MORSES POND ANNUAL REPORT: 2023

PREPARED FOR THE TOWN OF WELLESLEY

BY WATER RESOURCE SERVICES, INC.

DECEMBER 2023

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This report documents the implementation of the 2005 Comprehensive Morses Pond Management Plan through 2023 with a focus on the most recent year of activity. Program elements have included: 1) phosphorus inactivation, 2) plant harvesting, 3) low impact development demonstration, 4) education, and 5) dredging. Dredging was completed in 2013 and low impact development demonstration was done earlier than dredging, and these elements have been covered in past reports to the extent that further inclusion is unnecessary. The history of the other elements has also been covered in a cumulative fashion is past reports, most recently December of 2017, so this report has been streamlined to cover mainly the actions of 2023 within the context of the overall management plan and past progress and related data. Additionally, some of the approach applied to Morses Pond was extended to additional, smaller ponds within Wellesley as of 2018 and those efforts are included in this report for completeness.

Phosphorus Inactivation

Operational Background

Phosphorus entering through Bogle Brook and Boulder Brook was determined to be the primary driver of algae blooms in Morses Pond. Dry spring-summer periods fostered fewer blooms than wetter seasons in an analysis of over 20 years of data, although very wet conditions can flush the pond fast enough to also limit blooms. Work in the watershed to limit phosphorus inputs is a slow process and has limits related to urbanization that are very difficult to overcome. Reduction in the phosphorus content of lawn fertilizer is believed to be reducing inputs to the pond, but with so much developed land in the watershed, loading is still excessive. Inactivation of incoming phosphorus can counter those inputs and has been used extensively and successfully in Florida and with increasing frequency in other states to limit the impact of development on lakes there. The comprehensive plan called for a similar effort at Morses Pond.

A phosphorus inactivation system was established at Morses Pond in the spring of 2008. After testing and initial adjustment in 2008, the system has been operated in the late spring and part of summer in 2009 through 2023. The system has been modified over time, with simplification and a different aluminum chemical applied since 2014. The system has been automated since 2016, with control from a smart phone as needed. When a set amount of precipitation has occurred (normally 0.1 inch), the pumps turn on and polyaluminum chloride is fed into the Bogle Brook and Boulder Brook tributaries slightly upstream of the pond at rates of 40 to 80 gallons per hour. The tank serving Bogle Brook holds 2000 gallons, while the tank serving Boulder Brook holds 1000 gallons; Bogle Brook provides roughly twice the flow provided by Boulder Brook and is therefore treated at twice the rate. The system runs for 4 hours in response to a triggering precipitation event, although the duration is adjustable. The system is activated from the week before Memorial Day until about the week after 4th of July, although this is also adjustable as warranted and leftover aluminum is applied during summer when available. By treating incoming stormwater during the late spring period, Morses Pond can achieve a low enough phosphorus concentration to avoid algae blooms for the summer. If there is enough inflow to raise the phosphorus level, this also translates into increased flushing that tends to minimize algae blooms as well.

A total of 5277 gallons of polyaluminum chloride were applied to Morses Pond in 2022, representing 3113 lbs of aluminum, just slightly less than the average since system automation in 2016 (Table 1) but over 1000 lbs less than the average since program inception. All the aluminum was applied before the end of the first week of July, but July and August were rainy months, so there was considerable additional untreated runoff input into Morses Pond during the summer. Precipitation during the May-June 2023 period was 5.7 inches, an inch below the program average for that period. Precipitation for May-August was 22.6 inches, second only to 2021 since the inactivation program began and about 50% above average. There were 14 treatment days in May, June, and early July, after which the aluminum supply was exhausted and not replenished. The higher rainfall in July and August flushed the pond to a large degree, limiting the impact of treatment but also preventing the development of severe blooms. Internal recycling of phosphorus within the pond appears to have been increasing and may again have been a factor in algae growth during the summer of 2023.

Analysis of Program Results

Water quality is assessed prior to the start of treatment, normally in May, again in early summer, usually in the last week of June, and yet again at least once and more often twice later in the summer in up to three areas: the north basin, the transition zone to the south basin just south of the islands, and near the town beach at the south end of the pond (Figure 1). The sampling near the beach includes the actual swimming area and a point to the NW in the deepest part of the pond. Visual and water quality checks are made on an as needed basis, as part of normal operations or in response to complaints, major storms, or town needs. The water quality record for 2023 (Table 2) incorporates field and laboratory tests at multiple sites. A summary of phosphorus data for key periods since 2008 is provided (Table 3) to put the treatments and results in perspective. It is intended that total phosphorus will decrease through the treatment, such that values in the south basin, assessed in the swimming area near the outlet of the pond, will be lower than in the north basin, with the transition zone exhibiting intermediate values. Based on data collected since the early 1980s, total phosphorus in the south basin in excess of 20 µg/L (0.02 mg/L) tends to lead to algal blooms, while values <20 µg/L minimize blooms and values near 10 µg/L (0.01 mg/L) lead to highly desirable conditions.

Total phosphorus concentrations in 2023 (Table 2) were higher than desired and similar to what was observed in the even wetter summer of 2021. There was an issue with one of the pumps, preventing timely input of aluminum during some storms, but the typical quantity of aluminum from recent years was delivered. It may have prevented an even more dramatic rise in phosphorus concentration but did not achieve the 20 ug/L target by the start of summer. Further, the very wet July and August added considerable phosphorus that was not treated and very low oxygen in water deeper than 10 feet promoted release of phosphorus from sediment. There were more algae than in recent years, but the flushing effect of so much rain minimized accumulation in the pond.

Total Kjeldahl nitrogen values were moderate to high in 2023 (Table 2), mostly 0.4 to 0.5 mg/L in surface samples from the pond and 0.7 to 1.8 mg/L in the deepest water. A portion of the pond stratifies and loses oxygen, allowing ammonium to build up through decomposition with minimal mixing in that zone. Ammonium is not measured directly but is the dominant form of nitrogen in deep water with the elevated TKN values.

Table 1. Summary of Phosphorus Inactivation Effort, 2008-2023.

Year	Applied Alum (gal)	Applied Aluminate (gal)	Aluminum Mass (lbs)	# of Treatment Days	May-June Precipitation (in)	May-August Precipitation (in)	Notes
2008	2000	1000	2240	5	6.2	16.7	Testing and adjustment phase, most treatment in July
2009	6002	2900	6595	16	5.9	16.1	Some elevated storm flow untreated
2010	4100	2080	4630	13	6.1	14.5	Additional chemical applied after early July
2011	5000	2475	5569	14	8.0	17.8	Some equipment failures. Additional chemical applied in August in response to bloom
2012	6000	3000	6720	19	6.9	14.4	Equipment problems hampered dosing during treatment
2013	6055	2785	6476	20	13.7	19.1	Very wet June (26.7 cm), unable to treat all storm flows; continued treatment through July
	Polyaluminum chloride						
2014	5985		3531	12	5.5	11.8	No treatment after 1st week of July, first year using polyaluminum chloride
2015	7900		4661	14	6.2	10.5	Leftover chemical used in summer, but little treatment after first week of July
2016	5800		3422	13	4.7	7.3	Only a little over half of the chemical was used by early July, remainder by August 15th
2017	6000		3540	17	8.3	13.9	Two deliveries of chemical were made and all was used by early July
2018	5400		3186	11	4.9	14.1	Two deliveries of chemical were made and all was used by the end of July
2019	5100		3009	14	8.5	17.8	Three deliveries (the 1st was a half load and portions of loads 2 and 3 were used on other ponds) of chemical were made and all was used by the mid-July
2020	4668		2754	9	4.9	9.1	Two deliveries made, parts of both used on other ponds. Limited treatment in June due to dry weather, extended treatment in to August
2021	5395		3183	12	7.5	24.6	Two deliveries made, parts of both used on other ponds. All Al used by early July , while it rained most of July, adding a lot of untreated water to Morses Pond
2022	5188		3061	16	3.7	10.2	Two deliveries made, but only 2500 gal added to Morses Pond before July. Additional treatments in July, Aug, and Sept.
2023	5277		3113	14	5.7	22.6	Two deliveries made, all used by July 4th. Considerable additional rain in July and August.

Figure 1. Current system layout and water quality sampling sites in Morses Pond.

Table 2. Water quality record for Morses Pond in 2023.

	Date	Time	Depth	Temp	DO	DO	Sp. Cond	pH	Turbidity	CHL	Secchi	Total P	TKN	Nitrate N	Total N
Station	MM.DD.YY	HH:MM:SS	meters	°C	mg/l	% Sat	µS/cm	Units	NTU	µg/l	meters	mg/L	mg/L	mg/L	mg/L
Bogle	05.20.23											0.1250	0.8870	0.4660	1.353
Boulder	05.20.23											0.6510	3.7900	0.5110	4.301
MP-NB1	05.20.23											0.0340	0.5300	0.2630	0.793
MP-NB2	05.20.23											0.0404	0.4820	0.2650	0.747
MP-T1	05.20.23											0.0361	0.4460	0.1200	0.566
MP-T2	05.20.23											0.0308	0.4740	0.1710	0.645
MP-1	05.20.23	10:52:10	-0.1	18.1	9.6	121	577	8.1	6.0	4.8	2.8	0.0191	0.3680	0.2180	0.586
	05.20.23	10:52:53	1.0	17.7	9.6	121	576	8.2	4.1	7.2					
	05.20.23	10:53:37	2.0	17.5	9.3	117	577	8.1	3.2	11.4					
	05.20.23	10:54:03	3.0	15.3	7.4	89	559	7.8	3.0	22.4					
	05.20.23	10:54:44	4.0	12.1	2.8	32	638	7.3	2.6	9.0					
	05.20.23	10:55:30	5.0	11.1	0.3	3	665	7.0	2.3	4.9					
	05.20.23	10:56:27	5.8	10.7	0.0	0	671	6.7	5.3	2.9		0.0223	0.5360	0.1730	0.709
MP-B	05.20.23											0.0213	0.4320	0.2250	0.657
MP-NB1												0.0308	0.4200	0.0580	0.478
MP-NB2												0.0382	0.4680	0.1170	0.585
MP-T1												0.0361	0.4450	0.1090	0.554
MP-T2												0.0329	0.3260	0.0660	0.392
MP-1	06.26.23	10:17:33	0.2	24.6	9.8	119	571	7.8	0.9	6	2.7	0.0298	0.3700	0.0800	0.450
	06.26.23	10:18:04	1.0	24.1	10	118	569	7.7	1.0	8.6					
	06.26.23	10:18:36	2.0	22.1	9	111	552	7.5	1.6	20.3					
	06.26.23	10:19:22	3.0	18.6	6	67	585	7.2	7.4	12.5					
	06.26.23	10:20:27	4.1	14.6	0	2	621	6.8	6.4	8.2					
	06.26.23	10:21:01	5.0	12.3	0	1	667	6.7	6.1	6.1					
	06.26.23	10:21:54	6.0	11.3	0	1	694	6.8	5.2	3.6		0.0351	0.6810	0.0500	0.731
MP-B												0.0255	0.3370	0.0500	0.387
Bogle	07.10.21	10:05:30	0.2									0.0935	0.6130	0.5160	1.129
Boulder	07.10.21	10:20:22	0.2									0.1280	0.9790	0.9850	1.964
MP-1s	07.10.21	11:30:10	0.2									0.0319	0.5720	0.0500	0.622
MP-1	07.20.23	11:05:55	0.4	28.2	9.4	122	522	8.0	2.9	4.2	2.0	0.0266	0.4050	0.0500	0.455
	07.20.23	11:06:18	1.0	27.1	9.2	117	522	7.8	4.1	5.7					
	07.20.23	11:06:45	2.0	26.0	5.9	74	501	7.4	5.1	14.2					
	07.20.23	11:07:34	3.0	22.6	0.0	0	542	6.9	4.6	6.9					
	07.20.23	11:08:04	4.0	17.1	0.3	3	604	6.8	6.0	7.6					
	07.20.23	11:08:27	5.0	13.6	0.2	2	667	6.8	6.5	6.6					
	07.20.23	11:08:59	6.0	11.7	0.2	2	708	7.0	7.9	2.9					
MP-NB1												0.0520	0.5070	0.0709	0.578
MP-NB2												0.0436	0.3610	0.1130	0.474
MP-T1												0.0351	0.4660	0.0526	0.519
MP-T2												0.0306	0.4360	0.0500	0.486
MP-1	08.24.23	11:15:08	0.3	23.2	9.0	106.6	413	7.6	3.0	9.4	1.9	0.0319	0.4160	0.0825	0.499
	08.24.23	11:15:44	1.0	22.8	7.8	91.3	413	7.5	3.5	9.6					
	08.24.23	11:16:23	2.0	22.0	2.7	31.4	422	7.1	2.7	5.0					
	08.24.23	11:17:06	3.0	20.8	0.9	10.5	441	6.9	2.5	11.4					
	08.24.23	11:17:51	4.0	17.1	0.2	2.6	628	6.9	3.5	4.5					
	08.24.23	11:18:32	5.0	13.7	0.1	1.0	698	7.1	5.1	2.4					
	08.24.23	11:19:10	6.0	12.3	0.0	0.1	743	7.2	6.0	3.6		0.1230	1.8400	0.0500	1.890
MP-B												0.0308	0.4450	0.0939	0.539

Table 3. Water quality testing results relative to the phosphorus inactivation system

