Report For:
Lake Shirley Improvement Corporation
Shirley, MA 01464

Lake Shirley Lake Management Annual Report 2022-2023

Source: www.lakeshirley.com

Prepared by:
Aquatic Restoration Consulting, LLC
18 Sunset Drive
Ashburnham, MA 01430

December 2023

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INTRODUCTION

The Lake Shirley Improvement Corporation (LSIC) contracted Aquatic Restoration Consulting, LLC (ARC) to perform the fall aquatic plant survey and summarize the lake management activities that occurred during the prior year (October 15, 2022 through October 14, 2023) in accordance with the Order of Conditions (MassDEP File No. 208-1168 for the Town of Lunenburg and 284-0474 for the Town of Shirley). This report summarizes the LSIC management activities, data evaluation and recommendations. The report is organized in a semi-chronological order of activities for the 2022-2023 year:

- winter water level drawdown,
- water quality monitoring,
- herbicide/algaecide treatment,
- fall aquatic plant survey and prior year data comparison,
- education and outreach activities; and
- recommended changes (if appropriate) from the management program.

WINTER WATER LEVEL DRAWDOWN

Winter water level drawdowns in combination with targeted herbicide treatments have shown combined success as a nuisance weed management strategy in Lake Shirley. The primary mechanism through which water level drawdown controls aquatic plants is exposure to dry and freezing conditions for an extended period. Ice movement and scour also have an effect. Not every year is a “good” drawdown year as frequent rainfall, fluctuating water levels, early insulating snowfall, groundwater seepage and other factors can limit freezing and drying. Bottom substrates can also affect how well the drawdown works, as mucky and peaty soils (as are often seen in cove areas) are more resistant to drying.

Winter water level drawdown of Lake Shirley has been used for many years mainly to manage the growth of nuisance aquatic plant growth. The Metcalf & Eddy Diagnostic Feasibility study prescribed an optimal drawdown of up to nine feet, but due to impacts on shallow private wells, the drawdown is limited to six feet. The drawdown has worked well to control nuisance growth of milfoil (*Myriophyllum heterophyllum* and *M. spicatum*) and fanwort (*Cabomba caroliniana*) in the shallow margins of the lake, but the effectiveness is variable year-to-year as the technique requires sustained lowered water level and freezing temperatures absent of insulating snowfall. Some plant species, particularly those that produce seed or winter turions, are often less impacted (e.g., tapegrass/wild celery, pondweeds and naiads) and can show increased growth following a drawdown. Plants in areas deeper than the drawdown zone (>6 feet) are generally not impacted by this technique. The current drawdown practice in Lake Shirley reduces nuisance plant growth within the drawdown zone lessening the need for additional herbicide use.

The goal of LSIC is to achieve a seasonal drawdown, up to six feet, on an annual basis. The drawdown is accomplished by opening the two gates at the Lake Shirley dam in the fall (on or after October 15). The drawdown rate is monitored and maintained at approximately two to three inches per day. The desired depth is typically achieved by December 1, but weather conditions (precipitation) can prohibit achievement of the target level. Additionally, ice and debris can clog the gates limiting the depth of the drawdown. The gates are adjusted to balance desired water level and downstream river flow once the target depth is achieved. LSIC provides notification to the Conservation Commissions and lake residents prior to initiating the drawdown.

The lake is generally refilled by April 1 of the following year. The lake refills quickly during ice melt and spring flows given its large watershed (over 9,000 acres). This is not a precise process and is highly dependent on precipitation. Both the drawdown and refill are monitored closely by LSIC in coordination with the Lunenburg dam caretaker. The caretaker records lake level and stream flow readings no less than weekly between October and April and adjusts the outlet gates as needed.

The target drawdown depth of six feet was not achieved during the 2022-2023 drawdown season. A maximum of 5.4 feet was achieved on November 9, 2022. There was a complaint by one resident regarding a well sputtering, so one gate was closed and there were no further complaints. Unfortunately, there was significant rainfall during the drawdown season and the water began to rise after the maximum depth was reached on November 9. Average air temperatures were above freezing for most of November and December, and January had several days of average temperatures above 40°F. The average drawdown depth during January and February, the coldest months, was only 0.6 feet. This was not a good weather year for drawdown.

Water was flowing over the spillway on January 28, 2023 due to the rains and only receded seven inches before the lake was refilled for the season on March 12, 2023. LSIC does not have downstream flow estimates this season due to a damaged gage. LSIC will replace the gage this winter season while the water level is down. Given all the rain, it was difficult to manage downstream flow. If flows exceed the maximum average flow target[1], it was not due to drawdown activities. It is assumed that downstream flow was maintained above the 7.0 cfs recommendation during lake refill given all the rain. Table 1 provides water level monitoring data. There were no fish kills reported in Lake Shirley during the drawdown period.

Table 1. 2022-2023 Water Level Monitoring Data

Date	Mid Valve	Low Valve	Level (in)	Notes	Rate (in/day)
9/28/22	Closed	Closed	-5		
10/5/22	Closed	Closed	-5		0.0
10/12/22	Closed	Closed	-5		0.0
10/15/22	Closed	Closed	-3	Heavy Rain the 14th	0.7
10/15/22	Open	Open	-3	Start Drawdown	0.0
10/16/22	Open	Open	-7		-4.0
10/17/22	Open	Open	-10		-3.0
10/19/22	Open	Open	-16		-3.0
10/22/22	Open	Open	-25		-3.0
10/26/22	Open	Open	-37		-3.0
10/30/22	Open	Open	-49		-3.0
11/2/22	Open	Open	-53		-1.3
11/3/22	Open	Open	-55		-2.0
11/6/22	Open	Open	-61		-2.0
11/8/22	Open	Open	-63		-1.0
11/9/22	Open	Closed	-65	Well problem	-2.0

[1] less than 56.3 cubic feet per second (cfs) recommended in the Eutrophication and Aquatic Plant Management in Massachusetts General Environmental Impact Report (GEIR)

Date	Mid Valve	Low Valve	Level (in)	Notes	Rate (in/day)
11/12/22	Open	Closed	-63		0.7
11/14/22	Open	Closed	-61		1.0
11/17/22	Open	Closed	-58		1.0
11/21/22	Open	Closed	-56		0.5
11/26/22	Open	Closed	-55		0.2
12/2/22	Open	Closed	-50		0.8
12/5/22	Open	Closed	-48	Clean debris	0.7
12/9/22	Open	Closed	-46		0.5
12/14/22	Open	Closed	-44		0.4
12/18/22	Open	Open	-42		0.5
12/21/22	Open	Open	-37	Heavy Rain	1.7
12/24/22	Open	Open	-30		2.3
12/27/22	Open	Open	-24		2.0
1/3/2023	Open	Open	-21	Rain	0.4
1/13/23	Open	Open	-19		0.2
1/19/23	Open	Open	-18		0.2
1/26/23	Open	Open	-8		1.4
1/28/23	Open	Open	1		4.5
2/1/23	Open	Open	3		0.5
2/5/23	Open	Open			-0.8
2/8/23	Open	Open	-2		-0.7
2/12/23	Open	Open	-4		-0.5
2/14/23	Open	Open	-6		-1.0
2/18/23	Closed	Open	-7		-0.3
2/25/23	Closed	Open	-7		0.0
3/5/23	Closed	Open	-4		0.4
3/8/23	Closed	Open	-1		1.0
3/12/23	Closed	Closed	1	Lake Filled	0.5

* only 24 days of water level drawdown due to rain; red text indicate water flowing over spillway

WATER QUALITY MONITORING

The LSIC volunteers performed routine water quality monitoring during the 2023 summer season. Monitoring included measurements of water clarity, in-situ measurements and collection of nutrient and phytoplankton samples (when water clarity drops below five feet) for analytical analysis. Results of the monitoring program are discussed below.

Secchi Disk Transparency

Secchi disk transparencies (SDT) were recorded on a weekly basis at three locations (Figure 1) starting in May and lasting through the end of August 2023. SDT is a measure of water clarity and is used as an indicator of possible presence of suspended sediments and algae. Water with clarity greater than four feet is often deemed water suitable for swimming. The Order of Conditions established a SDT minimum of five feet before additional testing is required by the LSIC. If readings fall below five feet, the LSIC is required to collect grab samples for phytoplankton analysis. These data are used to ascertain if an algal bloom is forming and whether an algaecide treatment is warranted. SDT remained above five feet in 2023; the minimum clarity was 5.2 feet during July and most of August 2023 in the upper North Basin (Figure 2). Water clarity in 2023 ranged from 5.2 to 9.4 feet, which was about a half foot lower than the maximum clarity in 2022. Clarity is typically best in the South Basin and worst in the Upper North Basin, but the Upper North and North Basin stations were similar this past year. Overall, average clarity was the greatest at all sampling stations in 2022 (Figure 3).

In-situ Measurements

LSIC volunteers collected in-situ measurements of temperature, dissolved oxygen, specific conductivity, pH and turbidity at each of the three stations (Figure 1) on June 15th, July 19th and August 22nd, 2023. Data are presented on Table 2. Note that the table does not include the pH data. The reported numbers appeared erroneously high. The volunteers will send the meter to the manufacturer for service.

Lake Shirley is considered a Class B warm waterbody by Massachusetts Surface Water Quality Standards. As such, epilimnetic (surface) water temperatures are not expected to exceed 28.3°C. Temperatures did not exceed this threshold in 2023 (Table 2). Dissolved oxygen data were generally desirable and remained above the 5.0 milligrams per liter (mg/L) minimum except at water depths greater than seven feet. The lake stations monitored did not exhibit thermal stratification (Figure 4), but the deep hole in the South Basin was not evaluated and is expected to show stratification and low dissolved oxygen in the hypolimnion (bottom waters).

The state standard for pH (log scale of the hydrogen and hydroxide ion concentrations) is between 6.5 and 8.3 standard units (SU). Lake Shirley pH exceeded this standard at all station and sample events. The maximum recorded was 10.2 SU. While excessive photosynthetic activity can drive pH numbers to extremes, these data appear uncharacteristically high. The pH probe may be failing and will be sent to the manufacturer for a check and service.

There are no state numerical standards for specific conductivity or turbidity. Specific conductivity is a measure of the electrical conductance (ability to pass electrical current) of water. The higher the conductivity, the higher the number of ions there are in the water. Conductivity is a relatively stable parameter and changes over time can indicate changes in the system (e.g., pollutant inputs). Conductivity values below 100 microsiemens (µS) are low and values above 500 µS are high. Lake Shirley values averaged 278 µS, slightly lower than 2022 but comparable to the 2021 average (270 µS). The maximum conductivity was 380 µS and recorded in the North Basin. Turbidity in lakes below three nephelometric turbidity units (NTU) is considered desirable. Lake Shirley surface water turbidity was elevated at times in 2023 and generally worse at the bottom and as the summer progressed.

