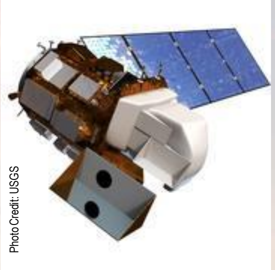
Harmful Algal Blooms and Toxins: U.S. Geological Survey Monitoring, Research, and Development

U.S. Department of the Interior
U.S. Geological Survey

USGS

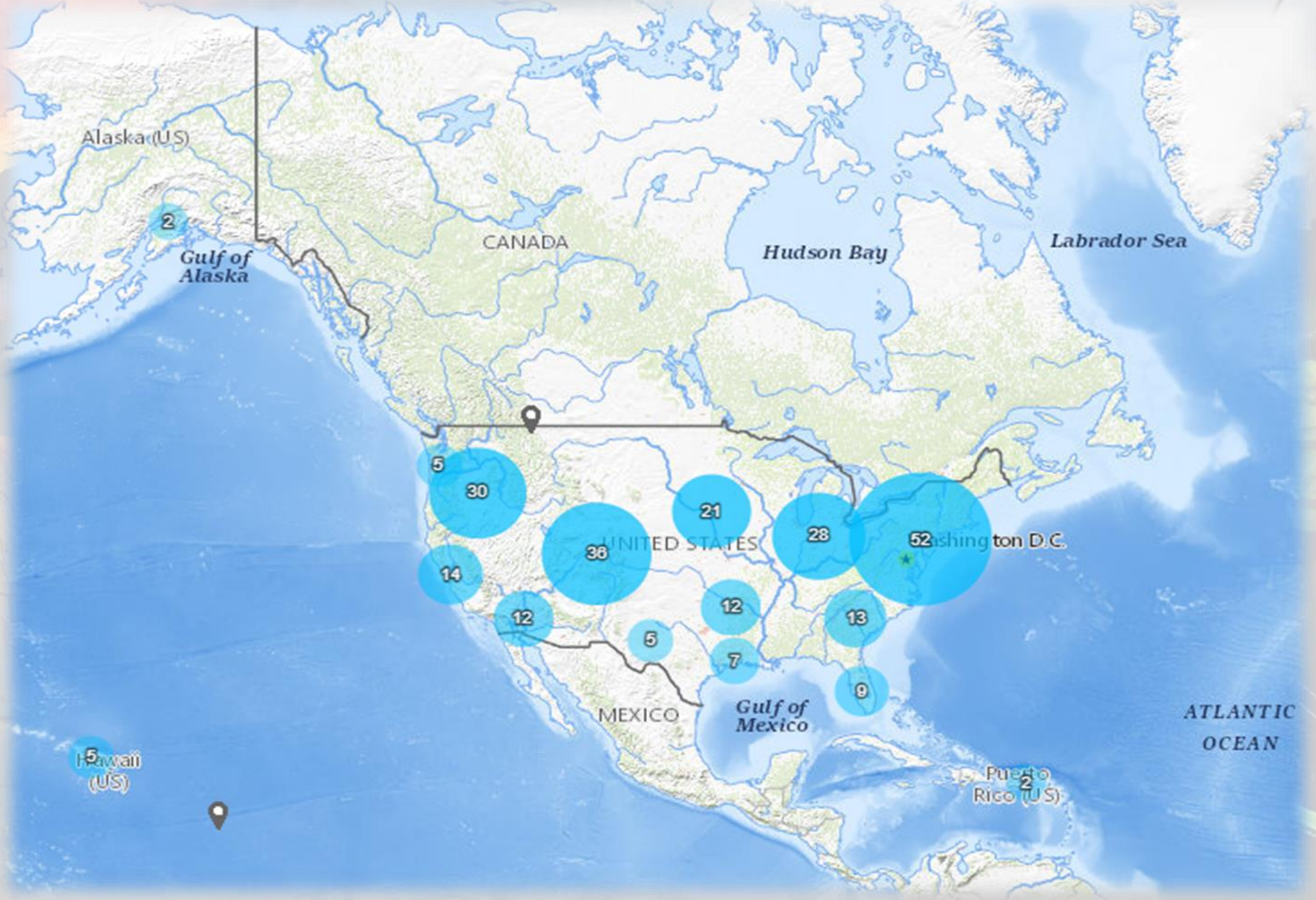


Mission: The USGS mission is to monitor, analyze, and predict current and evolving dynamics of complex human and natural Earth-system interactions and to deliver actionable intelligence at scales and timeframes relevant to decision makers.

Vision: Lead the Nation in 21st century integrated research, assessments, and prediction of natural resources and processes to meet society’s needs.

What Do We Do: As the Nation’s largest water, earth, and biological science and civilian mapping agency, USGS collects, monitors, analyzes, and provides science about natural resource conditions, issues, and problems. Our diverse expertise enables us to carry out large-scale, multidisciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers.

USGS Footprint



USGS Harmful Algal Bloom and Toxins Science

- Developing field and laboratory methods to identify and quantify harmful algal blooms and associated toxins.
- Understanding occurrence, causal factors, environmental fate and transport, ecological processes, and effects of environmental exposure.
- Developing tools to inform management decisions.

Harmful Algal Toxins and Blooms –

Strategic Vision Document for Integrated Science

Designed as an Information Resource for USGS Scientists Prioritizing and Planning HABs Research

- Summarizes Gaps in Scientific Knowledge on Algal Blooms and Algal Toxins
- Identifies Opportunities for USGS Science to Address Those Critical Gaps
- Presents a Vision of Integrated USGS HAB Science for Practical Application by Decision Makers

Contacts: Victoria Christensen (vglenn@usgs.gov) and Keith Loftin (kloftin@usgs.gov)

Sandpiper near bloom, photo by Serguei Drovetski, USGS

USGS

USGS Environmental Health Algal Toxins and Harmful Algal Blooms IST

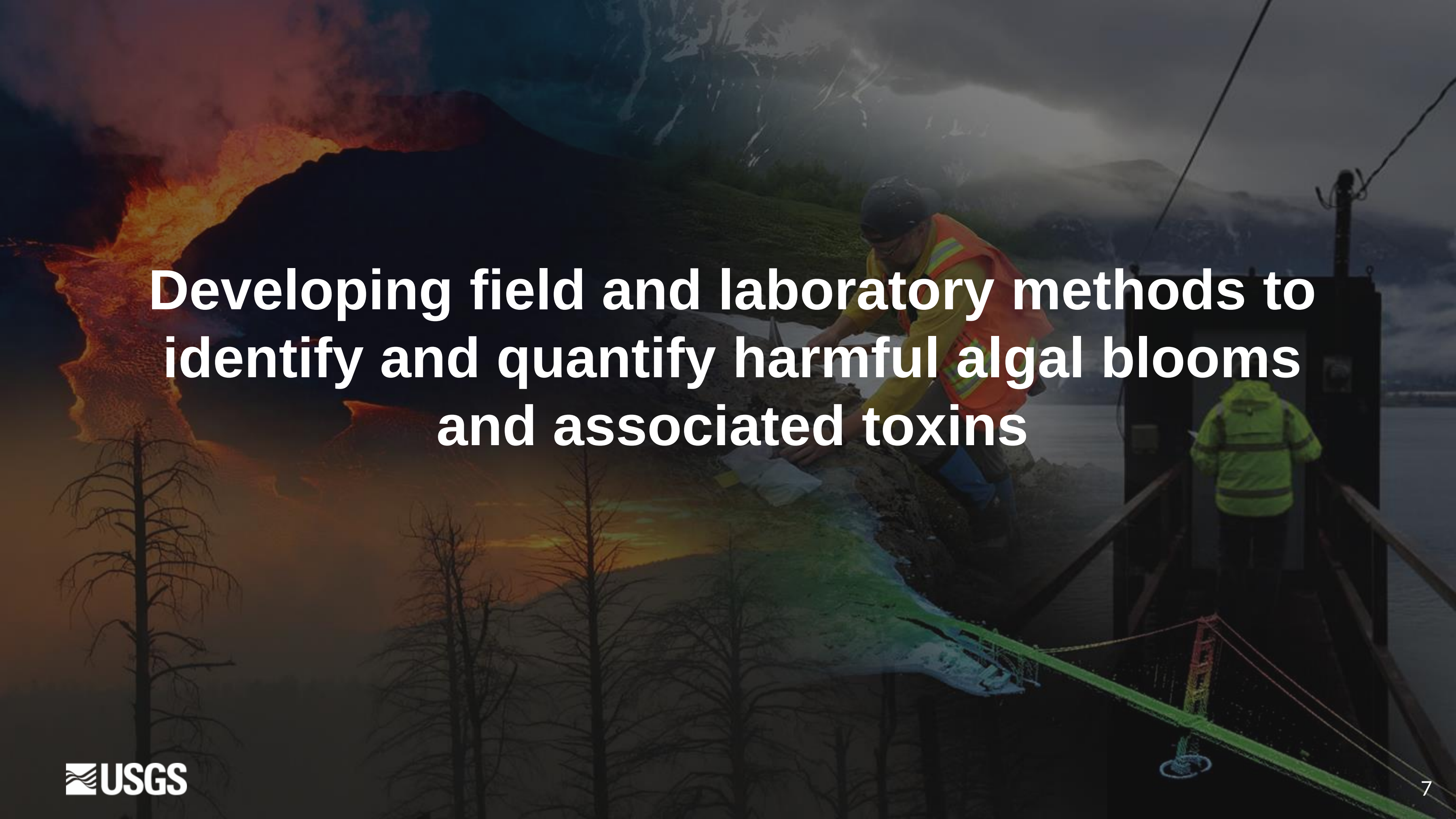
National Scope Integrated Science to Understand the Causes, Controls, Fate, Exposure, and Effects of Algal Toxins

Objective: Identifying conditions where occurrence, fate, transport, and exposure pathways coincide to understand when adverse health risks may or may not occur. The collective nationally scoped work of the team can be grouped into four major research topics:

1. **Toxin Exposure and Effects:** understanding exposure pathways and adverse health impacts.
2. **Cause, Control and Fate of Toxins:** understanding the variability of toxin occurrence and concentrations in the environment and factors that may lead to toxin production and exposure.
3. **Advancing Methods:** continued development of methods for the detection, identification, and understanding of algal toxins.
4. **Decision Support Tools:** development of tools for prediction and evaluation of socio-economic costs to support management decisions

Contacts: Keith Loftin (kloftin@usgs.gov)
Lisa Reynolds Fogarty (lrfogart@usgs.gov)

USGS



Developing field and laboratory methods to identify and quantify harmful algal blooms and associated toxins

USGS

U.S. Geological Survey Techniques and Methods

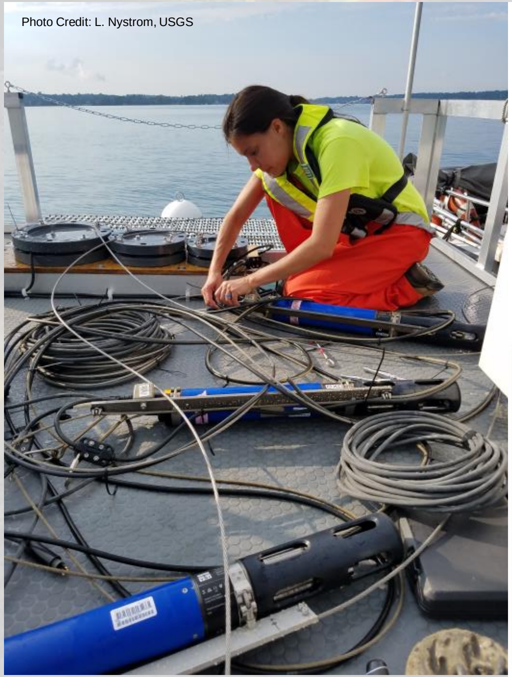
Field Techniques for the Determination of Algal Pigment Fluorescence in Environmental Waters: Principles and Guidelines for Instrument and Sensor Selection, Operation, Quality Assurance, and Data Reporting

Objective: Provide information on the selection and use of field fluorescence sensors by the USGS for in-place determination of the presence, relative abundance, and qualitative estimates of algal pigment concentrations in environmental waters in ways that are consistent and comparable across studies, sites, and instruments.

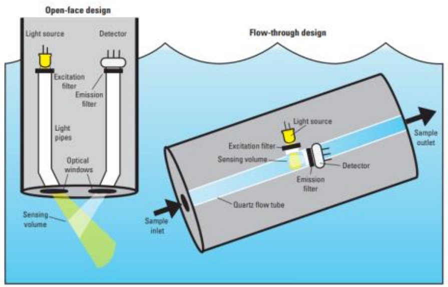
Contact: Guy Foster (gfoster@usgs.gov)

Foster, G.M., Graham, J.L., Bergamaschi, B.A., Carpenter, K.D., Downing, B.D., Pellerin, B.A., Rounds, S.A., and Saraceno, J.F., 2022, Field Techniques for the Determination of Algal Pigment Fluorescence in Environmental Waters: Principles and Guidelines for Instrument and Sensor Selection, Operation, Quality Assurance, and Data Reporting, U.S. Geological Survey Techniques and Methods Book D1 Chapter 10, in press.

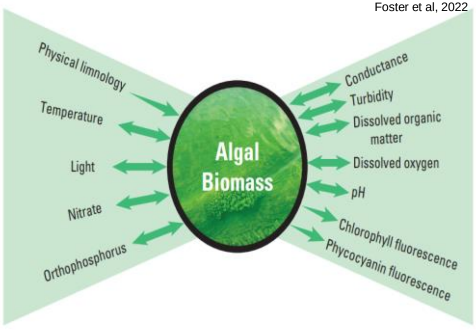
Photo Credit: L. Nystrom, USGS



Foster et al., 2022



Foster et al, 2022



USGS

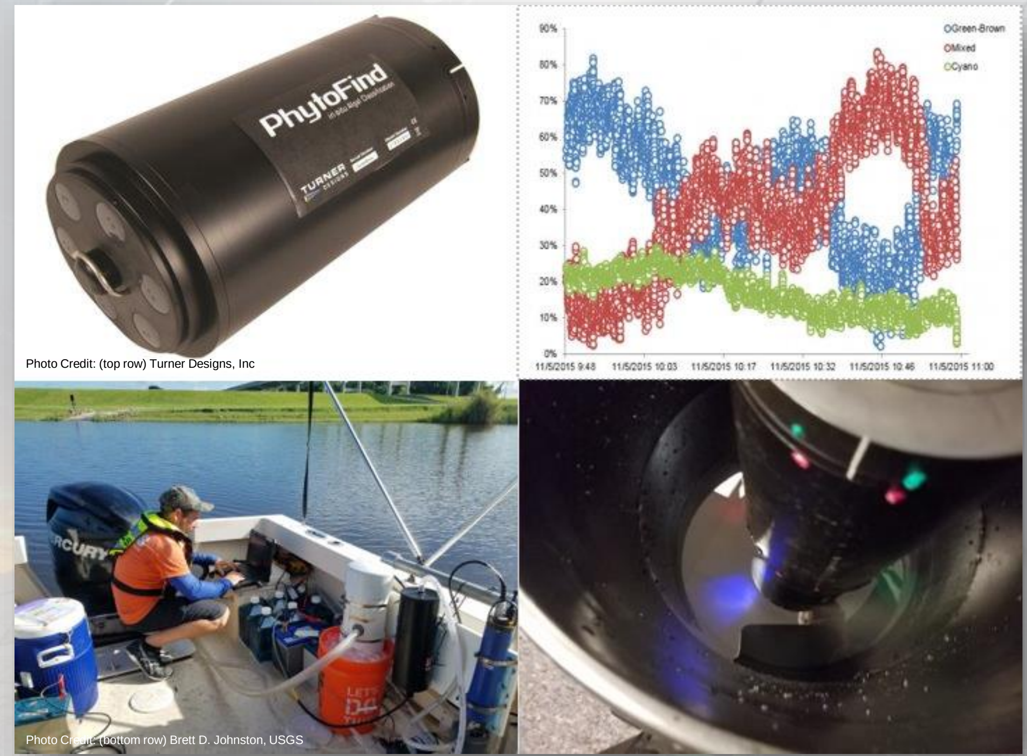
Technology Evaluation: *In situ* Algal Classification tool

Objective: Determine the suitability of the tool for use in USGS monitoring of algal biomass and relative community composition.

Approach: Follow a comprehensive test plan to evaluate the tool under laboratory and field conditions. Produce a USGS Scientific Investigations Report detailing the results.

Results will: Inform USGS scientists, stakeholders and the public on the response of tool under the conditions tested.

Contact: Brett D. Johnston (bjohnsto@usgs.gov)



Johnston, B.D., Graham, J.L, Foster, G.M., and Downing, B.D., Technical Note—Performance Evaluation of the PhytoFind, an In-Place Phytoplankton Classification Tool: Principles and Guidelines for Instrument and Sensor Selection, Operation, Quality Assurance, and Data Reporting, U.S. Geological Survey Scientific Investigations Report, in press.

USGS

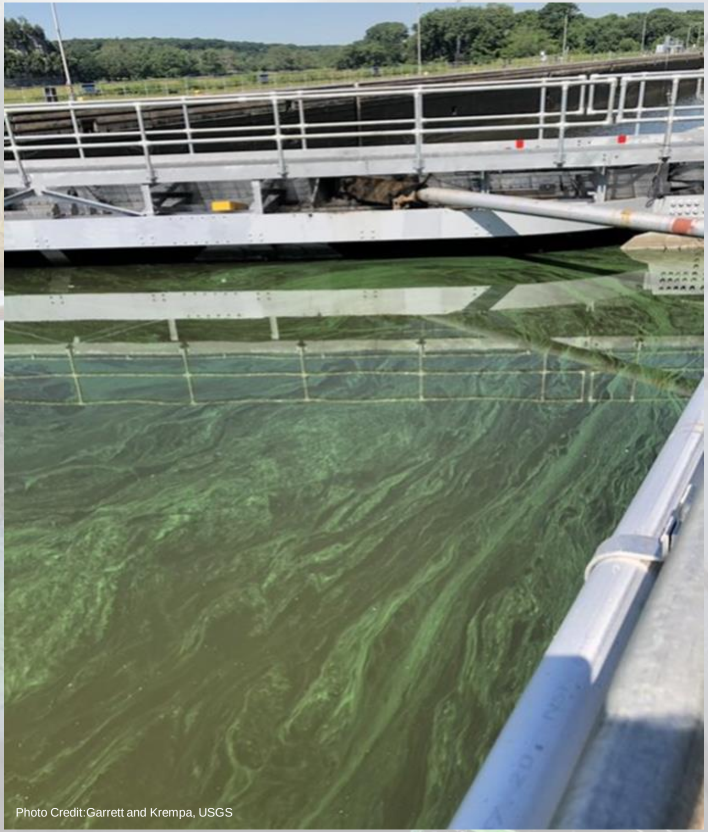
Proxies Project

Objective: Develop a suite of proxies to identify, characterize, and understand HAB occurrence and development in flowing waters.

Approach: Initial focus in Illinois River Basin using data from continuous sensors, then expand to larger regional or national scope, leveraging data from current networks.

Results will: Lay the foundation to support HAB forecasting

Contact: Jenny Murphy (jmurphy@usgs.gov)



2021 CyanoHAB in lock and dam at Illinois River near Starved Rock State Park

USGS

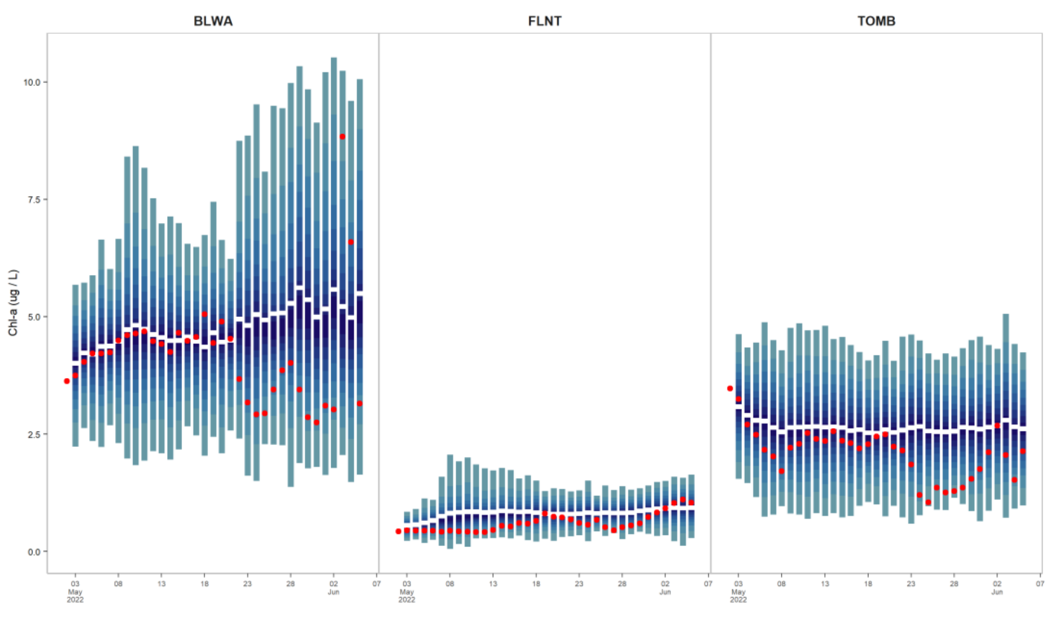
Forecasting River Chlorophyll *a* as part of the NEON Forecast Challenge

Objective: Develop an automated workflow for forecasting river chlorophyll *a* with associated uncertainty 35 days into the future.

