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February 2023

TO: The Town of Bolton
FROM: Hannah Moore, Administrative Manager
CC: George Knoecklein, Owner, Principal Limnologist
Re: Lower Bolton Lake 2023 Monitoring Results

Discussion of 2023 Water Quality Results

This summary letter presents the results of Lower Bolton Lake water quality monitoring and aquatic plant surveying in 2023. Water quality data was collected by volunteer monitors monthly from April through November at the deepest location in the lake (Station 1). Monitoring consisted of collecting temperature and dissolved oxygen profiles, water clarity data, and water samples from the top and bottom of the water column for analysis of total phosphorus and total nitrogen concentration.

The water quality data included in this summary is assessed using the CT DEEP categorization of lakes, which is primarily based on the amount of nutrients in surface waters during summer conditions (**Table 1**). Due to constraints of chlorophyll analysis, we typically assess lake status based on total phosphorus, total nitrogen, and Secchi depth (water clarity) only.

The goal for Lower Bolton is oligo-mesotrophic, meaning surface water TP and TN concentrations below 15 ppb and 300 ppb respectively, and a Secchi depth of 4 meters or deeper.

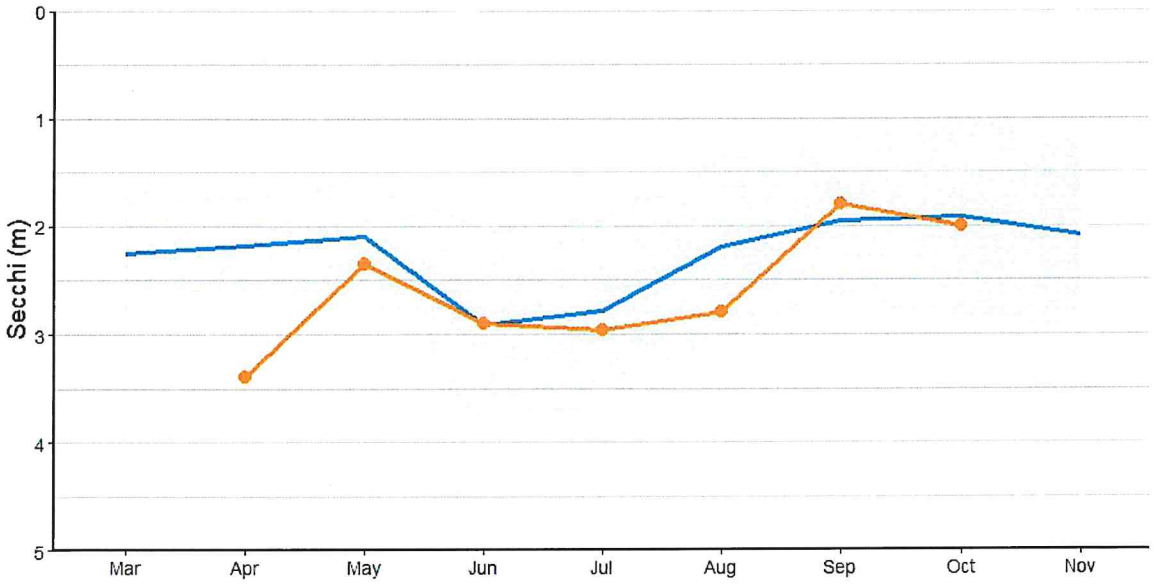
Table 1. Parameters and defining ranges for trophic states of lakes in Connecticut.

Category	Total phosphorus (ppb)	Total Nitrogen (ppb)	Secchi Depth (m)	Chlorophyll *a* (ppb)
Oligotrophic	0 -- 10	2 -- 200	6 +	0 -- 2
Oligo-mesotrophic	10 -- 15	200 -- 300	4 -- 6	2 -- 5
Mesotrophic	15 -- 25	200 -- 500	3 -- 4	5 -- 10
Meso-eutrophic	25 -- 30	500 -- 600	2 -- 3	10 -- 15
Eutrophic	30 -- 50	600 -- 1000	1 -- 2	15 -- 30
Highly Eutrophic	50 +	1000 +	0 -- 1	30 +

Water Clarity

Water clarity in 2023 ranged from best clarity of 3.4 meters in April to worst clarity of 1.7 meters in mid-September (**Figure 1**). Ideally, the water clarity in Lower Bolton should be no less than 3 meters. However, the water clarity in 2023 was similar to or better than the long-term mean in most months. In particular, the April Secchi depth of 3.4 meters was the best April clarity reading NEAR has recorded by more than half a meter.

