SUSTAINABLE RESTORATION OF AN OLIGOTROPHIC WATER BODY IMPACTED BY 'CYANOHABS' AND TREE POLLEN, WHITE POND, CONCORD MASSACHUSETTS

SOURCE: Higgins Environmental Associates, Inc.
RESTORATION METHOD: PASSIVE HARVESTING, SUSTAINABLE REMOVAL AND COMPOSTING OF CYANOHABs AND TREE POLLEN USING THE A-POD TECHNOLOGY (U.S. Patent No. 10,745.879)

Project Summary

- As part of ecological restoration activities from August 2021 to December 2023 to improve the water quality of White Pond, HEA used a patented (No. 10,745.879) aquatic suspended solids harvesting and removal technology, called the A-Pod, to passively trap (harvest), concentrate and permanently remove (2022) approximately 388.5 dry to moist U.S. pounds of cyanoHAB and similar suspended solids (pollen, and fragments of leaves, pine needles and macroalgae) from White Pond.   In year 2023, HEA removed a total of 349 pounds of tree pollen (pine and oak) and pine sap flakes primarily. CyanoHABs at concentrations of concern did not occur in 2023. The A-Pod technology is a physical collection, concentration and separation process for permanently removing suspended solids in water (i.e., cyanoHABs and similar). At White Pond, the A-Pods were used in passive mode, leveraging natural water body currents to trap and remove cyanoHABs without the use of chemicals, biologic substances, or physical alterations such as dredging or covering of sediment. Removed cyanoHABs, tree pollen and similar suspended solids were biodegraded on land.

Credits:

- **Town of Concord, Natural Resources Division**: A majority of funding for work in year 2022 and 2023 was provided under contract with the Town of Concord, Massachusetts.
- **National Science Foundation (NSF):** Additional funding during years 2020-2022 for research and development (R&D) for the A-Pod Technology (U.S. Patent No. 10,745,879) at White Pond and elsewhere was provided by the National Science Foundation (NSF Grant No. 2025679). HEA has additional NSF R&D samples and results for White Pond and other water bodies but this presentation focuses on work completed under contract to the Town of Concord.

Disclaimer:

- Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation or the Town of Concord.

References and Sources

- Additional references and sources of information are provided at the end of this presentation. If not referenced on slides, information is provided by Higgins Environmental Associates, Inc. (HEA) under contracts noted in Credits.

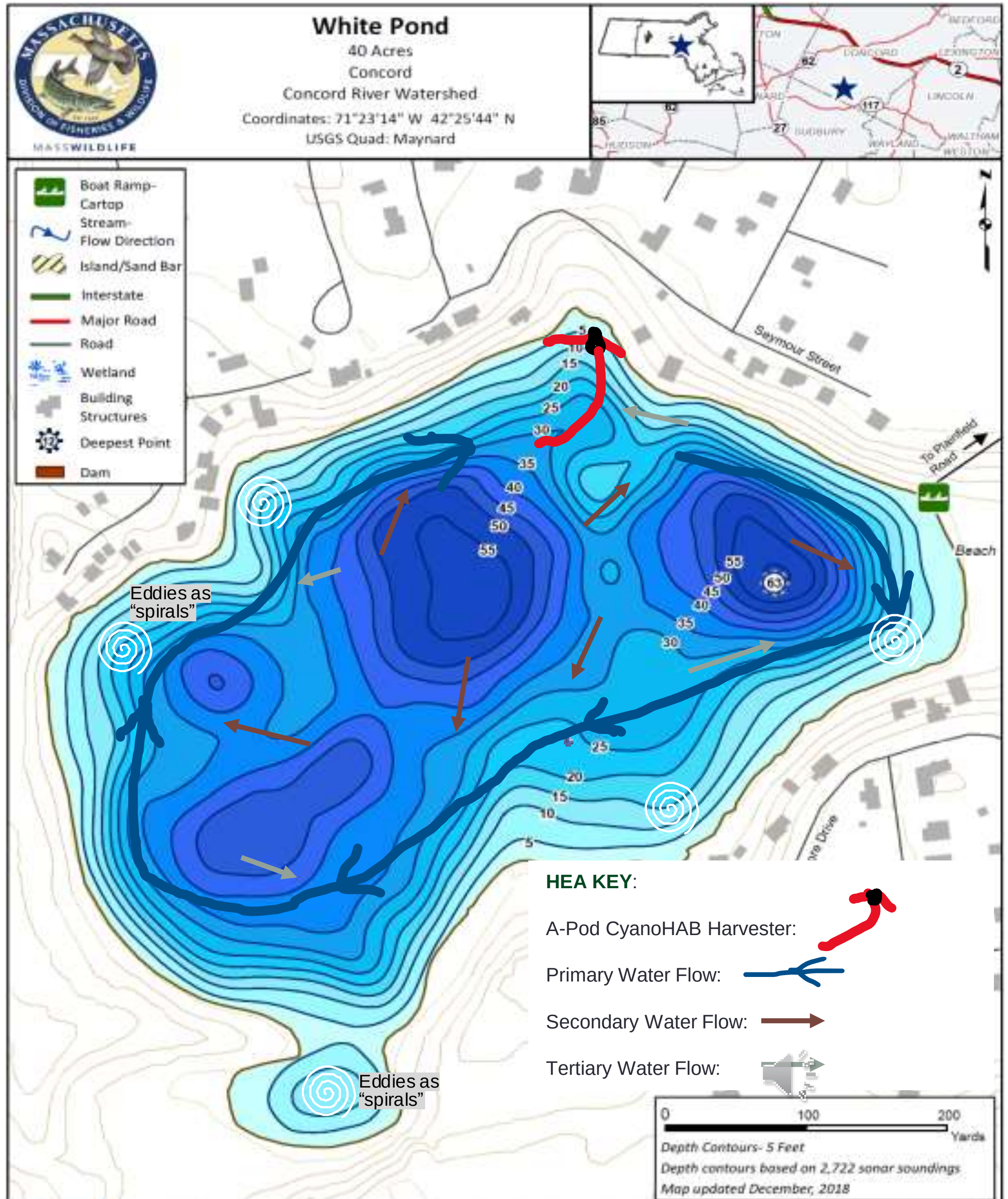
What is Passive Harvesting of CyanoHABs?

- Permanent removal and physical separation of cyanoHABs from water using A-Pods by leveraging naturally-occurring water flow and cyanoHAB characteristics ☺ Power of empirical earth sciences.

- White Pond has no surface water inlets or outlets. However, strong and sustained clockwise water currents (6-8 feet/minute; top 4 feet primarily) are created and driven by wind fetch, water incompressibility, turbulent friction and drag, bathymetry and shoreline morphology. Water current velocity decreases with depth but was measured to 10 feet below the water surface. Ekman Flow (1902) but without the Coriolis affect for small water bodies like White Pond.

- CyanoHABs, as suspended solids in water, follow vertical and lateral water flow fields i.e., they get pushed to and around the edges, dragged down to the center, then pulled and pushed up again, and repeat, in addition to their own diel vertical migration and separation forces. - includes Coulombs Law, centripetal force and Tea Leaf Paradox flow patterns solved by Einstein (1926).

- HEA mapped these natural water and cyanoHAB flow field patterns with hydrological drogues set and tracked on transects across the pond and at different depths (2, 4 and 10 feet) and times of the year.



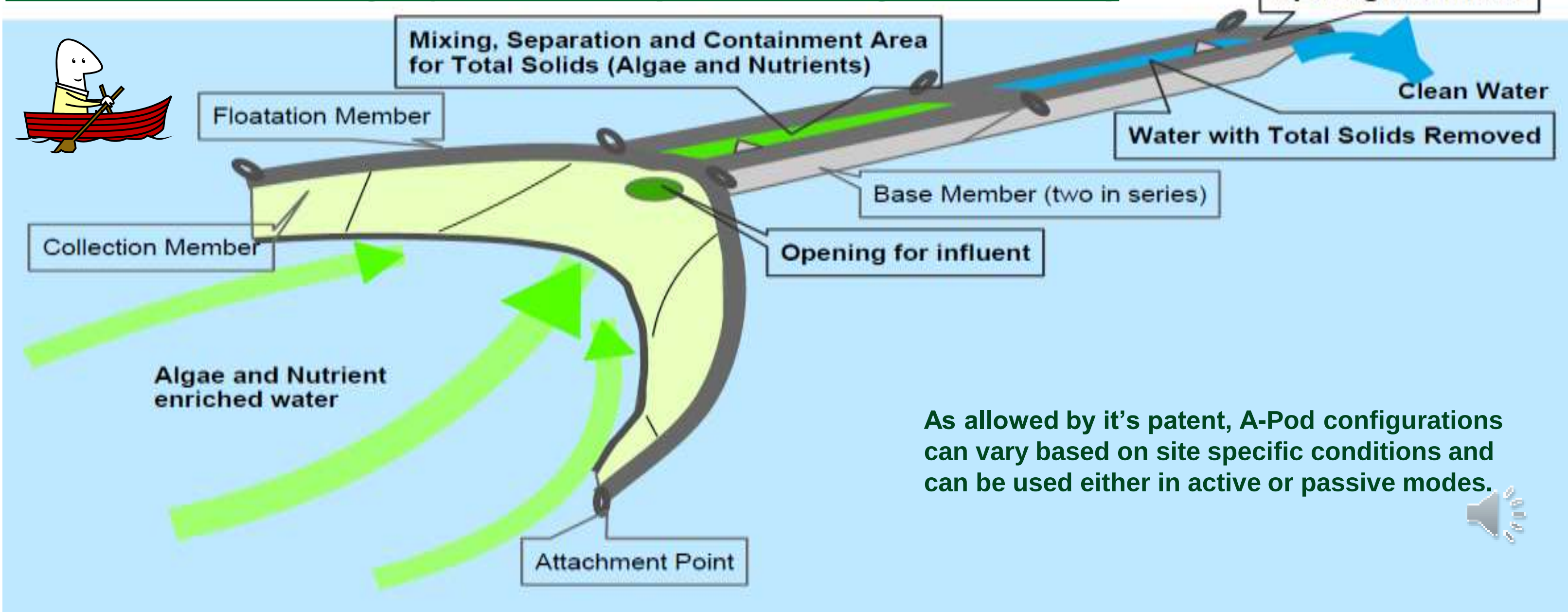
Summary of the A-Pod Technology

- A-Pods float on water, targets, concentrates and traps suspended cyanoHABs and solids for permanent removal from a water body. Fully scalable and not dependent on heavy infrastructure or related disturbance.

