Report For:
Lake Shirley Improvement Corporation
Shirley, MA 01464

Lake Shirley Lake Management
Annual Report 2020-2021

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

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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, 2020 through October 14, 2021) 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 2020-2021 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 has 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 six-foot drawdown 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 2020-2021 drawdown season. A maximum of 5.0 feet was achieved on December 24. Average drawdown from December 1 through the end of February was 4.3 feet. A concern about a low pressure well condition was reported on November 11, 2020 but this was attributed to a pump issue at the residence. While both gates were closed as of March 30, 2021, the lake did not return to full volume until April 24, 2021. Table 1 provides the water level and flow 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 2021 summer season. Monitoring included measurements of water clarity, in-situ measurements and collection of nutrient and phytoplankton samples 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 early October 2021. SDT is a measure of water clarity and is used as an indicator of possible presence of suspended sediments and algae. Water with clarities 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 at or above five feet in 2021; the minimum clarity was 5.0 feet in May and early June 2021 in the North Basin (Figure 2). Water clarity in 2021 ranged from 5.0 to 9.0 feet, which was three feet less than the maximum clarity in 2020. In 2020, the range of clarity was 5.2 to 12.8 feet and in 2019, the range was 5.5 to 10 feet. Clarity is typically better in the South Basin and worse in the Upper North Basin. This trend was consistent with the last three 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 July 30 and August 30, 2021. Data are presented on Table 2.

Table 1. 2020-2021 Water Level and Outflow Monitoring Data

Date	Mid Valve	Low Valve	Level (in)	Notes	Rate (in/day)
9/14/2020	Closed	Closed	-5		
9/21/2020	Closed	Closed	-7		0
9/25/2020	Closed	Closed	-8		0
9/30/2020	Closed	Closed	-7	0.6" rain	0
10/6/2020	Closed	Closed	-8		0
10/11/2020	Closed	Closed	-9		0
10/15/2020	Open	Open	-8		0
10/18/2020	Open	Open	-18		-3
10/22/2020	Open	Open	-30		-3
10/25/2020	Open	Open	-39		-3
10/27/2020	Open	Open	-45		-3
10/29/2020	Open	Open	-50		-3
11/1/2020	Open	Open	-55		-2
11/4/2020	Open	Open	-60		-2
11/7/2020	Open	Closed	-63		-1
11/11/2020	Closed 200	Closed	-63	Well problems	0
11/17/2020	Closed 200	Closed	-62		0
11/22/2020	Closed 200	Closed	-62		0
11/27/2020	Closed 200	Closed	-58		1
12/1/2020	Closed 200	Closed	-54	Rain 1.8	1
12/5/2020	Open	Open	-51		1
12/6/2020	Open	Open	-45	Precipitation 2.0	6
12/10/2020	Open	Open	-48		-1
12/16/2020	Open	Open	-53		-1
12/18/2020	Open	Open	-55	12" snow	-1
12/20/2020	Closed	Open	-57		-1
12/24/2020	Open 200	Open	-60		-1
12/27/2020	Open	Open	-48		4
1/1/2021	Open	Open	-20		6
1/6/2021	Open	Open	-50		-6
1/10/2021	Closed	Open	-54		-1
1/13/2021	Closed	Open	-57		-1
1/20/2021	Closed	Open	-50	1.34" Rain	1
1/25/2021	Closed	Closed 150 Turns	-53		-1
1/30/2021	Closed	Closed 150 Turns	-52		0

Date	Mid Valve	Low Valve	Level (in)	Notes	Rate (in/day)
2/5/2021	Closed	Closed 150 Turns	-55		-1
2/10/2021	Closed	Closed 150 Turns	-56		0
2/16/2021	Closed	Closed 150 Turns	-57		0
2/21/2021	Closed	Closed 150 Turns	-57		0
2/25/2021	Closed	Closed 150 Turns	-55		1
3/1/2021	Closed	Closed 150 Turns	-53		1
3/4/2021	Closed	Closed 240 Turns	-51		1
3/10/2021	Closed	Closed 240 Turns	-46		1
3/15/2021	Closed	Closed 240 Turns	-42		1
3/20/2021	Closed	Closed 240 Turns	-39		1
3/25/2021	Closed	Closed 240 Turns	-35		1
3/30/2021	Closed	Closed	-31	DPW Closed Dam	1
4/5/2021	Closed	Closed	-25		1
4/10/2021	Closed	Closed	-20		1
4/15/2021	Closed	Closed	-17		1
4/20/2021	Closed	Closed	-7	1.5: Rain 4/16/21	2
4/24/2021	Closed	Closed	0	Lake Filled ConCom Notified	2

Figure 1. Water Quality and Secchi Disk Transparency Locations

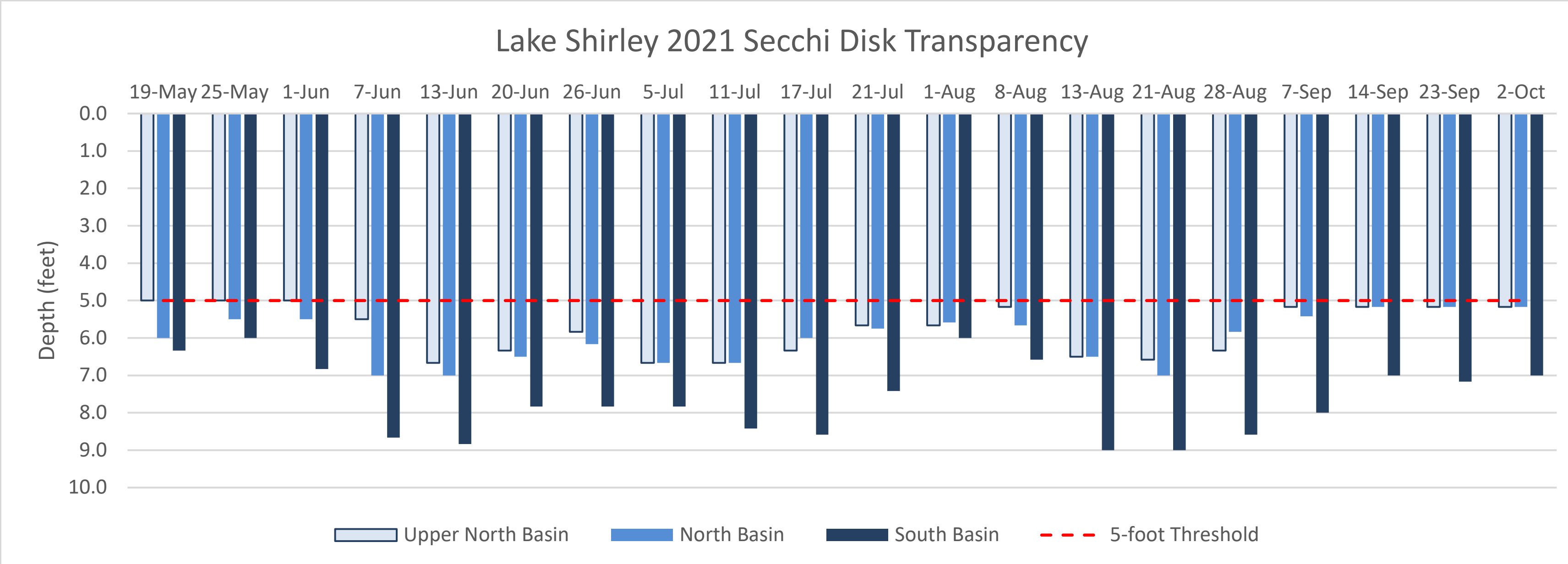


Figure 2. Lake Shirley 2021 Secchi Disk Transparency.

Table 2. Lake Shirley 2021 In-Situ Data.

30-Jul-21

Station	Depth (ft)	Temp (DegC)	DO (mg/L)	Spec. Cond. (uS)	pH (su)	Turb (NTU)
1	0	24.9	6.50	257	7.2	0.3
1	1	25.0	6.31	255	7.2	0.8
1	2	25.0	6.34	254	7.2	0.3
1	3	25.0	6.33	256	7.2	1.1
1	4	25.0	6.77	257	7.3	1.1
1	5	25.0	6.62	254	7.3	1.0
1	6	25.0	6.62	256	7.3	0.7
1	7	23.8	3.90	257	7.1	0.9
1	8	23.4	3.69	272	7.0	0.8
1	9	22.3	3.82	255	6.9	6000 bottom
2	0	24.3	7.19	273	7.5	1.5
2	1	25.3	7.06	273	7.5	1.6
2	2	25.3	6.95	271	7.5	1.3
2	3	25.2	7.08	272	7.5	1.0
2	4	25.3	7.16	273	7.5	1.7
2	5	25.3	7.18	269	7.5	1.5
2	6	25.4	7.19	274	7.5	0
2	7	24.8	7.11	271	7.5	0
2	8	24.4	5.76	268	7.4	2.3
3	0	25.2	7.16	272	7.5	1.6
3	1	25.2	7.30	270	7.5	0.9
3	2	25.2	7.43	272	7.6	0.6
3	3	25.2	7.42	272	7.6	0.1
3	4	25.3	7.50	272	7.6	0.2
3	5	25.3	7.46	270	7.7	0.3
3	6	25.2	7.30	272	7.6	2.3
3	7	25.2	7.12	272	7.6	4.9
3	8	25.0	7.19	269	7.6	0.1
3	9	25.1	7.21	272	7.6	0.3

30-Aug-21

Station	Depth (ft)	Temp (DegC)	DO (mg/L)	Spec. Cond. (uS)	pH (su)	Turb (NTU)
1	0	25.4	6.83	266	8.1	2.8
1	1	25.4	6.97	266	7.9	2.7
1	2	25.4	6.79	266	7.9	2.8
1	3	25.4	6.85	266	7.8	1.7
1	4	25.4	6.81	267	7.8	2.1
1	5	25.4	6.81	267	7.8	2.0
1	6	25.4	6.42	266	7.7	1.5
1	7	24.5	6.72	263	7.7	1.5
1	8	24.8	6.75	252	7.7	19.5 bottom
2	0	26.1	6.75	290	7.6	1.5
2	1	26.1	6.69	287	7.6	0.8
2	2	26.1	6.55	290	7.6	0
2	3	26.1	6.64	288	7.6	0.5
2	4	26.1	6.45	284	7.6	0.3
2	5	25.4	6.48	273	7.6	0
2	6	24.9	6.11	273	7.5	0
2	7	24.9	5.51	272	7.5	0
2	8	24.7	4.92	273	7.4	0
3	0	26.2	6.42	273	7.7	0
3	1	26.2	6.55	273	7.7	0.1
3	2	26.2	6.56	273	7.6	0
3	3	26.2	6.40	273	7.6	0.1
3	4	26.1	6.38	273	7.6	0
3	5	25.6	6.41	273	7.6	0
3	6	25.3	6.39	272	7.6	0
3	7	25.3	6.23	272	7.6	0
3	8	25.0	5.89	271	7.6	0
3	9	25.0	5.79	273	7.5	11.0 bottom

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 2021, but it was exceeded at all three locations in July 2020. Dissolved oxygen data were desirable and remained above the 5.0 milligrams per liter (mg/L) minimum except for the North 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 Shirly pH remained within this range on the dates monitored in 2021. pH in 2020 exceeded the standard, specifically during July and August. Photosynthesis, respiration and decomposition influence pH and these changes occur throughout the day. It is likely that photosynthesis occurring from the excessive plant density contribute to the rise in pH as plants will remove carbon dioxide from the water.

