Report For:

Town of Harvard
Bare Hill Pond Watershed Management Committee
Harvard Massachusetts

Bare Hill Pond In-Lake Water Quality and Plant Survey - 2023

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Introduction

Aquatic Restoration Consulting, LLC (ARC) performed in-lake water quality monitoring and an aquatic plant survey within Bare Hill Pond in 2023. The intent of these surveys was to document 2023 summer conditions and compare these data to previous years, identifying any trends or concerns. This year we continued the expanded water quality monitoring program that was implemented in 2022. The expanded program adds the months of April, August, September, and October and three monitoring stations. The intent of the monitoring program expansion is to record temperature and dissolved oxygen depth profiles and measure phosphorus concentrations near the sediment during multiple seasons. We will utilize these data to evaluate the potential of phosphorus loading from sediments, which may be fueling the recent algal blooms, experienced in 2020 and 2021. Not all date and stations are sampled. The decision to include/exclude is made by scientist based on prior data. For example, the scientist may skip the October sampling if the lake has already undergone destratification and is in a completely mixed state.

The Bare Hill Pond Watershed Committee (Committee) has conducted winter water level drawdowns periodically since 2002. Early drawdowns were limited to the depth of the outlet (3.5-foot drawdown) but the installation of a pump system enables the Committee to increase the drawdown depth. Substantial reductions in plant cover and density were observed in association with initial extended water level drawdowns and these conditions have remained consistent following subsequent drawdowns. A shift in species dominance from tall growing vegetative propagators (spread through fragmentation or by rhizomes) to low growing seed producers was observed. A history of drawdown depth and summary of conditions reported by the Committee is provided in Table 1.

Given that non-native species growth regains community dominance in shallow water following cessation of winter water level drawdown[1] and the potential benefit of improved flushing (removing accumulated phosphorus), the Committee wishes to continue the drawdown program for nuisance aquatic plant management. This report summarizes data collected in 2023 and provides a comparison over several years, with an emphasis on the comparison within the last five years.

[1] see comparison of 2014 data vs data post drawdown in prior reports (https://www.harvard.ma.us/bare-hill-pond-watershed-management/pages/annual-other-reports)

Table 1. History of Bare Hill Pond Winter Drawdowns.

Winter Season	Water Level Reduction and Summary of Following Growing Season Observations
2002-03	1.5 Feet
2003-04	3.5' gravity drawdown
2004-05	3.5' gravity drawdown
2005-06	3.5' gravity drawdown. These first few created evidence of efficacy in drawdown zone and no evidence of substantial issues
2006-07	5' gravity and pump drawdown. Some increase in efficacy
2007-08	5' gravity and pump drawdown. Good freeze and improvement
2008-09	3.5' gravity drawdown. Per request to see if a year off pumping would work - limited efficacy and rebound in plants
2009-10	6' gravity and pump drawdown. Planning started for beach excavation and the storm water rain gardens
2010-11	6.5' gravity and pump drawdown. Continued incremental efficacy and no harm detected
2011-12	7' gravity and pump drawdown. More efficacy and depth needed for the beach excavation project
2012-13	6' gravity and pump drawdown. Backed off partway through process to see if efficacy could be maintained
2013-14	No drawdown. Year off to see if lower frequency worked - phosphorous stable, some re-emergence in spots
2014-15	5.5' drawdown. Heavy snowfall runoff - phosphorous increase and increased observance of invasives by residents in 5 – 8 foot zone but overall reduction in plant volume and at transect sites
2015-16	6.0’ drawdown. Very mild winter with an extended warm, dry and sunny growing season following
2016-17	5.75’ drawdown. Very mild winter, even warmer than previous year. Wet spring and summer; water level higher than past years
2017-18	6' drawdown. Cold long winter with freezing temperatures into April. Period of hot humid weather leading to a pattern of extended wet weather. Water levels remained high throughout the summer.
2018-19	4.5’ drawdown. While 6’ was the goal, it was difficult to achieve the desired drawdown depth due to precipitation. The early portion of the summer was wet and overcast but come July it was warm and dry.
2019-20	6.0’ drawdown. Warm November and March. Very low precipitation/snow cover
2020-21	Attempted 6.5'. Equipment issues prevented holding that depth beyond November. Lake was about 3.0' down during a short period of freezing
2021-22	6.5’ drawdown. This season was typical in terms of temperatures and precipitation for most months except November which was below average. Snowpack was slightly below normal.
2022-23	7.5' due to operator error; Corrective actions were taken in as discussed with the Conservation Commission. Warmer & wetter winter.

Influence of Weather

Ideal conditions for a winter water level drawdown to control rooted plants is a consistent cold winter (consecutive days below freezing) with little rain or snow. Snow insulates the ground preventing the hard freeze necessary to kill plant roots. Looking at the historic weather conditions recorded at Fitchburg Airport since 2009 during the Nov 15 through Mar 15 winter season, the winters of 2013-2014 and 2014-2015 had the lowest average minimum temperatures (18.0 and 17.2°F, respectively (Figure 1). The number of days when the low temperature fell below 30°F was 102 during 2013-2014, representing 84% of the days during the period of analysis; similarly, 92 days experienced low temperatures below 30°F in 2014-2015 representing 76% of the time (Figure 2). The next two winters were milder with average lows in mid-20 degrees with fewer days below 30°F. 2017-2018 and 2018-2019 were cold years with 98 and 95 days with low temperatures (81% and 79% of the days) with an average low of 19.5 and 20.2°F, respectively. From the winters of 2019-2020 through 2023 the number of days below 30°F averaged 86. Average low temperature for the same period was 24.4°F, 1.7°F warmer than the average low since 2009. The number of low temperatures days were evenly distributed between December, January and February. The 2022-2023 drawdown period was wet with just under 19 inches of precipitation at the Fitchburg airport, like 2009-2010 and 2020-2021 (Figure 3).

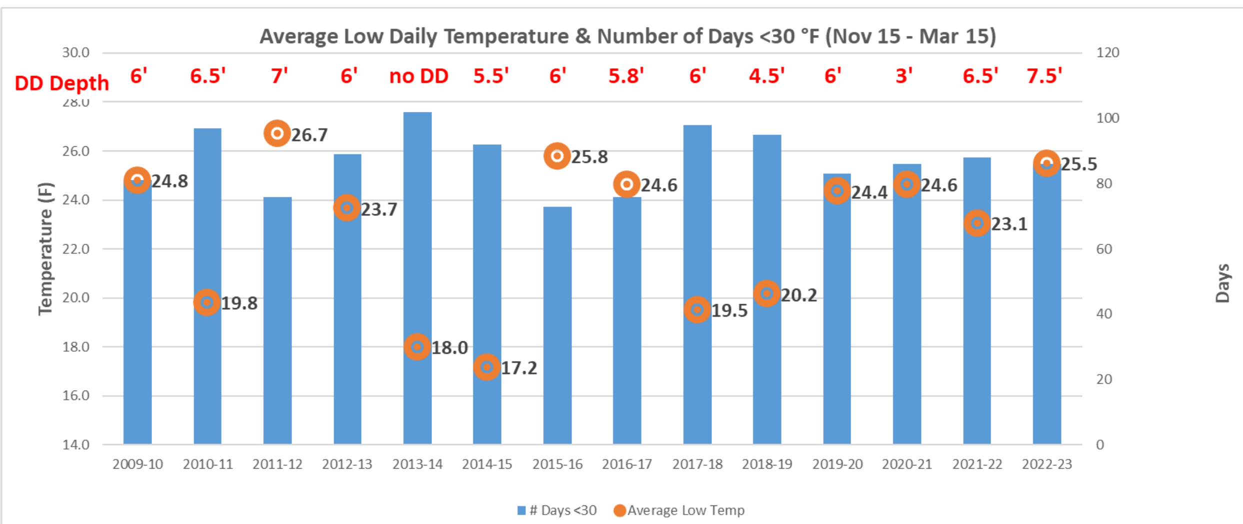

Figure 1. Average Low Air Temperature and Number of Days below 30°F during the Winter Season.

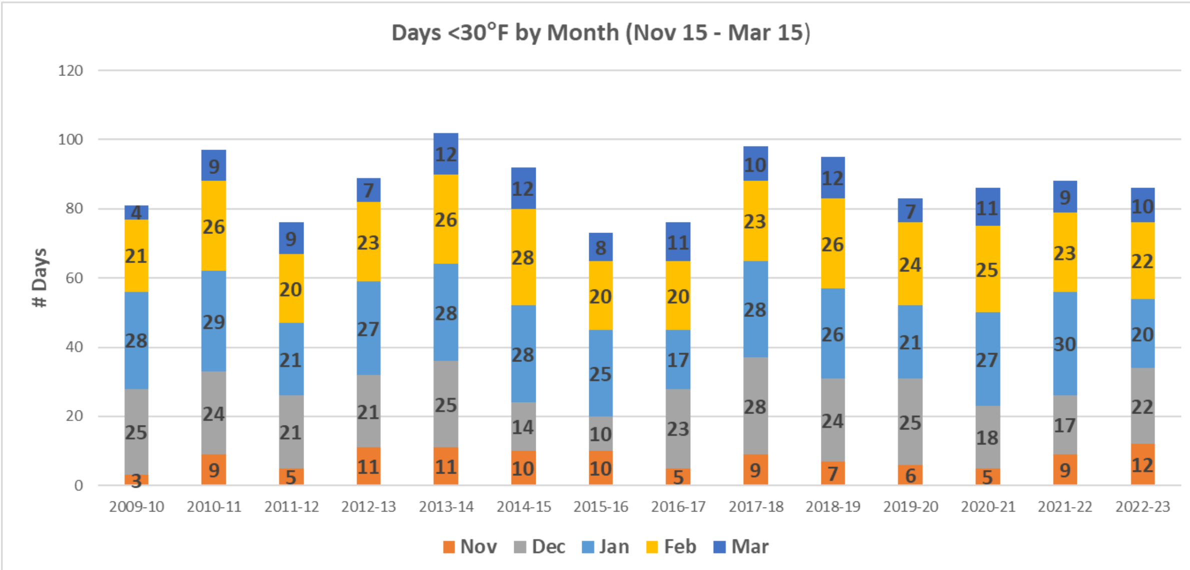

Figure 2. Number of Days with Air Temperatures below 30°F during the Winter Season.