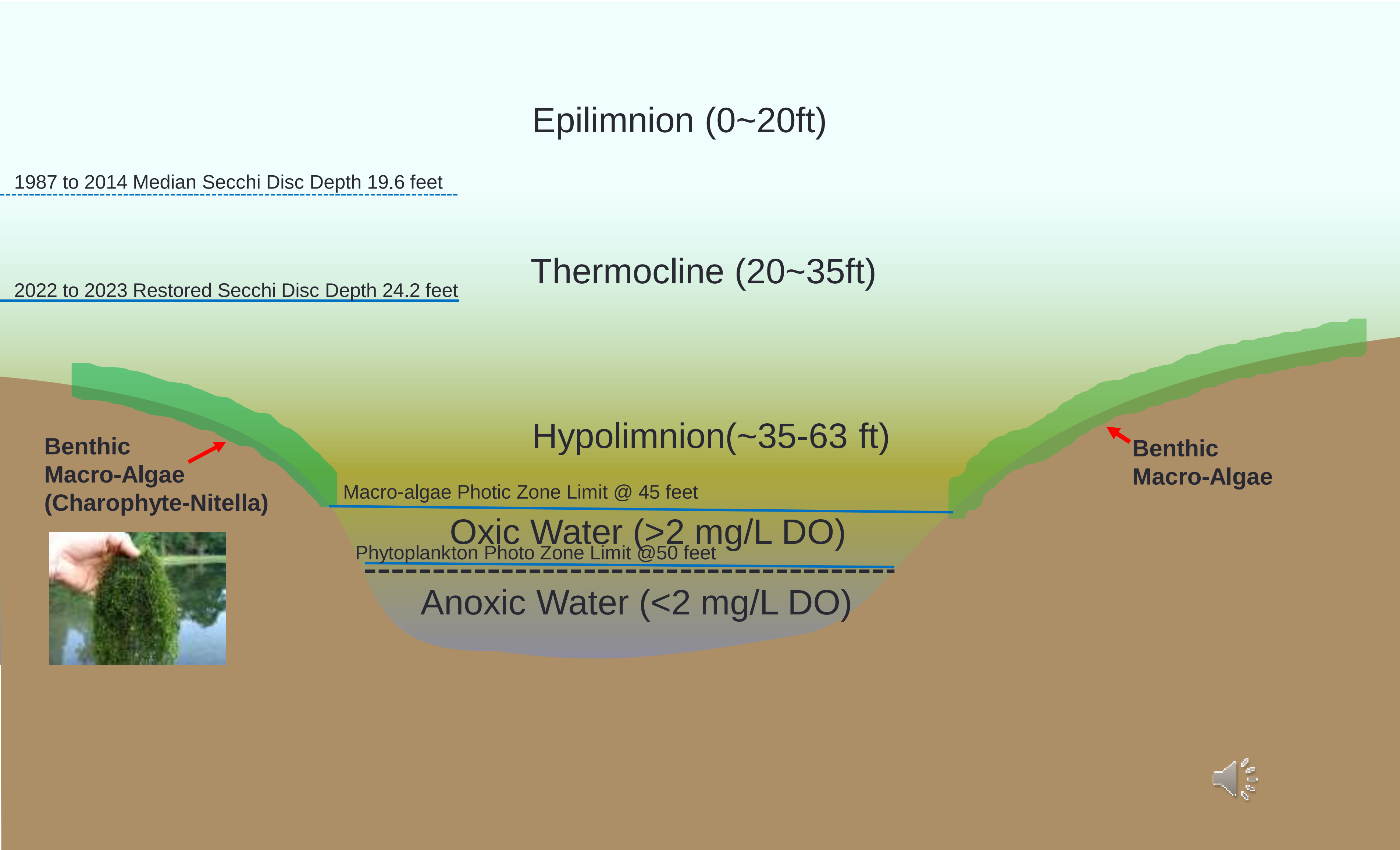
- A-Pods actually work with the cyanoHABs to quickly gather and remove excess nutrients from fresh, estuarine and marine waters and sediment. CyanoHABs are the A-Pod's "eco-miners" and they have evolved over billions of years to gather and retain available nutrients.

- Rapid deployment and efficient at controlling and preventing health and environmental risks posed by cyanoHABs and external nutrient loading sources such as tree pollen.

A-POD Removing CyanoHABs (Harmful Algae Blooms)



Schematic of White Pond, Concord, MA



Simplified Figure for Illustrative Purposes Only

Summary of Year 2023

- Microcystis/Dolichospermum only detected at low concentrations in whole lake water or beach monitoring concentrations in June to early July – Microcystis was documented to be colonizing on tree pollen in the pond. As such, tree pollen was removed from the pond using the A-Pod technology. There were no cyanoHAB-related water use restrictions in year 2023.

- In 2023, the A-Pod passively trapped and removed 349 moist US pounds of mostly tree pollen (oak and pine) and similar suspended solids (pine sap flakes, pine needles, oak tree “catkins”).

- 2023 water clarity median of 24.2 feet; same as 2022. This remains above the historic 30 year (1987-2017) median of 19.6 feet.

- Surface water total phosphorus <10 ug/l above 50 feet in September 2023.

- High abundance and diversity of Phytoplankton and Zooplankton.

- Biogeochemical conditions support phosphorus sedimentation under even anoxic conditions. Dissolved oxygen content increased with depth versus past 50 years (since 1972).

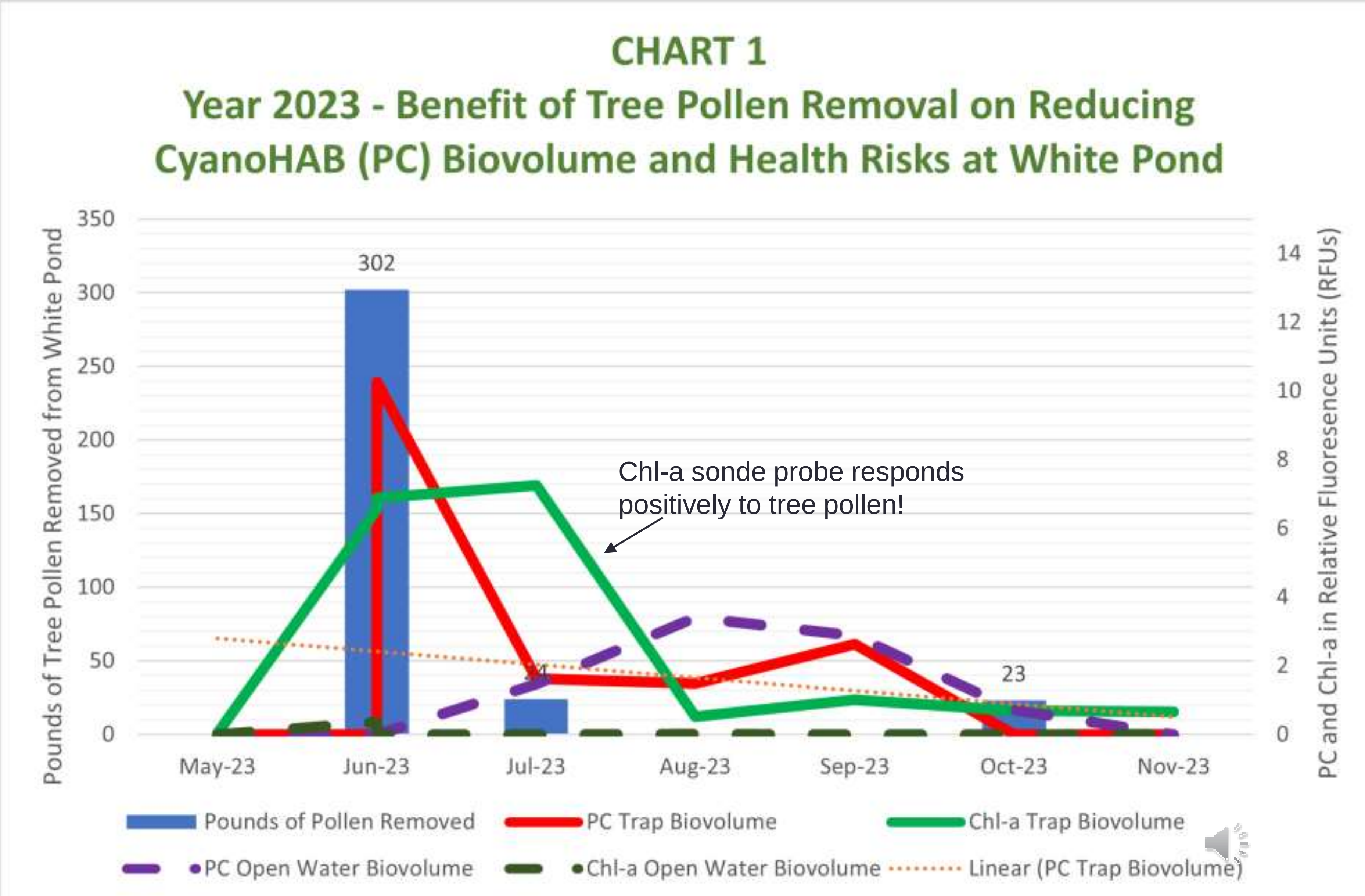
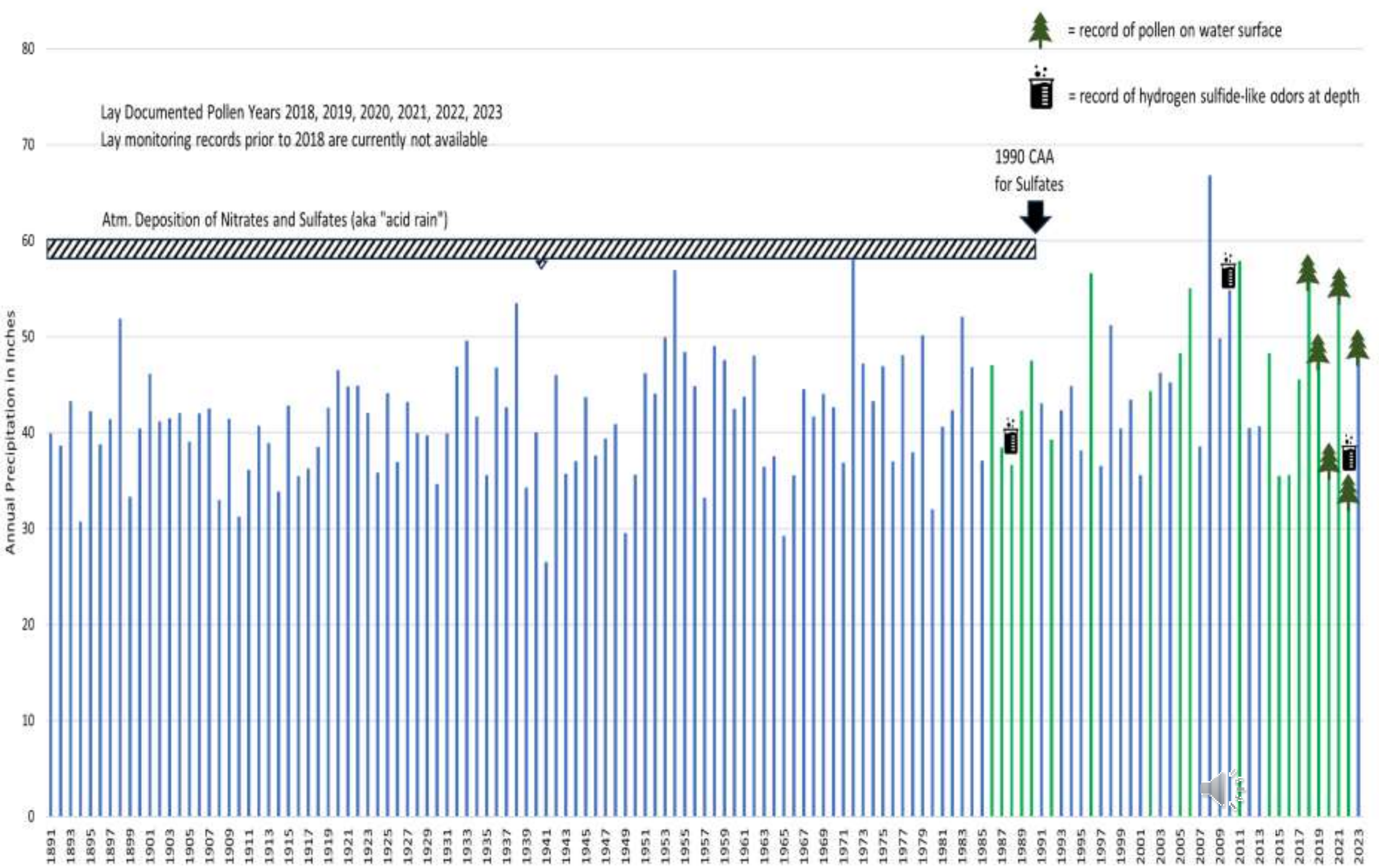