Approach: Participate in the NEON forecasting challenge by contributing daily forecasts of chlorophyll *a* at river challenge sites using machine learning models.

Results will: Expose HABs Proxies Project to forecasting workflows and test the effectiveness for machine learning models to forecast river chlorophyll *a.*

Contact: Jake Zwart (jzwart@usgs.gov), Jenny Murphy (jmurphy@usgs.gov)



USGS HABs Proxies Project river chlorophyll *a* forecasts issued on May 2, 2022 as part of the NEON forecasting challenge https://projects.ecoforecast.org/neon4cast-docs/ . Blue bars represent 90% confidence intervals, white bars are the mean of ensemble forecasts, and red points are observations.

USGS

How to Monitor for Cyanotoxins in the Sacramento – San Joaquin Delta, California

Objective: Use a variety of methods to understand the status and trends of cyanotoxins within the Delta

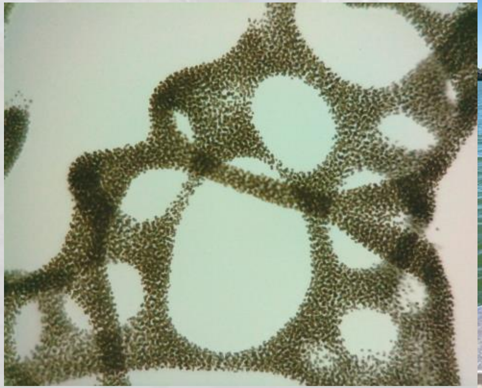
Approach: Collect bi-weekly and monthly cyanotoxin samples with whole water and SPATT samples and analyze with LC-MS and ELISA methods.

Results will: Inform what methods and approaches cooperators can use for a long-term monitoring program in the Delta.

Contact: Keith Bouma-Gregson (kbouma-gregson@usgs.gov)

Tamara Kraus (tkraus@usgs.gov)

Photo Credits: USGS CA WSC, Keith Bouma-Gregson, Tamara Kraus



USGS

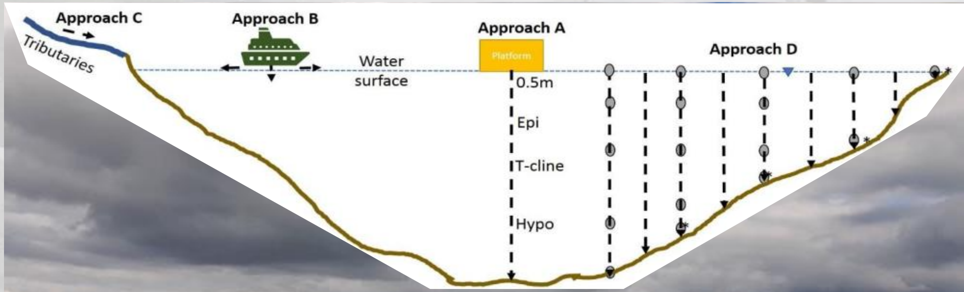
Advancing the Understanding of CyanoHABs in New York State: The CyanoHABs Advanced Monitoring Pilot

Objectives: Inform the development of monitoring strategies for CyanoHABs across New York State and enhance understanding of the ecological factors associated with CyanoHAB development in lakes.

Approach: A) automated monitoring platforms (USGS led); B) nearshore mapping (USGS led); C) tributary monitoring and assessment (DEC led); D) intensive lake characterization (DEC led).

Results will: Provide key information about CyanoHABs in New York State and contribute to efforts to effectively monitor for, communicate about, and develop new and refine existing mitigation strategies for CyanoHABs.

Contact: Guy Foster(gfoster@usgs.gov)
Jennifer Graham (jlgraham@usgs.gov)



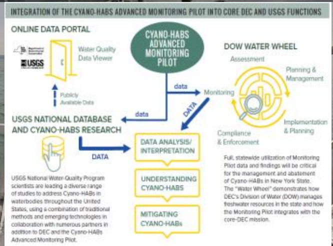


Photo Credits: Top, L. Nystrom, USGS; Bottom, USGS webcams

USGS | NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

Multi-Modal UAS Sensor System for Harmful Algal Bloom Mapping and Monitoring on Lake Champlain

Members of UVM's UAS Team.

Objective: Develop, design, and deploy a UAS-based system (Unmanned Aircraft Systems) for HAB water sampling and mapping to advance the state-of-the-art in sensing the location and characteristics of HABs.

Approach: Integrate UAS-based mapping of HABs using multispectral imagery with UAS-based water sampling, targeting areas on Lake Champlain with known HABs where information is currently lacking with respect to the spatial extent, temporal patterns, toxicity, and species of the HABs.

Results will: Allow the application of geospatial analytical techniques that incorporate the geographical extent of blooms, the spectral properties of the UAS imagery, and the HAB characteristics (concentration, species, and toxicity) from the sampled data. Mapping algorithms will enable data integration into an online decision-support system (DSS).

Contact:
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Charles Culbertson: cculbert@usgs.gov

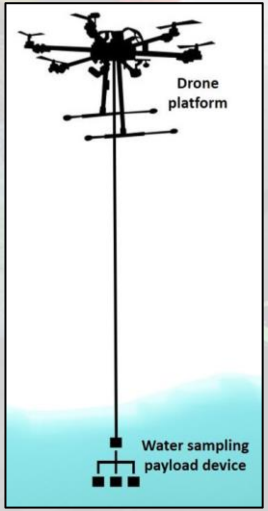


Photo credits: Jarlath O'Neil-Dunne, University of Vermont

Comparison of Imaging Flow Cytometry (IFC) and Manual Counts for Assessing Ecological Status and Harmful Cyanobacterial Blooms

Objectives: (1) assess how well IFC identification and enumeration align with manual identifications and enumeration in split phytoplankton samples, and (2) assess how preservation affects the efficacy of IFC analysis.

Approach: Split samples were analyzed by traditional microscopy as well as on a laboratory-based McLane Research Laboratories, Inc. Imaging FlowCytobot (IFCB).

Results will: Inform interpretation and application of IFC based HAB monitoring.

Contact: Sabina Gifford (srgifford@usgs.gov)

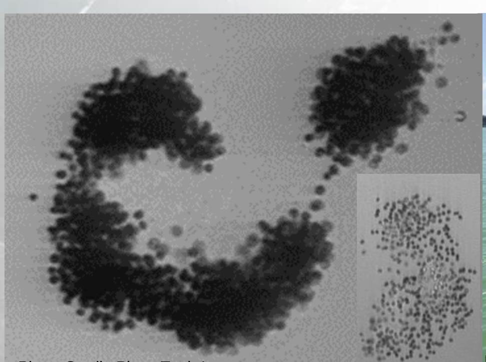
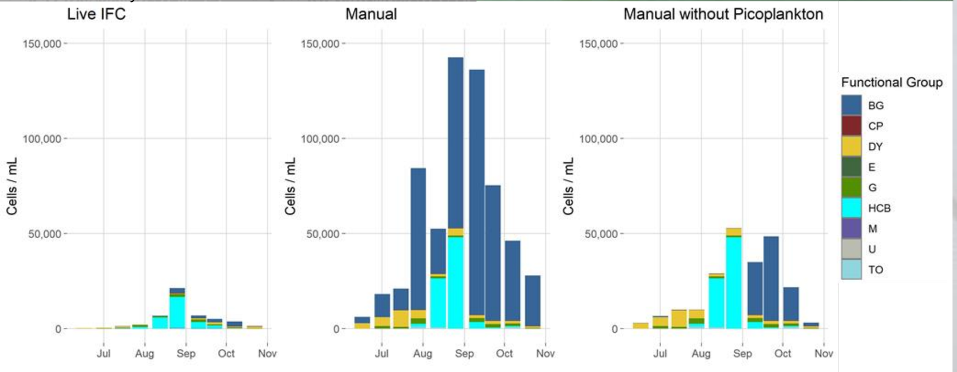


Photo Credit: PhycoTech Inc.

Photo Credit: Sabina Perkins



Preliminary information – subject to revision. Not for citation or distribution.
Community composition by Functional Group for Owasco Lake in 2020 for Live IFCB compared with Traditional Manual Microscopic Counts and those same count estimates with picoplankton removed.

USGS NEW YORK STATE OF OPPORTUNITY Department of Environmental Conservation

Assessing efficacy of Solid Phase Adsorption Toxin Tracking (SPATT) as an Indicator of the Presence of Cyanotoxins in the New York Finger Lakes

Objective: Assessing utility of Solid Phase Adsorption Toxin Tracking (SPATT) ‘samplers’ as a tool in monitoring for the presence and relative concentrations of cyanotoxins in the Finger Lakes, where concentrations are commonly below the detectable limit for Enzyme-Linked Immunosorbent Assays (ELISA) in whole water discrete samples.

Approach: Samplers were deployed on three of the Finger Lakes at three depths between June 2019 – November 2019 at approximately 2-week intervals. Deployments were paired with whole water sample collection for cyanotoxins, cyanobacterial genes by qPCR, and phytoplankton identification and enumeration. Sampler extracts were analyzed for cyanotoxins by ELISA with confirmatory analysis by LC/MS and LC/MS/MS.

Results will: Identify whether cyanotoxins were detectable in SPATT samplers, compare cyanotoxin results from multiple analytical methods, compare results from SPATT samplers to cyanotoxin concentrations, qPCR, and phytoplankton data from discrete whole water samples, and provide insight on the strengths and weaknesses of the current technology as an indicator for the presence of cyanotoxins.

Contact: Michael Stouder (mstouder@usgs.gov)

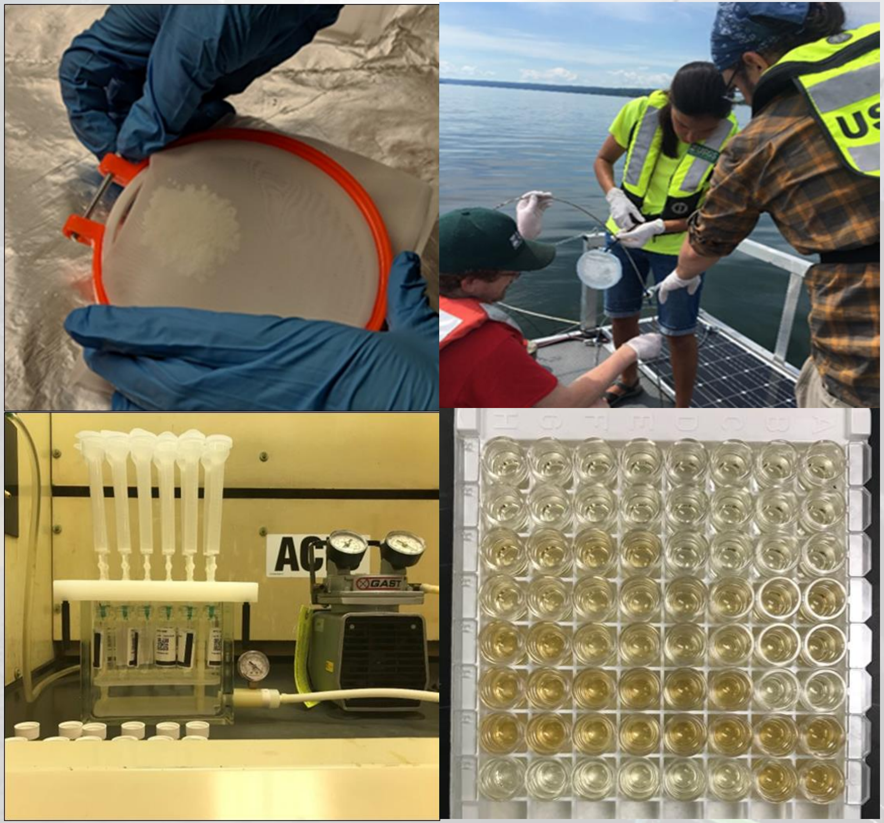


Photo Credits: USGS Upper Midwest WSC, Jennifer Graham, Joshua Rosen

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Use of Acoustic Doppler Current Profilers to Supplement and Inform HABs Monitoring

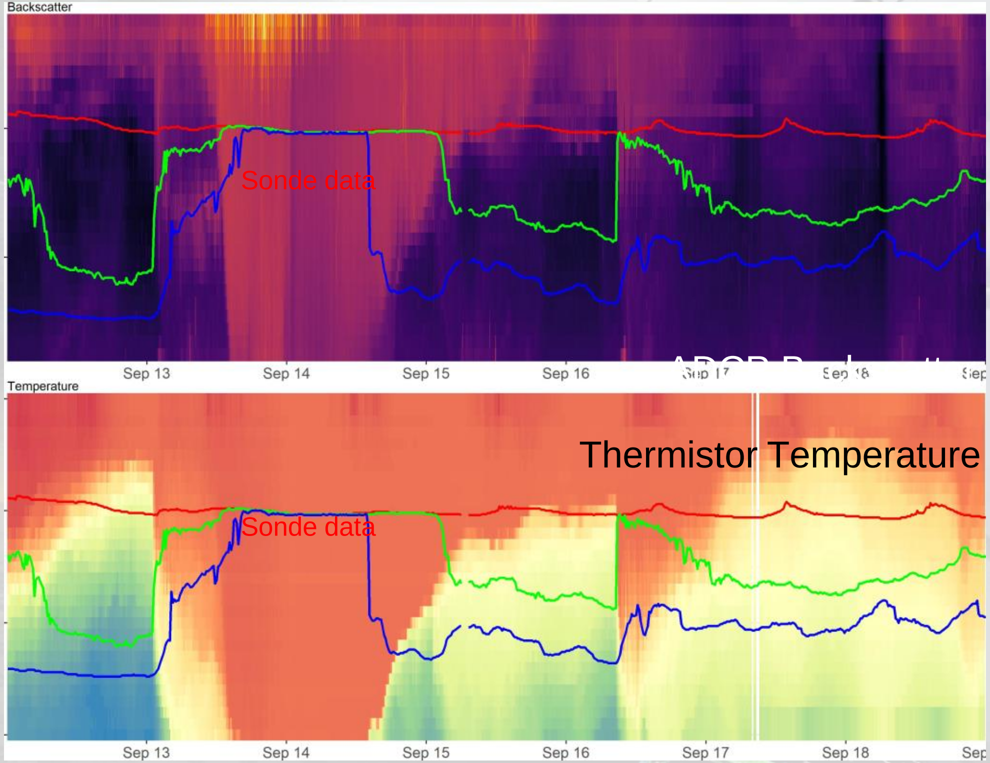
Objective: Test if and how ADCPs can be used to help monitor HABs:

- Can ADCPs be used as a surrogate for temperature measurements?
- Are circulation velocities in lakes large enough to measure?
- Can vertical phytoplankton migration be observed?

Approach: Analyze existing datasets and conduct new deployments

Results will: Demonstrate a new use of existing technology

Contact: Liz Nystrom (nystrom@usgs.gov)



Preliminary information – subject to revision. Not for citation or distribution.

HAB SmartScope: Cell Phone Imaging & AI Identification

Objective: Develop an inexpensive, portable system to identify cyanobacteria genera that can produce toxins.

Approach: Use cell phones, security camera lenses, and a simple focusing stand to take photomicrographs of phytoplankton samples, which will be used to train an artificial intelligence to identify about a dozen target HAB genera.

Results will: Allow users to identify potentially harmful cyanobacteria on site; allow increased frequency of monitoring; contribute to early warning systems.

Contact: Liz Nystrom (nystrom@usgs.gov)

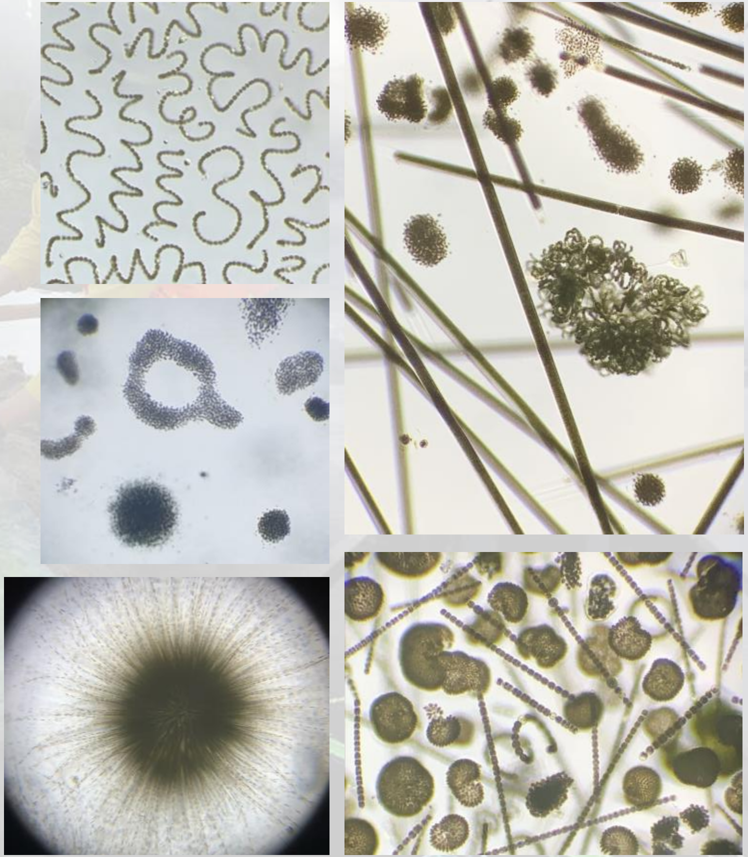


Photo Credits: Elizabeth Nystrom and Olivia Delgado

USGS

Rapid Identification of Harmful Algae

Objective: Provide rapid microscopic information about the dominant organisms in a bloom to our partners and the public

Approach: Quick analyses of bloom samples using traditional microscopy to identify potential cyanotoxin producers

Results will: Provide near-real-time information (12-24 hours) on dominant species that can inform additional actions such as testing for toxins

Cooperators: Drinking Water Utilities in Salem, Eugene, and Clackamas, Oregon

Contact: Kurt Carpenter kdcar@usgs.gov
OR Water Science Center

Photos by Kurt Carpenter, USGS

Species Identification, Isolation, and Culturing

Objective: Taxonomic identification of bloom organisms and their toxin profile

Approach: Live samples collected throughout the US sent for microscopic ID, isolation, culturing and cyanotoxin gene detection

Results will: Help with early detection of potentially toxic blooms

Cooperators: US Army Corps, US EPA, and many others

Contact: Barry Rosen
brosen@fgcu.edu
(USGS emeritus)

Photos by Barry Rosen, FGCU/USGS (emeritus)

Dolichospermum berezowskii
Cougar Reservoir, OR 7-6-22

Dolichospermum circinale
Payette River, ID 9-13-22

Compile and Harmonize National Chlorophyll Data

Objective: This project will gather discrete chlorophyll a data from 2005-2021.

Approach: Data will be obtained using existing, and newly modified pipelines from NWIS and WQP.

Results will: Serve to provide ground truth measurements for remote sensing and data for modeling of HABs over large spatial extent.