Figure 1. 2023 Secchi disk depths (orange line) and the long-term average for each station (blue line, with shading depicting +/- one standard deviation from the mean).



Water Temperature and Dissolved Oxygen

Lakes are mixed after ice out because they are uniformly cold, after which they begin warming. The April profile shows the lake had been warming for some time, as evidenced by the warm surface water (~19°C) and cold bottom water (10°C) water (**Figure 2**). The lake then quickly cooled down, likely due to a period of cold windy days, so by May 1st, the lake was fully mixed at a temperature of ~14°C. The lake was stratified from mid-May through August. Fall turnover occurred relatively early, with a fully mixed water column by mid-September.

In our analysis of the water quality and dissolved oxygen data collected by volunteer monitors, we noticed that profile data has only been recorded down to 5 meters from the surface each month. The deep spot in Lower Bolton Lake is around 6 meters, meaning that temperature and dissolved oxygen data from the bottom meter of the water column is missing. Unfortunately, this means that we cannot determine the beginning and end dates of bottom water anoxia. For example, in **Figure 3**, the May and June temperature profiles show that while oxygen was lessened in May and June, the water was not anoxic at 5 meters. However, it is very possible that dissolved oxygen did decrease below 1mg/L (become anoxic) below 5 meters.

Despite the lack of dissolved oxygen data below 5 meters, we can analyze the depth of the anoxic boundary in months when anoxic water was present above 5 meters. July 1st was the first sampling date during which anoxic water was present above 5 meters (**Figure 3**). The water depth on this date was recorded at 5.8 meters, and the anoxic boundary was 4.3 meters, meaning the bottom 1.5 meters of water was anoxic. The anoxic boundary

reached a maximum height of 2 meters from the bottom (4 meters from the surface) in mid-July. The anoxic boundary then began to decline, falling below 5 meters by early September.

Figure 2. Water temperature profiles at Station 1 in 2023 (data below 5 meters is missing).

