Upper, Middle, and Lower Willimantic Reservoirs

(aka Bolton Lakes)

- Nature of the In-Series Reservoirs - Critical Natural Features

(Mine will be a different perspective on the limnology and management of the system than you've heard)

- How is Climate Change Affecting Lake Ecosystems and how vulnerable are the Bolton Lakes?

- Monitoring Cyanobacteria and the 2023 Phycocyanin Study

- Hydrilla in Middle Bolton Lake; What can be expected?

- Questions and Discussion

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Willimantic Reservoirs

The Bolton Lakes…consist of a chain of impoundments in series. The watershed contains a large swamp wetland area (west of *Cedar Swamp* Road). Upper Bolton Lake is a shallow water body, much of which is a submergent-emergent marsh. As a consequence of the high concentrations of Colored Dissolved Organic Matter (CDOM), the water in Middle Bolton Lake is "tea colored". That results in strong thermal stratification and intense oxygen consumption at even relatively shallow depths.

Historically, most water flowed from the surface of Middle Bolton Lake over the spillway to Lower Bolton Lake. Water that reached the lower lake had been exposed to a maximum amount of sunlight (including UV that "bleaches" CDOM) and the lowest plant nutrient concentrations from the middle lake. As a result, Middle Bolton Lake was "tea color" due to CDOM while Lower Bolton Lake exhibited very clear, transparent water.

It is "One Ecosystem": three reservoirs in series.


Upper Bolton Lake 9/27/12


Upper Bolton Lake 9/27/12

Middle Bolton Lake 9/27/12

1970s

Middle Bolton Lake	Lower Bolton Lake
Area= 115 ac	178 ac
Max Depth 26 ft	26 ft
Mean Depth 3m (10 ft)	3.4m (11 ft)
Wshd/Lake Area 16.9	13.6
Wshd area 1,946 ac 8% developed, 86% Wooded or Wet	2,149 ac *(203 ac without Middle Bolton)*
Color 50	***25***
Total P 1979 **25-30 ppb**	**< 20 ppb**

Middle Bolton is > 85%+ of Lower Bolton Watershed

Middle Bolton was highly colored;
Lower Bolton was not

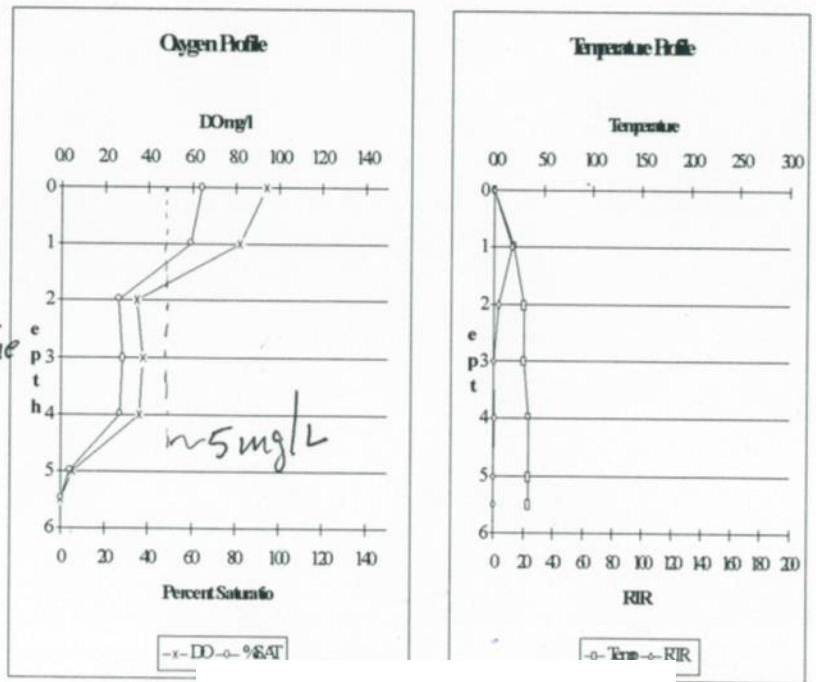
1987

Middle Bolton Lake

Winter Oxygen Loss

Station	1	
Date	3/4/87	
SECCHI	1.5	*meters*
Anoxic Boundry	4.84	*meters*
Sum RTRM	16	

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*
0	0.0	9.4	64	0	0
1	2.0	8.2	59	12	-200
2	3.0	3.5	26	3	-100
3	3.0	3.8	28	0	0
4	3.5	3.6	27	0	-50
5	3.5	0.5	4	0	0
5.5	3.5	0.0	0	0	0



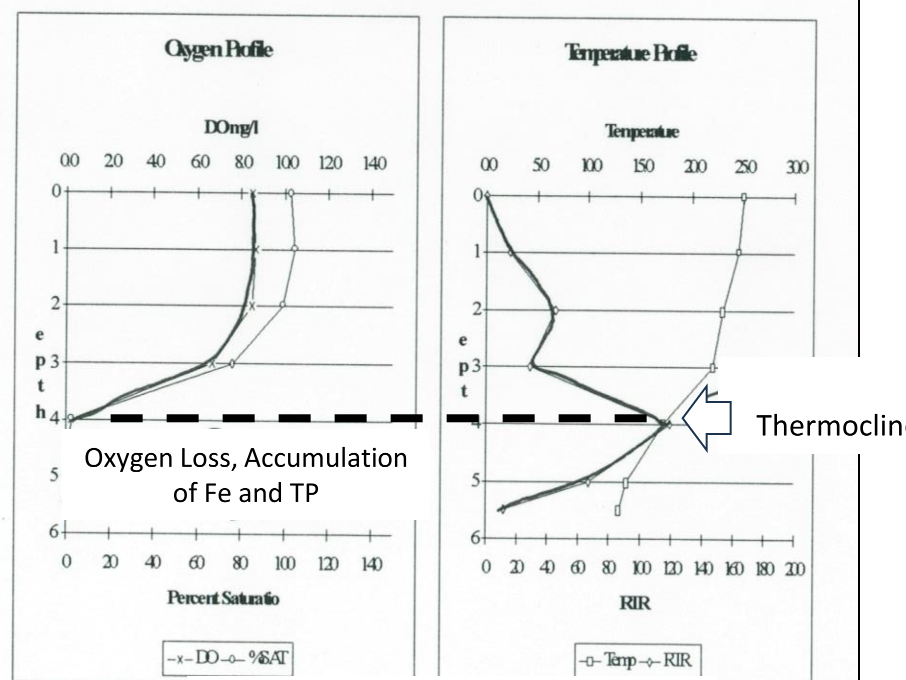
March 4, 1987

Middle Bolton Lake

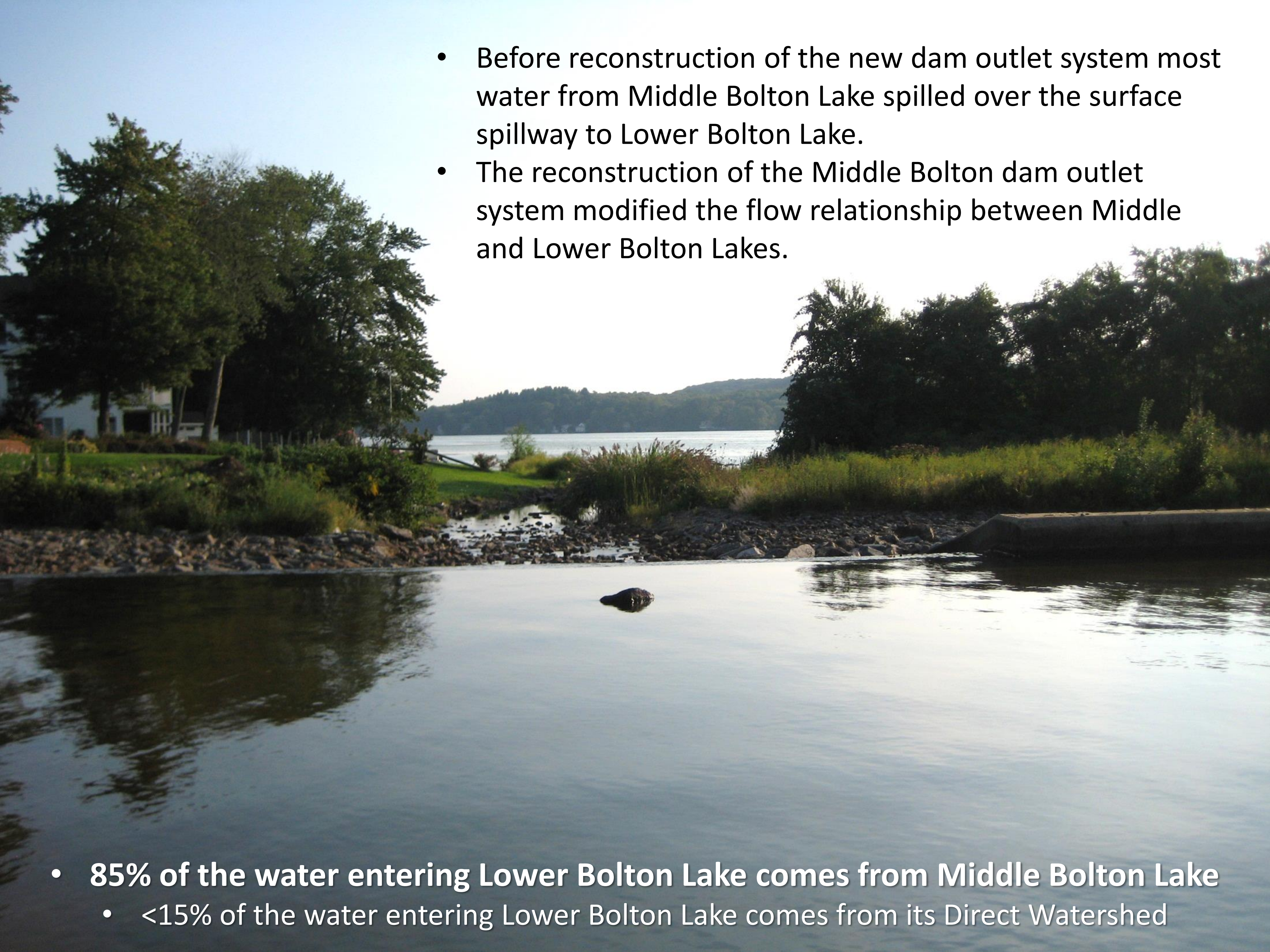
Oxygen Loss Up to the Thermocline by the end of June

