Report For:
Lake Shirley Improvement Corporation
Shirley, MA 01464

Lake Shirley Lake Management Annual Report 2021-2022

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December 2022

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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, 2021 through October 14, 2022) 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 2021-2022 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 lowering.

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 2021-2022 drawdown season. A maximum of 4.7 feet was achieved on December 9, 2021. Average drawdown from December 1 through the end of February was 3.7 feet. The LSIC did not receive any complaints from residents expressing concerns about low pressure well conditions during this drawdown period. Water was flowing over the spillway on March 31, 2022 signifying achievement of full lake refill. Downstream flow was maintained at less than 56.3 cubic feet per second (cfs) on average as recommended in the Eutrophication and Aquatic Plant Management in Massachusetts General Environmental Impact Report (GEIR). Downstream flow was maintained above the 7.0 cfs recommendation during lake refill. Table 1Table 1 & 2 provide water level and outflow monitoring data. There were no fish kills reported in Lake Shirley during the drawdown period.

WATER QUALITY MONITORING

The LSIC volunteers performed routine water quality monitoring during the 2022 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 September 2022. 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 2022; the minimum clarity was 5.2 feet during July 2022 in the upper North Basin (

). Water clarity in 2022 ranged from 5.2 to 11.3 feet, which was two feet greater than the maximum clarity in 2021. Clarity is typically best in the South Basin and worst in the Upper North Basin. This trend was consistent with the last several years.

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 14th, July 12th and August 3rd, 2022. Data are presented on Table 33.

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 exceeded this threshold in August 2022 (Table 3). Dissolved oxygen data were desirable and remained above the 5.0 milligrams per liter (mg/L) minimum except for the North

Table 1. 2021-2022 Water Level Monitoring Data

Date	Mid Valve	Low Valve	Level (in)	Notes	Rate (in/day)
9/1/2021	Open	Closed	3		
9/2/2021	Open	Closed	6	3" Rain	3.0
9/5/2021	Closed	Closed	5		-0.3
9/14/2021	Closed	Closed	5		0.0
9/23/2021	Closed	Closed	5		0.0
10/2/2021	Closed	Closed	3		-0.2
10/9/2021	Closed	Closed	6		0.4
10/14/2021	Closed	Closed	4		-0.4
10/15/2021	Open	Open	4	Start DD	0.0
10/16/2021	Open	Open	0		-4.0
10/18/2021	Open	Open	-6		-3.0
10/21/2021	Open	Open	-15		-3.0
10/23/2021	Open	Open	-21		-3.0
10/25/2021	Open	Open	-25		-2.0
10/28/2021	Open	Open	-25	Heavy Rain	0.0
11/1/2021	Open	Open	-19		1.5
11/5/2021	Open	Open	-24		-1.3
11/9/2021	Open	Open	-28		-1.0
11/10/2021	Open	Open	-30	Heavy Rain Friday	-2.0
11/14/2021	Open	Open	-33	Clean Valve	-0.8
11/15/2021	Open	Open	-34	Clean Pipe	-1.0
11/18/2021	Open	Open	-36		-0.7
11/19/2021	Open	Open	-37	Clean Valve	-1.0
11/21/2021	Open	Open	-39	Clean Valve	-1.0
11/24/2021	Open	Open	-41		-0.7
11/28/2021	Open	Open	-45	Clean Valve	-1.0
12/1/2021	Open	Open	-49		-1.3
12/4/2021	Open	Open	-52		-1.0
12/6/2021	Open	Open	-54		-1.0
12/9/2021	Closed	Open	-56		-0.7
12/14/2021	Closed	Open	-53		
12/18/2021	Closed	Open	-82		
12/26/2021	Closed	Open	-45		
12/31/2021	Closed	Open	-43		
1/6/2022	Closed	Open	-42		
1/11/2022	Closed	Open	-43		
1/16/2022	Closed	Open	-45		
1/21/2022	Closed	Open	-43		

1/26/2022	Closed	Open	-44		
2/1/2022	Closed	Open	-46		
2/10/2022	Closed	Open	-24		
2/17/2022	Closed	Open	-18		
3/2/2022	Closed	Open	-18		
3/7/2022	Closed	Open	-18		
3/12/2022	Closed	Open	-19		
3/16/2022	Closed	Open	-23		
3/17/2022	Open 100	Closed	-24		
3/19/2022	Open 60	Closed	-22		
3/25/2022	Open 60	Closed	-10		
3/29/2022	Open 60	Closed	-2		
3/31/2022	Open 60	Closed	Water over spillway		
4/2/2022	Closed	Closed	3		

Table 2. Outflow Monitoring 2021-2022

Date	Gage Reading	Flow (cfs)
10/20/2021	2.15	57.16
10/25/2021	2.1	52.41
11/1/2021	2.1	52.41
11/6/2021	2.1	52.41
11/11/2021	2.05	47.85
11/15/2021	2	43.24
11/25/2021	1.9	35.03
12/1/2021	1.82	29.36
12/8/2021	too dirty to read	
2/17/2022	2.1	52.41
2/22/2022	2.1	52.41
3/2/2022	2.1	52.41
3/7/2022	2.1	52.41
3/12/2022	2.1	52.41
3/16/2022	2.1	52.41
3/17/2022	1.54	14.23
3/19/2022	1.36	7.497
3/25/2022	1.36	7.497
3/31/2022	1.36	7.497
Water flowing over spillway. Lake filled		

Watershed (sq mi)	14.1
GEIR during DD (cfs)	56.3
Avg Outflow during DD (cfs)	46.2
GEIR during refill (cfs)	7.0
Avg Outflow during Refill (cfs)	9.2

