Benthic HABs Discussion Group

https://www.epa.gov/cyanohabs/epa-newsletter-and-collaboration-and-outreach-habs#benthic

October 20, 2020
12:30 – 2:00 pm PST

Announcements

- ITRC Harmful Cyano Bloom group will continue, with a benthic focus
- North American Lake Management Conference, November 16-20, 2020: https://www.nalms.org/nalms2020/
- National Monitoring Conference, April 19-23, 2021: https://www.nalms.org/2021nmc/
- Puddick J, van Ginkel R, Page CD, et al. Acute toxicity of dihydroanatoxin-a from *Microcoleus autumnalis* in comparison to anatoxin-a. *Chemosphere*. 2021;263:127937. doi:10.1016/j.chemosphere.2020.127937

Discussion group contact information

Facilitators

Jade Young	U.S. Army Corps of Engineers, Louisville District, Kentucky, USA	Jade.L.Young@usace.army.mil
Margaret Spoo-Chupka	Metropolitan Water District of Southern California, USA	Mspoo-chupka@mwdh2o.com
Keith Bouma-Gregson	California State Water Resources Control Board, USA	Keith.bouma-gregson@waterboards.ca.gov
Lesley D'Anglada	U.S. Environmental Protection Agency	Danglada.lesley@epa.gov

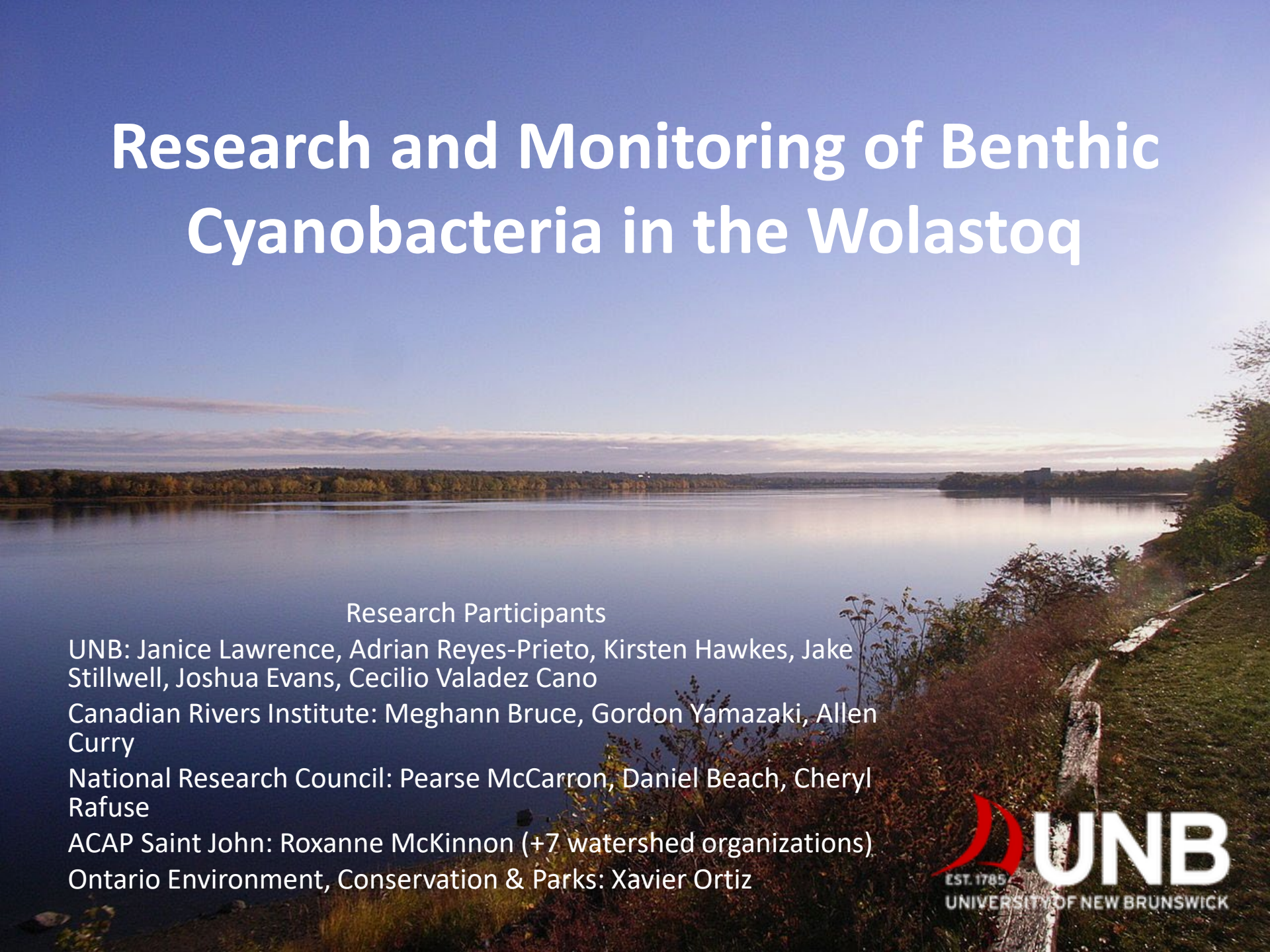
Webpage: https://www.epa.gov/cyanohabs/epa-newsletter-and-collaboration-and-outreach-habs#benthic

Presentations

Janice Lawrence, University of New Brunswick
Research and monitoring of benthic cyanobacteria in the Wolostoq River

Ben Holcomb and Kate Fickas, Utah Department of Environmental Quality
Benthic cyanobacteria in Zion National Park

Research and Monitoring of Benthic Cyanobacteria in the Wolastoq



Research Participants

UNB: Janice Lawrence, Adrian Reyes-Prieto, Kirsten Hawkes, Jake Stillwell, Joshua Evans, Cecilio Valadez Cano

Canadian Rivers Institute: Meghann Bruce, Gordon Yamazaki, Allen Curry

National Research Council: Pearse McCarron, Daniel Beach, Cheryl Rafuse

ACAP Saint John: Roxanne McKinnon (+7 watershed organizations)

Ontario Environment, Conservation & Parks: Xavier Ortiz

UNB
EST. 1785
UNIVERSITY OF NEW BRUNSWICK

Goals

- Provide background on 2018 & 2019 dog deaths along the Wolastoq
- Outline methods and results from 2019 survey and toxicity screening
- Overview data collected in 2020

Wolastoq (Saint John River) Dog Deaths

news Blue-green algae confirmed as cause of dogs' sudden deaths in Fredericton

Blue-green algae confirmed as cause of dogs' sudden deaths in Fredericton

Despite finding, provincial officials say water is still safe for swimming and other recreation

Elizabeth Fraser, Nathalie Sturgeon · CBC News ·
Posted: Aug 03, 2018 12:46 PM AT | Last Updated: August 7

From left to right, Sookie, Peekaboo and Nike all died suddenly only days apart after playing in the St. John River in the Fredericton area. (Photo: Submitted)

2018 – 3 dog deaths

New Brunswick

'Our little Flint didn't stand a chance': Fredericton woman warns dog owners about algae

Sandy Kitchen-Brewer's young hunting dog died Saturday after swimming in St. John River

Hadeel Ibrahim · CBC News · Posted: Jul 17, 2019 5:42 PM AT | Last Updated: July 17

Sandy Kitchen-Brewer says she tried to give her 16-week-old dog Flint mouth-to-mouth and CPR, but he died en route to the vet. (Submitted by Sandy Kitchen-Brewer)

2019 – 1 dog death

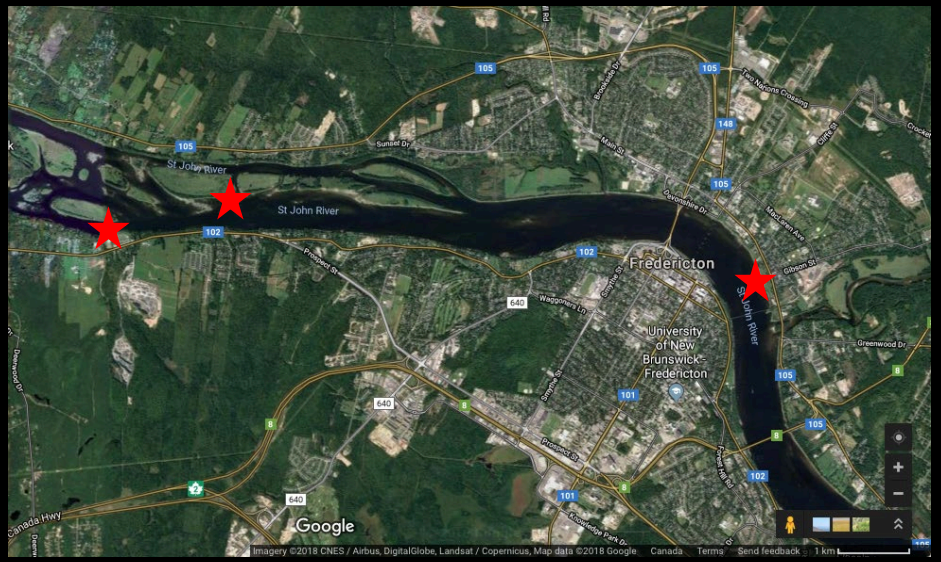
Wolastoq (Saint John) River Dog Deaths (cont'd)

Wolastoq –

- "Beautiful river"
- 673 km long
- < 1 km wide
- < 50 m deep

Fredericton region –

- 20 km section, just below Mactaquac dam



Wolastoq (Saint John) River Dog Deaths (cont'd)

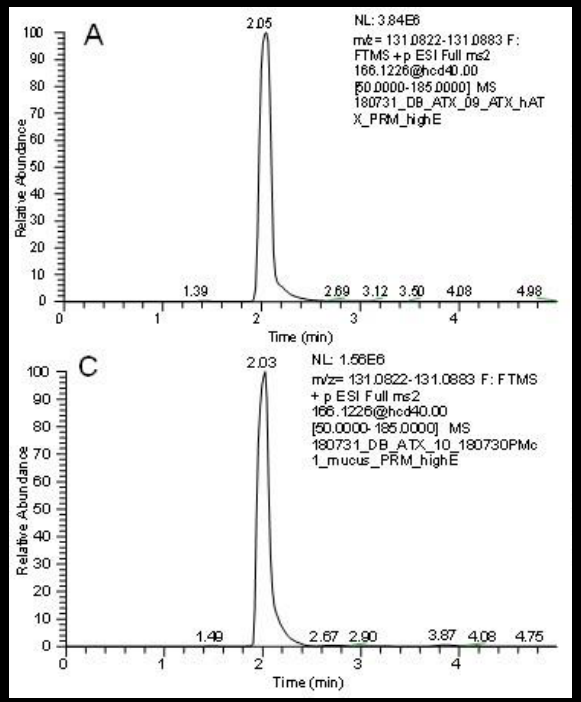
2018:

