EPA Region 9 Pre-meeting HABs Webinar presented in collaboration with California's Surface Water Ambient Monitoring Program (SWAMP)

April 5, 2017

Webinar Information

Date and Time: Wednesday, April 5, 2017; 9:00 AM – 1:00 PM (PDT)

This webinar will offer an overview of freshwater Harmful Algal Blooms (HABs) in drinking and recreational surface waters, including the causes of HABs, human and animal impacts and surveillance reporting, monitoring technologies, EPA regulatory guidelines, and nutrient dynamics that affect blooms. This webinar is in advance of the in-person HABs Meeting, April 25-27, 2017, in Cosa Mesa, California.

This webinar is open to all of our state, tribal, and federal partners, lake managers and water utilities. It will be presented via Adobe Connect. The final agenda is provided on the following page. The Adobe Connect and Call-in information will be provided to registered participants prior to the event.

Questions:

For additional information about logistics, please contact
Susan Keydel
US EPA Region 9
415-972-3106

keydel.susan@epa.gov

EPA Region 9 Pre-meeting HABs Webinar

April 5, 2017

Agenda

HABs Overview		
Time (PDT)	**Presentation Title**	**Presenter**
9:00 - 9:10 am	Welcome and Opening Remarks	Sue Keydel, U.S. EPA
9:10 - 9:50 am	Introduction to Harmful Cyanobacteria and Algae Blooms: Human Dimensions	Lorraine C. Backer, Centers for Disease Control and Prevention
9:50 - 10:20 am	Cyanotoxins in Freshwaters of the United States: Analytical Methods, Occurrence and Emerging Technologies	Keith Loftin and Guy Foster, U.S. Geological Survey
10:20 - 10:30 am	Break	
10:30 - 11:00 am	Guidelines and Regulatory Authorities for HABs	Lesley D'Anglada, U.S. EPA
11:00 - 11:30 am	Nutrients and HABs: Beyond the Classic Eutrophication Perspective	Christopher Gobler, Stony Brook University
11:30 am - 12:00 pm	Harmful Algal Blooms and Public Health Surveillance: The One Health Harmful Algal Bloom System (OHHABS)	Virginia Roberts, Centers for Disease Control and Prevention
12:00 - 12:30 pm	Development of Health-Based Action Levels for Recreational Exposures to Microcystins, Cylindrospermopsin and Anatoxin-a in California	Regina Linville, CA Office of Environmental Health Hazard Assessment
12:30 - 12:45 pm	Wrap Up & Overview of In-Person Meeting	Sue Keydel, U.S. EPA
12:45 pm	Adjourn	

EPA Region 9 Pre-meeting HABs Webinar

April 5, 2017

Biographies of Presenters

Dr. Lorraine Backer, MPH, is a Senior Scientist and Environmental Epidemiologist at the National Center for Environmental Health (NCEH), Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia. Dr. Backer created and led the Clean Water for Health Program for NCEH, which focused on the public health effects associated with drinking water from private wells, from 2007 to 2015. Dr. Backer has led CDC's HAB-related efforts since 1998, when *Pfiesteria piscicida* was found in the Chesapeake Bay, Maryland, USA. She collaborated with National Center for Emerging and Zoonotic Infectious Diseases (NCEZID) to create the One Health Harmful Algal Blooms System, a surveillance system designed to collect data on harmful algal bloom-related human and animal diseases as well as information about the blooms.
E-mail: lfb9@cdc.gov; Phone: 770-488-3426

Dr. Keith Loftin received his degrees from the University of Missouri-Rolla (now Missouri S&T) in Polymers and Coatings Chemistry, Environmental Engineering, and Civil Engineering with an Environmental Engineering Emphasis. He has worked as a Research Chemist for the U.S. Geological Survey's Organic Geochemistry Research Laboratory in Lawrence, Kansas, at the Kansas Water Science Center since 2004. He is the recipient of Rudolf Hering Medal (2002), an U.S. EPA Office of Water's Bronze Medal (2011), and an U.S. EPA Office of Water's Achievement in Science and Technology Award (2017). Dr. Loftin's research is generally focused on providing knowledge necessary to protect environmental health, economy, resources, and minimize exposures to environmental toxicants and infectious disease agents. Specifically, he has worked on analytical methods, occurrence, fate, transport, treatment, and effects of contaminants of emerging concern, pesticides, and harmful algal blooms at a national scale.
E-mail: kloftin@usgs.gov; Phone: 785-832-3543

Mr. Guy Foster has been a hydrologist with the U.S. Geological Survey in Lawrence, Kansas since 2009. He has also worked in the USGS Florida and Pacific Islands Water Science Centers. Mr. Foster's research is focused on novel application of water-quality sensor technology. He holds a BS in Oceanography from Hawaii Pacific University and an MS in Civil Engineering (Water Resources) from the University of Kansas.
Email: gfoster@usgs.gov; Phone: 785-832-3525

Dr. Lesley D'Anglada is a Senior Microbiologist with the United States Environmental Protection Agency (EPA). For the past nine years, Lesley has served as the Harmful Algal Blooms Lead for the Office of Science and Technology, Office of Water. Dr. D'Anglada is the manager of the EPA Drinking Water Health Advisories for Cyanotoxins and is the Office of Water representative on the Interagency Working Group for HABHRCA (Harmful Algal Blooms, Hypoxia, Research and Control Act). She has been a member of the World Health Organization's Water Quality and Health Technical Advisory Group (WQTAG) since 2010, an ex-officio member of the National HABs Committee since 2013, and co-editor of special issues of Toxins on HABs and Public Health since 2014. She received her Doctorate in

Public Health, Masters in Environmental Health and Bachelor Degree in Industrial Microbiology from the University of Puerto Rico.
E-mail: danglada.lesley@epa.gov; Phone: 202-566-1125

Dr. Christopher J. Gobler is a Professor within the School of Marine and Atmospheric Sciences (SoMAS) at Stony Brook University. He received his MS and PhD from Stony Brook University in the 1990s. He began his academic career at Long Island University (LIU) in 1999. In 2005, he joined Stony Brook University as the Director of Academic Programs for SoMAS on the Stony Brook – Southampton Campus. In 2014, he was appointed as the Associate Dean of Research at SoMAS and in 2015, he was named co-Director of the New York State Center for Clean Water Technology. In 2015, he was also named co-Editor of the international, peer-reviewed journal, *Harmful Algae*. In 2016, he was named the 40th most influential person on Long Island by the Long Island Press and was given the Environmental Champion Award by the U.S. EPA for his research efforts. The major research focus within his group is investigating how anthropogenic activities such as climate change, eutrophication, and the over-harvesting of fisheries alters the ecological functioning of coastal ecosystems. He has published more than 150 manuscripts in peer-reviewed journals on these topics.
E-mail: christopher.gobler@stonybrook.edu; Phone: 631-632-5043

Ms. Virginia Roberts is an Epidemiologist in the Waterborne Disease Prevention Branch, within the National Center for Emerging and Zoonotic Infectious Diseases at the CDC. She collaborates with state, territorial, and federal partners on waterborne disease outbreak surveillance, reporting, and prevention; manages surveillance activities for the One Health Harmful Algal Bloom System and the waterborne disease outbreak reporting module of the National Outbreak Reporting System; and coordinates a Great Lakes Restoration Initiative project designed to improve waterborne disease prevention capacity in Great Lake States. She received a joint MSPH in environmental and occupational health and epidemiology from Emory University in 2007.
E-mail: evl1@cdc.gov; Phone: 404-718-4871

Dr. Regina Linville is a toxicologist at the California Office of Environmental Health Hazard Assessment. She received her Bachelor's Degree in Environmental Sciences from UC Berkeley and her PhD in Ecology (with an emphasis in Ecotoxicology) from UC Davis. She works on human and ecological risk assessment of chemicals found in the environment, including cyanotoxins.
E-mail: regina.linville@oehha.ca.gov; Phone: 916-327-7336

Ms. Susan Keydel is a physical scientist with the U.S. EPA, in the Pacific Southwest (Region 9), Water Division. She currently serves as the EPA Region 9 technical coordinator for freshwater cyanoHAB issues, and as the EPA coordinator for California's Nonpoint Source Program and CWA 319 Grant. Previously, she worked on hazardous waste site remediation and risk assessment, as an EPA Region 9 Remedial Project Manager, at Massachusetts Department of Environmental Protection, and working for private contractors. Ms. Keydel has an MS in Agricultural and Environmental Chemistry and Toxicology from the University of CA – Davis, and a BA in Environmental Sciences from Hampshire College.
E-mail: keydel.susan@epa.gov; Phone: 415-972-3106

EPA Region 9 HABs Webinar and Meeting

Important Online Resources on HABs

This list is meant to provide important available resources to address HABs-related issues in support of the EPA Region 9 HABs Webinar on April 5, 2017, and Workshop on April 25-27, 2017. It is not a comprehensive list.

General Information

1. EPA's Cyanobacterial HABs Website
2. EPA's Cyanotoxins in Drinking Water Website
3. CDC Cyanobacteria and Algae Blooms Toolkit
4. National Oceanic and Atmospheric Administration (NOAA) HABs Webpage
5. Harmful Algal Bloom and Hypoxia Research and Control Act
6. Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water
7. NALMS Inland HAB Program
8. Public Meeting and Webinar Presentations: Cyanotoxins In Drinking Water
9. ASDWA HABs Website

Health and Ecological Effects

1. US EPA Health Effects Support Document for the Cyanobacterial Toxin Anatoxin-a
2. US EPA Health Effects Support Document for the Cyanobacterial Toxin Microcystins
3. US EPA Health Effects Support Document for the Cyanobacterial Toxin Cylindrospermopsin
4. Climate Change and Harmful Algal Blooms Fact Sheet
5. USEPA Health and Ecological Effects
6. USGS Slimy Summer Swimming: Harmful Algal Blooms in Lakes, Rivers and Streams Podcast
7. U.S.EPA Update on Development of Recreational Ambient Water Quality Criteria for Cyanotoxin

Monitoring

1. USGSs Guidelines for Design and Sampling for Cyanobacterial Toxin and Taste-and-Odor Studies in Lakes and Reservoirs
2. USEPA Cyanotoxin Detection
3. USGS Open-File Report 2015–1164: Field and laboratory guide to freshwater cyanobacteria harmful algal blooms for Native American and Alaska Native Communities.
4. Cyanobacteria Assessment Network (CyAN) Project
5. Summary of Cyanobacteria Monitoring and Assessments in USGS Water Science Centers
6. USEPA Method 544. Determination of Microcystins and Nodularin in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)

Monitoring
7. USEPA Method 545. Determination of Cylindrospermopsin and Anatoxin-a in Drinking Water by Liquid Chromatography Electrospray ionization Tandem Mass Spectrometry (LC/ESI-MS/MS)
8. USEPA Method 546. Determination of Total Microcystins and Nodularins in Drinking Water and Ambient Water by Adda Enzyme-Linked Immunosorbent Assay

HABs Guidelines
1. US EPA Drinking Water Health Advisory for the Cyanobacterial Toxin Cylindrospermopsin
2. US EPA Drinking Water Health Advisory for the Cyanobacterial Microcystins Toxins
3. WHO Cyanobacterial toxins: Microcystin-LR in Drinking-water
4. WHO Toxic cyanobacteria in water: A guide to their public health consequences, monitoring and management
5. WHO Guidelines for Safe Recreational Waters Volume 1 - Coastal and Fresh Waters

Management Strategy
1. EPA's Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water
2. CDC's Drinking Water Advisory Communication Toolbox
3. EPA's Drinking Water Cyanotoxin Risk Communication Toolbox
4. EPA's Water Treatment Optimization for Cyanotoxins
5. AWWA's Guidelines for Design and Sampling for Cyanobacterial Toxin and Taste-and-Odor Studies in Lakes and Reservoirs
6. AWWA's Assessment of Blue-Green Algal Toxins in Raw and Finished Drinking Water
7. AWWA's Optimizing Conventional Treatment for Removal of Cyanobacteria and Toxins
8. AWWA -Preparing for Cyanotoxins Events: Learning from Recent Utility and State Experiences Webinar; May 11, 2016
9. Record-breaking HABs in the U.S. in 2015
10. Possible funding sources for managing HABs and cyanotoxins in drinking water
11. NOAA Forecasting

State and Tribal HABs Program and Resources
1. USEPA List of State Resources
2. USEPA Region 9 Frequently Asked Question and Resources for HABs and Cyanobacterial Toxins
3. California Water Quality Monitoring Council HABs Webpage
4. California CyanoHAB Network (CCHAB)
5. California Harmful Algal Bloom Monitoring and Alert Program (CalHABMAP)
6. Hawaii State Department of Health Disease Outbreak Control Division: Stinging Seaweed Disease (Lyngbya)
7. Hawaii State Department of Health Disease Investigation Branch: Ciguatera Fish Poisoning

Please plan to join us for the EPA Region 9 HABs Meeting!

EPA will be holding an in-person Region 9 HABs Meeting on April 25-27, 2017.

Who: The intended audience of the HABs Meeting is state and tribal Clean Water Act (CWA) and Safe Drinking Water Act (SDWA) programs, lake managers, water utilities, U.S. EPA and other federal programs.

When: April 25, 26, and 27, 2017; Southern California Coastal Water Research Project, 3535 Harbor Boulevard, Suite 110, Costa Mesa, California

Objectives:

1. Learn about issues related to harmful algal blooms in freshwater and marine systems and share HABs-related goals, needs, tools and barriers, as they relate to HAB events response, monitoring, management, mitigation, and source water protection.
2. Identify short- and long-term next steps and key actions that federal, state, and tribal programs can take to address common HAB-related goals, needs, and barriers.
3. Build relationships among federal, state, and tribal Clean Water Act and Safe Drinking Water Act programs by making connections and identifying common goals.

Meeting Registration:

Please register for the EPA Region 9 HABs Meeting at the following EventBrite website:

- Meeting: https://www.eventbrite.com/e/us-epa-region-9-habs-meeting-registration-31422609872

At the meeting, each session will have discussions, and each day will offer networking opportunities.

If you cannot join us in-person, the full meeting will also be webcast. To participate remotely, please register and select the webinar option for each day you can participate.

EPA Region 9 HABs In-Person Meeting
Presented in collaboration with California's Surface Water Ambient Monitoring Program (SWAMP)

April 25 – 27, 2017

Draft Agenda

Day 1 – Tuesday, April 25, 2017

Marine and Coastal HABs		
Time (PDT)	**Presentation Title**	**Presenter**
12:00 - 1:00 pm	Registration	EPA
1:00 - 1:20 pm	Welcome and Opening Remarks	Sue Keydel, EPA, & Meredith Howard, SCCWRP
1:20 - 2:00 pm	Overview of Marine and Freshwater HABs - Droughts, Blooms, Warm Blobs, and Other Anomalies in the Eastern Pacific	Raphael Kudela, University of California, Santa Cruz
2:00 - 2:30 pm	Impacts of HABs on Fish and Shellfish Harvest	Vera Trainer, NOAA (presenting via Webinar)
2:30 - 3:00 pm	NOAA HABs Research and Infrastructure (ECOHAB, MERHAB and PCMHAB)	Marc Suddleson, NOAA
3:00 - 3:20 pm	Q&A and Open Discussion	
3:20 - 3:35 pm	Break	
3:35 - 4:05 pm	Forecasting HABs in the Coastal Zone: Are we there yet?	Clarissa Anderson, University of California, San Diego
4:05 - 4:35 pm	Remote Sensing and Forecasting Systems in Marine and Great Lakes	Richard Stumpf, NOAA
4:35 - 5:00 pm	Q&A and Open Discussion on Marine and Coastal Issues	EPA
5:00 pm	Overview of Day 2 and Adjourn	
5:00 pm	Networking Event, Location TBD	

Day 2 – Wednesday, April 26, 2017

Freshwater HABs Overview		
Time (PDT)	**Presentation Title**	**Speaker**
8:00 - 8:15 am	Registration	EPA
8:15 - 8:40 am	Introduction	EPA
8:40 - 9:10 am	The Ultimate Challenge: Mitigating harmful cyanobacterial blooms in a world experiencing human nutrient enrichment and climatic change	Hans Paerl, University of North Carolina
9:10 - 9:30 am	Temporal and Geographic Progression of *Prymnesium* (the 'Golden Alga') in the Southwestern United States	Dave Caron, University of Southern California
9:30 - 9:55 am	Q&A and Open Discussion	
9:55 - 10:10 am	Break	
States and Tribes HABs Experience and Efforts		
10:10 - 10:30 am	Utah's Efforts to Address Harmful Algal Blooms	Ben Holcomb, Utah Department of Environmental Quality
10:30 - 10:50 am	Washington's Anatoxin-a Experience	Joan Hardy, formerly with Washington Dept. of Health
10:50 - 11:20 am	Ohio EPA HAB Response and Lessons Learned	Heather Raymond, Ohio EPA (presenting via Webinar)
11:20 - 12:00 pm	Q&A and Facilitated Discussion – What is blooming and where – species, toxins, concentrations, locations	EPA facilitate
12:00 - 1:00 pm	Lunch	

Surface Water Blooms Monitoring		
1:00 - 1:20 pm	Guidelines for Design and Sampling of Cyanobacterial Toxin and Taste-and-Odor Studies	Jennifer Graham, U.S. Geological Survey (presenting via Webinar)
1:20 - 1:45 pm	Using Citizen Science to Monitor HABs	Jennifer Maucher, NOAA
1:45 - 2:05 pm	An Approach to Educating, Monitoring, and Managing Harmful Algal Blooms	Hilary Snook, U.S. EPA Region 1 (presenting via Webinar)
2:05 - 2:30 pm	Q&A and Facilitated Discussion on Surface Water Bloom Monitoring	EPA facilitate
2:30 - 2:45 pm	Break	

2:45 - 3:10 pm	Freshwater Harmful Algal Blooms in California and the Surface Water Ambient Monitoring Program's Statewide Assessment and Support Strategy	Katharine Carter, North Coast Regional Water Quality Control Board
3:10 - 3:40 pm	New HAB Monitoring and Assessment Techniques and Tools	Meredith Howard, Southern California Coastal Water Research Project
3:40 - 4:00 pm	Cyanobacteria and Citizens in the Eel River, Northern California	Keith Bouma-Gregson, University of California, Berkeley (presenting via Webinar)
4:00 - 4:20 pm	Applications of Remote Sensing & Satellite Data: Initial observations from 800 kilometers above California	Richard Stumpf, NOAA & Randy Turner, SFEI
4:20 - 4:50 pm	Q&A and Facilitated Discussion - Surface Water Bloom Monitoring	EPA facilitate
4:50 - 5:00 pm	Wrap-up and Adjourn	
5:00 pm	Networking Event, Location TBD	

Day 3 – Thursday, April 27, 2017

Management and Mitigation		
Time (PDT)	**Presentation Title**	**Speaker**
8:30 - 8:40 am	Welcome and Recap	EPA
8:40 - 8:50 am	Introduction to Management and Mitigation	SCCWRP
8:50 - 9:20 am	Waterbody Management Approaches for HABs	Mario Sengco, U.S. EPA
9:20 - 9:40 am	Application of DNA-based Tools for Algal Bloom Monitoring	Tim Otten, Bend Genetics, LLC
9:40 - 9:50 am	Q&A and Facilitated Discussion	
9:50 - 10:05 am	Break	
10:05 - 10:35 am	Managing Cyanobacteria in the East Bay Regional Park District	Hal MacLean, East Bay Regional District
10:35 - 10:55 am	From Green to Clean: Restoring Pinto Lake	Jackie McCloud, City of Watsonville, CA
10:55 - 11:15 am	One Size Does Not Fit All: Choosing an Appropriate Remediation and Management Approach for Water Quality	David Caron, University of Southern California
11:15 - 11:35 am	Permitting Requirements for Algae and Aquatic Weed Control	Philip Isorena, California State Water Resources Control Board
11:35 am - 12:00 pm	Open Discussion on Waterbody Management Approaches	SCCWRP facilitate
12:00 - 1:30 pm	Lunch – Optional working lunch on Cell ID with Microscopes	Jennifer Maucher, NOAA

Source Water Protection and Drinking Water Management		
1:30 - 1:40 pm	Introduction	EPA
1:40 - 2:10 pm	Preventing HABs at the Source: Tools and strategies for effective source water protection	Bo Williams, U.S. EPA
2:10 - 2:40 pm	U.S. EPA's Support Tools for Managing the Risks of Cyanotoxins in Drinking Water	Hannah Holsinger, U.S. EPA
2:40 - 2:55 pm	Break	
2:55 - 3:15 pm	Developing a Cyanotoxin Management Plan Case Study: Highlands Mutual Water Company	Amy Little, California State Water Resources Control Board
3:15 - 3:40 pm	HABs-Impacted Water Treatment in Full-Scale Practice: A comprehensive performance evaluation approach to optimization	Tom Waters, U.S. EPA (presenting via webinar)
3:40 - 4:30 pm	Open Discussion on Drinking Water Management and Source Water Protection	EPA facilitate
4:30 - 4:45 pm	Wrap up and closing thoughts	EPA and SCCWRP

(This page is intentionally blank.)

EPA Region 9 Pre-meeting HABs Webinar

April 5, 2017

Presentation Slides

(This page is intentionally blank.)

Introduction to Harmful Cyanobacterial and Algal Blooms: CDC's One Health Approach

Lorraine C. Backer

Senior Environmental Epidemiologist

EPA Region 9

April 5, 2017

National Center for Environmental Health

Division Name in this space

Harmful algal blooms

- What is a bloom?
  - A proliferation of microscopic and/or macroscopic algae in water
    - Supported by nutrients, warm water temperatures
- What makes a bloom harmful?
  - Bloom mass limits sunlight penetration
  - Bloom scenescence creates hypoxic conditions
    - Fish kills
    - Releases hydrogen sulfide
  - Bloom organisms may produce toxins
  - Substantial economic repercussions

Photo courtesy of Allan Wilson

Photo by Lorrie Backer

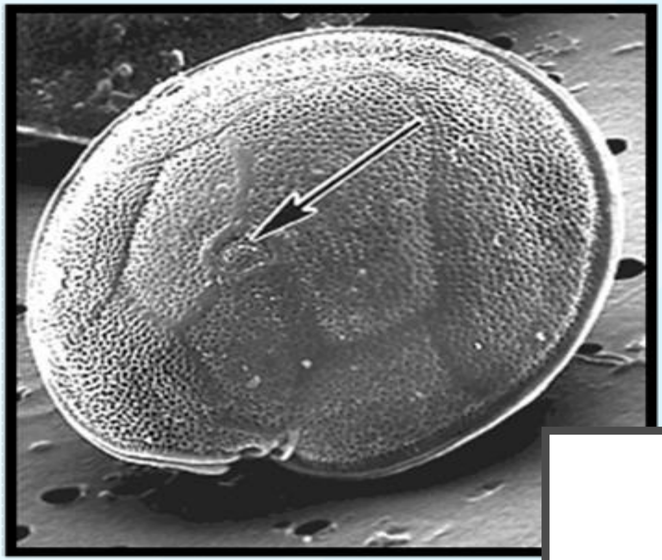
Copco Lake, California, Summer 2007. Photo by Lorrie Backer

Algal Toxins and Human Health: Marine Toxins

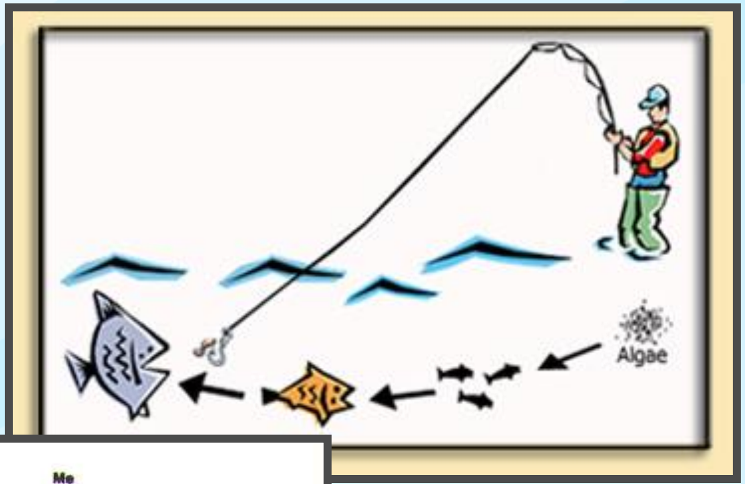
- Shellfish Poisonings
  - Diarrheic Shellfish Poisoning (DSP)
  - Neurotoxic Shellfish Poisoning (NSP)
  - Paralytic Shellfish Poisoning (PSP)
  - Amnesic Shellfish Poisoning (ASP)
- Ciguatera fish poisoning
- Fugu (Pufferfish) poisoning (tetrodotoxin)
- Pufferfish poisoning (saxitoxin)
- Respiratory illness (brevetoxins)

Ciguatera Fish Poisoning

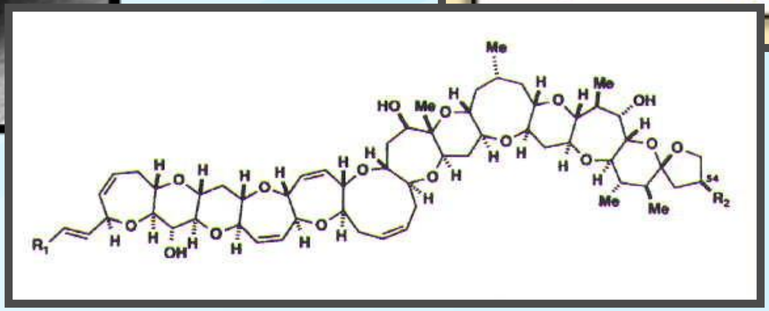
- Most common food poisoning associated with a non-infectious agent
- Most common food poisoning associated with eating finfish
- ~50,000 cases annually world wide, many more unreported



Gambierdiscus toxicus



Food web transfer



Ciguatoxin

Algal Toxins and Human Health: Cyanobacterial Toxins

- Skin rashes, allergic reactions
- Neurologic effects
- Liver damage
- Genotoxic
- Tumor promoting

What do we know about cyanobacterial toxins and health?

- Cyanotoxins are some of the most potent natural toxins known
  - Skin rashes, allergic reactions
  - Neurologic effects
  - Liver damage
  - Genotoxic
  - Tumor promoting
- Algal toxins can be in our drinking and recreational waters
- They can cause harm to animals, the local ecosystems, and sometimes to people

Cyanobacteria and cyanotoxins

Lyngbya wollei, Florida

Rash
Blistering
Respiratory irritation
Anaphylaxis (?)

Photo courtesy of Andy Reich

Microcystis aeruginosa, California

Microcystins measured on
nasal swabs after using the lake

Photo courtesy of Lorrie Backer

Algal Blooms from Summer 2016

Utah Lake, Utah, summer 2016.
Photo by permission, Rick Egan, The Salt Lake Tribune

Algal bloom in Lake Okeechobee, Palm Beach, Florida, summer 2016.
Photo by permission: Greg Lovett, The Palm Beach Post, via Associated Press

Cyanobacteria and cyanobacterial toxins: what are the important Public Health questions?

- Are people exposed to toxins when they use the lakes for recreation during algal blooms?
- What amounts of algal toxins in drinking and recreational waters do we need to worry about?

How can the public health community address HABS? One Health Approach

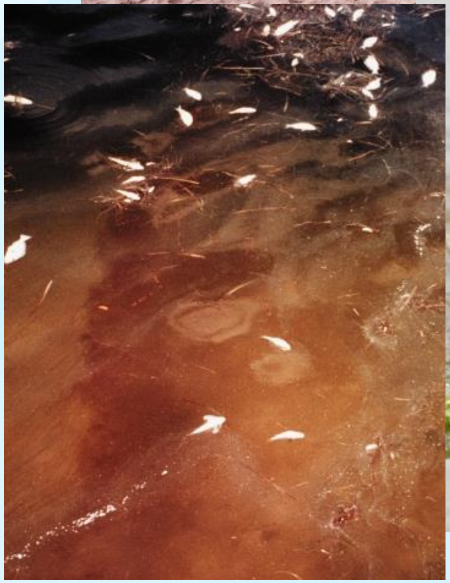
- The health of humans is connected to the health of animals and the environment.
- Animals share susceptibility to some diseases and environmental hazards such as HABs
  - Can serve as early warning signs of potential human illness.
  - Pet death may be indication of HAB toxicity
- Successful public health interventions require the cooperation of the human health, veterinary health, and environmental health communities.

- http://www.cdc.gov/onehealth/index.html

CDC's Activities

- Create effective risk communication strategies
- Assess community vulnerability
- Assess health effects
  - Disease surveillance
  - Animal sentinels
  - Epidemiology studies
  - Clinical assays
  - HAB tracking

Florida beach. Photo by Lorrie Backer

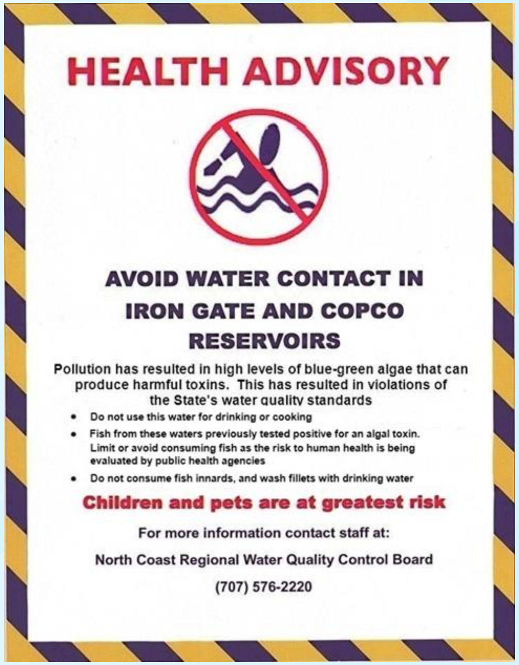


Florida Red Tide fish kill.
Photo by Lorrie Backer

Photo stock. Used with permission

Create effective communication strategies

- Supported state efforts



Public health response assistance

- Waterborne Disease Outbreak Investigation Tool Kit
  - https://www.cdc.gov/healthywater/emergency/preparedness-resources/drinking-water-outbreak-toolkit.html
  - Adding HABs component
- Freshwater HAB Tool Kit
  - http://www.cdc.gov/nceh/hsb/hab/hab_toolkit.htm

Veterinarian Reference

Blue-green Algae Blooms

When in doubt, it's best to stay out!

To report a blue-green algae bloom or related health event:

Call your local or state health department

For More Information:

Call the National Center for Environmental Health Harmful Algal Blooms Program (HABISS), Centers for Disease Control and Prevention: 866-556-0544

What are blue-green algae?

Cyanobacteria, sometimes called blue-green algae, are microscopic organisms that live in all types of water.

What is a blue-green algae bloom?

•Blue-green algae grow quickly, or bloom, when the water is warm, slow-moving, and full of nutrients.

What are some characteristics of blue-green algae blooms?

•Algae usually bloom during the summer and fall. However, they can bloom any time during the year.

•When a bloom occurs, scum might form on the water's surface.

•Blooms can be many different colors, from green or blue to red or brown.

•As the bloom dies off, you might smell an odor that is similar to rotting plants.

What is a toxic bloom?

Sometimes, blue-green algae produce toxins, such as microcystins.

•The toxins can be present in the algae or in the water.

Other important things to know:

•Swallowing water that has algae or algal toxins in it can cause serious illness.

•Dogs might have more severe symptoms than persons, including collapse and sudden death after swallowing the contaminated water while swimming or after licking algae from their fur.

•There are no known antidotes to these toxins. Medical care is supportive.

You cannot tell if a bloom is toxic by looking at it.

Exposure and Clinical Information

Information about the health effects from exposure to blue-green algae and toxins is derived from reports of animal poisonings.

Potential exposure route	Likely Symptoms and signs	Time to symptom onset**	Differential diagnosis includes the following	Possible laboratory or other findings
Swallowing water that is contaminated with blue-green algae (cyanobacteria) or toxins or licking it off fur or hair	**Hepatotoxins and nephrotoxins** Excess drooling, vomiting, diarrhea, foaming at mouth Jaundice, hepatomegaly Blood in urine or dark urine Malaise Stumbling Loss of appetite Photosensitization in recovering animals Abdominal tenderness	Minutes to hours	Acetaminophen or NSAID overdose, rodenticide ingestion, aflatoxicosis and other hepatotoxin poisonings	•Elevated bile acids, ALP, AST, GGT •Hyperkalemia •Hypoglycemia •Prolonged clotting tine •proteinuria •Presence of toxin in clinical specimens from stomach contents taken from animals that became ill
	Neurotoxins Progression of muscle twitches For saxitoxin, high doses may lead to respiratory paralysis and death if artificial ventilation is not provided.	Minutes to hours	Pesticide poisoning, myasthenia gravis, other toxin poisoning	Presence of toxin in clinical specimens from stomach contents taken from animals that became ill
Skin contact with water contaminated with blue-green algae or toxin(s)	**Dermal toxins** Rash, hives, allergic dermatitis	Minutes to hours	Other dermal allergens	Blue-green staining of fur or hair

Veterinarian Reference card (back)

Veterinarian Reference card (back)

Physician Reference

Blue-green Algae Blooms

When in doubt, it's best to stay out!

Grand Lake Saint Mary's , Summer 2010

To report a blue-green algae bloom or related health event:

Call your local or state health department

For more information:
http//www.cdc.gov/hab/links.htm
or
Call the National Center for Environmental Health Harmful Algal Blooms Program (HABISS) Centers for Disease Control and Prevention: 866-556-0544

What are blue-green algae?
Cyanobacteria, sometimes called blue-green algae, are microscopic organisms that live in all types of water.

What is a blue-green algae bloom?
•Blue-green algae grow quickly, or bloom, when the water is warm, slow-moving, and full of nutrients.

What are some characteristics of blue-green algae blooms?
•Algae usually bloom during the summer and fall. However, they can bloom anytime during the year.
•When a bloom occurs, scum might form on the water's surface.
•Blooms can be many different colors, from green or blue to red or brown.
•As the bloom dies off, you might smell an odor that is similar to rotting plants.

What is a toxic bloom?
Sometimes, blue-green algae produce toxins.
•The toxins can be present in the algae or in the water.

Other important things to know:
•Swallowing water that has algae or algal toxins in it can cause serious illness.
•Dogs might have more severe symptoms than persons, including collapse and sudden death after swallowing the contaminated water while swimming or after licking algae from their fur.
•There are no known antidotes to these toxins. Medical care is supportive.

You cannot tell if a bloom is toxic by looking at it.

What we know about exposure to blue-green algae and cyanotoxins and possible health effects

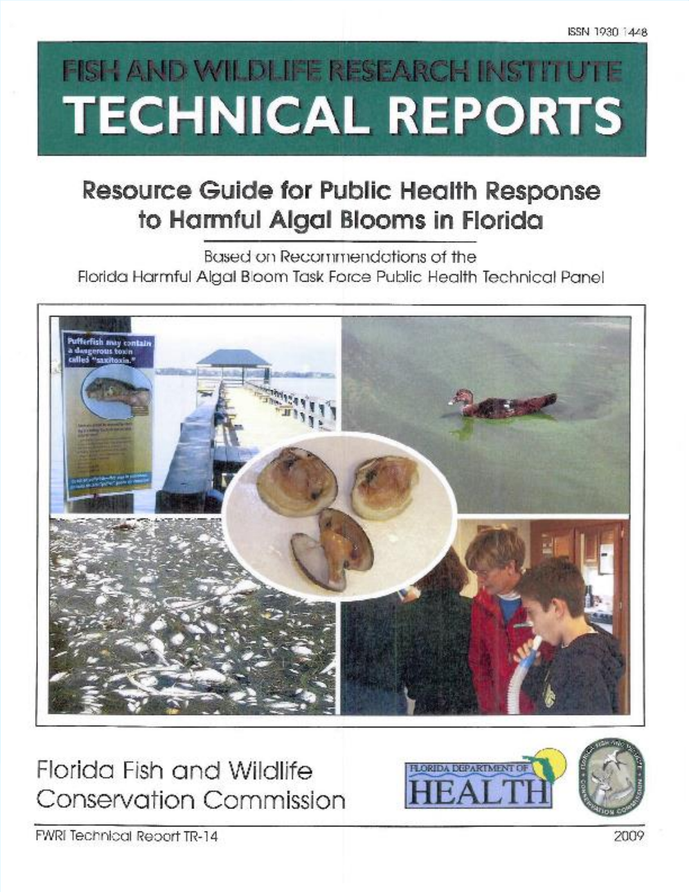
Information about human health effects from exposure to blue-green algae and toxins is primarily derived from a few epidemiology studies of recreational exposures; studies with laboratory animals; reports of extreme human exposure events, such as the use of toxin-contaminated dialysis water; and from animal (e.g., cattle and pet dog) exposures. References are available at: http//www.cdc.gov/hab/links.htm

Potential exposure route	Information source for possible symptoms and signs	Possible symptoms and signs
Swallowing water contaminated with blue-green algae (cyanobacteria) or toxins	Data from laboratory animal studies, extreme human exposure events, and animal exposures	**Hepatotoxins and nephrotoxins** Nausea, vomiting, diarrhea Bad taste in mouth Acute hepatitis, jaundice Blood in urine or dark urine Malaise, lethargic Headache, fever Loss of appetite **Neurotoxins** Progression of muscle twitches For saxitoxin: high doses may lead to progressive muscle paralysis
Skin contact with water that is contaminated with blue-green algae or toxins	Data from human studies	Allergic dermatitis (including rash, itching and blisters) Conjunctivitis
Inhaling aerosols contaminated with blue-green algae or toxins	Anecdotal evidence from human exposures and data from human studies	Upper respiratory irritation (wheezing, coughing, chest tightness, shortness of breath)

Physician Reference card (back)

Guidance for response

- Create response plans
  - Resource Guide for Public Health Response to Algal Blooms in Florida
    - http://myfwc.com/research/redtide/research/scientific-products/resource-guide/
- Create best practices for data collection
  - SWAMP (Surface Water Ambient Monitoring Program) in CA
    - Quality Control and Sample Handling Guidelines
    - http://www.waterboards.ca.gov/water_issues/programs/swamp/mqo.shtml



EPA Guidance for drinking and recreational waters (draft)

Cyanotoxin	Drinking Water Health Advisory (10-day)	
	Bottle-fed infants and pre-school children	School-age children and adults
Microsystins	0.3 µg/L	1.6 µg/L
Cylindrospermopsin	0.7 µg/L	3 µg/L

Draft recreational water guidance:

- Swimming advisory: not to be exceeded on any day
- Recreational criteria for waterbody impairment: not exceeded more than 10 % of days per recreational season up to 1 calendar year.

Microcytsins	Cylindrospermopsin
4 µg/L	8 µg/L

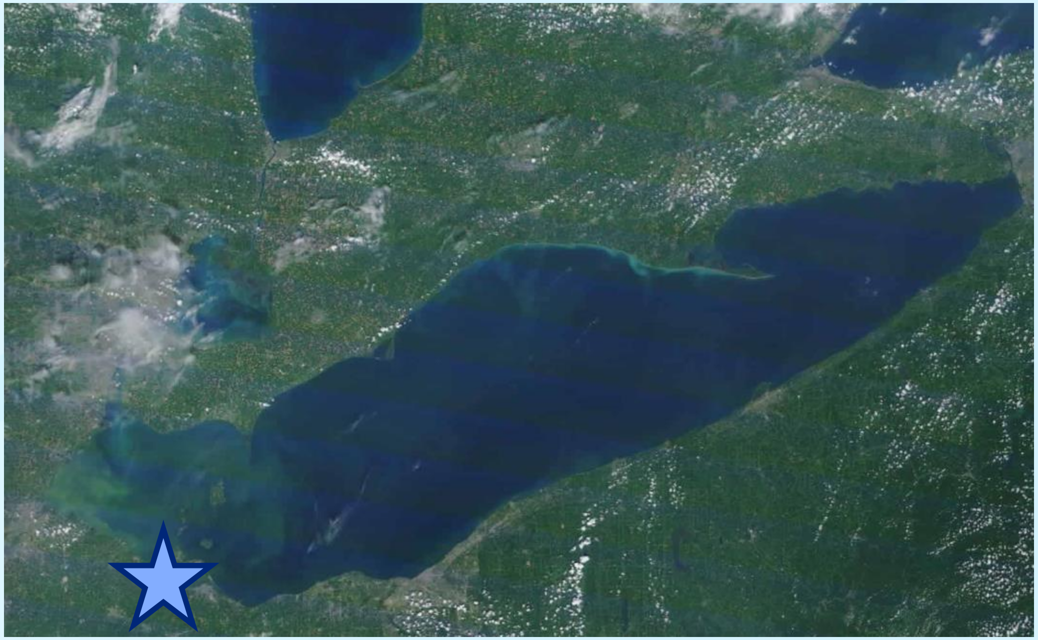
Assess community vulnerability: CASPER (Community Assessment for Public Health Emergency Response)

- Uses valid statistical methods to quickly gather information about health and basic needs
- Allows public health and emergency managers to prioritize their response and distribute resources accurately.
- Can be used to assess preparedness, response, and recovery

Centers for Disease Control and Prevention (CDC). Community Assessment for Public Health Emergency Response (CASPER) Toolkit: Second edition. Atlanta (GA): CDC; 2012.

CASPER example: HAB event affects Toledo drinking water source

- August 2014
  - *Microcystis* bloom in Lake Erie
  - Near Toledo’s water supply intake
  - Do Not Drink & Do Not Boil advisories for about 2 days



Satellite photo: MODIS 8-13-14

CASPER: September 11-15, 2014

- Contacted 314 households, 171 were surveyed
- Residents reported
  - Hearing about the advisory the day it was issued
    - Some used their water for bathing, washing hands, or for pets
  - Physical and mental health symptoms (e.g., GI, anxiety, stress)
    - Illnesses in pets
  - Use of alternative water sources at least the first day after advisory was lifted
- Conclusions
  - Focus educational efforts
    - Improve understanding of a drinking water advisory
    - Improve understanding that water is safe once the advisory is lifted

McCarty et al. 2016 Community needs assessment after microcystin toxin contamination of a municipal water supply – Lucas County, Ohio, September 2014. MMWR. 65(35):925-929.

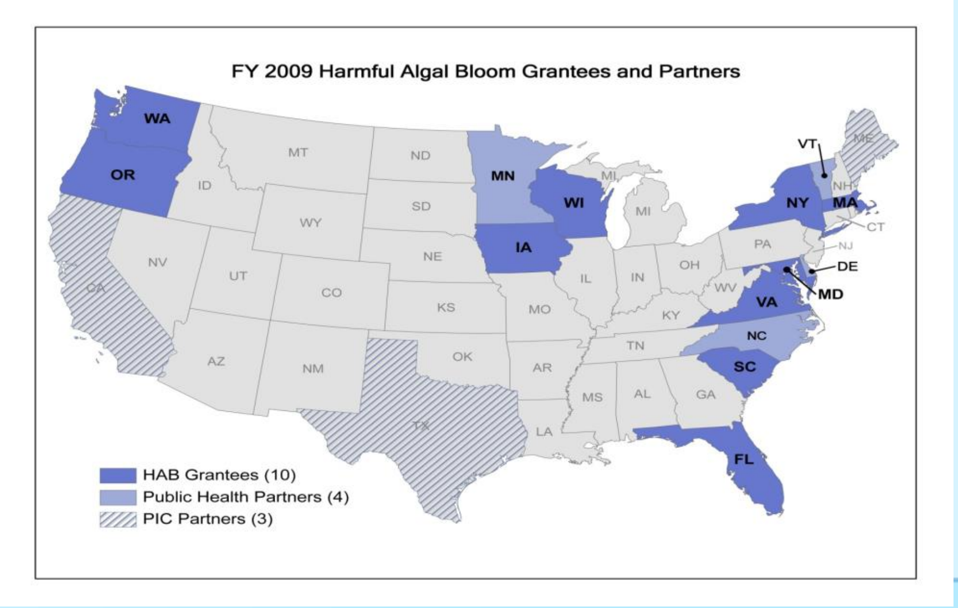
Public Health Surveillance

The ongoing, systematic collection, analysis, and interpretation of outcome-specific data for use in the planning, implementation, and evaluation of public health practice.

Teutsch and Churchill , Principles and Practice of Public Health Surveillance. 2000. Oxford University Press

Harmful Algal Bloom-related Illness Surveillance System (HABISS)

- CDC funded states through a cooperative agreement that closed in FY2013
- Enhanced One Health surveillance for HAB-related human and animal illnesses, HABs, data submitted to CDC
- At that time, no GL or US public health reporting system for single cases of illness associated with harmful algal bloom exposures.



HABISS FEATURES

- Collected and stored data on human health, animal health, and bloom characteristics in a single system
- Web-based, on the RDC platform
- Data managed with access
- Data accessible to partner states and CDC
- Funding discontinued in 2013

Photos by Lorrie Backer

Human HAB-related Illnesses Reported to HABISS (Jan 1, 2007 - Sept 10, 2009)

Illness Name	2007	2008	2009	Total
Ciguatera Fish Poisoning	33	46	30	109
HAB-related Rash (toxin unknown)	16	<5	14	31
HAB-related Illness (toxin unknown)	2	18	9	29
Saxitoxin Poisoning from Ingestion (PSP)	4	11	6	21
Microcystin Poisoning	0	<5	<5	5
Anatoxin-a Poisoning	0	0	<5	<5
Brevetoxin Poisoning NSP	<5	0	0	<5
Domoic Acid Poisoning from Ingestion (ASP)	0	0	<5	<5

Assess health effects: Animal sentinels

- Sea otters exposed to microcystins in Monterey Bay
- Birds exposed to surfactants in the Pacific Northwest
- Cattle deaths in Georgia from drinking water contaminated with microcystins
- …and our pets…

Photo by Lorrie Backer

Review of canine cyanotoxin poisonings in the US: 1920s to 2012 from three data sources

- Data sources
  - Harmful Algal Bloom-related Illness Surveillance System
  - Veterinary Medical Teaching Hospital (VMTH) necropsy and biopsy case records, University of California, Davis
  - Historical records from scientific publications, media, other electronically-available resources

Suspected or confirmed cases of canine cyanobacteria bloom-associated poisonings in the U.S.