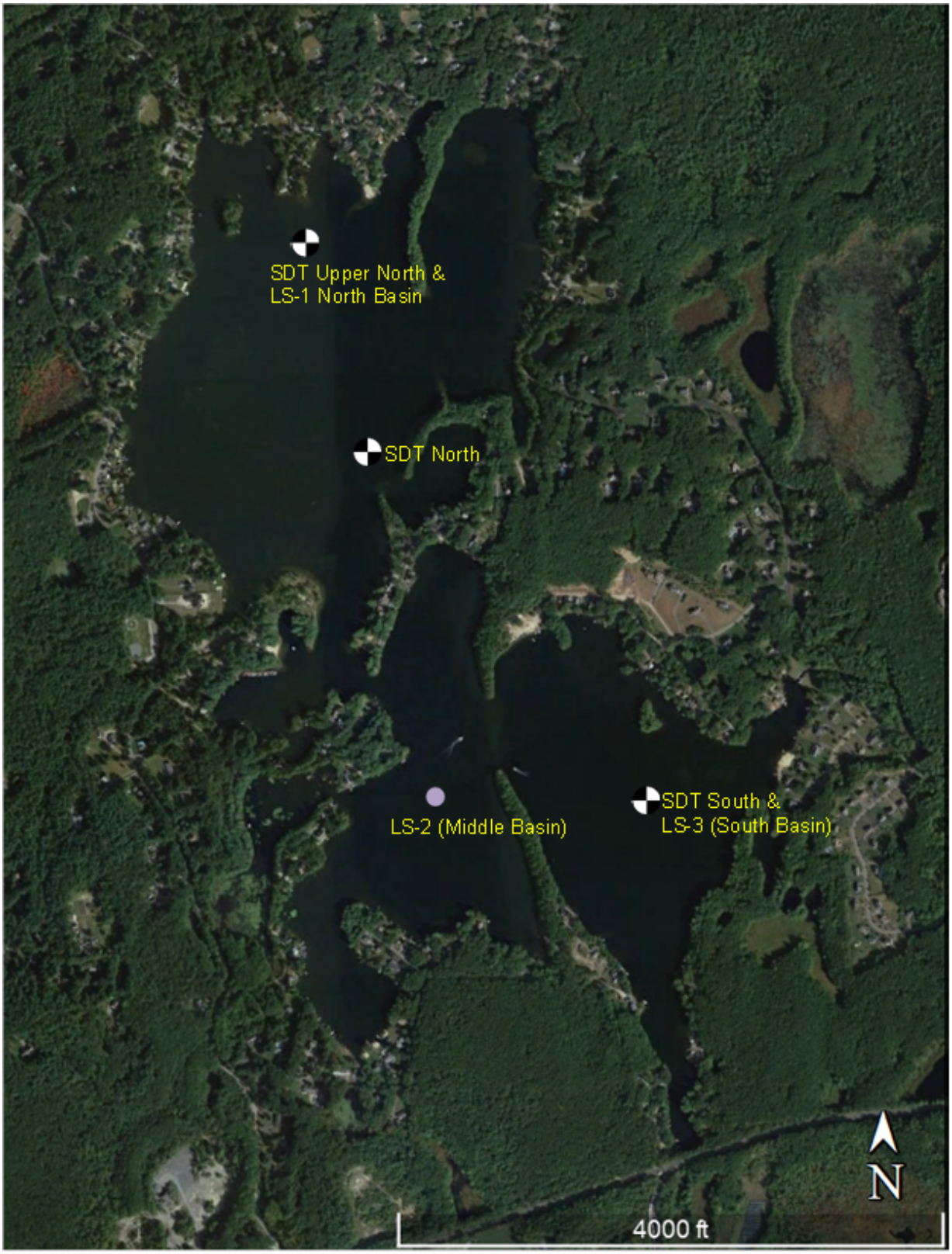


Figure 1. Water Quality and Secchi Disk Transparency Locations

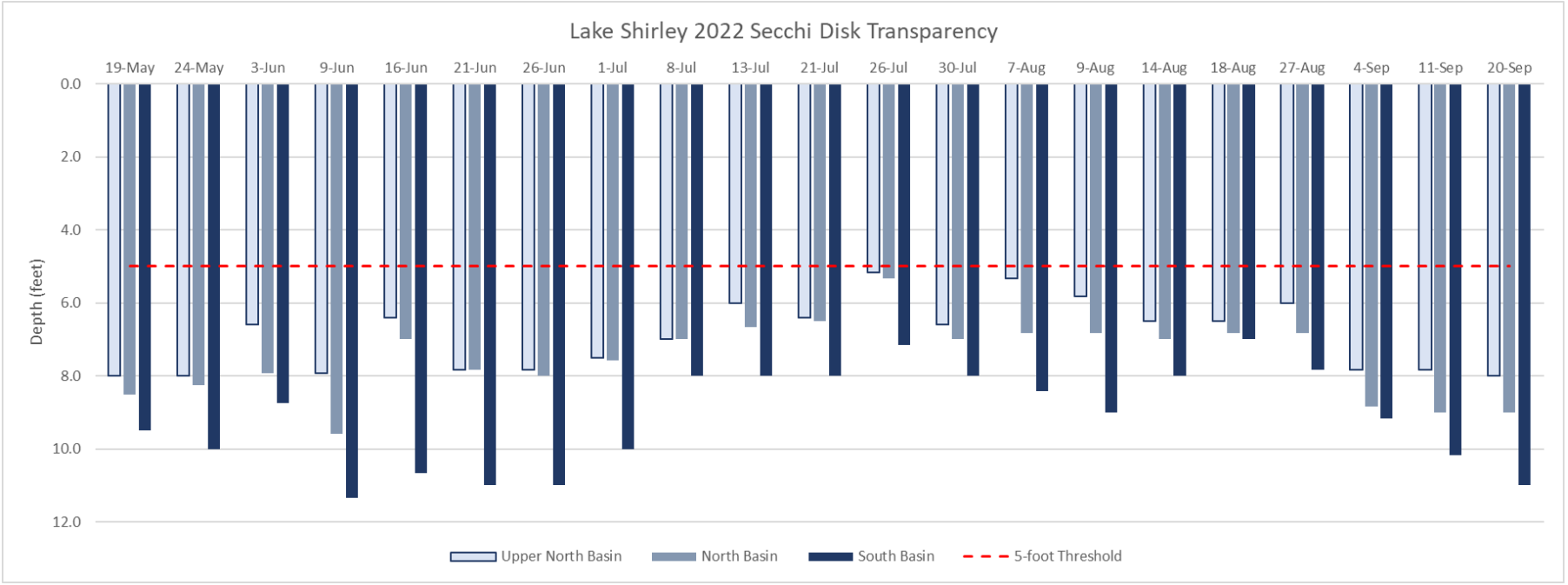


Figure 2. Lake Shirley 2022 Secchi Disk Transparency.

Table 3. Lake Shirley 2022 In-Situ Data.

14-Jun-22						
Station	Depth (ft)	Temp (DegC)	DO (mg/L)	Spec. Cond. (uS)	pH (su)	Turb (NTU)
1	0	24.8	8.62	296	8.1	0.1
1	1	24.8	8.77	296	8.8	1.8
1	2	24.8	8.61	296	8.2	1.3
1	3	24.8	8.87	297	8.2	1.9
1	4	24.8	8.88	296	8.3	1.8
1	5	24.3	8.91	298	8.2	2.2
1	6	23.8	8.55	300	8.0	2.4
1	7	23.7	8.23	299	7.9	2.7
1	8	23.3	8.24	281	7.7	6000 hit bottom
1	9					
2	0	25.2	7.90	294	7.8	0
2	1	25.1	8.00	294	7.8	3.2
2	2	25.1	7.93	296	7.8	3.3
2	3	25.1	7.99	296	7.8	2.2
2	4	25.1	7.98	297	7.7	1.7
2	5	24.9	8.03	296	7.7	1.7
2	6	24.8	8.03	296	7.8	1.3
2	7	24.2	8.04	293	7.7	1.5
2	8	23.9	8.08	295	7.7	2.2
2	9	23.8	7.78	296	7.7	1.2
3	0	25.1	8.23	294	7.8	2.8
3	1	25.1	7.98	294	7.7	3
3	2	25.1	7.90	294	7.7	2.7
3	3	25.1	7.88	291	7.7	2.7
3	4	25.1	7.91	294	7.8	2
3	5	25.1	7.71	291	7.8	1.8
3	6	24.8	7.82	293	7.8	1.2
3	7	24.6	7.85	291	7.8	1.3
3	8	24.3	8.05	294	7.8	1.2
3	9	24.1	7.70	292	7.7	1.2

12-Jul-22						
Station	Depth (ft)	Temp (DegC)	DO (mg/L)	Spec. Cond. (uS)	pH (su)	Turb (NTU)
1	0	26.4	8.45	300	7.9	7.3
1	1	26.4	8.43	300	8.2	5.9
1	2	26.4	8.23	300	8.2	5.1
1	3	26.4	8.24	306	8.2	4.7
1	4	26.4	8.37	306	8.2	5
1	5	26.4	8.24	304	8.2	4.7
1	6	26.4	8.30	306	8.2	4.7
1	7	26.4	8.20	306	8.2	20 hit bottom
1	8					
2	0	26.9	8.09	300	8.1	3.8
2	1	26.9	8.15	300	8.2	3.5
2	2	26.9	8.10	300	8.2	3.2
2	3	26.9	8.20	300	8.2	2.7
2	4	26.9	8.06	300	8.2	3.2
2	5	26.6	8.10	300	8.2	2.7
2	6	26.6	8.10	300	8.2	2.9
2	7	26.2	8.30	300	8.3	2.1
2	8	25.7	8.29	300	8.3	2.9
2	9	25.4	7.48	300	8.0	3.2
3	0	26.7	8.14	300	8.1	2.3
3	1	26.7	8.20	300	8.2	2.6
3	2	26.7	8.24	300	8.2	2.4
3	3	26.7	8.22	300	8.2	2.5
3	4	26.8	8.29	300	8.2	2.6
3	5	26.8	8.17	300	8.2	2.6
3	6	26.8	8.18	300	8.3	2.5
3	7	26.7	8.08	300	8.3	3.5
3	8					
3	9					

3-Aug-22						
Station	Depth (ft)	Temp (DegC)	DO (mg/L)	Spec. Cond. (uS)	pH (su)	Turb (NTU)
1	0	29.1	8	310	7.4	2.2
1	1	29.2	7.75	310	7.5	1.5
1	2	29.2	7.5	310	7.5	2.3
1	3	29.1	7.59	310	7.6	2.3
1	4	28.9	7.54	314	7.7	2.5
1	5	28.5	7.46	313	7.7	2
1	6	27.9	7.27	312	7.7	2.4
1	7	27.6	7.01	307	7.7	2.2
1	8	27.5	4.89	310	7.6	93 hit bottom
2	0	29.1	7.84	313	7.9	9.9
2	1	29.0	7.85	313	7.9	10
2	2	29.1	7.32	311	7.9	8
2	3	28.9	7.53	310	7.9	4.7
2	4	29.0	7.41	312	7.9	3.6
2	5	28.2	7.49	311	8.0	4.1
2	6	27.9	7.6	309	8.0	5.7
2	7	27.7	7.08	312	8.0	3.5
2	8	27.5	6.53	309	7.9	1.9
2	9	27.4	5.92	309	7.8	6.1
3	0	29.2	7.93	312	7.9	5.4
3	1	29.2	7.57	313	7.9	5
3	2	29.2	7.39	309	7.9	4.5
3	3	29.2	7.37	313	7.9	4.2
3	4	28.7	7.32	313	8.0	3.4
3	5	28.2	7.29	311	7.9	1.7
3	6	28.0	7.54	312	8.0	0.6
3	7	27.8	7.53	312	8.1	100.4
3	8	27.8	7.09	311	8.0	2.6
3	9	27.7	6.26	311	7.9	15.1 hit bottom

Basin at water depths greater than seven feet. The lake stations monitored did not exhibit thermal stratification (

Figure 3), 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 in the North Basin in June 2022. Photosynthesis, respiration and decomposition influence pH and these changes occur throughout the day. It is likely that photosynthesis contributed to the rise in pH. The plant biomass in Lake Shirley is excessive and likely caused substantial removal of carbon dioxide from the water.

