2017

HARMFUL ALGAL BLOOM

RESEARCH INITIATIVE

YEAR 2
PROJECT UPDATE

Track Blooms From the Source

Produce Safe Drinking Water

Protect Public Health

Engage Stakeholders



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YEAR 2 PROJECT UPDATE | JULY 2017

IN THE SUMMER OF 2014, toxic 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 first results are in from this Harmful Algal Blooms Research Initiative (HABRI), and state agencies are now better prepared to prevent and handle water issues from harmful algal blooms.

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Ohio Department of Natural Resources
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The University of Toledo
Tom Bridgeman, Professor, Environmental Sciences

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

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) will provide 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 (before 1:1 match by universities)	FUNDING SOURCE
Round 1	19	2015-2017	Complete	Final, this report	$2 Million	ODHE
Round 2	14	2016-2018	In progress	Preliminary, this report	$2 Million	ODHE
Round 3	TBD	2018-2020	Solicitation phase	N/A	$2.5 Million	ODHE and OEPA

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

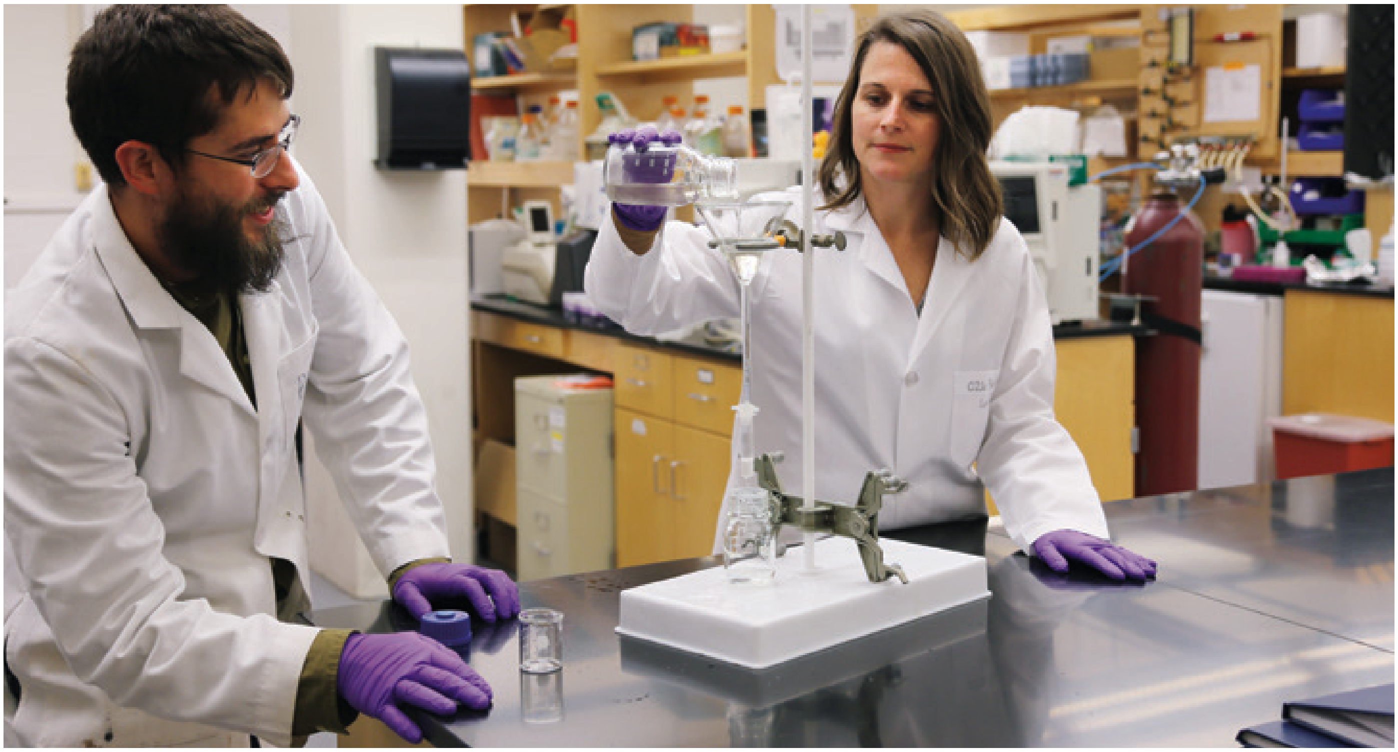
when elevated levels of the algal toxin microcystin in Lake Erie **threatened drinking water for over**

500,000

people in northwest Ohio.

