmospheric Administration

U.S. Department of Agriculture

U.S. Environmental Protection Agency

U.S. Geological Survey

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## Introduction

Ohio's Harmful Algal Bloom Research Initiative (HABRI) is a statewide response to the threat of harmful algal blooms. The initiative arose out of the 2014 Toledo drinking water crisis, where elevated levels of the algal toxin microcystin in Lake Erie threatened drinking water for more than 500,000 people in northwest Ohio. To better position the state to prevent and manage future algal water quality issues, the chancellor of Ohio's Department of Higher Education (ODHE) worked with representatives from Ohio's universities to solicit critical needs and knowledge gaps from state agencies at the front lines of water quality

crises. ODHE then funded applied research at ten Ohio universities to put answers in the hands of those who need them ahead of future harmful algal blooms.

Since 2015, the initiative has launched a new round of agency-directed research each year, with the first round of projects completed in spring 2017. The Ohio Department of Higher Education has funded all research, with matching funds contributed by participating universities. For the 2018 cohort, the Ohio Environmental Protection Agency (OEPA) provided matching funds for some of the research and monitoring activities undertaken as part of the statewide effort.

| ROUND   | NUMBER OF PROJECTS | TIME SPAN | STATUS   | RESULTS            | FUNDING AMOUNT<br>(before 1:1 match<br>by universities) | FUNDING SOURCE |
|---------|--------------------|-----------|----------|--------------------|---------------------------------------------------------|----------------|
| Round 1 | 19                 | 2015-2017 | Complete | Final, 2017 report | \$2 Million                                             | ODHE           |
| Round 2 | 14                 | 2016-2018 | Complete | Final, this report | \$2 Million                                             | ODHE           |
| Round 3 | 11                 | 2018-2020 | Awarded  | N/A                | \$2.5 Million                                           | ODHE and OEPA  |
| Round 4 | 10                 | 2018-2020 | Awarded  | N/A                | \$1.5 Million                                           | ODHE           |



## We're All Over the Map

Science teams are made up of faculty and students from ten Ohio universities, spanning the state with water monitoring networks, shared sample analysis and collaborative testing of drinking water treatment options. The teams are also all over the map in terms of expertise—from engineering to medicine to economics—and that's by design. Harmful algal blooms (HABs) have many causes, many impacts and many avenues for smart prevention and management.

## What We're Working Toward

Toledo's drinking water ban in August 2014 was a wake-up call to the state and the nation. Harmful algal blooms, which result from spring storms, summer temperatures and nutrient-rich water flowing into bodies such as Lake Erie, are a persistent and increasing issue that impact communities all over the world. The challenge is, we still don't know exactly what kind of risks the blooms might present, how to fully prevent them and the best ways to protect people and watersheds. So Ohio's HABRI science teams are on the case: working with front-line health, environmental and agricultural agencies to bring them the answers they need to get the state—and region—out ahead of HABs.

## HABRI Universities



The initiative arose out of the 2014

### **TOLEDO DRINKING WATER CRISIS**

when elevated levels of the algal toxin microcystin in Lake Erie threatened drinking water for over

**500,000**  
people in northwest Ohio.

*"Having, through HABRI, a consortium of university experts to take our priorities and quickly do critical, practical research, with conclusions that we can immediately use to inform policy and the public, is invaluable."*

— Craig Butler, Director  
Ohio Environmental Protection Agency





Photo by Jo McCully

## Breaking It Down

High-quality research—even driven by urgent needs—takes time. So HABRI divided the major research questions into bite-sized chunks for science teams to turn around in two years or less. Keeping in mind the four focus areas, the first group of projects, launched in 2015, tackled the entire range of open questions—from upstream nutrient movement in tributaries and algal bloom dynamics to water treatment and public health risks. Their final results are in, along with findings from the second round of projects, which were even more focused on explicit needs and knowledge gaps identified by front-line agencies. A third cohort of teams set out in 2018 to build on what we've learned and continue driving toward solutions that will better prepare Ohio for the next crisis.

## Contributing to the National and Global HABs Dialogue

With HABRI, Ohio has created a research and outreach framework that other states can use to help solve state-wide environmental issues. As part of that effort, Ohio's university research teams are also capturing their work in the form of publications for peer review, patents and policy briefs. These products, which contribute to efforts such as the World Health Organization developing health guidelines for algal toxins, help to position Ohio as an emerging leader in providing actionable data and systems solutions to this globally relevant threat.