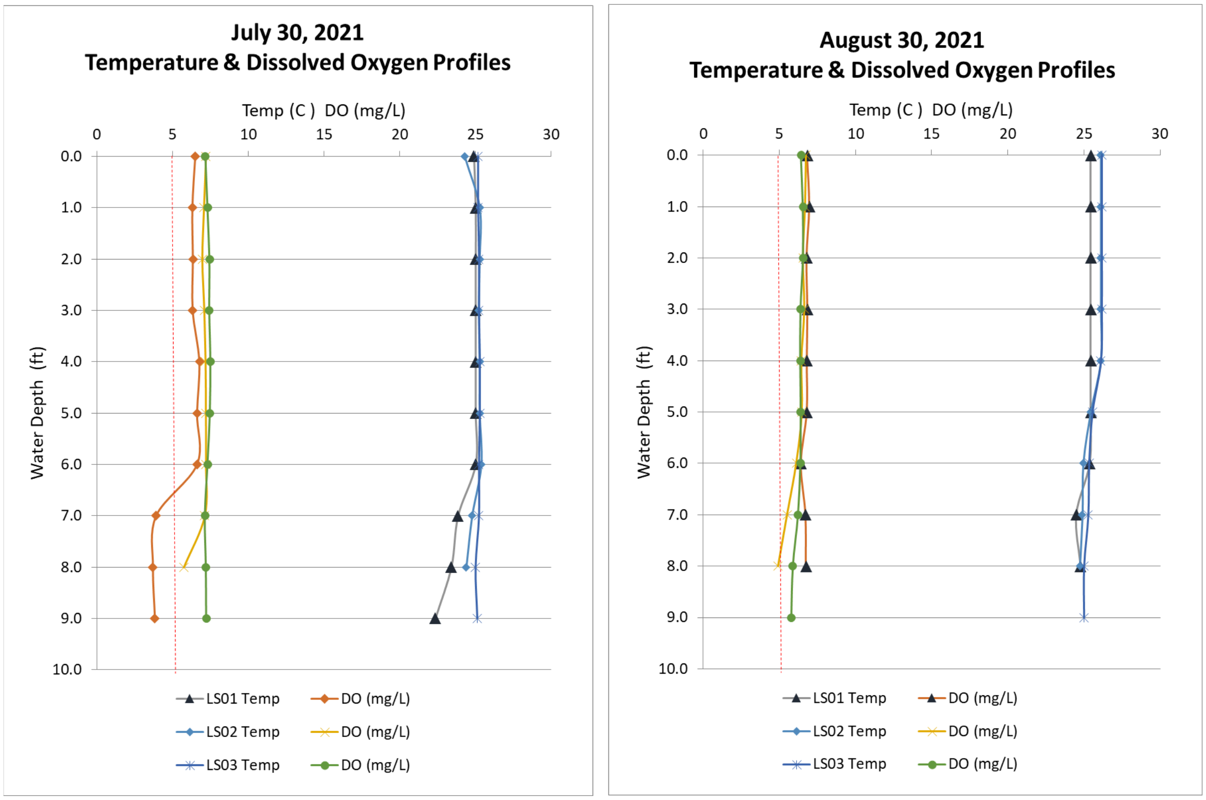


Figure 3. Lake Shirley 2021 Temperature and Dissolved Oxygen Profiles.

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 number of ions 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 270 µS and were comparable to the 2020 average (258 µS). Turbidity in lakes below three nephelometric turbidity units (NTU) is considered desirable. All surface water values recorded in Lake Shirley in 2021 were less than 3.0 NTU, although values near the bottom were higher. This is expected when sediment is resuspended due to disturbance (winds, boat traffic, fish etc.).

Nutrient Concentrations

LSIC volunteers collected grab samples at three locations in the lake at two depths (surface and bottom) on three dates during 2021. 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 2021 was generally low, ranging from <0.01 to 0.020 mg/L, averaging 0.013 mg/L. These concentrations are below the 0.020 mg/L threshold where algal blooms typically begin to be more frequent and problematic. The highest value (0.020 mg/L) was recorded at LS-3 (South Basin) at the bottom (Table 3). Surface TP concentrations in the North Basin are historically higher than the other locations, but data in 2020 suggests concentrations were similar to the South Basin. Bottom phosphorus concentrations did not show a pattern between basins or over time. TN concentrations ranged from 0.43 to 0.81 mg/L and are considered moderate (around 0.5 mg/L). TKN was also moderate.

Table 3. Lake Shirley 2021 Nutrient Concentrations

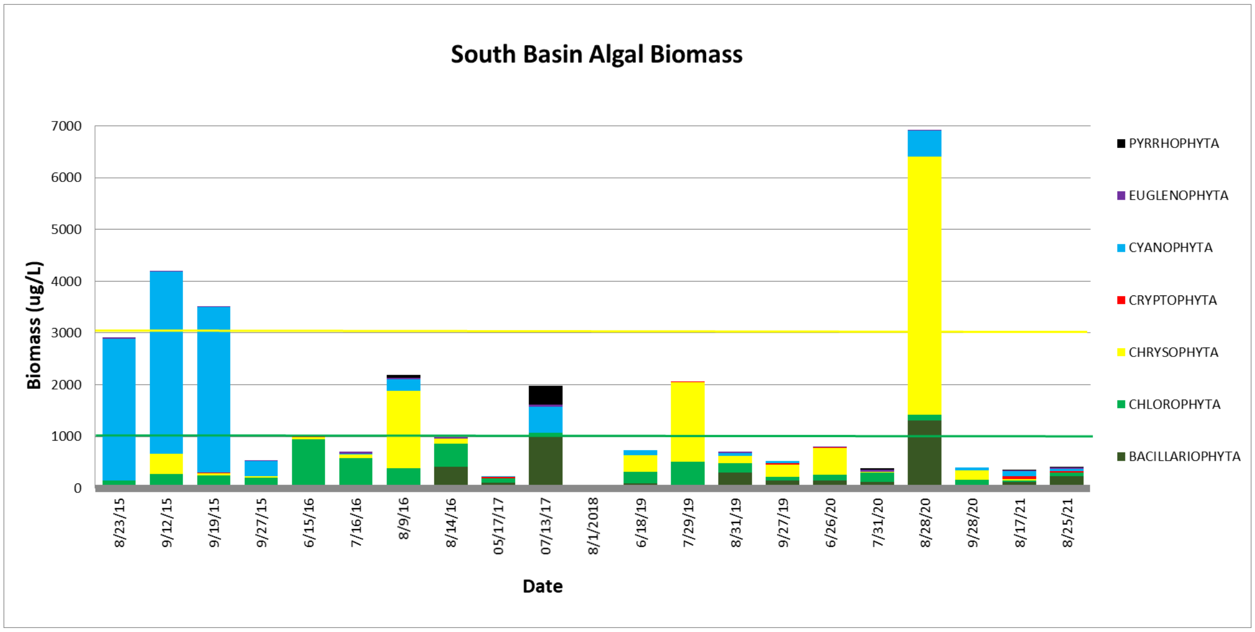
	SURFACE TP mg/L				BOTTOM TP mg/L		
	LS-1	LS-2	LS-3		LS-1	LS-2	LS-3
Minimum	0.011	<0.010	0.011		0.014	0.012	<0.010
Maximum	0.015	0.014	0.019		0.019	0.013	0.020
Average	0.014	0.010	0.015		0.017	0.012	0.012
	LS-1	LS-2	LS-3		LS-1	LS-2	LS-3
6/15/2021	0.015	0.014	0.019				
7/7/2021	0.011	0.010	0.016		0.014	0.012	0.020
7/30/2021	0.015	0.011	0.013		0.017	0.013	<0.010
8/30/2021	0.013	<0.010	0.011		0.019	0.012	0.011

	SURFACE TN mg/L				BOTTOM TN mg/L		
	LS-1	LS-2	LS-3		LS-1	LS-2	LS-3
Minimum	0.37	0.43	0.53		0.64	0.53	0.53
Maximum	0.81	0.57	0.62		0.81	0.60	0.63
Average	0.59	0.53	0.59		0.71	0.57	0.59
	LS-1	LS-2	LS-3		LS-1	LS-2	LS-3
6/15/2021*	0.37	0.56	0.53				
7/7/2021	0.45	0.43	0.62		0.64	0.53	0.61
7/30/2021	0.71	0.57	0.62		0.68	0.60	0.53
8/30/2021	0.81	0.54	0.59		0.81	0.58	0.63
* TKN not TN							

Phytoplankton

ARC collected grab samples for phytoplankton on two occasions in August 2021. Concentrations [cells/milliliter(mL)] were low and ranged from 517 cells/mL to 2,205 cells/mL (Appendix A). Cyanobacteria cells were 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 484 cells/mL on August 17, 2021 in the northwest cove of the North Basin.

Biomass data in 2021 suggest that cyanobacteria issues have been much less of a problem since the bloom observed in 2015 (Figure 4). Generally, phytoplankton biomass below 1,000 ug/L is considered low and between 1,000 and 3,000 ug/L algae issues become more noticeable, with variation based on the types of algae dominating. Biomass is 2021 was higher in the North Basin than the South but values were below 3,000 ug/L. The North Basin phytoplankton community was dominated by Bacillariophyta, specifically *Tabellaria fenestrate*, a diatom commonly found in mesotrophic-eutrophic waters. This diatom exists in open water as well as associated with vegetation.



