# Partnering to Mitigate Harmful Algal Blooms

## in the North Central Region of the United States


A UNIVERSITY-LED PARTNERSHIP BETWEEN EXTENSION AND WATER RESOURCES RESEARCH INSTITUTES

August 2019

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This document was prepared with financial assistance from the North Central Region Water Network and the Water Resource Research Institutes in the North Central Region and the Lower Mississippi River Basin.


Cover photos clockwise from top: NOAA Great Lakes Environmental Research Laboratory; Karl Hoppe, North Dakota State University; Grace Wilkinson, Iowa State University

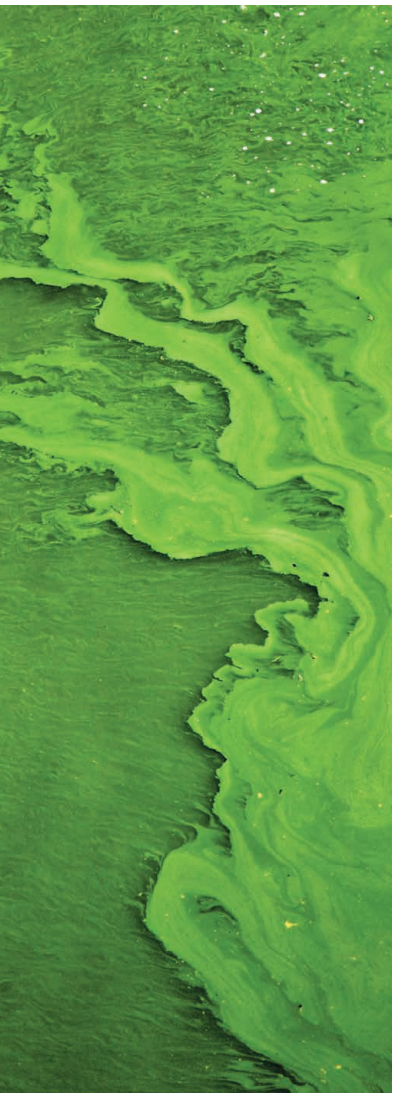
# INTRODUCTION

## Harmful Algal Blooms

Algae are terrestrial and aquatic organisms that produce energy through photosynthesis. They are a primary food source for other organisms and produce oxygen during their photosynthetic process. Rapid growth of algae, called algal blooms, occurs naturally across aquatic landscapes. One group of bacteria, cyanobacteria, has similar photosynthetic characteristics and functions in aquatic systems.

Cyanobacteria, often referred to as "blue-green algae," are common in nature and often increase drastically in late summer and early fall. Their excessive growth, often resulting in blooms, is encouraged by increases in nutrients (particularly phosphorus and nitrogen from soil and nutrient leeching from agricultural systems or municipal sewage wastes), warm water temperatures, sufficient light, and calm conditions. Many blooms, called harmful algal blooms, or HABs, are capable of producing dangerous toxins.

In 2014, HABs in Lake Erie affected the Toledo, Ohio drinking water supply, causing officials to ban tap water usage for drinking, cooking, and bathing for several days. Recreation, land value, drinking water, and human/animal health can all be negatively impacted by increased HABs. An influx of nutrients coming from the Mississippi River feeds algal blooms in the Gulf of Mexico that eventually die off. Their decomposition results in a loss of oxygen in the water causing the hypoxic zone to occur, resulting in aquatic habitat shifts, aquatic species death, and a downturn for the seafood and tourism economy (Rabalais et al 2002).



Mihály Kőles/Unsplash

HABs are increasing in frequency worldwide. A number of factors are thought to influence these increases, including changing climate conditions and increased nutrient loss to waterbodies from agriculture (Rabalais et al 2002; Sellner et al 2003). General climate predictions of increased temperatures and more frequent large precipitation events will stress landscapes and increase the likelihood of runoff events delivering nutrients to our waterbodies. This action will lead to more algal blooms and increase the chances of HABs. Waterbodies across the North Central Region play an important role in the landscape, but as these stressors continue to increase, local communities face the negative impacts of HABs.

There are over 80 known cyanotoxins produced by HABs; three of the more prominent ones are congeners of microcystin, cylindrospermopsin, and anatoxin-a (Ludek et al 2009). Microcystins, which are hepatotoxins (liver toxins), are likely the most prevalent cyanotoxins in the environment. These cyanotoxins are produced by multiple cyanobacteria, including some of the more common species in freshwater systems such as *Microcystis, Planktotrix, Oscillatoria, Dolichospermum* (also known as *Anabaena*), and *Aphanizomenon*. One other common toxin is saxitoxin, a neurotoxin, produced by both cyanobacteria and non-cyanobacteria species. This toxin is mainly associated with red tides and shellfish poisoning in marine systems.

While the US Environmental Protection Agency (USEPA) and World Health Organization (WHO) have developed guidelines for some of these toxins, and have established drinking water health advisories for microcystins and cylindrospermopsin, there are neither federal regulations in place under the Clean Water Act nor enforceable standards under the Safe Drinking Water Act. However, USEPA (2015) has listed the previously mentioned cyanotoxins on the current Contaminant Candidate Lists. This list identifies contaminants that may require regulation under the Safe Drinking Water Act.

"If states are left to develop their own response capacity… the opportunity to develop a more comprehensive and collaborative response strategy that intentionally engages the range of expertise both within a state and across the region is lost."

State health, natural resources, and agricultural agencies often take the lead on HAB issues with support from university researchers and extension professionals. Each state's collective capacity and responsibility varies across the North Central Region and generally depends on the frequency and severity of HABs in their respective state. If states are left to develop their own response capacity as the frequency and severity of blooms increase, the opportunity to develop a more comprehensive and collaborative response strategy that intentionally engages the range of expertise both within a state and across the region is lost. A more collaborative approach that includes university researchers and extension professionals can be more effective at addressing the complex issues associated with harmful algal blooms.

## Partnering to Mitigate HABs in the North Central Region of the United States

The pressing threat of HABs has led to increased research activity across many federal and non-governmental programs, including the United States Geological Survey's (USGS) Water Resources Mission Area. The Water Resources Research Act of 1964 created a national network of Water Resources Research Institutes (WRRI), administered by USGS. These comprehensive research-based entities are intended to coordinate with state and local agencies in safeguarding the nation's water resources.

WRRIs administer an annual competitive statewide program that focuses on local, state, and regional water resources problems. Each state individually sets research priorities; however, in 2017, nine WRRIs in the Upper Mississippi River Basin aligned their individual requests for proposals to include HABs as a focus area with the intent to gain, share, and synthesize knowledge on HABs in order to develop a regional product.

In 2018, with support from the North Central Region Water Network (NCRWN), this regional coordination initiative led to the formation of a twelve-state team partnering WRRIs and Cooperative Extension to assess current HABs outreach and education efforts and establish uniform recommendations for the North Central Region. Cooperative Extension, also a part of the Land-Grant University System, is often on the front lines of communicating research-based information to stakeholders. Using HABs as the focal issue, this team sought to inventory the available literature from WRRI-sponsored HABs research, inventory and identify gaps in Extension HABs publications and outreach efforts, and bring Extension and WRRIs together to assess programming needs.