## Are We Better Prepared Now?

Unfortunately, harmful algal blooms arise every summer in Lake Erie and in many other lakes, rivers and reservoirs. ODHE launched HABRI to get Ohio ahead of the problem and to prevent another drinking water advisory. HABRI is only three years old, but it has already yielded results.

- Early warning systems are giving water treatment plants a high-resolution picture of what could be affecting drinking water.
- Researchers are working directly with water treatment plant operators to provide practical guidance on producing safe drinking water.
- The Ohio Department of Natural Resources has changed the way they collect information on algal toxin concentrations in sportfish fillets, sampling more frequently during HAB season and from a wider range of Lake Erie locations to better understand how harmful algal blooms affect sportfish.
- OEPA modified its permit procedure to better safeguard Ohioans when HABRI projects showed that farm crops might take in microcystins from water treatment residuals. New HABRI research is now helping OEPA better assess exposure risk from these byproducts of water treatment.
- HABRI has driven information sharing and priority setting between universities and agencies, positioning Ohio to better prevent and manage future crises.

## HABRI: What We Do

Fifty-four science teams around the state of Ohio are hard at work getting answers about harmful algal blooms that will directly help state agencies prevent and manage future HABs-related issues and will position Ohio as a leader in understanding this emerging global threat. HABRI teams work under four basic mandates:

| FOCUS AREA                                                                                                                | CHALLENGE                                                                                                                                                                                                                                                                                                                                                        | CRITICAL NEEDS OR KNOWLEDGE GAPS IDENTIFIED BY AGENCIES*                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p>Track Blooms<br/>From the Source</p> | <p>Algal blooms are not necessarily “harmful” unless they contain certain algae species and have the right mix of conditions to make toxins such as microcystin. With standard detection methods, public health officials may have to wait for hours or even days to confirm whether blooms are toxic and how they are growing and moving in the water body.</p> | <ul style="list-style-type: none"> <li>• Rapid determination of whether blooms are toxic and where toxins are moving (even apart from the main algae mass)</li> <li>• Prediction capability for the location and severity of blooms, even months ahead of time</li> <li>• The ability to track nutrients and stormwater upstream and correlate them with particular sources, storm events and algal bloom characteristics</li> <li>• Assessment of bloom and toxin locations within the vertical water column</li> </ul> |
|  <p>Produce Safe<br/>Drinking Water</p> | <p>When pollutants end up in the water source for a city, water treatment officials need to know what they’re dealing with and how best to clear them out of the water. But toxins from harmful algal blooms present a relatively new challenge globally, and the detection and treatment protocols are not mature.</p>                                          | <ul style="list-style-type: none"> <li>• Laboratory testing of water treatment methods that give treatment facilities effective and cost-efficient options for clearing out algal toxins using their current infrastructure</li> <li>• Development of new, innovative techniques for producing safe drinking water</li> </ul>                                                                                                                                                                                            |
|  <p>Protect<br/>Public Health</p>      | <p>Algal toxins such as microcystin are known to have risks for humans and animals under certain circumstances. But the laboratory studies needed to make public health guidelines have not yet been updated and tailored for the more severe, persistent algal blooms we’re seeing in Lake Erie and other freshwater sources around the world.</p>              | <ul style="list-style-type: none"> <li>• New laboratory methods to detect the presence of algal toxins and their byproducts in living tissue such as blood</li> <li>• Laboratory studies on the effects of algal toxins at the cellular level and beyond</li> <li>• Testing of fish from affected water bodies to aid officials in advising anglers</li> </ul>                                                                                                                                                           |
|  <p>Engage<br/>Stakeholders</p>        | <p>Effective crisis prevention and management involves many different types of people who need to be connected—ahead of time. The Toledo water quality crisis provided a galvanizing event that revealed the need for closer ties among scientists, agencies, municipalities and landowners.</p>                                                                 | <ul style="list-style-type: none"> <li>• Development of more integrated response networks to sample water and quickly communicate results</li> <li>• Establishment of connections between various land management practices upstream and nutrient flows downstream</li> </ul>                                                                                                                                                                                                                                            |