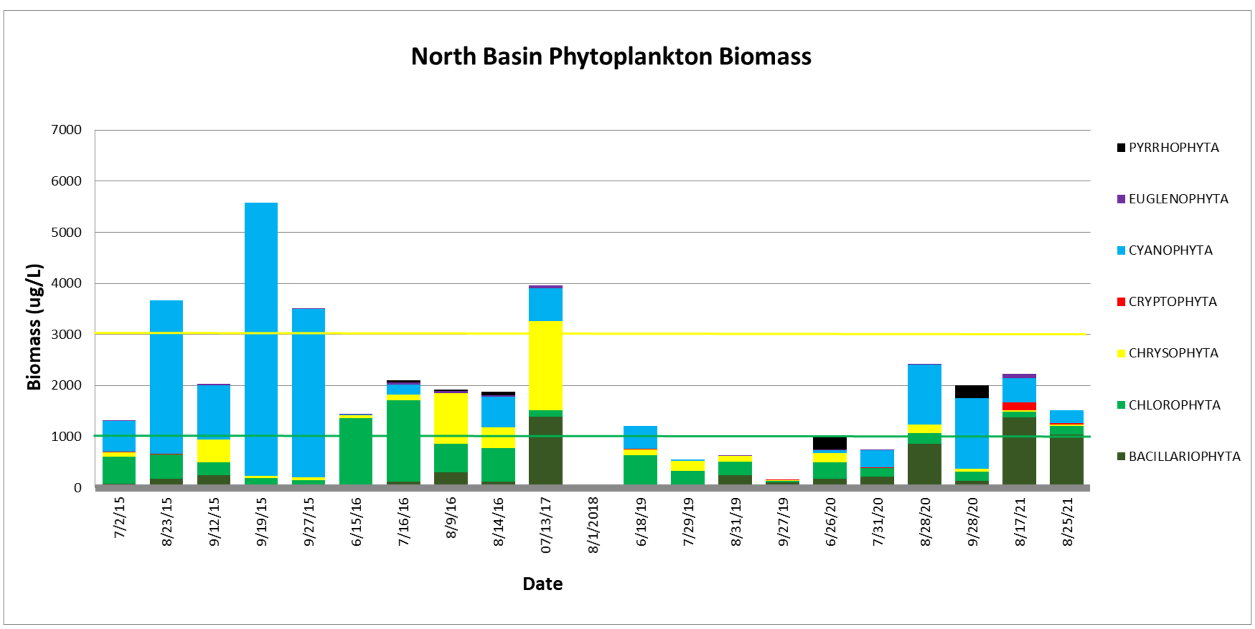


Figure 4. Lake Shirley Algal Biomass (2015-2021).

2021 HERBICIDE AND ALGAECIDE TREATMENTS

SŌLitude Lake Management biologists surveyed Lake Shirley aquatic plants on June 16th to evaluate if herbicide treatment was warranted. Both the pre- and post-treatment reports are provided in Appendix B. Although not as prevalent as last year, SŌLitude reported an increased amount of pondweed species around the margin of the lake. These species are leafy pondweed (*Potamogeton foliosus*), clasping leaf pondweed (*Potamogeton perfoliatus*) and snailseed pondweed (*Potamogeton bicupulatus*). Other target species include non-native curlyleaf pondweed (*Potamogeton crispus*), non-native fanwort (*Cabomba caroliniana*), tapegrass (*Vallisneria americana*). 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. In the 2019-2020 only a limited drawdown occurred and the following summer was warm, sunny and dry[1]. These native pondweeds are primarily seed producers and there was likely a seed bank in the sediment that favored their growth under the unusual 2020 climatic conditions and this effect was carried into the summer of 2021. It is unknown when and if the seed bank will be exhausted.

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 areas containing dense plants were not designated for treatment because they were proximal to undeveloped shorelines where contact recreation is minimal. 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. Specifically, SŌLitude adjusted treatment areas adjacent to Points 17, 18, 44 and 54 to avoid affecting these species (Figure 5). Approximately 62 acres were designated for treatment.

SŌLitude conducted treatment on July 28, 2021 using Tribune (diquat), Nautique (copper) and Red Eagle (flumioxazin). The herbicide treatment details are listed in Table 1 of the 2021 Year-End Treatment Report provided in Appendix B. Overall, 62 acres were treated using 55 gallons of Tribune, 90 gallons of Nautique and 20 pounds of Clipper, respectively. 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 on August 24, 2021. Treatment was deemed successful as it reduced densities of nuisance vegetation (pondweeds and wild celery) in the shallow areas around the lake. The application of Red Eagle for control of fanwort in May Street (proximal to observation point 45) and Flynn Road Cove area (proximal to points 36 & 37) was also successful. Fanwort was not observed in these areas during the post-treatment survey in August.

[1] Most of Massachusetts fell into Level 2 Significant Drought for the months of May through September 2020.

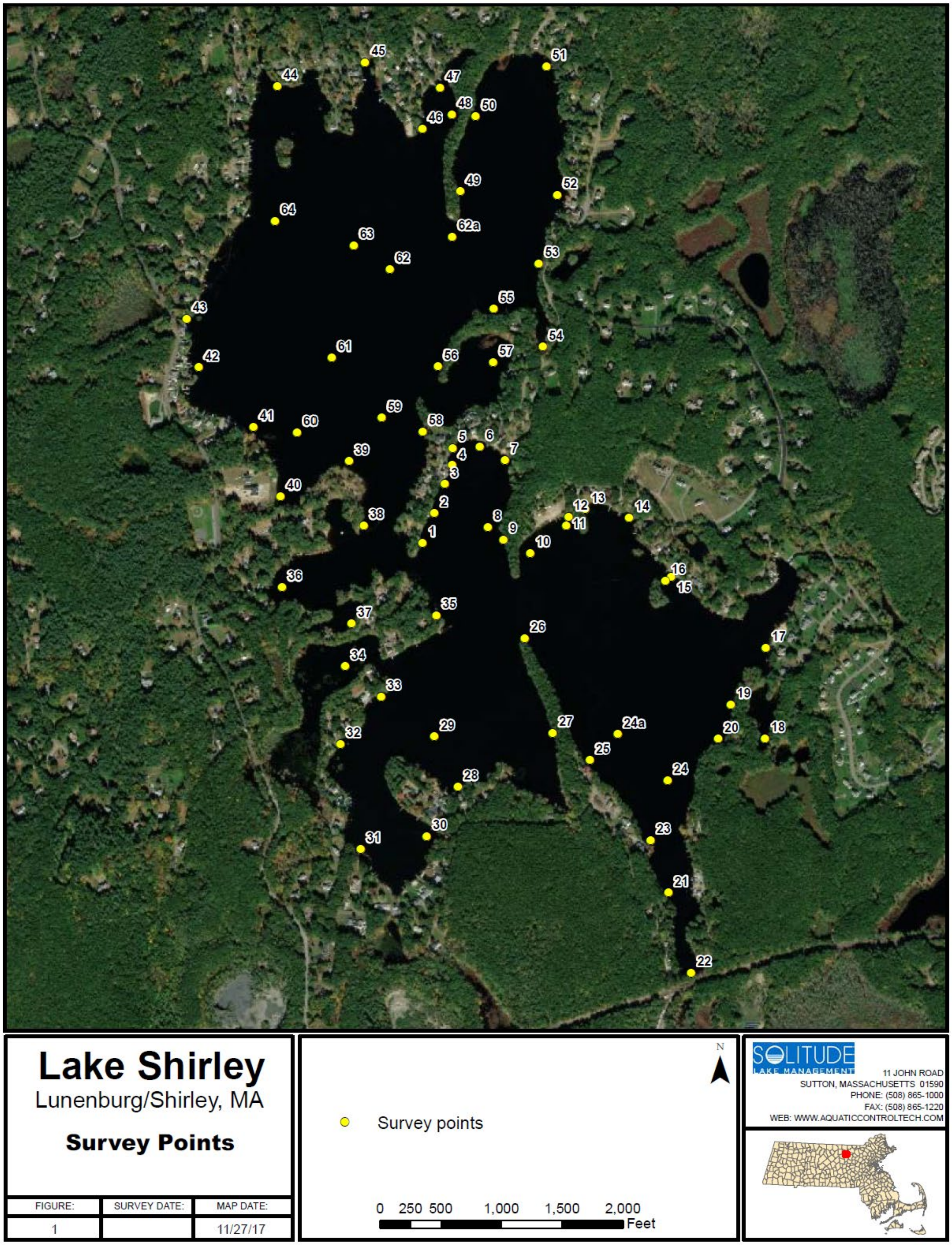


Figure 5. Lake Shirley Plant Survey Points.

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)[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, 62 contained plants (94%). Overall plant cover was similar to 2020 and biovolume was slightly less in 2021 than 2020 (Figure 6). Plant cover was greater than 50 percent (> category 2) at 66% of the sites containing plants. Biovolume exceeded 50% at only 11% of the sites. Most of the observation locations (65%) contained plants with a biovolume of 1-25%. Wild celery was the most frequently encountered plant (observed at 65% of the sites) with the two other management target species also very frequent (fanwort at 60% and European naiad at 47%, respectively). Fanwort frequency of occurrence increased by 8% over 2020. European naiad and wild celery frequency was slightly less in 2021 than 2020. When present in 2021, fanwort and wild celery were dense and dominated the community. Bladderwort, the next most abundant species was present at 23% of the sites (vs 43% in 2020) and the remaining plant species were much less frequent (<20%). Neither species of invasive milfoils (variable nor Eurasian) were encountered during the ARC survey.

The two native species SŌLitude avoided during treatments (coontail and Robbin's pondweed) were present in September 2020 but were infrequent (3% and 2% of the sites, respectively). Robbin's pondweed was dense and dominated the plant community at observation location 18 in September and was an area that did not received any treatment. Coontail was observed at point 54, also area where no treatment occurred. At the four sites excluded from treatment, wild celery (points 17 & 44), clasping leaf pondweed (point 17), Robbin's pondweed (point 18), and fanwort (point 54) dominated the plant community. These species could have shaded out the desirable natives over the summer having been left untreated, or this difference could illustrate natural variability over time.

[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.

Table 4. Lake Shirley Plant Survey Data (September 2021).