Contact: Sarah Spaulding
sspaulding@usgs.gov

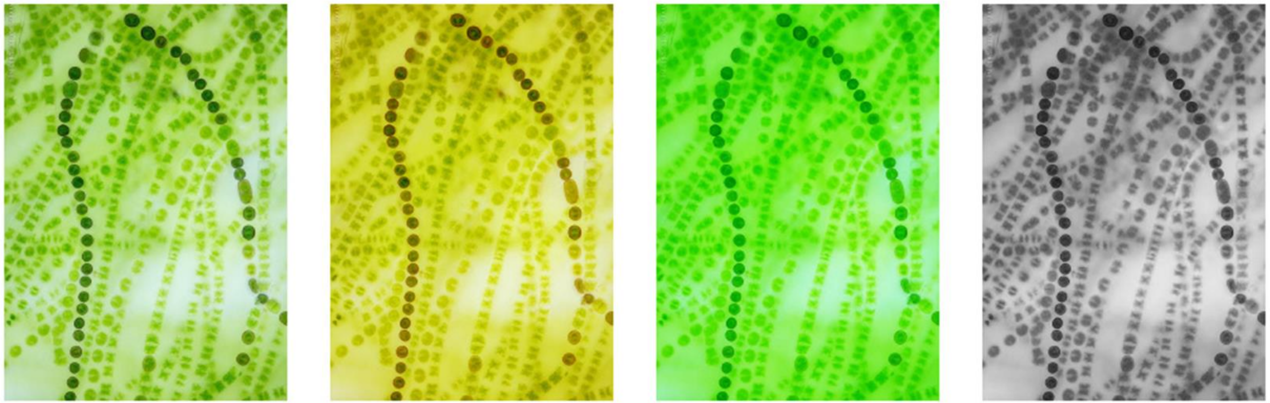


Photo Credits: S. Spaulding, U.S. Geological Survey

1. chlorophyll a, raw [mixture of chla + its degradation product, pheophytin]

2. pheophytin [addition of acid turns all chla to pheophytin]

3. **chlorophyll a, corrected** [phaeophytin is accounted for – to express viable chla]

4. chlorophyll mixture, unknown if raw or corrected

Discrete samples are collected in the field, filtered, and shipped on dry ice to laboratory. After extraction, solution is measured in a fluorometer to obtain (1). Sample is acidified and remeasured to obtain (2). Raw chlorophyll value *corrected* to express "pheophytin free" (3). Many values have unknown status, as data types may be mixed (4).

USGS

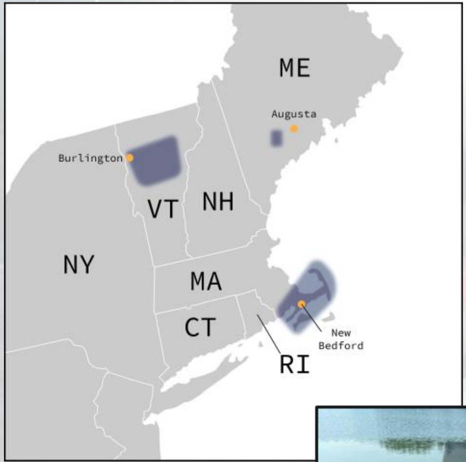
Evaluating Environmental DNA Lake Assessments: A Potential Early Warning Alert for the Presence of Cyanobacteria Associated with HAB Formation in New England Lakes

Objective: Relate temporal changes in eDNA signals to changes in lake water microbiotic communities responding to physical, chemical and biological influences

Approach: Use metabarcoding to target 16S and 18S loci to identify the microbiotic communities present at a location over the spring to fall cyanobloom season. Use qPCR for identification of specific organisms and genes associated with HAB formation and toxin production. Use time series analysis to identify environmental precursor conditions associated HAB development.

Results will: Describe the relations between environmental variables, and temporal changes in the greater microbial community structure (e.g., cyanobacteria, phytoplankton, zooplankton, fungi, and bacteria) prior to and during the formation of cyanobacterial blooms.

Contact:
Charles Culbertson: cculbert@usgs.gov
Alison Watts: alison.watts@unh.edu



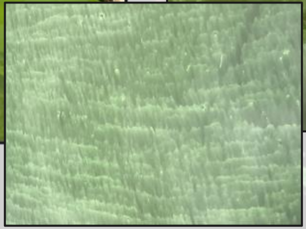


Photo credits: Charles Culbertson, USGS

Remote Sensing of Water Quality

Objective: Map turbidity, aquatic chlorophyll-a, dissolved organic matter, and water temperature from satellite imagery at the national.

Approach: Operationalize research-grade approaches to remote sensing water quality with moderate resolution satellite imagery (10 – 30 m) in four study basins to test methods and quantify uncertainty before applying at a national scale.

Results will: Augment existing data sources of spatial and temporal patterns in water quality to support monitoring, modeling, and prediction of algal blooms.

Contact: Tyler King (tvking@usgs.gov)

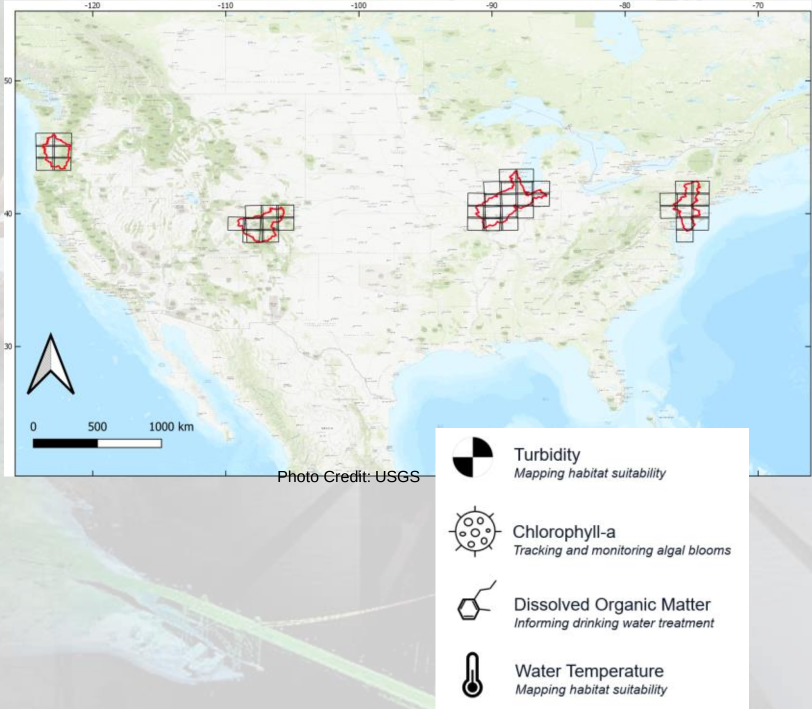


Photo Credit: USGS

USGS

Landsat 8/9 Provisional Aquatic Reflectance Science Product for Mapping Surface Water Quality Constituents

Objective: Standardize Landsat aquatic reflectance to map and characterize changes in surface water quality constituents (Chl-a, TSS, CDOM) across coastal and inland water environments.

Approach: Traditional ocean color radiative transfer models are modified for Landsat Operational Land Imager (OLI) and validated with NASA's Aerosol Robotic Network (AERONET). Implementation of Mixture Density Network (MDNs) for simultaneous retrieval of Landsat-based water quality constituents.

Results will: Potential to make contributions to the aquatic science and environmental monitoring capabilities for aquatic ecosystems, especially for coastal mapping applications and lake management practices.

Contact: Christopher Crawford (cjcrawford@usgs.gov)

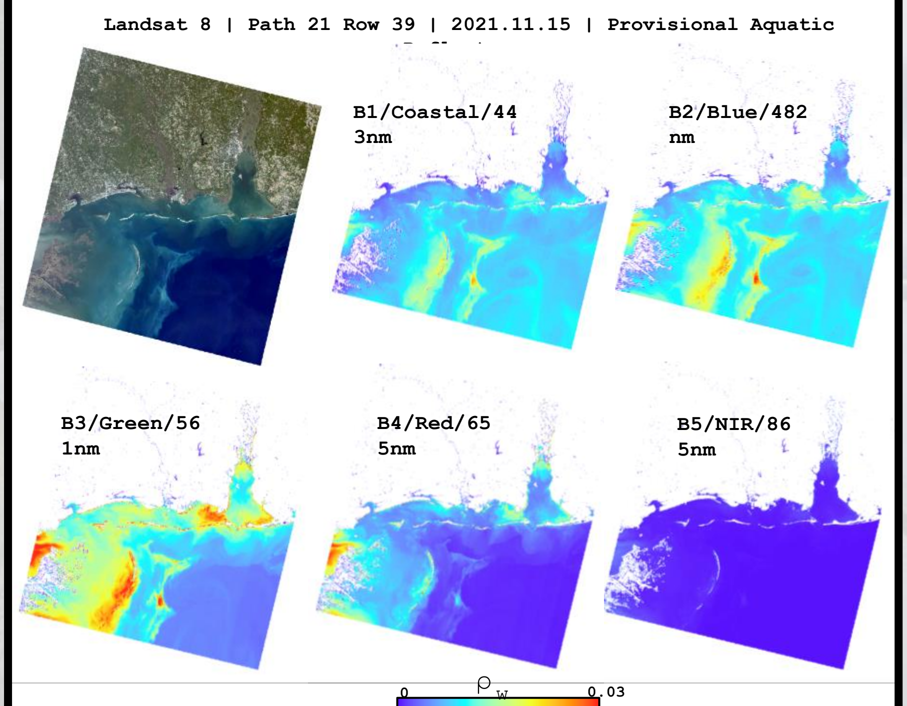


Photo Credit: USGS Landsat 8

USGS

Importance of Remote Near-Infrared (NIR) Aquatic Observations

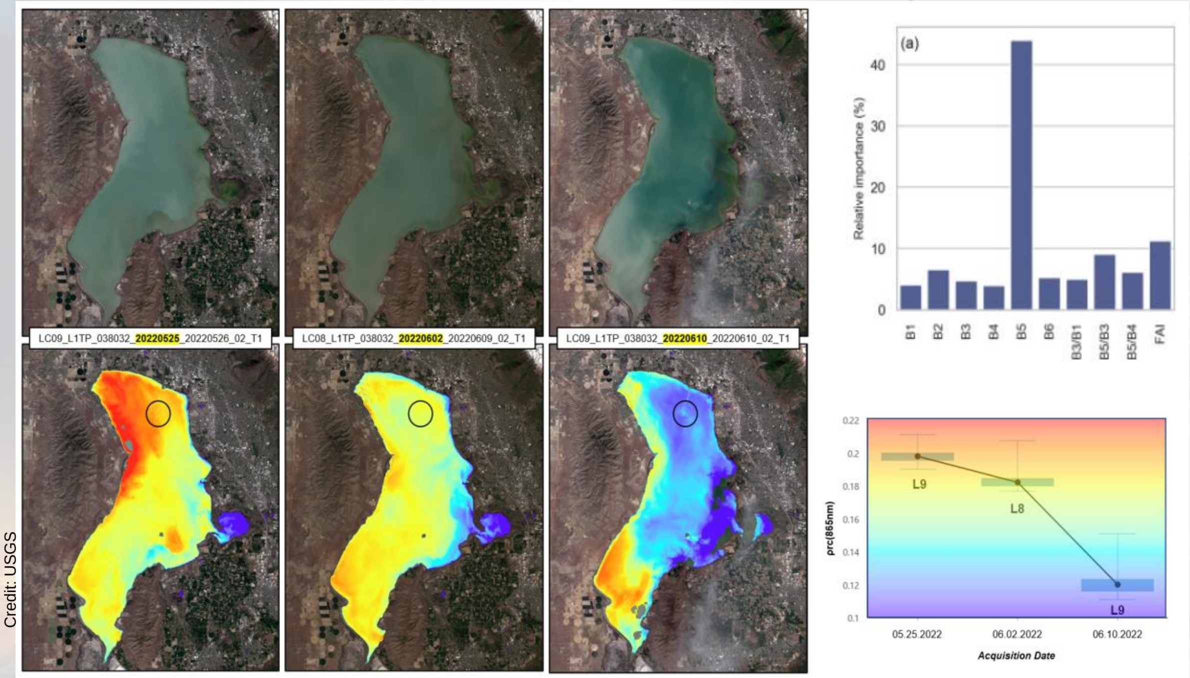
Objective: Quantify chlorophyll retrieval uncertainty from Landsat 8/9 using peer review published algorithms.

Approach: Use machine learning techniques to evaluate the relative importance of all Landsat 8/9 multispectral channels in retrieving chlorophyll when other optical water column constituents are present.

Results will: Inform future Landsat 8/9 aquatic science applications and product development goals.

Contact: Christopher Crawford
cjcrawford@usgs.gov

Credit: USGS



Landsat 8/9 imaging of Utah Lake capture a reduced NIR spectral signal as chlorophyll concentration decrease.

For more information:

Field-Validation of Remote Sensing CyanoHAB Algorithm

Objective: Evaluate the accuracy of the Cyanobacterial Index (CI) algorithm in the Sacramento – San Joaquin Delta.

Approach: Collect above-water hyperspectral radiometric data and water quality data affecting the optical properties of water and compare these field results with data from satellite imagery.

Results will: Identify water conditions that impact the accuracy of the CI algorithm and inform interpretation and analysis of satellite data in the Delta.

Contact: Keith Bouma-Gregson, CA Water Science Center (kbouma-gregson@usgs.gov)

Photo Credits: USGS CA WSC, Keith Bouma-Gregson

Satellite Monitoring of Algal Blooms in Texas and Oklahoma Reservoirs

Objective:

Developing a Near Real-Time Cloud Hosted Earth Observation Platform Powered by Google.

Approach:

Our approach will utilize:

- ✓ **Cloud hosted imagery,** Ingesting Landsat and Sentinel-2 imagery
- ✓ **Chlorophyll-a concentration:** Estimations calibrated using *in situ* data and calculated in near real-time to visualize current conditions.
- ✓ **Temporal statistics:** Time series of Chlorophyll-a concentrations to help interpret temporal variation.

Results will:

Contribute a Chl-a satellite retrieval methodology calibrated to the study area in a report, and aid reservoir managers in monitoring for the presence and behavior of aquatic Chl-a over time.

Contact:

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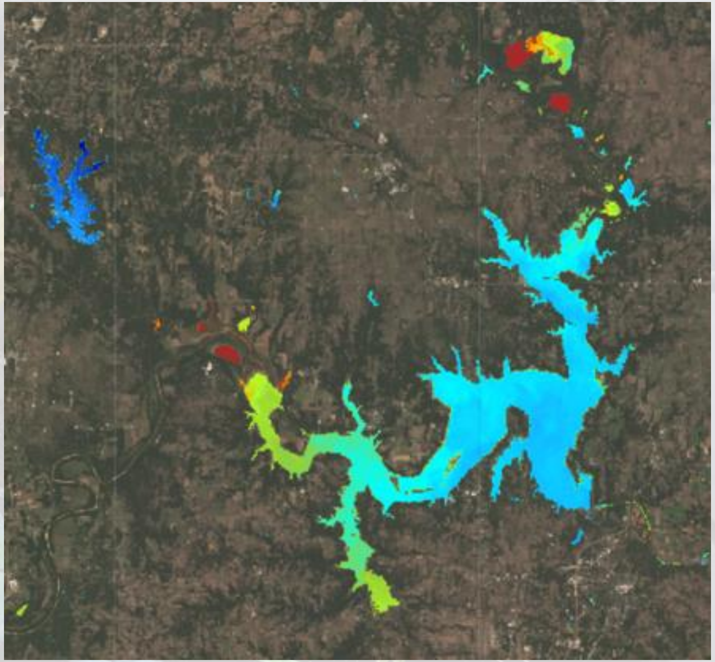


Lake Texoma; Victoria Stengel, USGS

USGS

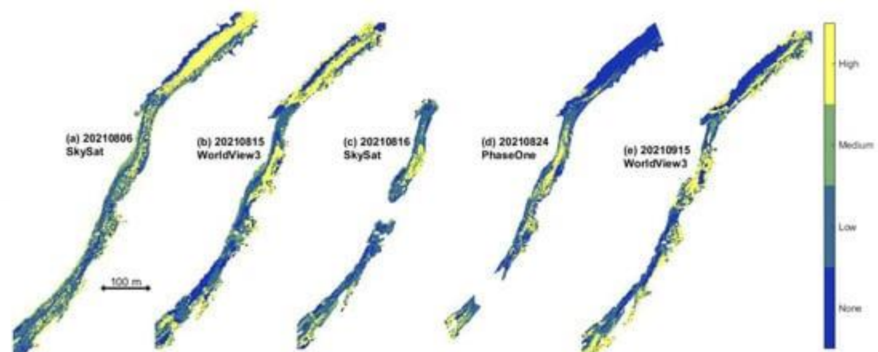
Mapping Benthic Algae and Cyanobacteria in River Channels from Aerial Photographs and Satellite Images: A Proof-of-Concept Investigation on the Buffalo National River, AR, USA

Objective: Develop a workflow for mapping benthic algae and cyanobacteria in shallow, clear-flowing river channels from readily available remotely sensed data and assess the feasibility of this approach through a case study on the Buffalo National River.

Approach: Use field data on algal density and water depth to calibrate a depth retrieval model and train a random forest classification algorithm.

Results will: Introduce a framework for more efficient, segment-scale mapping and monitoring of benthic algae on the Buffalo and other rivers.

Contact: Carl J. Legleiter (cjl@usgs.gov)



Legleiter et al, 2022

Integration of in Situ Sensors and Cyanobacteria Assessment Network (CyAN) Satellite Products to Estimate Nearshore, Toxic Cyanobacteria Blooms at Ohio Inland Lakes

Objective:
Verify satellite algorithms from HAB impacted lakes in Ohio, identify factors related to cyanotoxin production, and develop site-specific predictive models

Approach:
In situ data were collected on days with satellite overflights (OLCI Sentinel -3A and –3B) and analyzed for cyanotoxin concentration, cyanobacterial genes by qPCR, and nutrients

Results will: Provide data for an early-warning system and a tool for management decisions

Contact: Jessica Cicale (Microbiologist, project lead) jcicale@usgs.gov
Erin Stelzer (Microbiologist, molecular analyst) eastelzer@usgs.gov
Keith Loftin (Research chemist, CyAN) kloftin@usgs.gov

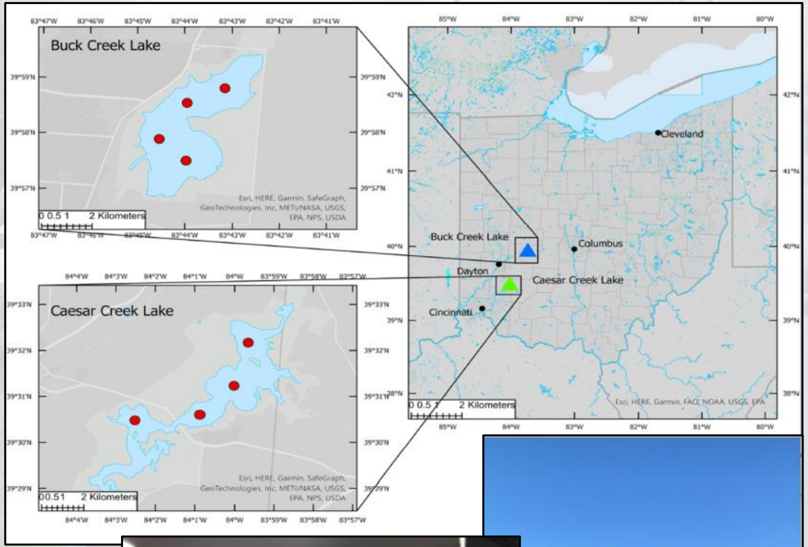



Photo credit: J. Cicale

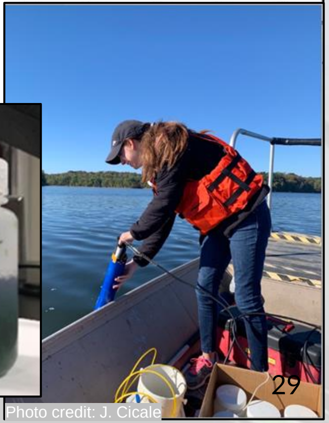


Photo credit: J. Cicale

USGS

Field Verification of Cyanobacteria Assessment Network (CyAN) Derived Satellite Products to Estimate Nearshore, Toxic Cyanobacteria Bloom Accumulation in Kansas Reservoirs

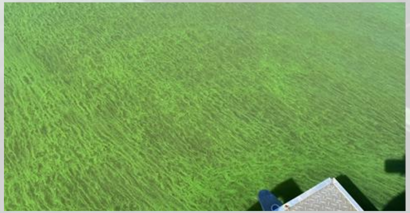
Objective: Validate satellite algorithms and improve the utility of CyAN as an early-warning indicator for harmful algal bloom (HAB) occurrence.

Approach: Collect discrete samples and instantaneously measured water-quality data, field fluorescence and lab values of algal pigments, phytoplankton community composition and abundance, field-based hyperspectral imaging, and other relevant data at HAB-affected reservoirs in Kansas.

Results will: Provide robust ground verification that enhances ability and utility of CyAN to monitor the occurrence of HABs and algal toxins in near-real time.

Contact:
Ariele Kramer (KSWSC Hydrologist – Water Quality) akramer@usgs.gov
Keith Loftin (Research Chemist, Algal and Other Environmental Toxin Laboratory (AET) Supervisor) kloftin@usgs.gov






Photos taken by USGS KSWSC Staff

USGS

Partners: Kansas Department of Health and Environment

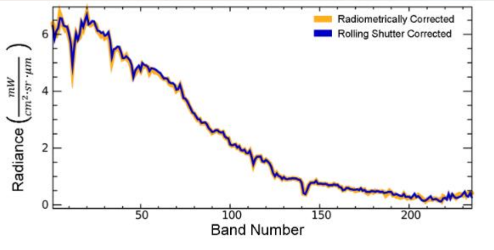
Advantages of Hyperspectral Imaging for Aquatics

Objective: Quantify the usefulness of hyperspectral imaging for retrieval of chlorophyll concentrations.

