HARMFUL ALGAL BLOOMS AND HYPOXIA IN THE UNITED STATES

A REPORT
ON
INTERAGENCY PROGRESS
AND
IMPLEMENTATION

PRODUCT OF THE

Interagency Working Group on
Harmful Algal Bloom and Hypoxia Research
and Control Act

March 5, 2018

DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WASHINGTON, D.C. 20502

March 5, 2018

Dear Colleagues:

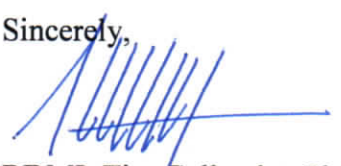
I am pleased to transmit to you *Harmful Algal Blooms and Hypoxia in the United States: An Interagency Progress and Implementation Report*. This report to Congress produced by the National Oceanic and Atmospheric Administration, in coordination with the Interagency Working Group on the Harmful Algal Bloom and Hypoxia Research and Control Act (IWG-HABHRCA) demonstrates how this Administration is enhancing the safety, security, and quality of life for the American people. Addressing these issues not only improves the well-being of hardworking Americans, but also reduces the negative economic impacts from declines in commercial fishing, recreation, and tourism revenue that may occur during these events. .

The 2014 reauthorization of the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act (HABHRCA 2014; P.L. 113-124) acknowledges continued concerns related to harmful algal blooms (HABs) and hypoxia, emphasizes the need for expanded and ongoing monitoring and forecasting, extends the scope of the legislation to include freshwater HABs and hypoxia, and recognizes the need for further coordinated Federal action to address these issues. Specifically, the legislation calls for the publication of a report that describes the proceedings of the IWG-HABHRCA, as well as the progress made on implementing the recommendations put forth in *Harmful Algal Blooms and Hypoxia in the United States Comprehensive Research Plan and Action Strategy: An Interagency Report* (RPAS). The RPAS was published on February 16, 2016, with the intent of "reducing, mitigating, and controlling hypoxia and harmful algal blooms in the United States."

In addition, HABHRCA required a separate plan for "reducing, mitigating and controlling hypoxia and harmful algal blooms in the Great Lakes". The IWG-HABHRCA published and transmitted the *Harmful Algal Blooms and Hypoxia in the Great Lakes Research Plan and Action Strategy: An Interagency Report* on August 24, 2017. After submitting the plan, HABHRCA requires biennial progress reports on the activities toward achieving the objectives of the plan.

This report fulfills these two legislated requirements.

Sincerely,



RDML Tim Gallaudet, Ph.D., USN Ret.
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About the National Oceanic and Atmospheric Administration

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About this Document

This document was developed by the Interagency Working Group on the Harmful Algal Bloom and Hypoxia Research and Control Act. The IWG-HABHRCA is organized under the National Science and Technology Council; Committee on Environment, Natural Resources, and Sustainability; Subcommittee on Ocean Science and Technology. The report is intended to meet the statutory requirements to address HABs and hypoxia, as prescribed by that Act.

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Abbreviations

ARS	Agricultural Research Service
BOEM	Bureau of Ocean Energy Management
CASPER	Community Assessment for Public Health Emergency Response
CCL	Contaminant Candidate List
CDC	Centers for Disease Control and Prevention
CPE	Comprehensive Performance Evaluation
CRMs	Certified Reference Materials
CyAN	Cyanobacteria Assessment Network
ERDC-EL	USACE Engineer Research and Development Center
FDA	Food and Drug Administration
FPMN	Freshwater Phytoplankton Monitoring Network
GLRI	Great Lakes Restoration Initiative
HAB	Harmful Algal Bloom
HABHRCA	Harmful Algal Bloom and Hypoxia Research and Control Act
HABs	Harmful Algal Blooms
IWG-HABHRCA	Interagency Working Group on HABHRCA
NARS	National Aquatic Resource Surveys
NASA	National Aeronautics and Space Administration
NGOMEX	Northern Gulf of Mexico
NIEHS	National Institute of Environmental Health Sciences
NIFA	National Institute of Food and Agriculture
NLA	National Lakes Assessment
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
NSTC	National Science and Technology Council
OHHABS	One Health Harmful Algal Bloom System
PMN	Phytoplankton Monitoring Network
R&D	Research and Development
RPAS	Harmful Algal Blooms and Hypoxia in the United States Comprehensive Research Plan and Action Strategy: An Interagency Report
STEM	Science, Technology, Engineering, and Mathematics
UCMR	Unregulated Contaminant Monitoring Rule
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Executive Summary

Researchers and policymakers recognize harmful algal blooms (HABs) and hypoxia (low-oxygen conditions) as some of the most critical water quality issues affecting our nation's waterways: freshwater and marine alike. Impacts include losses in income from declines in commercial fishing, recreation, and tourism; animal and human exposure and illness from contaminated water or seafood; and expenses related to monitoring, control, and management, including water treatment (Bingham et al., 2015).

Per the requirements of Section 603(j) of the 2014 reauthorization of the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA 2014; *Public Law 113–124*), this document presents to Congress the progress made by Federal agencies to implement the recommendations laid out in *Harmful Algal Blooms and Hypoxia Comprehensive Research Plan and Action Strategy: An Interagency Report* ("RPAS"). It also discusses the activities carried out under the national HABs and hypoxia program described in Section 603(A)(4) of HABHRCA 2014 (the "Program"), including the regional and sub-regional parts of the Action Strategy. In addition, the report fulfills the requirements of Section 605(b)(3)(I) by providing a report on activities toward achieving the objectives of the *Harmful Algal Blooms and Hypoxia in the Great Lakes Research Plan and Action Strategy: An Interagency Report* published on August 24, 2017. Furthermore, the report highlights Federal efforts, and emphasizes the widespread collaboration to address the causes and effects of HABs and hypoxia throughout the United States, including through the proceedings of the Interagency Working Group on HABHRCA (IWG-HABHRCA).

Since the publication of the RPAS, the Federal agencies in the IWG-HABHRCA have made important progress in addressing the causes of HABs and hypoxia, and in helping to mitigate their impacts. The Federal agency members of the IWG have been working with communities, resource managers, and other stakeholders to minimize impacts during an event, and to be prepared well in advance through forecasts, monitoring, policies, and other means. These achievements include:

Microcystis bloom, Ohio River, Cincinnati, OH (Credit: USEPA/ORD).

Increased understanding of human-health risks from exposure to HABs, and improved disease surveillance for human and animal exposure, illnesses, and death

- Conducted health-effects assessments to recognize human-health risks from exposure to HABs.
- Launched a one-health surveillance system (OHHABS) to collect data on individual human and animal cases of illnesses from HAB-associated exposures, as well as environmental data about HABs.

Improved understanding and management of the factors responsible for the occurrence and distribution of HABs and hypoxia

- Led the Great Lakes Water Quality Agreement (GLWQA), Annex 4 on Nutrients, a binational research and modeling effort with states and Canada to develop and adopt phosphorus reduction targets that will minimize HABs and hypoxia in Lake Erie. In 2017, the USEPA and four states released a draft Domestic Action Plan for Lake Erie that identifies how the United States will achieve its phosphorus reduction goals.

- Increased efforts to minimize the impacts of HABs and hypoxia, such as supporting states in developing nutrient criteria for water quality programs, supporting implementation of best management practices such as use of reactive or filter mats to act as a sorbent for soluble and total phosphorous from run off, and protecting drinking water by optimizing the use of oxidants and powdered activated carbon during early stages of drinking water treatment.

- Released strategy and began implementing a new $41 million Western Lake Erie Basin Initiative conservation effort to reduce nutrient losses from agricultural lands. Established a new Demonstration Farm Network in Ohio to demonstrate and assess practices, and educate stakeholders on successful conservation practices.

- Documented water quality effects of agricultural conservation in fields and watersheds around the nation, developed understanding of nutrient transport and developed innovative technologies for reducing nutrient loss, now used in domestic action plans and watershed implementation plans.

- Released assessment of the effects of conservation on cultivated croplands in the Western Lake Erie Basin, which has been used to inform conservation initiatives and domestic action plans.

- Reduced nutrient and sediment field losses through continued implementation of conservation practices, and avoiding, controlling, and trapping conservation systems on agricultural lands.

- Assessed the effects of climate change on HAB species along U.S. coastlines.

Strengthened and integrated new and existing monitoring and predicting capabilities for HABs

- Included cyanotoxins in drinking water monitoring programs.

- Improved monitoring efforts, including restoring and refining the Gulf of Mexico HABs forecast and the Pacific Northwest HAB bulletin for use by shellfish harvesters and other users; launched third-generation sensor systems, including autonomous underwater sensors for HAB toxins; and monitored small streams at edges of agriculture fields and nutrients in bays and the Great Lakes.

- Began developing a Cooperative Gulf of Mexico Hypoxia Monitoring Program.

- Advanced transition-to-operational capacity HAB (Lake Erie, Pacific Northwest, Gulf of Maine) and hypoxia (Gulf of Mexico and Chesapeake Bay) forecast models.

Algal bloom off Northern California's "Lost Coast" in 2014 (Credit: NOAA).

Developed effective guidance and recommendations for HABs for the protection of public health in drinking and recreational waters

- Developed health-based guidelines for cyanotoxins in drinking water.

- Developed guidance documents on risk communication and management strategies for water utilities and recreational managers on cyanotoxins.

Improved stakeholder communications, and expanded collaborations in research, management, and policy-related arenas

- Established a collaborative network of Gulf of Mexico hypoxia scientists and fisheries managers (state and Federal) to ensure that actionable findings on hypoxia impacts on fisheries are applied to management strategies.

- Collaborated with stakeholders, including farmers, the tourism industry, water resource and utility managers, academics, Federal agencies, nongovernmental organizations, the public, and others. This was done via webinars, public meetings and workshops, and individual discussions.

I. Introduction

What are HABs and Hypoxia?

HABs are caused by certain types of microscopic or larger plant-like cyanobacteria or algal species. Algae and cyanobacteria are considered to be the basis of most freshwater and marine food webs. Though usually benign, a small subset of these microalgae and cyanobacteria can form large blooms that adversely affect human and animal health and cause significant economic losses to local economies. They can produce toxins that kill fish, shellfish, livestock and wildlife, or sicken people if they ingest sufficient amounts of toxins (Byappanahalli et al., 2003; Carmichael and Boyer, 2016). Additionally, for this report, we consider blooms of the well-documented green algae *Cladophora* (Brooks et al., 2015) to be a HAB. Although not toxic, *Cladophora* can harm aquatic environments and recreation by forming large, dense mats that build up on beaches and in rivers and lakes, smothering life that lies under its mats.

Hypoxia is a condition where the concentration of dissolved oxygen (DO) in a portion of the water column decreases to a level that can no longer support living aquatic organisms, typically below 2-4 mg DO/liter (L). Low or zero oxygen conditions occur in waterbodies due to the confluence of physical, chemical, and biological processes. HABs also can exacerbate hypoxic events; and, concurrently, hypoxia can promote HABs by increasing phosphorus release from sediments (Correll, 1998).

A sign in Stuart, FL, warns of a HAB in June 2016. The National Centers for Coastal Ocean Science (NCCOS), through its HAB Event Response program, and in response to a request from the Martin County Board of County Commissioners, provided funds and identified experts to track the unprecedented bloom in Lake Okeechobee. This bloom began in May 2016 and expanded to the largest cyanobacterial bloom in the state in at least 10 years (Credit: NOAA/NCCOS).

HABs and hypoxia occur naturally, although human-influenced ecosystem changes such as excessive levels of nutrients such as nitrogen and phosphorus, extreme weather events, and invasive organisms can cause or exacerbate events. Research over the past 20 years indicates these types of events are increasing and becoming more severe in freshwater and marine systems (Zhang, 1994; Paerl et al., 1997; Paerl et al., 2008; Michalak et al., 2013; Cavole et al., 2016).

While researchers are uncertain of the full economic effects of HABs and hypoxia, regional studies show that losses in tourism, housing, and general business revenue can amount to hundreds of millions of dollars annually (Bingham et al., 2015).

Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA)

By the 1990s, researchers identified serious and large-scale water-quality problems in U.S. waters, including HABs and hypoxia, most notably in the northern Gulf of Mexico, Lake Erie, Chesapeake Bay, and Long Island Sound. These problems prompted Congress to pass HABHRCA in 1998. In recognition of the ongoing nature of HABs and hypoxia, and how they continue to affect the entire United States, Congress has reauthorized HABHRCA twice, mostly recently in 2014.

The 2014 HABHRCA reauthorization is unique for several reasons. It calls for Federal agencies to consult with stakeholders to obtain their input on actions that directly address their needs and concerns related to mitigating and preventing HABs and hypoxia. It expands the focus of HABHRCA to include a specific emphasis on HABs and hypoxia in the Great Lakes and in fresh waters around the country. Additionally, it recognizes the need for further coordinated action across the Federal sector to address these issues. The legislation also calls for Federal agencies to provide integrated assessments identifying the causes, consequences, and approaches to reducing HABs and hypoxia nationally, with particular emphasis on the Great Lakes. It calls for operational forecasting, observations, and modeling tools required to support forecasting, all of which are of particular relevance for the region.

Purpose and Scope of this Report

HABHRCA 2014 includes a provision for the Task Force (the IWG-HABHRCA) to develop and submit "a comprehensive research plan and action strategy to address marine and freshwater harmful algal blooms and hypoxia." Via the White House Office of Science and Technology Policy, the IWG-HABHRCA submitted the RPAS on February 16, 2016. HABHRCA 2014 directs the IWG-HABHRCA in Section 603 (j) as follows:

> *Not later than 2 years after the date the Action Strategy is submitted under section 603B, the Under Secretary shall submit a report to Congress that describes—*
>
> *(1) The proceedings of the annual Task Force meetings;*
>
> *(2) The activities carried out under the Program, including the regional and subregional parts of the Action Strategy;*
>
> *(3) The budget related to the activities under paragraph (2);*
>
> *(4) The progress made on implementing the Action Strategy; and*
>
> *(5) Any need to revise or terminate research and activities under the Program.*

This report addresses the aforementioned requirements from the statute. Furthermore, it shows Federal progress in responding to the recommendations laid out in the RPAS. The recommendations address the causes of HABs and hypoxia, and impacts on stakeholders, as well

as on marine and freshwater ecosystems throughout the United States and its territories. This is the third report produced per the requirements of Sec. 603B of HABHRCA.

In addition, Section 605(b)(3)(I) requires "progress reports on the activities toward achieving the objectives of the *Harmful Algal Blooms and Hypoxia in the Great Lakes Research Plan and Action Strategy: An Interagency Report*, which was published on August 24, 2017. Some activities and projects described in this report to Congress are responsive to, and/or complemented by, actions described in the biennial reports to Congress on activities directed by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (Hypoxia Task Force) (HABHRCA Section 604).

Given the information provided previously, this report describes the progress under the RPAS in Federal fiscal years 2016-2017, and includes future efforts planned through 2020. The HABHRCA legislation requires additional progress reports to cover subsequent periods. Additionally, while the RPAS focused on a national scope, this progress report will focus on regions of the country that typically experience HABs and hypoxia more frequently, including the Great Lakes, the Gulf of Mexico, the coasts of Florida, and the U.S. East and West Coasts.

Proceedings of the Interagency Working Group on HABHRCA

The IWG-HABHRCA is co-chaired by representatives from NOAA (Department of Commerce) and the USEPA. Additionally, it is composed of the following member agencies and departments:

- Centers for Disease Control and prevention (CDC), Food and Drug Administration (FDA), and the National Institute of Environmental Health Services (NIEHS), of the Department of Health and Human Services;
- United States Army Corps of Engineers (USACE) and the Department of the Navy, of the Department of Defense;
- United States Geological Survey (USGS), the Bureau of Ocean Energy Management (BOEM), the National Park Service (NPS), and the Fish and Wildlife Service of the Department of the Interior;
- National Aeronautics and Space Administration (NASA);
- National Institute of Food and Agriculture (NIFA), Natural Resources Conservation Service (NRCS), and the Agricultural Research Service (ARS), of the United States Department of Agriculture (USDA);
- State Department; and
- National Science Foundation (NSF).

The IWG-HABHRCA has a number of subgroups that meet at least once monthly, each headed by different agencies:

- HABs/Hypoxia, co-chaired by USDA and the USEPA;
- Great Lakes, chaired by NOAA;
- Implementation, co-chaired by the USEPA, NOAA, and USGS; and
- Certified Reference Materials and Standards, chaired by NOAA.

The IWG-HABHRCA meets regularly, holding biweekly meetings. These generally follow a similar format, in which the group reserves the first 30 minutes of each meeting for updates from leadership and the subgroups. It also allows time for group discussion on individual elements, including questions that arise regarding aspects of the reports that the group has produced, such as outlines or how to conduct data calls across all of the agencies; interesting questions or comments that members have received from stakeholders; and news items, including HAB and hypoxia events around the country, and how best to coordinate interagency response. Furthermore, the IWG discusses the highest priority work elements and progress underway within the member agencies. The IWG-HABHRCA reserves the final 30 minutes of each meeting for agency updates, including presentations from staff on a project or program at an agency that they wish to bring to the attention of the group. The presentations are good opportunities to increase awareness on current work, as well as for agencies to learn of projects on which they can collaborate. Indeed, the presentations have led to multiple collaborative efforts between agencies.

Additionally, the IWG-HABHRCA meets in person, on average, two times each year to hold strategy and planning sessions. The group held its most recent meeting of this type on April 18, 2017, and focused on planning; its next meeting is planned for April 2018. As a group, the IWG-HABHRCA developed a list of what they planned to accomplish over calendar year 2017, and began discussion of what agencies would like to see the IWG-HABHRCA accomplish over the coming years. Specifically, following were the objectives from that meeting, with updates covered throughout this report:

1. Planning

   Develop a list of what the IWG-HABHRCA would like to accomplish over 2017, and begin discussion for the next few years, irrespective of budget considerations

   - What is the IWG-HABHRCA collectively already doing? As a group, what optimally would we like to accomplish?

   - What are the top-line messages for communicating with the public and reporting to Congress, as well as within and to member agencies?

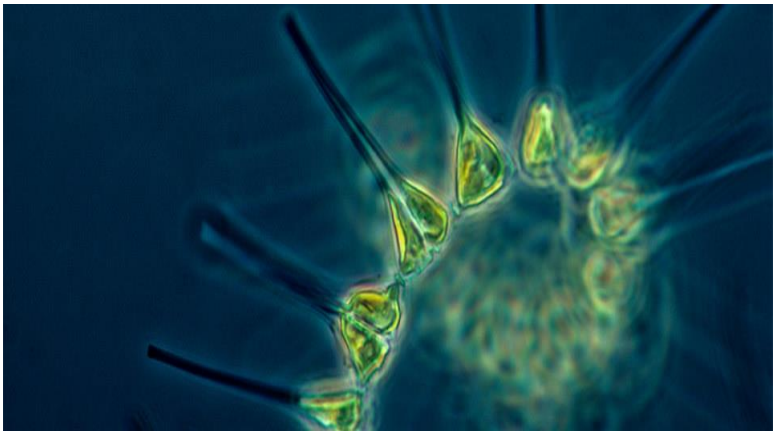
2. Team-Building

This is a good opportunity for us to reconnect and have a more in-depth conversation about our role in protecting public, economic, and ecological health.

Over the course of the meeting, the IWG-HABHRCA determined goals for the group for calendar year 2017. These included developing the following:

- A calendar, to be hosted on NOAA's website, which shows individual agencies' upcoming extramural funding opportunities. This was in direct response to requests from stakeholders about a need to facilitate finding information on HAB- and hypoxia-related external grant programs within the Federal Government. We now have links to different agencies' funding opportunities.

- Improved communications materials, in order to including one-page documents that define HABs and hypoxia, and outline potential impacts, written for different audiences, as necessary. Additionally, we planned to develop a list of "success stories" and compelling statistics.



Phytoplankton, like this species of Asterionella*, is the base of several aquatic food webs. In a balanced ecosystem, phytoplankton provide food for a wide range of creatures including birds, whales, shrimp, snails, and jellyfish (Credit: NOAA/NCCOS).*

II. Progress Made on Implementing the Action Strategy

Since the reauthorization of HABHRCA 2014, the IWG-HABHRCA has convened and coordinated with relevant federal agencies to discuss HABs and hypoxia issues in the United States. The IWG-HABHRCA also has conducted several webinars, held in-person meetings, and participated in conferences in all major regions around the country to discuss topics related to HABs and hypoxia with Federal partners and stakeholders. The group used this input to develop the RPAS, and to coordinate research and the development of useful and effective products. This section provides the progress made by the member agencies of the IWG-HABHRCA to implement the RPAS and address the recommendations identified.

The RPAS lists the following core actions for the member agencies of the IWG-HABHRCA to undertake the following:

1. Advance the scientific understanding of HABs and hypoxia;
2. Strengthen and integrate new and existing monitoring programs;
3. Improve predictive capabilities;
4. Improve stakeholder engagement and understanding of socioeconomic impacts; and
5. Expand collaborations in research, management, and policy-related arenas.

Actions to Advance the Scientific Understanding of HABs and Hypoxia

a. Develop certified reference materials (CRMs) and other standardized and validated detection and analysis methods for HAB toxins.

Federal agencies are researching how changing environmental conditions influence HABs and hypoxia. Member agencies of the IWG-HABHRCA have been working to increase the availability of analytical methods and CRMs to predict the onset and intensity of HAB-related toxin levels. To address this recommendation, members of the IWG-HABHRCA formed a subgroup on CRMs to examine intra- and interagency methods and approaches for developing and sustaining CRM availability. The subgroup on CRMs has been evaluating the published literature of most of the available toxin assessment standards, particularly those that are not CRMs, to determine their quality and their usefulness when highly accurate results are needed, such as for measuring levels in drinking water to ensure public safety. They also are developing a process guide for consistent sampling methods and testing procedures. Additionally, agencies have been working on developing and validating standardized analysis methods, as well as generating purified standard reference material to ensure consistency and comparability of results between laboratories and other testing environments. Federal agencies also are developing methods capable of analyzing edible fish, plant, or animal tissues for multiple toxins and testing such methods on reservoir, stream, and coastal food webs. The USEPA is conducting studies to verify the purity and concentration of toxins standards from several vendors to confirm the quality of the standards for toxicity studies. The USGS is providing analytical support to assist with this evaluation.

b. Conduct studies on toxins in food and on toxin mixtures.

The USEPA is conducting toxicological evaluations of several toxins to determine the potential risk of triggering adverse health effects. In addition, the USEPA is evaluating the oral toxicity from multiple microcystin congeners, which cause acute toxicity and liver and other cancers with prolonged exposure. This approach ultimately will help utilities, resource managers, and the government to manage the risks from cyanotoxins in drinking and recreational waters. The USGS hasprovided analytical support to the USEPA in support of this evaluation. Research is still needed to better confirm foodborne illness related to algal toxins due to a lack of accurate clinical methods for detecting toxins in biological specimens.

c. Develop more effective HAB suppression and control methods that have minimal environmental effects and lower cost.

Protecting source water from contamination reduces risks to public health from exposures to contaminated water, and can reduce treatment costs in drinking water supplies. Once a HAB toxin is detected and confirmed, control measures to protect the source water should be tailored to address the threat of HABs. NOAA is assessing the potential of control techniques, including new technologies such as bacteria-produced algicides to determine potential impacts on ecologically important species. NOAA has advanced nutrient control of bloom toxicity in Chesapeake Bay and other mid-Atlantic estuaries, and of brown tide blooms in Long Island Sound, the contribution of physical transport of Bay of Fundy seed algal populations from the

magnitude of Gulf of Maine red tides, and the role of upwelled nutrients on formation and magnitude of the Florida red tide. Several NOAA-supported studies are evaluating the effects of nutrient-loading and other factors on hypoxia in order to inform managers of effective mitigation strategies. Advanced understanding of the quantitative relationship between nutrient and hypoxia properties support several statistical and 3D time-variable models that have provided managers with an assessment of the progress of nutrient reduction actions, and guidance on nutrient-reduction-strategy revisions. Beneficiaries include the Mississippi River/Gulf of Mexico Hypoxia Task Force, Chesapeake Bay Program, Rhode Island Department of Environmental Management (Narragansett Bay hypoxia), and Green Bay Metropolitan Sewage District and Wisconsin Department of Natural Resources (Green Bay hypoxia).

Federal agencies also conduct research focused on developing cost-effective means for destroying cyanobacterial-HAB-causing organisms and their toxins. For example, USACE's Aquatic Plant Control Research Program is conducting research using pumps to form bubbles as a way to break up HABs. In addition, Federal agencies award grants to qualified small businesses to support high quality research related to HABs treatment techniques used to break up HABs in aquaculture production.

d. Understand the influence of climate change, atmospheric deposition of nutrients, and other contributing factors on the occurrence, frequency, and severity of HABs and hypoxia.

Federal agencies are researching how the development of HABs and hypoxia can be influenced by rising average water temperatures, low light, eutrophication, and other factors such as specific human-related and natural sources of nitrogen, phosphorus, organic matter, and metals. In 2013, EPA published the Impacts of Climate Change on the Occurrence of Harmful Algal Blooms, to summarize the potential impacts of climate change on harmful algal blooms in freshwater and marine ecosystems (USEPA, 2013). Current and planned research includes assessments on how changing weather patterns may affect the severity of HAB events over the coming decades, quantitative predictions of future changes in climate and anthropogenic nutrient inputs on the spatial and temporal extent of hypoxia, and the determination of bloom toxicity. The USEPA is developing, in collaboration with states, Lake Numeric Nutrient Criteria that will inform how phosphorus and nitrogen concentrations contribute to HABs and drinking and recreational water criteria and swim advisories.