This paper, accompanied by the resulting research and Extension inventories, provides:

1. **Narrative on the content of the inventories.**
2. **Recommendations for the messaging and delivery methods for HABs information as well as future research needs; potential funding sources for developing the recommended resources.**
3. **Commentary on the process and lessons learned during this project.**

## Project Team

**Figure 1. North Central Region Water Network**

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# RESEARCH AND OUTREACH ACTIVITY IN THE NORTH CENTRAL REGION STATES

Grace Wilkinson

While the twelve states in the North Central Region each have Water Resources Research Institutes and Cooperative Extension Units operating within their states, there is often regional collaboration among them. In order to identify common threads and opportunities for developing shared resources, it was necessary to first catalog the existing research projects and Extension products in each of the states. This section contains a narrative of the parameters and observations from each of these cataloging activities.

## State of the Water Resources Research Institute Funded Science

In 2018, WRRI staff inventoried the research conducted as part of the state competitive grant topic alignment effort including HAB-related projects funded between 2014 and 2017. The goal was to identify commonalities and major themes in order to coordinate and inform current and future research efforts. The inventory has since been curated and expanded to include the twelve states in the North Central United States that are part of the NCRWN. From 2014 to 2018, 30 research projects related to HABs were funded through this program, totaling over $2 million in federal and matching funds. A list of these projects has been provided in the appendix. Titles and abstracts for these projects were reviewed and categorized into thematic areas.

| Topic | Number of projects |
|---|---|
| Animal health | 2 |
| Human health | 1 |
| Identifying, monitoring, and treating | 5 |
| Landscape nutrient management | 5 |
| Prediction/Source detection | 15 |
| Other (economics; HAB effects on environment) | 2 |

**Table 1. WRRI 104(b) projects in the twelve North Central US states focused on HABs between 2014 and 2018 by primary topic.**

Using seed funding, these researchers are addressing topics that range from mitigating upstream transport of nutrients into water systems to the bacterial and chemical makeup of HABs in lakes and reservoirs. WRRI grant projects have predominantly addressed agriculture, or non-point source pollution, and have undertaken greater understanding of monitoring the early warning indicators, composition, and forecasting of future occurrences of HABs. Less studied among these

projects are the effects of HABs on health, the environment, and society. Projects focusing more generally on landscape best management practices for reducing nutrient loss were not included in this inventory unless their outcomes explicitly included outcomes on HABs; however, much research on reducing nutrient loss has been funded in this region.

This listing of projects is certainly not all-encompassing of the research conducted on HABs in the United States or even the Upper Mississippi River Basin or Great Lakes. The scope of this inventory is limited to the WRRI programs because of their proximity to their Cooperative Extension counterparts. The annual competitive statewide programs are advantageous in their flexibility and local nature. This allows for the development of a feedback loop where research results can immediately inform Extension communications, and Extension interactions with local communities can then influence research conducted through the annual competitive statewide program the next year, or even immediately if funds are available.

NOAA Great Lakes Environmental Research Laboratory

Harmful algal bloom in the western basin of Lake Erie in 2017.

## State of the Outreach in the North Central Region States

"The list, compiled in 2018, shows a widely disparate inventory of resources among states with some states having no outreach materials specific to HABs and other states having many."

In response to the inventory conducted for the WRRI annual competitive program, a team of Extension and WRRI representatives performed searches of HAB-related resources available through Extension websites of states in the North Central Region. Each participating state then reviewed and validated the list. The list, compiled in 2018, shows a widely disparate inventory of resources among states with some states having no outreach materials specific to HABs and other states having many.

During a working session at the December 2018 One Water Action Forum held in Indianapolis, members of the project team from 11 of 12 states completed a self-assessment activity in which they placed their state on a continuum of the perceived importance of HABs to their state as well as a continuum of the activity of their current program.

The self-assessment results were generally congruent with the outreach inventory. The focus of the materials on the inventory is on farm ponds in rural states, inland lakes (primarily in Minnesota and Nebraska), and the Great Lakes (primarily in Michigan and Ohio, with a dominant focus on Lake Erie). The impetus for most materials appears to be human and livestock health versus ecosystem health. There does not appear to be any materials focused on hypoxia in the Gulf of Mexico. There also appears to be a lack of emphasis on actions people can take to reduce HABs; however, it is possible that these materials were not uncovered in this search as they likely did not have appropriate keywords in the titles if there was a more general focus on reducing polluted runoff.

There are a wide variety of delivery mechanisms for the available outreach materials. Few appear to be in the form of traditional extension publications and are instead webpages (including blog posts), presentation slides available online, displays, and podcasts. These do not have built-in longevity and some of the weblinks collected for this project are already defunct or redirect to different information. During the December 2018 working session, team members ranked their priorities for products to develop; this information was incorporated into the "Products to Develop" section in this paper.

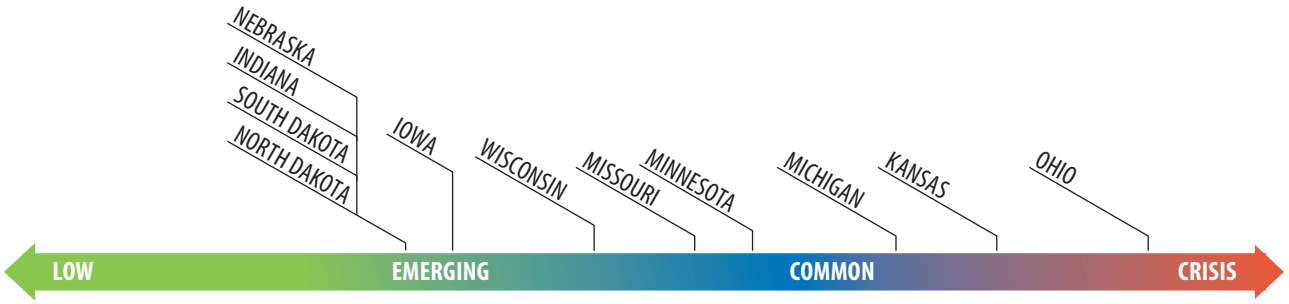



**Figure 2. Self-assessment of perceived importance of HABs to each state in attendance at December 2018 working session.**