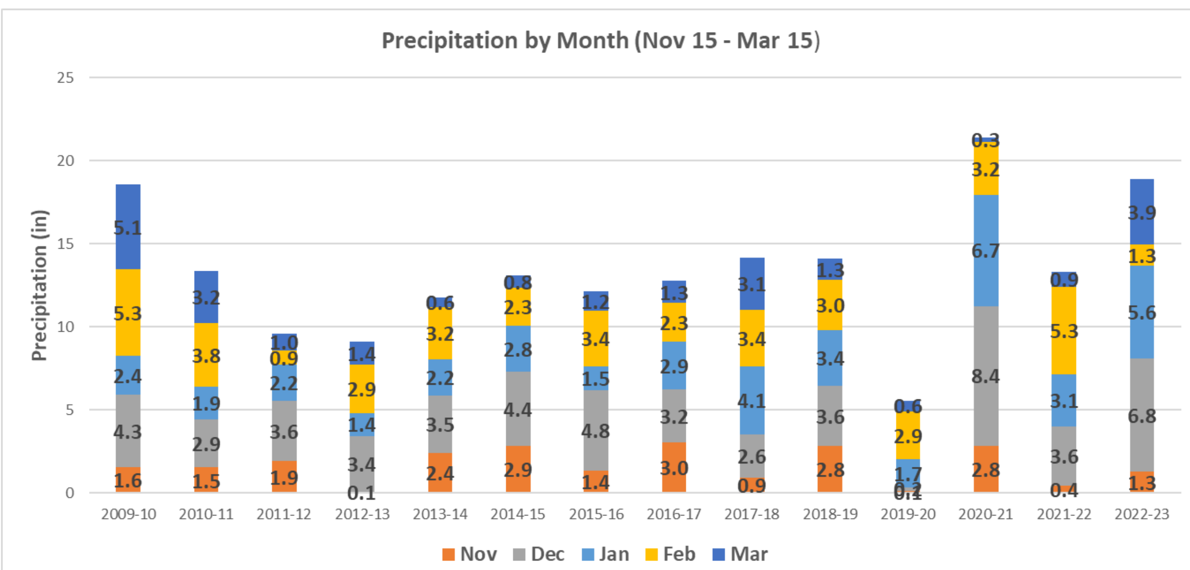

Figure 3. Precipitation during the Winter Season

In-Lake Sampling

In-lake sampling was conducted at five stations (Figure 4) on May 30, June 29, July 20 and August 13, 2023 (September & October sampling not yet scheduled). ARC used the same sampling methods as prior surveys for data collection consistency (see prior reports for methodology). In-situ water depth profile measurements of temperature, dissolved oxygen (DO), and specific conductivity were recorded at all five locations. ARC collected samples for total phosphorus (TP), dissolved phosphorus (DP) and total suspended solids (TSS) at the surface and approximately 0.5 feet above the sediment water interface (bottom) at BHP-2, at the surface at BHP-1 and TP at the bottom at stations BHP-3, 4 & 5.

Five sample locations (Figure 4):

- BHP-1 shallow basin in the south
- BHP-2 deep hole in the north/main basin BHP-2
- BHP-3 between BH-1 & BHP-2 south of Ministers Island
- BHP-4 south of Sheep, east of Spectacle Islands
- BHP-5 southeast of BHP-1 between Sheep and Four Acre Islands

The temperature and DO profiles suggest that the lake was weakly thermally stratified in May. DO concentrations have declined substantially since 2010. The hypoxic (low oxygen) layer is expanding and resulting in less desirable habitat for aquatic biota. Waters below ten feet were historically below the 5.0 mg/L threshold considered to support aquatic life, but data recorded since 2022 suggest that supportive waters are limited to about eight feet. This condition also facilitates the release of phosphorus from sediments, resulting in ideal conditions (warm water and plenty of phosphorus) for cyanobacteria blooms. The lake was anoxic (<2 mg/L oxygen) at a depth of 10 feet in 2021 and 2023 vs 12-14 feet in the past (Table 2, Figures 5 & 6). The anoxic layer was slightly reduced come August with anoxia starting at about 12 feet. DO at the added stations also exhibited anoxia at ten feet in July 2023. These conditions allow phosphorus release from iron in the sediments. The lake typically regains oxygen in the hypolimnion after mid-September when fall turnover (mixing) occurs.

Table 2 provides depth profile data through August 13, 2023. Figures 5 & 6 provide a graphical representation of temperature and DO data for the deep station (BHP-2) in comparison with the last five years.

Lake pH ranges from slightly acidic [<7 standard units (SU)] to basic (>7 SU). Higher pH values (>8.0 SU) are likely due to primary productivity when plants (macrophytes and/or phytoplankton) are photosynthesizing. During this process, carbon dioxide is removed from the water raising the pH of water. Lake water pH is typically the highest in the afternoon.

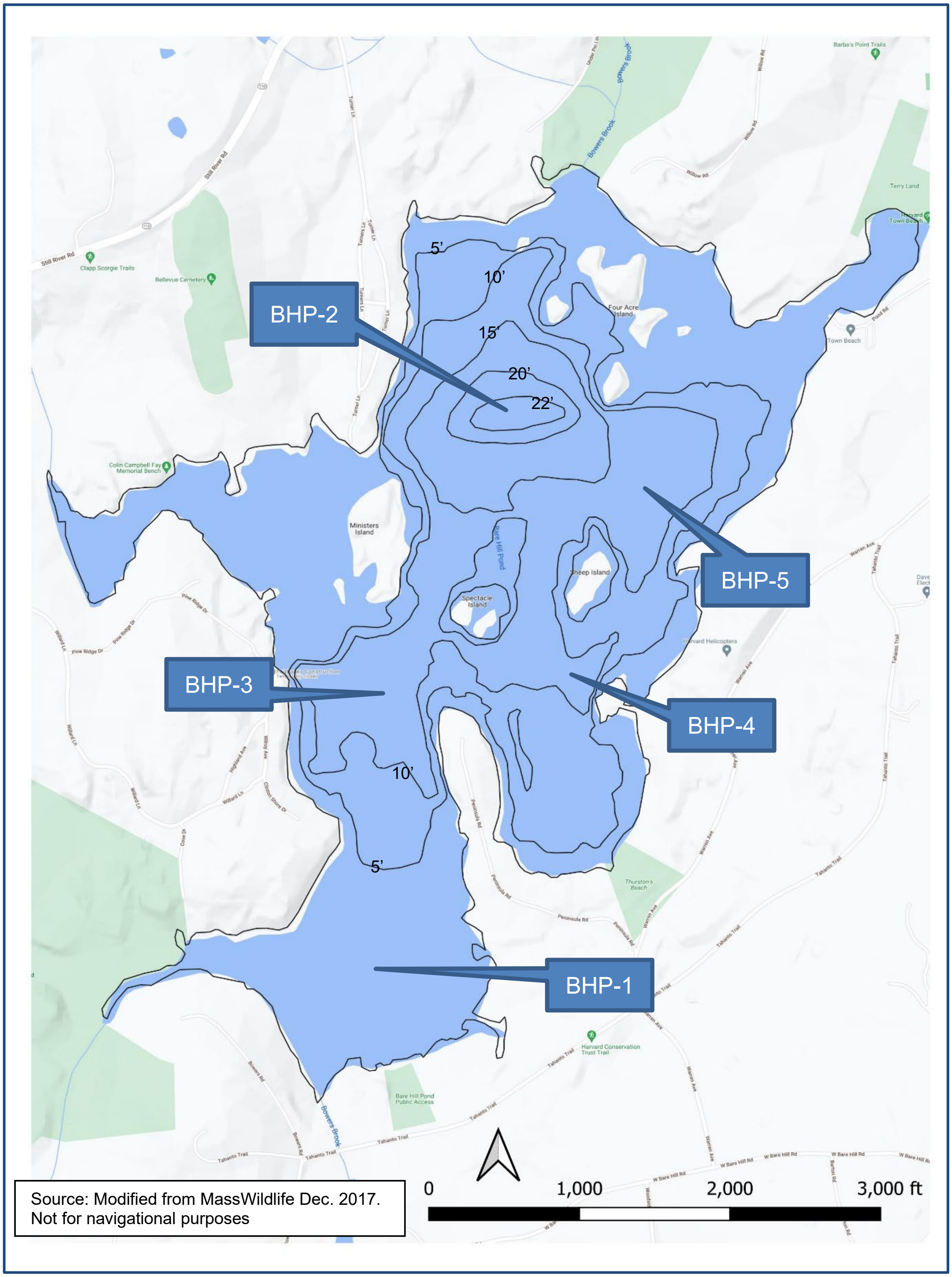

Figure 4. Bare Hill Pond Monitoring Stations.