Year	Location	Pre-Application TP (ug/L)	Early Summer TP (ug/L)	Late Summer TP (ug/L)	Observations
2008	North Basin	0.028	0.018	0.013	Mats observed, some cloudiness
	Transition Zone	0.031	0.022	0.014	Some cloudiness, brownish color
	Swimming Area	0.021	0.012	0.012	No blooms reported, first year without copper treatment in some time
2009	North Basin	0.035	0.040	0.063	Cloudy, some green algae mats
	Transition Zone	0.035	0.039	0.045	Cloudy
	Swimming Area	0.015	0.010	0.027	Generally clear, no blooms reported
2010	North Basin	0.026	0.046	0.053	Cloudy, green algae mats evident
	Transition Zone	0.028	0.021	0.032	Brownish color, minimally cloudy
	Swimming Area	0.019	0.015	0.043	Generally clear, no blooms until late August (Dolichospermum)
2011	North Basin	0.053	0.033	0.130	Cloudy, green algae mats evident
	Transition Zone	0.048	0.029	0.095	Slightly brownish
	Swimming Area	0.030	0.029	0.060	August bloom (Dolichospermum), dissipated after just a few days without treatment
2012	North Basin	0.032	0.024	0.048	Very dense plant growth, associated green algae mats
	Transition Zone	0.028	0.037	0.028	Brownish most of summer
	Swimming Area	0.020	0.027	0.024	Had bloom in mid-July (Dolichospermum), treated with copper
2013	North Basin	0.036	0.047	0.030	Water brownish, little visible algae; 1st year with newly dredged area within north basin
	Transition Zone	No Data	0.078	0.032	Generally elevated turbidity, but much of it is not living algae
	Swimming Area	0.024	0.033	0.028	Treatment lowered TP but not to target level; June flushing minimized algae biomass
2014	North Basin	0.030	0.022	0.020	Dense plant growths and green algae mats outside dredged area, water fairly clear
	Transition Zone	0.021	0.020	0.018	Dense plant growths, but water fairly clear
	Swimming Area	0.012	0.013	0.017	Water clear; Secchi to bottom in swimming area, no blooms reported
2015	North Basin	0.012	0.017	0.023	Dense plant growths and green algae mats outside dredged area, water fairly clear
	Transition Zone	0.008	0.015	0.014	Dense plant growths, but water fairly clear
	Swimming Area	0.005	0.005	0.014	Water clear; Secchi to bottom in swimming area, no blooms reported
2016	North Basin	0.012	0.009	0.005	Very dense plant growths after mild winter, but water still clear
	Transition Zone	0.019	0.016	0.005	Dense plant growths but water clear
	Swimming Area	0.014	0.005	0.005	Water clear; Secchi to bottom in swimming area, no blooms reported
2017	North Basin	0.031	0.031	0.013	Dense rooted plants, some algae mats
	Transition Zone	0.027	0.034	0.014	Dense rooted plants, few algae mats
	Swimming Area	0.017	0.018	0.015	Some cloudiness, but no visible algae blooms
2018	North Basin	0.030	0.018	0.016	Dense rooted plants, some algae mats
	Transition Zone	0.031	0.015	0.016	Some cyanobacteria in June, less in August
	Swimming Area	0.017	0.012	0.011	Some cyanobacteria in June, less in August, but water green at 20 ft of depth in early Sept
2019	North Basin	0.025	0.030	0.028	Water turbid with suspended sediment on most visits
	Transition Zone	0.020	0.034	0.022	Water turbid but on obvious cyanobacteria or algae mats
	Swimming Area	0.019	0.015	0.018	No cyanobacteria and few green algae mats observed in May-Aug, some cyanobacteria in
2020	North Basin	0.025	0.018	0.012	Plants very dense but few algal mats
	Transition Zone	0.042	0.030	0.012	Plants dense on most visits, water murky but few visible particles
	Swimming Area	0.038	0.011	0.015	Some cyanobacteria particles early in summer but clarity acceptable at all times
2021	North Basin	0.025	0.030	0.051	Much rain, samples from Bogle and Boulder with TP >0.6 mg/L 1st flush, >0.06 post-storm
	Transition Zone	0.023	0.039	0.051	Plants dominated by fanwort, harvesting effort high but could not keep up with growth
	Swimming Area	0.021	0.025	0.035	Water murky much of summer, but from rain, particulates, and natural color, not high algae
2022	North Basin	0.022	0.028	0.019	Very dry spring and summer, limited Al treatment before July
	Transition Zone	0.027	0.031	0.017	Plants dominated by fanwort, harvesting effort high but could not keep up with growth
	Swimming Area	0.018	0.021	0.015	Algal bloom of Planktothrix in late August into September
2023	North Basin	0.037	0.035	0.048	Average spring precipitation, very wet July and August
	Transition Zone	0.034	0.035	0.033	Plants dominated by Eurasian milfoil, harvesting effort high but could not keep up with growth
	Swimming Area	0.020	0.031	0.031	Decreased clarity included color, suspended sediment, and some cyanobacteria

Concentrations of TKN and nitrate in inflows from Boulder Brook were higher than those in Bogle Brook, but all were elevated. The continued high nitrogen inputs from Boulder Brook suggest upstream sources worth investigating. Nitrate was much lower but not negligible in the pond (Table 2), declining from a high near 0.2 mg/L in May to close to the detection limit at 0.05 mg/L by mid-summer and remaining low through August. The loss of nitrate favors cyanobacteria, which utilize this nitrogen source less than other algae.

There are usually summer oxygen deficiencies in the deep hole area (MP-1) with depressed or depleted oxygen by mid-summer in many years. In 2019 oxygen was low at 4 m by late June and at 3 m by mid-July. Conditions were somewhat better in 2020, but oxygen was minimal below 4 m of water depth by late July. In 2021 low oxygen was detected at 4 m in late June and 2 m in late July and August. In 2022 there was minimal oxygen deeper than 4 m by the start of August. Conditions in 2022 were more similar to those of 2020 but were still not desirable with regard to oxygen in deeper water. Oxygen data for 2023 were similar to those of 2021 and among the worst conditions observed since program inception. Given higher summer inflows in 2021 and 2023, this suggests that watershed inputs of organic matter, flushed from upstream wetlands by more intense precipitation, are a factor in pond oxygen levels. Yet those inputs mostly remain in the lake and add to the oxygen demand in coming years. Warmer summers also increase water temperature which in turn increases bacterial metabolism and oxygen demand, leading to lower oxygen concentrations. Additionally, warmer water accelerates rooted plant growth, which adds oxygen by day and removes it by night, causing higher high values and lower low values with substantial daily variability. This is a climate change effect, and the variation can be troublesome at the increased frequency of low oxygen levels.

The affected area in many years before 2020 has been <20% of the pond area and <10% of the pond volume, and no fishkills or even stress were observed in the pond. Low oxygen conditions in Morses Pond have affected at least 33% of the lake bottom in recent years and may have impacted more than half the area in 2023 with both oxygen demand in deep water and excessive rooted plant growth in shallow water. Low oxygen is a negative influence on water quality and pond ecology, and there were more dead fish in spring 2023 than any recent year. Aside from not supporting aquatic life based on the state standard for oxygen (5 mg/L), low oxygen allows phosphorus to be released from the affected sediment and can foster development of cyanobacteria at the sediment-water interface that later rise to form a bloom. This occurred in each of the last few years, with the 2022 event the worst, probably owing to low flushing on top of the other issues. Cyanobacteria accumulation was localized and not a threat to most lake uses, but the trend is concerning.

Conductivity is high in surface waters of Morses Pond and very high in deeper water, indicating large amounts of dissolved solids in the water, although conductivity does not reveal the nature of those solids. Salts from road management are a likely source, but natural inputs from upstream wetlands are also likely substantial. The pH is slightly elevated near the surface and declines with depth, with decomposition adding acids and lowering pH at deeper locations. The pH also tends to increase as water moves through the pond, with photosynthesis by algae and rooted plants removing carbon dioxide and raising pH. Values for pH in 2023 were between 6.7 and 8.2, an acceptable but rather wide range with a peak when spring plant biomass was at a maximum. Turbidity is moderate in most of the water column but was high enough to limit clarity to <2 m in summer 2023. Turbidity is caused by suspended solids, which in turn are a mix of algae and non-living particles, either organic or inorganic. In Morses Pond, most suspended solids are organic, either living algae or dead plant material, and these affect both clarity and oxygen.

Summer water clarity in 2023 was the lowest since the inactivation system was enhanced (Figures 2 and 3), although all recreational pursuits were still supported. High stormwater inputs supported more algal growth but were also a source of non-algal solids and color, both of which reduce clarity. High precipitation over the summers of 2021 and 2023 resulted in lower clarity than the much drier summers of 2020 and 2022, but that latter pair of years did not provide optimal clarity. Internal recycling of phosphorus in response to low oxygen appears to be a factor as well as external loading.

Experimentation with the timing and amount of aluminum has suggested a lower limit of about 3500 lbs per May-June application period or about 400 lbs per inch of precipitation for best results. Just over 3100 lbs of aluminum were applied by early July of 2023, representing 546 lbs per inch of precipitation in May and June, but the almost 17 inches of precipitation in July and August added a lot of untreated runoff. Further, the failure of one of the two pumps imposed spatial and temporal limits on treatment that reduced efficiency. Consequently, conditions were not appreciably better than before treatment was initiated in 2008.

The phosphorus inactivation history for Morses Pond has been divided into 3 periods: 2008-2010, 2011-2013, and 2014-2022, both in terms of system function and average summer water clarity data (Figures 2 and 3). The system worked well for 3 years, had equipment and operational problems for the next 3 years, then was modified and improved, leading to 6 years of low summer phosphorus and superior clarity. Conditions in 2020 and 2022 were not quite as desirable as in recent years, mostly owing to a dry

Figure 2. Average summer water clarity and total phosphorus in Morses Pond, 1994-2023.

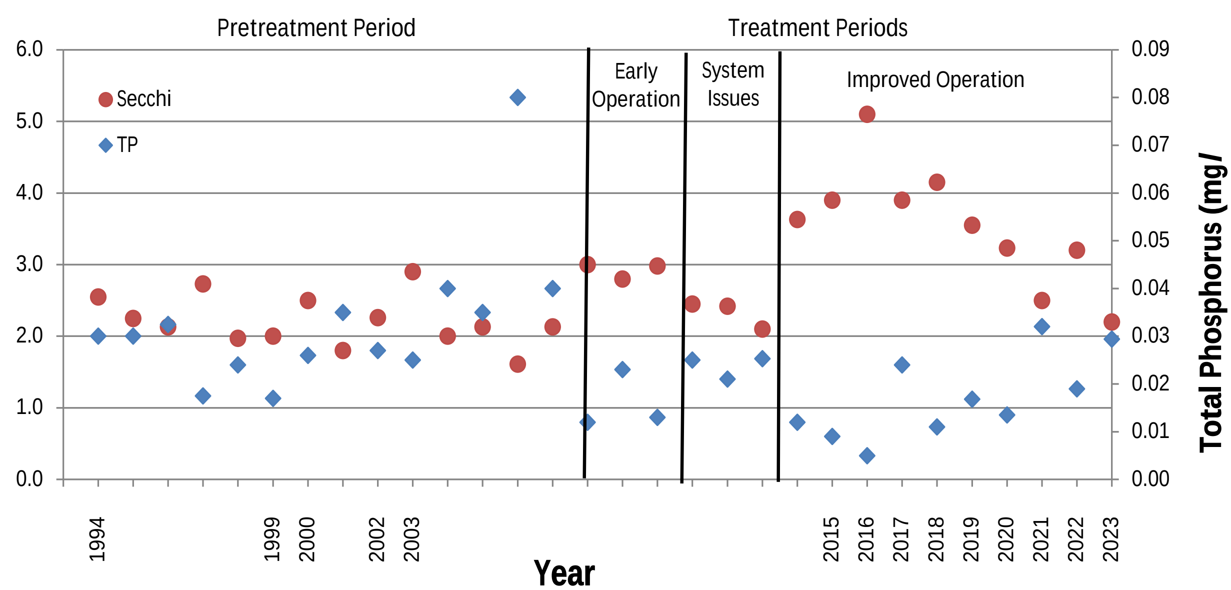
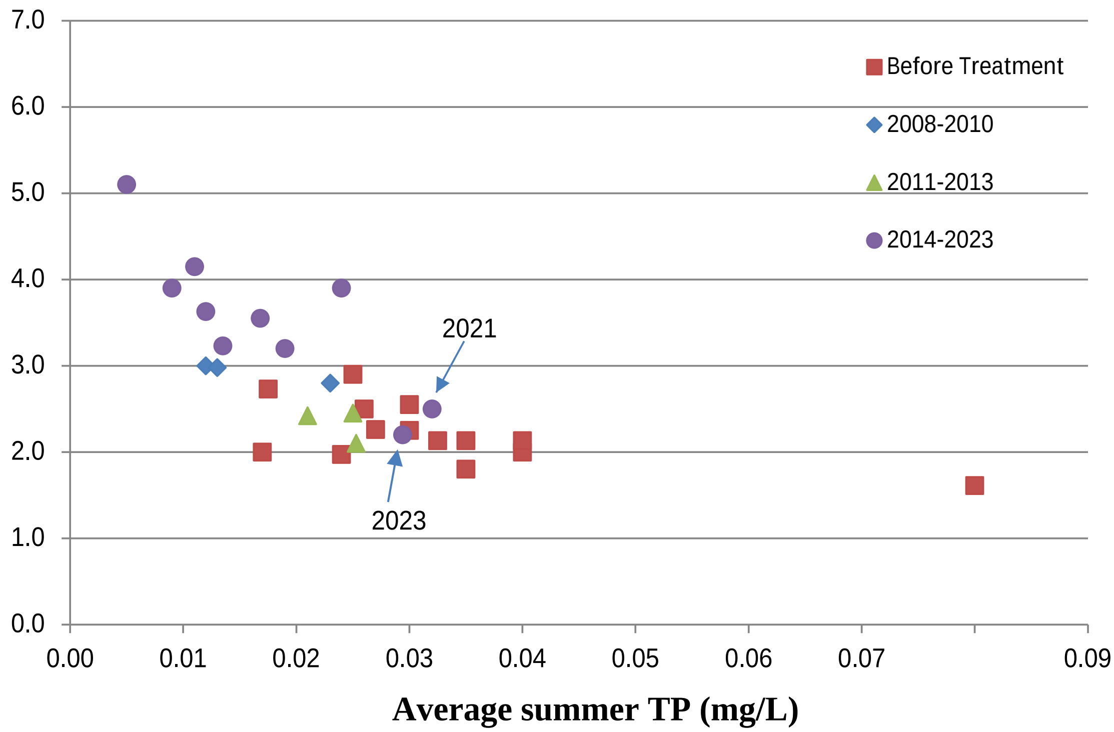