Station	1	
Date	6/25/87	
SECCHI	2.7	*meters*
Anoxic Boundry	3.88	*meters*
Sum RTRM	288	

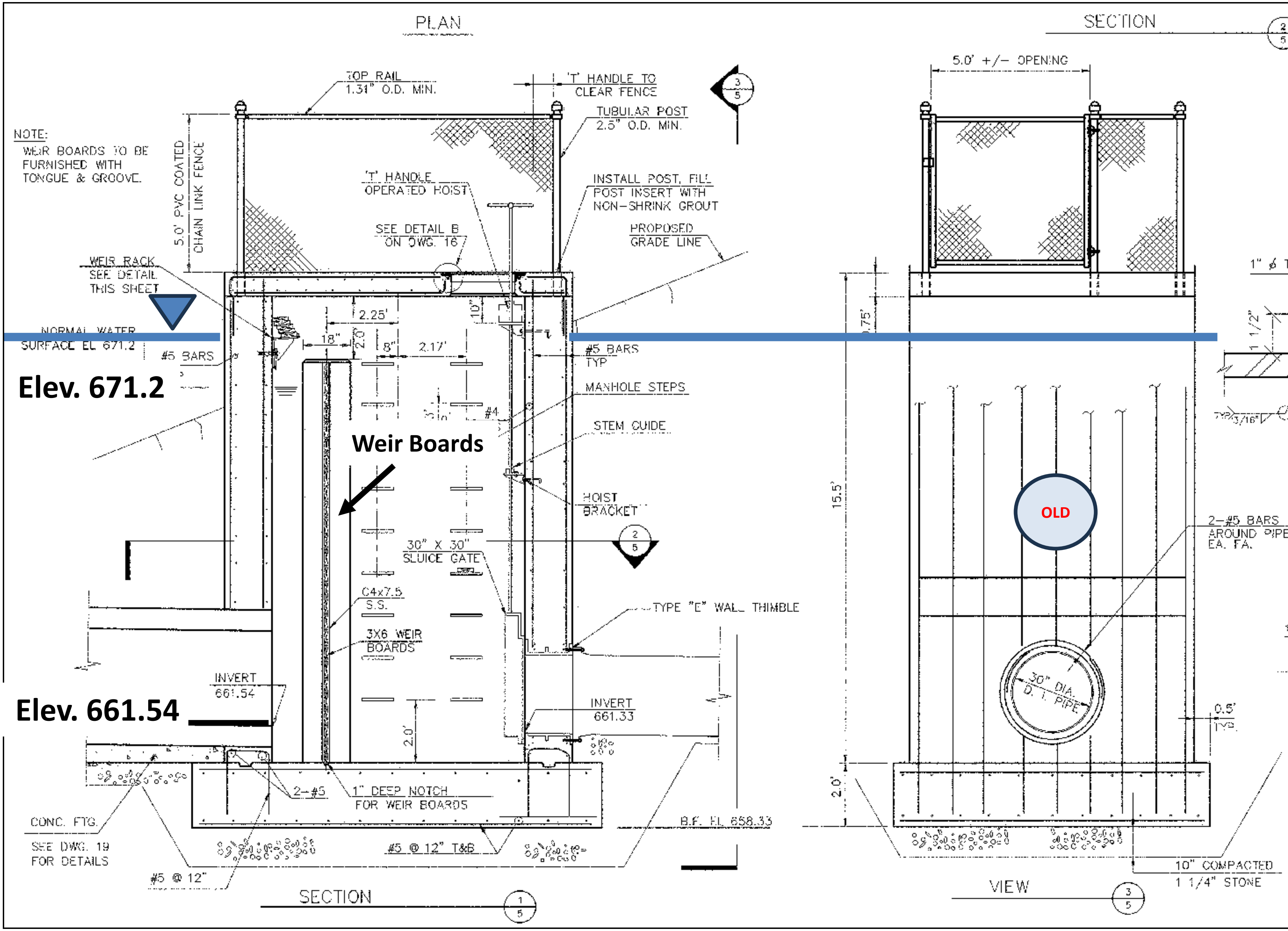
Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*
0	25.0	8.5	103	0	0
1	24.5	8.7	104	16	20
2	23.0	8.5	99	45	60
3	22.0	6.7	77	29	40
4	17.2	0.2	2	119	192
5	13.7	0.1	1	67	200
5.5	13.0	0.0	0	11	60



June 25,1987



- Before reconstruction of the new dam outlet system most water from Middle Bolton Lake spilled over the surface spillway to Lower Bolton Lake.
- The reconstruction of the Middle Bolton dam outlet system modified the flow relationship between Middle and Lower Bolton Lakes.
- **85% of the water entering Lower Bolton Lake comes from Middle Bolton Lake**
  - <15% of the water entering Lower Bolton Lake comes from its Direct Watershed



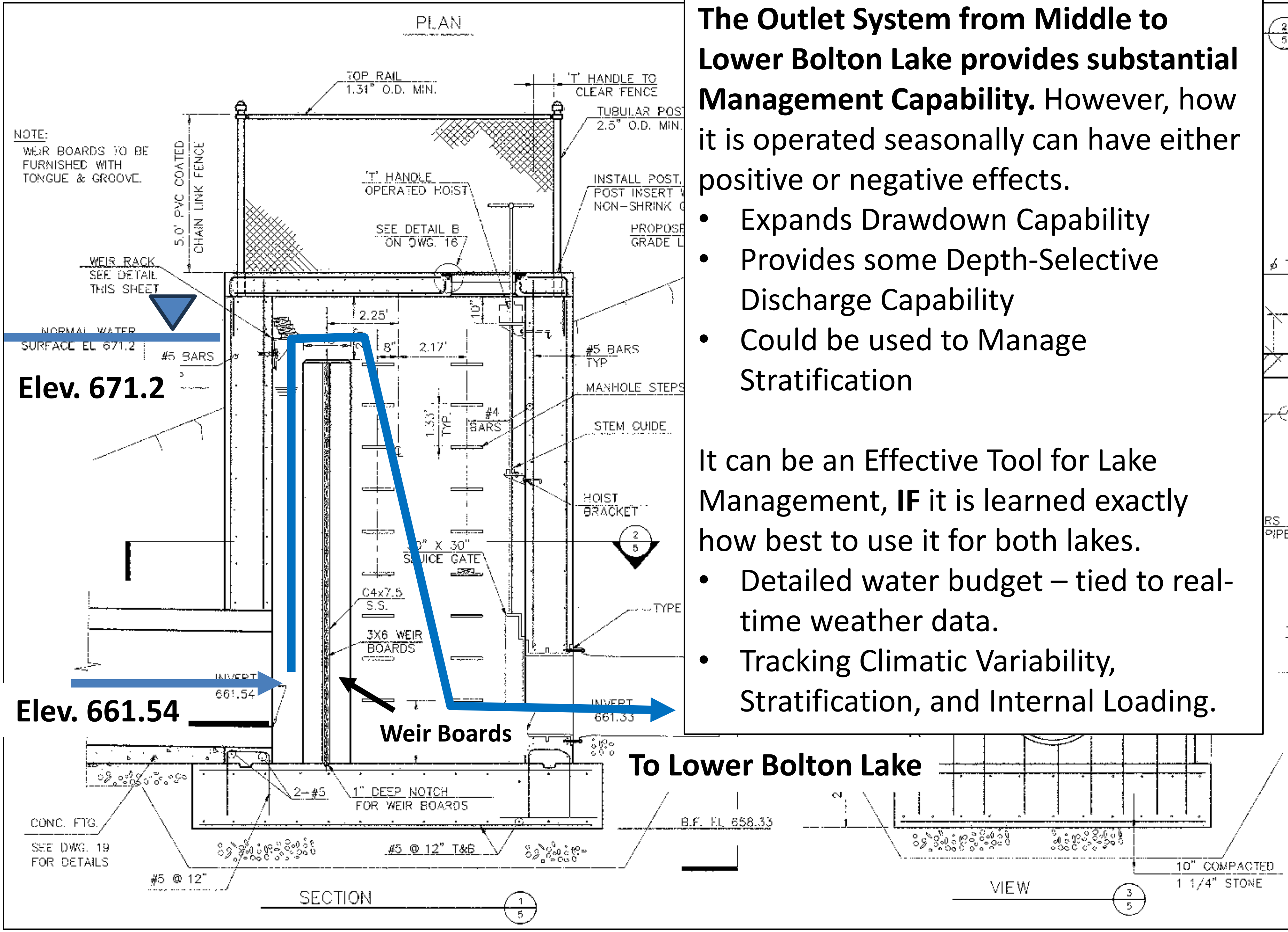
MIDDLE BOLTON

The Outlet System from Middle to Lower Bolton Lake provides substantial Management Capability. However, how it is operated seasonally can have either positive or negative effects.

