Ins and Outs of HABs

E. Ashley Bair

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OTCO Workshop

October 16, 2019

Water Quality Profiling Supporting Data-Driven Source Water Management of Harmful Algal Blooms

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Outline

HAB SOURCE WATER MANAGEMENT PRACTICES

WATER COLUMN PROFILING

PROFILE DATA INSIGHTS

TARGETED APPLICATION OF ALGAECIDES

CASE STUDIES

HAB Source Water Management Practices

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Current Technologies

Mitigation

- Mixing/Destratification
- Hypolimnetic oxygenation/aeration
- Ultrasonication
- Algaecide

Monitoring

- qPCR
- Toxin screening
- Cell enumeration
- Satellite
- Profiling

- How much algaecide should we use?
- Where should we apply it?
- How often should we apply it?

Algaecide Use

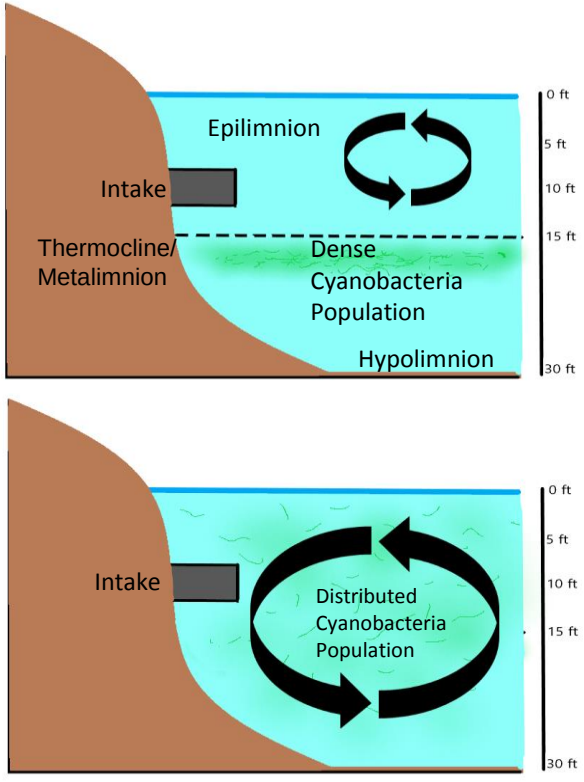
- Ohio EPA algaecide permits restrict use of algaecides when cyanobacteria cell counts are > 100,000 cells/mL (with exceptions)
- Ohio EPA notes that algaecides are effective:
  - Cyanobacteria cell count <10,000 cells/mL
  - Early application reduces the potential for release of high concentrations of toxins associated with denser blooms
  - Use algaecides when cyanobacteria concentrations in the source water are low or blooms are not yet visually apparent
- Should you:
  - Apply algaecide in response to surface or intake water quality observations? (can be too late)
  - Apply early? (can be costly)

Drawbacks – Limited Insight

- Reservoirs are three-dimensional, intakes are one-dimensional
- Reservoirs are highly variable across horizontal and vertical gradients
  - Temperature
  - Nutrients
  - Light intensity
  - Primary Productivity
- Responding to grab sample information is like judging a hamburger after eating a sesame seed off the bun

Drawbacks – Overlook Stratified Layers of Cyanobacteria blooms

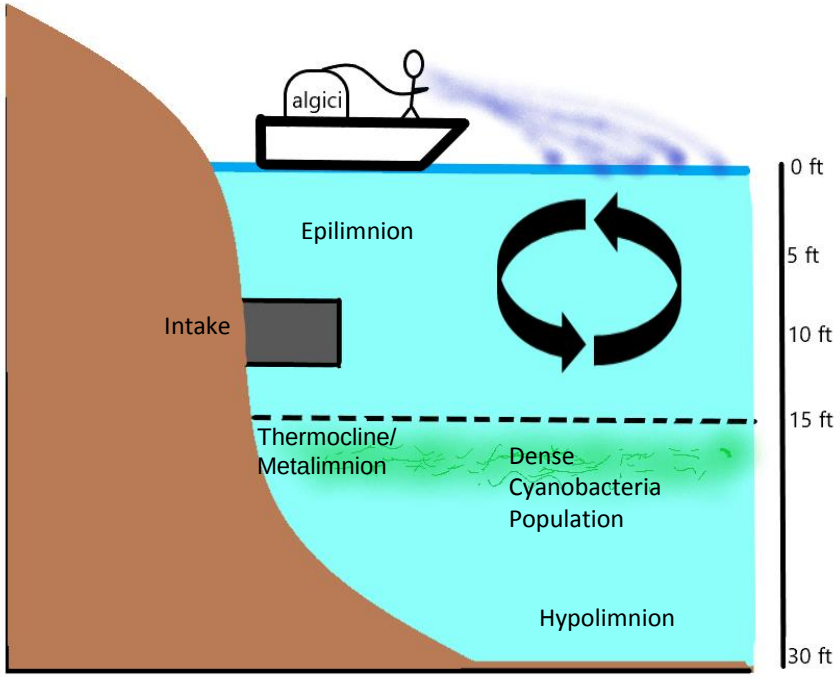
- Cyanobacteria are known to stratify and concentrate at varying depths, (eg metalimnion) (Thomas & Märki, 1949; Lund, 1959; Zimmermann, 1969; Klemer, 1976; Konopka, 1989; Davis et al., 2003, Walsby et al., 2003)
    - This includes potentially toxic species such as *Planktothrix*
- Dense population may rise to intake depth
- Population may rise above thermocline, subject to mixing and entrance into intake
- Loss of thermocline forces mixing in lower depths, distributing cyanobacteria throughout water column



Hypothetical distribution of Planktothrix *sp.* in Evans Lake before and after thermocline disappearance resulting from cooling epilimnion temperatures.

Drawbacks – Wasteful application of algaecide

- Epilimnion mixes well
- Little mixing between epilimnion and metalimnion
- Application of algaecide at the surface may not reach stratified cyanobacteria
- Algaecide used up on other organic matter or diluting, never reaching stratified cyanobacteria



Water Column Profiling

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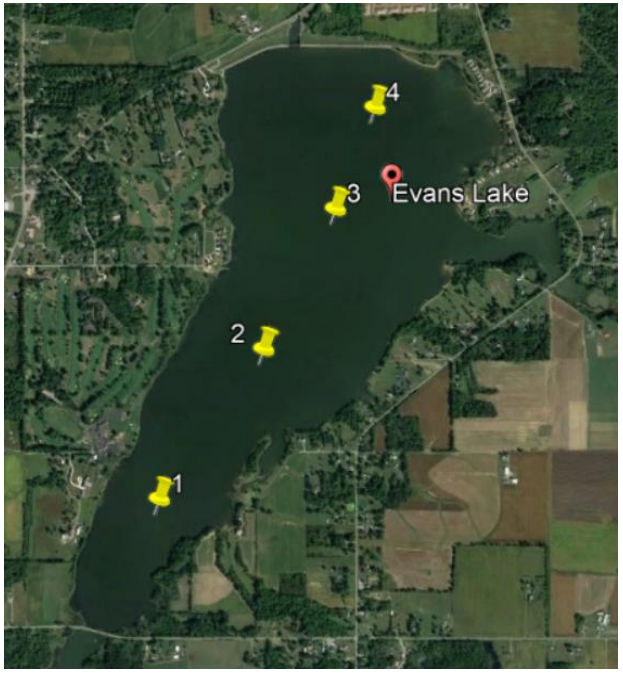
Water Column Profiling - Tools

- Boat
- Sonde
  - Temperature
  - Phycocyanin RFU (cyanobacteria pigment)
  - Chlorophyll RFU (photoautotroph pigment)
  - Dissolved Oxygen %
  - pH
  - Dissolved Organic Matter
- PPE – Sunglasses, sunscreen, lifejacket

Water Column Profiling – Plan a Protocol

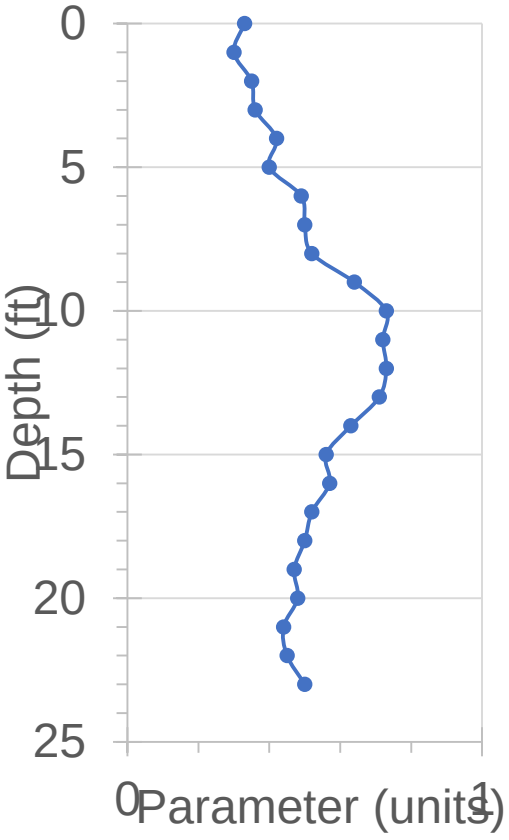
- Start date
- Frequency
- Sampling Sites
  - Ends and middle
  - Plant Intake area
  - Near Stream Inlets
  - Intake from River source
- Sampling Depths
- Consistency Matters!!!