Figure 1. Water Quality and Secchi Disk Transparency Locations

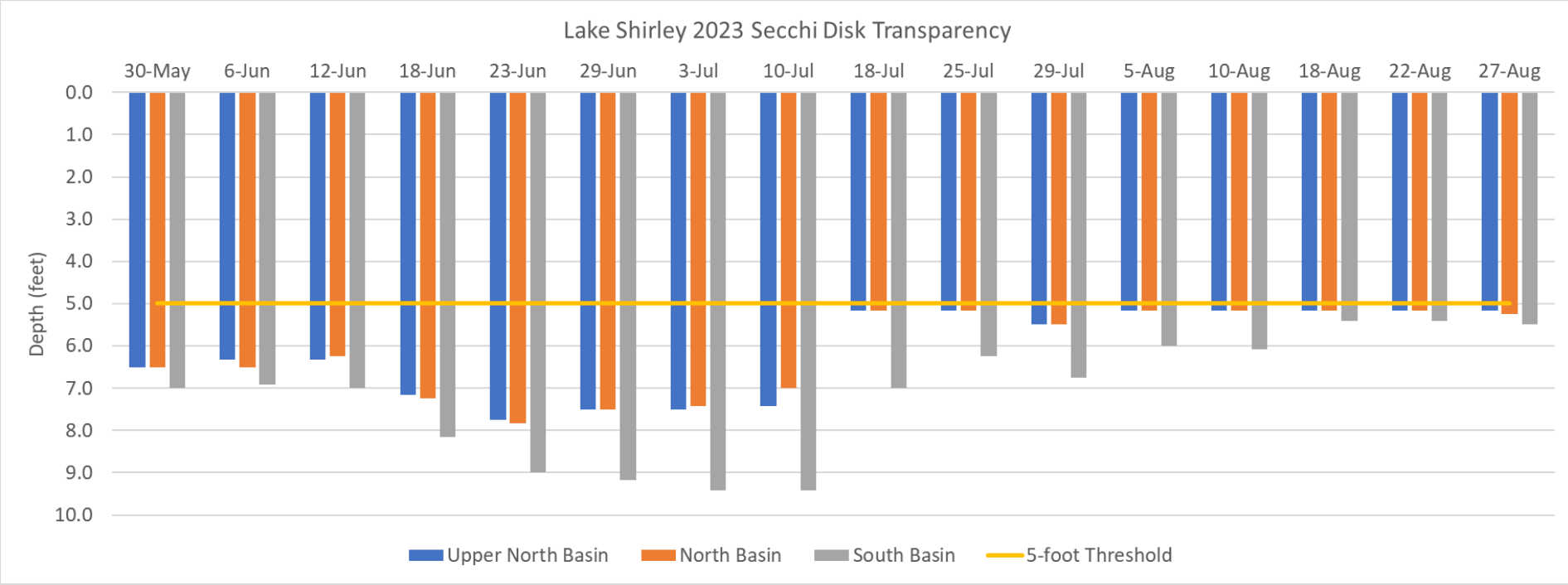
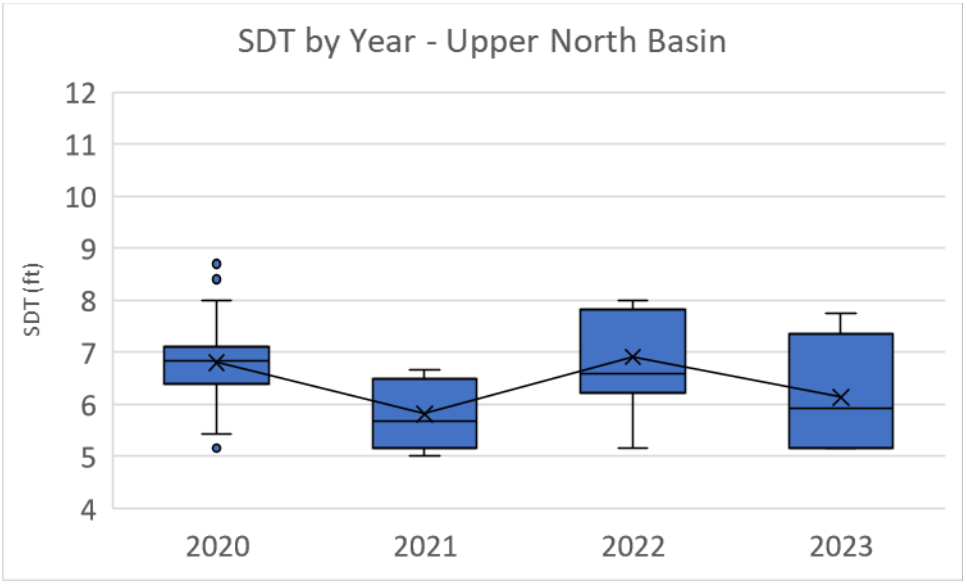
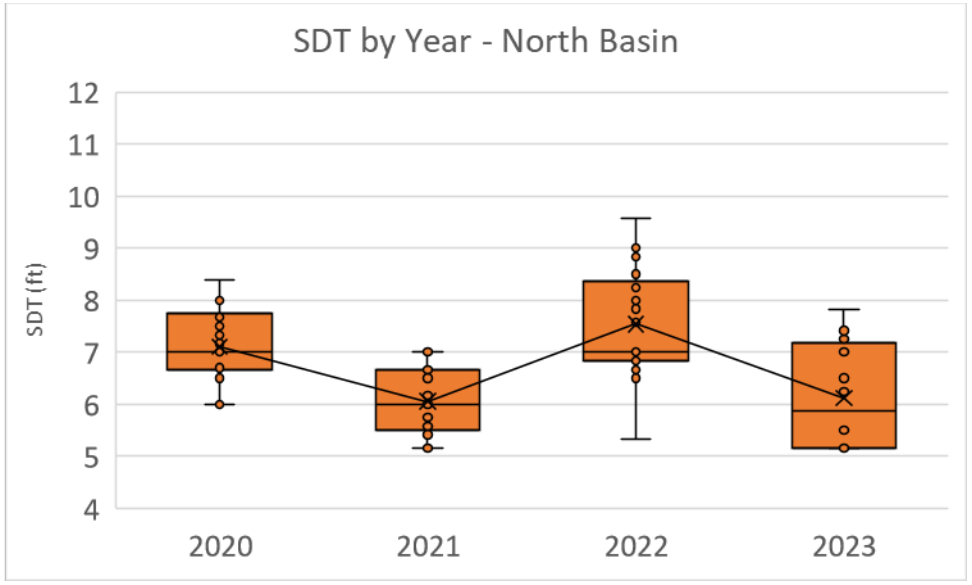


Figure 2. Lake Shirley 2023 Secchi Disk Transparency.





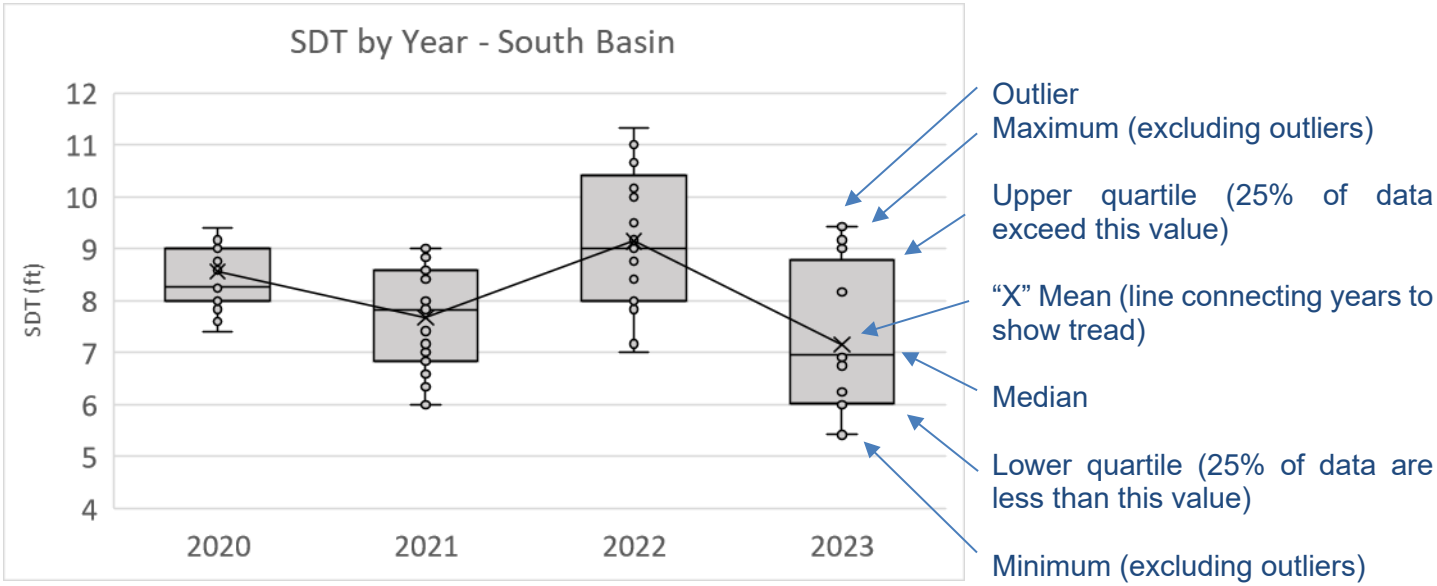


Figure 3. Box & Whiskers Plot SDT by Year

Table 2. Lake Shirley 2023 In-Situ Data.

15-Jun-23						19-Jul-23						22-Aug-23					
Station	Depth (ft)	Temp (DegC)	DO (mg/L)	Spec. Cond. (uS)	Turb (NTU)	Station	Depth (ft)	Temp (DegC)	DO (mg/L)	Spec. Cond. (uS)	Turb (NTU)	Station	Depth (ft)	Temp (DegC)	DO (mg/L)	Spec. Cond. (uS)	Turb (NTU)
1	0	23.6	8.37	310	2.4	1	0	28.3	7.97	254	4.4	1	0	24.4	8.96	253	11.3
1	1	23.6	8.50	310	2.6	1	1	28.3	7.97	254	4.4	1	1	24.4	9.1	255	9.2
1	2	23.4	8.49	300	2.9	1	2	28.3	8.03	253	4.5	1	2	24.3	9.15	252	8.2
1	3	23.2	8.28	310	2.9	1	3	28.3	7.56	255	5.5	1	3	24.2	8.97	252	6.9
1	4	23.2	8.34	380	2.8	1	4	27.4	7.47	255	6.3	1	4	22.9	8.54	255	16.3
1	5	22.4	7.87	310	4.6	1	5	26.9	6.64	250	4.4	1	5	22.7	8.3	252	15.9
1	6	22.2	7.96	310	3.4	1	6	25.3	5.87	233	21.1	1	6	22.7	8.25	249	16.2
1	7	21.1	7.18	300	10.6	1	7	24.1	4.71	231	19.7	1	7	22.4	7.27	249	18.1
1	8					1	8	23.6	4.20	228	17.7	1	8	22.0	6.27	249	19.0
1	9					1	9	23.6	1.81	223	11.0						
2	0	24.2	8.61	319	7.8	2	0	28.3	7.84	279	6.2	2	0	25.2	8.99	263	13.3
2	1	24.2	8.12	317	8.7	2	1	28.4	7.83	280	6.7	2	1	25.2	8.93	262	14.1
2	2	24.2	8.07	310	8.2	2	2	28.4	7.59	277	6	2	2	25.2	8.81	263	12.6
2	3	24.2	8.15	320	7.1	2	3	28.3	7.67	279	6.2	2	3	25.1	8.85	263	11
2	4	24.1	8.05	320	6	2	4	28.2	7.91	278	4.9	2	4	24.6	8.88	263	21.5
2	5	24.1	7.98	319	5.2	2	5	27.6	7.66	274	6.5	2	5	23.6	8.55	265	23.8
2	6	23.7	7.97	316	6.2	2	6	26.8	7.38	272	11.2	2	6	23.3	7.86	266	22.1
2	7	22.4	8.14	315	22.5	2	7	26.2	6.91	266	15.5	2	7	22.9	4.18	276	41.9
2	8	21.3	8.16	319	23.5	2	8	25.1	5.48	262	21.3	2	8				
2	9					2	9	24.7	3.60	262	21.2	2	9				
3	0	23.8	8.83	318	4.8	3	0	28.3	7.90	271	6	3	0	24.9	9.2	262	13.9
3	1	23.7	8.08	318	4.7	3	1	28.3	7.74	273	7.7	3	1	24.9	8.42	260	16
3	2	23.8	7.98	317	4.5	3	2	28.3	7.65	273	7	3	2	24.9	8.51	260	18.3
3	3	23.8	8.02	317	3.6	3	3	28.3	7.98	271	6	3	3	24.8	8.48	261	13.6
3	4	23.7	7.71	317	4.1	3	4	28.1	7.65	272	5.3	3	4	24.8	8.4	262	11.5
3	5	23.6	7.91	317	3.7	3	5	28.1	7.69	272	4.9	3	5	24.2	8.31	262	14.3
3	6	23.6	7.99	317	3.3	3	6	27.4	7.47	268	16.9	3	6	23.9	7.79	259	18.8
3	7	23.6	8.10	316	3.4	3	7	26.5	6.95	265	23.9	3	7	23.6	7.17	260	21.3
3	8	23.1	8.07	317	3.3	3	8	25.7	5.11	262	22.5	3	8	23.1	6.68	260	16.3
3	9	20.6	7.56	318	27.8	3	9	24.3	2.48	257	20.6	3	9	22.3	2.8	275	50.2

*pH data excluded. Reported numbers appeared erroneously high.