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 302 µS and were slightly higher but still comparable to the 2021 average (270 µS). The maximum conductivity was 314 µS. Turbidity in lakes below three nephelometric turbidity units (NTU) is considered desirable. Lake Shirley surface water turbidity was elevated in during August 2022, with the highest values around 10 NTU recorded in the Middle Basin.

Nutrient Concentrations

LSIC volunteers collected grab samples at three locations in the lake at two depths (surface and bottom) on two dates during 2022. SŌLitude, the herbicide application contractor, collected surface water quality samples at three locations as well. 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. The samples collected by SŌLitude were analyzed for total Kjeldahl nitrogen (TKN) and total phosphorus (TP). TKN is a component of total nitrogen (TN) and consists of organic nitrogen and ammonia. TP in 2022 was low to moderate, ranging from <0.010 to 0.025 mg/L, averaging 0.014 mg/L. TP exceeded the 0.020 mg/L threshold where algal blooms typically become more frequent and problematic in June and July within the North Basin. The highest value (0.025 mg/L) was recorded at LS-1 (North Basin) at the bottom (Table 4). Surface TP concentrations in the North Basin are historically higher than the other locations. Bottom phosphorus concentrations were generally higher in July than June, and the North Basin contained higher concentrations than other basins. TN concentrations ranged from 0.44 to 15.0 mg/L and are considered excessive. Values above 1.0 mg/L often indicate substantial loading and increase the probability of algal blooms. The source of nitrogen is unknown, but values were the highest in the North Basin and declined 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.

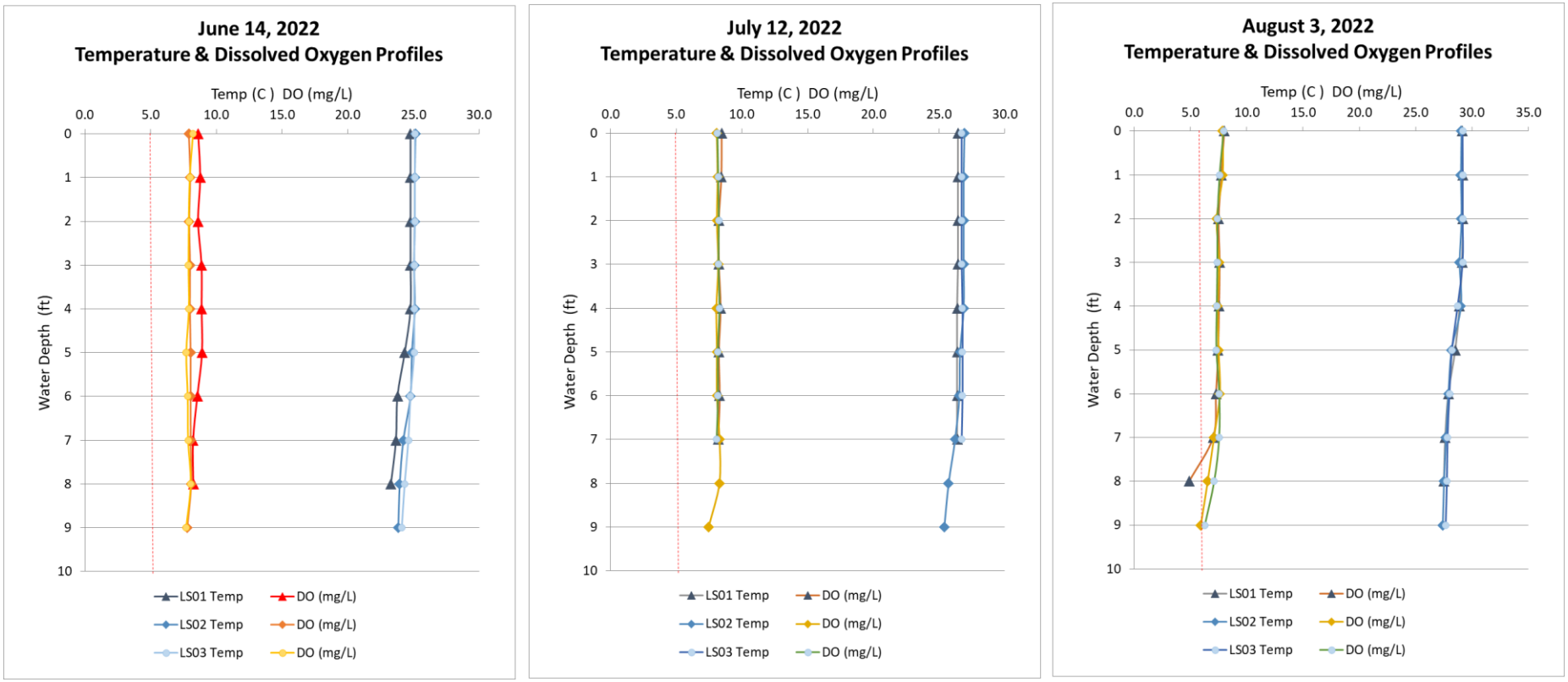


Figure 3. Lake Shirley 2022 Temperature and Dissolved Oxygen Profiles.

Table 4. Lake Shirley 2022 Nutrient Concentrations

	SURFACE TP mg/L			BOTTOM TP mg/L		
	LS-1	LS-2	LS-3	LS-1	LS-2	LS-3
6/14/2022	0.022	<0.010	<0.010	0.016	0.013	<0.010
7/6/2022*	0.013	0.013	0.010			
7/12/2022	0.023	0.015	0.013	0.025	0.014	0.013
	SURFACE TN mg/L			BOTTOM TN mg/L		
	LS-1	LS-2	LS-3	LS-1	LS-2	LS-3
6/14/2022	0.65	0.44	0.42	0.52	0.37	0.50
7/6/2022*	0.61	0.45	0.52			
7/12/2022	15.00	3.20	0.79	3.20	<0.30	0.63
*SOLitude samples; only TP and TKN at surface						
Extremely high concentrations						

2022 HERBICIDE AND ALGAECIDE TREATMENTS

SŌLitude Lake Management biologists surveyed Lake Shirley aquatic plants on July 6th to evaluate if herbicide treatment was warranted. Both the pre- and post-treatment reports are provided in Appendix A. Although not as prevalent as last year, SŌLitude reported that the problematic pondweed species around the margin of the lake were not as abundant in 2022, but others have increased in abundance, snailseed pondweed (*Potamogeton bicupulatus*) and thin-leaf (small) pondweed (*P. pusillus*). Non-native fanwort (*Cabomba caroliniana*) was observed at 47% of the observation locations and was dominant at nine locations. The non-native, curly-leaf pondweed (*P. crispus*) was found at 68% of the observation locations. Neither species of non-native milfoils [variable milfoil (*Myriophyllum heterophyllum*) nor Eurasian milfoil (*Myriophyllum spicatum*)] were observed.

The reason for the change in species composition and density is unknown but shifts in community composition are not uncommon, especially when management activities and climatic changes occur. It is not uncommon to see an increase in seed producers in lakes performing drawdowns since the seed bank in the sediment favor their growth over plants that depend on overwintering root systems.

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.