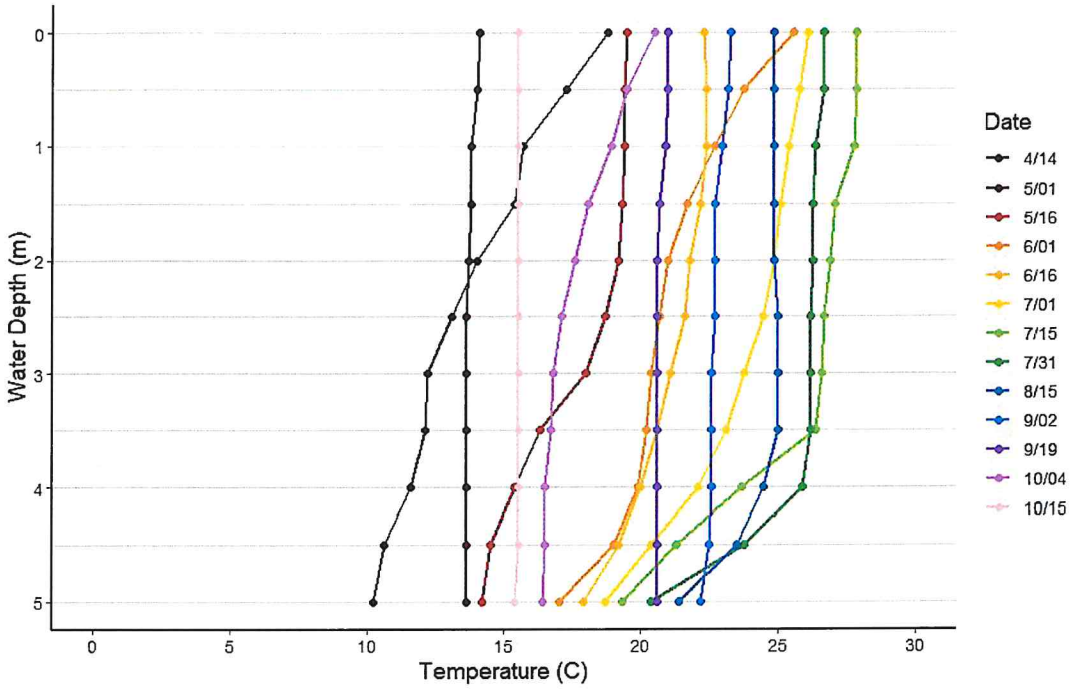
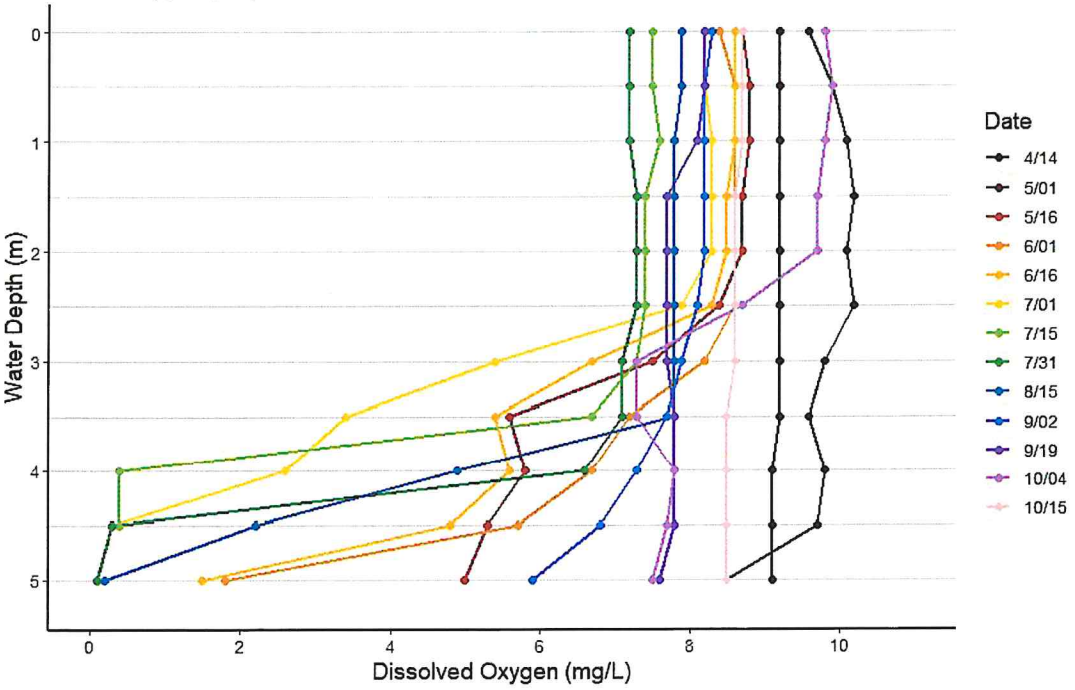


Figure 3. Dissolved oxygen profiles at Station 1 in 2023 (data below 5 meters is missing).



Nutrients

The goal for Total Phosphorus concentration in Lower Bolton surface waters is ideally 10 ppb but acceptable up to 15 ppb. In 2023, TP in the surface water was highest at the beginning and end of the sampling season, during the periods of spring and autumn lake mixing (**Figure 4**). TP was above the 15-ppb threshold in April, May, and October. TP concentration in the surface water was excellent in June at 7 ppb. Data indicates that there was a general decline in TP concentration between April and June, but once bottom TP began increasing in July due to internal loading, the surface TP increased as a consequence. There was also a late season TP increase in October from 12 ppb to 20 ppb.

The goal for Total Nitrogen (TN) in the surface waters is ideally 200 ppb and tolerably 300 ppb. TN in Lower Bolton surface water exceeded 300 pbb in April (barely) and in August, September, and October (**Figure 5**). TN was lowest in July.