\*For a complete list of priorities identified by the agency advisory board, see pages 32-36



2018



# HARMFUL ALGAL BLOOM FOCUS AREAS

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Track Blooms  
From the Source



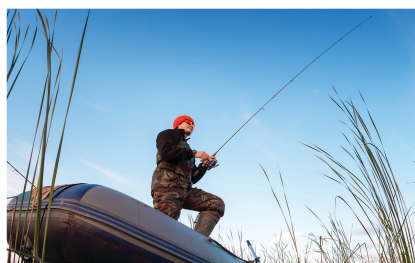
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# Track Blooms From the Source

Projects in this focus area aim to improve use of existing technologies, as well as develop new methods to detect, prevent and mitigate harmful algal blooms and their impacts. This will help to ensure drinking water safety and a healthy environment for lakeshore residents by connecting many of the potential causes and effects of harmful algal blooms, from the runoff that fuels them to the toxins that contaminate water supplies, to what makes them produce toxins in the first place.



Monitoring tributaries for nutrients that cause algal blooms

Early warning systems for bloom activity

Understanding blooms better for smarter management

## Projects in this Focus Area

**Determining Sources of Phosphorus to Western Lake Erie from Field to Lake**  
Lead: Heidelberg University, The Ohio State University

**HAB Avoidance: Vertical Movement of Harmful Algal Blooms in Lake Erie**  
Lead: The University of Toledo

**Seasonal Quantification of Toxic and Nontoxic *Planktothrix* in Sandusky Bay by qPCR**  
Lead: Bowling Green State University

**An Investigation of Central Basin Harmful Algal Blooms**  
Lead: The Ohio State University

**How Quickly Can Target Phosphorus Reductions Be Met? Robust Predictions from Multiple Watershed Models**  
Lead: The Ohio State University

**Early Season (March) Phosphorus Inventory of Offshore Waters of Lake Erie**  
Lead: Bowling Green State University





# Algal Blooms Don't Just Happen in the Western Basin

**W**hile much of the current research on harmful algal blooms focuses on Lake Erie's western basin, researchers at Ohio State's Stone Lab, along with partners from Defiance College and Kent State University, are also exploring what's happening in the central basin, from Pelee and Kelleys Islands to Erie, Pennsylvania.

Goals include identification of cyanobacteria – the blue-green algae that form harmful algal blooms – that bloom in the central basin, and whether they are capable of producing toxins such as microcystins, which can negatively affect the liver. This information helps guide decision-making processes for state and federal agencies with timely information about water conditions and potential steps they need to take to keep residents safe.

Samples were collected from the central basin between 2013 and 2017 to identify the cyanobacteria in the water, and to measure water quality parameters such as temperature, dissolved oxygen and phosphorus and nitrogen content. A partnership with Lake Metroparks, located in Lake County just east of Cleveland, also allowed the researchers to collect samples near a beach in the park district.

Scientists from NOAA's National Centers for Coastal Ocean Science (NCCOS) used imagery from MODIS and MERIS satellite sensors to quantify bloom biomass in the central basin between 2003 and 2017. Because satellite imagery requires fewer dedicated resources than targeted water sampling, an ongoing goal for the research team is helping the agency make interpretation of those images more relevant to local needs. Linking size and density of the algal blooms to data provided by the water samples is a part of that effort.

*The researchers found that central basin blooms occurred earlier in the year than western basin blooms, and that June and early July central basin blooms are mostly made up of Dolichospermum. Sampling indicated that this cyanobacterium can produce saxitoxins, which are of emerging concern in Ohio waters.*

In 2016 and 2017, more frequent sampling in June-August targeted identification of any algal toxins in the water. This included quantifying the cyanobacterial genes responsible for producing microcystins, saxitoxins and cylindrospermopsins, three toxins of concern in Lake Erie, to hopefully use the presence of those genes to predict algal toxicity in the future. Partners from the Northeast Ohio Regional Sewer District completed that work.