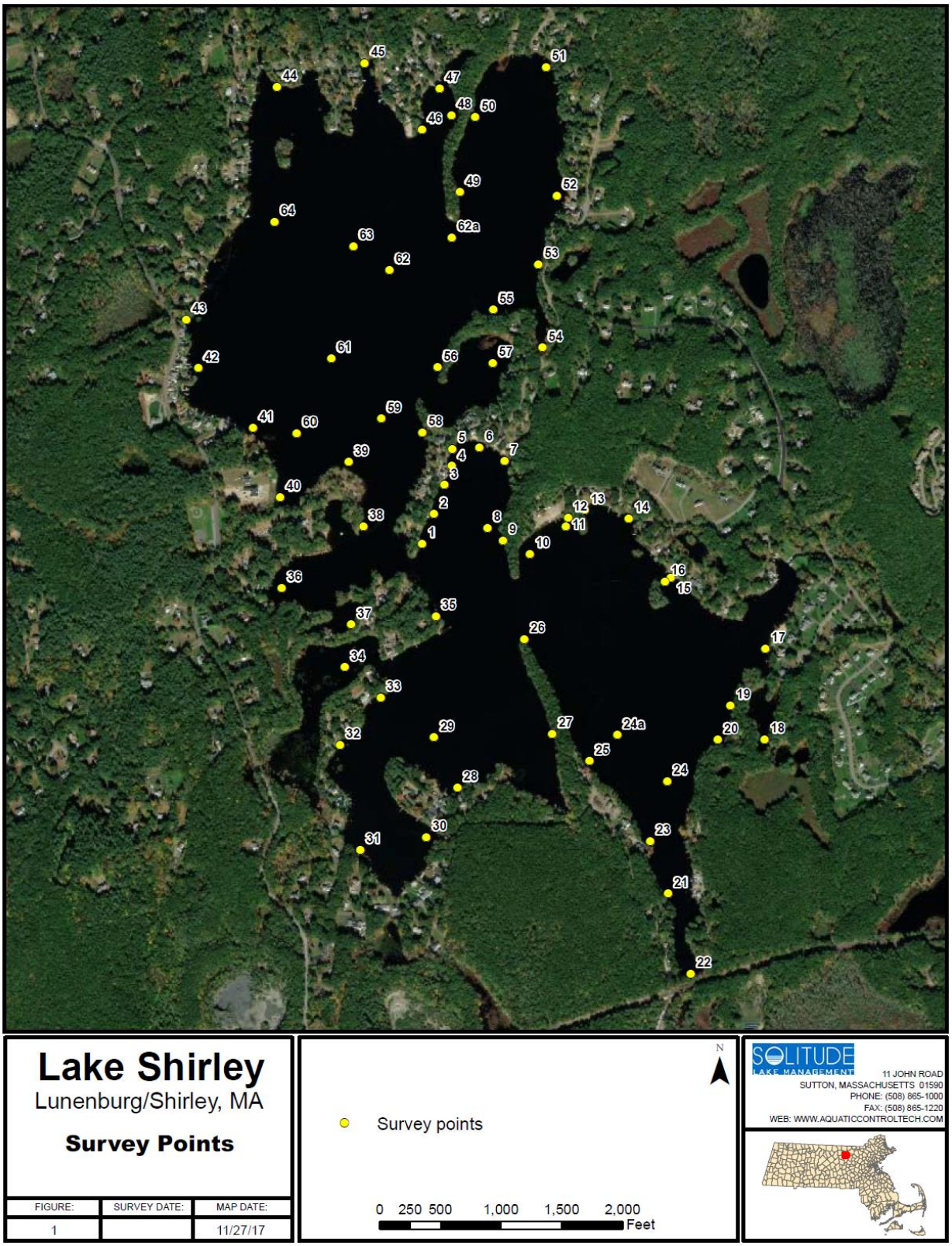


Figure 4. Lake Shirley Plant Survey Points.

Approximately 70 acres were designated for treatment and the Commission approved treatment on July 20th.

SŌLitude conducted treatment on July 27, 2022 using Tribune (diquat), Nautique (copper) and a follow up treatment with Tribune on August 23rd near the Town of Shirley Town line. Eleven acres of treatment were added to the expected 70 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 81 acres were treated using 60 gallons of Tribune. The herbicide treatment details are listed in Tables 1 and 2 of the 2022 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.

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 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)[1] 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 5.

Of the 66 observation locations, 59 contained plants (89%). Overall plant cover and biovolume were similar to 2021 (Figure 5). Plant cover was greater than 50 percent (> category 2) at 41% of the sites containing plants, lower than in 2021. Biovolume exceeded 50% at 16% of the sites. Most of the sites (79%) exhibited biovolume of 1-25% or 25-50%. Wild celery was the most frequently encountered plant (observed at 69% of the sites) with the two other management target species also very frequent (fanwort at 54% and European naiad at 39%). Fanwort frequency of occurrence decreased by 6% over 2021. European naiad also showed a decrease from 47% in 2022. Wild celery frequency was slightly higher in 2022 verses 2021 (69% vs 65%, respectively). When present in 2022, fanwort and wild celery were dense and dominated the community.

[1] 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.

Table 5. Lake Shirley Plant Survey Data August 2022.

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	6.7	4	3	D											T		S												3	2
2	6.9	4	3	D																								S	2	1
3	6.3	4	3	D		S									T													S	4	2
4	5.3	4	2	D		S									S													S	4	2
5	4.3	4	3	D		D									S														3	1
6	7.4	1	1	D		S							S		T													T	5	3
7	3.9	0	0																										0	0
8	7.2	4	3	D																									1	0
9	6.1	0	0																										0	0
10	7.8	4	3	D																									1	0
11	6.2	2	1			D									M								S						3	2
12	2.8	1	1																									T	1	1
13	5.2	2	1	D		T									D													T	4	2
14	4.6	3	1			D									M								M						3	2
15	5.7	4	2			D									S								T					T	4	3
16	5.7	4	1			D									S	T							D						4	3
17	4.0	3	1			D									S		S						D						4	3
18	4.5	4	2	T																				T	D	D		S	5	4
19	7.4	0	0																										0	0
20	3.5	0	0																										0	0
21	5.4	4	1	T		D							T		M														4	2
22	4.2	2	2	D											S		T			S								S	5	4
23	7.0	3	1	S		D									M		M											S	5	3
24	8.2	4	2	D		S									S	M	D									T		M	7	5
24a	7.5	4	2	D											M	S												S	4	3
25	5.5	3	1	S	T	D									D		M											S	6	3
26	4.7	0	0																										0	0
27	5.8	0	0																										0	0
28	4.5	2	1			M											M						M	S					4	3
29	6.0	4	2	D		M							S		T													M	5	3
30	4.5	1	1			S													T										2	1
31	4.4	1	1															T	T										2	2
32	6.0	3	1		S	D									M														3	1
33	4.8	4	1	T	T	D										S													4	1
34	3.6	4	3	T	S	D			T		D		S															T	7	4
35	6.3	4	2	M		D									S														3	1
36	7.6	1	1	D	D		S																						3	0
37	4.2	2	1	M		S							M			D								M					5	3
38	6.1	4	3		S	D																						S	3	1
39	3.7	4	2			D										S	D											S	4	3
40	2.2	2	1			M																							1	0
41	6.3	4	2		D	D																							2	0
42	5.8	4	2		D	D															T							M	4	2
43	3.0	3	2	M		D												D	S				S						5	3
44	5.0	1	1		T	S							T															T	4	2
45	4.3	1	1	T	T												T												3	1
46	5.2	4	1		M	D							S																3	1
47	5.0	1	1			T																							1	0
48	5.6	4	2	T	M	D																							3	0

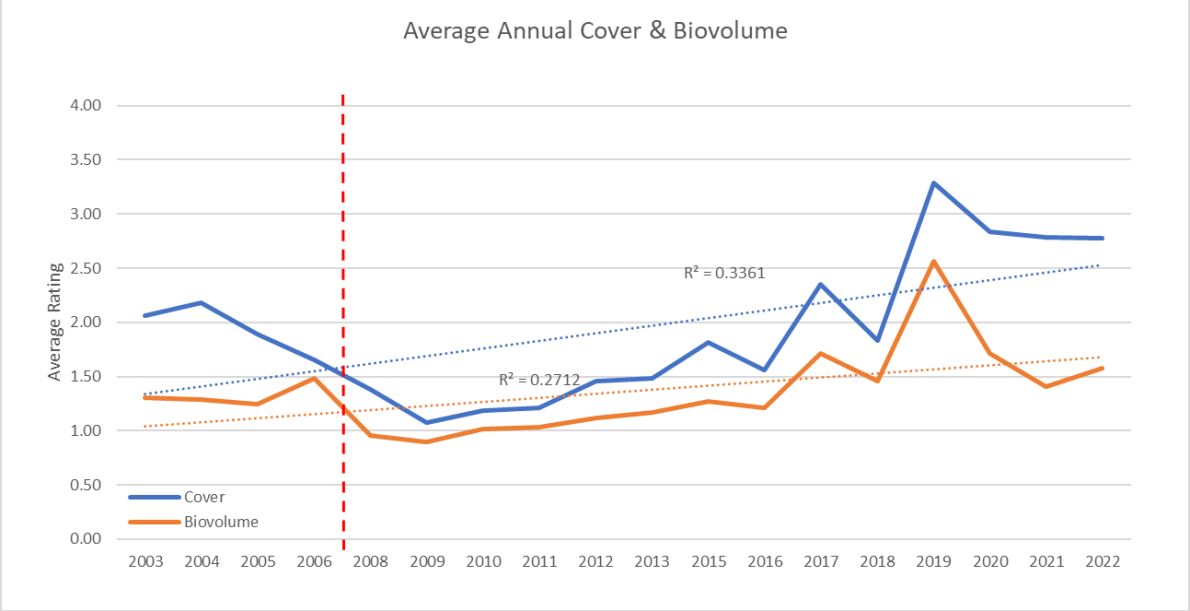
Table 6 (continued). Lake Shirley Plant Survey Data August 2022.