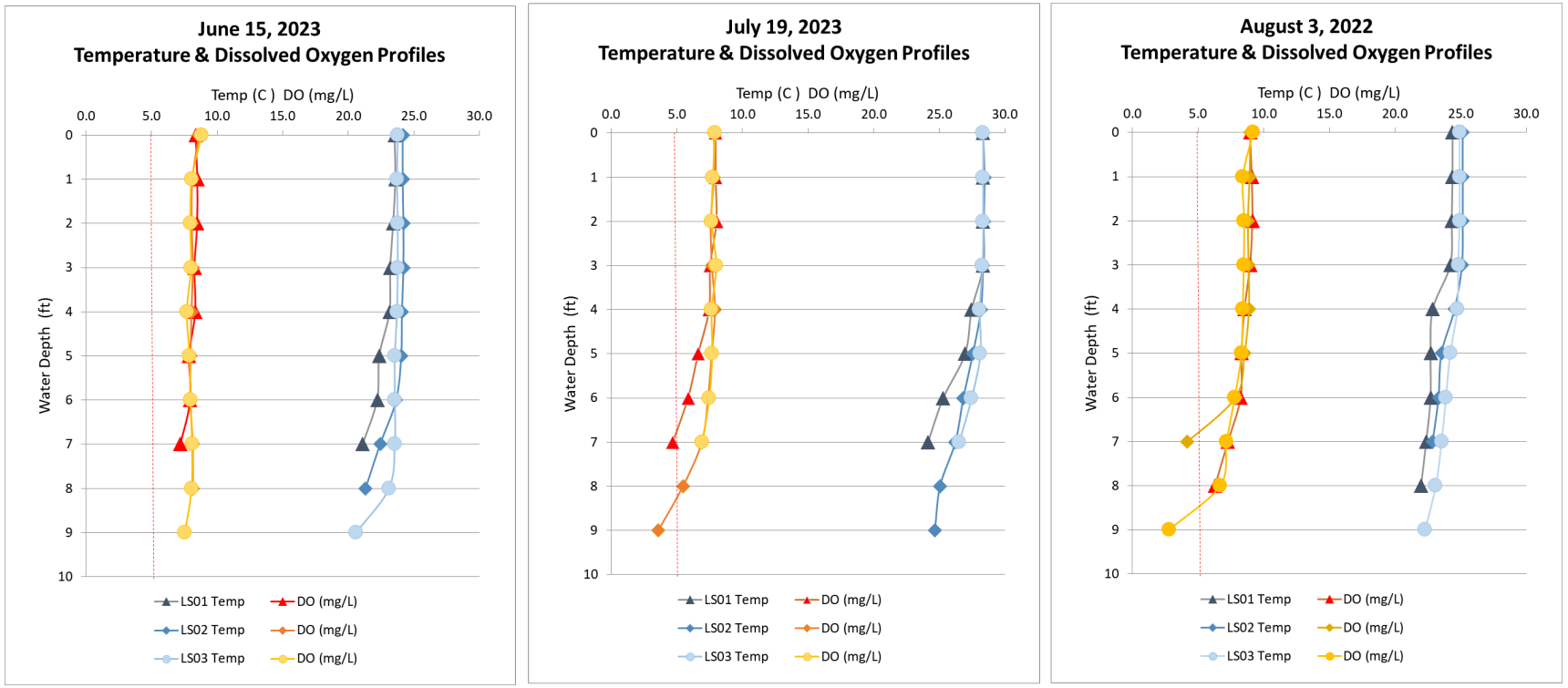


Figure 4. Lake Shirley 2023 Temperature and Dissolved Oxygen Profiles.

Nutrient Concentrations

LSIC volunteers collected grab samples at three locations in the lake at two depths (surface and bottom) on three dates during 2023. LSIC samples were analyzed for nitrogen and phosphorus, the two nutrients that influence algal growth. Phosphorus is the nutrient in shortest supply in freshwater systems and is commonly referred to as the limiting nutrient, meaning that primary production (algae and plant growth) is controlled or limited by the amount of phosphorus in the system. TP in 2023 was generally low to moderate; concentrations ranged from <0.010 to 0.056 mg/L, averaging 0.018 mg/L. TP equaled or exceeded the 0.020 mg/L threshold where algal blooms typically become more frequent and problematic at the bottom sample locations in July in the North Basin and in August at all three basins. The highest value (0.056 mg/L) was recorded at LS-1 (North Basin) at the bottom (Table 3). Surface TP concentrations in the North Basin are historically higher than the other locations, but values were more comparable to the other two basins in 2023. TN concentrations ranged from 0.44 to 1.3 mg/L and are moderately to slightly elevated. Values above 1.0 mg/L often indicate substantial loading and increase the probability of algal blooms. Generally, TP and TN values are highest in the North Basin and decline in the outflow direction (north, middle, south) which may indicate a source from the main tributary (Catacoonamug Brook) or a direct load within the North Basin. This pattern was more muted in 2023. The summer of 2023 was the second rainiest summer in Boston's history, and this additional, more frequent precipitation may have flushed out much of the accumulated nutrients.

Phytoplankton

LSIC volunteers collected grab samples for phytoplankton on two occasions on July 19, 2023 and August 22, 2023. Concentrations [cells/milliliter(mL)] were low and below the level when algicides are warranted (<20,000 cells/mL) (Figure 5). Cyanobacteria cells were elevated in the South Basin during August but still well below the 70,000 cells/mL used as the threshold for the Department of Health to issue a contact recreation advisory or beach closure. The maximum cell count for cyanobacteria (blue green algae) was 13,614 cells/mL on August 22, 2023 in the northwest cove of the North Basin.

Phytoplankton biomass was above the threshold where algae become visually apparent in August in all basins (Figure 6). The community was mostly chrysophtes (primarily *Dinobryon*) and cyanobacteria (*Chroococcus*). *Dinobryon* are commonly found in freshwater lakes and can produce unpleasant odors in high densities. Neither of these genera are common toxin producers.

Table 3. Lake Shirley 2023 Nutrient Concentrations

	SURFACE TP mg/L			BOTTOM TP mg/L		
	LS-1	LS-2	LS-3	LS-1	LS-2	LS-3
6/15/2023	<0.010	<0.010	<0.010	0.016	0.011	<0.010
7/19/2023	0.019	0.013	0.015	0.027	0.017	0.015
8/22/2023	0.019	0.016	0.017	0.056	0.021	0.020
	SURFACE TN mg/L			BOTTOM TN mg/L		
	LS-1	LS-2	LS-3	LS-1	LS-2	LS-3
6/15/2023	0.67	0.58	0.88	0.58	0.52	0.50
7/19/2023	0.71	0.44	0.57	0.64	0.60	0.52
8/22/2023	0.70	0.64	0.68	0.98	1.30	0.64
Exceed TP desirable threhold concentration						

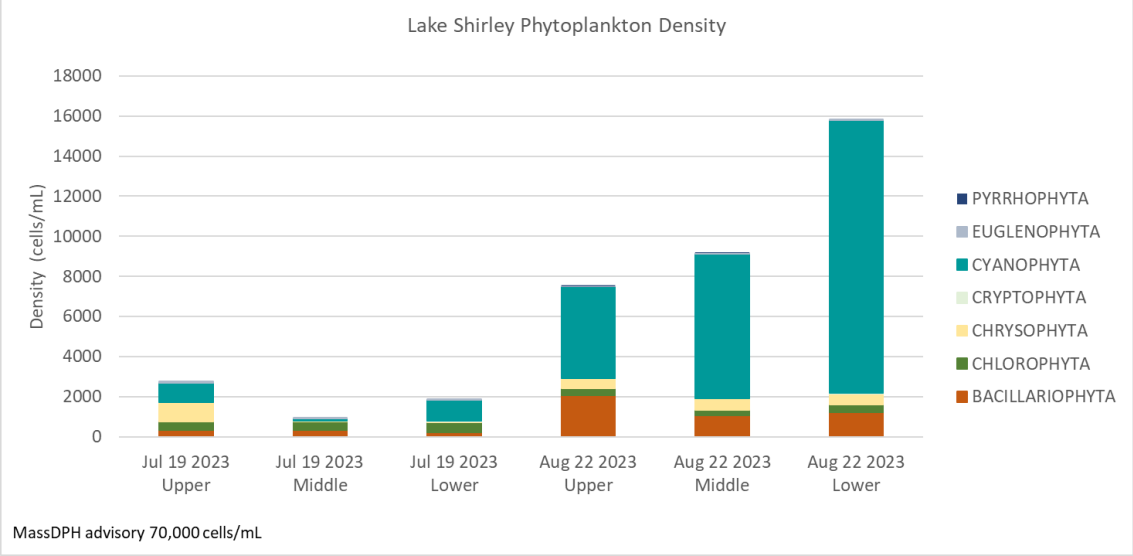


Figure 5. Phytoplankton Density 2023

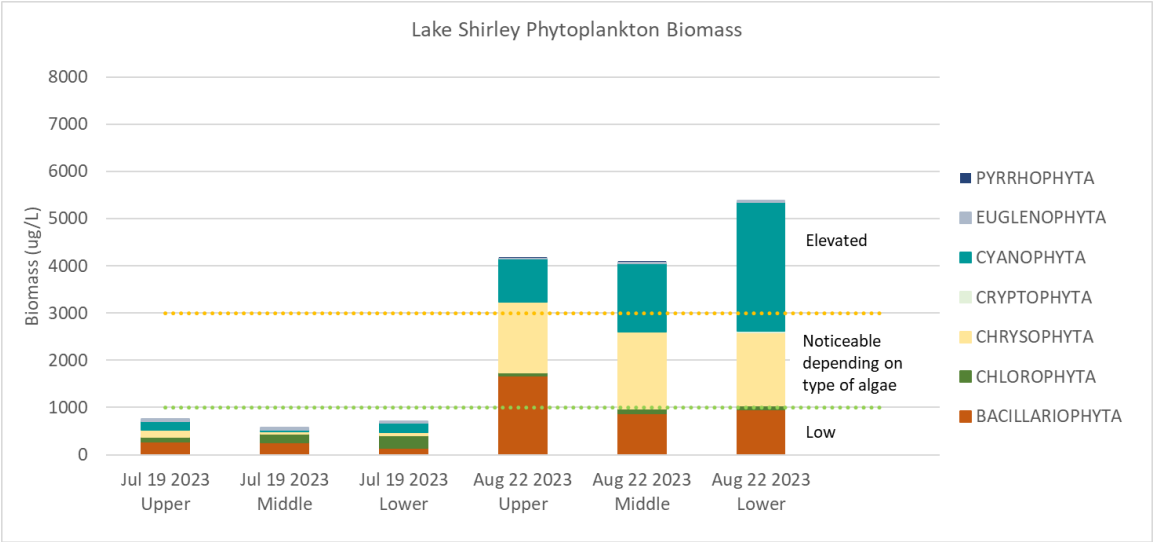


Figure 6. Phytoplankton Biomass 2023

2023 HERBICIDE AND ALGAECIDE TREATMENTS

SŌLitude Lake Management biologists surveyed Lake Shirley aquatic plants on June 13th to evaluate if herbicide treatment was warranted. Thin-leaf pondweeds (*Potamogeton* spp.*)* were dominant and encountered frequently during the survey. These native species were also very common in 2022. Non-native fanwort (*Cabomba caroliniana*) was widespread and observed at 44% of the observation locations and was dominant at ten locations. The non-native, curly-leaf pondweed (*P. crispus*) was found at 23% of the observation locations. Neither species of non-native milfoils [variable milfoil (*Myriophyllum heterophyllum*) nor Eurasian milfoil (*Myriophyllum spicatum*)] were observed. Both the pre- and post-treatment reports are provided in Appendix A.

These pre-treatment data were similar to last year with slightly less biovolume. This is likely due to the timing of the survey. The 2023 survey was conducted three weeks earlier than in 2022. Timing and weather can affect aquatic plant growth due to water temperatures and quantity and intensity of solar radiation. It is not unexpected to observe an abundance of seed producing species, like pondweeds, early in the season especially following winter water level drawdowns. The seed bank from prior years exists in the sediment and favor their growth over plants that depend on overwintering root systems. This is especially apparent following successful drawdown years when the ice and cold temperatures leave an open environment the following spring.

As prescribed in the Lake Management Plan, areas where plant biomass was greater than 50% or contained non-native species were proposed for treatment. Some candidate areas were not designated for treatment due to their proximity to undeveloped shorelines and/or the presence of non-nuisance species (ex. Stonewort/Chara, waterlilies) or to avoid areas with coontail (*Ceratophyllum demersum*) and Robbins Pondweed (*Potamogeton robbinsii*), both of which are desirable species that have become less abundant over time. The management objective is to preserve and encourage increased coverage of these species.

Approximately 34.5 acres were designated for treatment and the Commissions approved treatment on June 20th (Lunenburg) and June 26th (Shirley).

SŌLitude conducted treatment on July 11, 2023 using Tribune (diquat) and Nautique (copper). Although there were reports of extensive nuisance plant densities in August, a follow up treatment with diquat was not conducted this year. Twenty-two acres of treatment were added to the expected 34.5 acres based on observations in the field on the day of treatment. Field changes are allowed by the Commission if the applicator observes any additional areas of non-native curly-leaf pondweed or topped-out, problematic vegetation locations not identified on the pre-treatment map. A total of 56.5 acres were treated using 88.5 gallons of Tribune and five gallons of Nautique. The herbicide treatment details are listed in Table 1 of the 2023 Year-End Treatment Report provided in Appendix A. There were no fish kills reported in Lake Shirley prior to, during or following the herbicide treatments.

