Report For:

Town of Harvard
Bare Hill Pond Watershed Management Committee
Harvard Massachusetts

Bare Hill Pond In-Lake Water Quality and Plant Survey - 2022

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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 2022. The intent of these surveys was to document 2022 summer conditions and compare these data to previous years, identifying any trends or concerns. This year we expanded the water quality monitoring to include the months of April, August, September, and October and added three new monitoring stations. The intent of the monitoring program expansion is to record temperature and dissolved oxygen depth profiles and 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 recent algal blooms, experienced in 2020 and 2021.

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 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 2022 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.

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. 2019-2020 had fewer days (83) below 30°F, representing 68% of the winter period and slightly higher average low temperature of 24.4°F. 2020-2021 was a very close match with 2019-2020, with differences in timing of cold weather and precipitation. The number of days below 30°F were 22 in November and December vs 31 last drawdown season. The month with the most cold days was January in 2021. The Fitchburg airport reported over 11 inches of precipitation in November and December in 2020 compared to less than a half inch in these months during 2019 (Figure 3). The inability to sustain a lower water level due to equipment and precipitation made the winter of 2020-2021 a poor drawdown year with limited to no plant control. Temperatures during the 2021-2022 season were very similar to the prior two season, with the average low around 23°F and 88 days with temperatures below freezing. 2021-2022 was wetter than 2019-2020 but drier than 2020-2021. Snowpack was low, which made for desirable drawdown conditions.

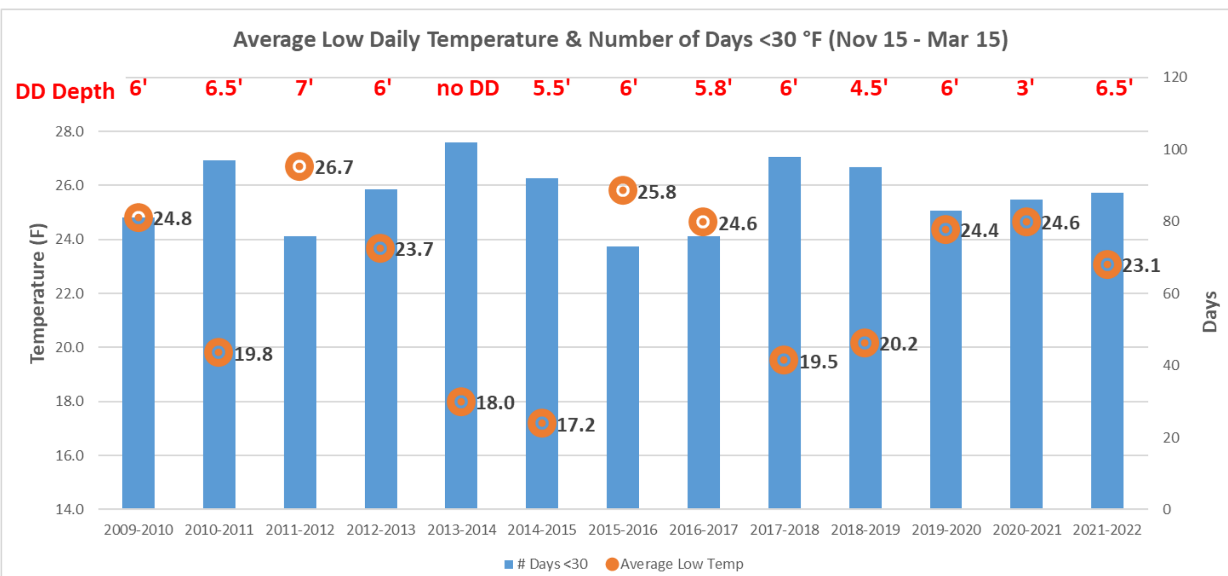

Figure 1. Average Low Air Temperature and Number of Days below 30°F during the Winter Season.

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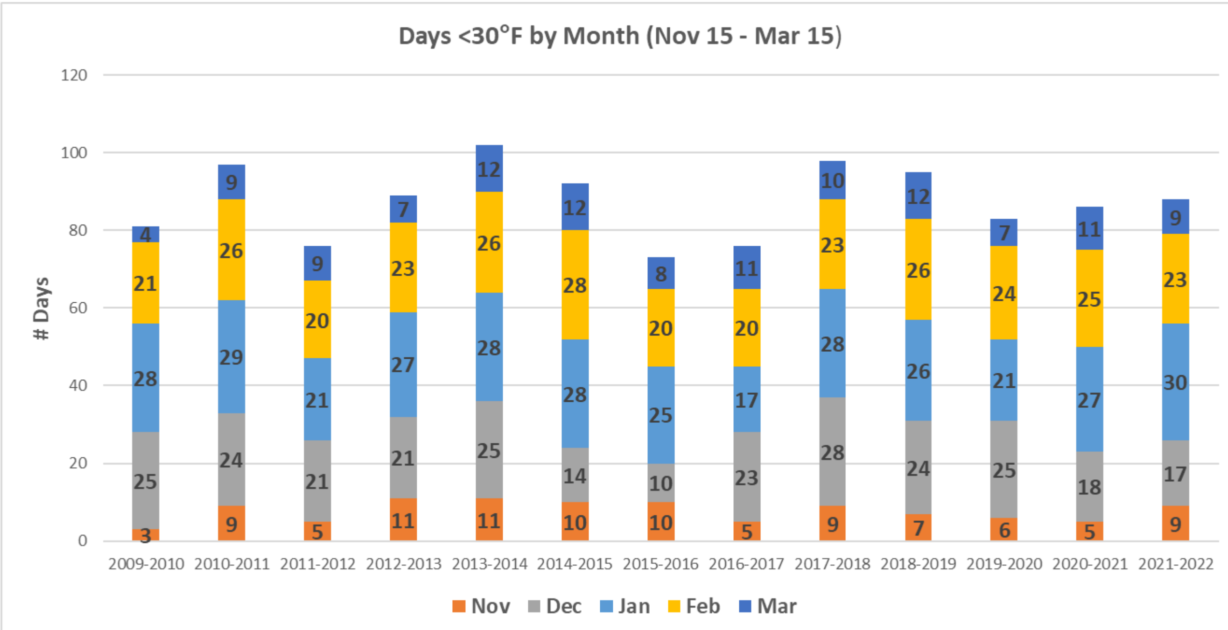


Figure 2. Number of Days with Air Temperatures below 30°F during the Winter Season.