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	5.0	4	2		M	D									S		T												4	2
50	6.0	4	2		S	D																						S	3	1
51	5.0	4	2	T	S	D										S													4	1
52	6.5	4	2		S	D										S						M							4	2
53	6.8	4	2	T		D									T	S													4	2
54	2.0	3	3	D	S	T		S							S		T	T	T				S					D	10	7
55	4.9	4	4	D												T												M	3	2
56	4.0	0	0																										0	0
57	6.0	4	1	T		M									S		M							T				T	6	4
58	5.2	4	2	S	T	M										D												T	5	2
59	8.9	4	2	T												D	S												3	2
60	4.6	4	2		D	D																	T						3	1
61	6.0	4	2		D																								1	0
62	7.5	2	2		D																								1	0
62a	8.6	1	1		T																								1	0
63	7.0	2	2		D																								1	0
64	7.7	1	1										S																1	1
Frequency of Occurrence				32	23	41	1	1	1	0	1	0	8	0	24	12	13	3	4	1	1	1	9	4	1	2	0	24		
Frequency of Occurrence (%)[1]				54%	39%	69%	2%	2%	2%	0%	2%	0%	14%	0%	41%	20%	22%	5%	7%	2%	2%	2%	15%	7%	2%	3%	0%	41%		
Density When Present (%)																														
			Dense	50%	30%	63%	0%	0%	0%	0%	100%	0%	0%	0%	8%	25%	15%	33%	0%	0%	0%	0%	22%	0%	100%	50%	0%	4%		
			Moderate	9%	13%	12%	0%	0%	0%	0%	0%	0%	13%	0%	25%	8%	31%	0%	0%	0%	0%	100%	22%	25%	0%	0%	0%	17%		
			Sparse	9%	30%	17%	100%	100%	0%	0%	0%	0%	63%	0%	46%	50%	23%	0%	25%	100%	0%	0%	33%	25%	0%	0%	0%	46%		
			Trace	31%	26%	7%	0%	0%	100%	0%	0%	0%	25%	0%	21%	17%	31%	67%	75%	0%	100%	0%	22%	50%	0%	50%	0%	33%		

[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 5. Lake Shirley End of Growing Season Plant Cover & Biovolume over Time

Bladderwort, also very abundant, was present at 41% of the sites, up from 23% in 2021. Neither species of invasive milfoils (variable nor Eurasian) were encountered during the ARC survey.

Coontail, a native species that was abundant before the use if herbicides (2007), was not encountered during the year end survey in August 2022 but was present during the pre-treatment survey at three locations (points 1, 4 and 5 on Figure 4). Coontail was found at two locations during the year end survey (point 1 and 54) in 2021. Coontail was not observed at point 54 during the pre-treatment survey. The three pre-treatment locations in 2022 also contained target control species: fanwort and curly-leaf pondweed. 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. The lack of observations in August 2022 does not indicate the disappearance of the species; 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 in 2021 and at the same site in 2022. This is a designated non-treatment area – one of two areas designated as a habitat preservation zone.

Species richness (number of different species observed) at each observation location in 2022 ranged from one to 10 (Table 5Table 5), with an average of 3.1. After removing richness data for the managed target species (fanwort, European naiad, curly-leaf pondweed and wild celery), average species richness declines to 1.6. Overall richness in 2022 was greater than 2021 (Figure 6); five species observed in 2022 were not seen in 2021 (curly-leaf pondweed, musk grass, watershield, big leaf pondweed and leafy pondweed) and four species seen in 2021 were not seen in 2022 (bur-reed, blue-green algae, coontail and bog moss), for a net gain of one species in 2022.

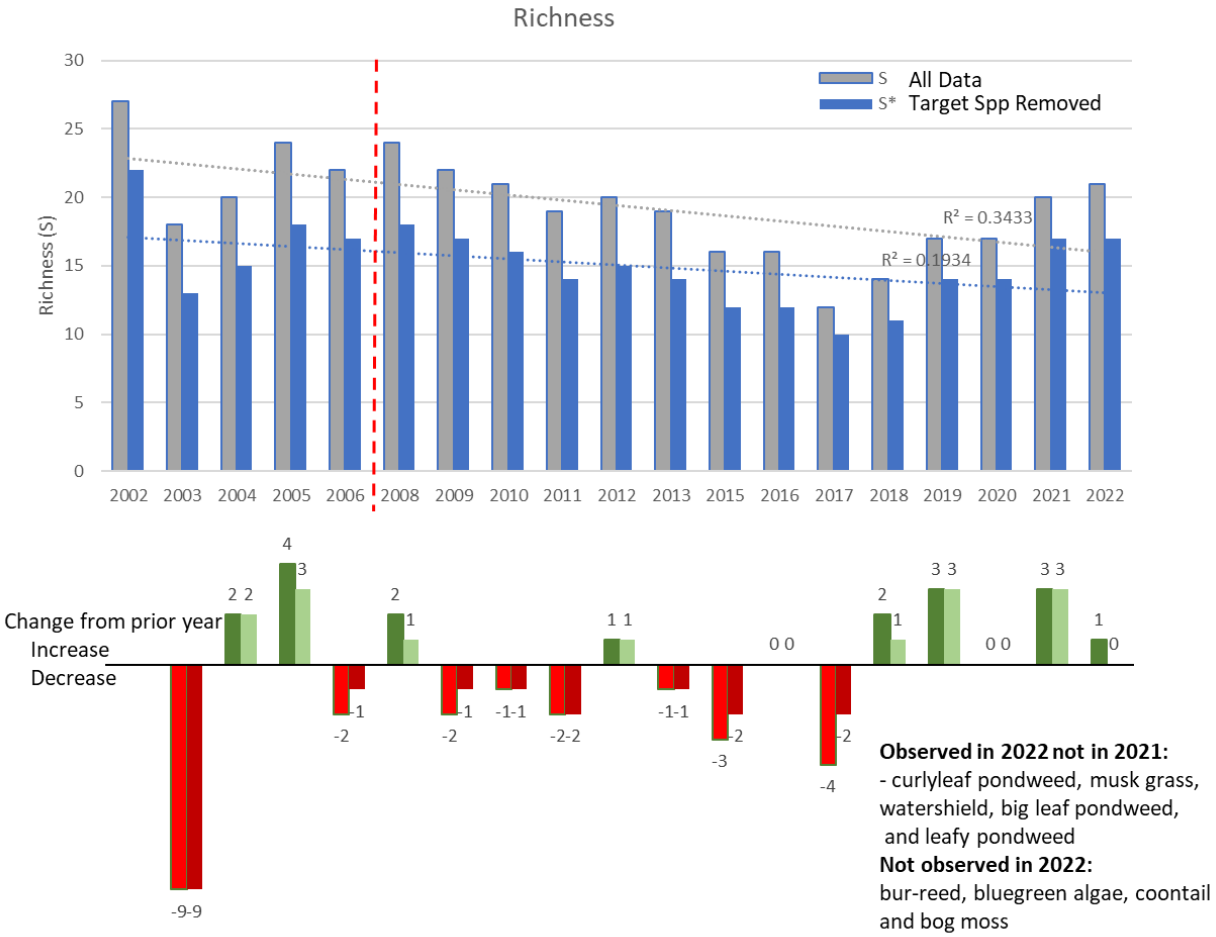
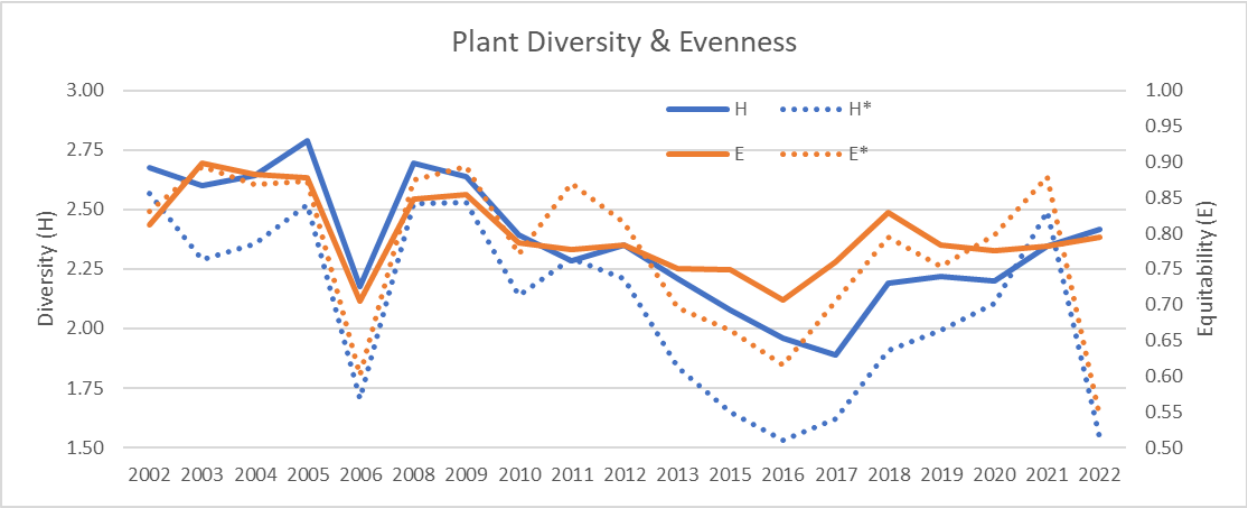


Figure 6. Lake Shirley End of Growing Season Plant Species Richness

Two other common metrics used to summarize and assess biotic communities are diversity and evenness. 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 has gradually increased since 2017, with and without the managed species. Evenness has been comparable since 2019 when including the managed species, but generally has improved since 2016 (Figure 7). Diversity in 2022 and 2021 was 2.42 and 2.34, respectively. Removing the target management species from the population, diversity (H*) decreases drastically in 2022 from 2021 (1.53 vs 2.49, respectively). This is because the non-target population becomes overwhelming dominated by two species: bladderwort and bushy pondweed.