Visualizing Water Column Data

- Scatter Chart
  - Y-axis: Depth (values in reverse order)
  - X-axis: Parameter
- Track the impact of any HAB management technology (Phycocyanin peaks)
- Track the performance of mixing or aeration (Dissolved Oxygen)
- Understand relative HAB risk throughout the reservoir

Depth (ft)	Sample 1
0	0.33
1	0.3
2	0.35
3	0.36
4	0.42
5	0.4
6	0.49
7	0.5
8	0.52
9	0.64
10	0.73
11	0.72
12	0.73
13	0.71
14	0.63
15	0.56
16	0.57
17	0.52
…	…



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Profile Data Insights

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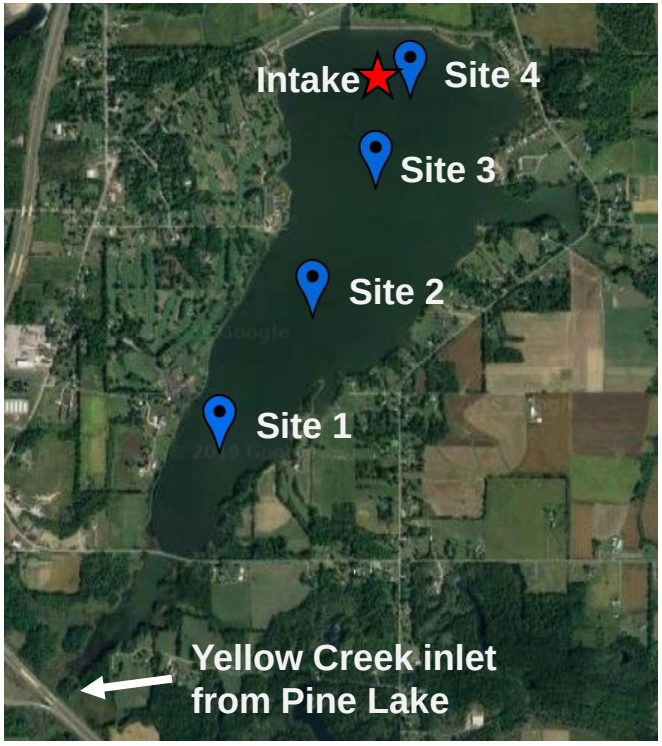
Poland, OH
Water Treatment Plant



- Near Youngstown, OH
- Profiling since 2018
- 4 Sample Sites
- Average max depth 30ft (Site 3)
- Intake at 10 feet (Site 4)
- Surface Area 582 acres
- Max volume 12,574 ac-ft

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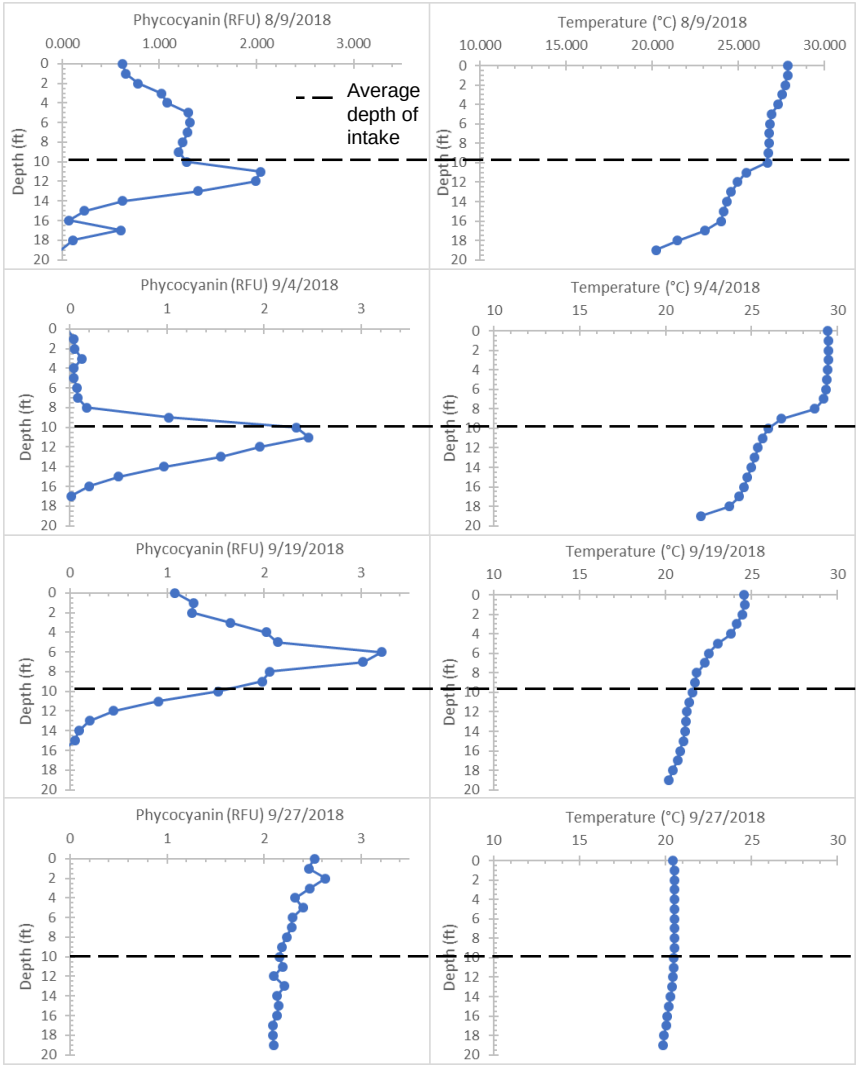
Water Column Profiling Trends

- Phycocyanin peaks observed in metalimnion
- Peaks sometimes cross intake depth
- Peaks disappear when thermocline disappears



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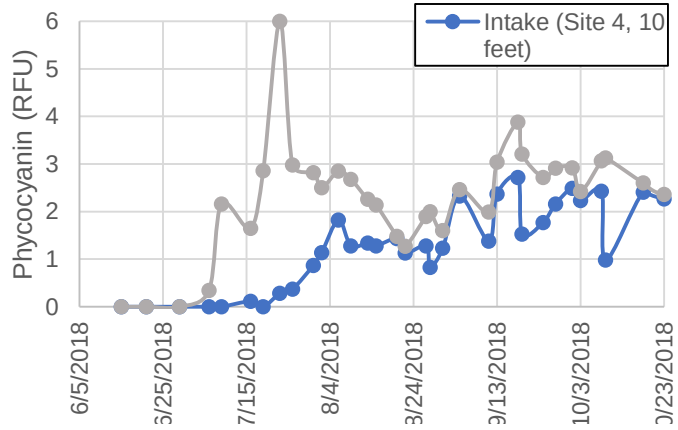
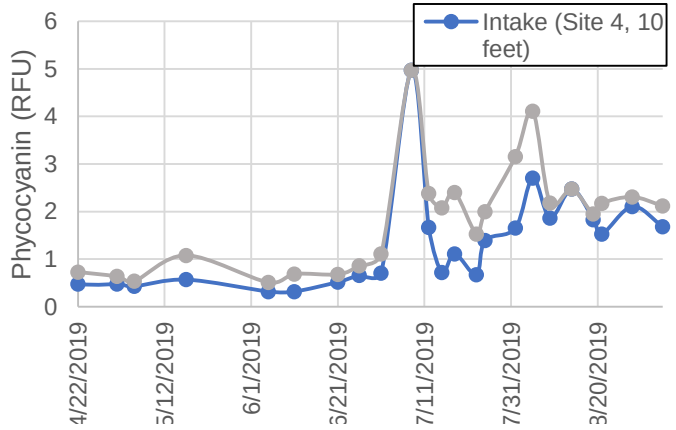
Insight: Max Phycocyanin Peak

- Max phycocyanin is the maximum value at a particular sample date at each site, or across all sample sites (Excel formula “=MAX(range))
- Whole lake and site maximum values are usually not directly at the intake
- Identify phycocyanin peaks
- Early identification of bloom before it reaches intake or surface





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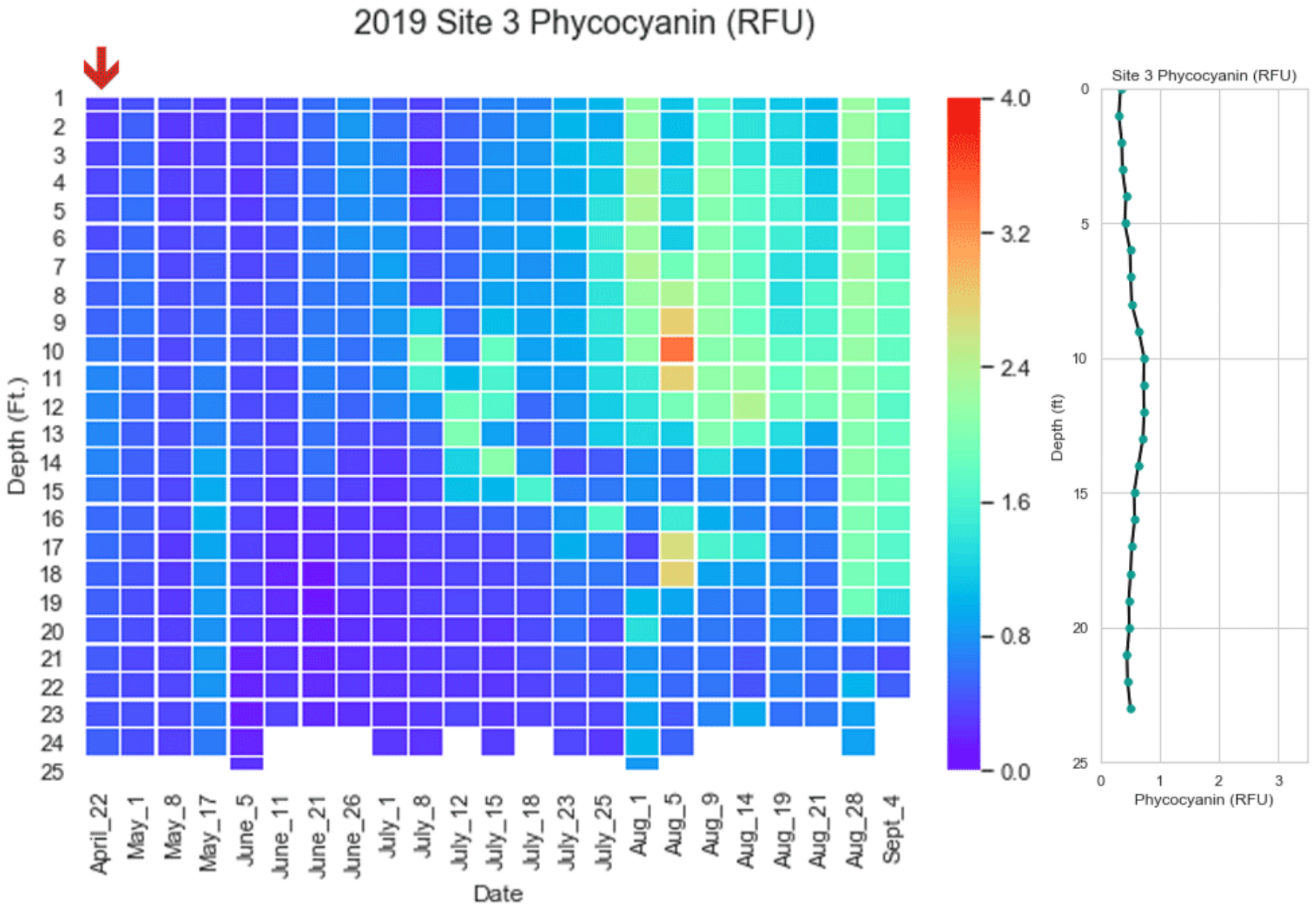