SŌLitude conducted a post treatment survey to evaluate herbicide efficacy. Treatment was deemed successful as it reduced densities of nuisance pondweeds in the shallow areas around the lake. Unfortunately, the growth of other species increased substantially by late summer, especially tapegrass, naiad and fanwort.

END OF SEASON PLANT SURVEY

Aquatic Restoration Consulting, LLC performed a late summer plant survey. The purpose of the survey was to document conditions at the end of the growing season and compare these results to prior annual surveys. ARC used the same 66 survey locations (Figure 7) as prior surveys and observed plants at these locations using both a rake-toss and underwater video. Both plant cover (estimated percent area containing plants in two dimensions) and biovolume (estimated percent volume containing plants in three dimensions)[2] were estimated using a semi-quantitative (0-4) ranking system as follows:

0 = 0% 1 = 1–25% 2 = 26–50% 3 = 51–75% 4 = 76–100%

The presence of species and their relative densities were recorded. Relative densities were categorized as trace (only one or two plants present), sparse (multiple plants but not abundant, about a handful), moderate (multiple plants but not dominant, about a rake full) and dense (dominant component of assemblage, more than one rake full). Results of the survey are provided in Table 4.

Of the 66 observation locations, 60 contained plants (91%). Overall plant cover and biovolume was the highest since 2019 (Figure 8). Plant cover was greater than 50 percent (> category 2) at 76% of the sites containing plants, doubled from 2022. Biovolume exceeded 50% at 36% of the sites, also more than twice the 2022 survey data. Most of the sites (64%) exhibited biovolume of 0-50%.

[2] Note that “cover” is interchangeable with “density” in prior consultant reports and “biovolume” is interchangeable with “biomass”. ARC believes cover and biovolume are more precise descriptions of what is actually observed. For coverage, the scientist is estimated the areal coverage of the survey point with plants and biovolume is estimating the percent of the water volume occupied by plants.

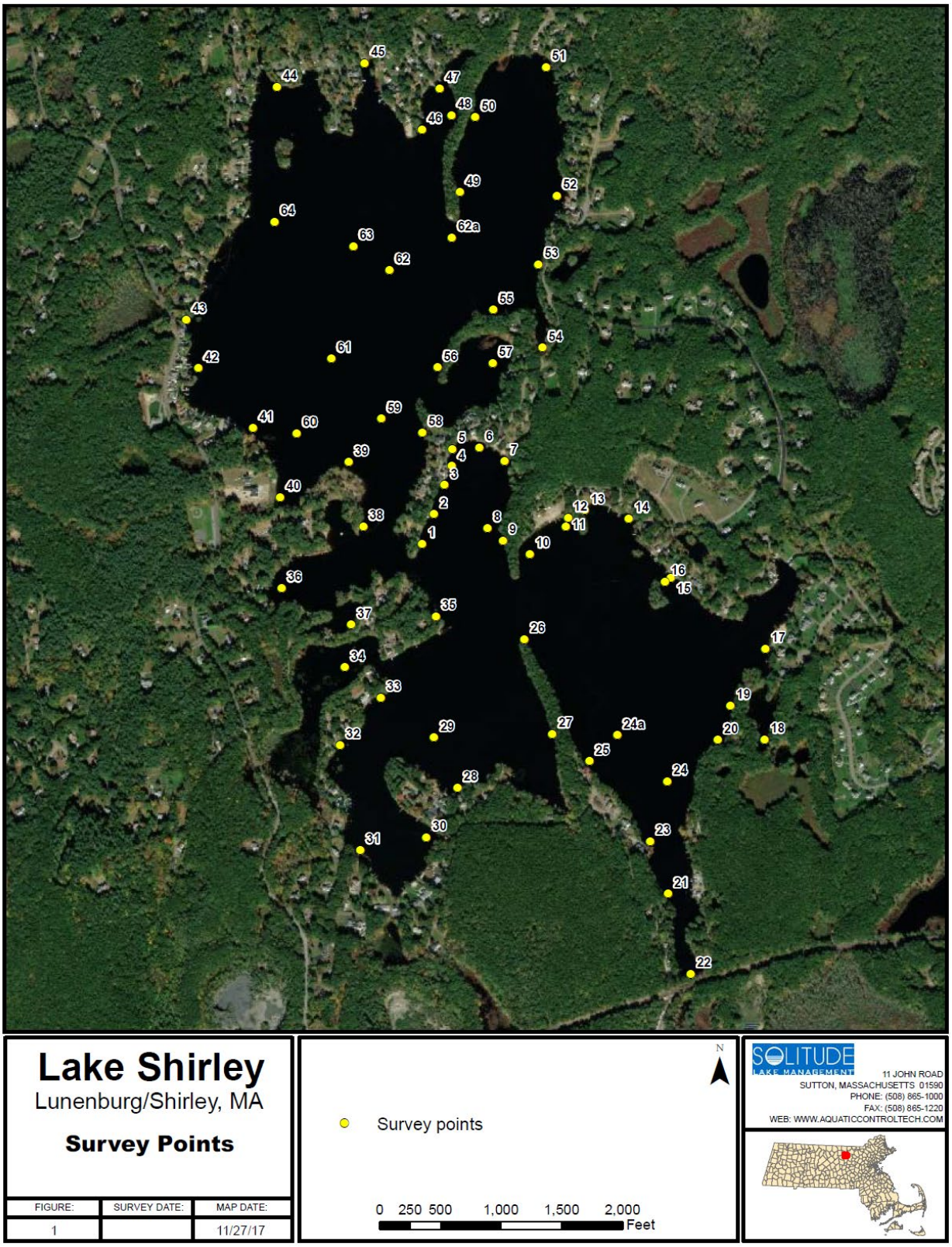


Figure 7. Lake Shirley Plant Survey Points.

Table 4. Lake Shirley Plant Survey Data September 17, 2023.

Point	Water Depth (ft)	Cover	Bio-volume	Cc	Nm	Va	Pc	Bb	Bs	BG	Chara	Cd	FG	Moss	Nf	Ngrac	Nit	No	Nv	Pa	Pf	Pg	Pp	Ppus	Pr	Pz	Spar.	Usp	Species Richness	Richness w/o Target Sp[2]
1	9.0	4	4	D																									1	0
2	8.5	4	4	D																									1	0
3	8.0	4	4	D	M																							S	3	1
4	8.0	4	3	D																									1	0
5	7.0	4	3	D																								T	2	1
6	8.5	4	3	D	D																								2	0
7	6.0	4	2	S	M	D																							3	0
8	9.3	3	3	D																									1	0
9	8.7	4	4	D																									1	0
10	9.5	4	3	D																								S	2	1
11	6.5	3	2	S	M	M									T													T	5	2
12	3.0	2	1	S		S												T										T	4	2
13	6.0	4	3	D		S																						T	3	1
14	5.0	4	2		M	D																							2	0
15	5.0	3	2	S		D																	T						3	1
16	5.0	1	1	T		T																	T						3	1
17	5.0	1	1			S																	S					T	3	2
18	5.0	4	2		T								S				D								M			T	5	4
19	9.0	4	2	D	T	S																							3	0
20	3.6	0	0																										0	0
21	6.6	4	2	D	S	M									T														4	1
22	5.0	4	4	D	S										T		T											M	5	3
23	8.0	3	2	D	S	T																							3	0
24	9.0	2	2	D																									1	0
24a	10.0	2	2	D																									1	0
25	6.5	4	2	S		D																	T						3	1
26	3.3	0	0																										0	0
27	7.7	4	2	D													T											S	3	2
28	4.3	3	1	S	T	M																	S						4	1
29	8.3	4	3	D		S																							2	0
30	5.0	4	2		M	D																						M	3	1
31	4.0	2	2	S	S	S			S									S	S										6	3
32	5.5	4	2	S	S	D				T																		S	5	2
33	7.0	4	2	M	D	D																						S	4	1
34	4.3	4	3	D	D	D							S		T			S	T									T	8	5
35	6.6	4	2	D		M									T													T	4	2
36	8.3	4	3	D	D																								2	0
37	5.6	4	2	D	M	S												T										S	5	2
38	8.0	4	3	D	T	S											T											S	5	2
39	4.0	0	0																										0	0
40	4.1	4	4		T	D									S								S						4	2
41	6.3	4	2		M	D									S														3	1
42	6.0	4	2		D	M									M														3	1
43	3.0	4	2		S	D									S			M											4	2
44	4.5	2	1	T		M															M								3	1
45	4.3	4	2	D	M																								2	0
46	6.3	4	3		D	M																						T	3	1
47	6.0	4	4	D	D										T													T	4	2
48	6.0	4	4		D	D																							2	0

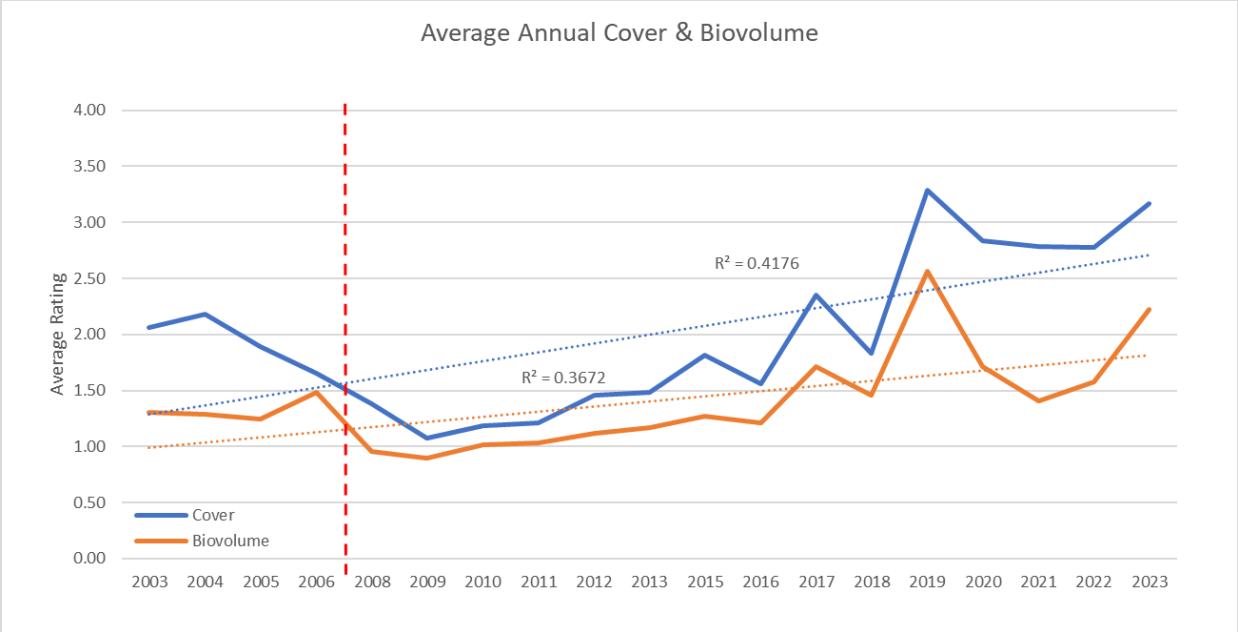
Table 4 (continued). Lake Shirley Plant Survey Data September 17, 2023.

Point	Water Depth (ft)	Cover	Bio-volume	Cc	Nm	Va	Pc	Bb	Bs	BG	Chara	Cd	FG	Moss	Nf	Ngrac	Nit	No	Nv	Pa	Pf	Pg	Pp	Ppus	Pr	Pz	Spar.	Usp	Species Richness	Richness w/o Target Sp[2]
49	7.0	4	2	S	M	M											S												4	1
50	6.5	4	4	M	D	M									S													S	5	2
51	5.0	4	4		D	D																							2	0
52	6.3	4	2		D	M									M														3	1
53	7.0	4	2	M		D									T													S	4	2
54	2.6	4	2	D		T				T			S					S										S	6	4
55	8.0	4	4	D								T																T	3	2
56	3.6	0	0																										0	0
57	7.0	4	4	D		S									T													T	4	2
58	8.0	4	3	D	D	D									T													T	5	2
59	11.0	0	0																										0	0
60	6.3	3	2		M	D																							2	0
61	10.5	0	0																										0	0
62	9.5	1	1		S																								1	0
62a	8.5	1	1	T	T																								2	0
63	10.0	1	1		S																								1	0
64	8.0	4	1		D					S																			2	1
Frequency of Occurrence				44	37	38	0	0	1	3	0	1	3	0	15	0	5	6	2	0	1	0	6	0	1	0	0	25	15	
Frequency of Occurrence (%)[1]				73%	62%	63%	0%	0%	2%	5%	0%	2%	5%	0%	25%	0%	8%	10%	3%	0%	2%	0%	10%	0%	2%	0%	0%	42%		
Density When Present (%)																														
			Dense	66%	35%	42%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
			Moderate	7%	27%	26%	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	17%	0%	0%	100%	0%	0%	0%	100%	0%	0%	8%		
			Sparse	20%	22%	24%	0%	0%	100%	33%	0%	0%	100%	0%	27%	0%	20%	50%	50%	0%	0%	0%	50%	0%	0%	0%	0%	40%		
			Trace	7%	16%	8%	0%	0%	0%	67%	0%	100%	0%	0%	60%	0%	60%	33%	50%	0%	0%	0%	50%	0%	0%	0%	0%	52%		

[1] – Frequency of occurrence (%) is the number of observations where plants are present (# observed/59 total observations with plants)
[2] – Richness w/o Target Species is richness at the sample location not including fanwort (Cc), European naiad (Nm), wild celery (Va) and curly-leaf pondweed (Pc).