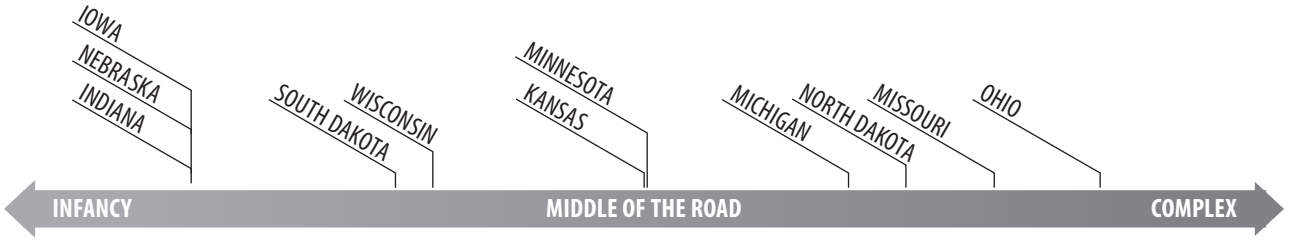


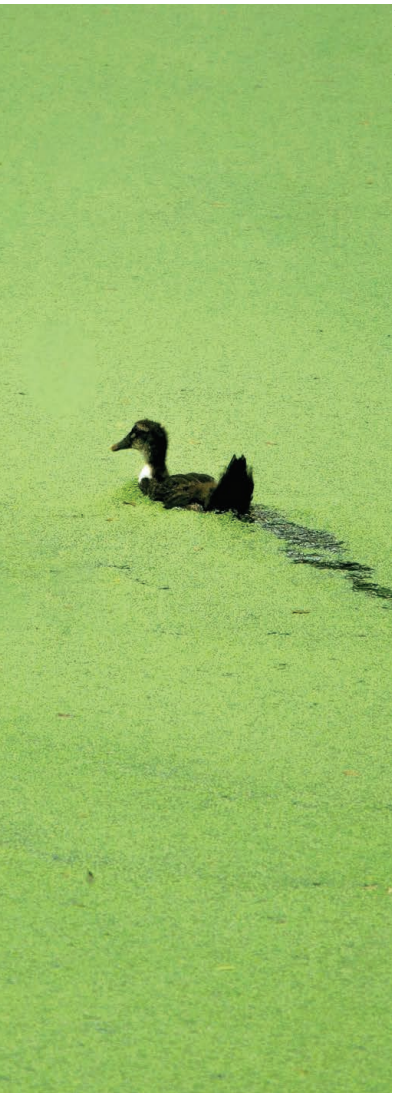

**Figure 3. Self-assessment of current HABs outreach program in each state in attendance at December 2018 working session.**

# RECOMMENDATIONS

As a team, the Extension/WRRI HABs Partnership identified five key topic areas in which to develop messaging for outreach materials:

1. **General HABs Knowledge**
2. **Identifying, Monitoring, and Treating HABs**
3. **Human Health and HABs**
4. **Animal Health and HABs**
5. **Landscape Nutrient Management Practices and HABs**

Partnership members self-selected into sub-groups to develop key messaging for each of three audiences: the **general public** (any person who might encounter HABs); the **engaged citizen** (individuals interested in taking action with HABs knowledge learned); and **water professionals** (those actively working in professions that may deal with the prevention, identification, treatment, or monitoring of HABs). Additionally, the Partnership discussed at length the various regional products that could be developed to deliver those messages, and a sub-group further refined and prioritized those product recommendations.



Noshad Arefin/Unsplash

## General HABs Knowledge

There is a need across the region to provide basic information on HABs. The products developed with this messaging are a "one-stop shop" for high-level HABs information. For states that are lacking in resources or public demand to provide more in-depth HABs information on specific topics, these products provide a base-level introduction to HABs.

### KEY MESSAGING: GENERAL PUBLIC

- HABs in the North Central Region of the US are mainly caused by several types of cyanobacteria, commonly referred to as blue-green algae.
- Not all cyanobacteria produce toxins, but if and when they do, the toxins can cause mild to serious health issues to humans and animals.
- Occurrences and severity of HABs may increase with warmer temperatures and increased phosphorus runoff from land application of fertilizers and animal waste, soil runoff, and municipal sources.
- Decrease phosphorus and nitrogen use near water bodies as HABs need these nutrients to grow.
- Don't feed waterfowl, such as ducks and geese, as their excrement may increase nutrient input into the water body.

### KEY MESSAGING: ENGAGED CITIZEN

- Know which labs, universities, or state agencies can help in identifying whether an algal bloom is actually a HAB.
- Encourage forums that involve researchers, agency personnel, practitioners, farmers, riparians, and other landowners to discuss how HABs can be managed or prevented.
- Collaborate with lake associations and water citizen groups to post signage about HABs if they routinely occur and are not well-publicized by state or local agencies.

### KEY MESSAGING: WATER PROFESSIONALS

- Identifying and reporting the presence of HABs help determine their patterns of occurrence and can help alert the public when a concern arises. To help in this effort, the Center for Disease Control has launched the One Health Harmful Algal Bloom System (OHHABS), a voluntary reporting system available to all state and territorial health departments to help track HAB occurrence.
- Seeking research opportunities is encouraged to further knowledge on predicting and controlling HABs, and determining the environmental drivers of HABs and toxin production.

## Identifying, Monitoring, and Treating HABs

Identifying, monitoring, and treating HABs are the logical next steps for those in regions experiencing HABs. Those that see algal blooms will wonder if they are harmful algae or nuisance algae; water professionals and citizen groups like watershed coalitions and lake associations will be interested to know how they can control them. There are many resources that exist outside of Extension for identifying, monitoring, and treating HABs, particularly those offered by the Environmental Protection Agency and state agencies (who typically house a monitoring program for HABs or beach closures). Extension products can provide information specific to identifying, monitoring, and treating HABs that then refer people to these additional resources.

> "Those that see algal blooms will wonder if they are harmful algae or nuisance algae; water professionals and citizen groups… will be interested to know how they can control them."

### KEY MESSAGING: GENERAL PUBLIC

- There are many factors that affect the growth and bloom of harmful algae in the lakes and waterbodies. To name a few, main factors relate to weather (temperature, sunlight, humidity), upstream watershed management (nutrients, sediment, bacteria), and water condition (nutrients, pH, dissolved oxygen, turbidity, cyanotoxins, etc.). Blooms usually happen when the right combination of the factors are met, usually during intense agricultural activity in spring, hot drought period in summer, or early fall.
- While some HABs will have a distinctive look, many can be difficult or impossible to differentiate from harmless algae with the naked eye.
- You cannot tell if a HAB is producing toxins just by looking at it. In general, keep out of the water if there are visible scums or the water appears bright green, blue-green, red, or pink. Keep your pets from drinking or playing in the water.

- Know the relevant contact to report suspected blooms. This will likely be a local office of your state's agency charged with environmental protection or natural resources management. Additionally, your state's department of health is likely to request reports of related illness.

## KEY MESSAGING: ENGAGED CITIZEN

- You can't visually detect if a bloom is producing toxins. Sampling and identification of HABs is best left to professionals. Familiarize yourself with the public agencies responsible for monitoring and testing public waters.
- For private waters, there may be contractors in your area that provide identification services; some public agencies maintain lists of these private entities.
- Identify local literature regarding "jar" and "stick" tests. Microscopic colonies of planktonic blue-green algae can't be lifted from the water on a stick; long, filamentous colonies of green algae can. Common planktonic blue-green algae (HABs) will often float to the surface of a jar of water; planktonic green algae and diatoms will settle to the bottom.
- If HABs have been seen in the past in the lake, a simple monitoring of weather conditions (air temperature and precipitation) near the lake (or at www.cocorahs.org community-led weather station network) and watershed management (crop planting and harvesting, fertilizer application, barren soil) can be used to increase awareness of potential blooms.

