EPA

Water Research Webinar Series

Hosted by EPA's Office of Research and Development

Schedule & Recordings: epa.gov/water-research/water-research-webinar-series

October 28, 2020 from 2:00-3:00 pm ET

Health Effects Associated with Harmful Algal Blooms and Algal Toxins

A certificate of attendance will be provided for this webinar

Webinar Slides: Located under "Handouts" in the right navigation bar of your screen.

To Ask a Question: Type in the "Questions" box located in right navigation bar on your screen.

Webinar Support: Send email to webcastinfo@cadmusgroup.com

Disclaimer: The views expressed in these presentations are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency. Any mention of trade names or commercial products does not constitute EPA endorsement or recommendation for use.

EPA at 50

Progress for a Stronger Future

EPA turns 50 this year! Join us in our year-long anniversary celebration. epa.gov/50

Certificates of Attendance

Requirements:

1. You must be registered or in a room with someone who is.

2. You must attend the webinar for 60 minutes.
3. If in a room with others, the names of people not logged in must be provided by the person who is logged in. All certificates will be sent to the email address of the person who is logged in. **Click here to submit additional names online**

Note

Acceptance of certificates is contingent on organization requirements—EPA cannot guarantee acceptance. Closed-captioned recordings of the webinars are provided below for later viewing and as a training resource; certificates cannot be provided for viewing webinar recordings.

Upcoming EPA Webinars

Small Drinking Water Systems Webinar Series

November 17: *Creating Resilient Water Utilities*

Registration and Additional Information

Tools and Resources Webinar Series

November 18: *Drinking Water Models and Tools*

Registration and Additional Information

Water Research Webinar Series

November 18: *Property Values and Water Quality: Supporting Decisions with the Hedonic Model*

Registration and Additional Information

Presentation

Some, but not all, types of harmful algal blooms (HABs) are overgrowths of toxin-producing algae in fresh or marine waters that can adversely affect human and animal health and local economies. Cyanobacteria (also known as blue-green algae) are a type of bacteria that exhibit characteristics of algae and can form these HABs. Cyanobacteria HABs (CyHABs or CyanoHABs) typically occur in nutrient rich, warm surface water bodies and have the potential to produce potent toxins. Occurrence of CyHABs is increasing globally, and blooms are accompanied by sporadic reports of human and animal illnesses and deaths. This webinar will summarize the state of the science and describe how a One Health approach to CyHABs can inform human health risks.

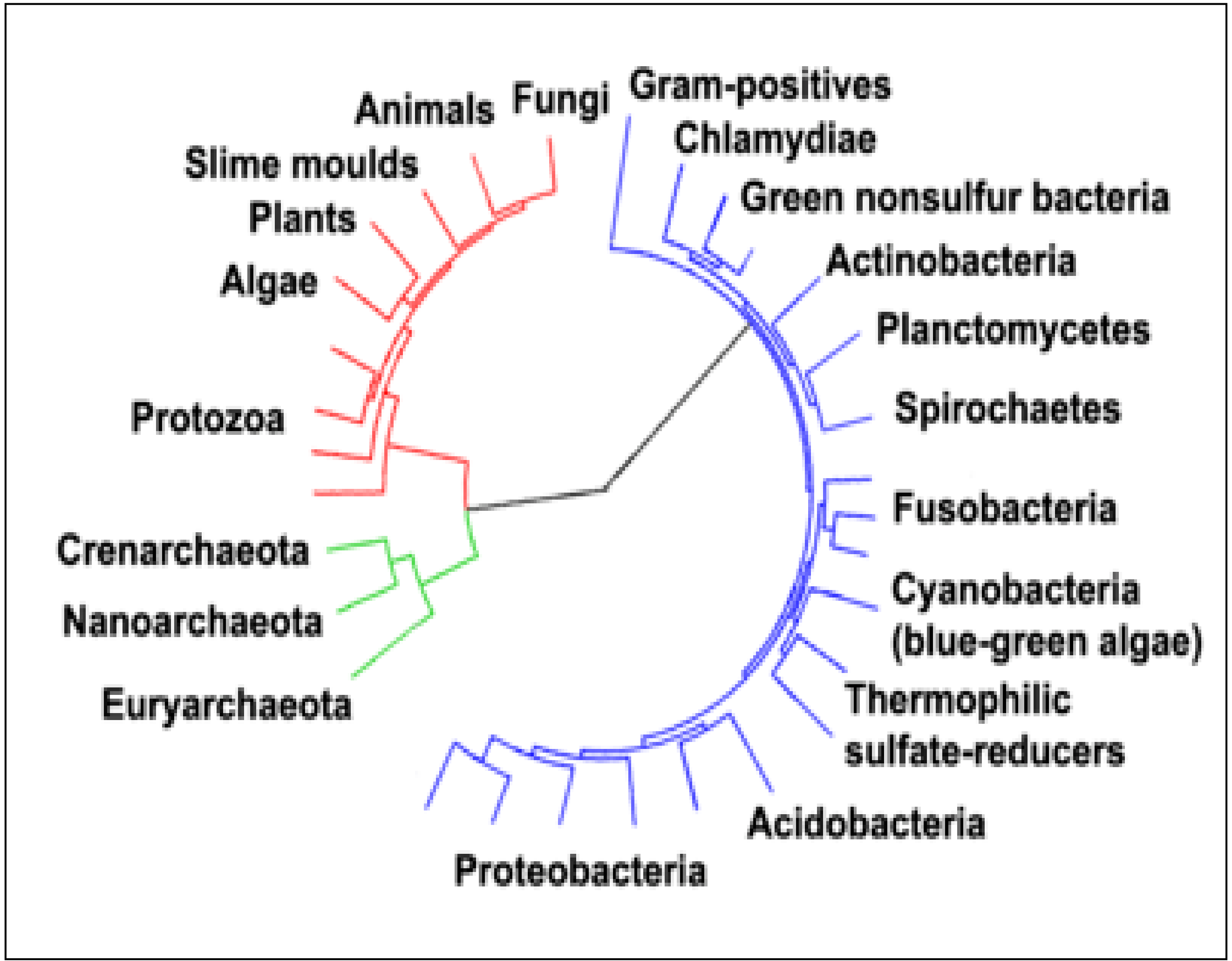
Elizabeth D. Hilborn, DVM, MPH, DACVPM (email: hilborn.e@epa.gov)

For over 20 years, Dr. Hilborn has worked as an environmental health scientist and epidemiologist with EPA's Office of Research and Development (ORD). She is currently with ORD's Center for Public Health and Environmental Assessment where her research focuses on emerging infections and the health effects of environmental and waterborne contaminants, such as toxic cyanobacteria. Dr. Hilborn earned a B.S. in biology from the University of North Carolina at Chapel Hill and a Doctorate in Veterinary Medicine at North Carolina State University. She also completed her Master of Public Health at the University of North Carolina at Chapel Hill, served as a Fellow in the Centers for Disease Control and Prevention's Epidemic Intelligence Service, and is Board Certified in the American College of Veterinary Preventive Medicine.