Table 2. Bare Hill Pond Water Depth Profiles 2023.

BHP-1						BHP-1					
May 30, 2023						June 29, 2023					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	22.41	9.23	7.2	222	0.4	0	27.07	8.15	7.0	212	2.0
1	22.45	9.19	7.2	222	0.6	1	27.07	8.12	7.0	212	1.5
2	22.00	9.01	7.2	220	0.8	2	27.05	8.20	7.0	213	1.6
3	21.58	9.17	7.2	221	1.0	3	25.22	8.25	7.0	216	1.8
4	21.61	9.20	7.2	221	1.2	4	24.78	7.45	6.7	213	2.0
5	21.59	9.19	7.2	221	15.0	5	23.37	7.60	6.6	196	2.4
BHP-2						BHP-2					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	23.58	8.84	7.3	223	5.2	0	26.97	8.41	7.4	218	2.6
2	23.50	8.89	7.3	223	3.5	2	26.92	8.43	7.4	218	2.8
4	23.13	8.95	7.2	222	2.2	4	25.99	8.49	7.4	218	3.0
6	22.95	8.87	7.2	222	2.4	6	24.78	8.47	7.3	217	3.3
8	21.25	8.84	7.1	222	2.6	8	24.58	8.35	7.2	217	3.6
10	20.75	8.14	6.8	221	3.0	10	23.10	7.40	6.8	223	4.2
12	18.26	6.44	6.5	218	3.3	12	20.90	5.80	6.6	223	5.1
14	16.70	4.68	6.4	217	3.9	14	19.30	3.43	6.4	224	6.3
16	15.09	3.13	6.3	217	4.9	16	17.88	1.77	6.3	221	8.3
18	12.83	1.38	6.2	217	6.6	18	15.82	1.90	6.3	220	8.4
20	11.92	0.00	6.3	220	10.3	20	13.88	0.00	6.4	224	11.4
22.5	11.00	0.00	6.4	239	189.9	22	12.68	0.00	6.7	245	4.4
						23.5	11.74	0.00	6.8	263	19.4
BHP-3						BHP-3					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	22.43	9.00	7.2	223	1.8	0	27.30	8.39	7.2	217	1.4
2	22.48	8.97	7.2	222	1.8	2	26.62	8.50	7.2	217	1.4
4	22.43	8.99	7.2	222	1.9	4	25.73	8.53	7.2	217	1.4
6	21.52	8.97	7.1	222	1.9	6	24.54	8.32	7.0	216	1.5
8	21.08	8.66	7.0	222	1.9	8	24.18	7.61	6.8	212	1.5
10	19.06	7.50	6.7	219	2.0	10	23.86	6.59	6.6	212	1.7
12	18.73	7.03	6.6	219	2.2	12	20.74	4.55	6.4	224	3.0
						13.5	20.09	2.44	6.4	226	13.2
BHP-4						BHP-4					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	22.11	9.11	7.3	222	1.7	0	27.30	8.50	7.4	221	0.9
2	22.14	9.05	7.2	222	1.7	2	26.69	8.57	7.4	219	0.9
4	22.10	9.06	7.2	222	1.8	4	25.53	8.78	7.3	217	1.0
6	21.65	9.00	7.1	222	1.8	6	24.76	8.56	7.2	217	1.1
8	21.13	8.78	7.0	221	1.9	8	24.58	8.42	7.1	218	1.2
10	20.74	8.10	6.8	222	2.2	10	23.45	7.66	6.8	224	1.3
11.5	18.71	7.76	6.8	218	84.5	12	21.15	6.52	6.6	224	1.7
						12.5	20.46	5.82	6.7	224	2.2
BHP-5						BHP-5					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	23.50	8.97	7.3	223	1.2	0	27.18	8.58	7.5	219	0.0
2	23.42	8.40	7.3	223	1.2	2	27.19	8.57	7.4	218	0.0
4	23.14	8.98	7.2	223	1.1	4	27.08	8.56	7.3	220	0.0
6	22.83	8.81	7.1	223	3.5	6	25.93	8.41	7.0	221	0.0
8	21.19	8.82	7.0	222	3.8	8	24.49	7.93	6.7	240	0.1
10	19.21	7.66	6.7	219	1.1	10	22.93	7.29	6.7	224	0.1
11.5	18.45	5.94	6.6	219	1.4	12	20.81	4.45	6.5	225	4.2

Table 2. Continued.

BHP-1						BHP-1					
July 20, 2023						August 13, 2023					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	29.18	8.60	7.3	202	1.2	0	25.07	7.80	6.6	198	1.0
1	28.46	8.60	7.2	201	1.2	1	25.07	7.84	6.6	198	1.4
2	28.30	8.52	7.0	200	1.1	2	24.99	7.86	6.6	198	2.1
3	27.73	7.33	6.6	196	1.3	3	24.35	8.21	6.7	200	2.4
4	26.81	6.06	6.4	190	1.8	4	23.79	7.15	6.4	199	2.5
5	26.11	7.84	6.6	187	1.5	5	23.42	4.43	6.0	198	2.4

BHP-2						BHP-2					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	30.41	8.17	7.4	205	2.2	0	26.61	8.96	7.9	204	3.6
2	30.41	8.25	7.3	205	2.4	2	26.60	8.88	7.8	203	3.6
4	28.09	8.37	7.2	202	2.9	4	26.33	8.93	7.7	203	3.7
6	27.35	7.80	6.9	201	3.8	6	25.91	8.68	7.3	203	3.6
8	26.10	3.86	6.2	184	4.6	8	25.35	7.12	6.9	202	3.8
10	23.55	0.55	6.2	215	4.8	10	23.99	2.54	6.3	205	4.1
12	21.09	0.00	6.3	226	5.0	12	22.44	0.10	6.4	213	5.0
14	19.45	0.00	6.3	226	5.2	14	20.08	0.10	6.6	242	3.9
16	17.74	0.00	6.2	234	5.7	16	17.83	0.10	6.6	246	3.0
18	16.10	0.00	6.4	216	5.6	18	15.78	0.10	6.6	256	2.8
20	14.23	0.00	6.7	243	4.1	20	13.68	0.10	6.9	275	5.7
22	12.63	0.00	7.0	277	9.0	22	12.66	0.10	7.0	318	5.9
23	12.25	0.00	7.0	288	14.5						

BHP-3						BHP-3					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	29.80	8.39	7.2	203	1.5	0	25.46	8.70	7.2	202	1.6
2	29.77	8.39	7.2	203	1.5	2	25.32	8.71	7.2	202	2.4
4	27.69	8.46	7.0	201	1.5	4	24.82	8.70	7.2	202	2.7
6	26.95	7.87	6.7	198	1.6	6	24.53	8.10	7.0	201	2.9
8	25.90	4.25	6.2	181	2.1	8	24.11	6.50	6.5	199	3.1
10	23.04	0.27	6.2	213	3.4	10	23.50	2.64	6.2	205	3.0
12	21.34	0.00	6.5	234	4.6	12	21.72	0.09	6.4	232	3.2
						12.5	21.45	0.10	6.4	232	4.6

BHP-4						BHP-4					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	29.86	8.26	7.0	205	1.2	0	25.98	8.85	7.5	203	3.5
2	28.46	8.42	7.2	205	1.3	2	25.46	8.77	7.3	203	3.6
4	27.61	8.32	7.1	205	1.4	4	24.83	8.68	7.2	203	3.6
6	27.21	7.39	6.8	203	1.6	6	24.61	8.52	7.1	203	3.6
8	26.22	4.38	6.3	192	1.8	8	24.33	6.96	6.6	202	3.3
10	23.94	0.29	6.1	212	3.7	10	23.86	3.65	6.3	203	3.0
12	21.79	0.00	6.5	231	5.2	11.5	22.69	0.09	6.3	212	3.7

BHP-5						BHP-5					
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	30.66	8.05	7.3	207	0.7	0	26.94	8.95	7.9	206	3.0
2	30.26	8.10	7.3	206	0.8	2	26.90	9.01	7.8	205	3.1
4	28.49	8.28	7.2	205	1.0	4	26.64	9.06	7.7	205	3.2
6	27.29	7.78	6.8	203	1.3	6	26.26	9.12	7.6	205	3.2
8	26.13	3.79	6.3	204	1.5	8	25.60	8.54	7.0	205	3.2
10	24.44	0.00	6.2	221	2.7	10	24.50	1.58	6.3	208	3.9
12	22.12	0.00	6.6	349	2.5	11.5	23.31	0.09	6.3	225	4.0