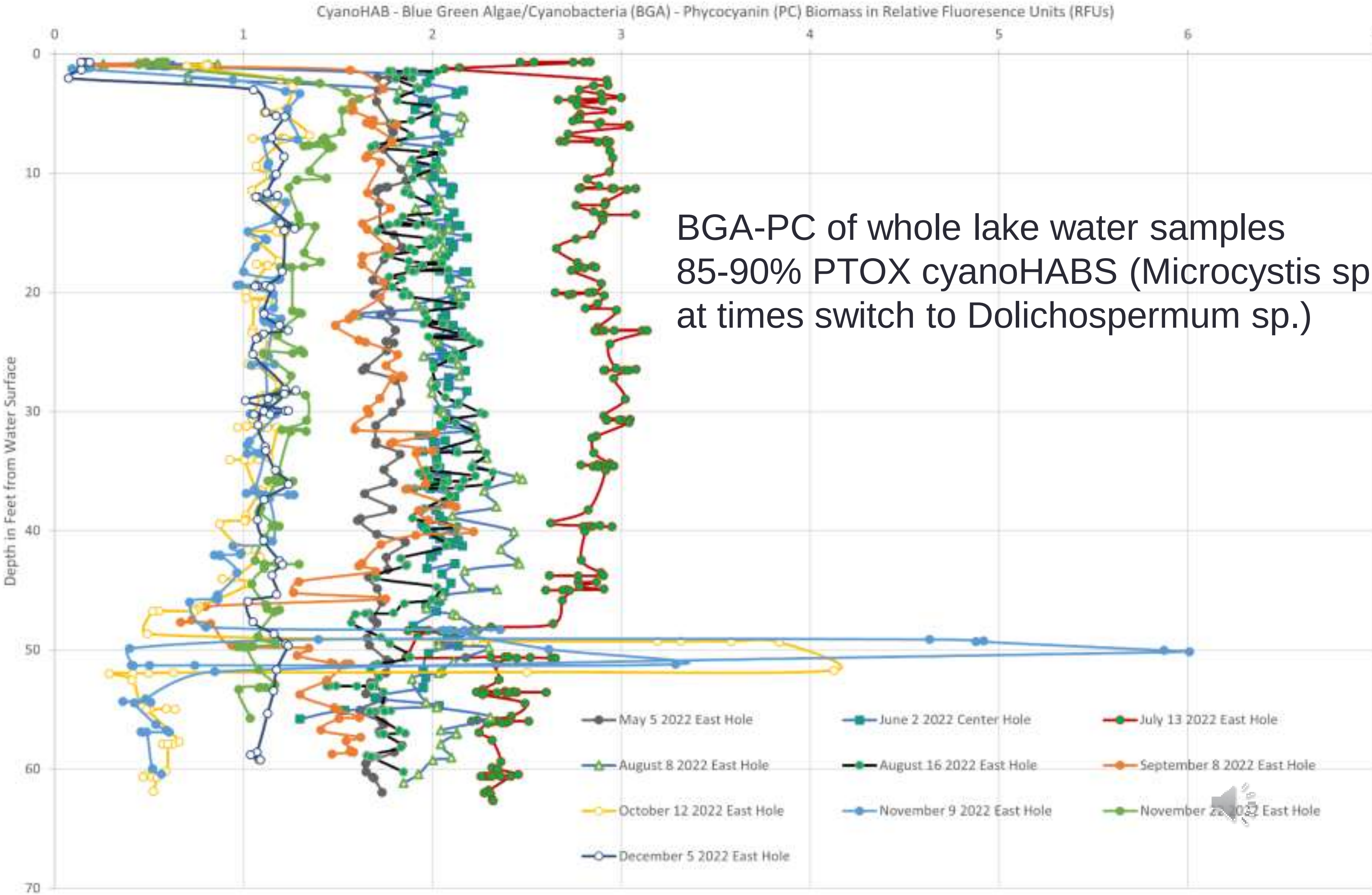
CHART 1
Year 2023 - Benefit of Tree Pollen Removal on Reducing CyanoHAB (PC) Biovolume and Health Risks at White Pond
Pounds of Tree Pollen Removed from White Pond
PC and Chl-a in Relative Fluoresence Units (RFUs)
350
300
250
200
150
100
50
0
14
12
10
8
6
4
2
0
302
23
Chl-a sonde probe responds positively to tree pollen!
May-23
Jun-23
Jul-23
Aug-23
Sep-23
Oct-23
Nov-23
Pounds of Pollen Removed
PC Trap Biovolume
Chl-a Trap Biovolume
PC Open Water Biovolume
Chl-a Open Water Biovolume
Linear (PC Trap Biovolume)

1891 to 2023 Annual Precipitation (inches); Pollen Years and CyanoHAB Bloom Events (in green)



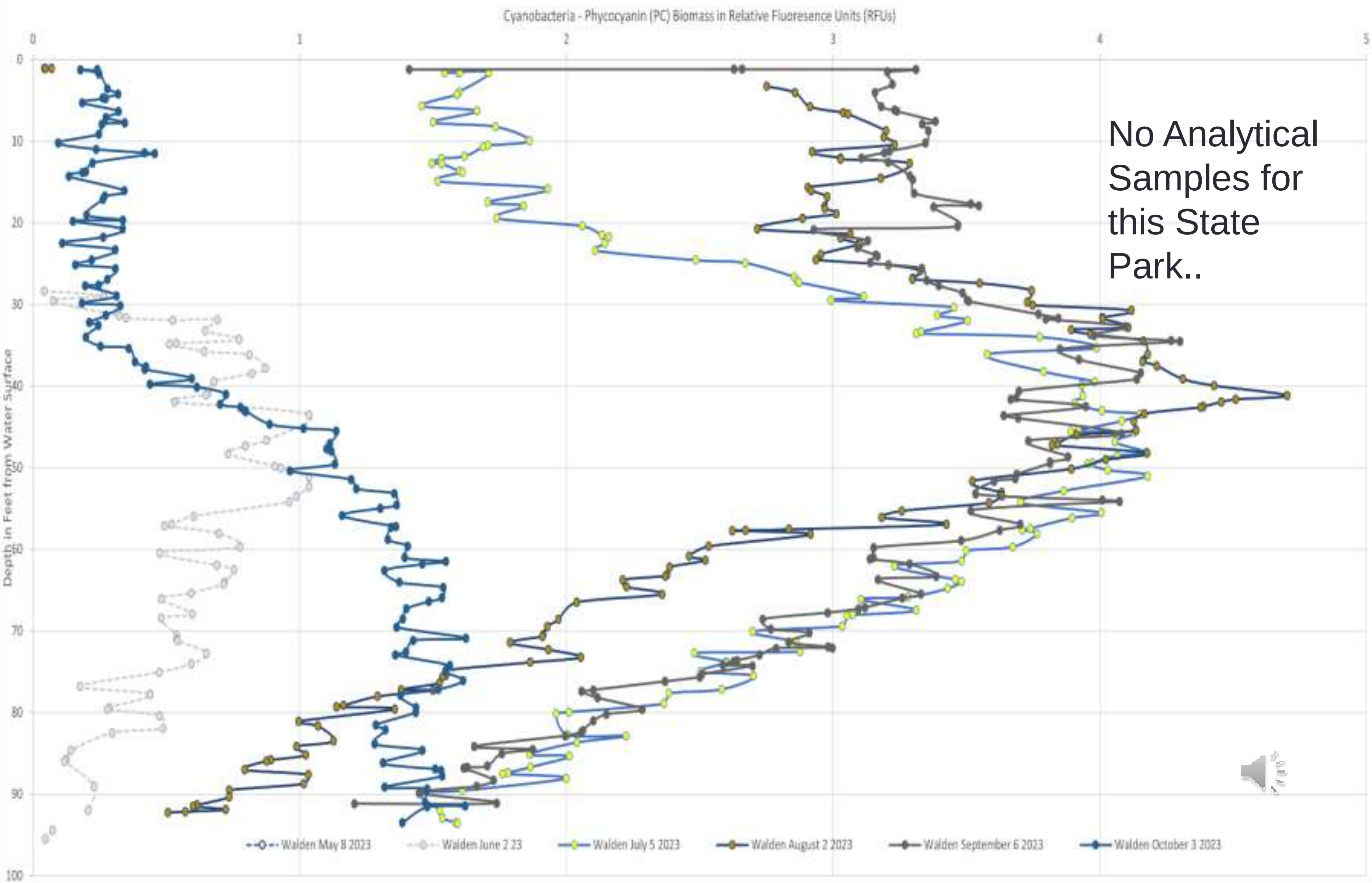
Sources: https://www.mass.gov/info-details/precipitation-data#precipitation-database
https://www.ncdc.noaa.gov/cdo-web/search Walker W.W. (2015) and Lay Monitoring data records