Point	Water Depth (ft)	Cover	Bio-volume	Cc	Nm	Va	Bb	BG	Cd	FG	Moss	Nf	Ngrac	Nit	No	Nv	Pf	Pg	Pp	Ppus	Pr	Pz	Spar.	Usp	Species Richness	Richness w/o Target Sp^2
1	9.0	4	2	D					T					S											3	2
2	8.7	4	3	D																				M	2	1
3	8.3	4	2	D																					1	0
4	7.7	4	2	D		M																			2	0
5	4.8	1	1	D																					1	0
6	8.0	0	0																						0	0
7	4.7	1	1	T															T						2	1
8	9.7	4	2	D																					1	0
9	8.3	4	2	D		S							T											S	4	2
10	9.7	4	3	D																					1	0
11	6.9	3	2	M		D								M					M					S	5	3
12	2.6	4	1	D		M												T						T	4	2
13	6.3	4	1	M	T	D		S						M										S	6	3
14	6.0	3	1	M		D													S					T	4	2
15	5.0	1	1		T	D													M						3	1
16	6.5	2	1	S	T	D																		T	4	1
17	5.9	3	2	T		D						T						S	D			S			6	4
18	7.3	4	2	T						M											D	T			4	3
19	5.7	0	0																						0	0
20	6.3	3	1	T		D													S						3	1
21	6.3	2	1			D								T											2	1
22	5.3	4	1	T		S					D														3	1
23	7.8	4	2		S	D						D							S					T	5	3
24	9.7	4	2	D	T							S												M	4	2
24a	10.0	3	3	D																					1	0
25	6.6	4	2	S	M	D							T						S					M	6	3
26	3.0	0	0																						0	0
27	7.0	1	1	S																				T	2	1
28	3.9	3	1	T		S						S	S					M	D						6	4
29	8.7	4	3	D																					1	0
30	5.3	3	1	T		M																			2	0
31	5.4	1	1	T		S																	T		3	1
32	4.8	4	1	S															T				D	M	4	3
33	7.3	4	2	S	D	D							S												4	1
34	4.8	4	3		D	M									S										3	1
35	6.6	4	3	D		D																		T	3	1
36	8.8	1	1					T																	1	1
37	5.6	1	1	T		M																			2	0
38	8.7	3	1	M		D								S											3	1
39	5.7	3	1			D																			1	0
40	3.2	2	1		M	D													S	T					4	2
41	6.9	4	1		D	S																			2	0
42	6.2	3	1		S	D				M															3	1
43	4.3	4	2	M	D	M									M										4	1
44	6.0	4	2	M	T	D				T												M			5	2
45	4.7	2	1		S																				1	0
46	5.3	2	1		M	T																			2	0
47	5.6	2	1		S	S							T												3	1
48	6.6	2	1		S	D																			2	0
49	7.3	4	1		M	D						T													3	1
50	7.0	4	1		M					S			S							S					4	3

Table 4 continued. Lake Shirley Plant Survey Data (Sep 2020).

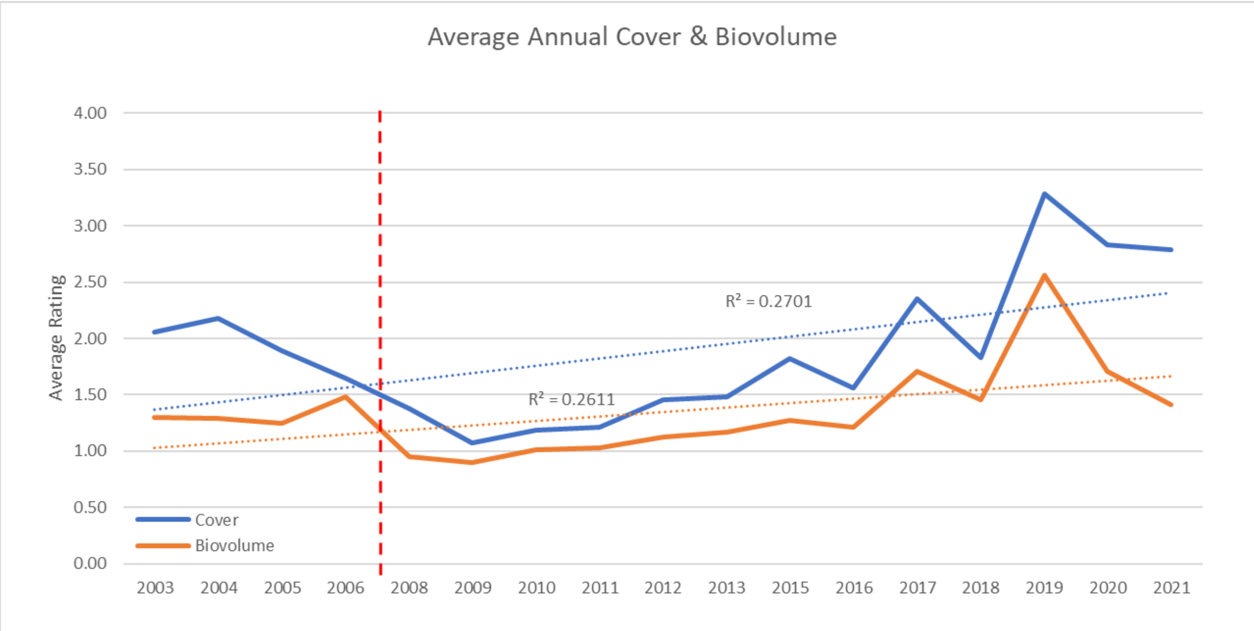
Point	Water Depth (ft)	Cover	Bio-volume	Cc	Nm	Va	Bb	BG	Cd	FG	Moss	Nf	Ngrac	Nit	No	Nv	Pf	Pg	Pp	Ppus	Pr	Pz	Spar.	Usp	Species Richness	Richness w/o Target Sp[2]
51	5.8	4	1		T	D							S												3	1
52	6.8	1	1	S		S							T												3	1
53	7.4	3	1		T	D																			2	0
54	3.6	4	3	D	S		S		T							T								M	6	4
55	8.2	4	4	D																					1	0
56	6.5	2	1			D																			1	0
57	6.8	4	1		S	T						M	S							T					5	3
58	6.8	2	1	T		D							S	S											4	2
59	11.2	0	0																						0	0
60	6.8	2	1		D	M																			2	0
61	10.3	1	1		S																				1	0
62	10.8	3	1		D					S															2	1
62a	9.3	4	1		D																				1	0
63	10.2	1	1		S																				1	0
64	8.3	2	1		S	S				M															3	1
Frequency of Occurrence				37	29	40	1	2	2	6	1	6	10	6	2	1	0	3	11	3	1	3	2	14		
Frequency of Occurrence (%)[1]				60%	47%	65%	2%	3%	3%	10%	2%	10%	16%	10%	3%	2%	0%	5%	18%	5%	2%	5%	3%	23%		
Density When Present (%)																										
			Dense	41%	24%	58%	0%	0%	0%	0%	100%	17%	0%	0%	0%	0%	0%	0%	18%	0%	100%	0%	50%	0%		
			Moderate	16%	17%	18%	0%	0%	0%	50%	0%	17%	0%	33%	50%	0%	0%	33%	18%	0%	0%	33%	0%	36%		
			Sparse	16%	34%	20%	100%	50%	0%	33%	0%	33%	60%	50%	50%	0%	0%	33%	45%	33%	0%	33%	0%	21%		
			Trace	27%	24%	5%	0%	50%	100%	17%	0%	33%	40%	17%	0%	100%	0%	33%	18%	67%	0%	33%	50%	43%		

[1] – Frequency of occurrence (%) is the number of observations where plants are present (# observed/62 total observations with plants)

[2] – Richness w/o Target Species is the richness at the sample location not including fanwort (Cc), European naiad (Nm) or wild celery (Va).

Key to species

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



Red dash indicates when herbicide treatments began

Figure 6. Lake Shirley End of Growing Season Plant Cover & Biovolume over Time

Species richness (number of different species observed) at each observation location in 2021 ranged from one to six (Table 4), with an average of 3.0. After removing richness data for the managed target species (fanwort, European naiad and wild celery), average species richness declines to 1.1. Overall richness in 2021 was greater than 2020 (Figure 7). Three additional native species were encountered: water marigold (*Bidens beckii*), bluegreen algae, and grassy pondweed (*Potamogeton gramineus*). These species are not "new" to the lake and have been observed during prior surveys.

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 https://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 8). Diversity in 2021 and 2020 was 2.34 and 2.20, respectively. Removing the target management species from the population, diversity (H*) yields a greater value in 2021 than 2020 (2.49 vs 2.10, respectively). The diversity in 2021 was the highest since 2009.