There is clear evidence of internal loading at the deep spot sampling station. Both TP and TN concentrations at the lake bottom rose significantly between June and August, in line with the period of oxygen loss.

Figure 4. 2023 total phosphorus concentrations.

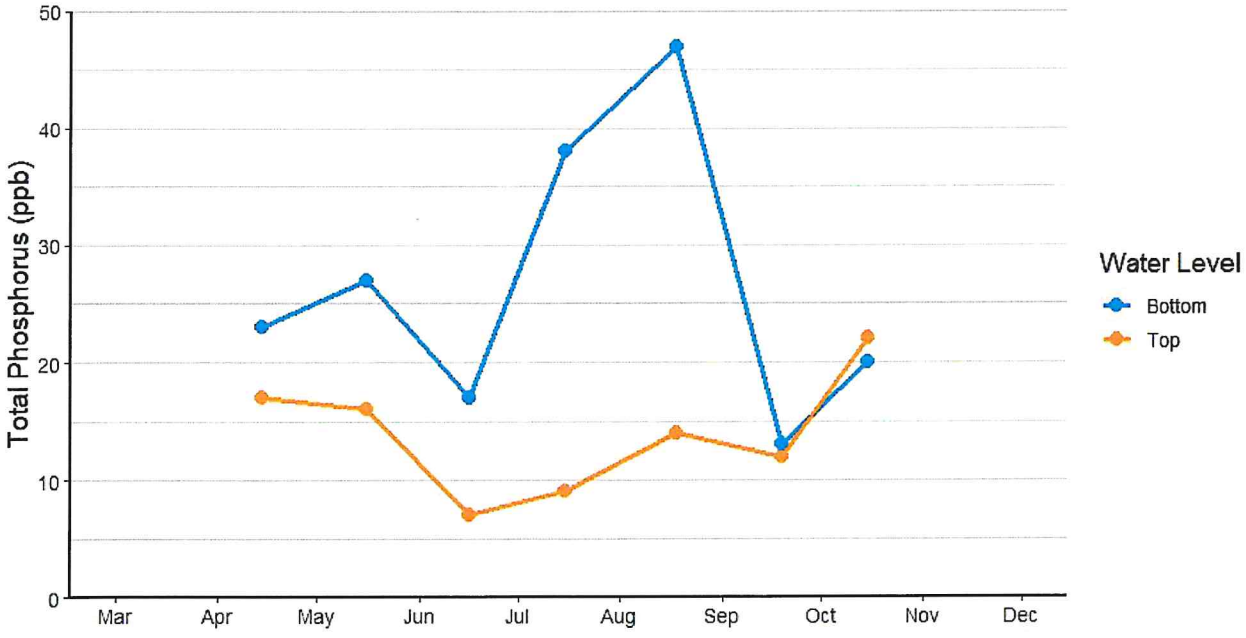
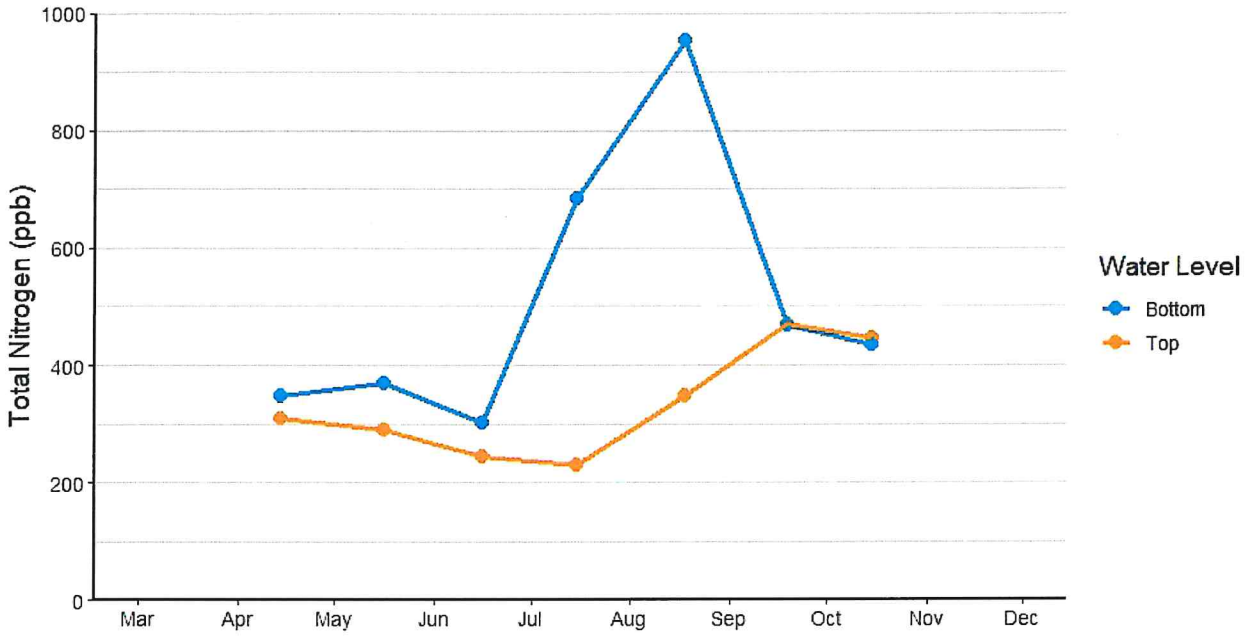