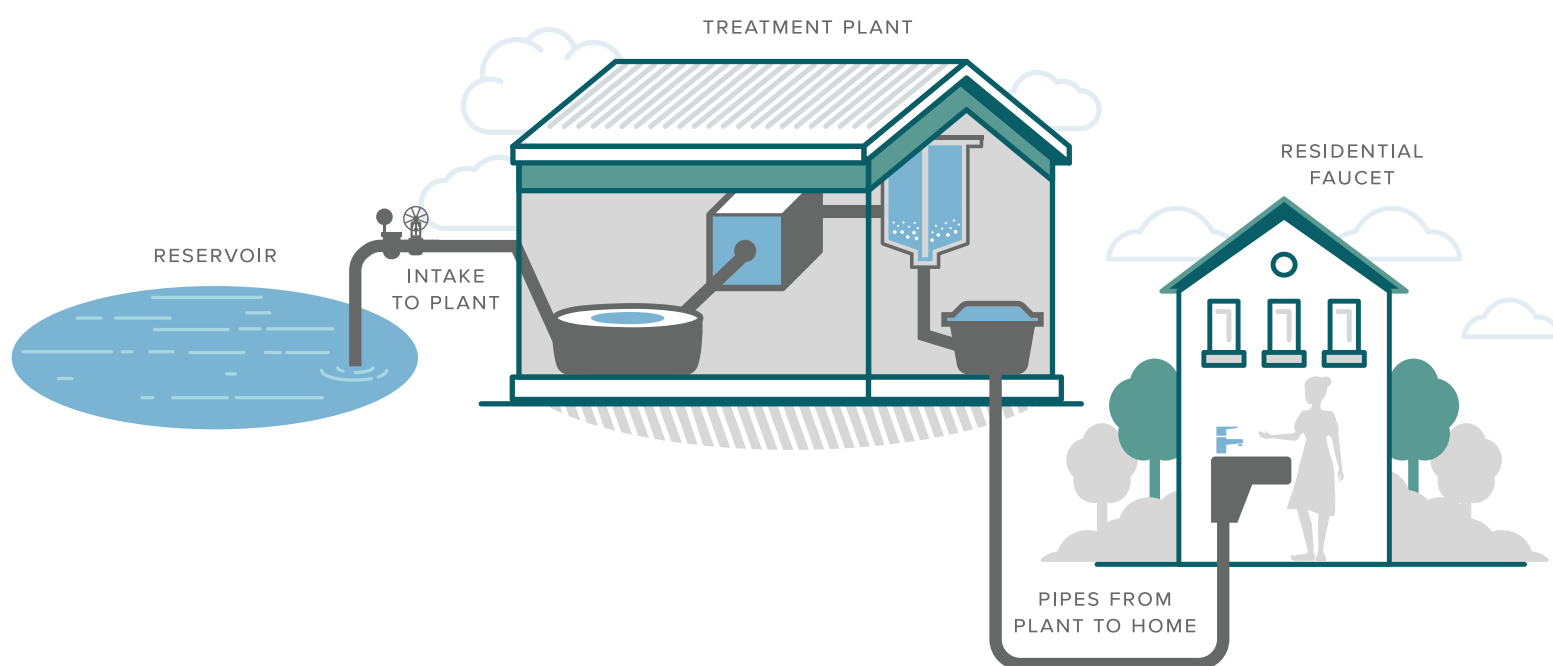
The researchers found that central basin blooms occurred earlier in the year than western basin blooms, and that June and early July central basin blooms are mostly made up of *Dolichospermum*. Sampling indicated that this cyanobacterium can produce saxitoxins, which are of emerging concern in Ohio waters. *Microcystis*, the main cyanobacterium present in western basin blooms, was found in the central basin in August and September when the western basin bloom spread eastward.





# Produce Safe Drinking Water

One of the most direct public impacts of algal blooms was seen in August 2014, when a harmful algal bloom in Toledo caused a “Do Not Drink” order to be issued for more than two days, an impact felt by residents and businesses alike. With direct guidance from state agencies at the front lines of algal drinking water crises like this one, HABRI researchers are developing new treatment methods that will give public health and water treatment professionals the tools they need to make informed decisions when water supplies are threatened by algal blooms.