"HABRI has put Ohio at the leading edge of coordinated HABs management compared to other state and even national counterparts. Being able to comment on the research projects from the proposal stage onward, we can make sure that the results will be applied and scalable."

— **Beth Messer, Acting Chief**
Division of Drinking and Ground Waters, Ohio Environmental Protection Agency



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 now in, along with preliminary results 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 will 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. The Ohio Department of Higher Education launched HABRI to get Ohio ahead of the problem and to prevent a situation like Toledo's 2014 "Do Not Drink" advisory from happening again. HABRI is only two years old, but it has already yielded results.

- Early warning systems in Maumee and Sandusky bays have given water treatment plants a much higher-resolution picture of what's coming down the pike from Lake Erie.
- HABRI research has provided new answers and practical guidance about producing safe drinking water for cities and towns dealing with algal toxins in their water sources.
- HABRI research has started to fill critical knowledge gaps about the risks that algal toxins present for human health.
- HABRI has driven information sharing and priority setting between universities and agencies, positioning Ohio to better prevent and manage future crises.
- A more integrated process has emerged for sample collection and analysis in the state.

HABRI: What We Do

Thirty-three 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*
Track blooms from the source	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.	• Rapid determination of whether blooms are toxic and where toxins are moving (even apart from the main algae mass) • Prediction capability for the location and severity of blooms, even months ahead of time • The ability to track nutrients and stormwater upstream and correlate them with particular sources, storm events and algal bloom characteristics • Assessment of bloom and toxin locations within the vertical water column
Produce safe drinking water	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.	• Laboratory testing of water treatment methods that give treatment facilities effective and cost-efficient options for clearing out algal toxins using their current infrastructure • Development of new, innovative techniques for producing safe drinking water
Protect public health	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.	• New laboratory methods to detect the presence of algal toxins and their byproducts in living tissue such as blood • Laboratory studies on the effects of algal toxins at the cellular level and beyond • Testing of fish from affected water bodies to aid officials in advising anglers
Engage stakeholders	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.	• Development of more integrated response networks to sample water and quickly communicate results • Establishment of connections between various land management practices upstream and nutrient flows downstream

*For a complete list of priorities identified by the agency advisory board, see pages 50-54.

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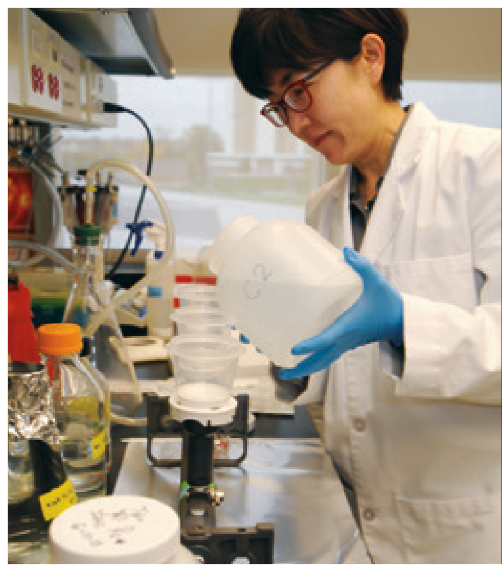