Figure 5. 2023 total nitrogen concentrations.



Aquatic Plants

The aquatic plants in Lower Bolton Lake were surveyed on June 22nd and September 19th 2023.

During the June 22nd survey, 10 aquatic plant species were found in the lake, along with Filamentous Algae (**Table 2**).

Potamogeton amplifolius (Large-leaf Pondweed), *Nitella sp.* (Stonewort), and *Najas guadalupensis* (Southern Naiad) were dominant, meaning they were present at greater than 20% of all survey waypoints (**Maps 1 – 3**).

Single *Potamogeton crispus* (Curly-leaf Pondweed) plants were found in two locations on the lake's northeast shore (**Map 4**). All plants were immediately pulled and removed from the lake.

Clouds of Filamentous Algae were present in several locations along the lake's shoreline (**Map 5**). Filamentous algae is often found in areas of elevated nutrient concentrations, such as at the mouth of inlets that carry excess nutrients into the lake.

13 aquatic plant species were observed during the September 19th survey (**Table 2**). The same three species were dominant.

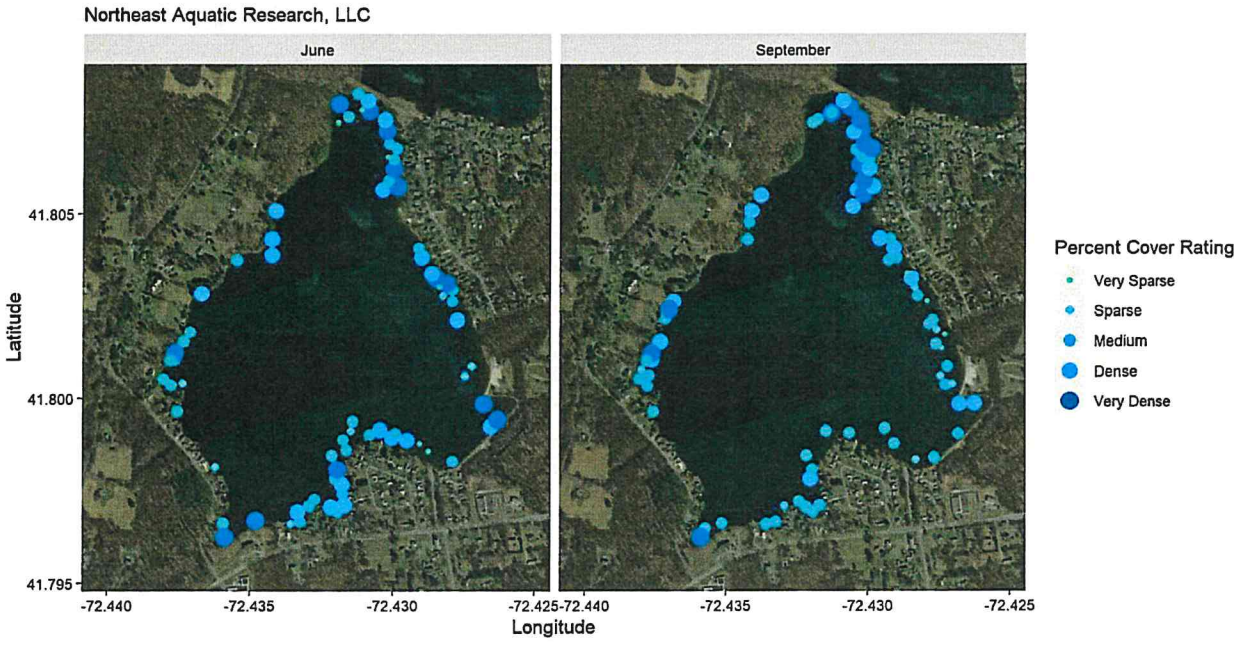
Curly-leaf Pondweed was not found in the lake in September, but the invasive species *Glossostigma cleistanthum* (Mudmat) was found in two locations (**Map 6**). Mudmat is a very small, low-lying plant that grows in shallow water with sandy substrate.