What are Cyanobacteria?

Also known as:

- Blue-green algae
- Harmful algal blooms
- Toxic algae

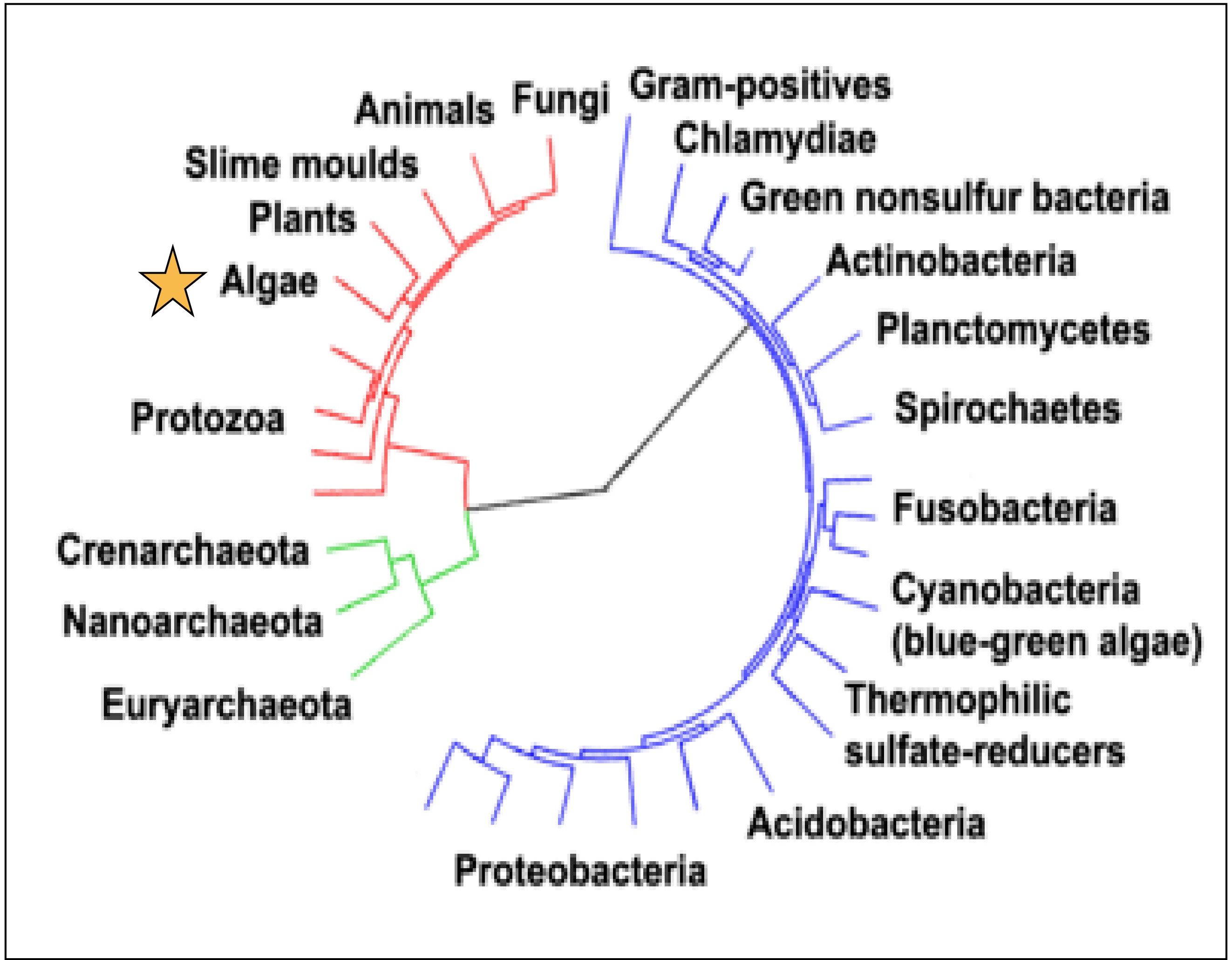


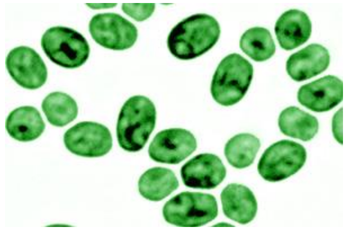
What are Cyanobacteria?

Also known as:

- Blue-green algae
- Harmful algal blooms
- Toxic algae

- Cyanobacteria are not algae





Cyanothece, Pakrasi Lab

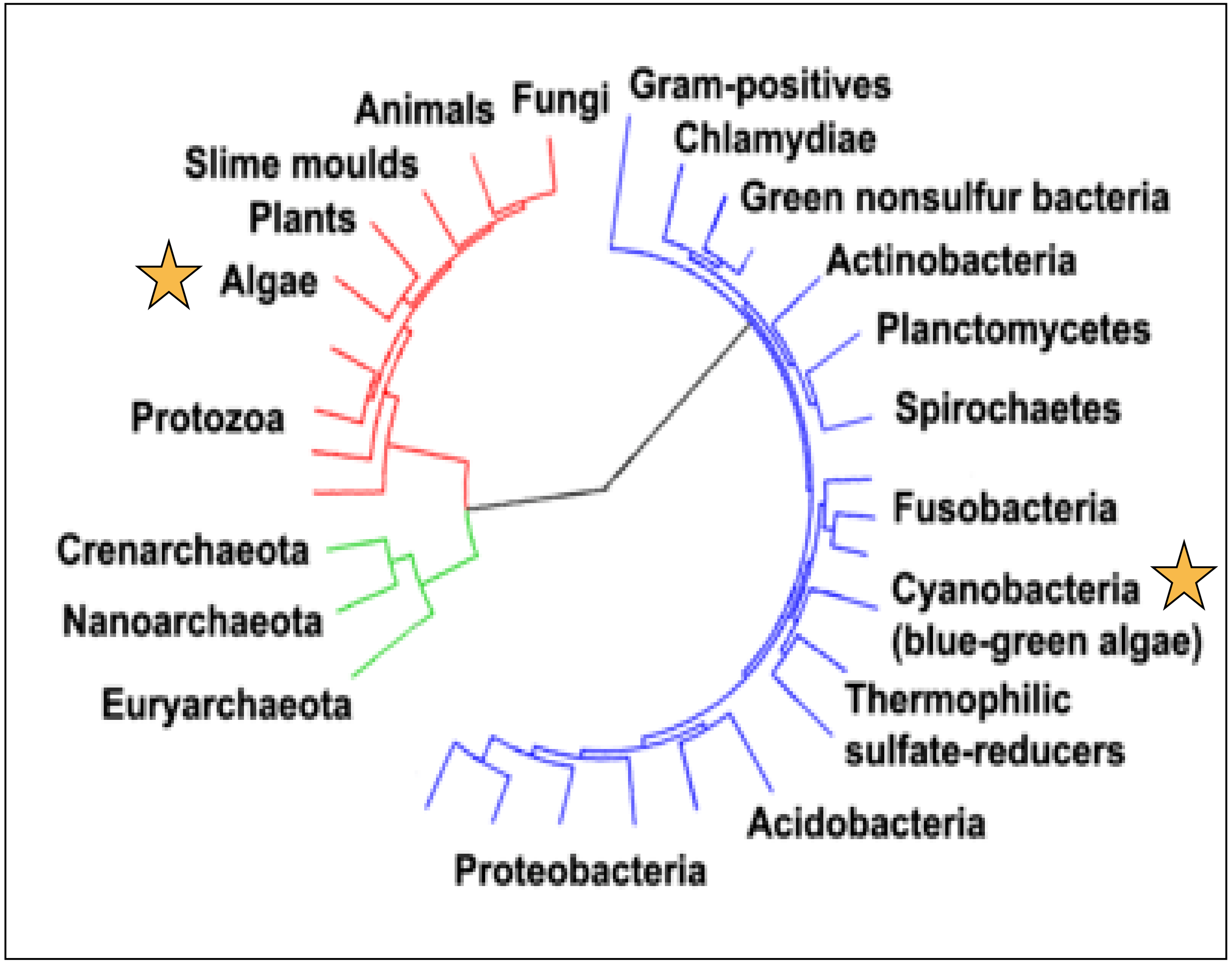
What are Cyanobacteria?

Also known as:

- Blue-green algae
- Harmful algal blooms
- Toxic algae

Anabaena / Dolichospermum, Marta Demarteau

- Cyanobacteria are photosynthesizing bacteria



Cyanobacteria are Globally Abundant

- Warm, stable, eutrophic conditions favor growth
- Aquatic 'blooms'
- Can produce potent toxins
  - Increased microcystins production at higher temps.
- Nitrogen and/or phosphorous limited
  - Nutrient control is key to reducing occurrence

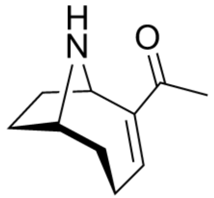
World Health Organization Guideline Values for Cyanobacteria in Freshwater

Guidance Level	Health Risks
≥20,000 cells/mL	Gastrointestinal illness, skin irritation, etc.
≥100,000 cells/mL	Potential for long term illness
Scum formation	Potential for acute poisoning

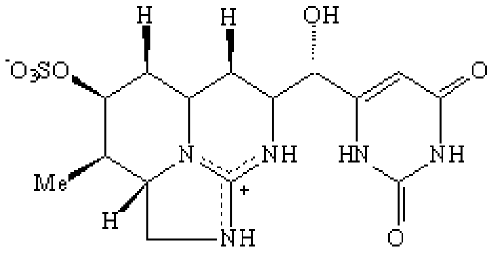
https://www.epa.gov/cyanohabs/world-health-organization-who-1999-guideline-values-cyanobacteria-freshwater

Common Cyanobacteria Toxins (Cyanotoxins)

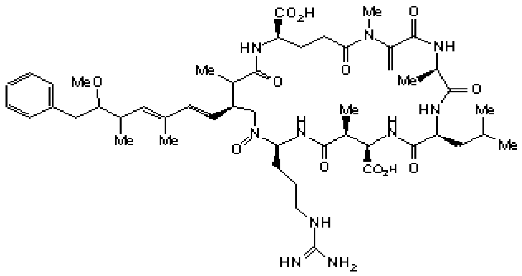
- **Anatoxin-a** – Neurotoxic alkaloid
  - Mimics the effects of acetylcholine
  - Convulsions, diarrhea, vomiting, “very fast death factor”



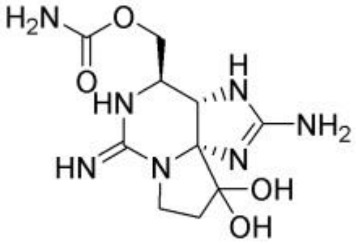
- **Cylindrospermopsins** – Cytotoxic alkaloid
  - Affects multiple tissues
  - Inhibits protein synthesis, toxic metabolites



- **Microcystins** – Hepatotoxic cyclic peptides
  - Potent protein phosphatase inhibitors



- **Saxitoxins** – Neurotoxic nonterpene alkaloids
  - Sodium channel blocker, agents of Paralytic Shellfish Poisoning



EPA Health Advisory Concentrations for Microcystins and Cylindrospermopsin

Recreational Ambient Water Swimming Advisories:

- **Microcystins: 8 µg/L**
- **Cylindrospermopsin: 15 µg/L**

EPA Issues Recommendations for Recreational Water Quality Criteria and Swimming Advisories for Cyanotoxins. December 2019, EPA 823-D-19-002

Drinking water health advisory (10 day):

- **Microcystin: 1.6 µg/L adults; 0.3 µg/L preschool children**
- **Cylindrospermopsin: 3 µg/L adults; 0.7 µg/L preschool children**

EPA, Office of Water, 820F15003, June 2015

Potential Sources of Human Exposure to Cyanobacteria and Cyanotoxins

- Drinking and recreational waters
- Hemodialysis treatment for renal insufficiency
- Aquatic foods – fish and invertebrates
- Ambient water – fountains, near shore aerosols
- Cyanobacteria – food ingredients and supplements
- Produce – contaminated irrigation water