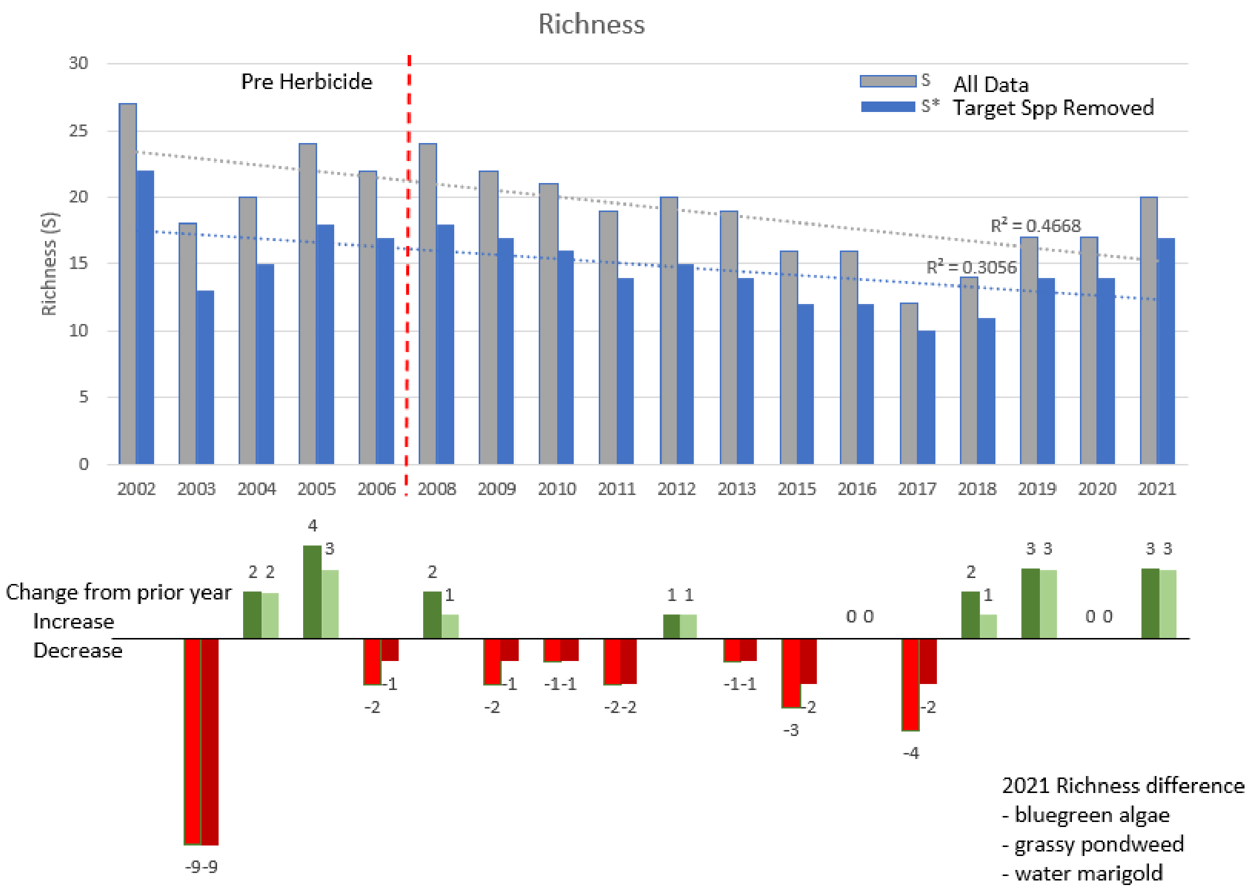


Figure 7. Lake Shirley End of Growing Season Plant Species Richness

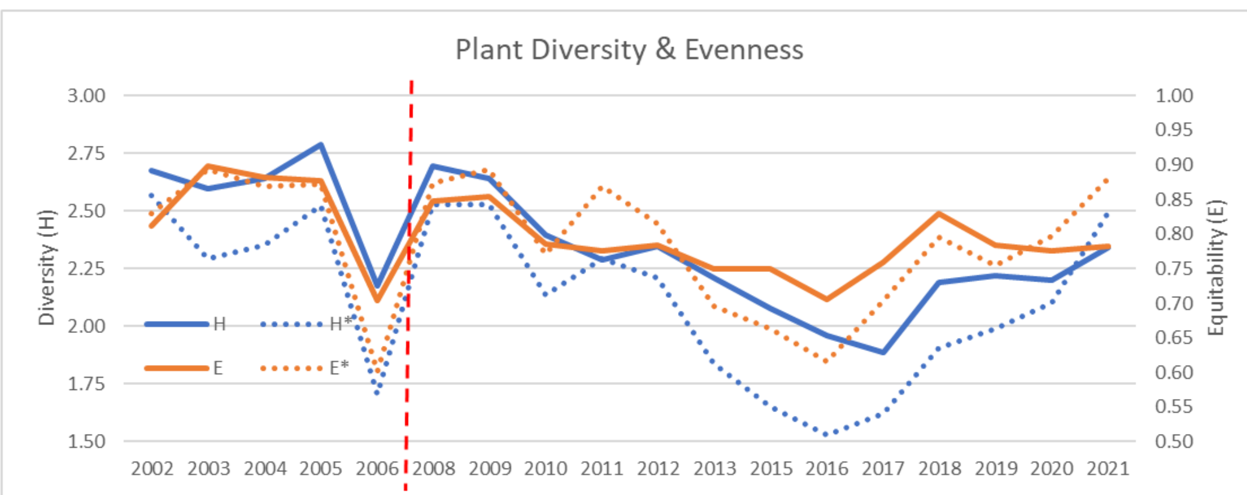


Figure 8. Lake Shirley Plant Diversity and Evenness over Time

Evenness was the same in 2021 and 2020 at 0.78 considering the entire population. With the target species removed, evenness (E*) was higher in 2021 (0.88 in 2021 and 0.79 in 2020), suggesting that species were more evenly represented with less dominance by a few species.

The non-native invasive plant species, European naiad was less abundant in 2021 vs 2020 but fanwort was slightly more prevalent (37 vs 33 locations in 2021 vs 2020 respectively). The herbicide Tribune was applied in the May Street cove area in 2021 to control fanwort and was successful as fanwort was not observed in the late August or September survey. Tribune was also applied in the Flynn Road area. Fanwort was not observed at point 36 and only a trace amount was observed at point 37 during the September survey. The fanwort treatment in 2020 continued to provide relief from excessive fanwort density in 2021. Fanwort was not observed during the September 2021 survey within the Pearl Street cove treatment area (points 46-48). These areas were dominated by wild celery and European naiad. There were small changes in other species that are typically found at relatively low frequencies from year to year (Table 5).

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

	Common Name	Genus species	Sep-11	Sep-12	Aug-13	Oct-15	Oct-16	Oct-17	Sep-18	Sep-19	Sep-20	Sep-21
Target Non-native Invasives	Eurasian milfoil	Myriophyllum spicatum	4	6								
	Variable milfoil	Myriophyllum heterophyllum	1	1	1	1						
	European Naiad	Najas minor	46	54	36	13	40		39	60	35	29
	Fanwort	Cabomba caroliniana	18	13	25	19	18	7	19	50	33	37
	Curlyleaf pondweed	Potamogeton crispus			1		2					
Target Native	Wild celery	Valisneria americana	48	42	38	38	52	32	30	50	42	40
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.	1	20						3	1	6
	Musk grass	Chara sp.			20	12	1	11				
	Stonewort/Musk grass	Nitella/Chara sp							29			
	Bluegreen algae											2
	Filamentous green algae						5	6		16	8	6
Similar Bladderworts	Bladderwort	Utricularia sp.	8	1	5	10	6	22	16	50	27	14
	Eastern purple bladderwort	Utricularia purpurea	13	3	3							
	Little floating bladderwort	Utricularia radiata		1								
Free floating	Watermeal	Wolffia sp.										
	Giant duckweed	Spirodela polyrhiza										
	Duckweed	Lemna minor	3									
Similar floating leaves	Watershield	Bresenia schreberi			1				2			
	White waterlily	Nymphaea odorata	2	2	2	2	3			4	2	2
	Yellow waterlily	Nuphar variegatum	2	6	6	2				6	2	1
Similar naiad	Bushy pondweed	Najas flexilis	14	24	51	48	50	40	10	30	9	6
	Northern (Thread-like) naiad	Najas gracillima							20		7	10
Similar pondweeds	Clapsing pondweed	Potamogeton perfoliatus	1	3	1	4	8	3	7	12	12	11
	Richardson's pondweed	Potamogeton richardsonii										
Other Pondweeds	Grassy pondweed	Potamogeton gramineus	11	10	3							3
	Flatstem pondweed	Potamogeton zosterformis							1	2	1	3
	Big leaf (Large leaf) pondweed	Potamogeton amplifolius										
	Floating (broad-leaf) pondweed	Potamogeton natans										
	Leafy pondweed	Potamogeton foliosus								1	6	
	Thin-leaf (Small) pondweed	Potamogeton pusillus	5	20	7	9	2	1		17	1	3
	Ribbonleaf pondweed	Potamogeton epihydrus	1	3	2	1	1	1	2	1		
	Robbins' pondweed	Potamogeton robbinsii	1	1	1	1	2	1	1		2	1
	Sago pondweed	Potamogeton pectinatus					2					
	Coontail	Ceratophyllum demersum	6	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	8	4	3							
	Water marigold	Megalodonta beckii										1
	Water purslane	Ludwigia palustris										
	Water starwort	Callitriche sp.										
	Bog moss	Musci sp.				1		6	3			1

Darkness of red shading indicates relative abundance where darker shade represents higher 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. 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. The public 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 posters 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 2020-2021

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 2021-2022, LSIC will continue with the winter water level drawdown, herbicide treatments (including Tribune or similar), 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. 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) and continue discussions with the Town of Lunenburg and MassDEP regarding a possible Section 319 grant for a pilot alum tributary dosing project.

LSIC intends to implement the winter water level drawdown to a target depth of six feet during the winter of 2021-2022. 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 has provided their recommendations in their annual report (Appendix B) which includes:

- an early season plant survey and herbicide treatment if curly-leaf pondweed density is extensive,
- mid-season survey and treatment targeted at extensive growth of wild celery, naiad and milfoil using Reward with the possible addition of a copper-based herbicide/algaecide (Nautique or Captain) for improved control of wild celery.
- Identify another location dominated by fanwort to use Clipper or Tribune (i.e., flumioxazin) since it was successful at controlling fanwort in the application areas in 2020 & 2021, 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 2021-2022 management season.