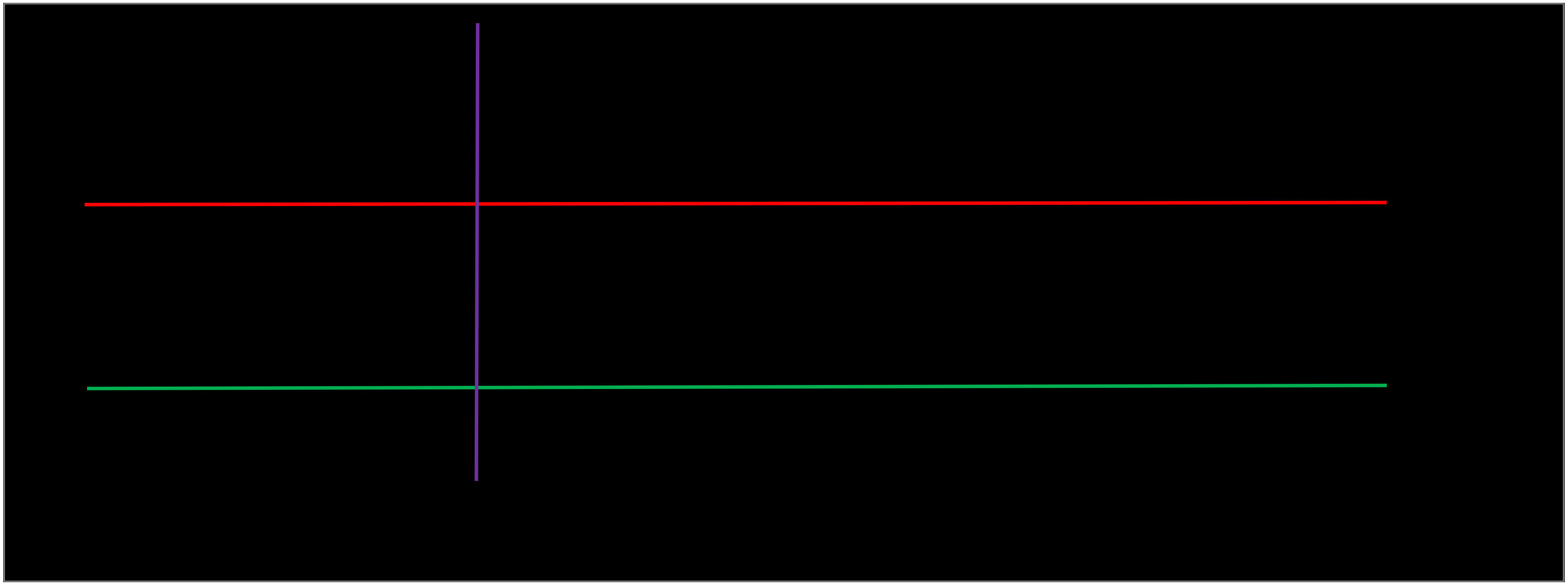
Figure 3. Relationship between summer water clarity and total phosphorus in Morses Pond.



spring that offered limited opportunity to treat incoming stormwater. Conditions in 2021 and 2023 were even less desirable, given excessive inflows after the treatment period was over. Clarity and algae remained acceptable for contact recreation in all years, but the phosphorus inactivation system has yielded variation in results and has practical limits on its effectiveness. Problems with pumps in recent years have also created limitations and an overhaul of the system is recommended sometime soon.

Algal data for 1996-2022 (Figure 4) indicate that algae biomass and composition can be very variable, depending on combinations of nutrient levels, light, temperature, and flushing. Morses Pond phytoplankton biomass was frequently elevated prior to spring phosphorus inactivation, but since then biomass values have not exceeded the general threshold of 3 mg/L that signals low clarity (note that there is no official threshold for algae, but the red line in Figure 4 is a useful guide). Phytoplankton biomass as an annual spring/summer average was below the 1 mg/L threshold indicative of low biomass after the system adjustments of 2014 until 2019 and cyanobacteria have represented only a small amount of biomass each year until 2022. In 2019 the 1 mg/L threshold was just slightly exceeded, but the average algal biomass increased further in 2020 through 2023. There have been small peaks in biomass at times, but no blooms that would prompt beach closure or other recreational impairment since improved operation of the phosphorus inactivation system in 2014.

Figure 4. Summer average algae biomass divided into major algae groups for 1996-2023.



In 2018-2023 some cyanobacteria of the problem genus *Aphanizomenon* were present, and have increased each year, but no surface blooms developed, and no beach closure has been needed. The progression of increasing algae since the minimum in 2015 is evident, however, and suggests that the decreasing level of treatment through 2020 needed to be reversed. However, the extremely wet summers of 2021 and 2023 negated that effort. 2022 represented an unusually hot, dry year with less treatment with aluminum prior to summer, and this is reflected in the algae data (Figure 4). The average algal biomass was about the same as for 2021 but more cyanobacteria were present, including *Aphanizomenon*. Algae in 2023 were similar to those of 2021 with some additional Chrysophyta (golden algae) in 2023. While cyanobacteria were still well below the abundance threshold at which the MA DPH recommends posting waterbodies with warnings to avoid contact, the inactivation system was not able to deliver the level of control enjoyed prior to 2020.

An eastern shoreline accumulation of the cyanobacterium *Planktothrix*, which grows in deeper water with elevated phosphorus concentrations and rises to form surface scums, was observed in 2022 but did not occur in 2023. Those scums are often blown by the wind into dense shoreline accumulations, as was the case in Morses Pond in mid- to late August of 2022. High inflows and pond flushing in 2023 appeared to prevent such accumulations. This alga can be toxic and shoreline accumulations have been implicated in dog deaths at other lakes, so the affected shoreline was posted with warning signs for several weeks in 2022. No toxicity was reported, and the accumulations dissipated within two weeks.

The increase in cyanobacteria in recent years suggests a need for additional management. Continued tracking of the algae community is warranted, but reactive management options are limited mostly to algaecide application. Keeping the deep water oxygenated or treating the pond area deeper than about 10 feet directly with aluminum represent proactive steps that could be taken to minimize cyanobacteria. Perhaps most critical would be an overhaul of the phosphorus inactivation system to maximize performance and an extension of treatment further into summer as needed when precipitation is substantial. The unpredictability of climate change effects is a factor and the ability to continue treatment as warranted provides flexibility. Current permits for the inactivation system allow treatment through August but purchase of aluminum products has been kept to no more than 6000 gallons per year since 2016, partly a matter of cost and partly because the inactivation system has not been performing optimally. Oxygenation, in-lake treatment, and expanded inactivation of incoming stormwater are not mutually exclusive, however, and either oxygenation or a one-time treatment of parts of the pond exposed to anoxia with aluminum would be appropriate.

Zooplankton have also been sampled, and while not as tightly linked to nutrients as algae, provide important information on the link between algae and fish (Figures 5 and 6). Zooplankton biomass varies strongly between and within years. Values <25 μg/L are minimal, and values higher than 100 μg/L are preferred as rough thresholds, with high values desired for both algae grazing and fish food. Morses Pond values span that range and more. Values in later summer are expected to be lower than in late spring or early summer, as fish predation by young-of-the-year fish (those hatching that year) reduces populations of zooplankters. Spring levels will depend on water quality, predation by adult fish, and available algae, which are food for zooplankton. The dominant zooplankton groups are cladocerans and copepods, both

Figure 5. Zooplankton abundance for 1996-2023.

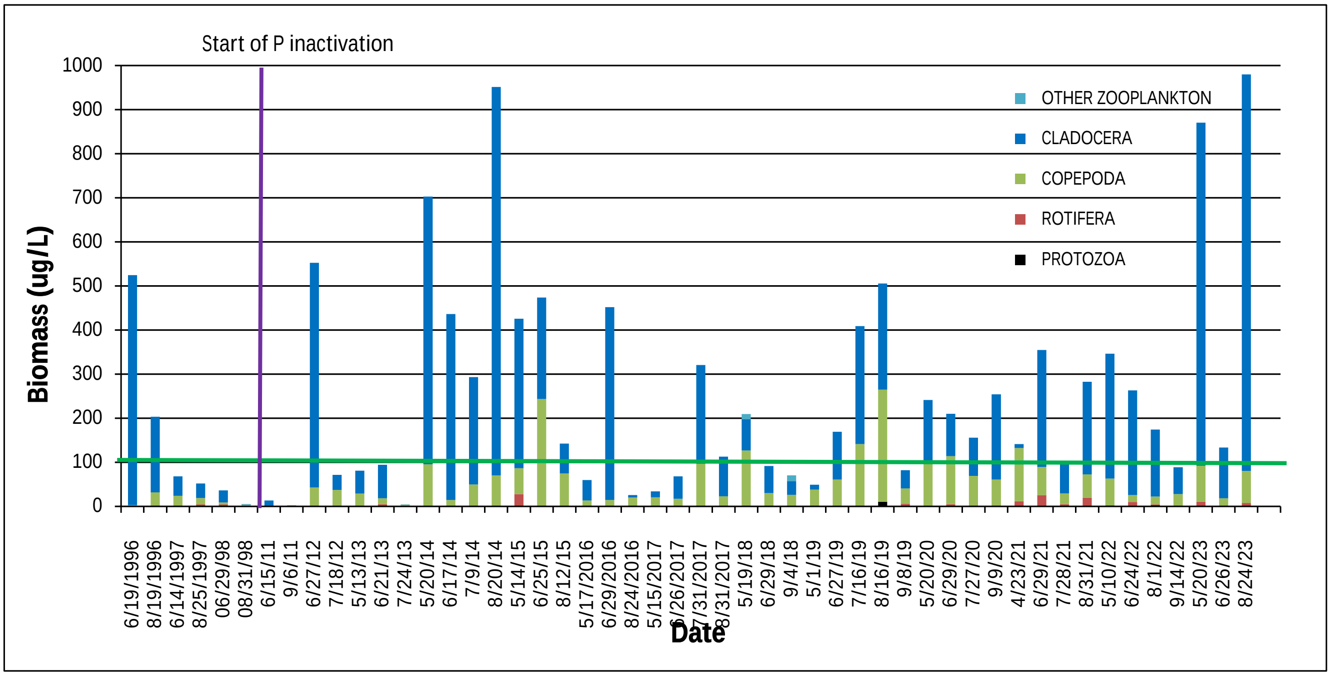
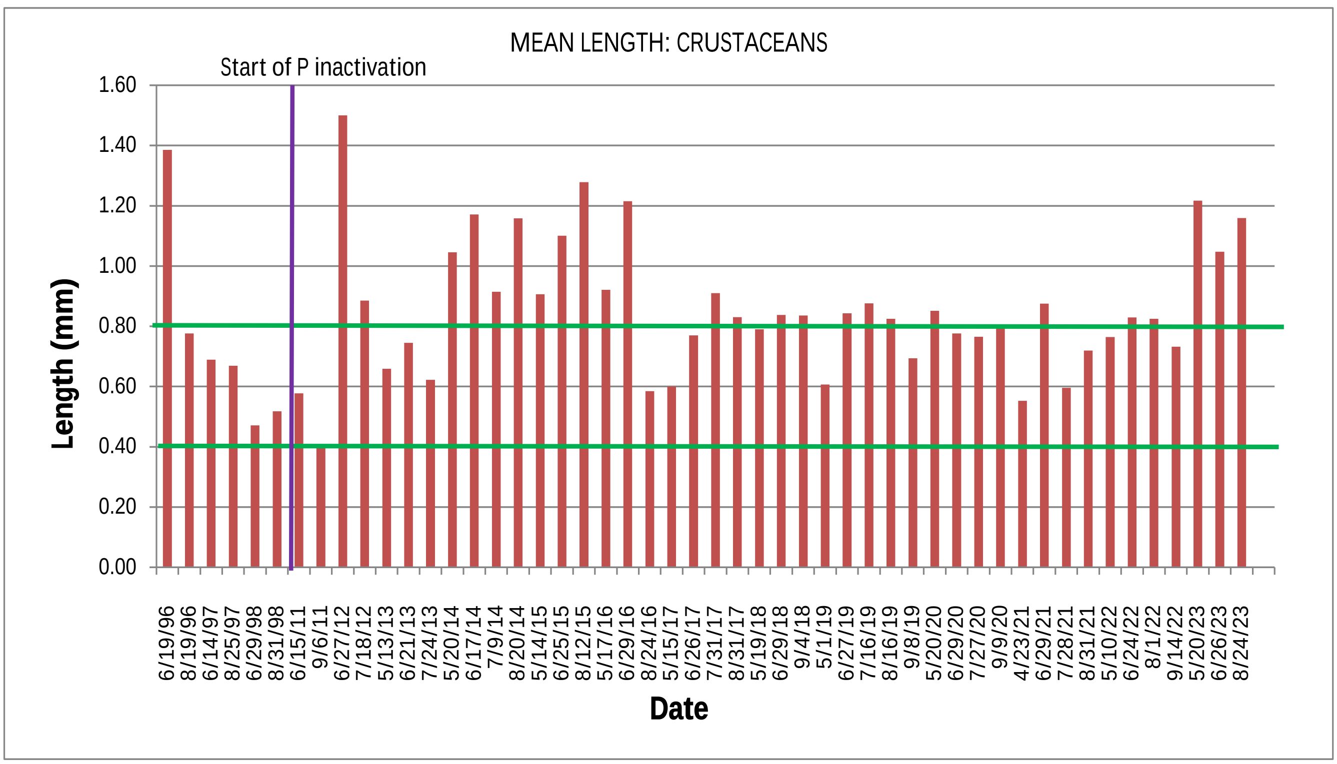


Figure 6. Crustacean zooplankton mean length, 1996-2023.



groups of micro-crustaceans. *Daphnia*, among the larger cladocerans, filter the water to accumulate algae as food, and can increase water clarity markedly.