Key to species

Bb - *Bidens beckii* [water marigold]	Nv - *Nuphar variegatum* (yellow waterlily)
BG - Bluegreen algae	Pa - *Potamogeton amplifolius* (big leaf pondweed)
Cc - *Cabomba caroliniana* (fanwort)	Pg - *Potamogeton gramineus* (grassy pondweed)
Cd - *Ceratophyllum demersum* (coontail)	Pf - *Potamogeton foliosus* (leafy pondweed)
FG - Filamentous green algae	Pp - *Potamogeton perfoliatus* (clasping pondweed)
Nf - *Najas flexilis* (bushy pondweed)	Ppus - *Potamogeton pusillus* (thin-leaf [Small] pondweed)
Ngrac - *Najas gracillima* (northern [thread-like] naiad)	Pr - *Potamogeton robbinsii* (Robbins' pondweed)
Nm - *Najas minor* (European Naiad)	Pz - *Potamogeton zosterformis* (flatstem pondweed)
Nit - *Nitella sp.* (stonewort)	Spar - *Sparganium sp.* (bur-reed)
No - *Nymphaea odorata* (white waterlily)	Usp - *Utricularia sp.* (bladderwort)
	Va - *Vallisneria americana* (wild celery)



Red dash indicates when herbicide treatments began.

Figure 8. Lake Shirley End of Growing Season Plant Cover & Biovolume over Time

Fanwort was the most frequently encountered plant in September 2023, and was observed at 73% of the sites containing plants. Fanwort was dense at 66% of the locations. Water celery (*Vallisneria americana*) and the non-native Naiad (*Najas minor*) were observed at 63 and 62% of the site with plants. Both plants were mostly moderate or dense when observed. The fourth most abundant was bladderwort (*Utricularia* spp.) at 42%, however this genus was more likely to be sparse or trace when observed. All other species observed were at or less than 25% of the observation locations. Neither species of invasive milfoils (variable nor Eurasian) were encountered during the ARC survey.

Coontail, a native species that was abundant before the use of herbicides (2007), was encountered once (point 55, Figure 7) during the year end survey in September 2023 but was not encountered during the pre-treatment survey. Coontail was found at two locations during the year end survey (point 1 and 54) in 2021, but not during the 2022 ARC survey. While there is natural presence/absence variability with all plants, coontail is often more difficult track because it lacks true roots and is more often found floating freely absorbing nutrients from the water column. However, it is obvious that this plant has declined in abundance over time, which could be related to vegetation management, competition with non-natives, or the availability of nutrients. Robbin's pondweed was observed at one site (point 18) during the end of the season survey. It is consistent observed at this location, which is a designated non-treatment area – one of two areas designated as a habitat preservation zone. Water depth of this cove is about six feet and could be subjected to effects of winter water level drawdown.

Species richness (number of different species observed) at each observation location in 2023 ranged from one to eight (Table 4Table 4), with an average of 2.8, down from a maximum of 10 last year. After removing richness data for the managed target species (fanwort, European naiad, curly-leaf pondweed and wild celery), average species richness declines to 1.0. Overall richness

in 2023 was 15, the lowest since 2018 (Figure 9); this pattern was true with and without target species. Seven native plants were not seen in 2023 but were observed in 2022: four pondweeds (large leaf, grassy, thin-leaf, and flatstem pondweed), northern naiad, water marigold and a macroalga muskgrass. Curlyleaf pondweed (non-native) was also not seen in 2023. Coontail, one of the target preservation species, and bluegreen algal mats were observed in 2023 but not 2022. This resulted in a net loss of six species in 2023. It should be noted that nuisance levels of native pondweeds were observed late summer 2022 and treated in August that year which could account for some of reduced pondweed observances.

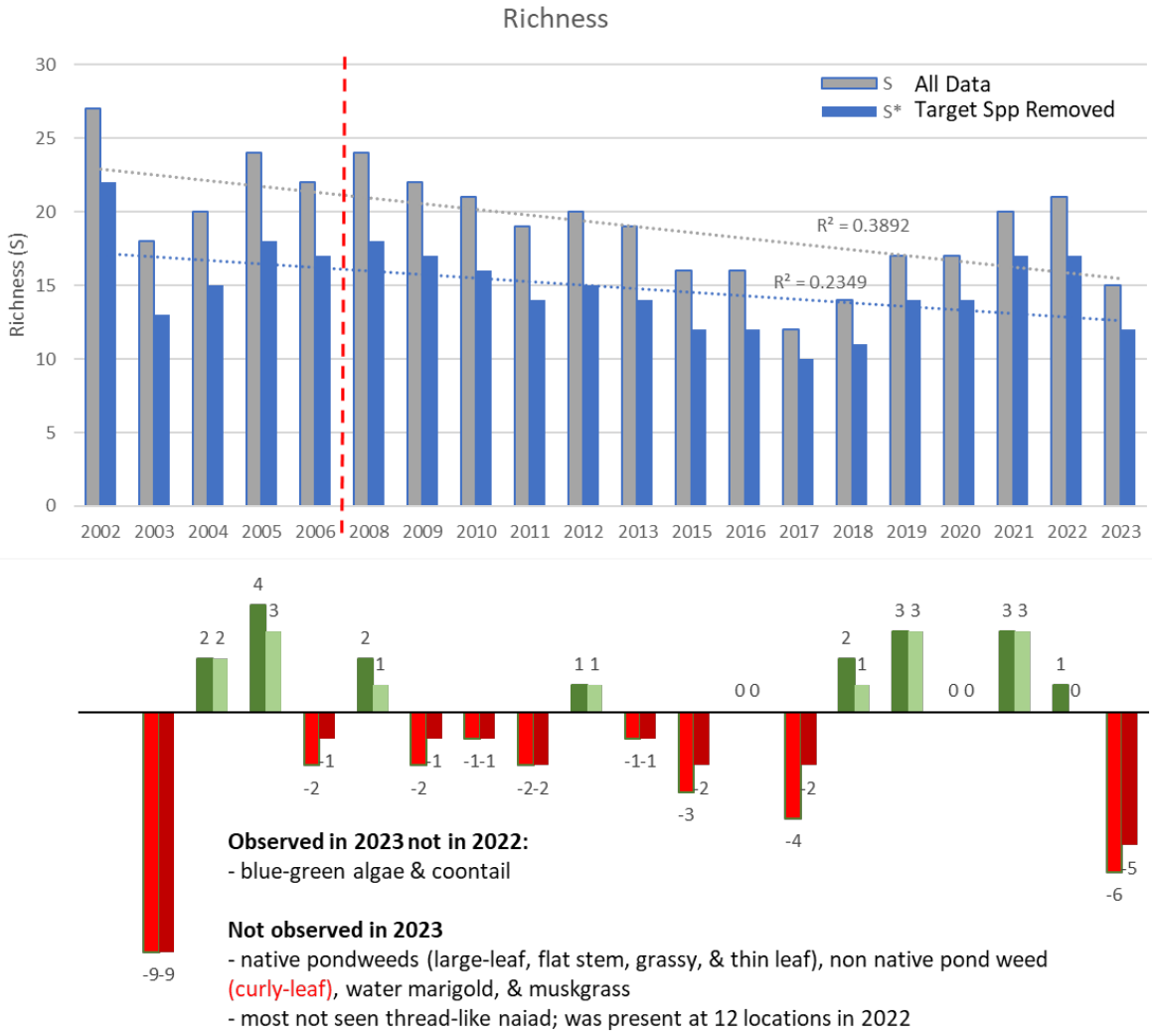


Figure 9. Lake Shirley End of Growing Season Plant Species Richness

Looking at the overall plant density and biovolume together, it is interesting that the cover and volume of plant matter has increased in 2023 but there's been a reduction in species richness (Figure 10). This suggests that a few numbers of species are comprising the biomass. This also coincides with the frequency and density of increased fanwort, European naiad and wild celery observations reported in Table 4.

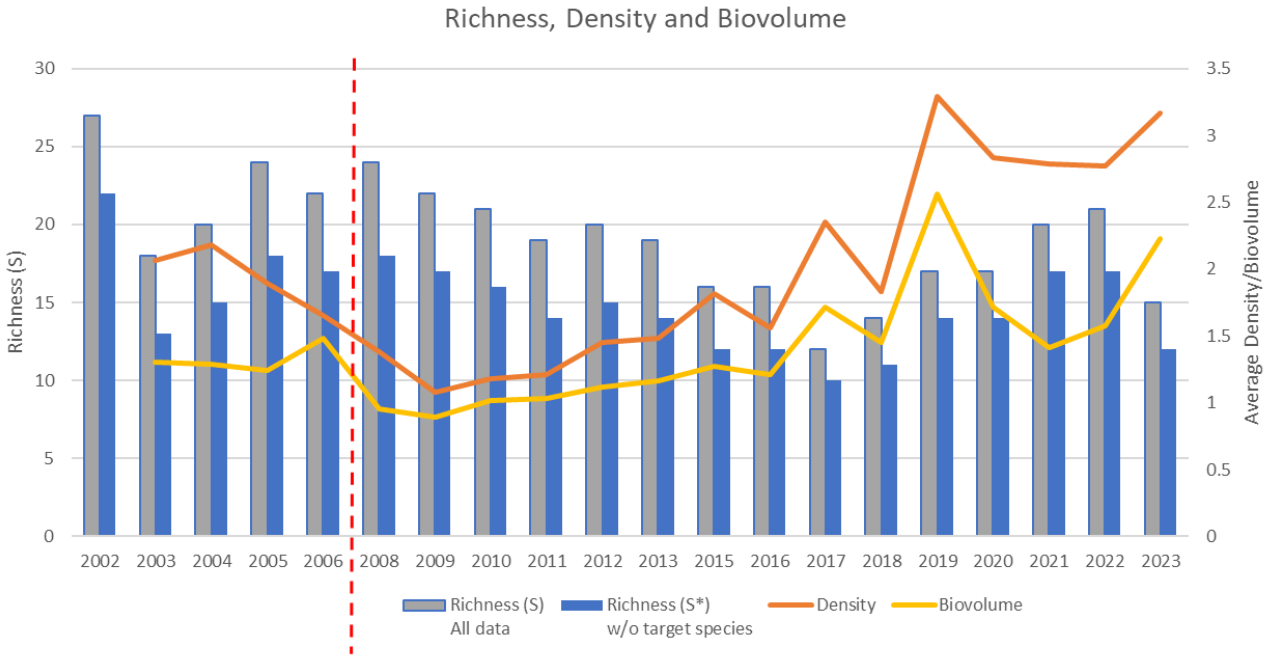


Figure 10. Species Richness, Plant Density and Biovolume over Time

The fewer number of species but extensive density/cover and biomass explains the reduction of plant diversity and evenness indices in 2023. The diversity index, Shannon Index (H), considers both species richness and abundance (i.e., dominance). The higher the H value the greater the diversity and evenness, or lack of dominance by a few species. Values closer to zero indicates that richness is low and the community is dominated by only a few species. The Shannon Index is often discussed along with an equitability (or evenness) index. Evenness is expressed on a scale of 0 to 1, where values closer to 1 indicated that species are evenly represented in the community. Evenness value (E) near 0 indicates dominance by only a few species. These two indices are described in detail, including formulas, in the Lake Shirley Long Term Macrophyte Monitoring Assessment Report – 2002-2019 prepared by ARC in April 2020 (available at www.lakeshirley.com/resources.html).

Plant diversity and evenness has gradually increased since 2017, with and without the managed species, but recent data show a marked decline in 2023. 2023 metrics are still above the lowest values calculated for 2016 & 2017 but are concerning. (Figure 11). Diversity (H) in 2023 and 2022 was 2.06 and 2.42, respectively. Removing the target management species from the population, diversity (H*) still shows a decrease in 2023 from 2022 (1.94 vs 2.27, respectively). Evenness (E*) slightly improved when the target species were removed suggesting that the plant community was more evenly represented (less dominance by a few species). In other words, when only the desirable plants were assessed, the community was dominated by only a few species. This is common when aggressive non-native species invade waterbodies.