Number reported	HABISS 2007-2011	Media Search Late 1920s to 2012	VMTH 1984-2011
Number of events/number of animals	55/63	115/260	44/45
Reported number of sick or dead dogs	63	260	45
Number (%) of cases where exposure biochemically confirmed	8 (13%)	20 (8%)	2 (4%)
Number (%) of cases published in the peer-reviewed literature	63 (100%)	62 (25%)	1 (2%)

Backer et al. Toxins 2013(5):1597-1628

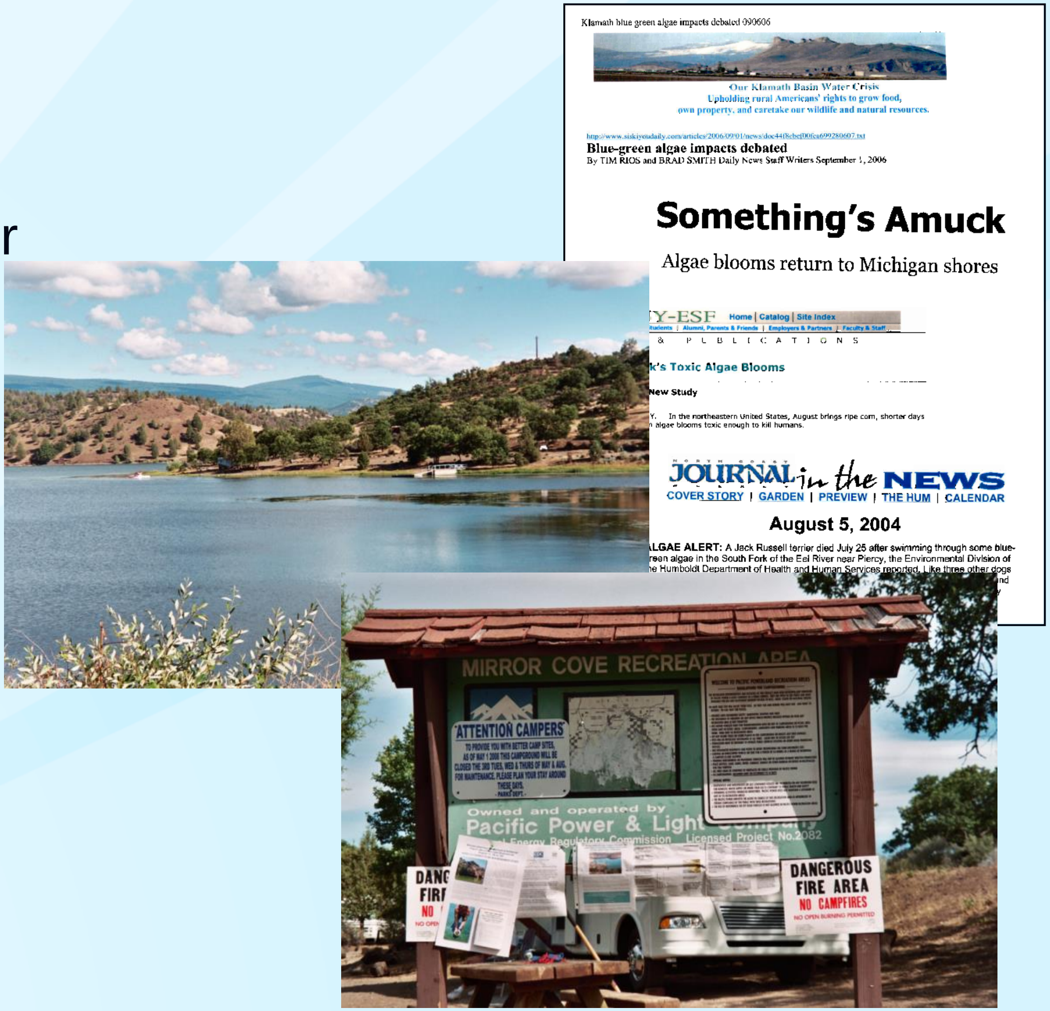
One Health Approach

- Enhance disease surveillance if veterinarians report to a public health system
- Use monitoring data for exposure assessment
- Expand experimental analytic methods to clinical testing
- Share data for diagnosis, treatment
- Provide feedback for ecologic research and monitoring

Assessing human health effects: epidemiology studies

Human exposures to cyanobacteria blooms during recreational activities

- Study locations
  - Michigan—Bear Lake
  - California—Klamath River reservoirs
- Exposure
  - Microcystins in blood samples and nasal swabs
  - Microcystins in air and water
- Health effects
  - Self-reported symptoms



Photos by Lorrie Backer

Collaborators

- National Center for Environmental Health, CDC
- National Center for Emerging Zoonotic and Infectious Diseases, CDC
- Mote Marine Laboratory
- Greenwater Laboratory
- Lovelace Respiratory Research Institute
- Wright State University
- Other Federal Agencies (NOAA)
- State and local public health agencies
- Officials or others at study site
- California Department of Health
- Siskiyou County
- Karuk Tribe
- Pacific Corporation

Photo by Lorrie Backer

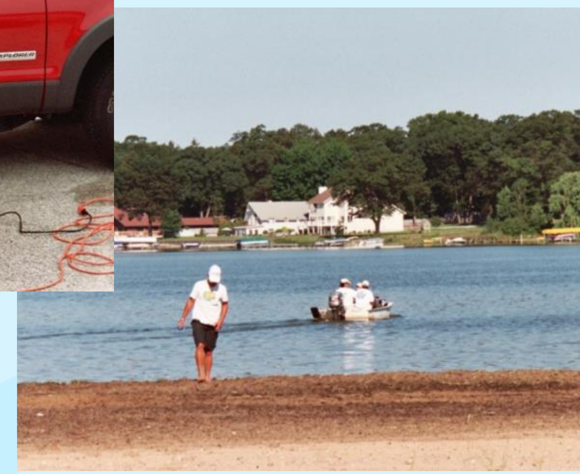
Epidemiology Study Design

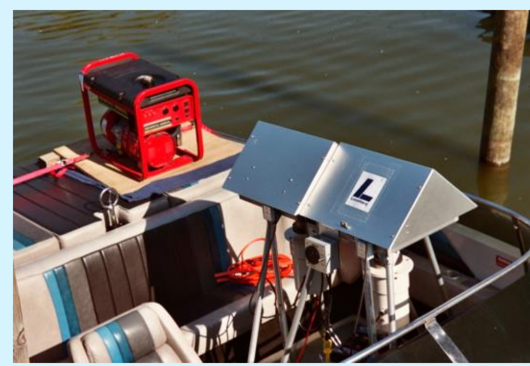
- Study population
  - Planning recreational activities in lake with a cyanobacteria bloom (exposed)
  - Planning recreational activities in lake with no cyanobacteria bloom (control)
- Compared data collected for exposed and control groups

Photos by Lorrie Backer

Environmental Data Collection

- Water samples
  - Viruses
  - Water quality
  - Algal taxonomy
  - Microcystins
- Ambient air samples
  - High-volume
    - Particle size
    - Mircocystins
- Personal air samples
  - Microcystins





Photos by Lorrie Backer

Health Data Collection

- Questionnaires
  - Pre-exposure
  - Post-exposure
  - Follow-up (7-10 days later)
- Post exposure plasma samples
  - Microcystins
- Nasal swabs
  - Microcystins

Photos by Lorrie Backer

Results

- Microcystins detected in lake water and air in both blooming lakes
- Microcystins not detected in blood samples
- No change in symptom reporting
- *Microcystins detected on nasal swabs*

Backer et al., Harmful Algae, 2003;41:1-10
Backer et al., Marine Drugs, 2008; 6 ISSN 1660-3397

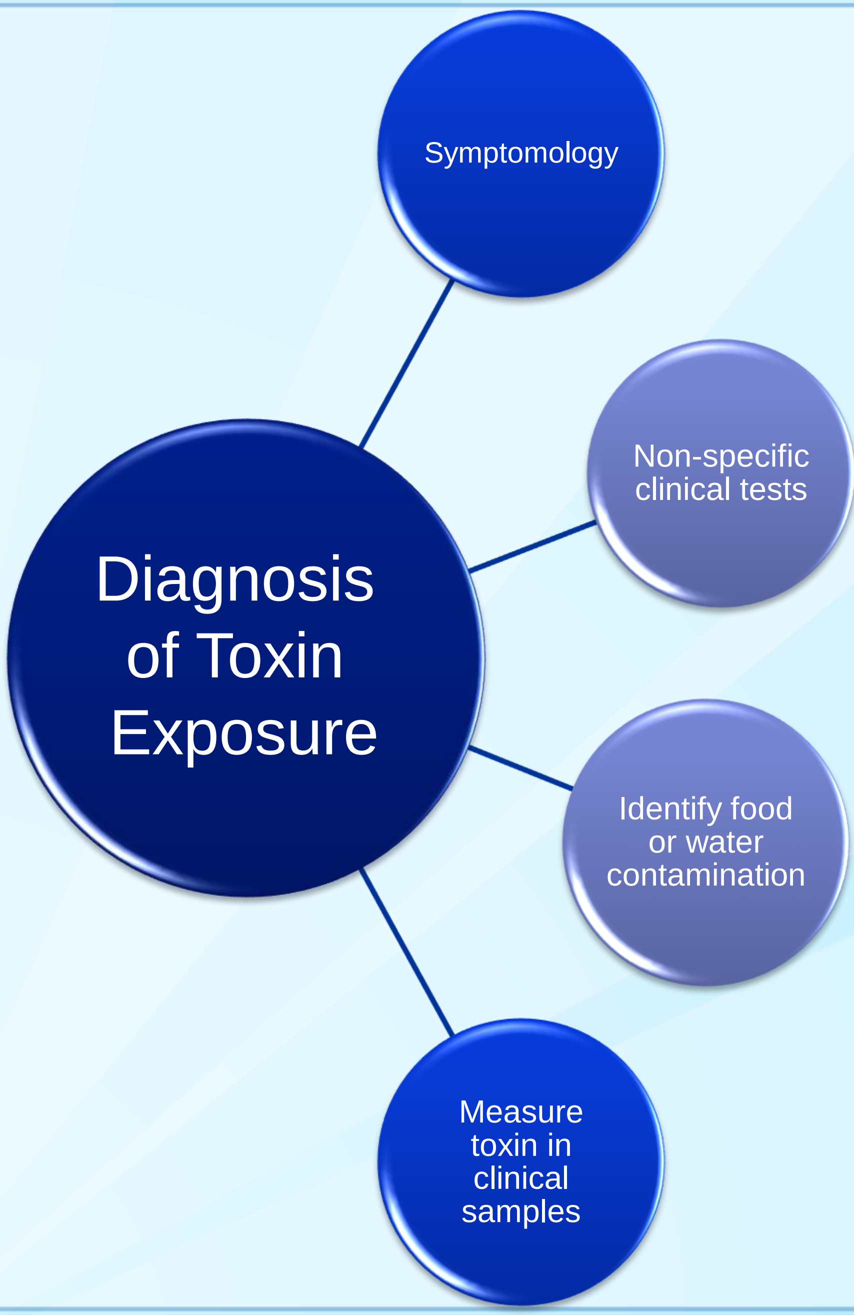
Photos by Lorrie Backer

Assess health effects: Clinical assays

Methods Development
Division of Laboratory Sciences
National Center for Environmental Health

Beth Hamelin

bhamelin@cdc.gov



Toxins measured in clinical samples at CDC

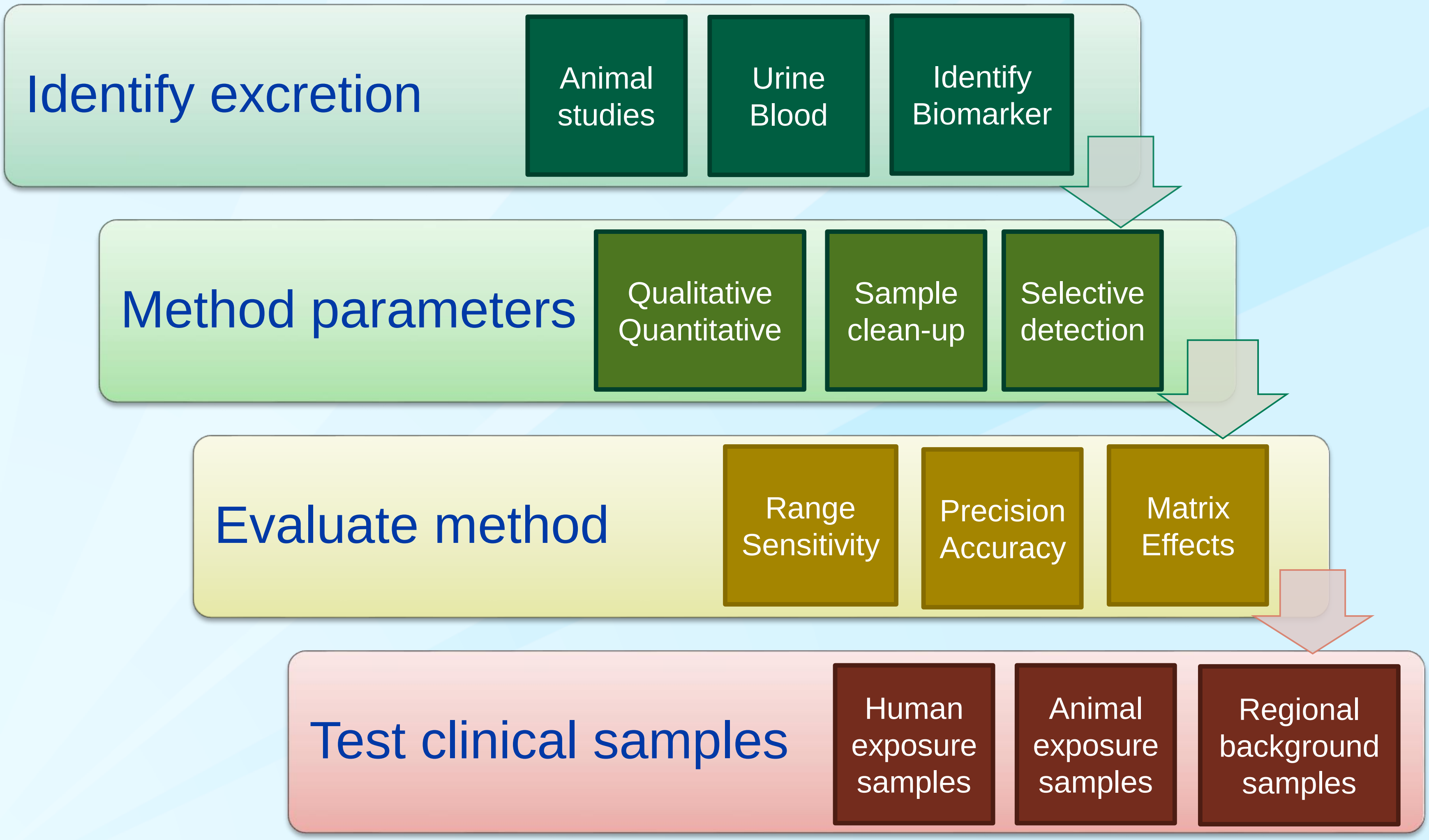
Current Capabilities

Saxitoxin
Neosaxitoxin
Gonyautoxins
Tetrodotoxin

In Development

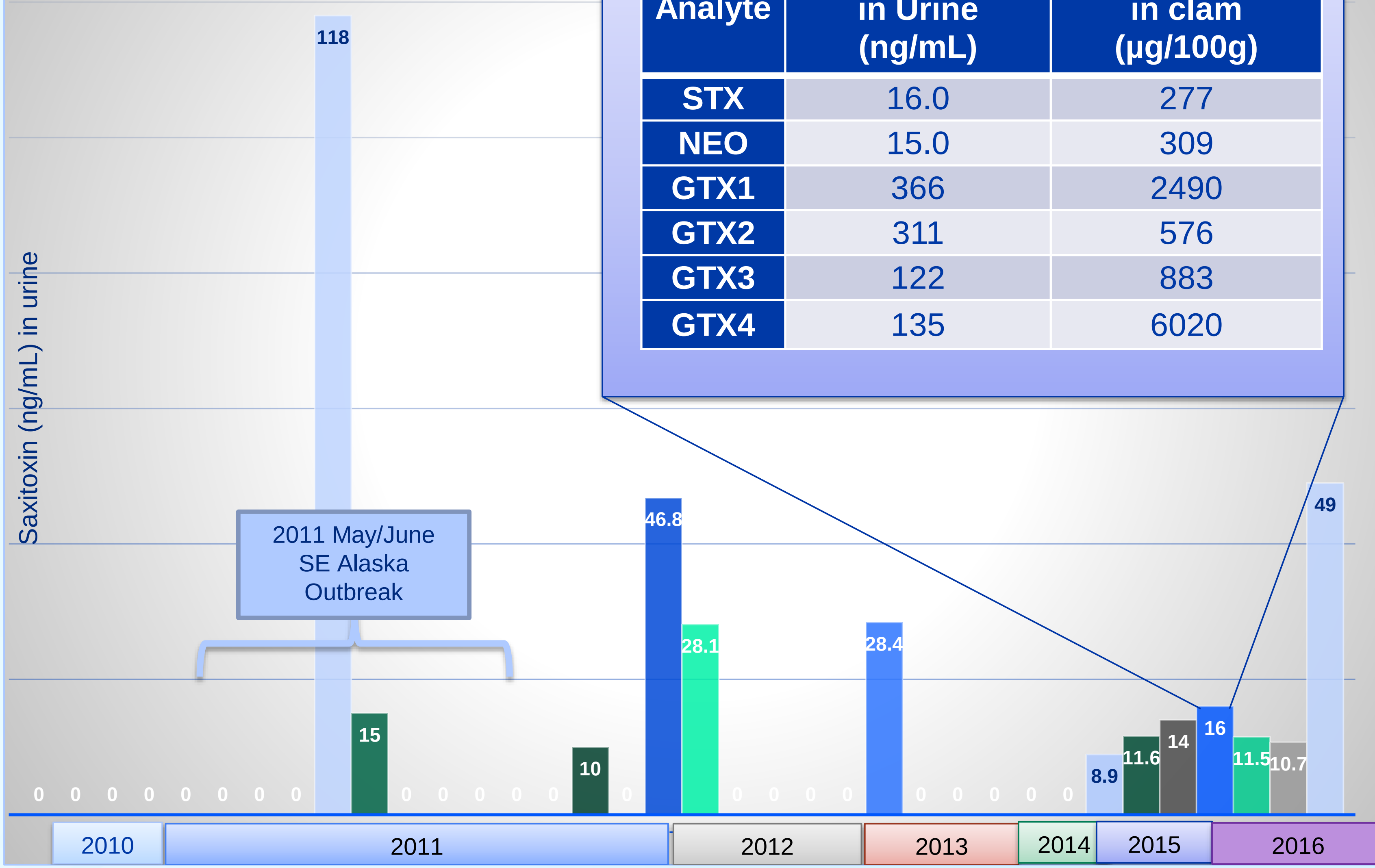
Microcystins
Domoic Acid

Development of Analytical Method to Detect Toxin Exposures



Suspected Human Expo

Saxitoxin Analysis in Urine



New capabilities 2016

Analyte	Concentration in Urine (ng/mL)	Concentration in clam (µg/100g)
STX	16.0	277
NEO	15.0	309
GTX1	366	2490
GTX2	311	576
GTX3	122	883
GTX4	135	6020

Assess health effects:
Environmental Public Health Tracking

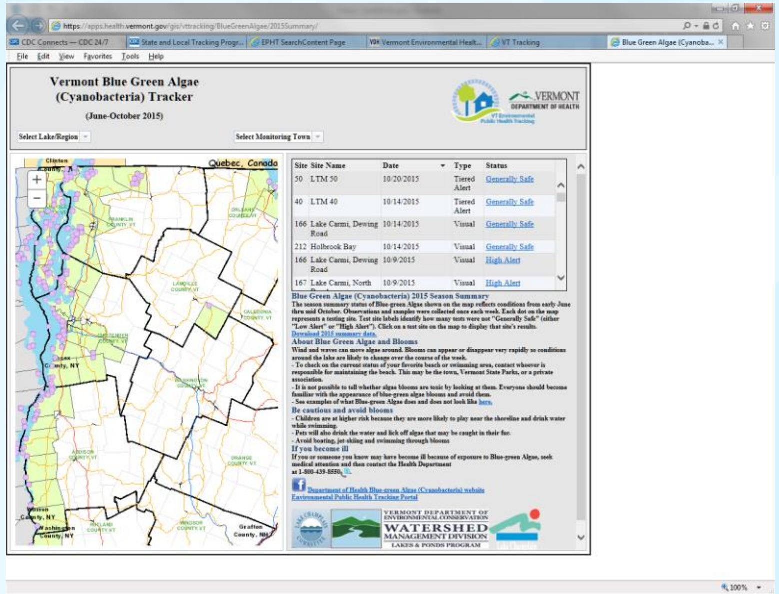
Tracking HAB Events

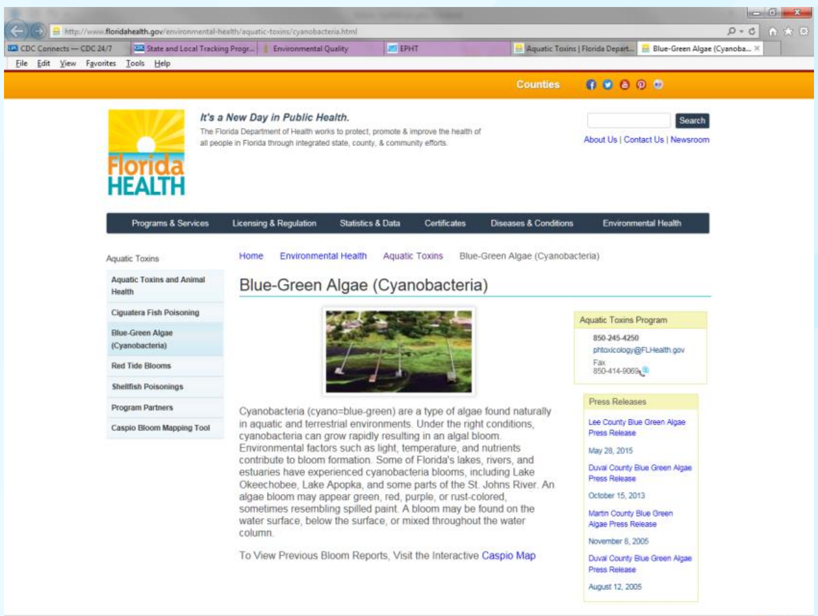
Michele Monti

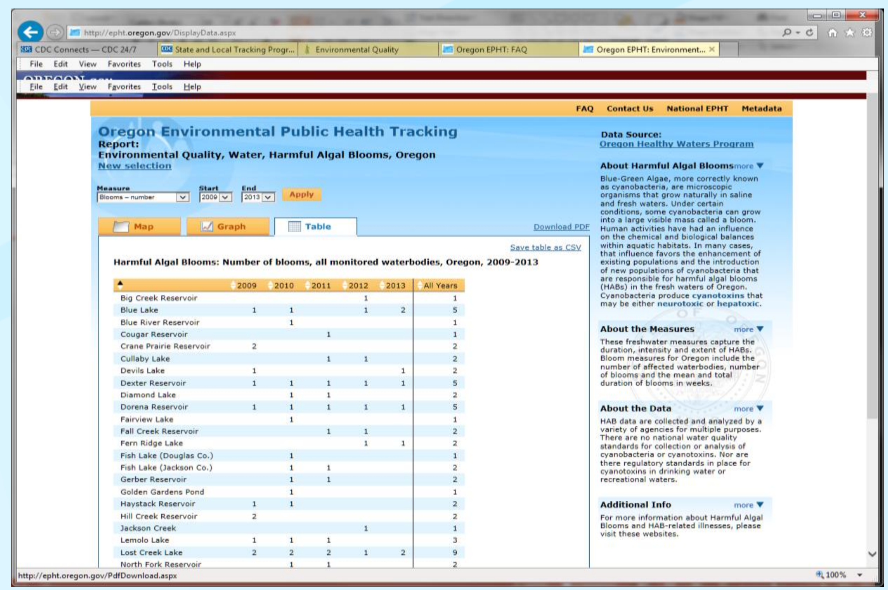
hjn8@cdc.gov

Tracking States and HABs Data

- Harmful Algal Bloom Task Force
  - Under Climate Change Subcommittee
  - Indicators and measures for marine and freshwater HABs
  - 10 states participating: FL, IA, KS, MA, MD, MI, OR, VT, WA, WI
- Completion of HAB recommendations on hold
  - EPA's efforts to create and publish draft criteria for microcystins and cylindrospermopsin for recreational water in 2016.
  - Work will resume once criteria are published.


Vermont Blue Green Algae
(Cyanobacteria) Tracker
(June-October 2015)
Select Lake/Region
Select Monitoring Town
VERMONT
DEPARTMENT OF HEALTH
WATERSHED
MANAGEMENT DIVISION

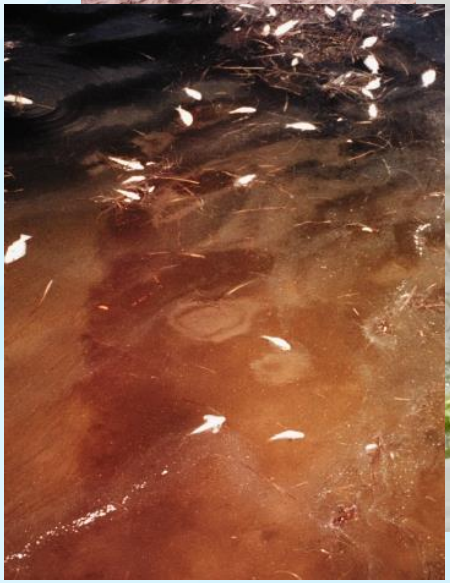

Counties
It's a New Day in Public Health.
Florida HEALTH
Programs & Services
Licensing & Regulation
Statistics & Data
Certificates
Diseases & Conditions
Environmental Health
Home
Environmental Health
Aquatic Toxins
Blue-Green Algae (Cyanobacteria)
Aquatic Toxins Program
Press Releases
To View Previous Bloom Reports, Visit the Interactive Caspio Map


Oregon Environmental Public Health Tracking
Report:
Environmental Quality, Water, Harmful Algal Blooms, Oregon
New selection
Map
Graph
Table
Harmful Algal Blooms: Number of blooms, all monitored waterbodies, Oregon, 2009-2013
Data Source:
Oregon Healthy Waters Program
About Harmful Algal Blooms
About the Measures
About the Data
Additional Info

CDC's Activities

- Create effective risk communication strategies
- Assess community vulnerability
- Assess health effects
  - Disease surveillance
  - Animal sentinels
  - Epidemiology studies
  - Clinical assays
  - HAB tracking

Florida beach. Photo by Lorrie Backer



Florida Red Tide fish kill.
Photo by Lorrie Backer

Photo stock. Used with permission

Thank you.

Contact information:

Lorraine C. Backer
lfb9@cdc.gov
770-488-3426

Cyanotoxins in Freshwaters of the United States: Occurrence and Emerging Technologies

Keith A. Loftin, Jennifer L. Graham, and Guy M. Foster
U.S. Geological Survey

EPA Region 9 HAB Workshop
April 5, 2017

Laboratory Measurement of Cyanotoxins

Each Step Effects the Final Result and What it Means!

Study Design and Sample Collection

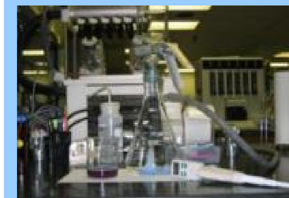




The Laboratory

Laboratory Processing

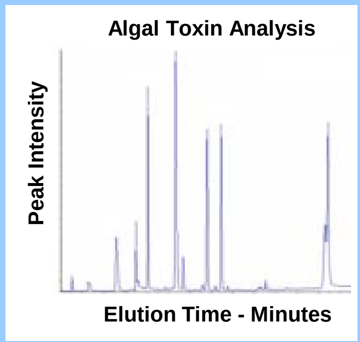




Analysis

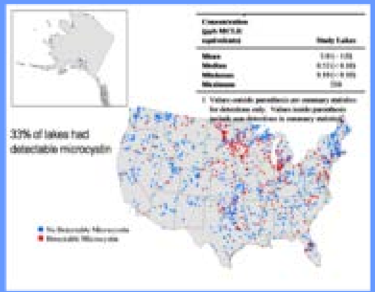


Data Reduction And Laboratory QA/QC



Study Results

Data Release, Interpretation And Project QA/QC



USGS
science for a changing world

So Many Methods... Which One Should We Use?

	Freshwater Cyanotoxins				
	Anatoxins	Cylindrospermopsins	Microcystins	Nodularins	Saxitoxins
Bioloigcal Assays (Class Specific Methods at Best):					
Mouse	Yes	Yes	Yes	Yes	Yes
PPIA	No	No	Yes	Yes	No
Neurochemical	Yes	No	No	No	Yes
ELISA	Yes	Yes	Yes	Yes	Yes
Chromatographic Methods (Compound Specific Methods):					
Gas Chromatography:					
GC/FID	Yes	No	No	No	No
GC/MS	Yes	No	No [1]	No	No
Liquid Chromatography:					
LC/UV (or HPLC)	Yes	Yes	Yes	Yes	Yes
LC/FL	Yes	No	No	No	Yes
Liquid chromatography combined with mass spectrometry can analyze cyanotoxins very specifically.					
LC/IT MS	Yes	Yes	Yes	Yes	Yes
LC/TOF MS	Yes	Yes	Yes	Yes	Yes
LC/MS	Yes	Yes	Yes	Yes	Yes
LC/MS/MS	Yes	Yes	Yes	Yes	Yes

1 MMPB method is used for total microcystins in some cases, especially for tissues.

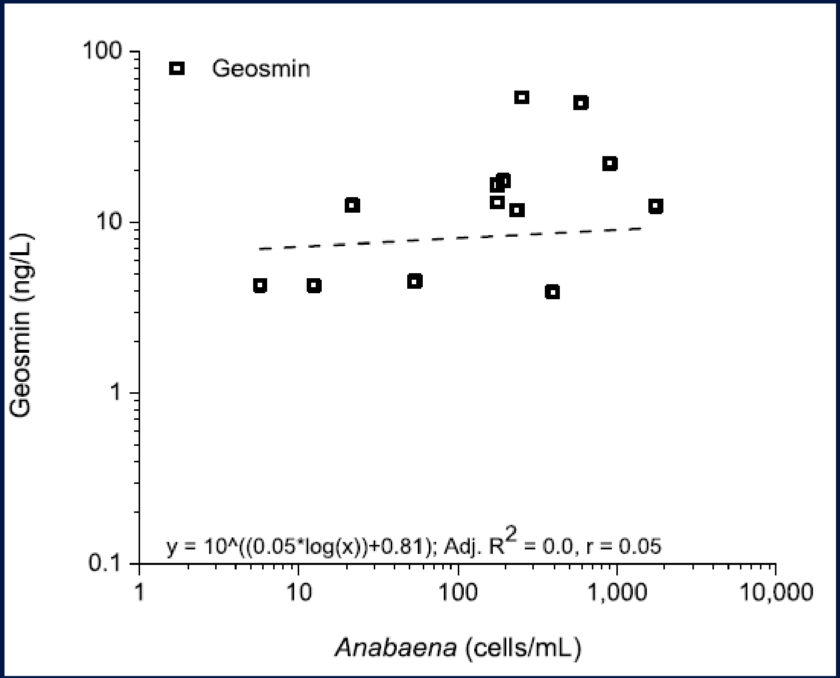
USGS
science for a changing world

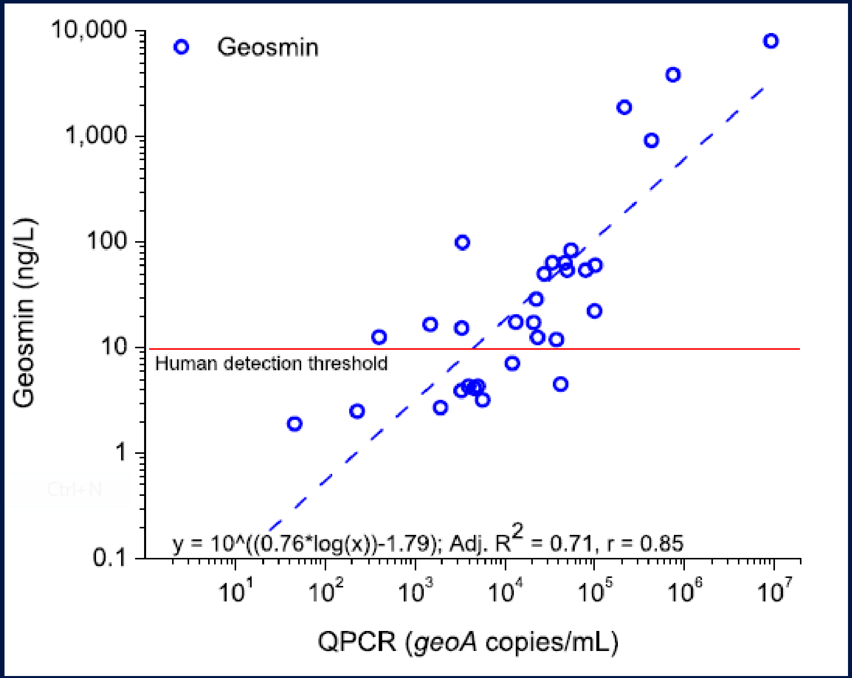
What Does Each Method Really Do For Me?

	Specificity
Biological Assays (Class Specific Methods at Best):	
Mouse	Non-specific, test must be rapid therefore endpoint usually death.
PPIA	Of the freshwater cyantoxins, only microcystins are known to inhibit protein phosphatase.
Neurochemical	Of the freshwater cyanotoxins, only anatoxins and saxitoxins are known to inhibit neurochemical processes.
ELISA	Compound and toxin class specificity dependent on antibody or mix of antibodies used.
Chromatographic Methods (Compound Specific Methods):	
Gas Chromatography:	
GC/FID	Only the anatoxins have been routinely measured. Derivitization is typically required.
GC/MS	Only the anatoxins have been routinely measured. Derivitization is typically required.
Liquid Chromatography:	
LC/UV (or HPLC)	Variable. Subject to interference with co-eluting matrix.
LC/FL	Variable. Subject to interference with co-eluting matrix.
Liquid chromatography combined with mass spectrometry can analyze cyanotoxins very specifically.	
LC/IT MS	Second in compound specificity only to LC/TOF MS.
LC/TOF MS	Accurate mass capability makes this technique the most specific.
LC/MS	Weaker cousin of LC/MS/MS. Fourth most specific.
LC/MS/MS	Third most specific technique routinely employed

USGS
science for a changing world

Genetic Data Improve Understanding of the Occurrence of Cyanobacteria and Associated Compounds

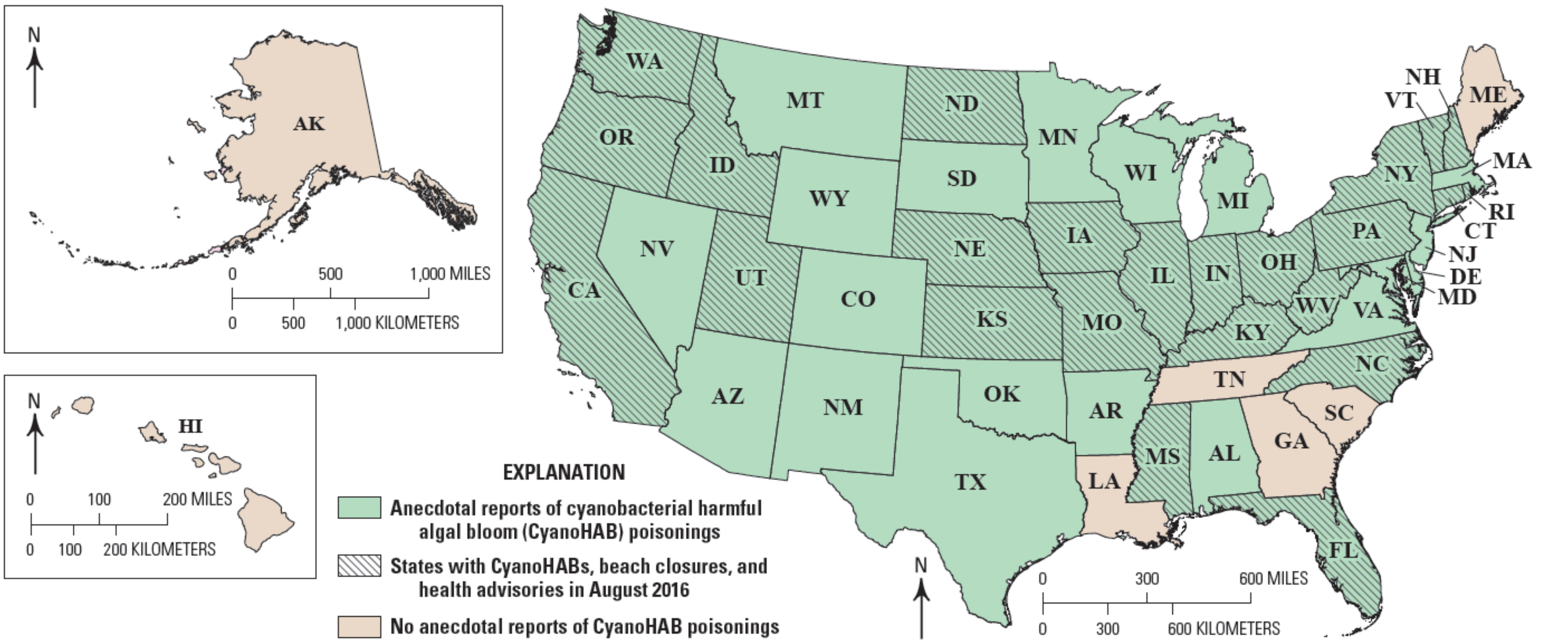




USGS
science for a changing world

Otten et al., 2016, Applied and Environmental Microbiology

In August 2016, At Least 19 States Had Beach Closures or Health Advisories

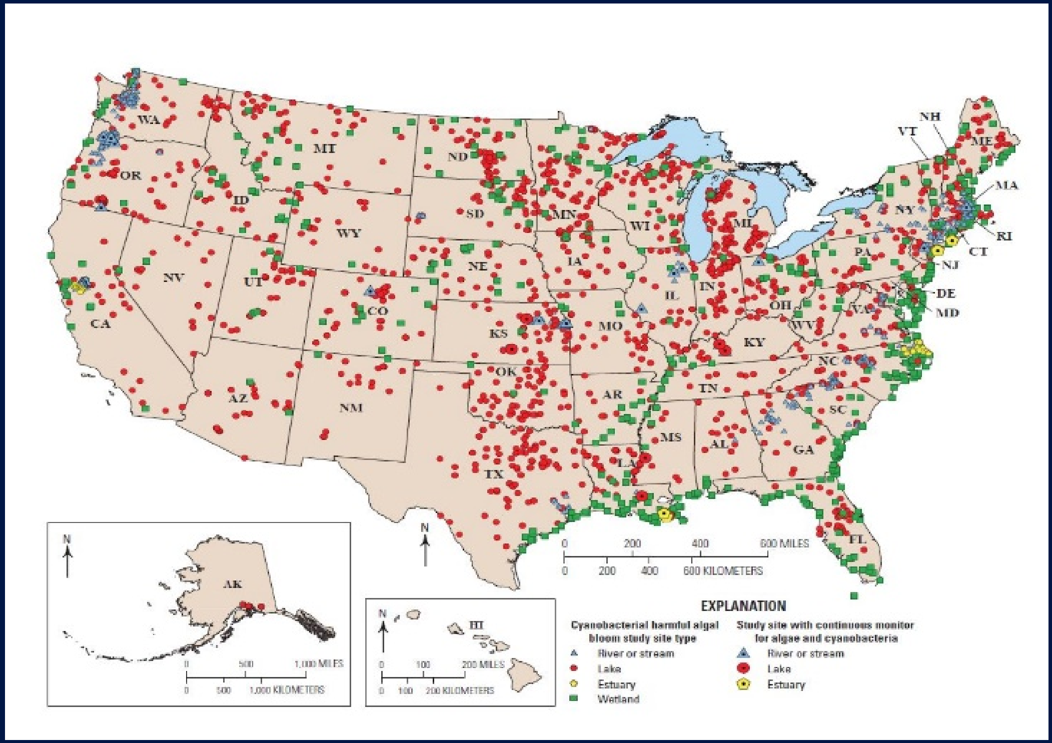


Graham and others, 2016, USGS OFR 2016-1174
http://dx.doi.org/10.3133/ofr20161174

USGS science for a changing world

Cyanotoxins Are Detected in All Types of Waterbodies Throughout the Nation

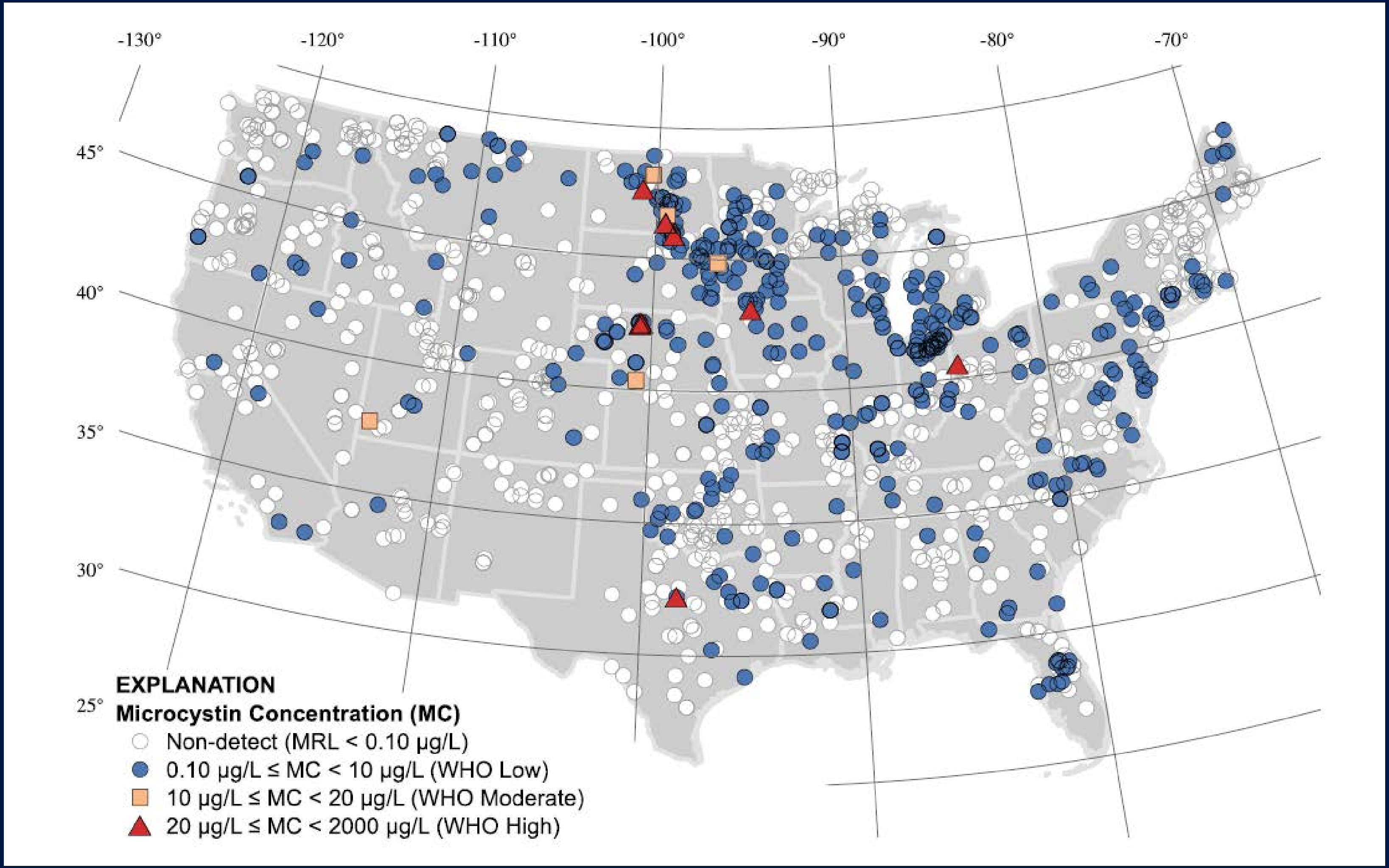
- Small Streams
- Lakes and Reservoirs
- Great Lakes
- Rivers
- Inland and Coastal Wetlands
- Estuaries



USGS
science for a changing world

Graham and others, 2016, USGS OFR 2016-1174
http://dx.doi.org/10.3133/ofr20161174

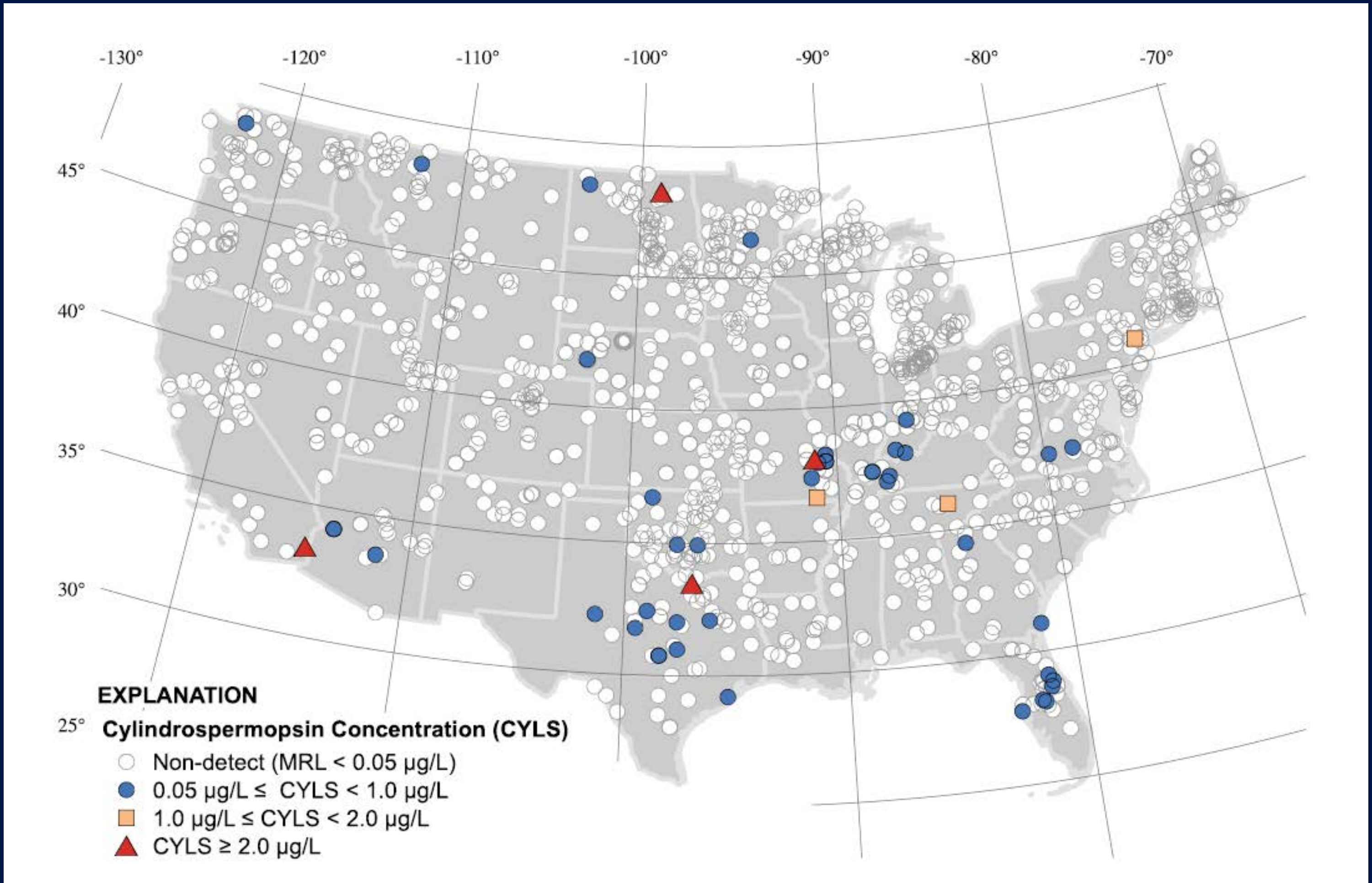
In the 2007 National Lakes Assessment, Microcystins Were Detected by ELISA in About 32% (n=1252) of Analyzed Samples



USGS
science for a changing world

Loftin and others, 2016, Harmful Algae
https://toxics.usgs.gov/highlights/2016-05-31-cyanotoxins_in_lakes.html

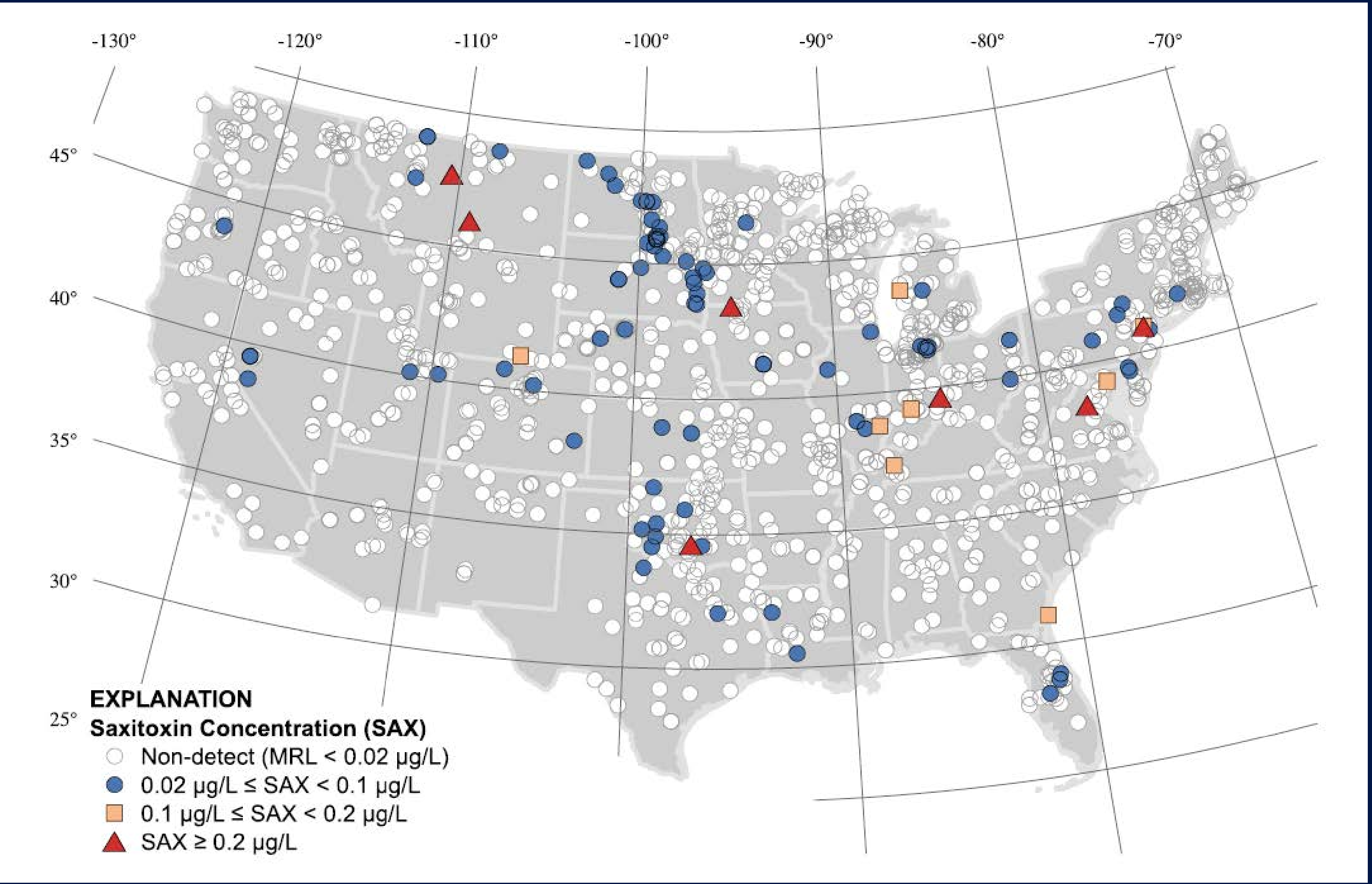
In the 2007 National Lakes Assessment, Cylindrospermopsins Were Detected by ELISA in About 4% (n=1252) of Analyzed Samples



USGS science for a changing world

Loftin and others, 2016, Harmful Algae
https://toxics.usgs.gov/highlights/2016-05-31-cyanotoxins_in_lakes.html

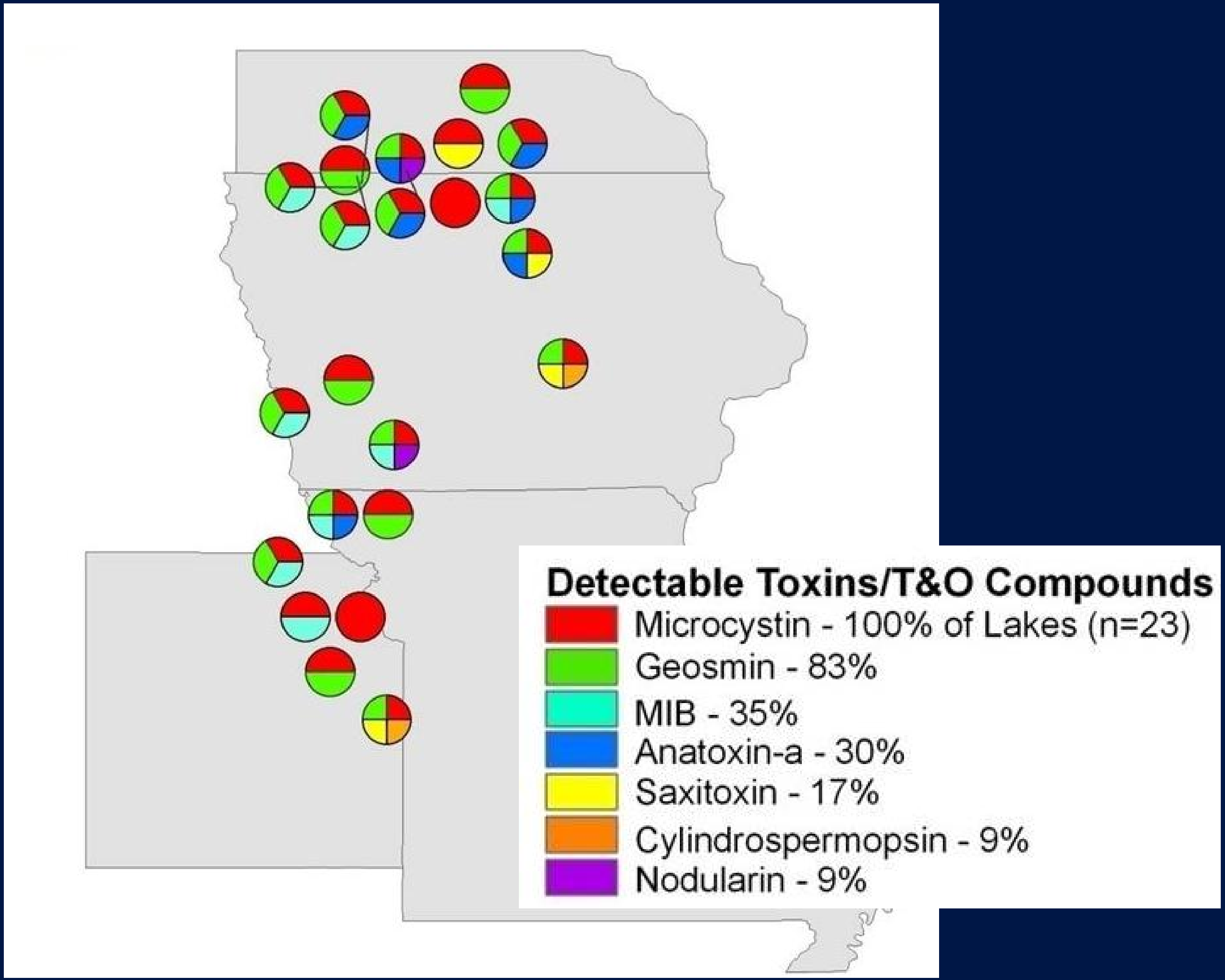
In the 2007 National Lakes Assessment, Saxitoxins Were Detected by ELISA in About 8% (n=678) of Analyzed Samples



USGS
science for a changing world

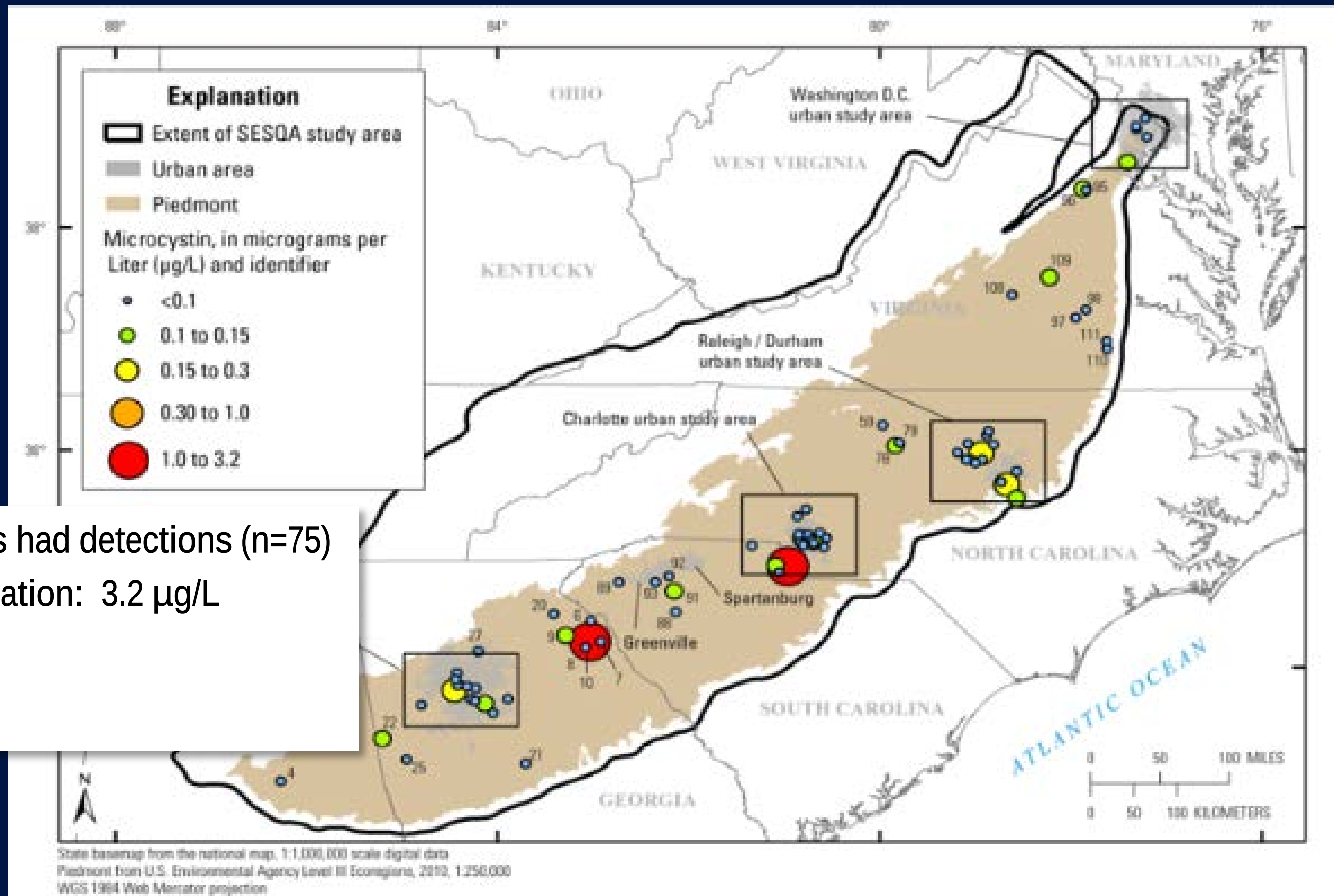
Loftin and others, 2016, Harmful Algae
https://toxics.usgs.gov/highlights/2016-05-31-cyanotoxins_in_lakes.html