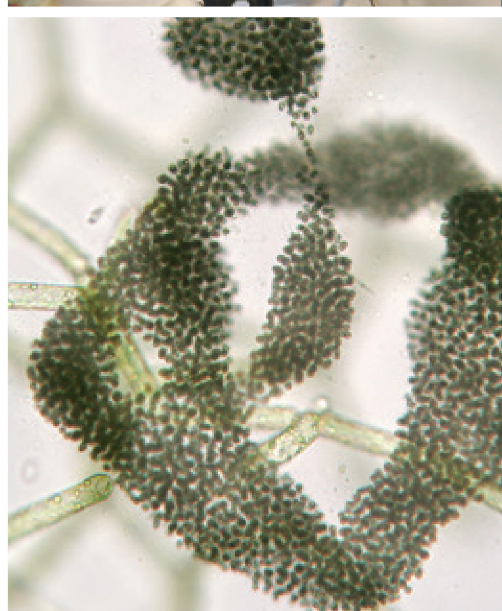

Track Blooms From the Source

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

ROUND 1

HAB Detection, Mapping and Warning Network: Sandusky Bay
Lead: Bowling Green State University

HAB Detection, Mapping and Warning Network: Maumee Bay Area
Lead: University of Toledo

Identifying the Best Strategy to Reduce Phosphorus Loads to Lake Erie from Agricultural Watersheds
Lead: Heidelberg University

ROUND 2

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: 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

Early-Warning Systems for Lake Erie Algal Blooms

With harmful algal blooms, advance warning is power when it comes to safe drinking water. Two new integrated monitoring networks for Lake Erie's western basin, where harmful algal blooms are most common, alert plant operators about bloom activity near water treatment plant intake zones. Two HABRI-funded water quality monitoring buoys, or sondes, have been linked with 16 others in the Great Lakes Observing System (GLOS) and are augmented by weekly cruises between the Oregon and Toledo water intake points during summer. The monitoring arrays provide real-time data about water quality—including the presence of algae and algal toxins—available online and reported in weekly emails to water utility managers and other stakeholders.

HABRI researchers at the University of Toledo and Bowling Green State University who are running these monitoring systems were able to warn water treatment facilities of approaching blooms in the western Lake Erie Basin during both the 2015 and 2016 seasons. In the 2016 event, researchers alerted the Toledo and Oregon water treatment plants about a harmful algal bloom in Maumee Bay that was located just five miles from the water intakes, although the plants' own buoy and water samples didn't show a bloom. The water treatment facilities were then able to adjust their internal procedures to handle the water safely.

A related HABRI project focuses upstream of Lake Erie, monitoring both nutrient amounts and their sources (fertilizer, manure, human or wild animal waste) in the rivers and streams flowing to Lake Erie. This project integrates and augments an existing array of river monitoring stations

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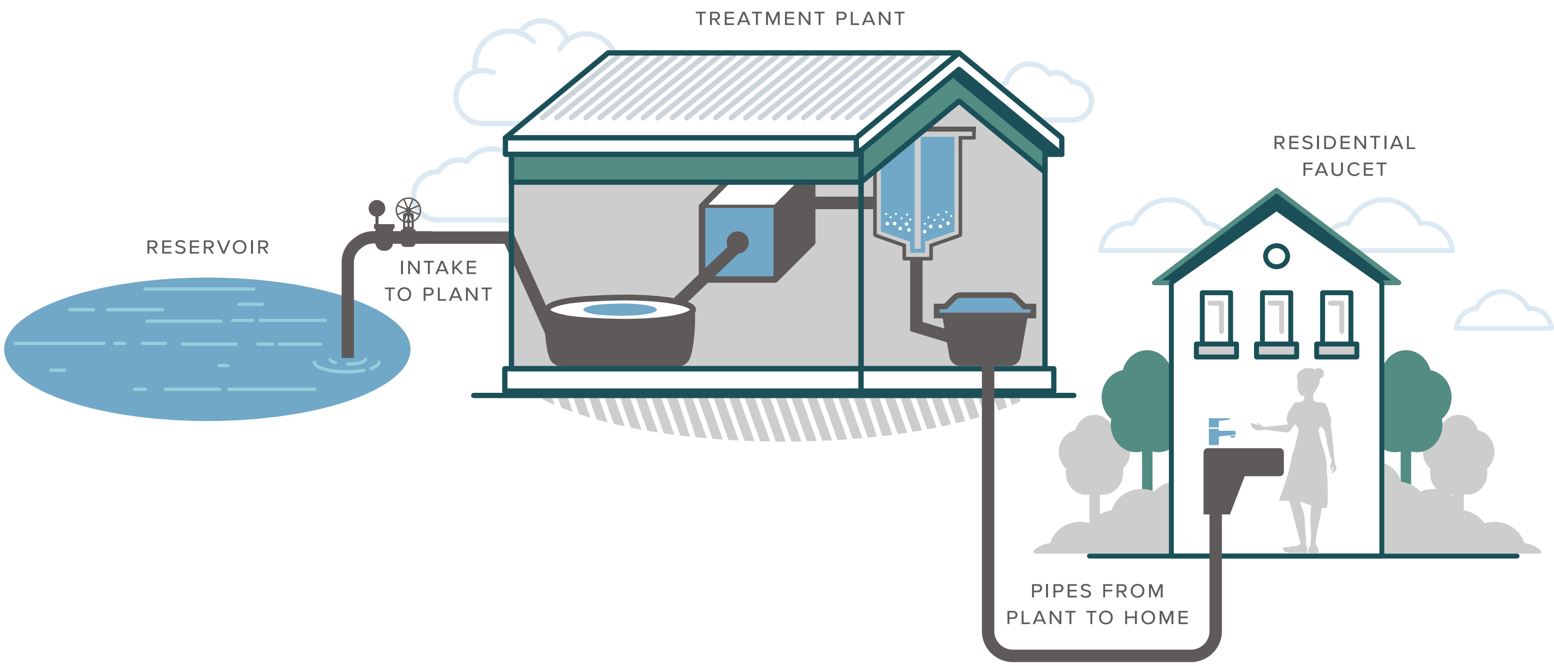
maintained by a combination of federal, state and university partners to identify possible high phosphorus-contributing locations and different sources of phosphorus runoff that may contribute to loading into Lake Erie.