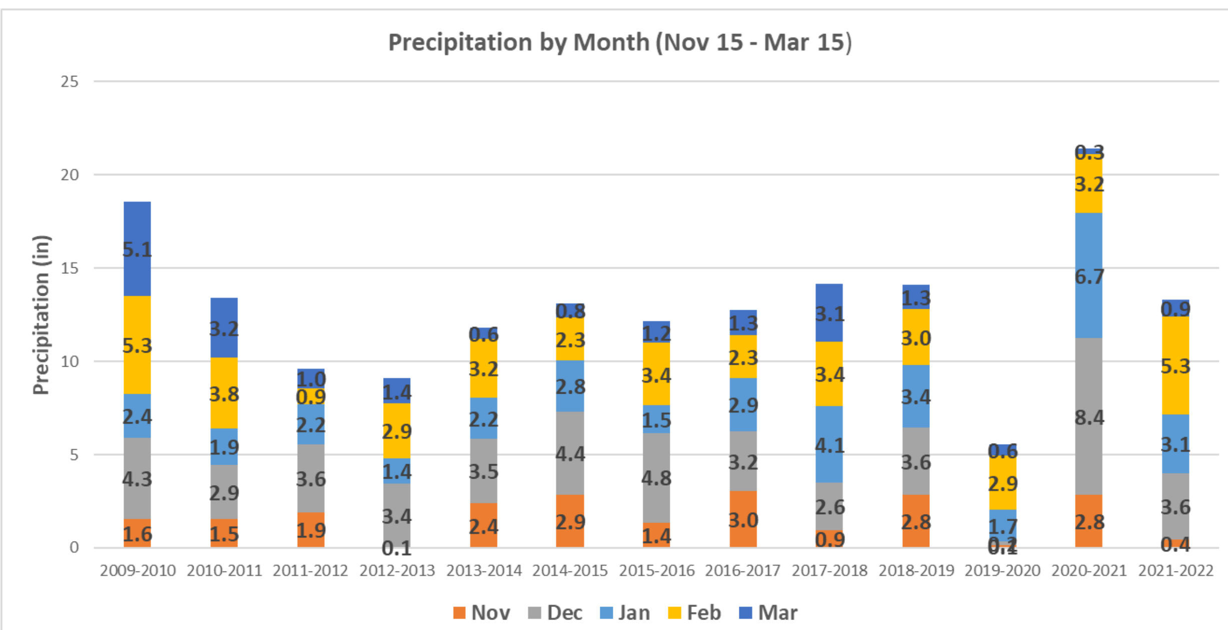


Figure 3. Precipitation during the Winter Season

In-Lake Sampling

In-lake sampling was conducted at five stations (Figure 4) on April 28, May 27, June 30, July 26, and August 20, 2022 (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 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 thermally stratified in May, earlier than in past years. 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 10 feet were historically below the 5.0 mg/L threshold considered to support aquatic life, but 2021 data 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 vs 12-14 feet in the past (Table 2, Figure 5). July 2022 oxygen data are slightly better than 2021, with anoxic concentrations staring below 11 feet in July. The anoxic layer was reduced come August with anoxia starting at about 17 feet vs 11 feet in July 2022. This suggests that there was some mixing that may have occurred between the sample dates. Winds in August were above average in 2022 with an average daily wind speed of 9.3 miles per hour (mph) between the June and July sample dates[2]. Even though there was some mixing, the lake remained anoxic for several feet allowing phosphorus release from iron in the sediments. DO at the added stations did not exhibit anoxia, with the exception of BHP-4 in July.

Table 2 provides depth profile data through August 20, 2022. Figure 5 provides 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.

[2] The average hourly wind speed in Harvard, Ma during the month of August is between 3.8 and 4.1 mph. Source: Weatherspark.com

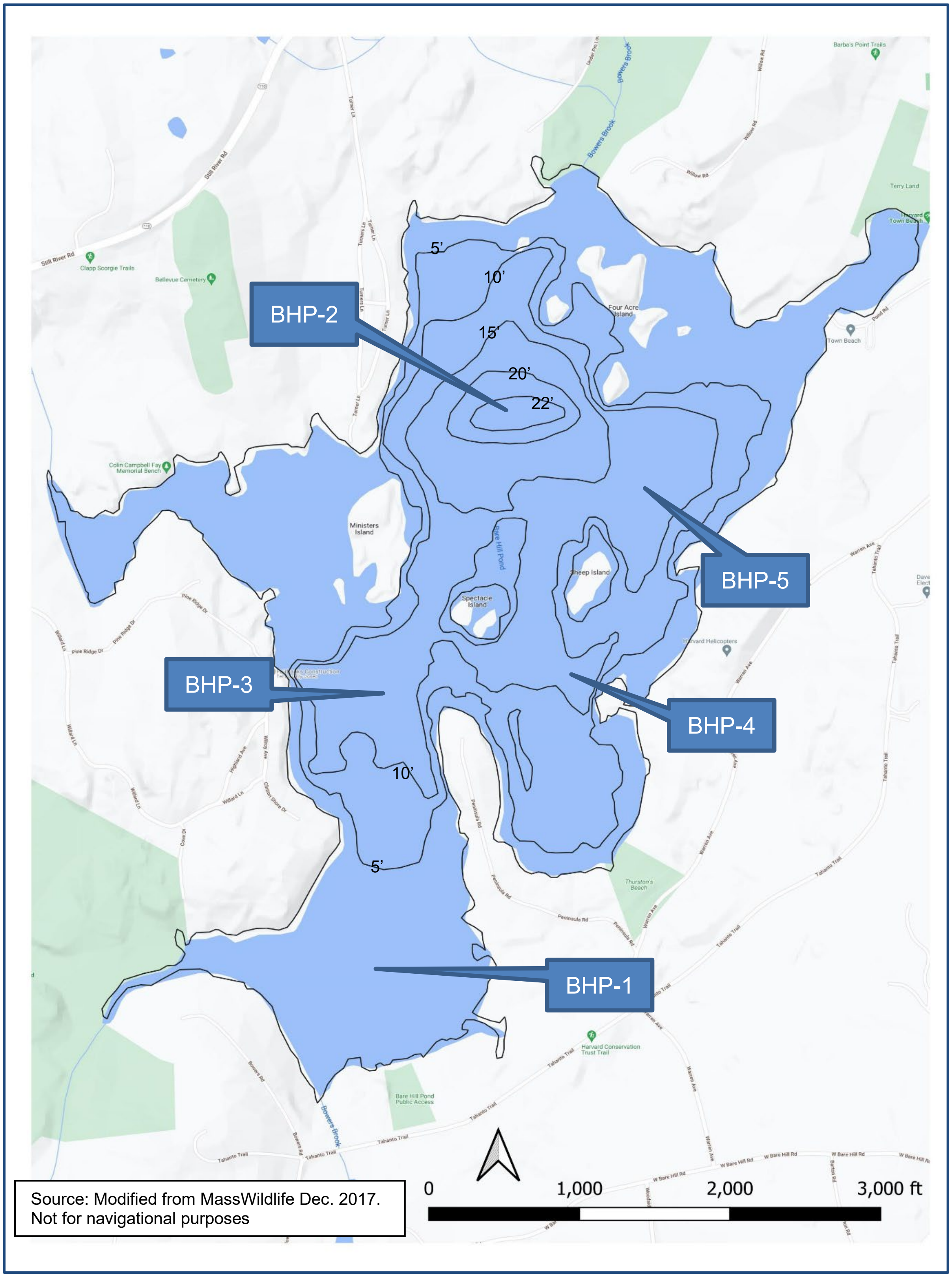


Figure 4. Bare Hill Pond Monitoring Stations.