CHART 4
Year 2022 Monthly White Pond CyanoHAB Population Variance

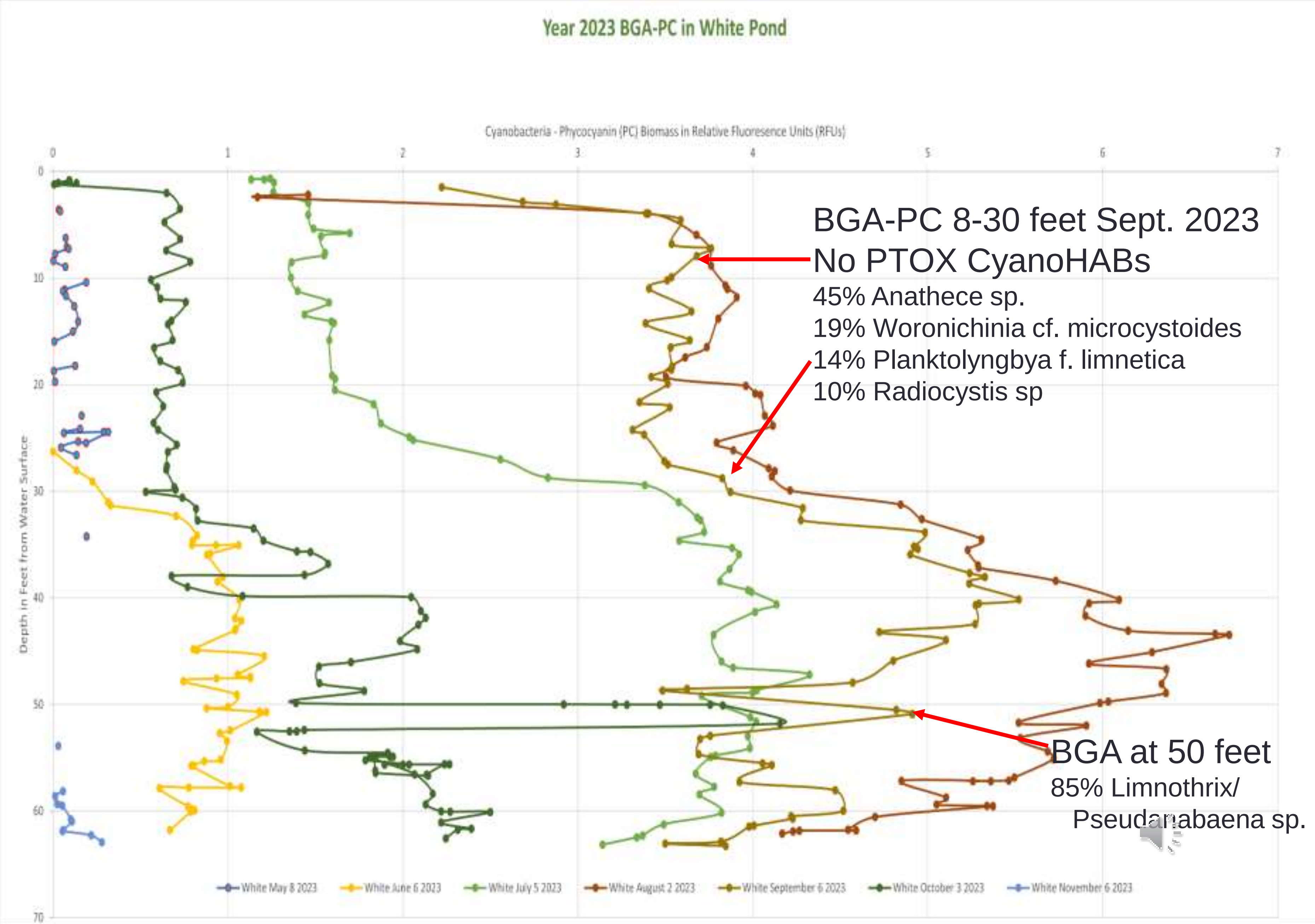


BGA-PC of whole lake water samples
85-90% PTOX cyanoHABS (Microcystis sp.
at times switch to Dolichospermum sp.)

Year 2023 BGA-PC in Walden Pond

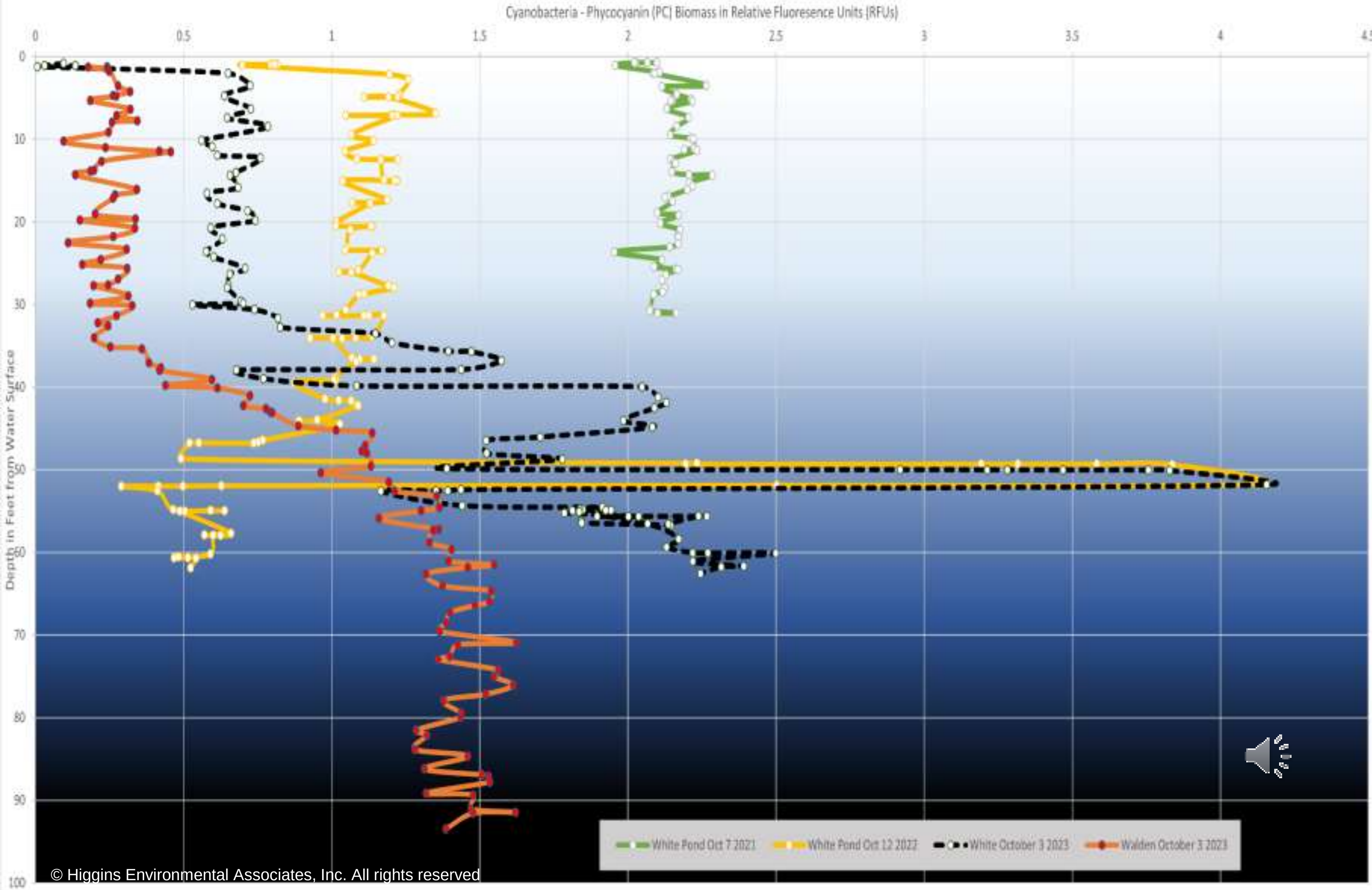


No Analytical Samples for this State Park..