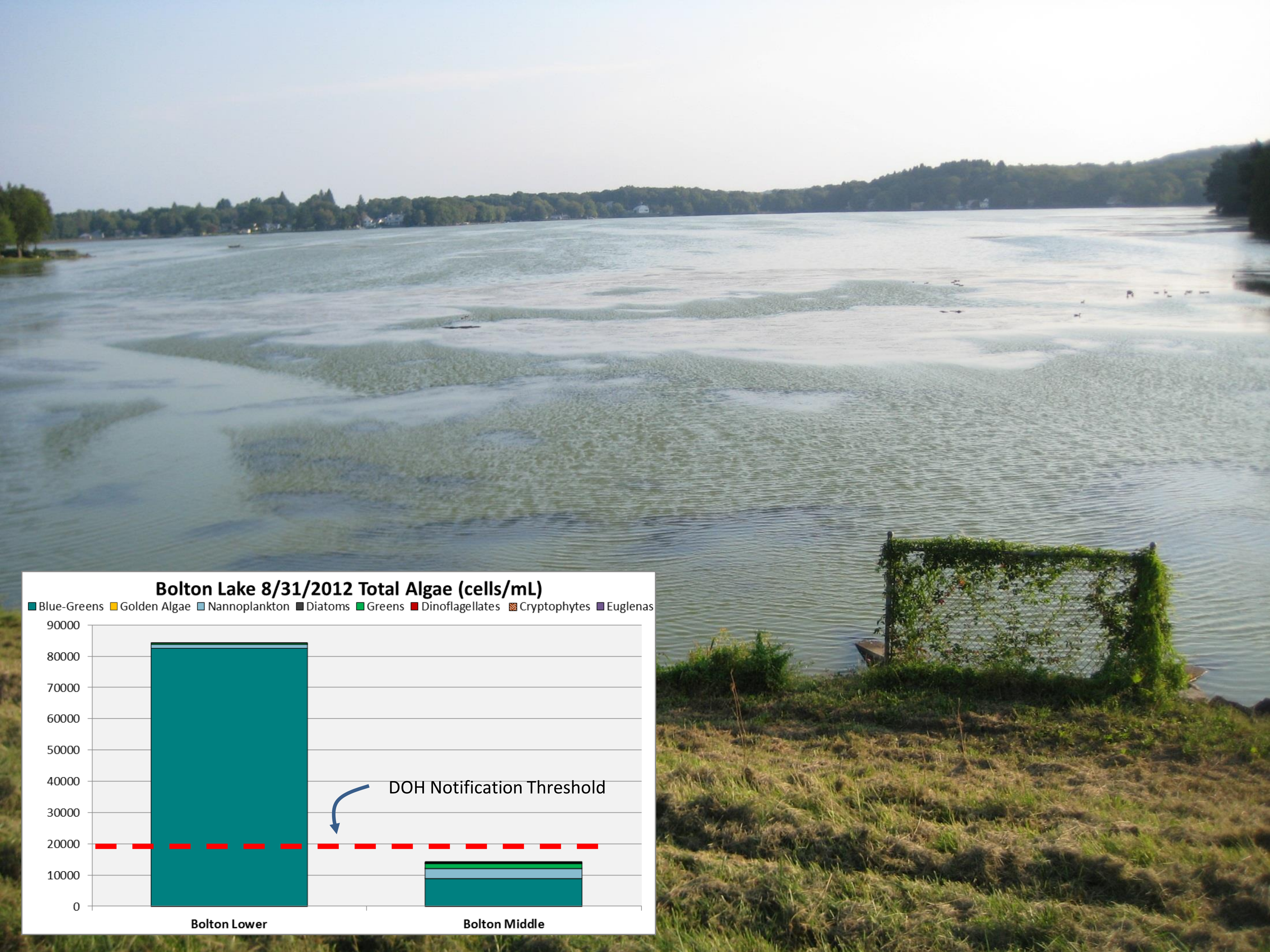
- Expands Drawdown Capability
- Provides some Depth-Selective Discharge Capability
- Could be used to Manage Stratification

It can be an Effective Tool for Lake Management, **IF** it is learned exactly how best to use it for both lakes.

- Detailed water budget – tied to real-time weather data.
- Tracking Climatic Variability, Stratification, and Internal Loading.



MIDDLE BOLTON


Bolton Lake 8/31/2012 Total Algae (cells/mL)
Blue-Greens
Golden Algae
Nannoplankton
Diatoms
Greens
Dinoflagellates
Cryptophytes
Euglenas
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
DOH Notification Threshold
Bolton Lower
Bolton Middle

Middle Bolton Lake August 2012

Middle Bolton Lake

August 2012

Lower Bolton Lake August 2012

Lower Bolton Lake

What caused the Cyanobacteria Bloom in 2012?

- External Nutrient Loading?
- Unusually Large Internal Load (related to climate)?
    - In Lower Bolton Lake?
    - In Middle Bolton Lake (transferred via outlet gate)?

Climate Change in the Northeast 1980 to 2018

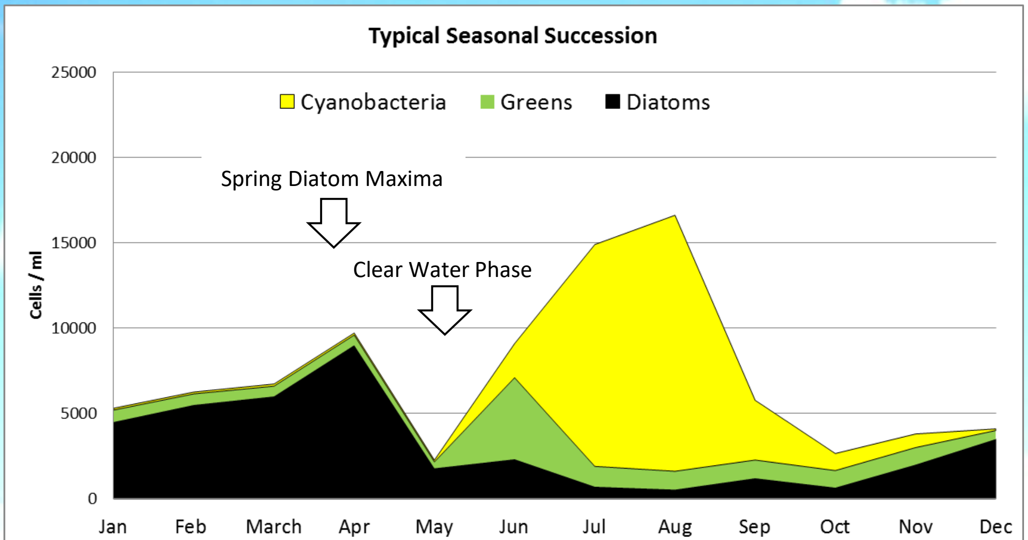
https://climatereanalyzer.org/
Burpee, 2021

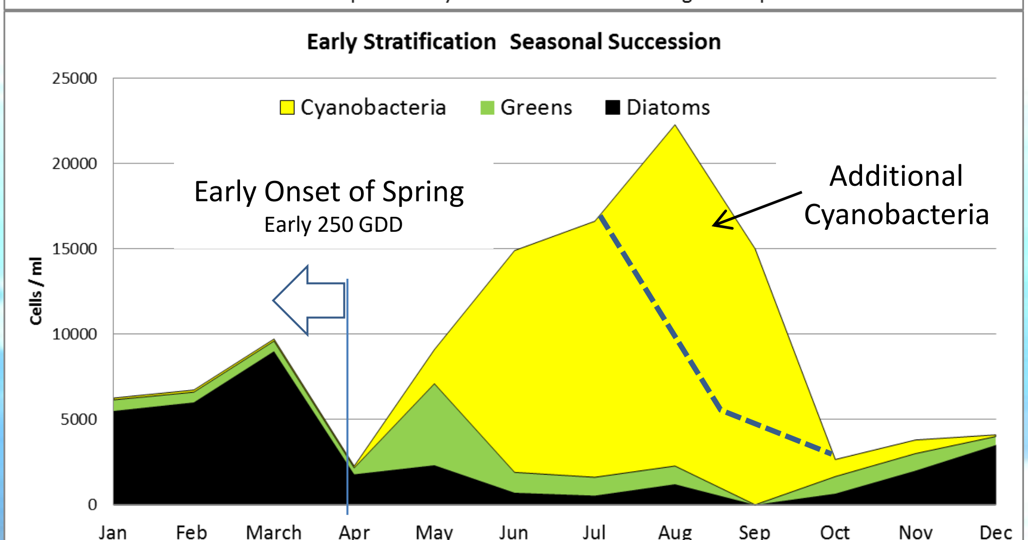
1980 to 2018

		DJF	MAM	JJA	SON
	Average Annual	**Winter**	**Spring**	**Summer**	**Autumn**
Average Increase Temperature deg. C	1.5	**2**	0	1	**2**
Precipitation cm	4	**5**	-3	-1	**3**
Wind Speed meters/second	-0.8	-0.9	-0.8	-0.8	-0.6

- Average Temperature is increasing most rapidly during Winter and Autumn
- Stratification and Growing Seasons are Beginning Earlier and Ending later
- Precipitation is also increasing most rapidly during Winter and Autumn
- Wind Speeds are Decreasing, with similar seasonal change

The past 38 years.