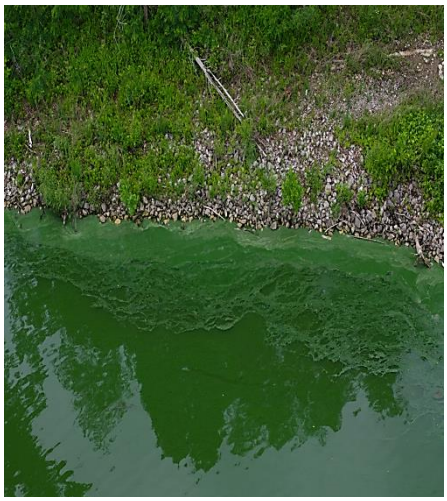
e. Develop case definitions for the spectrum of HAB-related illnesses, and produce clinical therapeutic guidance for the spectrum of illnesses associated with exposure to HAB cells and toxins.

In 2016, the CDC launched One Health Harmful Algal Bloom System (OHHABS), a reporting tool that allows public-health officials to report information on HAB exposures and subsequent health effects over time. OHHABS will provide the information needed by the CDC to characterize the HAB toxin poisonings, including refining case definitions, describing disease progression, and will help the CDC, other scientists, and health-care providers to identify successful treatments.

Actions to Strengthen and Integrate New and Existing Monitoring Programs

a. Strengthen long-term HAB and hypoxia monitoring activities

Federal agencies have developed programs, methods, and techniques to monitor for HABs and hypoxic zones in U.S. fresh and marine waters. Agencies have expanded monitoring capabilities to develop better monitoring techniques and improve understanding of the relative contributions of causal factors in the development of HABs or hypoxia. For example, agencies support research on Lake Erie to assess the impact of quagga mussels (*Dreissena bugensis*) on phosphorus-management strategies, and how internal phosphorus cycling affects HABs and hypoxia.



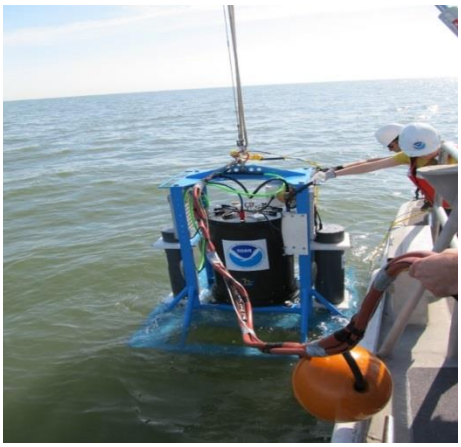
Cyanobacteria (Dolichospermum) bloom, Harsha Lake, OH (Credit: USEPA/ORD).

NOAA has in place a multi-partner sustainable monitoring program that encompasses the northern Gulf of Mexico hypoxic zone, and advances ecosystem management objectives for mitigating hypoxia, ocean acidification, and other ecosystem stressors. This project will help strengthen long-term monitoring activities in the Gulf of Mexico watershed and coastal zone. Furthermore, NOAA supports citizen-science monitoring efforts via the Phytoplankton Monitoring Network (PMN) and Freshwater Phytoplankton Monitoring Network (FPMN) to monitor and report on HAB species in the coastal, Great Lakes, and Alaska regions.

The USGS conducts long-term monitoring of nutrients and other water-quality characteristics in rivers and streams through the National Water Quality Network, which measures multiple annual delivery of nitrogen, phosphorus, and carbon compounds to coastal waters and the Great Lakes from their major tributaries. The sources and quantities of nutrients delivered by streams to the Great Lakes, coastal areas such as the Northern Gulf of Mexico, and estuaries such as the Chesapeake Bay are monitored at 117 freshwater sites. Annual updates from the monitoring sites are available to the public, including nutrient concentrations, loads, and yields. These data, along with data aggregated from numerous other agencies, are used to evaluate trends in critical water quality parameters including nutrients and sediment. These data are used by management agencies to track progress in nutrient control practices and to determine progress in meeting water quality goals.

The USDA combines its missions for resource assessment and agricultural and natural resources research in support of the Conservation Effects Assessment Project (CEAP). Under CEAP Watershed Assessment Studies, USDA NRCS and ARS, and their university partners, collaborate to assess the effects of conservation practices on water quality, water availability, and soil resources in small agricultural and rural watersheds. CEAP assesses reductions in nutrients and sediment from implementing conservation practices. Assessments are carried out at field and watershed scales. CEAP watersheds are located around the nation, with many in the Mississippi River Basin, the Western Lake Erie Basin, and the Chesapeake Bay.

As part of the National Aquatic Resource Surveys (NARS), the USEPA, states, and tribes have been monitoring for cyanobacteria and cyanotoxins in a series of surveys conducted in lakes, rivers/streams, coastal waters, and wetlands in the United States. The USEPA and its partners regularly monitor HAB toxins at more than 1000 sites throughout the United States each summer as part of the NARS. The USEPA also provides assistance at the regional scale to build capacity in local HAB monitoring programs including such things as analysis, monitoring, and analytical support.



NOAA scientists deploy an ESP in Lake Erie in 2016 (Credit: NOAA/GLERL).

In 2007, and again in 2012, the National Lakes Assessment (NLA) included indicators associated with the risk of potential exposure to cyanotoxins, including an analysis of microcystin levels and two related indicators, cyanobacteria and chlorophyll-*a*. In 2017, the NLA included these same indicators and added cylindrospermopsin. Additionally, the USEPA's National Wetland Condition Assessment 2011 and 2016, National Rivers and Streams Assessment 2013-2014, and the National Coastal Condition Assessment (NCCA) 2015, which includes the Great Lakes, added analysis of microcystin to the suite of existing indicators, including chlorophyll-*a*. The USEPA and USGS are collaborating on microcystin analyses for the National Wetland Condition Assessment 2016 and the National Coastal Condition Assessment 2015. Through a collaboration with the USGS, the NCCA was also able to expand the list of algal toxins that are being analyzed as part of the 2015 assessment. The USEPA's Great Lakes National Program Office (GLNPO) has long term monitoring programs in place to measure and assess water quality, nutrient concentrations, chlorophyll-*a*, and the abundance and diversity of zooplankton, phytoplankton and benthic communities. Almost 100 fixed station sites are sampled each spring and summer to assess the ecological health of the lakes, evaluate trends and identify emerging problems. Each Summer GLNPO also conducts dissolved oxygen surveys to measure and calculate the oxygen depletion rate of hypoxic waters in the central basin of Lake Erie. The phytoplankton monitoring component is being enhanced to collect additional data at nearshore sites and a pilot effort to collect year round samples with the use of automated samplers.

In addition, the USEPA builds capacity by supporting monitoring programs in the regions and specifically to tribal communities, and working with citizen scientists, trained water professionals, drinking water suppliers, academic researchers, and the public via the Cyanobacteria Monitoring Collaborative to map and understand harmful cyanobacteria occurrences, and their spatial and temporal distribution in waterbodies. Finally, the USEPA released methods for detecting cyanotoxins in drinking water and included ten cyanotoxins or cyanotoxin groups on the list of contaminants to monitor in public drinking water systems across the nation as part of the fourth Unregulated Contaminant Monitoring Rule (UCMR 4).
The Environmental Systems Branch at the USACE Engineer Research and Development Center (ERDC-EL) has been working in partnership with the USACE Great Lakes and Ohio River Division, the University of Cincinnati, the USEPA, and state partners to assess the use of

airborne and satellite imagery for detection of water quality indicators (e.g., chlorophyll, phycocyanin, and turbidity) of HABs in small lakes and reservoirs. This includes in the Ohio River, and Harsha Lake in OH. Specifically, the work includes assessing the range of available satellite sensors and variety of remote sensing algorithms that could be used to assist with early detection and monitoring.

Monitoring efforts for nutrients are still needed to address the research gap on how sediments affect links between internal phosphorus cycling in the water column and the proliferation of HABs and hypoxia. The USEPA is conducting studies to provide a modeling framework and tested computational methods for linking watershed loadings of nutrients to the loss in beneficial uses from algal blooms causing degraded reservoir, lake, stream, and wetland water quality and risks to ecologic and human health. Combining environmental data such as nitrogen and phosphorous levels, hydrodynamic data, sunlight and temperature data, and *in-vivo* cyanobacterial densities could provide short-term predictive capabilities useful to recreational water users and drinking water treatment operators to reduce exposure and optimize treatment processes. In addition, more studies are needed to determine the effect of phosphorus, nitrogen, and sediment in Lake Erie in particular, to identify response strategies to more effectively address HABs and hypoxia events.

b. Integrate new monitoring technologies into emerging U.S. and global ocean-observation systems.

Federal agencies have developed new observing systems capable of transmitting real or near real-time information from remote locations in marine and freshwater systems to collect wide streams of environmental data that can be used to trigger early warnings and improve HAB or hypoxia characterization. For example, Environmental Sample Processors (ESPs) are positioned in Lake Erie, the Gulf of Maine, and the Pacific Northwest and California coast as real-time monitoring laboratories for HABs. Another HAB detector, the Imaging Flow Cytobot, is being commercialized and expanded along the Texas Gulf coast. Underwater autonomous vehicles (e.g., gliders) are being tested for mapping the Gulf of Mexico hypoxic dead zone, which will greatly enhance monitoring in complement with ship surveys and fixed observing systems. In cooperation with state and local agencies, USGS sensors are monitoring current conditions for chlorophyll, an algal pigment and biomass indicator, at over 50 stations in 17 states on inland rivers, lakes, and along the marine coasts and disseminating the information on the Internet to the public. In addition, Federal agencies are establishing rapid-response protocols for detecting HAB toxins. For example, the Food and Drug Administration (FDA) is working with the seafood industry to develop methods to detect HAB toxins in seafood, and NOAA is developing rapid-response test kits and Solid Phase Adsorption Toxin Tracking to assess the presence of HAB species and toxins in local waterways.

NOAA, the USEPA, and other federal agencies are working with the Alliance for Coastal Technologies, University of Louisiana Lafayette and others to pilot the use of continuous nitrate sensors at a number of locations in and around the Gulf of Mexico. An important goal of the pilots is to better understand how new sensors and data can be effectively integrated for improved monitoring and communication about nutrient levels in the Gulf. These pilots are an extension of the Interagency Nutrient Sensor Challenge that has been helping to accelerate the

development of low cost continuous nutrient sensors. These will be deployed at a number of sites including the Florida panhandle; Mobile Bay; Mississippi Sound; Louisiana Hypoxic Zone; Lake Pontchartrain and Coastal Texas.

c. *Develop a rapid-response strategy for assessing HAB exposure.*

Researchers in a number of agencies are working to establish rapid sample collections and response protocols for detecting HAB toxins in humans and animals. The FDA is currently working with the seafood industry to develop new and rapid assessment methods to detect HAB toxins in seafood. NOAA also prioritizes the development of rapid-response test kits that communities, schools, or interested stakeholders can use to determine the presence of HAB species and toxins in local waterways. In addition, Water Research Institutes in several states have been established to help develop new tools to better understand and predict cyanobacterial HABs. The USEPA developed the Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems Fact Sheet (USEPA, 2014) to provide information to drinking water operators on health effects, sampling methods, and the effectiveness of treatment techniques to remove cyanotoxins. The USEPA also developed the Drinking Water Cyanotoxin Risk Communication Toolbox (USEPA, 2016c) to support public water systems in communicating information to their consumers before, during, and after a bloom event.

USEPA's Tools and Resources to Prepare for and Reduce Risks from Cyanotoxins in Drinking Water

Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems Fact Sheet
Provide information to drinking water operators on health effects, sampling methods, and the effectiveness of treatment techniques to remove cyanotoxins.

Drinking Water Cyanotoxin Risk Communication Toolbox
For states, tribes, and public water systems to use in communicating with the public before, during, and after HAB events (USEPA 2016c).

Cyanotoxin Management Plan Template and Example Plans
To assist states, tribes and public water systems in developing their own system specific cyanotoxin management plan, includes potential steps for monitoring, treatment and communication activities (USEPA 2016b).

Water Treatment Optimization for Cyanotoxins
To support public water systems in developing monitoring and treatment optimization approaches for cyanotoxins to achieve the best performance possible from each treatment process (USEPA 2016d).

Cyanotoxins in Drinking Water Webpage
To include these documents and other resources on impacts from HABs and cyanotoxins to drinking water.

Actions to Improve Predictive Capabilities

a. *Develop, improve, and validate HAB and hypoxia models and remote sensing*

Early warnings may be used to protect human and animal health by providing information of HAB and hypoxia events. Researchers use data to allow fishermen, drinking water and other resource managers, veterinarians, and others to make preparations and inform the public of the potential for a deleterious bloom. One major effort is the Cyanobacteria Assessment Network (CyAN), a multi-agency effort led by the USEPA and performed jointly with NASA, NOAA, and the USGS. The purpose of this project is to develop an early-warning indicator system to detect algal blooms in U.S. freshwater and marine systems using satellite data.

In addition, NOAA provides a number of HAB and hypoxia forecasts that routinely are applied in many coastal areas, with operational HAB forecasts in the Gulf of Mexico for the Florida and Texas coasts, and operational forecasts for Lake Erie *Microcystis* blooms. These also include warnings Gulf of Maine red tide; *Pseudo-nitzschia* blooms off California and the Pacific Northwest; and hypoxic zones in Lake Erie, the Gulf of Mexico, Chesapeake Bay, Narragansett Bay, and Green Bay. NOAA has an experimental HAB bulletin in western Lake Erie, which provides bi-weekly forecasts for *Microcystis* blooms in the basin, as well as an experimental hypoxia warning system for Lake Erie in Cleveland, OH.

Regarding the development of models, the USEPA is developing and applying scenario-based ecosystem models to better understand and predict aquatic ecosystem response and recovery to changing nutrient loads and other stressors, such as HABs. Using an integrative modeling approach, researchers will be able to quantitatively evaluate hypoxia causes and impacts and develop outreach tools to communicate advanced understanding to coastal managers and other stakeholders. The USGS is developing predictive statistical models based on real time sensor data and samples of toxins in water. Among factors found meaningful by the USGS for daily predictions of the occurrence of algal toxins, chlorophyll and phycocyanin sensor readings had the highest correlation to microcystin in a recent study (Foster et al., 2017).

b. Develop enhanced surveillance for human and animal exposure, illnesses, disease, and death resulting from HAB toxins.

Federal agencies are developing methods to analyze multiple toxins in edible fish, plants, and animal tissues and testing these methods on reservoir, stream, and coastal food webs. The CDC launched OHHABS in June 2016 to collect data on individual human and animal cases of illnesses from HAB-associated exposures, as well as environmental data about HABs. Simultaneously, the CDC went live with a new HAB-associated illnesses website to provide information for the public on how to identify HABs and protect themselves from illness. This site also includes health promotion materials, such as reference cards for veterinarians, physicians, and the public about HABs. To inform stakeholders and the public of the launch of the website and OHHABS, the CDC engaged in a variety of communication activities, including outreach to over 80 internal and external partners, social media messaging, and a media advisory. In total, 41 news articles and one broadcast story (with an estimated reach of 4,042,276 people)

mentioned the CDC's HABs website or OHHABS. In the two months following the launch, the new HABs website received 15,497 page views.

The USEPA is also working to estimate human exposure to cyanotoxins over specific geographic areas. The health of those communities with a history of cyanobacteria blooms detected via satellite may be evaluated retrospectively by the analysis of existing health records as part of the CyAN project. The FDA is working to determine ciguatoxin levels in food fish from U.S. waters. The FDA, as well as the CDC, is developing methods to quantify and characterize absorbed doses of cyanotoxins in biological samples to support the interpretation of associated health effects. Still, larger and more complete datasets are needed to develop improved forecasting and decision-making products.

Actions to Improve Stakeholder Engagement and Socioeconomic Understanding

a. Improve communication and coordination among health and environmental agencies so that reports of HAB-associated animal poisonings are used as an indicator of potential human-health risk. Develop science-based guidelines for cyanotoxins.

The IWG-HABHRCA has prioritized improving coordination and communication among the health and environmental agencies, as well as with outside stakeholders, since the publication of RPAS. During the IWG-HABHRCA bi-weekly meetings, members present on ongoing and planned projects, and use the time to discuss possible ways for agencies to coordinate in the future. Moreover, through the IWG's subgroups, agencies have a chance to develop specific documents and research plans, such as the RPAS and the Great Lakes HAB and Hypoxia Plan, as well as communications tools for informing the public of the risks presented by HABs and hypoxia. This includes encouraging veterinarians for example, through discussions with the American Veterinary Medical Association, to report HAB-related poisonings in animals to local and state health departments. The IWG continues to develop communications tools, and to seek out opportunities to interact with the public.

In support of the 2015 Drinking Water Protection Act, the USEPA will continue assessing occurrence, toxicology and epidemiology data for additional cyanotoxins that could be present in sources of drinking water as stated in the Algal Toxin Risk Assessment and Management Strategic Plan (USEPA 2015a), submitted to Congress in November 2016. The USEPA increased understanding on the human-health risks from exposure to HABs, listing cyanotoxins in the Contaminant Candidate List (CCL) for further assessment of health effects data. The USEPA also included ten cyanotoxins or cyanotoxin groups in the fourth UCMR4 to be monitored in public water systems. By publishing the Drinking Water Health Advisories for the cyanotoxins microcystins (USEPA 2015c) and cylindrospermopsin (USEPA 2015b) to assist Federal, state, and local officials, and managers of public or community water systems, the USEPA helps to protect public health from cyanotoxins in drinking water. Along with the health advisories, the USEPA developed Health Effects Support Documents for the Cyanobacterial Toxins Anatoxin-a (USEPA 2015d), Cylindrospermopsin (USEPA 2015e), and Microcystins (US EPA 2015f), and materials regarding feasible analytical methods, monitoring, and treatment options. In 2016, the USEPA released a Drinking Water Cyanotoxin Risk Communication Toolbox. The USEPA also developed liquid chromatography/tandem mass spectrometry

(LC/MS) methods for the determination of microcystins and nodularins (USEPA 2015g), and cylindrospermopsin and anatoxin-a (USEPA 2015h) in drinking water. Later in 2016, the USEPA published an ADDA ELISA Method for microcystins and nodularins (USEPA 2016a). The USEPA will continue evaluating the human-health risk from drinking water contaminated by these and other toxins and will determine and issue, if needed, health advisories for those algal toxins. CDC developed a Drinking Water Advisory Communication Toolbox that includes information about communicating HABs-related issues to the public.

In December 2016, the USEPA published draft guidance for Human Health Recreational Ambient Water Quality Criteria and/or Swimming Advisories for Microcystins and Cylindrospermopsin (USEPA, 2016e), for consideration by states and local health agencies to protect the public from contact, including incidental ingestion of cyanotoxins during primary contact recreation. In July 2017, the USEPA released several materials to assist recreational waterbody managers interested in monitoring and responding to cyanobacteria and cyanotoxins in recreational waters. These materials also include a recreational water communication toolbox for cyanobacterial blooms and a recommendations document for monitoring for cyanobacteria and cyanotoxins in recreational waters.

Since 2015, the USEPA has facilitated regional HABs workshops across the country to provide information on human health risks, prevention, control and management of blooms, and effective treatment techniques in drinking water. The agency is using the workshops as opportunities to improve networking and communication among states, tribes, and Federal partners. Other Federal agency-sponsored workshops and groups have been conducted to expand research, share information, and create networking opportunities to continue research efforts on the human and ecological-health risks. In several regions of the country, the USEPA supports tribal communities directly to monitor, predict and manage HABs that appear in their source and drinking waters.

b. *Identify susceptible populations at higher risk for HAB-associated adverse health effects*.

The CDC expects to use the Community Assessment for Public Health Emergency Response (CASPER) to identify needs quickly in HAB-affected communities. The USEPA worked with the University of Cincinnati and Miami University to evaluate the effect of cyanobacteria in susceptible individuals, especially those with chronic rhinitis. The goal was to identify cyanobacteria allergen(s) responsible for causing sensitization in these individuals, and to understand the relationship between cyanobacteria allergenicity and toxicity (Geh et al., 2015). The USEPA is evaluating biological samples for cyanotoxin concentrations to characterize associated health effects among humans and animals and possibly identify populations that could be at higher risk based on exposed doses or demographic characteristics. The USEPA is also conducting laboratory mouse bioassay studies regarding exposure to common algae and cyanobacterial toxins with the intention of generating information on adverse health effects one might expect to see in people and animals. OHHABS data collected by the CDC over time will contain information to further identify vulnerable populations based on factors such as exposure-related activities, health history, and geographic location.

c. Expand stakeholder engagement.

A primary need that the IWG-HABHRCA heard from stakeholders is for a unified, common web presence that provides basic information on HABs and hypoxia, as well as information on Federal activities. The IWG-HABHRCA created a site, hosted on NOAA's website, that is intended to serve as a "one-stop shop" for stakeholders. It links to websites maintained by member agencies; includes downloads of the products that the working group has created; and also provides basic background details on the history of HABHRCA, the IWG-HABHRCA, and HABs and hypoxia. Furthermore, a new feature of this site is a funding calendar that includes details on Federal funding opportunities (FFOs) and requests for proposals (RFPs) that routinely are put out by the member agencies, and relate to HABs and hypoxia.

To expand stakeholder engagement and to improve coordination and communication, the USEPA is conducting Regional HABs workshops across the country. These workshops provide information related to human health risks, prevention, control and management of blooms and effective treatment techniques in drinking water, as well as opportunities to build relationships among federal, state, and tribal Clean Water Act and Safe Drinking Water Act programs by making connections and identifying shared HAB-related goals, needs, and barriers. For example, on April 2017, the USEPA Region 9, in collaboration with California's State Water Board Surface Water Ambient Monitoring Program, hosted a HABs webinar and a three-day workshop for state, tribal, and local health and environmental programs, as well as water utilities, to share HABs information and allow networking. In addition, the USEPA leads the Inland HABs Discussion Group, along with the CDC and USGS, a multi-agency group of public-health officials from states, counties and tribes, academia, and Federal agencies that holds webinars to discuss issues related to research, monitoring, human and ecological health risk assessment, education, and outreach.

Another activity tailored to expand stakeholder engagement is the National HAB Committee, on which several Federal agencies serve as *ex-officio* members to provide a collective voice for the academic, management, Federal, and other stakeholder communities to facilitate coordination and communication of HAB activities at a national level. Activities tailored to educate and engage the community also include the monitoring programs working with citizen scientists.

To improve communications with health and environmental agencies, the USEPA has a Cyanobacterial HABs website to provide information for water professionals, drinking water suppliers, academic researchers, and the public on cyanobacteria and their toxins in freshwater systems. The USEPA also produces a current news monthly Freshwater HABs Newsletter that focuses primarily on freshwater HABs, and provides information on upcoming events, conferences, and webinars, useful resources, beach closures and health advisories and recently published journal articles. The USEPA also collaborates with the USGS, the USACE, FEMA, Coast Guard, and Maritime Administration in workgroups, such as the Upper Mississippi River Basin Association (UMRBA) HABs workgroup to share monitoring and laboratory capacities. UMBRA produced a response manual for HABs in 2016. UMBRA increases efforts to minimize the impacts of HABs and hypoxia such as developing nutrient criteria for water quality programs in OK, the use of reactive or filter mats to act as a sorbent for soluble and total phosphorous from runoff.

d. Evaluate socioeconomic impacts of HABs and hypoxia, and the costs of mitigation.

There are many knowledge gaps related to the socioeconomic impacts of HABs and hypoxia, particularly for events that occur in inland lakes, including assessments of the effects of individual HAB or hypoxia events; models of the socioeconomic costs of HAB and hypoxia impacts on food, drinking water, recreation, natural resources, home values and more; and the cost-effectiveness of prevention, control, and mitigation strategies, including nutrient reductions, to support decision-makers and inform prioritization. NOAA is coordinating with Federal agencies and economic experts to organize a workshop to discuss research methods and needs related to economics and HABs. The focus of NOAA's HABHRCA-authorized FY16 Northern Gulf of Mexico (NGOMEX) competitive program was on hypoxia impacts of the Gulf of Mexico dead zone. The funded studies apply several population- and ecosystem-based models to assessing and predicting the effects of the hypoxic zone on fisheries under various nutrient management and Mississippi River diversion scenarios. State and Federal fisheries managers are involved as project investigators or members of advisory committees. A component of the multiagency CyAN project will estimate economic value of detecting water quality using remote sensing data. Additionally, the CDC CASPER project identifies relevant needs quickly in HAB-affected communities.

Actions to Expand Collaborations in Research, Management, and Policy-Related Arenas

a. Continue and expand relevant research, management, and policy collaborations.

USDA's National Institute of Food and Agriculture (NIFA) provides grants to fund high priority research, education, and extension projects that are intended to develop conservation methods, processes to support organic farming, cover-crop breeding, and technologies that meet the requirements of the National Organic Program (NOP) while protecting soil, water, and other resources. Furthermore, the USDA NRCS works to reduce nutrient and sediment field losses through continued implementation of conservation practices. Cumulatively as of 2016, for the Mississippi River Basin Initiative (MRBI), NRCS reached 93% of a nitrogen reduction goal, 83% of a phosphorous reduction goal, and 67% of a sediment reduction goal. Nearly 75% of the nutrient management implementation goal of 500,000 acres in the MRBI was also accomplished, cumulatively from 2010-2016.

To continue research efforts related to the occurrence and human-health related risks from exposure to cyanotoxins in drinking water, the USEPA listed cyanotoxins in the CCL, a list of drinking water contaminants that are known or anticipated to occur in public water systems, and that currently are not subject to USEPA drinking water regulations. The USEPA also included ten cyanotoxins or cyanotoxin groups in the UCMR 4 to be monitored in public water systems. The USEPA uses the UCMR rule to collect occurrence information on unregulated contaminants that are suspected to be present in drinking water. Together, the CCL and the UCMR monitoring provide a basis for future regulatory determinations and, as warranted, actions to protect public health. In 2015 and 2016, the USEPA released Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water (USEPA 2015i) and Cyanotoxin Management Plan Template and Example Plans (USEPA 2016b) to assist state, tribes and public water systems as

they develop their own management strategies. The USEPA worked in collaboration with four states and five drinking water utilities to develop the example plans.

b. Develop guidelines and tests for HAB toxins in drinking and recreational water, and improve toxin removal during drinking water treatment.