## Projects in this Focus Area

**Discovery of Enzymes and Pathways Responsible for Microcystin Degradation**  
Lead: The University of Toledo

**Optimization of Carbon Barriers for Effective Removal of Dissolved Cyanotoxins from Ohio's Fresh Water**  
Lead: University of Cincinnati, The Ohio State University

**Evaluation of Optimal Algaecide Sources and Dosages for Ohio Drinking Water Sources**  
Lead: University of Akron

**Evaluating Home Point-of-Use Reverse Osmosis Membrane Systems for Cyanotoxin Removal**  
Lead: The University of Toledo

**Kinetic Models for Oxidative Destruction of Cyanotoxins in Raw Drinking Water**  
Lead: The Ohio State University





### How Much is Too Much?

**L**ike any standing body of water, reservoirs that collect water to be used as drinking water tend to grow algae. In the case of reservoirs in the Lake Erie watershed, these algae could well be cyanobacteria capable of producing toxins – *Microcystis* or *Aphanizomenon*, for example – and generally tend to clog up pipes and filters or interfere with other treatment steps, so water treatment plants use algaecides to control their growth.

The problem with killing off cyanobacteria in this way is that quite often, the algaecide may kill non-target organisms like diatoms and green algae, and the dead cyanobacteria release toxin from their cells into the water. The optimal dosage for a given algaecide addressing a certain type of algae is a delicate balance between what kills a reasonable amount of target organisms, such as cyanobacteria, and what keeps toxin release to a minimum.

Researchers at the University of Akron have developed optimal treatment protocols for four water treatment plant reservoirs – City of Akron, City of Barberton, City of Norwalk and City of Willard – that balance algal bloom removal with avoiding toxin release. All plants are now able to use a lower concentration of algaecide than they did before, resulting in a treatment cost savings while keeping drinking water safe for their residents. In-field trials in the City of Akron reservoir with the lower algaecide doses were effective at suppressing cyanobacterial growth for two weeks.

The experimental protocols used to establish those customized treatment protocols are available for other water treatment plants, so their staff can determine which algaecide source and concentration would be optimal for their own reservoir. The researchers are also providing education and outreach materials to participating water utilities to help inform users about the basics of harmful algal blooms and the best ways to manage them safely.

Algaecide dosage experiments were also used as a weeklong experiment for a Women in Engineering summer camp for middle schoolers, held at the University of Akron, that introduces girls to biomedical, civil, chemical, electrical and mechanical engineering topics.

In addition to collaborations with the participating water treatment plants, the project also allowed the researchers to interact more productively with personnel at OEPA and other HABRI researchers. At least one new research proposal involving multiple universities is being prepared for submission.