Table 2. Bare Hill Pond Water Depth Profiles 2022.

BHP-1						BHP-1						BHP-1					
April 27, 2022						May 27, 2022						June 30, 2022					
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)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	13.3	10.15	6.56	136	0.0	0	22.81	8.82	7.68	143	0.0	0	26.4	9.13	8.70	213	0.0
1	13.31	10.10	6.9	136	0.0	1	22.79	8.79	8.08	142	0.0	1	26.4	9.22	8.62	213	0.0
2	13.32	10.14	7.67	136	0.0	2	22.73	8.71	8.06	142	0.0	2	26.4	9.29	8.68	213	0.0
3	13.33	10.14	8.03	136	0.0	3	21.46	8.16	8.02	142	0.0	3	26.36	9.43	8.68	214	0.0
4	13.34	10.13	8.12	136	0.0	4	20.36	8.12	8.05	143	0.0	4	26.22	9.7	8.62	215	0.0
5	13.33	10.09	8.21	136	0.0	5	20.33	8.09	7.98	143	0.0	5	26.22	9.47	8.47	214	0.0

BHP-2						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)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	13.31	9.71	7.1	13	0.0	0	22.40	8.82	8.28	144	0.0	0	25.588	8.19	7.61	214	0.0
2	13.32	9.72		136	0.0	2	22.40	8.82	8.05	144	0.0	2	25.88	8.16	7.57	214	0.0
4	13.32	9.73		136	0.0	4	22.38	8.80	8.00	144	0.0	4	25.87	8.18	7.25	214	0.0
6	13.31	9.72		136	0.0	6	22.40	8.79	8.03	143	0.0	6	25.77	8.16	7.24	214	0.0
8	13.32	9.71		136	0.0	8	22.39	8.77	8.11	143	0.0	8	24.67	7.90	7.17	213	0.0
10	13.31	9.65		136	0.0	10	22.19	8.48	8.24	144	0.0	10	24.1	7.44	7.12	212	0.0
12	13.27	9.56		136	0.0	12	16.67	5.16	8.56	140	0.0	12	22.72	5.77	7.23	211	0.0
14	12.97	8.87		136	0.0	14	14.78	4.23	8.29	141	0.0	14	20.75	2.61	7.51	210	0.0
16	12.01	8.47		136	0.0	16	14.47	4.45	8.15	140	0.0	16	19.23	1.25	7.42	210	0.0
18	11.90	8.26		136	0.0	18	13.85	3.68	7.89	140	0.0	18	17.27	0.96	7.05	207	0.0
20	11.77	7.75		137	0.0	20	13.17	2.09	7.58	143	0.0	20	14.36	0.00	6.88	214	0.0
22	11.40	6.50	6.6	138	0.0	22	12.94	1.10	7.31	147.30	0.0	22	13.13	0.00	6.99	244	0.0

BHP-3						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)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	13.26	9.76		136	0.0	0	21.93	8.62	7.77	144	0.0	0	25.88	8.36	7.72	213	0.0
2	13.26	9.77		135	0.0	2	21.96	8.60	7.64	144	0.0	2	25.86	8.43	7.85	214	0.0
4	13.25	9.75		135	0.0	4	21.97	8.59	7.63	144	0.0	4	25.90	8.42	7.44	214	0.0
6	13.25	9.78		135	0.0	6	21.89	8.58	7.58	144	0.0	6	22.89	8.46	7.42	213	0.0
8	13.25	9.75		135	0.0	8	21.83	8.51	7.47	144	0.0	8	25.4	8.21	7.34	213	0.0
10	13.25	9.75		135	0.0	10	18.25	6.47	7.57	141	0.0	10	23.79	7.12	7.38	212	0.0
12	13.24	9.79		136	0.0	12	15.82	2.93	7.92	141	0.0	12	22.18	4.74	7.64	213	0.0

BHP-4						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)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	13.36	9.79		137	0.0	0	22.37	8.58	7.76	144	0.0	0	25.95	8.34	7.59	214	0.0
2	13.35	9.79		137	0.0	2	22.37	8.57	7.54	144	0.0	2	26.06	8.33	7.45	214	0.0
4	13.37	9.79		137	0.0	4	22.38	8.57	7.47	144	0.0	4	26.02	8.34	7.18	214	0.0
6	13.37	9.79		136	0.0	6	21.33	8.30	7.50	144	0.0	6	25.91	8.22	7.06	214	0.0
8	13.37	9.80		137	0.0	8	21.20	8.25	7.51	143	0.0	8	25.09	7.88	6.90	213	0.0
10	13.36	9.78		136	0.0	10	20.81	7.35	7.52	144	0.0	10	23.61	6.19	6.73	211	0.0
11.9	13.7	9.78		137	0.0	12	19.92	7.20	7.64	142	0.0	12	21.77	2.95	6.95	211	0.0

BHP-5						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)	Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec. Cond (us/cm)	Turbidity (NTU)
0	13.44	9.85		138	0.0	0	22.48	8.80	7.69	144	0.0	0	26.21	8.24	7.53	215	0.0
2	13.45	9.86		138	0.0	2	22.49	8.79	7.44	144	0.0	2	26.21	8.21	7.32	215	0.0
4	13.46	9.87		138	0.0	4	22.49	8.81	7.37	145	0.0	4	26.15	8.22	6.99	215	0.0
6	13.45	9.86		138	0.0	6	22.48	8.80	7.34	144	0.0	6	25.61	8.10	6.92	214	0.0
8	13.44	9.85		138	0.0	8	22.48	8.76	7.30	144	0.0	8	25.20	7.99	6.83	213	0.0
10	13.46	9.88		138	0.0	10	22.45	8.10	7.33	144	0.0	10	24.09	6.72	6.65	212	0.0
12	13.48	9.83		138	0.0	12	18.84	4.55	7.58	142	0.0	12	23.00	4.40	6.86	213	0.0

Table 2. Continued.

BHP-1						BHP-1					
July 26, 2022						August 20, 2022					
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	27.61	8.30	7.42	222	24.9	0	25.34	7.48	6.51	233	0.0
1	27.63	8.33	7.59	222	30.0	1	24.92	7.46	6.72	233	0.0
2	27.61	8.35	7.40	222	24.9	2	24.72	7.56	6.73	233	0.0
3	27.63	8.27	7.29	223	16.0	3	24.7	7.50	6.80	232	0.0
4	27.63	824	7.26	223	14.0						