Appendix A
Lake Shirley Phytoplankton

		17-Aug-21											
		Site #2 North Basin				Site #3 South Basin				Site #4 North Basin NW Cove			
Group	**Species**	**Density #/mL**	**Density Percent**	**Biomass ug/L**	**Biomass Percent**	**Density #/mL**	**Density Percent**	**Biomass ug/L**	**Biomass Percent**	**Density #/mL**	**Density Percent**	**Biomass ug/L**	**Biomass Percent**
Chrysophyta	Achnanthes linearis												
Chrysophyta	Achnanthes minutissima	29	1.4	1	0.1	8	1.0	0	0.1				
Cyanobacteria	Anabaena flos-aquae												
Cyanobacteria	Anabaena planctonica					8	1.0	15	4.2				
Cyanobacteria	Anabaena variabilis	44	2.1	68	3.0	16	2.0	37	10.6	17	0.8	37	2.6
Chlorophyta	Ankistrodesmus falcatus	73	3.5	4	0.2	24	3.0	1	0.2	33	1.5	1	0.1
Cyanobacteria	Aphanizomenon flos-aquae	392	18.9	395	17.7	49	6.1	46	13.1	434	19.7	492	34.2
Chlorophyta	Botryococcus braunii												
Chlorophyta	Chlamydomonas sp.	73	3.5	24	1.1	32	4.0	11	3.0	67	3.0	22	1.5
Chrysophyta	Chromulina sp.	15	0.7	0	0.0								
Chrysophyta	Chrysococcus rufescens												
Chlorophyta	Coelastrum microporum												
Bacillariophyta	Coscinodiscus sp.												
Chlorophyta	Cosmarium sp.					8	1.0	2	0.5				
Chlorophyta	Crucigenia crucifera	29	1.4	7	0.3								
Chlorophyta	Crucigenia quadrata	29	1.4	4	0.2	24	3.0	2	0.6	17	0.8	3	0.2
Chlorophyta	Crucigenia tetrapedia												
Cryptophyta	Cryptomonas erosa	276	13.3	143	6.4	97	12.1	51	14.5	401	18.2	208	14.5
Chrysophyta	Cyclotella stelligera	73	3.5	4	0.2	16	2.0	1	0.3	17	0.8	1	0.1
Chrysophyta	Dinobryon sertularia	29	1.4	9	0.4	81	10.1	18	5.3	33	1.5	12	0.8
Chlorophyta	Elakatothrix gelatinosa												
Chrysophyta	Eunotia pectinalis	15	0.7	10	0.5								
Chrysophyta	Fragilaria crotonensis												
Pyrrhophyta	Glenodinium sp.					8	1.0	6	1.6	17	0.8	12	0.8
Chrysophyta	Kephyrion littorale												
Chrysophyta	Kephyrion spirale									17	0.8	1	0.1
Chrysophyta	Mallomonas sp.					16	2.0	6	1.8	17	0.8	6	0.4
Bacillariophyta	Melosira granulata angustissima									17	0.8	33	2.3
Cyanobacteria	Microcystis aeruginosa	29	1.4	12	0.5					33	1.5	13	0.9
Bacillariophyta	Navicula rhynchocephala									17	0.8	5	0.3
Chrysophyta	Nitzschia capitellata					8	1.0	3	0.8				
Chrysophyta	Nitzschia frustulum												
Chlorophyta	Oocystis lacustris					8	1.0	3	0.7				
Chlorophyta	Oocystis pusilla	29	1.4	3	0.1	32	4.0	6	1.8	84	3.8	16	1.1
Chlorophyta	Pandorina morum												
Chlorophyta	Pediastrum duplex												
Chlorophyta	Planktosphaeria gelatinosa	44	2.1	5	0.2					17	0.8	2	0.1
Chlorophyta	Quadrigula closterioides	29	1.4	4	0.2								
Cryptophyta	Rhodomonas minuta	479	23.1	10	0.4	292	36.4	6	1.7	752	34.1	15	1.0
Chlorophyta	Scenedesmus bijuga									17	0.8	5	0.3
Chlorophyta	Scenedesmus quadricauda	29	1.4	8	0.3	8	1.0	2	0.6	67	3.0	15	1.1
Chlorophyta	Schroederia sp.												
Chlorophyta	Selenastrum minutum	15	0.7	0	0.0								
Chlorophyta	Sphaerocystis schroeteri	87	4.2	30	1.4	8	1.0	1	0.3	50	2.3	28	1.9
Chlorophyta	Staurastrum gracile	15	0.7	8	0.4								
Chlorophyta	Staurastrum sp.												
Bacillariophyta	Stephanodiscus hantzschii												
Chrysophyta	Synedra rumpens	15	0.7	2	0.1								
Bacillariophyta	Tabellaria fenestrata	131	6.3	1379	61.8	16	2.0	117	33.4	67	3.0	481	33.4
Chlorophyta	Tetraedron minimum	15	0.7	1	0.0	16	2.0	1	0.2				
Chlorophyta	Tetraedron regulare	15	0.7	2	0.1	8	1.0	1	0.3				
Chlorophyta	Tetraedron sp.					8	1.0	0	0.1				
Euglenophyta	Trachelomonas hispida	15	0.7	30	1.4								
Euglenophyta	Trachelomonas volvocina	29	1.4	55	2.5	8	1.0	15	4.4	17	0.8	31	2.2
Chlorophyta	Ulothrix sp.	29	1.4	12	0.5								
	Total	**2075**	**100.0**	**2230**	**100.0**	**802**	**100.0**	**349**	**100.0**	**2205**	**100.0**	**1441**	**100.0**

		25-Aug-21											
		Site #2 North Basin				Site #3 South Basin				Site #4 North Basin NW Cove			
Group	Species	Density #/mL	Density Percent	Biomass ug/L	Biomass Percent	Density #/mL	Density Percent	Biomass ug/L	Biomass Percent	Density #/mL	Density Percent	Biomass ug/L	Biomass Percent
Chrysophyta	Achnanthes linearis									13	1.0	2	0.1
Chrysophyta	Achnanthes minutissima					18	3.4	1	0.2				
Cyanobacteria	Anabaena flos-aquae					4	0.7	14	3.6				
Cyanobacteria	Anabaena planctonica	14	1.0	46	3.0	4	0.7	6	1.5				
Cyanobacteria	Anabaena variabilis												
Chlorophyta	Ankistrodesmus falcatus	70	5.0	3	0.2	25	4.8	1	0.2	65	5.0	2	0.1
Cyanobacteria	Aphanizomenon flos-aquae	126	8.9	191	12.5	14	2.7	15	3.8	52	4.0	72	5.6
Chlorophyta	Botryococcus braunii					4	0.7	11	2.9				
Chlorophyta	Chlamydomonas sp.	98	6.9	32	2.1	92	17.8	30	7.5	157	12.0	51	3.9
Chrysophyta	Chromulina sp.					7	1.4	0	0.0	52	4.0	1	0.1
Chrysophyta	Chrysococcus rufescens									13	1.0	1	0.1
Chlorophyta	Coelastrum microporum	14	1.0	13	0.9					39	3.0	31	2.4
Bacillariophyta	Coscinodiscus sp.	14	1.0	11	0.7					13	1.0	10	0.8
Chlorophyta	Cosmarium sp.												
Chlorophyta	Crucigenia crucifera												
Chlorophyta	Crucigenia quadrata					14	2.7	1	0.3				
Chlorophyta	Crucigenia tetrapedia									13	1.0	1	0.1
Cryptophyta	Cryptomonas erosa	56	4.0	29	1.9	28	5.5	15	3.7	130	10.0	68	5.3
Chrysophyta	Cyclotella stelligera	70	5.0	4	0.3	7	1.4	0	0.1	39	3.0	2	0.2
Chrysophyta	Dinobryon sertularia	28	2.0	8	0.6					13	1.0	2	0.1
Chlorophyta	Elakatothrix gelatinosa					7	1.4	1	0.2				
Chrysophyta	Eunotia pectinalis												
Chrysophyta	Fragilaria crotonensis									13	1.0	132	10.2
Pyrrhophyta	Glenodinium sp.					4	0.7	2	0.6	39	3.0	27	2.1
Chrysophyta	Kephyrion littorale					4	0.7	0	0.1	52	4.0	5	0.4
Chrysophyta	Kephyrion spirale												
Chrysophyta	Mallomonas sp.	14	1.0	5	0.4	4	0.7	1	0.3				
Bacillariophyta	Melosira granulata angustissima												
Cyanobacteria	Microcystis aeruginosa	98	6.9	19	1.2	18	3.4	8	1.9	65	5.0	35	2.8
Bacillariophyta	Navicula rhynchocephala												
Chrysophyta	Nitzschia capitellata												
Chrysophyta	Nitzschia frustulum									13	1.0	2	0.1
Chlorophyta	Oocystis lacustris					4	0.7	1	0.3				
Chlorophyta	Oocystis pusilla	154	10.9	42	2.7	39	7.5	8	2.1	78	6.0	14	1.1
Chlorophyta	Pandorina morum					4	0.7	10	2.5	13	1.0	18	1.4
Chlorophyta	Pediastrum duplex									13	1.0	0	0.0
Chlorophyta	Planktosphaeria gelatinosa									13	1.0	2	0.2
Chlorophyta	Quadrigula closterioides												
Cryptophyta	Rhodomonas minuta	294	20.8	6	0.4	127	24.7	3	0.6	183	14.0	4	0.3
Chlorophyta	Scenedesmus bijuga					4	0.7	0	0.1				
Chlorophyta	Scenedesmus quadricauda	14	1.0	4	0.2	11	2.1	3	0.9	26	2.0	7	0.5
Chlorophyta	Schroederia sp.	14	1.0	1	0.0	4	0.7	0	0.0				
Chlorophyta	Selenastrum minutum												
Chlorophyta	Sphaerocystis schroeteri	154	10.9	76	5.0	25	4.8	9	2.4	78	6.0	30	2.3
Chlorophyta	Staurastrum gracile									13	1.0	7	0.5
Chlorophyta	Staurastrum sp.	14	1.0	3	0.2								
Bacillariophyta	Stephanodiscus hantzschii	28	2.0	3	0.2								
Chrysophyta	Synedra rumpens					4	0.7	0	0.1	13	1.0	2	0.1
Bacillariophyta	Tabellaria fenestrata	112	7.9	1023	67.3	21	4.1	228	57.2	39	3.0	752	58.3
Chlorophyta	Tetraedron minimum	14	1.0	1	0.0								
Chlorophyta	Tetraedron regulare	14	1.0	2	0.1	11	2.1	1	0.3	39	3.0	5	0.3
Chlorophyta	Tetraedron sp.												
Euglenophyta	Trachelomonas hispida												
Euglenophyta	Trachelomonas volvocina					14	2.7	27	6.7				
Chlorophyta	Ulothrix sp.									13	1.0	6	0.5
	Total	**1416**	**100.0**	**1521**	**100.0**	**514**	**100.0**	**399**	**100.0**	**1305**	**100.0**	**1289**	**100.0**

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

(Prepared by SŌLitude Lake Management)

Lake Shirley
Lunenburg/Shirley, Massachusetts
2021 Year-End Treatment Report

December 14, 2021

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 (#WM04-0000631).

2021 Management Program Summary

Program Task	Date Completed
Early Season Survey/Sample Collection	June 16, 2021
Received Approved License to Apply Chemicals	July 22, 2021
Herbicide Treatment	July 28, 2021

Pre-Treatment Survey

This year's pre-treatment survey was conducted on June 16th. The survey was conducted according to the expanded methodology used in recent years, which is a combination of SLM's historical qualitative assessment and

Geosyntec's more quantitative procedures. In addition to recording data on the general plant assemblage, point data was collected at 66 data points throughout the lake. At each point, data was collected on the species composition (species present), plant growth density and plant biomass. These are the same locations and point #'s used by Geosyntec in past reports. The pre-treatment survey serves to assess the growth of all invasive species [fanwort (*Cabomba caroliniana*), curly-leaf pondweed (Potamogeton crispus), Eurasian milfoil (*Myriophyllum spicatum*) and variable milfoil (*Myriophyllum heterophyllum*)] as well as identify any nuisance growth of native plant species.

Although not as abundant as last year, several seed producing pondweed species were again commonly observed during the survey, mostly along the shallower margins of the lake. These species are variable (or grassy) pondweed (*Potamogeton gramineus*), leafy pondweed (*Potamogeton foliosus*), clasping leaf pondweed (*Potamogeton perfoliatus*) and snailseed pondweed (*Potamogeton bicupulatus*). No milfoils were observed but fanwort was present in many areas of the lake.