The USEPA is working on several research projects to assess the effectiveness of methods to remove toxins during water treatment. These include a study on optimizing the application of chemicals and procedures during the early stages of drinking water treatment and removing cyanotoxins from source waters and developing the resource Water Treatment Optimization for Cyanotoxins. The USEPA is also working with Ohio Environmental Protection Agency (OH EPA) to develop a Comprehensive Performance Evaluation (CPE) Protocol for HAB Control in surface-water treatment plants. In 2016, the USEPA also released Cyanotoxin Management Plan Template and Example Plans to assist state, tribes and public water systems as they develop their own management strategies following recommendations provided in the 2015 Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water. The USEPA worked in collaboration with four states and five drinking water utilities to develop the example plans.

III. Additional Activities Carried Out Under the Program, Including the Regional and Subregional Parts of the Action Strategy

This section is responsive to Section 603(j)(2) of the HABHRCA 2014 to "*report the activities carried out under the nation's HABs program, including the regional and sub-regional parts of the Action Strategy"*. It also provides the information required by Section 605(b)(3)(I) for "progress reports on the activities toward achieving the objectives of the *Harmful Algal Blooms and Hypoxia in the Great Lakes Research Plan and Action Strategy: An Interagency Report*, which was published on August 24, 2017. The following illustrates information on specific regional and subregional activities undertaken by the IWG-HABHRCA's member agencies since 2014. For further information on specific, related current and planned activities, please see Appendix 1.

Northeastern United States

- In 2017, NOAA was in its first year of producing a weekly forecast bulletin for HABs in the Gulf of Maine that predicts the size, location, and transport of bloom. In the Gulf of Maine, blooms of the toxic algae that cause "red tides" occur annually. Red tides can pose a public health threat, an economic threat to state shellfish industries, and negatively impact the tourism industry in the Gulf of Maine.

- USEPA researchers have been studying the temporal and spatial variability of water quality and cyanobacteria in two Rhode Island ponds with different ecological conditions. During the 2017 growing season, the USEPA conducted twice-weekly samplings at seven sites across each pond during bloom season and will continue once-monthly sampling through winter. The goal of this research is to understand how the relative concentrations of chlorophyll *a*, phycocyanin, and microcystin vary spatially within the ponds and over time.

Pacific Northwest

- NOAA-supported researchers and staff developed a predictive model for *Pseudo-nitzchia* blooms and domoic acid in the Pacific Northwest. NOAA will run the forecast in demonstration mode, distributing bulletins to managers in 2017.

- In early fall 2017, NOAA researchers, Washington State fisheries managers, and academics worked to provide ongoing monitoring and testing using ESPs and other *in situ* sensors to determine whether it was safe to open the razor clam fishery. This was significant, given that the fishery not only provides a major source of tourism revenue and food for communities, but also because it is coming on the heels of a closure two years ago that had some considerable economic and social impacts. In the few weeks preceding the shellfish harvest, NOAA and our partners were able to predict and detect the HAB that potentially could have shut down the fishery. NOAA and its partners were able to provide an early warning, so that managers could begin testing early on. In fact, the forecast was one of the factors in the decision by the Washington Department of Fish and Wildlife to increase the bag limit on the number of clams each person could collect. This helped the communities that depend on recreational harvesting for tourism dollars. In fact, recreational razor clam harvesters set a record for one-day digger trips (17,800 diggers) on April 30, and generated $7M and 77,800 digger trips over the 11-day opening in Long Beach, Washington.

Southeastern United States

- The USGS published new scientific findings on the occurrence of algal toxins in small streams in the southeastern United States (Loftin et al., 2016). This finding broadens the scientific knowledge base on the prevalence of algal toxins in U.S. freshwaters. The USGS demonstrated that algal toxins can be reliably predicted using phycocyanin sensors deployed in streams and lakes that serve as source waters for public supply and for recreation (Francy et al., 2016; Foster and Graham, 2016; Graham et al., 2017). These findings will lead to better prediction of HABs and serve as an early warning system to protect public health and the environment.

Gulf of Mexico

- NOAA is leading development of the Cooperative Gulf of Mexico Hypoxia Monitoring Program, a multi-partner sustainable monitoring program that encompasses the northern Gulf of Mexico hypoxic zone, and advances ecosystem management objectives for mitigation of hypoxia, ocean acidification, and other ecosystem stressors.

- Research workshops, like the Annual NOAA/Northern Gulf Institute's Gulf of Mexico Hypoxia Research Coordination Workshops, and groups such as the National Water Quality Program Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (also known as the Hypoxia Task Force) are working to expand research, share information, and create networking opportunities. The USGS Toxic Substances Hydrology Program

continues research studies on HABs and associated toxin mixtures, and encourages research on occurrence and human health risks from exposure to HABs.

Midwest, Not Including Great Lakes

- In 2016, the USGS started delivering real-time data to the public from more than 60 chlorophyll sensors in streams, lakes, estuaries, and coastal areas. Data from these sensors help to predict the onset and development of algal blooms that can cause taste and odor problems and possible toxin production in source waters for public supply and in recreational waters. Sensor-data has been used since 2013 to predict probability of geosmin and microcystin occurrence in Cheney Reservoir, an important drinking-water supply for the city of Wichita, Kansas. Wichita uses these tools to help inform drinking-water management strategies. The USGS, in collaboration with the USEPA, states, and tribes, published the largest survey of cyanotoxins in the nation's lakes. Scientists sampled 1,161 lakes across the nation for several cyanotoxins including cylindrospermopsin, microcystins, and saxitoxin. This study found multiple classes of cyanotoxins were present in lakes and reservoirs in diverse settings across the United States.

Great Lakes

- NOAA has made vast improvements in detecting, monitoring, and forecasting HABs. NOAA's HAB Forecast bulletin for Lake Erie transitioned to operations in 2016. NOAA is developing forecasts to warn Lake Erie drinking-water managers when hypoxic water approaches intake pipes.

- Under the Great Lakes Restoration Initiative (GLRI), Federal agencies have allocated significant expenditures since 2010 for a wide array of projects aimed at reducing nutrient loading into the Great Lakes. As an example, in response to the 2014 drinking water ban in Toledo, Ohio, Federal and state agencies quickly received nearly $12 million in GLRI funds for projects intended to reduce and monitor HABs in western Lake Erie. More than $67 million of GLRI funds were invested in the Lake Erie basin from 2010 through 2016 to reduce nutrient pollution and to support related science and monitoring work. Many new and innovative projects are being funded that will have direct impact on achievement of nutrient reduction goals to minimize the impacts of HABs and hypoxia in the Great Lakes. A significant portion of the GLRI investments are targeted to restoration and supporting science in high-priority watersheds and receiving waters that have high potential or known risk for experiencing HABs and/or hypoxia events, including the Fox River-Green Bay, Saginaw River-Saginaw Bay, and Maumee River-western Lake Erie.

- The USEPA will continue working with other Federal agencies and Canada on the actions to reduce phosphorus loadings that will minimize HABs and hypoxia in the Great lakes basin under the Great Lakes Water Quality Agreement. In 2014, Federal agencies worked with Canada and the states in Lake Erie basin to identify through scientific assessment and modeling, reductions necessary to curb HABs and hypoxia in Lake Erie. Multiple models were employed to generate load response curves of eutrophication indicators and reductions on the order of 40% were set to spring runoff from the Maumee

River. In 2016, Canada and the United States adopted these phosphorus reductions targets in the Lake Erie to minimize the extent of hypoxic zones which maintain algal species consistent with health ecosystems and to avoid biomass of cyanobacteria at levels that could pose a threat to humans or the ecosystem. Furthermore, in 2017, the USEPA released a draft Domestic Action Plan at the national level – as well as Ohio, Michigan, Indiana, and Pennsylvania, at the state level – for reducing phosphorus to Lake Erie.

- In 2010, the United States and Canada signed an agreement, the Great Lakes Water Quality Agreement (GLWQA), to reduce excess phosphorus levels that contribute to HABs in Lake Erie. The agreement includes ten annexes and the U.S. activities are coordinated by the USEPA. Annex 4 on nutrients, includes the recommendations and actions to manage phosphorus and other nutrients such as minimizing the extent of hypoxic zones and maintaining cyanobacteria biomass at levels that do pose a threat to human or ecosystem health in the Waters of the Great Lakes. In 2016, through the Nutrients Annex, the United States and Canada committed to reduce 40% of total phosphorus loadings entering the Western Basin and Central Basin of Lake Erie. Annex 4 also provides recommendations to conduct and share research, monitoring and modeling needed to establish, report on and evaluate the management of phosphorus and other nutrients associated with HABs.

- In 2016, the USDA began implementing $41 million to the Western Lake Erie Basin Initiative conservation effort to reduce nutrient losses from agricultural lands in the Great Lakes basin and released an assessment of the effects of conservation on cultivated croplands in the Western Lake Erie Basin, which has been used to inform conservation initiatives and domestic action plans. In addition, the USDA released a new Demonstration Farm Network in Ohio to implement, document and highlight successful conservation practices. It also began a new project on stacked conservation practices for successive water quality treatment.

- In 2017, the USDA released a new assessment and report on the instream effects of conservation practices on cultivated croplands, the second in a series. This analysis considers the impact of conservation adoption on instream and delivery dynamics of nutrient and sediment and draws attention to the need to consider legacy loads and associated time-lags when setting conservation goals and determining metrics of success. Once fully functional, conservation practices adopted in 2012 will reduce edge of field phosphorus losses by 17 percent, reduce phosphorus deposition in the Western Lake Erie hydrological system by 30 percent, and reduce phosphorus delivery to Lake Erie by 3 percent, relative to 2003-2006 values. Continued adoption of comprehensive conservation plans will help to increase the benefits of conservation practice adoption. Innovative conservation practices, such as phosphorus removal structures among others, are being implemented and evaluated to reduce dissolved phosphorus sources.

- The National Agricultural Library at the USDA has created an online, automatically updated bibliography to help track the science related to agricultural operations and Great Lakes harmful algal blooms and hypoxia, "Great Lakes Harmful Algal Blooms and Hypoxia: Agricultural Aspects". While it is not a complete listing of all the literature on

the topic and does include some citations that may not have a strict agriculture focus, the bibliography's value is in providing a look at current research findings that strengthen the science base needed for effective agricultural policy and management actions to address HABs and hypoxia.

Lake Erie Harmful Algal Bloom Early Season Projection

9 May, 2017 Projection 01

The severity of the western Lake Erie cyanobacterial harmful algal bloom (HAB) is dependent on input of bioavailable phosphorus, particularly from the Maumee River during the loading season (March 1-July 31). This product provides an estimate based on a combination of measurements to date and model predictions into July. The final seasonal forecast will be made in early July with more data and a comprehensive set of models.

In March and April, the Maumee River had discharge and phosphorus loads below average. High rains the beginning of May produced a substantial load so far in May. There is some uncertainty in discharge over the next six weeks. The forecast favors precipitation remaining close to normal, which would result in a milder bloom, only slightly more severe than last year. However, the possibility of several rainfall events increase the range of uncertainty to more severe blooms. The projection will be updated approximately weekly with new data and weather models through the end of June.

Total bioavailable phosphorus (TBP) is the sum of dissolved phosphorus (which is ~100% available for HAB development), and the portion of particulate phosphorus that is available for HAB development. The TBP loads are projected to June 20th using river forecasts from the National Weather Service Ohio River Forecast Center, and to the end of the loading season using past data.

Stumpf (NOAA National Ocean Service), Johnson (Heidelberg University), and Dupuy (CSS at NOAA)

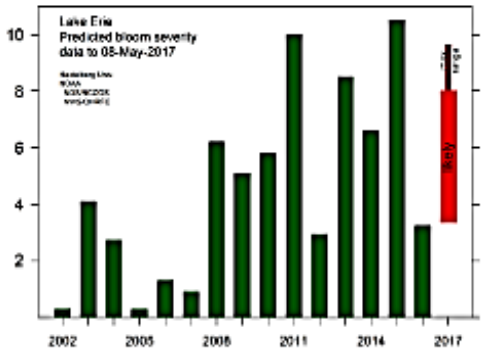


Figure 1. Projected bloom compared to previous years. The wide bar is the likely range of severity based on data from the last 15 years. The narrow bar is the potential range of severity. There is some uncertainty in rainfall over the next several weeks, causing the large uncertainty in the potential bloom severity.

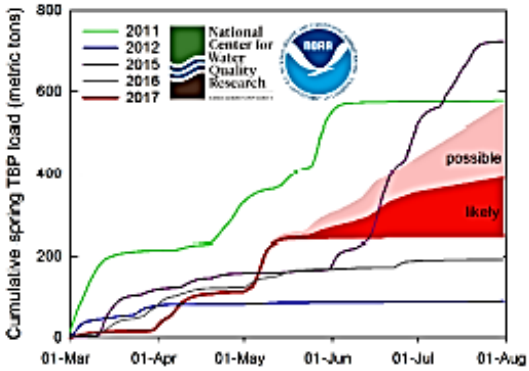


Figure 2. Cumulative total bioavailable phosphorus (TBP) loads for the Maumee River (based on Waterville). Each line denotes a different year. 2017 is in red, the solid line is the measured load to May 8th, the likely range for the remainder of the loading season in red area and possible range in light red area. The load will pass 2016 this week, but is likely to be lower than either 2011 or 2015.

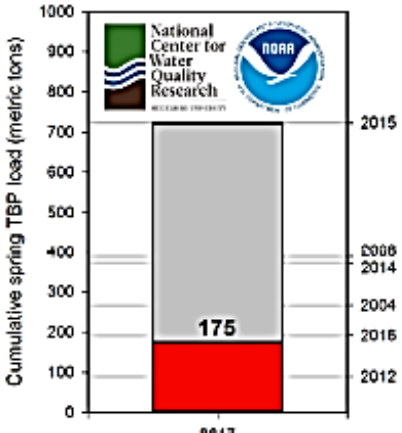


Figure 3. Total bioavailable phosphorus (TBP) load accumulated from the Maumee River near Waterville to date. The right axis denotes the TBP load from selected previous years. Current loads have surpassed 2012, and equaled 2016 on May 08.

Figure 4. True color image from May 8 2017 taken by the MODIS on NASA's Terra satellite. A plume of sediment from the Maumee River extends down the Ohio coast to Sandusky Bay. Small plumes are also evident around the smaller rivers. Shallow areas also show sediment stirred up from strong winds.

For more information visit: http://www.heidelberg.edu/academiclife/distinctive/ncwqr or http://coastalscience.noaa.gov/research/habs/forecasting/

An example of the operational Lake Erie HAB Bulletin, May 9, 2017. (Credit: NOAA)

IV. Need to Revise or Terminate Research and Activities under the Program

The HARBRCA legislation calls for the revision or termination of research and activities when they are complete or no longer needed. The IWG-HABHRCA and its member agencies do not see any need to terminate or revise activities and research under the program unless funding is not available or is limited.

V. Budget Related to HAB and Hypoxia Activities under the National Program

According to GAO-17-119, twelve agencies spent approximately $101 million between FY2013 and FY2015 on activities related to HAB research, monitoring, or other areas. Per the report, five agencies in particular had the largest expenditures on HAB-related activities: NOAA ($39.4 million),[1] NSF ($15.4 million), EPA ($14.5 million), USGS ($9 million), and NIEHS ($8 million). Other agencies, including those who participate in the IWG-HABHRCA, also reported millions of dollars in related expenditures. Furthermore, agencies reported expanding HABs-related projects since the end of that period. As discussed in this report, agencies clearly are investing more annually in HAB and hypoxia research, monitoring, forecasting, and mitigation measures. For more information on agency-specific expenditures, please refer to GAO-17-119 (GAO, 2016).

Conclusion

The programs, policies, and other activities highlighted in this progress report will help Congress and researchers to understand the causes and effects of HABs and hypoxia, to better monitor and detect HABs, and to improve surveillance of toxins and humans and animal diseases. The agencies involved have also been working since the publication of the RPAS report to increase and improve collaborations with stakeholders, as well as to develop risk communication materials and guidance to better understand and communicate health-related impacts of HABs and hypoxia.

As agencies proceed with the activities listed in Appendix 1, they have a clear vision for responding to the recommendations put forth in RPAS, complying with the 2014 reauthorization of the HABHRCA. These activities will focus among other areas on developing and validating methods for forecasting, predicting, and detecting HAB toxins; conducting studies on toxins in food and drinking water; and developing monitoring techniques and models. The agencies will work to understand the influences of temperature and nutrient input on the occurrence and severity of HABs and hypoxia, and improve toxin removal during drinking water treatment. Nevertheless, many challenges remain. These challenges include needs for the following:

- **Established strategies for effective prevention, suppression, and control of HABs within watersheds and affected waterbodies**.

[1] These numbers differ from those reported to Congress in NOAA's HABHRCA Spending tables, which include hypoxia work.

Although several methods for the control and treatment of HABs have been tested and evaluated by the Federal agencies, researchers need to develop effective HAB suppression and control methods that have minimal environmental effects and lower costs. In addition, questions remain regarding the effectiveness of measures and strategies to control nutrients and the implementation of these measures to improve water quality and reduce HAB formation.

- **A rapid-response strategy for assessing HAB exposure.**
  With the development of increasingly accurate clinical methods, research will be needed to confirm exposure and foodborne illnesses related to algal toxins. In addition, researchers will need to investigate relationships between multiple classes and metabolites of toxins, and humans and animals, through inhalation, dermal, and ingestion exposures. Although OHHABS data collected by the CDC over time will help Federal agencies identify susceptible populations at higher risk for HAB-associated adverse effects, researchers and physicians need case definitions for the spectrum of HAB-related illnesses, along with clinical therapeutic guidance for the spectrum of illnesses associated with exposure to HAB cells and toxins.

- **Understanding of the influence of climate change, atmospheric deposition of nutrients, and other contributing factors on the occurrence, frequency, and severity of HABs and hypoxia.**
  Although work is underway to address some of the factors that contribute to HABs and hypoxia occurrence and severity, monitoring efforts for nutrients are still needed to address the research gap on how sediments affect internal phosphorus cycling in the water column and the proliferation of HABs and hypoxia. The analysis of the environmental data, such as nutrient levels, temperature and cyanobacterial densities could provide useful information to recreational water managers and drinking water treatment operators that will help identify response strategies to more effectively address HABs and hypoxia events.

- **Evaluation of the economic and socioeconomic impacts of HABs and hypoxia, and the costs of mitigation.**
  There are many knowledge gaps related to the economic and socioeconomic impacts of HABs and hypoxia, particularly for events that occur in inland lakes. More assessment of the socioeconomic impacts of individual HAB or hypoxia events are needed to determine which types of events require the greatest attention and resources. Also needed are models of the socioeconomic costs of HAB and hypoxia impacts (on food, drinking water, recreation, natural resources, as well as aesthetic impacts and lost ecosystem services). Finally, information is needed to characterize the cost-effectiveness of prevention, control, and mitigation strategies, including nutrient reductions, to support decision-makers and inform prioritization.

- **National datasets on human exposure and cyanobacterial blooms monitoring.**
  Although the Federal agencies in the IWG-HABHRCA are working to estimate human exposure to cyanotoxins over specific geographic areas, and estimate toxins levels in

water and food, more complete datasets are needed to develop improved forecasting and decision-making products.

Continued and improved conservation, implementation, and agricultural management practices to reduce nutrients and sediment losses from agricultural lands.

Managing nutrient losses from the urban and agricultural landscapes is at the crux of addressing HABs and hypoxia across the United States. While agencies are working hard with communities to encourage and improve conservation, and to develop and implement nutrient reduction strategies, it is clear that there are many locations that need further assistance from the government. Furthermore, there is a need for refined research into methods that are more effective at limiting nutrient loss, while remaining cost-effective for the landowners and stakeholders implementing them.

The IWG-HABHRCA will continue coordinating and information sharing among the Federal agencies to fully implement the RPAS's goals and objectives and conduct relevant research, guidance, and polices. In addition, the IWG will continue engaging stakeholders through different forums to keep them aware of research and emerging issues.

Appendix 1. IWG Anticipated Agency Actions on HABs and Hypoxia from 2016 to 2020

This appendix lists the activities anticipated to be carried out by the Federal agencies members of the IWG in response to Section 603(j)(2) of the HABHRCA 2014 to address the recommendations under the five core actions listed in Chapter 7 of the RPAS. Key activities were identified during the development of this document and are not intended to be an exhaustive list.

1. Actions to Advance the Scientific Understanding of HABs and Hypoxia

Develop certified reference materials (CRMs) and other standardized and validated detection and analysis methods for HAB toxins.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Validate rapid screening and confirmatory methods for neurotoxic shellfish poisoning toxins in molluscan shellfish.	Multi laboratory validation of LC-MS method for NSP toxins in Eastern oyster and hard clams.	Multi-lab validation complete.	Evaluation by ISSC laboratory methods committee.	FDA	Sara Handy Sara.Handy@fda.hhs.gov	2018
Assess validated LC/MS method for monitoring neurotoxic shellfish poisoning toxins in molluscan shellfish	Verification of method efficacy.	Samples for assessment have been collected.	Additional collections and analysis of collected samples.	FDA	Sara Handy Sara.Handy@fda.hhs.gov	2018
Validate confirmatory LC-MS/MS for Caribbean Ciguatoxin-1 (C-	Validate a confirmatory detection method for the presence of C-CTX-1.	Method under optimization.	Complete validation.	FDA	Sara Handy Sara.Handy@fda.hhs.gov	2018

CTX-1) in fish						
Develop and validate methods for management of lipophilic shellfish toxins	Develop methods for shellfish toxins responsible for diarrheic shellfish poisoning (DSP) and Azaspiracid Shellfish Poisoning (AZP).	Validation of LC-MS/MS method for DSP complete for clam, Commercial PPIA kit validation in progress (with kit developer), New AZP toxin (AZA59) discovered on west coast (Co-PI on NOAA led MERHAB).	Extend LC-MS/MS method for DSP for oyster and mussel, Complete PPIA validation for ISSC, and determine human health risks for AZA59 in Puget Sound region (Co-PI on NOAA led MERHAB).	FDA	Sara Handy Sara.Handy@fda.hhs.gov	2018
Assess ploidy on neurotoxic shellfish poisoning toxins in eastern oysters	Assessing ploidy's impact on toxin accumulation and depuration.	Lab exposures to *K. brevis* completed.	Analyses of accumulation and depuration rates for PbTX.	FDA	Sara Handy Sara.Handy@fda.hhs.gov	2019
Development of analytical methods for improved measurement and monitoring of toxins related to harmful algal blooms in freshwater systems	Develop and refine liquid chromatography /mass spectrometry (LC/MS) based methods for toxin analysis.	Year 3 of 4-year project.	Laboratory work underway.	USEPA	Heath Mash mash.heath@epa.gov	2019
Develop Strategies and Methods for employing next Generation qPCR Array and	The purpose of this project is to provide the USEPA regions with improved tools to detect the genetic signatures of toxin producing cyanobacteria.	QAPP completed, supplies and equipment purchased, analytical services secured. First field	QAPP approval, qPCR method development, Sampling began April 18, 2017.	USEPA	Michael Davis, EPA Region 7, davis.michael@epa.gov	2019

PhyloChip Microarrays	Sampling and field validation started Spring 2017.	season almost complete. Team also received ORD Innovation Grant dollars to work with the state of Kansas on Milford Lake.				
Develop methods for assessing tissue levels of algal toxins in aquatic food webs.	Develop a method capable of analyzing edible fish, plant or animal tissues for multiple toxins	Year 3 of 4-year project.	Sampling and laboratory work underway – 'total' microcystin extraction method (MMPB) has been developed and tested using 3 microcystin congeners. MMPB method successfully used to detect microcystins in spiked fish tissue samples and in fish exposed to microcystins in an experiment stream facility phosphate study.	USEPA	James Lazorchak azorchak.jim@epa.gov	2019
Tools for the characterization of *Prymnesium parvum*	Preliminary studies will focus on identifying key *Prymnesium* toxins produced	Year 3 of 4-year project.	Sampling and laboratory work underway.	USEPA	Tammy Jones-Lepp jones-	2019

and related toxins	in inland ponds/lakes, many of which are on Tribal lands.				lepp.tammy@epa.gov	
Toxic algae in-vivo fluorescence sensor	Develop in-vivo fluorescence sensors to measure trends in *Prymnesium parvum* population.	Year 3 of 4-year project.	Sampling and laboratory work underway. *Prymnesium parvum* culturing is active and initial 3-D fluorescence scanning is underway.	USEPA	Michael Elovitz elovitz.michael@epa.gov	2019
Toxic Gene-Specific Monitoring for Harmful Algal Blooms Using Meta-Transcriptomic and RT-qPCR Approaches	1. Use a combination of microscopy and genus- or species-specific PCR to identify cyanobacterial species compositions and succession in a bloom. 2. Explore, through meta-transcriptonomic analysis, in situ toxic gene expression to reveal unknown or unmeasured toxins, and find novel gene targets for developing toxic gene assays.	Year 2 of 4-year project 1.Evaluated the roles of qPCR and RT-qPCR in early-warning of CyanoHAB with association of cyanotoxin concentrations. One manuscript has been prepared. 2. Examined toxic cyanobacterial species, phytoplankton community successions, and the relationships between ELISA measurements and the biomasses of	1.Sampling and laboratory work underway at Harsha Lake, Ohio; Region 7 lake water samples; and National stream water samples 2. Developed a full set of qPCR assay to detected toxic cyanobacterial genus or species. 3.Explore novel genes associated with toxin producing, bloom-	USEPA	Jingrang Lu lu.jingrang@epa.gov	2019

		phytoplankton, cyanobacteria and *Microcystis*, and between the nutrients and the biomasses during blooms in an Ohio lake. A paper has been accepted. 3. An analysis of microbial transcriptomic mRNA sequences revealed active cyanobacterial populations, genes (especially those associated with toxin release, nitrification and phosphorus utilization). A manuscript is preparing. 4. Evaluation of efficacy of microcystin treatment using qPCR and RT-qPCR targeting on MC producing genes.	producing, etc.			
The Use of a Polyphasic Approach to Track the Presence of Cyanobacteria-	Develop a molecular toolbox that can identify and detect the genetic signatures of cyanobacterial and non-cyanobacterial targets linked	Year 3 of 4-year project.	Sampling and laboratory work underway.	USEPA	Jorge Santo Domingo santodomingo.jorge@epa.gov	2019