Lois Wolfson, Michigan State University

## KEY MESSAGING: WATER PROFESSIONALS

- Positively identifying HAB organisms is a specialized skill, even among water professionals. If you don't have relevant training, familiarize yourself with local professionals who do. Identification resources that go to genus or species level will usually be based upon microscopy.
- A fluorometer or optical probe that can detect the pigment phycocyanin is a useful tool in determining the presence of a bloom (although not in identifying the responsible organism).
- The CyAN app is a new collaborative effort by the USEPA, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and USGS and is publicly available (at present only) to Android devices (Boykin 2019). It applies an algorithm to flag satellite images for surface blue-green blooms on a map interface that includes more than 2,000 of the United State's larger lakes and reservoirs.
- Although they can be tenacious, blue-green algae respond to commonly used algaecides or chemical coagulants that remove nutrients and suspended particles from the water column. Chemical applications are associated with some environmental risks and should only be trusted to trained and licensed professionals in public or common waters.

- Benthic HABs are even more tenacious and may require the application of different algaecides in series or combining and algaecide, herbicide, and surfactant.
- Continuous records of HAB driving factors (weather, watershed management) and available statistical models (USGS) can be used for HAB prediction. Occasional water sampling during long drought periods and increased agricultural activity in a watershed can be used for early detection of growth of cyanobacteria.

## Human Health and HABs

Both humans and domestic animals can come into contact with HABs, either through drinking contaminated water, eating fish, or recreating in lakes and rivers. Ingesting toxins produced by some HABs can lead to neurological problems, including respiratory distress and convulsions (neurotoxins), and gastrointestinal illnesses, liver, and kidney diseases (hepatotoxins). Contact with the skin (dermatoxins) can cause rashes and skin irritation. In addition to these acute effects, the effects of chronic exposure to cyanotoxins are difficult to study and not well understood. Human health concerns may be a key entry point for raising concern among many populations and policymakers.

"Human health concerns may be a key entry point for raising concern among many populations and policymakers."

### KEY MESSAGING: GENERAL PUBLIC

- You cannot tell if an algal bloom is producing toxins just by looking at it.
- Keep out of the water if there are visible scums or the water appears bright green, blue-green, red, or pink. Also, keep your pets from drinking or playing in the water.
- If you were exposed to HABs and are now experiencing symptoms, contact a poison control center or your doctor.
- Report suspected HAB-toxin symptoms to your state or local department of health.

### KEY MESSAGING: ENGAGED CITIZEN

- Post signage around your lake concerning HABs and health-related concerns.
- Talk with your neighbors about best management practices for reducing HABs.
- Establish monitoring programs to help identify where blooms are occurring.
- Use HAB reporting and forecasting systems where available to plan activities in or near water bodies that contain HABs.

### KEY MESSAGING: WATER PROFESSIONALS

- Encourage legislators to develop science-based standards for HAB toxins in recreational and drinking water.

- Hold programs to teach people about HABs and human health issues.
- Share methods and protocols with other professionals for HABs education and response.
- Participate in discussions, workshops, and seminars to learn latest research and activities to reduce and manage HABs.

## Animal Health and HABs

In some states, like North Dakota and Missouri, the primary public concern regarding HABs resulted from pet and livestock deaths from drinking or coming into contact with algal toxins. While humans might attribute their symptoms to other common illnesses, animals that ingest toxins may suffer sudden death from acute toxicity, placing more importance on preventing animals from coming into contact with blooms.

### KEY MESSAGING: GENERAL PUBLIC

Karl Hoppe, North Dakota State University Extension

- Pets or livestock should not play, wade, swim, or drink from water bodies with blooms.
- Drinking water from stagnant ponds or other water-containing structures, like lagoons or dugouts, can cause sudden death in animals including livestock and pets.
- The neuro and liver toxins that are produced by cyanobacteria can show symptoms of poisoning within 20 minutes of ingestion. These symptoms include weakness, staggering, difficulty in breathing, convulsions, and death.

### KEY MESSAGING: ENGAGED CITIZEN

- Report impacted water bodies to responsible monitoring agencies and inform other pet owners and livestock users through community groups or public signage.
- If you suspect an animal has suffered poisoning from a bloom, contact a veterinarian to confirm the cause of death. If the death was caused by the bloom, report it to responsible monitoring agencies.

### KEY MESSAGING: WATER PROFESSIONALS

- Water supplies impacted by HABs should be treated or left unused until tested safe and the bloom has disappeared.
- Blooms usually do not persist; rain, heavy winds or cooler temperatures may inhibit or break up blooms, mixing the cyanobacteria into the water body within a few days.
- Under continuing favorable conditions, blooms may last for several weeks. Cyanobacteria can survive under ice and throughout winter conditions.

## Landscape Nutrient Management Practices and HABs

"Nutrient management practices that address both nitrogen and phosphorus losses are a primary prevention strategy for HABs."

Anthropogenic sources of nutrients are a primary contributor to the development of HABs in aquatic ecosystems. Agricultural, or non-point source systems, are inherently leaky systems, and their impacts on aquatic systems are increased by climate change. Forecasting how nutrients leave the landscape is a challenge because of the unpredictability of weather conditions. However, the use of nutrient management practices can minimize nutrient loss from agricultural systems and benefit farmers and those downstream. Nutrient management practices that address both nitrogen and phosphorus losses are a primary prevention strategy for HABs.

### KEY MESSAGING: GENERAL PUBLIC

- The actions of an individual can have watershed-level impacts locally and downstream. Individuals should be encouraged to think holistically when considering actions on their property.
- State and federal cost-share programs are available to assist with implementing nutrient management practices.
- Farm organizations, private sector companies, Extension, and research institutions can provide technical assistance, support, problem troubleshooting, and serve as an informational forum to support practice implementation.
- Nutrient management practices that provide cost savings to the individual, thus economic savings and the net profit gained through nutrient management practice use, should be emphasized.

Kevin Erb, UW–Madison Division of Extension

### KEY MESSAGING: ENGAGED CITIZEN

- Farmers and landowners are encouraged to assess their farms for nitrogen and phosphorus loss risk potential and test tile drainage to determine any contribution to nutrient loading downstream.
- Findings from field and farm assessments and monitoring should be addressed through water quality management strategies and conservation practice implementation.
- Farmers and landowners should be encouraged to lead by example through signage, statements, and testimonials to peers and the public regarding their efforts to mitigate nutrient losses.

### KEY MESSAGING: WATER PROFESSIONALS

- Farmers, golf course managers, and homeowners should focus on the efficiency of nitrogen and phosphorus use and apply fertilizer inputs using the right source, timing, rate, and placement.
- Erosion control and soil quality restoration on both urban and rural landscapes are the best defenses against excessive phosphorus loss. These long-term nutrient management strategies will provide additional benefits to the landowner as well as helping retain valuable topsoil.

- Private sector partners like certified crop advisers are the front-line messengers who can provide nutrient management information to farmers and landowners. Collaborations with crop advisers are an effective method for sharing information about nutrient management for managing HABs.
- Watershed associations, coalitions, or management authorities can establish a watershed total maximum daily load (TMDL) at the threshold where HABs can be controlled and encourage citizens living in the watershed to adopt management practices. A TMDL can be used to measure progress and establish targets for citizens to achieve.