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. Specifically, treatment areas were adjusted adjacent to Points 17, 18, 44 and 54 to avoid affecting these species.

Given the success of the pilot treatment using Clipper (flumioxazin) last year in Pearl Street Cove, additional treatment with Clipper (flumioxazin) herbicide in the May Street cove and the cove north of Flynn Road (marked in yellow on the map) was proposed.. These coves will be treated with 100 ppb of flumioxazin and a low dose of diquat. In the other 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 also be applied in areas dominated by tapegrass.

Due to the presence of non-native curlyleaf pondweed, fanwort and nuisance growth of native plants, approximately 62 acres were designated for treatment. The pre-treatment report, which includes plant survey data and the proposed treatment map (**Figure 1**), is **attached**. The Commission approved this treatment at their July 21st meeting.

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	0.526	0.555	0.367
Total Phosphorus	mg/L	0.019	0.014	0.015

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 28th, for target species as specified in the pre-treatment report. Treatment was conducted with Reward (diquat), Nautique (copper) and Clipper (flumioxazin) herbicides. All proposed areas were treated.

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 2** shows the GPS recorded treatment tracks. A summary of the treatment specifications is as follows.

Table 1 – Herbicide Treatment Specifications

Treatment Date	July 28th
Product	Tribune (diquat) & Nautique (copper) & Red Eagle (flumioxazin)
Treatment Area	62 acres
Quantity	55 gallons – Tribune 90 gallons – Nautique 20 pounds – Red Eagle
GPS Tracks	See Figure 2
Applicator name	John Maday, MA Certification #AL-0048473
Site Conditions	Weather: Mostly Cloudy, light winds 4-8 MPH Variable, 68°F Water Temp: 26.8°C at surface, 24.5°C near bottom Dissolved Oxygen: 7.8 mg/l at surface; 4.7 mg/l near bottom (9-feet) Water clarity: 5'8"

Post Treatment Inspection

A post-treatment inspection was conducted on August 24th to evaluate the efficacy of the herbicide treatment. Overall, the treatment worked well on the targeted species, especially the pondweeds and the fanwort in the May Street and Flynn Road Cove. Tapegrass biomass was also reduced in the treatment areas. 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 2022

Based on the results of the 2021 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 tapegrass 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 2022 is as follows

Table 2 – Proposed Plan for 2022

Task	Schedule	Notes/Criteria
Early Season Survey	Mid/late April	Survey for early emerging plants, primarily curlyleaf 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 curlyleaf 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

Reward (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 Reward and a copper-based herbicide (Nautique) or algaecide (Captain/copper sulfate) should be used to increase effectiveness and produce more desirable results.

Given the successes now of the fanwort treatment in the Pearl Street Cove, May Street Cove and Flynn Road Cove, we recommend identifying other areas of the lake that could benefit from this type of treatment. The on-going issue with the use of flumioxazin is that under current regulations, the same areas of the lake can only be treated once every 4 years unless it's in the immediate vicinity of a high-use area such as a beach or boat launch. While it is possible this condition may be lifted in the future, for it will be necessary to either rotate the areas treated with Clipper or treat subsections of larger areas of fanwort over the course of multiple years.

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 2022, 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 2022 and beyond. If you have any questions regarding this report, please feel free to contact me. We look forward to working you again in the year ahead.

590 Lake Street
Shrewsbury, MA 010545

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

Date: July 9, 2021

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 16th, we are recommending treatment to approximately 62-acres of Lake Shirley to manage nuisance weed growth. Although not as prevalent as last year, we continue to see an increased amount of pondweed species around the margin of the lake. These species are leafy pondweed (*Potamogeton foliosus*), clasping leaf pondweed (*Potamogeton perfoliatus*) and snailseed pondweed (*Potamogeton bicupulatus*). Other target species include non-native curlyleaf pondweed (*Potamogeton crispus*) and tapegrass (*Vallisneria americana*).

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) 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. Specifically, we have adjusted treatment areas adjacent to Points 17, 18, 44 and 54 to avoid affecting these species.

Given the success of the pilot treatment using Clipper (flumioxazin) last year in Pearl Street Cove, the LSIC wishes to conduct additional treatment with Clipper (flumioxazin) herbicide in the May Street cove and the cove north of Flynn Road (marked in yellow on the map). These coves will be treated with 100 ppb of flumioxazin and a low dose of diquat. In the other 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 also be applied in areas dominated by tapegrass.

Treatment is tentatively scheduled for July 27th.

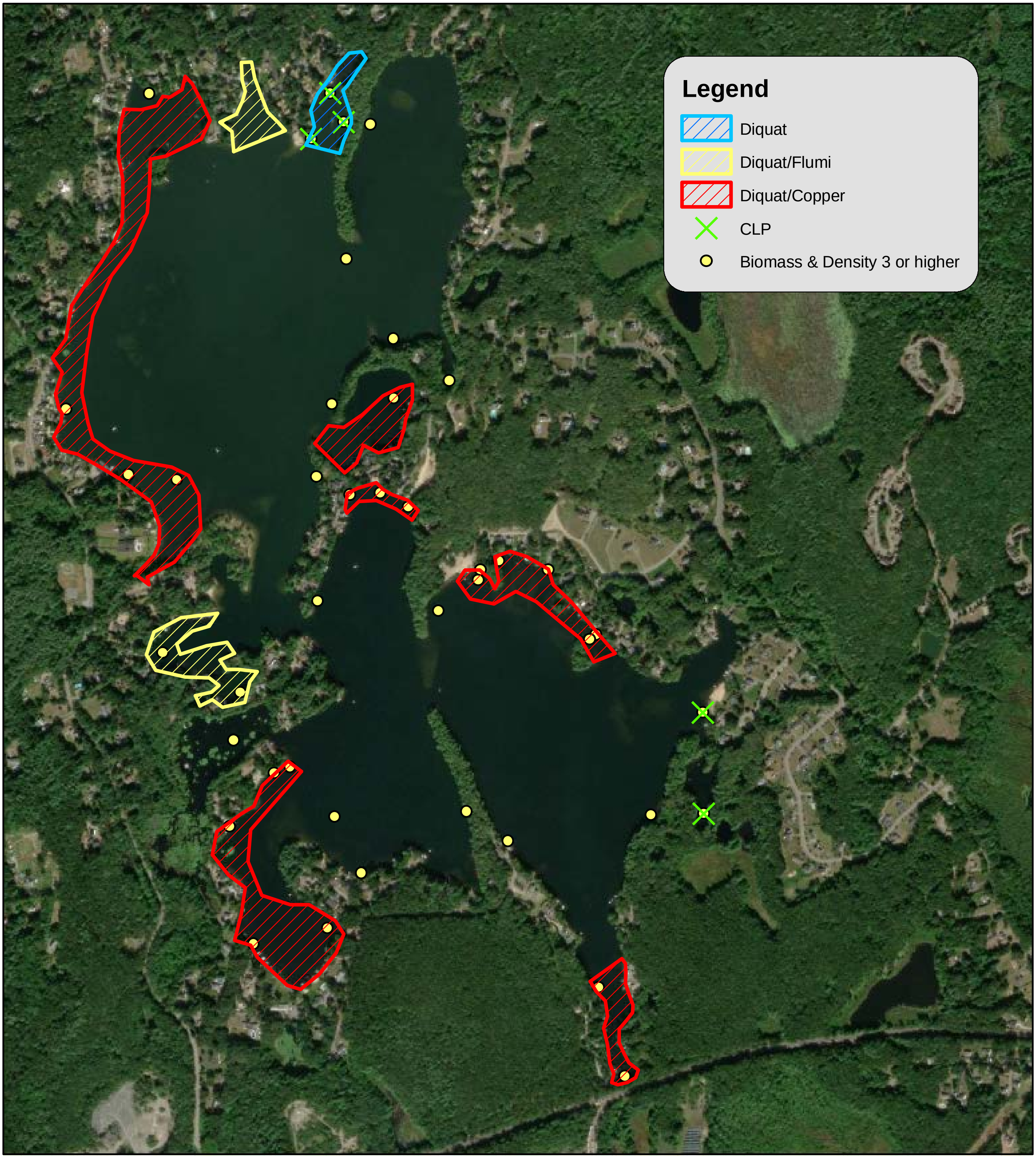
A map of the recommended treatment areas is attached as well as the June survey data table. On the map of the proposed treatment areas, the data points that meet management criteria are included. The LSIC will be attending upcoming meetings of the Conservation Commissions to discuss this plan and answer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

Regards,
SOLitude Lake Management

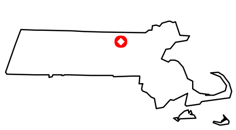
Dominic Meringolo
Senior Environmental Engineer/Project Manager

Proposed Treatment Areas (July 2021)

SOLITUDE
LAKE MANAGEMENT
888.480.5253
solitudelakemanagement.com



Lake Shirley
Lunenburg, MA



Lake Shirley

0 1,000 2,000 Feet

1:11,865

N

Map Date: 7/9/2021
Prepared by: DMM
Office: SHREWSBURY, MA

Table 1: Aquatic Vegetation Survey Results

Date: June 16, 2021 X= Present D = Dominant

Plant Species: Common Name	Scientific Name	# stations present	# stations dominant	% stations present	% stations dominant	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
Fanwort	*Cabomba caroliniana*	19	10	29%	15%	D	D			X	X	X			X	D	D	D									D					
Waterweed	*Elodea canadensis*	0	0	0%	0%																											
Wild Celery	*Valisneria americana*	21	8	32%	12%	X				X	X	D															X					
Bladderwort	*Utricularia Sp.*	9	5	14%	8%	X																				D		D	D	D	X	
Musk Grass	*Chara sp.*	0	0	0%	0%																											
Stonewort	*Nitella sp.*	11	5	17%	8%					X	X	X																				
Snailseed Pondweed	*Potamogeton bicupulatus*	4	3	6%	5%																											
Slender Naiad	*Najas flexillis*	1	0	2%	0%																											
Variable Leaf Pondweed	*Potamogeton gramineus*	0	0	0%	0%																											
Filamentous Algae	*Various*	2	2	3%	3%																											
Northern Naiad	*Najas gracilima*	0	0	0%	0%																											
Curlyleaf Pondweed	*Potamogeton crispus*	5	0	8%	0%																	X	X									
Ribbon-leaf Pondweed	*Potamogeton epihydrus*	15	4	23%	6%										X	X	X			X	X	D					X					
Clasping-leaf Pondweed	*Potamogeton perfoliatus*	25	11	38%	17%					D	D	X			D	X	X	X	D	D	D	X	D		D		X				D	
Leafy Pondweed	*Potamogeton foliosus*	9	6	14%	9%							X																				
Coontail	*Ceratophyllum demersum*	2	0	3%	0%																											
Flatstem Pondweed	*Potamogeton zosteriformis*	0	0	0%	0%																											
Yellow Waterlily	*Nuphar variegata*	7	0	11%	0%																											
White Waterlily	*Nymphaea odorata*	9	2	14%	3%																											
Aquatic Moss	*Fontinalus sp.*	0	0	0%	0%																											
Robbin's Pondweed	*Potamogeton robbinsii*	0	0	0%	0%																											
					Species Richness	3	1	0	0	4	4	5	0	0	3	3	3	2	1	2	2	3	2	0	1	1	4	1	1	1	2	0
					Plant density Index	3	3	0	0	3	3	3	0	0	3	3	3	3	3	3	2	3	3	0	3	3	4	2	1	2	3	0
					Plant biomass index	4	4	0	0	3	3	4	0	0	3	3	4	3	4	4	3	4	3	0	4	3	4	2	2	2	3	0