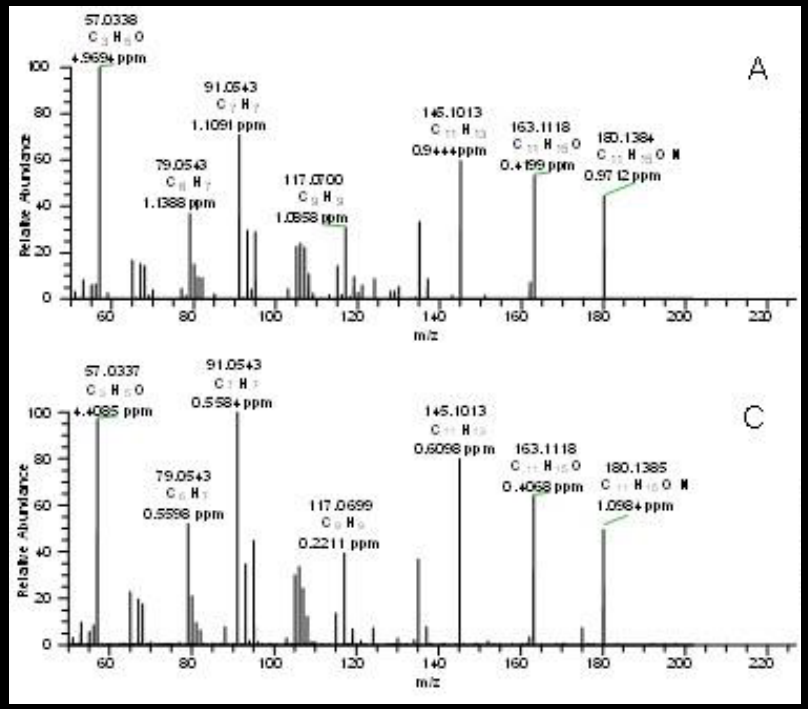
- Material collected by dog owners, DELG & NBPVL
- NRC positively identified anatoxin-a

NRC Analysis:

A) Anatoxin-a standard

C) Dog mucus



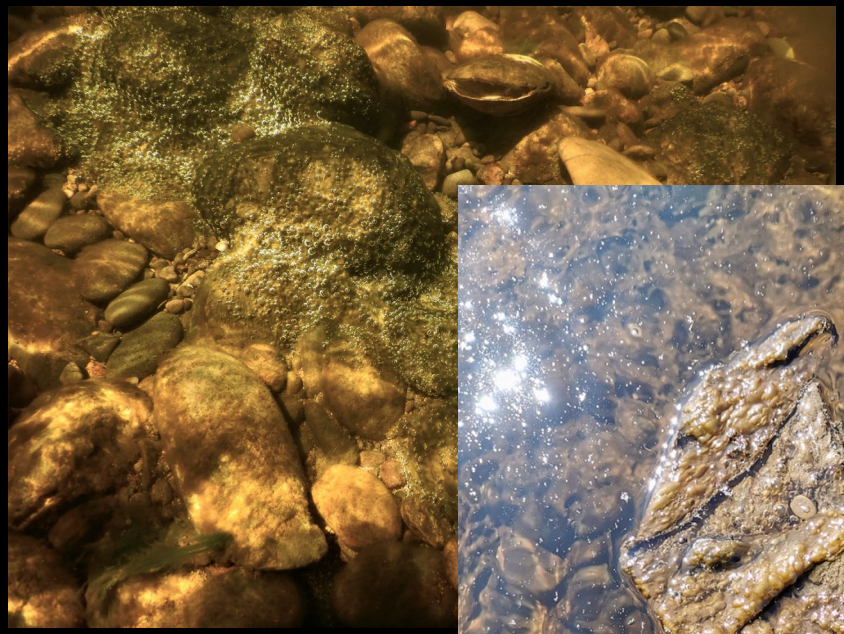


Wolastoq (Saint John) River Dog Deaths (cont'd)

- No blooms, but benthic and epiphytic mats washed up on shore
- Dominated by filamentous cyanobacteria

Detecting and Monitoring in the Wolastoq

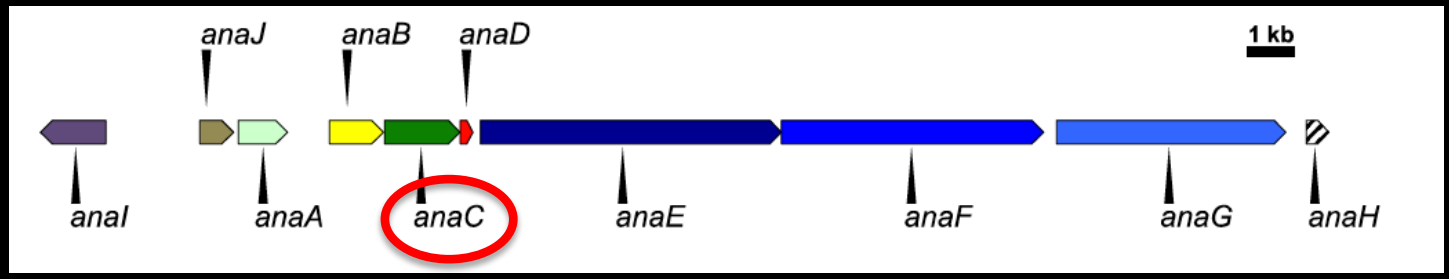
Targeted Field Surveys:

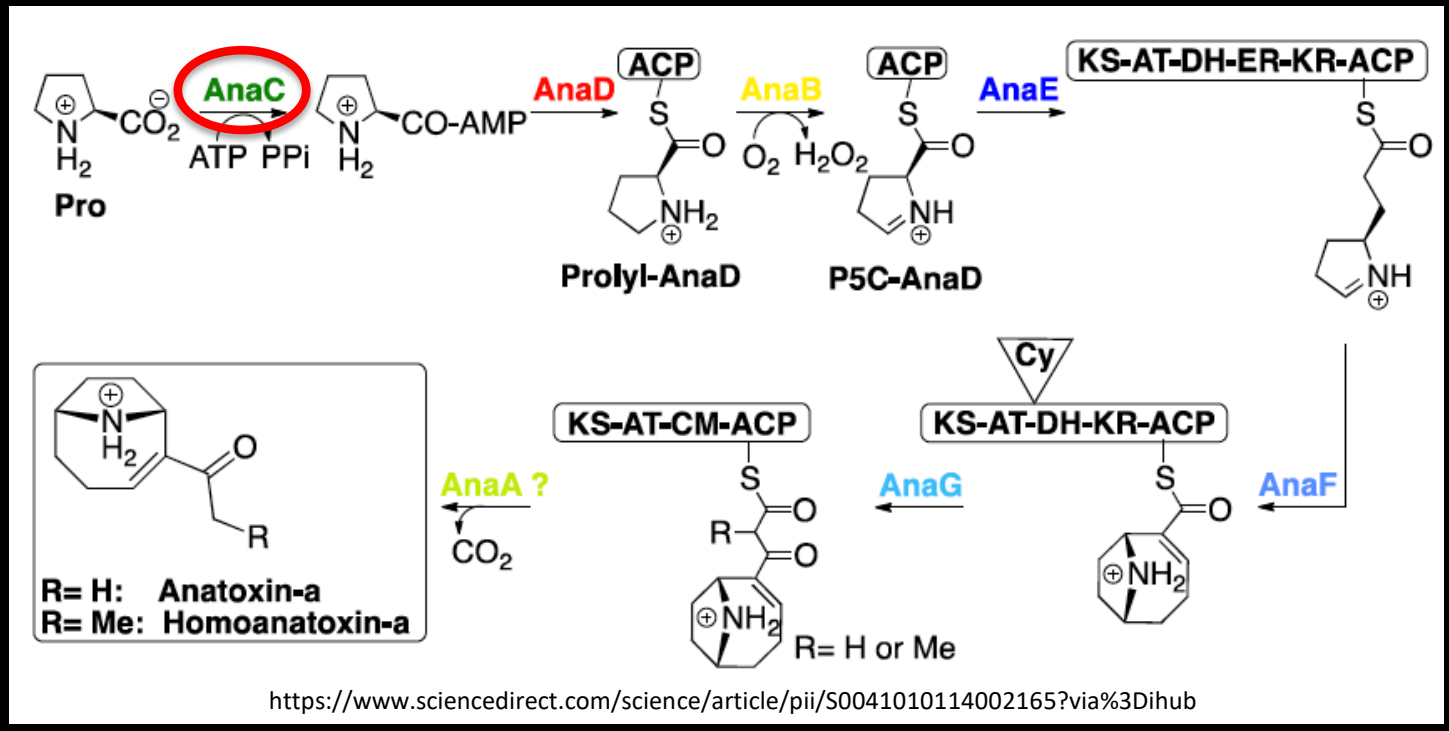


Photos: Meghann Bruce

Detecting and Monitoring in the Wolastoq (cont'd)

Genetic approaches:





https://www.sciencedirect.com/science/article/pii/S0041010114002165?via%3Dihub

Detecting and Monitoring in the Wolastoq (cont'd)

2019 *anaC* PCR screening:

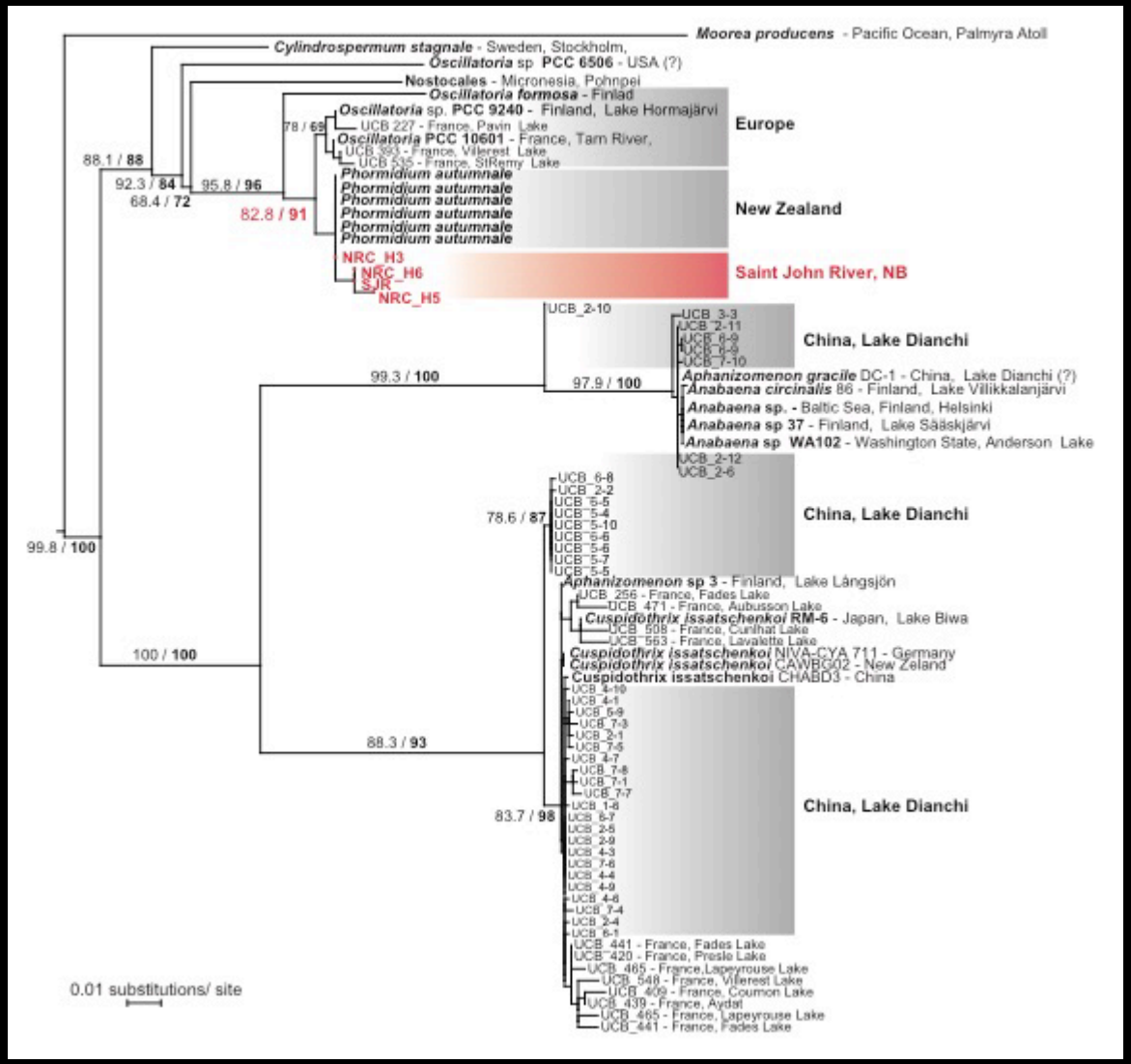
Site	June		July			August		September		Total
	6–7	19–20	3–4	17–18	30–31	15	28–29	11–12	25–27	
1	+	+	+	+	+	+	+	+	+	9/9
2	+	*	–	–	+	+	–	+	–	4/8
3	+	+	*	+	+	+	+	+	–	7/8
4	+	+	+	+	+	–	+	+	+	8/9
5	+	+	–	+	+	–	+	–	–	5/9
6	+	+	+	+	+	+	+	+	–	8/9
7	–	+	+	+	+	+	+	+	+	8/9
8	+	+	+	+	+	+	+	+	+	9/9
Total	7/8	7/7	5/7	7/8	8/8	6/8	7/8	7/8	4/8	

Summary from Jake Stillwell's honours thesis

Detecting and Monitoring in the Wolastoq (cont'd)

Anatoxin Gene Phylogeny (Preliminary):

- Wolastoq River samples fall in *Oscillatoria/ Phormidium/ Microcoleus* clade



Detecting and Monitoring in the Wolastoq (cont'd)

Isolate screening:

NRC Isolate Origin	Microscopy ID	ATX – LC-MS	AnaC gene
Hartt Island	*Leptolyngbya* sp.	+	+
	Leptolyngbya sp.	+	+
	Microcoleus sp.	ND	-
	Microcoleus sp.	+	+
	Microcoleus sp.	+	+
	Microcoleus sp.	+	+
	Phormidium sp.	+	+
	Phormidium sp.	+	+
	Phormidium sp.	ND	-
Carleton Park	*Leptolyngbya* sp.	ND	-
	Microcoleus sp.	+	-
	Phormidium sp.	+	-
	Phormidium sp.	ND	-
	Unknown	ND	+

Detecting and Monitoring in the Wolastoq (cont'd)

Quantitative Genetic Assay:

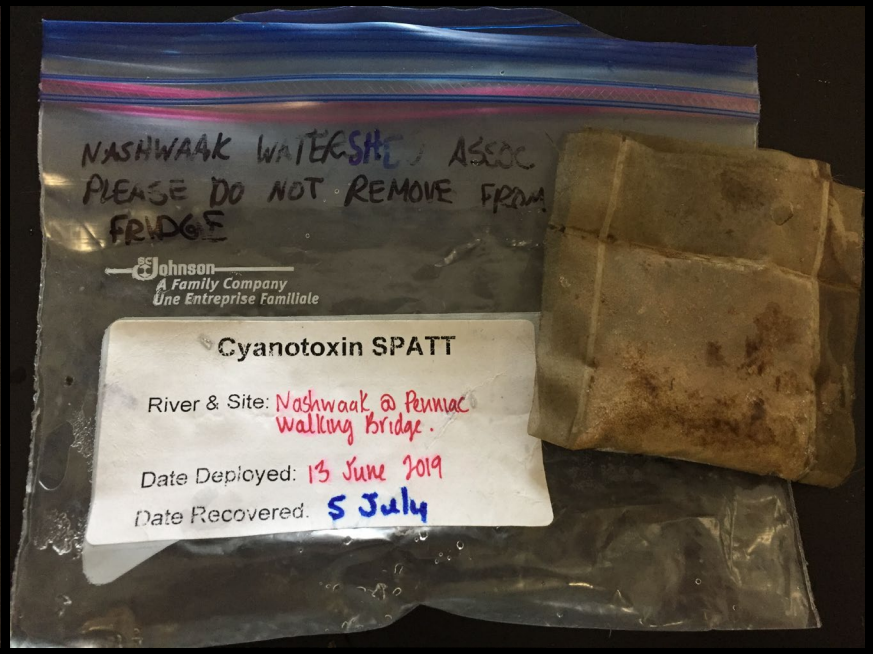
- droplet digital PCR (ddPCR)
- AnaC primer set (Rantala-Ylinen, 2011)
- 2019 samples (27 of 141 analyzed):

  max: 2.9 x 10^6 genes g^{-1} (w.w.)

Detecting and Monitoring in the Wolastoq (cont'd)

Anatoxin-a Detection:

- SPATT test deployments in 2019 in Fredericton region and downstream tributaries
- Assayed for 10 microcystins & 2 anatoxins



Detecting and Monitoring in the Wolastoq (cont'd)

- 41 SPATTs deployed May – October 2019
- 31 of 32 SPATTs in Fredericton region positive for anatoxin-a, no homoanatoxin-a or microcystins
- Max = 192 ng ATX g resin^{-1} day^{-1}
- Down river tributaries (9 samples) all negative

Where do we go from here?

2020:

- Mat survey, sampling, and SPATT deployment along Wolastoq (within NB boundaries)
- Detailed chemical analysis and ddPCR of 2019 & 2020 samples
- Metagenomic analysis of 2019 & 2020 mats to examine anatoxin-a biosynthesis pathways

Acknowledgements

- New Brunswick Department of Environment and Local Government & New Brunswick Provincial Veterinary Labs
- NB Environmental Trust Fund: “Your Environmental Trust Fund at Work”

New Nouveau Brunswick CANADA

EST. 1785 UNB UNIVERSITY OF NEW BRUNSWICK

Applications of Benthic Cyanobacteria: Zion National Park

Dr. Kate Fickas
Ben Holcomb
Utah Department of Environmental Quality
Division of Water Quality
October 20, 2020

UTAH DEPARTMENT *of* ENVIRONMENTAL QUALITY
WATER QUALITY

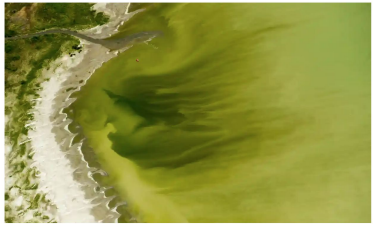
Outline

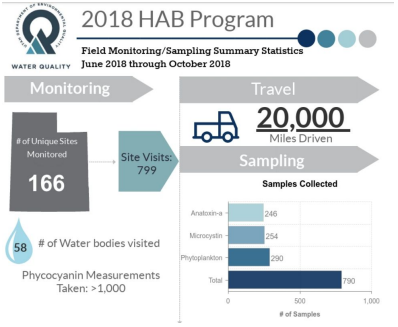
- Very quick background on Utah HABs
- Zion HAB Water Quality Risk Assessment
  - Dog death
  - Tracing
  - Sampling
  - Risk analysis
    - Recreation
    - Agriculture
    - Drinking Water
    - Ongoing Research/Questions
      - Nodularin
      - Human Illness
      - Phenology

Utah HABs History

Huge toxic algae bloom sickens more than 100 in Utah amid heatwave

Bacteria has spread rapidly to cover almost all of Utah Lake, turning the water bright green with a pea soup texture and leaving scummy foam along the shore





Health Watch		Warning Advisory	Danger Advisory
This is not a formal advisory level. Rather, these are indicators that a bloom may exist or may become more severe. Increased monitoring and surveillance are strongly recommended. Indicators may include: • Visual reports • Reports of animal or human illness • Detection of cyanotoxins or toxigenic cyannobacterial cell density below thresholds • Detectable levels should be defined using appropriate QA/QC procedures Consider cautioning users of the waterbody depending on specifics of the event and waterbody.	**Toxigenic Cyanobacterial Cell Density (cells/mL)** [1, 2, 3]	100,000 [A]	10,000,000
	Microcystins (µg/L) [1, 2]	8	2,000
	Cylindrospermopsin (µg/L) [3]	15 [B]	
	Anatoxin-a (µg/L) [3, 4, 5]	15	90
	Health Risks [1, 2, 3]	Potential for long-term illness Short-term effects (e.g., skin and eye irritation, nausea, vomiting, diarrhea)	Potential for acute poisoning Potential for long-term illness Short-term effects (e.g., skin and eye irritation, nausea, vomiting, diarrhea)
	Recommended Actions	Issue **WARNING** advisory to avoid primary contact recreation Post **WARNING** signs Sampling recommended at least weekly	Issue **DANGER** advisory to stay away from the waterbody Post **DANGER** signs Consider **CLOSURE** Sampling recommended at least weekly

2016 — 2017 — 2018 — 2019 — 2020

PhycoTech, Inc.