Multiple Toxins and Taste-and-Odor Compounds Frequently Co-Occur in Cyanobacterial Blooms



Graham and others, 2010, ES&T

Microcystins Occurred in 39% of Small Stream Sites Sampled in the Southeastern United States



39% of stream sites had detections (n=75)

Maximum concentration: 3.2 µg/L

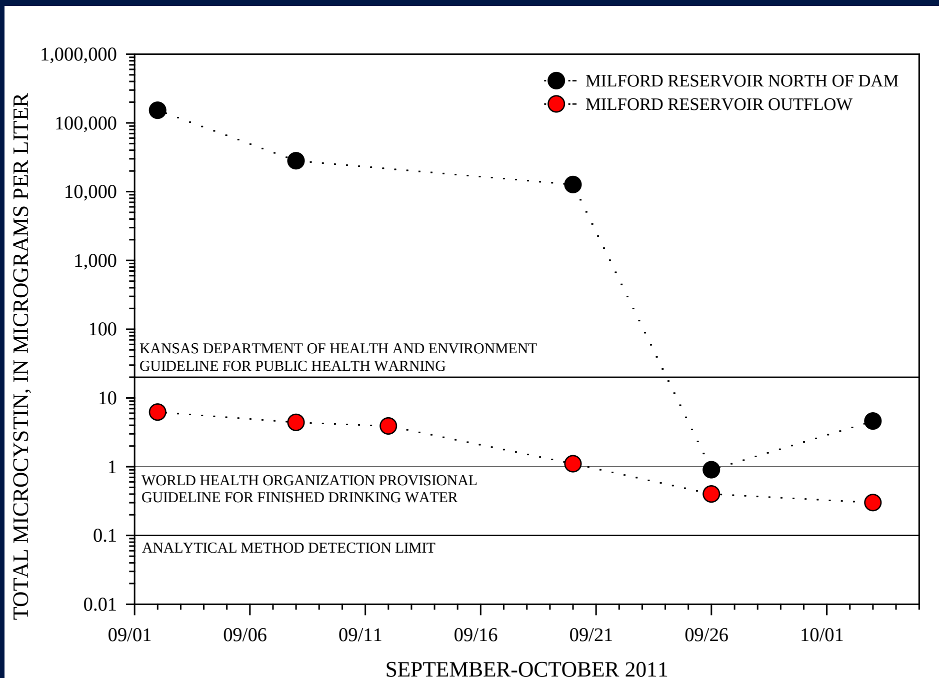
Median: 0.11 µg/L

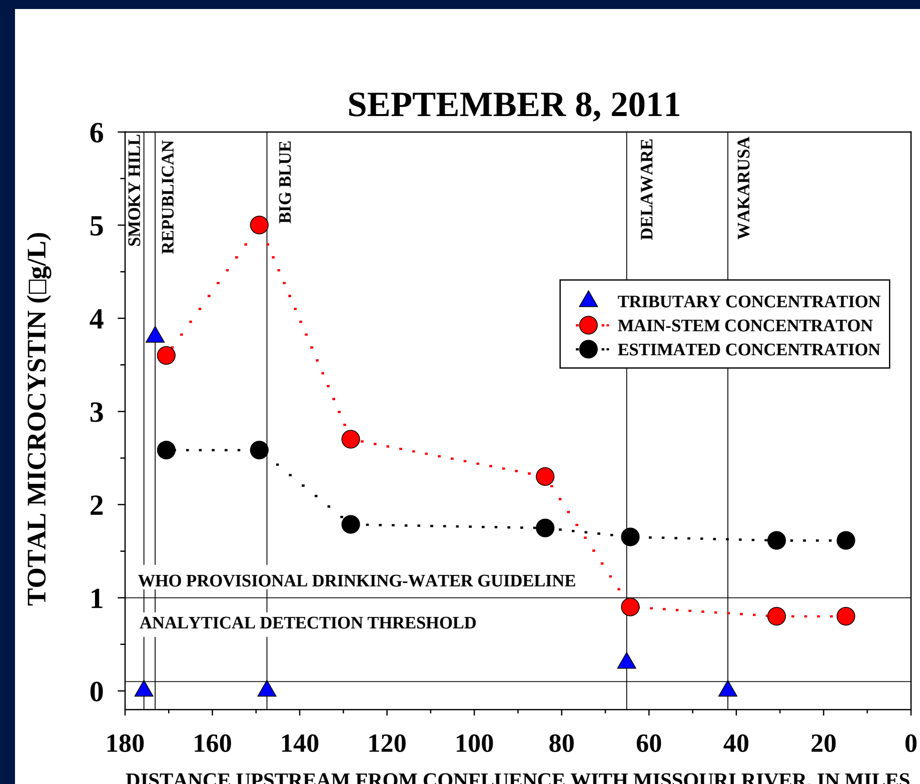
Mean: 0.29 µg/L

USGS science for a changing world

Loftin and others, 2016, Environmental Toxicology and Chemistry
https://toxics.usgs.gov/highlights/2016-02-17-algal_toxins_in_streams.html

Cyanobacteria and Associated Compounds May Be Transported for Relatively Long Distances Downstream from Lakes and Reservoirs

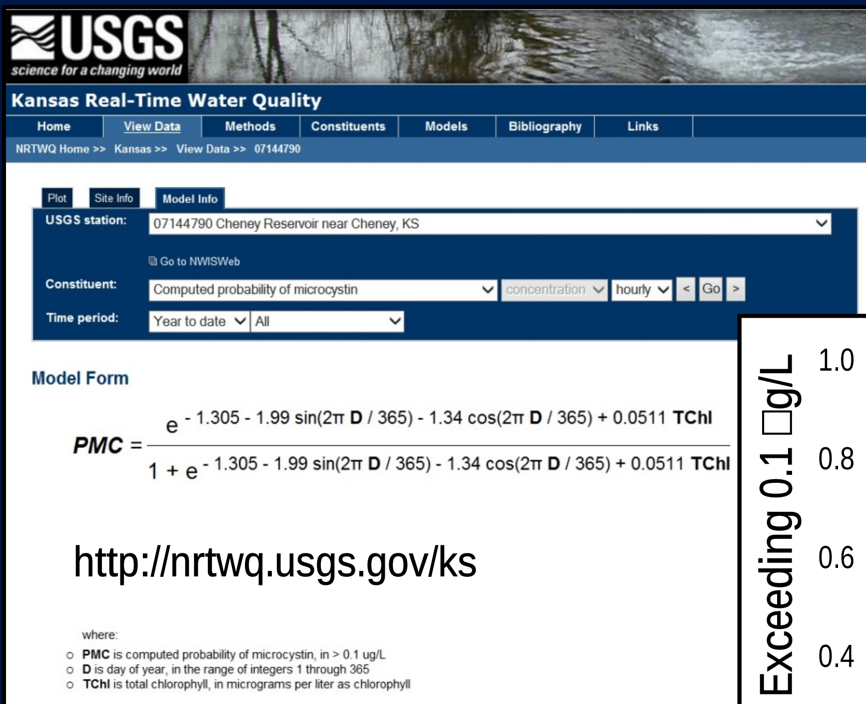


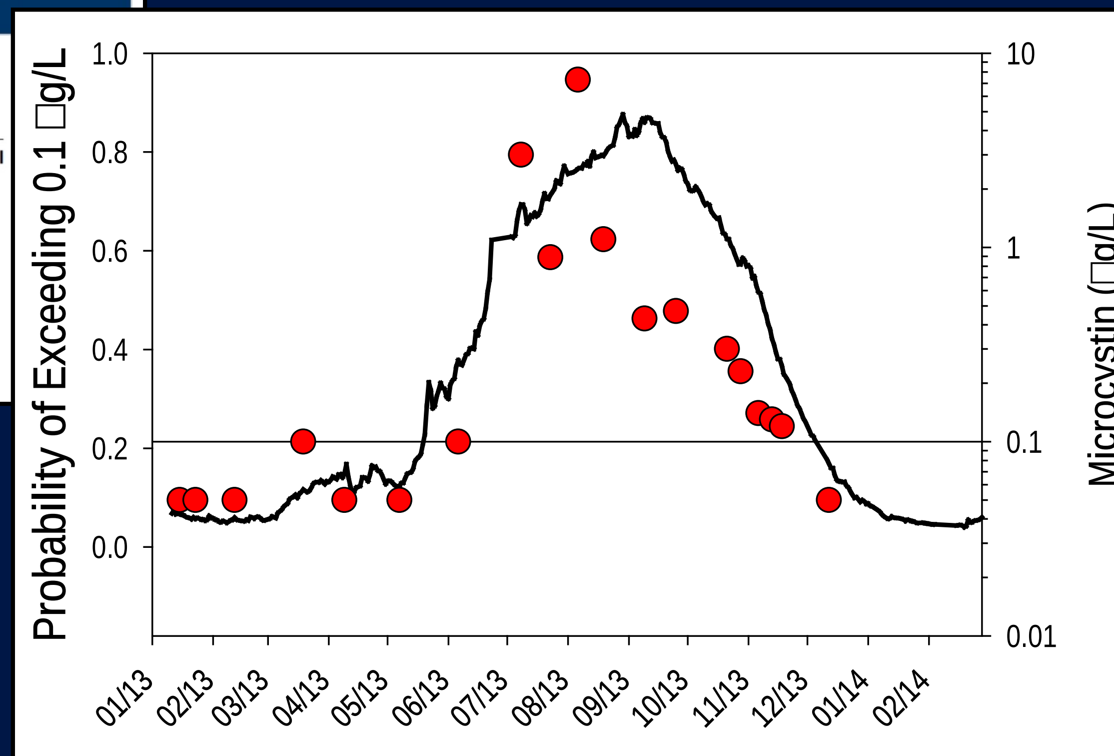


USGS
science for a changing world

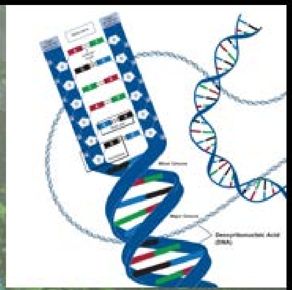
Graham and others, 2012, USGS SIR 2012-5129

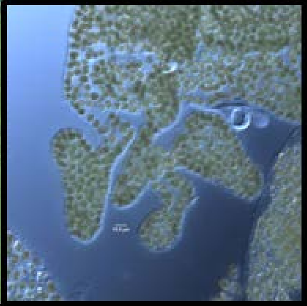
Continuous Water-Quality Monitors Can Be Used to Develop Models to Compute Probability of Cyanotoxin Occurrence in Real Time



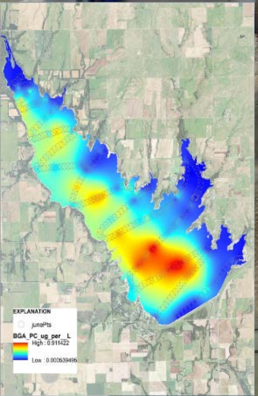


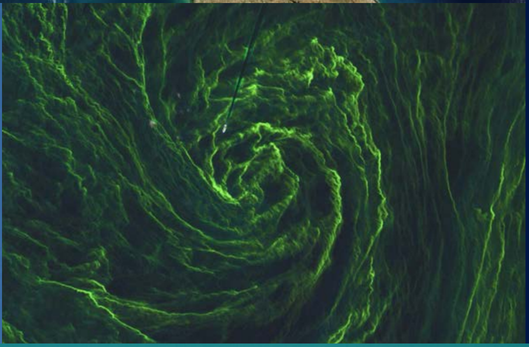
Stone and others, 2013, USGS OFR 2013-1123

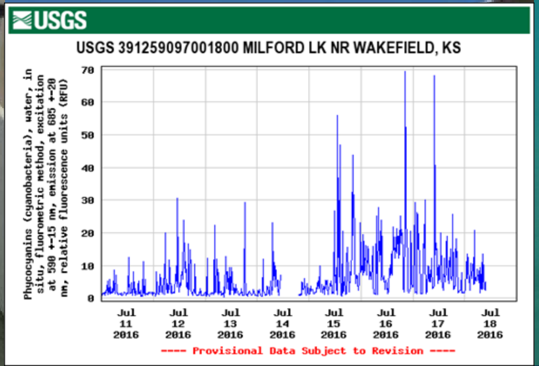


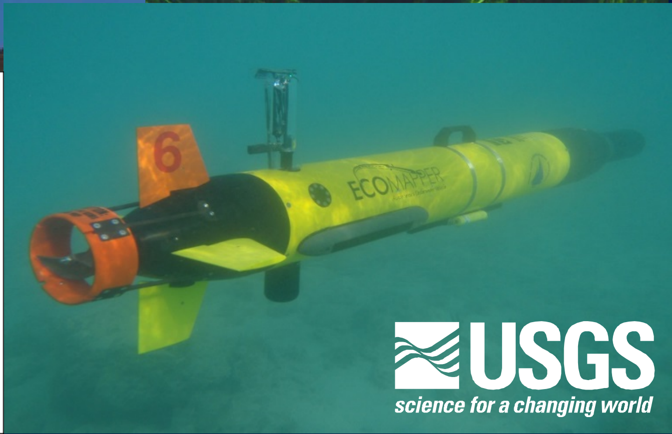


Applied technologies on HAB's- multiple approaches are needed to understand the issue



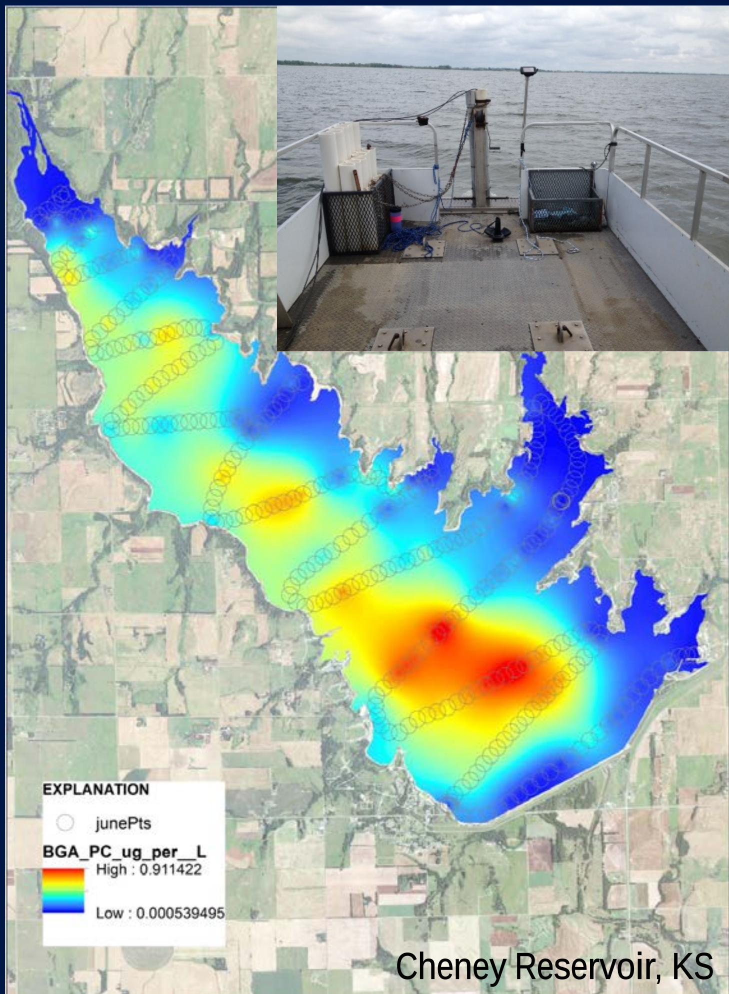




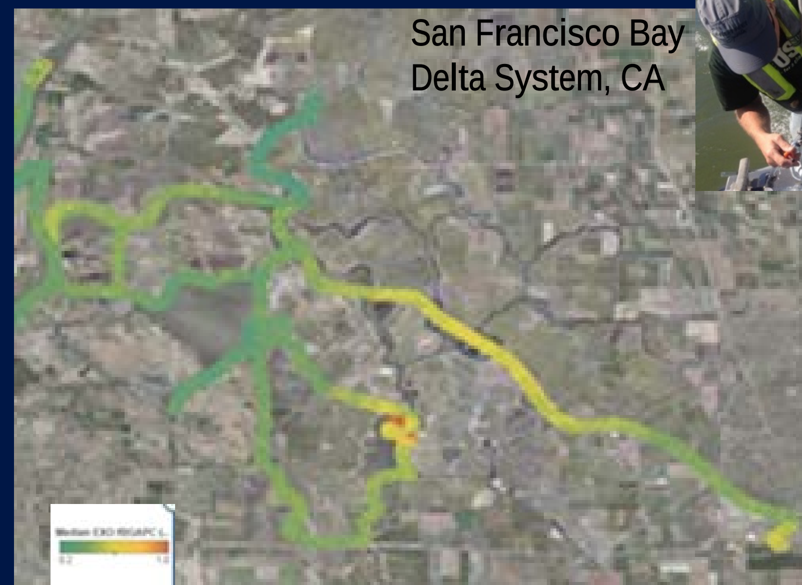


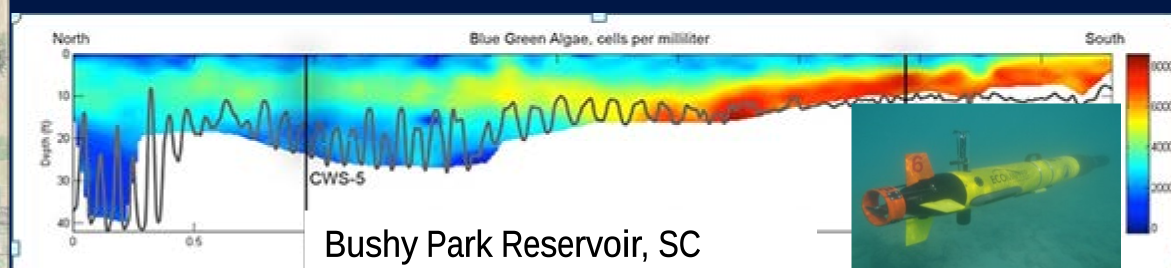
USGS
science for a changing world

New Sensor Technologies Allow New Applications, Such as High Resolution Spatial Data Collection



San Francisco Bay
Delta System, CA





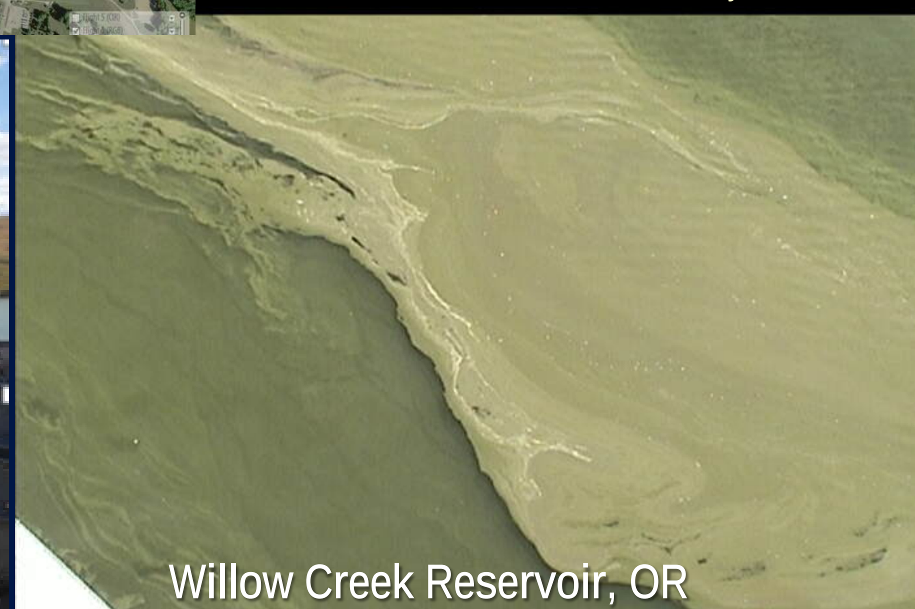
Foster, KSWSC
Bergamaschi, CAWSC
Journey, SAWSC

USGS
science for a changing world

Aerial- and Ground-Based Cameras Show Potential as Early Warning Indicators

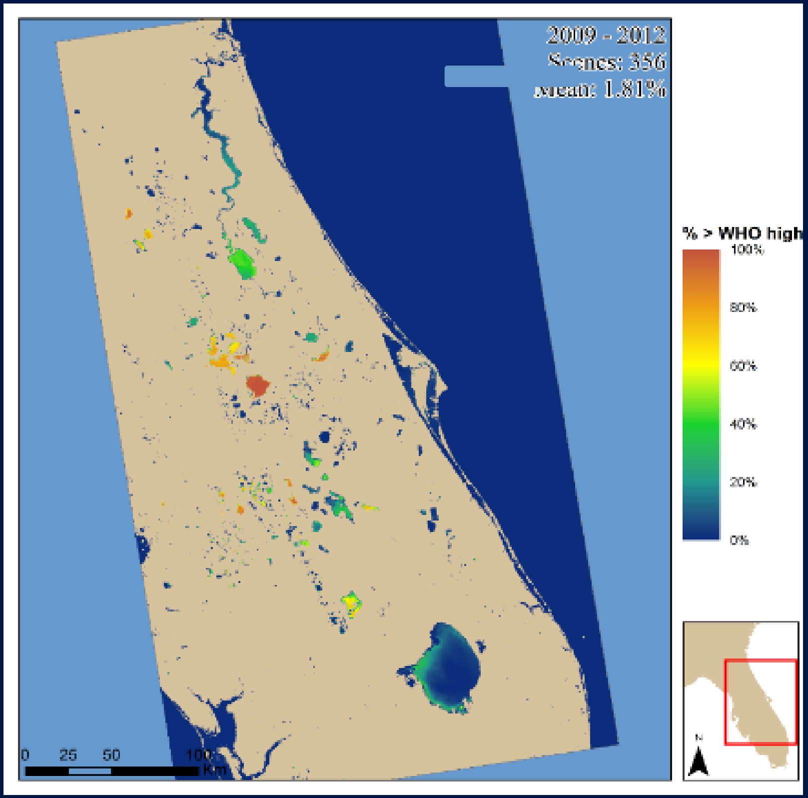
Courtesy of E. Emory

Courtesy of C. Smith



USGS
science for a changing world

Satellite (and Other Aerial) Imagery Captures Spatial Variability Across an Entire Lake Surface and on a Regional Scale

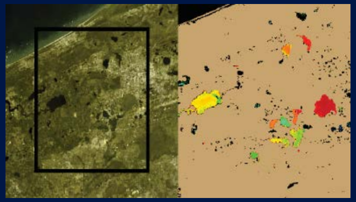


https://www.epa.gov/water-research/cyanobacteria-assessment-network-cyan-project
https://toxics.usgs.gov/highlights/2015-12-21-cyanobacteria_sensing.html

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NASA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE
USGS
science for a changing world

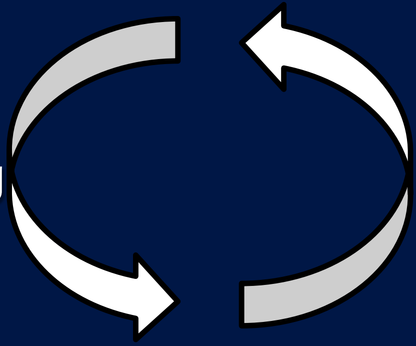
Tools that Utilize Satellites for Inland HAB Monitoring are Being Developed

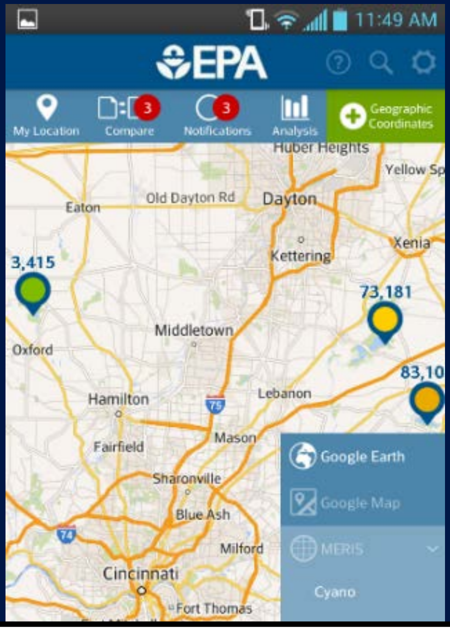
Cyanobacteria Assessment Network (CyAN) Project

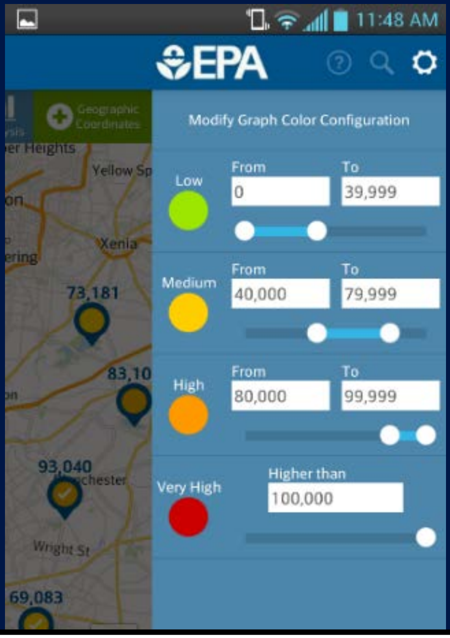


Remote Sensing

Field Data







UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NASA

NOAA — NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION — U.S. DEPARTMENT OF COMMERCE

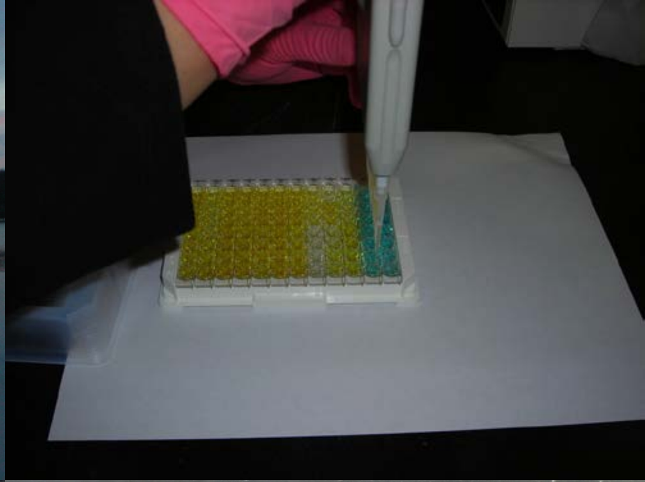
USGS science for a changing world

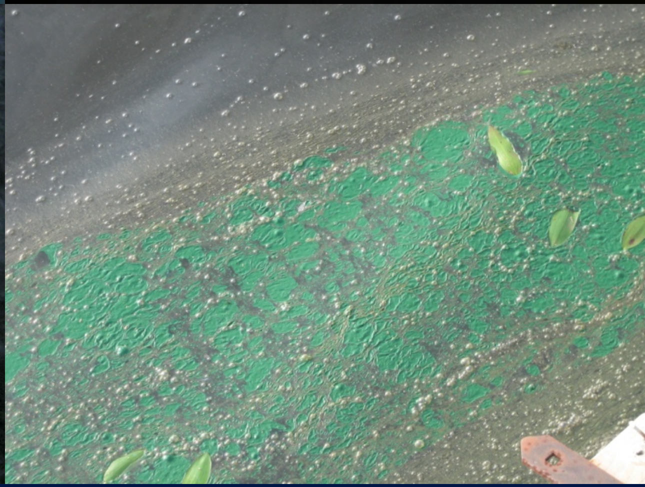
Unifying Themes in Harmful Algal Bloom Research

- Individual systems are unique.
- Spatial and temporal variability present challenges to data collection, analysis, and interpretation.
- Sensor technology including odor detection and genetic approaches provide important information on spatiotemporal variability and environmental influences.
- A variety of tools for early warning and prediction are being developed and used.

USGS
science for a changing world





Additional Information:

http://ks.water.usgs.gov/cyanobacteria/

kloftin@usgs.gov
785-832-3543

gfoster@usgs.gov
785-832-3525

USGS
science for a changing world

US EPA's Guidelines and other Regulatory Authorities for HABs

Lesley V. D'Anglada, Dr.PH
US Environmental Protection Agency
Office of Water/Office of Science and Technology

Region 9 HABs Meeting (Webinar)

April 5th, 2017

Presentation Overview

- Overview of current regulations and guidelines for cyanotoxins in drinking water.
- Describe the US EPA Health Advisories for Cyanotoxins and other related efforts.
- Overview of current regulations and guidelines for cyanotoxins in recreational water.
- Describe the current draft Recreational Criteria/Swimming Advisories.
- Opportunity for Questions.

Disclaimer

The views expressed in this presentation are those of the author and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

Current Regulations and Guidelines for Cyanotoxins in Drinking Water

water.epa.gov

Regulations and Guidelines in Drinking Water

- No Federal regulations for cyanobacteria or cyanotoxins in the U.S.
- Safe Drinking Water Act Requirements (SDWA Section 1412(b)(1))
  - Contaminant Candidate List (CCL)
    - List of unregulated contaminants that are known or anticipated to occur in public water systems and may require a drinking water regulation.
    - Cyanobacteria and their toxins included in CCL (1 , 2, 3 and 4).
  - Unregulated Contaminant Monitoring Rule (UCMR)
    - Collect data from selected public water systems.
    - Ten cyanotoxins on UCMR 4 for monitoring (2018-2021).
  - Regulatory Determination (RD)
    - Determine whether or not to regulate.
    - RD 1, 2 and 3 – No Regulatory Decision - not sufficient information.

Regulations and Guidelines in Drinking Water

Drinking Water Protection Act *(H.R. 212)*

- Signed on 2015 to amend the SDWA by adding Section 1459.
- Directs EPA to develop and submit a strategic plan for assessing and managing risks associated with algal toxins in drinking water provided by public water systems.

Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water

- Issued on November 2015 and includes steps and timelines to:
  - Assess human health effects and causes of HABs;
  - Provide a list of algal toxins present in drinking water systems;
  - Develop health advisories (if needed);
  - Treatment options;
  - Analytical and monitoring approaches;
  - Source water protection, and;
  - Collaboration and outreach.

EPA’s Drinking Water Health Advisories for Cyanotoxins

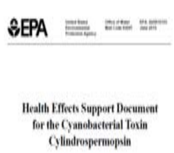
water.epa.gov

EPA Drinking Water Health Advisories (HA)

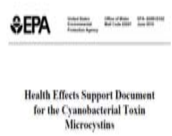
- Informal technical guidance (**non-regulatory**) for unregulated drinking water contaminants to assist federal, state and local officials, and managers of public or community water systems in protecting public health during emergency situations.
- **HA Represents: Concentration in drinking water at or below that is not expected to cause any adverse non carcinogenic effects for a specific exposure duration.**
  - One-day HA assumes a single acute exposure (children);
  - Ten-day HA assumes a period of one to two weeks exposure (children);
  - Chronic HA assumes a lifetime exposure (adults only).

Health Effects Support Documents (HESD)

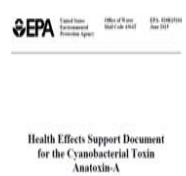
- Health Effects Support Document for microcystins, cylindrospermopsin and anatoxin-a
- Comprehensive review of occurrence, environmental fate and human health information.
- Externally Peer Reviewed
    - Data inadequate to develop an HA for anatoxin-a.


EPA

Health Effects Support Document
for the Cyanobacterial Toxin
Cylindrospermopsin


EPA

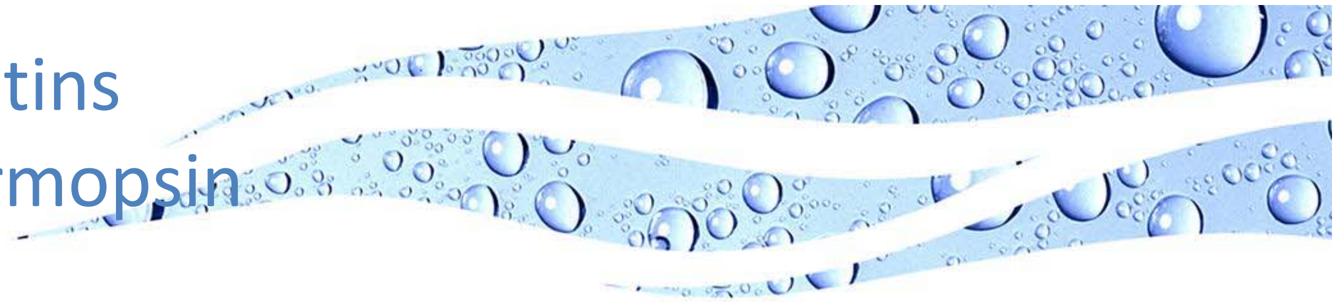
Health Effects Support Document
for the Cyanobacterial Toxin
Microcystins


EPA

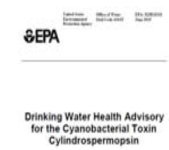
Health Effects Support Document
for the Cyanobacterial Toxin
Anatoxin-A

- https://www.epa.gov/nutrient-policy-data/health-effects-support-documents

HAs for Microcystins and Cylindrospermopsin

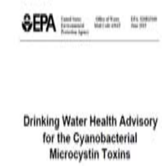


- In June 2015 EPA published Drinking Water Health Advisories (HAs) for microcystins (MCs) and cylindrospermopsin (CYL).
  - MC-LR is considered a surrogate for all microcystins.
  - Short term exposure (10-day) consistent with expected exposure pattern.
  - No lifetime or carcinogenic value derived.



EPA

Drinking Water Health Advisory for the Cyanobacterial Toxin Cylindrospermopsin



EPA

Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins

Toxins	10-day Health Advisory	
	Bottle-fed infants and pre-school children	School-age children and adults
MCs	0.3 µg/L	1.6 µg/L
CYL	0.7 µg/L	3 µg/L

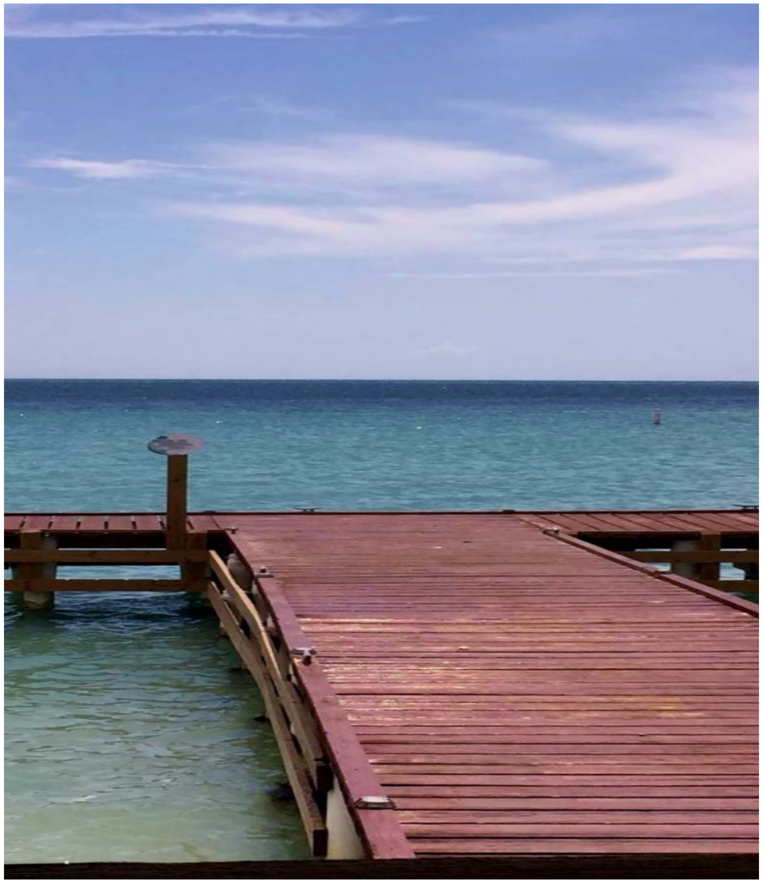
https://www.epa.gov/nutrient-policy-data/drinking-water-health-advisory-documents-cyanobacterial-toxins

Supplemental Documents and other efforts in support of the HAs

- Analytical methods development (April 2015/2016)
  - –544 (microcystins and nodularin-R)
  - –545 (anatoxin-a and cylindrospermopsin)
  - –546 (Adda ELISA Method for microcystins and nodularins).
- Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water (June 2015)
- Cyanotoxin Management Plan Template and Example Plans (November 2016)
- Water Treatment Optimization for Cyanotoxins Document (November 2016)
- Drinking Water Cyanotoxin Risk Communication Toolbox (November 2016)

Available in the *EPA's Cyanotoxins in Drinking Water* Webpage

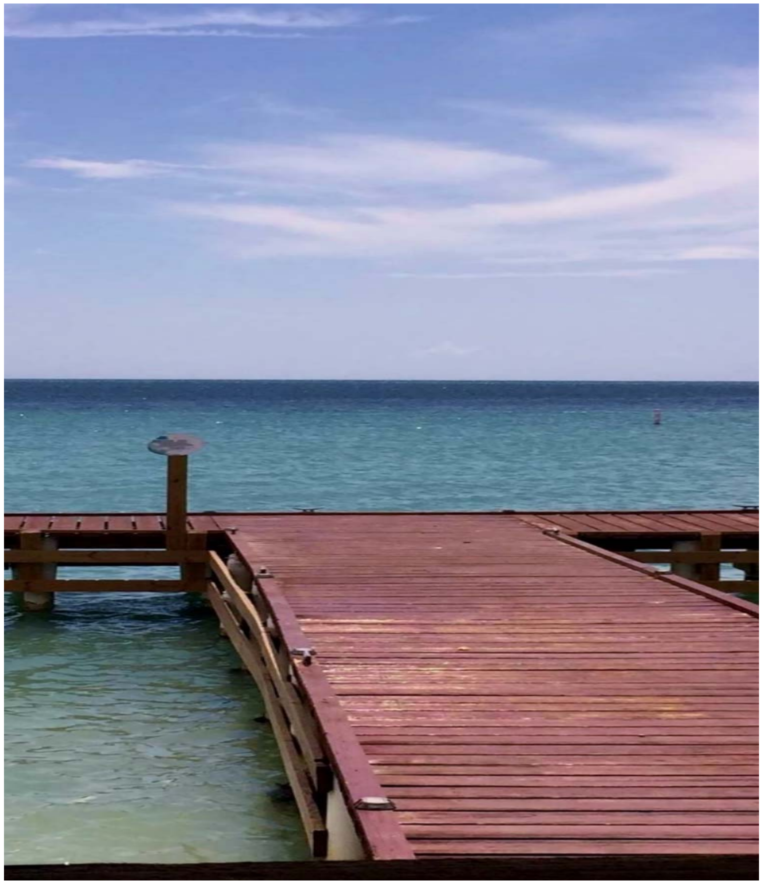
Current Regulations and Guidelines for Cyanotoxins in Recreational Water



Guidelines and Regulations in Recreational Water

- No federal regulations for recreational exposures to cyanobacteria/cyanotoxins.
- Guidance values for recreational water have been adopted by many countries and some states based on WHO guidelines.
- Clean Water Act Section 304(a)
  - EPA develops numeric values limiting the amount of chemicals present in our nation's waters to protect public health, aquatic life and recreational uses.
  - These criteria are **not rules** and States may adopt the criteria that EPA publishes, modify EPA's criteria to reflect site-specific conditions, or adopt different criteria based on other scientifically-defensible methods.

Overview of EPA's Draft Recreational Criteria/Swimming Advisories for Cyanotoxins



Draft Recreational Criteria/Swimming Advisories Summary

- On December 2016 EPA published draft values for microcystins (MCs) and cylindrospermopsin (CYL).
  - Consider MCs, CYL, and cyanobacterial cells as stressors
  - Focus on fresh waters, but consider potential effects at the estuarine interface.
  - Focus on oral ingestion, but consider dermal and inhalation exposure routes.
  - Evaluate exposure for different age groups.
  - Use peer-reviewed data to develop recommended values for MCs and CYL in recreational waters. Evaluate science describing health effects from exposure to cyanobacteria cells.
  - Use Agency-recommended recreational exposure values in a scenario which includes immersion and incidental ingestion of ambient water.
  - Characterize effects that are not quantified.

EPA's Draft Advisory Values for Recreational Exposures

Application	Draft Recreational Advisory Values	
	Microcystins	Cylindrospermopsin
	4 µg/L	8 µg/L
Swimming Advisory	Not to be exceeded on any day.	
Recreational Criteria for Waterbody Assessment	Not to be exceeded more than 10% of days per recreational season up to 1 calendar year.	

- Status:
  - Draft published in the FR for public comments for (ended March 20th).
  - Projected publication in 2017.
  - For more information contact John Ravenscroft (Ravenscroft.john@epa.gov)

https://www.epa.gov/sites/production/files/2016-12/documents/draft-hh-rec-ambient-water-swimming-document.pdf

Other HABs-related Guidelines and Activities

Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014 (HABHRCA)

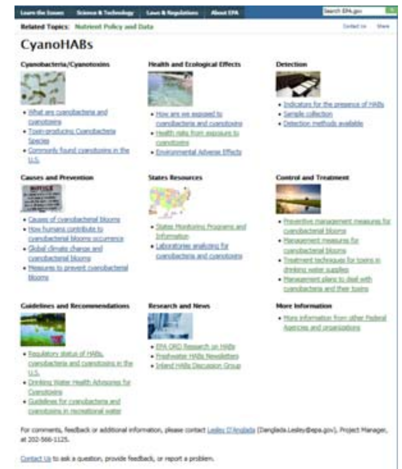
- Give EPA the authority for freshwater HABs.
- Stakeholder engagement and coordinate interagency research agenda.
- Form an Interagency Working Group (IWG).
  - Co-chaired by NOAA and EPA
  - NOAA, EPA, USGS, USDA, Navy, NIEHS, NSF, FDA, NPS, CDC, NASA, USACE, BOEM
  - Develop a Series of mandated reports
    1. **HAB and Hypoxia Comprehensive Research Plan and Action Strategy**
    2. **Report on Implementation of the HAB and Hypoxia Action Strategy**- *in progress*
    3. **Great Lakes Hypoxia and HAB Integrated Assessment** *(Incorporated into the Research Plan and Action Strategy)*
    4. **Great Lakes HAB and Hypoxia Plan** – *in progress*
    5. **Progress Report on Northern Gulf of Mexico Hypoxia (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2015)**

- IWG Listserve: **IWG-HABHRCA@noaa.gov**
- HABHRCA Website: **http://coastalscience.noaa.gov/research/habs/habhrca**

Outreach and Communications

EPA CyanoHABs Webpage

- 2012- information on Causes, prevention and mitigation, Human health and ecological effects, Detection methods, Available policies and guidelines, Research and News and a list of States HABs programs and laboratories



EPA Regional Workshops on HABs

- Region 8 (2015), Regions 5 and 10 (2016) and Regions 1, 7 and 9 (2017)

Freshwater HABs Newsletter

- 2014 - Monthly newsletter with news, recently published research, upcoming events, beach closures and Health Advisories, and more.

EPA's HABs Listserve: **epacyanohabs@epa.gov**

Contact Information

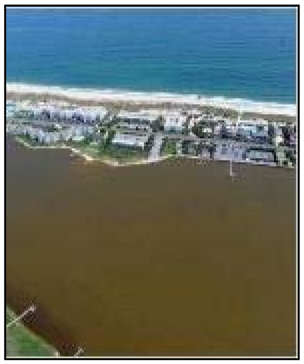
Lesley V. D'Anglada, Dr.PH
U.S. Environmental Protection Agency
Office of Water / Office of Science and Technology
Danglada.Lesley@epa.gov

EPA's Cyanobacteria HABs Website
www.epa.gov/cyanohabs

EPA's HABs Listserve
epacyanohabs@epa.gov

water.epa.gov

The complex relationship between nutrients and harmful algal blooms


Christopher J. Gobler

Stony Brook University
School of Marine and Atmospheric Sciences

Why have HABs expanded globally?

- More comprehensive assessment, monitoring, and assessment.
  - Toxins
  - Broader definition
- Anthropogenic transport
- Climate change
- Anthropogenic nutrient loading

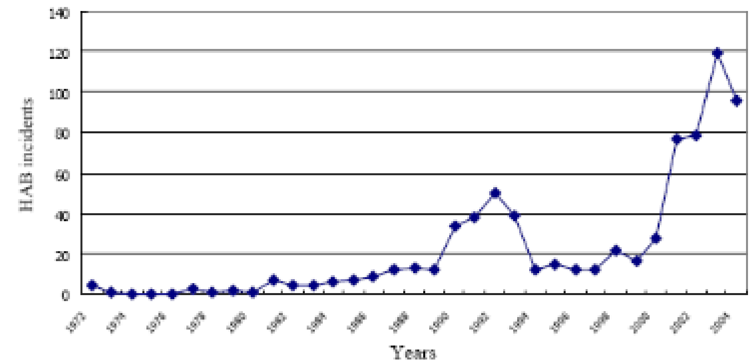
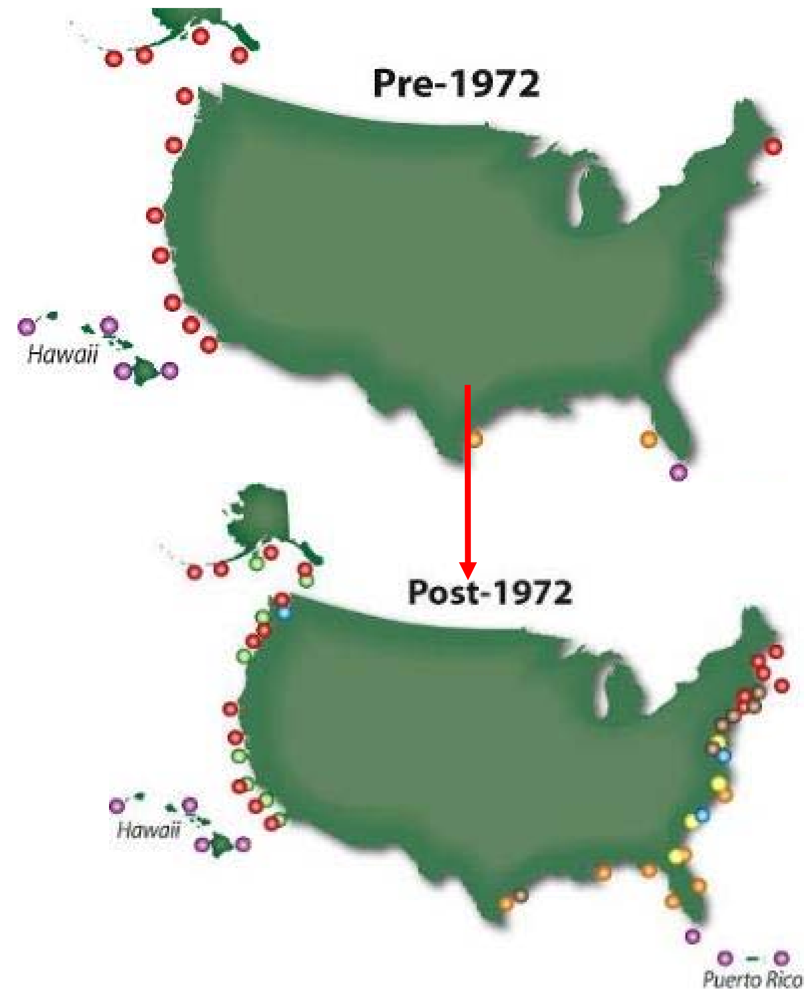
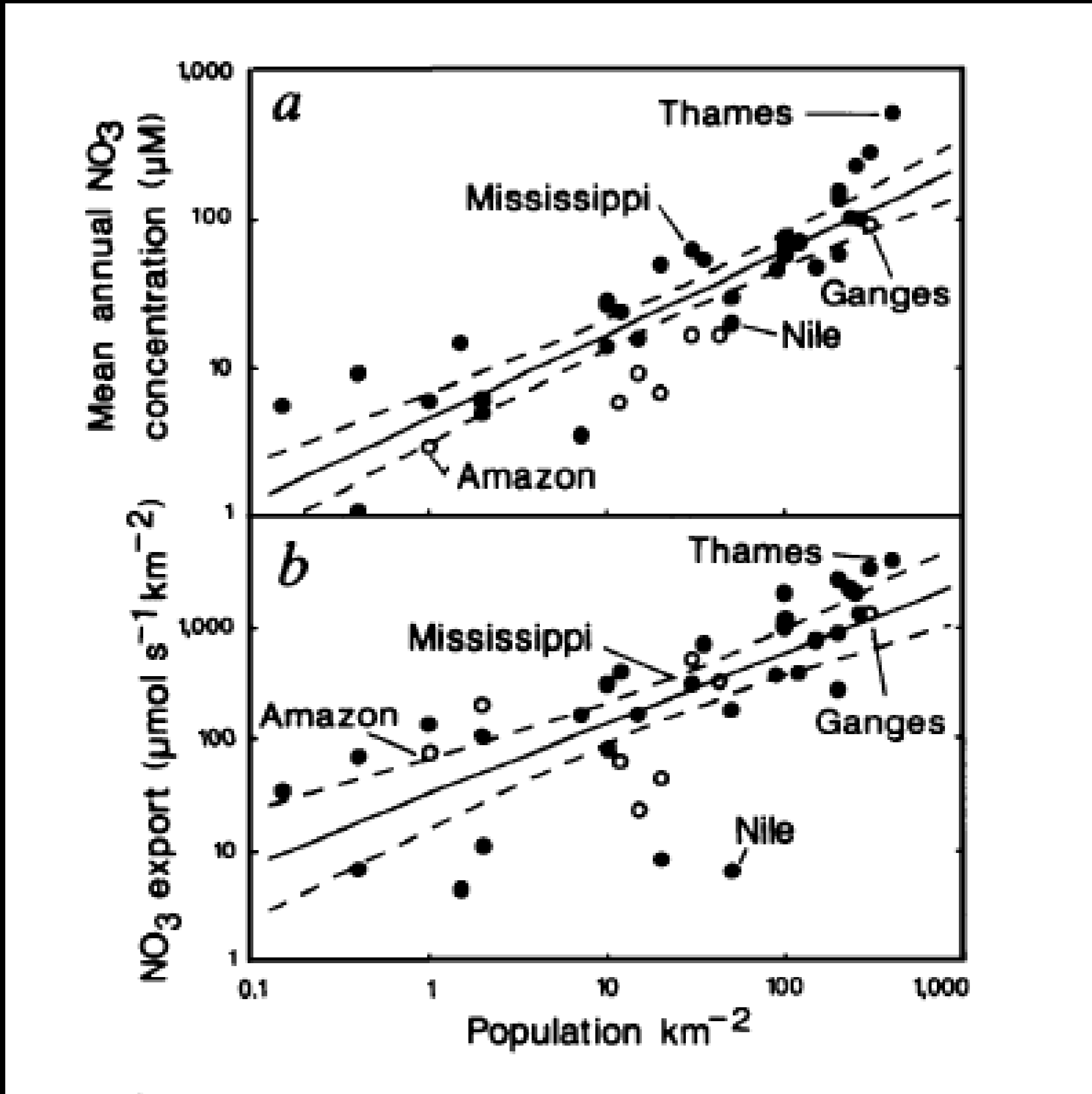


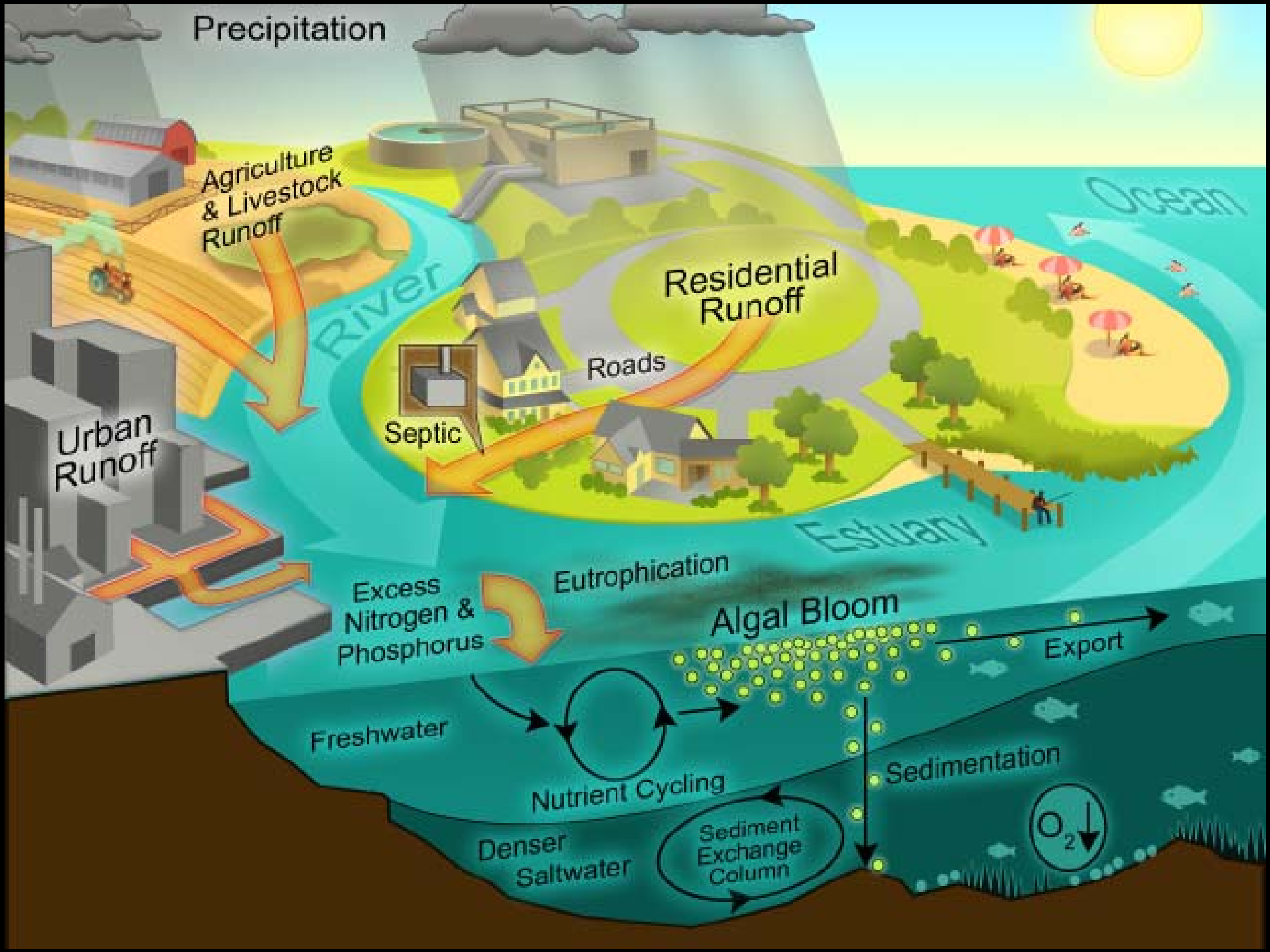
Figure 1 HAB incidents in coastal China from 1972 to 2004



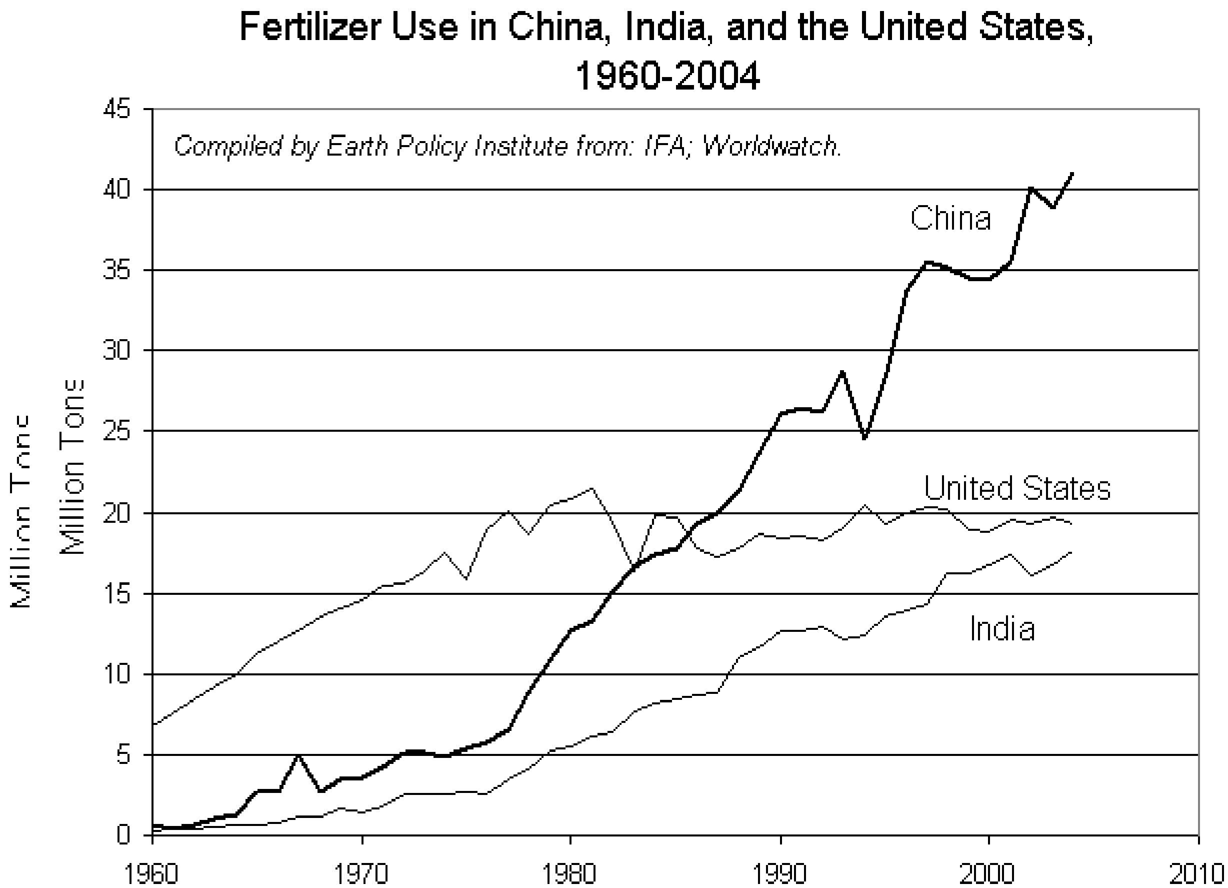
Nitrate levels in rivers can be predicted from watershed population density.