Note: Little change in metrics when including target species; increase in all parameters. Decline in diversity and evenness when target species removed, driven by species abundance (frequency of occurrence of similar species) without an increase in total number species present. Bladderwort and bushy pondweed overrepresented the non-target plant community in 2022.

Figure 7. Lake Shirley Plant Diversity and Evenness over Time

Diversity (H) and evenness (E) in 2022 was comparable to 2021 when considering the entire plant population. With the target species removed, there was a drastic difference in diversity (H*) evenness (E*), suggesting that the plant community was more evenly represented (less dominance by a few species) when the target species were included. 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.

The non-native invasive plant species abundance was relatively similar between 2022 and 2021, so this suggests that the frequency/dominance of only a few non-target species results in the decline of diversity among the desirable plants. Fewer sites contained European naiad and fanwort, but the difference was less than 10%. The fanwort treatment with Red Eagle (flumioxazin) in 2021 provided some relief from excessive fanwort density in 2021 at sample location 45, but fanwort density was moderate to dense at locations 36 & 37. Clipper (flumioxazin) was applied at the Pearl Street cove area (points 46-48) in 2020. Fanwort was observed at only one of these locations in 2022 at a reduced density during the August 2022 survey, suggesting that desirable control was achieved in this area for multiple years. This area was dominated by wild celery and European naiad in 2022. There were small changes in other species that are typically found at relatively low frequencies from year to year.

Table 7. Lake Shirley Species Frequency over the Last Ten Years.

	Common Name	Genus species	Sep-12	Aug-13	Oct-15	Oct-16	Oct-17	Sep-18	Sep-19	Sep-20	Sep-21	Aug-22
Target Non-native Invasives	Eurasian milfoil	Myriophyllum spicatum	6									
	Variable milfoil	Myriophyllum heterophyllum	1	1	1							
	European Naiad	Najas minor	54	36	13	40		39	60	35	29	23
	Fanwort	Cabomba caroliniana	13	25	19	18	7	19	50	33	37	32
	Curlyleaf pondweed	Potamogeton crispus		1		2						1
Target Native	Wild celery	Valisneria americana	42	38	38	52	32	30	50	42	40	41
Emergent Wetland	Arrow arum	Peltandra virginica										
	Arrowhead	Sagittaria latifolia	3									
	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.	20						3	1	6	13
	Musk grass	Chara sp.		20	12	1	11					1
	Stonewort/Musk grass	Nitella/Chara sp						29				
	Bluegreen algae										2	
	Filamentous green algae					5	6		16	8	6	8
Similar Bladderworts	Bladderwort	Utricularia sp.	1	5	10	6	22	16	50	27	14	24
	Eastern purple bladderwort	Utricularia purpurea	3	3								
	Little floating bladderwort	Utricularia radiata	1									
Free floating	Watermeal	Wolffia sp.										
	Giant duckweed	Spirodela polyrhiza										
	Duckweed	Lemna minor										
Similar floating leaves	Watershield	Bresenia schreberi		1				2				1
	White waterlily	Nymphaea odorata	2	2	2	3			4	2	2	3
	Yellow waterlily	Nuphar variegatum	6	6	2				6	2	1	4
Similar naiad	Bushy pondweed	Najas flexilis	24	51	48	50	40	10	30	9	6	24
	Northern (Thread-like) naiad	Najas gracillima						20		7	10	12
Similar pondweeds	Clapsing pondweed	Potamogeton perfoliatus	3	1	4	8	3	7	12	12	11	9
	Richardson's pondweed	Potamogeton richardsonii										
Other Pondweeds	Grassy pondweed	Potamogeton gramineus	10	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
	Thin-leaf (Small) pondweed	Potamogeton pusillus	20	7	9	2	1		17	1	3	4
	Ribbonleaf pondweed	Potamogeton epihydrus	3	2	1	1	1	2	1			
	Robbins' pondweed	Potamogeton robbinsii	1	1	1	2	1	1		2	1	1
	Sago pondweed	Potamogeton pectinatus				2						
	Coontail	Ceratophyllum demersum	3	4	1	1	1	3	5	1	2	
	Waterweed	Elodea sp.							1			
	Hedge hyssop	Gratiola sp.										
	Quilwort	Isoetes sp.							1			
	Small waterwort	Elantine minima	4	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 discussions 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 continued to be difficult for everyone due to the Covid-19 pandemic; in-person gatherings were limited. However, LSIC was able to accomplish the following:

- Updated the Lake Shirley website (https://www.lakeshirley.com/).
- Held monthly virtual association meetings via Zoom (in person when COVID cases were low). 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 2022-2023

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 2022-2023, 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 pre-treatment 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 2022-2023. The initiation of the drawdown started in October. Weather has been favorable thus far.

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 and herbicide treatment if curly-leaf pondweed density is extensive,
- 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.
- Identify another location dominated by fanwort for potential treatment with flumioxazin, and
- possible copper sulfate application if water clarity declines and phytoplankton sampling results suggest the potential formation of an algal bloom

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 2022-2023 management season.

Appendix A

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

(Prepared by SŌLitude Lake Management)

Lake Shirley
Lunenburg/Shirley, Massachusetts
2022 Year-End Treatment Report

October 26, 2022

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 treatments 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 (#WM04-0001042).

2022 Management Program Summary

Program Task	Date Completed
Early Season Survey/Sample Collection	July 6, 2022
Received Approved License to Apply Chemicals	July 25, 2022
Herbicide Treatment	July 27, 2022
Follow-up Herbicide Treatment	August 23, 2022

Pre-Treatment Survey

The survey 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.

There was some variation in the populations of the seed producing pondweed species. Variable (grassy) pondweed (*Potamogeton gramineus*) and leafy pondweed (*Potamogeton foliosus*) were not observed at all throughout the lake. Clasping leaf pondweed (*Potamogeton perfoliatus*) was observed at points 16, 39, 43, and 54, and was not the dominant species in any of these locations. Snailseed pondweed was the most dominant of the pondweed species seen last year. The plant was found at 35 of the 66 points and dominant at 21 of those locations. This means that Snailseed pondweed (*Potamogeton bicupulatus*) was found at 53% of all locations in the pond. Another pondweed species that has become more prominent is Small (lesser) pondweed (*Potamogeton pusillus*) which was found at 23 of the 66 points. Fanwort (*Cabomba caroliniana*) was found at 31 out of the 66 stations and was the dominant species in 9 of those locations. Curly-leaf pondweed was found at 45 of the 66 stations, representing 68% of the surveyed area. Similar to last year, no milfoil was observed in Lake Shirley this year.

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 presence of non-nuisance species (ex. Stonewort/Chara, Coontail, Robbins pondweed) or species such as fanwort (*Cabomba caroliniana*) of which management is limited. The flumioxazin treatments of years prior were very successful and offered great control of the target species in Pearl Street Cove, May Street Cove and the cove north of Flynn Road. Due to the fact that these areas responded well and exhibited very little regrowth, no areas were treated with flumioxazin in 2022. Diquat, a contact herbicide, was proposed for use and will have an immediate effect on the target plant population. The same rate (1.0-1.5 gallons per acre) was kept for this year's treatment program. Any areas that exhibited a dense population of tape grass would be treated with Nautique or copper sulfate.

Approximately 70 acres were designated for treatment. The pre-treatment report, which includes plant survey data and the proposed treatment map, is **attached**. The Commission approved this treatment at their July 20th meeting. As allowed in the approval, some areas were expanded/added on the day of treatment increasing the total treatment area to 81 acres.

Water Quality Sampling

As required by permit, water samples were collected during the pre-treatment survey in each basin of the lake and tested for Total Kjeldahl Nitrogen and Total Phosphorus. The results of this analysis along with a brief discussion of the results follows.

Water Quality Sampling Results

Parameter	Units	North Results	Middle Results	South Results
Total Kjeldahl Nitrogen	mg/L	0.605	0.452	0.518
Total Phosphorus	mg/L	0.013	0.013	0.010

Total Kjeldahl Nitrogen (TKN): Nitrogen is the second most important nutrient for plant and algae growth within a pond. TKN is a measurement of organic nitrogen and ammonia. Nitrogen is typically deposited in ponds from fertilization, and other human activity, as well as atmospheric deposition. TKN concentrations do not typically become troublesome until they reach 1.0 mg/L. The June sampling TKN measurements at Lake Shirley this year at all three sampling locations were below the threshold of 1.0 mg/L.

Total phosphorus: Phosphorus is considered the essential nutrient often correlating to the growth of algae in freshwaters. The two most common measurements of phosphorus are ***Total phosphorus*** and ***Dissolved phosphorus.*** Dissolved phosphorus is the measure of inorganic, dissolved, and reactive phosphorus that is readily available in the water column for algae growth. Total phosphorus is the measure of all phosphorus in a sample, which includes both dissolved and particulate forms that are often not available for active growth. Total phosphorus levels were within desirable levels (<0.2 mg/l) in all three stations.