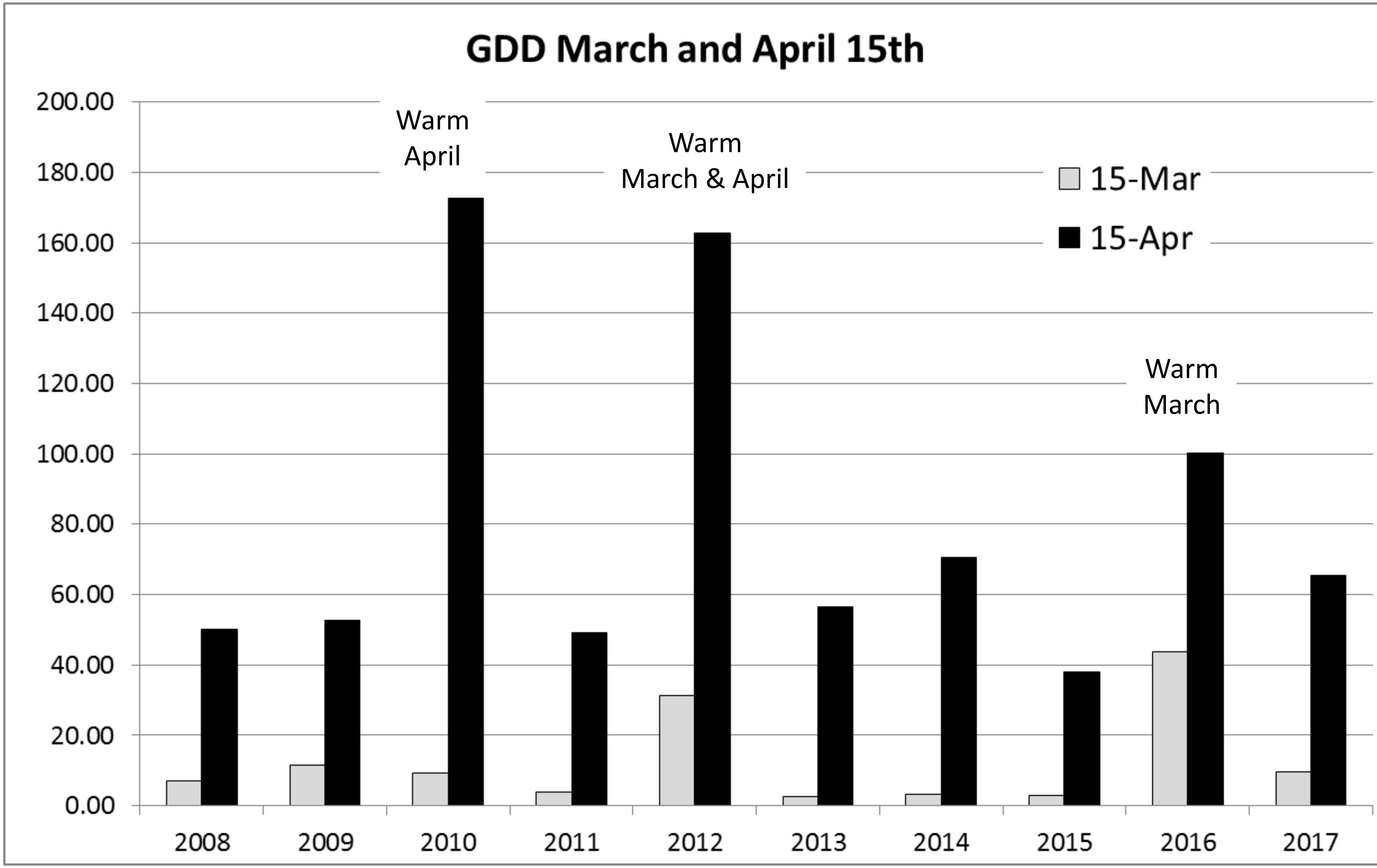




Mild Winter-Spring-Summer:

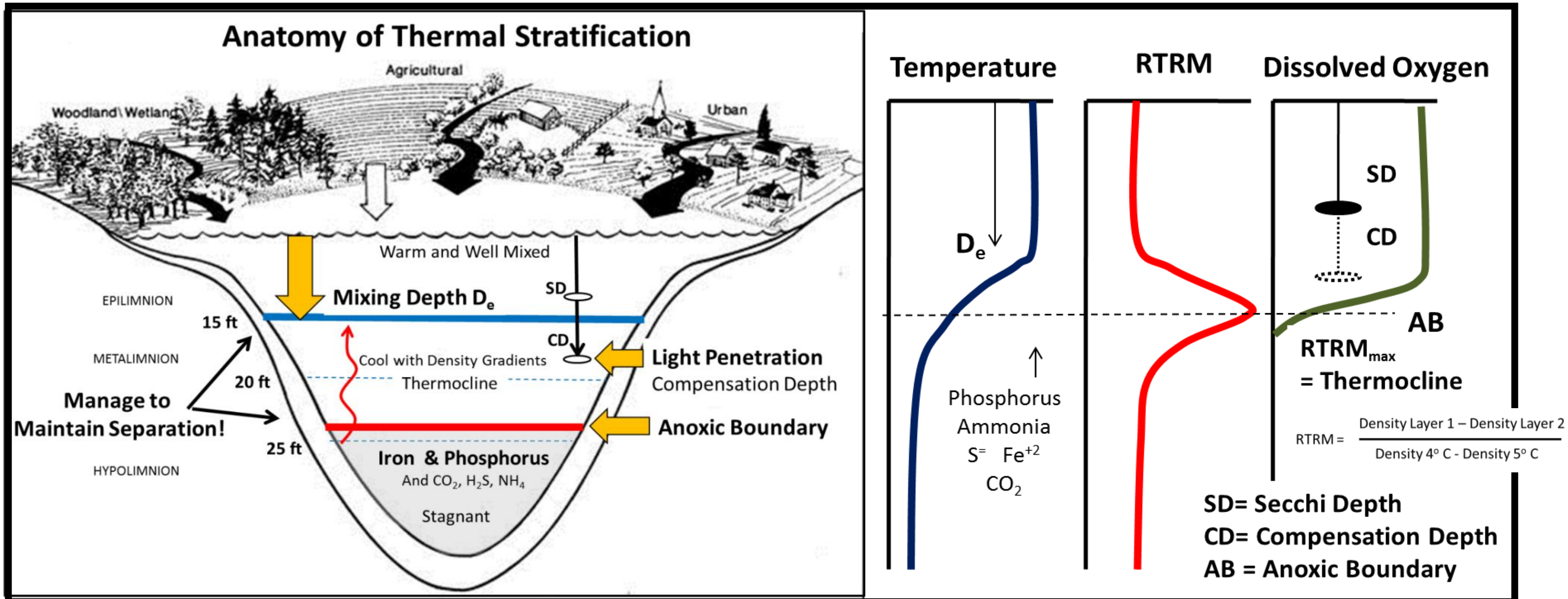
- Early Stratification
- Prolonged Stratification
- Increased Anoxic Factor
- Higher Anoxic Ascent (Less separation of D_e and AB)
- Greater ATEA Accumulation (Fe, Mn, $S^{=}$)
- Greater Internal P Loading
- Early Diatom Crash
- Early Nitrate Exhaustion
- Early Cyanobacteria
- More Intense Post-Turnover Bloom
- Cyanobacteria Persist through Winter

(Kortmann and Cummins, 2018)



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
15-Mar	7.14	11.32	9.12	3.73	31.13	2.42	3.13	2.96	43.61	9.61	12.42
15-Apr	50.06	52.73	172.61	49.12	162.68	56.34	70.37	37.91	100.13	65.51	81.75
15-May	260.27	298.64	400.82	256.70	391.24	241.27	258.52	327.79	266.43	278.06	297.97
15-Jun	726.12	684.90	925.18	762.45	864.07	691.63	691.23	792.38	750.23	717.03	760.52