Nutrient delivery processes



Fertilizer is the largest source of nitrogen to coastal waters



Compiled by Earth Policy Institute from: IFA; Worldwatch.

Some HABs are directly caused by anthropogenic nutrient loading…

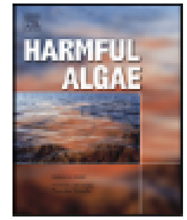
Harmful Algae 8 (2008) 3–13

ELSEVIER

Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal



Eutrophication and harmful algal blooms: A scientific consensus

J. Heisler[a,3], P.M. Glibert[b,*], J.M. Burkholder[c], D.M. Anderson[d], W. Cochlan[e], W.C. Dennison[b], Q. Dortch[f], C.J. Gobler[g], C.A. Heil[h,1], E. Humphries[i], A. Lewitus[j,k,2], R. Magnien[l,2], H.G. Marshall[m], K. Sellner[n], D.A. Stockwell[o], D.K. Stoecker[b], M. Suddleson[f]

(1) Degraded water quality from increased nutrient pollution promotes the development and persistence of many HABs and is one of the reasons for their expansion in the U.S. and other nations;
(2) The composition–not just the total quantity–of the nutrient pool impacts HABs;
(3) High-biomass blooms must have exogenous nutrients to be sustained;
(4) Both chronic and episodic nutrient delivery promote HAB development;
(5) Recently developed tools and techniques are already improving the detection of some HABs, and emerging technologies are rapidly advancing toward operational status for the prediction of HABs and their toxins;
(6) Experimental studies are critical to further the understanding about the role of nutrients in HABs expression, and will strengthen prediction and mitigation of HABs; and
(7) Management of nutrient inputs to the watershed can lead to significant reduction in HABs.

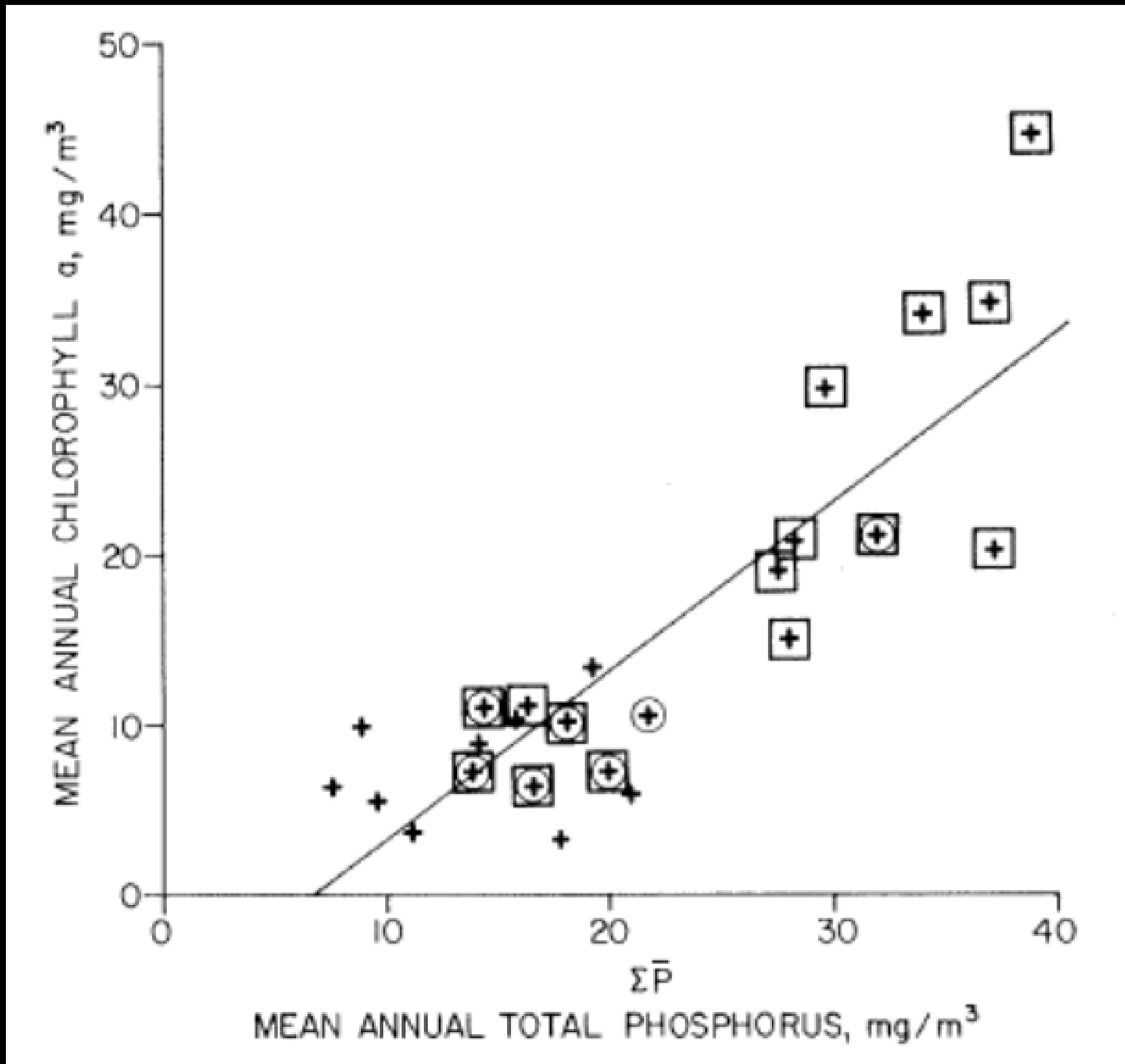
Freshwater cyanobacteria and their toxins

Freshwater cyanobacteria and nutrients

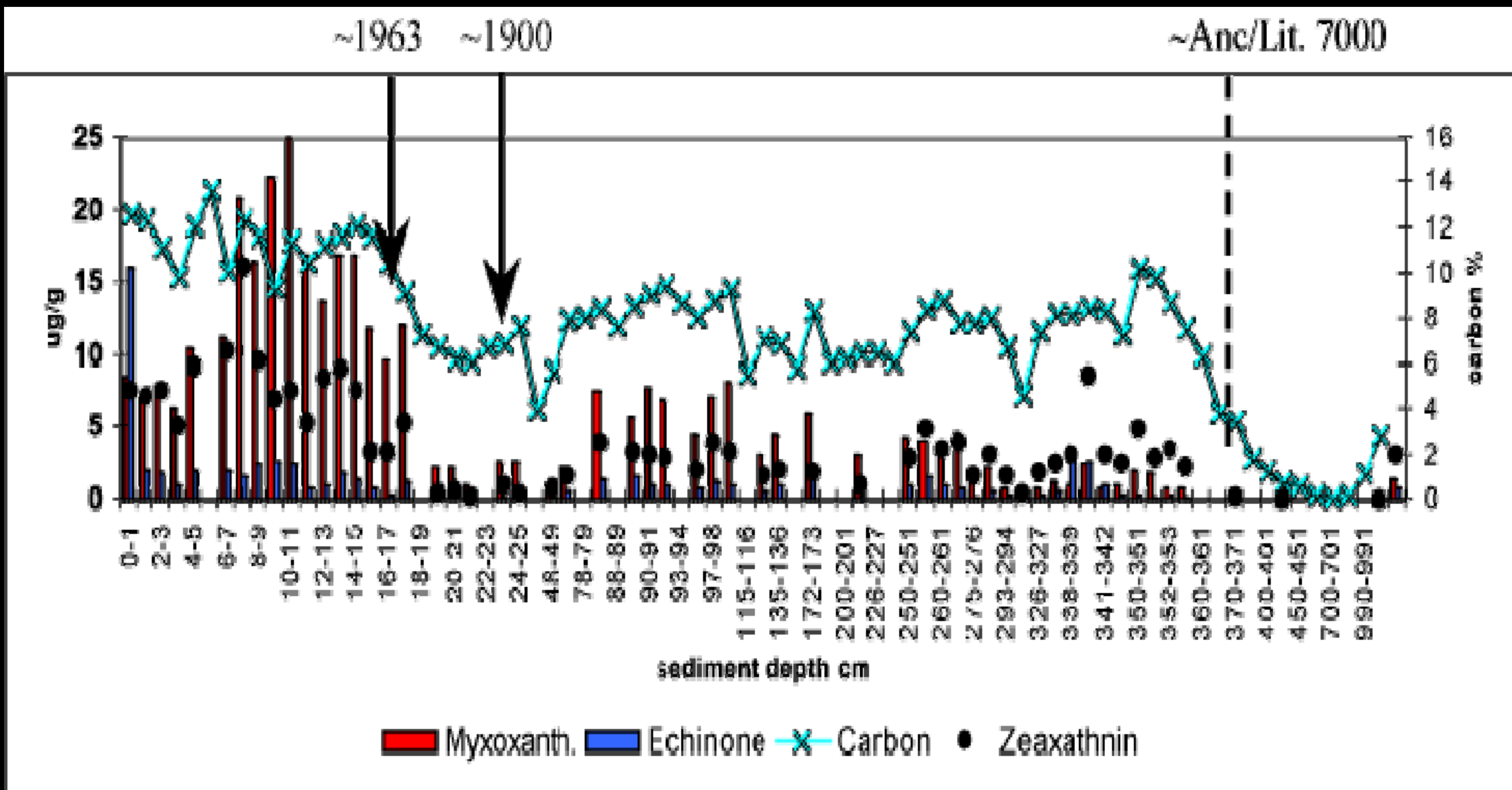
- As bodies of freshwater become enriched in nutrients, the relative abundance of cyanobacteria within phytoplankton community increases (Fogg, 1969; Renoylds & Walsby, 1975; Smith, 1986; Trimbee & Prepas, 1987; Renolds, 1987; Paerl, 1988b; Paerl, 1997 Watson et al., 1997; Paerl & Huisman, 2008).

- Summer phytoplankton communities are dominated by cyanobacteria at total phosphorus concentrations >100 µg P L^{-1} (Trimbee & Prepas, 1987; Jensen et al., 1994; Watson et al., 1997; Downing et al., 2001).

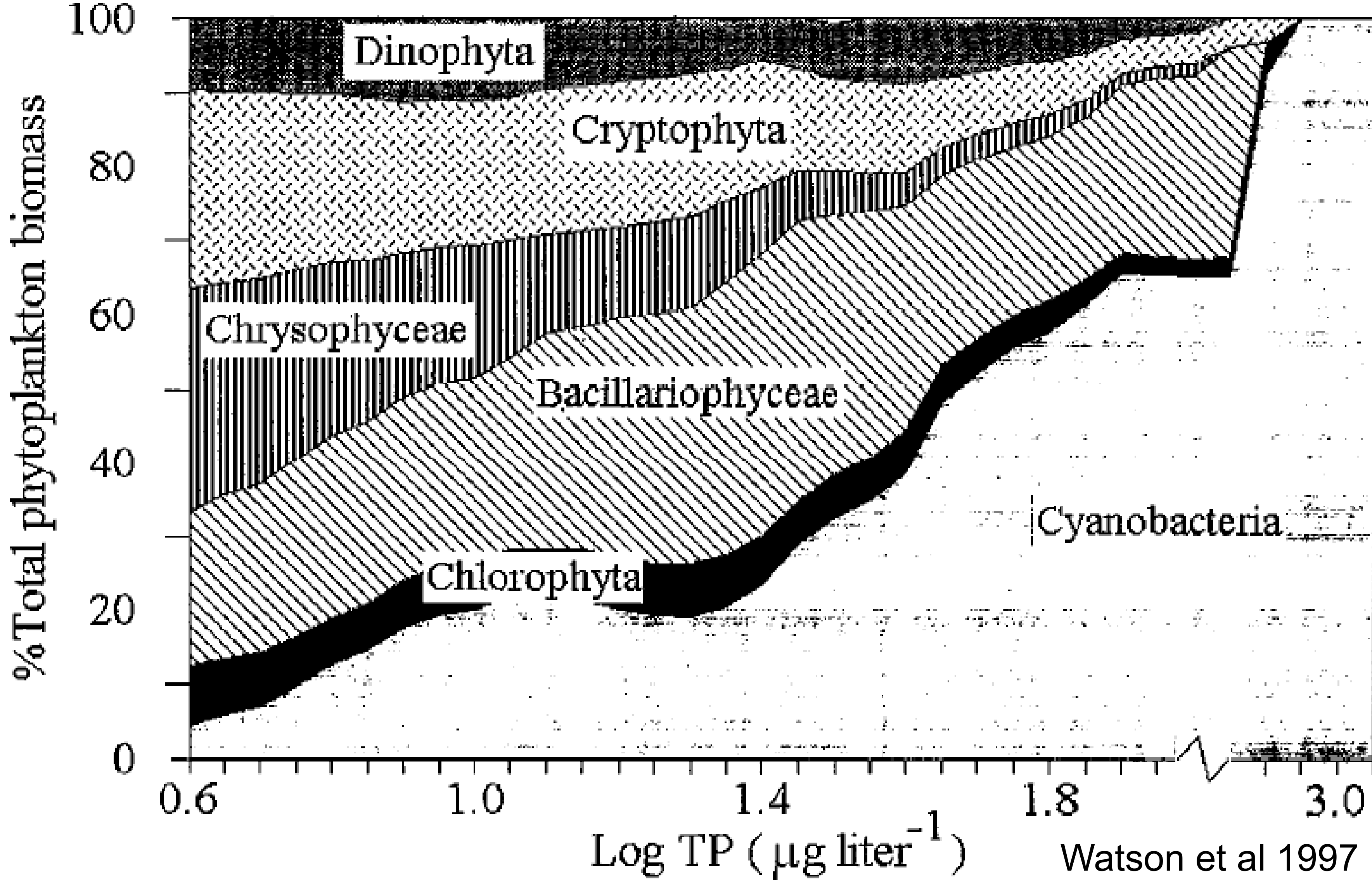
Chlorophyll and P in Canadian lakes



Cyanobacterial pigments in sediment, Baltic Sea



Phosphorus and freshwater cyanobacteria



Watson et al 1997

The Nitrogen/ Microcystin Link - Culture

OPEN ACCESS Freely available online PLOS | ONE

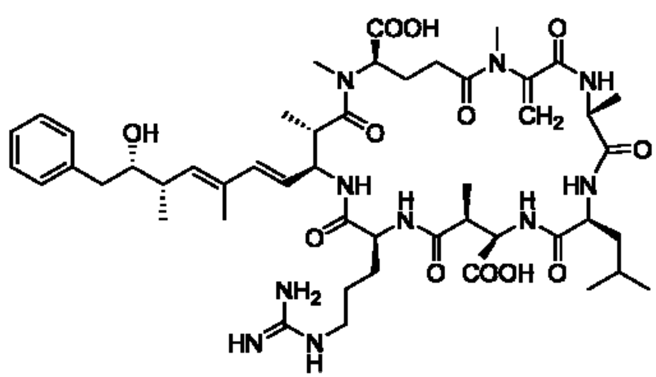
Global Transcriptional Responses of the Toxic Cyanobacterium, *Microcystis aeruginosa*, to Nitrogen Stress, Phosphorus Stress, and Growth on Organic Matter

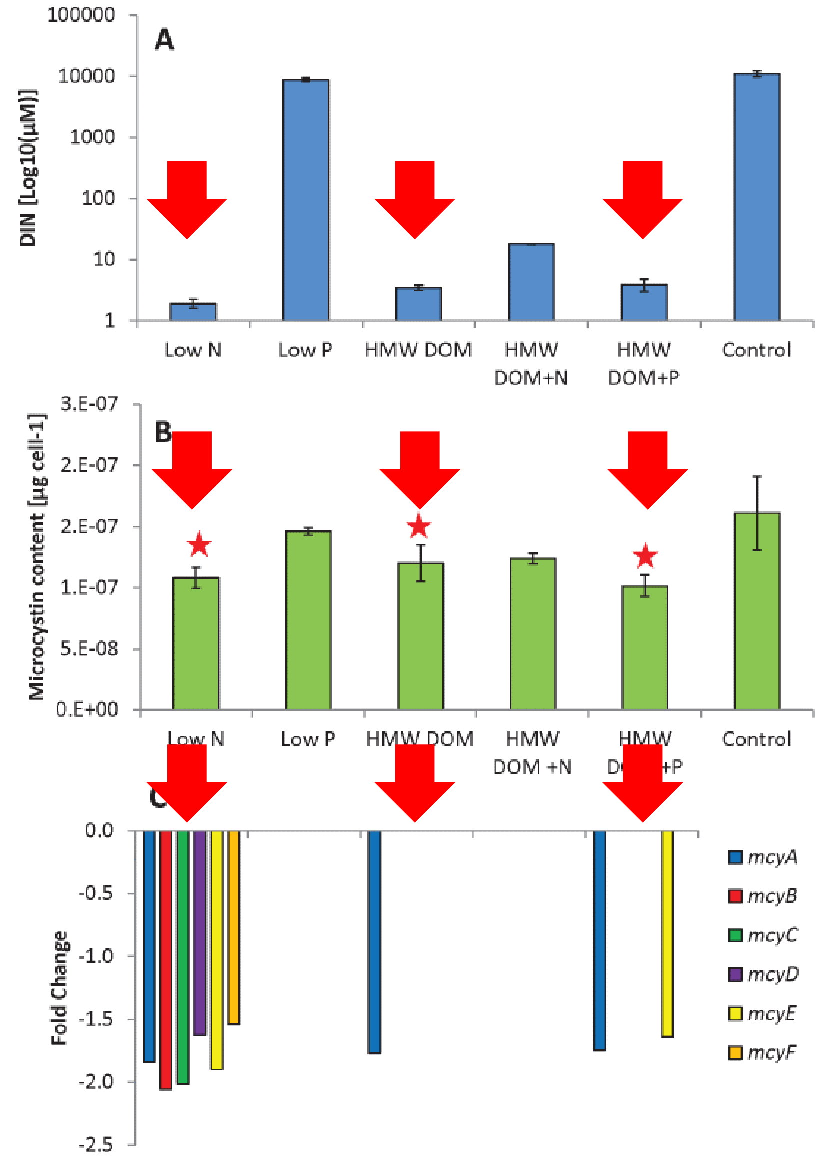
Matthew J. Harke, Christopher J. Gobler*

School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, New York, United States of America

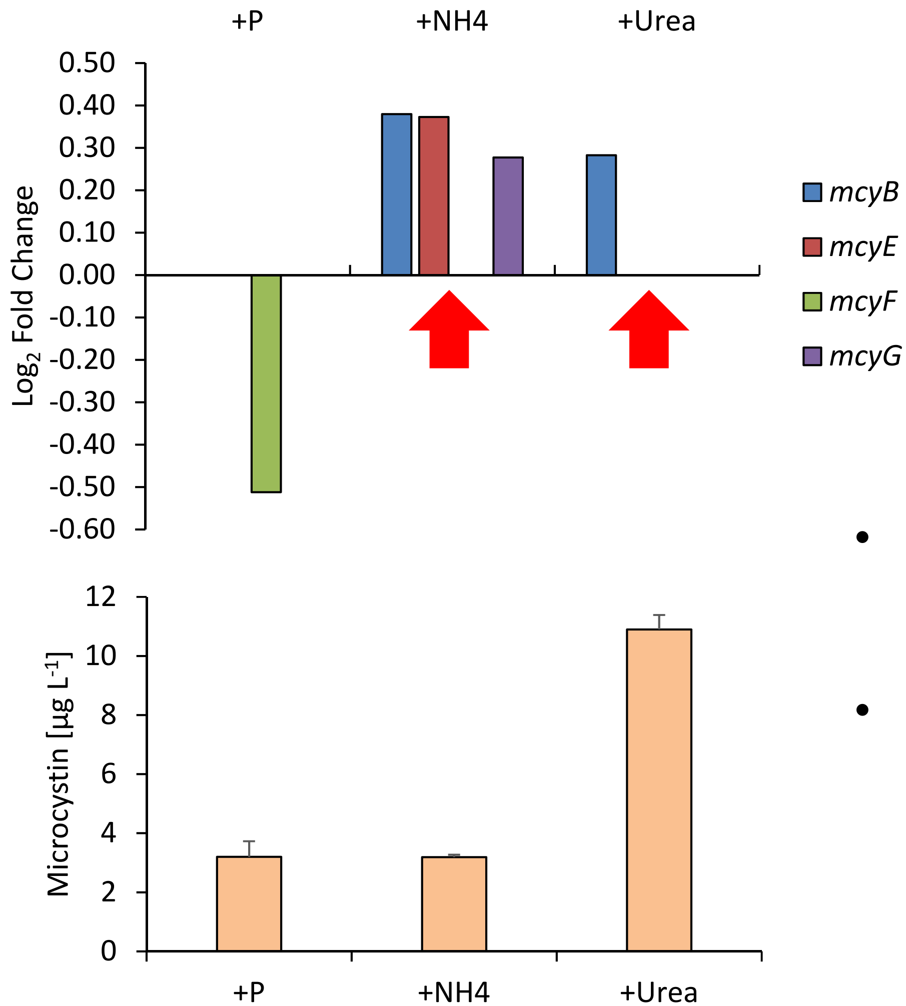
Received March 12, 2013; **Accepted** June 17, 2013; **Published** July 23, 2013

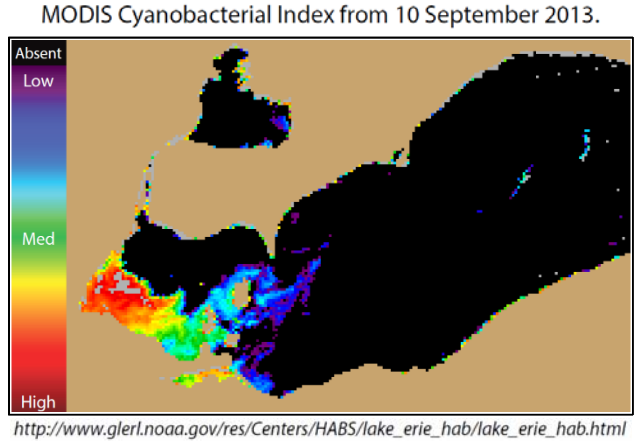
- low inorganic nitrogen
- less microcystin
- downregulation of microcystin synthetase genes
- Microystin contains 8 nitrogen atoms





The Nitrogen/ Microcystin Link – Natural Populations





Lake Erie Sept. 2013

- Additions of nitrogen promote transcription of some mcy genes.
- Additions of nitrogen from urea increase microcystin concentrations

Harke et al., 2016

Harmful Algae 54 (2016) 87–97

Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal

Review

The dual role of nitrogen supply in controlling the growth and toxicity of cyanobacterial blooms

Christopher J. Gobler[a,*], JoAnn M. Burkholder[b,1], Timothy W. Davis[c,1], Matthew J. Harke[a,1], Tom Johengen[d,1], Craig A. Stow[c,1], Dedmer B. Van de Waal[e,1]

[a] School of Marine and Atmospheric Sciences, Stony Brook University, 239 Montauk Hwy, New York 11968, USA
[b] Center for Applied Aquatic Ecology, North Carolina State University, Raleigh, NC 27606, USA
[c] NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI 48108, USA
[d] Cooperative Institute for Limnology and Ecosystems Research, University of Michigan, Ann Arbor, MI 48109, USA
[e] Department of Aquatic Ecology, Netherlands Institute of Ecology (NIOO-KNAW), Post Office Box 50, Wageningen 6700 AB, The Netherlands

United States Environmental Protection Agency

Office of Water EPA - 820-S-15-001

MC 4304T February 2015

Preventing Eutrophication: Scientific Support for Dual Nutrient Criteria

Summary

Nutrient pollution resulting from excess nitrogen (N) and phosphorus (P) is a leading cause of degradation of U.S. water quality. The scientific literature provides many examples that illustrate the effects of both N and P on instream and downstream water quality in streams, lakes, estuaries, and coastal systems. Development of numeric nutrient criteria for both N and P can be an effective tool to protect designated uses in the nation's waters. The purpose of this fact sheet is to describe the scientific basis supporting the water quality standards and are an effective tool for preventing nutrient pollution, for example, in helping to derive numeric limits in discharge permits. Development of numeric nutrient criteria is one aspect of a coordinated and comprehensive approach to nutrient management [7]. EPA has published several guidance documents to assist states and authorized tribes in deriving numeric nutrient criteria for both N and P to protect aquatic systems [8,9,10,11,12].

Why develop $\boxed{\text{criteria for both N and P?}}$

__*Microcystis* blooms promoted and/or made more toxic by excessive nitrogen:__

Gobler et al. 2007, 2016; Davis et al 2009, 2010; O'Neil et al. 2012. Harke et al, 2013, 2015, 2016; Harke and Gobler, 2015; Van Der Waal et al 2009, 2010, 2013, 2014; dozens more

Harmful Algae 8 (2009) 715–725

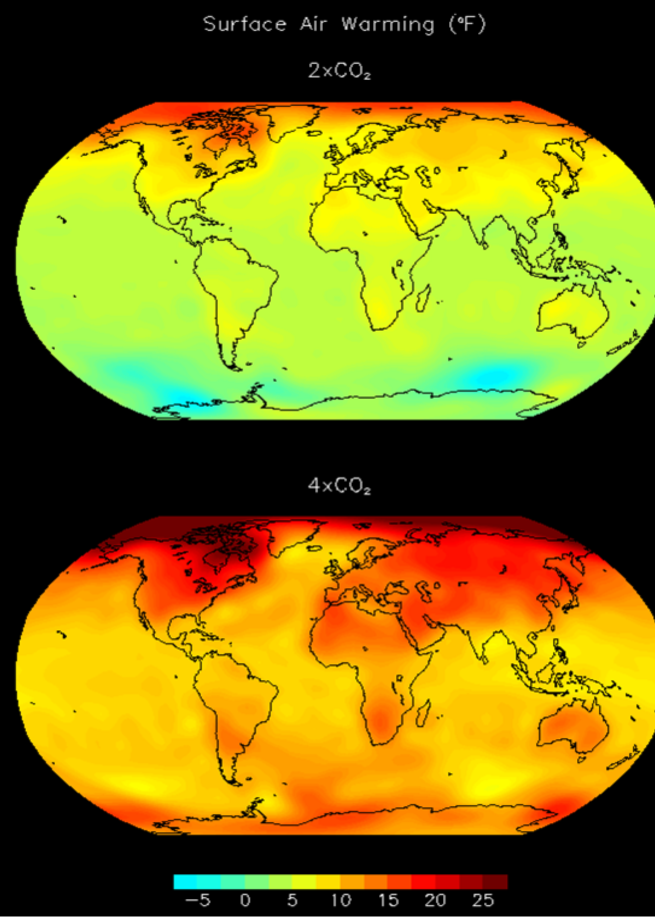
Contents lists available at ScienceDirect

Harmful Algae

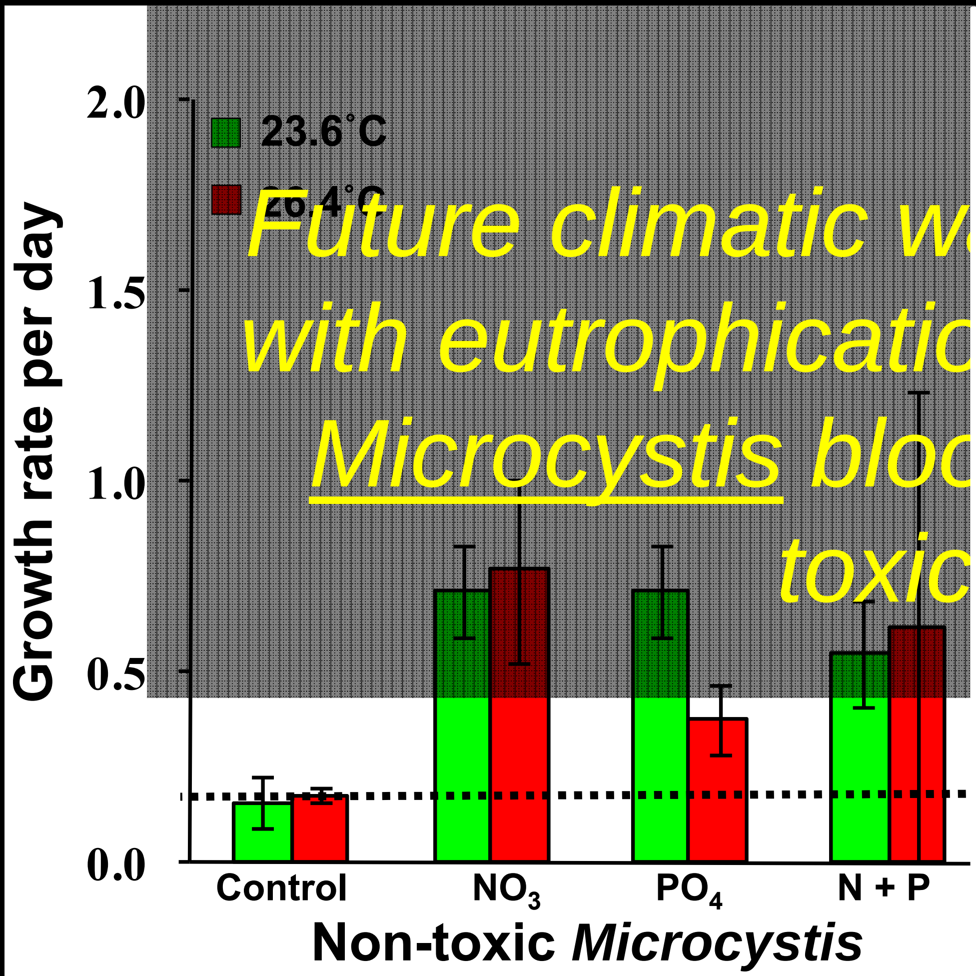
journal homepage: www.elsevier.com/locate/hal

The effects of temperature and nutrients on the growth and dynamics of toxic and non-toxic strains of *Microcystis* during cyanobacteria blooms

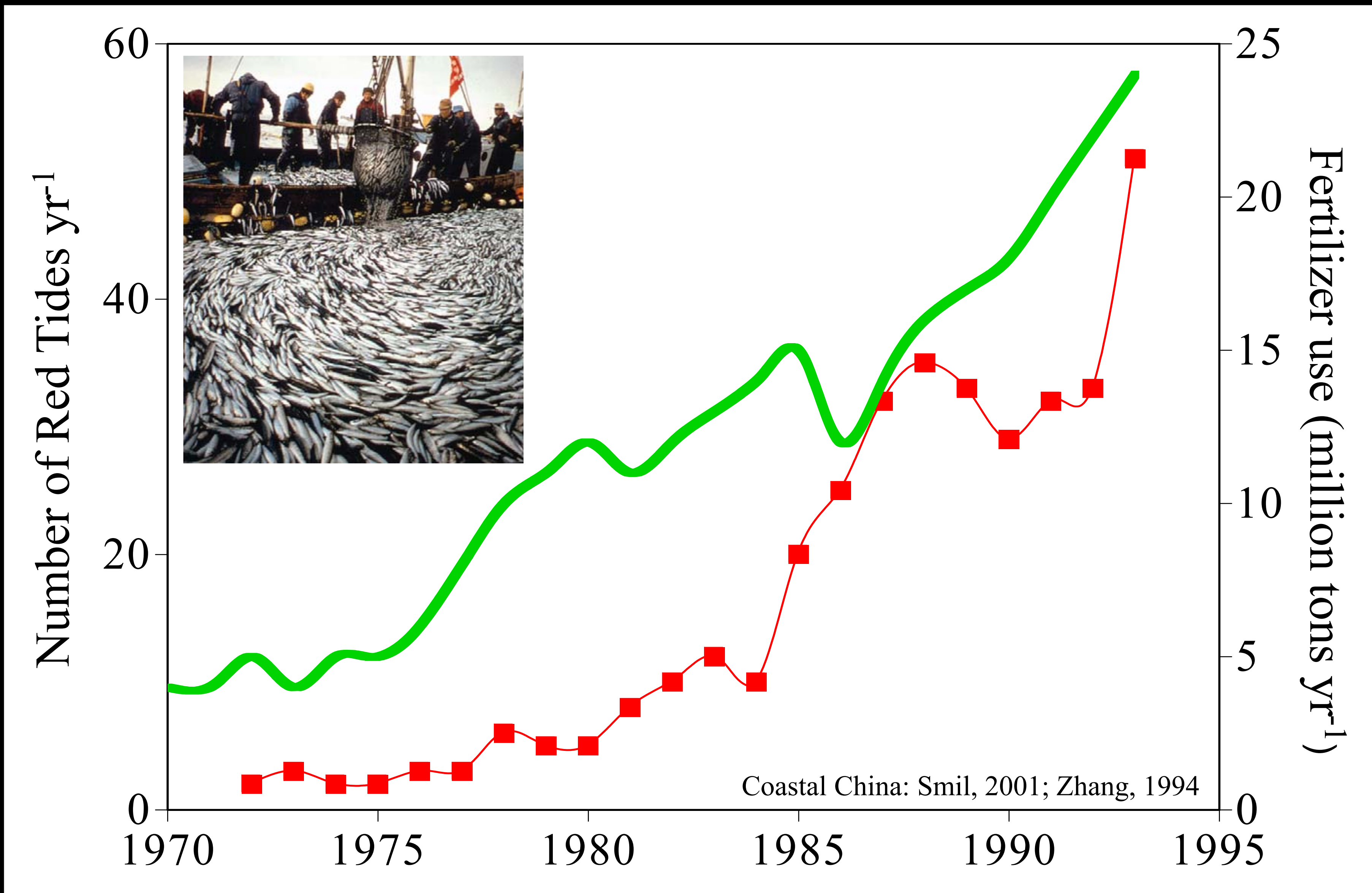
Timothy W. Davis[a], Dianna L. Berry[a], Gregory L. Boyer[b], Christopher J. Gobler[a,*]



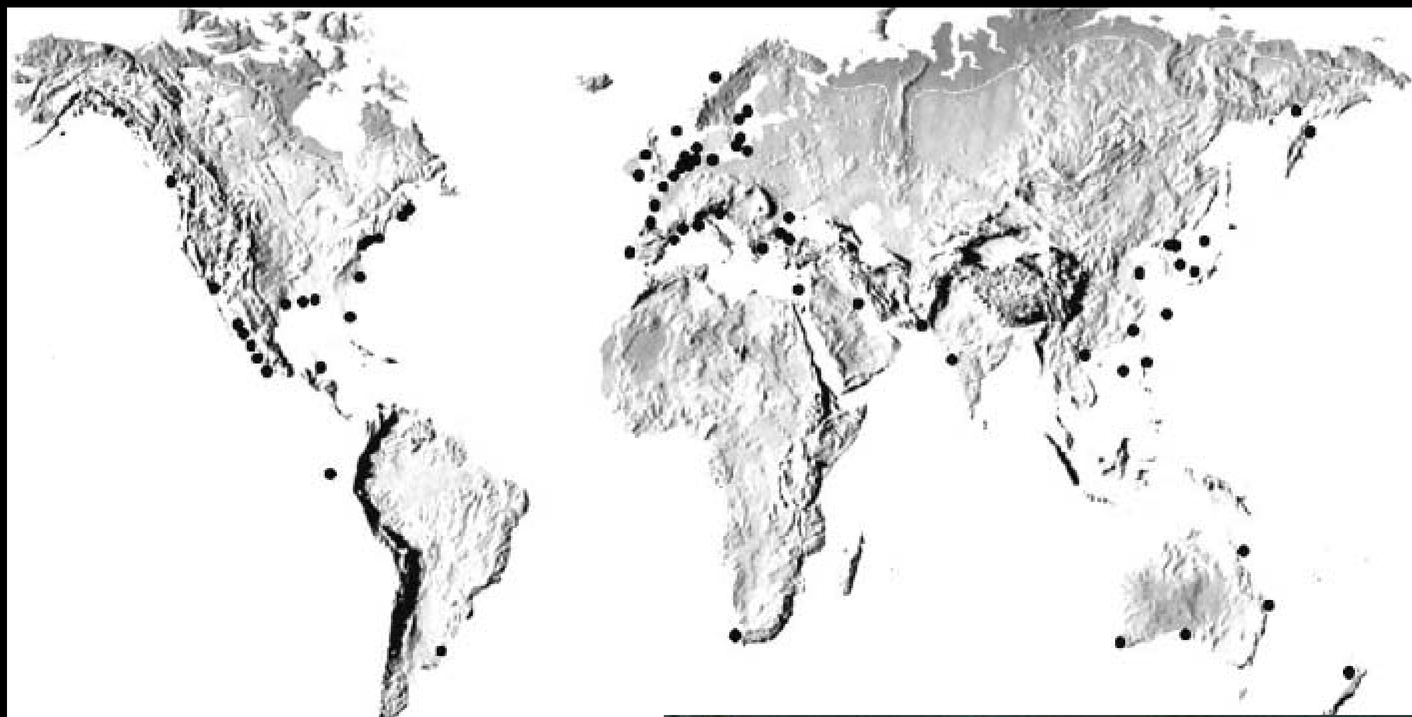
Interaction between temperature and anthropogenic nutrient loading

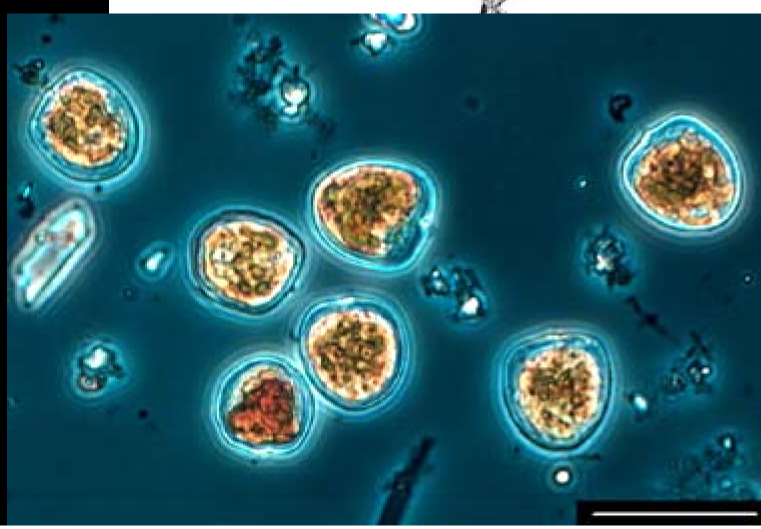


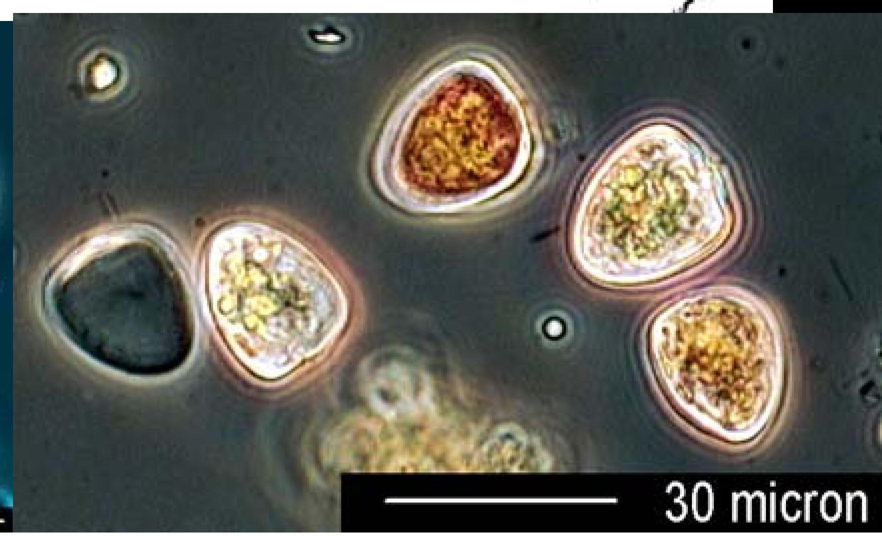
Nitrogen loading and HABs in China:



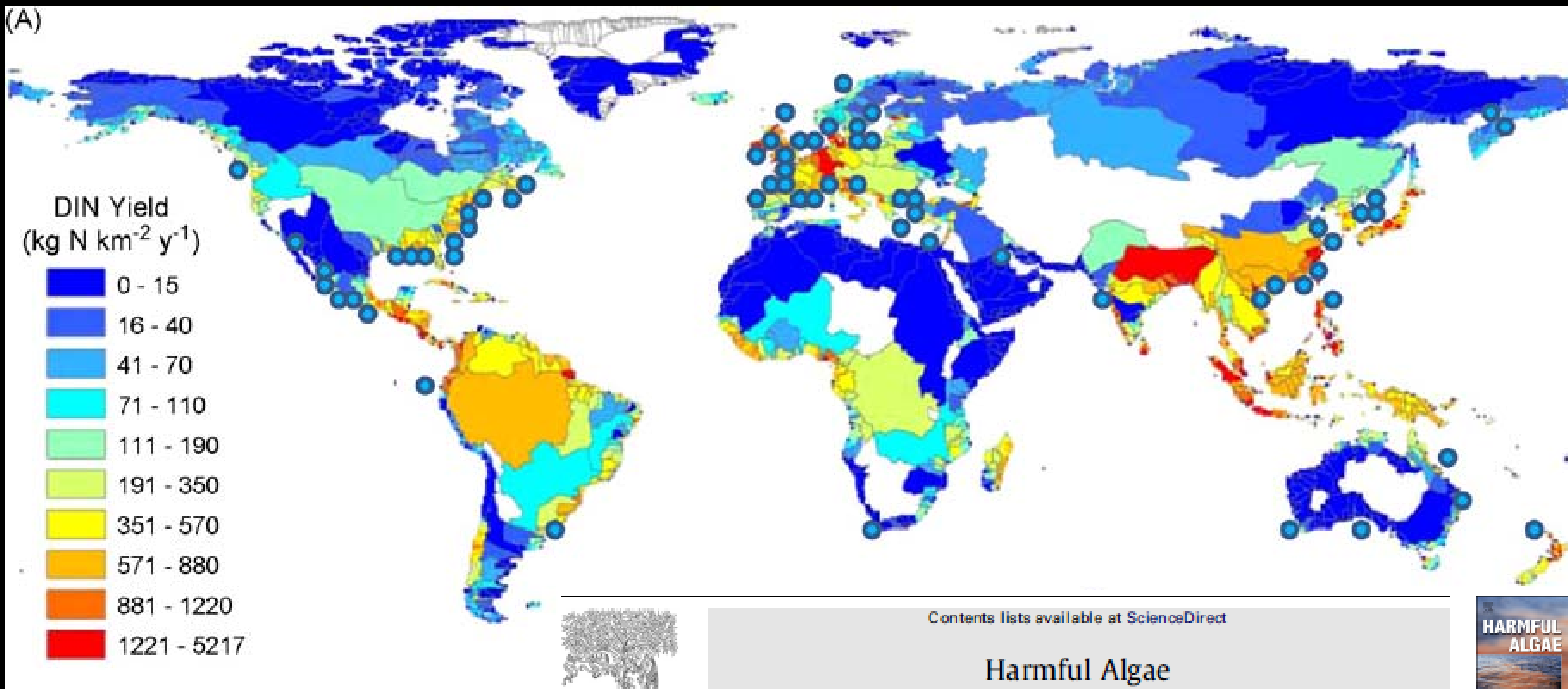
Prorocentrum minimum blooms







Prorocentrum minimum and nitrogen

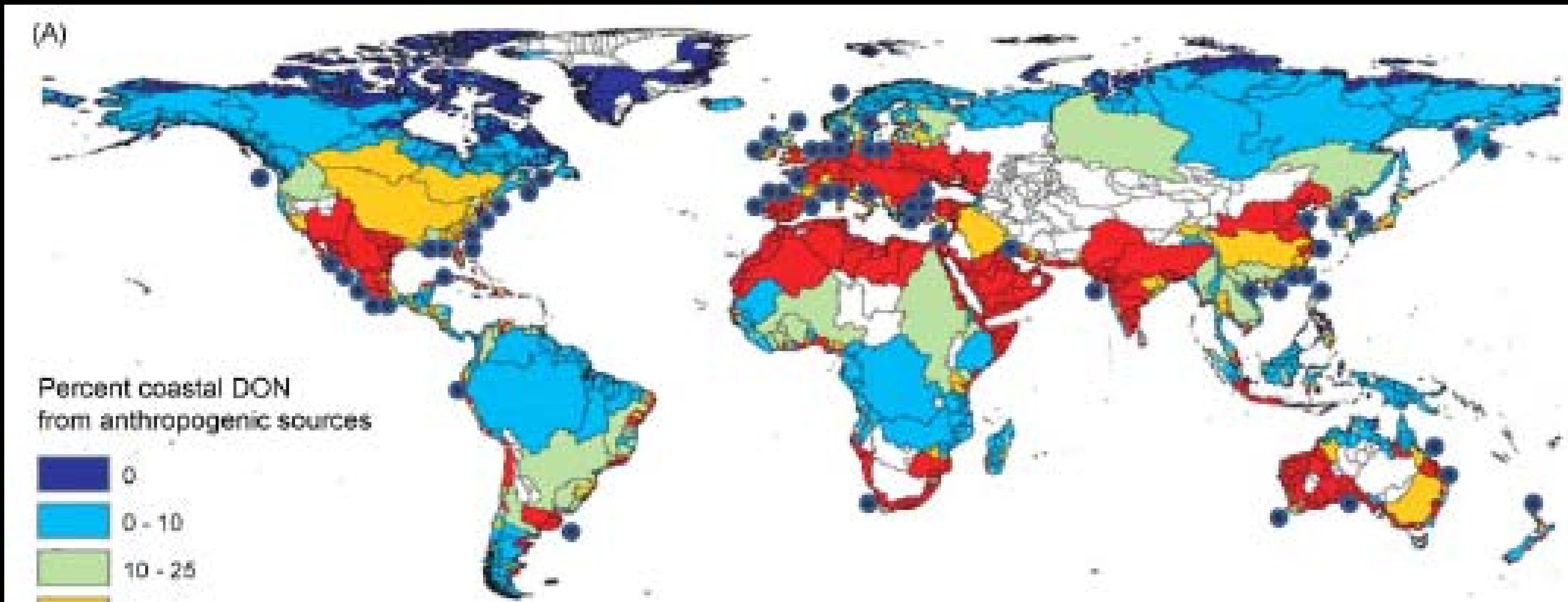


ELSEVIER
Contents lists available at ScienceDirect
Harmful Algae
journal homepage: www.elsevier.com/locate/hal

Prorocentrum minimum tracks anthropogenic nitrogen and phosphorus inputs on a global basis: Application of spatially explicit nutrient export models

Patricia M. Glibert[a,*], Emilio Mayorga[b], Sybil Seitzinger[b]

Prorocentrum minimum and anthropogenic DON



Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal

Prorocentrum minimum tracks anthropogenic nitrogen and phosphorus inputs on a global basis: Application of spatially explicit nutrient export models

Patricia M. Glibert[a,*], Emilio Mayorga[b], Sybil Seitzinger[b]

Estuarine, Coastal and Shelf Science 115 (2012) 399–413

Contents lists available at SciVerse ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Review

Harmful algal blooms: How strong is the evidence that nutrient ratios and forms influence their occurrence?