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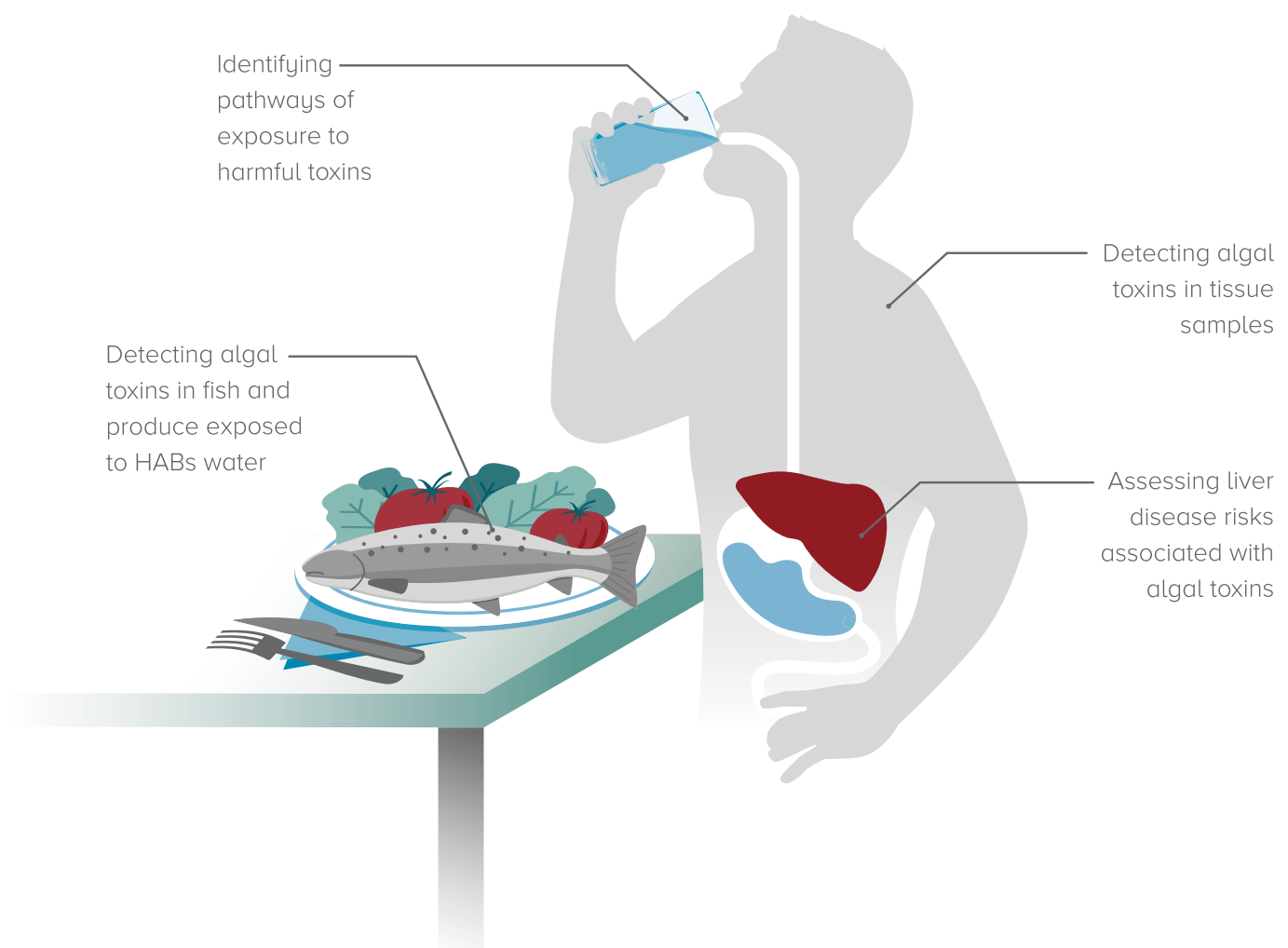
*The experimental protocols used to establish those customized treatment protocols are available for other water treatment plants, so their staff can determine which algaecide source and concentration would be optimal for their own reservoir.*





# Protect Public Health

While safe drinking water is a major focus for public health officials and researchers, scientists are also working to determine other ways that harmful algal blooms and the associated toxins—in particular microcystin—may impact human health. In this focus area, science teams develop techniques to better detect toxins in biological samples, study the effects of algal toxins on various types of cells and determine the significance of the different ways that people might be exposed to algal toxins—physical contact, eating fish, etc. These studies aim to assist agencies as they develop guidelines for handling harmful algal blooms in coming years.



## Projects in this Focus Area

**Characterization of Recreational Exposures to Cyanotoxins in the Western Lake Erie Basin**  
Lead: The University of Toledo

**A Comprehensive Approach for Evaluation of Acute Toxic Responses After Microcystin Ingestion**  
Lead: The Ohio State University

**Development of the MMPB Method for Quantifying Total Microcystins in Edible Lake Erie Fish Tissues**  
Lead: The Ohio State University





# Potential Sources of Exposure to Harmful Algal Blooms in Northwest Ohio Residents

**E**xposure to microcystins and other harmful algal bloom toxins can come in a number of forms. Most research and prevention measures focus on drinking water, while some studies have examined the effects of swimming in or otherwise coming in direct skin contact with impacted water.

Researchers collected information from individuals who use Lake Erie for recreation or during work to determine when, where and how different kinds of water exposure may be happening. The end goal in the next phase of the research (funded by HABRI round 3) is to connect those potential exposures to any self-reported health impacts, such as skin rashes or respiratory issues, which are common examples of health effects caused by cyanotoxins.

The researchers received 327 survey responses from recreational users – registered boaters, licensed anglers and residents within half a mile of the Lake Erie shoreline – who may be exposed to cyanotoxins through water-related activities like swimming or boating. Respondents were primarily male, college-educated recreational users who mostly spent time around Maumee Bay and the Lake Erie Islands. A majority of respondents use Lake Erie year-round, often for periods of three hours or more.

The water-related activities with the highest number of participants included walking on the shore, motorized boating, swimming, fishing and visiting nature areas. All reported activities in the survey involved some contact with lake water, and water skiing, tubing, jet skiing, wakeboarding and swimming had the greatest number of respondents who actually swallowed lake water during the activities.