Daphnia were present in Morses Pond in all monitored years, a good sign, and abundance was elevated in many samples. The late summer zooplankton population was sometimes sparse but overall the zooplankton community has adequate biomass to support the food web and provide substantial grazing capacity for algae consumption, which helps maintain water clarity. Biomass averages >100 μg/L and the mean crustacean zooplankton length is mostly in the range (0.5 to 0.8 mm) that suggests good balance between gamefish and their prey species. There is no indication of any aluminum toxicity to zooplankton; the treatment protocols minimize this probability.

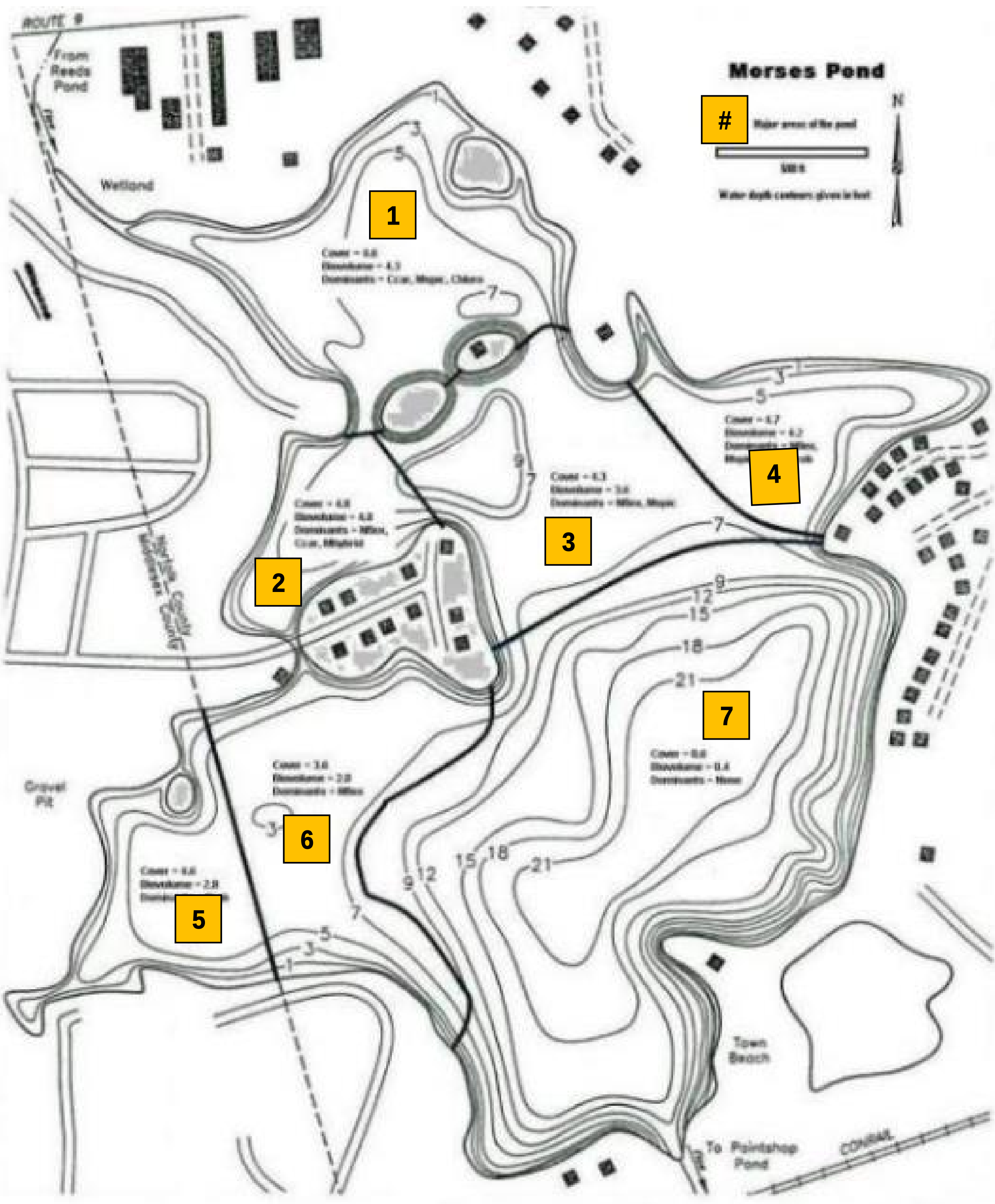
Zooplankton biomass in 2023 was very high in two of three samples (Figure 5) and was largely cladocerans, which are the best filter feeders. Mean length of crustacean zooplankton was at the high end of the range (Figure 6), indicating high grazing capacity and substantial food for fish that eat zooplankton. Zooplankton represents an important consumer of algae in Morses Pond and contributes to clarity even when phosphorus concentrations are higher than desired. However, most zooplankton cannot consume the larger filaments and colonies of bloom-forming cyanobacteria, and it is therefore important to exercise control over phosphorus concentrations to limit threats from that group of algae. The large average body length, even in late summer, suggests limited predation on zooplankton by small fish. The die off of fish in spring, most likely related to low oxygen at night in dense stands of rooted plants, may have limited reproduction in 2023 and therefore lowered predation on zooplankton.

Mechanical Plant Harvesting

Harvesting Strategy

The Town of Wellesley initiated the enhanced Morses Pond vegetation harvesting program in 2007. The zoned vegetation harvesting strategy originates from the 2005 pilot program and comprehensive management plan written that year. For the pilot program, Morses Pond was divided into seven zones in order to better track the harvesting process. Figure 7 shows these zones and Morses Pond bathymetry. Harvesting protocols have been adjusted through experience to maximize effectiveness and minimize undesirable impacts, such as free fragments that accumulate along shore. The goal is to complete one harvest all targeted areas by the end of June, sometimes using two harvesters, with a cutting order and pattern that limits fragment accumulation, especially at the town swimming beach. This usually involves cutting in area 6 first, with any work around the edge of area 7 second, followed by work in areas 2, 3 and 4 in whatever order appears warranted by conditions. Area 5 is in Natick and is usually not cut, and area 1 is the north basin and is also not cut, except for a channel for residences along the western side. A second cutting occurred from August into October until 2015, when the second cutting was initiated in late July and usually completed by sometime in September. More frequent plant surveys are now used to inform harvesting priorities, with occasional shifts in which zone is addressed in which order to best meet user needs.

Figure 7. Plant Management Sectors for Morses Pond.



The keys to successful harvesting include:

- Initiating harvesting by the Memorial Day weekend, sooner if plant growths start early in any year.
- Cutting with or against the wind, but not perpendicular to the wind, to aid fragment collection.
- Limiting harvesting on very windy days (a safety concern as well as fragment control measure).
- Using a second, smaller harvester to pick up fragments if many are generated.
- Cutting far enough below the surface to prevent rapid regrowth to the surface, but not so far as to cut desirable low growing species such as Robbins' pondweed.
- Minimizing travel time on the water with a cutting pattern that does not end a run any farther from the offloading point near the outlet than necessary.
- Preventive maintenance in the off season to minimize down time during the harvest season.
- Using trained personnel who know what to cut, where to cut, and how to avoid damage that would necessitate maintenance of the harvester.

The town has owned harvesters for over 35 years, with the oldest one retired a few years ago and the second oldest, and largest, retired in 2023 after a new large harvester was delivered. In 2019 a new, smaller harvester was put into service and was used instead of the larger, older harvester on many days, as the larger, older harvester was prone to breakdown at its age. This reduced efficiency by virtue of the smaller size of the new harvester and need for smaller loads and more transport time but was intended to minimize downtime. Operation of the larger harvester is what the plan was based on, and breakdowns that last for more than about a week during the harvesting season create conditions from which it can be hard to recover. Harvesting to maintain open water over much of the pond can be a challenging exercise even with properly functioning equipment, given issues with staffing, weather, and simultaneous needs in different parts of the pond. The area that affects the town beach complex has priority when resources are limited.

A decrease in efficiency when plant growth is dense can have a cascading effect that leads to unacceptable conditions over a larger area. The key is to cut before weeds get too dense but not before there is enough biomass to allow substantial collection during a harvesting run (the time between leaving the offloading area and returning to it). Aquatic plant harvesting is very much like mowing a lawn; if grass is allowed to get too high, cutting becomes difficult in one pass, clogging is an issue, and more frequent unloading of the grass catcher is needed. In the aquatic environment this problem can be magnified, as travel time to dump each load can be substantial. It is therefore important to stay ahead of plant growth when harvesting, maintaining maximum cutting rate and minimizing travel time. Equipment issues that reduce cutting time and allow plants to grow high and dense can prevent achievement of goals.

Harvesting Record

Records provided by the Town of Wellesley document the harvesting effort expended on Morses Pond (Table 4). Although the record is not always complete, records have been kept since 2007. Between May and October, from 2007 through 2023, harvesting was conducted on a range of 43 to 76 days. This represents a range of 303 to 537 total hours devoted to some aspect of the harvesting program, and 184 to 335 hours of actual harvesting time. In 2023 harvesting occurred on 48 days for a total of 435 hours with 358.5 hours actually spent cutting. Total loads of aquatic plants harvested have ranged from 54 to 211 per harvesting season, a wide range that reflects which harvester is being used and how full the hopper can be before offloading has to occur. Increased number of loads does not necessarily translate

Table 4. Harvesting record summary for Morses Pond.

Year	Days of Harvesting per Year	Total Hours per Year	Cutting Hours per Year	Total Hr/Day	Cutting Hr/Day	Total Loads	Total Weight	Weight/ Day	Weight/ Load	Weight/ Total Hr	Weight/ Cutting Hr
	(Days)	(Hr)	(Hr)	(Hr)	(Hr)	(Load)	(Pounds)	(Pounds)	(Pounds)	(Pounds)	(Pounds)
2007	49	359	255	7.3	5.2	109	NA	NA	NA	NA	NA
2008	43	NA	NA	NA	NA	NA	270320	6287	NA	NA	NA
2009	57	390	304	6.8	5.3	78	224060	3931	2891	575	738
2010	44	303	223	6.9	5.1	78	226960	5278	2900	749	1017
2011	54	414	291	7.7	5.4	102	292000	5407	2863	706	1003
2012	70	460	296	6.6	4.2	124.5	807760	11539	6488	1756	2729
2013	76	519.5	335	6.8	4.4	119.5	595277	7833	4981	1146	1777
2014	75	476.5	265.5	6.4	3.5	110	455220	6070	4138	955	1715
2015	57	363	268	6.4	4.7	90	607710	10662	6752	1674	2268
2016	48	350	252	7.3	5.3	85	521000	10854	6129	1489	2067
2017	43	454.5	183.5	10.6	4.3	54	348200	8098	6448	766	1898
2018	66	537	232	8.1	3.5	126.5	390185	5912	3084	727	1682
2019	62	472	277.5	7.6	4.5	126	344708	5560	2736	730	1242
2020	48	411	267	8.6	5.6	125.5	194525	4172	1550	473	729
2021	57	507.5	300.5	8.9	5.3	184	259084	4545	1408	511	862
2022	44	368.5	274.5	8.4	6.2	168	155534	3535	926	422	567
2023	48	435	358.5	9.1	7.5	211	302275	6297	1433	695	843
For 2012 and 2013, harvesting includes Area 1 before dredging, which had very dense plant growths and accounts for additional weight removed.											

into more plants harvested. A total of 211 loads were offloaded in 2023, the highest value recorded, but the actual weight of plants removed was below the long-term program average. Many smaller loads where therefore removed. The primary targets are invasive species and bigleaf pondweed but the only selectivity offered is based on depth of cutting; lower growing species are favored.