Southern Naiad coverage increased between June and September (**Map 3**). Though this species is native, it has the potential to become a nuisance.

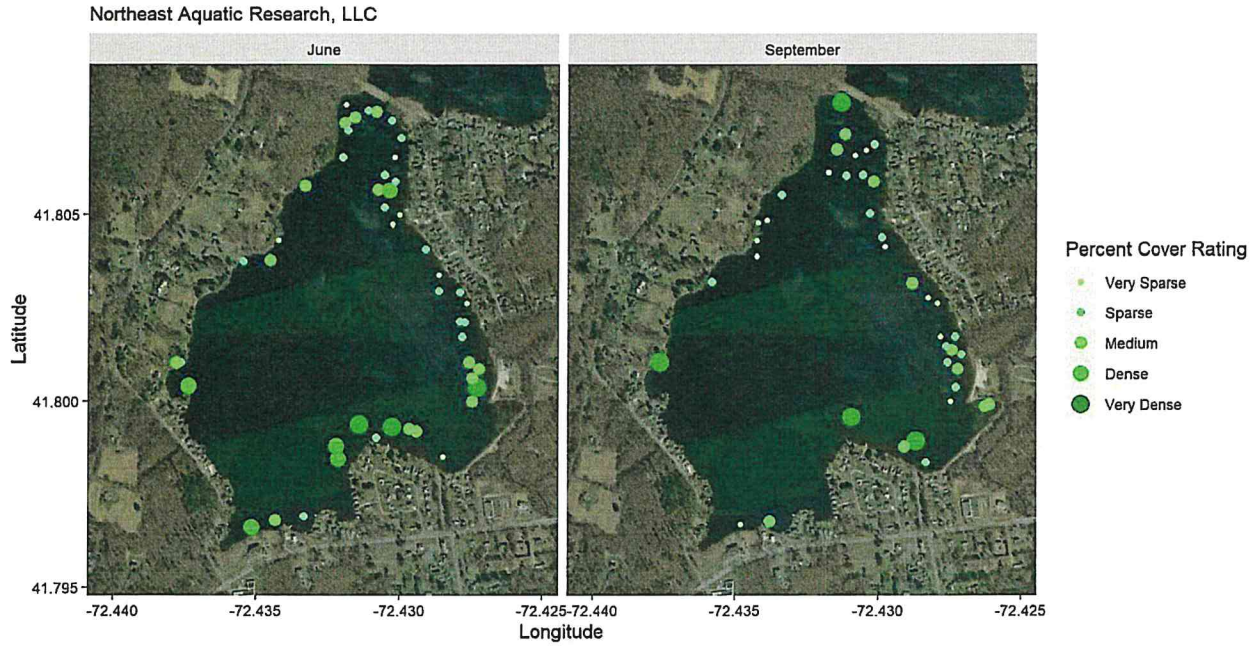
Table 2. Aquatic plant species present in Lower Bolton Lake in June and September 2023. Red text indicates invasive species. Blue text indicates dominant species.