Nearly half of recreational respondents did not report a change in their use of Lake Erie over the past five years. Of those who did change, many cited algae or water quality, along with changes in life or health, as the main reasons. About half of the respondents felt that more information on Lake Erie water quality, provided online or via email, would be beneficial to them.

This information can be used to target educational outreach efforts to specific audiences most likely to be exposed to cyanotoxins during recreational activities, and will be used to evaluate potential exposure and health effects during the next stage of the project.

About half of the respondents were willing to continue participating in the project, and the researchers will be able to target additional recruitment efforts based on knowledge gained from this round of surveys.

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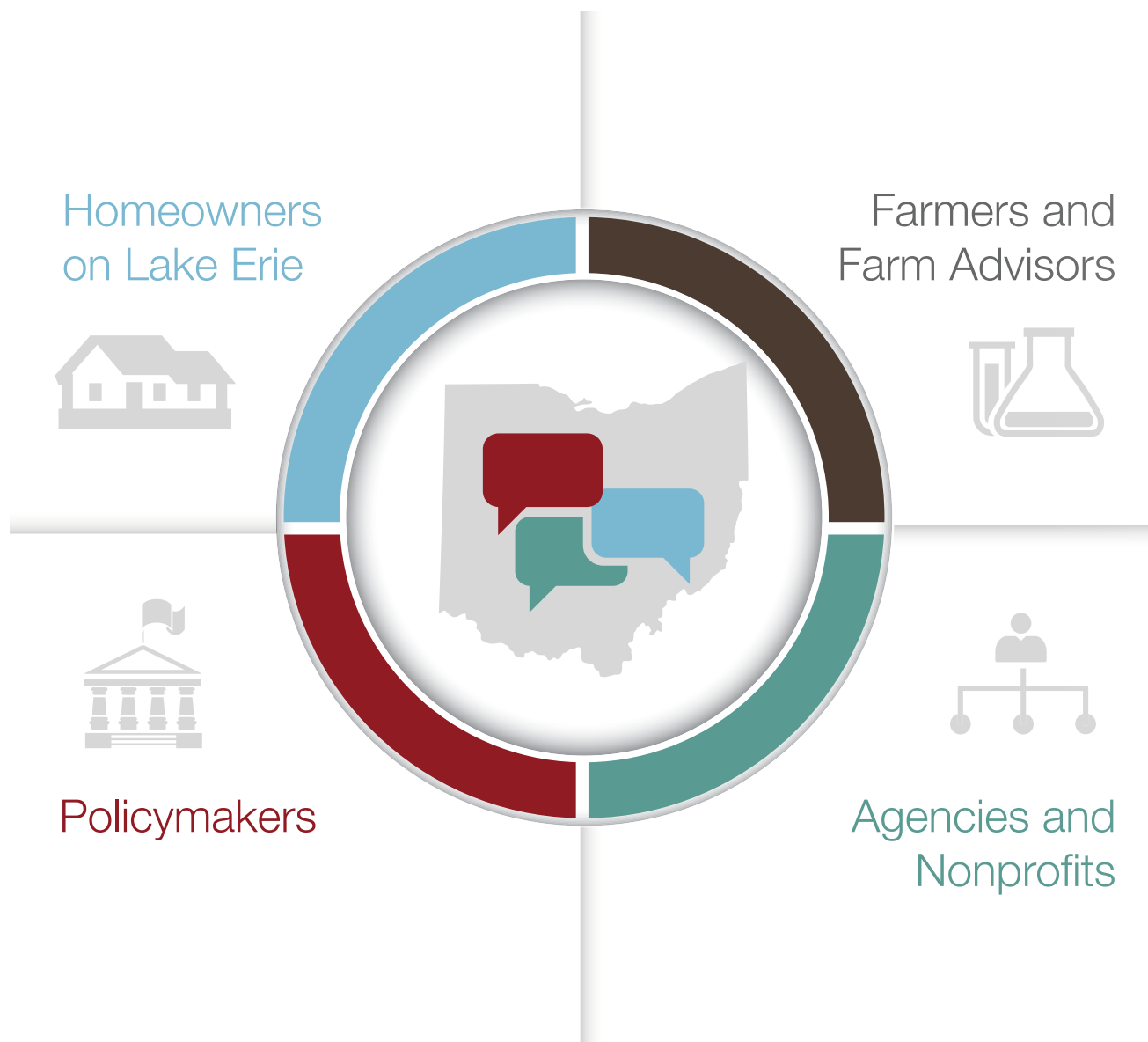
*Nearly half of recreational respondents did not report a change in their use of Lake Erie over the past five years. Of those who did change, many cited algae or water quality, along with changes in life or health, as the main reasons.*