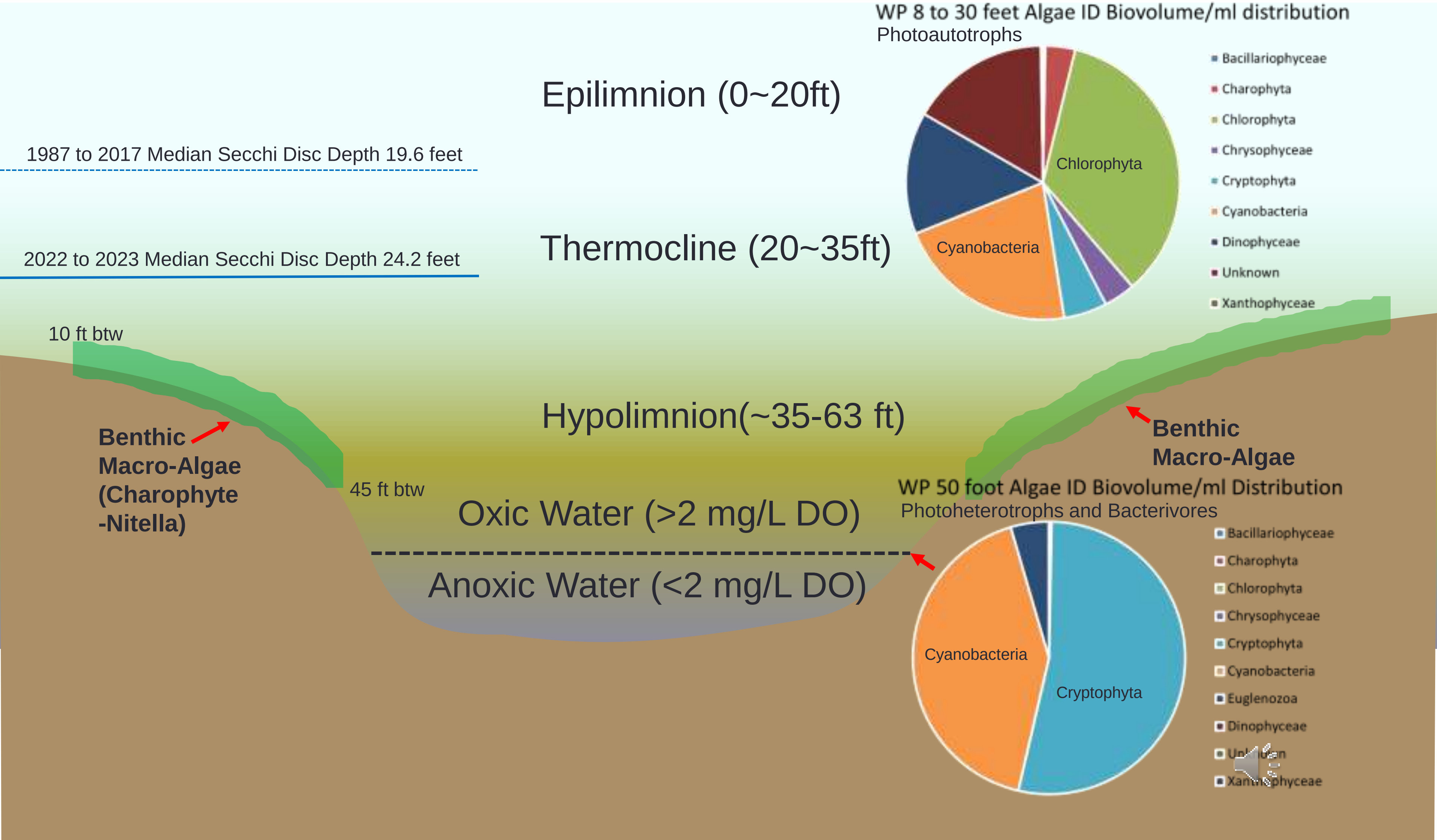


Year 2023 BGA-PC in White Pond
Cyanobacteria - Phycocyanin (PC) Biomass in Relative Fluoresence Units (RFUs)
0
1
2
3
4
5
6
7
Depth in Feet from Water Surface
0
10
20
30
40
50
60
70
BGA-PC 8-30 feet Sept. 2023
No PTOX CyanoHABs
45% Anathece sp.
19% Woronichinia cf. microcystoides
14% Planktolyngbya f. limnetica
10% Radiocystis sp
BGA at 50 feet
85% Limnothrix/
Pseudanabaena sp.
White May 8 2023
White June 6 2023
White July 5 2023
White August 2 2023
White September 6 2023
White October 3 2023
White November 6 2023

October Years 2021, 2022 and 2023 BGA-PC in Walden and White Ponds



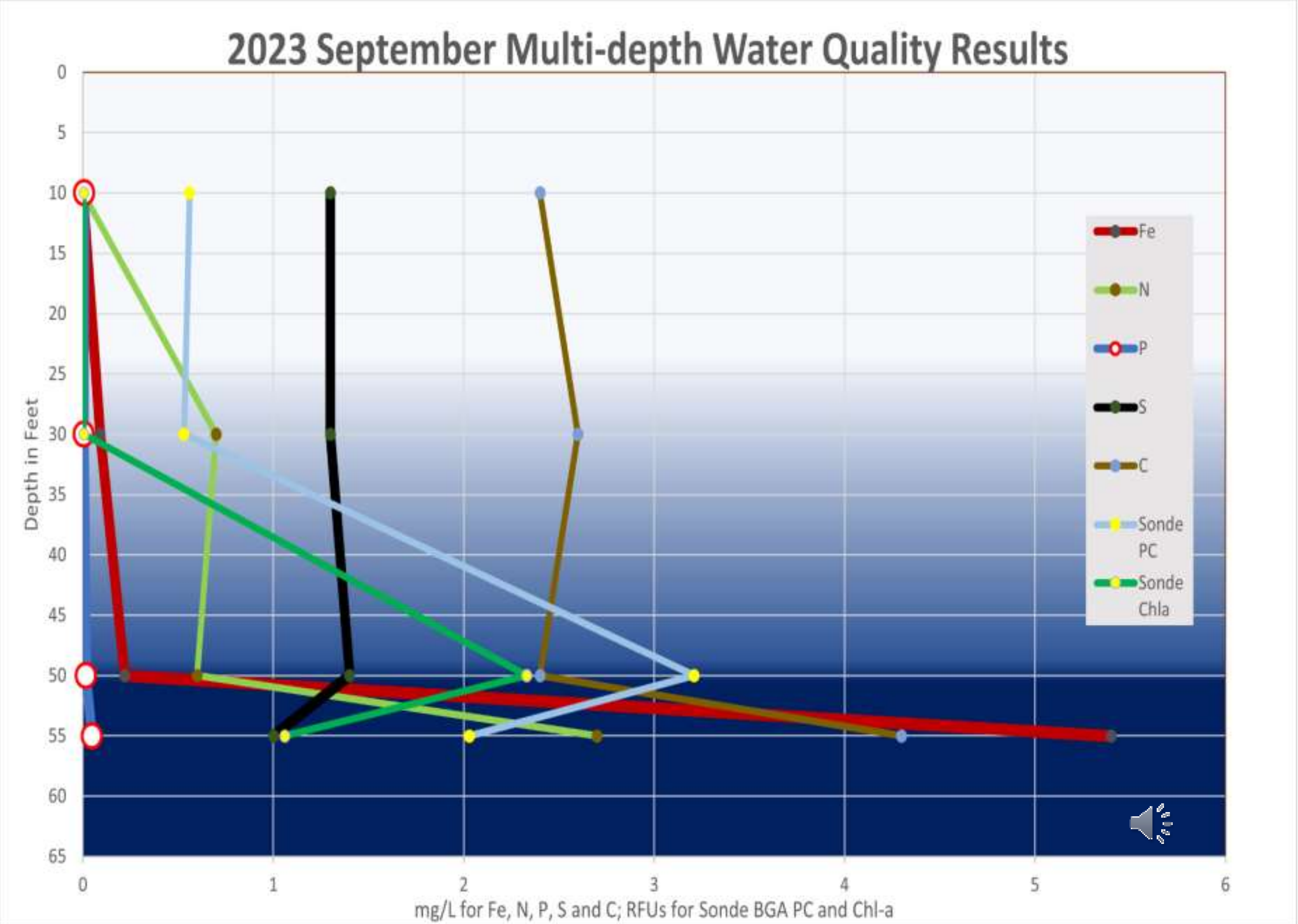
Diversity of Phytoplankton September 2023