Keith Davidson [a,*], Richard J. Gowen [b], Paul Tett [a], Eileen Bresnan [c], Paul J. Harrison [d], April McKinney [b], Stephen Milligan [e], David K. Mills [e], Joe Silke [f], Anne-Marie Crooks [b]

Journal of Environmental Management 146 (2014) 206–216

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Anthropogenic nutrients and harmful algae in coastal waters

CrossMark

Keith Davidson [a,*], Richard J. Gowen [b], Paul J. Harrison [c], Lora E. Fleming [d,e], Porter Hoagland [f], Grigorios Moschonas [a]

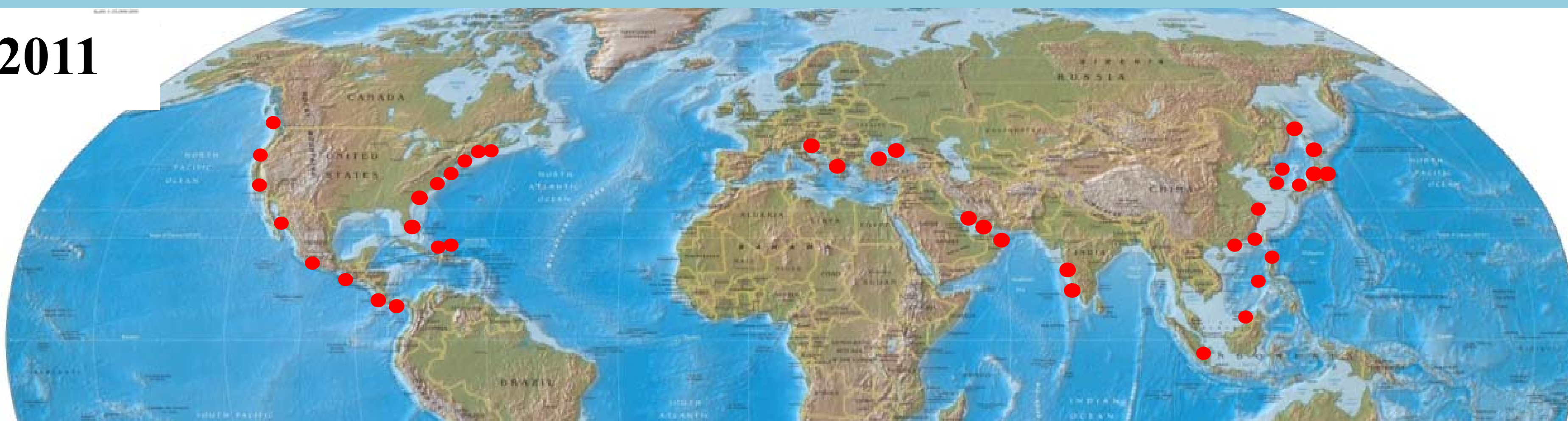
Some HABs display flexible nutritional ecology…

<u>Distribution of *Cochlodinium polykrikoides* blooms</u>

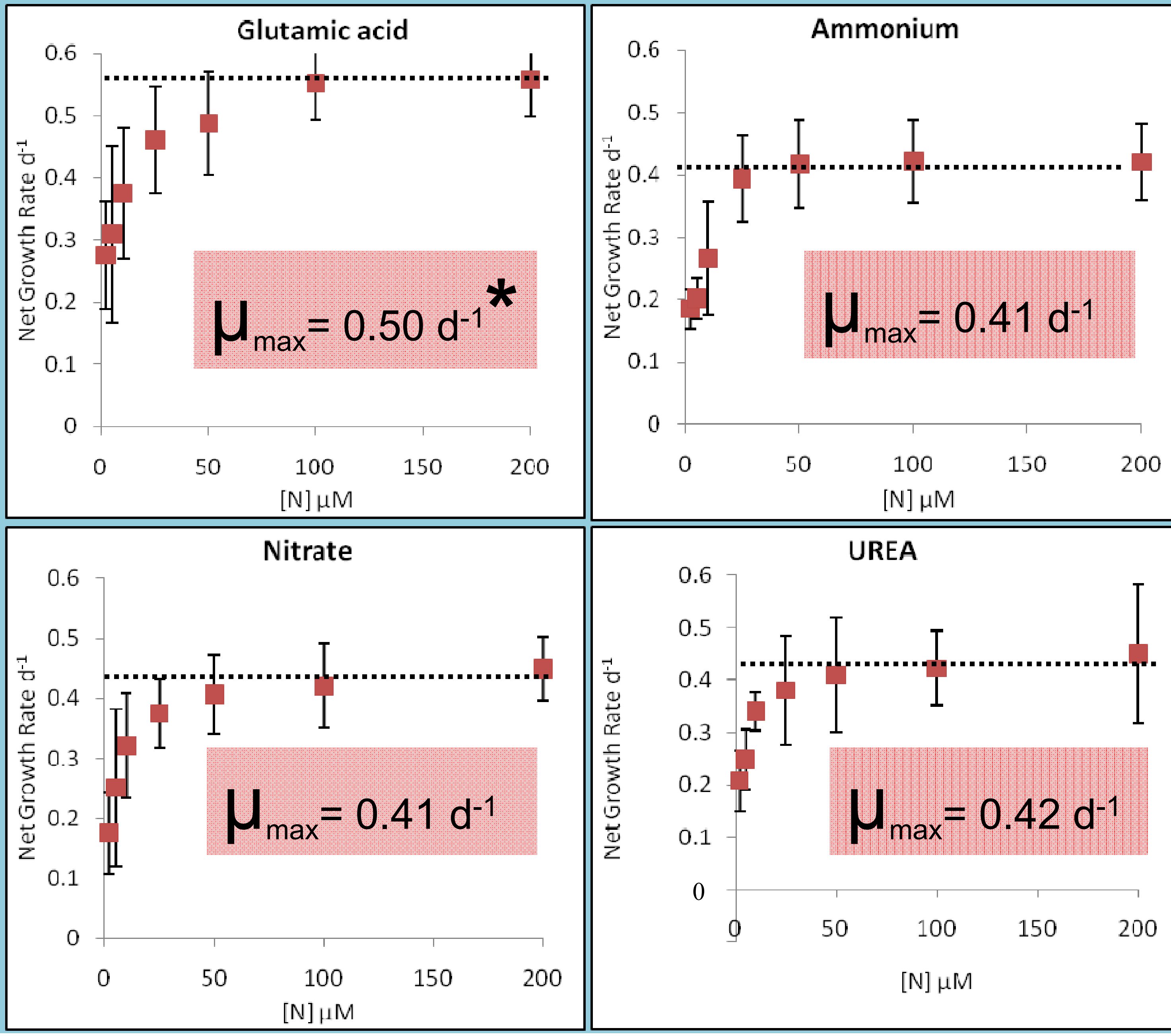
•Highly toxic to many forms of marine life

•*Cochlodinium* blooms have spread across the Northern Hemisphere in the past decade: Korea, Japan, China, Malaysia, Philippines, Indonesia, India, Spain, Italy, Canada, Arabian Gulf, Mexico, Guatemala, Costa Rica, Puerto Rico, North America.

2011



Cochlodinium grows well on many N sources but quickest on DON

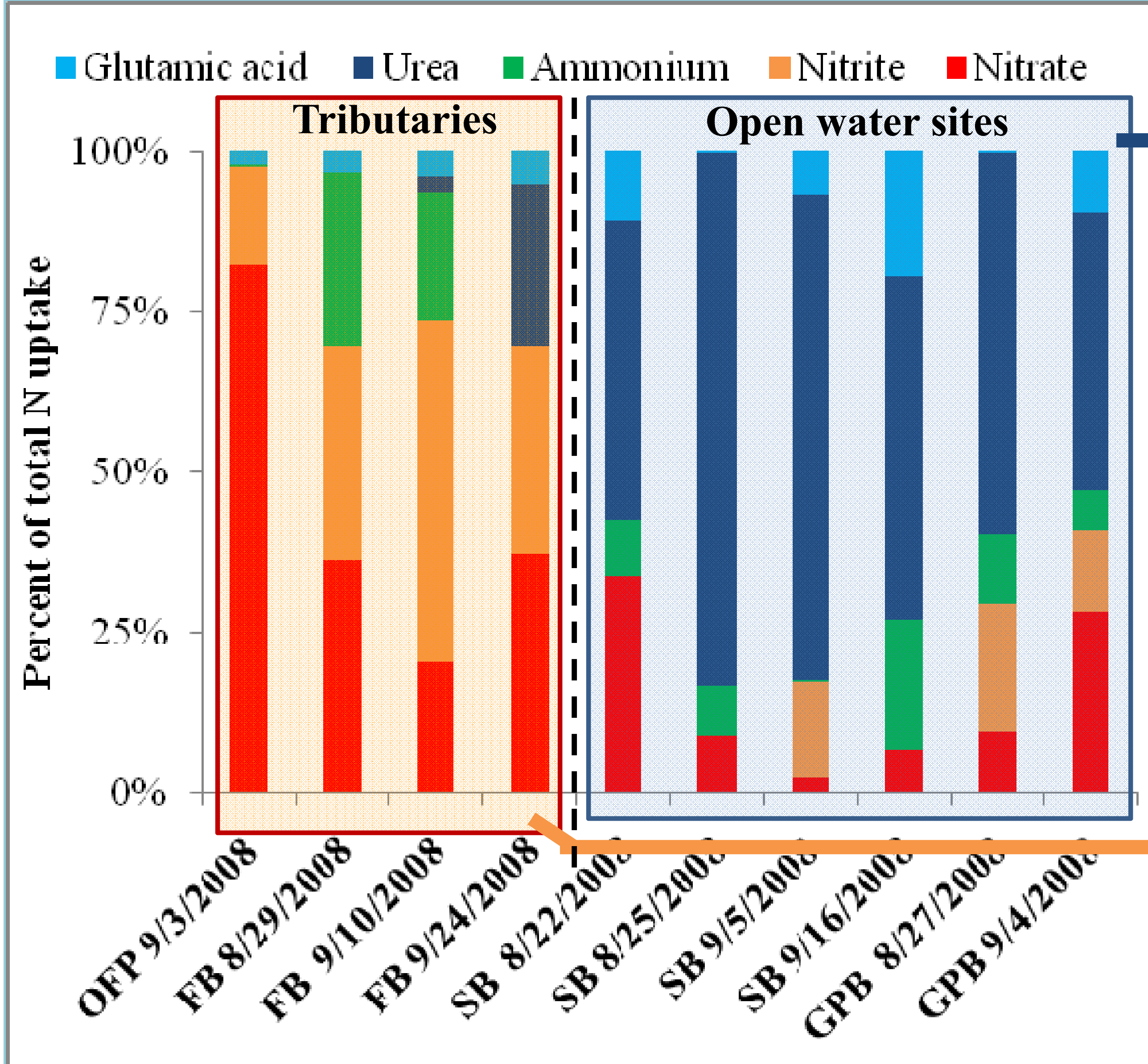


Gobler et al 2012

Sampling sites

Tributaries (high DIN) ***vs.***
open water sites (low DIN)

N uptake, > 20 µm



Open water sites: DON dominated uptake; Low [DIN]

Cp was 70 - 98% of cells > 20 µm for all ten experiments.

Tributaries: Mostly NO_3^-, NO_2^- uptake; shallow sites with high [NO_3^-]

Gobler et al 2012

The interactions between nutrients and some HABs are ecosystem dependent.

Puget Sound, northwest USA, *Alexandrium* blooms and PSP

Alexandrium in the Puget Sound

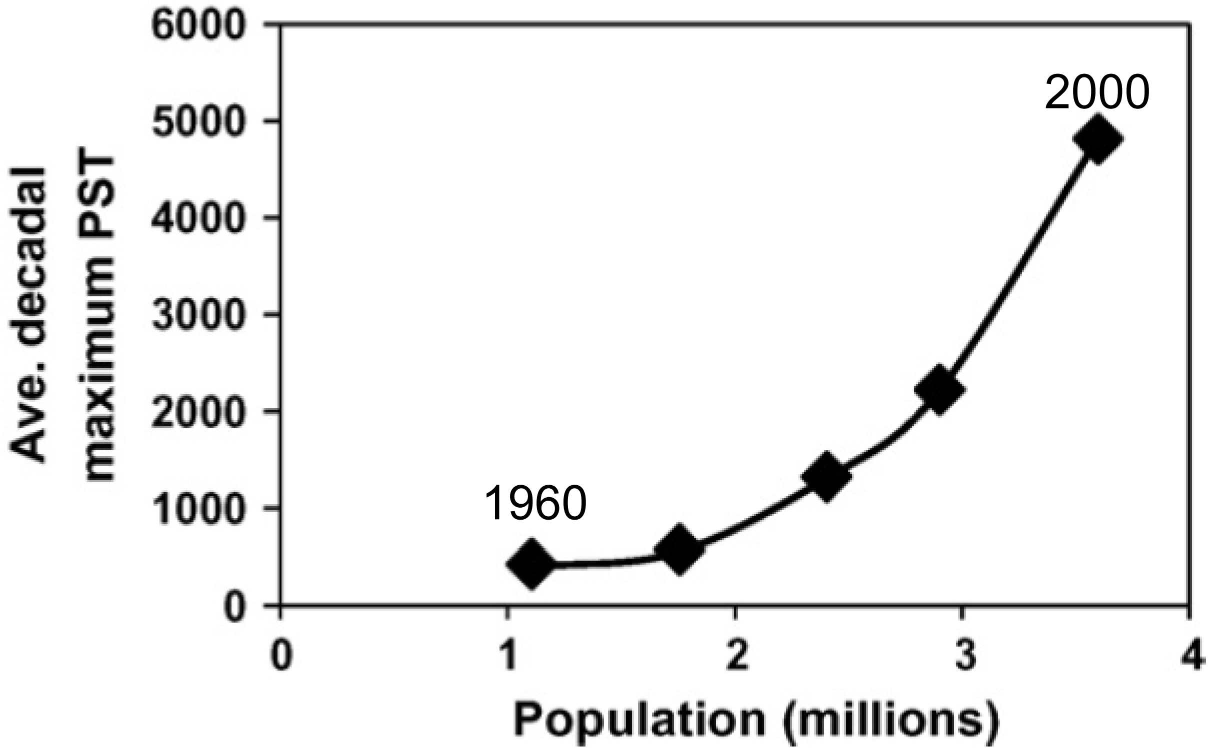
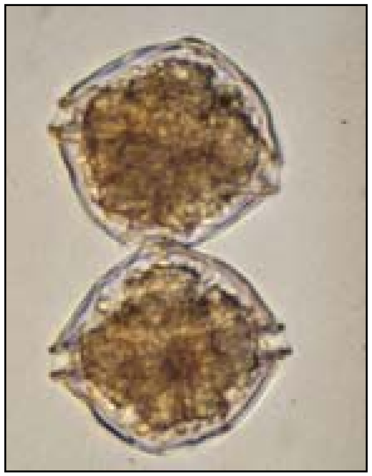


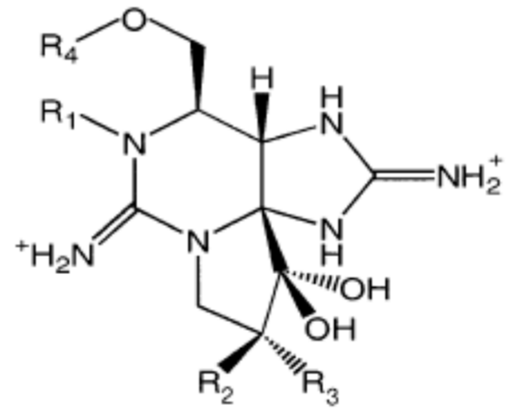
Fig. 2. Relationship between the growth in human population and the average decadal maximum paralytic shellfish toxins (PST) from dinoflagellate HABs from Puget Sound, Washington State, where continuous monitoring of paralytic shellfish poisoning has been ongoing since the mid-1950s. Human population data for the counties bordering Puget Sound for the past 40 years were derived from the U.S. census (redrawn from Trainer et al., 2003).

Alexandrium blooms in New York, USA

Alexandrium red tides and paralytic shellfish poisoning (PSP)

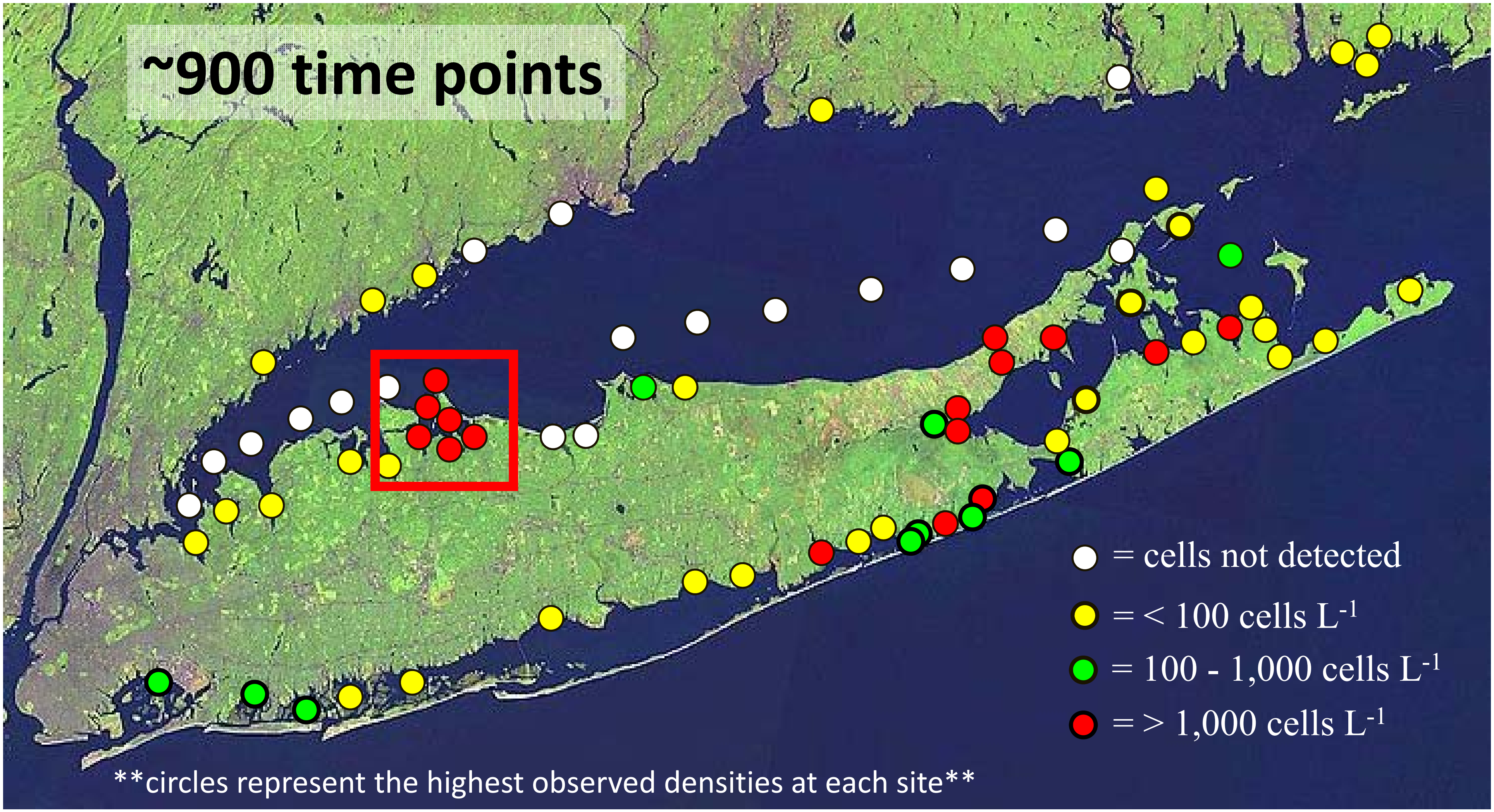


Alexandrium



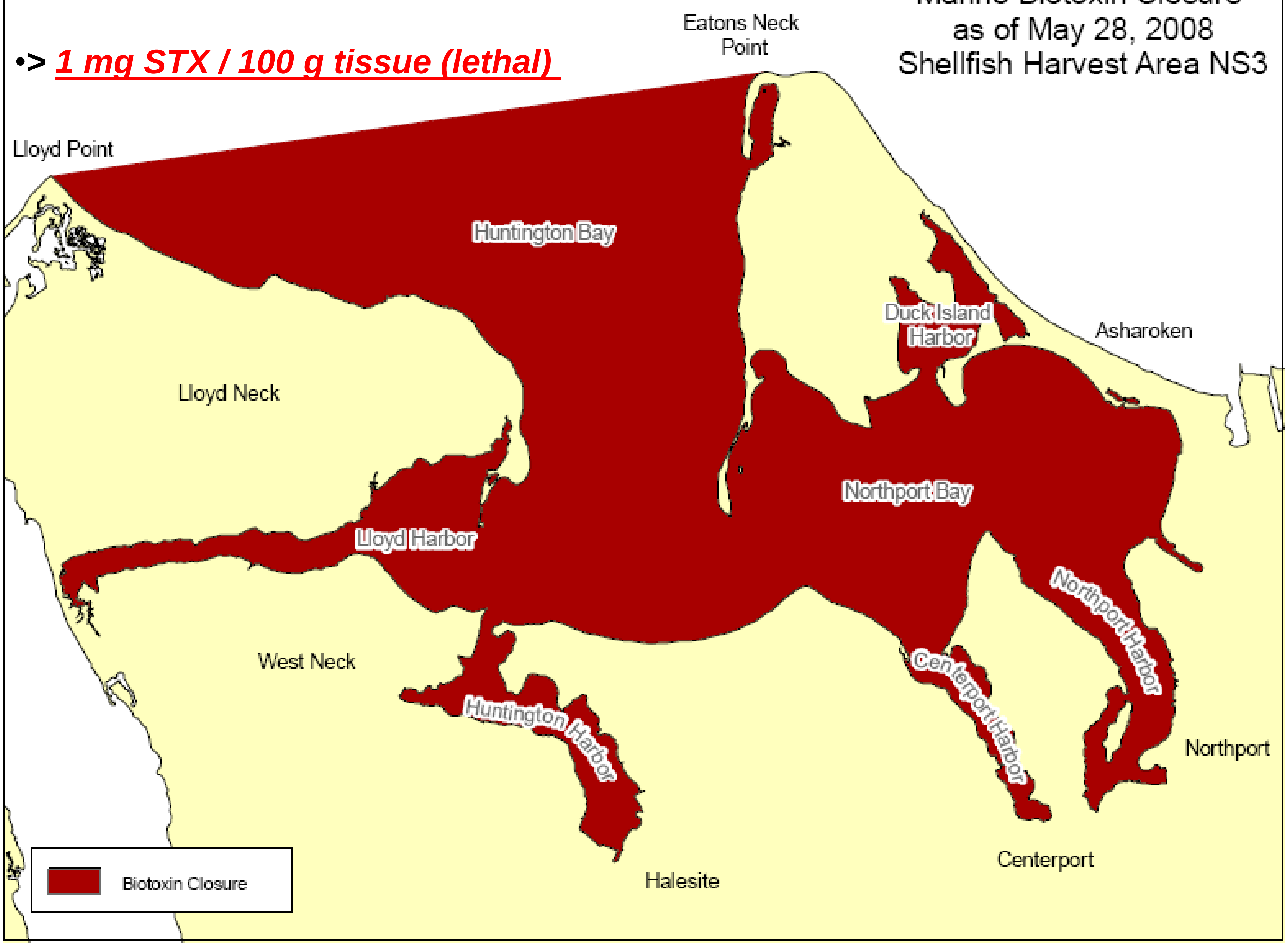
Saxitoxin

Presence of PSP-producing *Alexandrium* in LI and CT: 2007-2014

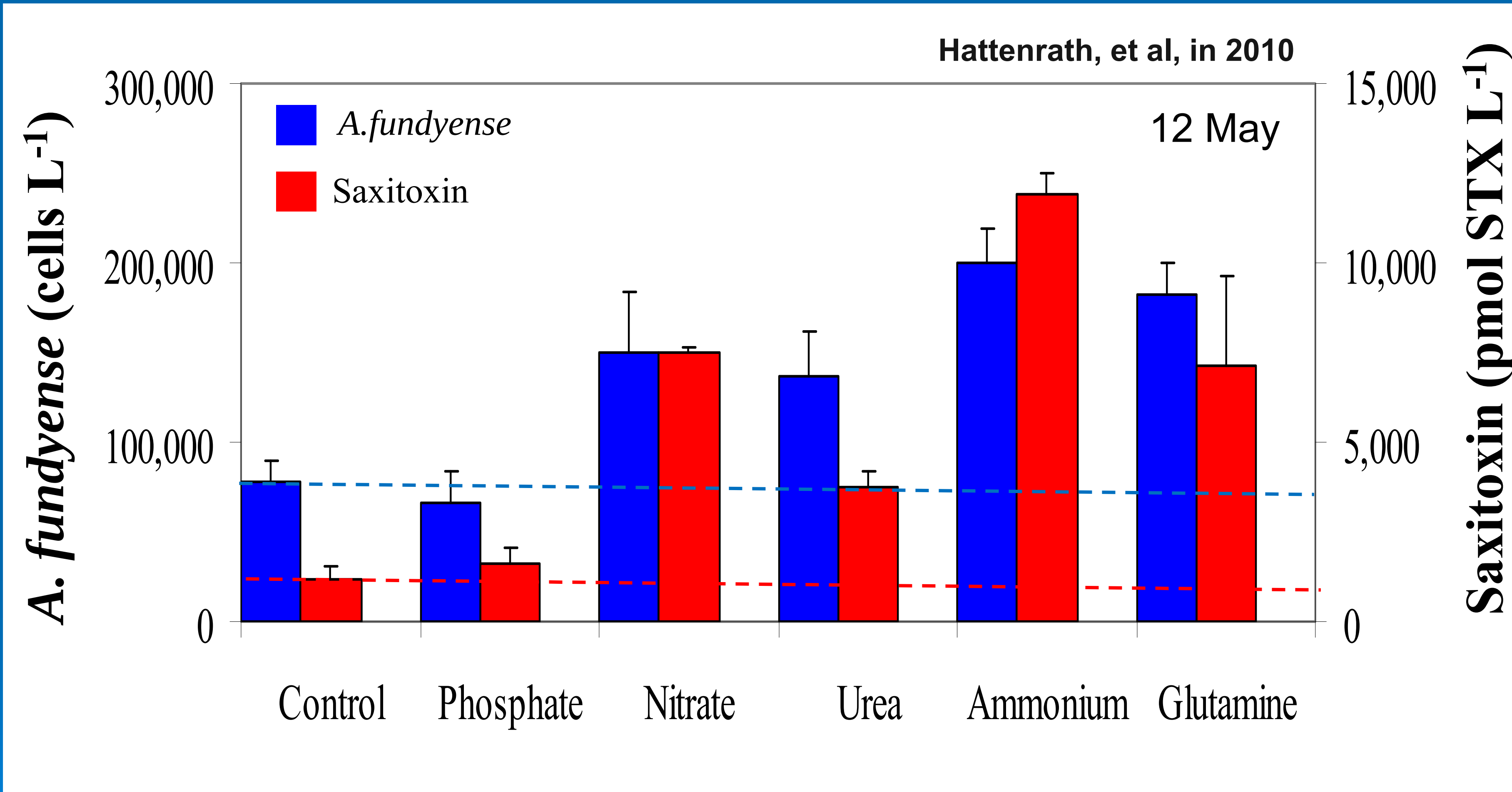


- *Alexandrium* found at 49 of 65 sites samples (75%)

- *7,000 acre closure in Northport – Huntington Bay*
- **>** ***1 mg STX / 100 g tissue (lethal)***

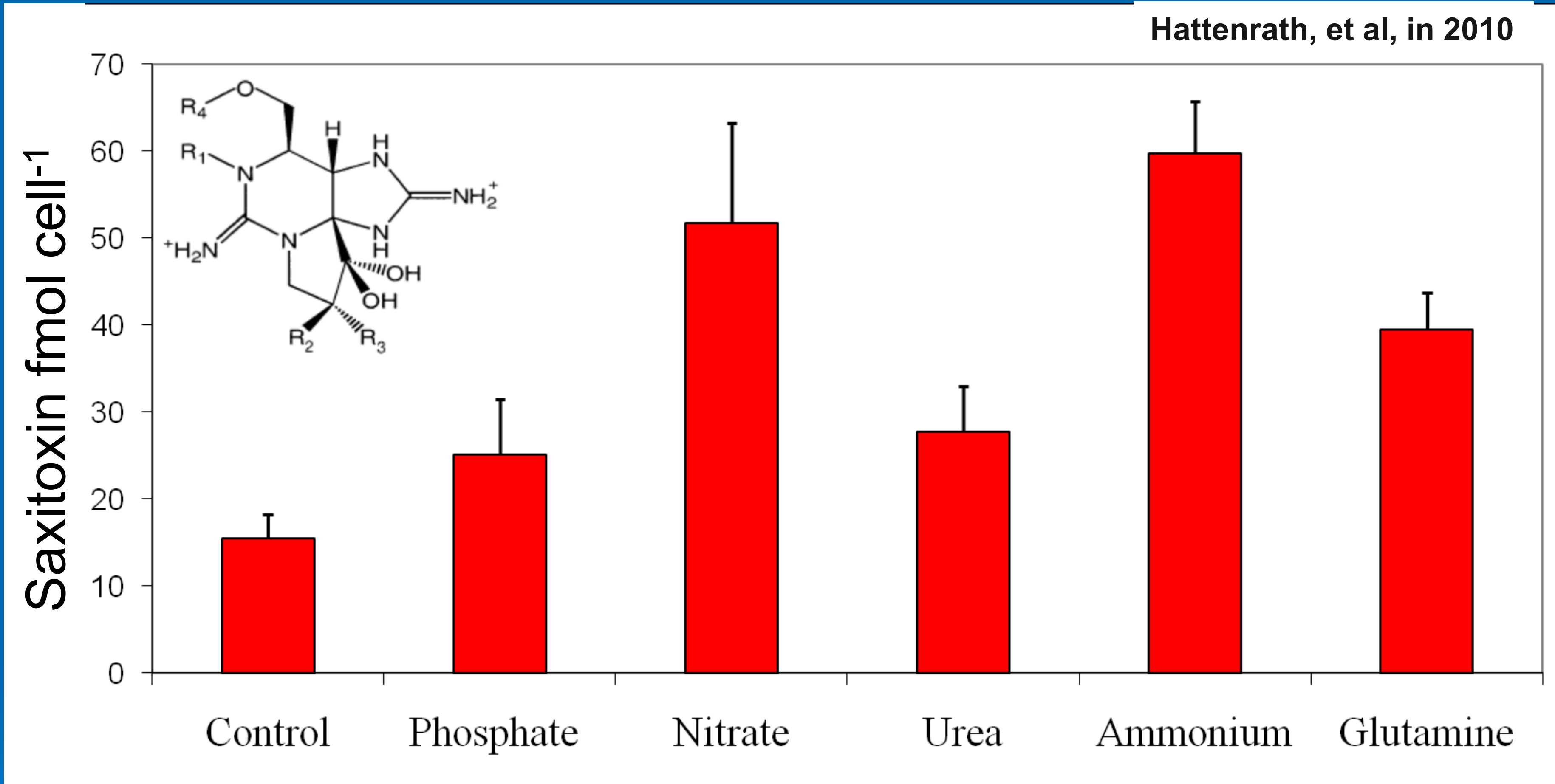


Impact of nutrient loading on *Alexandrium* densities and toxicity, 2008



- N increased both *Alexandrium* densities and toxicity

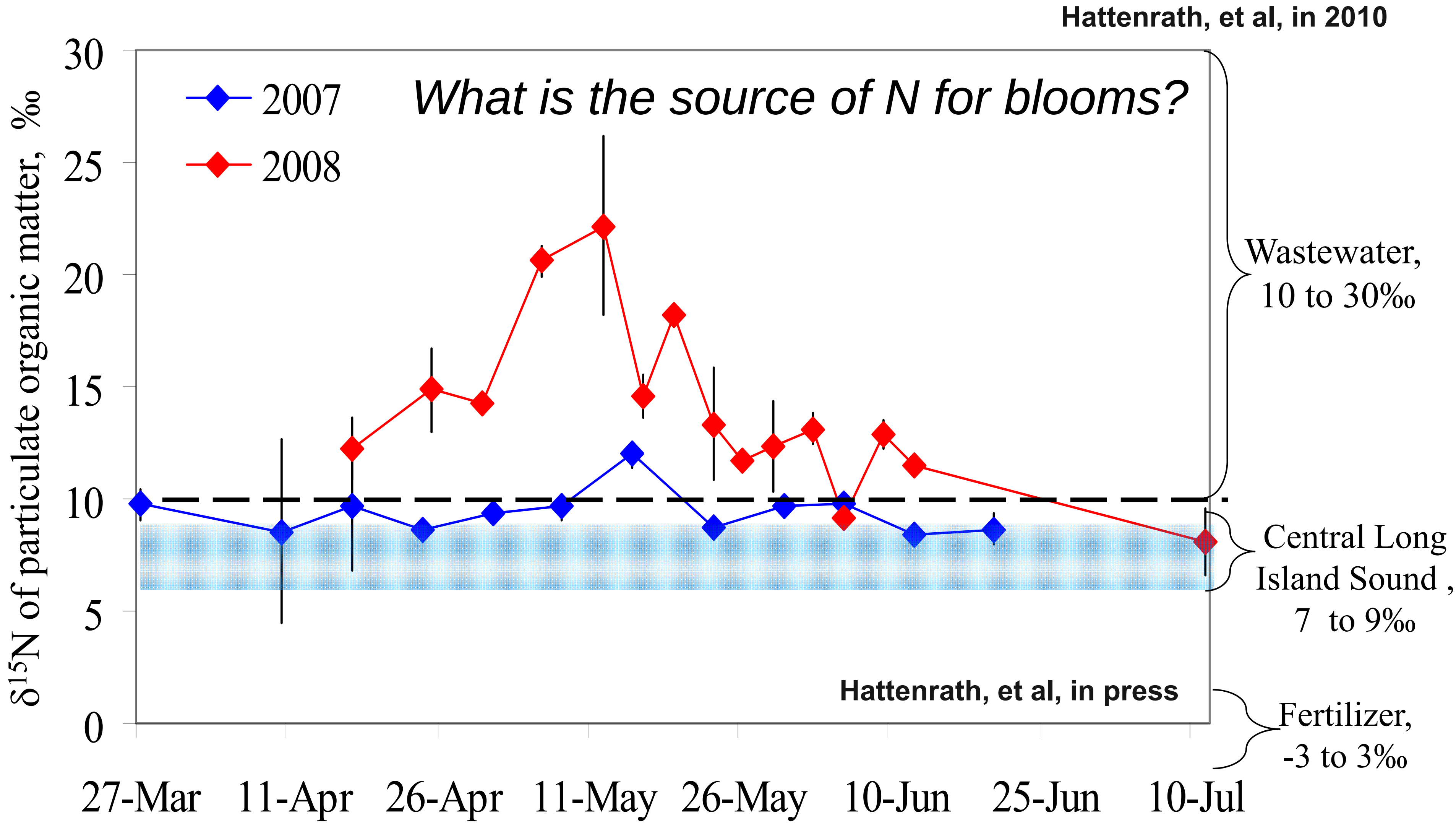
Impact of nutrient loading on saxitoxin per cell, 2008



- N significantly enhanced saxitoxin concentrations per cell in 66% of experiments ($p<0.05$).
- Toxin per cell decreases seen in the field due to nutrient stress.

What are the sources of nitrogen to blooms?

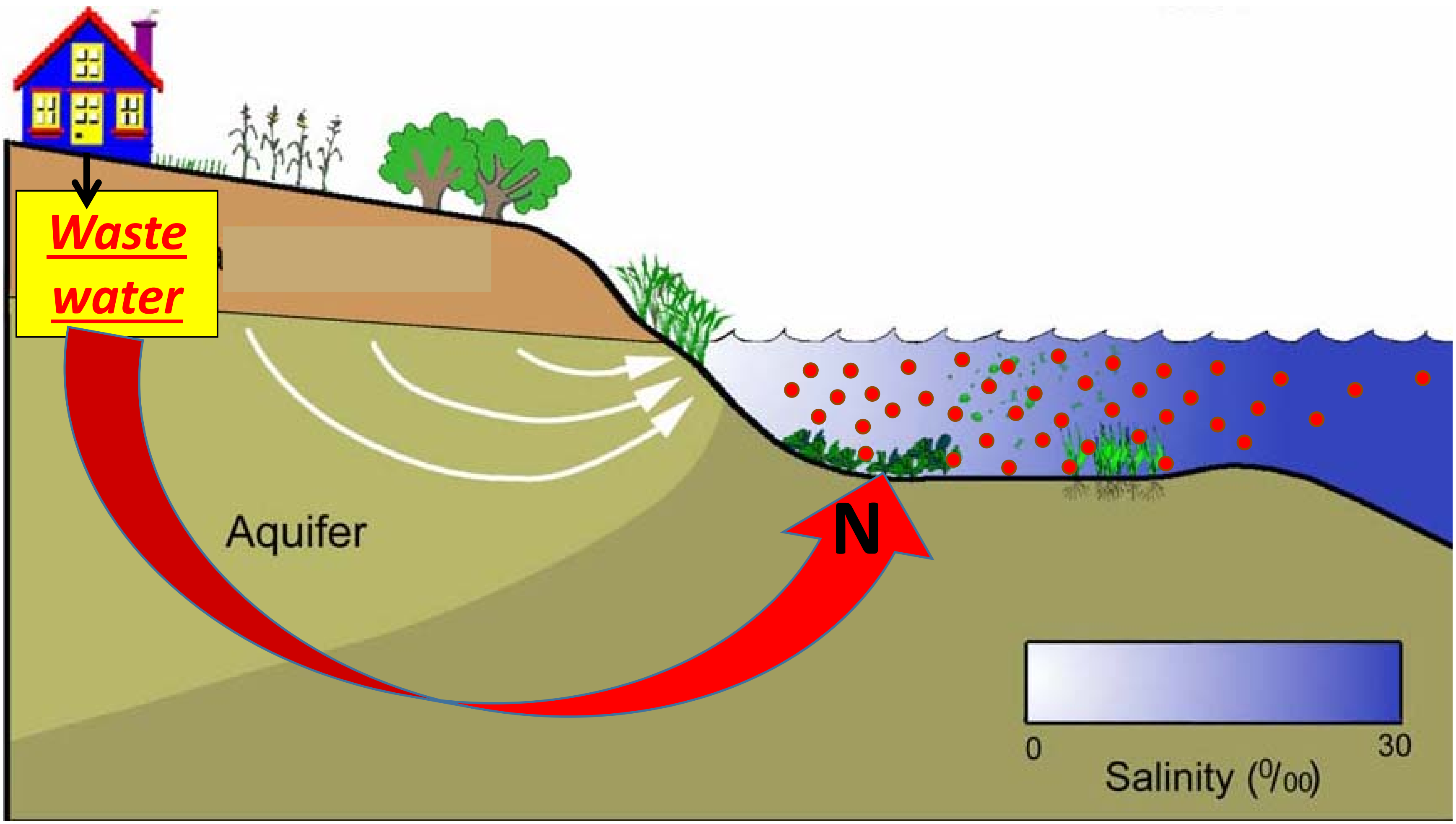
$\delta^{15}N$ of particulate organic matter from Northport Harbor



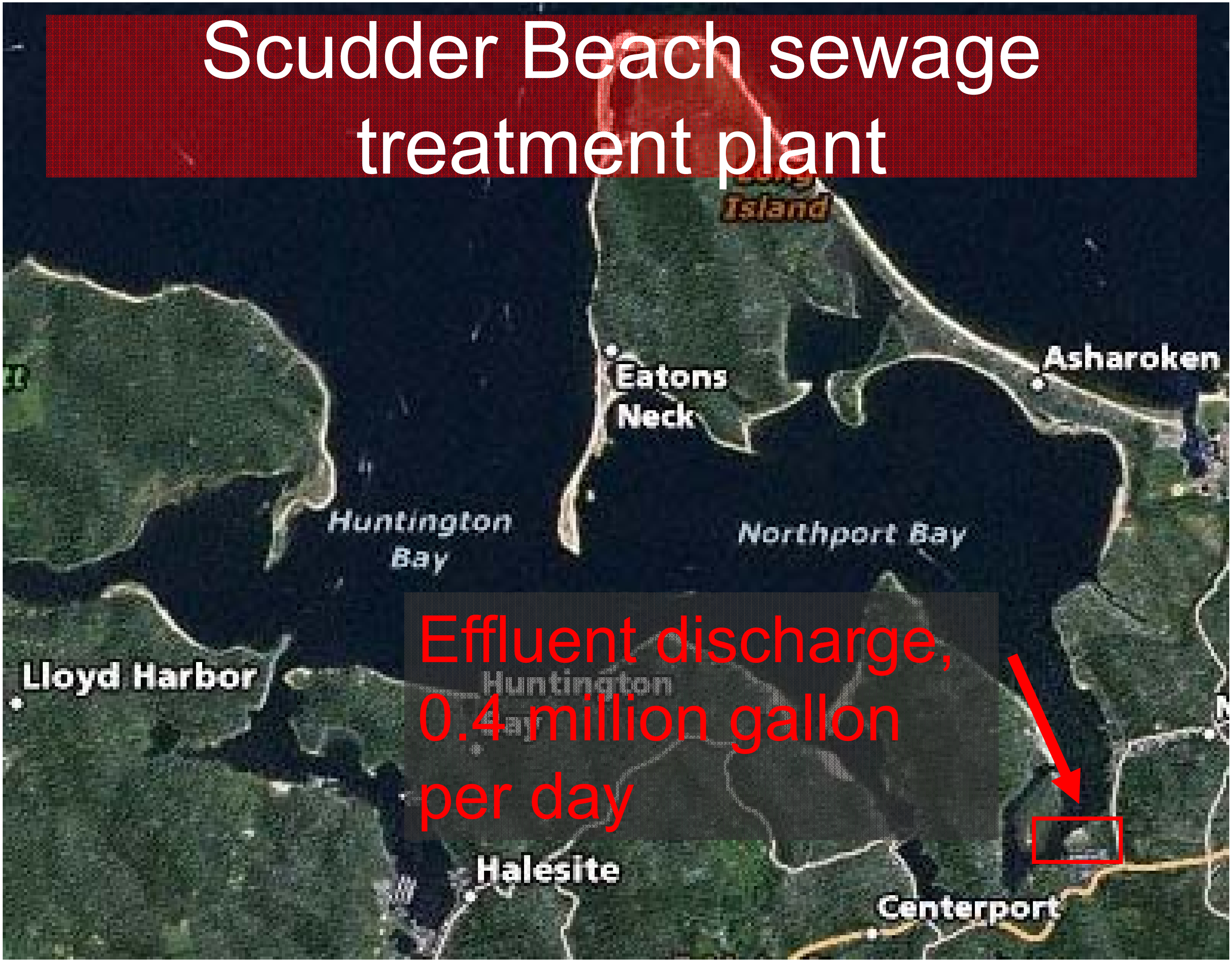
$\delta^{15}N$ of particulate organic matter was significantly ($p<0.001$) correlated to *A. fundyense* cell densities and saxitoxin, suggesting that blooms are using wastewater derived N

Wastewater-derived nitrogen loading promotes PSP in Long Island Sound.

-Hattenrath et al 2010, Harmful Algae

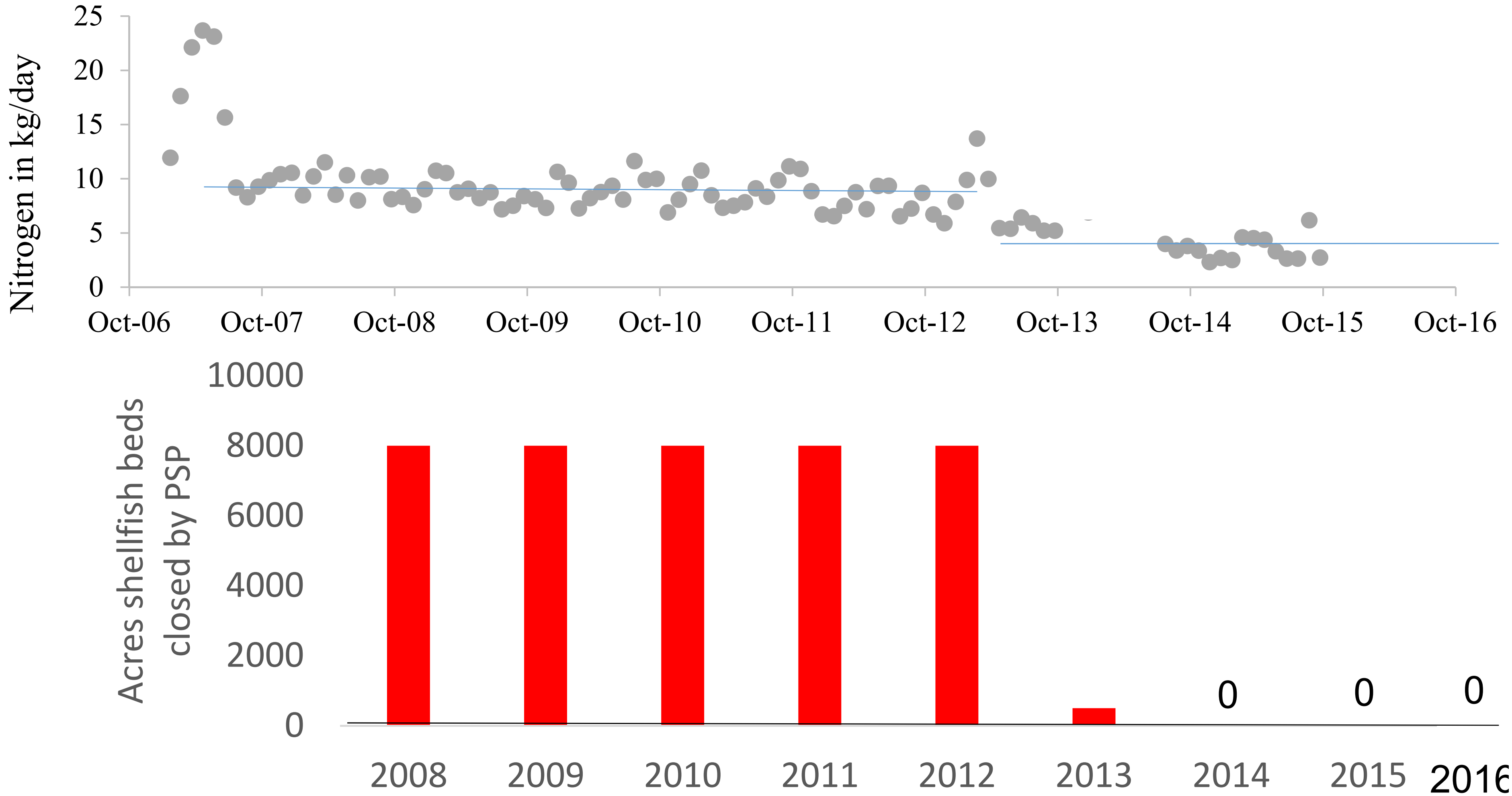


Scudder Beach sewage treatment plant



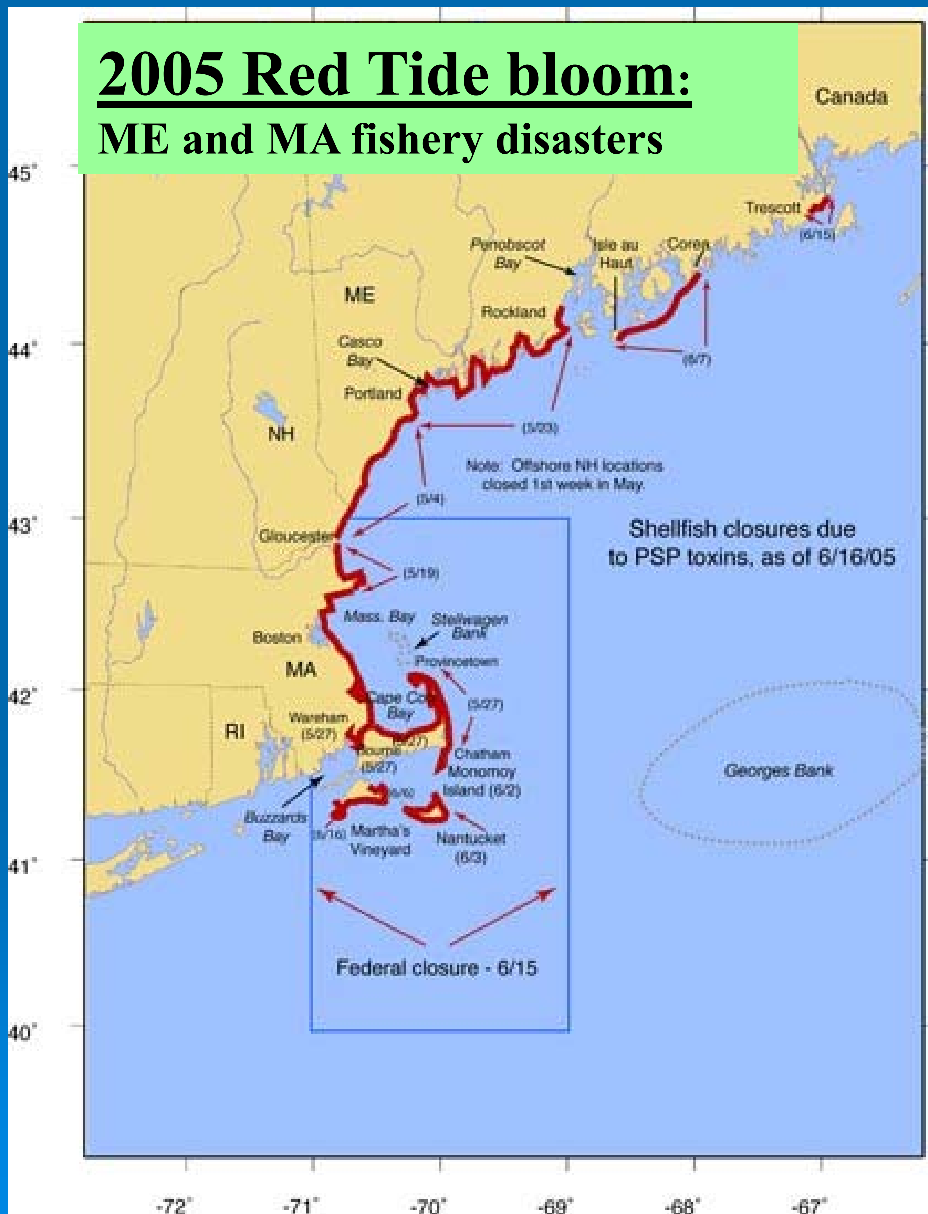
Effluent discharge, 0.4 million gallon per day

Acres of shellfish beds closed by PSP



Alexandrium blooms in northeast, USA

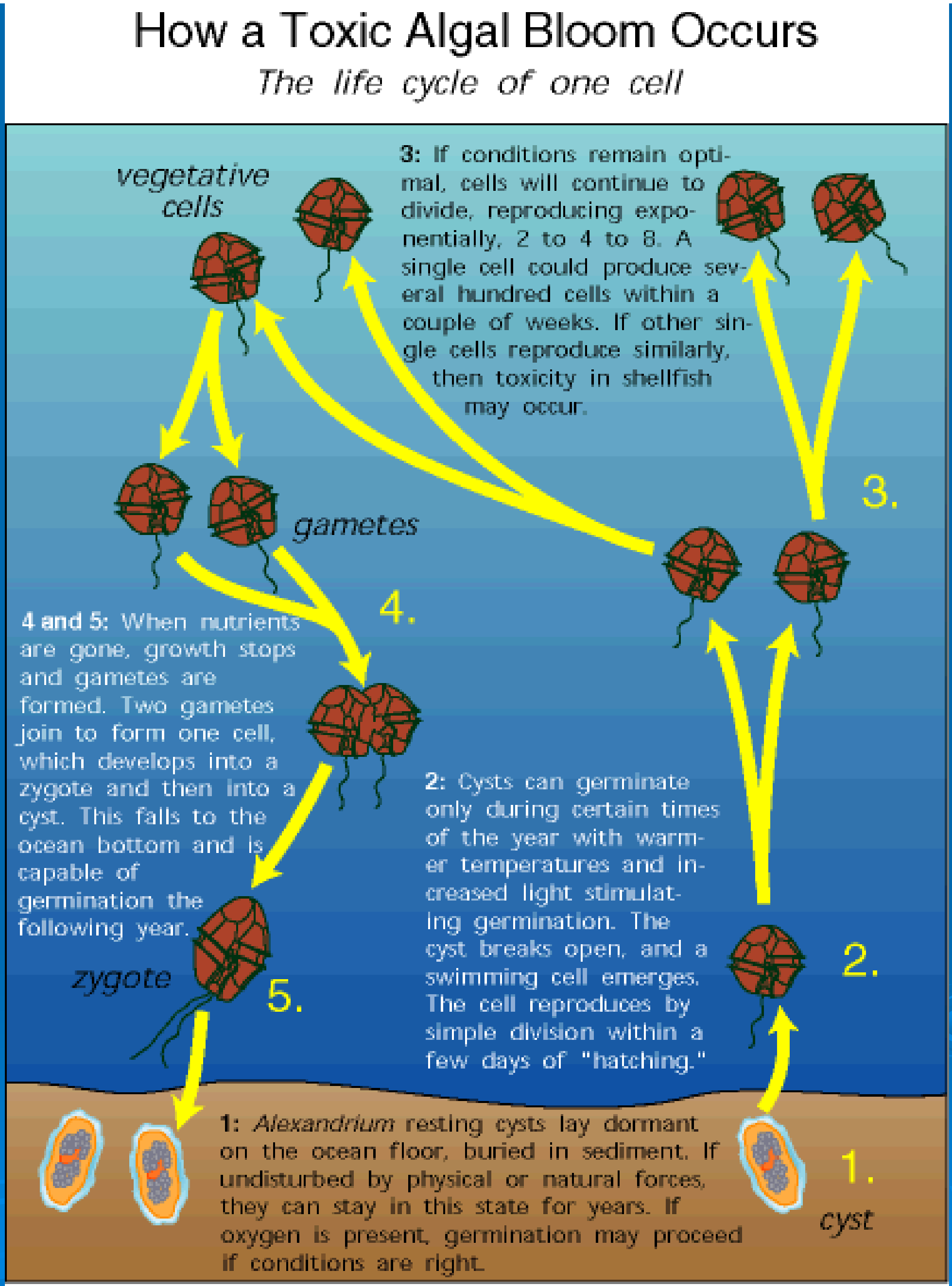
PSP in Gulf of Maine:



Anderson 1997, Jin et al. 2008

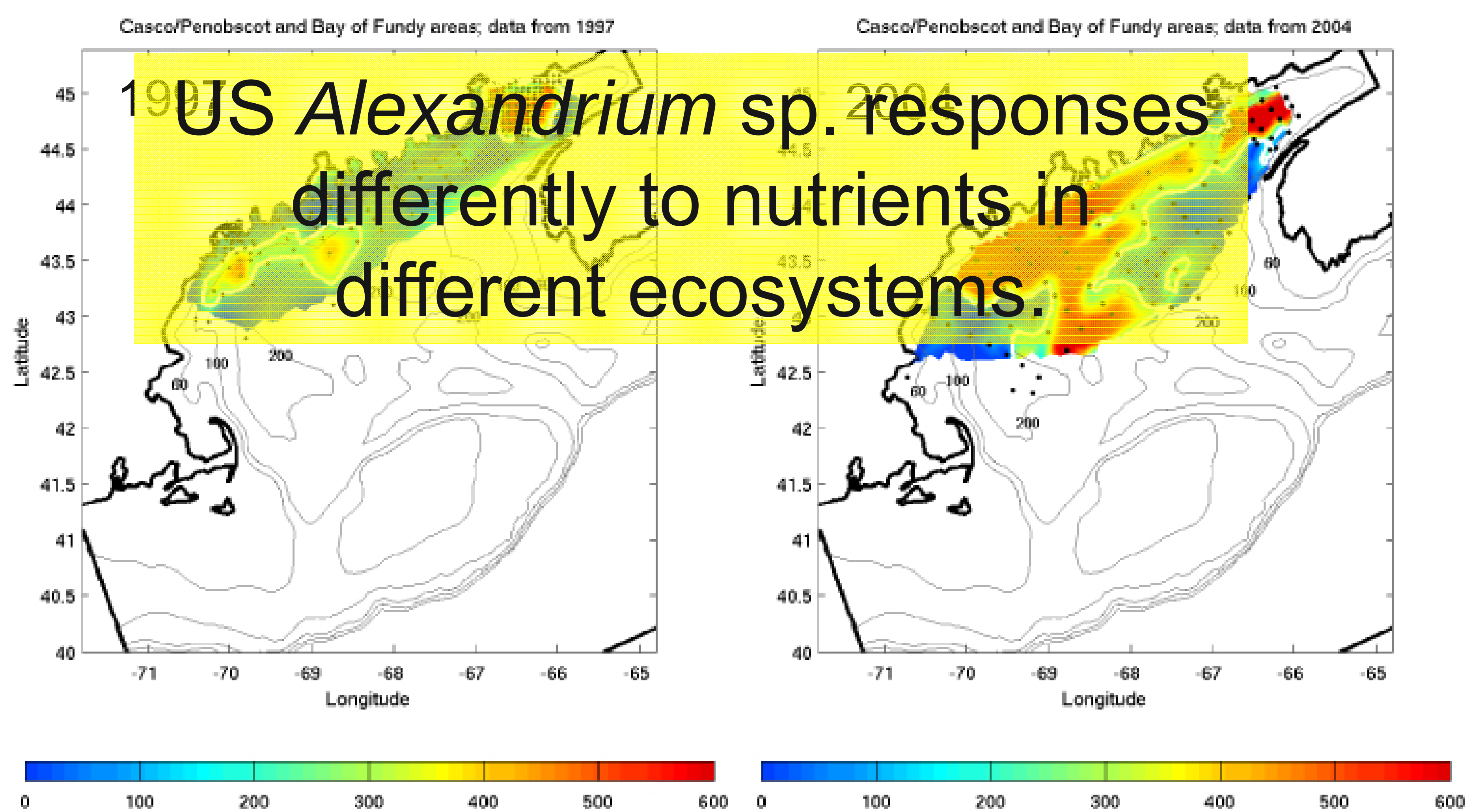
Alexandrium sp. Life History Strategy

- Cyst formation is a critical life stage adaptation for many dinoflagellate blooms.