# Engage Stakeholders

Complex issues like harmful algal blooms have many causes and many impacts—which means many different people have perspectives and roles to play in finding solutions. Researchers in this focus area are figuring out how information moves through existing networks of people and how to best use those networks—such as OSU Extension and farmer partnerships—to create effective collaborations to tackle harmful algal blooms.



## Projects in this Focus Area

**Farmer/Farm Advisor Water Quality Sampling Network**  
Lead: The Ohio State University





# Sampling Networks Involve Farmers Right From the Start

Experts say soluble phosphorus runoff from farms is an important driver of the harmful algal blooms plaguing Lake Erie and other lakes. In August 2014, a toxic bloom in western Lake Erie led to a two-day drinking water ban in Toledo, along with a renewed focus on preventing future problems.

209 farmers in the western Lake Erie basin worked with HABRI researchers to collect data about their own fields and the effects that their cropping, irrigation and soil management practices can have on downstream factors like nutrient runoff. Led by OSU Extension, these farmers collected information about conditions in 329 fields throughout the 2015-2017 field seasons, covering 15 counties and more than 11,000 acres of farmland. They used diffuse gradients in thin films (DGT) devices, small plastic plates that collect soluble phosphorus over time and can be analyzed after sampling is completed. Samples were collected in the spring and fall during the highest rainfall periods from outlets on field tiles or from drainage water management structures.

During calibration periods both in the lab and on fields, the researchers noted that samplers from the fall of 2015 underestimated phosphorus concentrations when compared to continuous monitoring, while spring 2017 samplers overestimated phosphorus concentrations. This was likely due to weather patterns, as the fall was very dry and the spring very wet. This knowledge should be taken into consideration when using the final data in management decisions.

*Overall results indicate a general relationship between higher soil phosphorus and higher phosphorus concentrations in water flowing from fields, but there was a lot of variation seen.*

While the farmers' data will be used to better understand the effects of variables such as farm practices, climate and soil type on the development of downstream harmful algal blooms, the farmers' participation also allowed for tight feedback loops that could inform their choices directly as they make business and land stewardship decisions. For example, one farmer noted the impact of cover crops on water and nutrient runoff from his field sites, encouraging an extended use of cover crops for water conservation in the future.

Overall results indicate a general relationship between higher soil phosphorus and higher phosphorus concentrations in water flowing from fields, but there was a lot of variation seen. This means that soil phosphorus testing can provide some measure of risk for phosphorus loss from the field, but other factors such as soil type, distance from the water and tillage choices play a significant role in that phosphorus loss as well.

Ultimately, this information can be used to test model predictions, ensuring that watershed managers, state agencies and legislators have the most current information when making decisions about how best to deal with freshwater harmful algal blooms without negatively impacting other economic sectors such as agriculture.



Since 2015, the Ohio Department of Higher Education has allocated **\$7.5 million** to solving the harmful algal bloom problem in Lake Erie.

HABRI arose out of the 2014 Toledo drinking water crisis when elevated levels of the algal toxin microcystin in Lake Erie threatened drinking water for over



**500,000**

PEOPLE IN NORTHWEST OHIO



The Ohio Environmental Protection Agency added **\$500,000 in funding** for 2018 HABRI projects.

Matching funds from participating universities doubled the impact of ODHE's HABRI investment to more than

**\$15**

**MILLION** in research funding.

TO DATE

**91**

Undergraduate Students

+

**86**

Graduate Students

have participated in **hands-on learning** opportunities offered by HABRI researchers.

**10**

UNIVERSITIES  
ACROSS THE  
STATE OF OHIO

*are working on solving the harmful algal bloom problem.*



HABRI breaks down research questions into bite-sized chunks that scientists can answer in **two years or less.**