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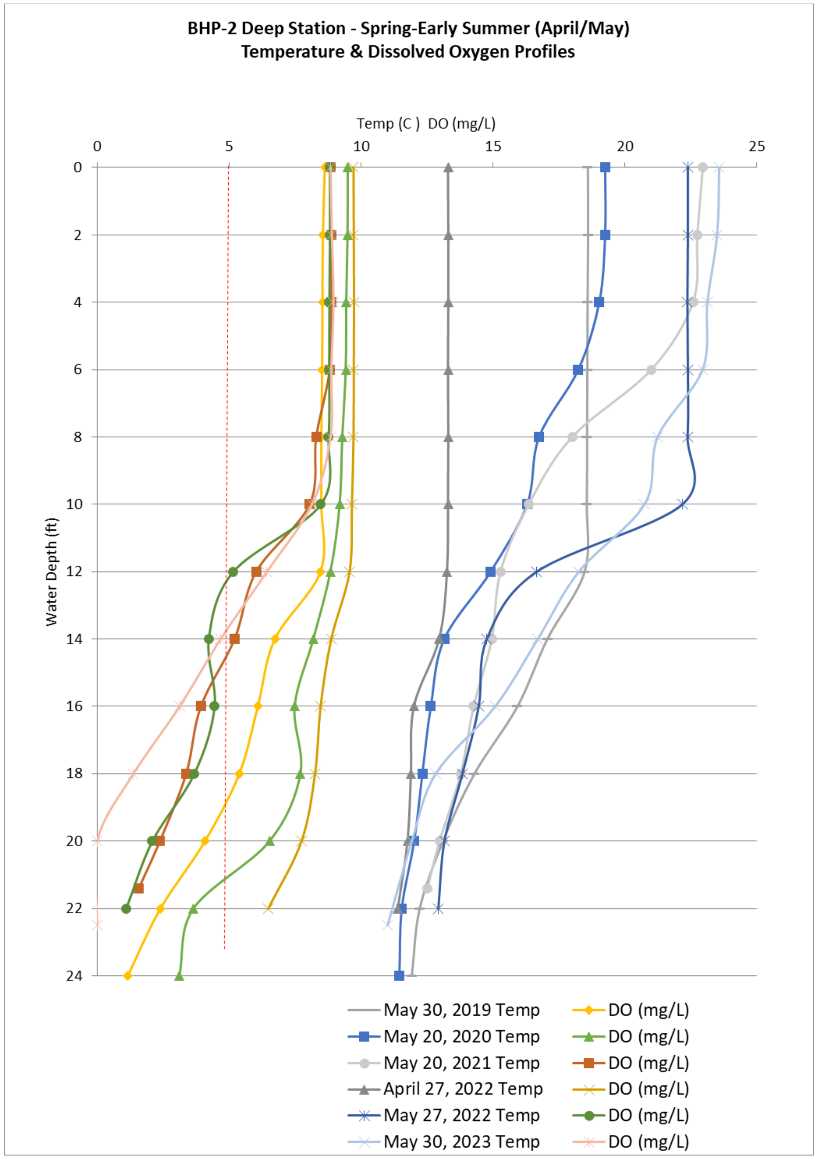


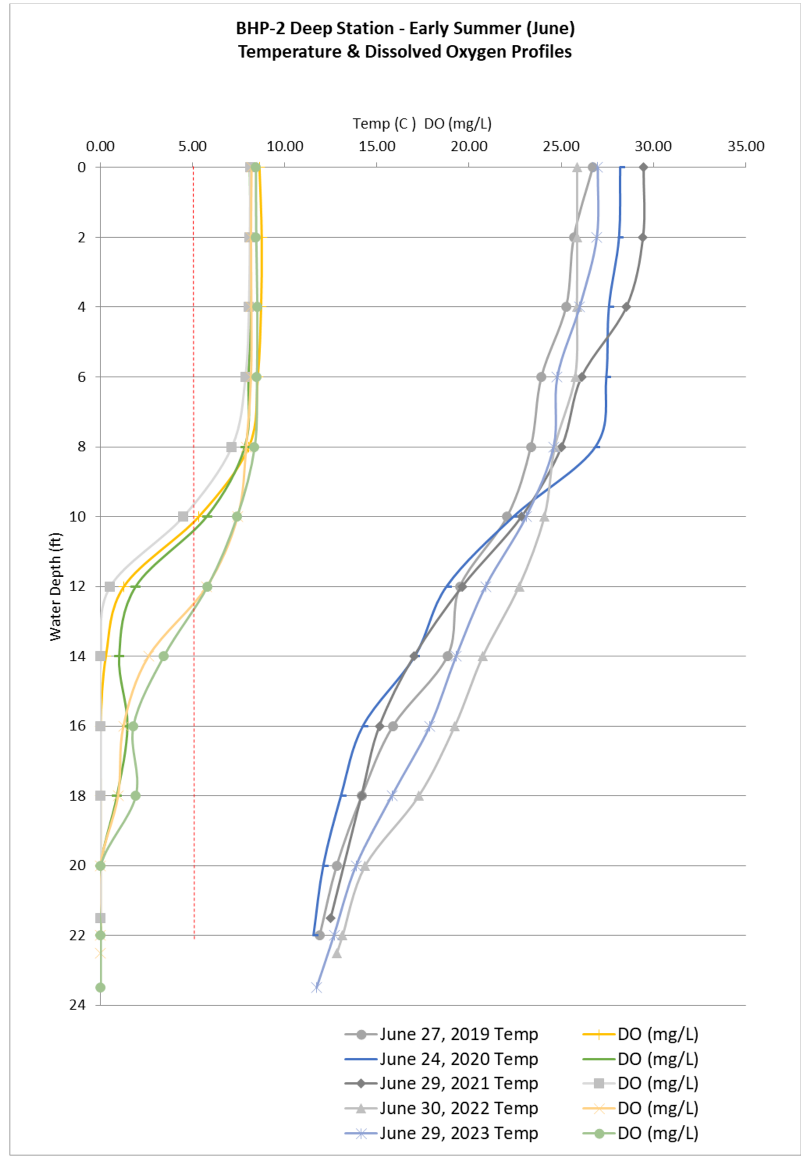
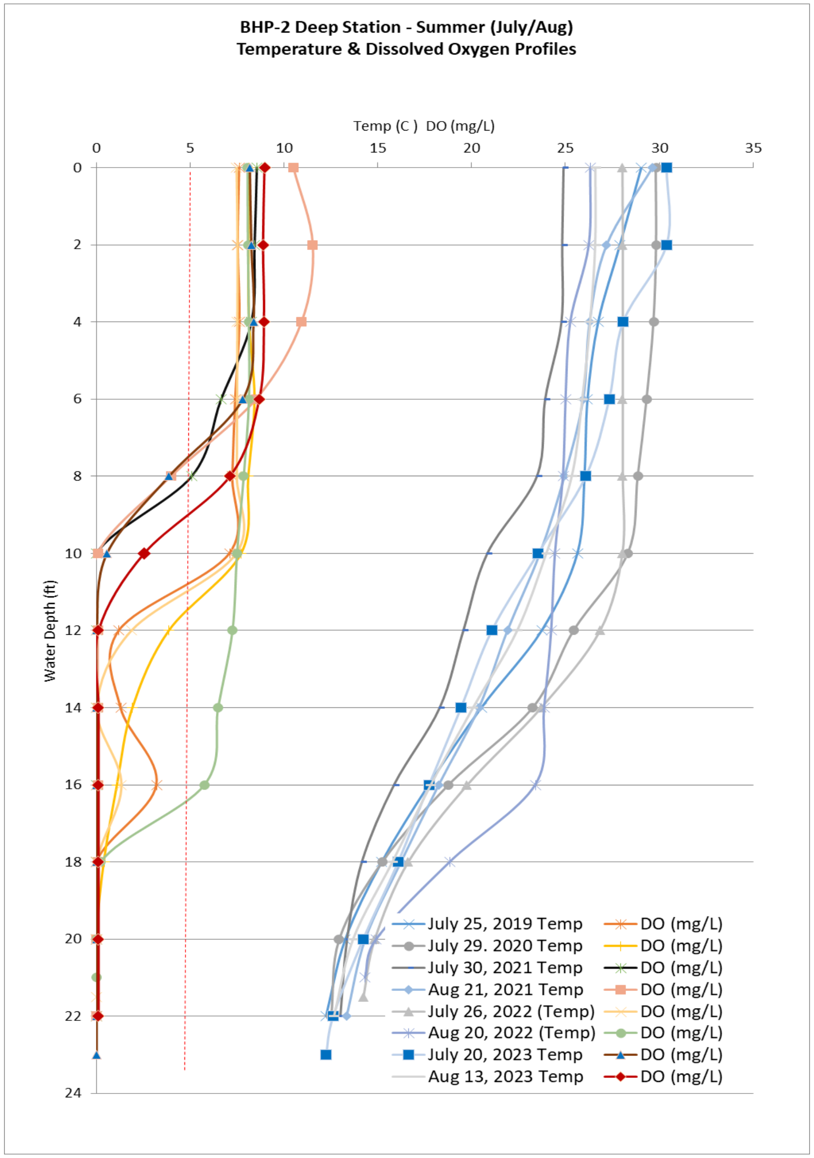


Figure 5. Temperature & Dissolved Oxygen Profiles at BHP-2 during Spring & Early Summer for 2019-2023.