Total weight of plants harvested, as measured upon entry to the composting facility (so there is some draining of water, but values are still wet weight) has ranged from 156,000 to 808,000 lbs. The 2023 biomass total was slightly more than 300,000 lbs, almost double the program low value from 2022 but still less than the program average. Weight per load declined by over 80% from its peak in 2015 to the low point in 2022 because at full capacity it is hard to empty the older, larger harvester; the aging conveyor cannot push a full load out of the barge, mainly due to friction and reduced power. Additionally, the larger harvester has been out of service for repairs several weeks per harvesting season and the smaller harvester holds less biomass per load. Replacement of the older, larger harvester in July 2023 raised the average load weight for 2023 to 1433 lbs/load, a 50% increase over 2022 but still less than half the average load weight since program inception. The results are illustrated in Figures 8-10. The larger, older harvester was the primary limit to program success; its replacement in late July of 2023 should herald a return to more efficient and effective harvesting.

An increasing number of non-cutting hours was observed from 2009 through 2014 (Figure 8) and appeared related to increases in time for maintenance and travel. From 2014 through 2017, records were kept for non-cutting hours in categories including transport time on the water, transport time on land, and maintenance. With a renewed emphasis on efficiency, the 2015 record indicates that non-cutting

Figure 8. Cutting and non-cutting hours associated with the harvesting program.

Figure 9. Total mass of plants removed by the harvesting program.

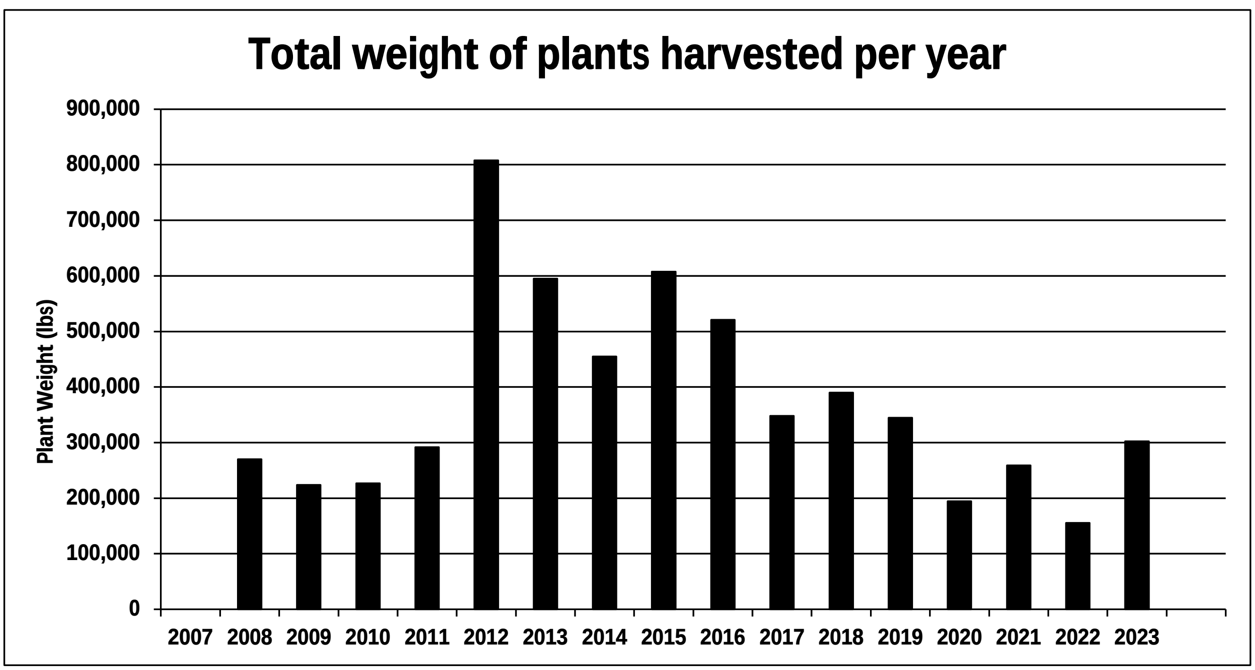
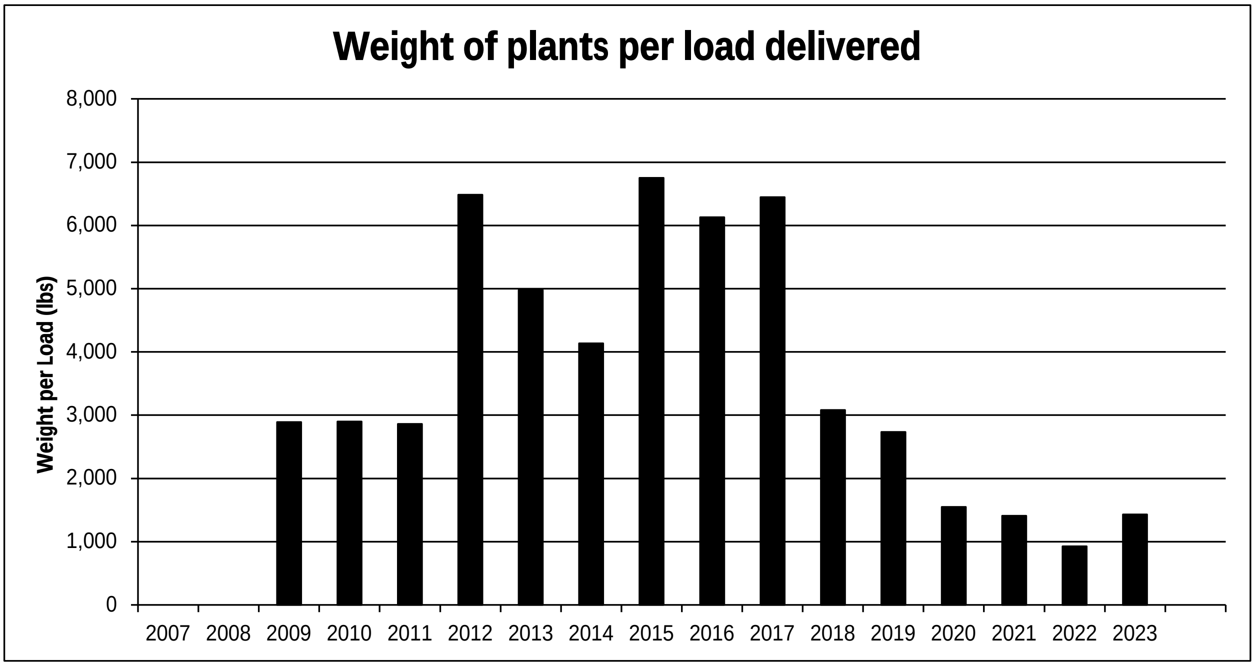


Figure 10. Mass of plants removed per load in the harvesting program.



time was roughly cut in half. Non-cutting time increased very slightly in 2016 but was still far less than in 2014 (Figure 8). Non-cutting time increased markedly in 2017, as the large harvester was working but not properly, resulting in low efficiency and an eventual breakdown. Note that this harvester experienced considerable downtime in 2016, but time not in use awaiting parts is not counted in the harvesting program.

Non-cutting time was reduced steadily from 2017 through 2020 but rose slightly in 2021 to 41% of total hours devoted to the harvesting program. Non-cutting hours were reduced in 2022, down to a level comparable to 2015-2016, and total hours were also similar to 2015-2016 values. Even less non-cutting time was recorded in 2023 and the cutting hours were the highest recorded for the program. Yet the weight per load and total weight of plants removed from Morses Pond was much higher in 2015 and 2016 than in 2022 or 2023. The current primary factor in non-cutting hours is transport time from the harvesting area to the offloading area with smaller loads. This inefficiency is a function of harvester limitation and mostly not correctable by operators using the harvesters available until late July 2023. The increase in total plant mass removed in 2023 (Figure 9) is partly a function of the increased hours and partly a result of getting the new, larger harvester.

The need to maximize cutting time conflicts with lower manageable load limits and more frequent trips back to the offloading location next to the outlet at the south end of the pond. Past efforts to establish other offloading points have met with resistance by shorefront residents and a renewed inquiry along those lines in 2020 raised similar concerns of truck traffic, noise, and odor. The new large harvester delivered in 2023 should solve much of the problem, but plant density is another factor of concern.

Plant density can be very high in areas of Morses Pond shallower than about 8 feet. Normally high density by natural growth is not achieved until sometime in June, by which time harvesting is in full swing and many problem areas should have been addressed. However, earlier growth has been an issue in several years, and there has been a gradual shift in earlier dominance by fanwort. Fanwort has been observed earlier and at greater dominance in other Massachusetts lakes as well in recent years, possibly a function of weather and climate changes. Eurasian and variable watermilfoil are perennial species that typically die back in a cold winter, but in both 2016 and 2023 the temperatures were high enough to allow continued growth. Additionally, curly leaf pondweed, an invasive species that achieves maximum abundance in spring, has surged in some years in Morses Pond. When plant growth achieves high density in late April or early May, before the harvesters are on the pond, it is very difficult to gain control even with fully functional harvesters. An earlier start to harvesting is needed but is difficult to achieve with other spring commitments by the same staff.

Harvesting was conducted in sector 2 on 15 days, in sector 3 on 25 days, in sector 4 on 20 days, and in sector 6 on 18 days. Additionally, the western shoreline of sector 1 was cut on several days, as was the eastern shore of area 6. Some days were split between sectors but on many days both harvesters were working in different sectors. Plants were very dense in some areas until early summer, a fair degree of control was achieved in mid-summer, then growths resurged in later summer despite a high degree of harvesting effort.

Plant Surveys

Plant surveys are conducted to support harvesting operations, assessing where the need is greatest and evaluating success. The timing of surveys has varied, sometimes before harvesting, sometimes after, and comparisons have been useful but not always consistent. A point-intercept methodology was applied to document the spatial distribution and percent cover and biovolume of aquatic plants at specific re-locatable sites. At each point the following information is recorded:

- The GPS waypoint.
- Water depth using a metal graduated rod or a mechanical depth finder.
- Plant cover and biovolume ratings using a standardized system.
- Relative abundance of plant species.

For each plant species, monitoring staff recorded whether the species was present at trace (one or two sprigs), sparse (a handful of the plant), moderate (a few handfuls of the plant), or dense (many handfuls of the plant) levels at each site. Plant cover represents the total surface area covered in plants (2 dimensions). For cover, areas with no plants were assigned a “0,” areas with approximately 1-25% cover were assigned a “1,” a “2” for 26-50%, a “3” for 51-75%, a “4” for 76-99%, and a “5” for 100% cover. Like plant cover, a quartile scale was used to express plant biovolume, defined as the estimated volume of living plant material filling the water column (3 dimensions). For biovolume, 0= no plants, 1= 1-25%, 2=26-50%, 3=51-75%, 4=76-100%, and 5= 100% of plants filling the water column.

After 2017 this approach was adjusted to be more responsive to management needs, focusing on a smaller number of points in each designated zone of the pond and surveying at least three times, allowing for evaluation of conditions before cutting, after the first cut, and after the second cut. The target condition, based on the assessment methodology above, is to have each targeted harvesting area exhibit an average biovolume of about 2 (25-50% of the water column filled with plants, mainly the bottom quarter to half) but not to restrict the coverage except in key access areas like the public beach, such that sediment is stabilized and habitat is maximized.

2023 Results

A total of 37 species are known from Morses Pond, with 19 plant species detected in 2023 (Table 5), slightly more than average for this waterbody. Eurasian watermilfoil, curly leaf pondweed, and fanwort, all invasive species, were very abundant. Only three more species were common, all native species with nuisance potential, including yellow and white water lilies and coontail. Variable leaf milfoil, abundant in some years, was not abundant in 2022 and was not encountered in 2023. Several other native species that are at least common were not observed either. This does not mean that they were necessarily absent, only that with extremely high densities of the three main invasive species, finding other plants was challenging. Overall species richness was the third lowest on record for Morses Pond. Oscillations in species richness are largely a function of less common species being found or not found in any given year and the date of the survey. The shift to 3 or even 4 surveys since 2018 has increased species detection, but richness was lower in 2023, owing to very dense stands of just three species. The dominant suite of species remains the same, with 3 of the 4 invasive submerged aquatic plant species dominating in 2023.

Note that *Trapa natans*, water chestnut, is also known from Morses Pond, but owing to the efforts of volunteer water chestnut pullers, it has never been found in the standard survey. Also note that *Lythrum salicaria* (purple loosestrife) is a peripheral invasive species that can be abundant but rarely picked up by the aquatic surveys.