Drinking Water Exposure


H.N. Ghanbari/AP

Reports of Drinking Water-associated effects

Australia

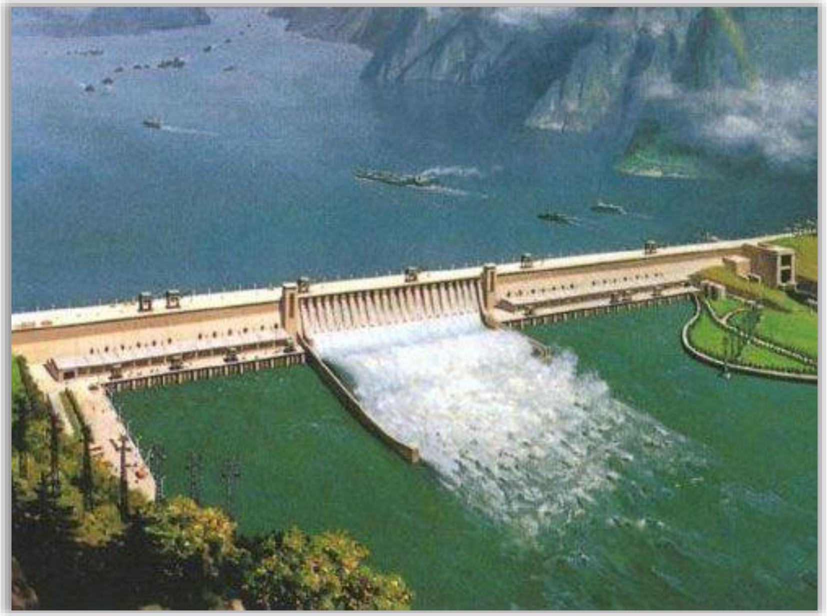
- **1979, Palm Island Outbreak Australia (Bourke et al. 1983)**
  - Bloom in reservoir, taste and odor problems, copper sulfate used
  - 150 persons sickened, > 100 persons required hospitalization
  - Liver damage and gastroenteritis confirmed
  - Subsequent investigation implicated *Cylindrospermopsis*

- **1981, Retrospective study, Australia (Falconer et al. 1983)**
  - Toxic *Microcystis* bloom in reservoir, copper sulfate used
  - A spike in liver enzymes was detected among community members

- **Case control study (El Saadi et al. 1995)**
  - Increased odds of gastroenteritis and dermatitis among those with river water exposure (drinking and body contact)

Studies of Drinking Water-associated effects

China



- **Yu 1995; Summary of multiple studies**
  - Higher rates of hepatocellular carcinoma among river and pond water consumers
- **Zhou 2002**; **Retrospective cohort study**
  - Higher risk of colorectal cancer among river and pond water consumers
- **Li 2011; Cohort study children**
  - Higher liver enzymes (AST, ALP) and serum microcystins among children who drank water from microcystin-contaminated surface vs. well water

Studies of Drinking Water-associated effects

Canada

- **Prospective study (Levesque, 2014).** Those drinking cyanobacteria - contaminated drinking water reported increased muscle pain, gastrointestinal illness, skin and ear problems

United States

- **1930, W. Virginia, Ohio (Tisdale, 1931)**

  Outbreaks of gastroenteritis among persons drinking contaminated Elk, Kanawha, Ohio River water

- **1998 – 2008, Massachusetts (Beaudeau 2014)**

  Retrospective study. Daily turbidity counts; cyanobacteria, fecal coliforms associated with elder hospital admissions for gastrointestinal illness

Microcystin Contamination of Drinking Water, Toledo, Ohio, August 1- 4, 2014

- **August 1, Microcystin contamination finished water**
- **Aug. 2, Do not drink order**

Water Intake, Water line courtesy – ClickOn Detroit

Water line. Toledo, August 3, 2014

Centers for Disease Control and Prevention
MMWR
Morbidity and Mortality Weekly Report
Weekly / Vol. 65 / No. 35 September 9, 2016

Community Needs Assessment After Microcystin Toxin Contamination of a Municipal Water Supply — Lucas County, Ohio, September 2014

Carolyn L. McCarty, PhD[1,2]; Leigh Nelson, MPH[2,3]; Samantha Eitniear, MPH, VPH[4]; Eric Zgodzinski, MPH[4]; Amanda Zabala, MPH[1,3]; Laurie Billing, MPH[1]; Mary DiOrio, MD[2]

- Household level survey, 171 households participated
- ‘Do not drink’ order resulted in:
- **16% reported a physical illness** (Gastrointestinal, skin disorders most commonly reported)
- **10% reported a mental health disorder** (Anxiety, loss of sleep and appetite most commonly reported)
- **8% reported disruption of activity** (Temporary displacement or loss of work)

Microcystin Exposure via Hemodialysis

Microcystin Exposure via Hemodialysis

- **1996 - Caruaru, Brazil**
  - Contaminated water used to prepare dialysate
  - > 50 people died
  - Microcystins found in serum, tissues