Producing Toxins, Toxin Production, and Toxin Inactivation	to toxin production.					
Develop Analytical Methods to Detect and Quantitate Human Exposures to Algal Toxin.	Develop analytical methods to detect and quantify human exposures to algal toxins.	Methods to detect human exposure to multiple paralytic shellfish toxins are developed, validated and have been applied to clinical samples.	Methods to detect human exposure to domoic acid and microcystins developed and validated.	CDC	Elizabeth Hamelin ehamelin@cdc.gov	2020
Isolate and Purify Caribbean Ciguatoxin-1 (C-CTX-1) Standard from Naturally Incurred Finfish	Generate C-CTX-1 purified standard reference material.	Fish collected extraction begun.	Bulk extraction and purification ongoing.	FDA	Sara Handy Sara.Handy@fda.hhs.gov	2020
IWG-HABHRCA Subgroup on Certified Reference Materials (CRMs)	The IWG-HABHRCA recommended the development of an interagency group specifically tasked with examining the possibility of developing CRMs and other standardized and validated detection and analysis methods. CRMs are critical tools used by nearly every branch of science to provide the fundamental understanding required to accomplish this goal. The project will make specific	The CRM subgroup has created communications materials outlining and explaining CRMs, analytical methods, and their necessity.	The group will create additional products, as necessary, and will continue to meet to share ideas and information.	NOAA	Caitlin Gould Caitlin.gould@noaa.gov	2020

	recommendations for products, to increase public awareness about CRMs and analytical methods for HAB toxins, to foster strategic federal and private partnerships to accelerate CRM development, and to further coordinate federal action under the HABHRCA.					
Develop Analytical Methods and Reference Materials	Analytical methods and reference materials are advanced in concert with other Federal agencies participating in the IWG-HABHRCA to support the development of standardized methods and training for testing laboratories and validation of their use to assure accurate and reproducible measurements nationwide.	CRM information document and goal of the subgroup completed and to be distributed to stakeholders.	The project will make specific recommendations for products, to increase public awareness about CRMs and analytical methods for HAB toxins, to foster strategic federal and private partnerships to accelerate CRM development, and to further coordinate federal action under the HABHRCA.	NOAA	John Ramsdell john.ramsdell@noaa.gov Mary Bedner, NIST mary.bedner@nist.gov	Ongoing
Develop Laboratory Methods for Evaluating Understudied Toxins	Continue expansion and validation of laboratory cyanotoxin detection techniques into all water	Several reports and journal articles have been published and are available in the	Future reports and journal articles will be made available	USGS	Jennifer Graham (jlgraham@usgs.gov)	Ongoing

and to Support Research Goals in Relevant Matrices.	types including lakes and reservoirs, rivers and streams, wetlands, estuaries, and groundwater to capture in situ production and toxin load contributions from inland transport.	USGS Publications Warehouse using the search terms "harmful algal blooms" "cyanotoxins," and/or "algal toxins" (https://pubs.er.usgs.gov/	through the USGS Publications Warehouse at https://pubs.er.usgs.gov/			
Conduct studies on toxins in food, and on toxin mixtures.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Yurok Tribe STAR Grant - Identifying, Assessing and Adapting to Climate Change Impacts to Yurok Water and Aquatic Resources, Food Security and Tribal Health	Identify areas of water resource vulnerability and resiliency, assess impacts on Yurok food security and tribal health, and increase the Tribe's adaptive capacity to prepare and respond to climate change. Goals are to improve understanding of current and future climate change impacts on water resources; increase awareness of climate change impacts on key subsistence foods, vulnerable sub-populations and tribal member health; and improve	Completed sampling and verification of domoic acid and paralytic shellfish poison levels in marine mussels; assessed location and 16 months temperature data on 27 tributaries and 19 springs; located public and private source water intakes; assessed domestic water sources for waterborne disease; conducted passive	Develop culturally meaningful educational materials for distribution and f or their website.	USEPA	Cynthia McOliver, McOliver.Cynthia@epa.gov	2018

	tribal capacity to monitor, communicate, and prepare for climate change impacts. Increasing HABs and cyanotoxin impacts to fisheries (key subsistence foods) are being evaluated.	sampling with Solid Phase Adsorption Toxin Tracking (SPATT) for toxins associated with harmful algal blooms in 19 creeks and 4 Klamath River mainstem sites. Additional outcomes are available from Year 3 annual report on the EPA Research Grants website, https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/10249/report/2017				
A survey of the composition and purity of commercially available cyanobacteria toxin standards	Survey the composition and purity of commercially available cyanobacteria toxin standards from a range of vendors.	Year 2 of 3-year project.	Laboratory work currently underway.	USEPA	Neil Chernoff chernoff.neil@epa.gov	2019
Comparative toxicity of microcystin congeners -RR, -LR, -LA, -YR, -LY, -LF	Evaluate the oral toxicity of microcystin congeners for which little peer-reviewed data currently exists.	Year 3 of 4-year project.	Laboratory work currently underway	USEPA	Neil Chernoff; chernoff.neil@epa.gov	2019
Effect of cyanobacterial	Investigate the impact of cyanobacterial toxins on	Year 3 of 4-year project	Laboratory work currently	USEPA	Vicki Richardson	2019

toxins on human cell lines	human intestinal epithelial cells and human hepatocytes.		underway.		richardson.vicki@epa.gov	
Mechanism of cylindrospermopsin (CYN)-induced toxicity in mammalian models	This study seeks to identify the cause(s) of coagulopathy (bleeding) in mice from exposure to cylindrospermopsin.	Year 3 of 4-year project.	Laboratory work currently underway.	USEPA	Neil Chernoff chernoff.neil@epa.gov	2019
Toxicity and potential food-web impacts of *Alexandrium monilatum* and its toxins	*Alexandrium monilatum* ,an emerging toxic HAB in the Chesapeake Bay and its toxin goniodomin A (GDA), have caused mortalities of wild and aquaculture fish and shellfish. Through a combination of laboratory and field experiments, examine impact and tropic transfer of GDA on sheepshead minnows, brine shrimp, copepods, oysters, blue crabs, menhaden, stripped bass in order to minimize impact on aquaculture and wild harvests.	Project initiated 8/31/17	New information would be obtained on the impacts of *A. monilatum* and its toxin, Goniodomin A, on finfish and shellfish both in the laboratory and in the field. This will be used to mitigate the effects of this emerging HAB on mariculture and oyster restoration practices.	NOAA	Quay Dortch quay.dortch@noaa.gov	2020

Development of a Mechanistic ROMS-RCA-HAB model for predicting *Prorocentrum minimum* and *Karlodinium veneficum* blooms in Chesapeake Bay	Develop a coupled hydrodynamic-biogeochemical model (ROMS-RCA) as a new HAB model for *P. minimum* and *K. veneficum* in the Chesapeake Bay to address the long-term impacts of nutrient enrichment and climate change on HAB events, fisheries and shellfish habitat.	Project initiated 8/31/17	A model would be developed for seasonal predictions of *Prorocentrum minimum* and *Karlodinium venificum* in CB. This would provide an important tool to the CB management community in terms of a HAB forecast model that includes nutrient drivers and mixotrophy as important controlling factors	NOAA	Quay Dortch quay.dortch@noaa.gov	2020

CIGUATOX: A study of Gambierdiscus "super bugs" and ciguatoxin fate in coral reef food webs	Characterize ciguatoxin production and flux into Caribbean reef food webs for prediction and prevention of Ciguatera Fish Poisoning (CFP) by identifying *Gambierdiscus* "super bugs" and development of molecular probes to characterize community structure in field samples, toxin detection methods and reference material, and a numerical toxicity model.	Project initiated 8/31/17	The predictive model on CFP occurrence will be validated and demonstrated. Forecast tools and risk models for CFP will aid in developing management strategies to minimize human illness.	NOAA	Marc Suddleson marc.suddleson@noaa.gov	2020
Develop more-effective HAB suppression and control methods that have minimal environmental effects and lower cost.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
HAB Mitigation using alum at Pinto Lake, City of Watsonville, CA	Successful treatment of Pinto Lake with alum to mitigate severe blooms, which have resulted in lake closure over several years, and been linked to over 33 sea otter deaths in Monterey Bay. The project is funded by a CWA 319 sub grant awarded by California's NPS Program.	In April 2017, the majority of the Lake was treated with Alum (118 thousand gallons of a mixture of aluminum sulfate, aka alum, and a pH buffered sodium aluminate) Treatment resulted in an average phosphorus reduction of 89 percent, with an	Continued implementation of watershed source management, targeting eroding riverbanks and fertilizer use. Quarterly monitoring of TP and TN in water post- treatment; monitoring	USEPA	Sue Keydel Keydel.susan@epa.gov	2018

		average nitrogen reduction of 30%. Toxic blooms were averted through the summer season. The first toxic bloom began 10/24/17.	watershed BMPs during storm season 2017-2018.			
Control of HAB booms - The dinoflagellate-specific algicide IRI-160: Isolation, characterization and potential impacts on ecologically relevant metazoan species	This project is a follow-up to a previous PCMHAB study that showed great promise for field applications. This study will complete isolation of the bacteria-produced algicide and apply it in laboratory experiments with single and mixed species. In addition, a preliminary field demonstration will be conducted, scaling up production of the compound or bacteria for application in the field.	Continued work to isolate the algicidal compound(s) in the algicidal filtrate, IRI-160AA, focusing on amines – identified four specific amines (putrescine, diethylamine, and ammonium) and conducted bioassays with them to determine response of several dinoflagellates species and a control cryptophyte species. Two papers were published during this period describing research on the bacterial algicide, IRI-160AA, and its impacts on dinoflagellate morphology and	Continue with algicide isolation and characterization, develop an assay for the algicidal compound(s) in water and sediments. continue to evaluate the effects of polyamines on dinoflagellates. Microcosm experiments with natural microbial populations will be conducted to determine responses of dinoflagellates and other microbial species to repeated dosing of the	NOAA	Marc Suddleson Marc.suddleson@noaa.gov	2018

		biochemistry.	algicide, and the effects of the algicide on microzooplankton grazing			
Sorption and recovery of total phosphorus	Evaluate the use of reactive media that will act as a sorbent for soluble and total phosphorus associated with agricultural runoff and/or effluent from wastewater treatment facilities.	Year 3 of 4-year project.	Field testing of reactive media underway in Clermont County Ohio waste water treatment plant.	USEPA	Mallik Nadagouda; nadagouda.mallikarjuna@epa.gov Ed Barth Barth.ed@epa.gov	2019
Floating Vegetation Islands	RESES grant for using Traditional Environmental Knowledge (TEK) for the development of leading indicators of ecosystem function, such as for water quality standards, biological criteria, and control of HABs. This grant was awarded by ORD to USEPA's Region 9 Office to collaborate on research benefiting communities for a qualitative study of the presence of microcystins during, and outside of, harmful algal blooms (HABs).	Floating vegetated islands were built and installed - the Colorado River Indian Tribes island was installed in Nov 2016, and the Chemehuevi Tribe island was installed in Feb 2017. Workshops on water quality were also conducted with tribal partners.	Monitoring and measurement of water quality through the use of data loggers is ongoing.	USEPA	Daniel Heggem Heggem.Daniel@epa.gov Bob Hall Hall.RobertK@epa.gov	Ongoing
Understand the influence of climate change, atmospheric deposition of nutrients, and other contributing factors on the occurrence, frequency, and severity of HABs and hypoxia.						

Action	Goal/Purpose	Achievements to October 2017	Activities to be Completed	Agency	Point of Contact	Expected Date of Completion
Observations and Modeling of Narragansett Bay hypoxia and Its response to nutrient management	In 2030, an intensive hypoxia event in Narragansett bay resulted in a large fish kill, prompting a new state law to impose N limits on wastewater treatment facilities that are the dominant source of nutrient load to the Bay. In 2013, the 50% N reduction target was met. This project used a multiple modeling approach to quantitatively assess the dynamic relationship between N loading and hypoxia, with the goal of informing the state of Rhode Island of the effectiveness of this N load reduction in mitigating hypoxia.	The project provided confirmatory evidence that the goal to reduce nitrogen loading into the Bay was achieved, determined, through quantitative analysis of monitoring and modeling results, that the N reductions led to a Bay-wide shift from eutrophic to oligotrophic conditions, and through independent confirmation from hypoxia models, informed the EPA and State Department that an additional 25% reduction in nitrogen loading is needed to comprehensively reduce hypoxia in all affected Bay regions.	N/A - Completed	NOAA	Alan Lewitus Alan.lewitus@noaa.gov	2016
Lake Erie	USEPA worked with Canada	Multiple models were	N/A (complete)	USEPA	Santina	2016

Ecosystem Modeling and Targets Development	and the states in Lake Erie basin to identify through scientific assessment and modeling, reductions necessary to curb HABs and hypoxia in Lake Erie.	employed to generate load response curves of eutrophication indicators. A suite of revised phosphorus load and concentration targets were formally adopted by the United States and Canada under the Great Lakes Water Quality Agreement in 2016.			Wortman wortman.santina@epa.gov	
USGS partnerships with universities to conduct HABs research	Through grants to the Water Resources Research Institutes (WRRI), the USGS is working with university, local, and state partners to better understand and predict HABs. Water Resources Research Institutes in the District of Columbia, Arkansas, Georgia, Indiana, Kentucky, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Washington, and Texas have ongoing studies.	Projects have been funded and research is in progress. Project details are available through the USGS State Water Resources Research Institute Program (WRRI) website https://water.usgs.gov/wrri	Project completion and delivery of final reports or journal articles.	USGS	Earl Greene eagreene@usgs.gov	2019
Green Bay Hypoxia: Biogeochemical dynamics, watershed inputs	The goal of this project was to forecast the impacts of hypoxia in the lower part of Green Bay in Lake	The scenario-based hypoxia forecast models were made available to users	N/A - Closed out	NOAA	Felix Martinez Feliz.martinez@noaa.gov	2017

and climate change	Michigan. Impacts were assessed with a comprehensive set of linked models of watershed loading, biogeochemical cycling, and hydrodynamics that are informed by downscaled regional climate scenarios to assess both current and future conditions.	through a management oriented platform integrating watershed and lake models which include visualizations, tables, figures, etc. that illustrated watershed and bay responses to changes in nutrient loading and climate. This web-based interactive prediction modeling tool can be used to inform resource agencies of the efficacy of watershed nutrient reduction strategies in reducing hypoxia and restoring water quality.				
Assess conservation practices and develop conservation planning tools that can improve agricultural water quality in the Midwest	This project aims to develop and evaluate practices for reducing surface water contaminants in artificially drained landscapes; evaluate practices to reduce runoff and sediment losses from urban sites; and develop and evaluate tools to optimize placement of conservation practices within Midwest	Using a paired edge of field approach and data from surface and subsurface (tile drainage) practices such as surface amendments (gypsum), subsurface P application, and the 4Rs have been evaluated.	Effects of specific 4R practices as well as the impact of stacked practices is still to be completed. Treatments (practices) have been identified and should be	USDA ARS	Kevin King kevin.king@ars.usda.gov	2020

	watersheds for improved environmental benefits.		implemented following crop harvest.			
Environmental effects and services resulting from prevailing and innovative land use and management practices within poorly drained Midwest landscapes	This ARS project aims at quantifying edge-of-field (EOF) and watershed scale environmental and ecologic impacts of conservation practices in three watersheds (Upper Scioto, Upper Wabash, Western Lake Erie Basin) in Ohio.	A network consisting of 20 paired edge-of-field sites has been established. The EOF sites generally contain surface and subsurface (tile drainage) collection point. Baseline data has been collected on the majority of sites.	Treatments have been identified for a majority of sites and visits with producers have been completed. Treatments should be implemented once harvest is complete.	USDA ARS	Kevin King kevin.king@ars.usda.gov	2020
Integrating Cell and Toxin Cycles of Karlodinium veneficum (Kf) with Key Environmental Regulators: In Situ Studies of Predictive Determinants for Bloom Toxicity	This study will assess the factors controlling Kf toxicity in Chesapeake Bay and other mid-Atlantic estuaries, and develop a management tool (mitotic index) for rapid and simple prediction of the potential of a bloom for becoming toxic or increasing toxicity potential.	The project has identified the initiation process for karlotoxin biosynthesis being the photorespiration product glycolate. The enzyme ketosynthase is found to act as a scaffold for karlotoxin production. Tasks to develop methodology for comparing digital microfluorimetry to flow cytometry and	Managers will be trained on how to utilize the mitotic index for rapid toxic bloom detection, and incorporate it into regular monitoring programs.	NOAA	John Wickham john.wickham@noaa.gov	2018

		optimization of the in situ growth rate estimation using the mitotic index have progressed significantly. Accurate image analysis has been achieved using the flat-field/shading correction method. Field sampling in Baltimore Harbor is delayed to summer 2018.				
Resolving the Effects of Resource Availability, Predation, and Competition on Brown Tide Dynamics via Metatranscriptomics	The purpose of this project is to develop markers that can be used in the field to elucidate the factors causing brown tides of *Aureococcus anophagefferen*, including specific anthropogenic factors such as nitrogen, phosphorus, organic matter, metals, low light, and others.	Conducted laboratory experiments to identify how pelagic predators, organic matter, Se, N, and P, affected growth rates of *Aureococcus* (brown tide). Conducted field surveys across the south shore of Long Island in New York during spring and summer in 2015 & 2016. Quantified plankton and nutrients. Conducted	Finish sequencing, analyzing and comparing transcriptomes and other samples from lab & field experiments & natural populations Update Suffolk County Harmful Algal Bloom Action Plan.	NOAA	Quay Dortch quay.dortch@noaa.gov	2018

		14 field experiments in 2015 & 2016 to assess transcript regulation in *Aureococcus* and co-occurring phytoplankton populations during field experiments that alter levels of nutrients, light, metals and predators. Collected transcriptome samples during all culture and field sampling. Analyzed some transcriptome samples from field surveys conducted in years prior to the award. Determined that P as well as N from DON drives brown tides but viral infection not a factor. Developed Suffolk County Harmful Algal Bloom Action Plan.				
Climate Change Impacts on the	The goals of this project are to investigate the effects of	Copepod grazing found to be lower on	Grazing experiments to	NOAA	Beth Turner Elizabeth.Turn	2018

Physiology and Trophic Dynamics of Harmful Algal Species from Delaware's Inland Bays	climate change on HAB species and the consequences of altered toxicity and nutritional quality of HAB species on micro- and mesozooplankton grazers	toxic algal species compared to non-toxic species, but no effect was found on egg production rates.	determine effects of higher temp and CO2 on toxicity and nutritional quality for copepod grazers.		er@noaa.gov	
Agriculture and Food Research Initiative (AFRI): Nitrogen and Phosphorus Cycling Competitive Grants Program	This program seeks to support research projects to evaluate the physical and biogeochemical processes affecting the flow, fate and transport, transformation, movement, and storage of nitrogen and phosphorus in plant and animal agricultural systems.	Annually funds research projects to advance this area. Projects periods are up to four years	Some highlights from funded projects are: Increasing our understanding of soil P availability and mobility and how these characteristics vary with soil type and agriculture practices is leading to reducing P loss from agriculture systems and contribute towards science based management plans. Another project demonstrated that diversified cropping systems lead to a more diverse soil	USDA NIFA	Nancy Cavallaro ncavallaro@nifa.usda.gov	2018

			microbial community reducing the number of ammonia-oxidizing bacteria, thus minimizing nitrogen losses. Other work has shown that nitrogen transport in watersheds during low flow conditions can increase dramatically with large storms such as those associated with tropical depressions and hurricanes.			
National Integrated Water Quality Program (NIWQP)	NIWQP grants contribute to the improvement of the quality and conservation of our Nation's water resources through research, education, and extension activities. Projects funded through this program will work to solve water resource problems by advancing and disseminating the knowledge base available	Development of new GIS-based assistive tools to support the adoption of best management practices in polluted watersheds. Adoption of on-farm water storage systems to provide irrigation water, while	Completion of ongoing grant projects and delivering of the research results to stakeholder in forms of extension. The last year this program received	USDA NIFA	James Dobrowolski jdobrowolski@nifa.usda.gov	2019

	to agricultural, rural, and urbanizing communities.	capturing nutrient-rich tailwater in the Mississippi Delta. Expansion of goCrop, an integrated mobile technology to enhance nutrient management program implementation, to include California.	appropriation was 2014, so there are no new awards.			
Ecological contributors to CyanoHABs	Relate sediment densities of cyanobacteria to observed densities of pelagic cyanobacteria to determine if specific areas serve as sources for initial cyanobacterial stocks.	Year 3 of 4-year project.	Field sampling underway.	USEPA	Alan Lindquist lindquist.alan@epa.gov	2019
Understanding harmful algal blooms and protecting the ecosystem and human health from their toxins.	What are the ecological impacts of algal toxins on aquatic life through direct exposure and through food chain bioaccumulation? Approach will be to assess whether algal toxins inhibit zooplankton grazing behavior and population dynamics, and impact of benthic filters. Test whether simultaneous and sequential exposure to multiple toxins, particularly the combination of microcystins and cylindrospermopsin, and	Year 3 of 4-year project.	Sampling and laboratory work underway. Acute toxicity Tests have been conducted on Lake samples from Harsha using lysed and unlyzed samples. acute C dubia, larval fathead minnow, mayfly and amphipod tests conducted on samples. No	USEPA	James Lazorchak lazorchak.jim@epa.gov	2019

	microcystins and anatoxins pose accumulative or synergistic risks to aquatic life.		acute toxicity found. In house cultures of M aeruginosa and A flosaque are currently being tested. Ohio EPA has been contacted to test lakes Erie bloom samples.			
Modeling reservoir algal community dynamics to link watershed to drinking water treatment and water recreation beneficial uses.	Provide a computational and modeling framework for linking watershed nutrient loadings to the degradation of reservoir water quality and resultant risks to human health and loss in beneficial uses.	Year 3 of 4-year project.	Database development.	USEPA	Christopher Nietch nietch.christopher@epa.gov	2019
A Data-Intensive Investigation of Temperature Impacts and Bloom Modeling.	Investigate the connections between air temperature, photic zone temperature and cyanobacterial bloom probabilities.	Year 3 of 4-year project.	Database development underway. An "R" based tool for lake morphometry has recently been released: https://cran.r-project.org/web/packages/lakemorpho/index.html	USEPA	Betty Kreakie kreakie.betty@epa.gov Jeff Hollister, hollister.jeffrey@epa.gov	2020
Cross-Regional Comparison of	Identify and quantify factors controlling *Dinophysis*	Project initiated 8/31/17.	The study would extend the	NOAA	Quay Dortch quay.dortch@nc	2020

Dinophysis Bloom Dynamics, Drivers, and Toxicity	blooms and Diarrhetic Shellfish Poisoning (DSP) across the US as a means of developing optimized regional early warning systems and management plans.		Imaging Flow CytoBot (IFCB) network nationally, advance understanding of the drivers and reason for the sudden national spread of *Dinophysis* and DSP, and advance toward creation of a national monitoring and early warning system		aa.gov	
Expanding the Options for Monitoring of DSP by Promoting the ISSC Approval of LC-MS/MS and Two Rapid Screening Approaches	Compare three analytical methods for Diarrhetic Shellfish Poisoning toxins in shellfish meats: LC-MS/MS, lateral flow immunoassay and phosphatase inhibition, submit proposals to the ISSC for approval for incorporation into the National Shellfish Sanitation Program (NSSP), and train users the approved methods.	Project initiated 8/31/17.	Submit proposals to the ISSC for approval of most effective method for incorporation into the NSSP, and train users the approved methods	NOAA	Quay Dortch quay.dortch@nc aa.gov	2020

Linking Process Models and Field Experiments to Forecast Algal Bloom Toxicity in Lake Erie	Add toxin production to models of cyanobacterial blooms in Lake Erie by (1) examination of historical data for correlation between environmental variables and toxin concentrations, (2) incorporation into numerical models of ecological and physical processes with hindcasting, nowcasting, and forecasting capabilities, and (3) conducting field and laboratory experiments to directly determine the influence of nitrogen, light, temperature, and other factors on the production and decay of HAB toxin.	Project initiated 8/31/17	Cyanotoxin forecast is demonstrated and applied as early warning alert to drinking water facilities.	NOAA	Felix Martinez felix.martinez @noaa.gov	2020
Predicted impacts of climate change on the success of alternative management actions in the Chesapeake Bay	The purpose of this project is to quantitatively predict the impacts of future changes in climate and anthropogenic nutrient inputs on the spatial and temporal extent of hypoxia in Chesapeake Bay, and on the effectiveness of various alternative management actions designed to reduce hypoxia and improve water quality. This project is a collaboration with EPA and	During the first year of the project, the input datasets and formulas were updated and evaluated for five of the six separate project models (three watershed models, two estuarine models, and 1 oyster population model). Preliminary model simulations show that	The modeling results will be translated into web based tools for use by regional managers and municipalities. These model outputs will be compared to those currently used for regulatory	NOAA	Kimberly Puglise Kimberly.puglise@noaa.gov	2021

	USGS.	climate change will negatively affect hypoxic conditions in the Chesapeake Bay, but this effect will be trumped by positive impacts resulting from mandated nutrient reductions.	purposes, and the results are eagerly anticipated by Chesapeake Bay resource managers.			
Explore temporal and spatial variability of water quality and cyanobacteria in two Rhode Island ponds	Increase our understanding of how water quality and cyanobacteria blooms vary across space and time between two ponds with different ecological conditions and history.	To date, we have completed one field season of sampling; on average conducting twice weekly sampling 7 sites across each pond.	Continues monthly sampling of ponds, as feasible, through winter and more intense sampling during the bloom season (approx. June-October).	USEPA	Jeff Hollister hollister.jeff@epa.gov	Ongoing
NGOMEX and CHRP	HABHRCA-authorized competitive programs to advance the development and application of scenario-based ecosystem models to quantitatively evaluate hypoxia causes and impacts, using an integrative modeling approach, and develop outreach tools to communicate advanced understanding to coastal managers and other stakeholders.		Advance development, application of scenario-based ecosystem models to quantitatively evaluate hypoxia causes and impacts, using an integrative modeling approach, and develop outreach	NOAA	Alan Lewitus alan.lewitus@noaa.gov	Ongoing

			tools to communicate advanced understanding to coastal managers and stakeholders. When funding is available, NCCOS will release an RFP.			