Scientific Name	Percent Frequency		Average Density	
	June	September	June	September
Ceratophyllum demersum	NA	0.5	NA	100
Chara sp	NA	4	NA	12
Eleocharis acicularis	2	0.5	10	5
Glossostigma sp.	NA	1	NA	18
Isoetes sp.	1	NA	20	NA
Najas flexilis	7	NA	18	NA
Najas guadalupensis	22	35	28	40
Nitella sp	30	21	26	21
Nymphaea odorata	1	NA	30	NA
Potamogeton amplifolius	47	37	45	48
Potamogeton bicupulatus	1	0.5	40	1
Potamogeton crispus	1	NA	1	NA
Potamogeton epihydrus	NA	0.5	NA	10
Potamogeton pusillus	NA	1	NA	33
Utricularia gibba	NA	0.5	NA	1
Utricularia radiata	NA	1	NA	3
Vallisneria americana	6	8	32	33
Filamentous algae	5	NA	15	NA

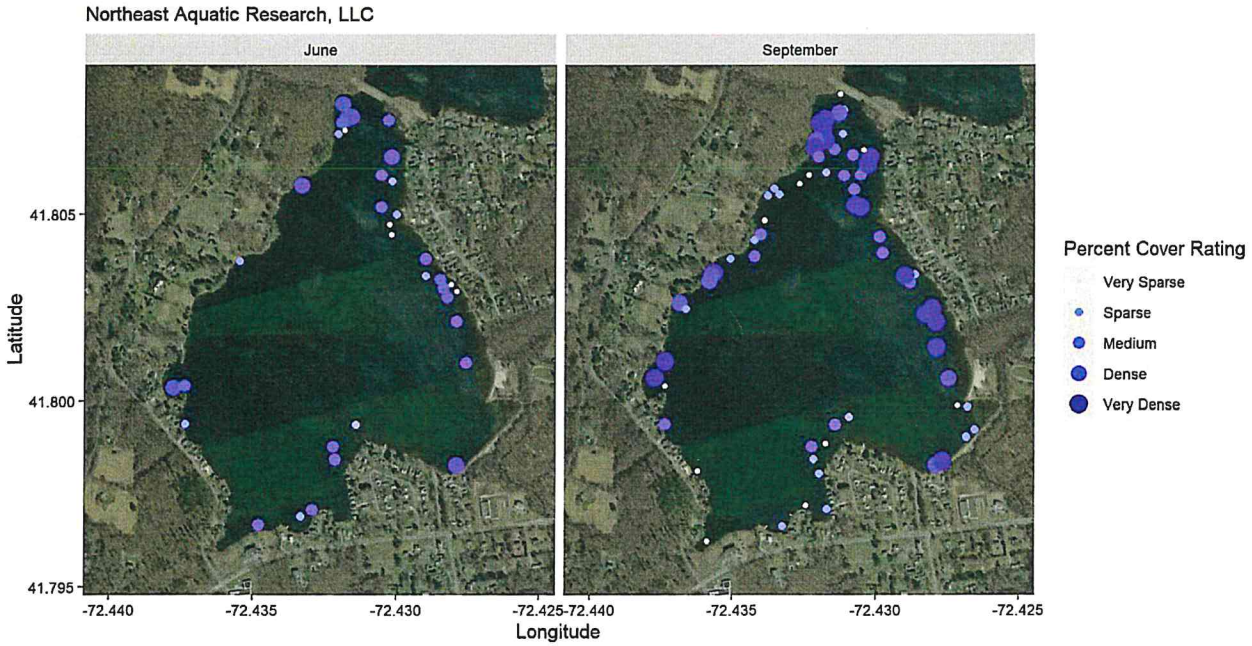
Map 1. Locations and densities of Large-leaf Pondweed (Potamogeton amplifolius) in June and September, 2023.