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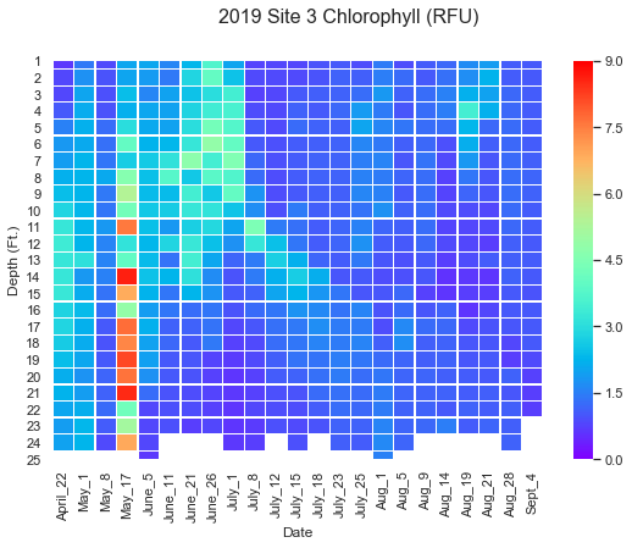
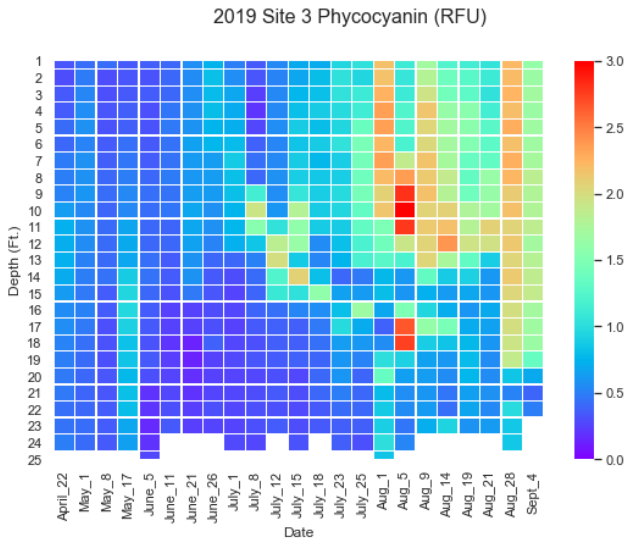
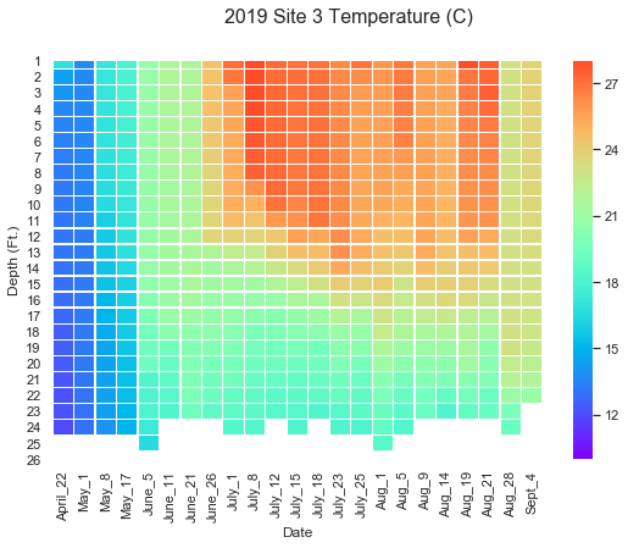
Parameters of Interest







- Chlorophyll – quantify primary productivity
- Phycocyanin – quantify phycocyanin specific productivity
- Temperature – Identify thermoclines and seasonal turnover

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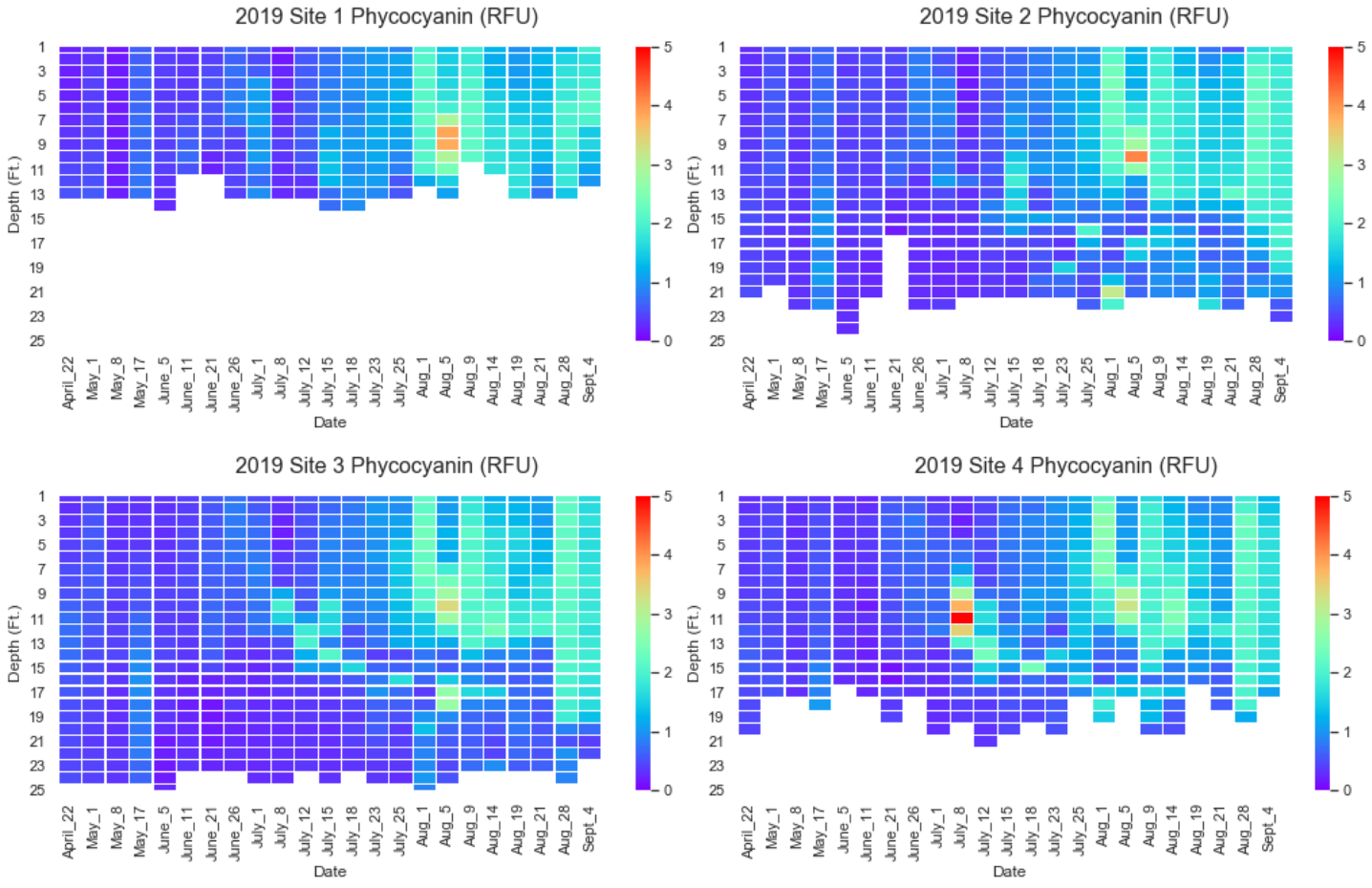
Comparison Between Sites



- Identify problems and problem areas early
- Identify stratification trends and limits

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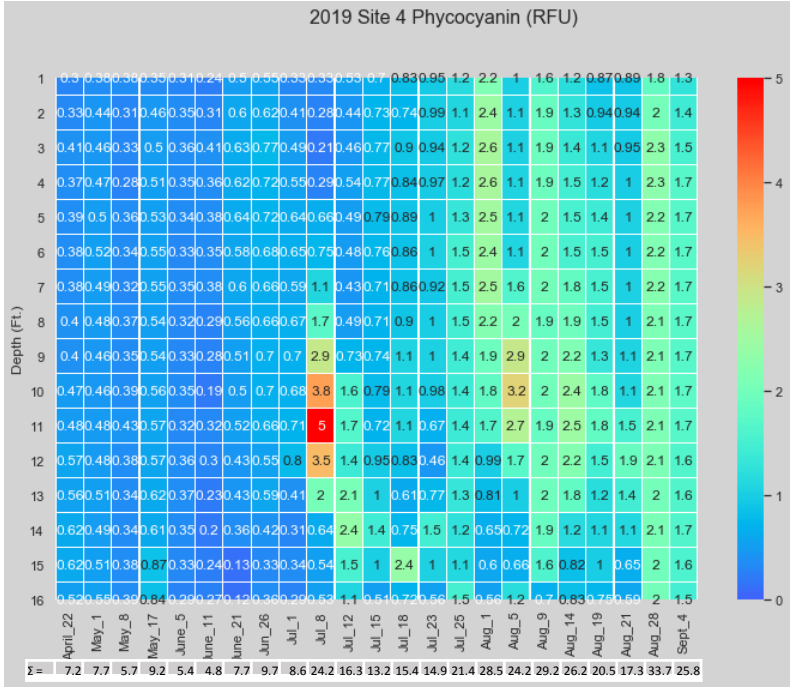
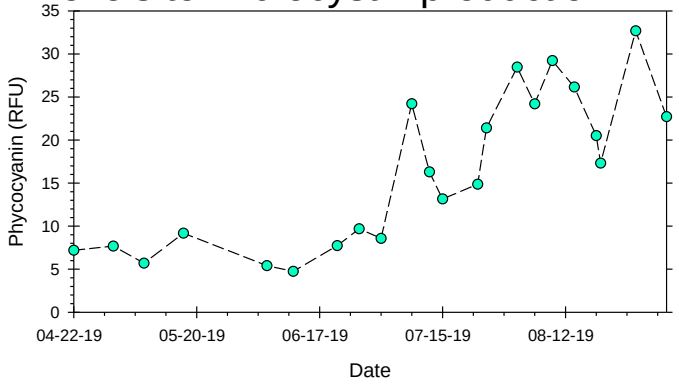
Insight: Total Depth Phycocyanin Over Time



- Total Depth Phycocyanin is the sum of phycocyanin values throughout the sample site for each date
- Plot Total Phycocyanin vs. Date
- Assess the performance of algaecide application
- Identify year-to-year trends in phycocyanin levels to microcystin production