UTAH PUBLIC HEALTH LABORATORY

Recreation Season Advisory Process

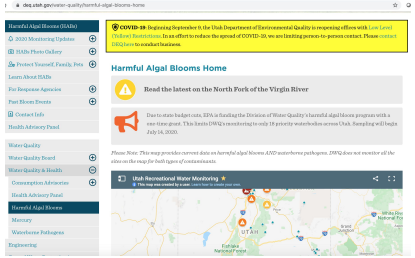
Detection

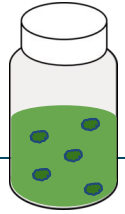
Advisory

HAB Advisory Program

Testing

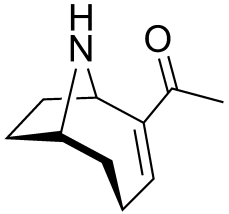
Communication





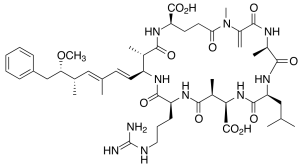
Monitoring

Cyanotoxins - ELISA & LCMS Analysis



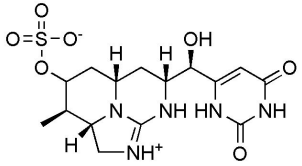
Anatoxin-a

- Neurotoxin
- Also known as Very Fast Death Factor (VFDF)
- Produced by many cyanobacteria species, including those found in Utah waterbodies



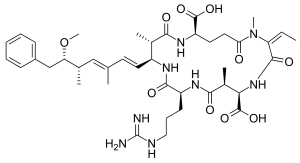
Microcystin

- Hepatotoxin
- Produced by many cyanobacteria species, including those found in Utah waterbodies



Cylindrospermopsin

- Hepatotoxin
- Nephrotoxin
- Produced by many cyanobacteria species, including those found in Utah waterbodies



Nodularin

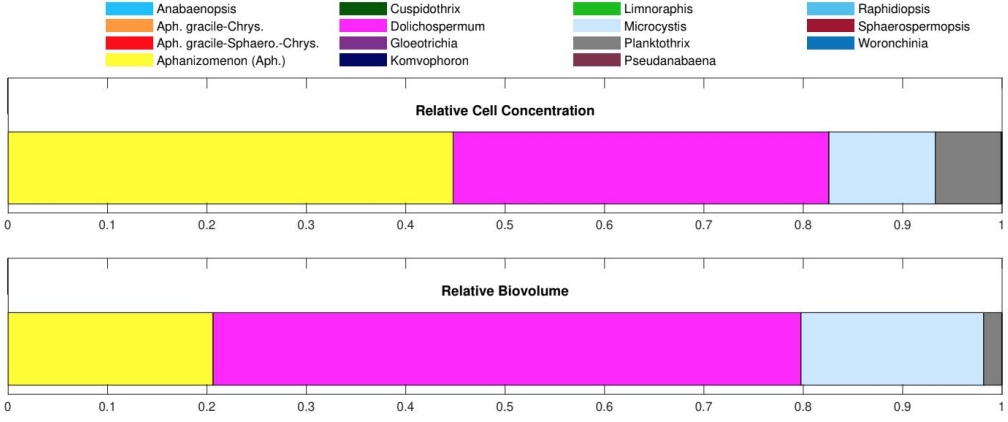
- Hepatotoxin
- Very similar to microcystin
- **<u>Not</u>** produced by many cyanobacteria species rarely found in Utah waterbodies***

Toxigenic Cell Density and Taxonomy

Sample ID: D20201002T192643
Customer ID: 336
Tracking Code: 200228-336
Sample Info: UTA-7-093020-C

System: Utah Lake
Site: UTA-7-093020-C
Station: 4917708
Level: Composite

Date Sampled: 9/30/2020
Date Received: 10/1/2020
Date Analyzed: 10/2/2020



Total Algal Concentration: 582928 cells/mL
HAB Concentration: 561280 cells/mL
HAB Relative Concentration: 96%

Total Biovolume: 175532625 um^3/mL
HAB Biovolume: 158258837 um^3/mL
HAB Relative Biovolume: 90%

! WARNING !

HAB concentration is high - Toxin testing recommended.

2020 Guidance

- Developed collaboratively with Utah Department of Health
- Benchmarked with EPA guidance and other States
- Not inclusive of all cyanotoxins
  - Not all toxins have been researched enough for developing guidance
  - UDOH/DWQ treats “new” cyanotoxins as binary presence/absence
- Only local health departments and UDOH have authority to issue public advisory
  - DWQ only makes recommendation

Health Watch		Warning Advisory	Danger Advisory
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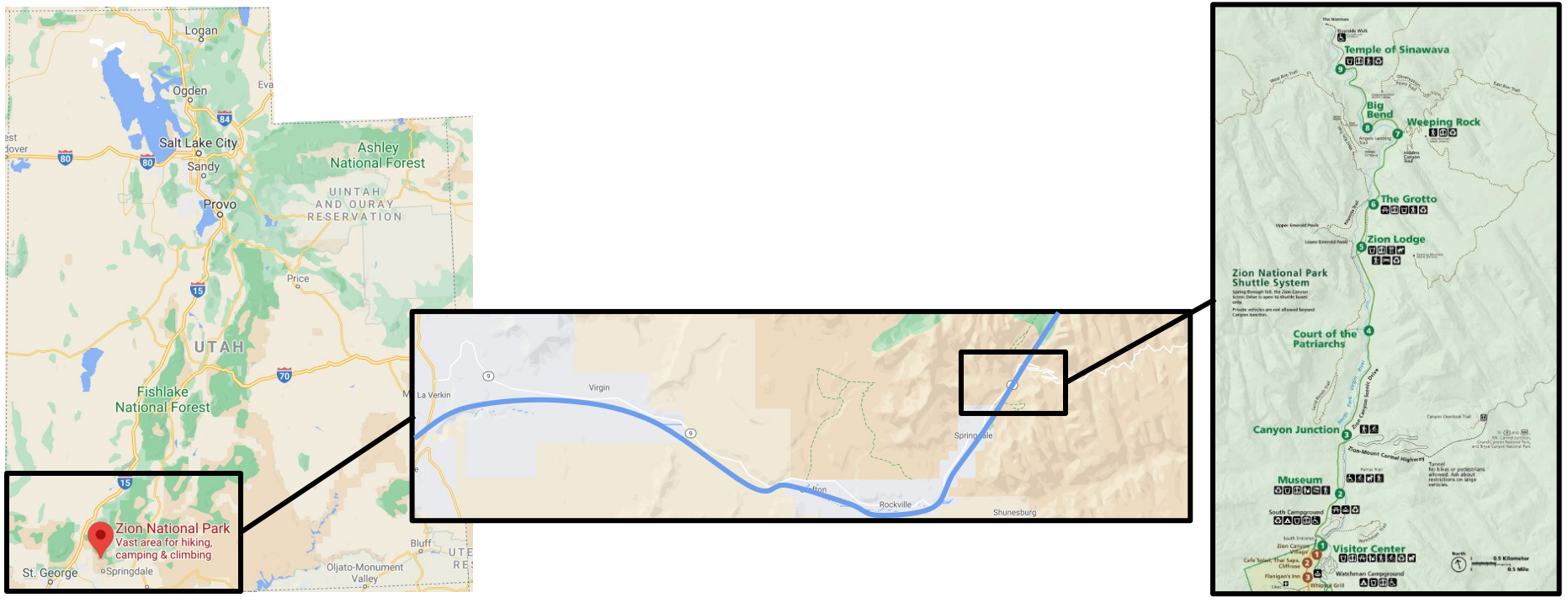
	Recommended Actions	Issue **WARNING** advisory to avoid primary contact recreation Post **WARNING** signs Sampling recommended at least weekly	Issue **DANGER** advisory to stay away from the waterbody Post **DANGER** signs Consider **CLOSURE** Sampling recommended at least weekly

[1] WHO, 1999. Toxic cyanobacteria in water.
[2] WHO, 2003. Guidelines for safe recreational water environments, Volume 1, Chapter 8: Algae and cyanobacteria in fresh water.
[3] EPA, 2019. Recommended human health recreational ambient water quality criteria or swimming advisories for microcystins and cylindrospermopsin.
[4] OHA, 2019. Oregon Health Authority. Recreational use public advisory guidelines: cyanobacterial blooms in freshwater bodies.
[5] CWQMC, 2016. California Water Quality Monitoring Council. Cyanobacteria guidance for recreational and related water uses (2016 update).
[A] Human symptoms have been reported between 5,000 – 100,000 cells ml (EPA 2019). At 5,000 – 100,000 cells/mL, LHDs should take into account contextual information and consider issuing an advisory.
[B] Data are sparse on where cylindrospermopsin advisory break points should be. Consult with UDEQ and UDOH as needed on this issue.

North Fork Virgin River



Report of Dog Death

- Dog died within 20 minutes of playing in the North Fork Virgin River in Zion NP
- Symptoms prior to death:
  - Seizures
  - Convulsing
  - Frothing at the mouth
  - Vomiting

Report a Bloom

24-Hour DEQ Environment Incidents Line:
(801) 536-4123

Call Utah Poison Control Center

If you believe you or your pet have been exposed to a harmful algal bloom, call **(800) 222-1222**.

Where is the pollution coming from?

NONPOINT SOURCE SUCCESS STORY

utah

Installing Management Practices Improves the North Fork Virgin River

Waterbody Improved

Flood-irrigated pastures grazed by cattle and wildlife contributed to *Escherichia coli* exceedances in the North Fork Virgin River watershed. As a result, the Utah Department of Environmental Quality (DEQ) included the upper North Fork Virgin River on Utah's Clean Water Act (CWA) section 303(d) list of impaired waterbodies in 2010 for failing to meet the *E. coli* standard for frequent primary contact recreation (2A). The lower watershed was listed in 2012. Landowners and agencies collaborated to implement recreational area improvements and best management practices in 2011–2017, and water quality has improved. *E. coli* data have not exceeded the standard since 2015. The DEQ Division of Water Quality (DWQ) will continue to collect data, and if no exceedances are observed, the North Fork of the Virgin River could be delisted for *E. coli* as early as 2020.

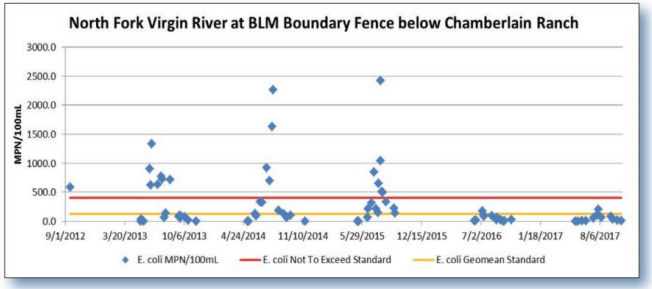


Figure 3. *E. coli* concentrations have dropped in the North Fork Virgin River.

https://www.epa.gov/sites/production/files/2018-12/documents/ut_nfvirginriver_1699_508.pdf

Ruling out other factors

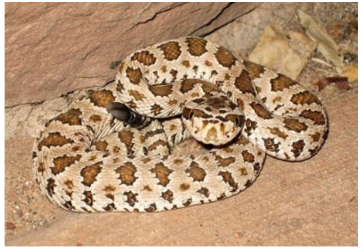
AMERICAN KENNEL CLUB

Symptoms of Water Intoxication in Dogs

Symptoms of water intoxication include:

- lethargy
- bloating
- vomiting
- loss of coordination (including stumbling, falling, or staggering)
- restlessness
- drooling
- pale gums
- dilated pupils
- glazed eyes

As the pressure in the brain increases and its cells begin to die off, the dog may have difficulty breathing, develop seizures, or slip into a coma.