The partners found that small losses of phosphorus due to current agricultural practices are prevalent throughout watersheds and are thus a major contributor to phosphorus runoff into the lake. This suggests that changes in those practices might make a substantial difference in reducing some of the spikes in phosphorus associated with heavy rainfall.

Combining data from GLOS with information from river sensors and existing climate models will also refine predictive tools that will give water managers more time to react to developing bloom events in the near future, and ultimately will lead to a better understanding of how to prevent harmful algal blooms altogether.

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

ROUND 1

Transport and Fate of Cyanotoxins in Drinking Water Distribution Systems
Lead: University of Toledo

Investigation of Water Treatment Alternatives in the Removal of Cyanotoxins
Lead: University of Toledo

Identifying Bacterial Isolates for Bioremediation of Microcystin-Contaminated Waters
Lead: Kent State University

Guidance for Powdered Activated Carbon Use to Remove Cyanotoxins
Lead: The Ohio State University

Prevention of Cyanobacterial Bloom Formation Using Cyanophages
Lead: The Ohio State University

Investigation of ELISA and Interferences for the Detection of Cyanotoxins
Lead: University of Toledo

Investigation of Water Treatment Alternatives in the Removal of Microcystin-LR
Lead: University of Kentucky, University of Toledo

Treatment of Cyanotoxins by Advanced Oxidation Techniques
Lead: University of Cincinnati

Development of Microcystin Detoxifying Water Biofilters
Lead: University of Toledo

ROUND 2

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

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

Stopping Algal Bloom Toxins at the Kitchen Tap

Researchers at the University of Toledo are taking drinking water protection out of the treatment plant and into homes by testing the effectiveness of reverse osmosis (RO) membranes, an essential component of drinking water purification systems installed under many residential kitchen sinks, at removing algal toxins from drinking water.

Reverse osmosis occurs when water is pushed through a semipermeable membrane with "holes" that are too small for anything but the water molecules themselves. The process removes minerals and particles that can cause undesirable flavors, but to the scientists, the removal of algal toxins would be an obvious additional benefit.

Partnering with NSF International (formerly the National Sanitation Foundation), the research focuses on systems commonly sold at home improvement stores, at a relatively low cost of $250-300. The goal is to develop a certification process for these home membrane systems that shows that they remove microcystin from drinking water, with the final certification protocol complete in early 2018.