From: Kortmann and Cummins, 2018



To Control Internal Loading and Vertical Transport

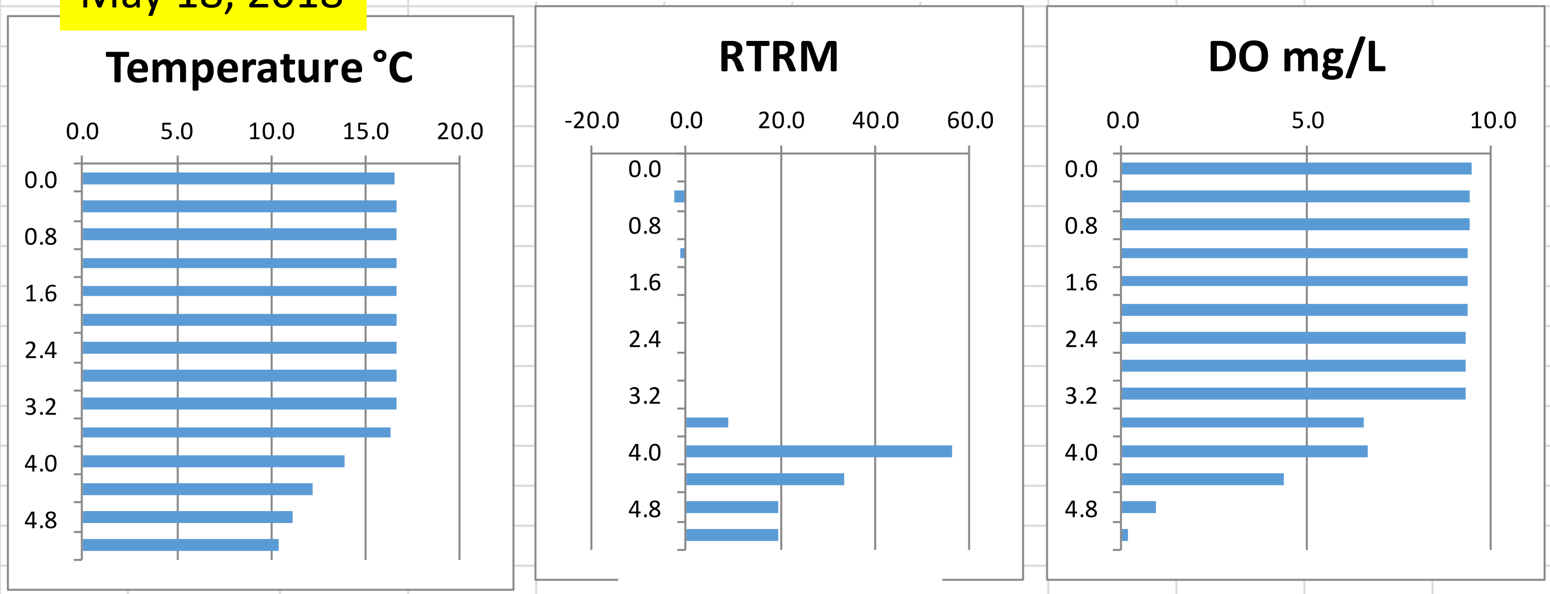
- **Maintain an aerobic sediment-water interface**
- **Maintain separation between Mixing Depth and Anoxic Boundary**
- **Add Sediment P-Binding Capacity: Al, Fe, Lanthanum, etc.**

(Be careful with sulfur loading! $AlSO_4$ $CuSO_4$)

(Kortmann, 2021)

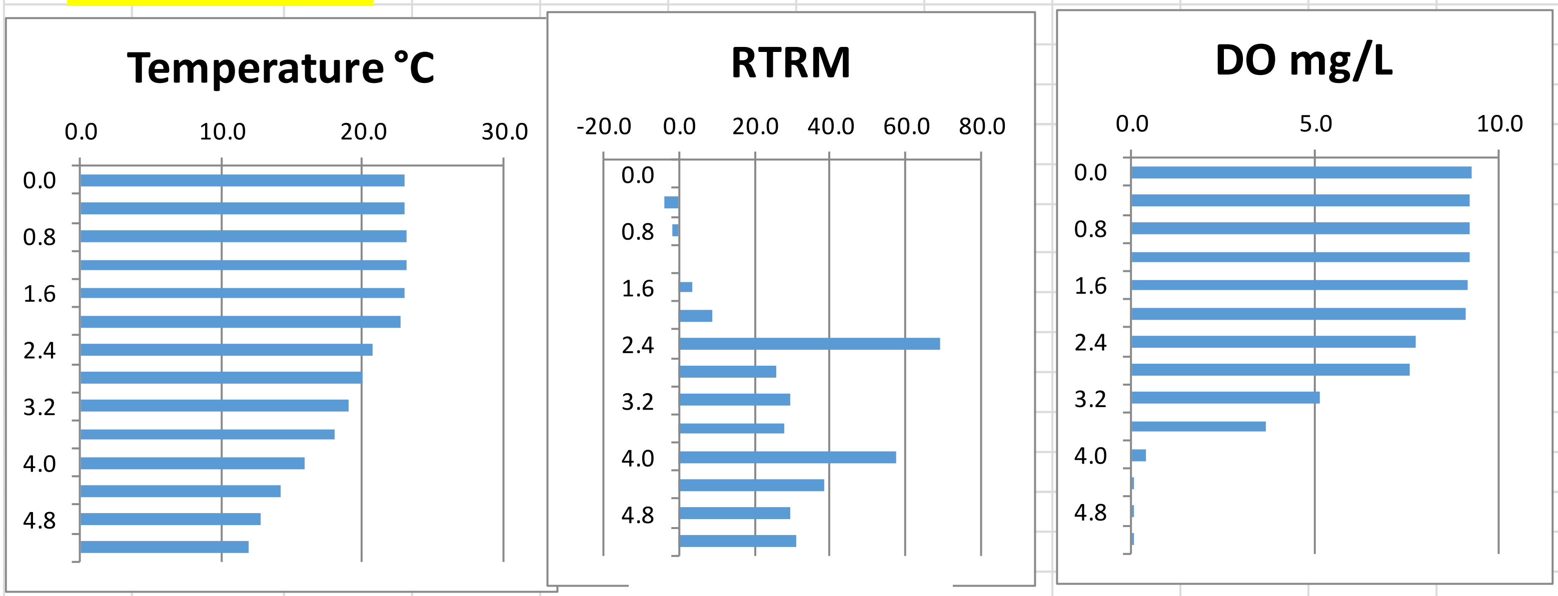
Lower Bolton Lake

May 18, 2018



RTRMsum 134

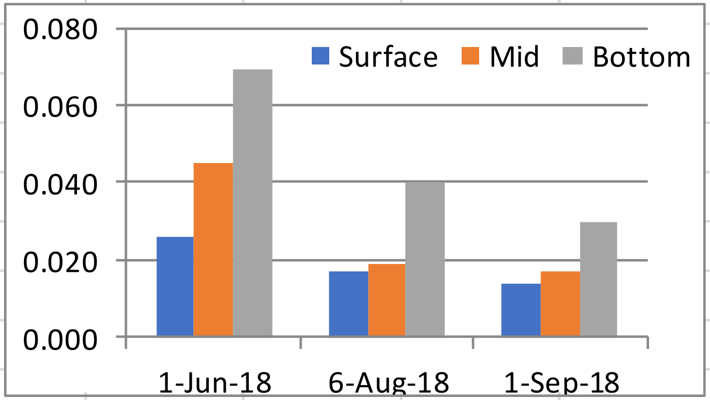
May 31, 2018



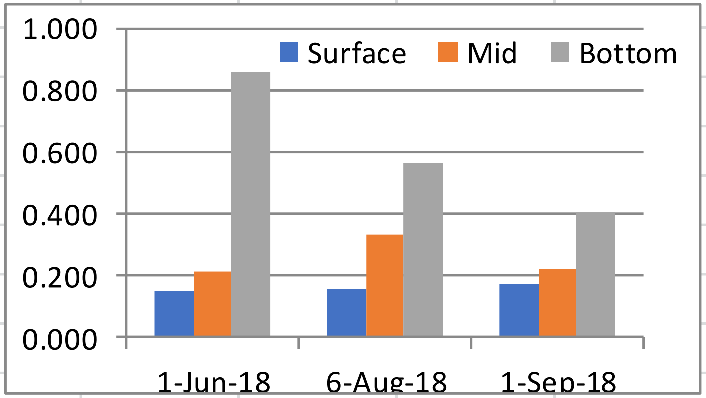
RTRMsum 316

Lower Bolton Lake

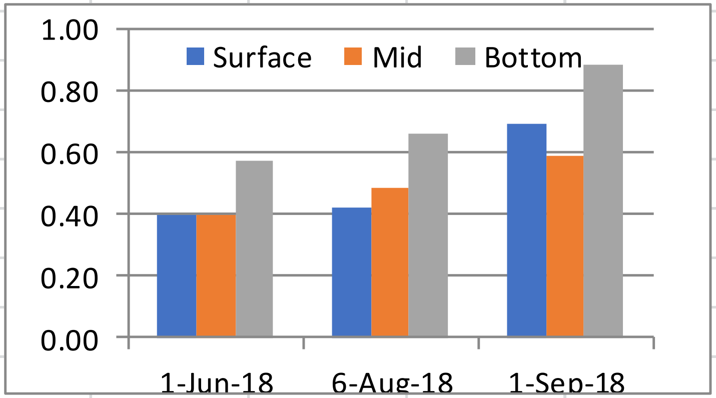
	TP		
	1-Jun-18	6-Aug-18	1-Sep-18
Surface	0.026	0.017	0.014
Mid	0.045	0.019	0.017
Bottom	0.069	0.040	0.030