Develop case definitions for the spectrum of HAB-related illnesses, and produce clinical therapeutic guidance for the spectrum of illnesses associated with exposure to HAB cells and toxins.

Action	Goal/Purpose	Achievements to October 2017	Activities to be Completed	Agency	Point of Contact	Expected Date of Completion
Use public health surveillance data to characterize and inform understanding of HAB-associated illnesses	Publish a summary of data collected in the One Health Harmful Algal Bloom System (OHHABS).	OHHABS launched in 2016, with additional components added in 2017 to support data collection and review.	Additional data collection, data review process, and surveillance report to be completed	CDC	Virginia Roberts evl1@cdc.gov	2020

Appendix 2. Actions to Strengthen and Integrate New and Existing Monitoring Programs

Strengthen long-term HAB and hypoxia monitoring activities						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Characterize and/or quantify the structure, function, and key processes of ecosystems in agricultural settings.	This ARS project evaluates how nutrients, pesticides, and sediments interact with watershed hydrology to influence mechanisms regulating water quality and aquatic ecosystem structure and function in agricultural watersheds; examine effects of water flow, climate-change-induced drought, and agricultural nutrient contaminants on stream microbial productivity and nutrient processing; and examine associations between fish species composition, hydrologic connectivity, and hypoxia in agricultural watersheds.	Ecological assessments identified seasonal patterns of excess sediment and nutrients as being influenced by changes in cropping patterns and conservation practices in shallow, low-gradient, low-flow bayous. Organic matter processing studies demonstrated rapid breakdown of agriculturally derived and natural riparian organic matter combined with excessive nutrients influenced dissolved oxygen dynamics in bayou waters. A study on depth manipulation through a weir was conducted	Sediment denitrification is underway on cores from various aquatic ecosystems (ditches, lakes, wetlands, tailwater recovery systems) to gain an understanding of denitrification rates and how they differ across habitats contributing to hypoxia Studies underway on the use of mixed vegetation in mitigating nutrients in agricultural runoff.	USDA ARS	Martin Locke, Research Leader martin.locke@ars.usda.gov Matt Moore, Lead Scientist matt.moore@ars.usda.gov Ron Bingner, Michael Jenkins, Richard Lizotte, Jason Taylor, Lindsey Yasarer	2020

		during a drawdown experiment to help understand how water depth, flow, and quality varies seasonally as farmers utilize bayous as additional sources of surface water irrigation.	Studies continue in LTAR / CEAP watershed (Beasley Lake) examining long-term effects of conservation practices on reduction of contaminant load and restoration of water quantity, quality, and lake productivity.			
Determining the presence of cyanotoxins in raw water drinking water sources for select Arkansas drinking water systems	Have an understanding of what cyanotoxins are present in raw water sources and determine if cyanotoxins are removed via conventional filtration. Sampling was conducted during Summer 2017.	Approximately 40 drinking water sources were sampled twice during the summer of 2017. Approximately 10 % of untreated source water contained detectible cyanotoxins. No treated water contained detectible cyanotoxins. This small data set seems to validate the understanding that a conventional surface water treatment plant	Publishing results in Fall 2017 Arkansas Drinking Water Newsletter.	USEPA	Jeffery Stone Jeffery.stone@arkansas.gov Jatin Mistry, EPA Region 6 mistry.jatin@epa.gov	2017

		optimized for disinfection byproducts and turbidity control is effective for eliminating cyanotoxins.				
Evaluation of crowd sourcing to locate and inform the public of algal blooms	A Regional Research Partnership Program (R2P2) Project between RTP/ORD and EPA Region 9 to identify if qualitative community perception of water quality via crowd sourced, citizen science input can support community and tribal management of lakes	Quantitative field monitoring and satellite derived water quality data, was used to develop Ushahidi code, which was tested, presented and transferred to tribes around Clear Lake, CA.	Project completed	USEPA	Blake Schaeffer/ORD schaeffer.blake@epa.gov	2017
Develop and standardize HAB monitoring methods	Publishing standard methods and approaches for field sensors that measure algal pigments, like chlorophyll and phycocyanin, and dissolved organic matter, and correlating these measures to harmful algal blooms and algal toxins.	A USGS Techniques and Methods (T&M) report describing the use of water quality sensors for measurement of algal pigments and fluorescent dissolved organic matter has been peer reviewed and is planned for publication in FY18. The T&M report will contain quality assurance and quality control specifications	Develop and standardize HAB monitoring methods	USGS	Jennifer Graham jlgraham@usgs.gov	2018

		for continuous measurement and calibration of sensors.				
Clear and Present Danger: Monitoring and Management of Lipophilic Shellfish Toxins in Washington State	The purpose of this project is to ensure that Washington State managers are fully trained on how to use transfers detection and analytical technologies, helping existing water and shellfish monitoring programs to add detection (rapid toxin screening) and quantification of DSP and AZP to their early warning and rapid response protocols.	A new toxin, azaspiracid 59 has been identified in Washington State, produced by *Azadinium poporum*. In total, 4 *Azadinium* species are present in the region.	Improved capability for Washington State managers to detect and analyze lipophilic shellfish toxins.	NOAA	Marc Suddleson Marc.Suddleson @noaa.gov	2018
Training Course on the Identification of Harmful Algae in United States Marine Waters	Provide coordinated training for state and local officials to improve regional capabilities for HAB monitoring, assessment, forecasting, and response. Coordination of resources among agencies could help advance training efforts, particularly if standardized methods are used. This project is a collaboration with FDA, CDC and IAEA.	Training courses held in 2016 and 2017.	Training course to be held in 2018 and transition from NOAA support to fee support will be completed by 2019.	NOAA	Quay Dortch quay.dortch@noaa.gov	2018
National Atmospheric Deposition Program	The program is a cooperative effort between many different groups, including federal, state, tribal and local	The NTN provides a long-term record of the acids, nutrients, and base cations in	This program provides essential continuous monitoring of	USDA NIFA	Karelyn Cruz karelyn.cruz@ NIFA.USDA.GOV	2018

	governmental agencies, educational institutions, private companies, and non-governmental agencies to measure atmospheric pollution and its effect on the environment.	U.S. precipitation across nearly 300 locations in the United States. This program provides key observations on nitrogen deposition, which plays a role in development of hypoxia.	atmospheric deposition. The program will be recompeted at the end of 2018.			
Puget Sound-wide Zooplankton Monitoring Program	The purpose of this project is to continue plankton monitoring throughout Puget Sound that started in 2014 to capture food web dynamics and ancillary water quality. This project is funded via PS NEP, led by Long Live the Kings Organization, and is a collaboration with the University of WA, Tulalip Tribes, Nisqually Tribe, Lummi Nation, Port Gamble S'Klallam Tribe, King County, NOAA Fisheries, and KWIAHT.	Preliminary data collected 2014-2016 additional data will be used to calibrate ecosystem model.	Calibration of foodweb model.	USEPA	Michael Rylko rylko.michael@epa.gov	2018
Small Stream Monitoring in the Lake Erie Watershed	The USGS Water Science Centers in Wisconsin, Ohio, Michigan, and Indiana are collaborating with the GLRI in placing streamflow and water quality monitoring stations in small streams at	Progress and publications can be found on the Web at: https://www.usgs.gov/centers/wisconsin-water-science-center/science/edge-	monitoring will be completed in 2018 followed by report preparation and publication in the next two years	USGS	Jon Hortness hortness@usgs.gov	2020

	the edge of agricultural fields where conservation practices are being implemented to better understand the effects of agricultural conservation practices on water quality. The study sites include the Fox River, which flows into Green Bay; a tributary to the Maumee River that flows into the western basin of Lake Erie; and a tributary to the Saginaw River that flows into Saginaw Bay. The results of the GLRI effort will be communicated to interested stakeholders to help guide similar efforts in the Great Lakes. This project is a collaboration with USEPA and ten other Federal agencies.	field-monitoring-great-lakes-restoration				
New Mexico Temporary Standard Implementation for Nutrient Thresholds	In collaboration with the state of New Mexico, EPA Office of Science and Technology, EPA Office of Wastewater Management, EPA R6, and the New Mexico Municipal League, EPA is providing contractor support to development NPDES discharger specific nutrient threshold temporary	Water Quality Standards Temporary Standard Implementation for Nutrient Thresholds.	Temporary Standard Implementation.	USEPA	Shelly Lemon, NMED shelly.lemon@state.nm.us Jennifer Brundage, Brundage.jennifer@epa.gov; Forrest John, EPA	2018

	standard implementation guidelines and demonstrations (proof-of-concepts)				R6 john.forrest@epa.gov	
Improving Tools for Monitoring Multiple HAB Toxins at the Land-Sea Interface in Coastal California (HAB-SICC)	Information from this project will be used to inform managers, the public and policy makers regarding the risks posed by occurrence of multiple toxins in the food web including local fish and shellfish. This project includes support for USGS.	The study will build on previous progress to develop a passive sampling monitoring tool (Solid Phase Adsorption Toxin Tracking, SPATT), to enhance the HAB toxin detection capabilities of California state management agencies' monitoring programs. The SPATT sampler would be improved to include routine detection of multiple toxins (e.g. domoic acids, saxitoxin, microcystins, cylindrospermopsin, anatoxin, and okadaic acids).	NOAA will use the information from this study to inform mangers, the public and policy makers regarding the risks posed by occurrence of multiple toxins in the food web, including local fish and shellfish	NOAA	Marc Suddleson marc.suddleson@noaa.gov	2019
Development and standardization of real time online toxicity monitors	Establish the efficacy using sentinel organisms as Online Toxicity Monitors (OTM) cyanotoxin production.	Year 3 of 4-year project.	Laboratory experiments to establish OTM sensitivity to HAB species and	USEPA	Joel Allen allen.joel@epa.gov	2019

			cyanotoxins will continue. Demonstration of OTM deployment will follow.			
Inland HAB Management	This work seeks to improve the understanding of HAB dynamics found in inland freshwater systems and using a source water monitoring approach and leverage high frequency data to optimize analytical efforts and management.	Year 3 of 4-year project.	Data from three HAB seasons are under review for development of predictive modeling of HAB events.	USEPA	Joel Allen allen.joel@epa.gov	2019
Detecting phytoplankton in water using flow cytometry, microscopy and hyperspectral image analysis.	Explore the feasibility of utilizing these technologies to determine linkages between optical signatures and physiological status of phytoplankton.	Year 3 of 4-year project.	Laboratory work underway.	USEPA	Robert Zucker zucker.robert@epa.gov	2019
Nutrient Monitoring in the Great Lakes Watersheds	USGS monitors nutrient loads (phosphorus and nitrogen) to the Great Lakes at 24 locations across the basin in the United States to help managers track changes over time. Two additional sites will be added in the Lake Erie basin in 2017 to support nutrient reduction	Monitoring results are reported annually in April for western Lake Erie watersheds by Ohio. These summaries published since 2014 can be accessed at lakeerie.ohio.gov. Concentration and	Monitoring projects are supported by Federal and state funds and may continue beyond 2020 to track improvements in meeting phosphorus	USGS	Jon Hortness hortness@usgs.gov	2020

	strategies developed under Annex 4 of the Great Lakes Water Quality Agreement. This project is a collaboration with the Great Lakes Restoration Initiative. USGS monitors nutrient loads (phosphorus and nitrogen) to the Great Lakes at 24 locations across the basin in the United States to help managers track changes over time. Two additional sites will be added in the Lake Erie basin in 2017 to support nutrient reduction strategies developed under Annex 4 of the Great Lakes Water Quality Agreement (GLWQA). This project is a collaboration with the Great Lakes Restoration Initiative. Specifically, enhanced monitoring in western Lake Erie Watersheds is underway to track progress under Annex 4 of the GLWQA	Loading information can be accessed at http://arcg.is/21i9CUF (USGS) and https://ncwqr.org/ (Heidelberg). Additional information on monitoring loads to the Great Lakes can be accessed at https://cida.usgs.gov/glri/projects/nearshore_health/forecast_loadings.html	loading limits to western Lake Erie identified in Annex 4 of the Great Lakes Water Quality Agreement.			
Oklahoma Reservoir Nutrient Threshold Development	USEPA Region 6 is supporting the state of Oklahoma in the development of nutrient response indicators that can serve as translators for the	Data aggregation and data exploration.	Threshold development.	USEPA	Monty Porter, OWRB monty.elder@deq.state.ok.us Forrest John, EPA	2019

	existing narrative nutrient criteria and be applied in various water quality programs. Modeling tools will also be developed to provide the necessary linkage between the response indicator endpoint and nutrient concentrations or loads. An additional goal is to review methods for identifying protective downstream values in the watersheds of lakes to ensure attainment of in-lake targets. This project is a collaboration with USEPA Region 6, Office of Science and Technology/NSTEPS, and the Oklahoma Water Resources Board.				R6 john.forrest@epa.gov; Jacques Oliver oliver.jacque@epa.gov	
Investigating Domoic Acid Biosynthesis and Toxic Bloom Formation Through Pseudo-nitzschia - Marine Bacteria Interactions	The overarching goal of this project is to gain an understanding of the biosynthetic machinery of domoic acid in PN and the influence of marine bacteria that leads to the synthesis of domoic acid and other kainoid families, which will provide fundamental new insights about chemical, molecular and biotic factors		Map out diverse domoic acid (DA) congeners; Examine biosynthetic machinery believed to produce DA; Investigate DA production in *Pseudo-nitzschia (PN)* in	NOAA	John Wickham john.wickham@noaa.gov	2020

	at work during PN bloom.		association with bacteria and natural blooms; Use molecular-genetic tools to define PN-bacteria interactions that produce DA; Use Bayesian statistics to assess contribution of bacteria versus other factors in toxic *PN* blooms.			
Uncovering the mechanisms behind wintertime occurrences of Paralytic Shellfish Toxicity in geoduck clam fisheries in southeast Alaska	Determine factors leading to Paralytic Shellfish Poisoning (PSP) toxins in geoduck clams in southeast Alaska, harvested during a wintertime dive fishery.	Project initiated 8/31/17	1) Determine the relationship between distributions of cysts of the PSP-toxin producing *Alexandrium* and geoduck toxicity; 2) identify whether cyst ingestion is a mechanism for geoduck clam toxicity; 3) determine if current geoduck harvest and/or management	NOAA	Marc Suddleson marc.suddleson@noaa.gov	2020

			approaches contribute to the frequent occurrence of wintertime toxicity in geoduck clams; and 4) involve geoduck clam dive industry and resource managers in research to ensure project outcomes meet stakeholder information needs.			
An early warning system for *Pseudo-nitzschia* HABs on Pacific Northwest outer-coast beaches	The purpose is to restore and refine the Pacific Northwest HAB Bulletin by enhancing monitoring and additional forecast models to more precisely predict HAB threats, thus reducing unnecessary shellfish closures and saving costs.	The project expands current monitoring infrastructure off WA and OR by including sites in known "hot spots" for toxic *Pseudo-nitzchia* blooms, and developing a short-term forecast (3-day) that will leverage a forecast model developed through ECOHAB, and a longer-term forecast (14-day) that would	The Pacific Northwest HAB Bulletin would be restored and improved upon by refining forecast information through enhanced monitoring and additional forecast models that will more precisely predict HAB threats, thus reducing unnecessary	NOAA	Marc Suddleson marc.suddleson@noaa.gov Tiffany Vance tiffany.vance@noaa.gov	2020

		predict bloom landfall trajectories.	shellfish closures and saving costs.			
Unregulated Contaminant Monitoring Rule	The UCMR 4 was published in the Federal Register on December 20, 2016. UCMR 4 requires monitoring for 30 unregulated contaminants, including 10 cyanotoxins or cyanotoxins groups [total microcystins, MC-LA,-LF,-LR,-LY,-RR,-YR, nodularin, anatoxin-a, cylindrospermopsin], between 2018 and 2020 using analytical methods developed by EPA and consensus organizations. This monitoring provides a basis for future regulatory actions to protect public health.	Year 1 of 5-year project	Year 1 (2017): Implementation preparations (notifications, inventory, database development, laboratory approval process); Years 2-4 (2018-2020): Sampling, analytical analyses, and reporting of results; Year 5 (2021): Conclude data reporting and finalize data set	USEPA	Melissa Simic simic.melissa@epa.gov	2021
Harmful algal bloom smart device application: using image analysis and machine learning techniques for classification of harmful algal blooms.	Northern Kentucky University and the ORD Cincinnati are collaborating to develop a harmful algal bloom detection algorithm that estimates the presence of cyanobacteria in freshwater systems by image analysis. Green and blue-green algae exhibit different Hue-Saturation-Value color	1 year of a 4-year project.	The Harmful Algal Bloom Classification Application (HAB APP) has been field tested and verified to classify both green and blue-green algae. The application is	USEPA	James Lazorchak lazorchak.jim@epa.gov	2020

	histograms in digital photographs. These differences are exploited by machine learning techniques to train a smart device (cellular phone, tablet, or similar) to detect the presence of cyanobacteria in a small surface portion of a freshwater system. A second app identify phytoplankton, zooplankton and macroinvertebrates using photographs taken by smart devices from an attached microscope.		being tested via fixed camera monitoring stations and optimized at several locations along the Ohio River and in Lake Harsha, a 22,000-acre reservoir which supplies six million gallons per day of drinking water to the Ohio county in which it lies and is a source of many recreational activities, including swimming, boating, and fishing. The presence will be verified by other detection instruments and *in vitro* by agency scientists and hysteresis techniques will be used to monitor the presence of			

			cyanobacteria on a periodic (*e.g.* daily, seasonally) basis at the monitoring stations. Further, the APP is being extended to classify harmful algae microscopically at the genus level using a convolutional neural network approach.			
Western Lake Erie basin tributary monitoring and assessments	EPA is partnering with States in the Maumee river basin (Indiana, Michigan and Ohio) to establish a long term water quality monitoring network to track phosphorus loads and concentrations against the new Lake Erie phosphorus reduction targets. This effort will require new and continued investments in high frequency, storm event driven sampling.	EPA provided funding to establish 5 new monitoring sites (automated water quality and flow) for 3 years EPA secured contractor support for a TMDL study that will assist Ohio, Michigan and Indiana in establishing appropriate nutrient targets and allocations for sub-watersheds to the	Add 3 more sites to network and seek funding to extend timeframe of monitoring through 2020 and beyond Completion of TMDL study with Methodology for allocating Lake Erie phosphorus targets to subwatersheds of the Maumee River. Establish	USEPA	Santina Wortman wortman.santina@epa.gov	2020

		Maumee.	subwatershed allocations and begin reporting progress annually in 2020			
Great Lakes nearshore monitoring enhancements	EPA is coordinating CWA and GLRI programs and funding to support enhanced monitoring of Lake Erie nearshore areas.	The 2015 National Coastal Condition Assessment was enhanced with 34 additional Lake Erie sites to allow for more refined assessments of the western, central and eastern basins. EPA provided CWA and GLRI funds to support Ohio's development of a new nearshore monitoring program, built on the NCCA – the Lake Erie Shoreline Monitoring and Assessment Program. In 2016 transects were added to map the central basin anoxic zone.	Analyze 2015 data and provide report on Lake Erie assessment. Ohio's Lake Erie nearshore program assesses water quality and habitat annually.	USEPA	Mari Nord nord.mari@epa.gov	2020
Great Lakes Cladophora Research	EPA is working with Environment Climate Change Canada to conduct	EPA co-chaired a technical workshop in January 2016 State of	EPA with Environment Climate Change	USEPA	Santina Wortman wortman.santin	2020

	targeted monitoring and modeling to better understand nuisance Cladophora growth and allow for future development of phosphorus targets in Lake Erie's eastern basin and the other Great Lakes.	the Science on Cladophora. EPA issued a Request for Applications in August 2017 for a collaborative Cladophora monitoring and modeling project.	Canada will establish a binational Cladophora research plan under GLWQA in 2018. EPA will support a concerted monitoring and modeling effort at several sentinel sites in 2018/2019. EPA and Environment Climate Change Canada will revisit the potential for setting phosphorus targets to limit Cladophora growth in 2020.		a@epa.gov	
Great Lakes Long Term Monitoring Programs	USEPA's Great Lakes National Program Office has long term monitoring programs in place to measure and assess water quality, nutrient concentrations,	Almost 100 fixed station sites are sampled each spring and summer to assess the ecological health of the lakes, evaluate	-The phytoplankton monitoring component is being enhanced to collect additional	USEPA	Todd Nettesheim Nettesheim.todd@epa.gov	2020 and beyond

	chlorophyll-a, and the abundance and diversity of zooplankton, phytoplankton and benthic communities.	trends and identify emerging problems. Each Summer GLNPO also conducts dissolved oxygen surveys to measure and calculate the oxygen depletion rate of hypoxic waters in the central basin of Lake Erie.	data at nearshore sites and a pilot effort to collect year round samples with the use of automated samplers. Monitoring results are made available online in the Great Lakes Environmental Database (GLENDA).			
HAB research and monitoring to meet the needs of state and local governments for improved understanding of bloom formation, detection, and prediction.	HAB research is being conducted in USGS Science Centers throughout the nation. Studies include both short- and long-term projects focused on quantifying blooms and associated toxins and taste-and-odor compounds. This effort is a collaboration with many state and local agencies in the states where the projects are being done. The program also helps develop field and laboratory methods to monitor for HABs.	Numerous reports and journal articles have been published and are available in the USGS Publications Warehouse* using the search phrase "Harmful Algal Blooms" "cyanotoxins," and "algal toxins" (https://pubs.er.usgs.gov/	Future reports and journal articles will be made available through the USGS Publications Warehouse at https://pubs.er.usgs.gov/	USGS	Jennifer Graham jlgraham@usgs.gov	2015-2020 and beyond
Assess status and trends of the quality	USGS monitors fish-, aquatic macroinvertebrate- and	Data on taxon occurrence and	Progress and publications can	USGS	Jennifer Graham	2020 and beyond.

of the nation's streams, rivers, and groundwater	algae-community samples, and conducts stream physical habitat surveys to assess the effects of multiple stressors—including algal toxins—on aquatic organisms in streams in several ecoregions.	abundance can be obtained from the Web site https://aquatic.biodata.usgs.gov/landing.action	be found on the Web at: https://water.usgs.gov/nawqa/ Data on aquatic communities can be obtained from the Water Quality Portal at https://www.waterqualitydata.us/		jlgraham@usgs.gov James Kreft jkreft@usgs.gov	
Real-time observatories in marine and freshwaters	Water-quality sensors at real-time measurement sites (number) for dissolved oxygen (651), temperature (2,672), nitrate (138), chlorophyll (64) and phycocyanin monitor lake and stream conditions and to understand the development of hypoxia, nuisance conditions, and harmful algal blooms. This project is a collaboration with several States and local agencies. Data from nitrate sensors reduces scientific uncertainties regarding source, fate, and transport of nutrients in the Mississippi River Basin to the Gulf of Mexico. The USGS is	Measurements are made at over 2000 locations throughout the nation and provided on a website at https://waterwatch.usgs.gov/wqwatch/	The numbers of sites at which chlorophyll and phycocyanin are measured will change and likely increase over time in response to local, state, and Federal needs.	USGS	Jennifer Graham jlgraham@usgs.gov Brian Pellerin bpeller@usgs.gov	2020 and beyond

	evaluating how real-time nutrient data can be used to improve our understanding of nutrient transport from the headwaters to the mainstem and ultimately to the Gulf. USGS and NOAA collaborate on the release of the spring estimate of the size of the Gulf hypoxic zone.					
Quantify the fate and transport of HAB toxins in aquatic environments. Multiple HAB toxins are monitored as well as taste-and-odor compounds.	HAB research is being conducted in USGS Science Centers throughout the Nation. Studies include both short- and long-term projects focused on quantifying blooms and associated toxins and taste-and-odor compounds. This effort is a collaboration with many state and local agencies in the States where the projects are being done. The program also helps develop field and laboratory methods to monitor for HABs in environmental samples.	Numerous reports and journal articles have been published and are available in the USGS Publications Warehouse using the search terms "harmful algal blooms" "cyanotoxins," and/or "algal toxins" (https://pubs.er.usgs.gov/)	These projects typically range in duration from one to five years. 2015-2020 and beyond. Future reports and journal articles will be made available through the USGS Publications Warehouse at https://pubs.er.usgs.gov/	USGS	Jennifer Graham (jlgraham@usgs.gov)	Ongoing
Support Klamath Basin Monitoring Program (KBMP)	The Klamath Basin Monitoring Program (KBMP) brings together and makes publicly accessible cyanotoxin and other WQ	Participants completed the eighth year of coordinated water quality monitoring of a wide	Continue support of the stakeholder watershed monitoring, KBMP	USEPA	Sue Keydel Keydel.Susan@epa.gov	Ongoing

	monitoring data from multiple watershed stakeholders, including the Klamath tribal water quality consortium (Karuk, Hoopa, Quartz Valley and Yurok tribes) and the Klamath Hydroelectric Settlement Agreement Interim Measure 15 Baseline and Public Health monitoring (conducted by Oregon DEQ, US Bureau of Reclamation, PacifiCorp, and Karuk and Yurok tribes)	suite of constituents, including cyanotoxins and algae species, from 254 miles of river, six reservoirs, and Upper Klamath Lake, from Oregon to the Klamath River Estuary in California. EPA Region 9 provided ELISA-microcystins analysis (up to 500 samples/yr). The KBMP continues to host data reporting, the Blue-Green algae Tracker mapping cyanotoxin impacted reaches, and semi-annual stakeholder meetings.	coordination, and EPA providing ELISA-Microcystin analysis to inform water quality conditions in the basin. Klamath Hydroelectric Settlement Agreement Interim Measure 15 monitoring is anticipated to continue annually until FERC transfer of the hydroelectric dams for decommissioning (est. 2020).			
Validation and Technology Transfer of Toxin Detection Methods	Promote the use of receptor binding assays (RBA) to user groups in need of testing methods for algal toxins in a variety of food products prior to export or domestic consumption. These methods have been validated (AOAC) and accepted by governing bodies (ISSC). Laboratory-	Conduct laboratory based training for members form the Sitka tribe in Alaska and provide technical support for establishing a testing laboratory capable of conducting regulatory analysis for algal	Establish a network of user laboratories in U.S. with FDA and CDC and internationally with IAEA, Regulatory approval for Sitka Environmental	NOAA	John Ramsdell john.ramsdell@noaa.gov	Ongoing

	based training sessions for customers provide technical guidance. These are needed to establish methods, conduct inter-laboratory validation exercises, and provide quality control on necessary reagents. This project's intent is to establish a network of user laboratories in U.S. with FDA and CDC and internationally with IAEA.	toxins in seafood. Host an IAEA supported workshop for product customers from Southeast Asian countries on the validation, performance and regulatory application of the RBA technology. Provide training in Africa and Arabian Gulf States.	Laboratory.			
Phytoplankton Monitoring Network and Freshwater Phytoplankton Monitoring Network	The purpose of this program is to train and support local volunteers at over 120 sites nationwide to monitor and report on HAB species. The programs intent to expand to Lake Erie and Alaska regions where HABs are a particular problem. This project is a collaboration with FDA and CDC.	A freshwater PMN has been implemented in partnership with EPA to include monitoring groups in the areas around Lakes Erie, Huron, Michigan and Superior, and also at nineteen inland lakes across Utah, Montana, Colorado, South Dakota, North Dakota, New York, Ohio, Minnesota, Missouri, and Kansas.	Expand customer accessibility to HAB observations by enhancing data serving capacity and visualization of the PMN database in collaboration with the National Center for Environmental Information.	NOAA	Steve Morton steve.morton@noaa.gov	Ongoing
Cooperative Gulf of Mexico Hypoxia Monitoring Program	A multi-partner, sustainable monitoring program that encompasses the northern	Eight Monitoring Work Groups established to	Sustainable cooperative monitoring	NOAA	Alan Lewitus alan.lewitus@noaa.gov	Ongoing