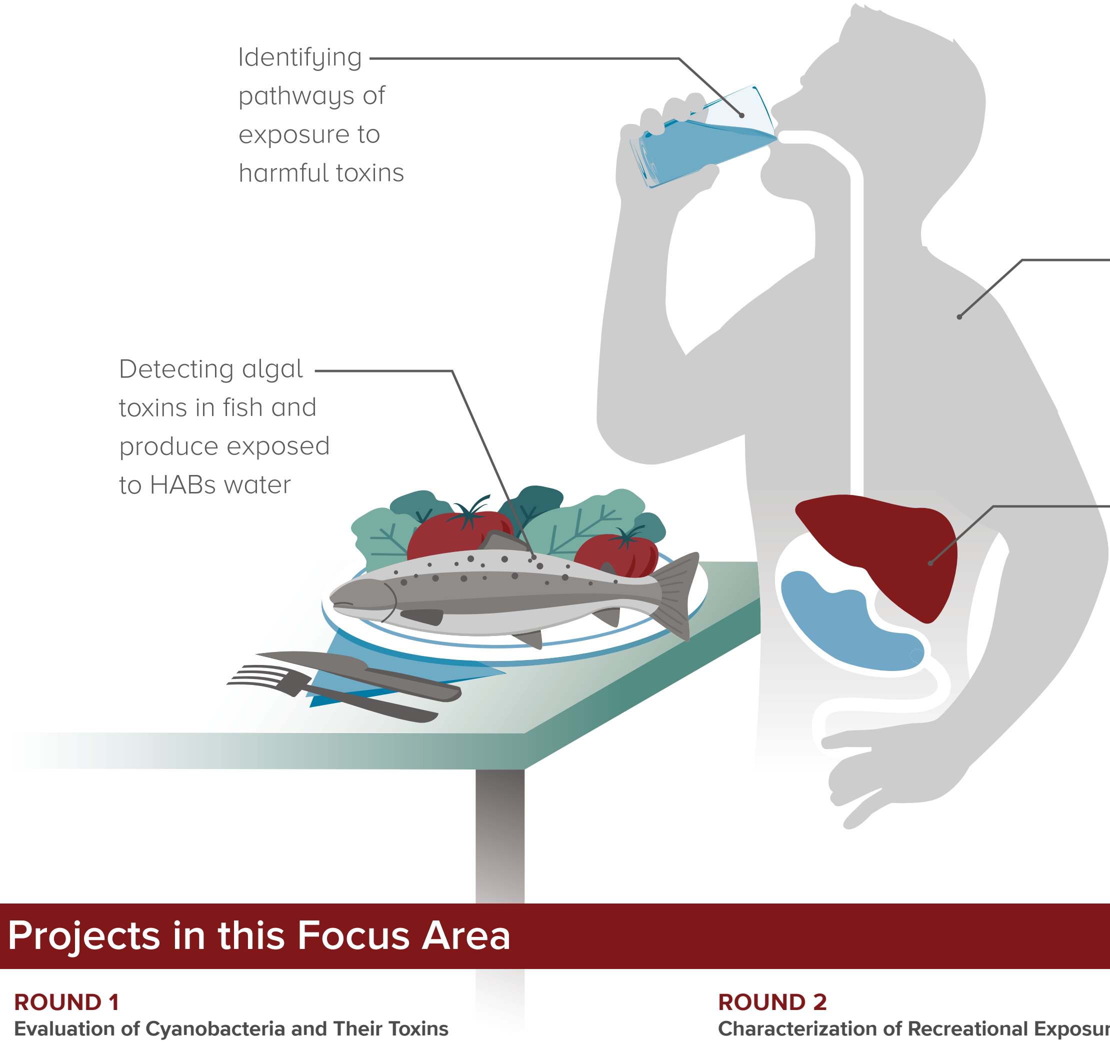
One of the challenges the researchers face is the chlorine that's added to drinking water to help disinfect it: the chemical attacks the filter membrane and can reduce its ability to filter out toxins. So they're developing some "accelerated aging" protocols based on previous research that shows that higher chlorine concentrations over a short time do the same damage as low concentrations over a longer time. This makes it possible to study chlorine's effects in detail without having to wait for it to act on the filter membranes in real time.