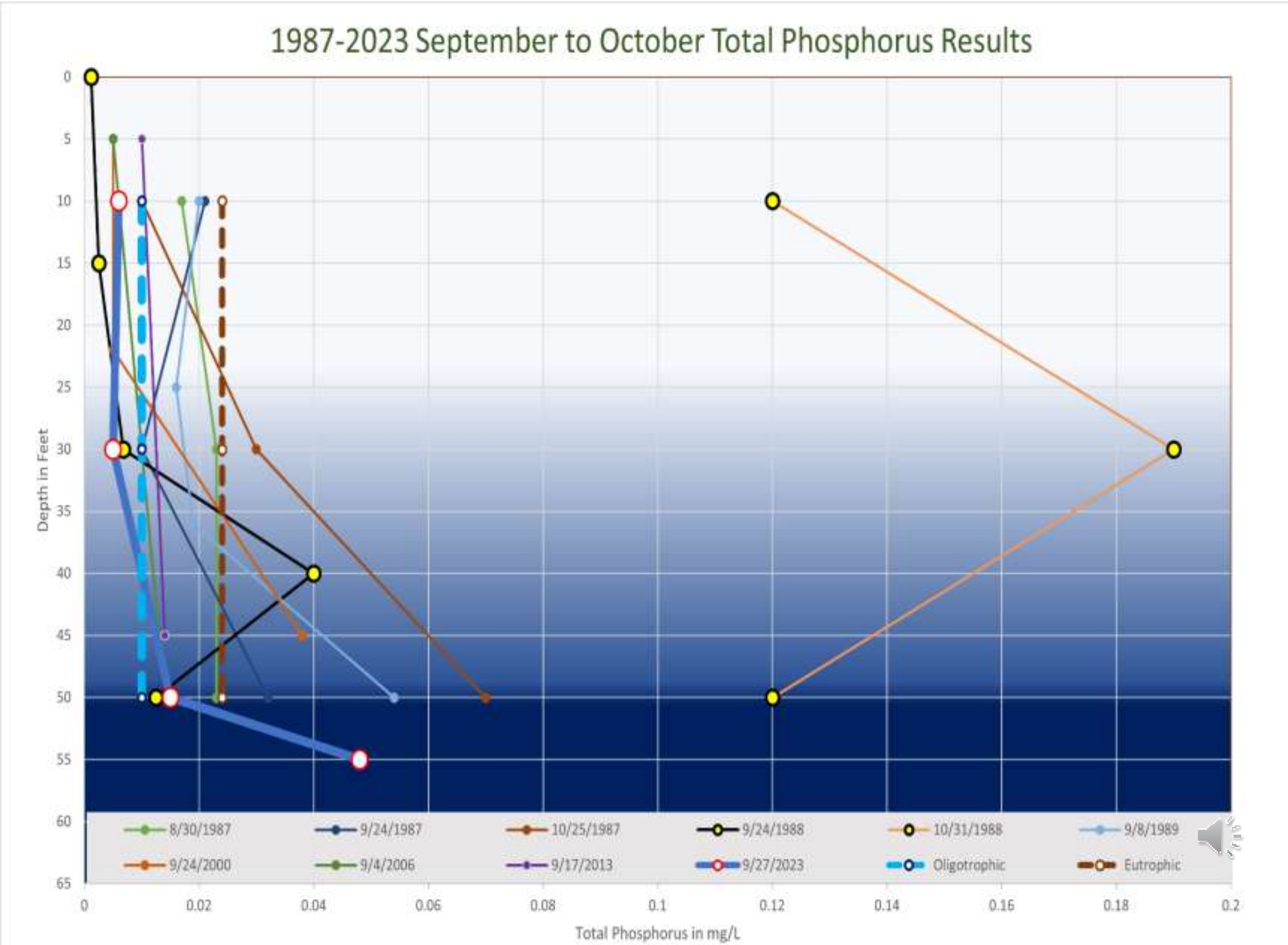


Simplified Figure for Illustrative Purposes Only

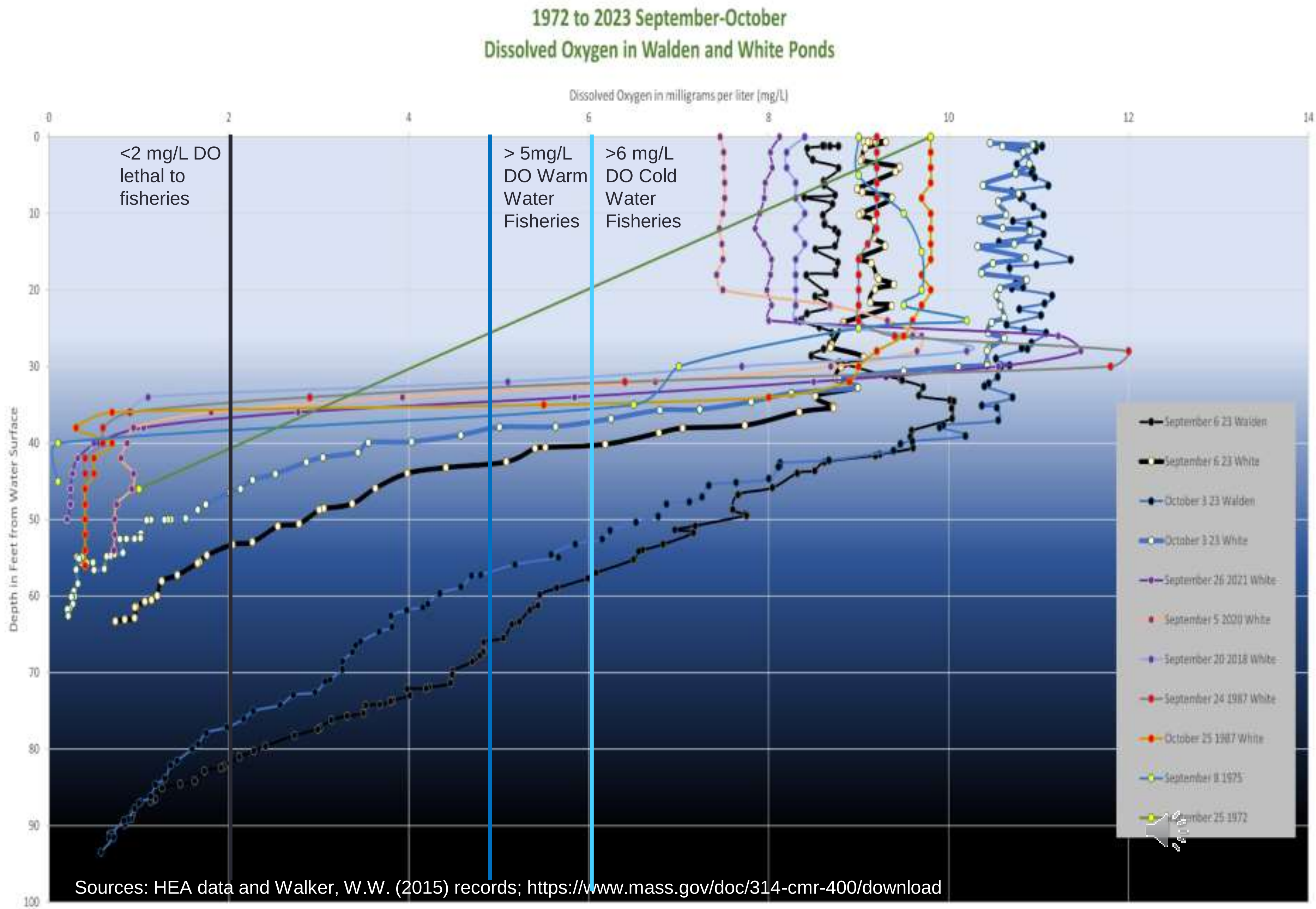
September 2023 Water Samples

Left to Right illustrations of Chl-a-rich seston degradation – an indicator of healthy biologic integrity (i.e., biological production = consumption within the water column). Water samples also visually and by lab analysis document an increase in iron content with depth which helps to bind and export phosphorus by sedimentation.


2023 September Multi-depth Water Quality Results
Depth in Feet
0
5
10
15
20
25
30
35
40
45
50
55
60
65
0
1
2
3
4
5
6
mg/L for Fe, N, P, S and C; RFUs for Sonde BGA PC and Chl-a
Fe
N
P
S
C
Sonde PC
Sonde Chla

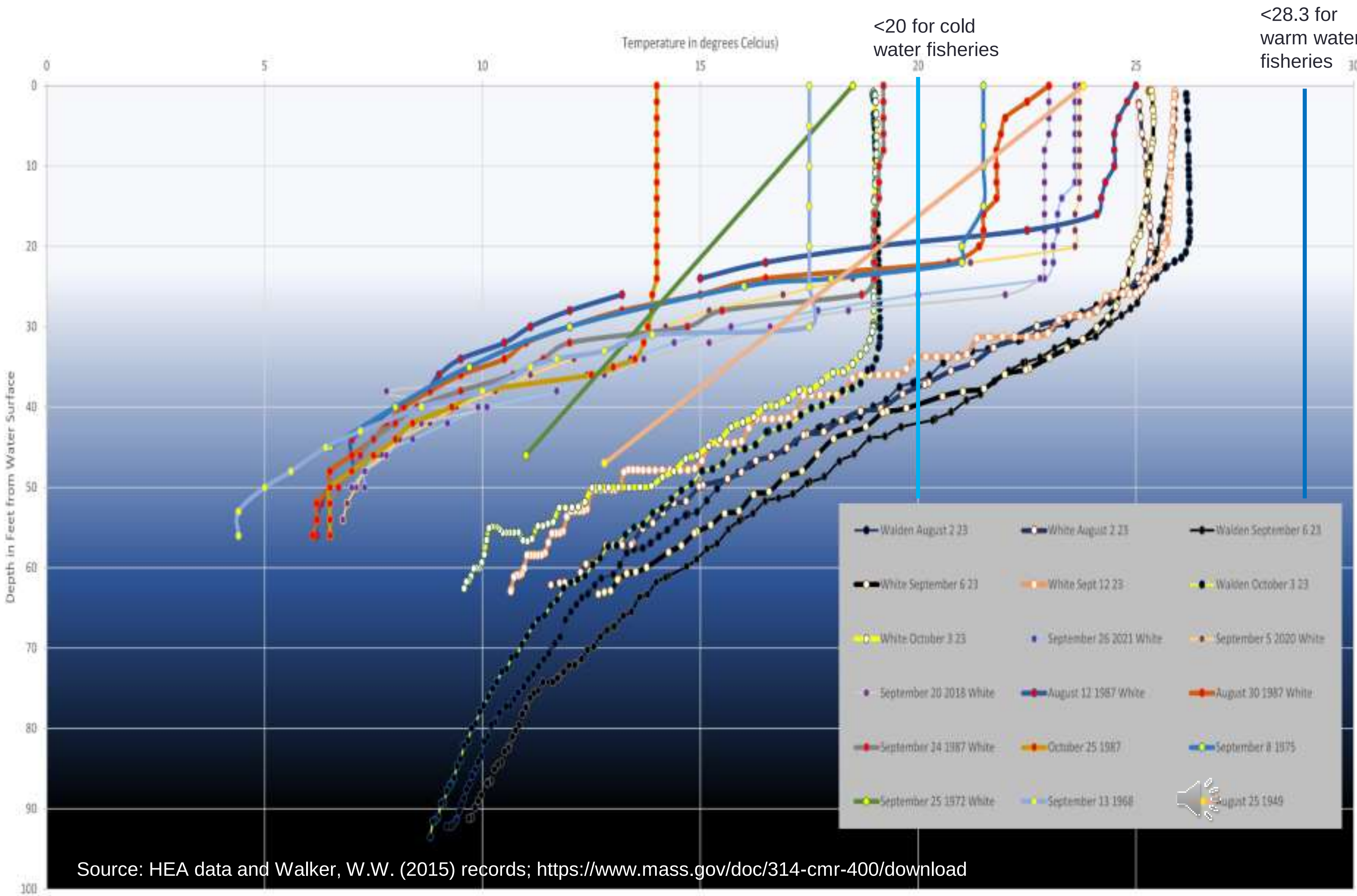


1987-2023 September to October Total Phosphorus Results
Depth in Feet
Total Phosphorus in mg/L
0
5
10
15
20
25
30
35
40
45
50
55
60
65
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
8/30/1987
9/24/1987
10/25/1987
9/24/1988
10/31/1988
9/8/1989
9/24/2000
9/4/2006
9/17/2013
9/27/2023
Oligotrophic
Eutrophic