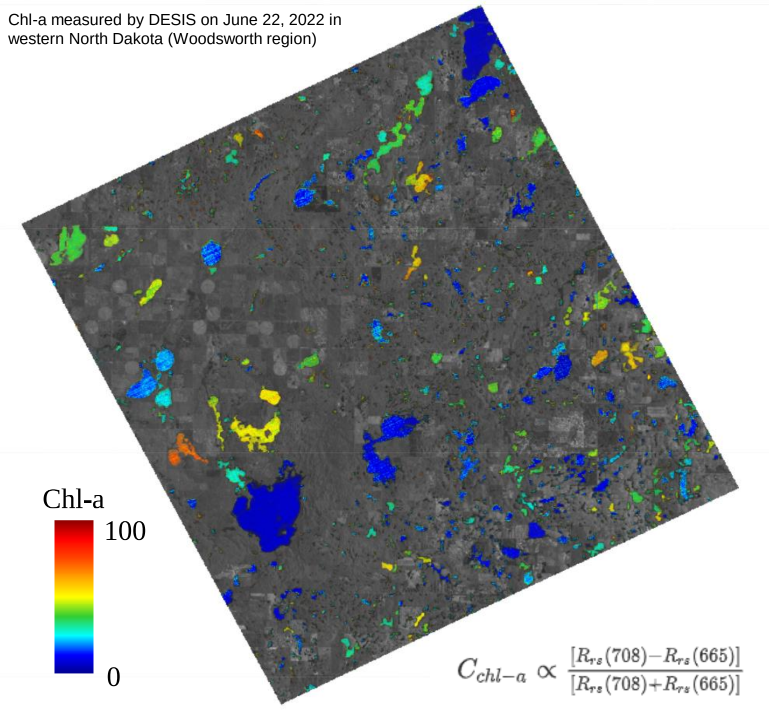
Approach: Use existing hyperspectral data from DESIS to retrieve chlorophyll concentrations from atmospherically-corrected aquatic reflectance.

Results will: Inform future Landsat mission measurement concepts, aquatic data processing techniques, and emerging aquatic science applications needs.

Contact: Christopher Crawford, cjcrawford@usgs.gov



(a) Water spectrum



USGS

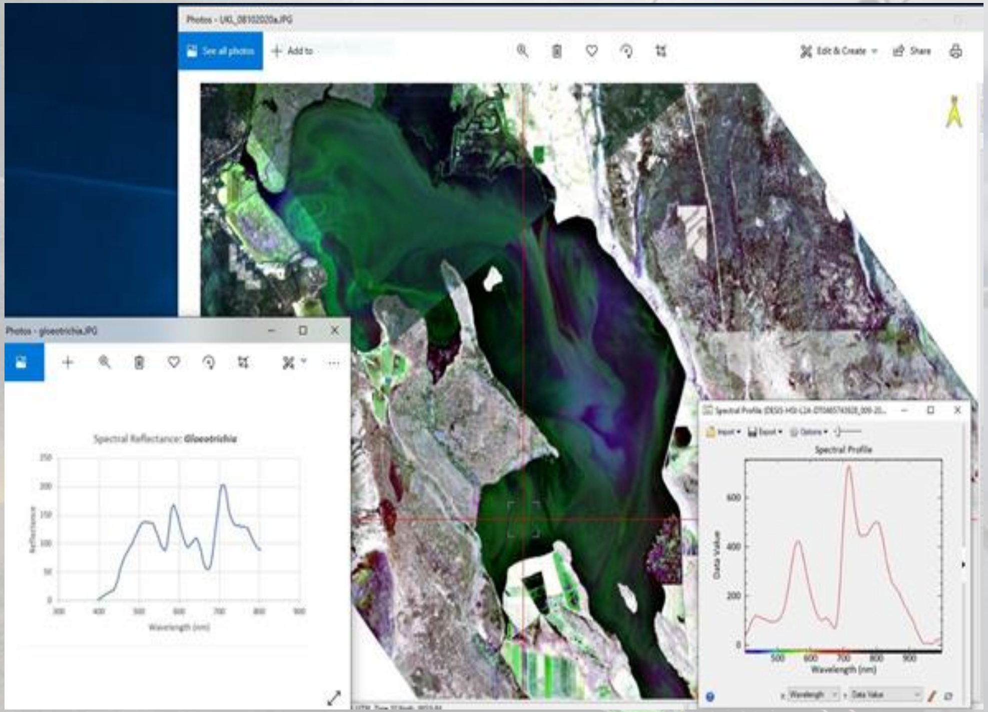
Building a Spectral Reflectance Reference Data Set for HAB-Forming Taxa

Objective: Develop a suite of remote sensing tools from satellite to microscope that help identify and characterize the reflectance characteristics of HAB phenomena

Approach: Collect satellite, aircraft and microscope images from hyperspectral cameras and sensors

Results will: Develop a reference data set of genus-specific spectral profiles of various HABs, including potential toxin producers

Contact: Terry Slonecker (tslonecker@usgs.gov)
Natalie Hall (nhall@usgs.gov)



Hyperspectral image of *Aphanizomenon* and other HABs in Upper Klamath Lake, Oregon

Photo Credit: B. Hilbrandt, City of Salem

USGS

Hyperspectral Characterization of Nuisance Algae in Oregon Cascade Range Rivers

Objective: Develop a reference dataset of spectra for periphyton to characterize their hyperspectral reflectance

Approach: Collect HS data from stream riffles using drone-, tripod-, and microscope-based spectrometers

Results will: Allow for efficient, remote monitoring of periphyton to understand impacts to water supplies

Cooperators: Eugene Water & Electric Board, USGS

Contact: Kurt Carpenter
OR Water Science Center
kdcar@usgs.gov


Photo by Kurt Carpenter, USGS

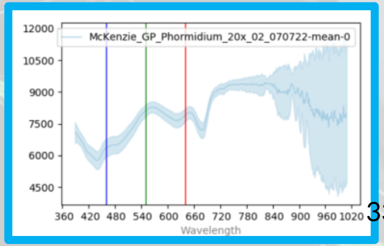

Photo by Kurt Carpenter, USGS


Photo by Kurt Carpenter, USGS

Photo by Adam Mumford, USGS


Photo by Brandon Overstreet, USGS


Photo by Kurt Carpenter, USGS



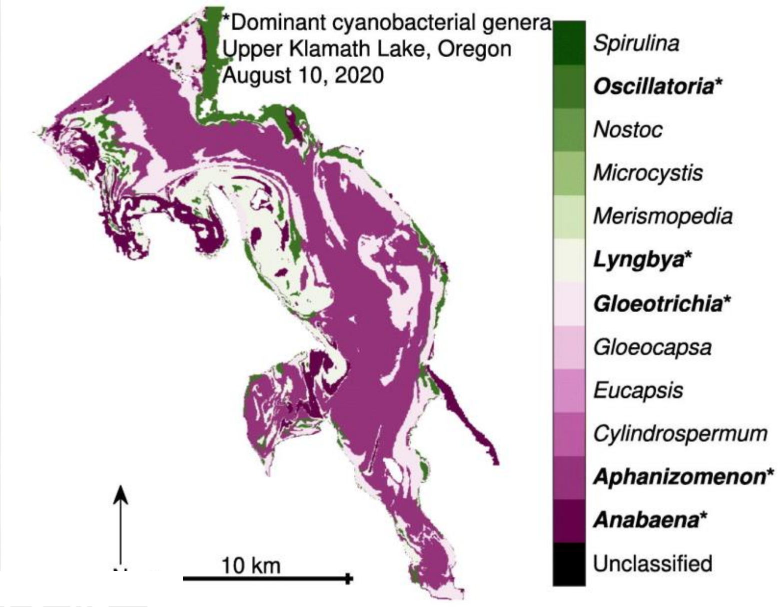
Spectral mixture analysis for surveillance of harmful algal blooms (SMASH): A field-, laboratory-, and satellite-based approach to identifying cyanobacteria genera from remotely sensed data

Objective: Provide more detailed information on the taxonomic composition of harmful algal blooms and enable synoptic monitoring and mapping via satellite remote sensing.

Approach: Perform multiple endmember spectral mixture analysis based on a cyanobacteria spectral library and a hyperspectral satellite image to infer the abundance of each genus on a per-pixel basis.

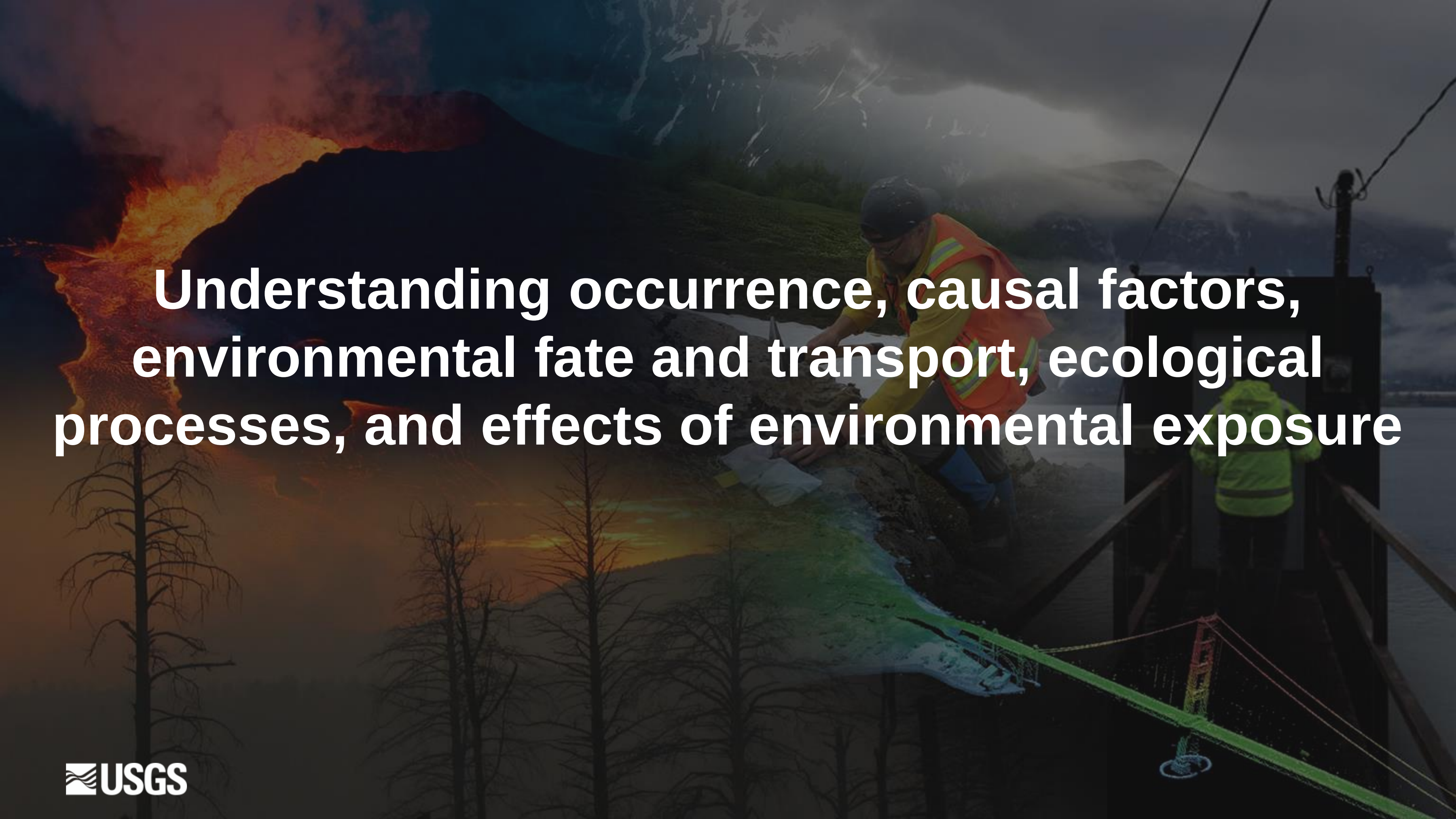
Results will: Allow remote sensing of algal blooms to move beyond presence/absence or estimates of pigment concentration and instead identify specific taxa of interest.

Contact: Carl J. Legleiter (cjl@usgs.gov)



Legleiter et al., 2022

USGS



Understanding occurrence, causal factors, environmental fate and transport, ecological processes, and effects of environmental exposure

USGS

NGWOS Illinois River Basin HAB Research and Monitoring

Objective: Collaborate with local and regional stakeholders to monitor, sample, and research the complexities of HABs within the Illinois River Basin.

Approach: Use a dense array of real-time in situ sensors and state-of-the-art sample techniques and laboratory methodologies to monitor HABs.

Results will: Compare sample and sensor data to HAB characteristics and identify new technologies that are effective at monitoring conditions that may indicate HAB occurrence and toxicity.

Contact: Heather M. Krempa (hkrempa@usgs.gov)

Photographs by Heather Krempa and Katherine Summers, U.S. Geological Survey

NGWOS Delaware River Basin: An Evaluation of SPATT Technology to Assess Cyanotoxins Variability and Transport in the Salem River, New Jersey

Objective: Evaluate the use of passive samplers, or Solid Phase Adsorption Toxin Tracking (SPATT) samplers, to examine the temporal variability of dissolved cyanotoxin occurrence in the Delaware River Basin, New Jersey.

Approach: 130 SPATT samplers were deployed for different time intervals, ranging from 1-14 days, at 11 sites in the Salem River during a 2020 bloom. Deployment locations consisted of flowing and impounded reaches along the Salem River. During retrieval, discrete water-column cyanotoxin samples were collected to develop a comparison of results from passive versus discrete cyanotoxin concentrations. Concentrations of four dissolved cyanotoxins (Anatoxin-a, Cylindrospermopsins, Microcystins, and Saxitoxins) were quantified by Enzyme-Linked Immunosorbent Assay (ELISA) with a subset of samples analyzed by Liquid Chromatography-Tandem Mass Spectrometry (LC-MS/MS) for comparison.

Results Will: Inform the USGS and scientific community on best practices for use of SPATT technology, such as optimal deployment times and understanding how environmental conditions may affect the efficacy of passive samplers.

Contact: Heather Heckathorn (haheck@usgs.gov)

USGS

Photo Credit: USGS NJWSC

Assessment of Algal Bloom Formation and Transport in the Fox River, Wisconsin

Objective:

Characterize algal bloom formation and transport in the Fox River from Lake Winnebago to Green Bay in Wisconsin. Provide data to support understanding the harmful algal bloom dynamics and support restoration of the Great Lakes by addressing science and data gaps important for predicting, forecasting, and managing harmful algal blooms in Green Bay.

Approach:

- Sampling in 2023-2024
- 3-5 synoptic sampling events at first visible bloom,
- 2 Lagrangian sampling approach conducted during peak bloom conditions that will follow the bloom downstream with sample collection based on estimated transport time
- Analysis will include algal biomass, and phytoplankton community composition. Samples will be collected and preserved for toxin and genetic analysis

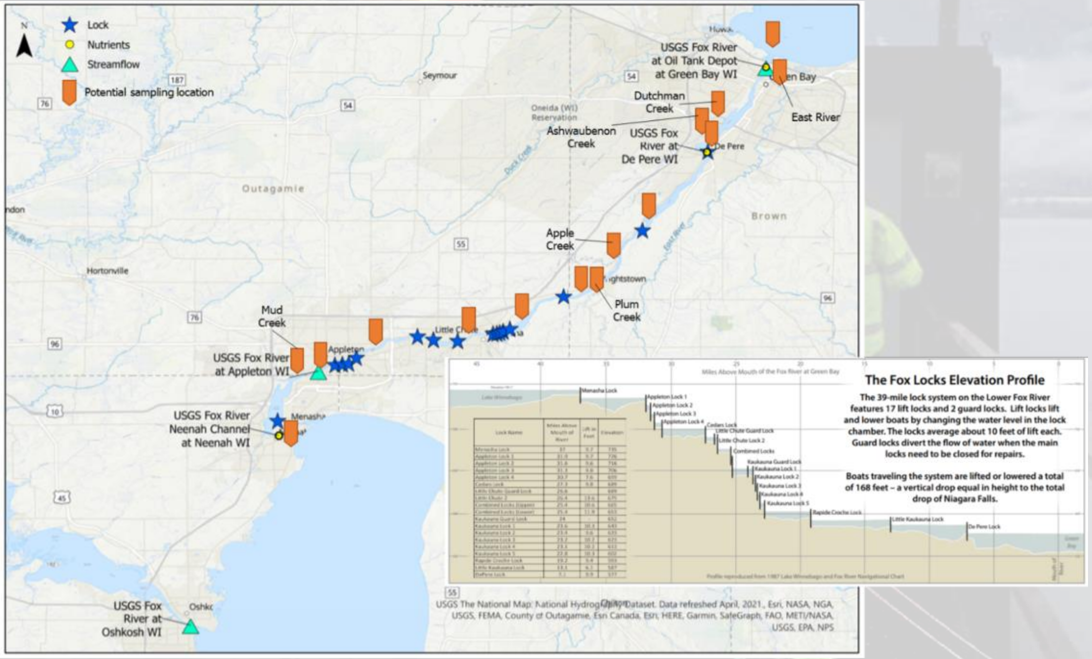


Image credit: Hayley Olds

Results will: Produce the first comprehensive data on bloom dynamics in the Fox River and potential transport to Green Bay nearshore

Contact: Hayley Olds (htolds@usgs.gov)

USGS

Cooperator: Wisconsin Department of Natural Resources

Lower Hudson River

Objectives: 1) Collect water quality samples from Yonkers, NY to Green Island, NY on the Hudson River to describe cyanobacterial transport and community dynamics; and 2) Integrate satellite-derived indices into the Hudson River Environmental Conditions Observing System.

Approach: High resolution spatial mapping and discrete sample collection along the 137-mile reach of the Lower Hudson River during satellite overpasses.

Results will: Enhance understanding of cyanobacterial communities and tools used as early indicators of potentially harmful algal blooms in the Lower Hudson River.

Contact: Natasha Scavotto (ndrotar@usgs.gov)

Picture credit: N Scavotto

Picture credit: S. Campana

Picture credit: S. Campana

Cyanobacteria and Cyanotoxins in the Nation’s Large and Coastal Rivers: A Pilot Study

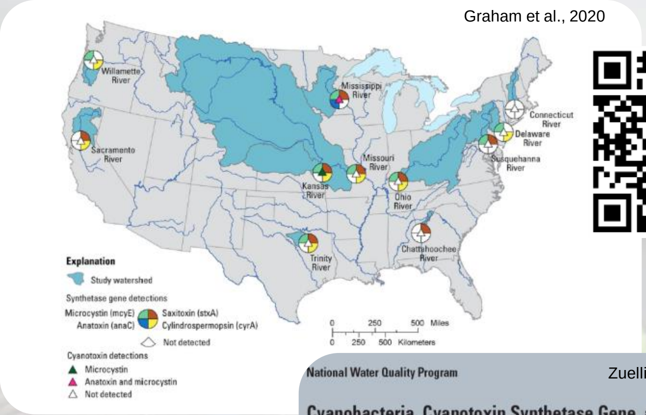
Objective: Describe occurrence of cyanobacteria, cyanotoxin synthetase genes, and cyanotoxins in large rivers across a range of water-quality and hydrologic conditions.

Approach: Analyses were added to routine sample collection at 11 sites in the National Fixed-Site Network during June through October 2017-2019.

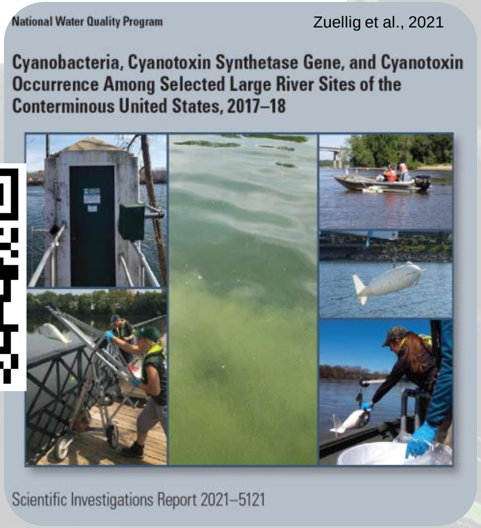
Results will: Contribute to the understanding of cyanobacteria and cyanotoxin occurrence in the Nation’s large rivers.