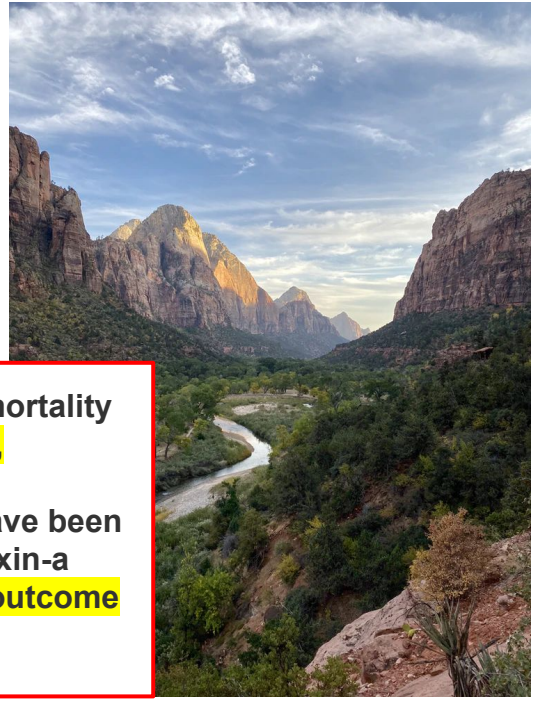
Anatoxin-a?

J Vet Diagn Invest 20:89–92 (2008)

Diagnosis of anatoxin-a poisoning in dogs from North America

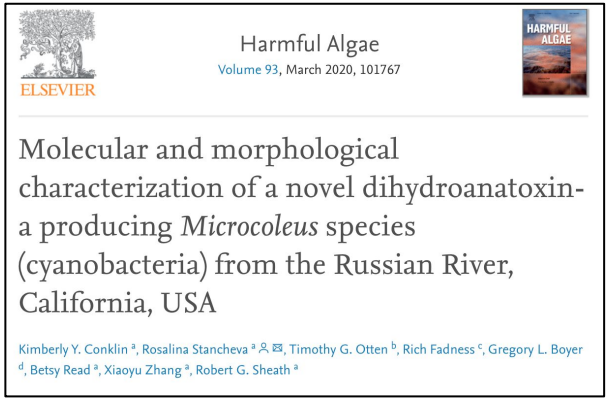
Birgit Puschner,[1] Brent Hoff, Elizabeth R. Tor

Abstract. Anatoxin-a, a toxin produced by several genera of blue–green algae, is considered a potent neurotoxin. Ingestion of water contaminated with the toxin results in acute neurological signs and often death. This report describes fatal cases of anatoxin-a ing by liquid chromatography/tandem mass spectro seizures and died within an hour after swimming dogs that died within 1 hour after swimming in a dogs as a cause of acute neurological signs and blooms in North America make this neurotoxin a associated with environmental water exposure. detection of anatoxin-a from environmental wate dying of acute neurotoxicosis. This demonstrates t North America and the importance of LC-MS/ death in cases of suspected blue-green algae toxic lesions.



"Anatoxin-a poisoning may result in high mortality with clinical signs of muscle fasciculations, seizures, collapse, cyanosis, and death.[5,10] Although only a limited number of cases have been reported, it appears that treatment of anatoxin-a poisoning is of little or no benefit, and the outcome is usually lethal."

What are we dealing with?



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Harmful Algae

Volume 93, March 2020, 101767

Molecular and morphological characterization of a novel dihydroanatoxin-a producing *Microcoleus* species (cyanobacteria) from the Russian River, California, USA

Kimberly Y. Conklin [a], Rosalina Stancheva [a], Timothy G. Otten [b], Rich Fadness [c], Gregory L. Boyer [d], Betsy Read [a], Xiaoyu Zhang [a], Robert G. Sheath [a]

RESEARCH ARTICLE

Widespread anatoxin-a detection in benthic cyanobacterial mats throughout a river network

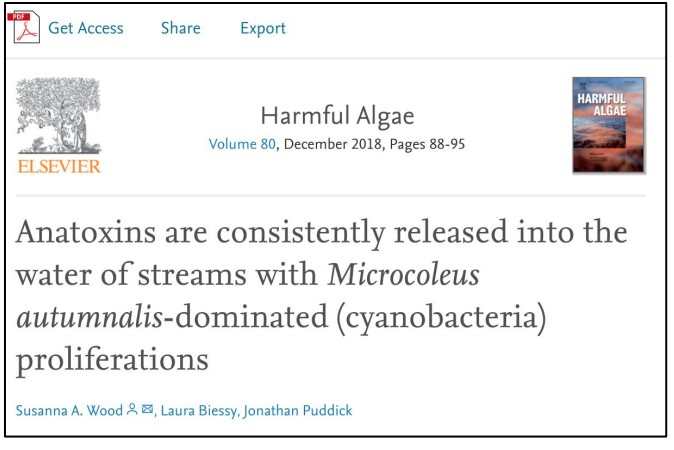
Keith Bouma-Gregson[1]*, Raphael M. Kudela[2], Mary E. Power[1]

1 Department of Integrative Biology, University of California, Berkeley, California, United States of America,
2 Ocean Sciences Department, University of California, Santa Cruz, California, United States of America

Widespread anatoxin-a detection in benthic cyanobacterial mats throughout a river network

Keith Bouma-Gregson, Raphael M. Kudela, Mary E. Power

Published: May 18, 2018 • https://doi.org/10.1371/journal.pone.0197669



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Harmful Algae

Volume 80, December 2018, Pages 88-95

Anatoxins are consistently released into the water of streams with *Microcoleus autumnalis*-dominated (cyanobacteria) proliferations

Susanna A. Wood, Laura Biessy, Jonathan Puddick

What are we dealing with?

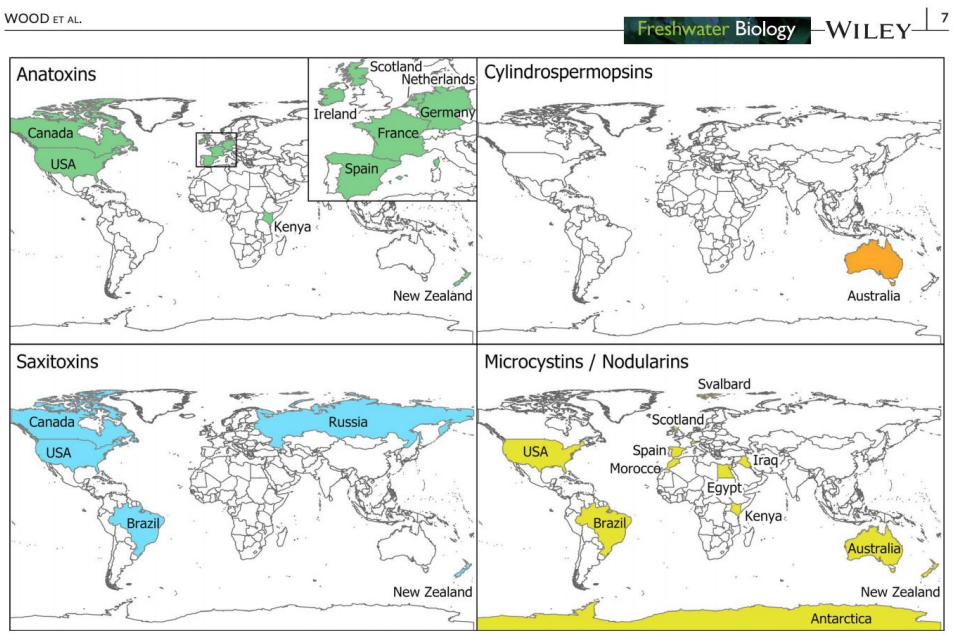
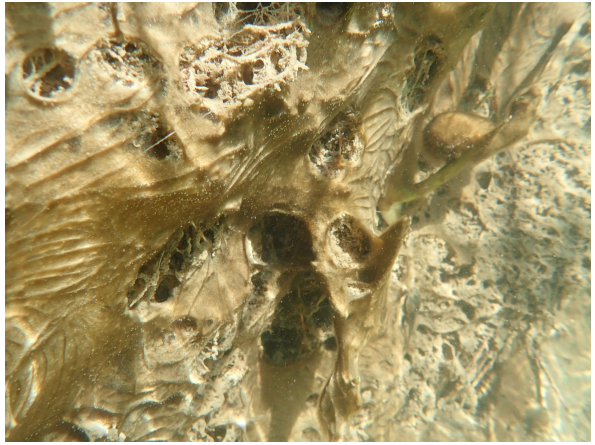
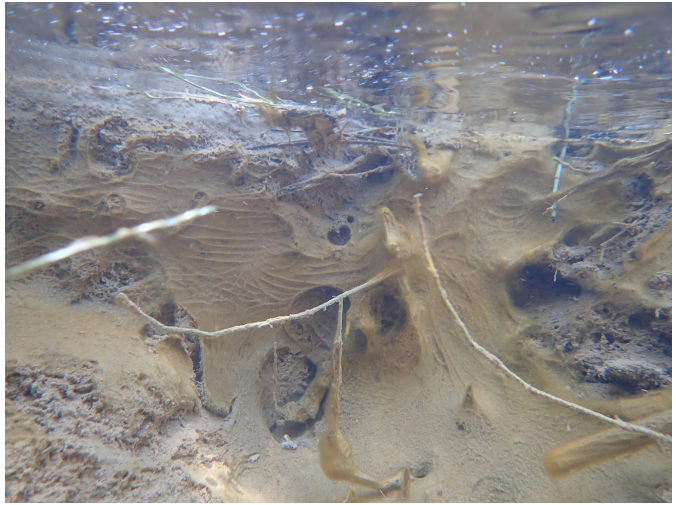


FIGURE 2 Global distribution of reported cyanotoxin detections from benthic cyanobacteria

Wood et al. 2020, https://onlinelibrary.wiley.com/doi/full/10.1111/fwb.13532#fwb13532-fig-0002

What are we dealing with?