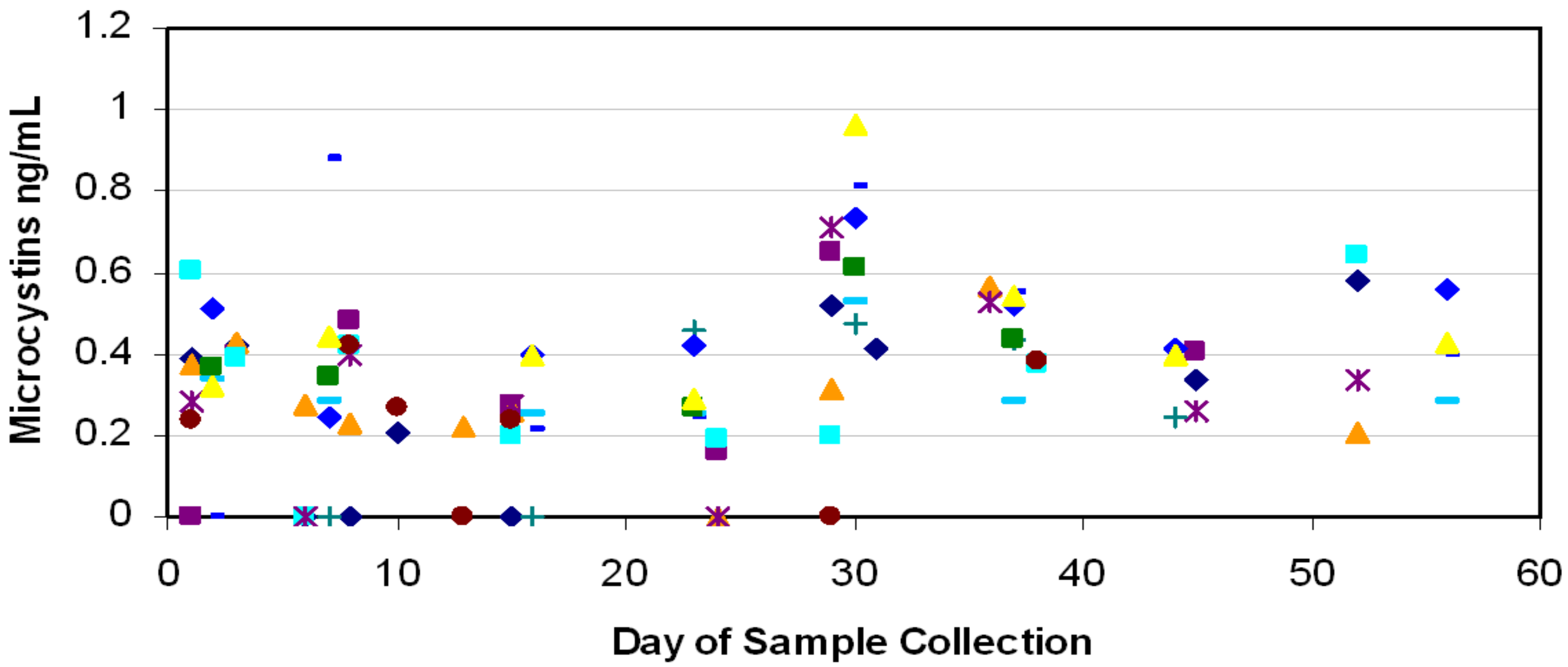
Jochimsen et al. NEJM 1998

- **2001 - Rio de Janeiro, Brazil**
  - 44 patients exposed
  - 13 had detectable serum microcystin concentrations
  - Patients followed and blood analyzed over 8 weeks

Soares et al. Environ Toxicol 2006

Sublethal Microcystin Exposure Event, 2001

- Thirteen patients exposed to microcystins via hemodialysis – detectable serum microcystins
- Followed for 8 weeks:
  - Microcystin LR $_{\text{equivalents}}$: 0.63ng/mL median (<0.16 - 0.96)



Soares et al. Environ Toxicol 2006

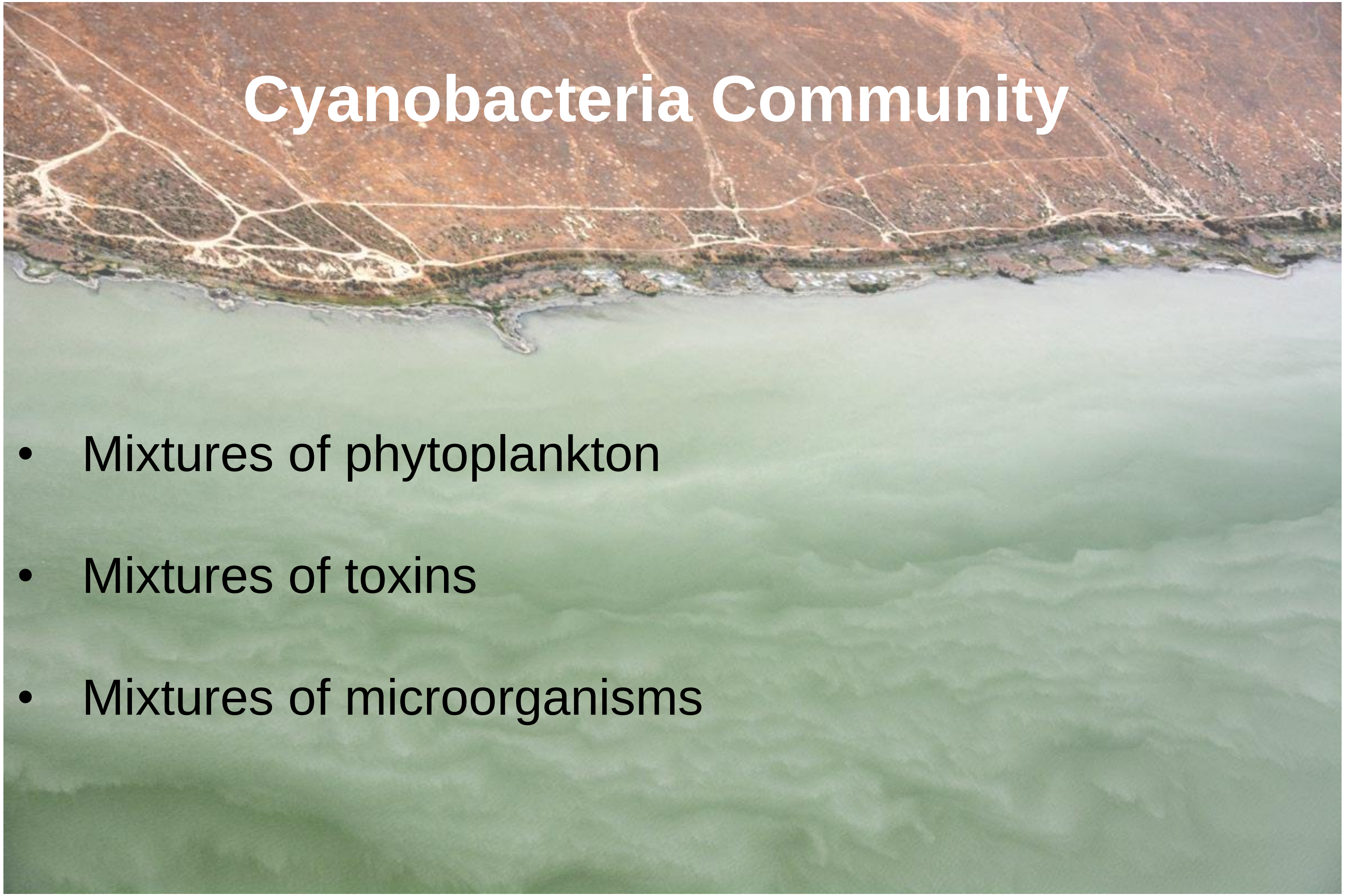
Summary of 2001 event: patients exposed to microcystins in dialysate

- Sublethal, low dose human microcystin exposure event
- Elevated liver enzymes, altered clotting function
  - Patients suffered mild – moderate mixed liver injury
- Few patients with evidence of exposure, incomplete data
- Suggested future evaluation of additional biochemical outcomes such as:
  - Products of lipogenesis
  - Clotting factor production
  - Plasma protein concentrations
  - Bile acid concentrations