Contact: Jennifer Graham (jlgraham@usgs.gov)

Graham et al., 2020



Zuellig et al., 2021



USGS

Cyanobacteria, Microcystin, and Taste-and-Odor Compounds in the Kansas River, KS

Objective: Characterize and describe water-quality conditions with an emphasis on cyanobacteria, microcystin, and taste-and-odor compounds in the Kansas River.

Approach: Compare cyanobacteria community composition and abundance, microcystin, geosmin, and 2-methylisborneol (MIB) sample results to continuous water-quality monitor data at 3 sites located downstream of HAB producing reservoirs in the Kansas River.

Results will: Improve understanding of relations among cyanobacteria, associated toxins, and taste-and-odor compounds, and continuous chlorophyll and phycocyanin fluorescence sensors.

Contact: Thomas Williams (tjwilliams@usgs.gov)

Kansas River at De Soto, KS; Thomas Williams; USGS; May 2016

Kansas River at De Soto Boat Ramp, KS; Ryan Waters; USGS; Sep 2022

USGS

The Nature Conservancy | City of Manhattan Kansas | Kansas Department of Health and Environment | Kansas Water Office | City of Lawrence | OLATHE KANSAS | The Capital City of Kansas Topeka | WaterOne Water District No. 1 of Johnson County | evergy

Downstream Fate and Transport of Cyanobacteria and Cyanotoxins in the Raritan Basin Water Supply Complex, New Jersey

Objective: Evaluate the downstream fate and transport of cyanobacteria and associated cyanotoxins from headwater lakes and reservoirs to drinking water intakes within the Raritan River Water Supply Complex in New Jersey.

Approach: A combination of passive samplers, discrete water-quality samples, and continuous monitoring were used over a one-year period to investigate the effects of spatial and temporal changes in water-quality conditions on cyanobacterial population, cyanotoxin production and transport.

Results will: Serve as a baseline to measure any future regulatory or mitigation actions to improve water quality.

Contacts:

- Heather Heckathorn (haheck@usgs.gov)
- Pamela Reilly (jankowsk@usgs.gov)

Photo Credit: USGS NJWSC (upper); NJ American Water (lower)

Characterization of Potentially Toxic Cyanobacteria Bloom Initiation in Slow-Moving Streams, Wetlands, and Oxbows and Subsequent Movement to Hydrologically Connected Reservoirs and Large Rivers

Objective: Characterize the hydrologic, water-quality, sediment, and biological conditions present during the formation and transport of cyanoHAB blooms in slow-moving streams, wetlands, and oxbows to receiving reservoirs and rivers.

Approach: Targeted collection of discrete samples and instantaneously measured water-quality data, phytoplankton community, field-based hyperspectral imaging, and other relevant data in wetlands, oxbows, and slow-moving streams.

Results will: Improve understanding of the temporal and spatial relation between the formation of potentially toxic cyanobacteria blooms in these waters and subsequent development of blooms in downstream reservoirs and large rivers.

Contact:

Ariele Kramer (KSWSC Hydrologist – Water Quality)
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Keith Loftin (Research Chemist, Algal and Other Environmental Toxin Laboratory (AET) Supervisor) kloftin@usgs.gov

SCAN ME

Photos taken by USGS KSWSC Staff

USGS

Partners: Kansas Water Office, Kansas Department of Health and Environment, Kansas Department of Wildlife and Parks, WaterOne

Cyanotoxin Occurrence Along the Freshwater to Marine Continuum: A Pilot Study in the Northeastern United States

Objective: Capture a snapshot of the regional occurrence of cyanobacteria and associated cyanotoxins in coastal rivers and estuaries throughout the North Atlantic Appalachian Region

Approach: Sampling along an upstream-downstream gradient in 5 watersheds during late summer 2020 using a combination of discrete samples and passive samplers.

Results will: Serve as a foundational database upon which more detailed studies can be developed and further understanding of the strengths and weaknesses of the use of passive samplers.

Contact: Guy Foster (gfoster@usgs.gov)
Jennifer Graham (jlgraham@usgs.gov)

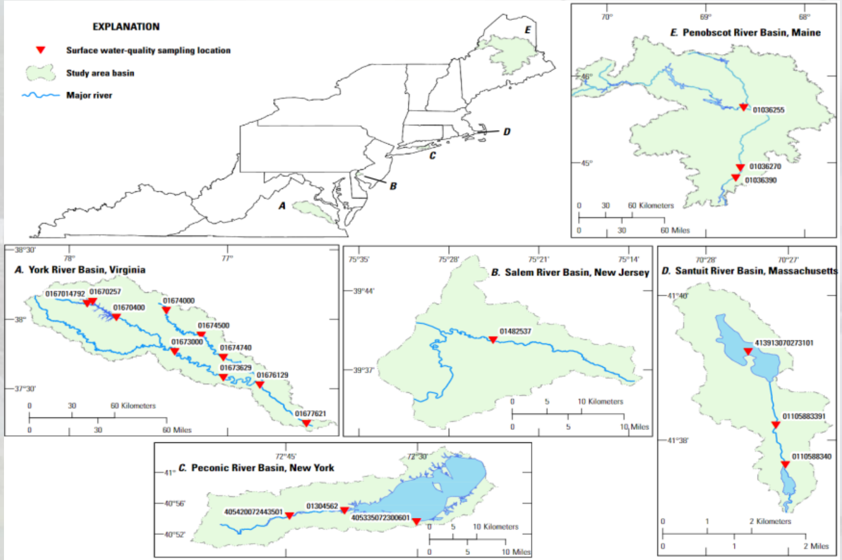


Photo Credits: U.S. Geological Survey

Study conducted by the North Atlantic Appalachian Region HAB Capability Team

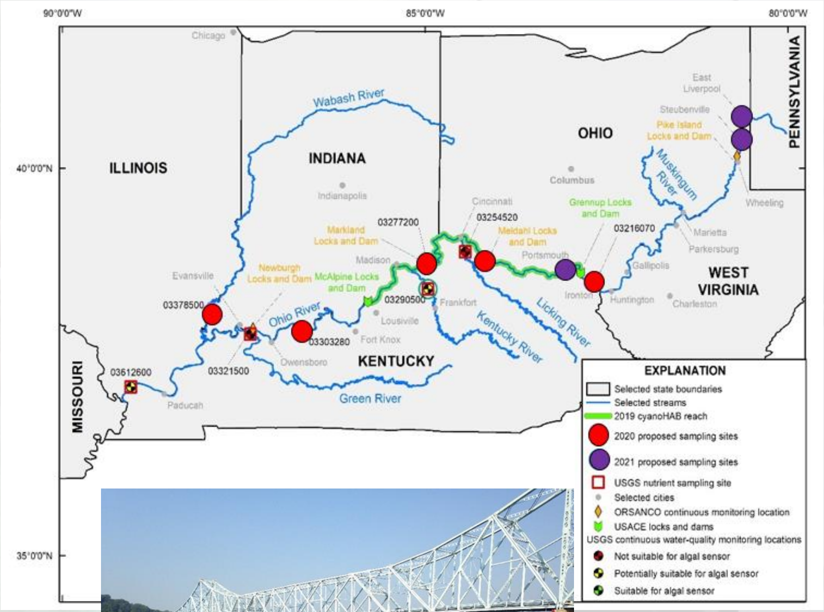
Identifying, Understanding, and Monitoring Cyanobacterial Harmful Algal Blooms in the Ohio and Wabash Rivers

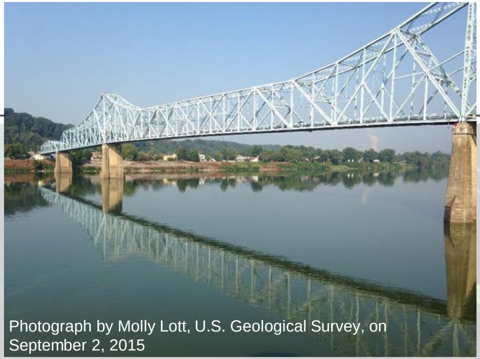
Objective:
Quantify cyanotoxin and nutrient concentrations, identify the cyanobacteria responsible for cyanotoxin production, and initiate monitoring strategies for the Ohio and Wabash Rivers

Approach:
Continuous monitors operated at 8 sites and discrete samples at all sites for total and dissolved nutrients, cyanotoxins, cyanobacterial 16S and toxin genes, and phytoplankton analysis

Results will: help water-resource managers make informed public health decisions by providing near-real-time advisories

Contact: Angela Crain (Hydrologist, project lead) ascrain@usgs.gov, Erin Stelzer (Microbiologist, molecular analyst eastelzer@usgs.gov, Amie Brady (Hydrologist, modeling) amgbrady@usgs.gov




Photograph by Molly Lott, U.S. Geological Survey, on September 2, 2015

Influence of HABs on mussels in the Clinch River, TN-VA

Objective: Determine if HABs are influencing the deaths of mussels in the Clinch River in east Tennessee and southwest Virginia.

Approach: The Clinch River has the most diverse mussel population of any river in the world. In 2016, aquatic biologist noted mussels were mysteriously dying in the fall. This pattern has continued. The USGS is using SPATT samplers to characterize toxin levels at several locations in the Clinch River during the summer and fall seasons. Mussel tissue was also analyzed.

Results will: Preliminary data show that algal toxin levels increased simultaneous with die offs. However, it is not clear if there is a cause-and-effect. The toxins may stress the mussels, making them vulnerable to pathogens.

Contact: Tom Byl (tdbyl@usgs.gov)

USGS

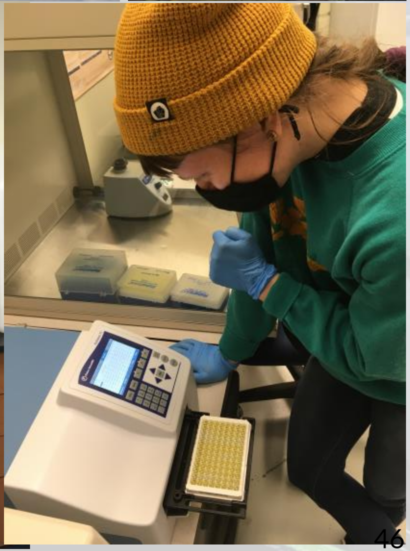


Photo Credits: Tom Byl

Cyanobacterial Occurrence and Bloom Development in Oligotrophic Adirondack Lakes

Objective:

1) Describe the contribution of toxic and non-toxic cyanobacteria to the overall phytoplankton community in oligotrophic lakes,
2) Determine if there are differences in cyanobacterial communities between lakes that have and have not had documented blooms, and
3) Evaluate whether bottom sediments in lakes that have had documented blooms are enriched with cyanobacterial resting stages (akinetes).

Approach: Lake pairs collocated within the same catchment were identified. In each pair, only one lake had documented cyanobacterial blooms. Lakes were sampled three times (June – November) in 2021 for integrated photic zone water samples and surface bottom sediments.

Results will: Provide insight on the attributes of oligotrophic lakes that may make them more susceptible to cyanobacterial bloom development and inform where data collection may be best focused, particularly in those systems where blooms have not historically occurred.

Contact: Michael Stouder (mstouder@usgs.gov)

Photo Credits: Elizabeth Nystrom, Sabina Perkins, Michael Stouder

USGS

NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

A Paleolimnological Approach to Understand the History of Cyanobacterial Occurrence in Oligotrophic Adirondack Lakes

Objective: Understand the historical occurrence of potentially toxic cyanobacteria in Moreau Lake and other oligotrophic Adirondack lakes, through assessments of paleolimnological proxies.

Approach: Sediment cores were collected using a USGS designed box corer. Historical cyanobacteria community composition will be characterized by targeted genetic analyses, cyanobacterial cultures, cyanobacterial akinete analysis, and algal pigment analysis techniques.

Results will: Study outcomes will enhance our understanding of cyanobacterial communities in oligotrophic lakes and provide foundational data to inform future process-based research. Understanding the nature of the phenomenon in Moreau Lake specifically will provide information needed to determine appropriate management efforts.

Contact: Sabina Gifford (srgifford@usgs.gov)

Photo Credit: Sabina Gifford

Photo Credit: Elizabeth Nystrom

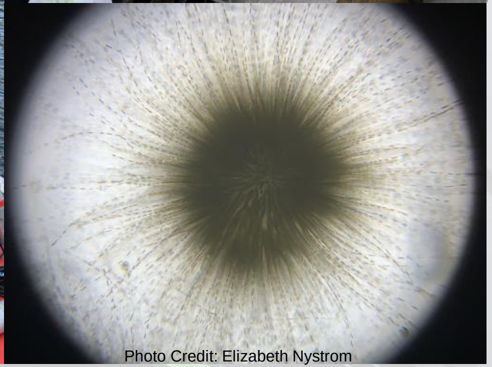


Photo Credit: Elizabeth Nystrom

Using Paleolimnological and SedDNA Reconstructions to Assess Links Between Warmer Winters and Summer CyanoHABs in Maine's Lakes

Objective: Investigate how interactive effects of trophic state and climate have broadly altered cyanobacterial occurrence in Maine lakes over the past 125 years; how decades with warmer winters have affected cyanoHAB occurrence, particularly *Gloeotrichia*, in Maine lakes over the past 125 years; how this relates to broader cyanobacterial diversity and cyanoHAB dominance through time.

Approach: Lake sediment records will be collected, dated, and analyzed for 12 lakes across the state. Sediment cores will be analyzed for algal pigments, sedDNA, and sediment chemistry. The lakes span a factorial framework of 3 climate zones x 3 trophic states.

Results will: Implement new sedDNA tools to substantially advance understanding of long-term patterns and drivers of cyanoHAB taxon abundances and community compositions across lakes spanning climate and trophic states. Provide a more comprehensive picture of drivers of cyanoHAB occurrences across various lake types.

Contact:

Jasmine Saros: jasmine.saros@maine.edu
Charles Culbertson: cculbert@usgs.gov

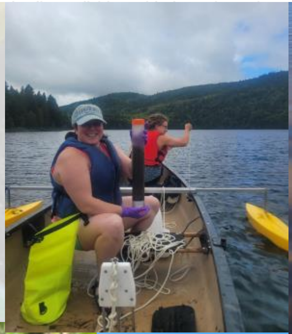
USGS

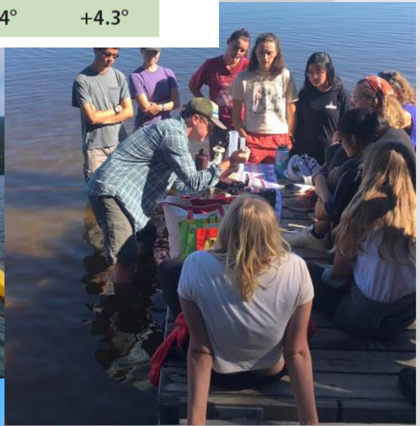
Average annual temperature by climate division, with changes in minimum (winter), maximum and average temperatures, 1895-2018. From Fernandez et al. (2020).

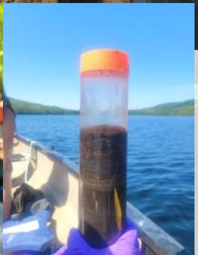
Temperature Changes by Climate Division, 1895–2018

Increases over long-term average

Annual average temperature		Maximum	Average	Minimum
Northern	38.2°	+2.4°	+3.1°	+3.7°
Interior	42.5°	+2.6°	+3.3°	+4.0°
Coastal	43.8°	+2.5°	+3.4°	+4.3°







Co-PI Countway testing for the cyanobacterium Gloeotrichia at Flagstaff Lake, Maine, using handheld qPCR technology.

Photo credits: Jasmine Saros, University of Maine

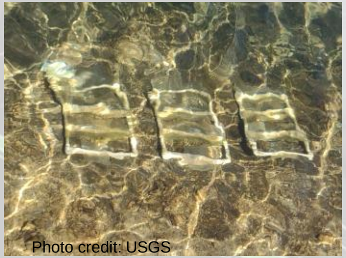
Does a Copper-Nitrate Synergy Drive Algal Blooms in Sierra Nevada Lakes?

Objectives: Test predictions of atmospheric copper deposition in Sequoia National Park lakes, determine if low levels of copper and nitrogen synergize to drive algal blooms in the lakes, and establish if copper is bioaccumulating in the food web and impacting fish and frog health.

Approach: Field sampling of water, sediment, and biota for copper; water quality monitoring, fish and tadpole health assessments, in situ algal growth experiments.

Results will: assist Sequoia National Park with understanding the causes of algal blooms and potential for copper deposition associated with pesticide use in the Central Valley.

Contact: Thea Edwards tedwards@usgs.gov
Erik Meyer erik_meyer@nps.gov



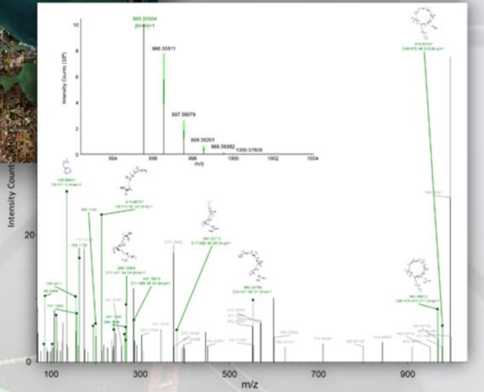
Understanding the HABs Toxicity in the Great Lakes

Objectives:
1) Determine diversity of cyanobacteria blooms spatially and temporally within blooms in the Great Lakes and resulting toxin profiles (congeners).
2) Identify environmental conditions associated with different microbial and toxin profiles.

Approach: Evaluate archived samples collected from the Great Lakes, representing different conditions for cyanobacteria, for algal toxin congeners. Relate toxins results to environmental conditions and metagenomic results (collaboration with NOAA).

Results will: provide the science and data needed to better understand and predict the toxicity of cHABs in the Great Lakes.

Contacts: Lisa Reynolds Fogarty (lrfogart@usgs.gov) and
Keith Loftin (kloftin@usgs.gov)



Lake Superior Cyanobacterial Bloom Initiation - Investigating the Influence of Watershed Sources and Loading of Nutrients, Sediment, and Cyanobacteria to the Nearshore

Objective: Assess how cyanobacterial seeding, nutrient and sediment loading, and tributary nutrient cycling contribute to the formation of cyanobacterial blooms along the nearshore of Lake Superior.

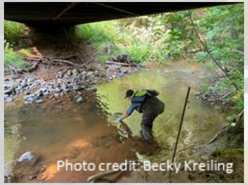
Approach: Collect water, suspended sediment, and streambed sediment samples in tributaries to determine nutrient and sediment loads, characterize cyanobacteria community composition, and measure in-stream nutrient cycling rates. Conduct hydrodynamic surveys to map storm plume from the tributaries out into the lake.

Results will: Provide managers information about when, where, and how tributaries may be contributing to the formation of algal blooms along the nearshore.

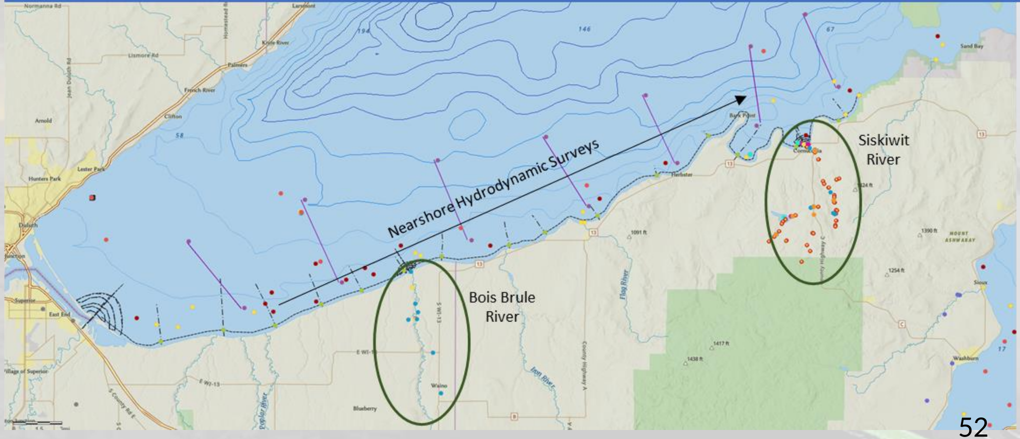
Collaborators include WI-DNR, EPA, NPS, University of Minnesota Duluth Large Lakes Observatory, the Lake Superior National Estuarine Research Reserve, Northland College Burke Center.