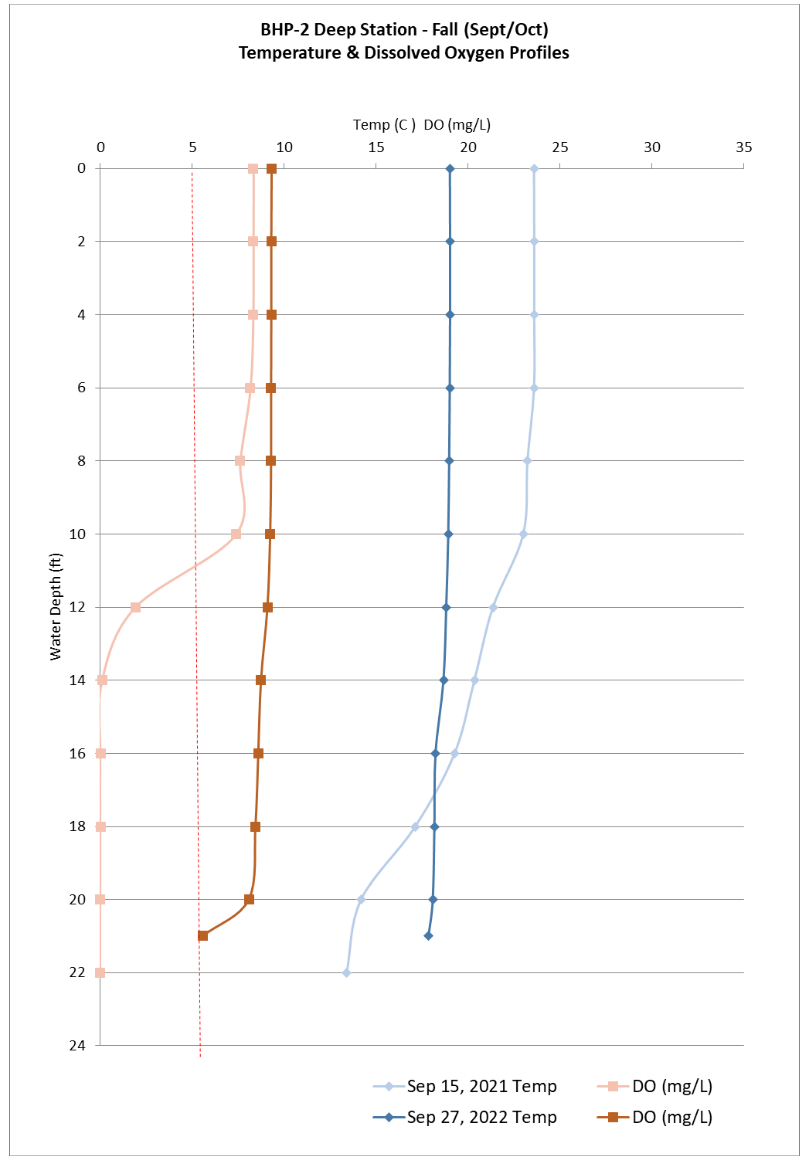


Figure 6. Temperature & Dissolved Oxygen Profiles at BHP-2 during Summer and Fall for 2019-2023.

Specific conductivity in 2023 was similar to prior years around lower 200's just over the desirable range threshold [<200 microsiemens per centimeter [µs/cm)]; values above 200 us/cm can be indicative of elevated dissolved pollutants and high productivity. It is common to have increased conductivity near the water-sediment interface where suspended solids increase conductivity. Surface and mid-depth values were comparable between stations.

Turbidity is measured in-situ with a probe. The probe sends a beam of light and the amount of light that is reflected back is used to calculate particle density in the water. The more light reflected, the more particles there are in the water. Turbidity was variable between July and August. It is not known if the elevated turbidity measurements were caused by phytoplankton, suspended solids and/or bubbles generated by boat traffic. TSS numbers were less than detection at all surface water samples. The highest TSS was recorded in the bottom sample in August.

Table 3 provides the results of phosphorus, TSS and water clarity (measured by Secchi disk transparency) during 2023. A comparison of phosphorus concentrations in the main basin (BHP-2) over time is illustrated graphically in Figure 7. TP surface concentrations were above the Massachusetts Department of Environmental Protection (MassDEP) target concentration of 0.030 mg/L[2] at the surface during June (BHP-2) and August (BHP-1).

Bottom water samples exceeded MassDEP's threshold at multiple location on multiple dates. This can be the result of suspended solids or phosphorus being released and/or accumulating in the hypolimnion. DP, the dissolved fraction of phosphorus, was detected in June and August suggesting that there is phosphorus that is readily available for algal uptake in both the surface and bottom waters. It should be noted that algal blooms were observed in 2020 and 2021, when TP values were generally below the MassDEP threshold suggesting that the threshold isn't low enough to be protective against blooms or the algae are obtaining their nutrients from bottom waters where TP and DP concentrations are greater.

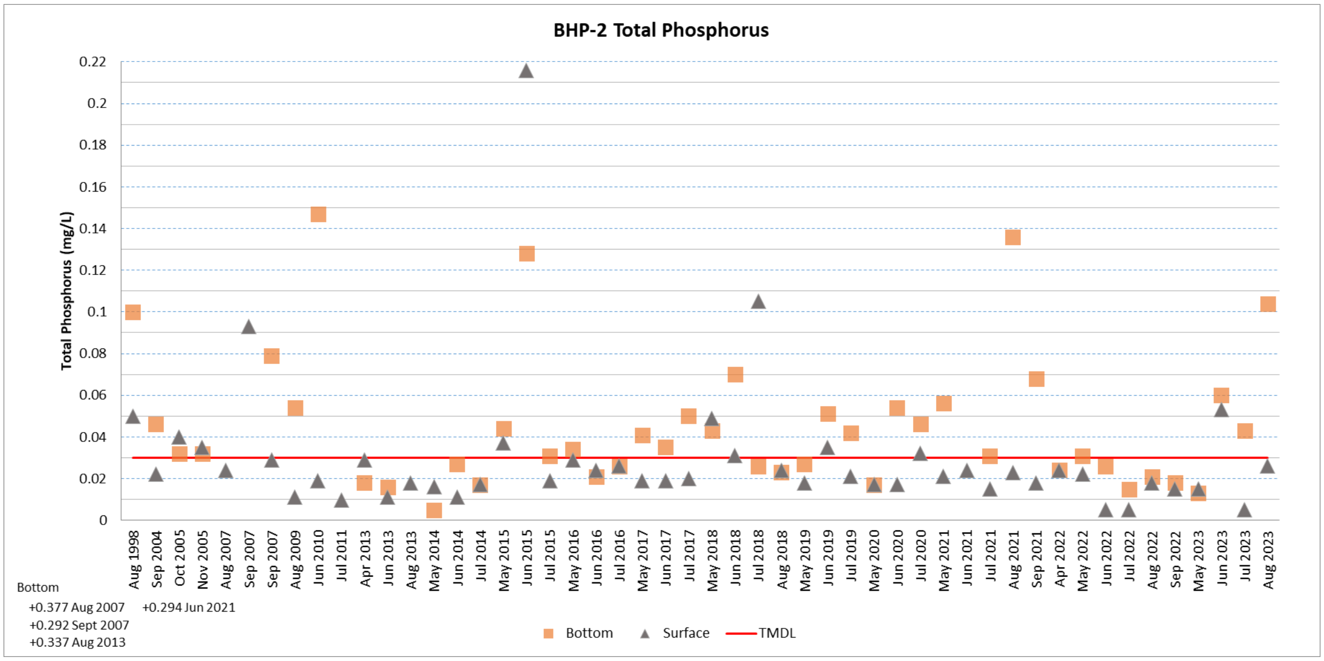
The Town of Harvard Board of Health (BOH) fluorometer readings and estimated cyanobacteria cell counts were generally below the 70,000 cells/mL advisory threshold in 2023, except the samples collected at 12 and 20 feet in July 2023 (Figure 8).

[2] Bare Hill Pond Bare Hill Pond, Harvard, MA. TMDL Report MA81007-1999-001 July, 1999 Massachusetts Department of Environmental Protection https://www.harvard.ma.us/sites/harvardma/files/uploads/bhp_tmdl.pdf

Table 3. 2023 Bare Hill Pond In-lake Water Quality Data.

Station	Date	Time	TP (mg/L)	DP (mg/L)	TSS (mg/L)	Secchi (ft)	
BHP-2 Surface	5/30/2023	18:00	0.015	<0.010	<5	12	
BHP-2 Bottom	5/30/2023	18:10	0.013	<0.010	5		
BHP-1 Surface	5/30/2023	18:35	0.017	<0.010	<5	5.2	bottom
BHP-3 Bottom	5/30/2023	18:40	0.020			12.1	
BHP-4 Bottom	5/30/2023	18:50	0.021			11.3	
BHP-5 Bottom	5/30/2023	19:00	0.022			11.8	
BHP-2 Surface	6/29/2023	16:30	0.053	<0.010	<5	11	
BHP-2 Bottom	6/29/2023	16:35	0.060	0.034	7		
BHP-1 Surface	6/29/2023	16:15	<0.010	<0.010	<5	5.5	bottom
BHP-3 Bottom	6/29/2023	17:05	0.047			10.3	
BHP-4 Bottom	6/29/2023	17:15	0.038			12.1	
BHP-5 Bottom	6/29/2023	17:40	0.042			11.4	
BHP-2 Surface	7/20/2023	17:15	<0.010	<0.010	<5	7.8	
BHP-2 Bottom	7/20/2023	17:20	0.043	<0.010	<5		
BHP-1 Surface	7/20/2023	17:40	0.012	<0.010	<5	5.5	bottom
BHP-3 Bottom	7/20/2023	17:50	0.011			8.2	
BHP-4 Bottom	7/20/2023	18:00	0.011			8.5	
BHP-5 Bottom	7/20/2023	18:10	<0.010			9.6	
BHP-2 Surface	7/26/2022	18:50	<0.010	<0.010	5	7.7	
BHP-2 Bottom	7/26/2022	18:55	0.015	<0.010	12		
BHP-1 Surface	7/26/2022	19:15	<0.010	<0.010	5	4.0	bottom
BHP-3 Bottom	7/26/2022	19:20	<0.010			7.5	
BHP-4 Bottom	7/26/2022	19:38	0.013			8.1	
BHP-5 Bottom	7/26/2022	19:50	<0.010			8.4	
BHP-2 Surface	8/13/2023	13:10	0.026	<0.010	5	6	
BHP-2 Bottom	8/13/2023	13:20	0.104	0.028	7		
BHP-1 Surface	8/13/2023	11:05	0.062	0.039	<5	5.0	bottom
BHP-3 Bottom	8/13/2023	11:30	0.028			6	
BHP-4 Bottom	8/13/2023	12:10	0.042			6.2	
BHP-5 Bottom	8/13/2023	14:30	0.031			6.6	