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	28.02	7.46	7.44	224	0.0	0	26.34	8.06	6.84	233	114
2	28.04	7.51	7.63	224	0.0	2	26.26	8.07	6.78	233	125
4	28.04	7.50	7.44	224	0.0	4	25.27	8.12	6.89	232	166
6	28.04	7.49	7.33	224	0.0	6	25.02	8.13	6.94	232	220
8	28.04	7.47	7.34	224	0.0	8	24.88	7.85	7.05	232	102
10	28.02	7.44	7.32	224	0.0	10	24.45	7.49	7.11	231	48
12	26.83	1.85	6.88	222	0.0	12	24.25	7.25	7.14	232	0.0
14	23.69	0.01	6.72	221	0.0	14	23.87	6.48	7.03	231	0.0
16	19.75	1.32	6.49	212	0.0	16	23.40	5.76	6.71	231	0.0
18	16.6	0.00	6.22	223	20.1	18	18.83	0.22	6.25	229	0.0
20	14.82	0.00	6.54	263	522	20	14.90	0.00	6.77	314	0.0
21	14.21	0.00	6.68	276	600	21	14.29	0.00	6.96	326	0.0

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	27.92	7.54	7.30	223	14.5	0	25.97	7.63	6.66	232	89
2	27.92	7.50	7.21	222	19.5	2	25.18	8.03	6.79	232	127
4	27.93	7.50	7.05	223	14.7	4	24.89	7.89	6.87	233	28
6	27.86	7.37	6.99	223	12.3	6	24.81	7.85	6.86	232	11
8	27.61	6.69	6.86	222	11.7	8	24.61	7.54	6.79	232	0.00
10	27.24	6.34	6.80	223	12.7	10	24.41	7.33	6.80	232	0.00
12	26.9	4.85	6.57	223	25.3	11	24.36	6.61	6.75	232	0.00

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	27.84	7.39	7.13	222	35.9	0	25.45	7.89	6.91	232	0.0
2	28.01	7.35	7.02	223	33.8	2	25.18	7.91	6.74	233	0.0
4	28.00	7.36	6.97	223	29.9	4	25.07	7.88	6.70	233	0.0
6	28.00	7.40	7.01	222	26.4	6	24.99	7.66	6.65	232	0.0
8	28.00	7.43	6.99	223	24.2	8	24.79	7.46	6.61	232	0.0
10	27.64	6.45	6.83	222	23.4	10	24.52	6.34	6.55	232	0.0
11.5	26.52	1.78	6.40	223	26.9	10.5	25.54	5.55	6.59	232	0.0

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	28.08	7.45	7.04	223	20.9	0	26.46	8.19	6.93	233	0.0
2	28.13	7.39	7.03	223	19.7	2	26.34	8.22	6.96	233	0.0
4	28.13	7.41	6.91	223	16.7	4	26.13	8.24	7.04	233	0.0
6	28.10	7.44	6.92	223	17.1	6	25.25	8.19	6.97	233	32
8	28.12	7.44	6.86	223	18.2	8	24.84	7.77	6.66	232	35
10	28.11	7.34	6.75	223	22.6	10.5	24.58	6.69	6.62	231.7	89
11.5	27.01	2.33	6.36	221	14.5						

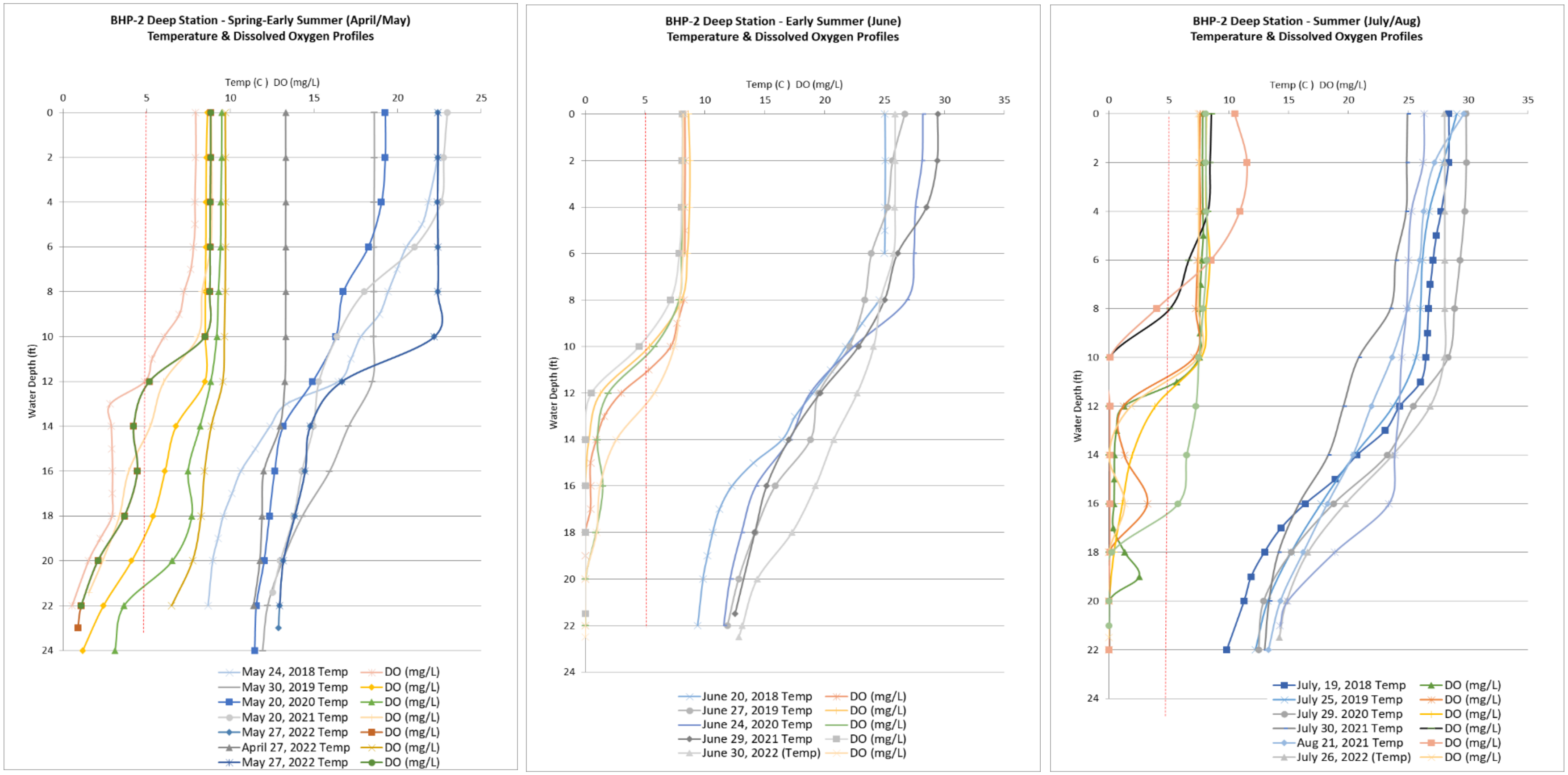


Figure 5. Temperature & Dissolved Oxygen Profiles at BHP-2 for 2018-2022.

Values Specific conductivity in 2022 was similar to prior years and around the upper end of the desirable range threshold [<200 microsiemens per centimeter [µs/cm)] for April and May but values increased over the next three months to 233 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 was variable between July and August. 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 are in the water. It is not known if the elevated turbidity measurements were caused by phytoplankton, suspended solids and/or bubbles generated by boat traffic. Boat traffic was heavy during both the July and August sampling events. TSS numbers in July were higher than detection, suggesting that there we particles other than dense bubbles in the water. We are still awaiting laboratory results from the grab sampling conducted in August.