## Products to Develop

Research-based messages for building awareness and facilitating action developed by the HABs project team will have utility for a broad range of audiences (listed in the sidebar on this page).

The Products team developed an inventory of existing HAB outreach materials available in the North Central Region, crowdsourced product needs from the HABs team and North Central One Water Action Forum participants and identified successful outreach tools used in Extension programming. Based on these assessments, the team recommends developing the following products for use in Extension and outreach programming for the primary audience. These products will be used by the primary audience to conduct outreach in peer-to-peer and professional development opportunities with other members of the primary audience and for programming specific to members of the secondary audience.

PRIMARY AUDIENCE OUTREACH PRODUCTS:

1. **Social media toolkit with content, photos, and graphics.**
2. **Regional webinar series for sharing HAB research and resources.**
3. **Bank of pre-written articles available for states to include in existing newsletters, blogs, and other communication channels.**
4. **A series of factsheets that can be customized with state-level branding.**
5. **HAB poster template.**
6. **In-person workshops in tandem with regional events on specific state of the science HAB-related topics.**
7. **HAB resource webpage with regional resources, research, and tools.**
8. **HAB videos for staff to use in educational programming, web-based, and social media outreach that use existing videos where applicable and filling gaps where needed.**
9. **Media Toolkit for educators.**

As a follow-on project to this report, a team will further refine and prioritize this list for regional development.

### CONSERVATION AND AGRICULTURAL PROFESSIONAL AUDIENCES FOR HAB MESSAGING:

PRIMARY AUDIENCES:

- Extension professionals and WRRI faculty and staff to inform their Extension and outreach programming, respectively.

SECONDARY AUDIENCES:

- Certified crop advisors
- Soil and water conservation district staff
- Agricultural and environmental engineers
- Consultants
- Private technical service providers
- Agricultural retailers and organization representatives
- Local watershed group staff
- Farmers and ranchers
- NGO staff
- Municipal and county staff
- County conservation boards
- Community development professionals
- Private sector planners
- Public and private utility staff
- Secondary science and agriculture educators
- Citizen scientists

### LOW-PRIORITY PRODUCTS

The team discussed several other potential products including creating a mobile HAB education trailer, a regional HAB newsletter, and HAB mobile apps. Because of the high development and maintenance cost of the education trailer and mobile app, the team placed a low priority on these two products. The team recommended developing an article bank to distribute through existing newsletters in the region to obtain a larger reach and impact with HAB information.

## Future Research Needs

There remains much to discover about HABs. Rebecca North, Assistant Professor of Water Quality at the University of Missouri, includes a slide in presentations about HABs titled "What we don't know about CyanoHABs," which concisely sums up research needs about the basic behavior of HABs:

- Which water bodies are most at risk?
- Are they toxic? Which toxins?
- Where are they coming from? What factors regulate their growth and/or toxin production?
- How long do toxins persist?
- Are they getting worse?

Team members identified additional topics for understanding the effects of HABs as well as applied research addressing public needs, including:

- New methods for treating HABs in lakes
- Long-term human health effects from HAB exposure
- Effects of HABs on aquatic organisms
- Effects of HABs on agricultural practices
- Effects of HABs on fisheries
- Developing models to predict HAB formation
- Warning systems to protect public health from HABs

While WRRIs have latitude in what research they fund – the Water Resources Research Act describes the scope of research as any "that fosters improvements in water supply reliability [and] the exploration of new ideas that address water problems or expand understanding of water and water-related phenomena" (p.2242) – there simply aren't enough financial resources available to study everything. WRRI funding is also contingent on a Congressional appropriation each fiscal year, so projects are typically limited to one- or two-year projects. Additionally, federal organizations like the Environmental Protection Agency have HABs research programs that are better suited to address long-range projects.

With that in mind, WRRIs in the North Central Region should work closely with their state agencies and Extension educators on an annual basis to identify the most pressing local concerns about HABs. With continued communication within the region, Institute-funded research will meet both local needs as well as contribute to the broader body of knowledge about HABs.

# IMPLEMENTATION FUNDING

Developing regional resources for HABs outreach and education will require financial resources for design and production. This team has access to $10,000 of implementation funding through NCRWN to begin creating the products listed previously. Priority will be given to those products that can be shared readily throughout the region, like the social media toolkit and pre-written newsletter articles. Beyond that, states or combinations of states may opt to pursue local funding opportunities to create resources using the targeted messaging developed through this project. This could be sourced from base programmatic funding at individual institutions or by pursuing external grants. A few examples of external funding opportunities include:

- American Water Environmental Grant Program
- Archer Daniels Midland "ADM Cares" Program
- Land O'Lakes Foundation
- McKnight Foundation
- Minnesota's Environment and Natural Resources Trust Fund
- State-administered Clean Water Act Section 319(h) Funding

By using consistent messaging across the region, resources developed locally can still be used as models for other states to adopt or reference in their outreach.

NOAA Great Lakes Environmental Research Laboratory

# LESSONS LEARNED

"The sheer magnitude of HABs as a subject area became abundantly clear just in looking at the Institute-funded research projects throughout the region."

The study of and communications about HABs is vast and complex – as is building a large, multi-state team. At the onset, the project objectives seemed straightforward: produce inventories of research and outreach in the region, and then provide recommendations and a path forward to remedy any gaps. Upon the conclusion of the planning phase of this project, the project team reflected on observations made throughout the process of preparing this white paper and the discussions that preceded it.

## Compartmentalizing HABs and Setting Parameters

Reiterated several times throughout this paper and supported by the breadth of the future research recommendations, existing and emerging literature on HABs crosses many disciplines and aspects of HABs mitigation, identification, management, and environmental and health-related impacts. The sheer magnitude of HABs as a subject area became abundantly clear just in looking at the Institute-funded research projects throughout the region. These projects were initially sorted into nine topic areas, and even then, the spectrum of HABs research topics was not entirely covered.

This project could not be completed given the time and resources allotted without setting strict parameters. Although a significant body of work on HABs, both research and outreach, is conducted outside of the Institutes and Extension, the team agreed to stick within those boundaries for consistency. Further, because the end-product was focused on Extension-based outreach, the team chose key topic areas that aligned with the needs of the main constituents of Extension, even though research spanned additional topic areas. Staying within these constructs was necessary and sometimes difficult, based upon the frequent discovery of additional resources from outside agencies and organizations.

## Variations Across the Region in Partnerships and Goals

While the North Central Region of the United States shares commonalities that result in mutual water resource concerns, each state's unique approach and interest in HABs made developing a shared vision more difficult. The reality is that land-grant universities are not the only or even preferred source for information about HABs, and identifying key partners in each state was imperative for assessing existing communication resources. Some states had as many as six state agencies involved in HABs tracking, response and outreach, whereas others had one agency that took the lead, or even no clear responsible party beyond individual HAB response. To be expected, agency involvement typically dictated the focus area for the state. For example, if the state health department was the lead agency dealing with HABs, the primary concern would be tracking cases of human exposure.