In the Gulf of Maine, cysts beds are the best predictor of blooms.

- Models do not require a nutrient-dependent growth rate.
- Nutrients do not effect bloom (Anderson et al 2008)



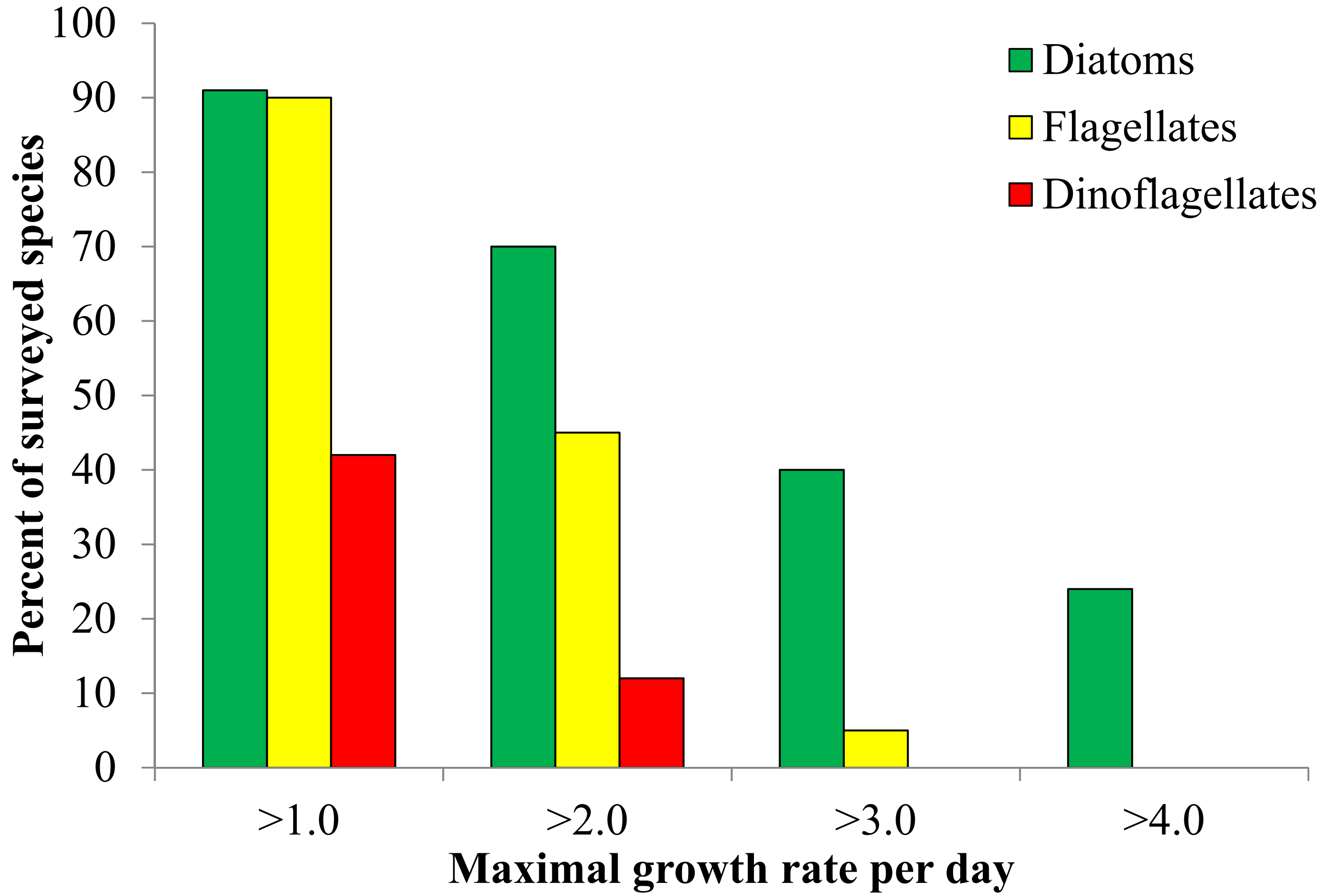
US *Alexandrium* sp. responses differently to nutrients in different ecosystems.

Small bloom in 1998

Large, system-wide bloom in 2005

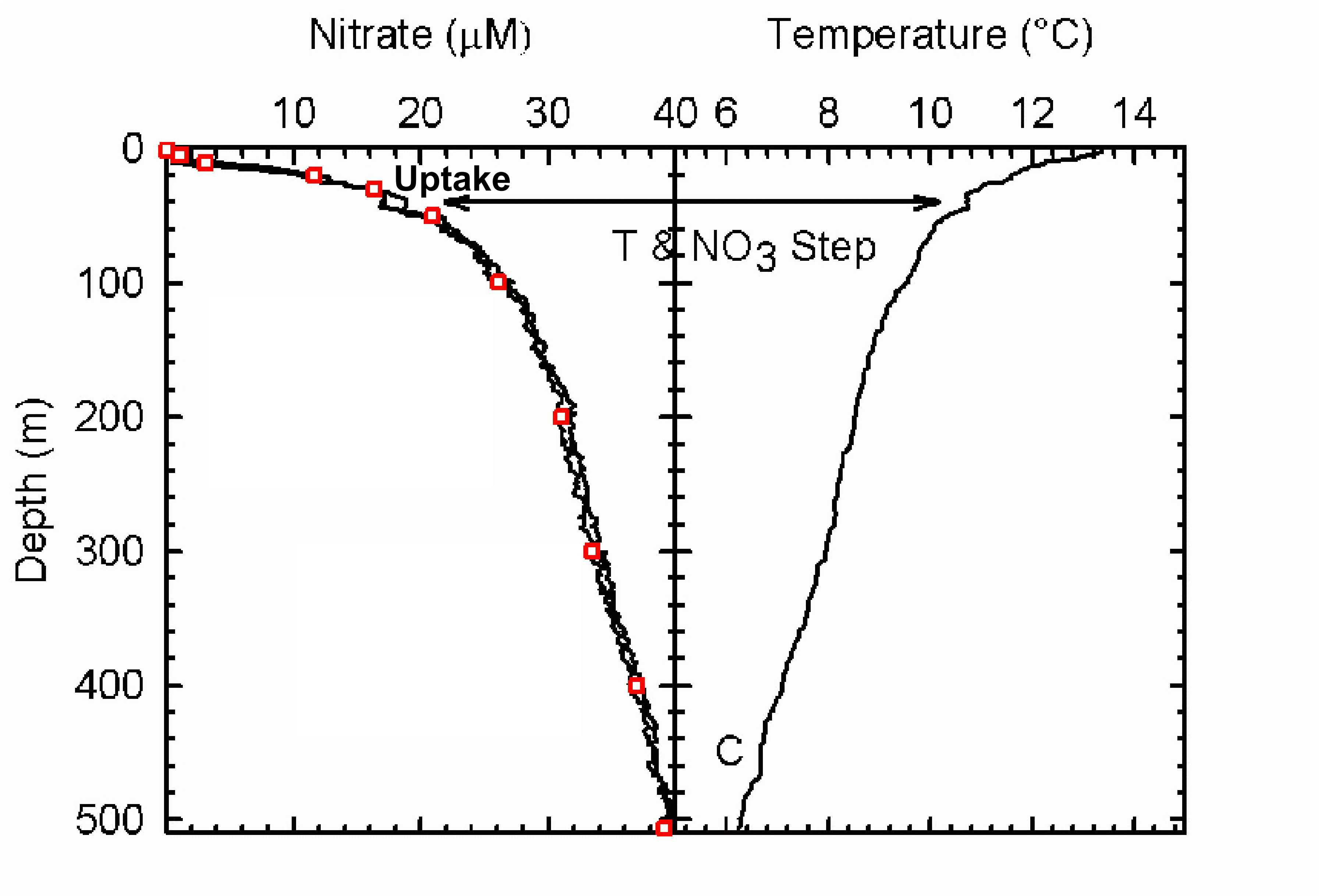
Some HABs dominate when inorganic nutrient levels are low…

Race to the top! Absent of nutrient limitation, diatoms win.

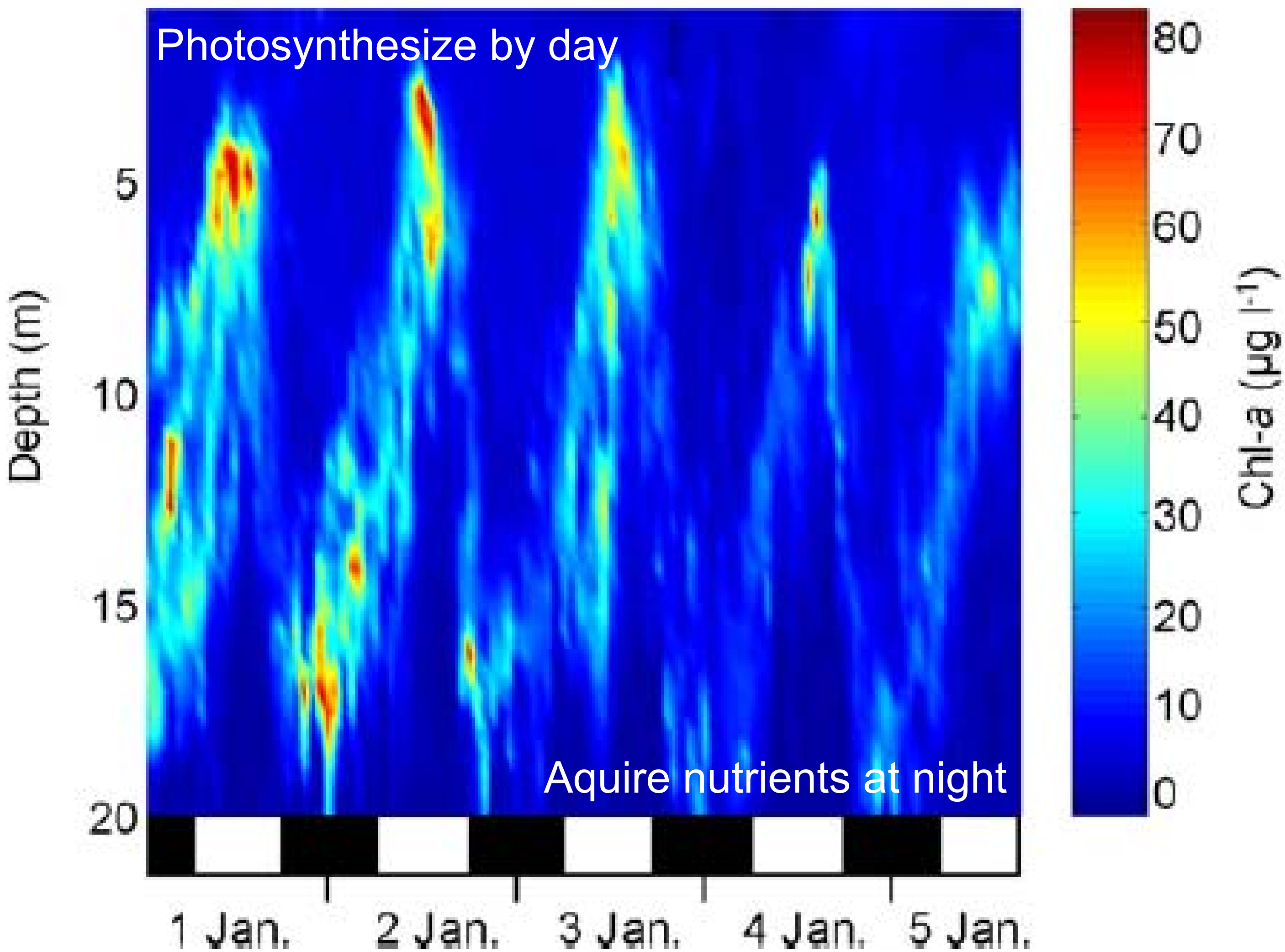


Smayda 1997, 100 species surveyed

Vertical trends in nutrients

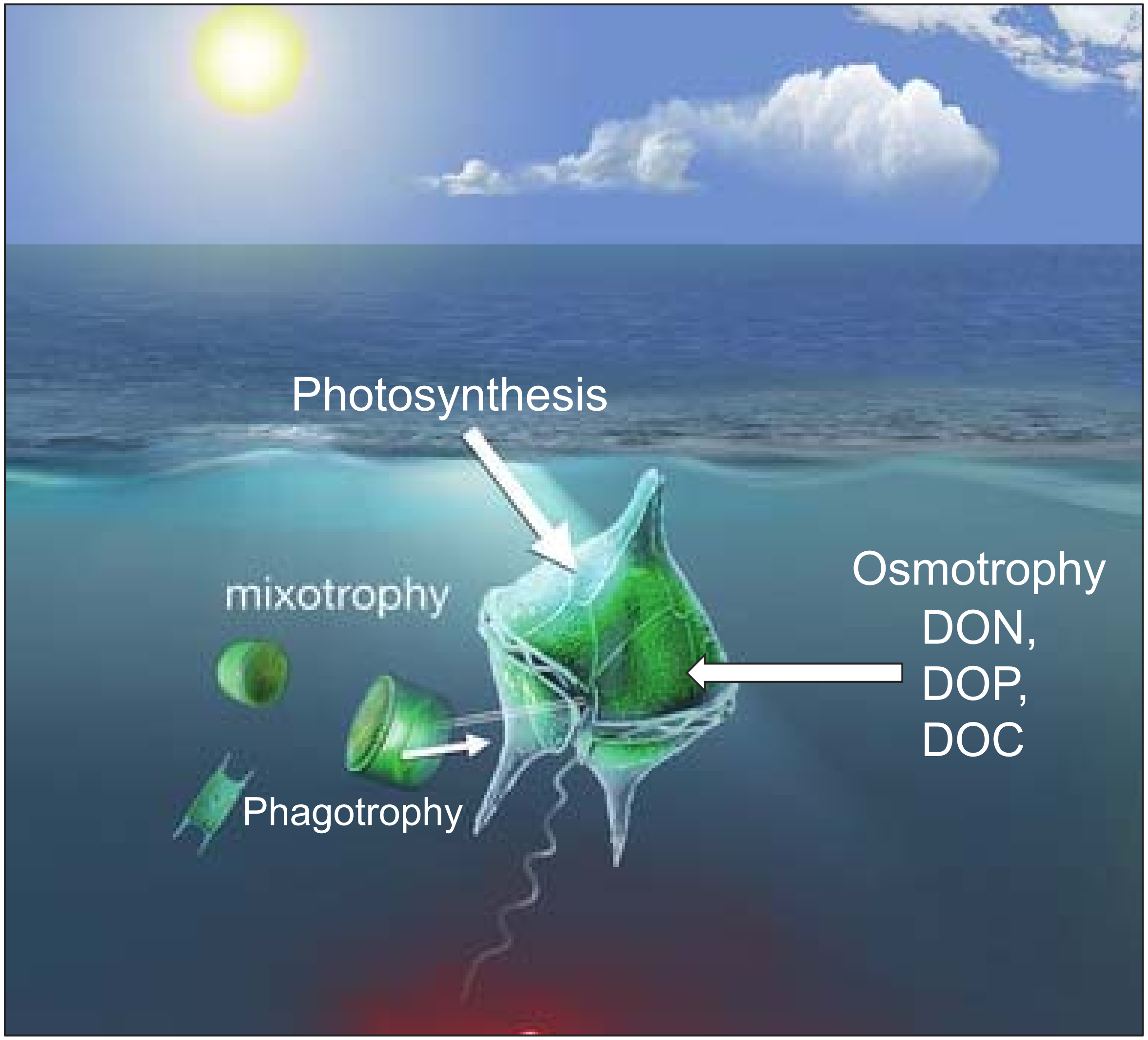


Diel Vertical Migration, *Gymnodinium catenatum*,

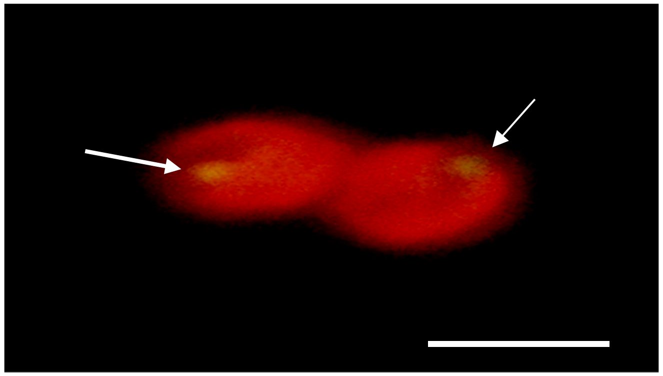


Doblin et al 2006

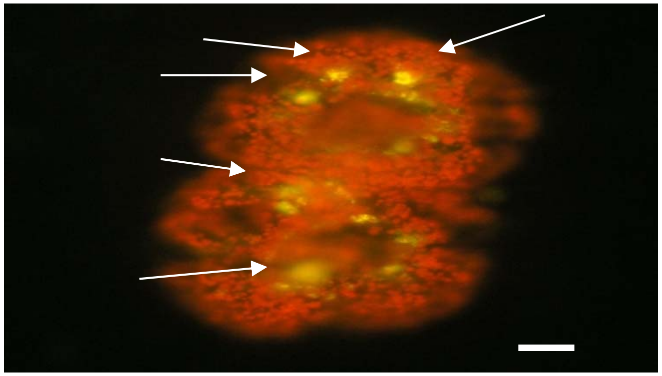
Most marine HABs are dinoflagellates; most dinoflagellates are **mixotrophic**.



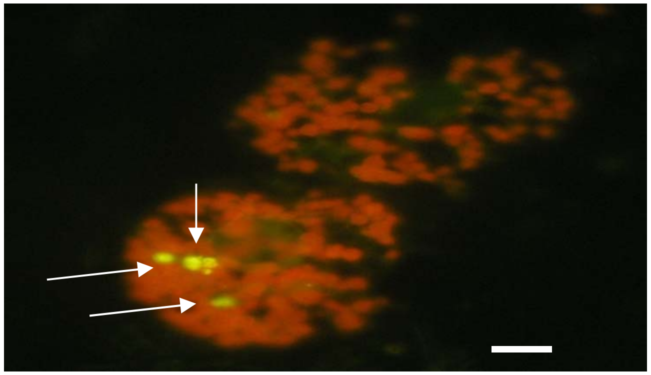
Feeding by mixotrophic dinoflagellates on cyanobacteria *Synechococcus*



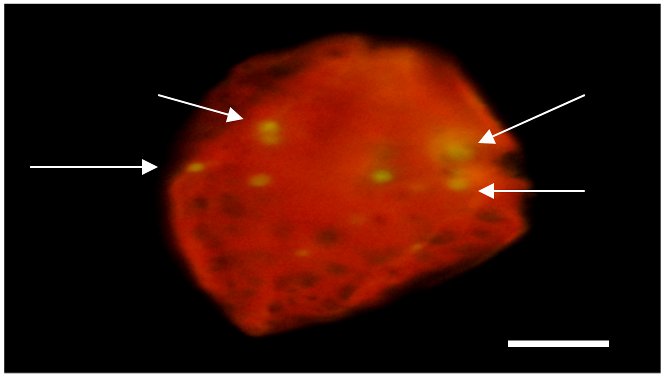
Heterocapsa rotundata



Gymnodinium catenatum



Cochlodinium polykrikoides



Prorocentrum micans

Scale bar = 10 µm

Jeong et al (2005a) Aquatic Microbial Ecology 41:131

Phagotrophic (feeding) dinoflagellates

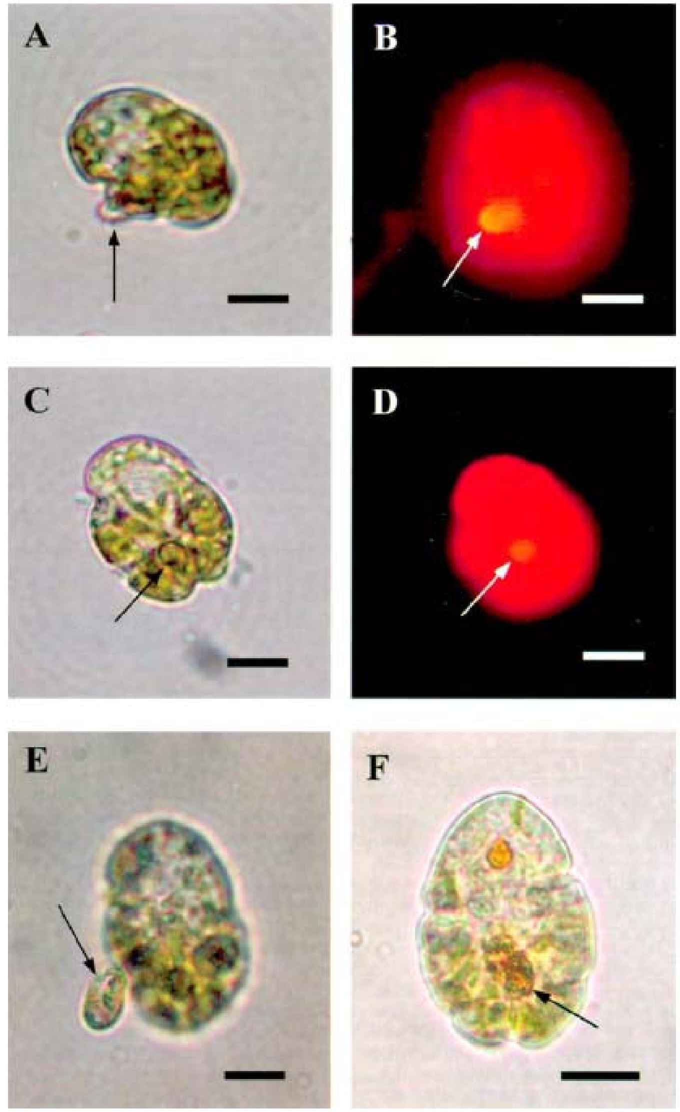
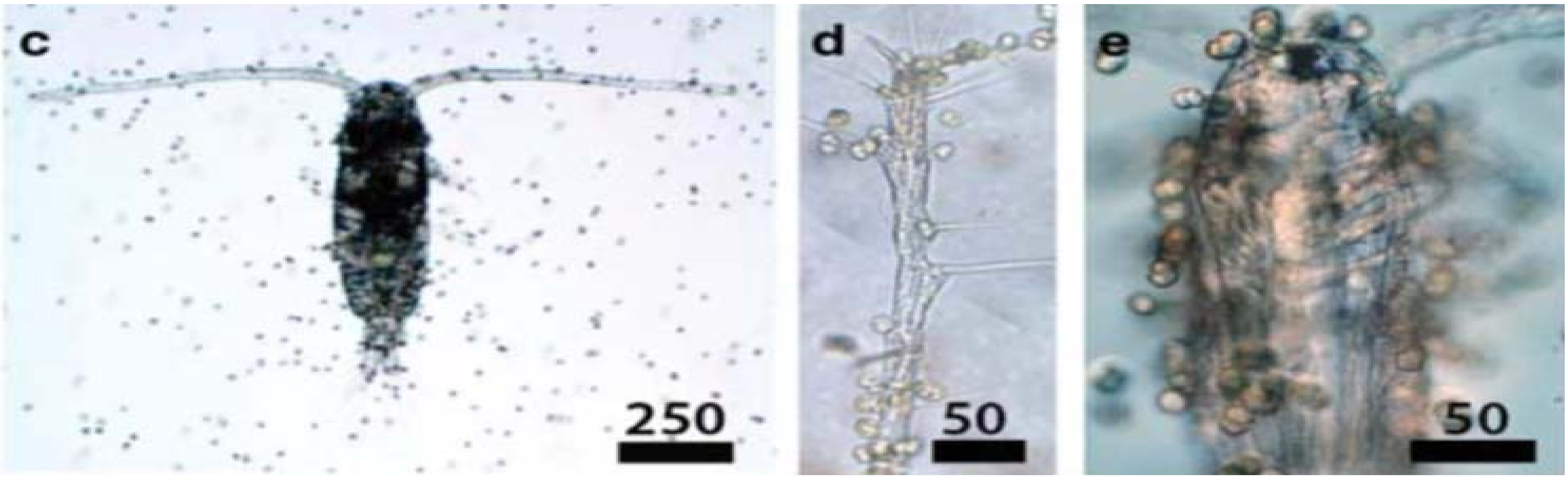


Fig. 1. The feeding process of *Cochlodinium polykrikoides*. **A, B**. *Cochlodinium polykrikoides* has engulfed approximately half of the body of an unidentified cryptophyte cell. **C, D**. An ingested cryptophyte cell inside the same predator cell as in (A). **E**. A *C. polykrikoides* has captured a *Rhodomonas* cell by the sulcus. **F**. Another *C. polykridoides* has ingested a *Rhodomonas* cell. Arrows indicate ingested prey cells. A, C, E, F are phase photomicrographs and B and D are photomicrographs taken using epifluorescence. All scale bars = 10 µm.

Protists can ingest prey of equal or larger size than themselves



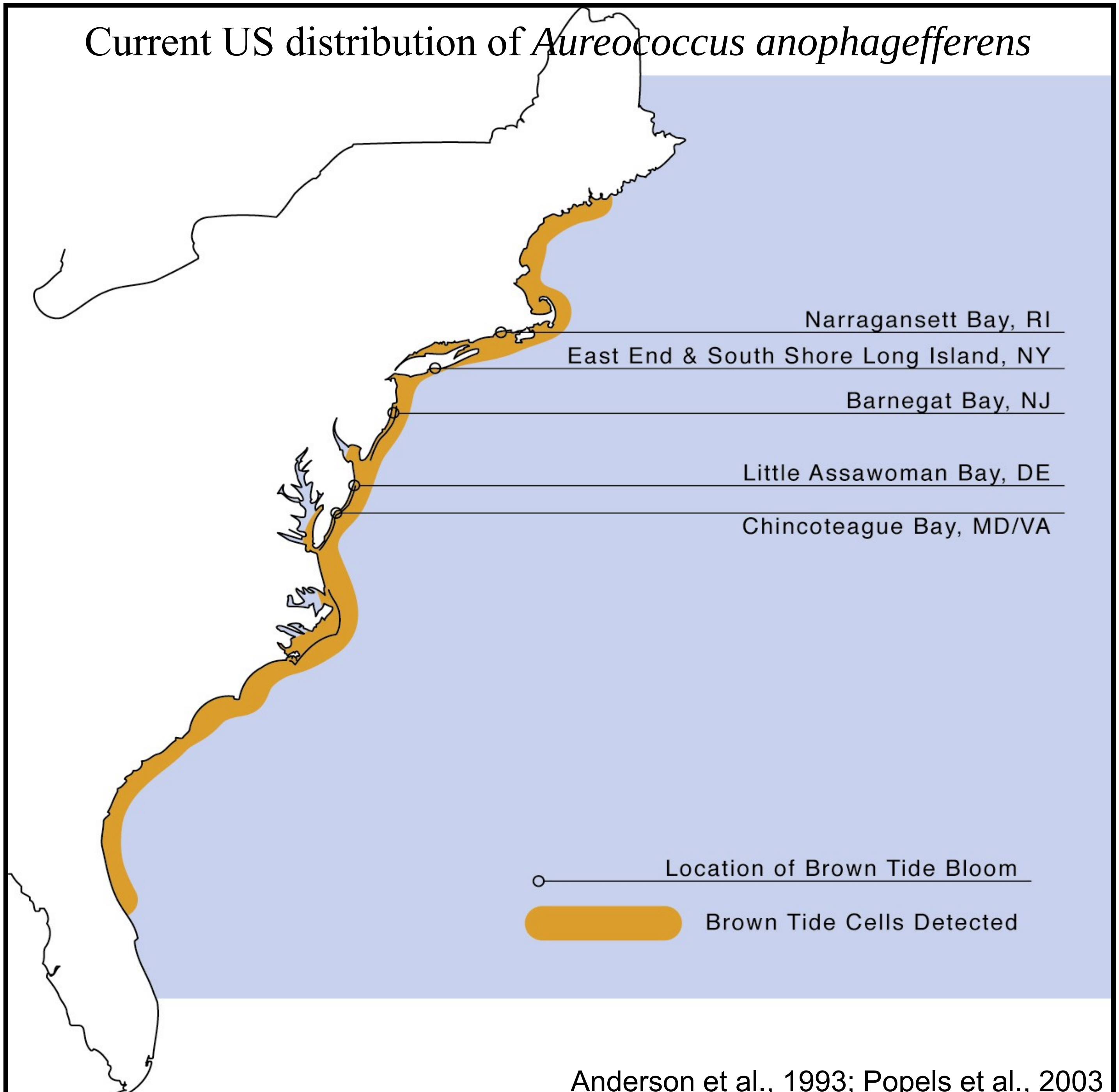
Berge et al. 2012

Dinoflagellate *K. armiger* swarms and attacks a copepod

Some some non-dinoflagellate HABs also dominate when inorganic nutrient levels are low…

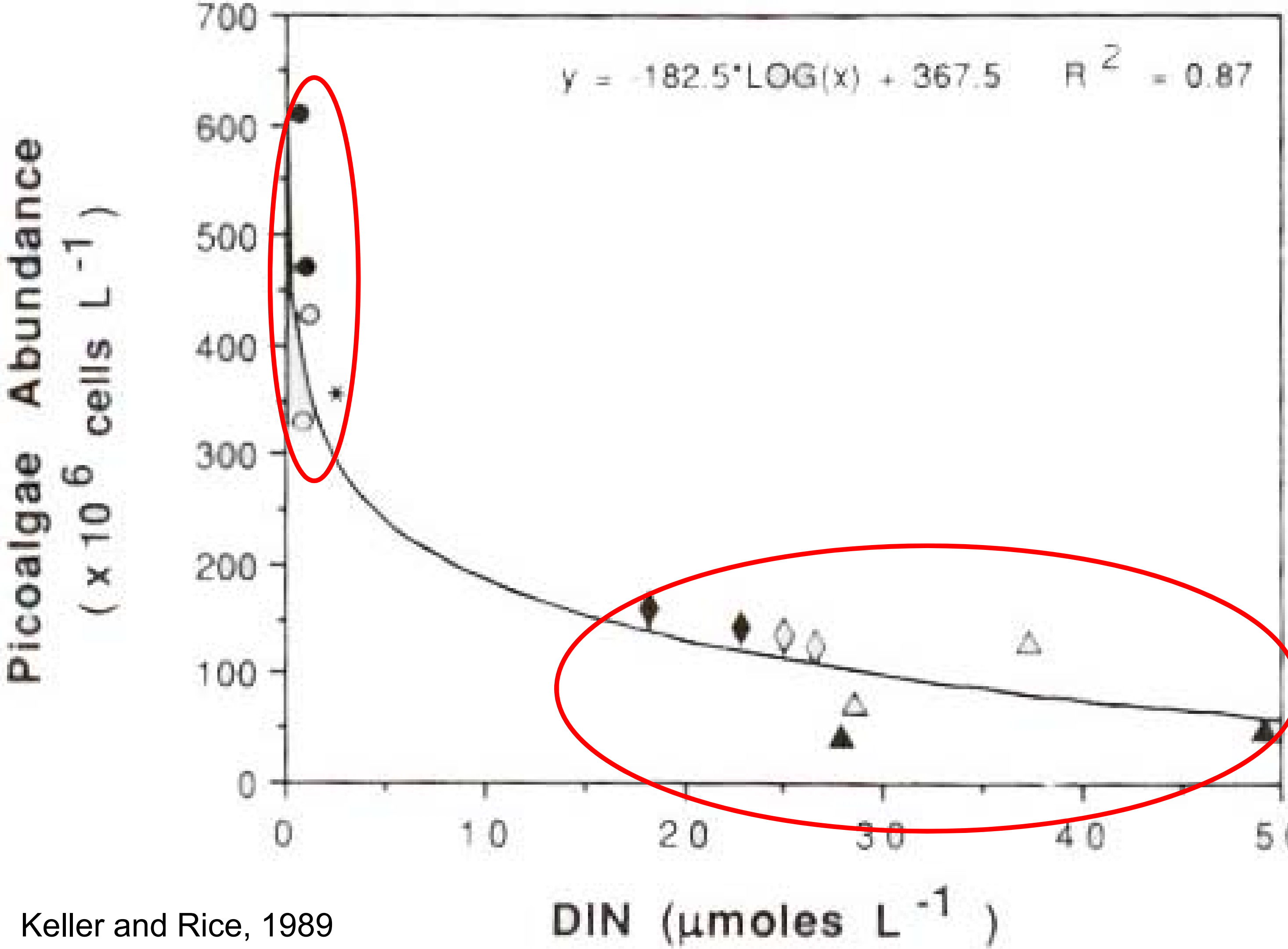

Brown tide

Current US distribution of *Aureococcus anophagefferens*



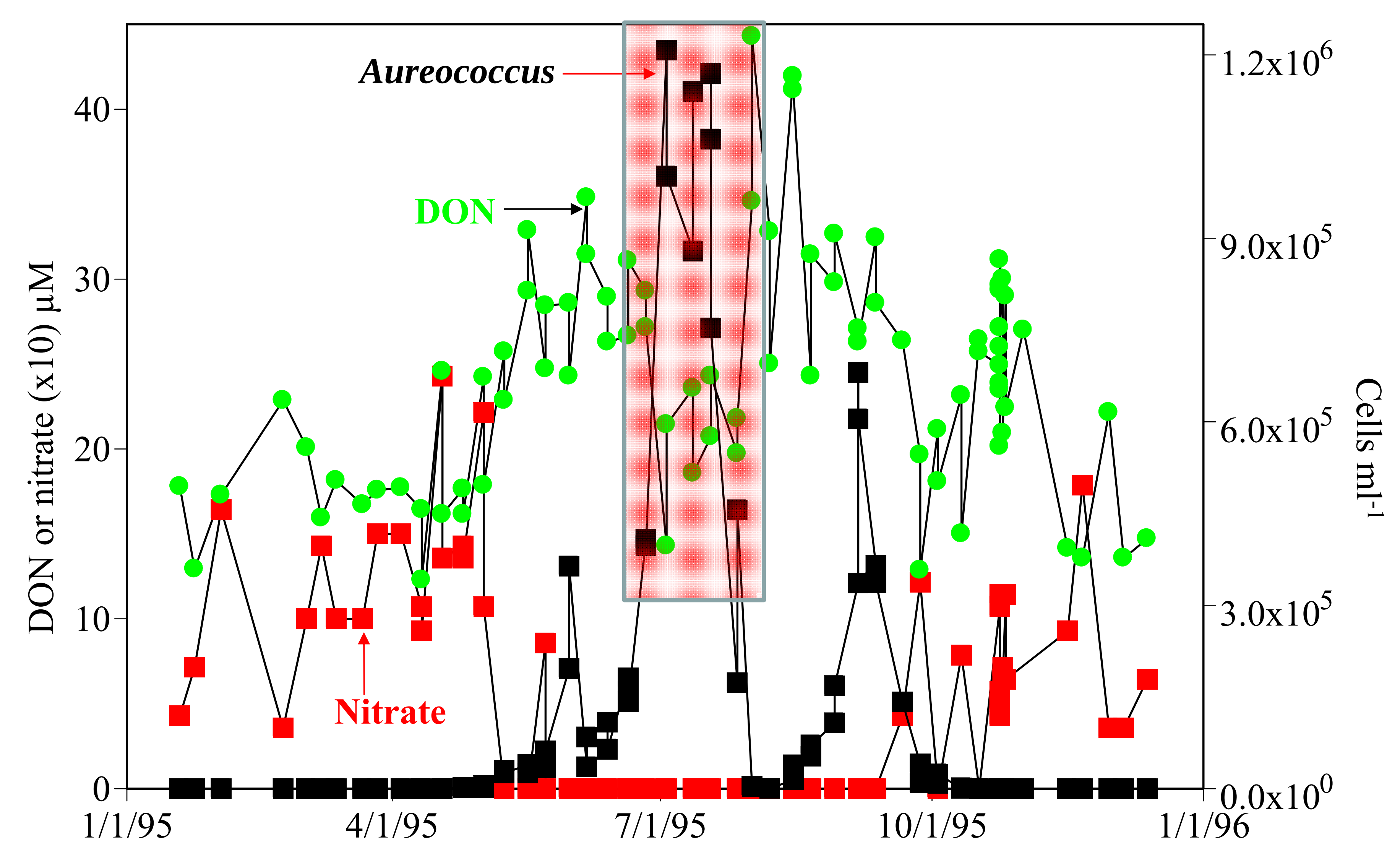
Anderson et al., 1993; Popels et al., 2003

Unlike other algal blooms, brown tides are not caused by inorganic nitrogen loading…



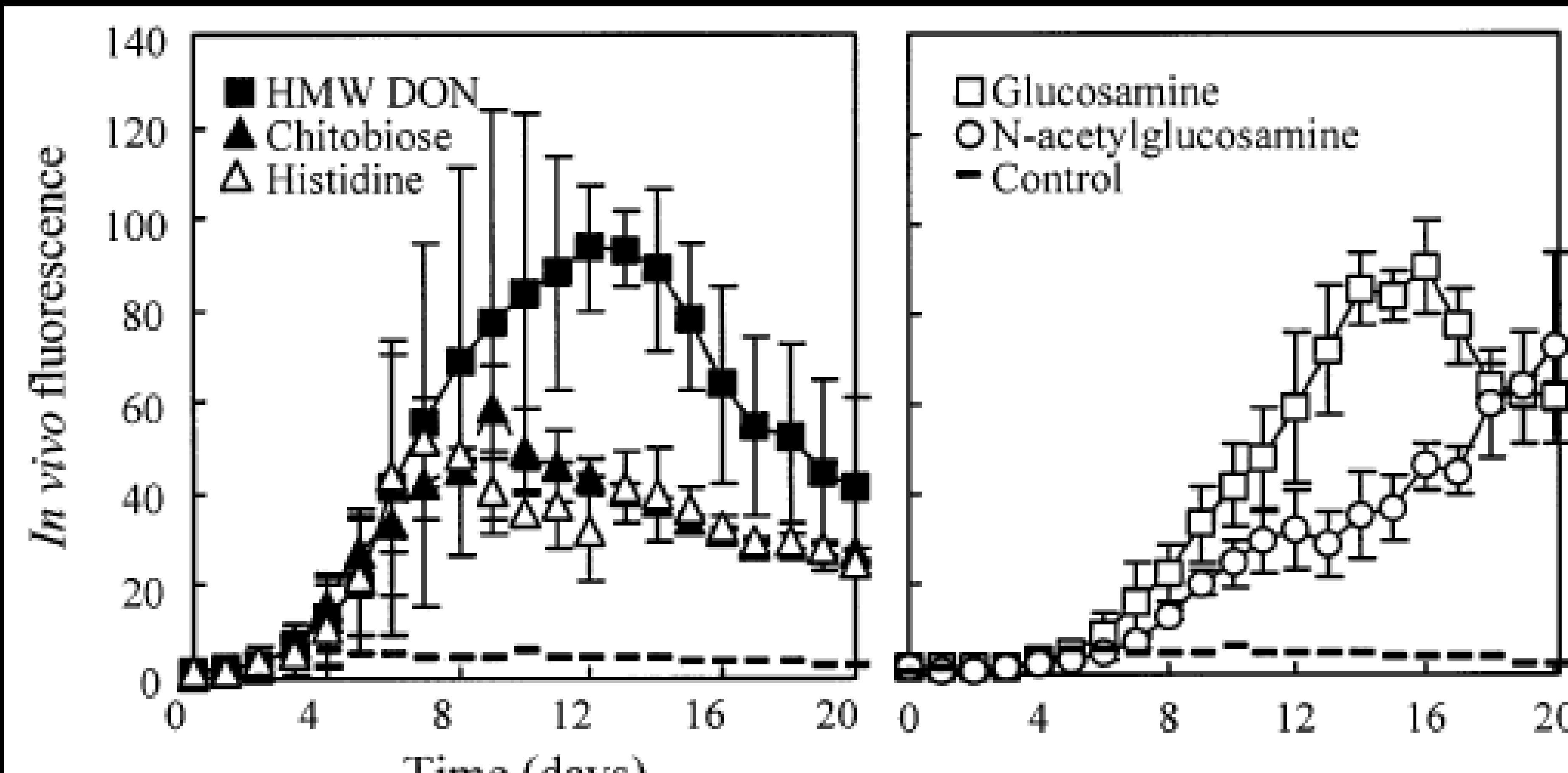
Keller and Rice, 1989

Organic Nutrients and brown tide



Gobler and Sunda 2012

Growth of **axenic** *A. anophagefferens* cultures exclusively on complex, organic nitrogen



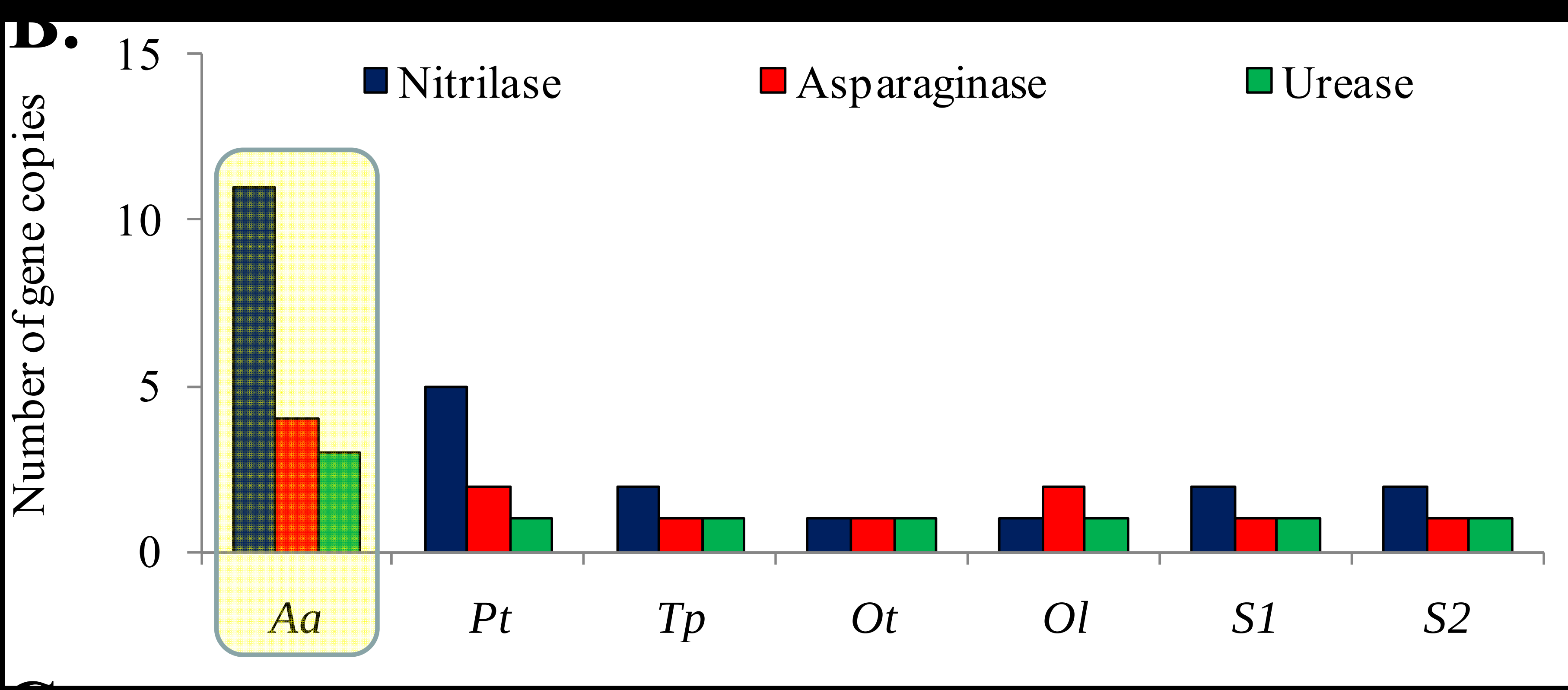
Berg et al., 2003

Nutrients and the *Aureococcus* genome

Niche of harmful alga *Aureococcus anophagefferens* revealed through ecogenomics

Christopher J. Gobler[a,b,1], Dianna L. Berry[a,b,2], Sonya T. Dyhrman[c,2], Steven W. Wilhelm[d,2], Asaf Salamov[e], Alexei V. Lobanov[f], Yan Zhang[f], Jackie L. Collier[b], Louie L. Wurch[c], Adam B. Kustka[g], Brian D. Dill[h], Manesh Shah[i], Nathan C. VerBerkmoes[h], Alan Kuo[e], Astrid Terry[e], Jasmyn Pangilinan[e], Erika A. Lindquist[e], Susan Lucas[e], Ian T. Paulsen[j], Theresa K. Hattenrath-Lehmann[a,b], Stephanie C. Talmage[a,b], Elyse A. Walker[a,b], Florian Koch[a,b], Amanda M. Burson[a,b], Maria Alejandra Marcoval[a,b], Ying-Zhong Tang[a,b], Gary R. LeCleir[c], Kathryn J. Coyne[k], Gry M. Berg[l], Erin M. Bertrand[m], Mak A. Saito[m,n], Vadim N. Gladyshev[d], and Igor V. Grigoriev[e,1]

DON enzymes in *Aureococcus*



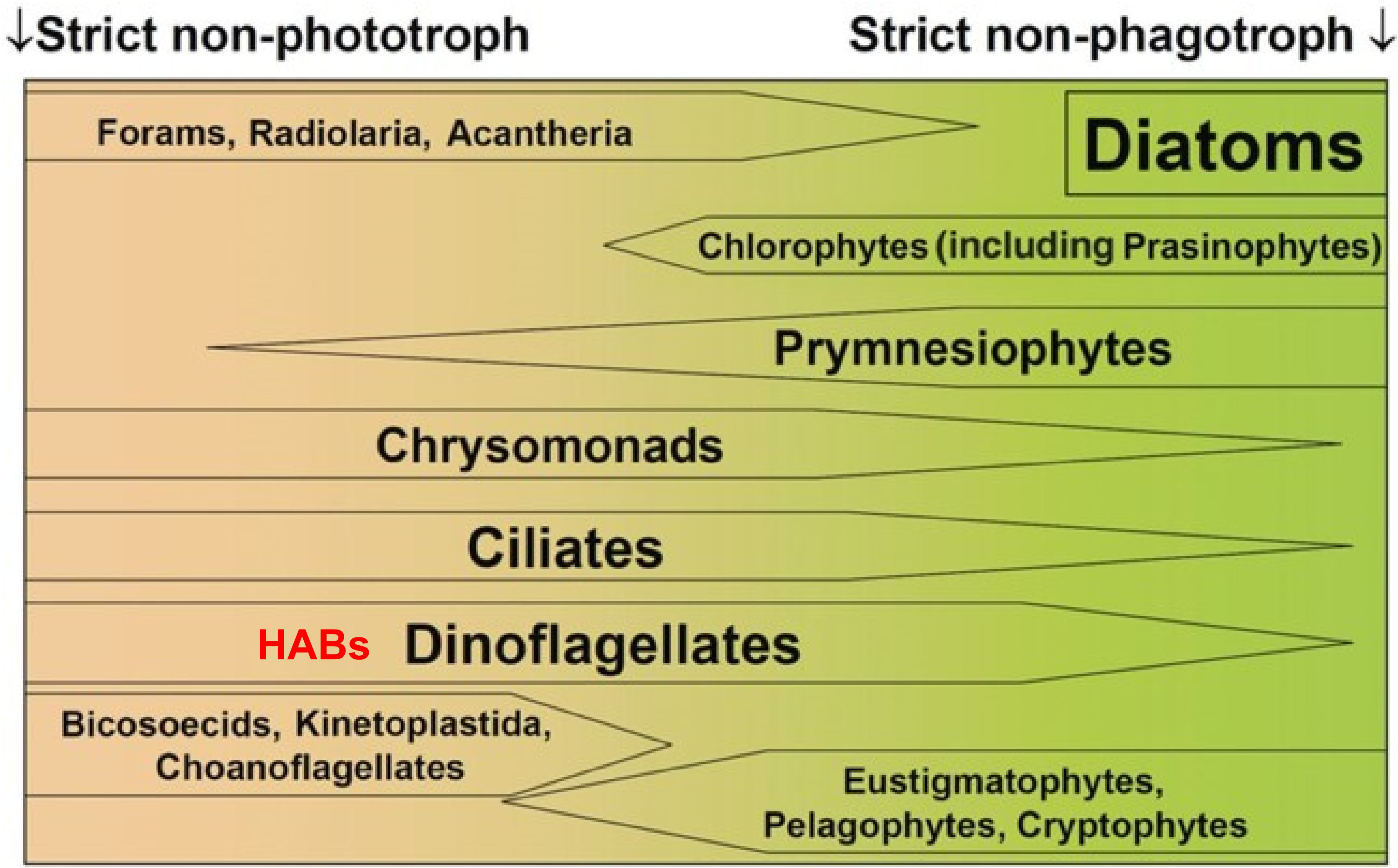
The organic niche:

- Many phytoplankton species rely on inorganic nutrients and sunlight to grow.