The chlorine trials are first completed on just the filter system components, to see in detail how the different membrane and support layers are affected. Once those characterizations are completed, the researchers will move on to drinking water that includes known levels of toxin to assess the filter system's effectiveness and complete the certification protocol.

The goal is to develop a certification process for these home membrane systems that shows that they remove microcystin from drinking water, with the final certification protocol complete in early 2018.

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

ROUND 1

Evaluation of Cyanobacteria and Their Toxins in a Two-Staged Model of Hepatocarcinogenesis
Lead: The Ohio State University

Fish Flesh and Fresh Produce as Sources of Microcystin Exposure to Humans
Lead: The Ohio State University

Impact of Microcystin on Pre-Existing Liver Disease
Lead: University of Toledo

Method Development for Detecting Toxins in Biological Samples
Lead: University of Toledo

ROUND 2

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

A Comprehensive Approach for Evaluation of Acute Toxic Reponses 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

Tracking Microcystin Exposure in Fish for Human Consumption

Lake Erie fish such as walleye and yellow perch often swim through algal blooms, absorbing potentially contaminated water through their gills and eating up smaller animals that in turn may have been exposed to toxin.

What isn't known so well is whether those fish actually retain any of the algal toxins they are exposed to, and if they do, whether those toxin concentrations are high enough to be of concern. Starting with the first round of HABRI funding, researchers at The Ohio State University have shown that there is some toxin accumulation, but findings also support the current Ohio Department of Health general guideline of eating no more than one fish meal per week from any Ohio water body.

The researchers used a new sensitive detection procedure to process fish samples from Lake Erie and Grand Lake St. Marys for the Ohio Environmental Protection Agency and the Ohio Department of Natural Resources. Results from fish caught in 2015 show that out of 73 analyzed fish, six had detectable levels of microcystin in edible tissues—which don't include the liver and other organs—and those levels were still well below consumption limits. Although none of the fish samples showed elevated levels of microcystin in the muscle tissue, fish didn't necessarily need to be swimming in a harmful algal bloom to have detectable microcystins in their tissues. Even some caught after a bloom event was over or caught in parts of Lake Erie relatively far from bloom areas contained very low levels of algal toxin.

As part of the second round of HABRI funding, the team is also working with other laboratories in Ohio and Florida to validate their new detection techniques. An additional testing method called MMPB quantifies total microcystin in tissue samples (instead of detecting specific types that may not add up to total microcystin concentrations with other methods). That approach allows agencies to issue any needed fish consumption warnings based on a conservative estimate of potential toxicity, while the more detailed analysis by type offers information specifically about some of the most toxic forms of microcystin.