The team had to synthesize messaging for topic areas that would cross the spectrum of HABs, knowing that not all state partners would have use or motivation for adopting or contributing to every area. Determining the "right formula" for regional goals that would be accessible for states with less-developed outreach programs and fewer partner agencies meant that advanced state programs served as models for the rest of the team.

## Building the WRRI and Extension Connection

Originally proposed as a secondary goal, strengthening the relationship between WRRIs and Extension staff in each state ultimately became a major impact of this project. The degree to

which WRRIs and Extension staff collaborated, or even knew one another, varied from state to state. This became apparent as early as the proposal writing process, when selecting team members in each state proved challenging. Many of the team members who committed did not see themselves as HAB subject-matter experts, but were willing to participate in order to learn more about HABs, enter into new partnerships, and contribute something of value to the region.

Deliberate space for open dialogue was key in building these relationships. The monthly meetings were designed for team participation in addition to providing key project updates. The agenda always included an open call for announcements of upcoming events and opportunities as well as specific discussion questions, like:

- In your experience, what are the most frequently asked questions about HABs?
- What agencies and organizations in your state are involved with responding to and communicating about HABs and how can we coordinate with them?
- What Extension products are most useful and who are our stakeholders?
- How do we incorporate recent research into our outreach products?

This discussion served as a valuable resource for developing the larger picture of HABs outreach and response across the region, and providing this information in real time fostered active conversation among team members. The team's only in-person meeting was held about halfway through the project and significantly advanced team interaction and dynamics. Ideally, a team like this, widespread physically and without pre-existing relationships, would kick off the project with an in-person meeting to build a base of familiarity with one another.

## Team Composition and Motivating Factors

"This team now has a framework for longstanding partnership efforts, but continuing to build a culture of collaboration will take intentional effort."

When developing the team, the original intention was to gather those Extension staff that were working the most with HABs in the state, and WRRI directors or staff that would ostensibly represent their funded researchers. As mentioned previously, the final team ended up being a mix of people who met the above criteria and those who were simply willing to participate. This was not necessarily a negative. As a planning grant, the funding did not provide for salary support for team members, so participating was a volunteer assignment. While this made it challenging at times to prioritize project work above regular duties, team members were committed to the larger goals of discovery and collaboration. Additionally, in many cases, the people communicating about HABs were not HAB experts, so the team related to those who will use the recommended messaging. Those team members who do work on HABs were invaluable resources, greatly increasing the collective knowledge of the group.

Overall, phase one of this project resulted in a better understanding of existing research and outreach in the North Central Region, new and strengthened relationships among WRRI and Extension staff, and a vision to move forward to elevate the region's portfolio of HABs research and outreach. This team now has a framework for longstanding partnership efforts, but continuing to build a culture of collaboration will take intentional effort. This may take the form of structured exchanges, like a symposium, or through intermittent communication on the existing project email list. Whatever the methods selected, partnering to solve water resource issues in our states is the best path forward.

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## Additional Resources

- CDC Harmful Algal Bloom Associated Illness Resources (including general information, health promotion materials, publications, data, and statistics) – www.cdc.gov/habs
- Cyanobacteria Assessment Network Mobile Application (CyAN app) – www.epa.gov/water-research/cyanobacteria-assessment-network-mobile-application-cyan-app
- EPA Harmful Algal Bloom Resources (including webinars, infographics, photos, and videos) – www.epa.gov/nutrientpollution/harmful-algal-blooms
- EPA Region V HABs Workgroup – contact Wendy Drake (drake.wendy@epa.gov)
- EPA State HABs Monitoring Programs and Resources – www.epa.gov/cyanohabs/state-habs-monitoring-programs-and-resources
- Minnesota LakeBrowser – lakes.rs.umn.edu
- One Health Harmful Algal Bloom System (OHHABS) voluntary reporting system – www.cdc.gov/habs/ohhabs.html
- NOAA Harmful Algal Blooms Resources (including videos, HAB forecasting, research) – oceanservice.noaa.gov/hazards/hab
- Upper Mississippi River Harmful Algal Bloom Response Resource Manual – www.umrba.org/wq/umr-hab-response-resource-manual.pdf

## Extension Inventory

**SPECIFIC TO HARMFUL ALGAL BLOOMS**

*This Extension inventory is a static view of the state of Extension HAB outreach in November 2018. This list is not meant to serve as an active resource.*

| Title | Type |
|---|---|
| Controlling harmful algal blooms in eutrophic lakes by combined phosphorus precipitation and sediment capping | Annual Report |
| Blue Green Algae in Wisconsin Ponds: Reduce Potential for Livestock Toxicity | Article |
| Blue-green Algae Poisoning Threatens Livestock | Article |
| Cyanobacteria Can be Toxic to Livestock, Wildlife, Humans | Article |
| Cyanobacteria Harmful to Livestock, Humans | Article |
| Drought Increases Cyanobacterial Poisoning Risk to Livestock | Article |
| Drought Like Conditions Threaten Livestock Water Quality | Article |
| Harmful Algal Blooms in the Great Lakes | Article |
| Hot Weather Increases Risk of Cyanobacterial Poisoning to Livestock | Article |
| Lake Erie harmful algae bloom threatens drinking water supplies | Article |
| Not Too Early to Watch for Blue-Green Algae | Article |
| Protecting Your Family and Pets from Harmful Algal Blooms | Article |

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| Title | Type |
|---|---|
| Reduce Heat Stress in Cattle | Article |
| Residents Encouraged to Avoid Blue-Green Algae | Article |
| The Cyanobacteria Stalemate in Wisconsin's Lakes | Article |
| Watch for Cyanobacterial Poisoning in Livestock | Article |
| Lake Erie HABs Bulletin | Bulletin |
| Toxic Algae in a Lake near Lincoln, Nebraska | County Extension Pub |
| 2016 Harmful Algal Bloom Research Initiative Kiosk | Display |
| Harmful Algal Blooms in Ohio Waters Outreach Poster | Display |
| Harmful Algal Blooms Kiosk Panel | Display |
| Sunday with a Scientist - Toxic Algae | Event |
| Blue-Green Algae and Livestock | Extension Article |
| The Concern of Blue-Green Algae in Livestock Water | Extension Article |
| Blue-Green Algae Poisoning in Domestic Animals | Extension Fact Sheet |
| Are Oligotypes Meaningful Ecological and Phylogenetic Units? A Case Study of Microcystis in Freshwater Lakes | Journal Article |
| Do high concentrations of microcystin prevent Daphnia control of phytoplankton? | Journal Article |
| Nitrogen availability increases the toxin quota of a harmful cyanobacterium, *Microcystis aeruginosa* | Journal Article |
| Unexpected population response to increasing temperature in the context of a strong species interaction | Journal Article |
| Valuing Lake Erie Beaches Using Value and Function Transfers | Journal Article |
| HABs Collaboratory Project - Publications and Documents | Multiple Articles |
| A little muck or a lot of yuck? | News Article |
| Algae are a-bloomin' but what does it mean? | News Article |
| Heavy rainfall may increase risk of algal blooms in Lake Erie, Saginaw Bay | News Article |
| Lake Erie Harmful Algal Bloom Early Season Projection report – May 17, 2016 | News Article |
| Late summer algae blooms may cause problems in farm ponds | News Article |
| The Toledo water supply shut down. Why "boil water" advisories were not enough | News Article |
| Toxins in Toledo's drinking water supply | News Article |
| Why is my lake turning colors? | News Article |
| Experimental Lake Erie HABs Tracer | Online Mapping |
| HABs Frequently Asked Questions | Online Mapping |
| Harmful Algal Blooms | Podcast |
| Sound Ag Advice: Cyanobacteria (Blue-Green Algae) | Podcast |
| Blue-green Algae: The Effects of Their Blooms in Wisconsin Waters | Presentation |
| Harmful Algal Blooms in Wisconsin Waters 2009-2012 | Presentation |
| Problem Extent | Presentation |
| What is Toxic Blue-green Algae | Presentation |
| Wisconsin Harmful Algal Blooms Program | Presentation |
| Harmful Algal Bloom Rapid Response Team | Program |