	Fe		
	1-Jun-18	6-Aug-18	1-Sep-18
Surface	0.148	0.159	0.177
Mid	0.210	0.334	0.222
Bottom	0.854	0.567	0.403



	TN		
	1-Jun-18	6-Aug-18	1-Sep-18
Surface	0.40	0.42	0.69
Mid	0.40	0.48	0.59
Bottom	0.57	0.66	0.88

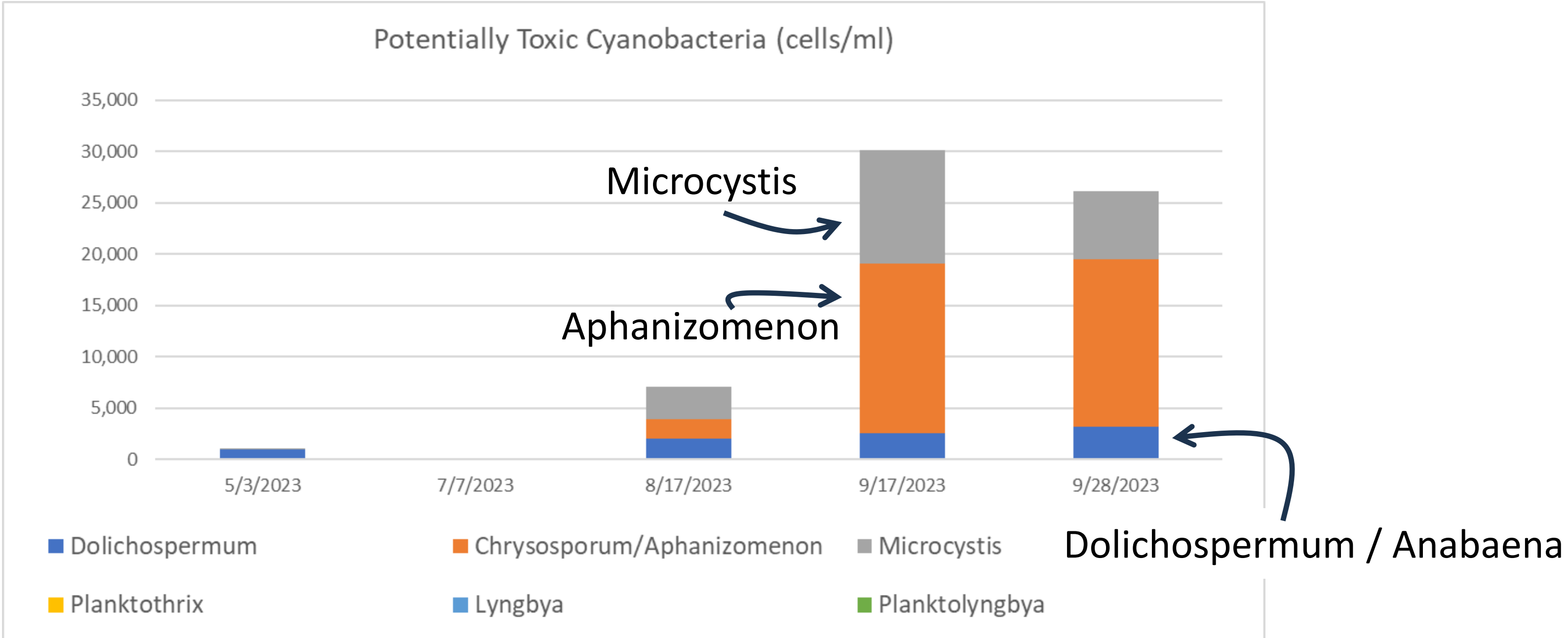


Monitoring Potential Risk from Cyanotoxins

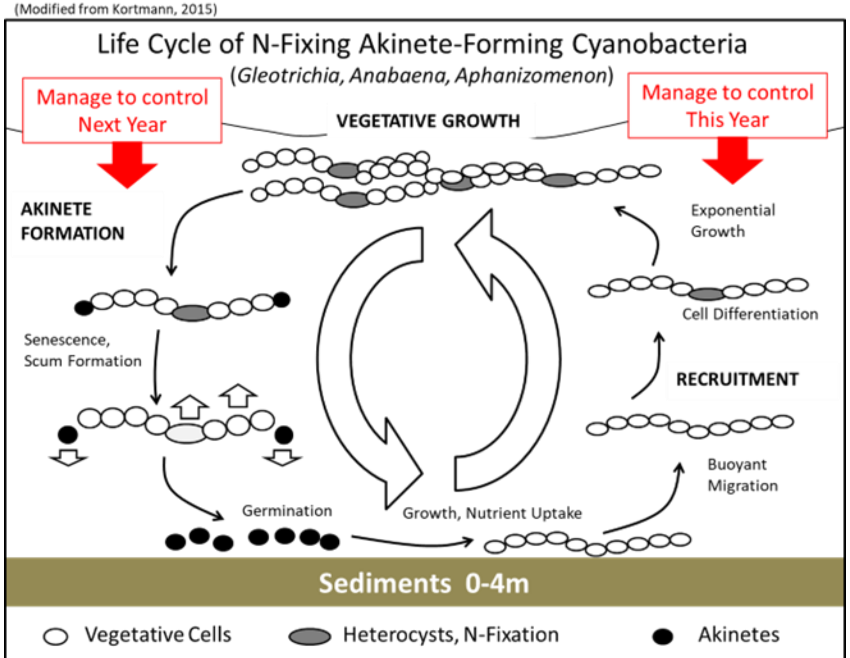
- Cyanobacteria Identification and Enumeration cells/ml
  - Turnaround Time, Analyst Skill Dependent
  - Total Cyanobacteria is what Health Departments Use (also Visual, Secchi, etc.)
  - Patchy Distribution, Especially Wind-drift Accumulations

- Fluorimetry for Phycocyanin (PC), (Chlorophyll, Phycoerythrin)
  - Correlation between Cells/ml and Phycocyanin (improves with Biovolume Estimates)
    - Immediate PC Reading estimates Cyanobacteria Density (and Risk)
    - Useful in Specific Suspect Locations (Accumulations)
  - Somewhat Specific to a Lake and its Phytoplankton Composition
    - Requires Lake-specific Data
  - Can Develop a Standard Curve Approach (Dilution Series of a Collected Concentrated Sample)

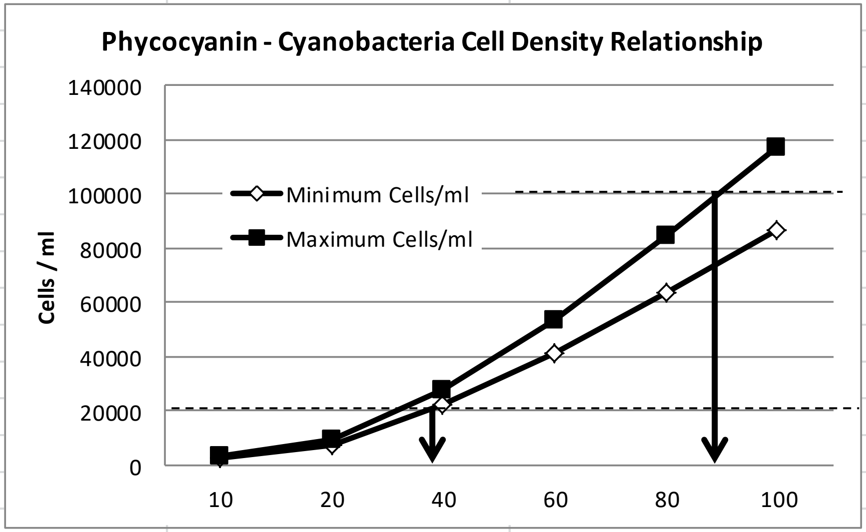
Bolton Lake PC Fluorimetry Study 2023

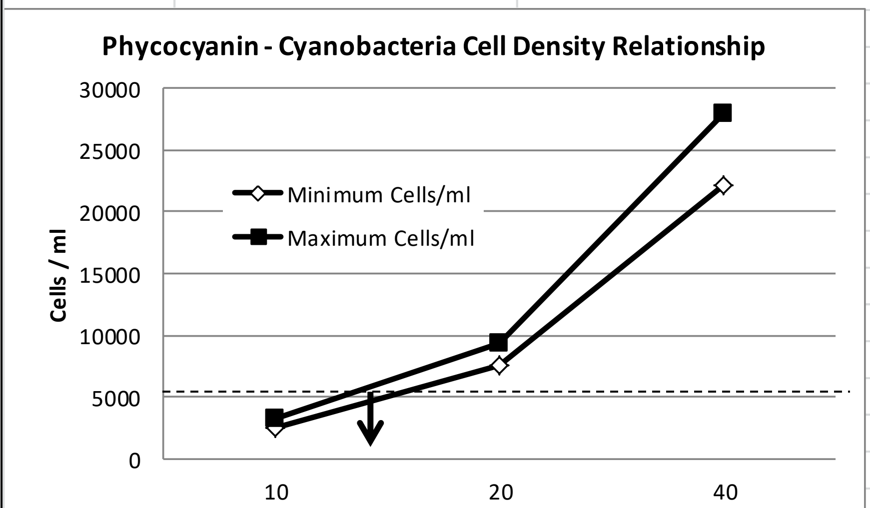


(Modified from Kortmann, 2015)



PC µg/L	Cyanobacteria Cell Densities (95% Confidence Interval)	
	Minimum Cells/ml	Maximum Cells/ml
10	2523	3222
20	7557	9377
40	22153	27887
60	41184	53237
80	63760	84471
100	86691	117116





(Modified from Brient, et.al., 2008)

(More monitoring and correlations between PC and Cells/ml is needed to refine an Alert System. Best correlations for a specific lake/phytoplankton composition.)