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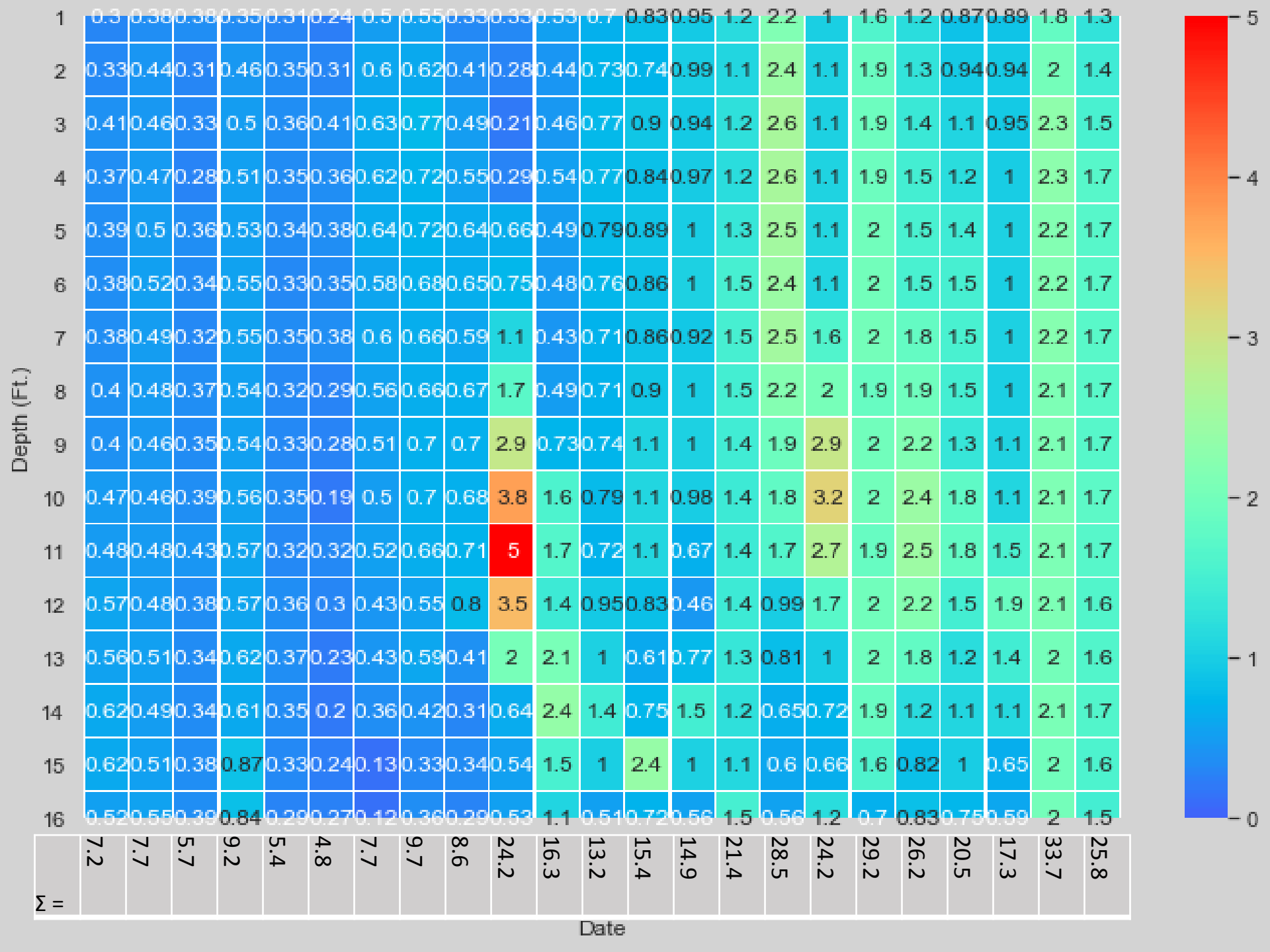
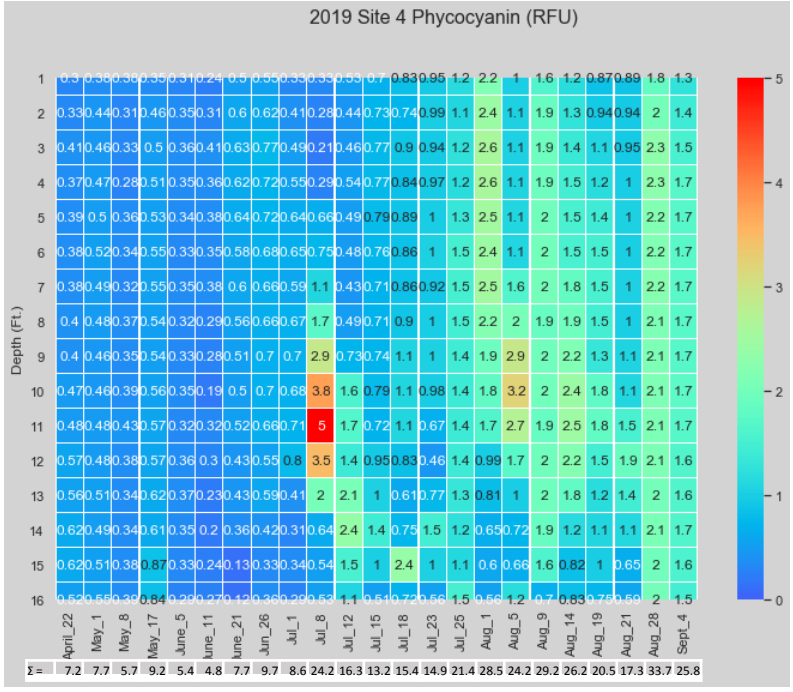

Depth (Ft.)
1 0.3 0.38 0.38 0.35 0.31 0.24 0.5 0.55 0.33 0.33 0.53 0.7 0.83 0.95 1.2 2.2 1 1.6 1.2 0.87 0.89 1.8 1.3
2 0.33 0.44 0.31 0.46 0.35 0.31 0.6 0.62 0.41 0.28 0.44 0.73 0.74 0.99 1.1 2.4 1.1 1.9 1.3 0.94 0.94 2 1.4
3 0.41 0.46 0.33 0.5 0.36 0.41 0.63 0.77 0.49 0.21 0.46 0.77 0.9 0.94 1.2 2.6 1.1 1.9 1.4 1.1 0.95 2.3 1.5
4 0.37 0.47 0.28 0.51 0.35 0.36 0.62 0.72 0.55 0.29 0.54 0.77 0.84 0.97 1.2 2.6 1.1 1.9 1.5 1.2 1 2.3 1.7
5 0.39 0.5 0.36 0.53 0.34 0.38 0.64 0.72 0.64 0.66 0.49 0.79 0.89 1 1.3 2.5 1.1 2 1.5 1.4 1 2.2 1.7
6 0.38 0.52 0.34 0.55 0.33 0.35 0.58 0.68 0.65 0.75 0.48 0.76 0.86 1 1.5 2.4 1.1 2 1.5 1.5 1 2.2 1.7
7 0.38 0.49 0.32 0.55 0.35 0.38 0.6 0.66 0.59 1.1 0.43 0.71 0.86 0.92 1.5 2.5 1.6 2 1.8 1.5 1 2.2 1.7
8 0.4 0.48 0.37 0.54 0.32 0.29 0.56 0.66 0.67 1.7 0.49 0.71 0.9 1 1.5 2.2 2 1.9 1.9 1.5 1 2.1 1.7
9 0.4 0.46 0.35 0.54 0.33 0.28 0.51 0.7 0.7 2.9 0.73 0.74 1.1 1 1.4 1.9 2.9 2 2.2 1.3 1.1 2.1 1.7
10 0.47 0.46 0.39 0.56 0.35 0.19 0.5 0.7 0.68 3.8 1.6 0.79 1.1 0.98 1.4 1.8 3.2 2 2.4 1.8 1.1 2.1 1.7
11 0.48 0.48 0.43 0.57 0.32 0.32 0.52 0.66 0.71 5 1.7 0.72 1.1 0.67 1.4 1.7 2.7 1.9 2.5 1.8 1.5 2.1 1.7
12 0.57 0.48 0.38 0.57 0.36 0.3 0.43 0.55 0.8 3.5 1.4 0.95 0.83 0.46 1.4 0.99 1.7 2 2.2 1.5 1.9 2.1 1.6
13 0.56 0.51 0.34 0.62 0.37 0.23 0.43 0.59 0.41 2 2.1 1 0.61 0.77 1.3 0.81 1 2 1.8 1.2 1.4 2 1.6
14 0.62 0.49 0.34 0.61 0.35 0.2 0.36 0.42 0.31 0.64 2.4 1.4 0.75 1.5 1.2 0.65 0.72 1.9 1.2 1.1 1.1 2.1 1.7
15 0.62 0.51 0.38 0.87 0.33 0.24 0.13 0.33 0.34 0.54 1.5 1 2.4 1 1.1 0.6 0.66 1.6 0.82 1 0.65 2 1.6
16 0.52 0.55 0.39 0.84 0.29 0.27 0.12 0.36 0.29 0.53 1.1 0.51 0.72 0.56 1.5 0.56 1.2 0.7 0.83 0.75 0.59 2 1.5
N = 7.2 7.7 5.7 9.2 5.4 4.8 7.7 9.7 8.6 24.2 16.3 13.2 15.4 14.9 21.4 28.5 24.2 29.2 26.2 20.5 17.3 33.7 25.8
Date
5
4
3
2
1
0

Insight: Total Depth Phycocyanin Over Time



- Total Depth Phycocyanin is the sum of phycocyanin values throughout the sample site for each date
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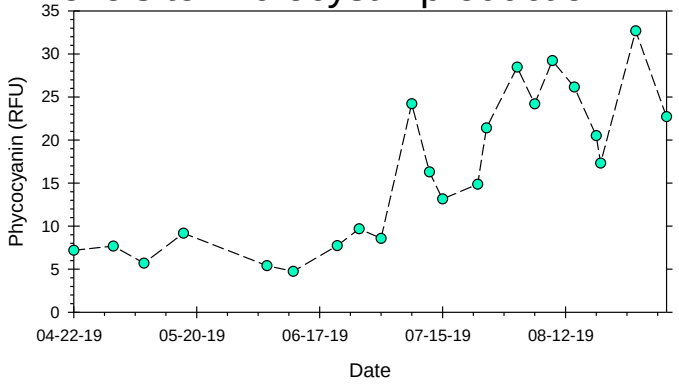