Herbicide Treatment

The herbicide treatment was conducted on July 27th, for target species as specified in the pre-treatment report. Treatment was conducted with Tribune (diquat). Two 1.5 acre areas located near the Shirley Town line were not treated during this initial treatment and the areas in Lunenburg were increased from 67 to 78 acres based on observations made on the day of treatment.

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 difficulty, **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 27th
Product	Tribune (diquat) & Nautique (copper)
Treatment Area	78 acres
Quantity	55 gallons – Tribune
GPS Tracks	See Figure 1
Applicator name	Rocco Notaro, MA Certification #AL-0053966
Site Conditions	Weather: Mostly Sunny, winds 10 MPH West, WNW, 76^{0}F

	Water Temp: 28.7^{0}C at surface, 27.0^{0}C near bottom Dissolved Oxygen: 7.9 mg/l at surface; 3.75 mg/l near bottom (9-feet) Water clarity: 5'7"

Follow-up Treatment

A follow-up herbicide treatment was conducted on August 23rd, and focused on the two areas of the lake that were not treated on July 27th (those located near the Shirley Town line). The total 3 acres was treated using 5 gallons of Tribune (diquat) for the target species noted in the pre-treatment survey. This treatment was carried out using a jon-boat equipped with a tank and pump that would dispense the herbicide sub-surface to the target plants. The treatment tracks for this treatment are also shown on **Figure 1**.

Table 2 – Herbicide Treatment Specifications

Treatment Date	August 23rd
Product	Tribune (diquat)
Treatment Area	3 acres
Quantity	5 gallons – Tribune
GPS Tracks	See Figure 1
Applicator name	Dominic Meringolo, MA Certification #-C0024004
Site Conditions	Weather: Mostly Cloudy, light winds 2-5 MPH NE, 67^{0}F Water Temp: 27.2^{0}C at surface, 24.8^{0}C near bottom Dissolved Oxygen: 7.6 mg/l at surface; 4.8 mg/l near bottom (9-feet) Water clarity: 5'9"

Post Treatment Inspection

A post-treatment inspection was conducted to evaluate the efficacy of the herbicide treatment. Overall, the treatment worked well on the targeted species, especially the pondweeds throughout the lake. 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 2023

Based on the results of the 2022 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. 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 2023 is as follows

Table 3 – Proposed Plan for 2023

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	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 2023, 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 2023 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.

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Shrewsbury, MA 010545

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

Date: July 12, 2022 (Rev July 18, 2022)

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 July 6th, we are recommending treatment to approximately 70-acres of Lake Shirley to manage nuisance weed growth. Although not as prevalent as in 2020, we continue to see an increased amount of pondweed species around the margin of the lake. This season the predominant species was snailseed pondweed (*Potamogeton bicupulatus*) however sparse amounts of leafy pondweed (*Potamogeton foliosus*) and clasping leaf pondweed (*Potamogeton perfoliatus*) were also observed. Other target species include non-native curlyleaf pondweed (*Potamogeton crispus*). Tapegrass (*Vallinsneria*) 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. We also collected additional points beyond the normal survey points where either curlyleaf pondweed or topped out pondweeds were observed. 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 plants that we would like to see expand in the lake based on recent management discussions.

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.

Treatment using Clipper (flumioxazin) over the last two years in Pearl Street Cove, May Street cove and the cove north of Flynn Road have worked well. No additional areas are proposed for 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 27th.

A map of the recommended treatment areas is attached as well as the July survey data table. On the map of the proposed treatment areas, the data points that meet management criteria as well as the extra points where nuisance conditions were observed 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

Proposed Treatment Areas (July 2022) - REV 7/18/22

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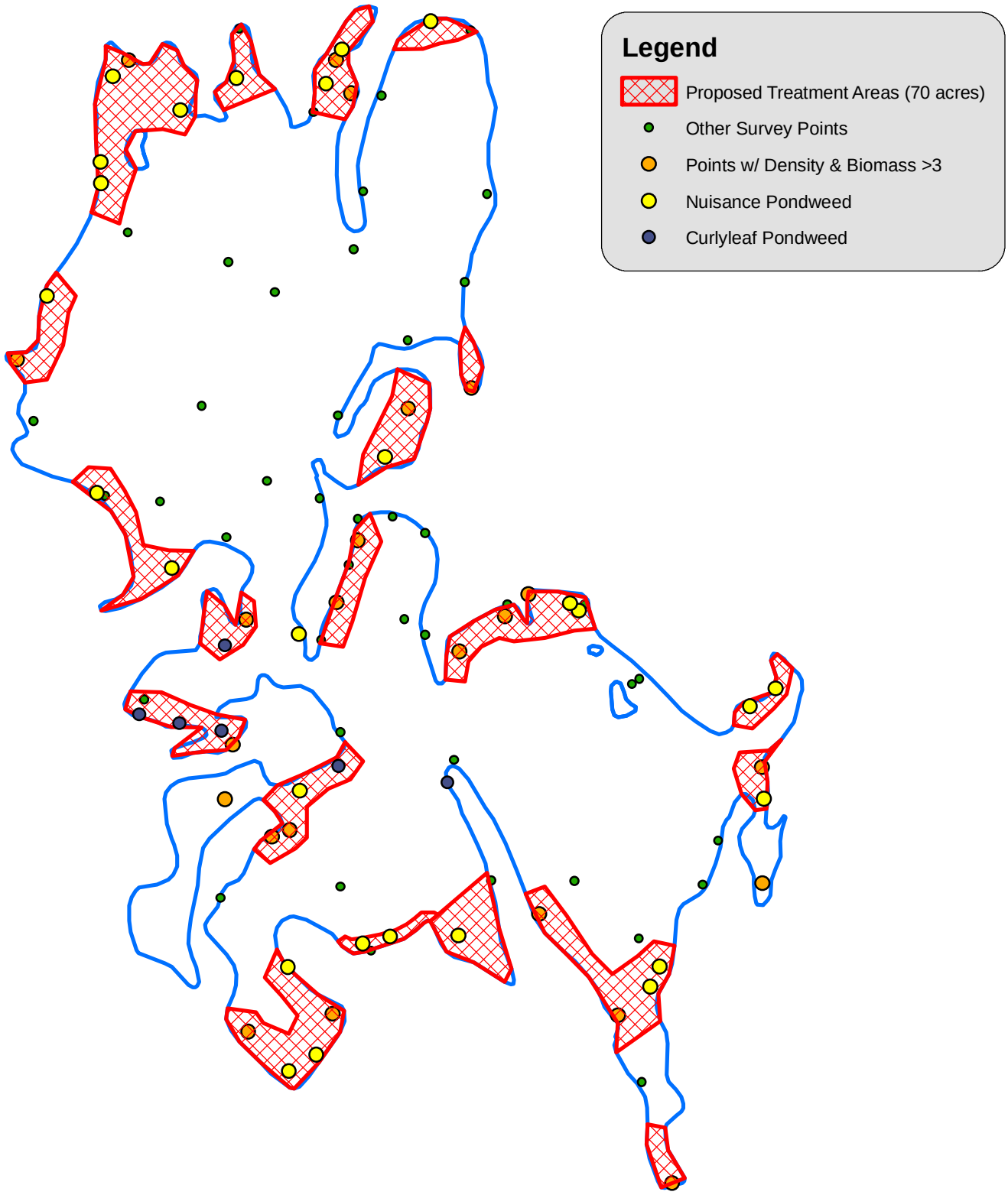
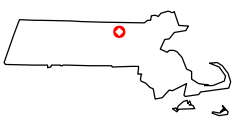


Lake Shirley
Lunenburg, MA



Lake Shirley

0 920 1,840 Feet

1:11,402

N

Map Date: 7/18/22
Prepared by: DMM
Office: SHREWSBURY, MA

X= Present D = Dominant

Plant Species	# stations present	# stations dominant	% stations present	% stations dominant	Monitoring Lo																																
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**
Cabomba caroliniana	31	9	47%	14%	X	X	X	X	X	D		D	D			X	D		X	X	D	X	X			X	X	X	X	X		X		D				
Elodea canadensis	3	0	5%	0%																			X															
Valisneria americana	24	5	36%	8%	X		X		X												X				D		X	X		X	X							X
Utricularia Sp.	17	4	26%	6%	X						D					D	X	X			X				X							D	X				X	
Chara sp.	0	0	0%	0%																																		
Nitella sp.	18	12	27%	18%						X								D					D					D	D									
Potamogeton bicupulatus	35	21	53%	32%	X	X		X					D	D				X			X		X	D	X	D	D	X	X	D				D	D	D	D
Najas flexillis	23	5	35%	8%		X					X		X				X	X	D	D			X		X				X				X				X	X
Potamogeton gramineus	0	0	0%	0%																																		
Various	0	0	0%	0%																																		
Najas gracilima	0	0	0%	0%																																		
Potamogeton crispus	45	0	68%	0%	X	X	X	X	X	X		X	X					X	X	X	X	X				X	X	X		X	X			X	X			X
Potamogeton epihydrus	3	0	5%	0%																																		
Potamogeton perfoliatus	4	0	6%	0%																X																		
Potamogeton foliosus	0	0	0%	0%																																		
Ceratophyllum demersum	3	0	5%	0%	X			X	X																													
Potamogeton zosteriformis	1	1	2%	2%																		D																
Nuphar variegata	6	0	9%	0%																															X	X		
Nymphaea odorata	4	0	6%	0%																																X		
Fontinalus sp.	0	0	0%	0%																																		
Potamogeton pusillus	23	2	35%	3%		X	X		X							X			X		X				X	X	X		X			X	D		X	X	X	
Potamogeton robbinsii	1	0	2%	0%																						X												
Species Richness					6	5	4	4	5	4	2	2	4	1	0	3	3	5	4	4	6	3	5	1	5	5	5	5	5	4	2	3	3	2	4	4	4	4
Plant density Index					2	3	3	3	3	1	2	2	2	3	4	1	3	2	2	2	3	4	2	1	2	4	4	2	1	3	1	2	3	2	4	3	2	3
Plant biomass index					2	3	2	3	2	2	2	3	2	4	3	2	3	2	1	1	3	4	2	2	2	4	3	2	2	3	1	1	2	2	4	3	1	4