Table 3 provides the results of phosphorus, TSS and water clarity (measured by Secchi disk transparency) during 2022. A comparison of phosphorus concentrations in the main basin (BHP-2) over time is illustrated graphically in Figure 6. TP surface concentrations were below the Massachusetts Department of Environmental Protection (MassDEP) target concentration of 0.030 mg/L[3] at the surface during all sample dates for BHP-1 and BHP-2. The surface samples at these locations were below the detection limit (0.010 mg/L) in June and July. The uncharacteristic low phosphorus is curious and could be the result of a laboratory error, the result of greater flushing with the drawdown removing more of the accumulated phosphorus from 2021, or settling of phosphorus and low loading due the drought this year.

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 April and May suggesting that there is phosphorus that is more 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.

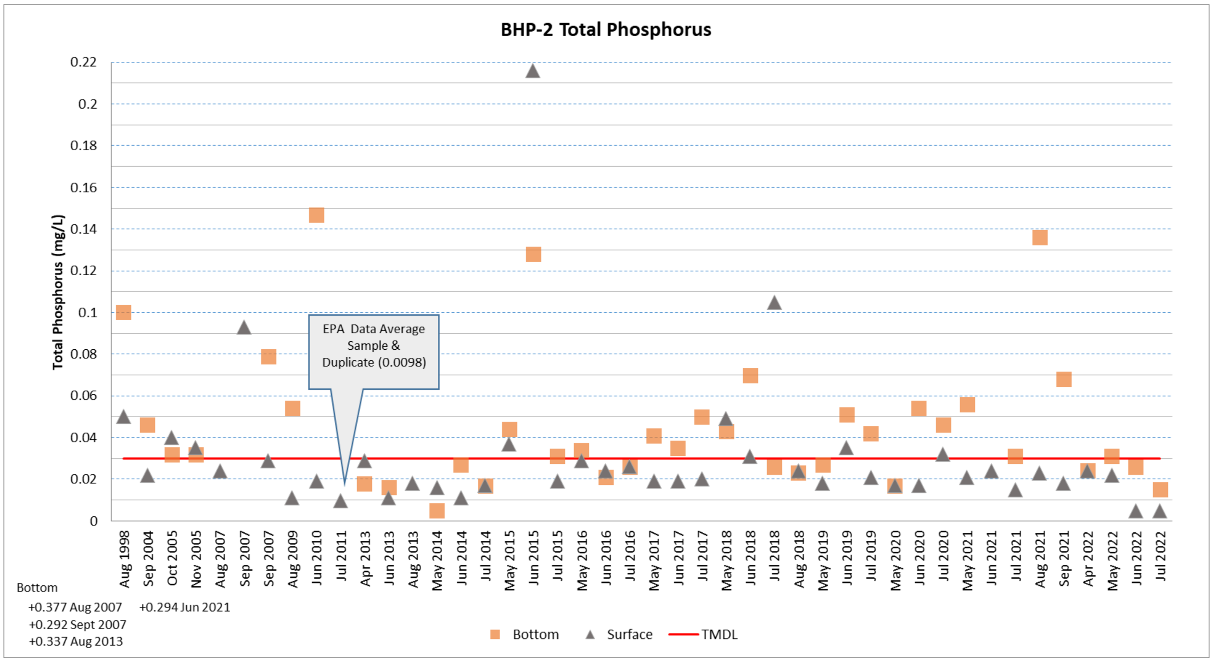
Like 2020 & 2021, we noted that during the filtering of the bottom phosphorus sample in July, the filter appeared green and suggested that there were enough algae present to cause the discoloration of the filter. However, this was not observed in later August. The Town of Harvard Board of Health (BOH) fluorometer readings and estimated cyanobacteria cell counts were generally below the 70,000 cells/mL advisory threshold in August, except the sample collected at 20 feet on August 2, 2022 (Figure 7). Lake mixing from high winds in August may have caused enough disturbance to prevent an accumulation of algae in the hypolimnion.

[3] 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. 2022 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	4/28/2022	16:45	0.024	0.027	7	11	
BHP-2 Bottom	4/28/2022	16:40	0.024	0.015	<5		
BHP-1 Surface	4/28/2022	17:00	0.071	0.018	5	5.5	bottom
BHP-3 Bottom	4/28/2022	17:15	0.105				
BHP-4 Bottom	4/28/2022	17:30	0.037				
BHP-5 Bottom	4/28/2022		Laboratory misplaced sample				
BHP-2 Surface	5/27/2022	17:40	0.022	0.018	<5	10.4	
BHP-2 Bottom	5/27/2022	17:45	0.031	0.022	14		
BHP-1 Surface	5/27/2022	18:10	0.017	0.014	<5	5.2	bottom
BHP-3 Bottom	5/27/2022	18:20	0.026				
BHP-4 Bottom	5/27/2022	18:30	0.032				
BHP-5 Bottom	5/27/2022	18:45	0.034				
BHP-2 Surface	6/30/2022	19:00	<0.010	<0.010	<5	12.3	
BHP-2 Bottom	6/30/2022	19:05	0.026	<0.010	10		
BHP-1 Surface	6/30/2022	19:30	<0.010	<0.010	<5	5.0	bottom
BHP-3 Bottom	6/30/2022	19:40	<0.010				
BHP-4 Bottom	6/30/2022	19:50	<0.010				
BHP-5 Bottom	6/30/2022	20:00	0.161				
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	8/20/2022	13:15	Awaiting Results from Analytical Laboratory			12.8	
BHP-2 Bottom	8/20/2022	13:25					
BHP-1 Surface	8/20/2022	10:10				4.2	bottom
BHP-3 Bottom	8/20/2022	10:40				12.2	
BHP-4 Bottom	8/20/2022	10:55				11	bottom
BHP-5 Bottom	8/20/2022	14:50				11.3	bottom