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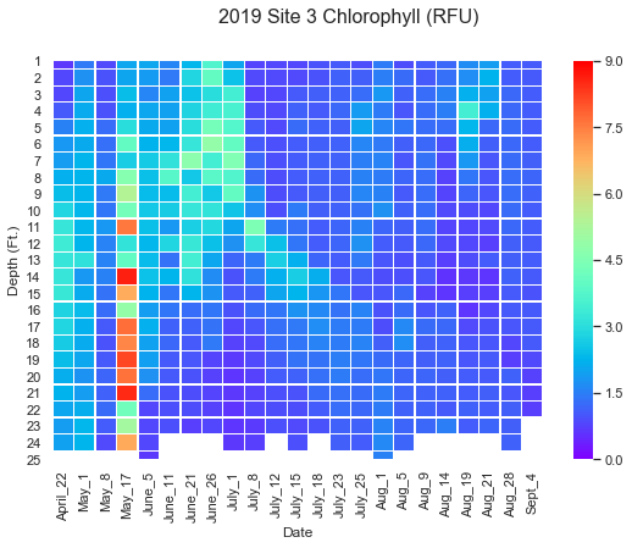
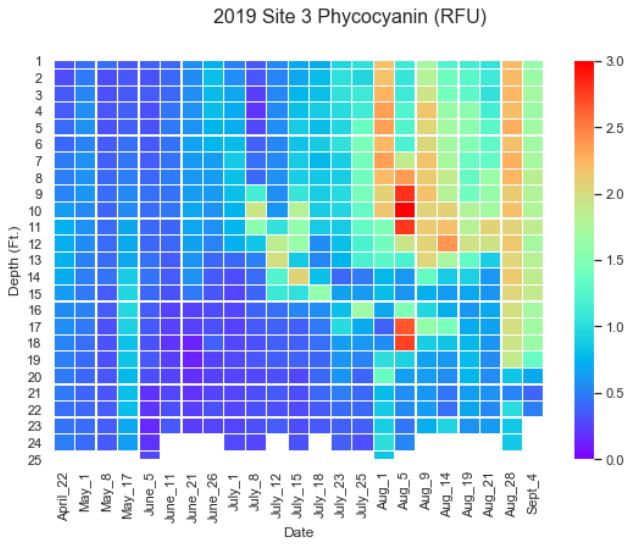
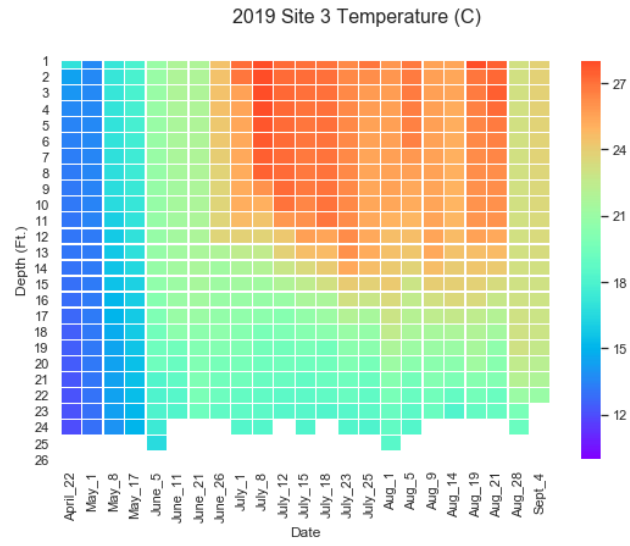
Targeted Application of Algaecides







- Sample depth with max phycocyanin for identification and enumeration
  - Ohio EPA recommends applying algaecides at 10,000 cells/ml
- Aim algaecide at depth with phycocyanin peaks
  - Especially important when phycocyanin peaks are below the thermocline

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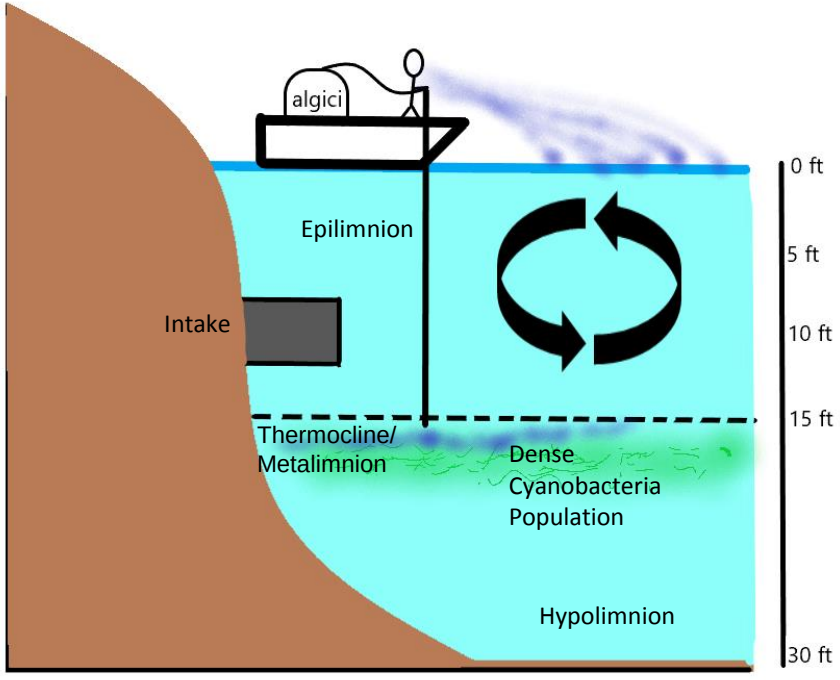
Targeted Application of Algaecide

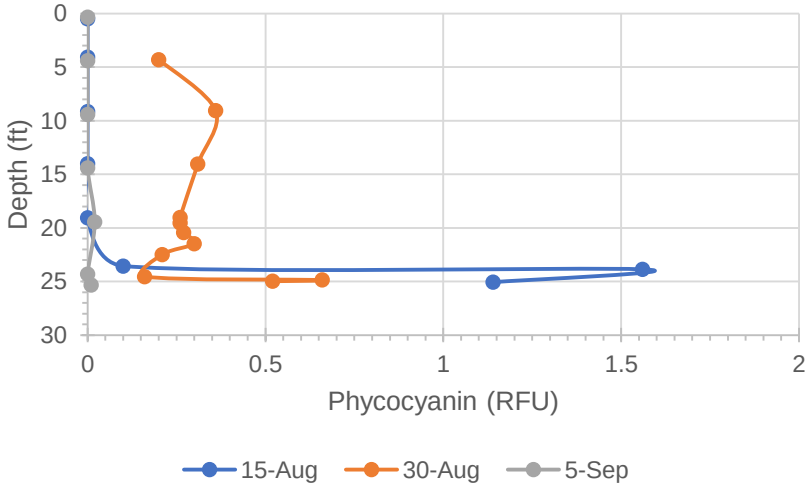
- Profile before algaecide application
- “Aim” for phycocyanin peaks
- Requires “rig” to pump algaecide
- Limitations – cannot apply as widely



Outcomes: Case Studies

Delphos, OH WTP

- Fall 2018-Winter 2019 persistent bloom of *Planktothrix rubescens* caused high raw microcystin
- Late-Summer Profiling showed stratified cyanobacteria bloom near reservoir bottom (>100,000 cells/mL)
- Targeted application followed by whole lake application decreased phycocyanin to below detectible levels throughout most of the water column



Delphos, OH WTP

Last Year –

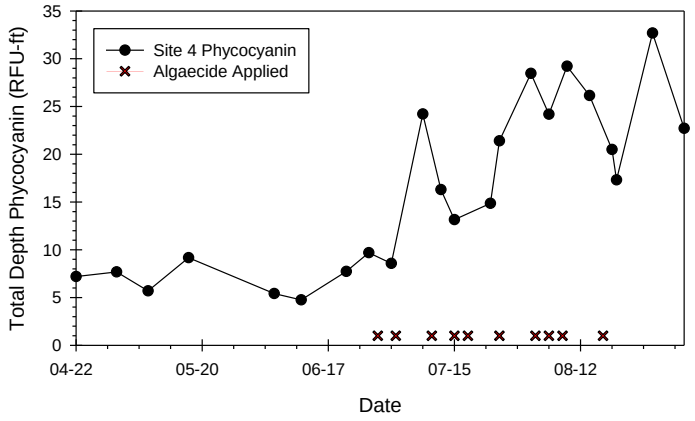
- Dosed 5-10 mg/L of PAC
- $96-190 / day on PAC for several months
- $37-74 / MG water treated

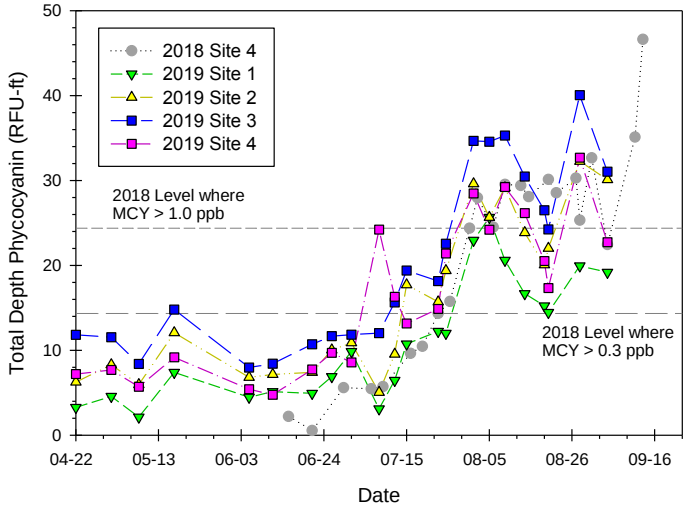
This year –

- Treated 450 MG reservoir
- Applied 1 barrel of algaecide each application
- ~$672 / application
- $1.49 x 10^-6 /MG treated
- Confidently paused algaecide application for additional cost savings

Poland, OH WTP

- 582 Acres, 4000 MG
- Poland OH WTP applied 40-75 gallons every 3-8 days
- Managed well when applying more frequently (3 days) and at all sites
- Next year would be beneficial to apply at all sites, increase dosage





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Poland WTP Cost Savings

- Manage HABs with low-dose, targeted EarthTec© Algaecide, use less PAC in treatment
  - Algaecide ~$500-$1200 / application (every week)
  - PAC ~$4000-$8000 / week

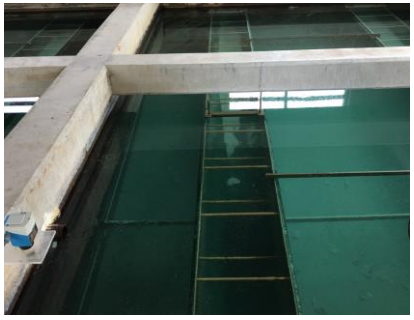
Summary

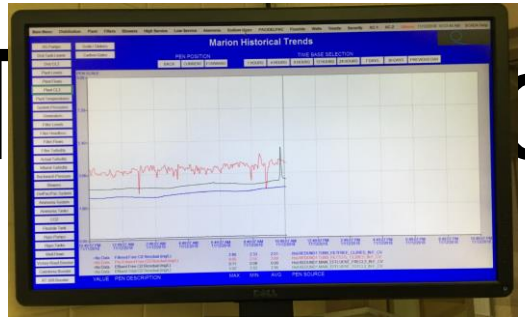
- If you aren’t profiling yet, start!
- Basic tools to assess risk (Total depth phycocyanin, max phycocyanin)
- Apply algaecide strategically (data driven insights)
  - Aim for problem locations
  - Apply regularly (weekly or as needed)
- Learn the thresholds in your reservoir
- Track source water management quantity, costs and impacts
  - Chemical cost/million gallons treated
  - Some reservoirs are harder to treat
- Focus on most important measures (phycocyanin, temperature)

Get on a Boat!