Hilborn et al. PLoS ONE 2013

Recreational Exposure

Cyanobacteria Community



- Mixtures of phytoplankton
- Mixtures of toxins
- Mixtures of microorganisms

Reports Recreational Water-Associated Illness

United Kingdom

- **1989 – outbreak report.** Soldiers canoe-training, developed acute gastroenteritis, elevated liver enzymes, apparent aspiration pneumonia (Turner, 1990)

Argentina

- **2007- case report.** Recreational boater immersed in heavy *Microcystis* bloom. Acute gastrointestinal and respiratory illness required intensive care, acute respiratory distress syndrome, elevated liver enzymes (Giannuzzi, 2011)

Reports of Recreational Water-associated illness

Finland

- **2002 - 2003 Prospective monitoring (Rapala, 2005)**
  - 7/50 freshwater samples saxitoxin positive
  - STX concentration (≤1mg/L)
  - *Anabaena lemmermannii* blooms

- Three children exposed to lake reported health effects
  - Fever
  - Eye irritation
  - Rash
  - Abdominal pain

Studies: Recreational Water Associated Illness

Australia

- **Prospective study (Pilotto, 1997)** found association between recreating in cyanobacteria-contaminated water (>5,000 cells/mL), and gastrointestinal illness, eye and mouth irritation 2-7 days later

- **Cross sectional study of *Lyngbya majuscula* exposure, (Osborne, 2007)**
  - Association between recreating in marine water during the previous 7 months and subsequent health effects. Any effects 349/1007 (35%), itching (dermal) 23%
  - Reported dose-response relationship

Recreational Water Exposures, Effects

United States

- **1935, 1945 – Case reports (Heise, 1949)** Allergic reactions to freshwater blue green algae

- **1952 –Case report (Cohen and Reif, 1953)**, child sensitized to *Anabaena* in lakes, recurrent rash

Human Illness, Animal Deaths, Freshwater HABs, Kansas, 2011

- 13 cases of HAB-associated human illness
  - Of 7 confirmed, adverse effects included:
  - Rash, gastrointestinal effects, eye and upper respiratory effects, fever, joint pain, pneumonia
- 5 dog deaths, 1 confirmed illness
  - Vomiting, diarrhea, lethargy, staggering, seizures
- Multiple Kansas lakes impacted by blooms and toxins

Trevino-Garrison et al. Toxins, 2015

2009 – 2010
Waterborne Disease Outbreak Reports

- Eleven algal bloom-associated Reports from New York (3), Ohio (6), Washington (2)
  - All outbreaks occurred at public or private lakes

- Sixty-one people became ill, no known deaths
  - 59% females
  - 66% <20 years of age
  - 59% sought health care*
  - 7 (12%) visited emergency room*
  - 2 (3%) hospitalized*

*** >1 category / person**

Multiple Health Effects Reported

- **Order of most commonly to least commonly reported:**
  - Dermal, Gastrointestinal effects
  - Respiratory, Nonspecific effects
  - Ear pain/effects
  - Neurologic effects
  - Muscle, Joint, Bone and/or Eye effects

- **Onset of illness after exposure was generally rapid**
  - Among outbreaks median onset <1 day

- **Most commonly to least commonly reported toxins:**
  - Microcystins
  - Anatoxin-a
  - Saxitoxins/cylindrospermopsin

31

Cyanotoxin Analysis among Eight Outbreaks

Outbreak	Anatoxin-a	Cylindro-spermopsin	Microcystins	Saxitoxins
1	-	-	112.5 µg /L	-
4**	0.1µg /L	ND	4.6 µg /L	ND
5	-	-	> 1000 µg /L	-
6**	ND	ND	0.2 µg /L	0.03 µg /L
7**	-	ND	20.8 µg /L	ND
8**	15.0 µg /L	9.0 µg /L	> 2000 µg /L	0.09 µg /L
9	0.2 µg /L	0.3 µg /L	0.3 µg /L	ND
10	-	-	< 6.0 µg /L	-

Maximum toxin values, +/- 1 day outbreak period

** Neurologic illness

Hilborn et al. MMWR January 10, 2014

What is One Health?

Animal illnesses/deaths preceded outbreaks

Affected animals	Anatoxin-a	Cylindrospermopsin	Microcystins	Saxitoxins
Fish kill, dog deaths	ND	ND	0.2 µg /L	0.03 µg /L
Heron illness, dog deaths	15.0 µg /L	9.0 µg /L	> 2000 µg /L	0.09 µg /L

National Wildlife Federation

https://clearlakecyanobacteria.wordpress.com/

One Health
Harmful Algal Bloom System (OHHABS)
Waterborne Disease Outbreak Reports

New OHHABS surveillance module includes:

- Human health events
- Animal health events
- Harmful algal blooms

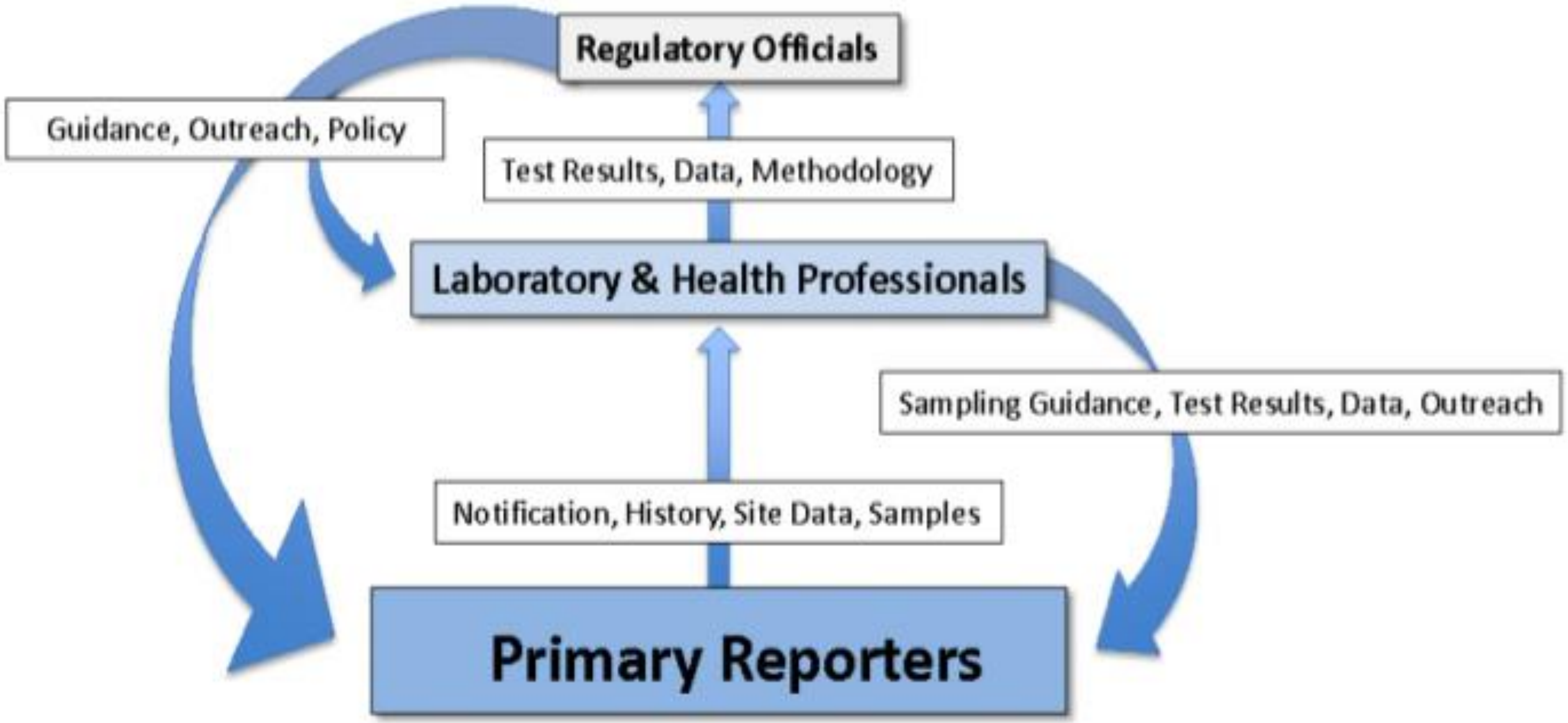
https://www.cdc.gov/habs/ohhabs.html

2016 – 2018 surveillance years, first report *in press*

One Health and Cyanobacteria in Freshwater Systems: Animal Illnesses and Deaths Are Sentinel Events for Human Health Risks

Elizabeth D. Hilborn [1,*] and Val R. Beasley [2]

Toxins **2015**, *7*, 1374-1395; doi:10.3390/toxins7041374



One Health and Cyanobacteria in Freshwater Systems: Animal Illnesses and Deaths Are Sentinel Events for Human Health Risks

Most useful sentinel events (illness or deaths):

- Livestock
- Dogs
- Fish

https://www.njtvonline.org/

A Section 508–conformant HTML version of this article is available at http://dx.doi.org/10.1289/ehp.1409558.

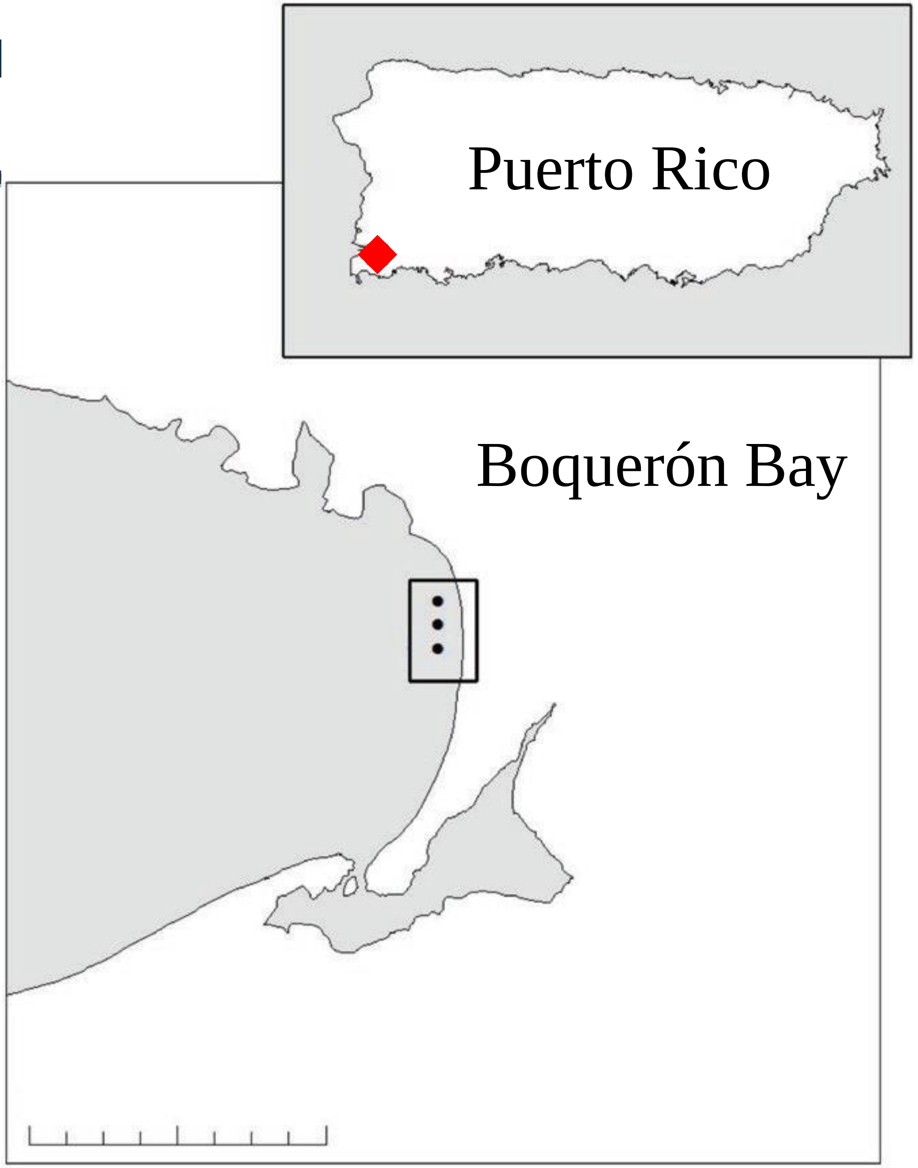
EHP 2016 Research

A Prospective Study of Marine Phytoplankton and Reported Il Recreational Beachgoers in Puerto Rico, 2009

Cynthia J. Lin,[1,2] Timothy J. Wade,[3] Elizabeth A. Sams,[3] Alfred P. Dufour,[4] Andrew D. Chap Elizabeth D. Hilborn[3]

- Recruited 15,726 people over 26 study days
- Recorded baseline health information – upon arrival
- Recorded day’s activity – at departure
- Recorded health effects-