"Bottom" indicates the Secchi disk reached the pond bottom



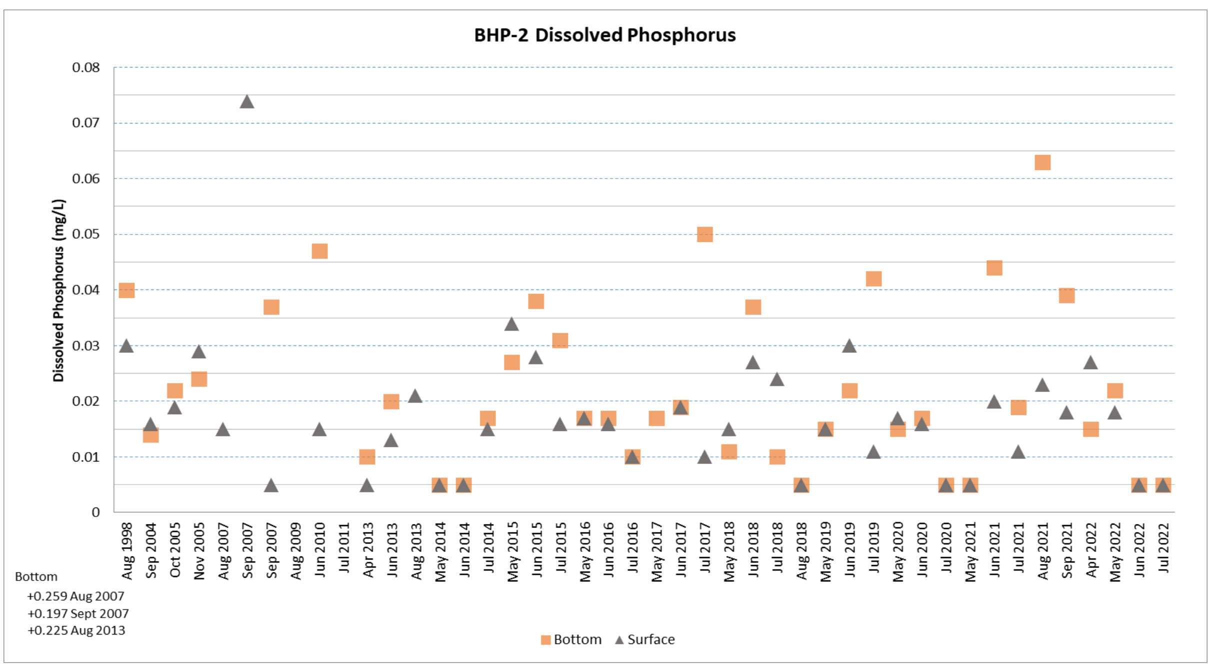
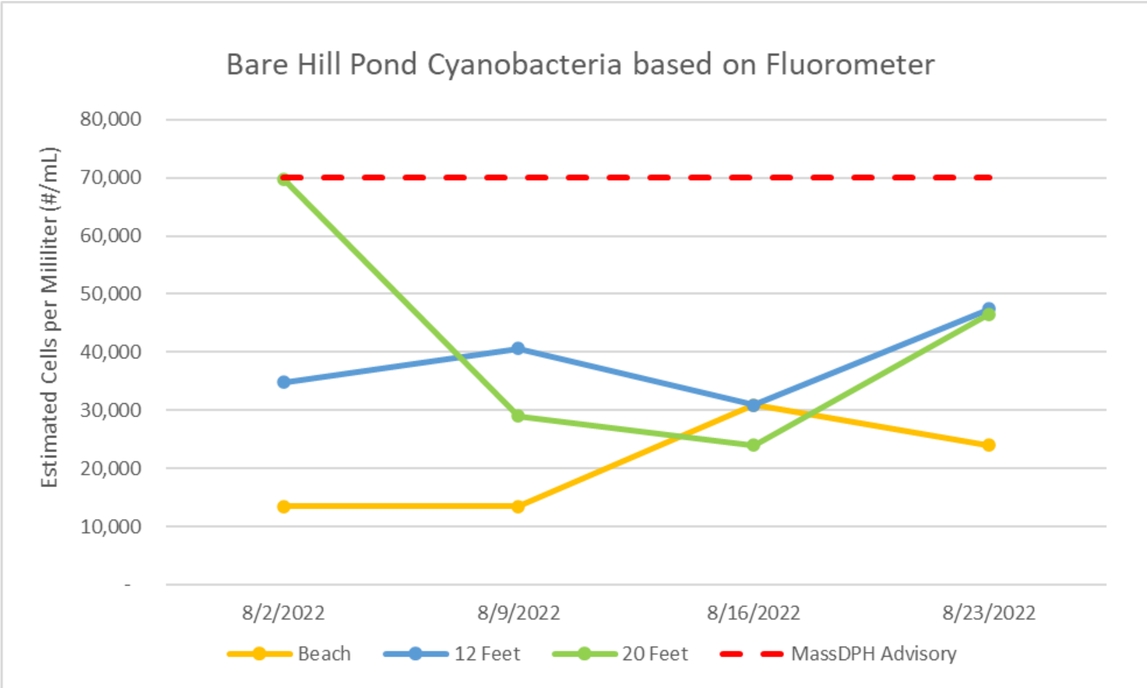


Figure 6. BHP-2 Total and Dissolved Phosphorus Concentrations.



Data provided by Town of Harvard Board of Health

Figure 7. Estimate Cyanobacteria Cells - August 2022.

Secchi disk transparency (SDT) in 2022 was much improved from 2021 due to the absence of an algal bloom. SDT ranged from 7.7 to 12.8 feet (range in 2021 was 3.0 to 12.4 feet). The lowest value was recorded in July. Clarity was above the MassDEP State Water Quality Standard for swimming (4 feet; Figure 8) during all monitoring events (through August 20, 2022). Clarity was greatest in August.

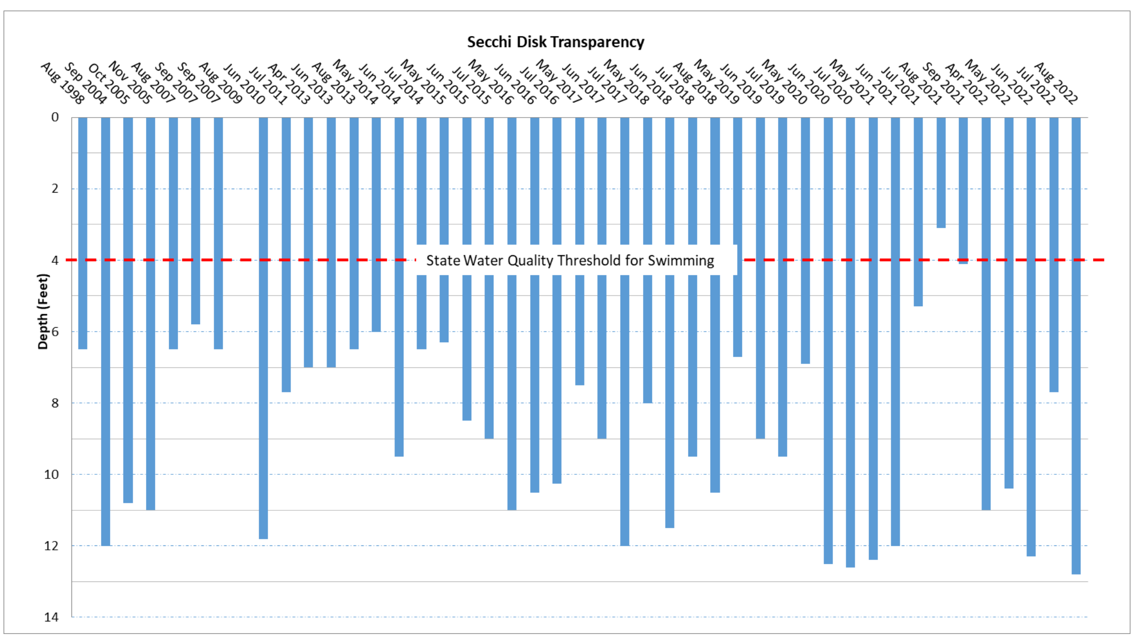


Figure 8. Bare Hill Pond (BHP-2) Secchi Disk Transparency.