	Gulf of Mexico hypoxic zone, and advances ecosystem management objectives for mitigation of hypoxia, ocean acidification, and other ecosystem stressors. This project is a collaboration with the EPA and USGS.	implement building blocks for the CHAMP, including Work Groups on States of Mississippi/Alabama, Louisiana, and Texas, Ocean Acidification/Oil and Gas, Fisheries, Hypoxia Task Force, RESTORE Act, and Autonomous Vehicles.	program.			
Synthesis, Observations and Response (SOAR)	The SOAR project provides environmental intelligence on coastal conditions to regional managers on Lakes Michigan, Huron, and Erie. This is a long-term monitoring program to ensure the consistency of monitoring methods, develop rigorous QA/QC and synthesizing, and make available monitoring data and coupling monitoring programs with predictive models for managers and public health officials.	The implementation of the project includes the deployment and support of on-water and remote sensing platforms where observations from these systems are used to create database products to evaluate restoration effectiveness, provide ecosystem assessment, report on restoration progress, and aid in decision support for regional managers.	Provide ongoing, long-term monitoring to regional managers in Lakes Michigan, Huron, and Erie, and provide relevant data to managers, as necessary	NOAA	Debbie Lee Deborah.lee@noaa.gov	Ongoing

Decision support tools to link phosphorus reductions to harmful algal blooms and source water protection	The intent of this effort is to sample weekly to obtain baseline information on bloom size, duration, and toxicity to help understand the interaction between rivers of HABs in Lake Erie and other HAB-prone regions of the Great Lakes including Saginaw Bay, Sandusky Bay, and Green Bay.	To-date, have continued to provide ongoing, weekly sampling during blooms, to obtain baseline information on bloom size, duration, and toxicity.	Provide ongoing, weekly samples of watersheds in the Great Lakes, including Saginaw Bay, Sandusky Bay, and Green Bay.	NOAA	Debbie Lee Deborah.lee@noaa.gov	Ongoing
NOAA GLERL ReCON network	The purpose of the ReCON project is to develop a national network of low-cost coastal buoys capable of seabed to sea-surface observations. Each system collects meteorological data and provides sub-surface measurements of chemical, biological, and physical parameters. The system is designed to allow controlled access to multi-institutional users through surface buoys and sub-surface sensor guest ports located on an underwater hub. This project is a collaboration with USEPA and USGS.	Collect ongoing meteorological data and provide sub-surface measurements of chemical, biological, and physical parameters.	Develop a national network of low-cost coastal buoys capable of seabed to sea-surface observations	NOAA	Debbie Lee eborah.lee@noaa.gv	Ongoing
Conservation Effects Assessment Project	The Watershed Assessment Studies Component of CEAP	On-going watershed and field sampling and	On-going long-term assessments	USDA NRCS	Lisa Duriancik, lisa.duriancik@	Ongoing

(CEAP) Watershed Assessment Studies	conducts small watershed scale studies across the US to quantify water and soil resource outcomes of conservation practices and systems and to enhance understanding of processes. Interactions among practices are investigated as well as modeling enhancements, watershed targeting approaches, and socioeconomic factors. Practice standards are developed or updated to improve effectiveness and address gaps. This work is conducted in collaboration with USDA ARS, USDA Farm Service Agency, NOAA, USGS, USEPA, universities, and other partners.	assessment analyses. Peer reviewed publications released.	in 16 watersheds across the nation		wdc.usda.gov	
National Aquatic Resource Surveys (NARS)	Series of EPA/State/Tribal studies designed to report on the condition of lakes, rivers/streams, coastal waters and wetlands across the conterminous U.S. In addition to key biological, chemical and physical indicators, cyanotoxins (e.g., microcystins) and other	In 2007, 2012 and again in 2017, the NLA included indicators associated with the risk of potential exposure to cyanotoxins, including an analysis of microcystin levels and two related indicators,	The NARS is an ongoing program with plans to continue sampling and assessment. For the NRSA 2018/19 plans call for analyzing microcystins and	USEPA	Sarah Lehmann lehmann.sarah @epa.gov	Ongoing

	parameters are included for each of the surveys: the National Lakes Assessment (NLA), the National Rivers and Streams Assessment (NRSA), the National Coastal Condition Assessment (NCCA), and the National Wetland Condition Assessment (NWCA).	cyanobacteria and chlorophyll a. The 2012 report was published in December 2016. In 2017, cylindrospermopsin was added to the NLA as well. In 2013/14, microcystins were included in the NRSA. In 2015, the National Coastal Condition Assessment included microcystins along with a broader suite of algal toxins parameters. In 2011 and 2016, the National Wetland Condition Assessment included microcystins.	cylindrospermopsin. Reports for information collected in the NRSA 2013/14 and NCCA 2015 are due out over the next year. The NWCA 2016 report will follow.			
Kansas City Urban Lakes	Continue a long-term urban lake monitoring program, since 2010, in providing human health data on under-monitored lakes in public parks.	Completed three sampling events for approximately 30 lakes. Completed sample analysis for nutrients and toxins.	Upload data into WQX – should be done before the end of this month.	USEPA	Michael Davis, EPA Region 7, davis.michael @epa.gov	Ongoing
USEPA Region 8 Analytical Support to State and Tribes	USEPA's Region 8's laboratory provides analytical support to states and tribes during bloom	Provided routine analytical support to ND, CO, UT, MT, and Turtle Mtn.	We expect to continue to offer analytical support in 2017.	USEPA	Tina Laidlaw Laidlaw.tina@epa.gov	Ongoing

	events and facilitates routine monitoring on lakes and reservoirs that regularly experiences HAB events. The Regional laboratory provides routine analytical support to ND, CO, UT, MT, and Turtle Mountain, and during blooms events to SD, UT, ND, and CO.	Bloom event monitoring provided for SD, UT, ND, and CO.				
USEPA Region 8 Deployment of a Continuous Monitoring Buoy	USEPA's Region 8's laboratory deployed a continuous monitoring buoy on Canyon Ferry Reservoir, MT due to frequent blooms.	Buoy deployed from April - October. Continuous data recorded.	Buoy deployed in another lake in 2017.	USEPA	Jeff McPherson mcpherson.jeffrey@epa.gov	2017
USEPA Region 9 Analytical Support to State and Tribes	USEPA's Region 9 laboratory is providing ELISA -microcystins analysis to support states and tribes responding to HABs. The lab is finalizing method validation for ELISA-Anatoxin-a analysis before making analytical services available.	Provided analysis of approximately 160 water samples for microcystins by ELISA in 2017. Progress on validation of ELISA-Anatoxin-a analysis, by coordinating with CA agencies conducting anatoxin analysis.	We expect to continue to offer ELISA-microcystins analytical support in 2018. Continue efforts on validation of ELISA-Anatoxin-a analysis, by coordinating with CA agencies conducting anatoxin analysis. The planned	USEPA	Sue Keydel Keydel.Susan@epa.gov	Ongoing

			acquisition of a liquid chromatography/ mass spectroscopy/mass spectroscopy to support PFAS and cyanotoxin analysis is on hold			
Cyanobacteria Monitoring Collaborative (CMC)	A multi-tiered interdisciplinary program that provides consistent data collection efforts on identifying and documenting HABs, monitoring activities, provides an educational component, and provides tools for insights to appropriate management of the waterbody.	Program is moving forward and expanding from regional to national, to international interests.	Updates on phone Apps that notify key public officials of HAB occurrence, further website development, data visualization development, ongoing hands on training and workshops.	USEPA	Hilary Snook snook.hilary@epa.gov	Ongoing
Clear Lake Task Force Monitoring Program	The Clear Lake Task Force, a group of tribes and local agencies, conduct monitoring of HAB for public health posting. USEPA Region 9 provides analytical support for microcystins analysis. Data collected by the Clear Lake Task Force also supports other ongoing studies (3.2 D and 3.1 T)	Provided analysis of approximately 140 water samples for microcystins by ELISA in 2017.	We expect to continue to offer analytical support in 2018.	USEPA	Sue Keydel Keydel.Susan @epa.gov	Ongoing

Louisiana Coastal Dissolved Oxygen Criteria Re-Evaluation	The state of Louisiana is in the process of re-evaluating current dissolved oxygen criteria for Louisiana coastal waters due to periodic hypoxic conditions extending from Gulf federal waters. This project is a collaboration with the Louisiana Department of Environmental Quality and the US EPA Region 6.	Data collection completed and state interim report identifying options.	Criteria development approach.	USEPA	Amanda Vincent, LDEQ amanda.vincent@la.gov Forrest John, EPA R6 john.forrest@epa.gov; Jacques Oliver Oliver.jacque@epa.gov	Ongoing
Chesapeake Bay and San Francisco Bay Nutrients Monitoring	A monitoring network in 2004 at the Chesapeake Bay to document changes in nutrients throughout the watershed. This project is a collaboration with the Chesapeake Bay Program. A similar program is underway in 6 states contributing to the San Francisco watershed.	Progress and publications can be found on the Web at https://chesapeake.usgs.gov/	Progress and publications can be found on the Web at https://chesapeake.usgs.gov/	USGS	Ken Hyer ken.hyer@usgs.gov Michael Chotkowski nchotkowski@usgs.gov	2019 for San Francisco Bay Ongoing for Chesapeake Bay
Assess status and trends of the quality of the nation's streams, rivers, and groundwater	USGS conducts long-term monitoring of nutrients and other related water-quality characteristics in surface through the National Water Quality Network and groundwater-quality networks. The sources and quantities of nutrients	Annual statistics for concentrations, loads, and yields are reported on Web for 2015 and 2016 at https://cida.usgs.gov/quality/rivers/home	Annual updates to nutrient load estimates are available at https://cida.usgs.gov/quality/rivers/home	USGS	Jennifer Graham jlgraham@usgs.gov	Ongoing

	delivered by streams to the Great Lakes, coastal areas such as the Northern Gulf of Mexico, and estuaries such as the Chesapeake Bay and San Francisco Bay are monitored at 113 freshwater sites. Annual updates from the monitoring sites are available to the public, including nutrient concentrations, loads, and yields. These data, along with data aggregated from numerous other agencies, are used to evaluate trends in critical water quality parameters including nutrients and sediment. In FY17, USGS began a pilot study to monitor for harmful algae and algal toxins at 11 sites on major rivers nationwide.					
Integrate new monitoring technologies into emerging U.S. and global ocean-observation systems.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Expanding environmental intelligence assets in	NOAA-GLERL is incorporating two integrated projects that will increase the	Launched the ESP in Lake Erie in 2016, and continued to use	Will continue use of the ESP in Lake Erie, and to	NOAA	Debbie Lee Deborah.lee@noaa.gov	2016

western Lake Erie	capacity to monitor and forecast bloom events. The projects are the ESP to monitor microcystin toxins and the hyperspectral fly-overs of western Lake Erie to determine bloom biomass. This project supplements NOAA Great Lakes HAB monitoring program and aids in developing models that can forecast bloom density, vertical and horizontal movement, and toxicity. It also aids in synthesizing and making available monitoring data and coupling monitoring programs with predictive models and serving that information to managers and public health officials.	the technology in 2017. Performed hyperspectral fly-overs of the region, as well.	perform hyperspectral fly-overs of the region.			
Glider Application to Gulf of Mexico Hypoxic Zone Monitoring; Pilot Study and Transition to Operations	Glider application to hypoxic zone monitoring in the Gulf of Mexico.	Proof of Concept complete; Pilot study ongoing.	Continued deployment of gliders for pilot study, completion of feasibility report for hypoxia monitoring applications	NOAA	David Hilmer david.hilmer@noaa.gov	2018
Implementing the *Karenia brevis* "tricorder" to Improve Red Tide	The study would build off an earlier ECOHAB project that developed a rapid, sensitive, and specific assay for the	Volunteer monitor training: Field trials held: Standard quantitation curves	Identify commercial partner to produce the detection	NOAA	John Wickham john.wickham @noaa.gov	2018

Monitoring and Management in the Gulf of Mexico	detection of *K. brevis* based on nucleic acid amplification technology, and adapted it for use with the QuadPyre, a handheld sensor. The current study demonstrates and transfer the handheld genetic sensors to monitoring end users, beginning with the FL FWRI and AL DPH.	developed; Eight Amplifire tricorders purchased: *K. brevis* rbcl gene expression quantified.	system. Integrate tricorder into GCOOS and PNW operations.			
Expanding Harmful Algal Bloom Mitigation in the Gulf of Mexico with Operational Support and Training for the Imaging FlowCytobot Network	Extends work (supported by ECOHAB and NCCOS/CCMA) to develop the IFCB to detect and quantify HAB cells rapidly (including in real-time) and continuously. This project will transition the IFCB to a commercial product (through McLane Research Laboratories), thus increase its availability for HAB early warning.	Progress in transition of IFCB to operations.	Operational IFCBs at sites along Texas coast.	NOAA	Marc Suddleson marc.suddleson@noaa.gov	2018
Improved Gulf of Mexico Harmful Algal Bloom forecast	Joint NOAA / NASA project is aimed at increase resolution of forecast for harmful algal blooms along the Florida and Texas coasts to provide an “every beach, every day" forecast of the risks posed by toxic algal blooms. Develop citizen monitoring network to	Year 2 of 3-year project.	Develop citizen monitoring network to provide daily results that will allow near real-time notification of the public about prevalence of toxic aerosols	NOAA	Rick Stumpf Richard.stumpf@noaa.gov	2019

	provide daily results that will allow near real-time notification of the public about prevalence toxic aerosols along beaches in Florida and Texas. This project is a collaboration with USGS, GCOOS, and Mote Marine Laboratory.		along beaches in Florida and Texas.			
Modeling reservoir algal community dynamics to link watershed to drinking water treatment and water recreation beneficial uses.	Provide a computational and modeling framework for linking watershed nutrient loadings to the degradation of reservoir water quality and resultant risks to human health and loss in beneficial uses.	Year 3 of 4-year project.	Database development.	USEPA	Christopher Nietch nietch.christopher@epa.gov	2019
Inland HAB Management	Comprehensive management of risks to multi-purpose freshwaters posed by cyanoHABs requires the integration of monitoring, analysis, and predictive modeling using a source water monitoring paradigm. Typically, sampling and quantification of cyanoHAB status are triggered by visual observations of water color or surface scums. At best, cyanobacterial cell counts or analysis of microcystin and	Data Collection 2015-17 HAB seasons Three presentations given: High Frequency monitoring of cyanoHABs and cyanotoxin production to characterize periods of greatest risk on an inland reservoir at the 8th WHO Symposium; Cyanotoxin occurrence associated with cyanoHAB	Data Collection 2018 HAB season and Data Analysis and Reporting	USEPA	Joel Allen Allen.joel@epa.gov	2019

	other toxins has been performed at set intervals regardless of the water's bloom status. This standard sampling regime is retrospective and in no way provides stakeholders the ability to prepare for blooms prior to their occurrence. Water quality status technologies providing time-relevant, high-frequency data collection and analysis can be used to develop short-term empirical models for bloom state prediction and trigger changes in risk management approaches. Generally, it is known that increased nutrients and temperature are contributing to increasing cyanoHAB events. Combining environmental data such as nitrogen and phosphorous levels, hydrodynamic data, sunlight and temperature data, and in-vivo cyanobacterial densities could provide short-term predictive capabilities useful	events on an inland reservoir at SETAC 2016; and Lake Harsha: Three Years of HABs Monitoring at 9th WHO Symposium. Manuscript submitted pending publication: Can qPCR and RT-qPCR be Used as Monitoring Variations of Microcystin Producers and Early Warning Their Blooms?				

	to recreational water users and drinking water treatment operators to reduce exposure and optimize treatment processes.					
An early warning system for *Pseudo-nitzschia* HABs on Pacific Northwest outer-coast beaches.	The purpose is to restore and refine the Pacific Northwest HAB Bulletin by enhancing monitoring and additional forecast models to more precisely predict HAB threats, thus reducing unnecessary shellfish closures and saving costs.	The project expands current monitoring infrastructure off WA and OR by including sites in known "hot spots" for toxic *Pseudo-nitzchia* blooms, and developing a short-term forecast (3-day) that will leverage a forecast model developed through ECOHAB, and a longer-term forecast (14-day) that would predict bloom landfall trajectories.	The Pacific Northwest HAB Bulletin would be restored and improved upon by refining forecast information through enhanced monitoring and additional forecast models that will more precisely predict HAB threats, thus reducing unnecessary shellfish closures and saving costs.	NOAA	Marc Suddleson marc.suddleson@noaa.gov Tiffany Vance tiffany.vance@noaa.gov	2020
The Alliance for Coastal Technologies (ACT): National-scale efforts towards the evaluation of observing	ACT proposes to work in close collaboration with U.S. IOOS Program Office and Regional Associations (RAs), IOOS federal and non-federal partners, local and regional resource managers, academic			NOAA		2020 and beyond.

	researchers and the private sector to improve operational observation capabilities through the quantification of existing instrument performance, and the introduction of new technologies, and enhanced communications. ACT's mission is to foster the creation of new ideas, new skills, new technologies, new capabilities, and new economic opportunities in support of the sustained national IOOS. The current 5-year grant focuses on technologies to detect harmful algae and their toxins. ACT contributes to ensuring the consistency of monitoring methods, developing rigorous QA/QC and synthesizing and making available monitoring data. This project is a collaboration with USEPA and USGS.					
Third Generation Environmental Sensor Platform	This system can be deployed in many different environments and has the capacity to sample and analyze for HAB species and	NOAA has deployed an ESP off the Pacific Northwest	Deploy new units in California, Gulf of Maine, and Lake Erie.	NOAA	Greg Doucette Greg.doucette@noaa.gov	2020 and beyond.

	toxins in near real time. The data are transmitted to a central processing center where they are analyzed and data sent to relevant managers. This project is a collaboration with USEPA and NSF.					
Autonomous, Underwater Sensors for Harmful Algal Bloom Toxins	The purpose of the project is the development of autonomous, in-water sensors able to detect individual HAB species and the toxins they produce. Given that bloom toxicity determines the potential for adverse effects on humans and wildlife, the overall aims of this project are to develop, validate, and deploy autonomous, underwater sensors for the detection of multiple HAB toxin classes on board the 2nd (2G) and 3rd (3G) generation ESP platforms. This project is a collaboration with USEPA and NSF.	We worked with the Monterey Bay Aquarium Research Institute to develop the ESP, an autonomous, underwater sensor that detects both harmful algae of the genus *Pseudo-nitzschia* and the potent neurotoxin they produce, domoic acid.	We are developing a new application that will allow the ESP to detect another class of algal toxins: paralytic shellfish poisoning toxins. Several partners are investigating the use of this sensor technology to monitor harmful algal blooms along the coasts of New England (Woods Hole Oceanographic Institution) and the Pacific Northwest (NOAA West Coast Center for	NOAA	Greg Doucette Greg.doucette@noaa.gov	2020 and beyond.

			Oceans and Human Health). We envision the ESP as an integral part of the US Integrated Ocean Observing System (IOOS), providing critical information on harmful algal blooms to coastal resource managers. A follow-on project funded by the National Science Foundation will transition the ESP's HAB species and toxin detection capabilities onto an autonomous underwater vehicle (AUV). Deployment of the AUV-mounted ESP will provide an unprecedented ability to track			

			HABs in both time and space while measuring changes in cell abundance and toxicity, along with other factors such as temperature, salinity, and nutrients, characteristics that may influence growth and toxin production in these algae.			
Phytoplankton Monitoring Network and Freshwater Phytoplankton Monitoring Network	The PMN is a community-based network of volunteers monitoring marine and freshwater phytoplankton and HABs. The PMN provides volunteer citizen-scientists with meaningful opportunities for hands-on science engagement. The benefit of PMN is a national network that support the HAB forecast by identifying landing of HABs, identify coastal landing of HABs not detected by the forecast, and by providing national		To continue to develop and provide a national network that support the HAB forecast by identifying landing of HABs, identify coastal landing of HABs not detected by the forecast, and by providing national monitoring of HABs beyond the	NOAA	Steve Morton steve.morton@noaa.gov	Ongoing

	monitoring of HABs beyond the regional HAB forecasts. This project is a collaboration with USEPA.		regional HAB forecasts			
Cyanobacteria Monitoring Collaborative (CMC)	The cyanobacteria monitoring component of this program is developing techniques that are beginning to demonstrate forecasting capabilities for bloom predictions.	Protocols are under development.	Collect data.	USEPA	Hillary Snook ook.hilary@epa.g v	Ongoing
USGS and NPS partnership to work on high-priority water-quality issues in national parks, including harmful algal blooms.	The USGS and NPS Water-Quality Partnership program empowers USGS scientists and National Park Service (NPS) resource managers to work in partnership to support a broad range of policy and management needs related to high-priority water-quality issues in national parks, including harmful algal blooms. There are ongoing HAB-related projects at several national parks including Isle Royale National Park, Sleeping Bear National Lakeshore, Pictured Rocks National Lakeshore, and Voyageurs National Park.	Progress and publications can be found on the USGS/National Park Service Water-Quality Partnership Program website https://water.usgs.gov/nps_partnership/	Progress and publications can be found on the USGS/National Park Service Water-Quality Partnership Program website https://water.usgs.gov/nps_partnership/	USGS, NPS	Mark Nilles manilles@usgs.gov	Ongoing
Develop and standardize HAB	Publishing standard methods and approaches for field	A USGS Techniques and Methods (T&M)	The final report will be made	USGS	Jennifer Graham	2018

monitoring methods	sensors that measure algal pigments, like chlorophyll and phycocyanin, and dissolved organic matter, and correlating these measures to harmful algal blooms and algal toxins.	report describing the use of water quality sensors for measurement of algal pigments and fluorescent dissolved organic matter has been peer reviewed and is planned for publication in FY18. The T&M report will contain quality assurance and quality control specifications for continuous measurement and calibration of sensors.	available through the USGS Publications Warehouse at https://pubs.er.usgs.gov/		(jlgraham@usgs.gov)	
Develop a rapid-response strategy for assessing HAB exposure.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Public health communication tools and resources during HAB events with potential health consequences.	Collaborate with state, federal, or other partners on public health communications tools and resources related to HAB exposures (people/animals).	Launch of a CDC HAB-associated illnesses website, including reference materials for the general public, and health care providers. Addition of a HABs section to the Drinking Water	Evaluate additional opportunities to engage and support partners on HABs and public health (e.g., community of practice)	CDC	Lorraine Backer lfb9@cdc.gov Virginia Roberts evl1@cdc.gov	Ongoing.