- Get out of the plant and onto your reservoir
- Understand the risks and dynamics throughout your reservoir
- Make informed decisions on reservoir management
- Don’t forget your flip flops!

Monitoring of Algal Toxin Treatment Barriers Using Decision Support Software





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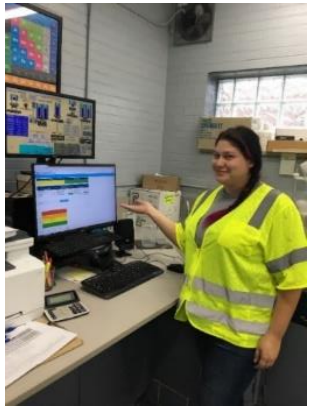
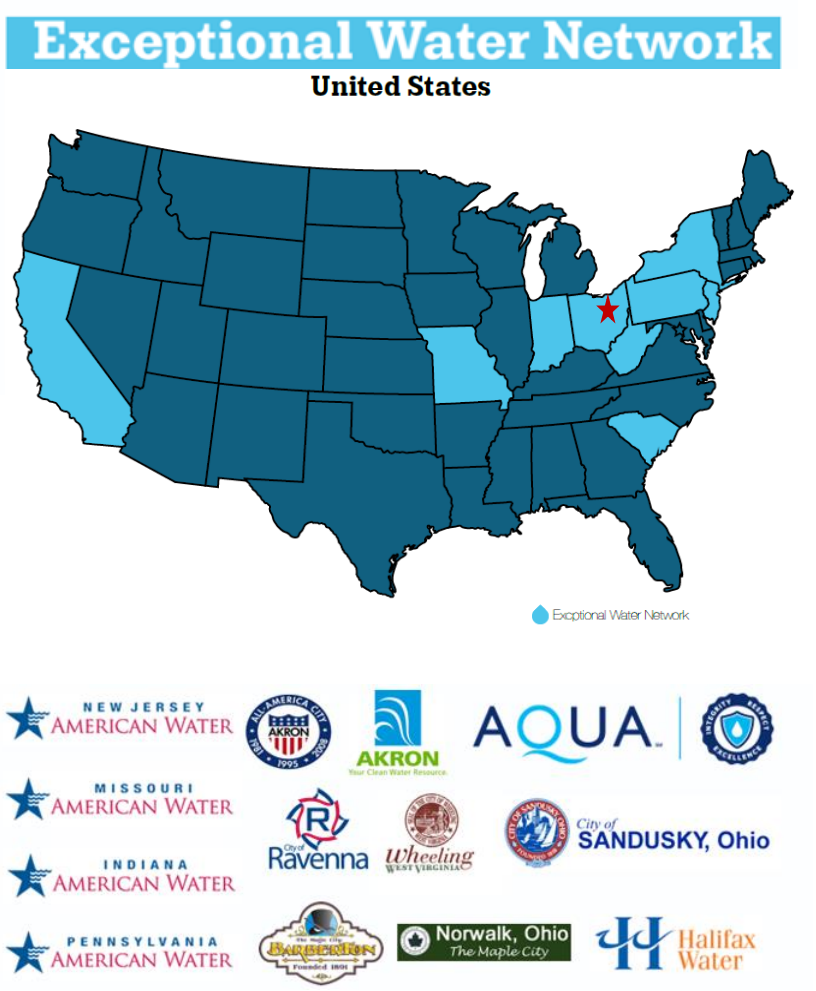
Fontus Blue develops solutions and supports people *making exceptional drinking water* for the public





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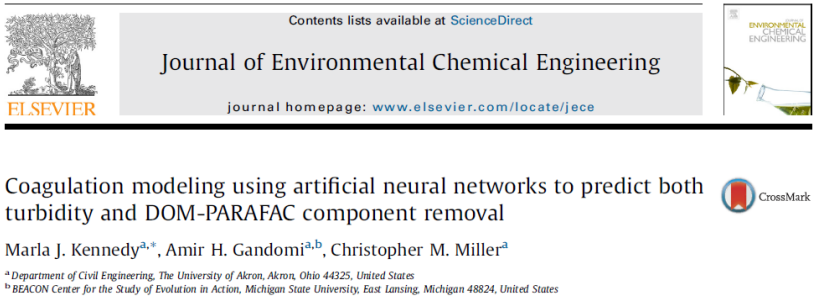
- Spinout company from the University of Akron (UA)
- Based on 25+ years of applied research-experience at UA
- Created Decision Blue® platform to support and develop drinking water quality expertise

The University of Akron
College of Engineering

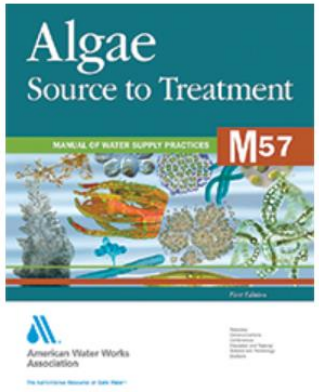


Decision Support for toxin barriers

EPA United States Environmental Protection Agency

Water Treatment Optimization for Cyanotoxins

Version 1.0



Ohio Ohio Environmental Protection Agency

Developing a Harmful Algal Bloom (HAB) Treatment Optimization Protocol

Guidance for Public Water Systems

American Water Works Association | Hazen | Saint Louis University

Hazen-Adams CyanoTOX (Ver. 2.0)

Hazen-Adams CyanoTOX (Version 2.0)
(Cyanotoxin Tool for Oxidation Kinetics)
Tool Developed by C. Adams, B. Stanford, E. Arevalo, A. Reinert, and E. Rosenfeldt

and much more…..

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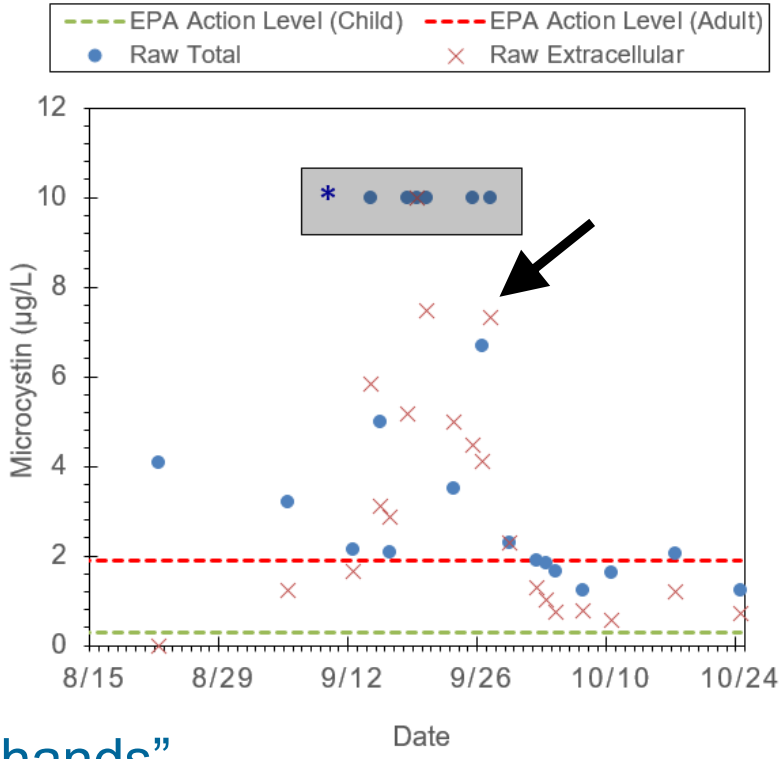
2017 HAB EVENT CONT.

- Data collection included toxin, qPCR (gene counts), satellite, and raw water sonde
- Management was proactive – added “high” performance PAC and started working with Fontus Blue
- Significant toxin production Sept. 2017 in Evans Lake raw water intake, total > 10 ug/L for several weeks and extracellular > 7 ug/L!

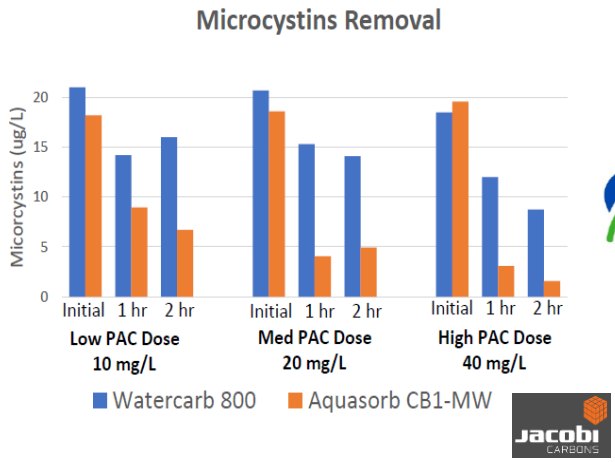


“We had a fight on our hands”
Struthers Production Manager

2017 HAB SUMMARY

Maintained compliance by:

- Dosing PAC at 20-25 mg/L (jar test results from OEPA) with assistance of PAC calculator



Ohio Environmental Protection Agency

DecisionBlue® PAC Calculator

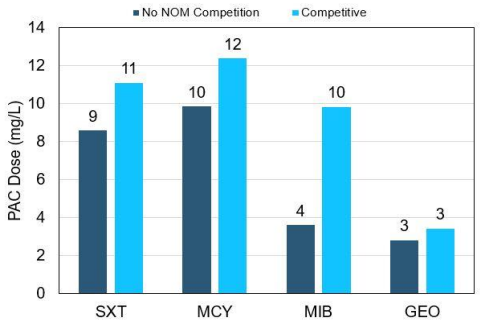
	Saxitoxin (SXT)		Microcystin (MCY)		MIB		Geosmin (GEO)	
Initial:	0.9	ppb	10.0	ppb	10.0	ppt	5.0	ppt
Target:	0.3	ppb	3.0	ppb	5.0	ppt	4.0	ppt