"Bottom" indicates the Secchi disk reached the pond bottom
Red shade – exceeded MassDEP recommended phosphorus threshold



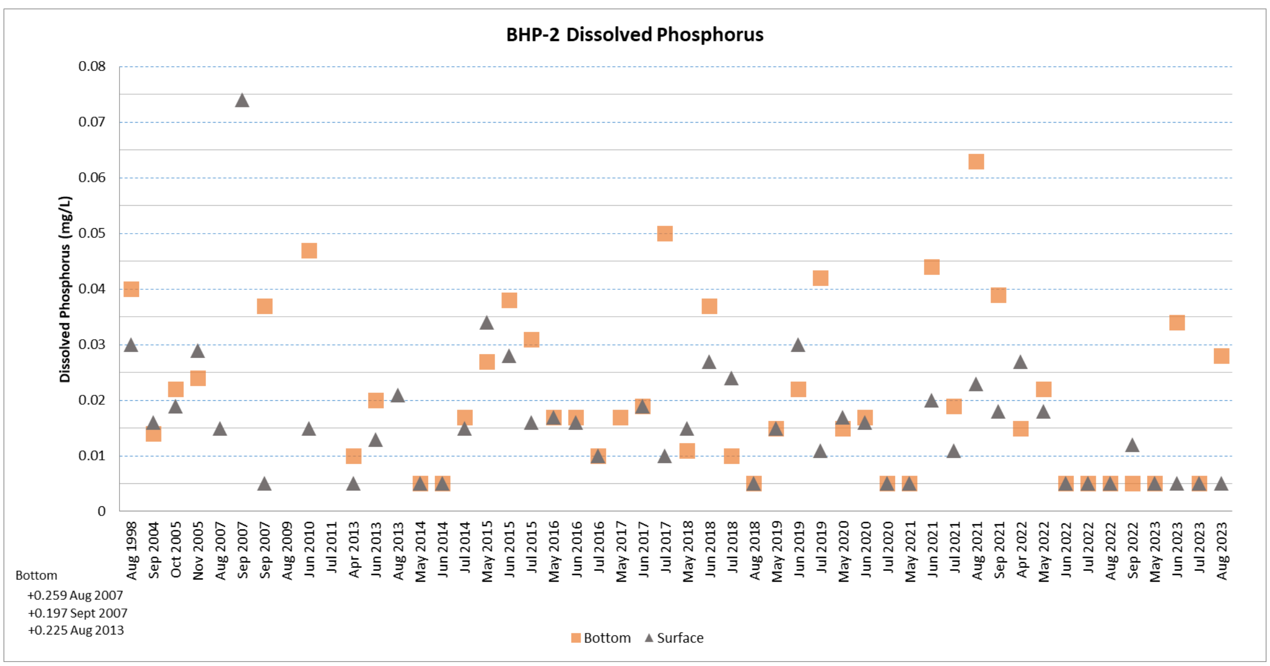
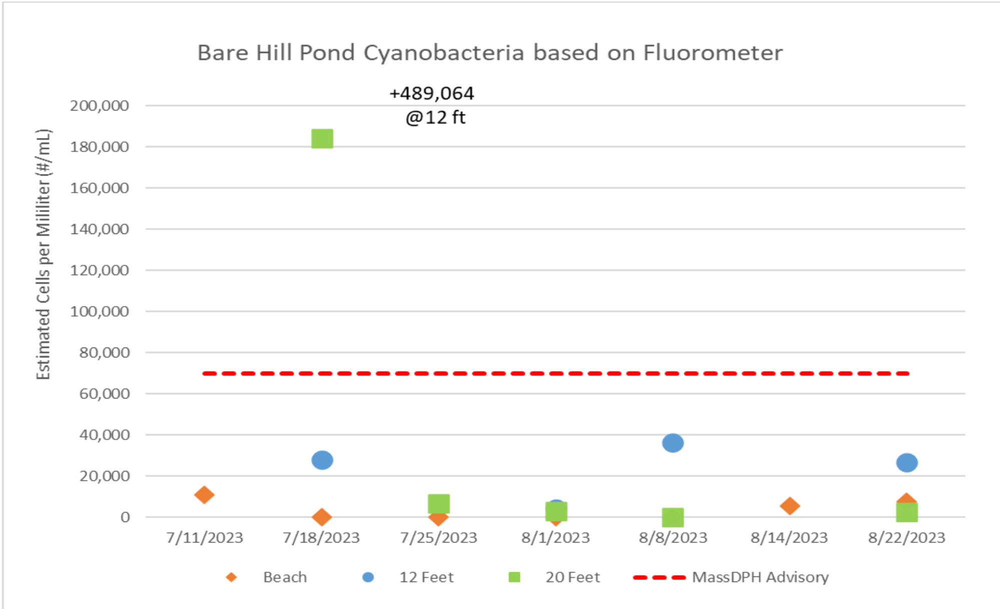


Figure 7. BHP-2 Total and Dissolved Phosphorus Concentrations.



Data provided by Town of Harvard Board of Health

Figure 8. Estimate Cyanobacteria Cells.

Secchi disk transparency (SDT) in 2023 was much improved from 2021 due to the absence of an algal bloom. SDT ranged from 6.0 to 12.1 feet (range in 2021 was 3.0 to 12.4 feet). The lowest values were recorded in August. Clarity was above the MassDEP State Water Quality Standard for swimming (4 feet; Figure 9) during all monitoring events (through August 13, 2023). Clarity was greatest in May.

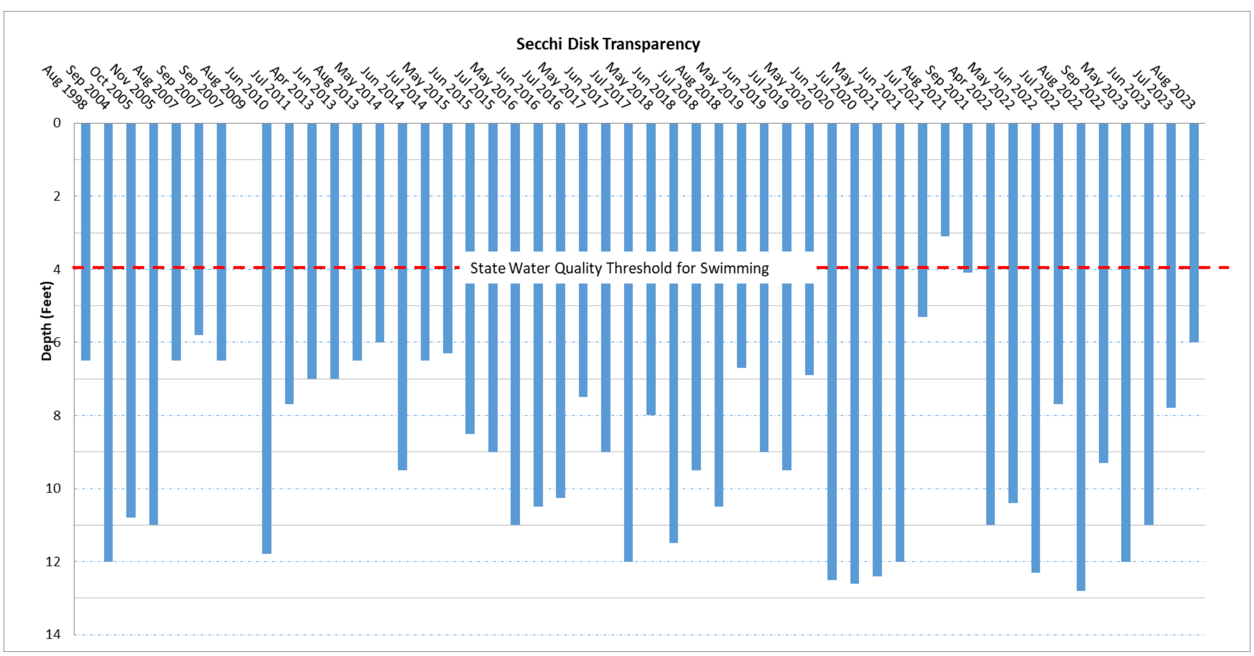


Figure 9. Bare Hill Pond (BHP-2) Secchi Disk Transparency.

In-lake Plant Survey

ARC conducted a plant survey on August 13, 2023. We used the same methods employed during the previous surveys conducted since 1998. ARC mapped pond aquatic vegetation along the five transects (A through E) established in 1998. We also repeated the eight points added in 2016 (F through I). Each transect was divided into a series of observation points and were located using Global Positioning System (GPS). A total of 60 points were assessed during the survey.

The plant survey focused on macroscopic fully submerged (e.g., milfoil), floating-leaved (e.g., pond lily), and/or free-floating plants (e.g., duckweed). At each transect point, we recorded the percent cover of all plants, the percent biovolume (as measured by the amount of the water column filled with plants) using a semi-quantitative (0-4) ranking system. Species observed in each transect were identified and assigned a relative density based on all species present (Table 4). Water depth was also recorded at each transect point. These data are presented in Table 5.