Recreational Lakes & Reservoirs

"Caution"- Potential Developing Bloom
> 35 µg/L Phycocyanin

"Toxin Warning" – Potential Risk Exists
> 85 µg/L Phycocyanin

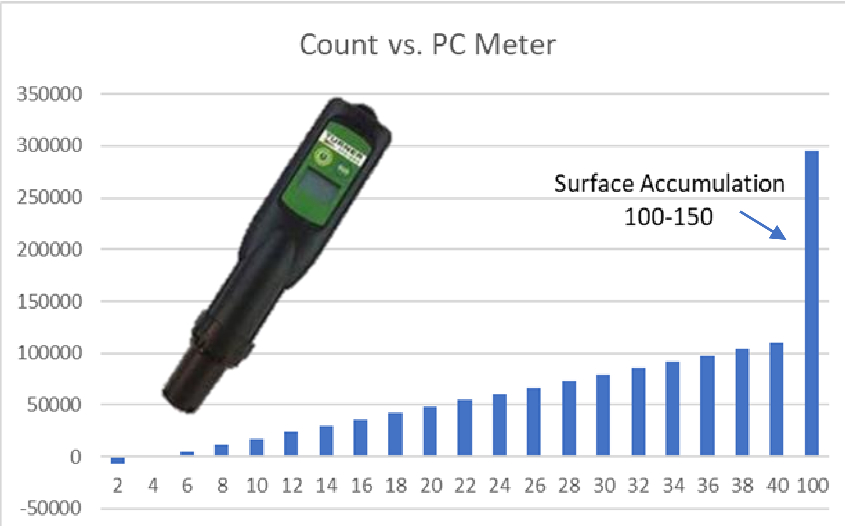
Supply Source Water Reservoirs

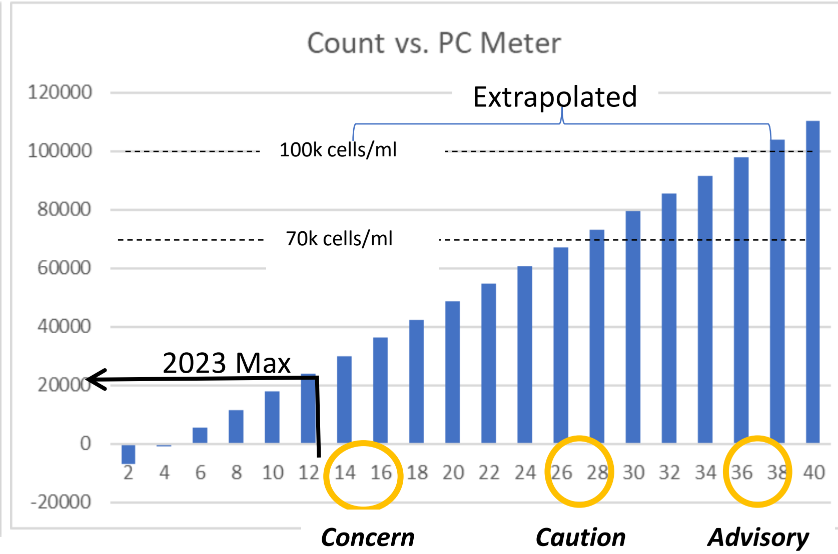
"Caution"- Potential Developing Bloom
> 15 µg/L Phycocyanin
Initiate Toxin Monitoring

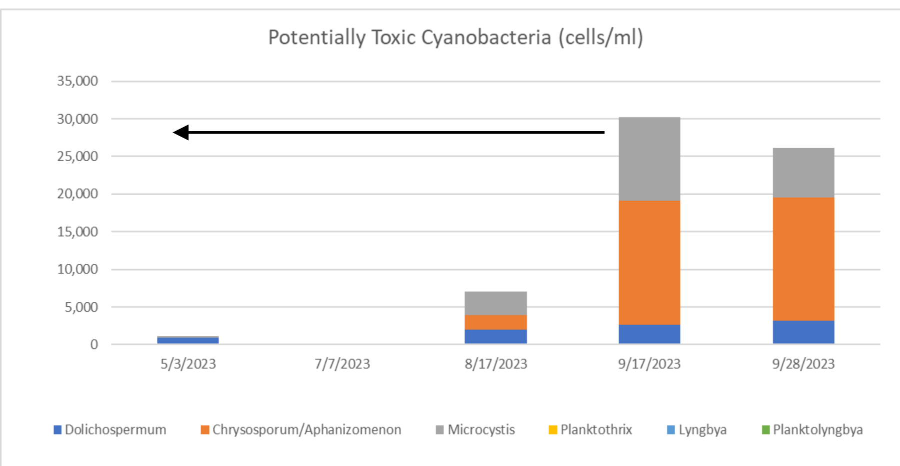
>25 µg/L Phycocyanin
Activate Bloom Response Plan

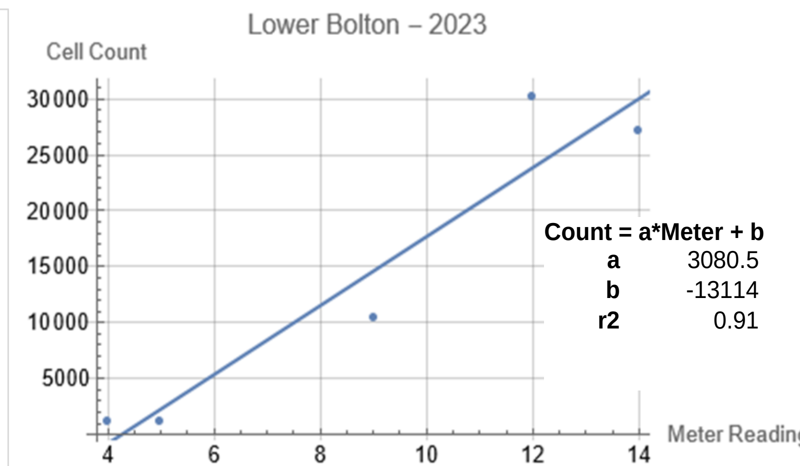
Lower Bolton Lake Preliminary Cyanobacteria to Phycocyanin Meter Reading Relationship

	5/3/2023	7/7/2023	8/17/2023	9/17/2023	9/28/2023			
Phycocyanin Meter	5	4	9	12	14			
Biovolume Toxin Producers	0.479331	0.02598	3.04832	13.070105	11.31862		correl PC:Biovolume Toxin	0.930753344
Biovolume All Cyanobacteria	0.479331	0.44166	4.49454	13.070105	11.76894		correl PC:Biovolume All	0.953811328









Hydrilla verticillata

- Grows to 25 ft long, creating dense floating mats of vegetation.
- Reproduces from fragments (one leaf whirl adequate)
- Reproduces from Turions (“Seeds”)
- Reproduces from Tubers on roots (subterranean turions, like small potatoes)