***Non-native, invasive species**

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

Table 1: Aquatic Vegetation Survey Results

Date: June 16, 2021

X= Present

Plant Species						Monitoring Locations																								
Common Name	*Scientific Name*	# stations present	# stations dominant	% stations present	% stations dominant	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**
Fanwort	*Cabomba caroliniana*	19	10	29%	15%	D				X					X	D							D	D		X				X
Waterweed	*Elodea canadensis*	0	0	0%	0%																									
Wild Celery	*Valisneria americana*	21	8	32%	12%	X			D	D	D		D			X				X			X		X	X				
Bladderwort	*Utricularia Sp.*	9	5	14%	8%		X						X													T			D	
Musk Grass	*Chara sp.*	0	0	0%	0%																									
Stonewort	*Nitella sp.*	11	5	17%	8%													D		X										D
Snailseed Pondweed	*Potamogeton bicupulatus*	4	3	6%	5%							D								X	D									
Slender Naiad	*Najas flexillis*	1	0	2%	0%																									
Variable Leaf Pondweed	*Potamogeton gramineus*	0	0	0%	0%																									
Filamentous Algae	*Various*	2	2	3%	3%																									
Northern Naiad	*Najas gracilima*	0	0	0%	0%																									
Curlyleaf Pondweed	*Potamogeton crispus*	5	0	8%	0%																				X	X	X			
Ribbon-leaf Pondweed	*Potamogeton epihydrus*	15	4	23%	6%		D	D				X	X		D	X														
Clasping-leaf Pondweed	*Potamogeton perfoliatus*	25	11	38%	17%		X				X	X	X			X		X	D		X									
Leafy Pondweed	*Potamogeton foliosus*	9	6	14%	9%								X		X					D					D	D	D			
Coontail	*Ceratophyllum demersum*	2	0	3%	0%																		X							
Flatstem Pondweed	*Potamogeton zosteriformis*	0	0	0%	0%																									
Yellow Waterlily	*Nuphar variegata*	7	0	11%	0%				X		X	X	X		X							X								
White Waterlily	*Nymphaea odorata*	9	2	14%	3%				X	X	X	X	X									D		X				D		
Aquatic Moss	*Fontinalus sp.*	0	0	0%	0%																									
Robbin's Pondweed	*Potamogeton robbinsii*	0	0	0%	0%																									
Species Richness						2	3	1	3	3	4	5	7	0	4	4	0	2	1	4	2	2	3	2	3	5	2	1	1	2
Plant density Index						3	3	3	4	4	4	3	3	0	3	3	0	2	4	4	4	4	3	4	3	4	3	4	4	4
Plant biomass index						3	4	3	4	3	4	4	4	0	4	3	0	2	3	3	3	4	4	3	4	4	3	3	3	3

***Non-native, invasive species**

Table 1: Aquatic Vegetation Survey Results

Date: June 16, 2021 X= Present

Plant Species Common Name	*Scientific Name*	# stations present	# stations dominant	% stations present	% stations dominant	52	53	54	55	56	57	58	59	60	61	62	62a	63	64	AVERAGES
Fanwort	*Cabomba caroliniana*	19	10	29%	15%			X												
Waterweed	*Elodea canadensis*	0	0	0%	0%															
Wild Celery	*Valisneria americana*	21	8	32%	12%				D	D	X	D		X			X			
Bladderwort	*Utricularia Sp.*	9	5	14%	8%															
Musk Grass	*Chara sp.*	0	0	0%	0%															
Stonewort	*Nitella sp.*	11	5	17%	8%								D	X	D	X	D			
Snailseed Pondweed	*Potamogeton bicupulatus*	4	3	6%	5%									D						
Slender Naiad	*Najas flexillis*	1	0	2%	0%														X	
Variable Leaf Pondweed	*Potamogeton gramineus*	0	0	0%	0%															
Filamentous Algae	*Various*	2	2	3%	3%											D		D		
Northern Naiad	*Najas gracilima*	0	0	0%	0%															
Curlyleaf Pondweed	*Potamogeton crispus*	5	0	8%	0%															
Ribbon-leaf Pondweed	*Potamogeton epihydrus*	15	4	23%	6%			X									X			
Clasping-leaf Pondweed	*Potamogeton perfoliatus*	25	11	38%	17%						X								D	
Leafy Pondweed	*Potamogeton foliosus*	9	6	14%	9%			D			D									
Coontail	*Ceratophyllum demersum*	2	0	3%	0%			X												
Flatstem Pondweed	*Potamogeton zosteriformis*	0	0	0%	0%															
Yellow Waterlily	*Nuphar variegata*	7	0	11%	0%			X												
White Waterlily	*Nymphaea odorata*	9	2	14%	3%			X												
Aquatic Moss	*Fontinalus sp.*	0	0	0%	0%															
Robbin's Pondweed	*Potamogeton robbinsii*	0	0	0%	0%															
					Species Richness	0	0	6	1	1	3	1	1	3	1	2	3	1	2	2.121212121
					Plant density Index	0	0	4	4	3	3	4	3	4	3	2	3	2	2	2.666666667
					Plant biomass index	0	0	4	4	3	4	3	3	3	3	3	3	3	2	2.803030303

***Non-native, invasive species**

FIGURE 2: GPS Treatment Tracks (July 28, 2021)

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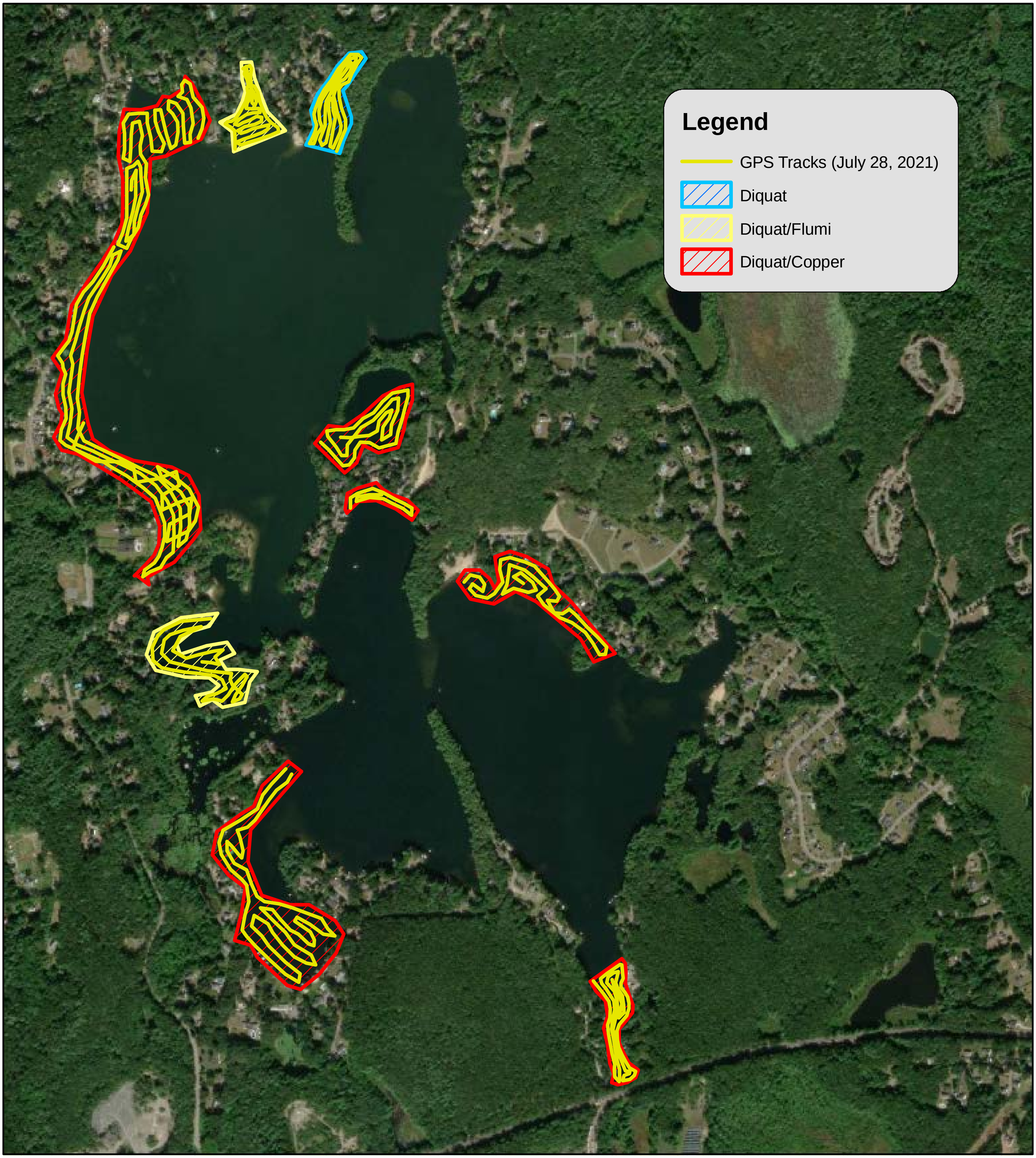
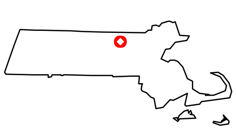


Lake Shirley
Lunenburg, MA



Lake Shirley

0 1,000 2,000 Feet

1:11,865

N

Map Date: 12/13/21
Prepared by: DMM
Office: SHREWSBURY, MA