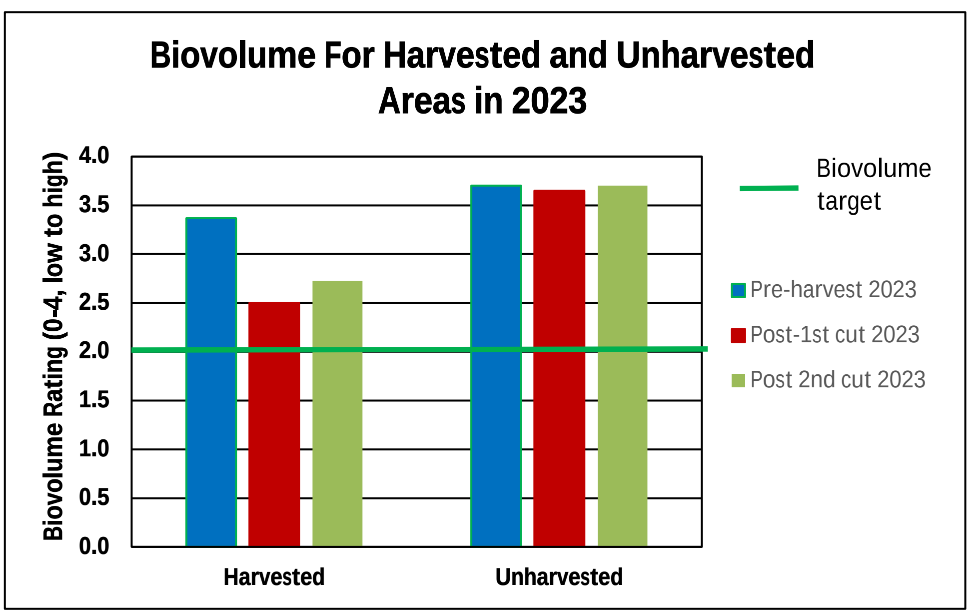
Biovolume is a function of ice out date, the rate of plant growth, the date of the survey and any harvesting effort. The 3-4 survey per year approach allows tracking of conditions and progress of harvesting in target zones of the pond. Morses Pond exhibited high vegetation biovolume in the spring 2022 pre-harvest survey (Figure 11). Note that the pre-harvest plant biovolume for areas that are routinely harvested was lower than that of areas that are not harvested, suggesting some carryover effect from past harvesting, but not a large difference. The spring pre-harvest conditions were among the worst observed over the last 15 years, with topped out growths of curly leaf pondweed and Eurasian watermilfoil. Curly leaf pondweed normally peaks in abundance in spring and has been abundant in some previous years, but it was the extreme density of milfoil over a large area of the upstream half of the pond that was most striking. With a very mild winter, Eurasian watermilfoil does not appear to have died back, continuing growth and expansion right through the winter. Milfoil was dense in areas where it is rarely even common and may have restricted the growth of many native species and even the competing, invasive fanwort.

Biovolume did not increase appreciably in unharvested areas over the summer, given already very high biovolume readings in May. Biovolume in harvested areas was about 30% lower than for unharvested

Table 5. Aquatic plants in Morses Pond.

		Plant Rating for Year																
Scientific Name	**Common Name**	**2005**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Brasenia schreberi	Watershield							P	P					P				
Callitriche sp.	Water starwort	P		P														
Cabomba caroliniana	Fanwort	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Ceratophyllum demersum	Coontail	C	C	C	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Chlorophyta	Green algae	C	C	C	A		P	C	P	P	A	A	P	P	P	P	P	P
Cyanobacteria	Blue green algae		P		C	P	P		P	P	P			P			P	
Decodon verticillatus	Swamp loosestrife	C	P		P	P								P	P	P	P	P
Elodea canadensis	Waterweed	C	C	C	C	C	C	C	C	A	A	A	C	P	P	P	P	P
Lemna Minor	Duckweed	P	P	P	P	P	P	P		P		P	P	P	P	P	P	P
Lythrum salicaria	Purple loosestrife	P	P	P	P	P	P			P				P	P	P	P	P
Myriophyllum heterophyllum	Variable watermilfoil	P	C	C	A	A	A	C	C	C	A	A	A	A	A	C	P	
Myriophyllum spicatum	Eurasian watermilfoil	A	A	A	A	C	C	A	A	C	A	A	C	C	A	C	A	A
Najas flexilis	Common naiad	C	C	C	C	P	P	P	P	P	P		P	P	P	P	P	P
Nymphaea odorata	White water lily	C	C	C	C	C	C	C	P	P	P	P	P	P	C	C	C	C
Nuphar variegatum	Yellow water lily	C	P	P	P	P	P	P	P	P	P	A	C	C	C	C	C	C
Polygonum amphibium	Smartweed	P	P	P	P	P	P	P	P	P		P	P	P	P	P	P	P
Pontederia cordata	Pickerelweed	P		P	P			P		P			P	P	P	P	P	
Potamogeton amplifolius	Broadleaf pondweed	C	C	C	C	C	C		C	C	C	C	P	C	C	C	C	P
Potamogeton crispus	Crispy pondweed		C	C	C	P	P	P	C	C	A	A	P	P	P	P	C	A
Potamogeton epihydrus	Ribbonleaf pondweed		P	P	P	P	P	P	C	P		P	P	P	P	P	P	P
Potamogeton perfoliatus	Claspingleaf pondweed					P	P		P	P			P	P	P	P	P	P
Potamogeton pulcher	Spotted pondweed	P			P	P	P	P	P	P	P		P	P	P	P		
Potamogeton robbinsii	Fern-leaf pondweed	C	C	C	C	P	P	P	C	A	C	A	C	P	P	P	P	P
Potamogeton spirillus	Spiral seed pondweed					P	P	P	P	P	P			P	P	P	P	
Potamogeton zosteriformis	Flatstem pondweed						P	P			P		P	P	P			
Ranunculus sp.	Water crowfoot										P				P			
Salix sp.	Willow				P													
Sagittaria gramineus	Submerged arrowhead	P	P	P		P	P			P			P				P	
Sparganium sp.	Burreed														P			
Spirodela polyrhiza	Big duckweed	P				P		P										
Typha latifolia	Cattail			P										P	P	P	P	P
Trapa natans	Water chestnut																	
Utricularia geminiscapa	Bladderwort	P	P		P		P	P		P	P		P	P	P	P	P	P
Utricularia gibba	Bladderwort	C				P				P			P	P	P	P		
Valisneria americana	Water celery				P	P	P			P		P	P	P	P			
Wolffia columbiana	Watermeal	P			P		P											
	# of Species	23	20	20	24	24	25	20	18	25	18	15	23	27	28	24	24	19
	P=Present, C=Common, A=Abundant																	

Figure 11. Biovolume comparison in areas with and without harvesting over time in 2023.



areas, the difference being the effect of harvesting. Yet the target biovolume rating of 2 (25-50% of water column filled) was not met overall after either the first or second rounds of harvesting (Figure 11). The very high biovolume over the northern half of the pond by the time harvesting was initiated in late May created challenges that could not be overcome even after the new harvester arrived in late July. An earlier start to harvesting in years with mild winters is needed and is being considered but presents staffing challenges as well. The primary alternative would be an herbicide treatment to get invasive species under control and reduce the level of need when harvesting commences.

Considering the individual sectors of Morses Pond, none met the goal of a biovolume rating <2 after either the first or second cuts (Figures 12 and 13). The decrease in biovolume compared to unharvested areas is obvious, but the actual goal for each of the target areas was not achieved. Again, starting the harvesting when plants are already very dense makes it very hard to recover desirable conditions. Cutting is slower, the barge fills faster, and more time must be spent hauling plants to the offloading point and to the composting area. The load limitation on both older harvesters further reduces the rate of progress. The level of effort in 2023 was as high as ever but the results were not as desired. The addition of the new harvester in late July helped but was a case of "too little too late" for 2023.

Looking at past years, 2016 with its mild winter presented similar conditions and only area 6 met the goal of biovolume <2 after the first cut. In most other years the goal was achieved after the first cut in all or 3 out of 4 target areas, even in 2022 with similar harvester issues but a lot less plant biovolume at the start of the harvesting season. The situation is different after the second cut, with most areas not meeting the goal after 2018. This is partly a problem of harvester breakdowns and partly a function of the increased dominance of fanwort, which is not high enough in the water column to be cut before the end of June in most years but arrives at the surface in July over a very large area. This change over the period of the harvesting program appears to be climate based and has been observed in other lakes as well. Harvesting in recent years has not been able to keep pace with fanwort growth over the summer.

The new harvester may provide the means to achieve the plant biovolume goal after the first and second cuts, but this will still require major effort by the harvesting staff. As that staff has other duties as well, and the weather plays an important but unpredictable role, there is a risk that not all target areas can be maintained at a desirable plant density all spring and summer. As the dominant species are all invasive species, herbicide treatment to reset the plant community is worth consideration. Use of herbicides (or any chemical classified as a pesticide) is not generally allowed on public property in Wellesley, this represents a regulatory challenge. As the wells adjacent to Morses Pond are important to public water supply, use of herbicides is a concern for human health beyond the pond itself. Yet the active ingredient fluridone has been used to control both species of milfoil and fanwort in many lakes, including water supplies, and is approved for such use in Massachusetts at concentrations up to 20 ppb, enough to greatly suppress growth in Morses Pond. Discussion of this option has commenced among town departments. Such control over the primary invasive species would allow the harvesting program to be more focused and potentially stay ahead of problems, rather than requiring extreme effort to reduce already high plant biovolume in the pond.

Figure 12. Biovolume comparison over time for each sector after first cut.

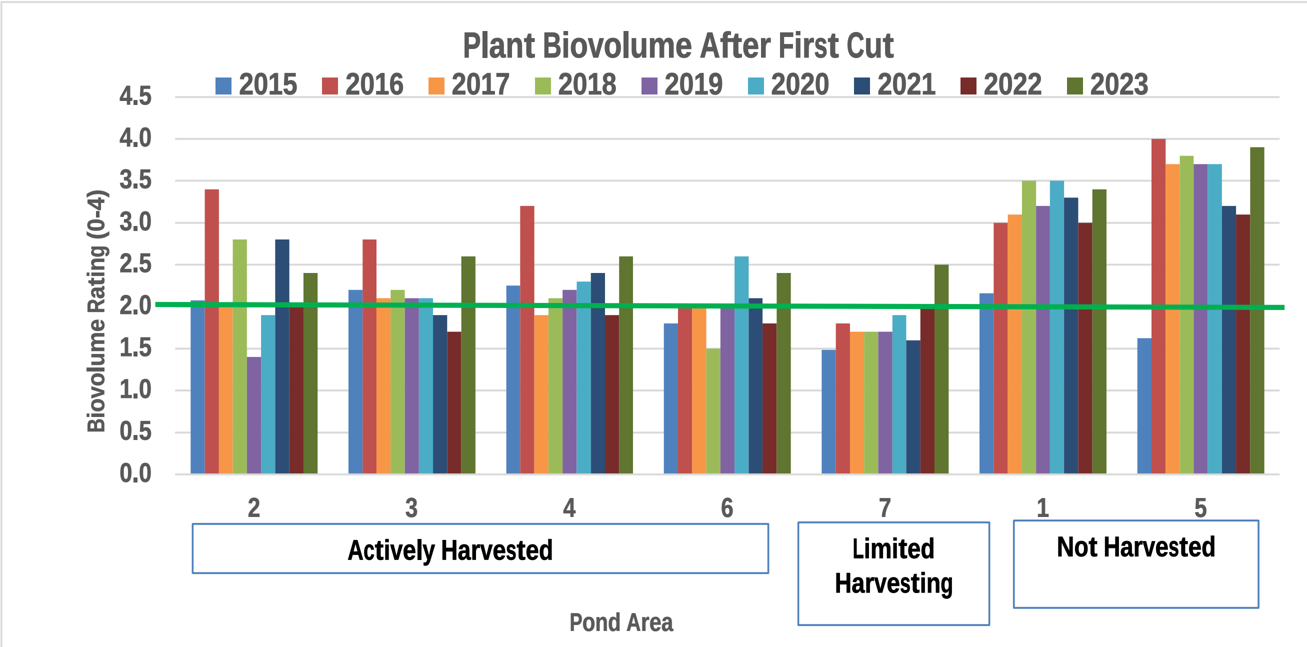
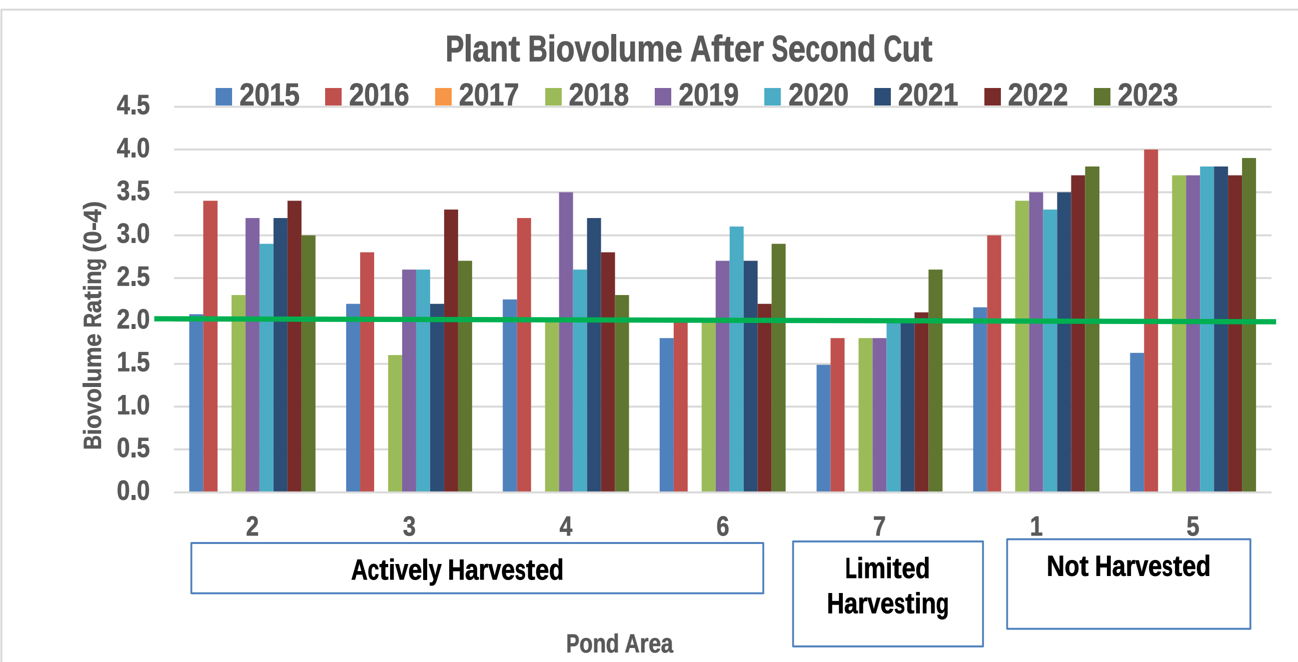


Figure 13. Biovolume comparison over time for each sector after second cut.