PAC Retention Time: 120 mins

Calculate

	Saxitoxin (SXT)		Microcystin (MCY)		MIB		Geosmin (GEO)	
No NOM Competition Adsorption Dose:	8.6	mg/L	9.9	mg/L	3.6	mg/L	2.8	mg/L
Competitive Adsorption Dose:	11.1	mg/L	12.4	mg/L	9.8	mg/L	3.4	mg/L

Controlling compound: Microcystin



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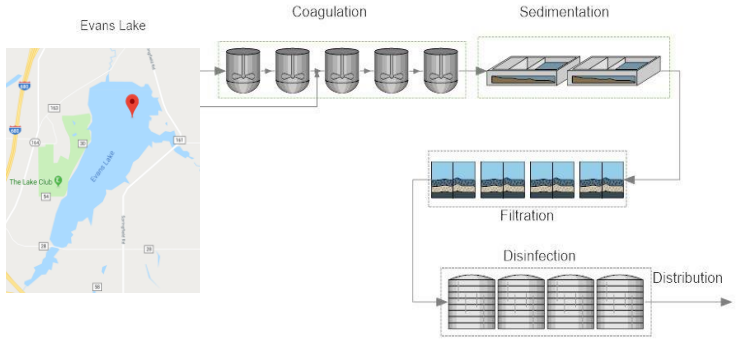
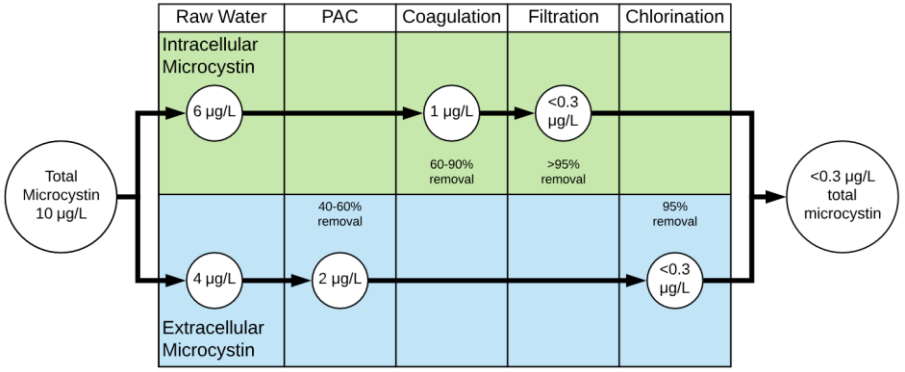
THE BUILDING OF HAB MONITOR™

After events of 2017, Fontus decided to build HAB monitor that could:

- Automate treatment barrier calculations for a water utility
- Incorporate published research
- Be customized for different treatment barriers
- Be conservative in treatment barrier calculations





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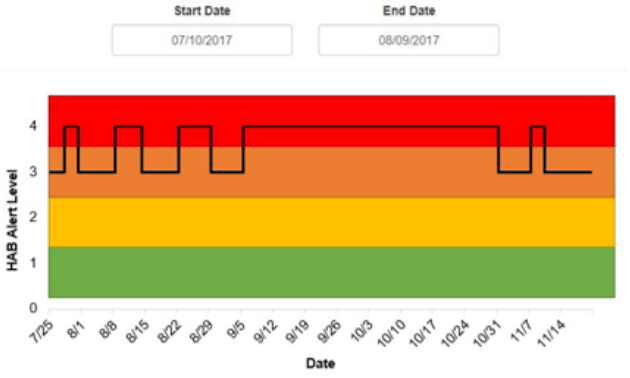
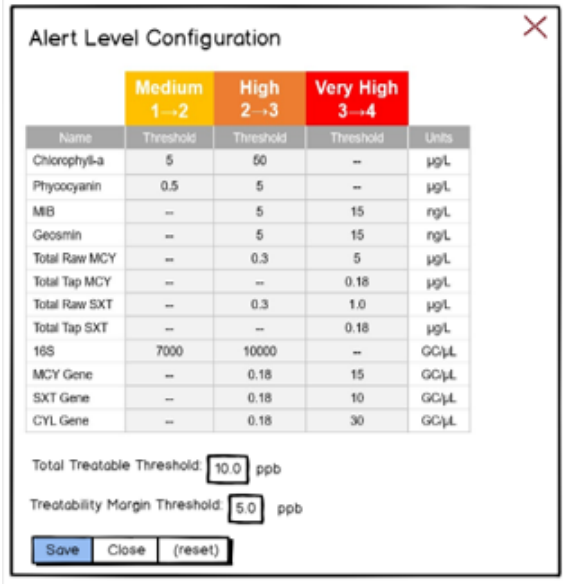
HAB Alert level framework

- Simplify “all” data into single HAB Alert Level framework
- Customize alert levels for multiple parameters
- Data inputs can be manual or SCADA





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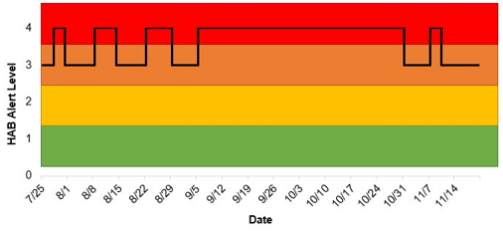
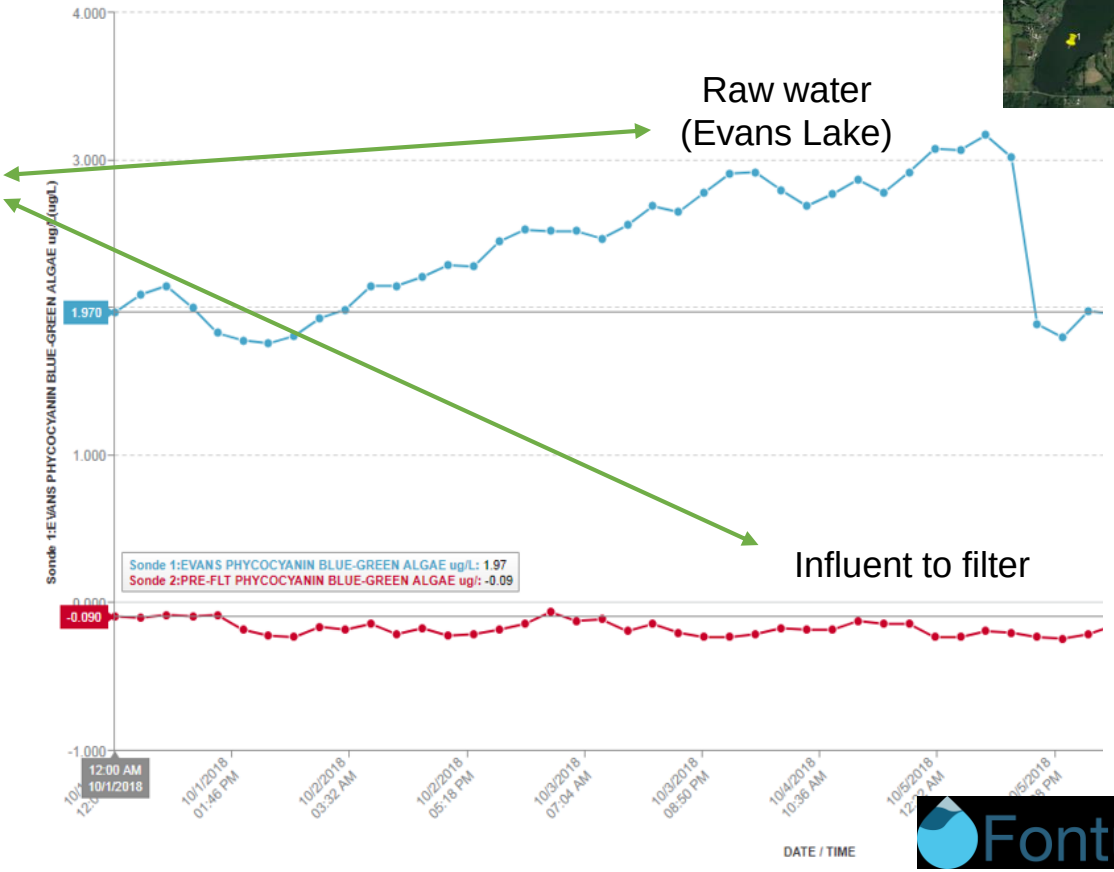
HAB ALERT AT STRUTHERS

HAB Alert Level



Phycocyanin sonde data monitoring:

- Raw water
- Treated water



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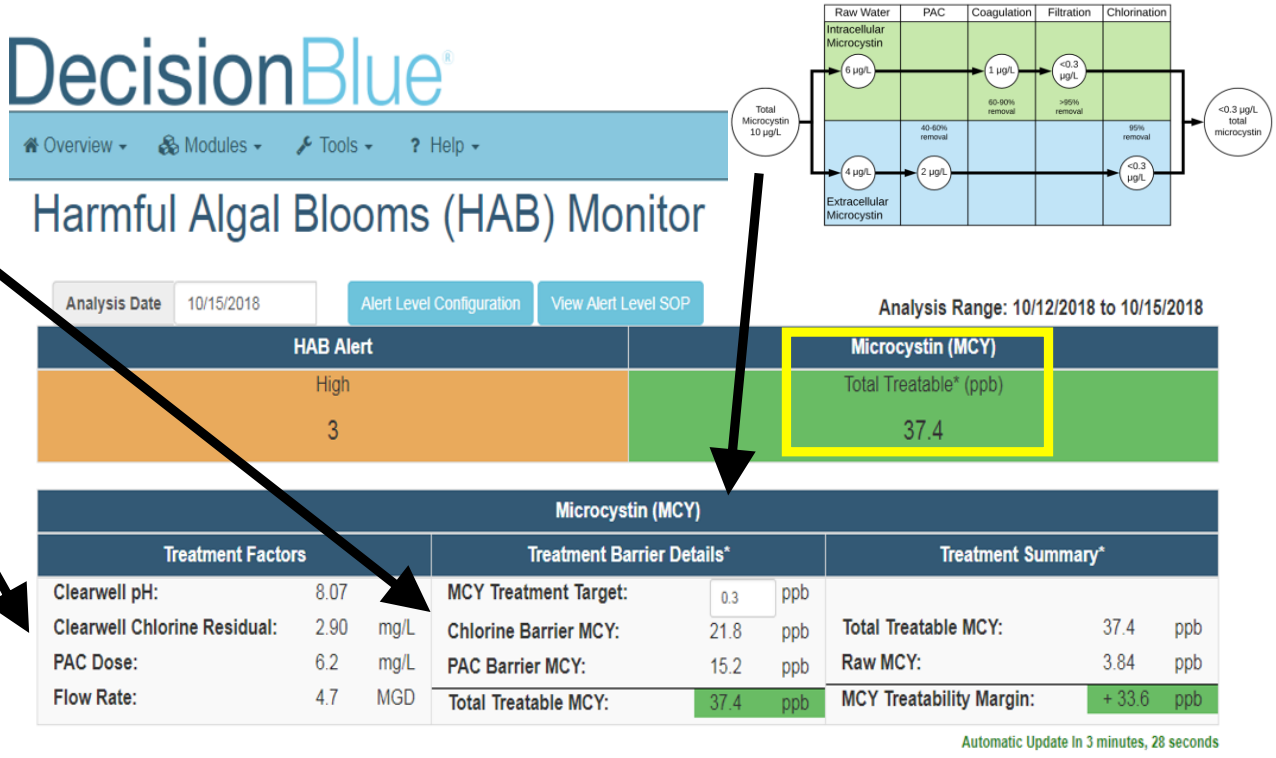
Exceptional Water for Everyone, Every Day