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	Locations																																
Scientific Name					34	35	36	37	38	39	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
Cabomba caroliniana	31	9	47%	14%		D	X							X	D				D					X	X	X		X									
Elodea canadensis	3	0	5%	0%																	X										X					
Valisneria americana	24	5	36%	8%	X	X					X	X	X	X	X					D	D	X		D	X			X			X					
Utricularia Sp.	17	4	26%	6%		X	X						X												X		D	X		X						
Chara sp.	0	0	0%	0%																																	
Nitella sp.	18	12	27%	18%	X					X						D						X	D	X		D				D	X	D	D	D	D	
Potamogeton bicupulatus	35	21	53%	32%	D	X	D	D	D		D			D	X		D	D	X		X			X	D			D			D					
Najas flexillis	23	5	35%	8%					X	D	X	D	D	X						X			X	X							X					
Potamogeton gramineus	0	0	0%	0%																																	
Various	0	0	0%	0%																																	
Najas gracilima	0	0	0%	0%																																	
Potamogeton crispus	45	0	68%	0%	X	X	X	X	X	X			X		X	X	X	X	X	X	X		X	X	X	X	X	X					X	X	X		
Potamogeton epihydrus	3	0	5%	0%	X					X															X												
Potamogeton perfoliatus	4	0	6%	0%						X				X											X												
Potamogeton foliosus	0	0	0%	0%																																	
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Potamogeton zosteriformis	1	1	2%	2%																																	
Nuphar variegata	6	0	9%	0%	X									X											X			X									
Nymphaea odorata	4	0	6%	0%	X									X											X												
Fontinalus sp.	0	0	0%	0%																																	
Potamogeton pusillus	23	2	35%	3%		X												X	X			D			X	X	X	X									
Potamogeton robbinsii	1	0	2%	0%																																	
Species Richness					7	6	4	2	3	5	3	2	4	7	4	2	2	3	4	3	4	3	3	6	10	4	3	7	0	2	5	1	2	2	2	0
Plant density Index					4	2	2	4	3	2	4	2	2	4	3	1	2	4	3	1	3	2	3	2	4	3	1	3	0	1	2	1	2	2	1	0
Plant biomass index					4	3	2	4	3	1	4	2	2	4	4	1	2	4	3	2	2	3	1	2	4	1	1	3	0	1	3	1	1	1	1	0

X= Present

Plant Species *Scientific Name*	# stations present	# stations dominant	% stations present	% stations dominant
Cabomba caroliniana	31	9	47%	14%
Elodea canadensis	3	0	5%	0%
Valisneria americana	24	5	36%	8%
Utricularia Sp.	17	4	26%	6%
Chara sp.	0	0	0%	0%
Nitella sp.	18	12	27%	18%
Potamogeton bicupulatus	35	21	53%	32%
Najas flexillis	23	5	35%	8%
Potamogeton gramineus	0	0	0%	0%
Various	0	0	0%	0%
Najas gracilima	0	0	0%	0%
Potamogeton crispus	45	0	68%	0%
Potamogeton epihydrus	3	0	5%	0%
Potamogeton perfoliatus	4	0	6%	0%
Potamogeton foliosus	0	0	0%	0%
Ceratophyllum demersum	3	0	5%	0%
Potamogeton zosteriformis	1	1	2%	2%
Nuphar variegata	6	0	9%	0%
Nymphaea odorata	4	0	6%	0%
Fontinalus sp.	0	0	0%	0%
Potamogeton pusillus	23	2	35%	3%
Potamogeton robbinsii	1	0	2%	0%

	AVERAGES
Species Richness	3.651515152
Plant density Index	2.378787879
Plant biomass index	2.303030303

Figure 1 - 2022 Treatment Areas & Treatment Tracks (July 27th & August 23rd)

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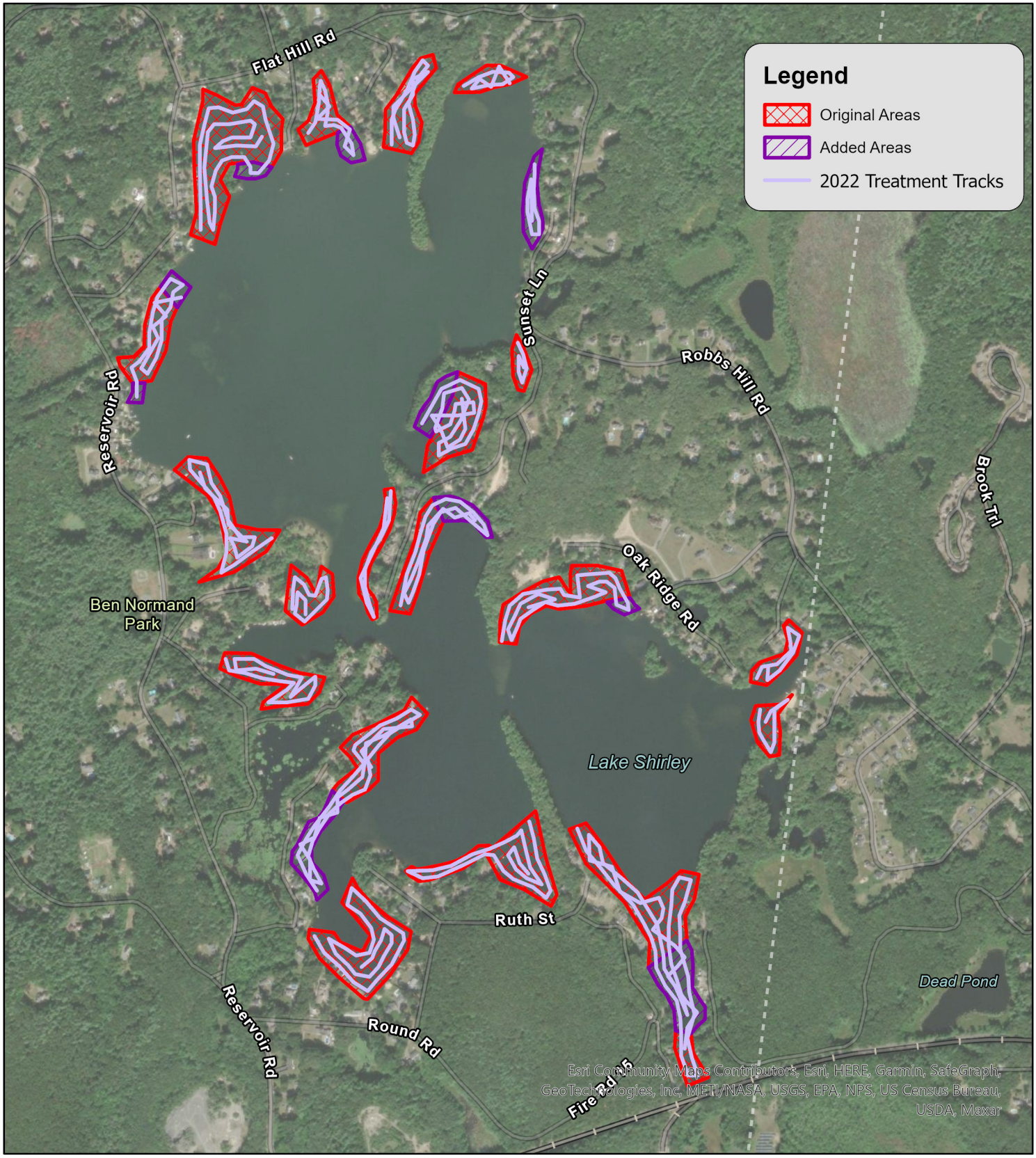
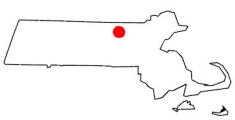


Lake Shirley
Lunenburg, MA



Lake Shirley

0 950 1,900 Feet

1:11,872

N

Map Date: 10/26/22
Prepared by: DMM
Office: SHREWSBURY, MA