Taxonomic Discovery

System Name: North Fork of Virgin River **Site:** Narrow **Preservative:** Live

Report Notes: 1250

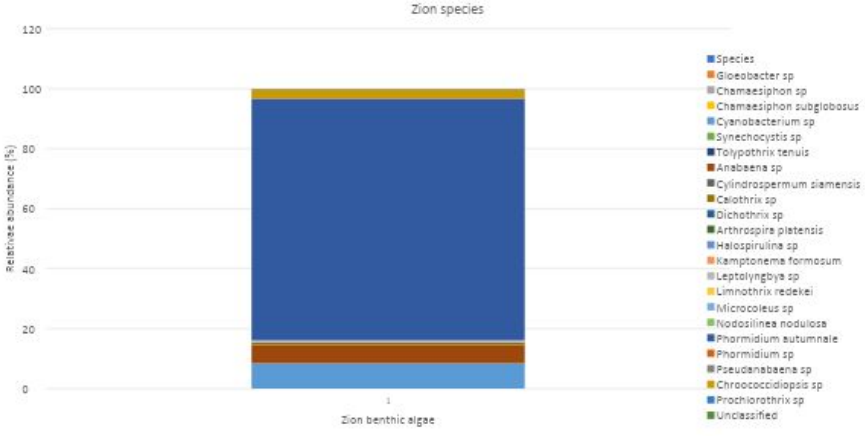
Division: **Cyanophyta**

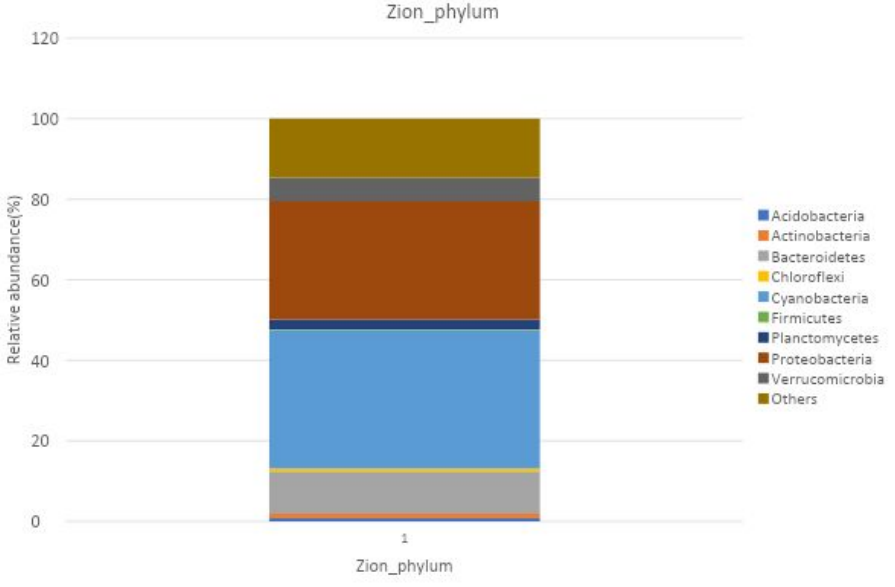
Taxa ID	Genus	Species	Subspecies	Variety	Form	Morph	Structure	Relative Concentration
4199	*Microcoleus*	*spp*	.	.	.	.	Vegetative	24.00

Summary for Division ~ Cyanophyta (1 detail record) **Sum Total Cyanophyta** 24.00

Division: **Miscellaneous**

Taxonomic Discovery





Courtesy of Prof. Ramesh Goel, University of Utah

Toxin Discovery

Anatoxin-a results from algal mat sampling - July 9, 2020

Utah DEQ/DOH HAB Guidance

	Warning Advisory	Danger Advisory
Toxigenic Cyanobacterial Cell Density (cells/mL) [1, 2, 3]	100,000 [A]	10,000,000
Microcystins (µg/L) [1, 2]	8	2,000
Cylindrospermopsin (µg/L) [3]	15 [B]	
Anatoxin-a (µg/L) [3, 4, 5]	15	90
Health Risks [1, 2, 3]	Potential for long-term illness Short-term effects (e.g., skin and eye irritation, nausea, vomiting, diarrhea)	Potential for acute poisoning Potential for long-term illness Short-term effects (e.g., skin and eye irritation, nausea, vomiting, diarrhea)
Recommended Actions	Issue **WARNING** advisory to avoid primary contact recreation Post **WARNING** signs Sampling recommended at least weekly	Issue **DANGER** advisory to stay away from the waterbody Post **DANGER** signs Consider **CLOSURE** Sampling recommended at least weekly

Who is at risk?

01	**Recreation**	• Zion averages ~500,000 visitors/ month in spring and summer • North Fork Virgin River a major draw
02	**Drinking Water**	• City of Springdale pulls water from the North Fork Virgin River
03	**Agriculture**	• Several cities/municipalities pull water from the North Fork Virgin River for irrigation

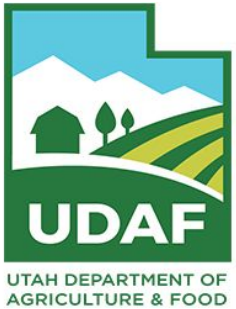
Who is at risk?

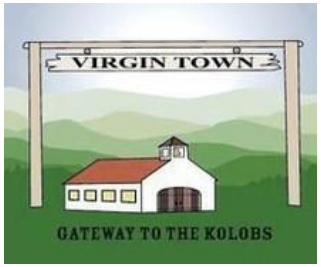
01

Recreation

- Zion averages ~500,000 visitors/ month in spring and summer
- North Fork Virgin River a major draw

Stakeholder Coordination





Stakeholder Coordination

Talking Points

Zion Nat. Park Dog Fatality HABs

July 6, 2020

Update: July 17 (11:30 a.m.)

Recreation

UPDATED TALKING POINTS (07/17/20):

NEW NPS Section:

1. The Utah Division of Water Quality (DWQ), the Utah Department of Health (DOH), the National Park Service received updated sample results from the U.S. Environmental Protection Agency Region 8 lab in Denver on Wednesday, July 15 from the North Fork of the Virgin River. These results show anatoxin-a concentrations greater than 550 micrograms per liter in some samples of the cyanobacteria. Toxins were not detected in the water column. Cyanotoxin levels detected in the cyanobacterial growth are currently much greater than the DWQ/DOH recommended danger advisory threshold for cyanotoxins dissolved in water. Humans and animals can ingest varying amounts of the growth material and/or toxins, making exposure risk difficult to characterize. Even very small pieces of the cyanobacterial growth may contain enough cyanotoxin to cause harm and these pieces may be invisible.
2. Cyanobacteria are a natural part of aquatic environments. Some exist in the water column or on the surface while others form colonies on the riverbed. They look like mats or a film that cling to rocks and vegetation below or at the waterline.
3. Some cyanobacteria may produce dangerous liver and nervous system toxins; when in abundance, toxin concentrations can elevate to levels that affect the health of organisms exposed to them, including people, pets, and livestock. **CHILDREN ARE ESPECIALLY VULNERABLE TO CYANOTOXINS.** Anatoxin-a can be absorbed through eyes, nose, or mouth by swimming in or submerging accidentally or unknowingly into contaminated water. Symptoms include skin rash, salivation, drowsiness, tingling, burning, numbness, pain, incoherent speech, vomiting, and diarrhea.
4. The likely cyanobacteria blooming in the Virgin River is the genus *Tychonema*. It forms colonies that can be red, yellow, tan, green, brown, or black in color. It produces the cyanotoxin called anatoxin-a, which impacts the nervous system. The toxin was detected at levels in the park far above the recommended health threshold for primary recreation (swimming) at multiple locations.
5. In response to new sample results provided on July 15th from the EPA, Zion National Park has issued a **DANGER** advisory for the parts of the Virgin River within park that states the public should **"AVOID CONTACT WITH THESE WATERS UNTIL FURTHER NOTICE: HARMFUL ALGAE PRESENT"**

New Downstream Towns Section:

1. On other areas of the North Fork of the Virgin River, outside of Zion National Park borders,the Southwest Utah Public Health Department has issued a public health warning. Signs are posted to advise recreators of the risks associated with exposure. Residents should adhere to the following guidelines:
   a. Do not swim in this area.
   b. Avoid areas of algae scum.
   c. Keep animals away.
   d. Do not ingest the water.
   e. Clean fish well and discard guts.
2. Pet owners should be careful not to let animals play in the river, drink from the river or eat algal scum.
3. This warning does not apply to Quail Creek Reservoir, Sand Hollow Reservoir, or the Santa Clara River basin.
4. Further monitoring and sampling are planned for recreational areas outside of the park with some results due by early next week.
5. Please visit https://deq.utah.gov/water-quality/protect-yourself-during-harmful-algal-blooms to learn how to keep yourself, family, and pets safe in recreational waters.

New DDW Section:

Drinking Water

1. The Utah Division of Drinking Water is working with local utilities to ensure finished drinking water that originates from the river is free of cyanotoxins. Currently, the Washington County Water Conservancy District, Zion National Park, and the Towns of Virgin and Rockville are not using the North Fork of the Virgin River as a drinking water source. Continued tests of Springdale drinking water and agricultural water have not detected the presence of cyanotoxins. Advanced water treatment technologies can remove cyanotoxins. The Town of Springdale will continue testing finished drinking water to make sure the water is safe.

New UDAF Section:

1. The Utah Department of Agriculture and Food suggest: Livestock producers provide a different drinking water source for livestock and restrict livestock access to the North Fork of Virgin River where possible. There is limited information on plant uptake of cyanotoxins. The main concern is protecting irrigators from these cyanotoxins. Practice good hygiene especially those areas that come in contact with irrigation water.

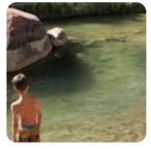
Agriculture

USA TODAY

Puppy dies at Zion National Park in toxic algae bloom that is dangerous to humans, animals

Anatoxin-a, a nervous system cyanotoxin that is produced by harmful cyanobacteria, was found in the North Fork of the river as of Friday night as ...

Jul 15, 2020



Recreation Guidance: Apples to Oranges

Planktonic/Lake HAB Sampling

- Most reasonable maximum
- Target scum to understand worst case scenario for exposure (direct ingestion of cyanobacterial cells)
- Lentic environments present ability for toxins and cells to “hang out” in the water column or surface - targeted sampling is key

Benthic HAB Sampling

- How does worst case scenario for exposure (direct ingestion of cyanobacterial cells) occur?
- Lotic environments mean cells, toxins could be much more mobile than lakes
- What’s the risk to a given recreator if they swim/splash/play in a river with benthic mats?

Recreation Guidance: Apples to Oranges

Worst Case Scenario: Lakes

Worst Case Scenario: NFV?