		Advisory Communications Toolkit (DWACT). Use of the Community Assessment for Public Health Emergency Response (CASPER) to assess community knowledge about the 2014 *Microcystis* bloom in Lake Erie. Ongoing collaboration with other agencies on communication materials.				
Investigating illness and outbreaks related to HABs	Develop a module for detecting and investigating HAB-related illnesses and outbreaks within an overall waterborne disease outbreak investigation toolkit.	Drafts completed.	N/A (completed)	CDC	Lorraine Backer lfb9@cdc.gov	2018
Fund method development through Prevention, Control, and Mitigation of HABs Program	Develop, working with the seafood industry, new, rapid assessment methods to detect HAB toxins in seafood.			NOAA		2020

Appendix 3. Actions to Improve Predictive Capabilities for HABs and Hypoxia

Develop, improve, and validate HAB and hypoxia models and remote sensing						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Transitioning to Operations NOAA-supported Statistical Hypoxia Models and Forecasts in the Gulf of Mexico and Chesapeake Bay	Transition to operations a multiple statistical model framework for hypoxia forecasting and assessment in the Gulf of Mexico and Chesapeake Bay, based on quantitative relationships between nutrient loading and hypoxic zone size. Seasonal forecasts produced annually. This project is a collaboration with USGS.	NOAA demonstrated capability of running models; transition plan ongoing.	NOAA NCCOS will run scenario forecasts in 2018.	NOAA	Alan Lewitus alan.lewitus@noaa.gov	2017
CEAP Special Studies: CEAP-Croplands in the Western Lake Erie Basin	CEAP-Croplands supported an assessment of agricultural conservation practice adoption across the Western Lake Erie Basin in 2003-06, as part of the CEAP-1 national survey, and in 2012, as part of a Special Study of WLEB. The two surveys allowed assessment of changes in practice adoption and impacts over time. Two reports were developed from	Report released October 2017	Area is being resurveyed as part of CEAP 2.0 and will be re-assessed in future years	USDA NRCS	Lee Norfleet lee.norfleet@wdc.usda.gov	2017

	the work, including one released in April 2016 that discusses edge of field impacts and one that will be released in August 2017 that discusses watershed scale impacts on instream dynamics and load delivery to Lake Erie. These reports provide a science-based understanding of conservation practice impacts, successes, and outstanding needs across Western Lake Erie Basin, as related to water quality, soil health, and farm sustainability. Thus, these reports may be used to inform conservation planning and field and watershed scales.					
Seasonal Forecasting of *Karenia brevis* Blooms in the Eastern Gulf of Mexico.	Produce seasonal red tide forecasts based on upwelling driven nutrient availability patterns, complementing the short-term forecasts from the NOAA HAB-OFS. The seasonal forecast would produce predictions on the location and timing of blooms, allowing managers (e.g. FWC, FL Dept.	Provides short term 3-D water movement forecasts for the weekly Florida Red Tide Report and on a web site. http://ocgweb.marine.usf.edu/hab_tracking/HAB_trajectories.html. Provided 2016 seasonal forecast.	Continue short terms forecasts and provide 2018 forecast. Begin transition to operations if warranted.	NOAA	Quay Dortch quay.dortch@noaa.gov	2018

	Agriculture and Consumer Services) to prepare when and where to focus sampling efforts.					
Inter annual variability of PSP toxicity in eastern Maine: testing the leaky gyre hypothesis and improving regional forecasts and management.	Improve Gulf of Maine HAB Forecast Model for the eastern Gulf of Maine by determining source of HAB cells that initiate bloom.	In 2017 deployed 4 moored sensors with HAB cell & toxin sensors in high energy Bay of Fundy and downstream into Gulf of Maine.	Repeat moorings in 2018. Improve models.	NOAA	Quay Dortch quay.dortch@noaa gov	2019
Improved Gulf of Mexico Harmful Algal Bloom Forecast	Joint NOAA / NASA project is aimed at increased resolution of the operational forecast for harmful algal blooms along the Florida and Texas coasts to provide an "every beach, every day" forecast of the risks posed by toxic algal blooms. This project is a collaboration with USGS, GCOOS, and Mote Marine Laboratory.	Funding through NOAA, NASA, CDC and others has allowed for the development of necessary tools for detecting HABs, monitoring their development, transport, toxicity and determining their effect on local wildlife, humans and socioeconomics. We have now reached a point in several regions where the understanding of these blooms is mature enough to put	The ultimate goal is to provide an "every beach, every day" forecast for HABs in the Gulf of Mexico, and elsewhere around the country.	NOAA/ NASA	Rick Stumpf richard.stumpf @noaa.gov	2019

		into place the detection and monitoring tools, and to bring these systems into an operational capacity. Although several regions have been or are anticipated to be operational over the next decade, we still have a long way to go to reach a National Forecast capacity for HABs. We continue to refine the forecasting tools based on research results and the development of more useful detection and monitoring tools.				
Transition Chesapeake Bay Hypoxia Forecast	Provide an operational real time, short term forecast of hypoxic conditions in the Chesapeake Bay to enable several stakeholder groups to make informed decisions (e.g. recreational fishermen, commercial fishermen, water quality managers, resources managers). This project is a collaboration with USEPA	Transition Plan completed.	Transition forecast to operations.	NOAA	Becky Baltes Becky.Baltes@noaa.gov	2019

	and USGS.					
Ecosystem Response and Recovery	The goal of this research is to improve understanding and prediction of aquatic (freshwater, estuarine, marine) ecosystem response and recovery to changing nutrient loads and other stressors. Ecosystem properties related and impacted by nutrients include biotic community structure, e.g., algal composition.	Year 2 of 5-year project.	Data collection Narragansett Bay, Mobile Bay, and Puget Sound. Ecosystem Models for Response and recovery and Nutrient-enhanced coastal acidification and hypoxia (NECAH) will be applied to these systems as well as to the Northern Gulf of Mexico and Lake Michigan.	USEPA	James Hagy hagy.jim@epa.gov	2019
Monitoring and multimedia modeling approaches for verifying nutrient reductions.	The goal of this research is to improve our scientific understanding of the systems of best management practices that most effectively address nutrient issues and the breadth of implementation that is needed before positive results can be achieved and measured at different watershed scales and for different endpoints, e.g.,	Year 2 of 5-year project.	Creation of simulated time series of agricultural N and P losses to the Mississippi River Basin (MRB), creation of additional time series of losses under different BMPs, provision of all-time series to	USEPA	Heather Golden golden.heather@epa.gov	2019

	target nutrient concentrations, loads, and eutrophication response.		Ecosystem models for response and recover and nutrient-enhanced coastal acidification and hypoxia (SSWR 4.02B).			
Cyanobacteria Assessment Network (CyAN)	CyAN is a multi-agency project among NASA, NOAA, USGS, and the USEPA to develop an early warning indicator system using historical and current satellite data to detect algal blooms in U.S. freshwater systems. This research supports federal, state, and local partners in their monitoring efforts to assess water quality to protect aquatic and human health.	Standardized algorithm intercomparison metrics have been developed, presented and incorporated into recommendations to the International Ocean Colour Coordinating Group. Developed a method for examining temporal changes in cyanobacteria harmful algal bloom spatial extent for state level assessment, transferable to different spatial areas. Developed a method for examining cyanobacteria harmful algal bloom frequency of occurrence for	CONUS MERIS CI data delivery to EnviroAtlas, CFERST, Estuary Data Mapper, Report on Environment, DW Maps teams. Expansion of data availability to CONUS state DEPs/DEQs.	USEPA	Blake Schaeffer Schaeffer.blake @epa.gov	2019

		recreational and resolvable surface drinking water systems. Production and delivery of MERIS CI composites for the full mission at 300 m for the full continental United States (CONUS). These MERIS CI data are available for project collaborators evaluation. Production and delivery of Sentinel-3 OLCI 2017+ forward stream and data is being made available to project collaborators and science team members. A metadata file and release notes have been included with the data distribution. Three webinar training sessions for state and federal collaborators on SeaDAS software,				

		RS tools, and Android mobile application. CyAN mobile application is in production and available for states to beta test with new 2017 satellite data. Support to Utah DEQ for Utah Lake and USACE for Lake Okeechobee.				
IOOS COMT: Inter-comparison of Hypoxia Models for the Northern Gulf of Mexico and Seasonal Forecasts and Nutrient Load Scenarios.	Skill assessment of 3D time variable hypoxia models and transition to operations. Hindcast simulation of hypoxic zone dynamics presented to Mississippi River/Gulf of Mexico Hypoxia Task Force in 2016. This project is a collaboration with USEPA and NRL.	Nutrient reduction targets for N and P presented to Hypoxia Task Force to guide hypoxia mitigation strategies.	Transition forecast to operations.	NOAA	Becky Baltes becky.baltes@noaa.gov	2020
Integration of Runoff Risk Forecasts into Hypoxia Forecast Models	The Runoff Risk Forecast (RRF) is a decision support tool providing guidance to farmers and producers on when to avoid applying fertilizers and manure to their fields in the next ten days. Following the guidance will reduce the risk that freshly applied nutrients will be	A partnership with EPA Great Lakes Restoration Initiative has resulted in multiple grants to expand and enhance the RRF tools in additional Great Lakes states in the next year.	RFP to assess coastal ecosystem benefits of watershed nutrient reductions due to RRF use.	NOAA	Alan Lewitus alan.lewitus@noaa.gov	2020

	transported into nearby water bodies. The aim is to quantify the benefits of the RRF to nutrient load reductions and incorporate these results into hypoxia scenario forecast models. This project is a collaboration with USEPA and USGS.					
User-driven tools to predict and assess effects of reduced nutrients and hypoxia on living resources in the Gulf of Mexico	Predict effects of reduced size of the hypoxic zone and reduced nutrient loading on fish and shellfish growth rate potential, biomass, and catch using simulation models, and develop management tools that can be used to weigh costs and benefits of alternative management strategies, and improve resource assessments.	Initial integration of datasets into ROMS and GRP models has begun, workshop conducted in Feb. 2016 to bring together advisory panel, which includes fisheries managers to solicit input.	Develop management tools in collaboration with fisheries managers that can be readily applied to test alternative management strategies to reduce hypoxic volume, and investigate subsequent effects on fish growth, population dynamics (e.g. abundance and biomass), and fisheries catches.	NOAA	Dave Hilmer david.hilmer@noaa.gov	2020 and beyond.
Synthesis and integrated modeling of long-term data sets to support	Integrate existing datasets using probabilistic modeling approaches to more fully evaluate the spatiotemporal	Hypoxia cruise data collected and processed, space-time geostatisitcal model	Integrate existing datasets using probabilistic, data-centric	NOAA	Dave Hilmer david.hilmer@noaa.gov	2020 and beyond.

fisheries and hypoxia management in the Northern Gulf of Mexico	dynamics of hypoxia and to understand and predict the ecosystem impacts of hypoxia, particularly the consequences for regional fisheries and for ecological indicators of upper-trophic-level fish community, which are currently being used or developed to monitor the state of the Gulf ecosystem.	is being developed. Information on bottom dissolved oxygen and species diversity from summer and fall SEAMAP cruises was compiled and made available as two key indicators used to monitor the status of the Gulf Ecosystem.	modeling approaches to more fully evaluate the spatiotemporal dynamics of hypoxia and to understand and forecast effects on fisheries and ecosystem impacts.			
Using linked models to predict the impacts of hypoxia on Gulf Coast fisheries under scenarios of watershed and river management	Link the Dynamic Land Ecosystem Model (DLEM) for the watershed, Delft3D model for diversions, Finite Volume Community Ocean Model (FVCOM)-WASP model for hydrodynamics and water quality, and fish and shrimp population models to provide a quantitative basis for evaluating the effectiveness and efficiency of watershed management action designed to reduce nutrient loadings and hypoxia.	Development of a strategy for linking the watershed model DLEM, the diversions model Delft3D, and the hydrodynamics-water quality model FVCOM-WASP. Initial implementation of the linking of the three models for three selected years (2010-2012), DLEM model development underway, Deft3D model development underway, FVCOM-WASP model development underway, progress on	Link well-established models quantify fish and shrimp population responses to various combinations of nutrient loadings and diversion operations, and present the results so they directly inform management.	NOAA	Dave Hilmer david.hilmer@noaa.gov	2020 and beyond.

		coding of the individual-based population model into FVCOM using FVCOM's particle tracking bookkeeping, and, synergistic modeling efforts begun.				
An early warning system for *Pseudo-nitzschia* HABs on Pacific Northwest outer-coast beaches.	The purpose is to restore and refine the Pacific Northwest HAB Bulletin by enhancing monitoring and additional forecast models to more precisely predict HAB threats, thus reducing unnecessary shellfish closures and saving costs.	The project expands current monitoring infrastructure off WA and OR by including sites in known "hot spots" for toxic *Pseudo-nitzchia* blooms, and developing a short-term forecast (3-day) that will leverage a forecast model developed through ECOHAB, and a longer-term forecast (14-day) that would predict bloom landfall trajectories.	The Pacific Northwest HAB Bulletin would be restored and improved upon by refining forecast information through enhanced monitoring and additional forecast models that will more precisely predict HAB threats, thus reducing unnecessary shellfish closures and saving costs.	NOAA	Marc Suddleson marc.suddleson@noaa.gov Tiffany Vance tiffany.vance@noaa.gov	2020
Operational Lake Erie Hypoxia Forecasting for Public Water	Provide public water systems with advance warning of lake circulation events that are likely to cause changes in	1) A stakeholder workshop was conducted to gather feedback from end	1) Develop, validate, and test a coupled hydrodynamic-	NOAA	Felix Martinez felix.martinez@noaa.gov	2020 and beyond.

Systems Decision Support	raw water quality by developing an operational hypoxia forecast model for Lake Erie, coupled to an existing real-time, fine-scale hydrodynamic model. This project is a collaboration with the USEPA and USGS, which provided water quality data critical to the development of the forecast models.	users on forecast type, format, and timing most useful for water plant operations. 2) New physical dissolved oxygen model was been developed, tested, and used for the 2017 hypoxia season. Model successfully predicted coastal upwelling effects with potential to impact drinking water plants. 3) A test webpage with nowcasts/forecasts of the dissolved oxygen model was developed and is being assessed for public release.	ecological model to forecast the nature and movement of hypoxic water in Lake Erie. 2) Develop a transition plan for the project's models.			
Watershed modeling of sources and contributions, transport, and delivery of nitrogen, phosphorus, and carbon from coastal rivers downstream to receiving waters such as the Gulf of Mexico, Chesapeake Bay, and the Great	Models such as the USGS' SPAtially Referenced Regressions on Watershed (SPARROW) provide consistent approaches to estimating nutrient sources in coastal areas. Long-term data on nutrient enrichment has been used in SPARROW models, which examine nutrient sources for freshwater streams, lakes, and coastal	In 2016, the USGS and USDA released an assessment of the benefits of conservation practices at https://www.usgs.gov/news/new-study-quantifies-benefits-agricultural-conservation-upper-mississippi-river-basin	The USGS is working with the IJC, Environment Canada, and the provinces of Ontario and Saskatchewan to complete a binational SPARROW model. Model output will identify	USGS	Jennifer Graham jlgraham@usgs.gov	2020 and beyond.

Lakes. Models help to test scenarios for decision making on best management practices.	areas, and in new methods for detecting trends in nutrient loads. SPARROW models identify major sources of nutrients and sediments to coastal areas, the Great Lakes, and inland lakes in the eastern US. Models are available for the conterminous United States in major watersheds including the Mississippi River, Chesapeake Bay, and binational Great Lakes. This project is a collaboration with USDA ARS.	.	the relative importance of nutrient sources and loads geographically in the Great Lakes watershed. The results are planned for publication in FY18. Regional SPARROW models that collectively represent major areas of nutrient enrichment and loading nationwide, are being updated to 2012 conditions. These models are planned for release prior to 2020.			
Develop new statistical models to predict algal toxins and blooms using real-time sensor data from lake and river monitoring stations	Studies are being conducted to identify types of HAB-forming algae and associated compounds, and develop real-time and early warning systems in high-valued water bodies used for	Several real-time models estimating the probability of cyanotoxin and taste-and-odor occurrence are available through the National Real-	Reports and journal articles are available through the USGS Publications Warehouse* by	USGS	Jennifer Graham jlgraham@usgs.gov	Ongoing

	recreation and drinking-water throughout the Nation. Many studies employ new and developing sensor technology to detect algal pigments and develop surrogate relations to estimate the concentration or probability of cyanotoxin occurrence.	Time Water-Quality website at https://nrtwq.usgs.gov/ For example, a study of the primary drinking water supply for Wichita, Kansas combined long-term discrete and continuous water-quality data to develop models that estimate the probability of microcystin occurrence in near real time.	searching on Harmful Algal Blooms "cyanotoxins," and "algal toxins" at https://pubs.er.usgs.gov/			
Decision-support tools to link phosphorus reductions to HABs and source water protection.	To provide data supporting the Lake Erie HAB Tracker, which has been used in Lake Erie since 2014 and slated for transition to operations in FY18.	The Lake Erie HABs Bulletin went fully operational in July 2017.	Weekly sampling data have been used to develop the now-operational Lake Erie HAB Tracker.	NOAA	Debbie Lee Deborah.lee@noaa.gov	Ongoing
NGOMEX and CHRP	HABHRCA-authorized competitive programs to advance the development and application of scenario-based ecosystem models to quantitatively evaluate hypoxia causes and impacts,		Advance the development and application of scenario-based ecosystem models to quantitatively evaluate hypoxia	NOAA	Alan Lewitus alan.lewitus@noaa.gov	Ongoing

	using an integrative modeling approach, and develop outreach tools to communicate advanced understanding to coastal managers and other stakeholders.		causes and impacts, using an integrative modeling approach, and develop outreach tools to communicate advanced understanding to coastal managers and other stakeholders. When funding is available, NCCOS will release an RFP for these programs.			
Lake Erie Seasonal HAB Forecasts	The Lake Erie seasonal forecast for the cyanobacterial bloom depends on an ensemble of models, and also includes an early season projection, extending up to two months prior to the final forecast.	The Lake Erie HAB Forecast became fully operational in July 2017.	Improvements to the NWS River Forecast Center models for river discharge are being incorporated and evaluated for the early season projections, and the models for the forecast are being reevaluated.	NOAA	Rick Stump Richard.stumpf@noaa.gov	Ongoing
Integration of	The Runoff Risk Forecast	A partnership with	NOAA will	NOAA	Alan Lewitus	2020

Runoff Risk Forecasts into hypoxia forecast models	(RRF) is a decision support tool providing guidance to farmers and producers on when to avoid applying fertilizers and manure to their fields in the next ten days. Following the guidance will reduce the risk that freshly applied nutrients will be transported into nearby water bodies. The aim is to quantify the benefits of the RRF to nutrient load reductions and incorporate these results into hypoxia scenario forecast models. This project is a collaboration with USEPA and USGS.	EPA Great Lakes Restoration Initiative has resulted in multiple grants to expand and enhance the RRF tools in additional Great Lakes states in the next year.	release an RFP to assess coastal ecosystem benefits of watershed nutrient reductions due to RRF use		alan.lewitus@noaa.gov	
Lake Erie HAB Forecast System	The Lake Erie HAB Forecast System includes several formats of products to support public and local government needs. It incorporates satellite data, field data, and numerical models to generate timely information on the location and likely intensity of the blooms. A new satellite was launched in 2016, which will provide greater resolution of the blooms. This needs to be	The Lake Erie HABs Bulletin went fully operational in July 2017.	NOAA anticipates to improve the resolution of its remote sensing activities, and therefore, the accuracy of its forecasts.	NOAA	Rick Stumpf richard.stumpf@noaa.gov	Ongoing

	incorporated in the monitoring and forecasts. Also, 3D modeling of the blooms and evaluation of toxicity patterns will improve the accuracy and value of the forecasts. Adding OLCI satellite data to the bulletin, begin evaluations of output of 3-D modeling.					
CEAP-2: The second Conservation Effects Assessment Project (CEAP) National Assessment (2015-2016), on Cultivated Cropland and pastureland.	This project aims to quantify trends in conservation practice adoption on cultivated cropland across the US and provide the first assessment of conservation practice adoption on pastureland across the US. A Modeling component allows assessment of the impacts of current (2015-16), past (2003-06), and alternative scenario agricultural conservation practices on edge of field losses, deposition/legacy dynamics, and load deliveries to watershed outlets. Allows evaluation of conservation efforts impacts on agroecological indicators, including yields, soil health,	Survey completed	On-going assessment	USDA NRCS	Lee Norfleet lee.norfleet@wdc.usda.gov	Ongoing

	water quantity and quality, and impacts on biodiversity, which in turn enables development of improved practice standards and comprehensive conservation planning. Project CEAP contributes to development of conservation planning tools to improve agroecological benefits across the US, including a reduction of agriculture's impact on water quality and an improvement of the nation's soil health. This work is conducted in collaboration with USDA ARS, USDA NASS and universities.					
Cyanobacteria Monitoring Collaborative (CMC)	The cyanobacteria monitoring component of this program is developing techniques that are beginning to demonstrate forecasting capabilities for bloom predictions. This project will help ensure consistency of monitoring methods, implement rigorous benchmarks of quality assurance and quality control, and making available monitoring data. This project	A Region 1 Quality Assurance Project Plan has been developed and approved for this program. Regional monitoring entities have implemented the approach and 2017 samples will be analyzed jointly in November. Program cyanobacteria	A workgroup analysis day will take place in December analyzing all samples collected as part of the cyanobacteria monitoring collaborative. Cyanobacteria identifications and bloom	USEPA	Hillary Snook snook.hilary@epa.gov	Ongoing

	is a collaboration with the University of New Hampshire.	identifications and bloom notification submittals have also seen an increase in 2017.	notifications are ongoing, and a core workgroup meeting will be held in November.			
Salish Sea Ecosystem Model	The Salish Sea Ecosystem Model, supported by the USEPA and the USACE is used to determine hypoxia relationship to nutrient loading throughout the Salish Sea, at moderately high resolution. It comprises a physical-biological coupled model with FVCOM as the physical model and CE-QUAL-ICM as the biogeochemical model. Currently ocean acidification module is being added and resolution enhanced. This project is a collaboration with PNNL and WA Ecology. Other ongoing research includes linking the Salish Sea Model with the USEPA's ecohydrological model [Visualizing Ecosystem Land Management Assessments	Model has been calibrated for one year and is being used to run scenarios.	Finalize and calibrate ocean acidification module and improve resolution.	USEPA	Ben Cope cope.ben@epa.gov	Ongoing

	(VELMA] to simulate effects of land use and climate scenarios on riverine transport of terrestrial nutrients and contaminants to the Puget Sound estuarine-ocean system.					
Modeling reservoir algal community dynamics to link watershed to drinking water treatment and water recreation beneficial uses.	Provide a computational and modeling framework for linking watershed nutrient loadings to the degradation of reservoir water quality and resultant risks to human health and loss in beneficial uses.	Year 3 of 4-year project.	Database development.	USEPA	Christopher Nietch nietch.christopher@epa.gov	2019
Develop enhanced surveillance for human and animal exposure, illnesses, disease, and deaths resulting from HAB toxins.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Use public health surveillance data to characterize and inform understanding of HAB-associated illnesses	Publish a summary of data collected in the One Health Harmful Algal Bloom System (OHHABS).	OHHABS launched in 2016, with additional components added in 2017 to support data collection and review.	Additional data collection, data review process, and surveillance report to be completed	CDC	Virginia Roberts evl1@cdc.gov	2020
Ciguatera fish poisoning: assessing toxin levels in implicated food fish species from	To identify ciguatoxin levels in food fish from endemic waters	All samples have been collected and analyzed.	Analyze and publish data.	FDA	Sara Handy Sara.Handy@fda.hhs.gov	2018

endemic US waters						
Cyanobacteria Monitoring Collaborative (CMC)	This project will help identify short- and long-term effects of HABs and hypoxia on communities and the impact of HABs and hypoxia. Also, will provide information to explore the causes of HABs and the level of awareness of associated human-health risks by providing clear and easy-to-use reporting tools and communication mechanisms to pet owners, veterinarians, wildlife and fisheries personnel, medical and public-health officials, and others. This project is a collaboration with the USGS.	A phone App has been developed for citizen/public reporting of blooms to key state water quality contacts. Two public crowdsourcing databases have been established for reporting and documenting potential bloom occurrences and cyanobacteria image identifications. Program trainings in the region and national webinars have introduced and or trained an additional 400-500 individuals on the program in 2017. Quick start guides have also been produced for the bloomWatch and cyanoScope levels of the program.	Ongoing work with a simplified image based cyanobacteria key for program users is in development. Data visualization for the cyanomonitoring component is in progress, and website improvements and additional training tools are presently being worked on.	USEPA	Hillary Snook nook.hilary@epa.gov	Ongoing
Evaluate biological methods to provide evidence of ambient exposures to cyanotoxins and to	To support the development of methods to quantify and characterize absorbed doses of cyanotoxins in biological samples which will enhance	Year 3 of 4-year Project	Data collection underway	USEPA	Elizabeth Hilborn hilborn.e@epa.gov	2019

samples for cyanotoxin concentrations, characterize associated effects among humans and animals	the interpretation of associated health effects. The goal is to collect human and animal biological samples after they have experienced ambient exposures to harmful cyanobacteria. This project is a collaboration with the California Dpt. of Health and the California Dpt. of Fish and Wildlife and the Lake County Director of Health, the Clear Lake Cyanobacteria Task Force and community.					
Investigate ecological and food web impacts from HAB toxins.	USGS has ongoing research characterizing ecological and food web impacts of cyanotoxins. This research is conducted in collaboration with other federal, state, and local land and water management agencies.	A USGS study in Upper Klamath Lake demonstrated a link between microcystin and reduced young-of the year recruitment of federally endangered suckers. Progress and publications can be found on the Web at: https://or.water.usgs.gov/klamath/	Additional reports and journal articles will be published and made available through the USGS Publications Warehouse* https://pubs.er.usgs.gov/	USGS	Jennifer Graham jlgraham@usgs.gov	2020 and beyond Ongoing
Investigate ecological and food web impacts from HAB toxins.	USGS has ongoing research characterizing ecological and food web impacts of cyanotoxins. This research is conducted in collaboration	A USGS study in Upper Klamath Lake demonstrated a link between microcystin and reduced young-of	Additional reports and journal articles will be published and made available	USGS	Jennifer Graham jlgraham@usgs.gov	Ongoing

	with other federal, state, and local land and water management agencies.	the year recruitment of federally endangered suckers. Progress and publications can be found online https://or.water.usgs.gov/klamath/	through the USGS Publications Warehouse https://pubs.er.usgs.gov/			
Understanding the exposure patterns and potential for health risks from cyanotoxins and other toxin exposures to humans and other organisms.	Provide the science needed to understand how to economically and effectively minimize the risk, if any, to the health of humans and other organisms exposed to cyanotoxins (and other toxins, through inhalation, dermal, ingestion, and other exposure routes. This project is part of a larger effort of the USGS Environmental Health Mission Area to provide information that will help resource managers to understand how to effectively minimize potential risks to the health of humans and other organisms exposed to cyanotoxins and other biogenic toxins through recreational, drinking, and other exposure routes.	Publications can be found on the Web at: https://toxics.usgs.gov/highlights/	Additional reports and journal articles will be published and made available on the Web at: https://toxics.usgs.gov/highlights/ and through the USGS Publications Warehouse * by searching on "Harmful Algal Blooms" "cyanotoxins," and "algal toxins" at https://pubs.er.usgs.gov/	USGS	Mike Focazio mfocazio@usgs.gov	Ongoing