Table 4. Plant Survey Categories

Rank	Cover & Biovolume	Density Category	Description
0	No plants	Trace	Single to a few plants
1	1-25%	Sparse	Multiple plants but not abundant, about a handful
2	26-50%	Moderate	Numerous plants but not dominate, about a plant rake full
3	51-75%	Dense	Very abundant, more than a rake full
4	76-100%		

Aquatic Restoration Consulting, LLC

Table 5. 2023 Macrophyte Survey Data

Point	Cover	Bio-volume	Bs	BG	Cc	Cd	Ec	Eleo	FG	Iso	Macro	Mega	Mh	Mhum	Nf	Nm	No	Nv	Pa	Pc	Poly	Prob	Pspir	Pot	Sg	Spar	Usp	Va
A-1	3	2															D				D							
A-2	4	2	D						M						S		M	S									M	
A-3	4	2	D														S	D									S	
A-4	4	2	S		S	D			M						M		D										D	
A-5	4	2	T								S				S	T	T	S									M	S
A-6	4	2							M		T				M		T	T					S				T	S
A-7	2	1	S									S			M												S	
A-8	1	1									M										T						T	
A-9	1	1				S					S																	
A-10	0	0																										
A-11	0	0																										
A-12	0	0																										
A-13	1	1			T						T																T	
B-1	4	3	T		S				S						M	S	D	S									M	D
B-2	4	3			T										S		D										M	
B-3	4	2									D						M	T									S	D
B-4	4	2										D				M	S										S	D
B-5	4	2										D			M	S	M							T			S	D
B-6	4	2									D						M										M	S
B-7	4	2									D				S	S	M										S	S
B-8	4	2									D				S	M	M	S						T				M
B-9	4	2									D				S	S											M	D
B-10	4	2															D											S
C-1	4	3			D						D																D	
C-2	3	1		S	S																	D						
C-3	3	2			M								T									S						
C-4	4	3			D																							
C-5	1	1			T																							
C-6	0	0																										
C-7	1	1			T																							
C-8	4	2			M										M									S				D
D-1	4	4			D							S	M		S		D										S	D
D-2	4	2									D				S		M	M									S	S
D-3	4	2			T						M				S	S		S									M	D
D-4	4	2	T		S				S		D				S	S											T	D
D-5	4	2	M		S						D							S										D
D-6	4	2									D																S	S
D-7	4	2									D																	S
D-8	4	2									D																	S
D-9	4	2			T						D				S	S								T				M

Shaded cell indicates dominant species at observation point.

Table 5 (continued). 2023 Macrophyte Survey Data

Point	Cover	Bio-volume	Bs	BG	Cc	Cd	Ec	Eleo	FG	Iso	Macro	Mega	Mh	Mhum	Nf	Nm	No	Nv	Pa	Pc	Poly	Prob	Pspir	Pot	Sg	Spar	Usp	Va
D-10	4	2									D																M	S
D-11	4	2			T						D																	M
D-12	4	3			D																							
D-13	4	4			D																							
E-1	4	2			T				S		D					M												D
E-2	3	3			M								T				T											D
E-3	4	2			S																						T	D
E-4	3	2			D																							
E-5	4	3			D								T															
E-6	4	3			D							T	T															
E-7	4	3			D								S														T	
E-8	4	3			D																							
F-1	2	2			D																							M
F-2	4	3			D								S															
G-1	4	4			D								S				T										S	S
G-2	4	4			D												M											
H-1	4	2			S										M													D
H-2	2	2			M																						T	S
I-1	4	2			S												S										M	D
I-2	3	2			D								S															
Frequency of Occurrence			8	1	35	2	0	0	6	0	22	5	9	0	18	11	21	10	0	0	2	2	1	4	0	0	28	31
Frequency Dominant			2	0	15	1	0	0	0	0	16	2	0	0	0	0	6	1	0	0	1	1	0	0	0	0	2	15

Shaded cell indicates dominant species at observation point.

Key to species

Bs – *Brasenia schreberi* (watershield)	No – *Nymphaea odorata* (white-flower waterlily)
BG – *Cyanobacteria* (*Bluegreen algae*)	Nv – *Nuphar variegata* (yellow-flower waterlily)
Cc – *Cabomba caroliniana* (fanwort)	Pa - *Potamogeton amplifolius*
Cd - *Ceratophyllum demersum* (coontail)	Pc - *Potamogeton crispus*
Ec - Elodea canadensis (waterweed)	Prob – *Potamogeton robbinsii* (Robbins pondweed)
FG – filamentous algal mats	Pspir - *Potamogeton spirillus* (spiral pondweed)
Iso - *Isoetes* sp. (quillwort)	Pot – *Potamogeton* spp. (pondweeds)
Mega - *Megalondonta beckii* (water marigold)	Sg - *Sagittaria graminea* (duck potato)
Macro algae: Ni.f – *Nitella flexilis* and/or *Chara* (stonewort)	Spar – Sparganium sp. *(bur-reed)*
Mh – *Myriophyllum heterophyllum* (variable-leaf milfoil)	Usp – *Utricularia* spp. (bladderwort)
Nf - *Najas flexilis*	Va - Vallisneria americana (tapegrass)
Nm - *Najas minor* (brittle waternymph)	

Table 6 provides a comparison between the last five surveys. The “IN” column in Table 6 represents the sample locations that were susceptible to the prior year’s drawdown (“in” the drawdown zone). One would expect to see changes in this column with variation of drawdown depth, provided the weather is ideal (exposed shoreline is subjected to freezing temperatures for a prolonged period without the insulating effect of snow cover). The “OUT” column represents data at sample locations where water depths are greater than the drawdown depth (“out” of the drawdown zone). No change related to the drawdown is expected in these cells. Ranks shaded green represent a change of two or more categories lower than the previous year and, in general, represent a desired outcome. Numbers shaded red indicate a two category change higher (an increase in plant cover or biovolume over the previous year). The prior year’s drawdown depth is shown in parentheses next to the year.

Data for 2022 were expected to be more desirable than 2021 given the lack of drawdown depth maintained in the prior year. The survey data indicate cover conditions were slightly higher than 2021 (increased at eight locations and decreased at three locations) but five of the eight locations with increased cover occurred outside the drawdown. Data in 2023 were expected to be lower given the deeper drawdown, but the temperatures were not excessively cold and there was a lot of precipitation. Plant cover did decrease at seven locations, but only two were within the drawdown zone. However, the locations outside the drawdown zone still could have been influence by the drawdown (e.g., ice movement, colder temps etc.). Cover increased at five locations. These locations had more bladderwort (Utricularia spp.) and tapegrass (*Vallisneria americana*) than in 2022.

Biovolume decreased at one location but increased at five locations (four within the drawdown zone) from 2022. Three of the four areas which showed increases inside the drawdown zone were attributable to more tapegrass. The remaining area showed an increase in bladderwort. Both species are native but can be nuisance.

The increased bladderwort was also apparent lake wide (Table 7 and Figure 9) with 30 more observation points containing bladderwort. Tapegrass frequency of occurrence was similar to last year, but perhaps it became denser in 2023. Fanwort frequency increased by 18% in 2023 Robbins pondweed (*Potamogeton robbinsii*) decreased for a second year in row, but only by 3%. The decline in this species is unexplained. This plant is a beneficial native species, but it is most frequently observed along Transects C and E. These areas are outside the drawdown zone are currently dominated by fanwort. Brittle naiad was present again in the southern portion of the lake. It was first observed in the southern end in 2022. Tapegrass increased in abundance in 2022 and continued to expand in 2023. Select plant species frequency data are shown in Figure 10.

Table 6. Bare Hill Pond Cover and Biovolume Relative Change

		Cover								Biovolume							
		2020 (6.0')		2021 (3.0')		2022 (6.5')		2023 (7.5')		2020 (6.0')		2021 (3.0')		2022 (6.5')		2023 (7.5')	
	Point	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Transect A	1	4			2		4	3		4			1		3	2	
	2	2			3	2		4		1			2	2		2	
	3	4			4	4		4		1			2	3		2	
	4	4			2	4		4		1			2	3		2	
	5	4			3	4		4		1			2	2		2	
	6	4			3	4		4		1			2	2		2	
	7	1			4	2		2		1			1	2		1	
	8	2			3	4		1		1			1	1		1	
	9		1		3	3		1			1		1	1		1	
	10		1		0		4		0		1		0		1		0
	11		2		0		2		0		1		0		1		0
	12		0		0		1		0		0		0		1		0
	13	2			1	1		1		1			1	1		1	
Transect B	1	4			4	4		4		3			4	3		3	
	2	4			4	4		4		2			2	2		3	
	3	5			4	4		4		2			2	2		2	
	4	5			4	4		4		2			2	2		2	
	5	5			4	4		4		2			2	2		2	
	6	5			4	4		4		2			2	2		2	
	7	5			4	4		4		2			2	4		2	
	8	5			4	4		4		2			2	2		2	
	9	5			4	4		4		2			2	2		2	
	10	5			4	4		4		2			2	2		2	
Transect C	1	1			4	4		4		1			1	1		3	
	2		4		4		4		3		1		2		2		1
	3		4		4		4		3		2		2		2		2
	4		3		3		3		4		2		3		2		3
	5		1		0		0		1		1		0		0		1
	6		4		0		1		0		2		0		1		0
	7		4		0		4		1		2		0		2		1
	8		4		3	4			4		3		1	2			2
Transect D	1	4			5	4		4		2			4	1		4	
	2	4			4	4		4		2			4	1		2	
	3	4			4	4		4		2			4	1		2	
	4	4			4	2		4		1			3	1		2	
	5	4			4	4		4		1			3	2		2	
	6	4			4	4		4		2			2	1		2	
	7	4			4	4		4		2			3	1		2	
	8	4			5	4		4		2			1	1		2	
	9	4			5	4		4		1			1	1		2	
	10	4			4	4		4		1			1	1		2	
	11	4			4	4		4		1			1	1		2	
	12		4		2	4		4			2		1	2		3	
	13	0			2		4		4	0			2		3		4
Transect E	1	5			2	4		4		2			1	3		2	
	2	5			4	4		3		2			1	2		3	
	3		5		4	4		4			2		2	3		2	
	4		4		2	3		3			2		2	1		2	
	5		4		3		4		4		2		2		3		3
	6		4		4		4		4		2		2		4		3
	7		4		4		4		4		2		2		3		3
	8		3		2		4		4		2		1		3		3
Supplemental	F-1	1			0	0		2		1			0	0		2	
	F-2		5		4	3			4		2		2	2			3
	G-1	4			3	3		4		2			2	3		4	
	G-2		4		4		4		4		2		3		3		4
	H-1	1			1	0		4		1			1	0		2	
	H-2		4		2	4			2		2		2	2			2
	I-1	1			2	2		4		1			1	1		2	
	I-2		4		1		0		3		1		1		0		2