Contact:

Anna Baker (abaker@usgs.gov, tributary monitoring, project coordination)
Carrie Givens (cgivens@usgs.gov, microbial genetics)
Becky Kreiling (rkreiling@usgs.gov, nutrient cycling)



Multi-Agency Collaborative Research and Monitoring Locations



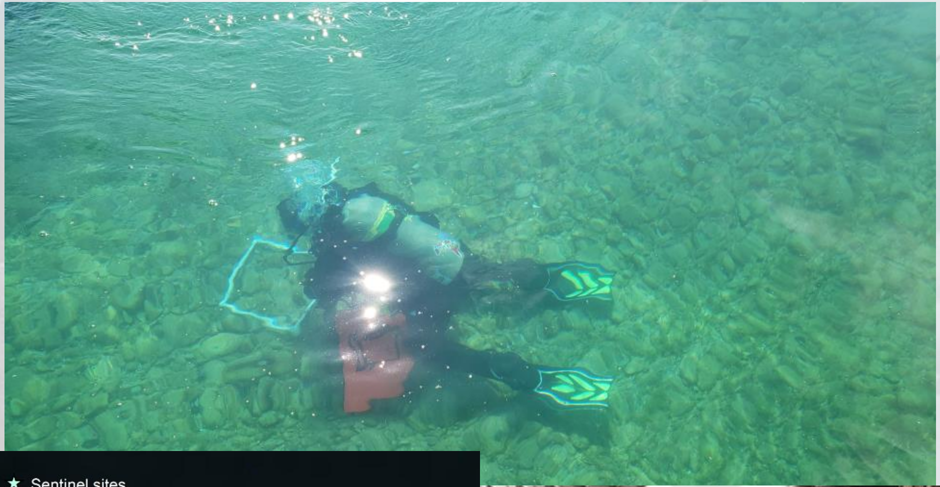
Great Lakes *Cladophora* Assessment

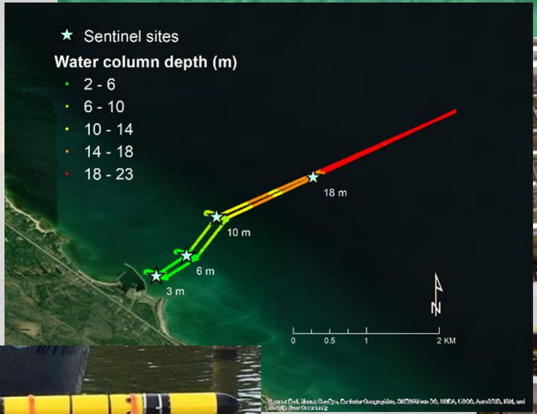
Objective: Assess *Cladophora* sp. and benthic algal distribution, abundance, and growth controls; along with the potential for management through nutrient reductions; along the US shoreline of Lakes Michigan, Huron, Erie, and Ontario.

Approach: Multi-scale assessment combining direct sentinel site monitoring with AUV and satellite remote sensing.

Results will: Inform ongoing, bi-national, management decisions on benthic algal control under the Great Lakes Water Quality Agreement.

Contact: Mary Anne Evans
maevans@usgs.gov





Photos by Mary Anne Evans and Pete Esselman, USGS

Beyond Microcystin: Biogeography of Cyanotoxins with a Network of SPATT Samplers, Phycocyanin Sensors, and Laboratory Analyses

Objectives:

1) Begin to understand the geospatial extent and patterns of cyanotoxins, including lesser studied neurotoxins such as anatoxin and saxitoxin
2) Evaluate SPATT passive sampler technology for the collection of cyanotoxin data across the Upper Midwest (Wisconsin, Minnesota, and North Dakota)

Approach:

- Sampling in 2019 and 2020
- Solid Phase Adsorption Toxin Tracking (SPATT) passive samplers deployed ~1 m below the surface over 2-week periods
- Water grab samples collected bi-weekly and analyzed for cyanotoxins and phytoplankton identification
- A suite of 32 cyanotoxins analyzed using LC-MS/MS

Results will: Expand the understanding of the geospatial extent and patterns of lesser studied cyanotoxins across the Upper Midwest and expand our knowledge of the usefulness of SPATT passive sampler technology for collection of cyanotoxin data.

Contact:

Hayley Olds (htolds@usgs.gov)
Victoria Christensen (vglenn@usgs.gov)

USGS

Photo credits: Upper Midwest WSC, Hayley Olds, Owen Stefaniak

Untangling Phytoplankton and Bloom Dynamics in the Lower Caloosahatchee River, FL: Insights from In Situ Nutrient Enrichment Bioassays

Objective: Test the short-term effects of NH_4, NO_3, urea, and PO_4 enrichment on phytoplankton dynamics and toxin production in the Caloosahatchee River.

Approach: Six individual nutrient enrichment field mesocosm experiments conducted at different times of the year from 2019-21.

Results will: Inform understanding of mechanistic effects of nutrient enrichment of phytoplankton succession, bloom initiation, and toxin production.

Contact: Viviana Mazzei, CFWSC
vmazzei@usgs.gov

Photo credits: CFWSC, Viviana Mazzei

USGS

Modeling the Relationship Between Environment and Phytoplankton Assemblage Structure in the Lake Okeechobee System, FL

Objective: To describe spatial-temporal patterns in Lake Okeechobee phytoplankton assemblages and identify potential drivers of harmful algal blooms and ecological thresholds.

Approach: Multidimensional community modeling and threshold indicator taxon analysis on phytoplankton samples collected monthly from 21 sites from 2019-21.

Results will: Identify significant predictors of phytoplankton dynamics and detect species-specific and assemblage level thresholds along predictor gradients.

Contact: Viviana Mazzei, CFWSC
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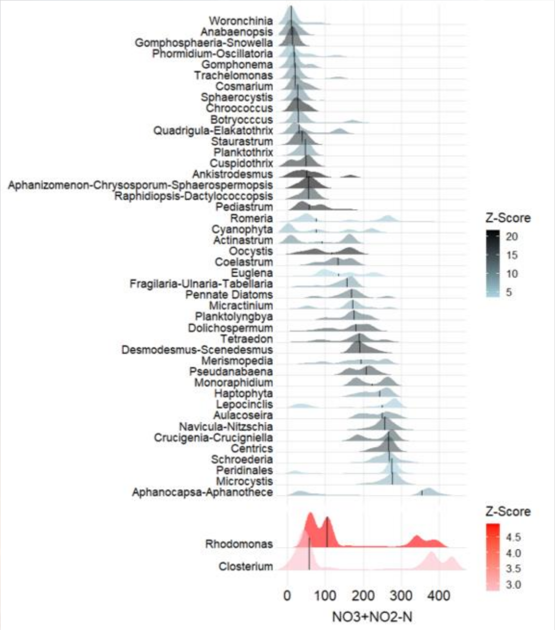
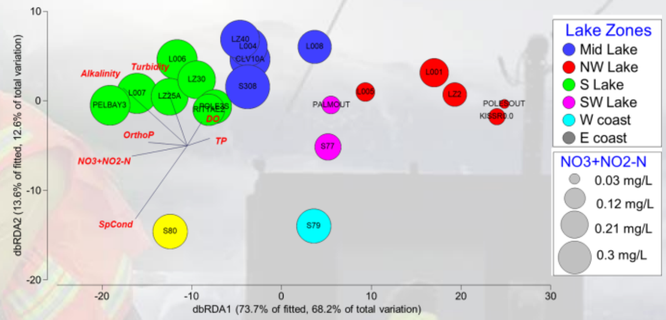
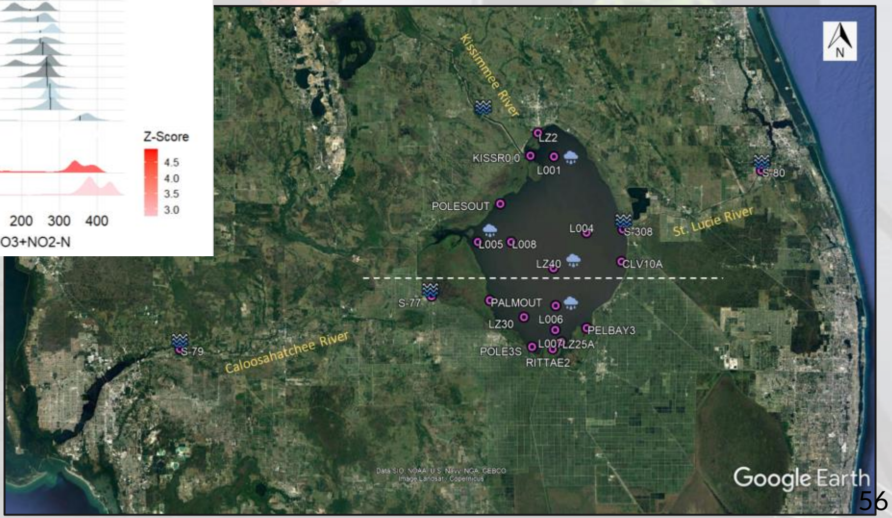






USGS

Photo credits: CFWSC, Viviana Mazzei

Review of Harmful Algal Bloom Effects on Birds with Implications for Avian Wildlife in the Chesapeake Bay Region

Objective: Characterized hazard and risk of harmful algal blooms and associated toxins to Chesapeake Bay wildlife

Approach: compiled and evaluated data from numerous sources for the period of 2000-2020

Results: having exceeded recreational use and drinking water thresholds at various times, microcystins are the dominant group that could affect wildlife. However, few wildlife mortality events were definitively linked to HABs. Findings available in forthcoming issue of Harmful Algae.

Contact: Barnett Rattner, USGS-EESC
brattner@usgs.gov
USGS Environmental Health Algal Toxins and HABs Team

Photo Credit: USGS

Photo Credit: Serguei Drovetski, USGS

Photo Credit: Barnett Rattner, USGS

Photo Credit: Peter C. McGowan USGS

Harmful Algal Blooms and Seabirds in Alaska: Assessing the Impacts of an Emerging Issue on Wildlife Health

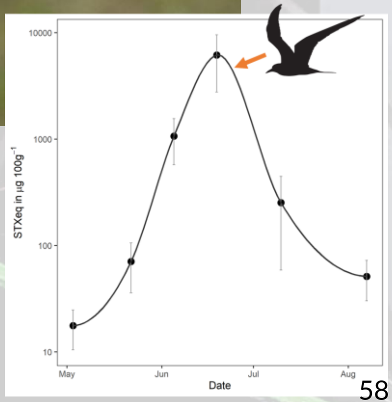
Objective: Determine impacts of harmful algal blooms (HABs) on seabirds in Alaska, including links between saxitoxin exposure and recent bird mortality events.

Approach: Apply a combination of field work, laboratory testing and captive trials to 1) respond to ongoing bird mortality events in Alaska; 2) evaluate whether bird mortality is causally linked to HAB toxins; 3) determine lethal/ effective doses of saxitoxin in wild birds.

Results will: Help determine the relevance of HAB toxins to seabird mortality events and assess the impacts of saxitoxin on wildlife health in Alaska. Identify future priorities for research and management efforts in the context of an emerging threat in northern waters.

Contact: Caroline Van Hemert (cvanhemert@usgs.gov) - Research Wildlife Biologist, Matthew Smith (mmsmith@usgs.gov) - Geneticist

Photo credits: G. Baluss, US Forest Service



From Van Hemert et al. 2022, *Harmful Algae*

Evaluation of Landscape Metrics in Proximity to Cyanotoxins

Objective: Investigate relationships between landscape characteristics and algal blooms (cyanotoxins, phytoplankton abundance) leveraging 2007 and 2012 National Lakes Assessment (NLA) data.

Approach: As part of the USGS Environmental Health Algal Toxins and HABS team, over 300 landscape metrics summarized at the NHD+ catchment scale were related to NLA observational data. Correlation matrices, bias analyses, and Random Forest are being used to reveal patterns in documented HABs across the US.

Results will: Improve our understanding of HABs on the landscape, specifically how they behave under different landscape contexts. Future applications to early warning systems, health implications, and risk assessment efforts.

Contact:
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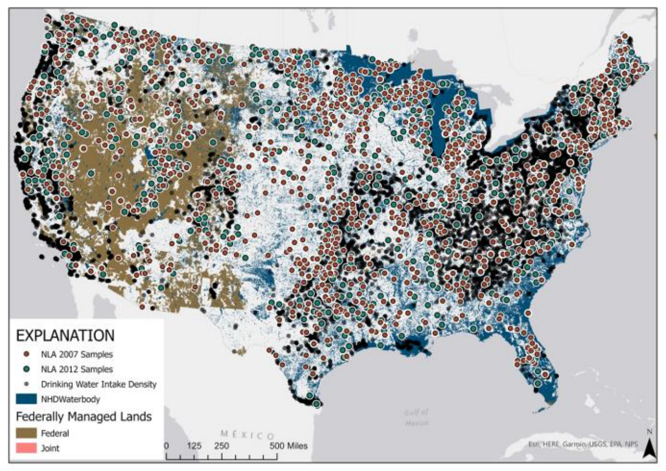
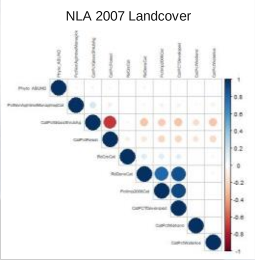
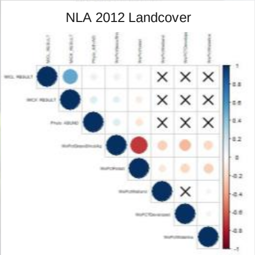
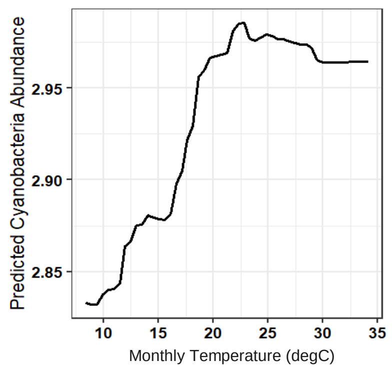
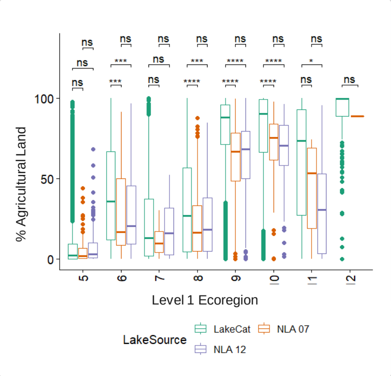
Stephanie Gordon (sgordon@usgs.gov, data management, modeling)
Brianna Williams (bmwilliams@usgs.gov, data management, GIS)











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Effect of Water-Injection Dredging Operations on Water Quality Downstream from Tuttle Creek Reservoir

Objective: Characterize the hydrologic, water-quality, sediment, and biological conditions present up- and downstream from the Tuttle Creek Reservoir outlet before, during, and after water-injection dredging demonstrations in Tuttle Creek Reservoir.

Approach: Targeted collection of discrete samples and instantaneously measured water-quality data, phytoplankton community, microcystin, taste-and-odor compounds, and other relevant data at multiple sites downstream from the Tuttle Creek Reservoir outlet including the Big Blue and Kansas Rivers.

Results will: Characterize potential downstream effects related to Tuttle Creek water-injection dredging on water quality including nutrients, biological contaminants like taste-and-odor and potential cyanoHAB events, and changes to ecosystem health.

Photos taken by USGS KSWSC Staff

Contact:

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Thomas Williams (KSWSC Hydrologist – Water Quality)
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USGS

Partners: U.S. Army Corps of Engineers

The Physiological Effects of Aeolian Dust and Volcanic Ash on HABs and Associated Toxin Production

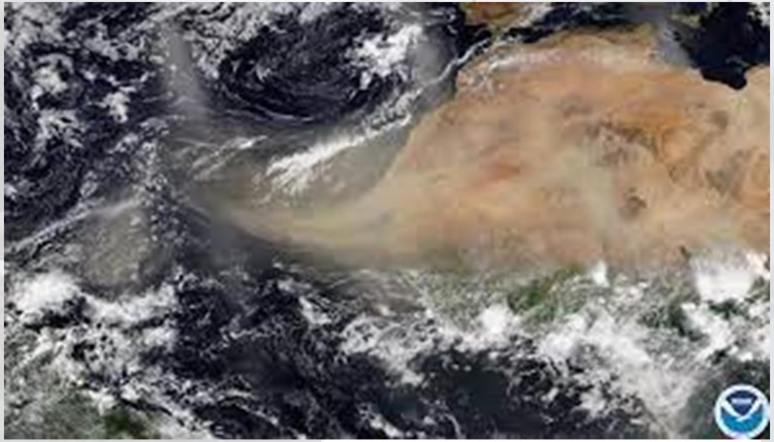
Objective: Characterize the effects of aeolian dust and volcanic ash on the growth and toxin production of cyanobacteria and algae associated with freshwater and marine HABs

Approach: Laboratory grown cultures of cyanobacteria and algae known to dominate HABs are dosed with varying concentrations of aeolian dust or volcanic ash.

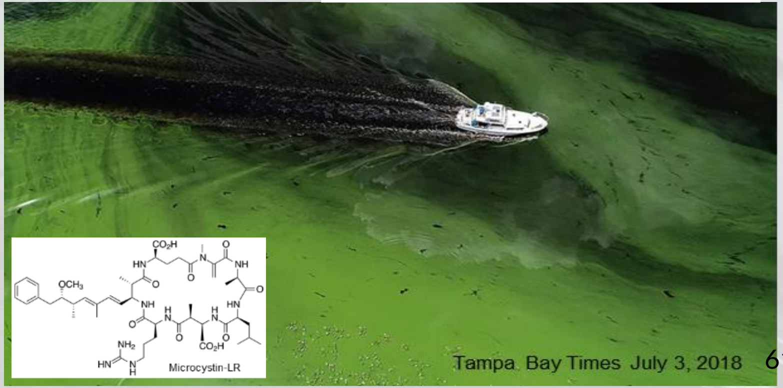
Results will: Samples are analyzed for the effects the aeolian dust or volcanic ash have on cellular integrity, growth rates, biomass and toxin production

Contact: John Lisle (St. Petersburg Coastal & Marine Science Center, Research Microbiologist) jlisle@usgs.gov

USGS



Saharan dust plume, seen by the NOAA-20 satellite on June 17, 2020. Credit: NOAA



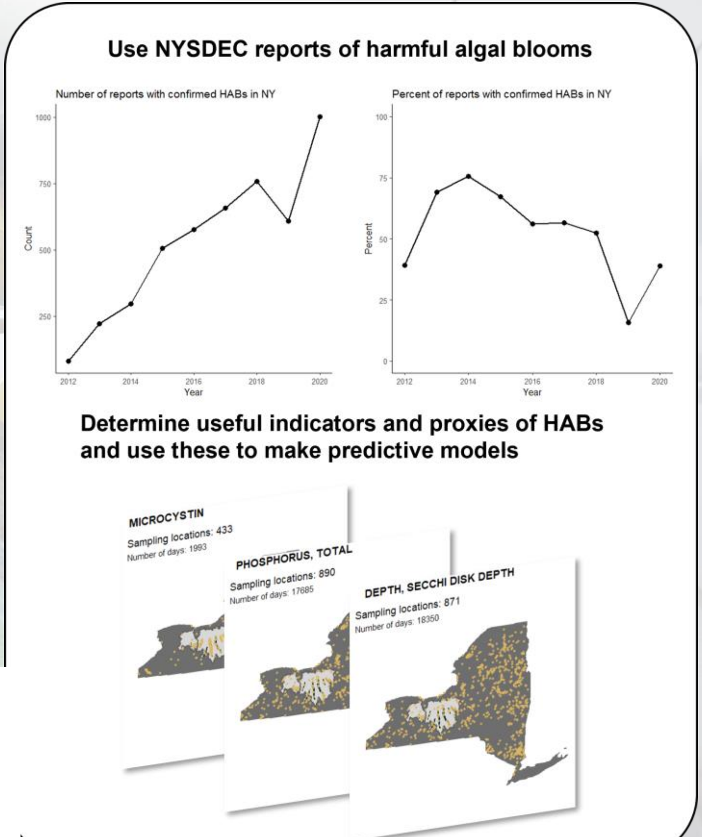
Predicting Harmful Algal Bloom Occurrence in the Finger Lakes

Objective: Predict the occurrence of harmful algal blooms in the Finger Lakes by combining reports of harmful algal blooms with various measures of water quality.

Approach: Determine the importance of various water quality measures for predicting HABs occurrence and develop a predictive model. Use machine learning approaches to draw inferences about how variables contribute to HABs prediction and to test the feasibility of making finer resolution predictions of HABs occurrence.

Results will: Help determine important factors for predicting HABs and leverage existing sensors to make more frequent HABs predictions.

Contact: Phil Savoy (psavoy@usgs.gov)



Data obtained from the NYSDEC division of water monitoring portal

Remote and Field Investigations of Cyanobacterial Harmful Algal Blooms in Michigan Inland Lakes

Objective: Monitor Michigan inland lakes for HABs using remote real time algal sensors and field collected toxin samples to support an early detection system for local communities and health officials.