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| Title | Type |
|---|---|
| Ohio Department of Higher Education Harmful Algal Bloom Research Initiative | Program |
| Understanding and predicting harmful algal blooms in Minnesota lakes | Program/Project |
| 10 things I should know about algal blooms | Publication |
| Cyanobacteria Poisoning (Blue-green Algae) | Publication |
| Harmful Algal Blooms in Ohio Waters | Publication |
| Identification and Management of Blue-green Algae in Farm Ponds | Publication |
| Toxic Algae in Nebraska Lakes | Publication |
| Your Pond Update Newsletter: Harmful algal blooms, ponds, and the basics of mitigation and management | Publication |
| HABs Monitoring QAPP - MI Dept of Environmental Quality | Report |
| One-Two-Three Punch Clobbers Toxic Algae, Restores Fremont Lake | Report |
| Lake Erie Harmful Algal Bloom Early Season Projections and Bulletins | Series |
| Lakes, Ponds & Streams FAQ | Web page |
| Harmful Algal Blooms | Webpage |
| Harmful Algal Blooms Q&A and Updates (2014) | Webpage |
| Keep Livestock Away from Blue-Green Algae | Webpage |
| Harmful Algae Blooms (HABs) | Website |
| Research In Focus: HABs | Website Section |
| What Are Harmful Algal Blooms? | Website Section |
| Algal toxins / Cyanobacterium | Website Section |

**RELATED TO HARMFUL ALGAL BLOOMS**

| Title | Type |
|---|---|
| Agriculture's role in protecting Lake Erie | Article |
| Be careful what you wish for when managing aquatic weeds | Article |
| Climate Change: Are you preparing for it? | Article |
| Fish Kills in Indiana - Their Causes and Prevention | Article |
| Good-quality Drinking Water Essential for Livestock | Article |
| Home and Yard Pollutants | Article |
| Monitoring Nebraska's Public Beaches - Water Quality and Health Alerts at Your Favorite Lake | Article |
| Phosphorus: Transport to and availability in surface waters | Article |
| The "500 lbs. Algae Adage…" Where did it come from? | Article |
| Tips to reduce water quality issues | Article |
| Understanding phosphorus in Minnesota soils | Article |
| What's the Point and Non-Point in Water Quality? | Article |
| The Illinois Nutrient Loss Reduction Strategy – Draft Available for Public Comment | Blog Article |
| Understanding the Natural World (in Illinois Master Naturalist Curriculum Guide) | Book |
| Field Guide to Sustainable Production of High-Quality Durum Wheat in North Dakota | e-book |
| Livestock Water Quality: A Field Guide for Cattle, Horses, Poultry and Swine | e-book |
| Reducing Nitrate Losses from Drained Lands | Extension Book Chapter |

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| Title | Type |
|---|---|
| Best Management Practices for Corn Production | Extension Fact Sheet |
| Phosphorus and Water Quality in Kansas | Fact Sheet |
| Water Information and Concern | Fact Sheet |
| Frequently Asked Questions of Nonpoint Source Pollution | FAQ |
| INDIANA SOILS: Evaluation for Agriculture and Home Sites | Field Book |
| Ag Alert - Watch for Cyanobacterial Poisoning in Livestock | Local Extension Publication |
| Phosphorus management is important to protect the Saginaw Bay | News Article |
| A River Runs Through Us: A Water Quality Strategy for the Land and Waters of the Red Cedar River Basin | Presentation |
| Big Chetac and the Red Cedar River Watershed | Presentation |
| Western Lake Erie Basin: Agriculture & Water Quality | Program |
| Agricultural Phosphorus and Water Quality | Publication |
| Controlling Algae in Irrigation Ponds | Publication |
| Drought Management: Water | Publication |
| Environmental Implications of Excess Fertilizer and Manure on Water Quality | Publication |
| Facts About Phosphorus and Lawns | Publication |
| Forestry Best Management Practices | Publication |
| Identifying and Managing Aquatic Vegetation | Publication |
| Managing Manure Phosphorus to Protect Water Quality | Publication |
| Algae Control in Lakes and Ponds | Publication |
| Blue Green Algae & Me | Publication |
| Nitrogen Behavior in the Environment | Publication |
| Nutrients and Water Quality for Lakes and Streams | Publication |
| Phosphorus Behavior in the Environment | Publication |
| Phosphorus Movement from Land to Water | Publication |
| Managing Ponds and Lakes for Aquaculture and Fisheries in Missouri: Controlling Nuisance Aquatic Vegetation | Publication |
| Algae Control in Stock Tanks, Ponds and Lakes | Publication |
| Wastewater Pond Operation, Maintenance and Repair | Publication |
| Water Quality and Nitrogen | Publication |
| Water Requirements for Beef Cattle | Publication |
| Zebra Mussels | Publication |
| Pasture pond is covered with algae. Will it be harmful to the cattle if they drink the water? | Question |
| Measuring Algal Toxins in Missouri Lakes | Report |
| 2016 Data Results: Algal Toxin Monitoring | Report |
| Algae Control (Missouri Department of Conservation) | Web Site |
| Harmful Algal Blooms and Blue-Green Algae (Missouri DNR) | Web Site |
| The Lakes of Missouri Volunteer Program 2019 Lake Report | Web Site |
| Total Phosphorus | Webpage |
| Protecting the Water: The Issue of Phosphorus | Webpage |

APPENDIX

## Research Titles and Abstracts

### Nutrient Removal from Agricultural Subsurface Drainage Using Denitrification 1 Bioreactors and Phosphate Adsorbents

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Landscape Nutrient Management Practices | 2014/2015 | South Dakota | $45,916 | $93,615 | Guanghui Hua, Christopher Hay, Christopher Schmit |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2015SD243B&Type=Annual

### The Role of Algal Species on Phosphorus Bioavailability

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2014/2015 | North Dakota | $15,592 | $31,184 | Khan Eakalak |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2014ND291B&Type=Annual

### Biopolymers for Phosphate Removal from Eutrophic Lakes

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Identifying, Monitoring and Treating | 2014/2015/2016 | North Dakota | $24,757 | $49,517 | Achintya Bezbaruah |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2015ND297B&Type=Annual