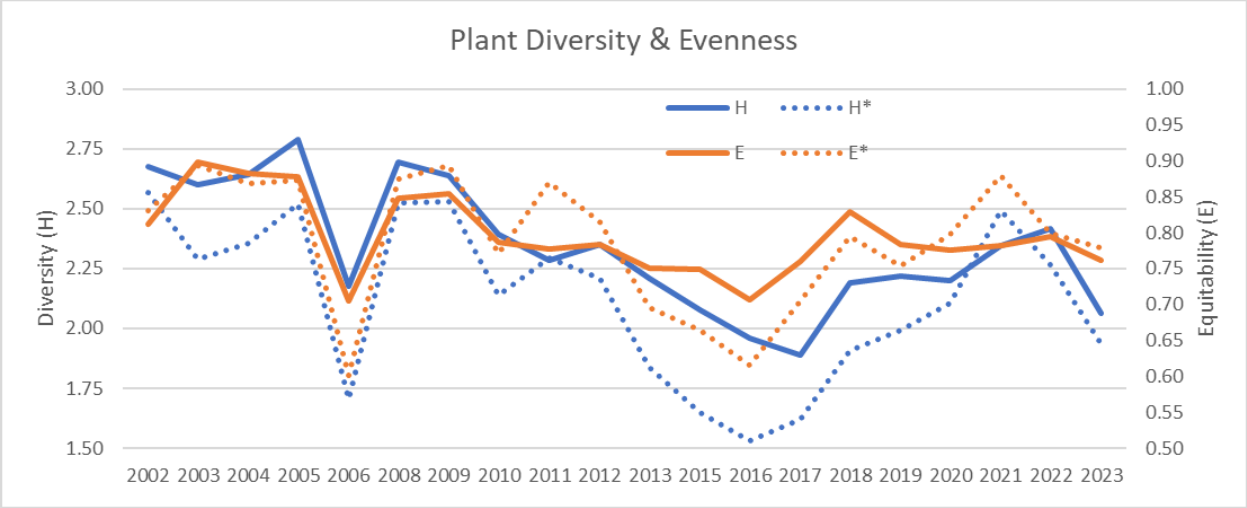


Figure 11. Lake Shirley Plant Diversity and Evenness over Time

The reduction in diversity and evenness from 2022 is likely due to the absence of native pondweed and naiad observations in 2023 that were present in 2022. Recall that native pondweeds reached nuisance levels in the summer of 2022 which were treated with herbicides on August 23, 2022, just after the end of year survey by ARC was conducted (August 21, 2022). It is likely these plants were still present but impaired during the survey.

The non-native invasive plant species abundance was much greater in 2023 with an increase of European naiad frequency at 14 sites (Table 5) and an increase of biovolume >50% at sites from 43% in 2022 to 62% in 2023. Similarly, fanwort observations increased by 12 sites (Table 5) and biovolume >50% increased from 59% in 2022 to 73% in 2023. There was no flumioxazin treatment in 2022 or 2023. Fanwort was dense in all areas previously treated in 2020 (observation point 47) and 2021 (points 36, 37 and 45), suggesting that the treatment is no longer providing any fanwort control and diquat is also ineffective.

Table 5. Lake Shirley Species Frequency over the Last Ten Years.

	Common Name	Genus species	Aug-13	Oct-15	Oct-16	Oct-17	Sep-18	Sep-19	Sep-20	Sep-21	Aug-22	Sep-23
Target Non-native Invasives	Eurasian milfoil	Myriophyllum spicatum										
	Variable milfoil	Myriophyllum heterophyllum	1	1								
	European Naiad	Najas minor	36	13	40		39	60	35	29	23	37
	Fanwort	Cabomba caroliniana	25	19	18	7	19	50	33	37	32	44
	Curlyleaf pondweed	Potamogeton crispus	1		2						1	
Target Native	Wild celery	Valisneria americana	38	38	52	32	30	50	42	40	41	38
Emergent Wetland	Arrow arum	Peltandra virginica										
	Arrowhead	Sagittaria latifolia										
	Bur-reed	Sparganium sp.							2	2		
	Pickerel weed	Pontederia cordata										
	Spike rush	Eleocharis sp.		2	2							
	Wool grass	Scirpus cyperinus										
Macro Algae	Stonewort	Nitella sp.						3	1	6	13	5
	Musk grass	Chara sp.	20	12	1	11					1	
	Stonewort/Musk grass	Nitella/Chara sp					29					
	Bluegreen algae									2		3
	Filamentous green algae				5	6		16	8	6	8	3
Similar Bladderworts	Bladderwort	Utricularia sp.	5	10	6	22	16	50	27	14	24	25
	Eastern purple bladderwort	Utricularia purpurea	3									
	Little floating bladderwort	Utricularia radiata										
Free floating	Watermeal	Wolffia sp.										
	Giant duckweed	Spirodela polyrhiza										
	Duckweed	Lemna minor										
Similar floating leaves	Watershield	Bresenia schreberi	1				2				1	1
	White waterlily	Nymphaea odorata	2	2	3			4	2	2	3	6
	Yellow waterlily	Nuphar variegatum	6	2				6	2	1	4	2
Similar naiad	Bushy pondweed	Najas flexilis	51	48	50	40	10	30	9	6	24	15
	Northern (Thread-like) naiad	Najas gracillima					20		7	10	12	
Similar pondweeds	Clapsing pondweed	Potamogeton perfoliatus	1	4	8	3	7	12	12	11	9	6
	Richardson's pondweed	Potamogeton richardsonii										
Other Pondweeds	Grassy pondweed	Potamogeton gramineus	3							3	1	
	Flatstem pondweed	Potamogeton zosterformis					1	2	1	3	2	
	Big leaf (Large leaf) pondweed	Potamogeton amplifolius									1	
	Floating (broad-leaf) pondweed	Potamogeton natans										
	Leafy pondweed	Potamogeton foliosus						1	6		1	1
	Thin-leaf (Small) pondweed	Potamogeton pusillus	7	9	2	1		17	1	3	4	
	Ribbonleaf pondweed	Potamogeton epihydrus	2	1	1	1	2	1				
	Robbins' pondweed	Potamogeton robbinsii	1	1	2	1	1		2	1	1	1
	Sago pondweed	Potamogeton pectinatus			2							
	Coontail	Ceratophyllum demersum	4	1	1	1	3	5	1	2		1
	Waterweed	Elodea sp.						1				
	Hedge hyssop	Gratiola sp.										
	Quilwort	Isoetes sp.						1				
	Small waterwort	Elantine minima	3									
	Water marigold	Megalodonta beckii								1	1	
	Water purslane	Ludwigia palustris										
	Water starwort	Callitriche sp.										
	Bog moss	Musci sp.		1		6	3			1		

Darkness of red shading indicates higher relative abundance.

EDUCATION AND OUTREACH

While the LSIC does not own the lake or dam, this volunteer-based lake association is dedicated to the protection and management of this system. LSIC works continually to further the education and outreach to lake association members, general public and town representatives. They hold monthly association meetings accessible to the public, where issues such as nutrient loading, responsible lakefront ownership, best management practices are presented and discussed. LSIC openly discusses goals and objectives and prioritization of volunteer funding to manage Lake Shirley. The largest limitation to their ability to educate and manage the lake continues to be the lack of funding and inability to control inputs and watershed land use, as these areas are privately owned or controlled by the Town of Lunenburg and/or Town of Shirley.

In the past, the LSIC has partnered with the Town of Lunenburg on a Low Impact Development (LID) Project as part of a three-year grant to reduce sedimentation and nutrient loading to the lake and control in-lake nuisance vegetation. As a result, the Town adopted Massachusetts Department of Environmental Protection (MassDEP) requirements for an 80% removal of total suspended solids for new developments and implemented five LID demonstration projects around Lake Shirley. These LID projects included constructed wetlands, raingardens, vegetated buffer strips and sediment capture forebays. Details of these projects are described in the Section 319 Non Point Source Pollution Project Report available at https://www.lakeshirley.com/assets/2009-low-impact-development-project.pdf. LSIC continues to search out grant opportunities and partner with the two municipalities.

This past year LSIC was able to accomplish the following:

- Updated the Lake Shirley website (https://www.lakeshirley.com/).
- Held monthly association meetings via Zoom and in person. The public was/is encouraged to attend. Lake management, watershed Best Management Practices, water quality, volunteer opportunities, etc. are recurring topics on the agenda.
- LSIC continues to utilize Facebook as well as the website to communicate with the public regarding best practices and notices of management activities, etc.
- Signage and poster notices were distributed around the lake notifying residents of the upcoming lake herbicide treatments. Individual notices were sent to residents in the areas designated for Tribune use.
- Treatment notices were published in the Sentinel and in the Lunenburg Ledger.

LAKE MANAGEMENT PROGRAM 2023-2024

LSIC continues to utilize a comprehensive approach focusing on management measures that they have physical control over and are within the limited funding level. For management year 2023-2024, LSIC will continue with the winter water level drawdown, herbicide treatments (including flumioxazin), algaecide treatment, if warranted, volunteer-based water quality & water clarity monitoring, and contract for an independent evaluation of aquatic plants at the end of the growing season. Herbicide treatment necessity will be evaluated based on the September 2023 survey, pre-treatment survey in the spring/early summer 2024 and plankton sampling. LSIC will continue to provide educational and outreach materials, continue to stress the importance of boat inspections and plant removal prior to launch and following boat removal (at the campground, homeowners, and their guests).

LSIC intends to implement the winter water level drawdown to a target depth of six feet during the winter of 2023-2024. The initiation of the drawdown started in October. Weather has not been favorable thus far due to above average temperatures preventing continuous days of freezing conditions.

SŌLitude is anticipating that herbicides will be required to control both nuisance native and non-native plant species. The lake is shallow with clear water and is expected to support lush growth with nutrient rich sediment. SŌLitude provides their recommendations in their annual report (Appendix A) which includes:

- an early season plant survey (mid/late April) and herbicide treatment if curly-leaf pondweed density is extensive (early/mid-May),
- mid-season survey (June/July) and treatment targeted at extensive growth of wild celery, naiad, milfoil and excessive pondweeds using diquat with the possible addition of a copper-based herbicide/algaecide for improved control of wild celery.
- possible copper sulfate application if water clarity declines and phytoplankton sampling results suggest the potential formation of an algal bloom.

SŌLitude noted significant changes plant presence/absence and abundance data from the pre-treatment survey to data conducted just prior to herbicide application. This has been a consistent pattern and is the result of timing. To acquire treatment approval from two Town Conservation Commissions on different meeting schedules, the pre-survey must be completed earlier than desired. This underestimates the potential plant biovolume come late July and August. Employing a second treatment was conducted but is not always the best approach. Therefore, the applicator will look back at the late survey data as a forecast mechanism to see which areas and which species will likely become problematic later in the summer and ensure these areas are addressed as needed in the pre-treatment plan.

SŌLitude will continue to provide ARC draft copies of the survey data and proposed treatment plans prior to submittal to the two Conservation Commissions. The intent of the ARC review is to discuss the preservation and encouragement of growth of two native species (coontail and Robbins pondweed) that have been less frequent in the lake over the years. SŌLitude will adjust the treatment plan if needed based on those discussions. SŌLitude will present all proposed treatments to the Conservation Commissions prior to implementation and proceed with treatments as prescribed in the Order of Conditions. No new herbicides or algaecides are proposed for the 2023-2024 management season, but flumioxazin in areas not previously treated may be discussed with the Commissioners during the pre-treatment meeting.

Appendix A

Lake Shirley Herbicide/Algaecide Pre-Treatment Plan and Post Treatment Report

(Prepared by SŌLitude Lake Management)

Lake Shirley
Lunenburg/Shirley, Massachusetts
2023 Year-End Treatment Report

November 28, 2023

Report Prepared by: SOLitude Lake Management
590 Lake Street
Shrewsbury, MA 01545

Report Prepared for: Ms. Joanna Bilotta, President
Lake Shirley Improvement Corporation (LSIC)
PO Box 567
Shirley, MA 01464
jobilotta@comcast.net

Dear Joanna:

In accordance with the aquatic plant management contract between SŌLitude Lake Management (SOLitude) and the Lake Shirley Improvement Corporation (LSIC) for Lake Shirley, the following document serves to provide this year's treatment and survey results, as well as management recommendations for next season. The continued objective of the program is to manage non-native and nuisance aquatic vegetation as well as potentially harmful cyanobacteria (blue-green algae) blooms. Multiple monitoring events, herbicide/algaecide treatment and reporting are key tasks of the project.