Approach: Analyze surface water samples for toxins including microcystin and other cyanotoxins. Verify algal trackers with a multi-parameter water quality sonde that includes chlorophyll-a and phycocyanin

Results will: Expand the understanding of how remote near-real-time fluorescence data can be used to monitor inland lakes as an early detection for possible HABs.

Contact: Tori Byers (vbyers@usgs.gov) and Amanda Bell (ahbell@usgs.gov)


Image Credit: Tori Byers, Upper Midwest WSC


Image Credit: Tori Byers, Upper Midwest WSC

USGS

Cyanotoxin Surveys for Drinking Water Protection in Oregon

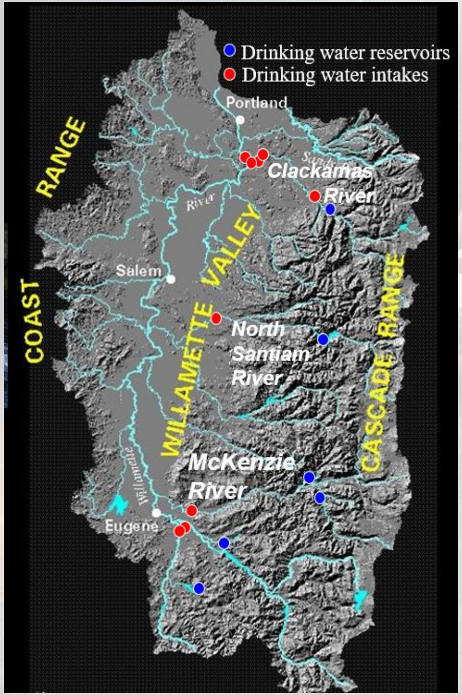
Objective: Examine occurrence of four cyanotoxins in critical drinking water supplies using ELISA

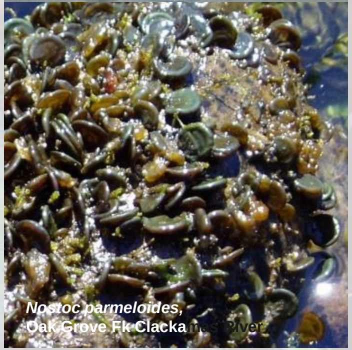
Approach: Deploy SPATTs, sample benthic colonies and collection of plankton net tow samples

Results will: Identify areas of toxin production and evaluate transport of toxins and cyanobacteria to drinking water treatment plant intakes

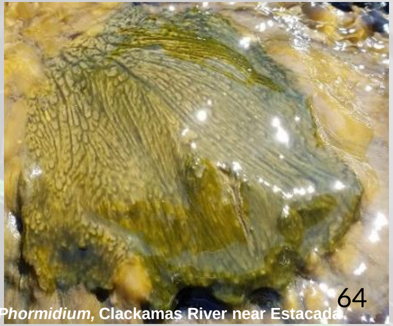
Cooperators: Drinking Water Utilities in Salem, Eugene, and Clackamas, Oregon

Contact: Kurt Carpenter
OR Water Science
Center kdcar@usgs.gov





Nostoc parmeloides, Oak Grove Fk Clackamas River



Phormidium, Clackamas River near Estacada

Photos by Kurt Carpenter, USGS

USGS

Monitoring Nutrient Responses to Wildfire in Oregon Drinking Water Reservoirs

Objective: Determine the effects of wildfire on reservoir nutrient and carbon budgets

Approach: Quantify continuous nitrogen, phosphorus, and carbon fluxes entering and exiting a reservoir by pairing discrete WQ samples with streamflow and continuous WQ monitoring

Results will: Allow managers to anticipate the possible increases in nutrient and carbon fluxes to reservoirs after wildfires and anticipate changes to outflow quality

Cooperator: U.S. Army Corps of Engineers

Contact: Noah Schmadel
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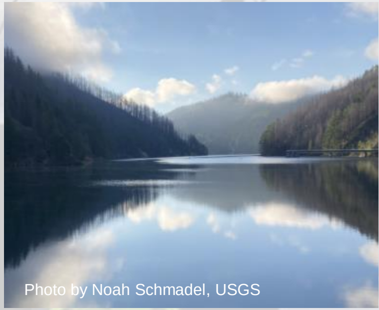
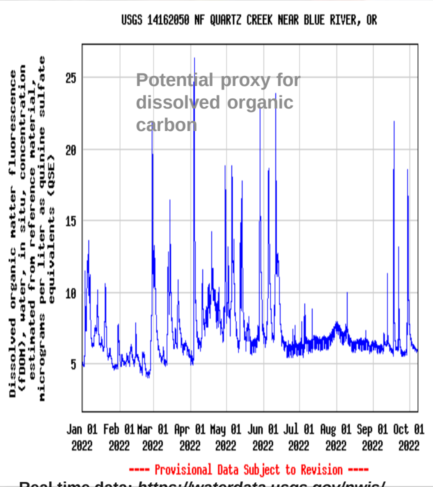
nschmadel@usgs.gov

USGS

Photo by Noah Schmadel, USGS





Real time data: *https://waterdata.usgs.gov/nwis/*
Photo by Noah Schmadel, USGS

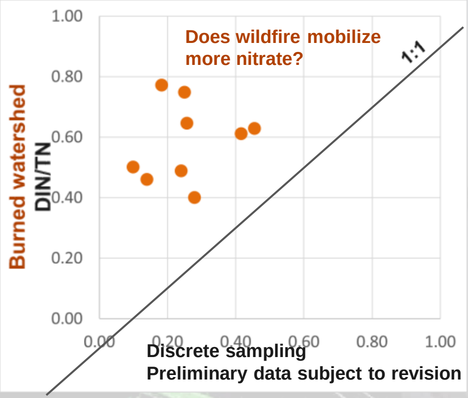


Photo by Noah Schmadel, USGS

SPARROW Nutrient Predictions

Objective: Inform assessments of HAB-impacted water bodies

Approach: Use predictions from recent SPARROW watershed models

Results will:
Provide estimates of water-quality conditions when monitoring is limited or non-existent

Contact: Dan Wise
dawise@usgs.gov

SPARROW Pacific Region Mapper

SPARROW Pacific Region Data Release

Estimated Mean Annual Loads Delivered to Lake Billy Chinook (MT/year; 90% CI)
Total Nitrogen: 3,870 (1,580 – 9,770)
Total Phosphorus: 280 (70 – 830)

Nutrient Sources

Total Nitrogen:
almost all from background sources delivered through spring discharge

Total Phosphorus:
mostly from geologic weathering delivered equally through spring discharge and surface runoff


Photo credit: Oregon Historical Society

USGS

Using a Novel Approach to Monitor Harmful Algal Blooms in a Coastal New Jersey System

Objective: Assess the transport of cyanobacteria and cyanotoxins from freshwater to marine systems.

Approach: Passive cyanotoxin samplers and continuous monitors were deployed in combination with weekly water-quality samples to investigate the effects of rapid changes in water-quality conditions of coastal lakes on cyanobacterial toxin production and transport to a marine system.

Results will: Improve the understanding of the efficacy of passive samplers for cyanotoxins in a coastal environment in addition to, or in place of, traditional sampling methods. Help NJ regulators understand the effects of freshwater HAB inputs to coastal systems.

Contacts:

- Erika Bernal (ebernal@usgs.gov)
- Brad Bjorklund (bbjorklund@usgs.gov)
- Kaitlin Bowen (kmbowen@usgs.gov)
- Heather Heckathorn (haheck@usgs.gov)
- Pamela Reilly (jankowsk@usgs.gov)

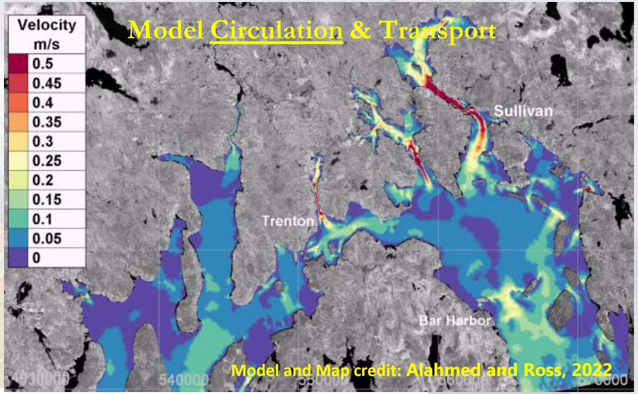
Photo Credit: USGS NJWSC

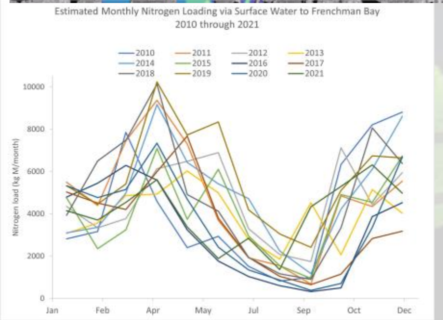
Amnesic Shellfish Poisoning (ASP) Decision Support in Connected Watershed-Estuary Systems

Objective: Improve understanding of circulation and residence time for waters in Frenchman Bay and the environmental conditions associated with *Pseudo-nitzschia* harmful algal blooms to: 1) permit prediction of *Pseudo-nitzschia* blooms and their toxicity, 2) provide more accurate delineations of the spatial extent and duration of shellfish harvesting closures in response to *Pseudo-nitzschia* blooms, 3) support new decision tools for monitoring strategies and mitigation measures in response to threats posed by *Pseudo-nitzschia* blooms.

Approach: Assemble and analyze historic and *in-situ* stream flow, water quality (salinity, temperature), weather (wind), tidal (currents, water levels), freshwater, and shellfish biotoxin data; develop numerical model hindcasts of ASP (Amnesic Shellfish Poisoning) events to provide spatial context to the measured data; use hindcast results as a basis for process-oriented numerical simulations; develop an online publicly available model forecast system for decision support.

Results will: Support resource management interests in more strategic sampling strategies at the onset and throughout ASP events. Improve the capacity to identify public health risks related to HABs and coastal pollution, reduce unnecessarily long harvesting closure times, and guide identification of locations where the blooms could be more concentrated, and harvesting should remain closed for an extended duration.





Estimated monthly nitrogen loading to Frenchman Bay from 23 tributaries. Estimates were derived from temperature and precipitation inputs to a water balance model to compute runoff and nutrient loads based on the Spatially Referenced Regression on Watershed attributes (SPARROW) model.

Contact:

Lauren Ross: lauren.ross1@maine.edu
Tom Huntington: thunting@usgs.gov

USGS





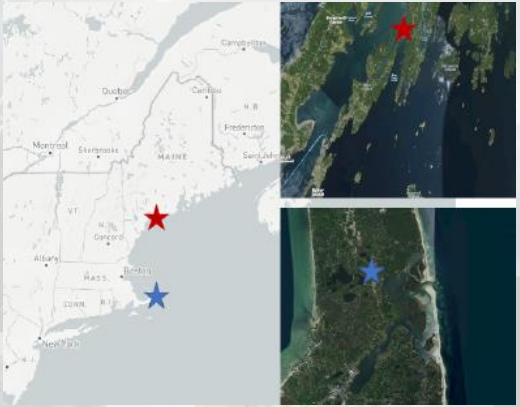

Photo credits: Lauren Ross, University of Maine

HAB Dinoflagellate Migrations Across Carbonate System Gradients in an Acidified Ocean

Objective: Characterize species growth and toxicity through a range of OA (ocean acidification) conditions and dynamics. Address gaps in understanding relationships between HAB behavior and OA, especially where it is associated with coastal eutrophication and hypoxia.

Approach: Through a set of lab- and field-based studies to gather data exploring the behavior of *Alexandrium catenella* and *Heterocapsa triquetra* associated with and in response to vertical OA gradients. Use dynamic modeling to develop a simplified representation of HAB/OA dynamics.

Results will: Provide a complete, well-integrated picture of the interrelationships between a regionally and globally important toxic HAB, OA, and coastal eutrophication/hypoxia within coastal habitats.
Through HAB hub and other automated data systems, the project will 1) improve resource management capabilities, 2) Create stakeholder driven products and outreach materials on OA & HABs, 3) develop and coordinate a NECAN (Northeast Coastal Acidification Network) advisory committee.



Salt Pond within the Nauset Marsh on Cape Cod (blue star) and Lombos Hole within Long Cove in Harpswell, ME (red star).

Platforms and sensors for field studies: (upper left) Salt Pond float with photovoltaic charging, winches and cellular telemetry, (center) a similarly outfitted pontoon barge that will be deployed in Lombos Hole, (right) an IFCB with directly connected sonde (AML Oceanographic), and (lower left) detail of winches (port and aft) that enable automated profiling and repositioning of sensors.

The CHANOS II carbonate system sensor (left) and a Wiz probe nutrient sensor by Systea S.p.A (right) will be integrated with PhytOARM for profiling at Salt Pond and Lombos Hole sites.

Photo credits: Mike Brosnahan, WHOI

Contact:
Mike Brosnahan: mbrosnahan@whoi.edu
Charles Culbertson: cculbert@usgs.gov

Identifying the Source and Taxa Producing Microcystins Detected in San Francisco Bay

Objective: Identify the source of persistent microcystins detected within San Francisco Bay

Approach: Collect samples in areas that could be producing microcystins, which are then transported into San Francisco Bay. Use DNA metabarcoding and LC-MS to identify the taxa potentially producing microcystins.

Results will: Help inform if nutrients discharged into San Francisco Bay could be responsible for microcystins within the Bay.

Contact: Keith Bouma-Gregson, CA Water Science Center (kbouma-gregson@usgs.gov)

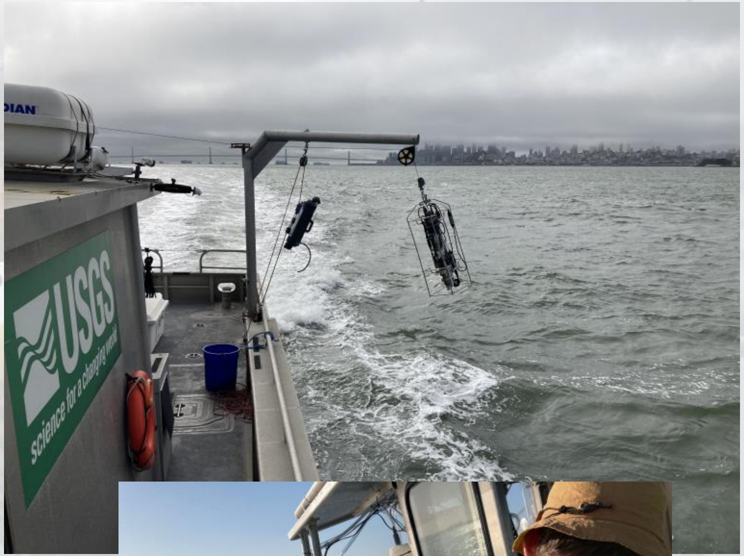


Photo Credits: USGS CA WSC, Keith Bouma-Gregson

Using Water Level Management to Reduce Cyanobacterial Bloom Toxicity

Objective: Identify the potential of water-level manipulation to reduce the toxicity of cyanobacterial blooms occurring in Lake Kabetogama in Voyageurs National Park.

Approach: Collect intact sediment cores to estimate the release of DIN and SRP and use both *in-situ* and laboratory incubation experiments to estimate nutrient controls over phytoplankton communities and cyanotoxin production during blooms.

Results will: Identify the role of drying and re-wetting on sediment nutrient flux in Lake Kabetogama and assess whether water level management to reduce this flux would also reduce toxicity by phytoplankton.

Contact: James Larson (jhlarson@usgs.gov)
Victoria Christensen (vglenn@usgs.gov)
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Photo credit: USGS


Photo credit: USGS


Photo credit: USGS

USGS

Assessing Harmful Algal Blooms of *Pseudo-nitzschia* in Coastal Marine Waters at Acadia National Park and the NPS Potential Role in Mitigation Through Water-Quality Control

Objective: Determine how physical, chemical, and biological conditions influence the development of *Pseudo-nitzschia* HABs in the coastal waters on Mount Desert Island (MDI), Maine.

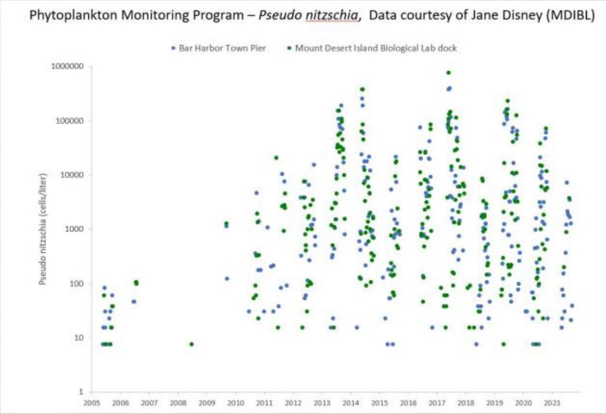
Approach: Deploy instrumentation for the continuous, real-time identification and quantification of the potentially toxic marine planktonic diatom *Pseudo-nitzschia*. Relate surface water nutrient concentrations, pH, DO, temperature and salinity, nutrient inputs from streams, toxin (domoic acid) concentrations in sentinel shellfish, and solar radiation to *Pseudo-nitzschia abundance* in the near-coastal waters of Acadia National Park.

Results will: Provide quantitative information on how temporal variability in nutrient concentrations and other climatic and surface water physicochemical conditions may influence *Pseudo-nitzschia* blooms. Data and analyses produced through this project will inform nutrient management options for reducing HAB growth and toxicity.

Contact:
Tom Huntington: thunting@usgs.gov
Mike Brosnahan: mbrosnahan@whoi.edu

Imaging flow cytobot (IFCB) for quantification of Pseudo-nitzschia. Mount Desert Island Biological Laboratory

Sentinel Shellfish bags to monitor shellfish toxicity at Mount Desert Island Biological Laboratory, Maine.



Time series of Pseudo-nitzschia cell counts (cells/Liter) at the MDIBL dock and Bar Harbor Town Pier on Frenchman Bay. Data courtesy of Jane Disney and her team at MDIBL.

USGS

Photo credits: Mike Brosnahan, WHOI

Algal Blooms, Water Quality, and Remote Sensing, Blue Mesa Reservoir, Curecanti National Recreation Area, Colorado

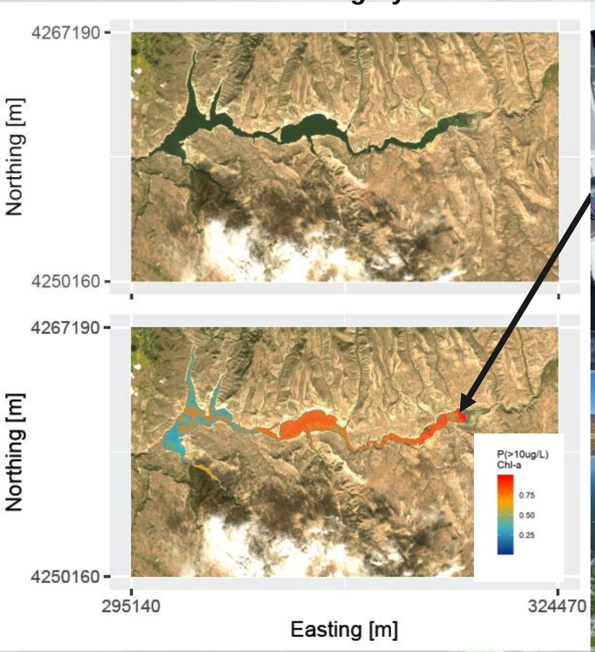
Objective: Develop remote-sensing methods to improve monitoring of algal blooms to protect public health.

Approach: Train remote sensing methods using discrete water quality observations of chlorophyll-*a* to create record of algal blooms from satellite imagery. Analyze discrete and continuous water-quality data (nutrients, algal taxonomy, Chl-a, pH, T, DOC, Diss. Oxy., major and trace elements) to identify drivers of algal blooms.

Results will: Improve understanding of processes leading to algal blooms in the reservoir and improve public notification of harmful algal blooms in the reservoir.

Contact:
Katie Walton-Day (water quality) kwaltond@usgs.gov
Tyler King (remote sensing) tvking@usgs.gov

Sentinel-2 Satellite Imagery: 9/28/2022



Blue Mesa Reservoir 9/28/2022
Photos by K. Walton-Day

USGS

Water-quality control (nutrient limitation) of harmful algal blooms (“red tides”) in coastal embayments of Cape Cod National Seashore

Objective: Understand nutrient dynamics and the role of nutrient limitation in bloom decline within the Nauset Marsh Estuary (Salt Pond), Cape Cod, and whether *Alexandrium catenella* populations are nutrient limited at the end of their bloom cycle.