HAB Monitor™ Treatment DETAILS

- Sequence of treatment barriers to achieve treatment target
- Incorporates current conditions (i.e. Treatment Factors)
- Total Treatable is current estimate of toxin barriers



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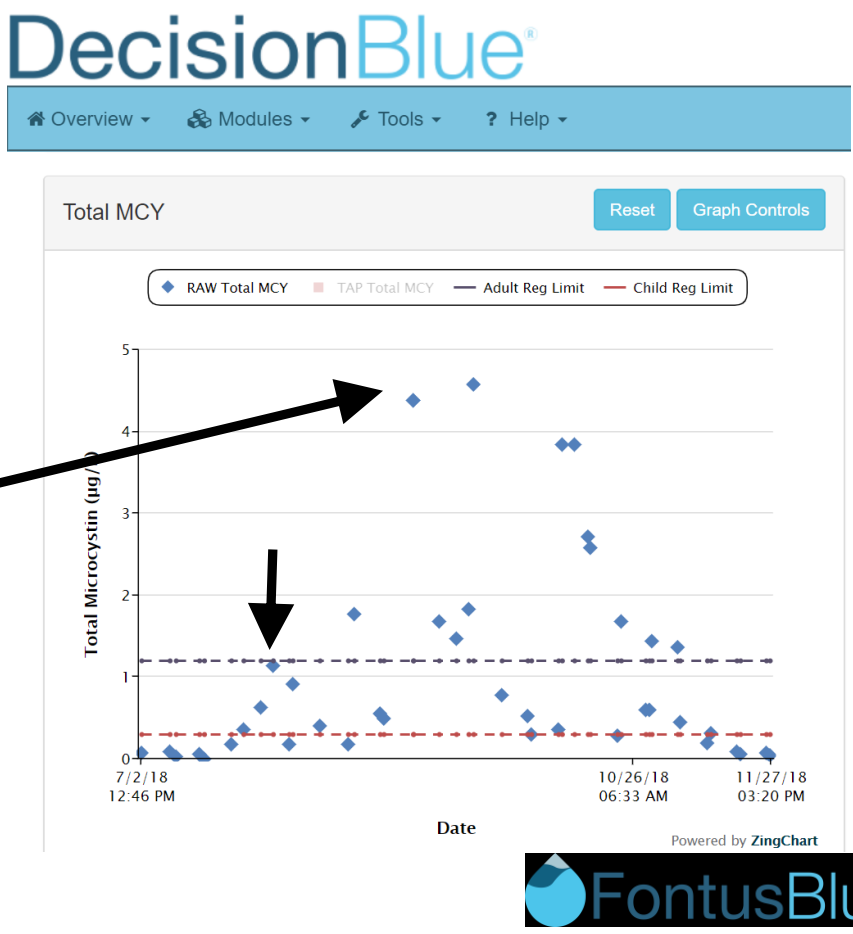
2018 HAB EVENT

What happened in 2018?

- Toxin production started in July, earlier than 2017
- Toxin peaked at ~ 5 ppb, lower than 2017 (algaecide application reduced peak?)

What did the staff do between sample events?



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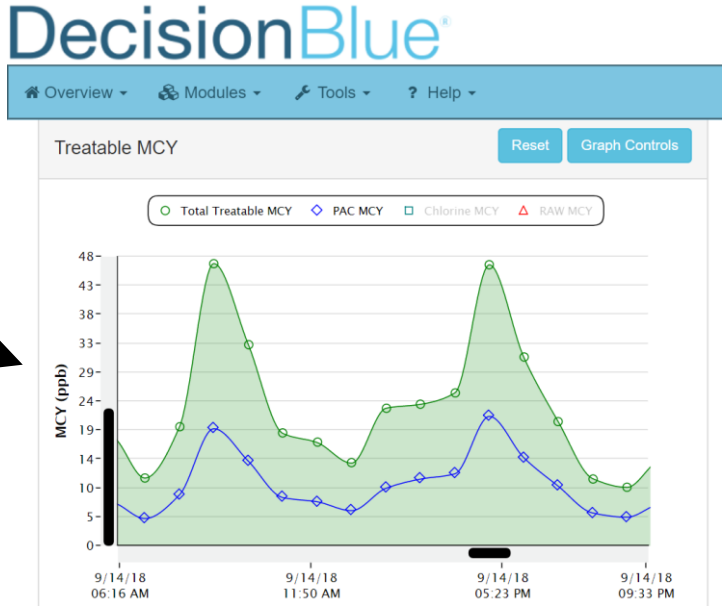
2018 HAB EVENT CONT.

Staff followed and observed:

- Total Treatable estimate for each toxin barrier
- Notification when Total Treatable was below 5 ppb

What about the measured tap levels?



Harmful Algal Blooms (HAB) Monitor

Analysis Date 09/18/2018 | Alert Level Configuration | View Alert Level SOP | Analysis Range: 09/18/2018 to 09/18/2018

Key Performance Indicators (KPIs)	
HAB Alert Level	Total Treatable Microcystin* (ppb)
3	4.7

Microcystin (MCY)

Treatment Factors			Treatment Barrier Details*			Treatment Summary*		
Clearwell pH:	8.69		MCY Treatment Target:	0.3	ppb			
Clearwell Chlorine Residual:	2.80	mg/L	Chlorine Barrier MCY:	1.7	ppb	Total Treatable MCY:	4.7	ppb
PAC Dose:	11.2	mg/L	PAC Barrier MCY:	2.7	ppb	Raw MCY:	4.58	ppb
Flow Rate:	4.4	MGD	Total Treatable MCY:	4.7	ppb	MCY Treatability Margin:	+ 0.2	ppb

Automatic Update in 4 minutes, 18 seconds

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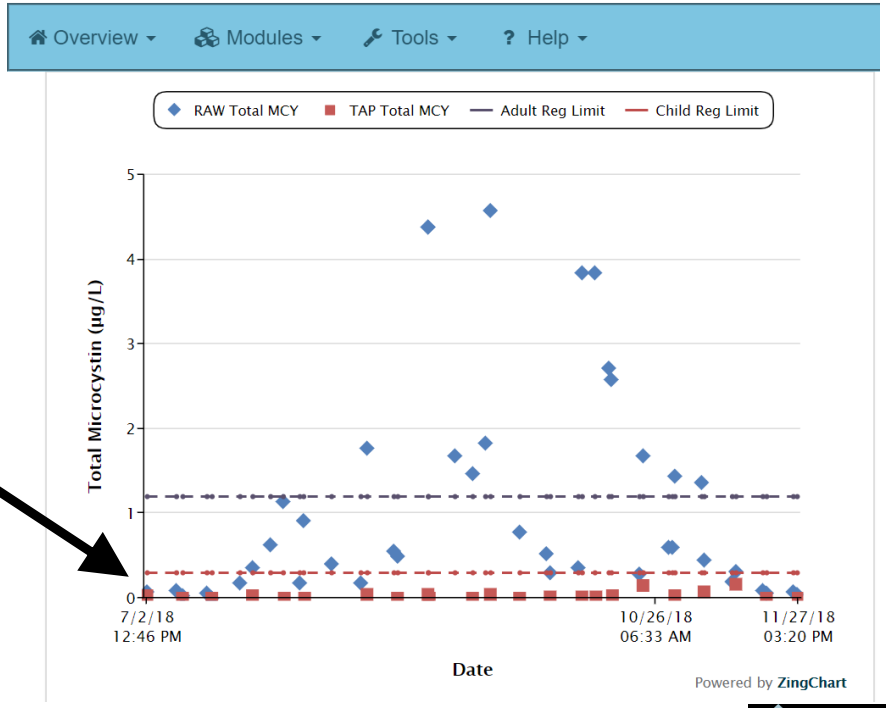
2018 HAB EVENT – TAP TOXIN

DecisionBlue®

Tap all below 0.3 ppb

The barriers work



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LESSONS LEARNED

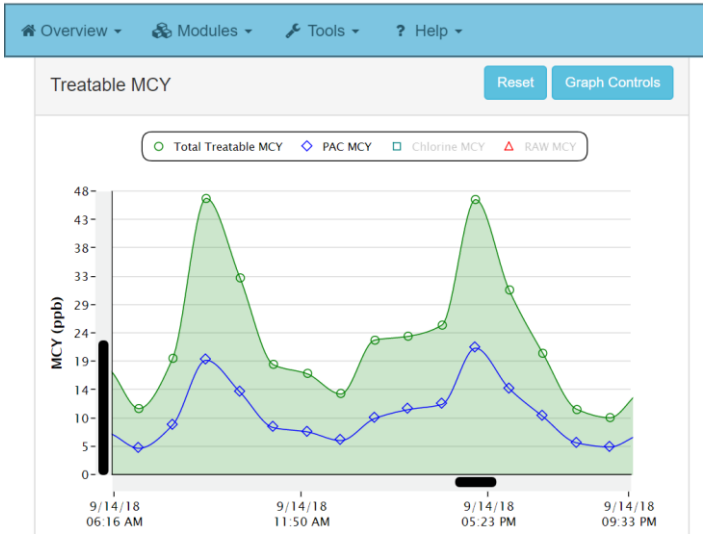
- Focus on Simultaneous Compliance (controlling water stability and corrosion while optimizing for toxin removal can be difficult)
- Small water quality changes can have a large impact on treatment barriers
- Combining the tools, embedded safety factors, with real-time data, and a visual environment where measures are clearly presented, allow operators to handle complex challenges

American Water Works Association | Hazen | Saint Louis University

Hazen-Adams CyanoTOX (Ver. 2.0)

Hazen-Adams CyanoTOX (Version 2.0)
(Cyanotoxin Tool for Oxidation Kinetics)
Tool Developed by C. Adams, B. Stanford, E. Arevalo, A. Reinert, and E. Rosenfeldt

DecisionBlue®



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Questions

Ashley Bair
ashley@fontusblue.com
440-339-1914

Acknowledgements

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