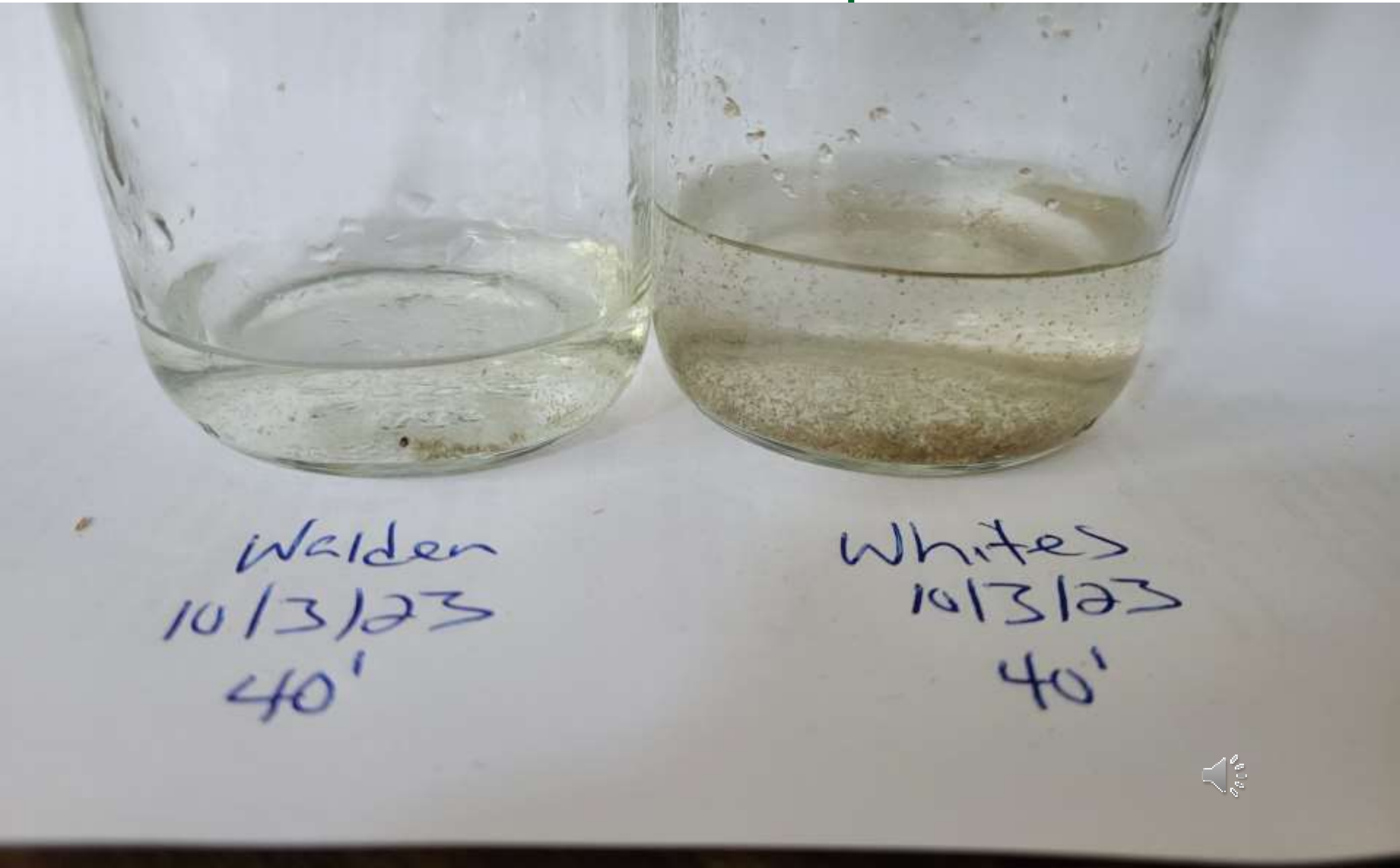
1972 to 2023 September-October
Dissolved Oxygen in Walden and White Ponds
Dissolved Oxygen in milligrams per liter (mg/L)
0
2
4
6
8
10
12
14
Depth in Feet from Water Surface
0
10
20
30
40
50
60
70
80
90
100
<2 mg/L DO lethal to fisheries
> 5mg/L DO Warm Water Fisheries
>6 mg/L DO Cold Water Fisheries
September 6 23 Walden
September 6 23 White
October 3 23 Walden
October 3 23 White
September 26 2021 White
September 5 2020 White
September 20 2018 White
September 24 1987 White
October 25 1987 White
September 8 1975
Sources: HEA data and Walker, W.W. (2015) records; https://www.mass.gov/doc/314-cmr-400/download

1949 to 2023 August to October Water Temperature in Walden and White Ponds

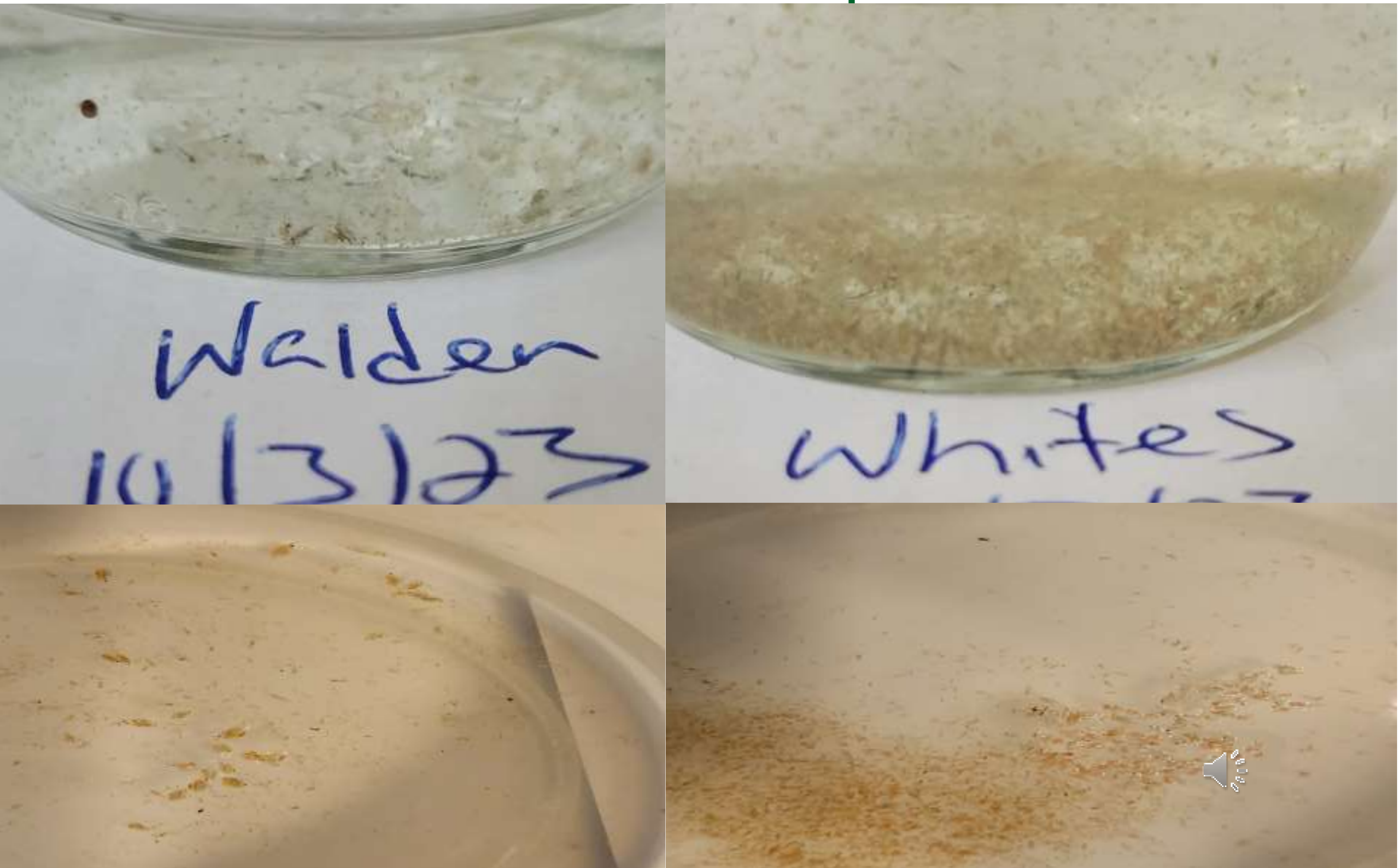


Source: HEA data and Walker, W.W. (2015) records; https://www.mass.gov/doc/314-cmr-400/download

Walden and White Zooplankton Tow



Walden and White Zooplankton Tow



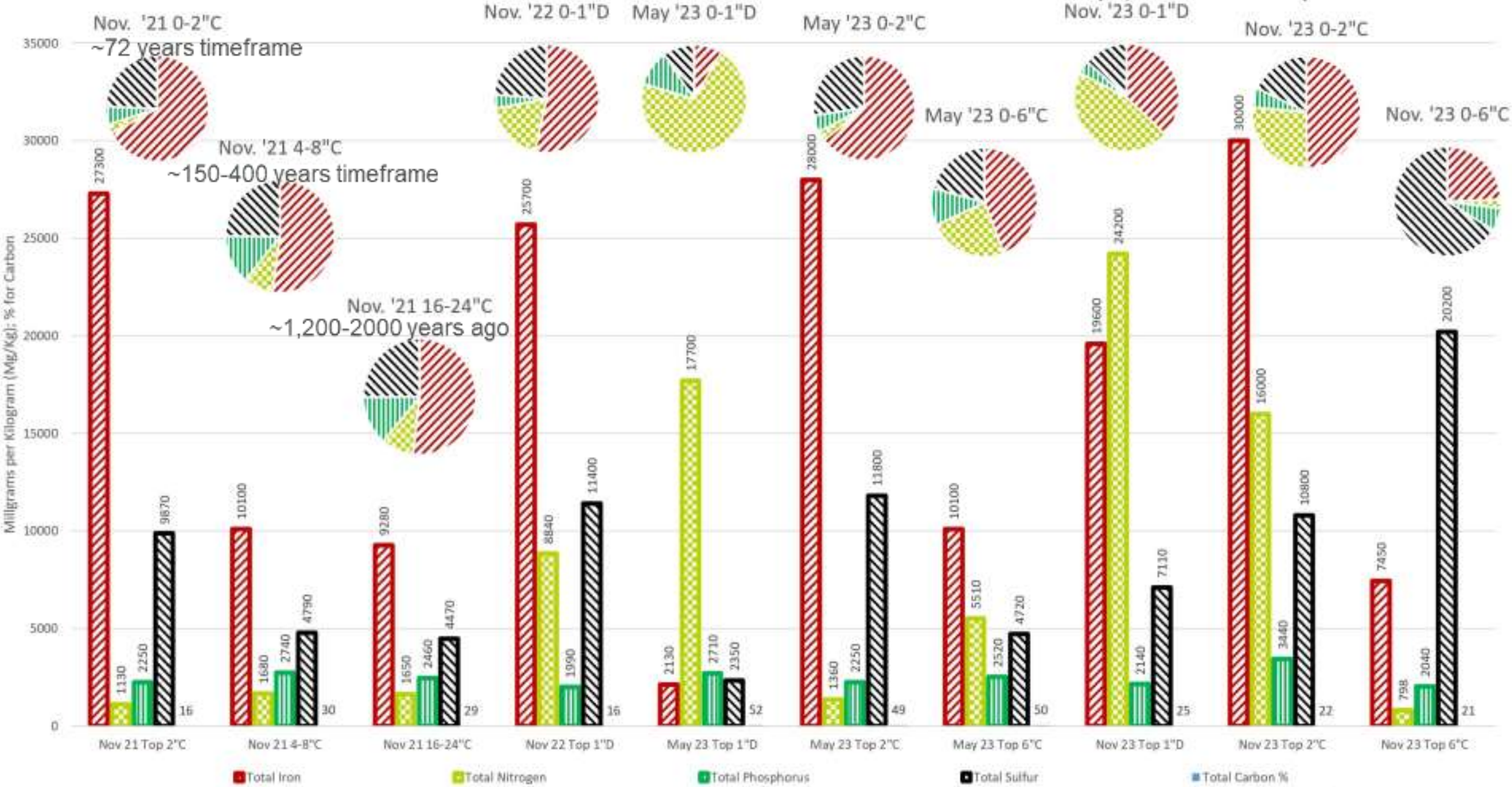
2023 Sediment Core Sample with minor Sulfide