  10-12 days after beach visit



Boquerón Bay Water Quality

Marine phytoplankton cells/ mL

Bacillariophyta (Diatoms)

- Median 386, Range:129 – 619

Cyanobacteria

- Median 132, Range: 0 – 1461

Dinophyta (Dinoflagellates)

- Median 37, Range: <1 – 106

Toxins

- Lyngbyatoxin-a - nondetect
- Debromoaplysiatoxin - nondetect

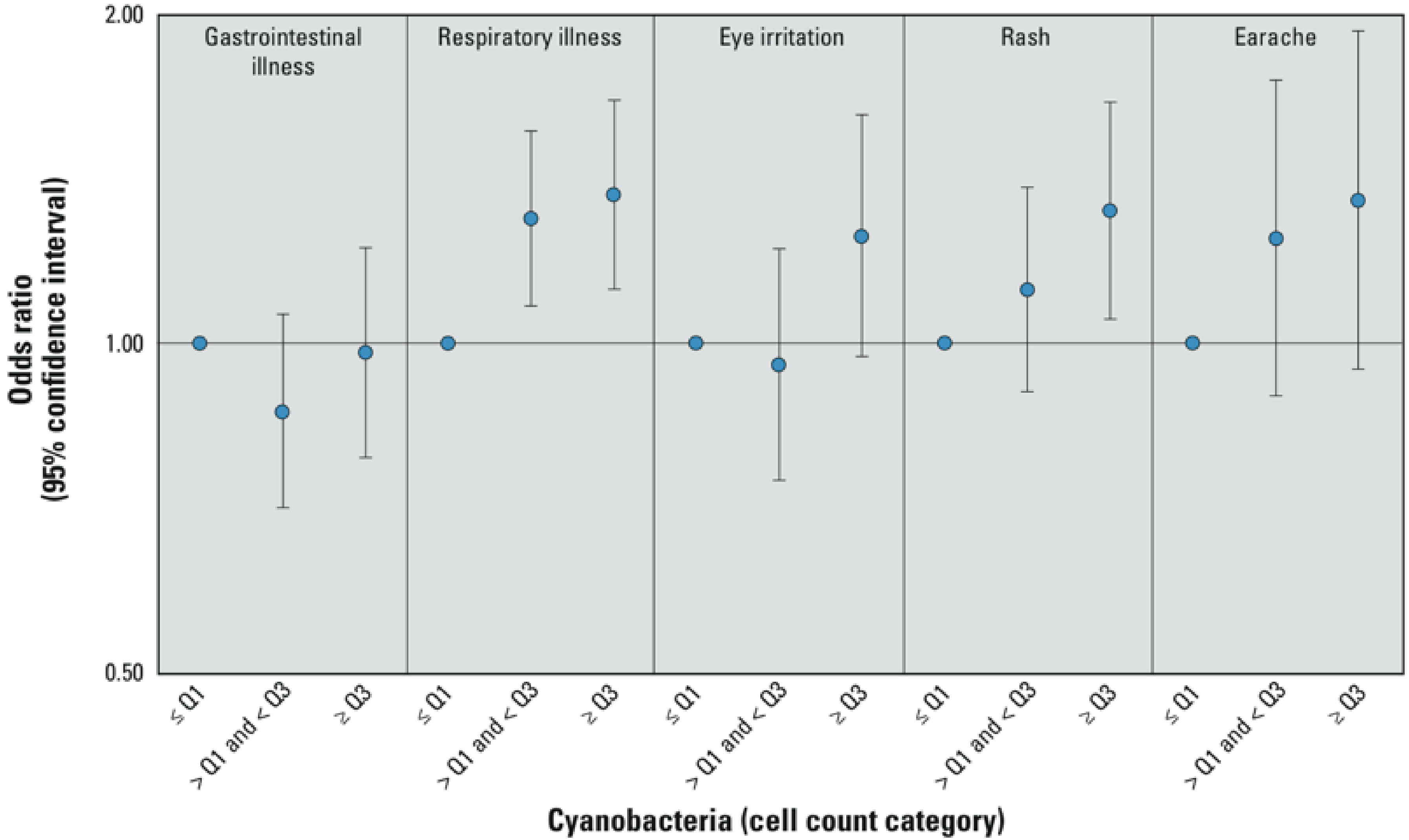
Fecal indicator

Enterococcus

- < 35 CFU/ 100 mL

Moorea producens / (Lyngbya majuscula), WHOI

Effect estimates among those with body immersion, n=12,111



EPA

toxins

MDPI

2017

Case Report

Recreational Exposure during Algal Bloom in Carrasco Beach, Uruguay: A Liver Failure Case Report

Flavia Vidal [1], Daniela Sedan [2], Daniel D'Agostino [1], María Lorena Cavalieri [1], Eduardo Mullen [1], María Macarena Parot Varela [1], Cintia Flores [3], Josep Caixach [3] and Dario Andrinolo [2,*]

- Family, including a 20 month old child, recreated on beaches in Southern Uruguay during January 2015
- Concurrent HAB in the Rio La Plata which flows out to sea near beaches
  - Recurrent bloom impacts people and animals
- Family members became ill after recreation
  - Adults recovered
  - Child experienced liver failure
- Child required liver transplant

Summary

- Animal illnesses and deaths can inform human health risk
- Recreational exposures:
  - Multiple routes of exposure, exposure to mixtures
  - Multiple nonspecific health effects are poorly characterized
  - Lack of public / provider awareness
  - Onset of illness may be rapid
  - Children may be more likely to become ill
- Rapid tests for toxins in biological samples/diagnostic tests are needed

Collaborators:

Wright State University, Dayton, Ohio

Wayne Carmichael, Jerome Servaites

Federal University of Rio de Janeiro, Brazil

Sandra Azevedo, Raquel Soares, Valéria Magalhães, Alvimar Delgado

US Environmental Protection Agency

Tim Wade (ORD), Edward Hudgens (ORD), Leslie D'Anglada (OW), Alfred DuFour (ORD), Elizabeth Sams (ORD), Cynthia Lin (ORISE)

Centers for Disease Control and Prevention

Virginia Roberts, Michele Hlavsa, Jonathan Yoder (NCEZID)

Lorrie Backer (NCEH)

GreenWater Laboratories, Palatka, Florida

Andrew Chapman

State Partners

- Erin Deconno, Jessica Egan, James Hyde, David Nicholas, Eric Wiegert (New York); Laurie Billing, Mary Di Orio, Marika Mohr (Ohio); Joan Hardy (Washington)

Questions?