Appendix 4. Actions to Improve Stakeholder Engagement and Socioeconomic Understanding

Improve communication and coordination among health and environmental agencies so that reports of HAB-associated animal poisonings are used as an indicator of potential human-health risk. Develop science-based guidelines for cyanotoxins						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Drinking Water Cyanotoxin Risk Communication Toolbox	Drinking water cyanotoxin management risk communication toolbox that is aimed to be a ready-to-use, "one-stop shop" with worksheets, press release templates, social media posts, and other quick-reference guides for utilities and states to use in communicating with the public before, during and after a cyanotoxin contamination event.	Published November 2016 https://www.epa.gov/ground-water-and-drinking-water/cyanotoxin-tools-public-water-systems	N/A (complete)	USEPA	Katherine Foreman Foreman.Katherine@epa.gov	2016
Cyanotoxin Management Plan Template and Example Plans	The template is intended to assist states, tribes and water utilities in developing their own cyanotoxin management plans specific for their locations. The template includes potential steps for monitoring, treatment and communication activities. To support systems as they develop their plans, EPA worked with five utilities to	Published November 2016 https://www.epa.gov/ground-water-and-drinking-water/cyanotoxin-tools-public-water-systems	N/A (complete)	USEPA	Hannah Holsinger Holsinger.Hannah@epa.gov	2016

	develop system-specific cyanotoxin management plans to provide examples for utilities to reference as they develop system-specific plans for their utility.					
Tools for Addressing the Risks of Cyanotoxins in Drinking Water Video	The video provides a brief overview of Tools for Addressing the Risks of Cyanotoxins in Drinking Water recently developed by USEPA to support drinking water systems in their cyanotoxin risk management activities.	Developed the script for the video.	Finalizing of video	USEPA	Katherine Foreman Foreman.Katherine@epa.gov	2017
Develop website materials and document for lake managers or public health officials responsible for overseeing recreational water bodies.	Provide information to lake managers or health officials interested in monitoring for—and responding to—cyanobacterial blooms in the water bodies they manage.	Website materials and monitoring document were completed in July 2017 although future updates are likely (https://www.epa.gov/nutrient-policy-data/monitoring-and-responding-cyanobacteria-and-cyanotoxins-recreational-waters), (https://www.epa.gov/sites/production/files/2017-07/documents/08_jul	Minor updates to reflect criteria magnitude, duration and frequency values are expected when recreational criteria for microcystins and cylindrospermopsin are made final.	USEPA	Shari Barash Barash.Shari@epa.gov	2018

		y_3_monitoring_document_508c_7.5.17.pdf)				
Human Health Recreational Ambient Water Quality Criteria and/or Swimming Advisories for Microcystins and Cylindrospermopsin	The purpose of the Human Health Recreational Ambient Water Quality Criteria and/or Swimming Advisories is to protect the public from incidental ingestion of microcystin and cylindrospermopsin during primary contact recreation.	Draft recommendations posted for public comment in Dec 2016. Public comment period closed in March 2017.	Currently revising draft document in response to public comments received. Next steps include internal Agency review of revised document.	USEPA	John Ravenscroft ravenscroft.john@epa.gov	2018
California CyanoHAB Response and Management resources development via the California Monitoring Council, California Cyanobacteria and HAB (CCHAB) Network and State Water Resources Control Board	Develop resources to respond to and manage HABs statewide including: guidelines for posting HAB-impacted recreational waters based on toxin levels; monitoring; developing SOPs and safety guidelines; maintaining list of labs doing HAB analyses; working with CyAN team on satellite data evaluation including HAB status and trends in observable waters; a web portal with a real-time map of known impacted waters, and links to resources; and training opportunities. The Monitoring Council and CCHAB Network bring together multiple state	California co-sponsored: the April 2017 EPA OW & Region 9 HABs/Cyanotoxin Workshop, a May 2017 Domoic Acid Workshop, and quarterly CCHAB full-day meetings; responded to reports of HABs in 171 waterbodies resulting in posting of 124 waters; conducted a "Pre-Labor Day Assessment of 43 highly visited waterbodies with a history of HABs to	Currently revising draft guidelines for HAB response. Will continue to engage and support partners on HABs and public health through efforts of CCHAB and Monitoring Council partners.	USEPA	Sue Keydel Keydel.Susan@epa.gov	2020

	agencies, as well as federal, local and tribal stakeholders, NGO's and water body mangers. (Partially supported with CWA 106 funds).	assure timely and accurate posting for the holiday weekend; developed and published a "Veterinarian Reference" fact sheet; continued work with CyAN team on satellite data evaluation, satellite web tool, and Android app review; continued to update and improve the Freshwater HAB event Map and tracking.				
Public health communication tools and resources during HAB events with potential health consequences.	Collaborate with state, federal, or other partners on public health communications tools and resources related to HAB exposures (people/animals).	Launch of a CDC HAB-associated illnesses website, including reference materials for the general public, and health care providers. Addition of a HABs section to the Drinking Water Advisory Communications Toolkit (DWACT). Use of the Community	Evaluate additional opportunities to engage and support partners on HABs and public health (e.g., community of practice)	CDC	Lorraine Backer lfb9@cdc.gov Virginia Roberts evl1@cdc.gov	Ongoing

		Assessment for Public Health Emergency Response (CASPER) to assess community knowledge about the 2014 *Microcystis* bloom in Lake Erie. Ongoing collaboration with other agencies on communication materials.				
Upper Mississippi River Basin Association HABs workgroup	USEPA Region 7 joined the Upper Mississippi River Basin Association Harmful Algal Bloom group to enhance knowledge and to create partnerships with the states of the Upper Mississippi River, as well as federal partners and others, in addressing harmful algal blooms (HABs) on the Upper Mississippi River (UMR). The working group developed a HABs response support manual. This project is a collaboration with USEPA Region 5, Upper Mississippi River states, USGS and USACE.	The working group developed a HABs response support manual: http://www.umrba.org/wq/umr-hab-response-resource-manual-8-2016.pdf.	Continue correspondence between states, UMBRA, and federal agencies. Future meetings of the workgroup and updates on monitoring capacities.	USEPA	Dave Hokanson dhokanson@umrba.org	Ongoing
Compilation of	This effort intent to share	Completed HABs	Continue roundtable	USEP	Amy Shields	Ongoing

HAB Programs and Capacities for Iowa, Kansas, Missouri, Nebraska, USGS, USACE and USEPA Region 7	monitoring and laboratory capacities with Iowa, Kansas, Missouri and Nebraska. This project is a collaboration with Kansas, Nebraska, Iowa, and Missouri, USGS, and USACE.	compilation of HAB capacities for state partners and federal agencies	discussions during sampling seasons as needed; EPA R7 HABs workshop was attended by all four R7 states. R7 will be participating and presenting in Kansas Harmful Algal Bloom Stakeholder meeting in winter 2018.	A	shields.amy@epa.gov	
Cyanobacteria Monitoring Collaborative (CMC)	The purpose is to increase the verification and documentation of likely HAB occurrences.	A phone App has been developed and put into use as of August 2016.	Regularly scheduled updates of the App will incorporate additional state agencies upon request.	USEPA	Hillary Snook snook.hilary@epa.gov	Ongoing
Identify susceptible populations at higher risk for HAB-associated adverse health effects.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Effects of exposure to algal/cyanobacterial toxins in mammalian models	The objective of this project is to increase our understanding of the results of exposures to common algal and cyanobacterial toxins in mammals using laboratory mouse bioassays.	Year 3 of 4-year project.	Laboratory work currently underway	USEPA	Neil Chernoff chernoff.neil@epa.gov	2019

Expand stakeholder engagement.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Demonstration Farm Network Blanchard River Demonstration Farm Network	The Blanchard River Demonstration Farm Network (Ohio) is a $1 million, five-year project and the first of its kind in Ohio. Three demonstration farms showcase innovative and standard agricultural practices that help reduce and prevent nutrient runoff. The Blanchard River Demonstration Farm network includes several crucial components: •Edge of field monitoring •Economic analysis •Participation and attendance •Project replication This project is carried out in collaboration with Ohio Farm Bureau.	The three farms in the Western Lake Erie Basin are testing various conservation methods to help reduce nutrient runoff and better protect water quality. The results of these new and traditional methods are being shared with farmers to help them determine what conservation practices might work best on their farms.	Researchers studying different conservation practices at the Blanchard River Demonstration Farms are narrowing their focus to four practices that appear to help reduce nutrient and sediment loss. 1. Adhering to Tri-State Fertility Guide recommendations 2. Improving soil health 3. Subsurface placement of nutrients 4. Disconnecting hydrologic pathways More information is	USDA NRCS	Doug Deardorff doug.deardorff@oh.usda.gov	2020

			available at: https://ofbf.org/2017/04/17/researchers-focusing-four-conservation-strategies-demo-farms/			
Demonstration Farm Network Lower Fox Demonstration Farm Network	Goals include: • Establish 2-4 demonstration farms within the Lower Fox Watershed to test new and standard conservation systems in reducing phosphorus and sediment. • Establish an efficient mechanism to share this technology and information with farmers, agribusiness, conservation agencies and the public. • Create opportunities for others to test their research, technical and program ideas at the demonstration farms. • Share information and lessons learned from the Lower Fox Watershed throughout the Great Lakes basin.	Achievements include USGS edge of field monitoring; Numerous "Field Days on the Fly"; and, Demonstration of Low Disturbance Manure application equipment.	The Network is working to provide better information on the effectiveness of conservation systems used to improve water quality, while also providing educational technology transfer opportunities through public field days.	USDA NRCS	Tom Krapf tom.krapf@wi.usda.gov	2021
National HAB Committee	Established to provide a collective voice for the	Hold several conference calls with	Conduct the 2017 US HAB	Multi-agency	Ex-Officio Members	Ongoing

	academic, management, and stakeholder communities, this committee's mission is to facilitate coordination and communication of HAB activities at a national level. The committee was formed after the need for better coordination within the HAB research and management communities—and for enhanced communication with federal agencies. Co-chaired by researchers from an academic institution and a non-profit marine research institution. Federal agencies serve as ex-officio members.	members and ex-officio members. Initiated planning the 2017 US HAB Symposium.	Symposium.	(USEPA, CDC, FDA, USGS, NSF, NOAA, NIH)	Lesley V. D'Anglada Danglada.Lesley@epa.gov Lorraine C. Backer lfb9@cdc.gov Stacey Degrasse Stacey.Degrasse@fda.hhs.gov Quay Dortch quay.dortch@noaa.gov Keith Loftin kloftin@usgs.gov Donald Rice drice@nsf.gov Marc Suddleson Marc.Suddleson@noaa.gov Fred Tyson tyson2@niehs.nih.gov	

Inland HABs Discussion Group	Group of public-health officials from states, Counties and Tribes, academia, and Federal agencies to discuss issues related to research, monitoring, human and ecological health risk assessment, education, and outreach. This group is led by USEPA, CDC and USGS.	Four National Webinars Conducted: March 2016 on HABs in the Great Lakes; October 2016 on Freshwater HABs Response Efforts; February 2017 on Toxin Monitoring, and May 2017 on Success Stories of HABs Prevention, Control and management Techniques	Three to four webinars plan per year	Multi-agency (USEPA, CDC, USGS)	Lesley D'Anglada Danglada.Lesley@epa.gov Lorrie Backer, CDC lbacker@cdc.gov Keith Loftin, USGS kloftin@usgs.gov	Ongoing
Regional HABs/Cyanotoxin Workshops and Meetings	Share information and build relationships among federal, state, and tribal CWA and SDWA programs by making connections and identifying shared HAB-related goals, needs, and barriers. This project is a collaboration with USEPA Regions. USEPA Regions also host annual nutrient meetings with the states that cover hypoxia issues and potentially HABs.	Seven regional workshops completed: Region 8 in 2015; Region 5 and Region 10 in 2016; and Region 1, Region 2, Region 3, Region 7 and Region 9 in 2017.	Conduct two workshops/meetings in 2018 in Region 4 and Region 6. Publish a Compendium of all Regional HABs workshops.	USEPA	Lesley D'Anglada DAnglada.Lesley@epa.gov Hannah Holsinger holsinger.hannah@epa.gov	2018
Cyanobacteria Monitoring Collaborative	Immediate notification to key agency officials upon the onsite submittal of an	A phone App has been developed for this purpose and is	Additional state agencies to be added upon the next	USEPA	Hillary Snook snook.hilary@epa.gov	Ongoing

(CMC)	occurring bloom.	now available to anyone that would like to use it. There are presently several state agencies signed up to receive notifications, and many waiting to be added to the App upon the next update.	App update.			
USEPA Region 8 Webinar Series	USEPA Region 8 hosted webinar series on HABs issues to share HABs information with states DEQ and health departments, and tribal environmental programs on HABs related issues.	Six webinars held in 2016.	Continue hosting webinars in 2017.	USEPA	Tina Laidlaw Laidlaw.tina@epa.gov	Ongoing
Freshwater HABs Newsletter	Monthly newsletter with a main focus primarily on freshwater HABs and provides information on upcoming events, conferences, and webinars, useful resources, beach closures and health advisories, current news and recently published journal articles	Twenty-one Newsletters published since January 2016. Twenty-four newsletters published from January 2014 to December 2015.	Monthly publication.	USEPA	Lesley D'Anglada DAnglada.Lesley@epa.gov	Ongoing

Evaluate socioeconomic impacts of HABs and hypoxia, and the costs of mitigation						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Effects of hypoxia on harvest dynamics and economics of the shrimp fishery in the northwestern Gulf of Mexico	The objectives of this proposal were to: (1) evaluate the effects of hypoxia on the spatial and temporal dynamics of shrimping effort and catch and the associated consequences for quantitative assessment models currently used to inform management of the fishery, (2) determine the spatial extent and nature of hypoxia effects on the spatial behavior and fishing activities of individual shrimp vessels, (3) quantify the economics consequences of hypoxia on the fishery using discrete choice models of fishing behavior, (4) identify the causal impact of hypoxia the economics of the fishery using quasi-experimental methods, and (5) develop a bioeconomic model of the shrimp fishery	The study found that the Gulf Hypoxic zone had a significant economic impact on the shrimp market – this provided the first quantitative evidence linking Gulf hypoxia to economic impacts. The study found that the hypoxic zone drives up the price of large shrimp relative to small shrimp, creating an economic impact that directly affects consumers, fishermen and seafood markets.	N/A - completed	NOAA	Dave Kidwell david.kidwell@noaa.gov	2016

	that can be used to assess the economic consequences of alternative nutrient and fishery management policies.					
Possible Funding Sources for Managing Cyanobacterial Harmful Algal Blooms and Cyanotoxins in Drinking Water Fact Sheet	This document provides an explanation of possible funding sources that can be used to manage cyanobacterial harmful algal blooms and cyanotoxins. These sources include the Safe Drinking Water Act and Clean Water Act revolving funds and other possible funding sources to support drinking water systems in managing risks to drinking water from harmful algal blooms and cyanotoxins.	Published January 2017 https://www.epa.gov/ground-water-and-drinking-water/cyanotoxin-tools-public-water-systems	N/A - Complete	USEPA	Hannah Holsinger Holsinger.Hannah@epa.gov	2017
HABs Socioeconomic Workshop	To meet with Federal agencies and economic experts to discuss research methods and needs related to social science and HABs.	Steering Committee formed, workshop plans ongoing.	Workshop convened and outputs inform development of PCMHAB competitive funding announcement.	NOAA	Marc Suddleson marc.suddleson@noaagov	2018
Estimating the Economic Benefits of Mitigating and Avoiding Harmful Algal Blooms	Economic value of detecting bloom events using remote sensing as part of the CyAN project.	Draft manuscript titled "Exploring the use of satellite remote sensing to monitor chlorophyll-a for nuisance and harmful algal blooms." for publication.	Perform economic analysis (pending funding).	USEPA	Michael Papenfus Papenfus.Michael@epa.gov	2019

Appendix 5. Actions to Expand Collaborations in Research, Management, and Policy-Related Arenas

Continue and expand relevant research, management, and policy collaborations.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Contaminant Candidate List Four	The CCL is a list of drinking water contaminants that are known or anticipated to occur in public water systems and are not currently subject to EPA drinking water regulations. Several cyanotoxins were included.	Published November 2016	N/A (complete)	USEPA	Meredith Russell Russell.Meredith@epa.gov	2016
Source Water Protection	Mapping program for source water protection and planning. Currently synthesizing and making available monitoring data.	Year 2 of project; reboot expected 2017	New Geoplatform version 2017	USEPA	Bo Williams williams.james@epa.gov	2018
Integration of Alternative Methods of Analysis into the Neurotoxic Shellfish Poisoning Monitoring and Management Framework	Obtain Interstate Shellfish Sanitation Conference (ISSC) approval for MARBIONC ELISA as the first non-mouse based method for testing for Neurotoxic Shellfish Poisoning (NSP) toxins in shellfish meats	Proposal for Limited use of MARBIONIC ELISA for NSP toxins in hard clams, sunray venus clams, oysters approved by ISSC; awaiting FDA concurrence before inclusion in National Shellfish Sanitation Program	Expand the list of species for which the ELISA method can be used, transfer this technology to appropriate end-users, and evaluate other methods of sample preparation and analysis for potential use in	NOAA	Quay Dortch quay.dortch@noaa.gov	2020

			biotoxin management programs.			
Annual NOAA/NGI Gulf of Mexico Hypoxia Research Coordination Workshops	Forum for communication between researchers and stakeholders, and mechanism for advancing monitoring, research, and modeling needs critical to managing hypoxia. This project is a collaboration with USGS, USEPA, NRL, NASA, USACE, and BOEM.	6th Annual Workshop completed in Sept. 2016.	7th Annual Workshop scheduled for January 2018.	NOAA	Alan Lewitus alan.lewitus@noaa.gov	Ongoing
Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (Hypoxia Task Force)	The group is working to (1) expand and encourage the use of science-based nutrient management and other practices that help to reduce nutrient losses; (2) identify opportunities for states to share information; and (3) create a network of leaders, including farmers, who strategize about agricultural-based nutrient losses. USGS, other Federal Agencies, 12 states, and a national tribal representative to address hypoxia in the Mississippi River and the northern Gulf of Mexico.	All 12 states continue to update and implement their state-level nutrient reduction strategies. The HTF continues to engage with SERA-46, a multi state Land Grant University research and extension committee to better understand knowledge gaps and share information. Farmer networks are in development, in addition to those that exist, as well as	A second point source measures report and the first nonpoint source report will be published in the near-term.	USEPA, USDA, DOI, USACE	Katie Flahive, flahive.katherine@epa.gov	Ongoing

		networks for other conservation professionals across the basin. In November 2017, the second biennial report to congress was published, describing the actions that the federal, state and tribal members of the HTF are taking towards the goal.				
Ohio River Basin HABs Scientific Workgroup	Collaboration among EPA, Ohio River Sanitation Commission, universities, and drinking water utilities in the Ohio River basin to exchange information, coordinate research and develop an Ohio River HABs watch web site.	Year 1 of an ongoing project.	ORSANCO commissioners approved the formation of a science workgroup to communicate and collaborate on HABs. First meeting to be held in 2018.	USEPA	Jim Lazorchak lazorchak.jim@epa.gov	Ongoing
Great Lakes HABs Collaboratory	In partnership with the Great Lakes Commission to: (1) establish the HABs Collaboratory by identifying and engaging the appropriate scientists and managers, (2) develop a common knowledge basis of current science and science needs, and (3) develop strategies for	The Great Lakes HABs Collaboratory was established in 2015. Numerous information-sharing opportunities have been provided including in person meetings, special sessions at scientific meetings, conferences,	Opportunities for information sharing will continue to be supported. Updates and additional information are available on the web at: http://www.glc.org/work/habs-	USGS	Jon Hortness hortness@usgs.gov	Ongoing

	transmitting key scientific information to managers and for getting management feedback to support science-based decisions.	and a HABs State of the Science Webinar series. Additional information is available on the web at: http://www.glc.org/work/habs-collaboratory	collaboratory			
Develop guidelines and tests for HAB toxins in drinking and recreational water, and improve toxin removal during water treatment.						
Action	**Goal/Purpose**	**Achievements to October 2017**	**Activities to be Completed**	**Agency**	**Point of Contact**	**Expected Date of Completion**
Water Treatment Optimization for Cyanotoxins	The Water Treatment Optimization for Cyanotoxins document supports public water systems in developing monitoring and treatment optimization approaches for cyanotoxins to achieve the best performance possible from each treatment process. It presents proactive approaches for water sampling and monitoring to help public water systems anticipate treatment needs and to treat cyanotoxins in drinking water. Information is presented for treating cyanotoxins using many types of water treatment.	Published November 2016 https://www.epa.gov/ground-water-and-drinking-water/cyanotoxin-tools-public-water-systems	N/A (complete)	USEPA	Tom Waters Waters.Tom@epa.gov	2016

Development of a Comprehensive Performance Evaluation (CPE) assessment protocol for HAB-impacted water treatment plants in collaboration with Ohio EPA	A series of four pilot CPEs will be conducted with selected Ohio surface water treatment plants, to support the development of a HAB CPE assessment protocol for HAB-impacted drinking water treatment plants (WTPs). The assessment protocol will evaluate WTPs for potential factors limiting water treatment performance especially during HAB. Each CPE will be conducted by a team comprised of representatives from (1) EPA's Technical Support Center (TSC) in Cincinnati; (2) Ohio EPA; and (3) Process Applications, Inc. (PAI)--a contractor for the EPA drinking water optimization program (called the Area Wide Optimization Program, or AWOP). The CPE teams will focus on water treatment plant design, operations/maintenance, and administration at each of the four treatment plants to optimize HAB control and treatment. This project is a collaboration with Ohio	Three of four CPE site visits completed as of September 2017.	One more CPE site visit is scheduled for January 2018.	USEPA	Rick Lieberman lieberman.richard@epa.gov	2018

	EPA. The HAB CPE assessment protocol will be shared with other states and primacy agencies after completion of the pilot project.					
Optimizing the application of oxidants and powdered activated carbon during the early stages of the water treatment process	Examine two early-stage unit operations in the drinking water treatment process that offer the greatest potential for reducing the risk of toxin passage to consumers' drinking water taps	Year 3 of 4-year project.	Completed laboratory work that evaluated the impacts of 3 different KMnO4 doses at two different pH levels and three different turbidities. Results have been submitted for peer review. Completed laboratory work to evaluate the impact of growth conditions, pH and initial suspension time on the propensity of cyanobacterial cells to release toxins upon exposure to KMnO4. Partial results have been presented at Ohio AWWA annual	USEPA	Nicholas Dugan dugan.nicholas@epa.gov	2019

			conference.			
Study on the removal of cyanotoxins from source waters using granular activated carbon	Evaluate the removal of cyanobacterial toxins by granular activated carbon (GAC) that has been pre-loaded with various concentrations of organic matter.	Year 3 of 3-year project.	Bench tests underway.	USEPA	Jonathan Pressman pressman.jonathan@epa.gov	2019

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Glossary of Terms

Algae – Simple plant-like, photosynthetic organisms that form the base of most aquatic food webs, ranging from microscopic, single-celled diatoms, dinoflagellates, and cyanobacteria, to large seaweeds.

Aquatic – Of, in, or pertaining to marine and fresh waters, including the Great Lakes, and concentrates herein on those in the US and its territories.

Best Management Practices – A method by which the adverse impacts of development and redevelopment are controlled through their application.

Clean Water Act – This act establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters (1948, 1972).

Cyanobacteria – Photosynthetic bacteria that frequently form harmful algal blooms in marine and fresh waters; also called blue-green algae.

Cyanotoxin – Toxins produced by cyanobacteria.

Dissolved oxygen – The amount of gaseous oxygen present in the water.

Drinking Water Protection Act – An amendment to the Safe Drinking Water Act to provide for the assessment and management of the risk of algal toxins in drinking water, and for other purposes.

Estuarine systems (Estuaries) – Systems that receive freshwater inputs from rivers, and that mix with ocean water.

Eutrophication – The enrichment of an ecosystem with chemical nutrients; typically compounds containing nitrogen, phosphorus, or both.

Food web – Also known as a food chain. The visual depiction of relationships between living things, what they feed on, and what feeds on them. For example: Little fish eat algae. Bigger fish eat the little fish. Humans eat the bigger fish.

Freshwater – Naturally-occurring water on the Earth's surface in ice sheets, ice caps, glaciers, icebergs, bogs, ponds, lakes, rivers and streams, and underground as groundwater in aquifers and underground streams. Freshwater salinity is less than 0.5 g/kg.

Harmful algal blooms (HABs) – A small subset of algal species – including diatom, dinoflagellate, and cyanobacterial blooms – that produce toxins or grow excessively, harming humans, other animals, and the environment. 93

Hypoxia – In reference to this report, waters that are, or have been, severely depleted of oxygen.

Hypoxic events – When a body of water experiences a deficiency of oxygen.

In situ – In the normal location.

Nuisance blooms – Excessive algal/cyanobacterial growth that can promote pathogens and cause detrimental effects like hypoxia, but that do not produce toxins.

Plankton – Diverse assemblage of organisms that live in the water column and cannot swim against a current.

Phytoplankton – Minute plant-like organisms and other photosynthetic organisms – including cyanobacteria, diatoms, and dinoflagellates – that live in water and cannot swim against a current.

Research Plan and Action Strategy – First report mandated by HABHRCA 2014. The Comprehensive HAB and Hypoxia Research Plan and Action Strategy will report on challenges related to HABs and hypoxia, ongoing and planned research, and the agencies' roles and responsibilities for evaluating and managing these issues.

Safe Drinking Water Act – Originally passed in 1974, the main Federal law that ensures the quality of Americans' drinking water. Under SDWA, EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards.

Salinity – Dissolved salt content of a body of water expressed as grams salt per kilogram of water.

Upwell/upwelling – The process by which warm, less-dense surface water is drawn away from along a shore by offshore currents and replaced by cold, denser water brought up from the subsurface.