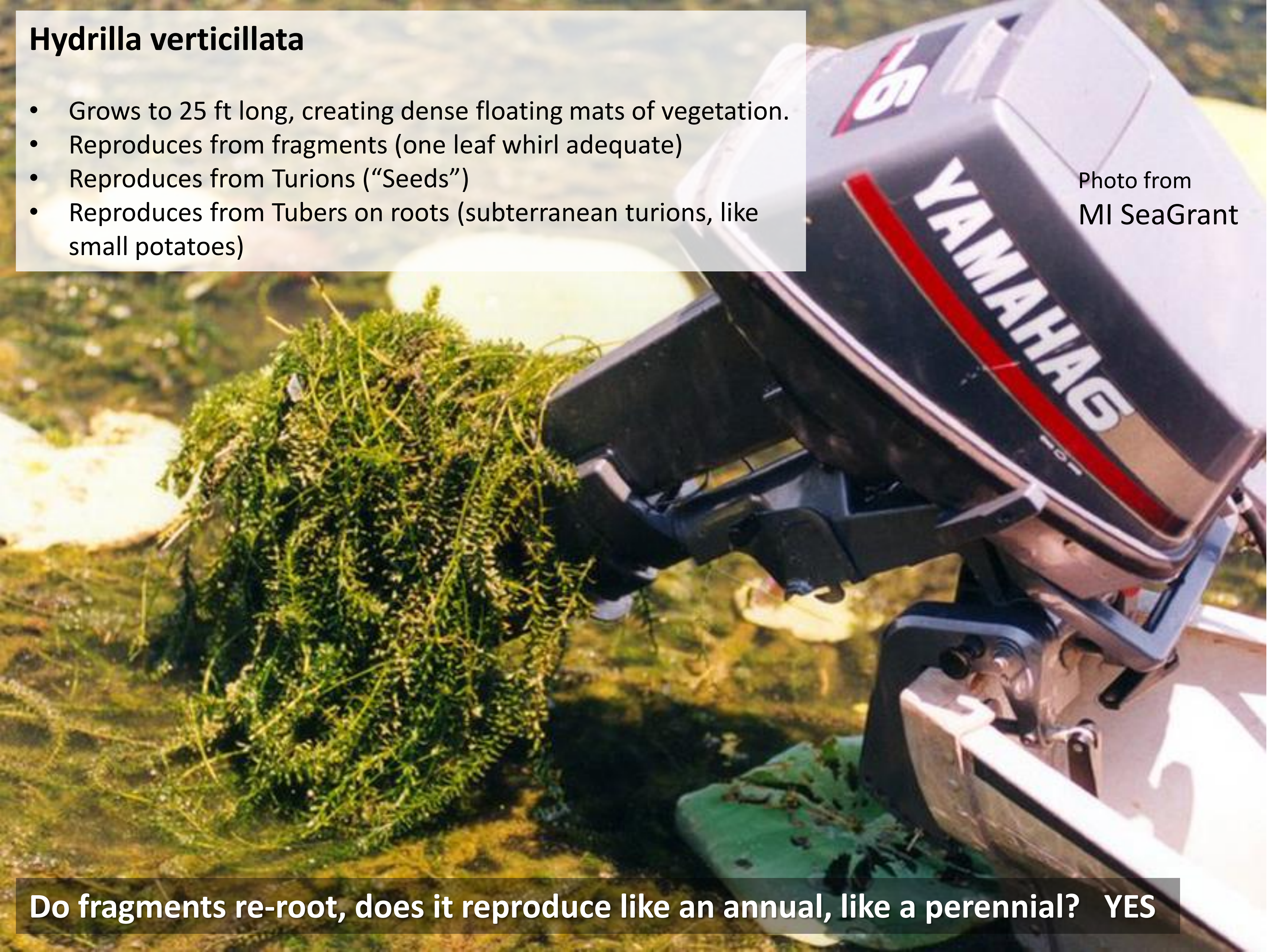
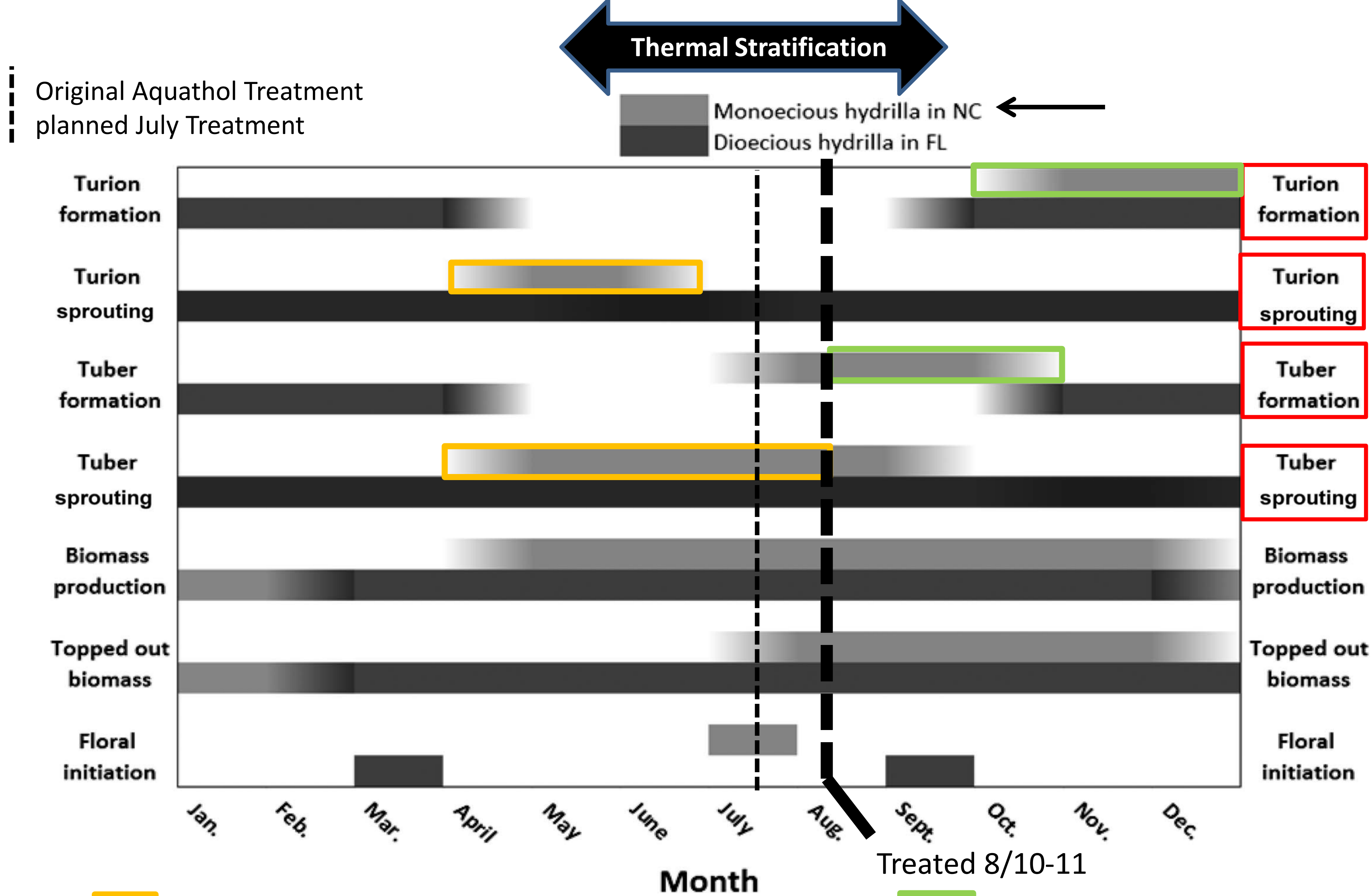


Photo from
MI SeaGrant

Do fragments re-root, does it reproduce like an annual, like a perennial? YES



Yellow box: Aquathol kills vegetative portions, desired timing is when maximum vegetation is exposed

Green box: Treatment is desired before significant production of Turions and Tubers

Further North sprouting is likely delayed, turion and tuber formation may be earlier.

Sarah True-Meadows, et. al., 2016. Monoecious hydrilla—A review of the literature, J. Aquat. Plant Manage. 54: 1–11

Hydrilla verticillata

Coventry Lake was initially area-selectively treated with Aquathol Herbicide
9-10 acres- Not Very Effective

Past Several Years Coventry Lake has been treated with Whole Lake Low-Dose Fluridone
Relatively Effective, Milfoil also controlled,

Remnant Colonies remain- Likely Additional Fluridone Treatment

Fluridone works on actively growing vegetation- doesn't affect Turions or Tubers
Tubers must germinate to be affected, hence multiple years of treatment.

Differences between Coventry Lake and Middle Bolton Lake Hydrilla:

- The strain of Hydrilla in MB Lake is that found in the Connecticut River (differs from Coventry Hydrilla)
- The MB Lake strain reportedly doesn't form Tubers (that might make Fluridone Treatment more effective)
- Will Hydrilla Spread to Lower Bolton Lake? Likely.

- USACE is actively studying what to do about Hydrilla in the CT River.
- Hydrilla has now been found in several area lakes.

Questions & Discussion

Additional Resources:

NJ DEP Harmful Algae Bloom Expert Team – Guidance:
https://dep.nj.gov/wp-content/uploads/hab/habmanagementplan-guidancedocument2024.pdf.

A few of my Previous Publications (available as pdfs):

*Kortmann, R.W. and D.D. Henry, (1987). ***Mirrors of the Landscape: An Introduction to Lake Management.*** Conn. Institute of Water Resources, US Dept. of the Interior, Univ. of Conn., Storrs, CT. 103 pp.

*Kortmann, R.W. and P.H. Rich, (1994). ***Lake Ecosystem Energetics: The missing management link.*** Lake and Reservoir Management Journal, 8(2):77-97.

*Kortmann, R.W. (2015). ***Cyanobacteria in Reservoirs: Causes, Consequences, Controls***. New England Water Works Assoc. Journal (June 2015).

*Kortmann, R.W. and E. Cummins (2018). ***Climate Change in the Northeast: What Might It Mean to Water Quality Management?*** New England Water Works Assoc. Journal

*Kortmann, R.W. (2020). ***Layer Aeration in Reservoirs: A 35 Year Review of Principles and Practice.*** New England Water Works Assoc. Journal, September 2020.

*Kortmann, R.W. (2021). ***Managing Reservoir Stratification in a Variable Climate***. New England Water Works Assoc. Journal, March 2021.