In-lake Plant Survey

ARC conducted a plant survey on August 20, 2022. We used the same methods employed during the previous surveys conducted in 1998 through 2021. 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 an 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%		

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Table 5. 2022 Macrophyte Survey Data

Point	Water	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	2.9	4	3	T		S				S							M	M				D		S				S	
A-2	3.0	2	2															S						D				T	
A-3	2.6	4	3	D													T	D	D					D				T	
A-4	3.0	4	3	S			S							T			D	D						S				M	S
A-5	3.0	4	2							S							D	T						T				T	S
A-6	3.8	4	2							M							D	S						T				S	S
A-7	4.0	2	2							T							S							S					D
A-8	4.8	4	1							D																			T
A-9	5.6	3	1							D							S												
A-10	9.4	4	1							D																			
A-11	11.2	2	1			S				D																			
A-12	12.5	1	1			T				M																			
A-13	4.6	1	1							M																			
B-1	3.0	4	3						S	M							S	S	D					D					D
B-2	3.0	4	2							M							D	D	S					D					D
B-3	3.0	4	2							S						T	D	S	S										D
B-4	3.8	4	2									S				M	D	S						S					D
B-5	3.6	4	2			T	T					D		T		T	D	M						S				T	D
B-6	3.6	4	2									D					M	D											M
B-7	3.6	4	4									M												D				S	S
B-8	3.6	4	2			T						S				T		M	T					D					S
B-9	3.6	4	2													T	D		M					S					M
B-10	3.5	4	2									M					D		S					D					S
C-1	5.0	4	1			S				D		D						T										T	
C-2	7.0	4	2			S																	D						
C-3	6.8	4	2			S								T									D						
C-4	10.0	3	2			D																							
C-5	12.0	0	0																										
C-6	12.0	1	1			T																							
C-7	12.0	4	2			M				S				S															
C-8	5.9	4	2			D				M				S		S													D
D-1	3.0	4	1			M				S		D						M					T						T
D-2	3.0	4	1									D					S	S											S
D-3	3.0	4	1									D					M	T											M
D-4	3.0	2	1									M							S										S
D-5	3.0	4	2	S						T		D					S		T					M					M
D-6	3.6	4	1									D												M					S
D-7	3.4	4	1									D				T		S						S					M
D-8	3.6	4	1							S		M					D							M					D
D-9	4.6	4	1							M		D												D					M

Shaded cell indicates dominant species at observation point

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Table 5 (continued). 2022 Macrophyte Survey Data

Point	Water	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	4.6	4	1									D				M								D					
D-11	5.0	4	1									D					S							M					T
D-12	5.3	4	2									M												D					
D-13	8.7	4	3			D																							
E-1	4.3	4	3							S		D					D												M
E-2	5	4	2									M		T			D											T	D
E-3	5.3	4	3			D				S		S																	M
E-4	6	3	1			D																	S						
E-5	7.3	4	3			D				S																			
E-6	7.7	4	4			D																							
E-7	8.7	4	3			D																							
E-8	9.3	4	3			D				T																			
F-1	4.5	0	0																										
F-2	6.3	3	2			D				S				S															
G-1	3.6	3	3			D								T				T						S					S
G-2	7.7	4	3			D												S						S					
H-1	3.6	0	0																										
H-2	6.0	4	2			D						S		T															S
I-1	4.0	2	1															S											D
I-2	11.0	0	0																										
	Frequency of Occurrence			4	0	24	2	0	1	25	0	23	0	9	0	8	22	21	9	0	0	1	4	25	0	0	0	10	32
	Frequency Dominant			1	0	15	0	0	0	7	0	14	0	0	0	0	12	4	2	0	0	1	2	10	0	0	0	0	10

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. Biovolume increased at five locations and decreased at five locations from 2021. All five of the sites with decreases occurred in the drawdown zone. Inside the drawdown zone the increases in biovolume in 2022 were attributable to more native pondweed (*Potamogeton spirillus*), non-native brittle naiad (*Najas minor*) and macro algae (*Chara* and *Nitella*). *Nitella* and *Chara* have been successful in occupying the drawdown zone and are considered a beneficial replacement for fanwort and milfoil because they are low growing (creating a carpet like condition) and rarely impede contact recreation. While brittle naiad is non-native, it too is low growing and is unlikely to impede recreation. Increases outside the drawdown were primarily due to denser non-native fanwort (*Cabomba caroliniana*) in Transect E. The decreased biovolume observed in the drawdown zone was primarily due to decreased fanwort in Transect D, which was partially replaced by Chara and native tapegrass (*Vallisneria americana*).

The species shift is also apparent lake wide (Table 7 and Figure 9). Fanwort frequency decreased by 7% in 2022, as did the native plant watershield (*Brasenia schreberi*) which is susceptible to drawdowns. Robbins pondweed (*Potamogeton robbinsii*) decreased by 13%. 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 this year. Brittle naiad has expanded in the southern portion of the lake. This area also had a lot more filamentous green algae, likely due to the high water temperatures, stagnant nature of the cove and shallow morphometry. Tapegrass increased in abundance and was observed at points not previously identified. Select plant species frequency data are shown in Figure 9.

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Table 6. Bare Hill Pond Cover and Biovolume Relative Change