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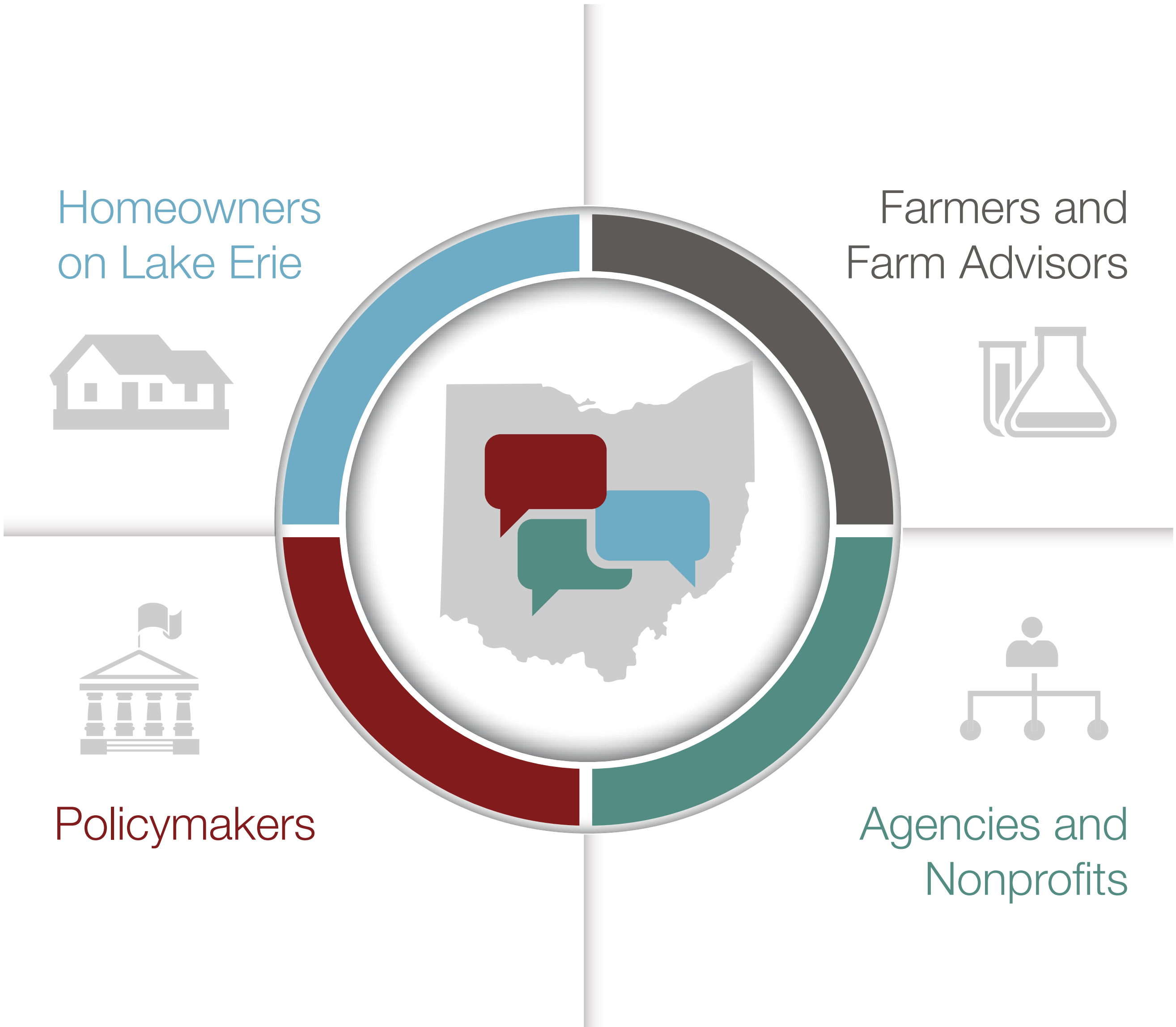
Engage Stakeholders

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

ROUND 1

Social Network Analysis of Lake Erie HABs Stakeholder Groups
Lead: Kent State University

Maumee Basin Lake Erie HABs Stakeholder Informed Decision-Making Support System
Lead: University of Toledo

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

Maumee Basin Lake Erie HABs Nutrient Management Options Comparative Analysis
Lead: The Ohio State University

Balancing Economic Tradeoffs with Zebra Mussel and Algal Bloom Management

Zebra mussels, an invasive species present in Lake Erie, have been shown to avoid *Microcystis*, the cyanobacteria that produce harmful algal blooms, when feeding. This behavior suggests that the mussels may actually be making harmful algal blooms worse by removing competition and allowing unhindered growth of toxic algae.

Those algal blooms, in turn, also take a toll on local economies, from recreational income to housing prices. This project aimed to develop an estimate for that loss in comparison to the cost of managing algal blooms to help local officials make cost-effective decisions when dealing with HABs.

The researchers found that housing values decrease by 7 to 16 percent when algal blooms in the area surpass the levels designated as safe for drinking water by the World Health Organization. Surveys at popular recreation spots also showed that anglers and beachgoers tended to substitute locations not affected by algal blooms when their favorite spots were closed, but that some people also decided to visit Lake Erie less often because algal blooms forced them to change their plans in the past.

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Currently, the researchers are combining the survey data with housing market information to create a comprehensive model of how zebra mussels and algal blooms affect the Lake Erie economy. The optimal management model being developed from this information will be applicable only to Lake Erie, but additional proposals to expand the model to the entire Great Lakes region are in the works.