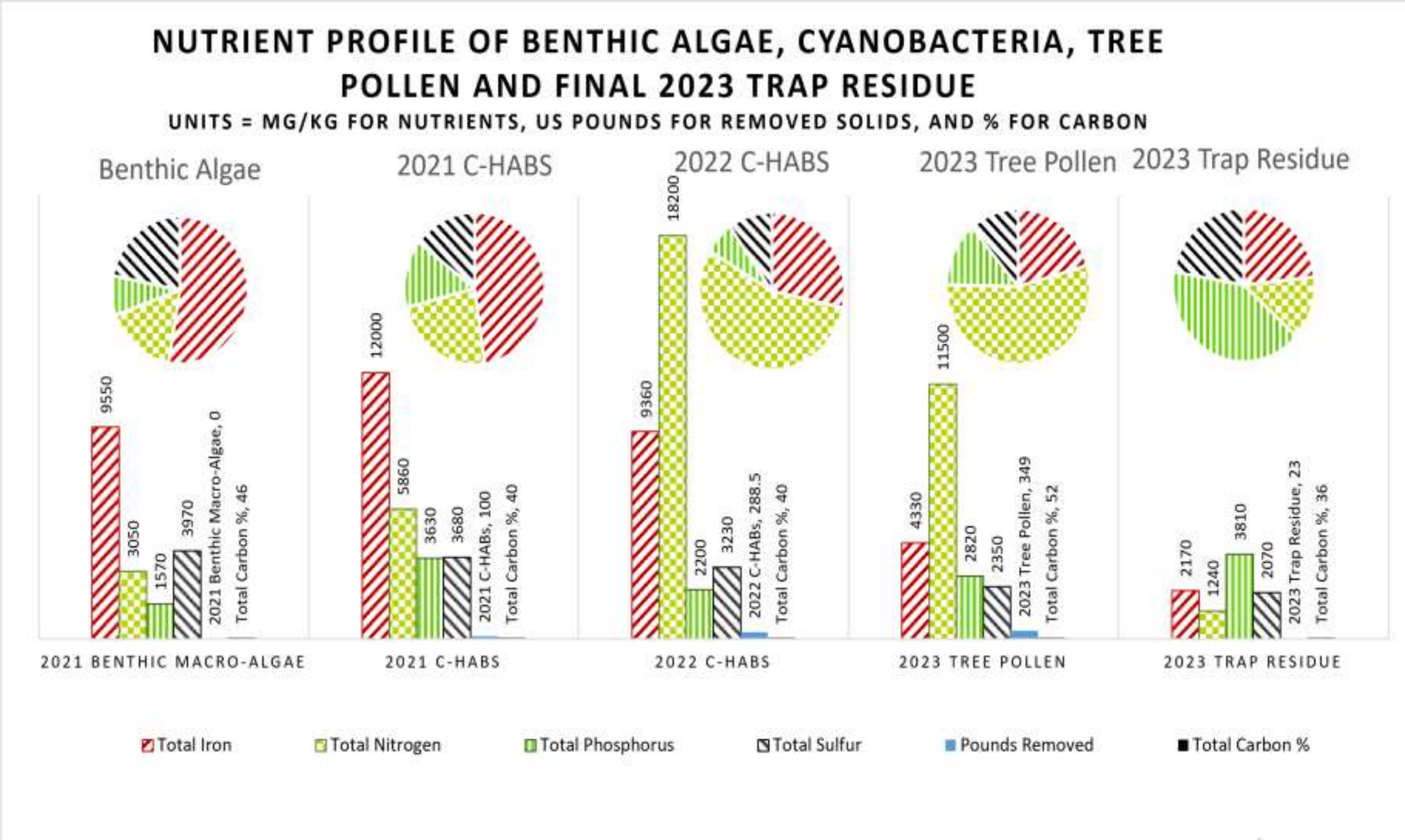
Based on radiocarbon dating: Top 6 inches deposited at @ 1 inch/36 years. After 6 inches its about 1”/100 years. There is only about 2 feet or 2,000 years of soft sediment accumulation in White Pond.

Brown color = oxidized deposition. Black solids interpreted as ferrous sulfide (FeS).

Nutrient Profile of Profundal Sediments 2012-2023

"C" = core sample; "D" = discrete sample





NUTRIENT PROFILE OF BENTHIC ALGAE, CYANOBACTERIA, TREE POLLEN AND FINAL 2023 TRAP RESIDUE
UNITS = MG/KG FOR NUTRIENTS, US POUNDS FOR REMOVED SOLIDS, AND % FOR CARBON
Benthic Algae
2021 C-HABS
2022 C-HABS
2023 Tree Pollen
2023 Trap Residue
9550
3050
1570
3970
2021 Benthic Macro-Algae, 0
Total Carbon %, 46
12000
5860
3630
3680
2021 C-HABs, 100
Total Carbon %, 40
9360
18200
2200
3230
2022 C-HABs, 288.5
Total Carbon %, 40
4330
11500
2820
2350
2023 Tree Pollen, 349
Total Carbon %, 52
2170
1240
3810
2070
2023 Trap Residue, 23
Total Carbon %, 36
2021 BENTHIC MACRO-ALGAE
2021 C-HABS
2022 C-HABS
2023 TREE POLLEN
2023 TRAP RESIDUE
Total Iron
Total Nitrogen
Total Phosphorus
Total Sulfur
Pounds Removed
Total Carbon %

White Pine (Pinus strobus) Pollen

Tree Pollen and Forest Particulates; Short-Range Atmospheric Deposition and External Loading of Terrestrial Nutrients to Water Bodies

- On June 20th we moved tree pollen with visually apparent Microcystis sp. colonization into our "C-Pod". Initial field PC BGA in the C-Pod measured at 54.75 RFUs; lab results for Microcystin toxins (MC) at 7.9 ug/L. On June 24, we sampled the same C-Pod contents again and had field PC BGA at 185.95 RFUs and lab MC at 52.9 ug/L. Results document rapid growth of Microcystis on tree pollen as a nutrient substrate. C-Pod contents and pollen removed on June 24th after sampling. In 2023, we removed 349 moist pounds of dry deposition (primarily pine tree pollen and forest particulates). In 2023, Walden Pond had less visual amounts of pine tree pollen and less pine trees in its air-shed than White Pond.

- USGS year 2001 nutrient loading calculations for Walden Pond attributed 47% (15 kg/year) of the annual external loading of P and 8.7% (75 kg/year) of N to atmospheric dry deposition of predominantly pollen. 27% of annual P loading was attributed to swimmers. (USGS, 2001).

- Oligotrophic Mirror Lake Study (NH): dry deposition (forest particulates: insects, plant parts, etc.) assessed after tree pollen season "…it represented an input of 11-13 umol P m^{-2} d^{-1} of lake surface. The input of P from atmospheric fallout was highly significant to the summer P economy of the lake and was 50- to 70-fold greater than the input of P from stream flow or rainfall in the same period" (Cole, et al, 1990).

- Pollen production since 1990 has increased by 21% per day and the number of pollen days has increased by 20 days/year due to climate change (temperature and CO2 increases). (Aderegg, et al, 2021) Tree pollen also occurs early in our otherwise low nutrient, clear-water (May to June) time for water bodies. Annual frequency and aerial extent of tree pollen production also increasing.

Final (partial) Thoughts

- Sustainable = Restoring and maintaining the naturally inherent biologic integrity of a water body.

- Biologic Integrity = The capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of the natural habitat of the region (source: Massachusetts Surface Water Quality Standards; 314 CMR 4.02, v. Nov. 12, 2021)

- Our land areas and water bodies have seen decades of pollutant impacts from acid rain (NOx, SOx) deposition 1800s-1990+, development and land use changes, climate change related increases in temperature, carbon dioxide and altered hydrologic cycles, and more recently (1990s+) increasing frequency, duration, magnitude and scale of external loading to water bodies by tree pollen and similar forest particulates (via direct deposition, stream and storm water flows through and near forested areas).

- PTOX vacuolate cyanobacteria are well suited ecologically to utilize annually-recurring, external loading of tree pollen and forest particulates as a nutrient substrate during the early, otherwise (often) low nutrient, clear-water season for surface water bodies.

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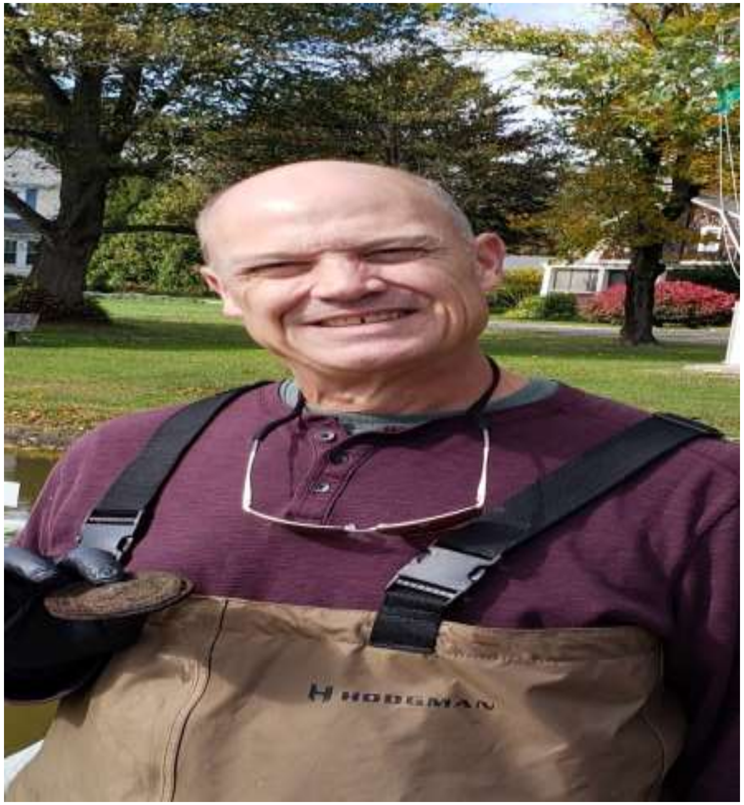

Jon Higgins holding a Nova Scotian lake iron nodule. My research on these led to the development of the A-Pod, C-Pod, P-Pod and S-Pod patented technologies. Ask me about what I've learned about them.