Increase by 2 or more ranks from prior year | Decrease by 2 or more ranks from prior year

Table 7. Select Species Frequency of Occurrence (%)

	Water Shield	Fanwort	Milfoil	Macro Algae	Filament Algae	Water Lily	Naiad	Pond Weed (Robins)	Bladder wort	Tapegrass
1998	13	4	79	0	25	29	0	79	40	0
2001	5	11	74	3	56	14	0	32	44	0
2004	8	0	44	2	42	15	0	54	44	0
2007	8	35	17	44	15	12	38	31	25	0
2010	52	70	30	85	70	35	74	81	22	0
2013	23	44	19	81	40	29	73	12	19	33
2014	27	73	27	31	10	29	4	15	29	15
2015	17	31	29	54	6	27	6	21	12	25
2016	25	43	42	45	23	27	30	28	8	38
2017	23	43	45	48	18	17	12	28	20	32
2018	20	42	30	43	10	28	25	32	15	30
2019	20	73	32	30	42	22	32	30	12	48
2020	18	37	7	40	12	38	8	23	0	40
2021	13	47	15	25	0	33	40	20	22	40
2022	7	40	15	38	42	50	50	7	17	53
2023	13	58	15	37	10	52	48	3	47	52
Increase/Decrease from prior year										
	7	18	0	-2	-32	2	-2	-3	30	-2

Naiad includes both native and non-native species occurrence.

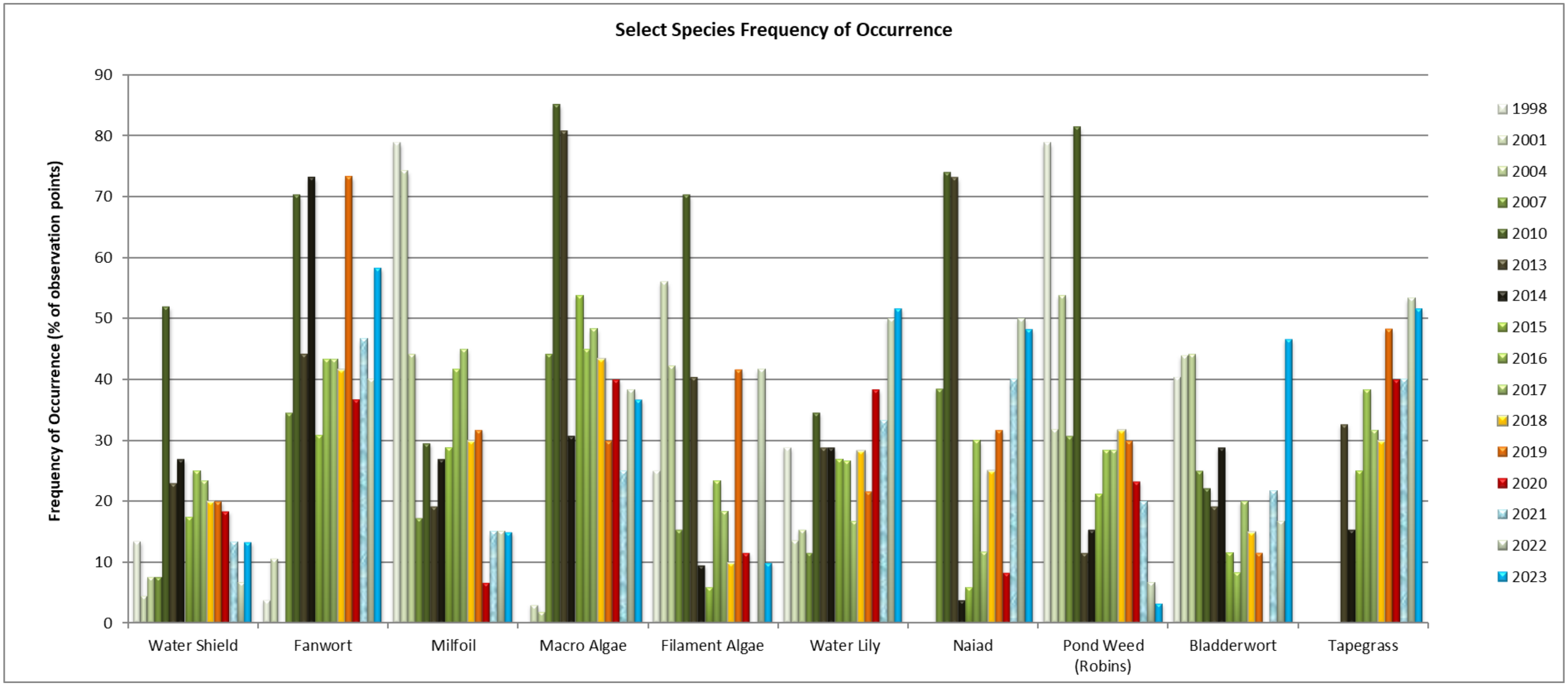


Figure 10. Bare Hill Pond Select Plant Species Frequency of Occurrence

Conclusion

Surface water total phosphorus concentrations were elevated in surface and in bottom waters of the in June and August. July was a wet month with low concentrations so some phosphorus could have been flushed out or diluted with higher water levels. With the sustained and expanding zone of low to no oxygen in portions of the lake deeper than 10 feet, internal loading remains a concern. The consecutive years of cyanobacteria blooms (2020 & 2021) are a symptom of warmer, low oxygenated, nutrient-rich waters. The Department of Health monitoring of photosynthetic pigments is helpful to track algal biomass and provide early warning of potential bloom. Secchi disk transparency was high early this year but declined over the summer, but still represents a substantial improvement over 2021.

The aquatic plant coverage was slightly increased over 2022 in the drawdown zone but decreased in deeper waters. The plant coverage reduction in deeper water could have been the result of the unintended deeper drawdown. Biovolume was slightly increased over 2022 with much of the plant volume attributable to two native species (bladderwort and tapegrass). Unfortunately, these species can become problematic for recreation even though they are native to New England. Many lakes have seen an increase in bladderwort this year; the cause is unknown. The density of fanwort has increased outside the drawdown zone but continues to be minimal in the drawdown zone. Non-native brittle naiad was comparable to last year and has not impeded recreation or reduce plant diversity in the lake. The lake has sustained a desirable coverage of low growing macroalgae and other native seed producing plants, such as pondweeds, in the drawdown zone following successful drawdown years.

We expanded the monitoring program in 2022 to better understand the cause of recent algal blooms. We suspect the lake may have reached a tipping point where the warming summers and increased availability of phosphorus from sediments will continue to result in more frequent and severe blooms. The sediment results from 2021 showed that phosphorus in the lake could increase by 0.02 mg/L if 20% of the sediment iron-bound phosphorus is released under anoxic conditions. Thankfully, the lake has been bloom-free thus far in 2023 and we may have avoided a potential bloom that was exhibited by the late July fluorometer readings. Although water clarity was low in August.

The pond's plant community is dense and diverse enough to support fish and wildlife, there are shifts in species composition between years, but the drawdown has proven to improve conditions; reduced dense monocultures of fanwort and milfoil in the drawdown zone and is encouraging growth of low growing beneficial plants that are less of a nuisance for recreation. The drawdown is likely improving flushing and ridding the lake of accumulated phosphorus from internal recycling over the summer. The weather may be the most influential factor as to whether the lake experiences a bloom or not. There is ample phosphorus available at the sediment water interface and whether cyanobacteria uptake that phosphorus and rise to the surface could be associated with weather patterns (light, temperature, precipitation, etc.) but this is still not well understood by phycologists. Conditions may become worse if algae and associated nutrients are not flushed out of the system.

Recommendations

We have expanded the water quality monitoring program in 2022 to include early and late season data and have added three monitoring stations to evaluate conditions in areas deep enough to go anoxic. These data will reduce data gaps and will assist in evaluating options for oxygen mitigation, if warranted. This program should be continued in 2024, especially since the first year was an outlier weather year with a severe drought and we experienced a wet start to this summer.

Given the success of the drawdown over the years in minimizing non-native fanwort and milfoil density within the drawdown zone and improved flushing, the Committee wishes to implement a 6.5-foot drawdown this coming winter. This will reduce non-native species abundance and provide an added benefit of reduced phosphorus retention. The aquatic macrophyte survey, and other fauna surveys performed by the Committee will continue an annual basis to assess year to year changes.