		Cover								Biovolume							
		2019 (4.5')		2020 (6.0')		2021 (3.0')		2022 (6.5')		2019 (4.5')		2020 (6.0')		2021 (3.0')		2022 (6.5')	
	Point	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Transect A	1	2		4			2		4	2		4			1		3
	2	3		2			3	2		2		1			2	2	
	3	4		4			4	4		2		1			2	3	
	4	4		4			2	4		3		1			2	3	
	5		4	4			3	4			3	1			2	2	
	6		5	4			3	4			2	1			2	2	
	7		5	1			4	2			4	1			1	2	
	8		2	2			3	4			2	1			1	1	
	9		2		1		3	3			1		1		1	1	
	10		4		1		0		4		2		1		0		1
	11		1		2		0		2		1		1		0		1
	12		0		0		0		1		0		0		0		1
	13		2	2			1	1			1	1			1	1	
Transect B	1	5		4			4	4		3		3			4	3	
	2		4	4			4	4			1	2			2	2	
	3		5	5			4	4			3	2			2	2	
	4		5	5			4	4			3	2			2	2	
	5		4	5			4	4			1	2			2	2	
	6		5	5			4	4			1	2			2	2	
	7		5	5			4	4			1	2			2	4	
	8		4	5			4	4			1	2			2	2	
	9		5	5			4	4			1	2			2	2	
	10		5	5			4	4			1	2			2	2	
Transect C	1		4	1			4	4			3	1			1	1	
	2		4		4		4		4		2		1		2		2
	3		4		4		4		4		3		2		2		2
	4		4		3		3		3		2		2		3		2
	5		1		1		0		0		1		1		0		0
	6		4		4		0		1		2		2		0		1
	7		4		4		0		4		2		2		0		2
	8		4		4		3	4			3		3		1	2	
Transect D	1	3		4			5	4		1		2			4	1	
	2		5	4			4	4			3	2			4	1	
	3		5	4			4	4			4	2			4	1	
	4	5		4			4	2		2		1			3	1	
	5	5		4			4	4		3		1			3	2	
	6		5	4			4	4			2	2			2	1	
	7	5		4			4	4		3		2			3	1	
	8		5	4			5	4			2	2			1	1	
	9		5	4			5	4			2	1			1	1	
	10		5	4			4	4			1	1			1	1	
	11		4	4			4	4			1	1			1	1	
	12		4		4		2	4			1		2		1	2	
	13		4	0			2		4		2	0			2		3
Transect E	1		4	5			2	4			1	2			1	3	
	2		5	5			4	4			1	2			1	2	
	3		5		5		4	4			2		2		2	3	
	4		5		4		2	3			2		2		2	1	
	5		5		4		3		4		3		2		2		3
	6		5		4		4		4		3		2		2		4
	7		5		4		4		4		3		2		2		3
	8		5		3		2		4		3		2		1		3
Supplemental	F-1		1	1			0	0			1	1			0	0	
	F-2		5		5		4	3			2		2		2	2	
	G-1		3	4			3	3			2	2			2	3	
	G-2		4		4		4		4		3		2		3		3
	H-1	1		1			1	0		1		1			1	0	
	H-2		4		4		2	4			2		2		2	2	
	I-1		1	1			2	2			1	1			1	1	
	I-2		4		4		1		0		1		1		1		0

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
Increase/Decrease from prior year										
	-7	-7	0	13	42	17	10	-13	-5	13

Naiad includes both native and non-native species occurrence

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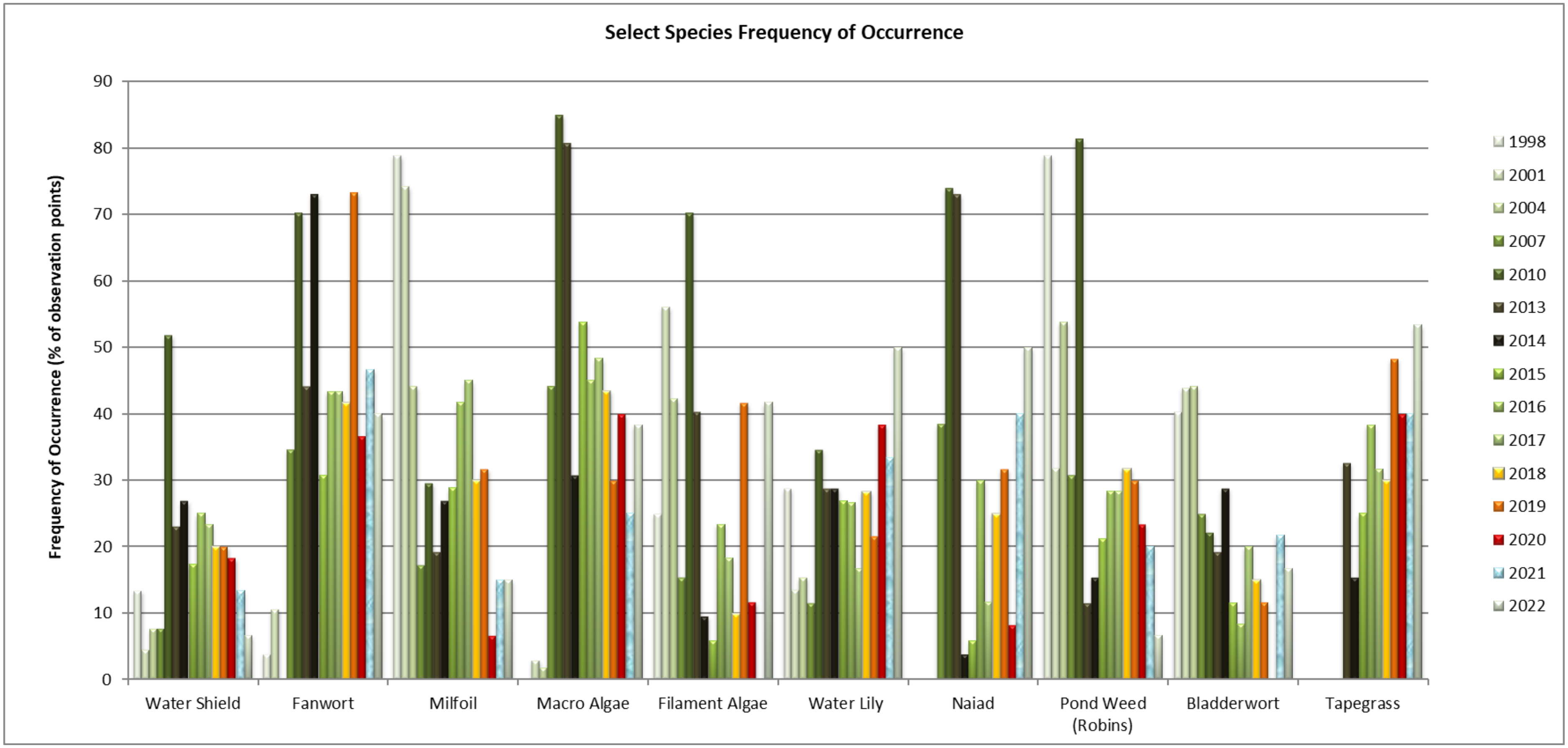
Figure 9. Bare Hill Pond Select Plant Species Frequency of Occurrence



Conclusion

Surface water total phosphorus concentrations were elevated in the south basin and in bottom waters of the main basin early in the season. Values were uncharacteristically lower than detection during July and August. This may be due to benefit of greater flushing with the drawdown removing more of the prior year's accumulated phosphorus. It also could be settling of phosphorus and low watershed loading due the drought this year, or a combination of all three possible theories. 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. Secchi disk transparency was high for the lake this summer and represents a substantial improvement over 2021.

The aquatic plant coverage was slightly increased over 2021 but this primarily occurred in waters deeper than the drawdown. Biovolume was consistent with 2021. However, the density of fanwort has increased outside the drawdown zone. Fanwort decreased in abundance and density inside the drawdown zone and replaced with macroalgae. Non-native brittle naiad has increased within the drawdown zone but has not seemed to impede 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 this year 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 and we may have avoided a potential bloom that was exhibited by early August fluorometer readings. The atypical windy August might have mixed the lake enough to lessen the accumulation of algae in deep water.

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 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. Conditions may become worse if algae and associated nutrients are not flushed out of the system.

Recommendations

We have reduced the monitoring of wetland plots and iris since data collected thus far have not revealed significant negative impacts associated with the drawdown. We have expanded the water quality monitoring program to include early and late season data and have added three monitoring stations to evaluate conditions is area 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 2023, especially since this year is an outlier weather year with a severe drought.

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.