Additional Plant Controls

Plant controls additional to mechanical harvesting have been applied in Morses Pond. Volunteer hand pullers search for and remove water chestnut each year. Hydroraking had occurred annually if needed in the public swim area, prior to setting up the ropes and docks, until use of benthic barrier in 2017 to limit plant growths. Shorefront owners had contracted to have hydroraking done in sections of shoreline in the same timeframe as the swim area was raked. A modified version of the hydrorake allowed sand to be moved below the water line and regrading of the swim area for better safety occurred in 2017 and 2018. Although the town no longer needs to have hydroraking on an annual basis, residents banded together and sponsored a hydroraking program in spring 2021.

Hand harvesting of water chestnut is practiced each year by a group of volunteers supported by the town. This effort has kept water chestnut in check, with only scattered plants found and removed each year. Preventing this invasive species from getting established in Morses Pond is an important function that a group within the Friends of Morses Pond has fulfilled well.

The benthic barrier chosen for use in the swim area, called Lake Bottom Blanket, has proven effective, durable, and relatively easy to install and remove. Three panels were installed in 2017 in late May and removed in early August. Those same panels, each 10 X 80 feet, were installed in late May of 2018 and left in place through early August 2019, with just inspection and light cleaning in May of 2019. Panels were removed, cleaned, and stored in August 2019. Sediment accumulation and plant growth suggests that the barrier can be installed and left in place for 2 summer seasons before removal is necessary to maintain effectiveness.

The pandemic resulted in suspension of normal beach operations and the benthic barrier was not installed in 2020. The beach was open without facilities, docks or lifeguards and with social distancing among family groups. “Beach rangers” checked people in and patrolled the beach area. The same mode of beach operation was employed in 2021 but the benthic barrier was re-installed with a new configuration and expanded coverage. Six 10 X 80-foot panels were installed, in a 3 X 2 panel arrangement that created a swimming area 240 X 20 feet just beyond the ropes at the top of the slope. These barriers keep a long area weed-free and facilitate “lap swimming”. The barriers remained in place until August of 2022 with just a light cleaning in June 2022. The panels were removed, cleaned, and stored in August 2022. Re-installation occurred in early June of 2023 and the barrier will remain in place until late summer of 2024 with some maintenance in June of 2024..

Education

Education programs are ongoing in Wellesley, but no new initiatives were implemented by WRS in 2023. The NRC website has useful information on protection of the environment and living a more sustainable lifestyle as a resident of Wellesley. Included is information on:

- Understanding stormwater and its impact on our streams and ponds.
- The impact of phosphorus on ponds.

- The importance of buffer strips and how to establish and maintain them.
- Managing residential stormwater through rain gardens, infiltration trenches, rain barrels and other Low Impact Development (LID) techniques.
- Organic lawn and landscape management.
- Tree maintenance and related town bylaws.
- Recycling needs and options.
- Energy efficiency in the home.

Wellesley also has bylaws relating to lawn watering and other residential activities that affect water quality in streams and lakes. The extent to which residents understand these regulations is uncertain, but the website helps in this regard. The right messages are being sent, but reception and reaction have not been gauged recently. A conservation-oriented day camp has been run at Morses Pond and sessions on aspects of the pond were included. No in-person education was conducted in 2020-2022 as a consequence of the pandemic.

MA DEP Study of Morses Pond

The MA DEP chose Morses Pond as one of its study lakes for 2022 under the Watershed Planning Program operating out of the Worcester office. Water quality that could be assessed by automated field equipment was logged at the deep hole station using a monitoring buoy. Additional sampling was conducted for laboratory water quality. Water depth and plant density were mapped over the pond area, although this was done when plant density was at its highest and the water level was about 1 foot lower than normal, resulting in interference and many erroneous or missing values. Benthic invertebrates were sampled, and fish tissue samples were collected for contamination assessment.

No report has been issued of which we are aware, but review of the available data suggested consistency with .data collected by WRS. Of greatest concern is the loss of oxygen in water as shallow as 10 feet, an impact on a substantial portion of the pond. As the work was done by the Watershed Planning Program, one might expect some recommendations for management, but the extent of analysis and interpretation remains unknown.

Management at Other Wellesley Ponds

There has been a desire to expand the success of the Morses Pond program to other waterbodies in Wellesley. This is a challenge, as many are small, shallow and receive considerable stormwater from highly developed watersheds. Not all are easily accessible for larger equipment. There is no economy of scale to be achieved, but it is possible to improve conditions to make these other ponds more favorable habitat, more aesthetically pleasing, and potentially to achieve other use goals, notably fishing. A report on the condition of eight ponds and the potential for improvement was prepared in 2017 based on 2016 field work. The ponds included were Abbotts, Bezanson, Duck, Farms Station, Icehouse, Longfellow, Reeds and Rockridge.

The new small harvester is used on Rockridge and Longfellow Ponds, where the previous small harvester had been used on a roughly annual basis. Harvesting occurred in July of 2020 and appeared to be successful. Only Rockridge Pond was harvested in 2021, for about 3 days with about 4000 pounds of plants removed. With water levels low in 2022, no harvesting was conducted outside Morses Pond. In 2023, Rockridge Pond received 3 days of harvesting effort with about 3500 lbs of vegetation removed.

Prior to 2019, Farms Station Pond had a thick coating of duckweed that could be removed by harvesting, but not efficiently, and alternative treatment with aluminum appears to have been successful in 2019 through 2023. The harvester could also be used on Bezanson and Reeds Ponds if needed. Bezanson did not exhibit plant problems in 2019 through 2023, an apparent function of aluminum treatment, as the main problem plant, coontail, gets its nutrition from the water column and can be controlled by reduced phosphorus availability. Plant problems in Reeds Pond are mainly a function of infilling at the inlet end; dredging is needed as harvester access to that area is too limited. Abbotts Pond and Duck Pond are too shallow for harvesting, not very accessible for heavy equipment, and do not really have rooted plant problems. Icehouse Pond is not accessible to the harvester, but access could be created if so desired.

The other aspect of Morses Pond management with transferability was phosphorus inactivation. While creating injection stations at each pond is not cost effective, the potential to treat each with a portable system was recognized. A commercially available tree sprayer unit mounted on a truck was obtained and dedicated to treating five of the Wellesley Ponds: Abbotts, Bezanson, Duck, Farms Station and Rockridge. Longfellow might benefit from treatment but is too large to address without extra effort that does not seem warranted at this time.

Simply spraying polyaluminum chloride onto the pond surface is not as effective or efficient as mixing it with incoming stormwater, but as a low-cost alternative to dosing stations this was deemed a worthwhile experiment. All needed equipment cost <$10,000 and the chemical was obtained from the tanks serving the Morses Pond phosphorus inactivation system. An initial treatment was performed in late June of 2018 in accordance with the projected dose needs from the 2017 report on those ponds, requiring about 207 gallons of polyaluminum chloride spread over 4 ponds (Abbotts Pond was not treated in late June 2018). Phosphorus and algae were assessed prior to and one week following treatment. A second treatment with double the dose of the first treatment was performed in late July of 2018, this time including Abbotts Pond, and water quality and algae were again assessed a week after treatment.

Treatment was repeated on June 10 and July 22 in 2019, with about 417 gallons of polyaluminum chloride spread over 5 ponds in each application (Abbotts @ 80 gal, Bezanson @ 40 gal, Duck @ 22 gal, Farms Station @ 112 gal, and Rockridge @ 163 gal). Phosphorus concentration and general pond condition was assessed before and after each treatment. This process was repeated in 2020 on June 22nd and August 17th of 2020 for the same ponds at the same doses.

In 2021 the rains came before any treatment had been conducted. After initial cessation of rain in early July, a treatment was performed on July 6th. Duck Pond was not treated, as flushing was still high, and Farms Station received a different aluminum polychloride solution, one with a higher aluminum concentration that halved the application volume, as a test from a new supplier. Abbotts, Bezanson, and

Rockridge Ponds were treated as in previous years with the same doses. Rain resumed and flushing was too high for the treatment to have made much difference. No further treatment was attempted in 2021.

Only one treatment was conducted on Bezanson, Farms Station, and Rockridge Ponds in early July of 2022. Results from Abbotts Pond and Duck Pond were not sufficient to support continued treatment, but the other ponds had responded well to treatment. A second treatment may not have been necessary in 2022, given very dry conditions, but staffing limitations prevented such treatment anyway in summer 2022.

Farms Station was treated with 55 gallons of the higher concentration polyaluminum chloride solution again on June 23, 2023, while 223 gallons of the polyaluminum chloride solution used in Morses Pond was applied to Bezanson (45 gal) and Rockridge (178 gal) Ponds on June 23, 2023. The very wet conditions of summer 2023 negated the value of further treatment that year.

Abbotts Pond showed limited response to treatment (Figure 14). Phosphorus did not decline to anywhere near the target level of 20 µg/L in 2018-2021 and the water was murky on all survey dates. Dominant algae included dinoflagellates and green algae in 2018 and green and blue-green algae in 2019 and 2020, with a return to green algae in 2021. Access was limited and coverage may not have been adequate. This is a very shallow pond dominated by stormwater inputs and more frequent treatment or a greater dose may be necessary if this approach is to succeed.

Bezanson Pond exhibited a desirable response to all treatments, showing declines in phosphorus (Figure 14) and algae to near desirable thresholds. No filamentous green algae mats formed in the years with treatment and microscopic algae were mostly desirable forms. Also striking was the decline in the vascular plant coontail (*Ceratophyllum demersum*), which is unusual among rooted plants in that it gets most of its nutrition from the water column instead of the sediment via roots. The treatment appears to have solved both algae and vascular plant problems in this pond (Figure 15), making it far better in its role as a dog swimming pool. Bezanson Pond did not develop algae or macrophyte problems in 2021 and 2023 but the water was murkier, a likely result of so much storm runoff input, and there was some floating coontail, probably dislodged by high inflows. Conditions were acceptable throughout the dry summer of 2022.

The clarity of Duck Pond improved as a result of treatment; aluminum coagulates and settles suspended solids even if not algae. However, there were few algae in Duck Pond, owing to short residence time, so the increased clarity represents a reduction in suspended non-algal particles. This is desirable but short-lived, as even a small storm can completely change the water in Duck Pond. Also, with increased clarity the thick sediment deposits, within a few inches of the pond surface in many areas, become more visible. Duck Pond needs to be dredged to restore any pond functions.

Farms Station Pond had a problem with duckweed (*Lemna minor*), a floating aquatic plant, and while algae biomass can be high, it was not the main problem for this pond. The treatment had a partial impact on the duckweed in 2018 (Figure 15), but growths were apparent even before the first treatment. Phosphorus concentration decreased in 2018, but not to the degree desired. Treatment was conducted earlier in 2019 and the duckweed cover never formed. Duckweed is another vascular plant that gets its nutrition from the water column, so the treatment addresses duckweed as well as algae. Phosphorus was decreased (Figure 14), although not quite to the desired level, but there were only some peripheral algal

Figure 14. Phosphorus before and after aluminum treatments of five Wellesley Ponds

Green vertical lines indicate treatment dates, red horizontal line indicates target P concentration