All management activities were consistent with the Order of Conditions [DEP File #284-0474 (Shirley), DEP File #208-1168 (Lunenburg)] and the License to Apply Chemicals issued by MA DEP (#WM04-0001193).

2023 Management Program Summary

Program Task	Date Completed
Received Approved License to Apply Chemicals	May 15, 2023
Early Season Survey	June 13, 2023
Herbicide Treatment	July 11, 2023

Pre-Treatment Survey

The pre-treatment survey, conducted on June 13th, incorporated a combination of SLM's historical qualitative assessment and Geosyntec's quantitative procedures, similar to surveys of prior years. Data on species composition, plant growth density, and plant biomass was collected at 66 different points throughout the lake. These points are identical to the point #'s associated with Geosyntec data in the past. A pre-treatment survey is conducted to determine the growth of all target species, such as fanwort (*Cabomba caroliniana*), curly-leaf pondweed (*Potamogeton crispus*), Eurasian milfoil (*Myriophyllum spicatum*) and variable milfoil (*Myriophyllum heterophyllum*). The survey also identifies any potential nuisance species based on native plant density.

Thinleaf pondweed (*Potamogeton spp*.) was the most common plant observed in this year's survey and was found at two-thirds of the survey points and was dominant at nearly half. Other target species include non-native curlyleaf pondweed. Other common native species observed this year include bladderwort (*Utricularia sp*.), macroalgae (*Nitella sp*. & *Chara sp*.) and clasping leaf pondweed (*Potamogeton perfoliatus*). Tapegrass (*Vallisneria americana*), which has been a common target in past treatments, was not very prominent this year, present at only 17% of the points and dominant at only 2%. Fanwort, which is non-native plant but not currently a target for management, was quite widespread this year, being present at 44% of the survey points, but dominant at only 15% of the points.

Per the Lake Management Plan, areas of the lake that exhibit either density or biomass factors of 3 or greater (>50%) are candidates for management. Additionally, any growth of non-native species, in this case curlyleaf pondweed and fanwort can also be treated. Some candidate areas were not designated for treatment due to their proximity to undeveloped shorelines and/or the dominance of non-nuisance species (ex. Stonewort/Chara, Coontail, Robbins pondweed) or the dominance was mostly of fanwort (*Cabomba caroliniana*) for which management action is limited due to budget constraints and practicality of effective herbicide options.

No areas were designated for treatment with flumioxazin in 2023 to manage fanwort Several key areas of the lake were treated in 2020 & 2021, but due to DEP restrictions on the use of flumioxazin, these areas cannot be treated again for a three year period (use of flumioxazin is restricted to once every four years) . Diquat, a contact herbicide, was proposed for use at a rate (1.0-1.5 gallons per acre) to control pondweeds and any areas that exhibited a dense population of tape grass would be treated with Nautique or copper sulfate.

Approximately 34.5 acres were originally designated for treatment. The pre-treatment report, which includes plant survey data and the proposed treatment map, is **attached**. The Lunenburg Conservation Commission approved this treatment plan at their June 20th meeting and the Shirley Conservation Commission approved the plan at their June 26th meeting . As allowed in the approval, some areas were expanded/added on the day of treatment due to observations of nuisance growth that have developed since the June 13th survey, increasing the total treatment area to 56.5 acres.

Herbicide Treatment

The herbicide treatment was conducted on July 11th, for target species as specified in the pre-treatment report. Treatment was conducted with Tribune (diquat) and Nautique (copper). As with all treatments, the lake community and the two towns were notified prior to treatment by LSIC. Several means of notification were utilized: placement of a written notice in the newspaper(s); placement of large, printed signs at major road intersections/locations around the lake and posting of numerous 8.5 inch by 11-inch orange colored, printed signs around the lake shoreline and other means of communication/notification.

The treatment was performed with a 20-foot airboat equipped with a tank, pump, and subsurface injection system. By injecting the diluted herbicide sub-surface, it eliminates the potential for aerial drift. GPS guidance was used to monitor the position of the boat and its relation to the treatment areas. The treatment proceeded smoothly and without any issues, **Figure 1** shows the final treatment areas and GPS recorded treatment tracks. A summary of the treatment specifications is as follows.

Table 1 – Herbicide Treatment Specifications

Treatment Date	July 11th
Product	Tribune (diquat) & Nautique (copper)
Treatment Area	56.5 acres
Quantity	88.5 gallons – Tribune 5 gallons - Nautique
GPS Tracks	See Figure 1
Applicator name	Rocco Notaro, MA Certification #AL-0053966
Site Conditions	Weather: Fair, winds 8-12 MPH West, 80°F Water Temp: 26.8°C at surface, 23.0°C near bottom Dissolved Oxygen: 7.7 mg/l at surface; 4.15 mg/l near bottom (9-feet) Water clarity: 5'3"

No algaecide treatments were required this year.

Post Treatment Inspection

A post-treatment inspection was conducted on September 5th to evaluate the efficacy of the herbicide treatment. Overall, the treatment worked well on the targeted species, especially the pondweeds throughout the lake. Unfortunately, the growth of other species had increased significantly by late summer, especially tapegrass, naiad and fanwort. These species were either not present or were present at levels below the management threshold at the time of the pre-treatment survey. As required in the new Order of Conditions, the final data point survey was completed by Aquatic Restoration Consulting LLC under separate contract with the LSIC.

Anticipated Management in 2024

Based on the results of the 2023 management program, we anticipate seeing continued, minimal growth of watermilfoil this coming summer, however there is a chance that curly-leaf pondweed will be present in significant proportions early in the season as well as fanwort a short time after. Native growth, primarily tape grass and naiad along with nuisance pondweeds, will also likely require management later in the season. We will continue to proceed and determine treatment needs based on the established criteria.

Changes in plant composition and density between the pre-treatment survey, the day of treatment and later in the season continues to be a challenge with the management program. Due to the fact that pre-treatment data needs to be collected, compiled and then presented to the Conservation Commissions at one of their regularly scheduled meetings before we can proceed with treatment, there are very often significant changes from when the data is collected and when the treatment is conducted. Additionally, since the data must be collected earlier in the season, it is not always reflective of the nuisance conditions that can become apparent at the lake in the late summer (late July through late August).

This was especially noticeable this year, with many reports of nuisance growth received from residents in the August to September timeframe. This year the survey was conducted a couple of weeks earlier than in 2022, so we recommend returning to a late June/early July survey and mid-late July treatment schedule. This should help alleviate the issue to some degree. Additionally, we recommend incorporating the previous fall survey data into the treatment plan as those areas that experienced nuisance growth in the late summer/fall can generally be expected to occur again the following year. Including this data into the treatment plan formulation should help address areas that will meet management criteria later in the summer.

One of the other likely reasons that this year's late summer conditions were particularly bad is the proliferation of fanwort. Aside from periodic, localized treatments with flumioxazin the LSIC relies primarily on the winter drawdown to control fanwort because widespread use of flumioxazin is not feasible given the current DEP restrictions of its use and whole lake treatment using fluridone is not financially feasible. Unfortunately recent drawdowns have been relatively ineffective due to warm weather and high water levels. This has allowed the fanwort to expand significantly in biomass.

While we continue to recommend planning for a two-treatment approach, herbicide applications can be combined, as has been the case in recent years, depending on observed growth and availability of funding. The proposed plan for 2024 is as follows

Table 2 – Proposed Plan for 2024

Task	Schedule	Notes/Criteria
Early Season Survey	Mid/late April	Survey for early emerging plants, primarily curly leaf pondweed but also milfoil. Survey will be conducted at established survey points but will not include full collection of data.
1st Treatment	Early/Mid May	Treat all areas of the lake with curly leaf pondweed and milfoil
Mid-Season Survey	Late June/Early July	Full data point survey
2nd Treatment	Mid-Late July	Treat any additional areas of non-native growth, plus selected areas of problematic native plant growth based on density/biomass criteria.
Late Season Survey (conducted by ARC)	Late September/early October	Full data point survey

Tribune (diquat) herbicide alone will provide good control of milfoil, curly-leaf pondweed and naiad. Tapegrass is sometimes more difficult to control and, if needed, a combination of Tribune and a copper-based herbicide (Nautique) or algaecide (Captain/copper sulfate) should be used to increase effectiveness and produce more desirable results. Areas of fanwort will be evaluated for treatment with flumioxazin based on conditions and budget.

Monitoring of water clarity and algal populations (as necessary) provides timely information to guide algaecide treatments should such treatments be warranted. It continues to be of paramount importance to ensure that the water clarity monitoring is conducted on a regular basis (weekly or bi-weekly depending on general observation) from May-October and that results are provided to SOlitude and other project partners so that algaecide

treatments are scheduled in a timely manner. Should treatment of the algae be required in 2024, copper sulfate is again proposed for use.

We recommend LSIC continue to pursue an integrated approach to manage nuisance plants and algae utilizing drawdown and herbicide/algaecide as required. To address overall lake management and long-term goals, the LSIC should continue the investigation and implementation of alternative in-lake methods, watershed management, public education and diagnostic assessments.

We hope this report will be of help to LSIC in planning for 2024 and beyond. If you have any questions regarding this report, please feel free to contact me. We look forward to working with you again in the future.

590 Lake Street
Shrewsbury, MA 010545

Phone: (508) 865-1000
FAX: (508) 865-1220
e-mail: info@solitudelake.com
Internet: www.solitudelakemanagement.com

Date: June 19, 2023

To: Lunenburg Conservation Commission

Shirley Conservation Commission

From: Dominic Meringolo, Senior Environmental Engineer/Project Manager

Re: Lake Shirley – Survey and Treatment Plan

Dear Commissioners,

Based on a survey conducted by our Biologist on June 13th, we are recommending treatment to approximately 34.5-acres of Lake Shirley to manage nuisance weed growth. Thinleaf pondweed (*Potamogeton spp*.) was the most common plant observed in this year's survey. Other target species include non-native curlyleaf pondweed (*Potamogeton crispus*). Other common native species observed this year include bladderwort (*Utricularia sp.*), macroalgae (*Nitella sp. & Chara sp*.) and clasping leaf pondweed (*Potamogeton perfoliatus*). Tapegrass (*Vallinsneria*), which has been a common target in past treatments, was not very prominent this year in most areas and does not require management.

Per the Lake Management Plan, areas of the lake that exhibit either density or biomass factors of 3 or greater (>50%) are candidates for management. Additionally, any growth of non-native species, in this case curlyleaf pondweed (*Potamogeton crispus*) can also be treated. Some candidate areas were not designated for treatment due to their proximity to undeveloped shorelines and/or the presence of non-nuisance species (ex. Stonewort/Chara, waterlilies).

Based on recommendation from Water Restoration Consulting the following areas will be checked again prior to treatment for the presence of coontail (*Ceratophyllum demersum*) and Robbins Pondweed (*Potamogeton robbinsii*), both of which are plants that we would like to see expand in the lake. If specimens of either species are observed, that area would not be treated.

Areas in the vicinity of points 1-7; Areas in the vicinity of points 21-22; Areas in the vicinity of points 30-31.

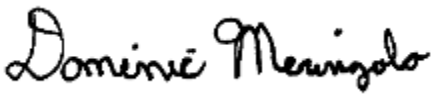
As was approved last year, we ask the Commission to allow us to make field changes on the day of treatment if we observe any additional areas of non-native curlyleaf pondweed or topped-out, problematic vegetation in other areas of the lake not depicted on the map.

No additional areas are proposed for flumioxazin (a/k/a Clipper) herbicide treatment this year. In the proposed treatment areas, Tribune (diquat) herbicide will be used for treatment at a rate of 1.0-1.5 gallons per acre and a copper-based product, either Nautique or copper sulfate, will be used as needed in areas dominated by tapegrass, however this should be quite limited this year.

Treatment is tentatively scheduled for July 11th.

A map of the recommended treatment areas is attached as well as the June 13th survey data table. On the map of the proposed treatment areas, the data points that meet management criteria are included. The LSIC & SOLitude Lake Management will be attending upcoming meetings of the Conservation Commissions to discuss this plan and answer any questions.