ZION
SEARCH &
RESCUE

Apples to Apples: Benthic Disturbance

Benthic Disturbance

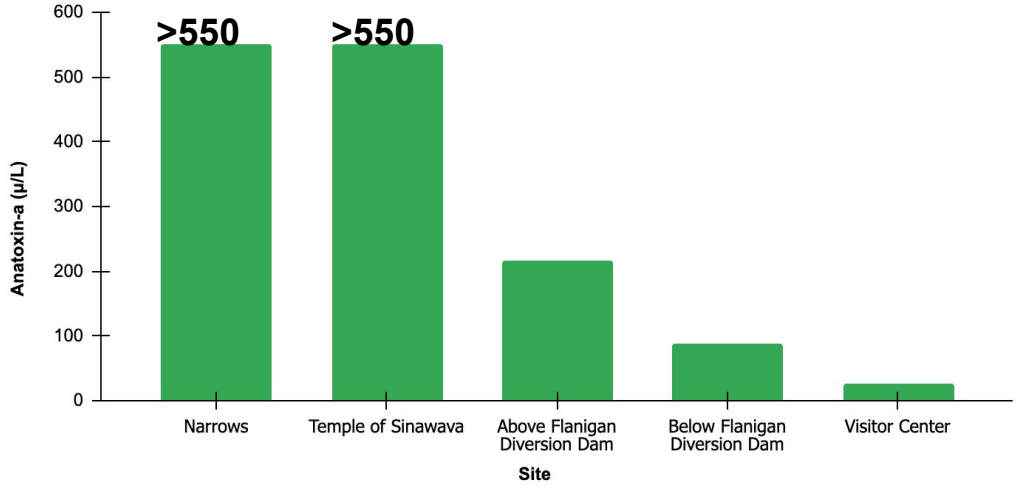
- Attempts to replicate worst case scenario for recreation exposure
- Mats get stirred up and human/pet ingests

Sample Collection

- Stomp in benthic mat for 10 seconds
- Collect with bucket
    - Subsample from bucket sample

Apples to Apples: Benthic Disturbance

Anatoxin-a results from benthic disturbance samples



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Recommended Actions	Issue **WARNING** advisory to avoid primary contact recreation Post **WARNING** signs Sampling recommended at least weekly	Issue **DANGER** advisory to stay away from the waterbody Post **DANGER** signs Consider **CLOSURE** Sampling recommended at least weekly

Sampling Toolbox

Sampling Methods

- Targeted algal matt
- Benthic disturbance
  - Disturb the mat with feet for 10 seconds
- Composite of water column

Communication: Signs

DANGER

AVOID CONTACT WITH THESE WATERS UNTIL FURTHER NOTICE

HARMFUL TOXIN PRESENT

The North Fork of the Virgin River contains cyanobacteria on the riverbed that produces anatoxin-a.

Anatoxin-a is especially dangerous to children.

Anyone in the water should not submerge their head. It can enter the body by swallowing water or through the nose, eyes, or open wounds.

Do not drink river water. The toxin cannot be filtered out by standard hiking filtration methods.

Keep dogs out of the water. This toxin can be fatal if ingested. Do not let them drink water from the river or irrigation ditches.

Contact the Utah Poison Control Center at (800) 222-1222 if you or your animals have unexplained illness or signs of poisoning.

Visit habs.utah.gov for more info. Report an algae bloom at (801) 536-4123

UTAH DEPARTMENT of ENVIRONMENTAL QUALITY

UTAH DEPARTMENT OF HEALTH

Communication: Website

Update September 15, 2020

The Danger Advisory for the North Fork Virgin River inside Zion National Park remains in place.

The Warning Advisory for the North Fork Virgin River outside Zion National Park remains in place.

What is the current situation?

Zion National Park Service (NPS) and the Utah Division of Water Quality (DWQ) have been monitoring benthic cyanobacteria in the North Fork of the Virgin River since July 7, 2020. Benthic cyanobacteria mats have been observed in varying densities within the river from The Narrows in Zion National Park down to Confluence Park in LaVerkin, Utah.

Routine monitoring and sampling continues both inside and outside the Park in order to gain a better understanding of the ongoing recreational risk from benthic cyanobacteria.

Cyanotoxin analysis has shown that anatoxin-a exists in high concentrations in the cyanobacteria mats and within the water column when mats are disturbed.

What are benthic cyanobacteria?

Cyanobacteria are a natural part of aquatic environments. While some

Danger Advisory

- **Waterbody closed**
- **Keep out of the water**

Due to state budget cuts, the harmful algal bloom program is being funded by EPA through a one-time grant. This limits DWQ's monitoring to 18 priority waterbodies in Utah.

Report a Bloom

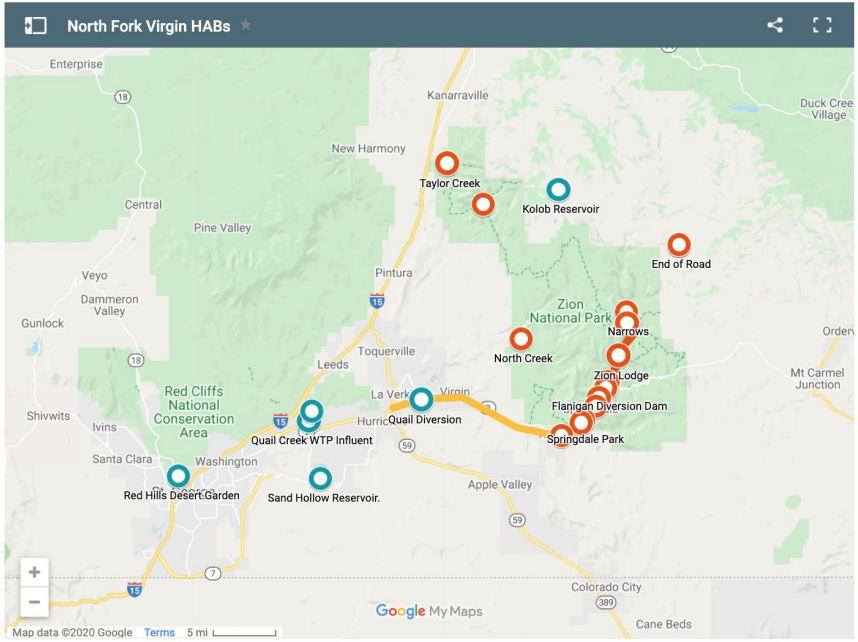
24-Hour DEQ Environment Incidents Line: (801) 536-4123

Call Utah Poison Control Center

If you believe you or your pet have been exposed to a harmful algal bloom, call **(800) 222-1222**.

Communication: Map

North Fork of the Virgin River Algal Bloom Monitoring 2020



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Who is at risk?

03 **Agriculture**

- Several cities/municipalities pull water from the North Fork Virgin River for irrigation

Strategic Monitoring and Communication

“The Utah Department of Agriculture and Food suggest: Livestock producers provide a different drinking water source for livestock and restrict livestock access to the North Fork of Virgin River where possible. There is limited information on plant uptake of cyanotoxins. The main concern is protecting irrigators from these cyanotoxins. Practice good hygiene especially those areas that come in contact with irrigation water.”

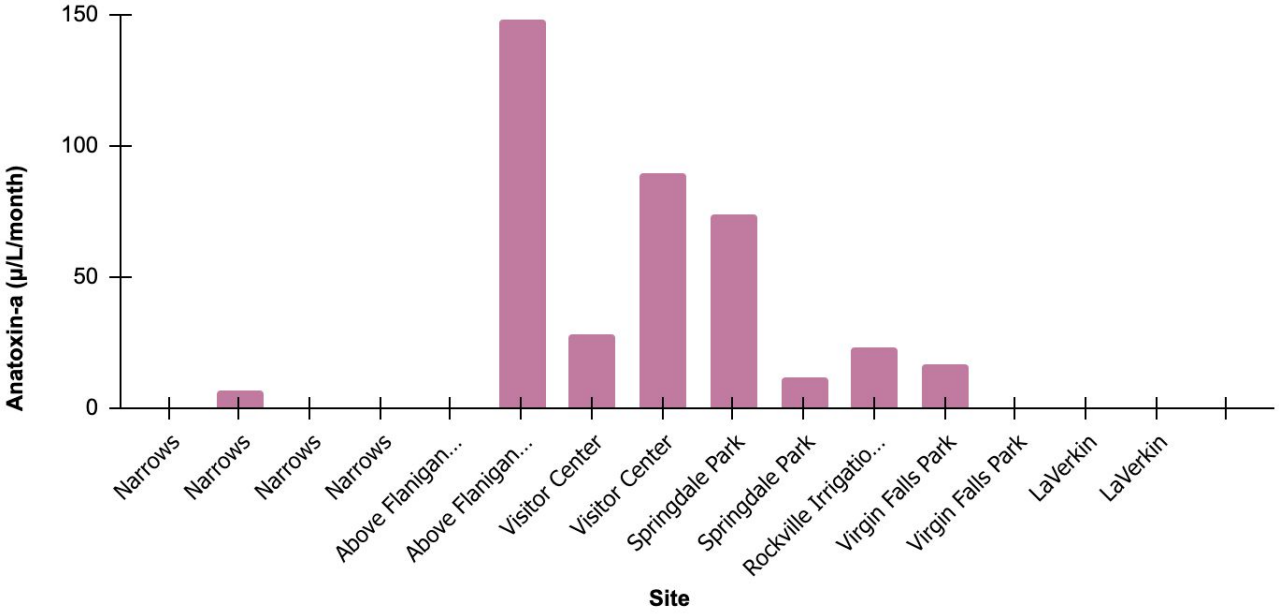
Sampling Method: SPATT Bags

SPATT Bags

- Solid Phase Adsorption Toxin Tracking
- Captures toxins over time
- What is the concentration of toxins flowing through the water column?
- Can leave in anywhere on the order of **hours** to **two weeks**

Bouma-Gregson et al. 2018,
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0197669

Sampling Method: SPATT Bags



Apples with oranges?

Sampling Method: SPATT Bags

What can SPATT bags tell us?

- Presence/absence of toxins flowing freely through the water column over time
- Relative magnitude of toxins from one site to the next
- Flashiness vs. steadiness of toxin release into water column
    - Allows us to understand risk to agriculture, recreation, drinking water seen through toxin flow

SITE	LATITUDE	LONGITUDE	FOR SPATT - DAYS	Anatoxin (ug/kg)	Anatoxin (ug/kg/day)	ATX (ng/g/month)
Above Flanigan Diversion Dam	37.214525	-112.975457	10	49.2	4.92	148
Above Flanigan Diversion Dam	37.214525	-112.975457	5	4.6	0.92	28
			x2			x5.3

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Who is at risk?

02

Drinking Water

- City of Springdale pulls water from the North Fork Virgin River

Drinking Water Response

- DDW requires system to monitor for cyanotoxins weekly until two consecutive source samples do not have toxins present
- Public notification requirement if cyanotoxins in drinking water exceed EPAs health advisory limits

Is drinking water safe?