Approach: 1)Conduct high-resolution monitoring and sample collection to quantify water column nutrients required for *Alexandrium* growth in Salt Pond during bloom development, peak, and decline; 2)Determine *Alexandrium* nutrient cell quotas during these same growth phases, revealing whether nutrient limitation occurs at the time of bloom decline.

Results will: Provide resource managers at Cape Cod National Seashore the information necessary to make informed decisions in developing adaptive management strategies to address recurring *Alexandrium* blooms in Nauset Marsh Estuary, particularly those related to contaminant inputs and nutrient control strategies.

Contact:
Mike Brosnahan: mbrosnahan@whoi.edu
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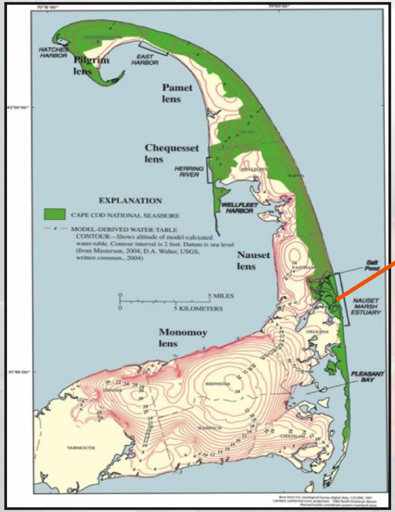



Photo Credit: Charles Culbertson, USGS

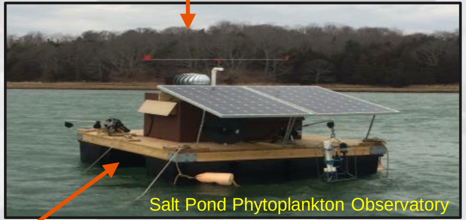


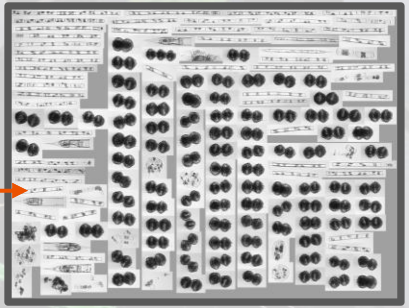
Photo Credit: Charles Culbertson, USGS

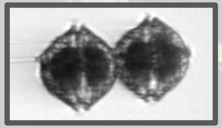

Photo Credit: Charles Culbertson, USGS

3 m Salt Pond water; estimated cell concentration ~4 x 10^6 cells/L


Photo Credit: McLane Research Laboratories, Inc.

Imaging FlowCytobot Deployed on Phytoplankton Observatory





Imaging FlowCytobot images from Salt Pond showing dominance of A. catenella cells

Algal Communities in Sequoia National Park

Objective: Rapidly monitor abundance of cyanobacteria, aquatic mosses, benthic and water column diatoms, and other algae in association with abiotic environmental data and presence of algal toxins.

Approach: Develop eDNA-based metabarcoding assays and tools coupled with traditional survey methods.

Results will: Assist Sequoia National Park with predicting blooms and protecting visitors from toxin related hazards.

Contact: Thea Edwards tedwards@usgs.gov
Erik Meyer erik_meyer@nps.gov

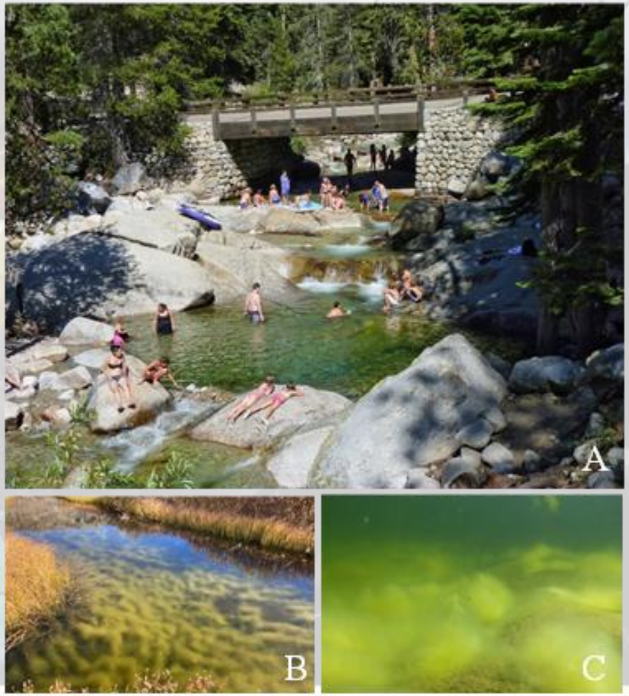


Fig. 1. Visitors enjoy SEKI's sparkling aquatic resources (A), but the clear streams and rivers are increasingly degraded by algal blooms (B, C).

Photo credit: USGS

Algal Toxin Mixtures in a Remote Setting: Voyageurs National Park

Objective: Assess algal toxins, phytoplankton communities, HAB drivers, and bloom heterogeneity in large lakes of Voyageurs NP.

Approach: Data collected through several long-term studies will be evaluated with computer models and multivariate statistics.

Results will: Help determine the drivers behind HAB and toxin formation in a remote area, with little to no influence from typical agriculture or urban nutrient sources.

Contact: Victoria Christensen
vglenn@usgs.gov

Identification and Distribution of Toxigenic Benthic Cyanobacteria in Yosemite

Objective: Study the diversity of toxigenic benthic cyanobacteria in Yosemite National Park and the toxins they produce.

Approach: Collect data at fixed transects and during back-country surveys. Use DNA metabarcoding, microscopy, and LC-MS to identify the taxa potentially producing cyanotoxins within the park.

Results will: Inform a monitoring plan and response strategy for toxic cyanobacteria in Yosemite.

Contact: Keith Bouma-Gregson, CA Water Science Center (kbouma-gregson@usgs.gov)

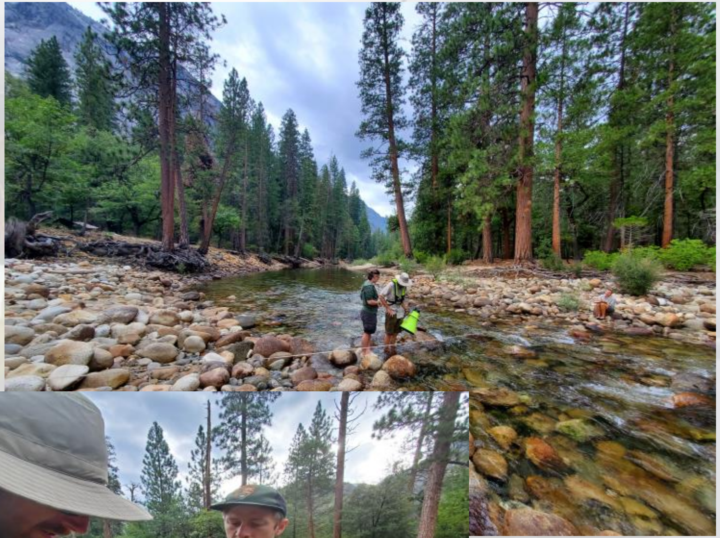


Photo Credits: USGS CA WSC, Keith Bouma-Gregson


Developing tools to inform management decisions

Structured Decision-Making Framework for Managing Cyanobacterial Harmful Algal Blooms in New York State Parks

Objective: Create a strategy for applying decision analyses tools to the complex natural resource challenge of cyanobacterial harmful algal bloom mitigation and management in New York State Parks

Approach: Use two New York State Parks as case studies to motivate and test a structured decision-making template

Results will: Provide a template for New York State Parks and serve as an example that other natural resource managers faced with cyanobacterial harmful algal bloom challenges can use to inform their decision-making processes

Contact: Jennifer Graham (jlgraham@usgs.gov)

Adaptive Management to Address HABs at a Natural Treatment System in Forest Grove, Oregon

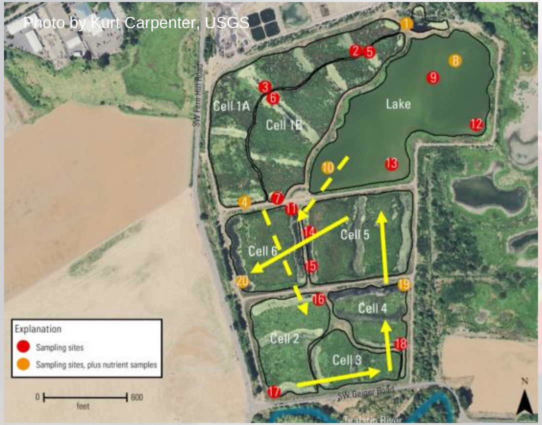
Objective: Improve WQ of NTS-treated wastewater effluent and foster beneficial types of algae (not HABs) to the Tualatin R. downstream

Approach: Continuous WQ monitor, synoptics for nutrients, algae, WQ field parameters, and stage

Results will: Inform managers about WQ and HAB potential related to operations and weather conditions

Cooperator: Clean Water Services

Contact: Kurt Carpenter
OR Water Science Center
kdcar@usgs.gov



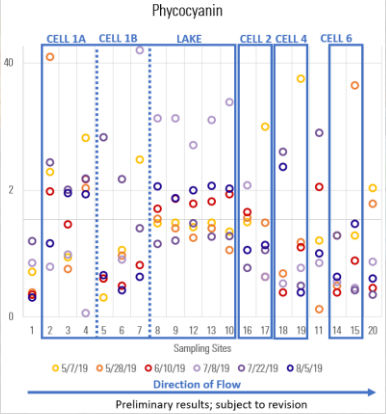
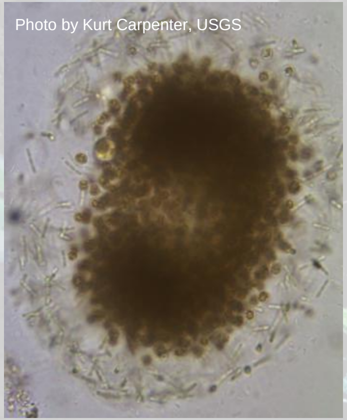


Photo by Kurt Carpenter, USGS



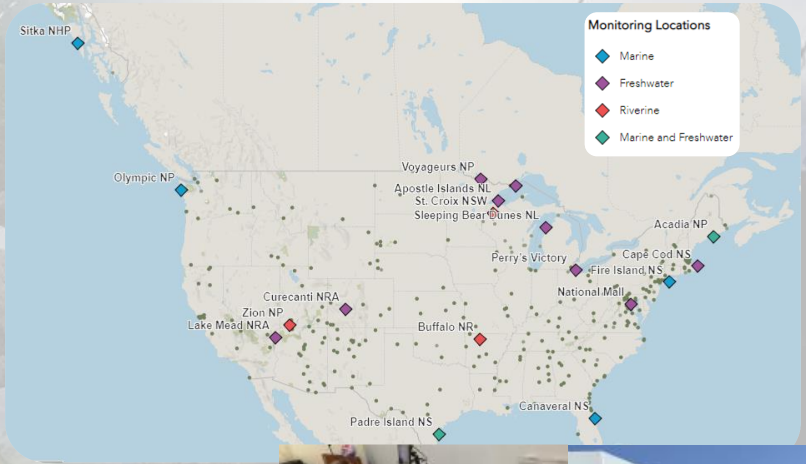
USGS-National Park Service Nationwide Harmful Algal Bloom Project

Objective: Develop a response strategy for potential toxin exposures from HABs in National Parks

Approach: A suite of monitoring methods implemented by parks in 2021 and 2022

Results will: Inform the development of a monitoring tool kit and rapid assessment protocols

Contacts: Jennifer Graham (jlgraham@usgs.gov)
Victoria Christensen (vglenn@usgs.gov)
Jamie Kilgo (jamie_kilgo@nps.gov)



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NATIONAL PARK SERVICE

Continuous Reservoir Profiling to Inform Drinking Water Management

Objective: Advance understanding of bloom formation and dynamics in drinking water reservoirs

Approach: Deploy continuous WQ profilers in reservoirs and downstream sites

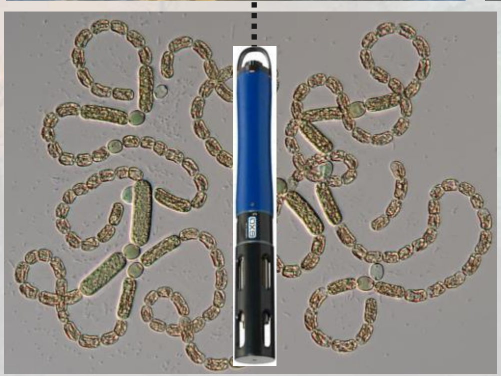
Results: Provide early warning for drinking water treatment and dam operations

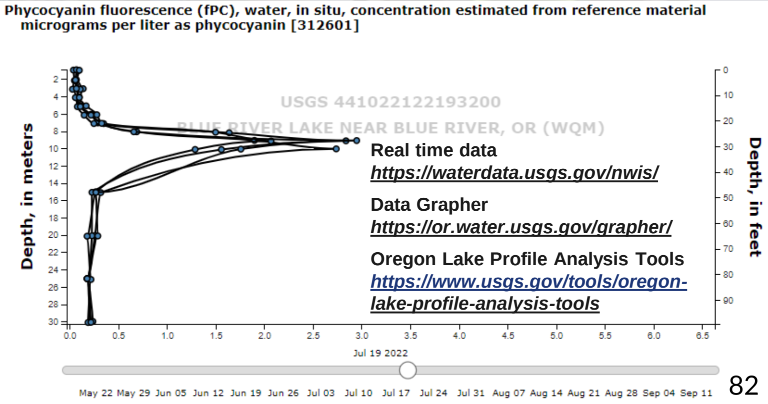
Cooperators: Drinking Water Utilities in Salem and Eugene, Oregon

Contact: Kurt Carpenter
OR Water Science Center kdcar@usgs.gov

Photo by David Weathers USGS

Photo by Chauncey Anderson USGS


Dolichospermum, Detroit Lake
Photo by Barry Rosen, USGS Emeritus



Real time data
https://waterdata.usgs.gov/nwis/

Data Grapher
https://or.water.usgs.gov/grapher/

Oregon Lake Profile Analysis Tools
https://www.usgs.gov/tools/oregon-lake-profile-analysis-tools

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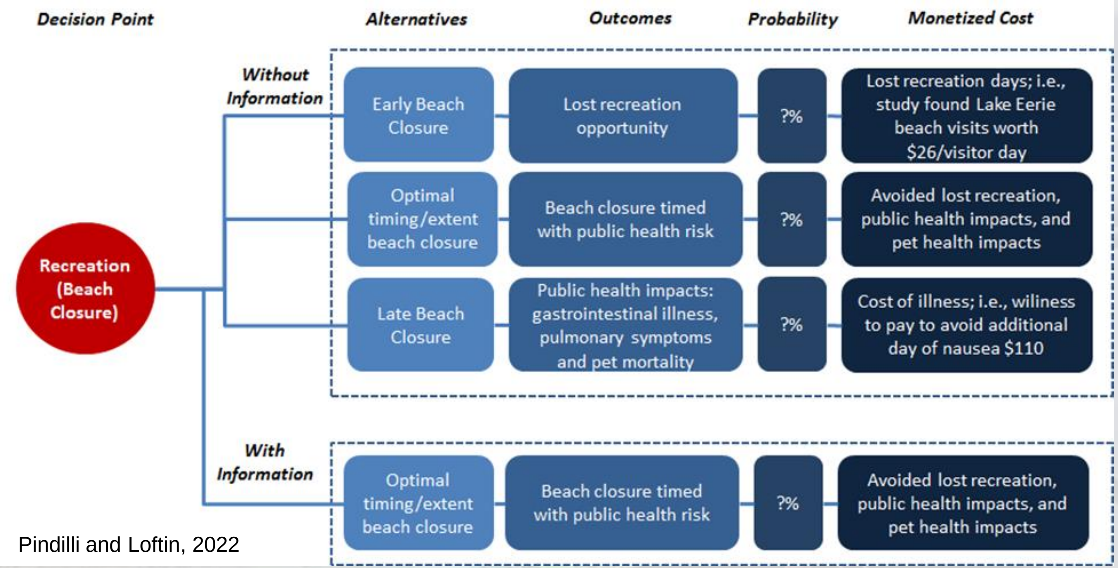
Value of CyanoHAB Early Warning System

Objective:
Estimate uses and value associated with CyanoHAB early warning system – recreation case study

Approach:
Quantify and monetize early or late beach closure impacts including human health and foregone recreation opportunities

See results here:



Pindilli and Loftin, 2022

Contact: Emily Pindilli (epindilli@usgs.gov)

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Valuation and Management of Toxic Harmful Algal Blooms at National Parks

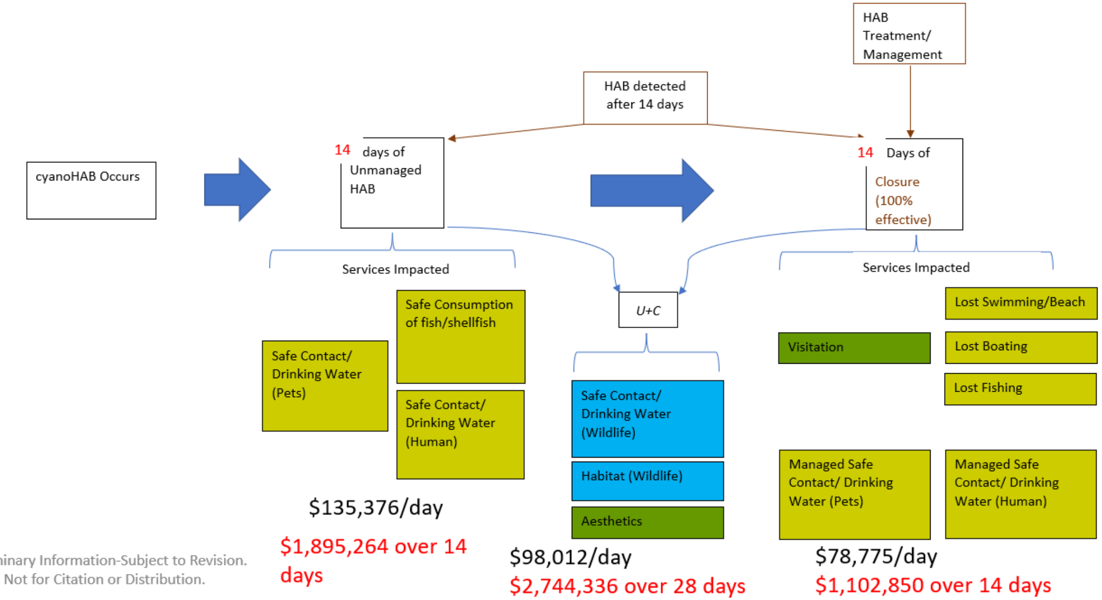
Objective:
Estimate lost recreation value to NP goers and inform dynamic management of toxic HABs

Approach:
Dynamic bioeconomic model exploring tradeoffs in intervention time and severity

Results will:
Quantify impacts and inform management tradeoffs around HABs at NPs

Contact: Ian Luby (iluby@usgs.gov)

Figure 2: Model for a Cyanobacteria Bloom at Sleeping Bear Dunes National Lakeshore



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Cyanobacterial Blooms, Loss of Recreational Opportunities, and Environmental Justice Areas in New York

Objective: To describe and quantify the impacts of cyanobacterial HABs through an environmental justice lens in New York State.

Approach: Geospatial analysis of existing data on beach closures due to cyanobacterial HABs will be compared to several metrics developed by New York State and the EPA to identify disadvantaged communities.

Results will: Enhance our understanding of the range of human impacts of Cyanobacterial HABs and provide foundational data to inform future environmental justice research.

Contact: Sabina Gifford (srgifford@usgs.gov)

Photo Credit: Sabina Gifford, USGS

USGS | New York State Parks, Recreation and Historic Preservation | New York State of Opportunity Department of Environmental Conservation

HAB Education and Outreach in Urban Settings

Objective: Train tomorrow's earth and environmental workforce and monitor small urban ponds and wetlands for HABs in middle Tennessee.

Approach: Earth science is the least diverse of all the STEM disciplines. The Lower Mississippi Gulf coast Water Science Center has a 25-year partnership with Tennessee State University to help develop students that participate in real-world environmental studies, such as HABs in Urban Ponds. Tenn Dept. of Environment and Conservation has joined the partnership to expand this monitoring program to many middle Tennessee surface waters. The monitoring includes SPATT samplers, water samples and field QW measurements.

Results will: These efforts will help to develop young scientists from diverse backgrounds through experiential learning. At the same time, it will give us a better understanding of urban HAB issues in middle Tennessee.

Contact: Tom Byl (tdbyl@usgs.gov)

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Photo Credits: Quest Agee and Tom Byl

For additional information or a copy of the presentation please contact:

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