Regards,
SOLitude Lake Management



Dominic Meringolo
Senior Environmental Engineer/Project Manager

Figure 1 - 2023 Proposed Treatment Areas

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888.480.5253
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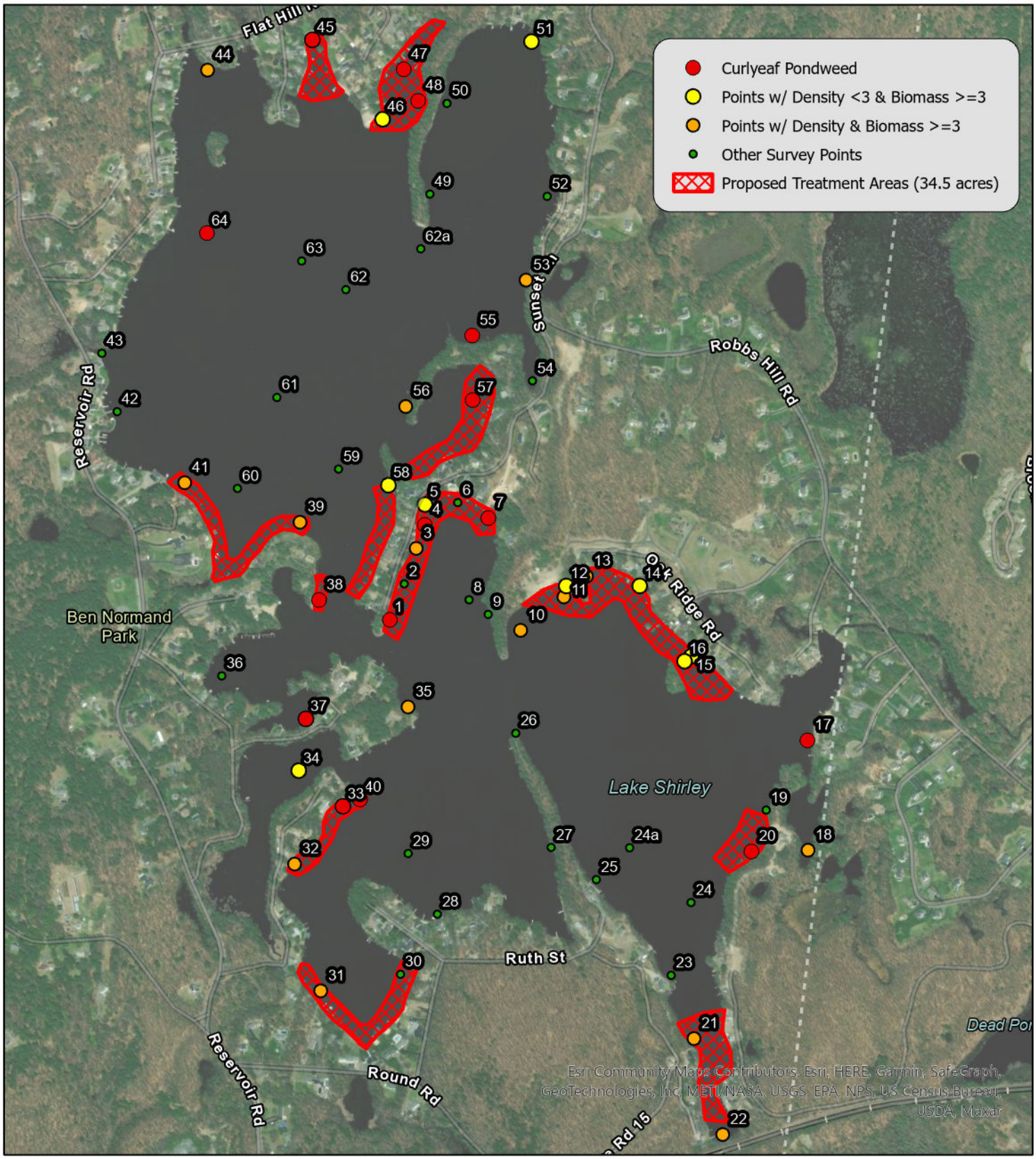

Lake Shirley
Lunenburg, MA

Lake Shirley

0 870 1,740 Feet

1:10,924

N

Map Date: 6/16/2023
Prepared by: DMM
Office: SHREWSBURY, MA

X= Present D = Dominant

Plant Species	# stations present	# stations dominant	% stations present	% stations dominant	Monitoring Locations																																						
Scientific Name					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	24a	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Cabomba caroliniana	29	10	44%	15%		D	D	X	D	D	X	X	X	X	X	X	D	X	X			X	D					X		D	X		D		D				X		D		X	
Elodea canadensis	0	0	0%	0%																																									
Vallisneria americana	11	1	17%	2%	D						X		X				X																					X						X
Eleocharis sp.	1	0	2%	0%																																								
Utricularia Sp.	12	0	18%	0%		X		X			X	X		X				X				X																X						X
Chara sp.	0	0	0%	0%																																								
Nitella sp.	11	2	17%	3%		X				X																	X									X								
Macro	10	2	15%	3%							D	D	X													X		X												X	X	X		X	
Potamogeton bicupulatus	0	0	0%	0%																																								
Najas flexilis	5	2	8%	3%																								D								X		D	X					
Potamogeton gramineus	1	1	2%	2%																																								
Various	0	0	0%	0%																																								
Najas gracillima	4	1	6%	2%															X																										
Potamogeton crispus	15	3	23%	5%	X			X			X										X			X						X								X			X	X	
Potamogeton amplifolius	2	1	3%	2%																				D	X													X						
Potamogeton epihydrus	1	0	2%	0%																																								
Potamogeton perfoliatus	11	5	17%	8%			X								X			D	X	D	X										X							D					
Potamogeton foliosus	0	0	0%	0%																																								
Ceratophyllum demersum	0	0	0%	0%																																								
Potamogeton zosteriformis	0	0	0%	0%																																								
Nuphar variegata	1	0	2%	0%																																								
Nymphaea odorata	0	0	0%	0%																																								
Fontinalis sp.	0	0	0%	0%																																								
Zosterella dubia	3	1	5%	2%				X													X	D																						
Potamogeton confervoides	1	0	2%	0%																																				X				
Potamogeton pusillus	0	0	0%	0%																																								
Potamogeton sp. (thin)	44	30	67%	45%		X	X	D	X	X	X	X	D	D	D	D	X	X	D	X	D				D	D	D				D				D	D		X	D		D	D	D
Potamogeton robbinsii	0	0	0%	0%																																							
Species Richness					2	4	3	5	2	3	6	4	4	3	3	2	3	4	4	2	4	3	1	2	2	2	2	3	0	2	3	0	1	0	1	3	1	4	5	3	2	2	4	3
Plant density Index					1	2	3	3	2	3	3	4	1	3	3	1	4	2	2	1	3	4	1	3	4	3	3	2	0	1	3	0	1	0	2	3	3	2	2	3	2	2	3	3
Plant biomass index					2	2	3	3	3	2	3	2	1	4	4	4	4	3	3	3	3	4	2	3	4	3	2	2	0	2	2	0	2	0	2	4	3	3	4	4	2	3	4	3

Key to Density and Biomass Indices		
Value	Density (% cover)	Biomass
0	Absent: 0%	No growth
1	Sparse: 1-25%	Scattered plant growth; or primarily at lake bottom
2	Moderate: 26-50%	Less abundant growth; or in less than half of water column
3	Dense: 51-75%	Substantial growth through majority of water column
4	Very Dense: 76-100%	Abundant growth throughout water column to surface

X= Present

Plant Species	# stations present	# stations dominant	% stations present	% stations dominant	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	62a	63	64	65	66	
Scientific Name																																	
Cabomba caroliniana	29	10	44%	15%					X	X	X									X	X												
Elodea canadensis	0	0	0%	0%																													
Vallisneria americana	11	1	17%	2%			X	X	X						X	X																	D
Eleocharis sp.	1	0	2%	0%							X																						
Utricularia Sp.	12	0	18%	0%				X												X	X												
Chara sp.	0	0	0%	0%																													
Nitella sp.	11	2	17%	3%			X	X	X					D								X	X						D				
Macro	10	2	15%	3%		X																											
Potamogeton bicupulatus	0	0	0%	0%																													
Najas flexilis	5	2	8%	3%																			X										
Potamogeton gramineus	1	1	2%	2%	D																												
Various	0	0	0%	0%																													
Najas gracillima	4	1	6%	2%									X				X								D								
Potamogeton crispus	15	3	23%	5%						D		D	X							X		X								D			
Potamogeton amplifolius	2	1	3%	2%																													
Potamogeton epihydrus	1	0	2%	0%						X																							
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Nymphaea odorata	0	0	0%	0%																													
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Potamogeton robbinsii	0	0	0%	0%																													
Species Richness					1	3	3	4	4	3	3	2	3	2	1	2	2	1	0	6	3	3	3	0	2	1	1	0	1	1	0	1	2.397058824
Plant density Index					2	3	3	2	3	2	2	3	3	3	1	2	1	3	0	3	3	1	2	0	1	2	2	0	1	1	0	2	2.088235294
Plant biomass index					2	4	1	2	4	3	3	4	3	2	1	3	2	3	0	4	3	2	3	0	2	2	1	0	1	2	0	1	2.426470588

Figure 1 - 2023 Actual Treatment Areas (56.5 acres) & Treatment Tracks

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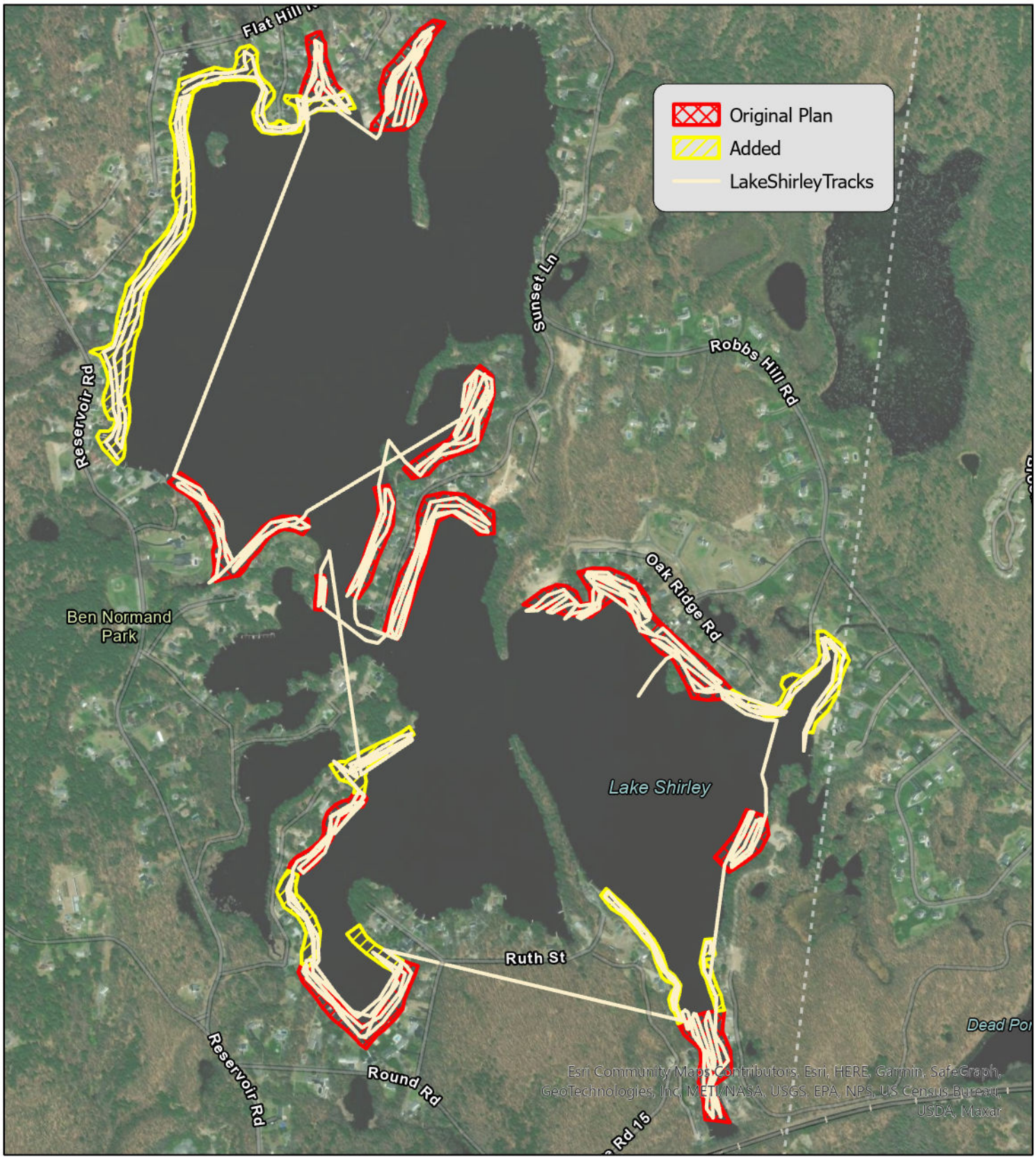

Lake Shirley
Lunenburg, MA

Lake Shirley

0 870 1,740 Feet

1:10,924

N

Map Date: 11/27/2023
Prepared by: DMM
Office: SHREWSBURY, MA