- Genomic, field, and lab studies has demonstrated *A. anophagefferens* can hydrolyze and utilize complex DON and DOC compounds (Mulholland, et al 2002; Berg et al., 1997, 2002, 2003; Fan et al 2003).

- While other species are ‘starving’ for nitrogen and / or carbon, *A. anophagefferens* can use organic nutrients to grow.

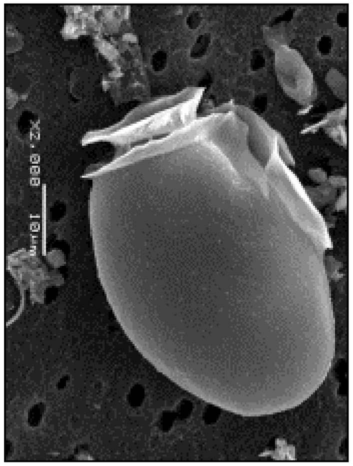
Heterotrophy among phytoplankton



Mitra et al 2014

Mainly heterotrophic HABs can be promoted by nutrients

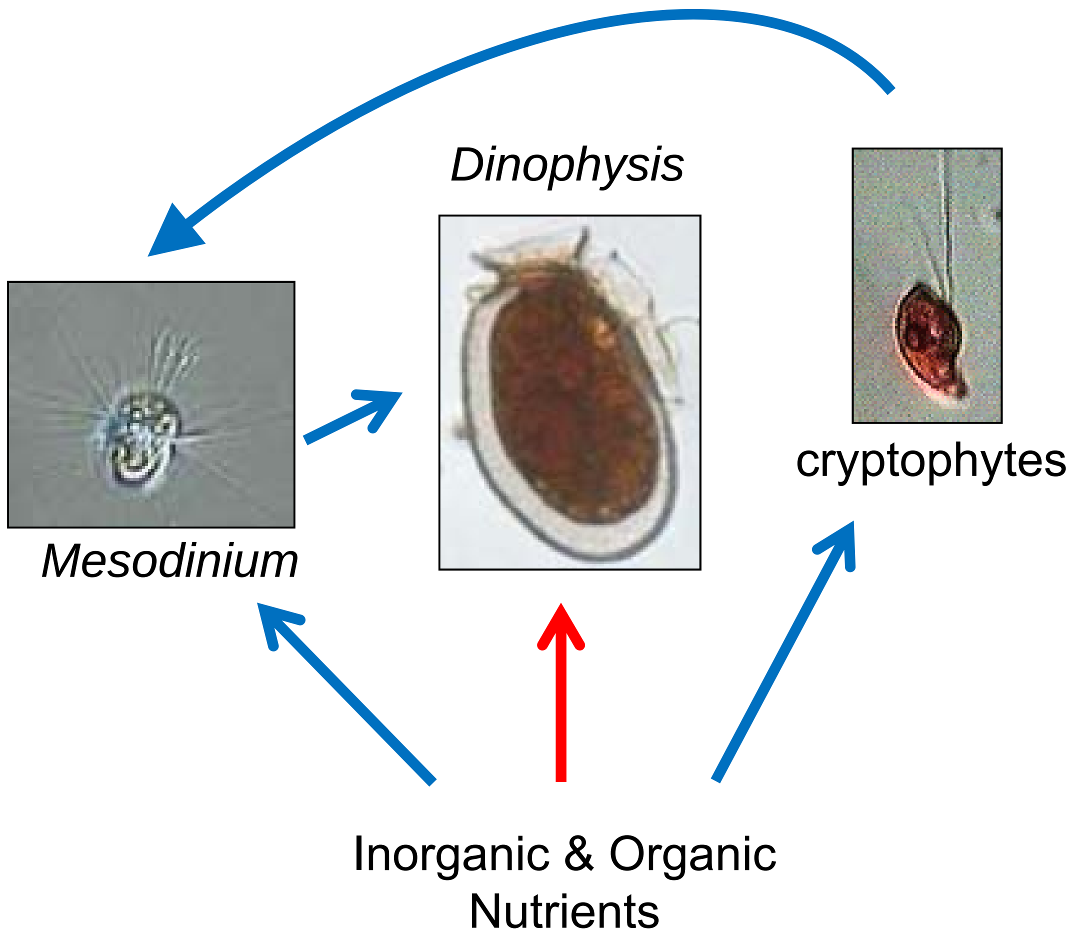
DSP-producing *Dinophysis*



Effects of inorganic and organic nitrogen on *Dinophysis*

- Both inorganic and organic nutrients significantly enhanced *Dinophysis* densities.
- Over a three year period, ammonium consistently and significantly enhanced *Dinophysis* densities in 10 of 11 experiments conducted.
- Hattenrath-Lehmann et al., 2015, PloS One

Are the effects of nutrients on Dinophysis direct or indirect?

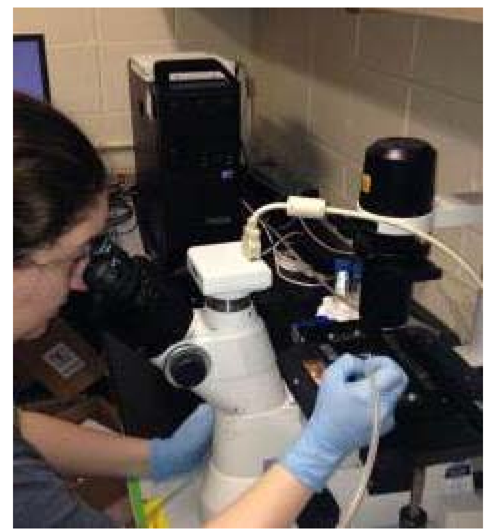


How do we resolve nutrient vs. trophic effects?

Answer: You need a culture

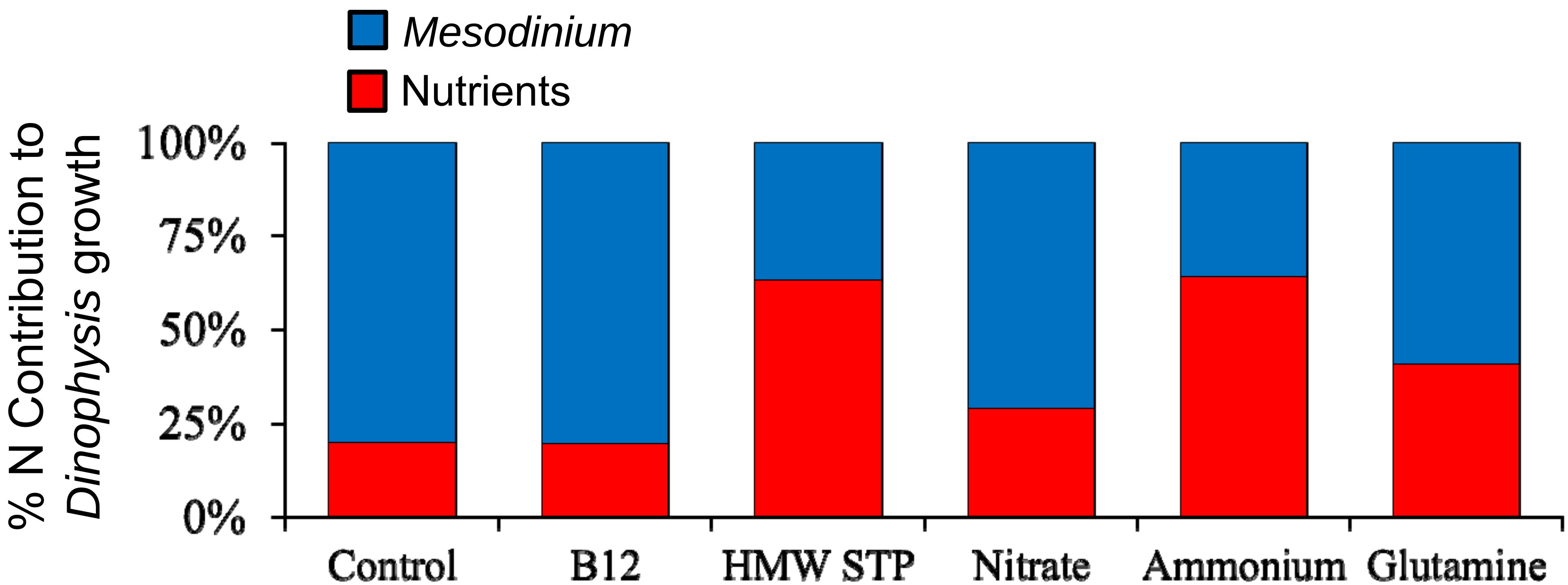
Inverted microscope

Bloom water



Determined graduate student

Nitrogen contribution to *Dinophysis* growth: Nutrients vs *Mesodinium*



Hattenrath-Lehmann et al., 2015, L&O

Nutrient ratios can affect phytoplankton community composition and HAB toxicity

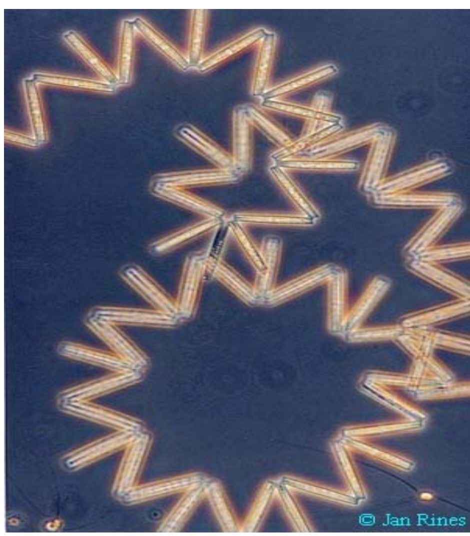
Nitrogen to silicon ratios

Shifting the N:Si atomic ratio above 1:1

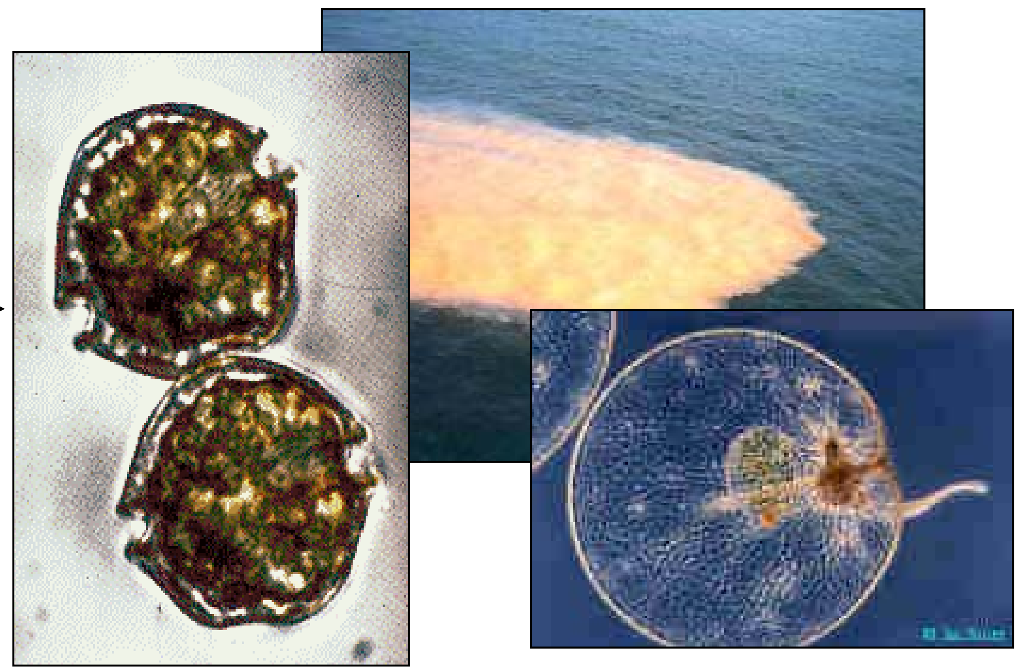
Diatoms typically need 1 mole of silicate for every mole of cellular nitrogen (Si : N = 1; Officer and Ryther 1982).

Increasing the N:Si ratio decreases diatom abundances and increases the proportion of flagellated algae, potentially harmful dinoflagellates (Smayda 1990; Gobler and Boneillo 2003; Gobler et al 2006).

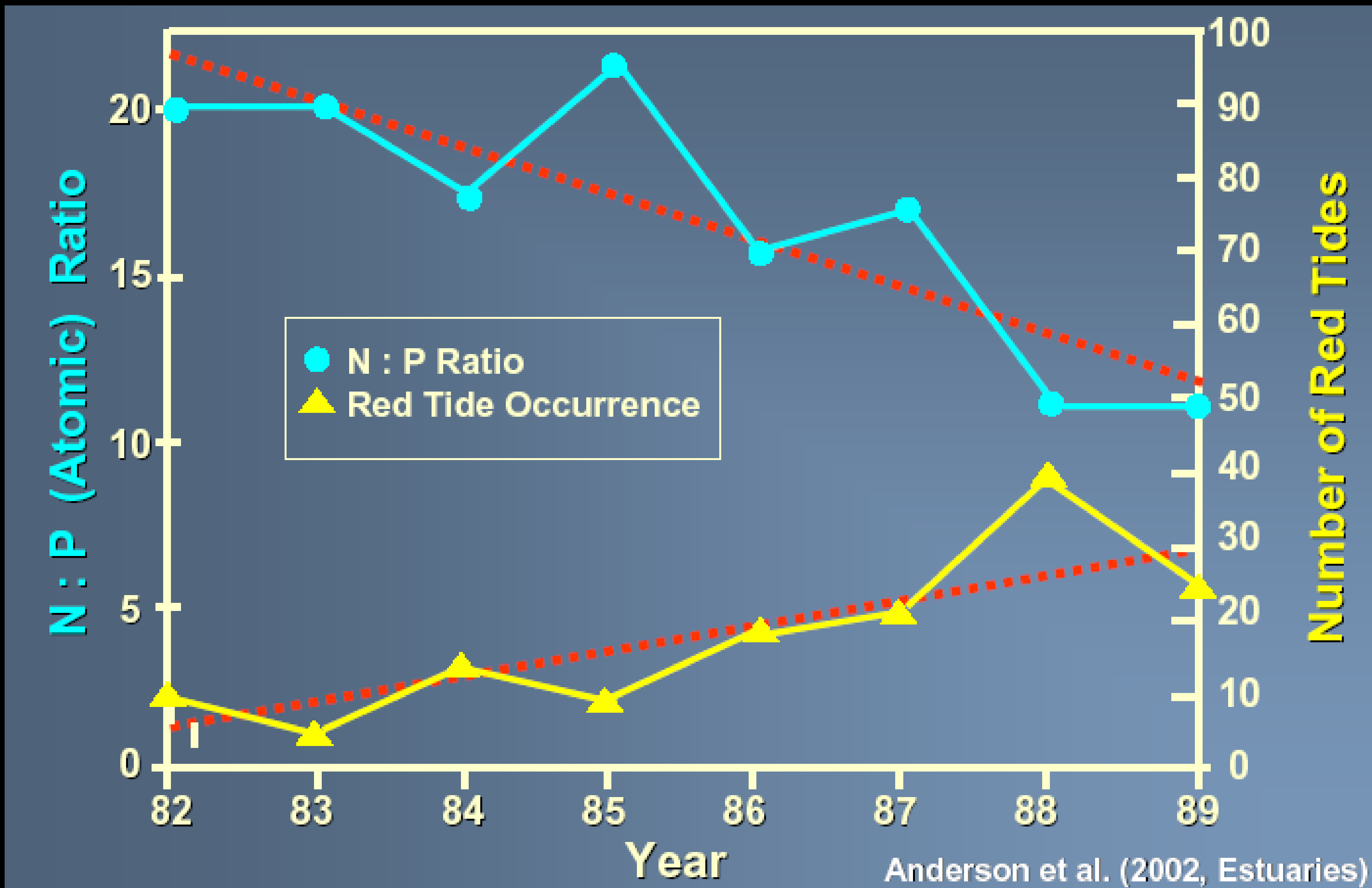
DIN: DSi < 1



DIN: DSi >1



N:P ratios and HABs in coastal China



Nutrient ratios can affect HAB toxicity

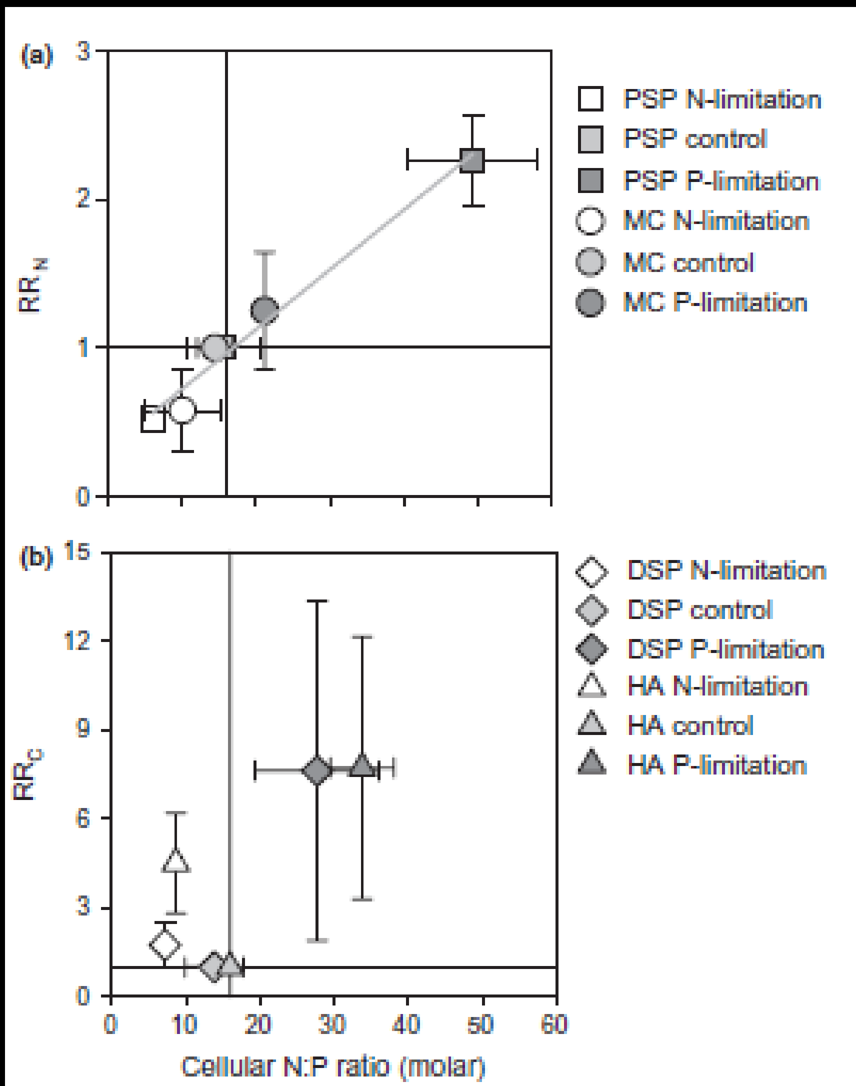
ECOLOGY LETTERS

Ecology Letters, (2014) 17: 736–742 doi: 10.1111/ele.12280

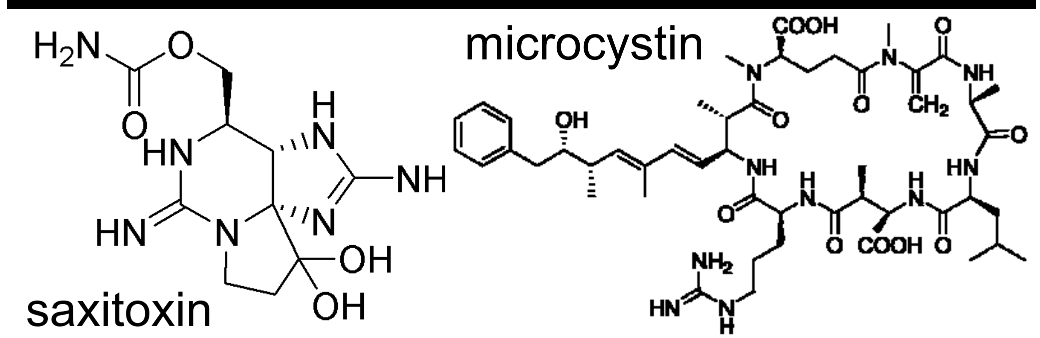
LETTER

Stoichiometric regulation of phytoplankton toxins

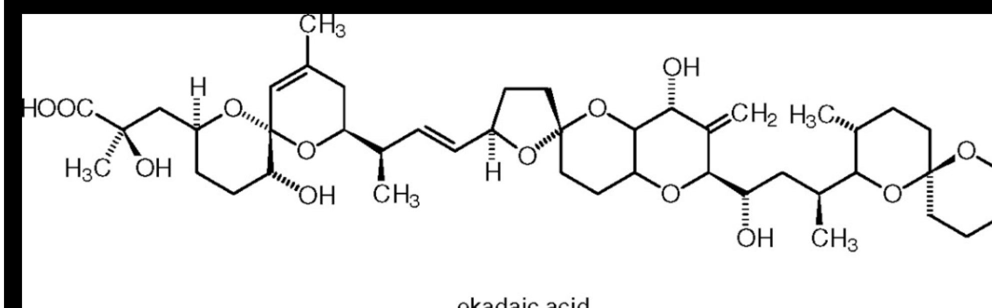
Dedmer Van de Waal



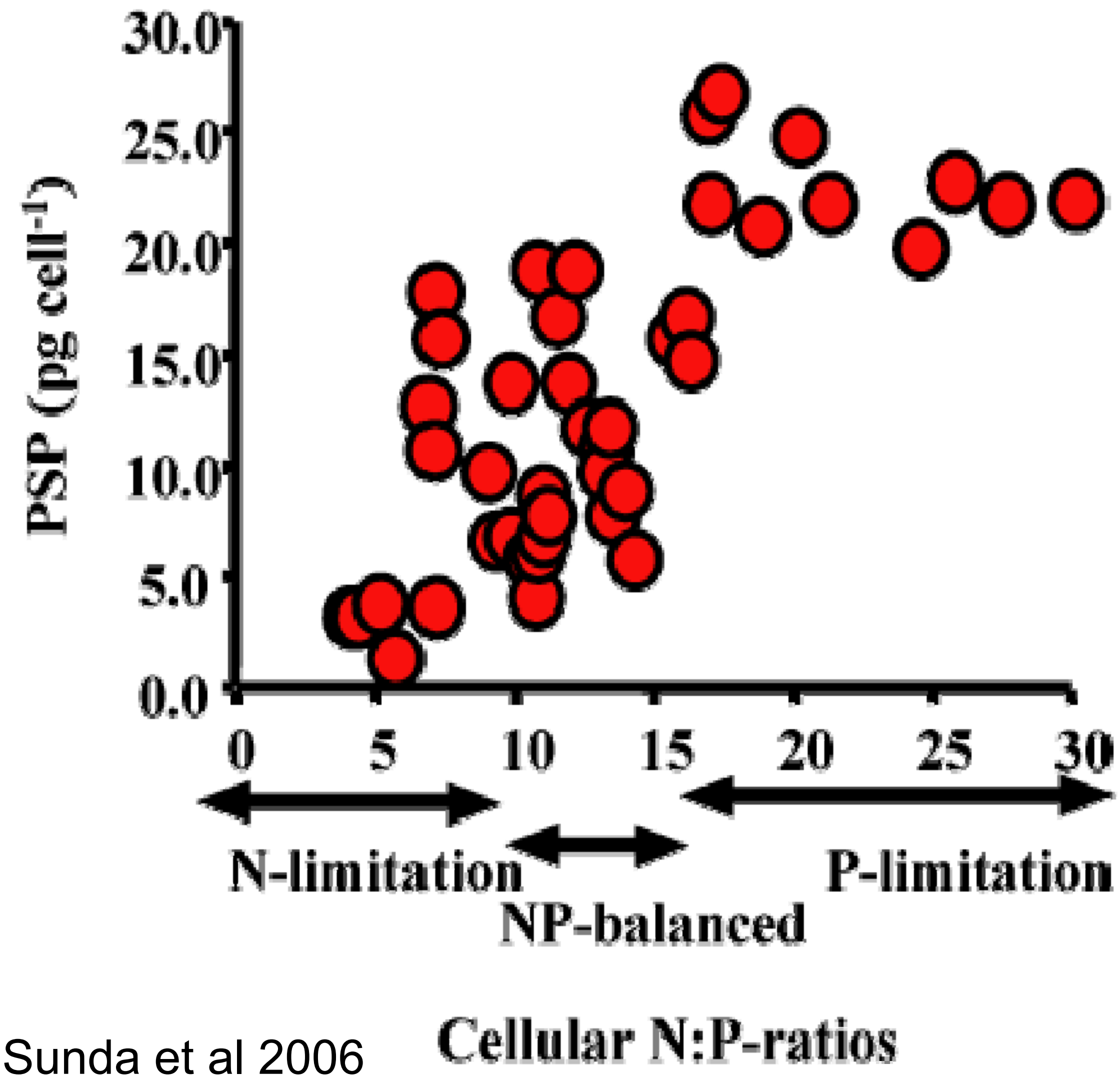
Nitrogen-rich



Carbon-rich

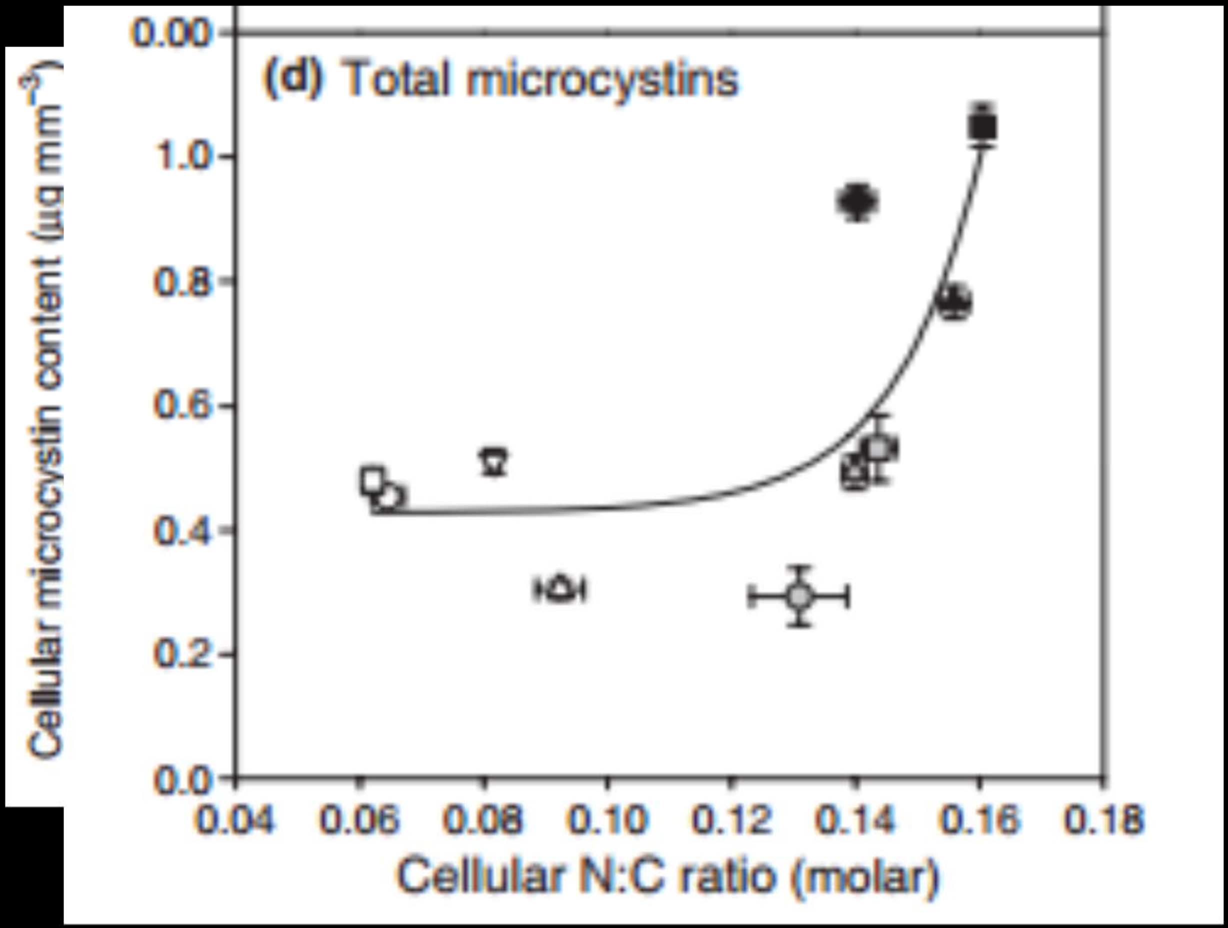


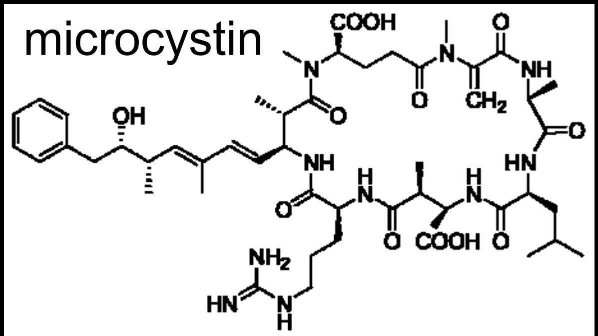
N:P ratios, nutrient limitation, and *Alexandrium tamarense* toxicity



Sunda et al 2006

Nitrogen and microcystin

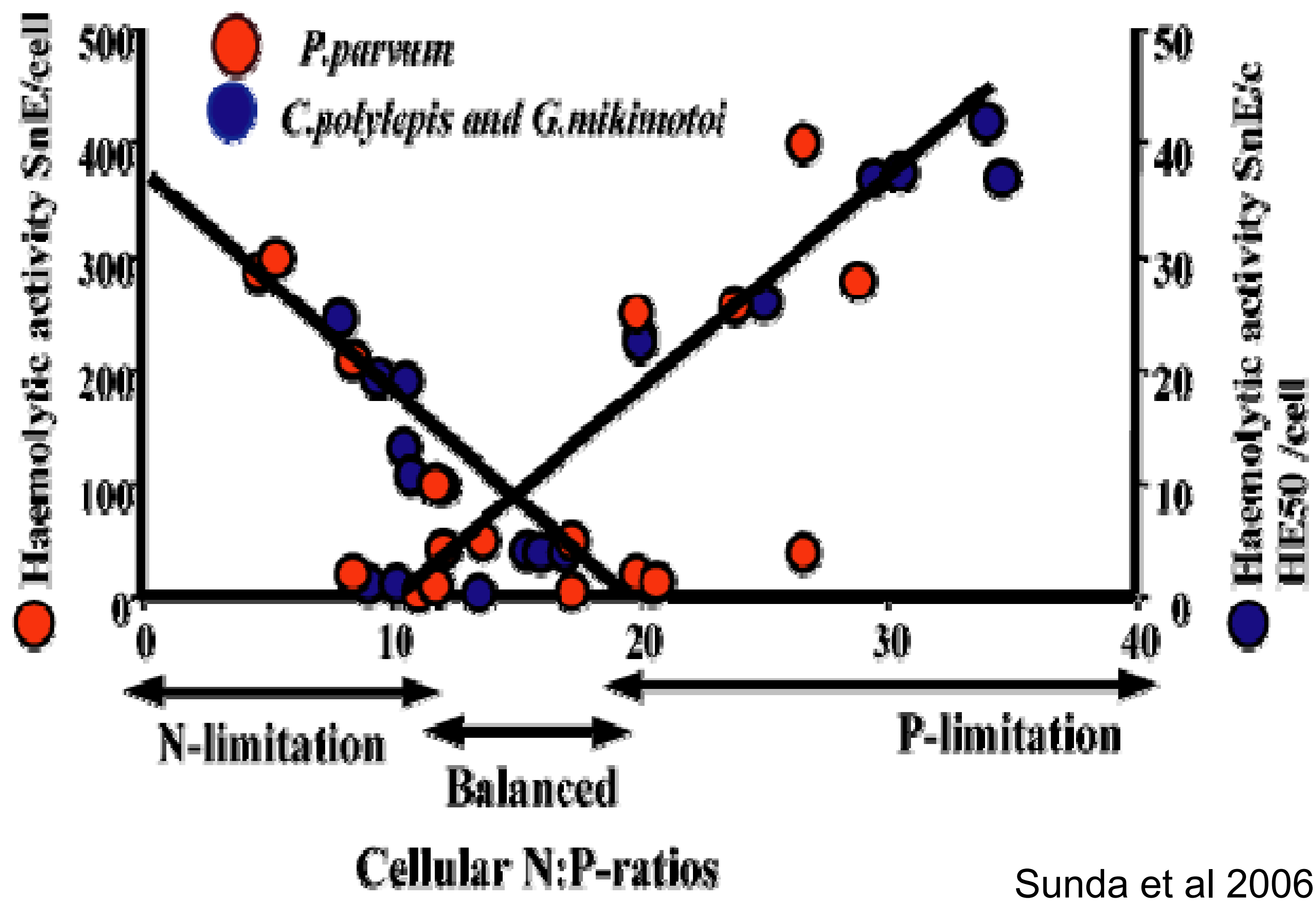




Dedmer Van de Waal et al 2014

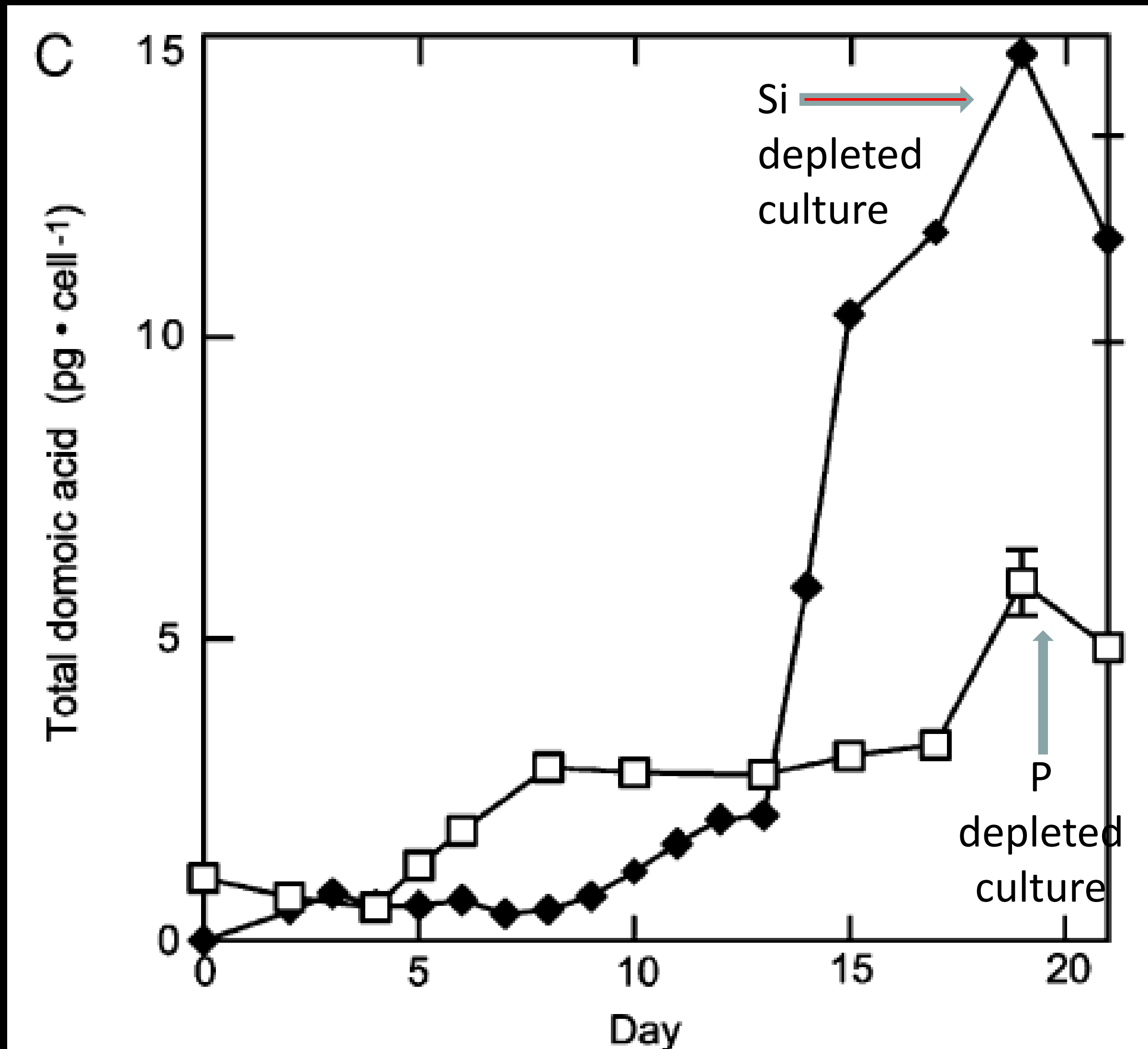

ECOLOGY LETTERS
Ecology Letters, (2014) 17: 736–742
doi: 10.1111/ele.12280
LETTER
Stoichiometric regulation of phytoplankton toxins

N:P ratios, nutrient limitation, and toxicity



Sunda et al 2006

Domoic acid & nutrient limitation



Lower nutrients = greater toxicity

Conclusions

- There are multiple examples HABs whose biomass AND toxicity are directly promoted by nutrient loading.
- Many important exceptions to this relationship exist: Some HABs thrive under low DIN, some become *more toxic* as nutrient levels decline.
- Nutrient ratios also influence HABs biomass and toxicity.
- The extent to which HABs are controlled by nutrients must be assessed on a case-by-case basis: HAB-species and ecosystem-specific.

National Center for Emerging and Zoonotic Infectious Diseases

Harmful Algal Blooms and Public Health Surveillance: The One Health Harmful Algal Bloom System (OHHABS)

Virginia Roberts, MSPH

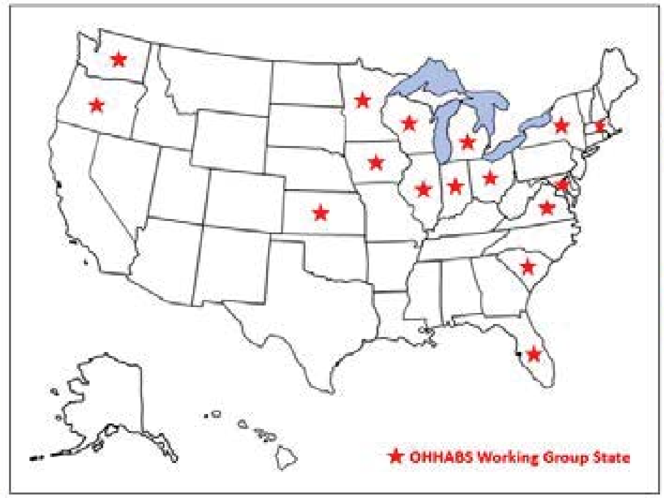
Epidemiologist

EPA Region 9 Harmful Algal Bloom Virtual Workshop

April 5th, 2017

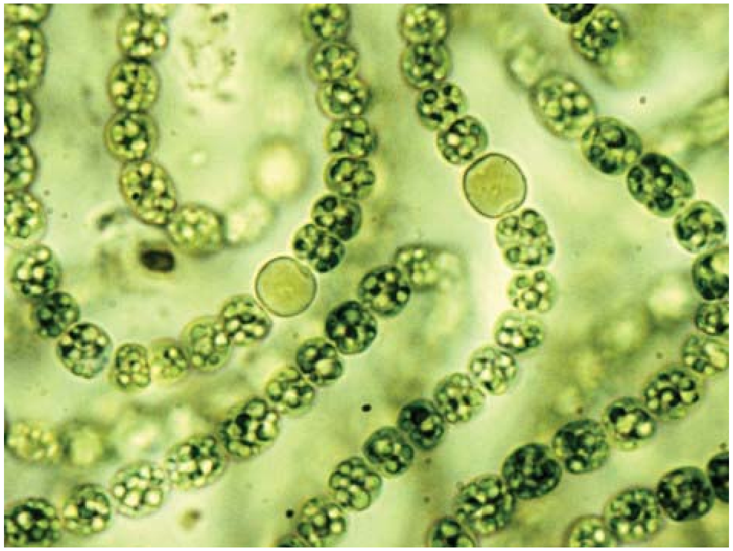
Acknowledgements

- Great Lakes Restoration Initiative (GLRI)
  - Regional Working Group
- OHHABS Working Group
  - State Partners
  - Federal and other partners
- CDC Health Surveillance Partners
  - CDC/National Center for Emerging and Zoonotic Diseases
  - CDC/National Center for Immunization and Respiratory Diseases
  - CDC/National Center for Environmental Health
  - IT Development: Northrup Grumman



Harmful Algal Blooms (HABs)

- Harmful algal bloom (HAB) – overgrowth of phytoplankton (cyanobacteria or microalgae) that can cause harm to animals, people, or the local ecology
  - Occur in warm, nutrient rich fresh or marine waters
- Adverse effects:
  - Economic (e.g., beach closures, shellfish harvest closures)
  - Ecologic (e.g., oxygen depletion, sunlight deprivation)
  - Health (e.g., human and animal illnesses)


Source: CA Water Boards - Cyanobacteria

Source: UCSB Biolum - Dinoflagellate

HABs and Public Health

- People can get sick from HAB toxins if they ingest them, inhale them, or if they expose their skin to them through activities like swimming.
- One Health issue – humans, animals, and the environment
- Emerging public health issue
  - Warming climate, nutrient pollution
- Challenges: identifying and characterizing HAB-associated illnesses

Source: Jill Siegrist

Source: USGS

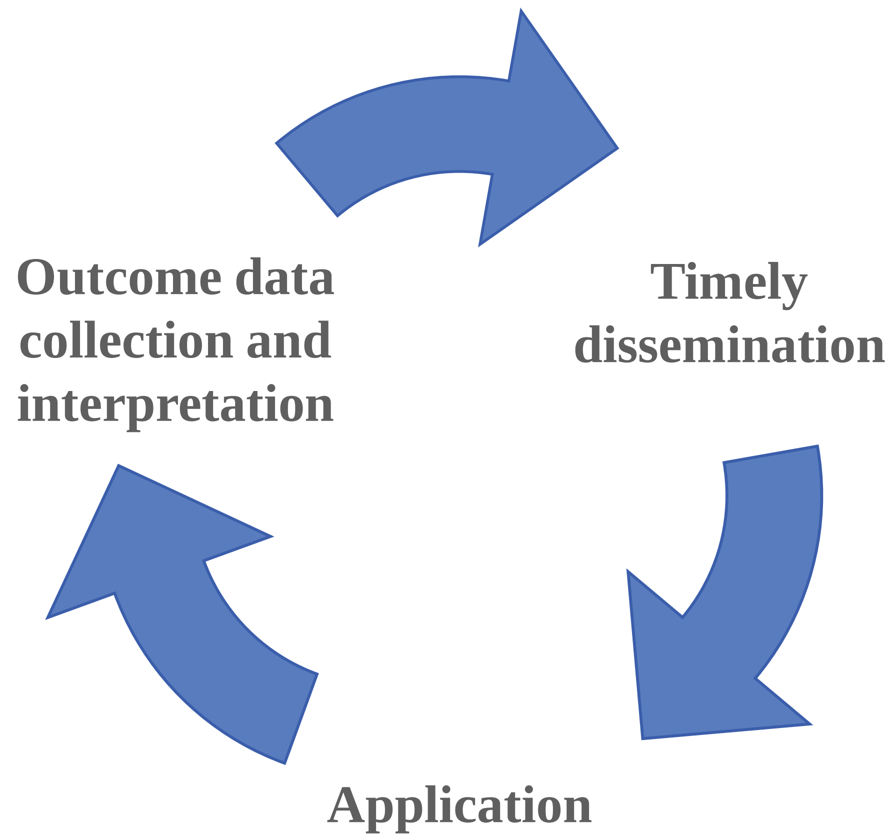
Source: David Zapotosky

An Emerging Public Health Issue

- Challenges: identifying and characterizing HAB-related illnesses
- Questions include:
  - Frequency and geographic distribution
    - How many cases of illness annually? Where? When?
    - Illnesses occurring more/less frequently?
  - Illness characterization
    - What are the symptoms of HAB-associated illness?
      - How does this differ by the type or amount of toxin?
    - How to interpret clinical, epidemiological, and environmental data?
      - Suspect, probable, confirmed case of illness?
  - Risk factors
    - How do factors such as age, route of exposure, and immune status affect susceptibility?
  - Prevention efforts—needs? impacts?