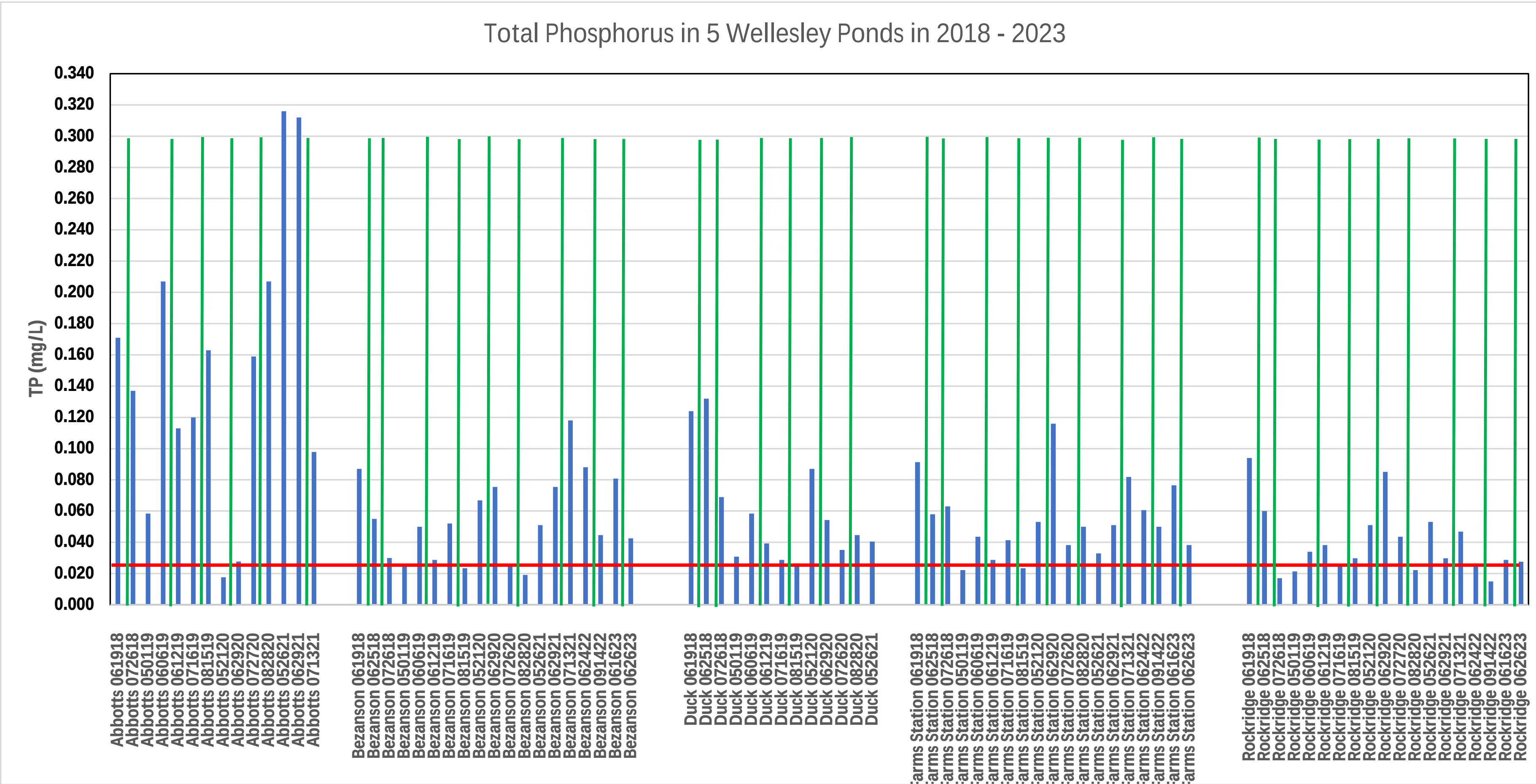


Figure 15. Photographic documentation of improvement in two Wellesley Ponds

Bezanson Pond August 2016

Bezanson Pond August 2020

Farms Station Pond Sept 2016

Farms Station Pond Aug 2018

Farms Station Pond Aug 2019

Farms Station Pond Aug 2020

mats and the pond looked good through the summer (Figure 15). Treatment in 2020 resulted in conditions similar to or slightly better than in 2019 (Figure 15), but there were some cyanobacteria mats that appeared near the outlet in August. No duckweed or algae problems were evident in 2021 but flushing was high. No duckweed was observed in 2022 or 2023 but some peripheral growths of filamentous green algae were observed. Overall, conditions in Farms Station Pond have been markedly improved by aluminum addition but continued addition appears necessary to maintain desired features.

Rockridge Pond exhibited desirable decreases in phosphorus (Figure 14), chlorophyll-a and algae biomass in response to treatment in 2018, approaching or achieving the target levels after the second treatment. In 2019 the treatment appeared to provide clear water, but phosphorus concentrations were not far above the desirable threshold even before treatment. There were some filamentous green algae, but not as much as in years prior to treatment, and there were no other problem species of algae detected. However, rooted plant growths were dense in the pond in May and June of 2019 and harvesting should probably have occurred earlier. The rooted plants may have limited algae as much as treatment did.

Phosphorus was higher in 2020 after the first treatment but the second treatment reduced it to the target level and algae were not a problem in 2020. Rooted plants were selectively harvested in July and that activity may have increased phosphorus by bottom disturbance. Treatment with aluminum should follow harvesting to achieve best results, but harvesting is not typically conducted until sometime in July and algae can be a problem in Rockridge Pond before that time. In 2021 there was just the one P inactivation treatment of Rockridge Pond, on July 6th, and harvesting was conducted for 3 days later in July, removing about 4000 pounds of vegetation. High inflow caused murky water and there was a visible oil sheen in a few areas on July 13th, but there were no substantial algae problems in 2021, probably a function of flushing. No harvesting occurred in 2022 and just a single aluminum treatment in early July was performed; conditions with respect to algae were generally desirable through summer 2022. Conditions in 2023 were similar to those in 2021, with dense plants in spring and considerable flushing during a wet summer. The single treatment in June did not greatly improve conditions and plant harvesting in July decreased clarity somewhat while opening the central area for fishing.

The phosphorus inactivation program for these smaller ponds showed variable results, generally positive for Bezanson, Farms Station, and Rockridge Ponds but less impressive for Abbotts and Duck Ponds, which were dropped from the treatment program after 2021. A different approach will be needed for Abbotts and Duck Ponds if improvement is to be gained. Dredging would help, but access to Abbotts Pond and the ratio of cost to potential benefits is questionable, this being more a wildlife area with minimal human use. Dredging Duck Pond, both to restore its detention capacity as a stormwater management feature and to enhance its aesthetic quality in a park setting adjacent to Town Hall, is desirable, and sediment testing was completed in 2023 to facilitate such dredging.

Dredging of Reeds and Duck Ponds has been recommended for several years and funds were allocated for testing in FY23. The soft sediment quantity in each pond was evaluated in fall of 2022. Duck Pond contains roughly 3500 cubic yards (cy) of mixed sand and organic sediment. Slightly less than 600 cy are in the eastern backwater area that may not be easily drained for conventional dredging, but almost 3000 cy could be removed by excavation equipment after removing the boards at the outlet and allowing the water level to decline. Duck Pond was last dredged in 1986 but it is not clear that all soft sediment was removed at that time. Reeds Pond contains about 5500 cy of mostly organic sediment, 3200 cy of which are in the upstream half of the pond and have virtually filled the pond in that area. All sediment could be removed by conventional excavation by lowering the pond level through a drain installed for that purpose when the pond was last dredged in 1999. The amount of sediment removed in 1999 is similar to what is now in the pond, although the small forebay at the upstream end of Reeds Pond has been excavated 8 times over the last 23 years with an average of about 100 cy removed each time.

Sediment quality testing was completed in spring of 2023 and a more detailed memorandum was submitted by WRS to the NRC with results. Metals and hydrocarbons are the most common contaminants that limit disposal options, and this was the case for both Reeds and Duck Ponds. Lead and arsenic were the metals of greatest concern, but cadmium, chromium, nickel and zinc were high enough to restrict disposal options in areas where human contact was possible. Aromatic petroleum hydrocarbons were also high enough to restrict disposal, but the sediment is not considered to be hazardous waste by normal regulatory definition. Urban lake sediments are routinely contaminated to a degree that restricts disposal, as was the case for the dredging in the northern portion Morses Pond in 2012-2013. Planning for dredging is continuing.

Summary and Needs for 2024

The Morses Pond management program in general and results from 2023 can be summarized as flows:

a. The phosphorus inactivation program has reduced phosphorus availability and algae abundance since 2008, with nearly ideal results between 2014 and 2019 with system modification. Water clarity and overall aesthetic appeal of Morses Pond have been increased as a result.
b. Results since 2019 have shown a decrease in phosphorus control and an increase in algal abundance. Thresholds that might lead to beach closure or other problems have generally not been exceeded, although peripheral accumulations of a potentially toxic cyanobacterium in late summer of 2022 did prompt posting to warn dog walkers of risks to pets. Cyanobacteria were partly controlled by high precipitation and flushing in 2021 and 2023.
c. Problems since 2019 can be traced to reduced application of aluminum and failures of equipment in an aging system that result in lower removal rates for phosphorus. An overhaul of the system with new pumps and tanks and some improvements to warning systems is advisable to maximize performance. Extending treatment through July and August may also be beneficial when elevated precipitation occurs but will increase operating costs by about 50%.
d. Low oxygen in water as shallow as 10 feet deep, representing about one third of the pond, is a concern. Low oxygen has occurred in the deeper parts of the pond in the past, but it is happening in shallower water for more of the growing season in recent years. Low oxygen limits habitat for fish and invertebrates and fosters internal recycling of phosphorus by mechanisms that favor cyanobacteria. This trend may be related to larger storms bringing more oxygen-demanding organic matter to the pond and can be reversed by either removing the accumulated organic sediment (i.e., dredging) or adding oxygen. Oxygen saturation technology is the most applicable approach for adding oxygen, but no action is recommended just yet.

e. The plant harvesting program has reduced plant abundance in targeted areas of Morses Pond compared to unharvested areas, but the program has been experiencing decreasing achievement of goals over the last 8 years. Impediments have included harvester breakdowns and limitations due to age and earlier and more aggressive growth of invasive species after mild winters.
f. The level of effort by harvesting staff has been relatively stable, but non-cutting time has generally risen as a function of greater transport time caused by the need to carry smaller loads (offloading issues with older, larger harvester and capacity limit with newer, smaller harvester). Dedicated manpower to the harvesting effort has not been a factor in any failure to achieve goals.
g. Delivery of a new, large harvester in July 2023 should solve most of the capacity problem. A new shore conveyor was also obtained, further aiding offloading operations. Off-season housing and care of equipment is a concern that should be addressed, but improved operation is expected for the foreseeable future.
h. An earlier start to harvesting is needed in years with mild winters, as early growth of plants can exceed harvesting capacity when active harvesting does not commence before late May. The pond manager should make a determination of projected plant growth in March and the DPW can consider starting harvesting by late April or early May in response.
i. The transfer of management approaches developed for Morses Pond to smaller ponds within Wellesley has resulted in improvements to three ponds: Bezanson, Farms Station, and Rockridge. All three have responded well to aluminum treatments and Rockridge has also been harvested in most years. Reeds and Duck Ponds need to be dredged and planning is underway for such projects. Abbotts Pond and Icehouse Pond are less accessible for management methods, are considered more as habitat features than recreational resources, and have not been accorded priority for improvement.

The following activities are recommended for 2024:

1. Orders of Conditions for the harvesting program was renewed in spring 2021 and the permit will need to be extended or re-issued in spring 2024. The need for a Section 401 permit as well will need to be investigated; consideration in 2021 lead to a determination that Section 401 did not apply, but the rationale was unclear, and confirmation should be sought.
2. The phosphorus inactivation program was permitted through the Wetlands Protection Committee in spring of 2021 and will need to be extended or re-issued in spring of 2024. This activity also requires an annual permit from the MA DEP, an online process known as a License to Apply Chemicals. Wellesley has an account that should allow for easy renewal once a valid Order of Conditions is issued.
3. The phosphorus inactivation system was maintained in fall of 2022 and spring of 2023, given the failure of multiple sensors and one of the pumps, as well as a need to relocate the precipitation sensor. The pump was repaired but failed again in 2023. Additional repair was completed under warranty, but it is apparent that the aging system should be replaced in full with several additional modifications to improve operation. A cost of approximately $100,000 is projected for complete system overhaul.
4. Conduct the water quality monitoring program as in recent years. Pay close attention to the algal community and consider options for further management if peripheral accumulations of cyanobacteria recur or if planktonic concentrations become elevated. Several options are available,

but a one-time treatment of about half the pond with aluminum is recommended. Such a treatment would apply a dose of aluminum to inactivate phosphorus in the surficial sediment exposed to low oxygen during summer and would cost about $125,000.

5. Continue to track dissolved oxygen over the range of depths in Morses Pond during the growing season. If concentrations <5 mg/L persist in water less than about 15 feet, consider oxygenation to improve oxygen and associated pond health. An appropriate system would cost on the order of $150,000 to install and about $25,000 per year to operate.
6. Acquire data and insights from the MA DEP Watershed Planning Program study of 2022 when available and adjust the monitoring program as appropriate.
7. The benthic barrier placement in the swim area was given a negative Determination of Applicability by the Wetlands Protection Committee that required no further permitting, but any need for renewal should be addressed through the Wetlands Protection Committee; a negative Determination of Applicability does not necessarily extend indefinitely. The barrier was placed in 2020, left in place through 2021, and removed and cleaned in August 2022, and re-installed in early June 2023. It will remain in place until August 2024, when it will be removed and cleaned. Affirmation of continued negative Determination of Applicability should be sought in late 2024 or early 2025.
8. While not a perceived need for 2024, any further hydroraking should probably be managed by the Town, given increasing permitting complexity and limited offloading sites with possible use conflicts. The work in 2021 required a lot of coordination effort and it may be best orchestrated by Town staff.
9. Plant monitoring should occur in late March and determination of the need for harvesting any earlier than late May should be conveyed to town staff. Harvesting should commence as early as needed to stay ahead of rooted plant growths, possibly in late April or early May.
10. Maintenance of harvesters and making the best possible use of them to keep up with plant growths is essential. Protective winter housing of harvesters is recommended. A focus on efficiency during actual harvesting operations is needed, but the primary limiting factors in recent years have been equipment problems. The new, large harvester is expected to improve results in 2024, but an earlier start to harvesting may still be needed when winter conditions are mild and early plant growth occurs.
11. Consideration should be given to treatment of Morses Pond with fluridone at a concentration between 10 and 20 ppb. This concentration is allowable in drinking water supplies and could greatly reduce the growth of the primary invasive species. This would improve conditions in the pond markedly and reduce pressure on the harvesting program for multiple years. It is appropriate to wait until results from the 2024 harvesting program are available to assess the impact of the new harvester, but open discussion of the use of a herbicide in Morses Pond is desirable, as there will be multiple challenges in approving such use.
12. Bezanson, Farms Station and Rockridge Ponds should be treated with aluminum in mid- to late June and again in late July as needed. It would be desirable to time one treatment of Rockridge Pond to immediately follow any plant harvesting performed in that pond.
13. Plan for dredging Reeds Pond and Duck Pond in 2024 or 2025. Sediment quantity and quality evaluation have been completed; engineering and permitting remain to be addressed.