The Utah Division of Drinking Water is working with local utilities to ensure finished drinking water that originates from the river is free of cyanotoxins. Currently, the Washington County Water Conservancy District, Zion National Park, and the Towns of Virgin and Rockville are not using the North Fork of the Virgin River as a drinking water source. Continued daily tests of Springdale drinking water and agricultural water have not detected the presence of cyanotoxins. Advanced water treatment technologies can remove cyanotoxins. The Town of Springdale will continue testing finished drinking water to make sure the water is safe.

Anatoxin-a DW Thresholds

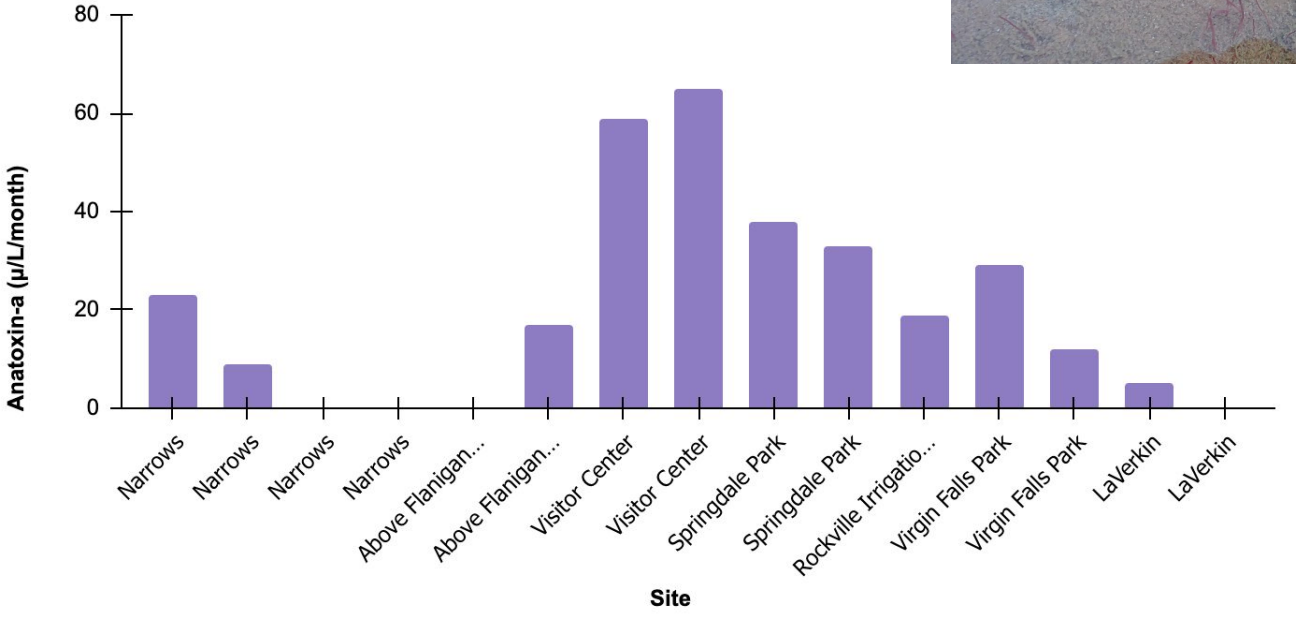
EPA has not issued an advisory level for anatoxin-a due to inadequate health effects data. Drinking water advisory levels used by other entities vary broadly.

- **Ohio**: 20 µg/L
- **Oregon**: 3 µg/L (everyone); 0.7 µg/L (children)
- **Washington**: 1 µg/L (Recreation value that use as a benchmark for drinking water)
- **Vermont**: 0.5 µg/L
- **Minnesota**: 0.1 µg/L
- **WHO**: 30 µg/L for drinking water

- There have been 23,757 analyses for anatoxin-a in finished drinking water as part of UCMR4, with 110 detections (59 of these occurring at the City of Houston, TX PWS). All detections have been <1 ug/L except for one detection at 13.22 ug/L at a system in New Jersey.

Ongoing Research and Concerns

Nodularin?



Published: 29 March 2012

Microbe-Microbe and Microbe-Host Interactions

Nodularin, a cyanobacterial toxin, is synthesized *in planta* by symbiotic *Nostoc* sp.

Michelle M Gehringer, Lewis Adler, Alexandra A Roberts, Michelle C Moffitt, Troco K Mihali, Toby J T Mills, Claus Fieker & Brett A Neilan

The ISME Journal **6**, 1834–1847(2012) | Cite this article

544 Accesses | **42** Citations | **3** Altmetric | Metrics

Consumption of benthic cyanobacterial mats and nodularin-R accumulation in freshwater crayfish (*Paranephrops planifrons*) in Lake Tikitapu (Rotorua, New Zealand)

Susanna A. Wood, Ngaire R. Phillips, Mary de Winton, Max Gibbs

Show more

https://doi.org/10.1016/j.hal.2012.10.003

Get rights and content

ORIGINAL RESEARCH ARTICLE

Front. Microbiol., 09 October 2017 | https://doi.org/10.3389/fmicb.2017.01963

Production of High Amounts of Hepatotoxin Nodularin and New Protease Inhibitors Pseudospumigins by the Brazilian Benthic *Nostoc* sp. CENA543

Jouni Jokela, Lassi M. P. Heinilä, Tânia K. Shishido, Matti Wahlsten, David P. Fewer, Marli F. Fiore, Hao Wang, Esa Haapaniemi, Perttu Permi and Kaarina Sivonen

Anatoxin-a Toxicosis

Human illness?

- NPS maintenance worker, shoveled HABs out of canals without PPE (before we knew)
- Permanent loss of neuromuscular function

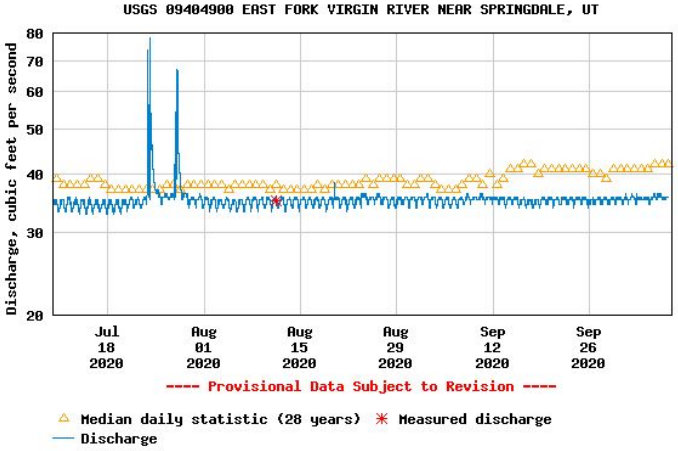
Additional Toxin Discovery

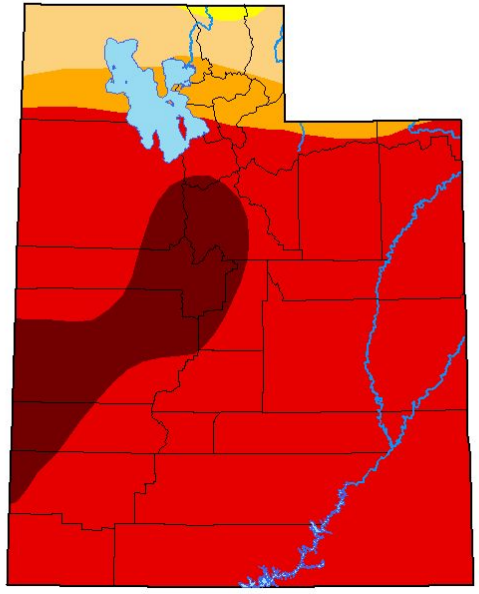
Table 3: Results reported in ng/mL (ppb). The analysis of the dhATX, dhHTX, epoxyATX, and epoxyHTX was qualitative due to a lack of quantification standards and are therefore reported as detected (+) or not detected (ND).

Sample ID	ATX	epoxyATX	dhATX	HTX	epoxyHTX	dhHTX
CYTEM4	**805**	ND	+	**0.56**	ND	+
CYCRA3	**10.5**	ND	+	**0.13**	ND	+
CYFLA27	**10.9**	ND	+	**0.08**	ND	+
MDL (ng/g):	*0.05*	*NA*	NA	*0.05*	*NA*	NA
Analyst Initials:	*AF*					
Date Analyzed:	*10/13/2020* *10/14/2020*					

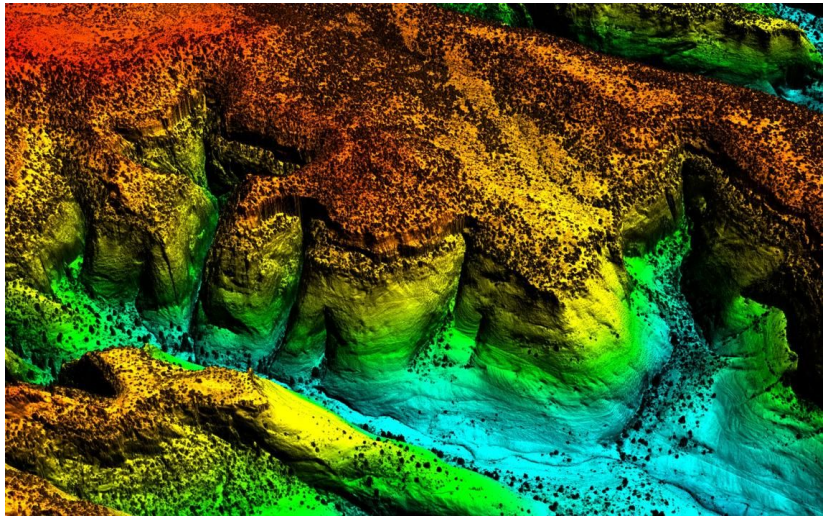
When will this end?

2020 "Nonsoon" season





How do we get a handle on spatial extent?



How do we get a handle on spatial extent?

https://poly.google.com/view/7_u0T_lcFcS

New Benthic HAB sightings

New Benthic HAB sightings

THANK YOU!

DOH
Dr. Nathan LaCross
Dr. Alejandra Moldanado

UDAF
Jay Olsen

EPA
Tina Laidlaw
Marcie Tidd
Donna Hill
Jake Crosby

NPS
Robyn Henderek
Jeff Bradybaugh
Cass Bromley
Jeff Axel
Deirdre Hanners

DEQ
Michelle Deras
Dr. Erica Gaddis
Jared Mendenhall
Amy Dickey

Others
Dr. Keith Bouma-Gregson
Dr. Ann St. Amand
Dr. Barry Rosen
Nathan Guymon
Dr. Keith Loftin
Dr. Ramesh Goel

QUESTIONS?