### Policy Tools for Reducing Nutrient Loads and Combating Harmful Algal Blooms (HABs) in Lake Erie: An Inventory and Assessment

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Landscape Nutrient Management Practices | 2015 | Ohio | $24,455 | $24,455 | John Hoornbeek |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2015OH445B&Type=Annual

## Transport and Transformation of Nitrogen, Phosphorus, and Carbon in Intermittent Streams

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2015 | Indiana | $14,998 | $30,020 | Adam Ward, Todd Royer |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2015IN384B&Type=Annual

## Controlling Harmful Algal Blooms in Eutrophic Lakes by Combined Phosphorus Precipitation and Sediment Capping

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Identifying, Monitoring and Treating | 2015/2016 | South Dakota | $43,294 | $86,681 | Kyungnan Min, Guanghui Hua |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2015SD244B&Type=Annual

## Effectiveness of Data Buoys as Early Warning Systems for cHABs (cyanobacterial Harmful Algal Blooms) in Lake Erie

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2016 | Ohio | $33,139 | $36,632 | Justin Chaffin, Douglas Kane |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2016OH484B&Type=Annual

## Predicting toxic cyanobacteria blooms in the Wabash River Watershed

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2016 | Indiana | $15,000 | $30,000 | Allison Rober, Kevin Wyatt |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2016IN395B&Type=Annual

## The role of iron mobility from anoxic sediments in stimulating harmful algal blooms

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2016/2017 | Iowa | $59,911 | $147,923 | Elizabeth Swanner |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2016IA267B&Type=Annual

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## Assessing the role of buffer strips in nutrient and organic matter export and mitigation of harmful algal blooms

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Landscape Nutrient Management Practices | 2017 | Minnesota | $29,701 | $59,404 | James Cotner |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2017MN388B&Type=Annual

## Characterizing the Link Between Algal Bloom Biomass and Methane Production in Ohio Reservoirs

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Other – HAB effects on environment | 2017 | Ohio | $29,806 | $49,483 | Ishi Buffam, Trinity Hamilton |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2017OH533B&Type=Annual

## Effects of Viruses on the Development of Harmful Algal Blooms

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Identifying, Monitoring and Treating | 2017 | Indiana | $15,000 | $30,063 | Zhi Zhou |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2017IN405B&Type=Annual

## Quantifying direct groundwater discharge to Lake Erie and vulnerability to hidden nutrient loads

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2017 | Ohio | $29,087 | $31,001 | Audrey Sawyer |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2017OH534B&Type=Annual

## Evaluation of Nitrate Removal Rates of Denitrification Bioreactors Using Agricultural Residue Media

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Landscape Nutrient Management Practices | 2017/2018 | South Dakota | $45,320 | $90,954 | Guanghui Hua, Christopher Schmit |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018SD267B&Type=Annual

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### Algae, stench, and death: are algal toxins present in Missouri fish?

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Human health | 2018 | Missouri | $21,085 | $44,370 | Rebecca North, Alba Argerich |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018MO156B&Type=Annual

### Assessing Nutrient Sources and Usage During Harmful Algae Blooms (HAB) and Eutrophication Events Using Stable Isotopes: Implications for Water Quality in the Wabash River

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2018 | Indiana | $15,000 | $31,322 | Greg Michalski |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018IN410B&Type=Annual

### Can health of aquatic wildlife indicate the quality of water resources?

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Animal health | 2018 | Ohio | $21,636 | $37,710 | Jeanine Refsnider |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018OH548B&Type=Annual

### Characterization of harmful algal blooms using small unmanned aircraft systems and watershed analysis in southern Illinois

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Identifying, Monitoring and Treating | 2018 | Illinois | $9,982 | $19,974 | Ruopo Li, Di Wu |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018IL340B&Type=Annual

### Does nutrient form control harmful algal bloom (HAB) toxin release?

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2018 | Kansas | $15,000 | $37,099 | Ted Harris |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018KS197B&Type=Annual

APPENDIX

## Estimating watershed residence times in artificially-drained landscapes and relation to nutrient concentrations

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2018 | Indiana | $15,000 | $30,014 | Lisa Welp |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018IN412B&Type=Annual

## Evaluating and predicting the risk of algal blooms in South Dakota lakes using remote sensing

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Prediction/Source Detection; Identifying, Monitoring and Treating | 2018 | South Dakota | $24,147 | $48,294 | Rachel McDaniel, Bruce Bleakley, John McMaine |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018SD268B&Type=Annual

## Evaluation of sub-lethal effects of neurodegenerative cyanotoxins on predator-prey interactions in a freshwater fish

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Animal health | 2018 | Indiana | $15,000 | $30,030 | Jessica Ward |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018IN409B&Type=Annual

## Mathematical Modeling of Freshwater Harmful Algal Blooms

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2018 | North Dakota | $2,250 | $4,500 | Halis Simsek |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018ND342B&Type=Annual

## Maumee River sediments as a nitrogen source or sink to Lake Erie: the competing roles of ammonium recycling and denitrification

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2018 | Ohio | $39,998 | $53,784 | Mark McCarthy |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018OH564B&Type=Annual

## Nonpoint Source Pollution Mitigation in an Urban Watershed

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Identifying, Monitoring and Treating | 2018 | Missouri | $21,795 | $43,591 | Dev Niyogi, Mark Fitch |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018MO157B&Type=Annual

## Nutrient Loading Forecasting for Western Lake Erie

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2018 | Michigan | $14,358 | $4,597 | Glenn O'Neil, Margaret Kalcic, Rebecca Muenich |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018MI251B&Type=Annual

## Nutrient removal from greenhouse wastewater using a phosphorus removal structure

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Landscape Nutrient Management Practices | 2018 | Indiana | $15,000 | $30,001 | Hye-Ji Kim, Chad Penn |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018IN411B&Type=Annual

## Quantification of tributary nutrient transport and HABs in Lake Wawasee, Indiana's largest natural lake

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATOR |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2018 | Indiana | $14,910 | $43,890 | Nate Bosch |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018IN408B&Type=Annual

## Stochastic Forecasting of Harmful Algae Blooms in Cheney Reservoir

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Prediction/Source Detection | 2018 | Kansas | $14,867 | $30,304 | Aleksey Y Sheshukov, Trisha L Moore |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018KS194B&Type=Annual

## The Economic Benefits of Mitigating Harmful Algal Blooms

| CATEGORY | YEAR | INSTITUTE | TOTAL FEDERAL FUNDS | TOTAL NON-FEDERAL FUNDS | PRINCIPAL INVESTIGATORS |
|---|---|---|---|---|---|
| Other - Economics | 2018 | Iowa | $30,000 | $60,000 | Yau-Huo (Jimmy) Shr, Wendong Zhang, Chuan Tang |

ABSTRACT: water.usgs.gov/wrri/grant-details.php?ProjectID=2018IA277B&Type=Annual

# Partnering to Mitigate Harmful Algal Blooms

in the North Central Region of the United States

NIWR
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IOWA STATE UNIVERSITY Extension and Outreach

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