Public health surveillance can help to answer these questions

- **Public health surveillance:**
  - ***The ongoing, systematic collection, analysis, and interpretation of outcome-specific data for use in the planning, implementation, and evaluation of public health practice.***



Teutsch and Churchill , Principles and Practice of Public Health Surveillance. 2000. Oxford University Press

Public health surveillance for HABs and associated illnesses

- NORS (web-based, national)
  - Voluntary state and territorial reporting of outbreak data (≥ 2 human illnesses) since 2009
  - Waterborne and foodborne HAB-associated outbreaks
  - Data collected via separate systems from 1970s-2008

NORS
National Outbreak Reporting System

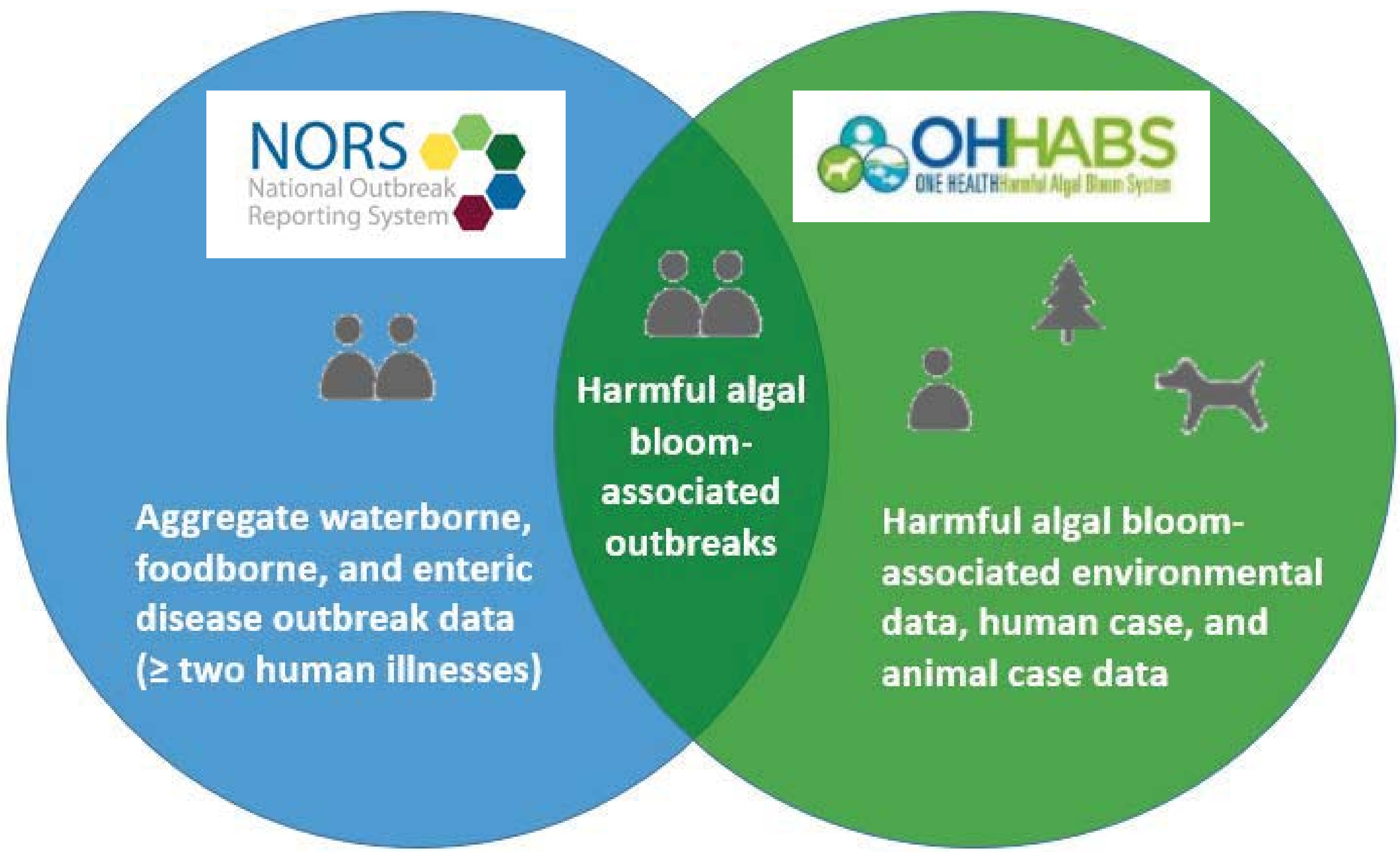
- HABISS (web-based, select states)
  - 2009-2013
  - Enhanced surveillance for HABs, human illness, animal illness

- OHHABS (web-based, national)
  - Launched in 2016
  - Voluntary state and territorial reporting of HABs, human illness, animal illness

OHHABS
ONE HEALTH Harmful Algal Bloom System

One Health Harmful Algal Bloom System (OHHABS)

- **Web-based reporting system linked to NORS**
  - OHHABS and NORS are linked in two ways:
    1. Share technical reporting features (same web platform, reporting structure)
    2. Collect different types of data about HAB-associated outbreaks



OHHABS
ONE HEALTH Harmful Algal Bloom System

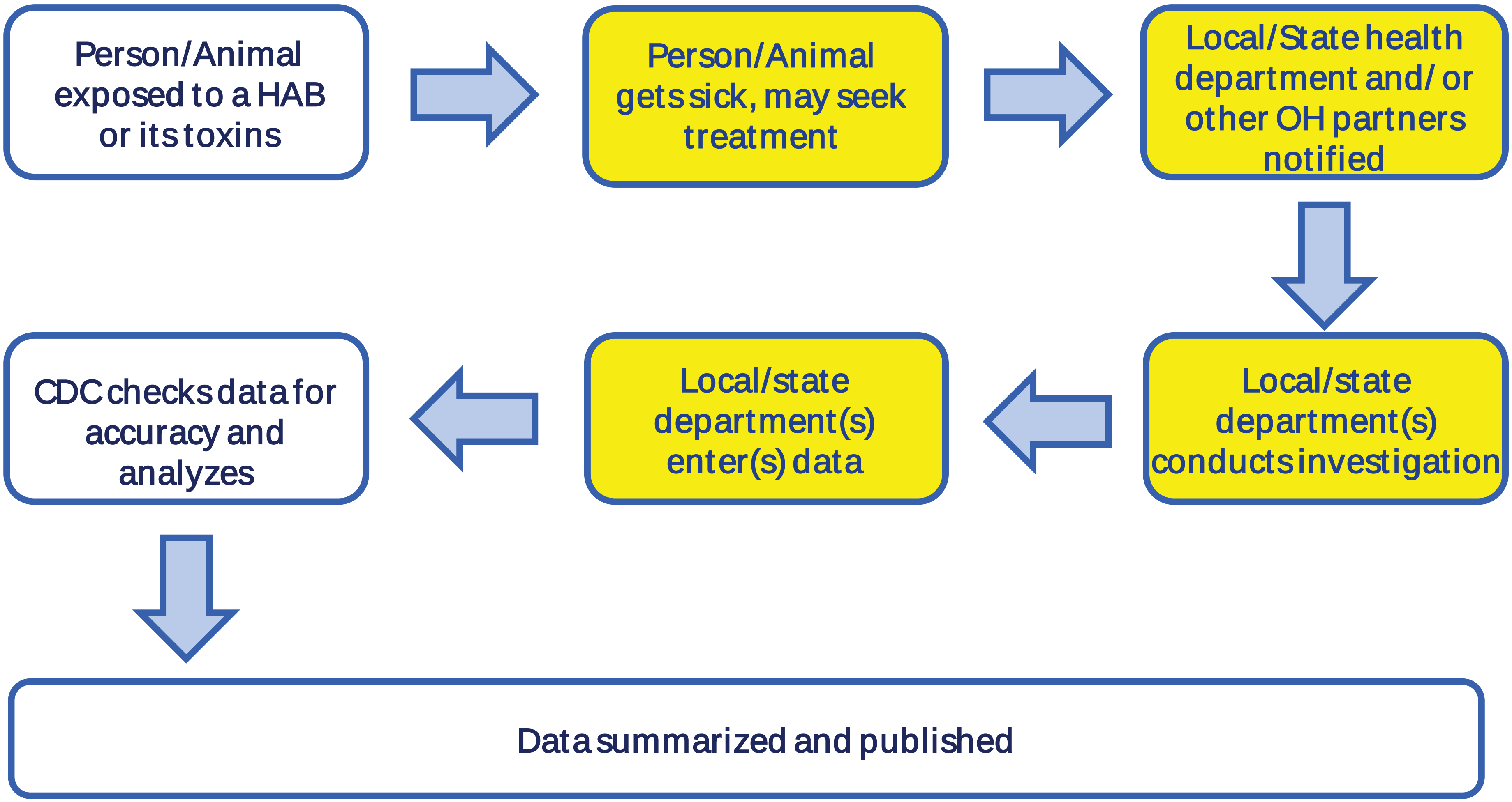
- Electronic reporting
  - Web-based, password-protected system
  - Informed by HABISS
  - Systematic data collection

- One Health surveillance for fresh and marine water events
  - HAB events (environmental data)
  - HAB-associated human cases of illness
  - HAB-associated animal cases of illness

- Voluntary reporting to CDC
  - Nationally available to local, state, and territorial public health partners
  - Their designated environmental health and animal health partners

- Reporting frequency
  - Event-based, not routine water monitoring
  - Not a real-time notification or case investigation system
  - Passive surveillance

General HAB-associated Illness Reporting Process

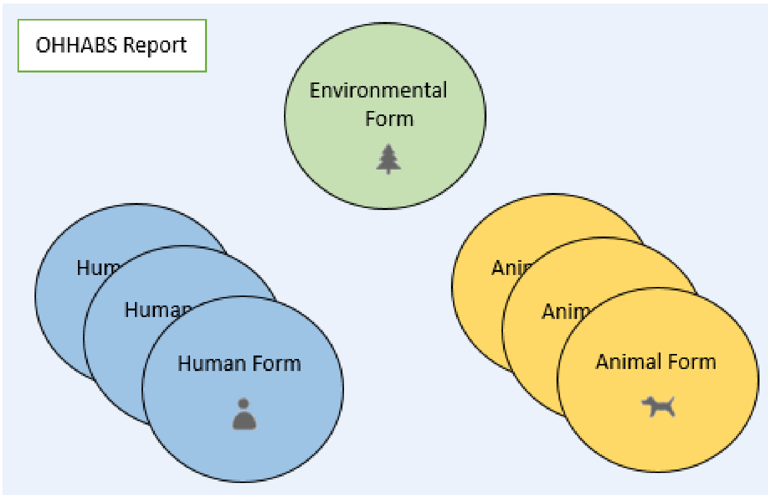


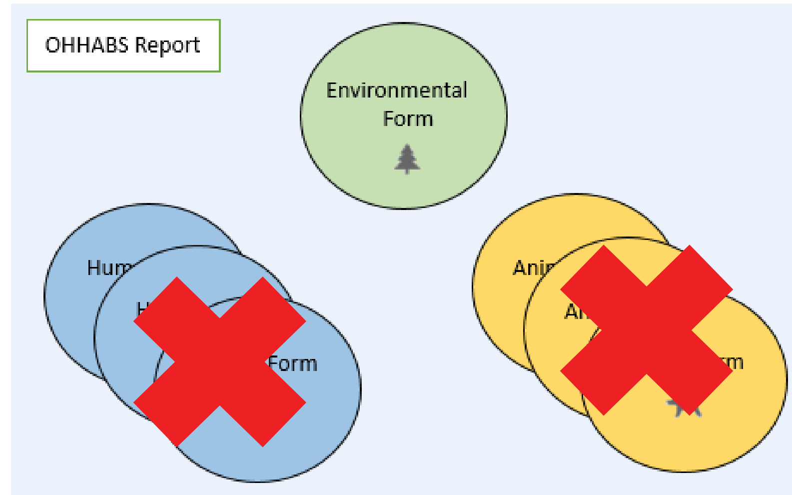
Data uses:

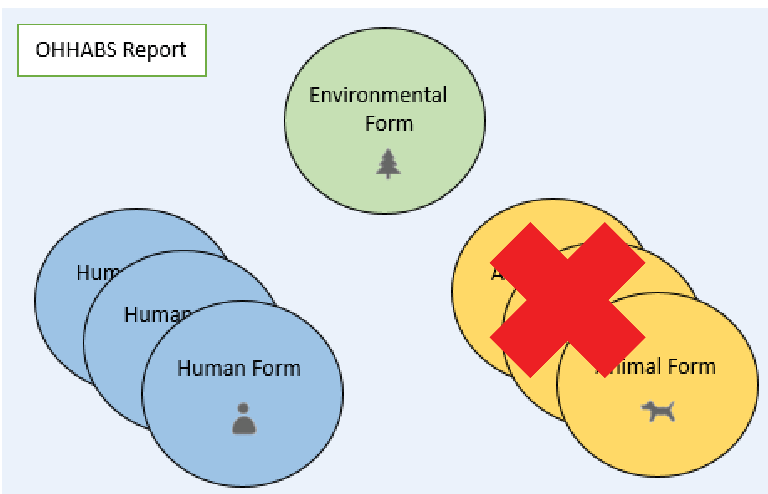
Summary reports, other publications, data and statistics

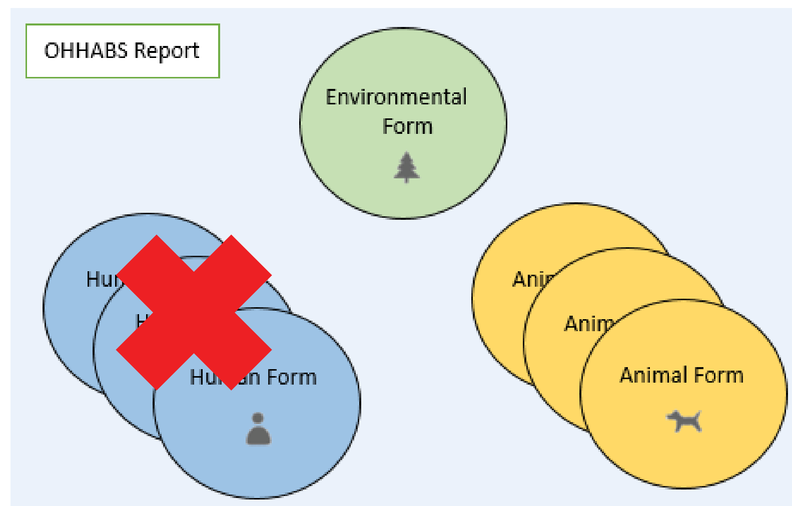
Development and support of programs, health promotion, and policies

How Are Events and Cases Reported in OHHABS?









What Data Can be Reported?

Form Type	Types of Data Collected
Environmental Form	• Location of the HAB event • Observed water body characteristics • Advisories and health warnings • Laboratory testing – event sample testing • Pathogens or toxins detected • Other data systems that contain associated information • Seafood catch or harvest location for HAB-associated foodborne illnesses
Human Form	• General case information (e.g., sex, age in years) • Exposures (e.g., activities, duration) • Signs and symptoms of illness • Medical and health history • Clinical testing • Pathogens or toxins detected in clinical samples
Animal Form	• General case information (e.g., type of animal, single/group of animals) • Exposures (e.g. activities, duration) • Signs of illness • Health information (e.g., veterinary treatment) • Clinical testing • Pathogen or toxins detected in clinical samples

How are OHHABS Events and Cases Classified?

1. HAB event definitions

Definition	Criteria		
HAB Event	Laboratory-based HAB data[1]	Observational or environmental data[2]	Associated illness
1. Suspect		Required to have 1	
2. Confirmed	Required		
3. Confirmed		Required	Required

[1] Laboratory detection (e.g., microscopic confirmation or DNA analyses) of cyanobacteria, other potentially toxin-producing algae, or algal/cyanobacterial toxins in a water body or finished drinking water supply

[2] Observational (e.g., scum, algae, water color change, sheen, photographic evidence, satellite data) or environmental (e.g., pH, chlorophyll, nutrient levels) data from a water body to support the presence of an algal bloom

Blue shaded cells: you must have at least one of the criteria described in the shaded cell.

2. HAB-associated case definitions—human

Definition	Criteria							
Human HAB-associated Case	Exposure[1]	Signs/ symptoms[2]	Public health assessment[3]	Professional medical diagnosis[4]	Other causes of illness ruled out	Observational or environmental data[5]	Laboratory-based HAB data[6]	Clinical data[7]

https://www.cdc.gov/habs/pdf/ohhabs-case-and-event-definitions-table.pdf

Login Screen

Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

OHHABS
ONE HEALTH Harmful Algal Bloom System

OHHABS - One Health Harmful Algal Bloom System

Form Approved
OMB No. 0920-1105
Expires 03/31/2019

Log In

Username:

Password:

Log In

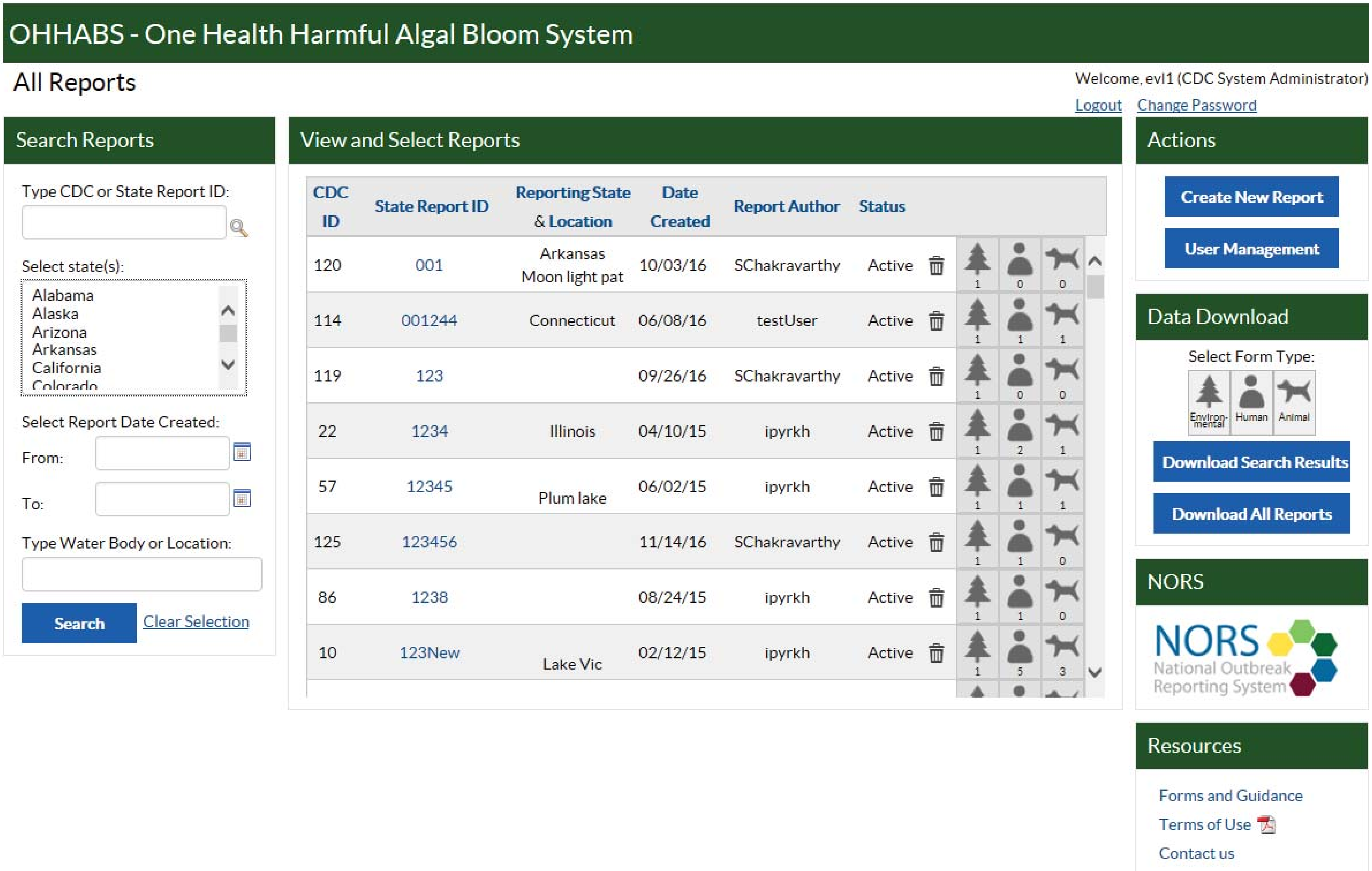
Forgot Password?

DISCLAIMER: The information contained herein is the property of the Centers for Disease Control and Prevention and its participating partners in the One Health Harmful Algal Bloom System (OHHABS). The holder shall keep all information contained herein confidential, shall disclose the information only to its employees with a need to know, and shall protect the information from disclosure and dissemination to third parties with the same degree of care it uses to protect its own confidential information.

Content source: Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases (NCEZID)

Public reporting burden of this collection of information is estimated to average 20 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. An agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to CDC/ATSDR Information Collection Review Office, 1600 Clifton Road NE, MS D-74, Atlanta, Georgia 30333; ATTN: PRA (0920-1105).

OHHABS Landing Page*



OHHABS - One Health Harmful Algal Bloom System

All Reports

Welcome, evl1 (CDC System Administrator)

Logout Change Password

Search Reports

Type CDC or State Report ID:

Select state(s):

Alabama
Alaska
Arizona
Arkansas
California
Colorado

Select Report Date Created:

From:

To:

Type Water Body or Location:

Search Clear Selection

View and Select Reports

CDC ID	State Report ID	Reporting State & Location	Date Created	Report Author	Status				
120	001	Arkansas Moon light pat	10/03/16	SChakravarthy	Active		1	0	0
114	001244	Connecticut	06/08/16	testUser	Active		1	1	1
119	123		09/26/16	SChakravarthy	Active		1	0	0
22	1234	Illinois	04/10/15	ipyrkh	Active		1	2	1
57	12345	Plum lake	06/02/15	ipyrkh	Active		1	1	1
125	123456		11/14/16	SChakravarthy	Active		1	1	0
86	1238		08/24/15	ipyrkh	Active		1	1	0
10	123New	Lake Vic	02/12/15	ipyrkh	Active		1	5	3

Actions

Create New Report

User Management

Data Download

Select Form Type:

Environ-mental Human Animal

Download Search Results

Download All Reports

NORS

NORS National Outbreak Reporting System

Resources

Forms and Guidance

Terms of Use

Contact us

*Example using test system data

Report Summary*

OHHABS - One Health Harmful Algal Bloom System

Go to: All Reports

State ReportID: MN_Report1

Welcome, evl1 (CDC System Administrator)
Logout Change Password

CDC Report ID: 80 **Report Author**: JYu **Date Created**: 8/5/2015 **Status**: Active

View and Edit Report

MN_Report1	State/Jurisdiction: Minnesota	Water Body: Clearwater Lake	Date of Notification 7/22/2015	Author: JYu	
Human1	Sex: M Age: 30	Location Name: Clearwater Lake	Date Illness Onset: 07/23/2015	Author: JYu	
Dog1	Type of Animal: Dog	Single Animal	Date Illness Onset: 07/23/2015	Author: JYu	

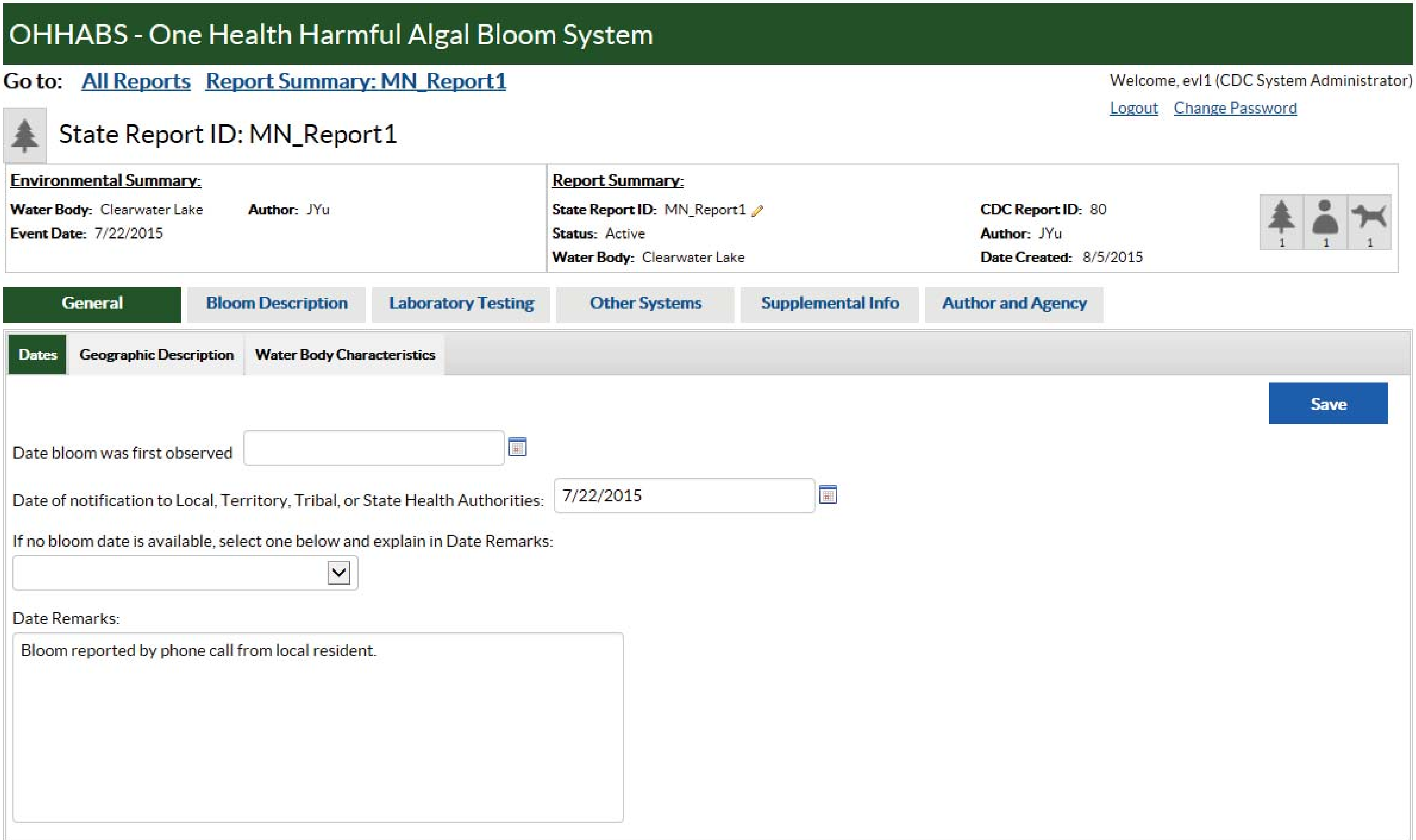
Actions:

Create New Form:

Environ-mental Human Animal

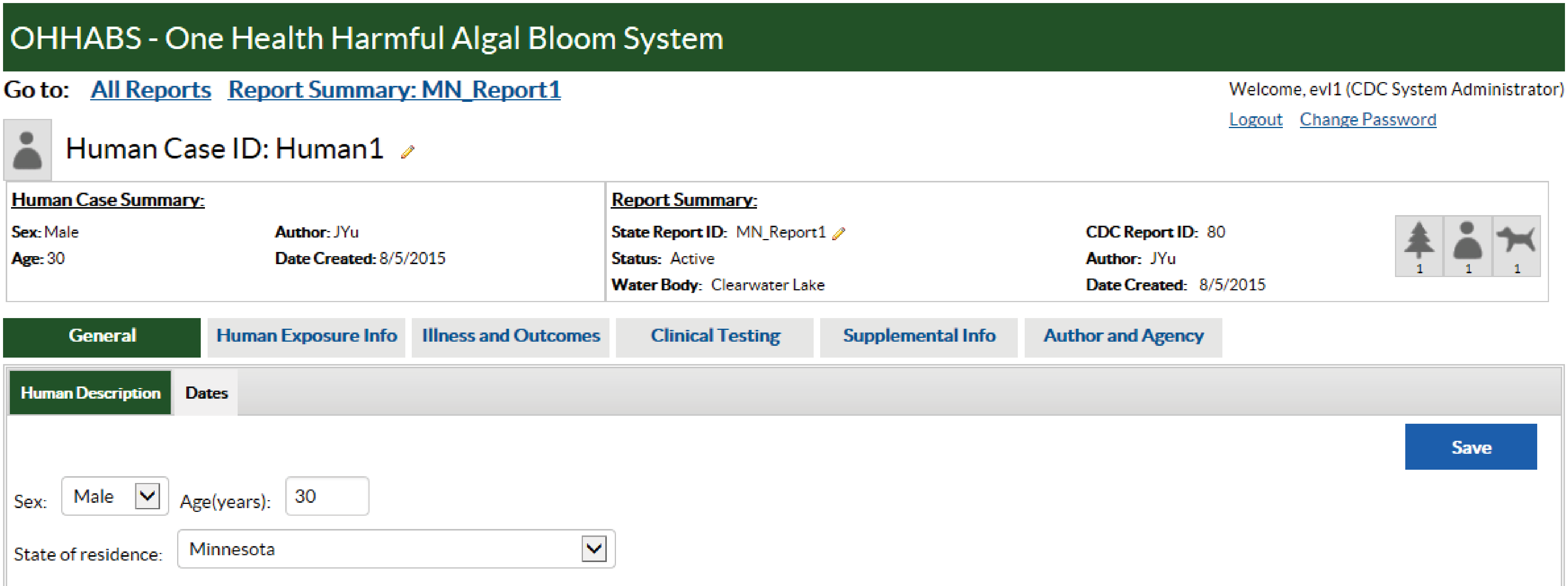
*Example using test system data

Environmental Form*



*Example using test system data

Human Case Form*



*Example using test system data

Animal Case Form*

OHHABS - One Health Harmful Algal Bloom System

Go to: All Reports Report Summary: MN_Report1

Welcome, evl1 (CDC System Administrator)
Logout Change Password

Animal Case ID: Dog1

Animal Case Summary:

Type: Dog
Single Animal

Author: JYu
Date Created: 8/5/2015

Report Summary:

State Report ID: MN_Report1
Status: Active
Water Body: Clearwater Lake

CDC Report ID: 80
Author: JYu
Date Created: 8/5/2015

1 1 1

General | Exposure Description | Illness and Outcomes | Clinical Testing | Supplemental Info | Author and Agency

Animal Description | Dates

Save

What is the category of animal(s) being reported?
Domestic pet

What type of animal(s) are you reporting?
Dog

Additional animal description (e.g. dog or cat breed, type of bird, amphibian, reptile, other, and other mammal)?
Beagle

Does this illness report describe a single animal or a group of animals (i.e., fish kills, flocks, or herds)?
(•) Single animal
( ) Group of animals

What is the age of the animal? 14.00 years

What is the weight of the animal? Select unit of measure

Did the animal die?
(•) Yes ( ) No ( ) Unknown

What condition was the animal found in? (check all that apply)
☐ Alive ☐ Fresh ☐ Scavenged
☐ Decomposed ☐ Unknown ☑ Not Applicable

*Example using test system data

Related Resources

- **OHHABS resources at www.cdc.gov/habs/ohhabs**
  - Guidance documents
  - Case and event definitions
  - Static and fillable PDF forms
- **Training webinars—recordings available upon request**
- **Harmful Algal Bloom – Associated Illness website for the general public at www.cdc.gov/habs**
- **Health promotion materials at www.cdc.gov/habs/materials/index.html**
  - OHHABS partner toolkit (fact sheet, slides, newsletter article, resources list)
  - Cyanobacterial Fact Sheet
  - Poster
  - Reference Cards for veterinarians, physicians, and the general public
- **For more information: NORSWater@cdc.gov**

Harmful Algal Bloom-Associated Illness website

www.cdc.gov/habs

CDC A-Z INDEX

Harmful Algal Bloom (HAB)-Associated Illness

Harmful algal blooms (HABs) are the rapid growth of algae that can cause harm to animals, people, or the local ecology. A HAB can look like foam, scum, or mats on the surface of water and can be different colors. HABs can produce toxins that have caused a variety of illnesses in people and animals. HABs can occur in warm fresh, marine, or brackish waters with abundant nutrients and are becoming more frequent with climate change.

GENERAL INFORMATION
Frequently asked questions...

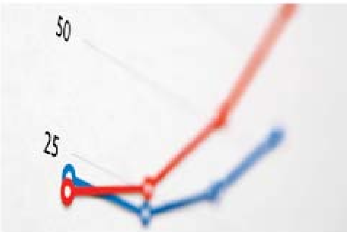
ILLNESS & SYMPTOMS
Signs, symptoms, and outcomes...

SOURCES OF EXPOSURE & RISK FACTORS
Who gets it and how...

HABS & THE ENVIRONMENT
Factors that promote growth of HABs...

PREVENTION & CONTROL
How to stay healthy and prevent illness...

Publications, Data, & Statistics



HAB Resources

- Health Promotion Materials
- One Health Harmful Algal Bloom System (OHHABS)

Healthy Water Sites

- Healthy Water
  - Drinking Water
  - Healthy Swimming
  - Global WASH
  - Other Uses of Water
  - WASH-related Emergencies &

Additional Considerations

- **Needs include**
  - Local and state resources/capacity for surveillance, water monitoring, investigation, and reporting
  - Clinical diagnostic tests for algal toxin exposures (e.g., urine)
  - Refined case definitions (clinical and environmental data)
  - Increased awareness of HAB-related illnesses (e.g., general public, clinicians)
  - Additional/Refined health-based guidance (e.g., health advisory levels) related to drinking water and recreational water exposures
  - New and improved tools to facilitate data collection and analysis
  - Optimization of environmental and health databases (e.g., data linkages)
  - Multidisciplinary partnerships, training, and communication resources

Conclusion

- OHHABS = One Health surveillance
  - OHHABS can link human and animal illness data with HAB events
  - Health surveillance for HAB-related illness will rely on more than traditional infectious disease or human illness surveillance partnerships
- Capacity extends beyond an electronic system
  - Resources, tools, relationships, education, and outreach
  - Future database linkages to optimize data use
- Data to inform prevention and mitigation of HAB-associated health effects

Thank you! Questions?

For more information, contact CDC
1-800-CDC-INFO (232-4636)
TTY: 1-888-232-6348 www.cdc.gov

Harmful Algal Blooms

Development of Health-Based Warning Levels for Recreational Exposures to Microcystins, Cylindrospermopsin and Anatoxin-a in California

Regina Linville, Ph.D.

Office of Environmental Health Hazard Assessment

California Environmental Protection Agency

OEHHA SCIENCE FOR A HEALTHY CALIFORNIA

CalEPA California Environmental Protection Agency

US EPA Region 9 HABs Webinar, April 5, 2017

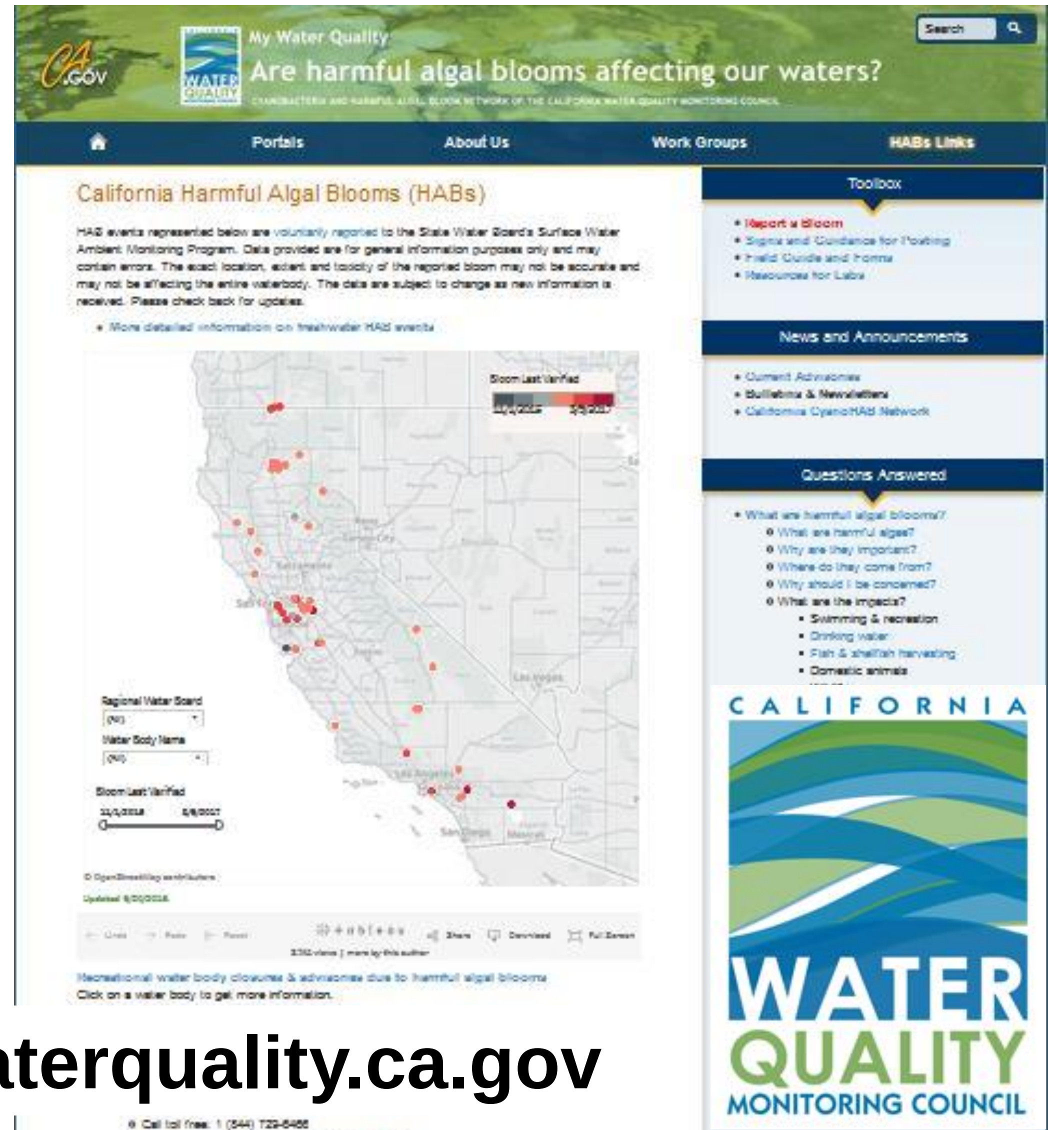
Developing California's Public Health Trigger Levels for Cyanotoxins in Recreational Waters

<u>Based on Risk Management</u>

- Conservative, health-based risk assessment of toxin exposure
- Health, social and economic benefits of water recreation
- Reliable public health messaging
- Understanding of the uncertainty

California Cyanobacteria and Harmful Algal Blooms Network (CCHAB)

- Local, Regional, State, Federal & Tribal Governments
- Academics & Researchers
- Other Stakeholders

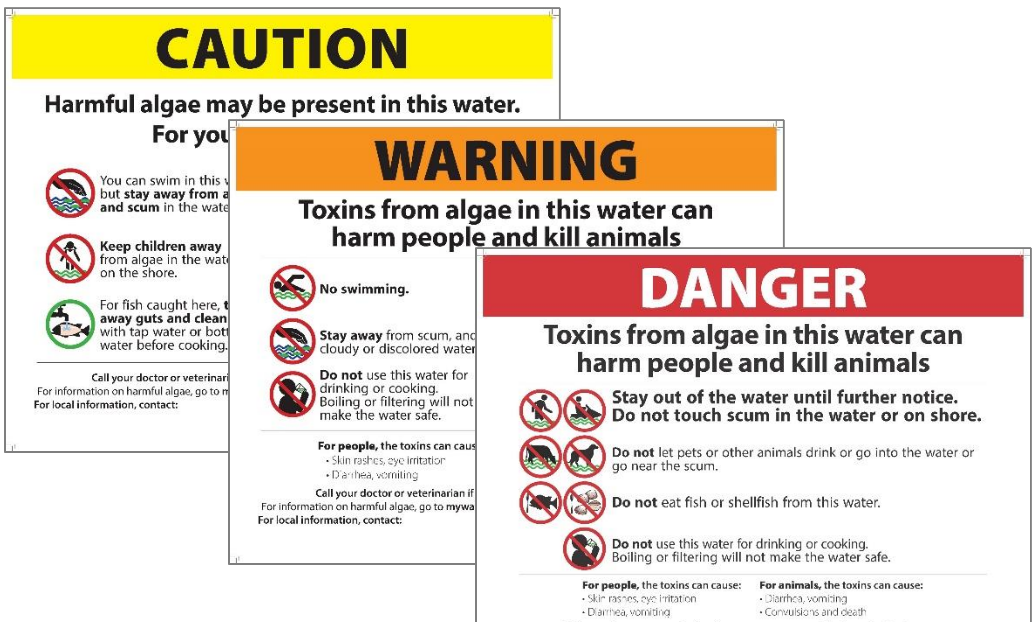


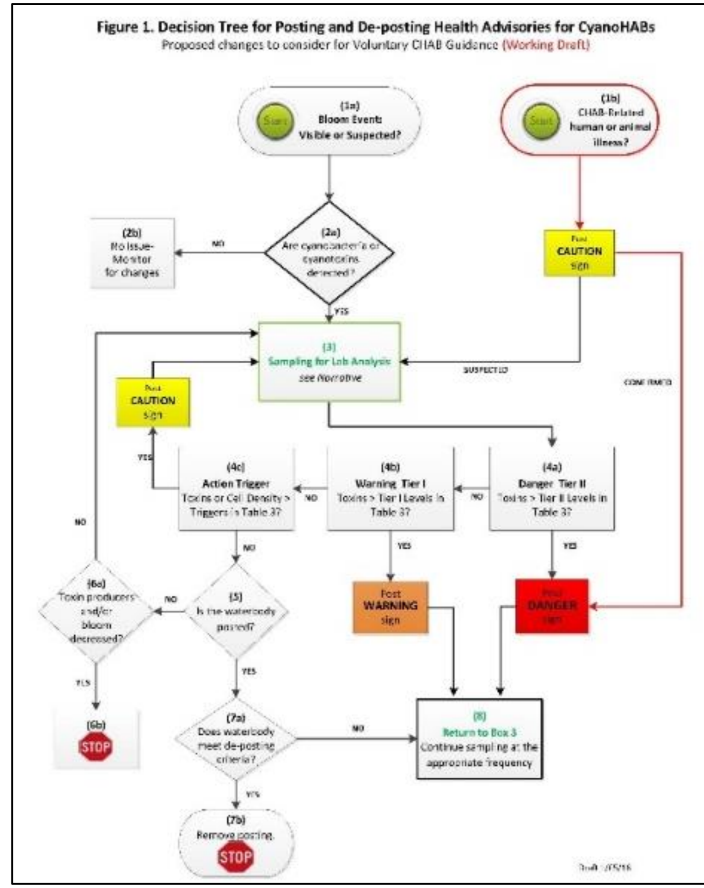
mywaterquality.ca.gov

CCHAB Voluntary Guidance for Recreational Waters

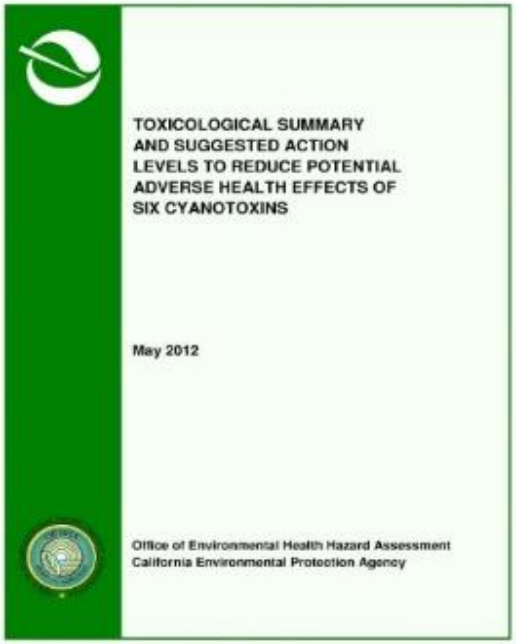
Table 1. CyanoHAB Trigger Levels for Human Health

	Caution Action Trigger	Warning TIER I	Danger TIER II
Primary Triggers [a]			
Total Microcystins [b]	**0.8** µg/L	**6** µg/L	**20** µg/L
Anatoxin-a	**Detection** [c]	**20** µg/L	**90** µg/L
Cylindrospermopsin	**1** µg/L	**4** µg/L	**17** µg/L
Secondary Triggers			
Cell Density *(Toxin Producers)*	**4,000** cells/mL	--	--
Site Specific Indicators of Cyanobacteria	Blooms, scums, mats, ect.	--	--





OEHHA's Cyanotoxin Risk Assessment (2012)


TOXICOLOGICAL SUMMARY AND SUGGESTED ACTION LEVELS TO REDUCE POTENTIAL ADVERSE HEALTH EFFECTS OF SIX CYANOTOXINS

May 2012

Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

- Three common cyanotoxins *microcystins, cylindrospermopsin, anatoxin-a*
- Action levels in recreational waters for people and domestic animals
- Action levels in fish for consumption

OEHHA's Recreational Action Level Development

Endpoints	
Microcystins	Liver effects in rats (Heinze 1999)
Cylindro-spermopsin	Kidney effects in mice (Humpage and Falconer 2003)
Anatoxin-a	Absence of effects in mice (Fawell et al. 1999)
Uncertainty Factor	1000 (animal → human; human → human; limited data)
Exposure estimate	Accidental ingestion of 250 mL water while swimming (0.25 L/d)
Duration	Short-term to subchronic (ongoing, repeated exposures over days to years)

CCHAB Triggers

OEHHA Action Levels

- Animal Study → Uncertainty Factors → Exposure Estimate
- Conservative Assumptions

Modified OEHHA Action Levels

- Adjust uncertainty and exposure assumptions
- Remains Conservative

Risk Management Decision

- Precautionary *or* Maximum

CCHAB: Microcystins

CAUTION → WARNING → DANGER

Trigger (µg/L)	0.8	6	20
Basis	OEHHA's Action Level	Modified OEHHA AL	Risk Management, WHO



CCHAB: Cylindrospermopsin

	CAUTION	WARNING	DANGER
Trigger (µg/L)	1	4	17
Basis	Precautionary Approach	OEHHA's Action Level	Modified OEHHA AL




CCHAB: Anatoxin-a

	CAUTION	WARNING	DANGER
Trigger (µg/L)	Detect	20	90
Basis	Precautionary Approach	Oregon’s Guideline	OEHHA's Action Level

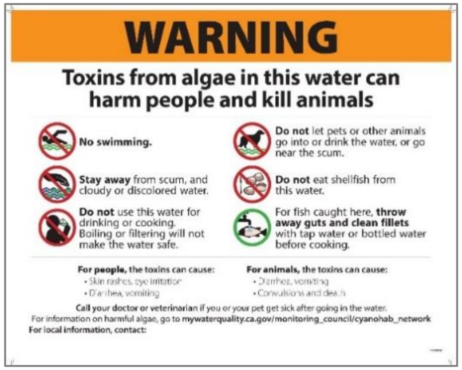



CCHAB: Public Health Postings

No Pets!

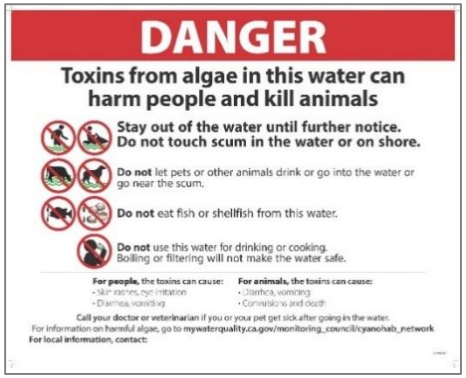
Don't let children play in algae.

Avoid algae and scum when swimming.



No Swimming!

No Pets!



No Water Contact!

No Pets!

Don't eat fish.

All Levels: Do not drink lake water or eat shellfish.

Comparison of US EPA and CCHAB Warning Levels: *Understanding the Uncertainty*

Reference Dose:

Limited data on oral exposures

Difficult to identify *lowest toxic dose for microcystins*

Exposure:

Concentration in recreational waters… ***imprecise***

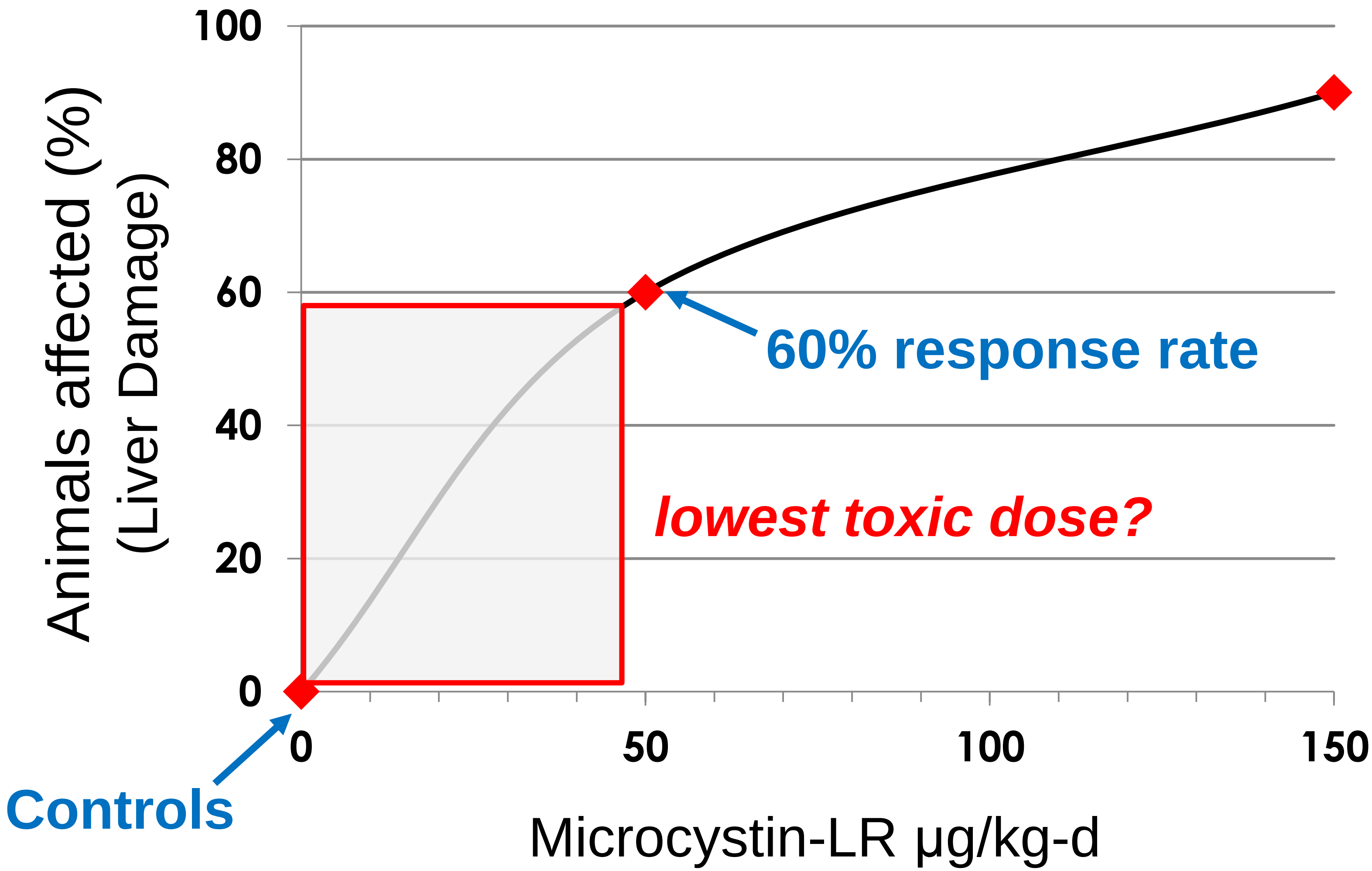
Estimation of recreational ingestion rates … ***imprecise***

Range of imprecision:

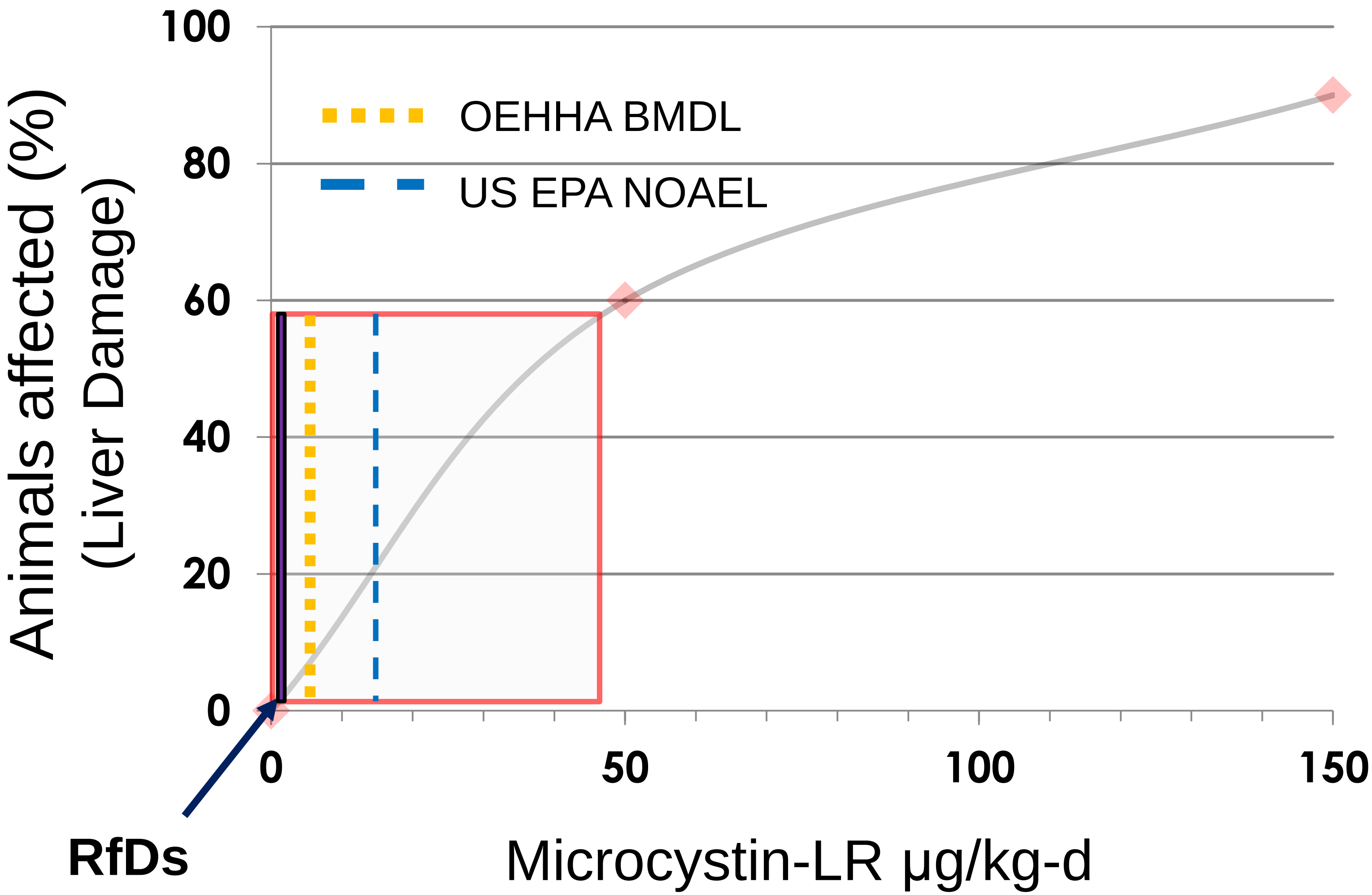
Difference in warning levels:

Microcystins	CCHAB Caution	CCHAB Warning	EPA REC Criteria
NOAEL or BMDL (µg/kg-d)	6.4	**6.4**	**15.8**
Uncertainty Factor	1000	300	300
RfD (µg/kg-d)	0.006	0.02	0.05
Ingestion Rate (L/d)	0.25	**0.1**	**0.33**
Advisory Level (µg/L or ppb)	**0.8**	**6**	**4**
Advice	No pets Avoid algae	No swimming No pets	No swimming

Microcystin Study: Heinze 1999



Microcystin Study: Heinze 1999



Cylindro-spermopsin	CCHAB Caution	CCHAB Warning	EPA REC Criteria
NOAEL or BMDL (µg/kg-d)		33	30
Uncertainty Factor		**1000**	**300**
RfD (µg/kg-d)		0.033	0.1
Ingestion Rate (L/d)		**0.25**	**0.33**
Advisory Level (µg/L or ppb)	**1**	**4**	**8**
Advice	No pets Avoid algae	No swimming No pets	No swimming

Addressing Anatoxin-a

Short-term Mouse Study[1]

- 28 days, gavage
- Numerous endpoints
- No likely treatment-relevant effects, *but*:
  - *Two unexplained deaths (can happen with daily gavage)*

OEHHA set NOAEL at 2.5 mg/kg-d (highest dose; basis of **CCHAB Danger posting**)

Oregon set NOAEL at 0.1 mg/kg-day (lowest dose without unexplained death; **CCHAB Warning posting**)

[1]Fawell and James, 1994; Fawell et al., 1999

Addressing Anatoxin-a

Other studies supporting OEHHA's NOAEL of 2.5:

- *5-day study in mice* (gavage)[1]: NOAEL = 2.5 mg/kg-d (deaths at 6.2 and 12.3 mg/kg-d)
- *10-day study in pregnant mice* (gavage)[1]: NOAEL = 2.5 mg/kg-d (maternal and developmental toxicity)
- *7-week study in rats* (drinking water)[2]*:* NOAEL = 0.5 mg/kg-d (highest dose)

Limited studies, but useful for support

[1] Fawell and James, 1994; Fawell et al., 1999

[2] Astrachan and Archer, 1981; Astrachan et al., 1980

Growing Problem

Drought, climate change and increasing nutrients

- New Areas
- New Impacts
- New Timing

Summary

- **Public health warning levels** for recreational exposures are available from US EPA and CCHAB
- **Public health signs** that are ready-made and customizable are available from CCHAB
- **Implementation can be flexible** – a tiered approach was shown here
- CCHAB recommends **public health warnings for anatoxin-a**
- **Pets and livestock** receive much higher exposures

Resources

CCHAB Guidance and Signage (2016 Updates):
www.mywaterquality.ca.gov/habs/resources/index.html#recreational

California HABs Portal: www.mywaterquality.ca.gov

California Cyanobacteria and Harmful Algal Blooms Network (CCHAB):
www.mywaterquality.ca.gov/monitoring_council/cyanohab_network/index.html

OEHHA's Risk Assessment: https://oehha.ca.gov/risk-assessment/document/toxicological-summary-and-suggested-action-levels-reduce-potential-adverse