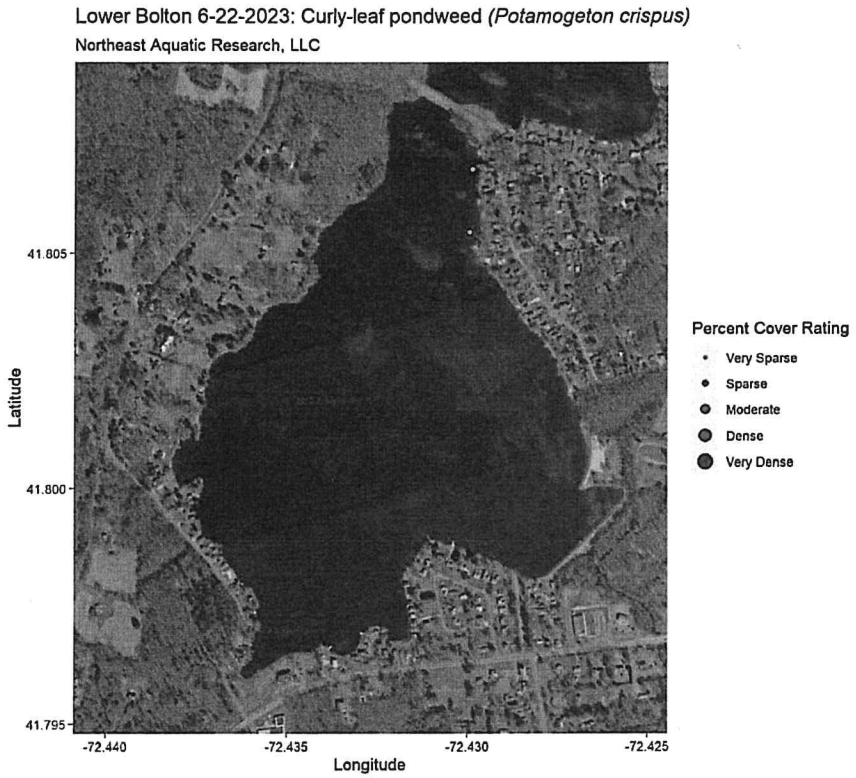
Map 2. Locations and densities of Stonewort (Nitella sp.) in June and September 2023.



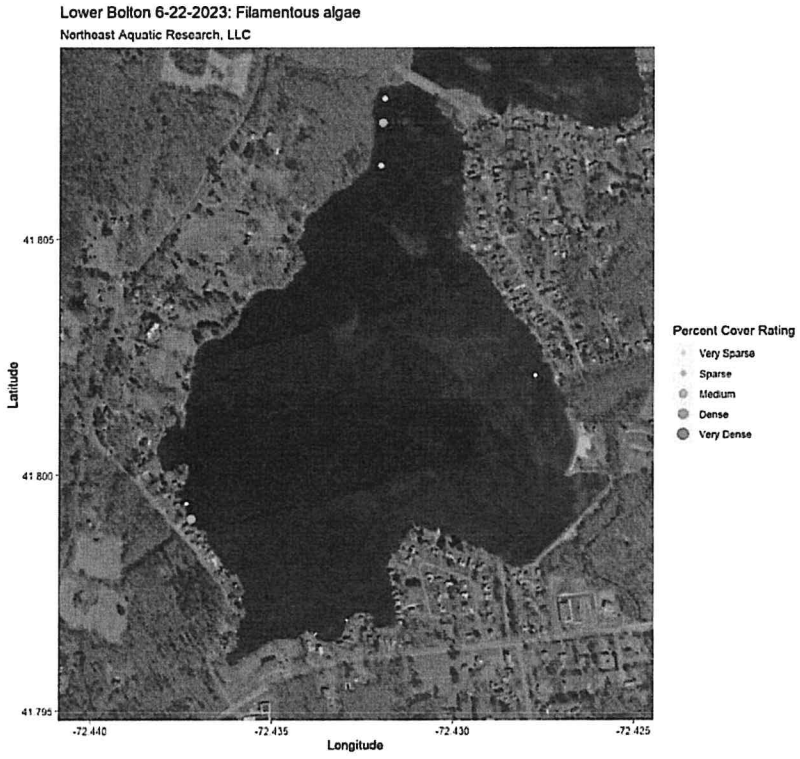
Map 3. Locations and densities of Southern Naiad (Najas guadalupensis) in June and September 2023.



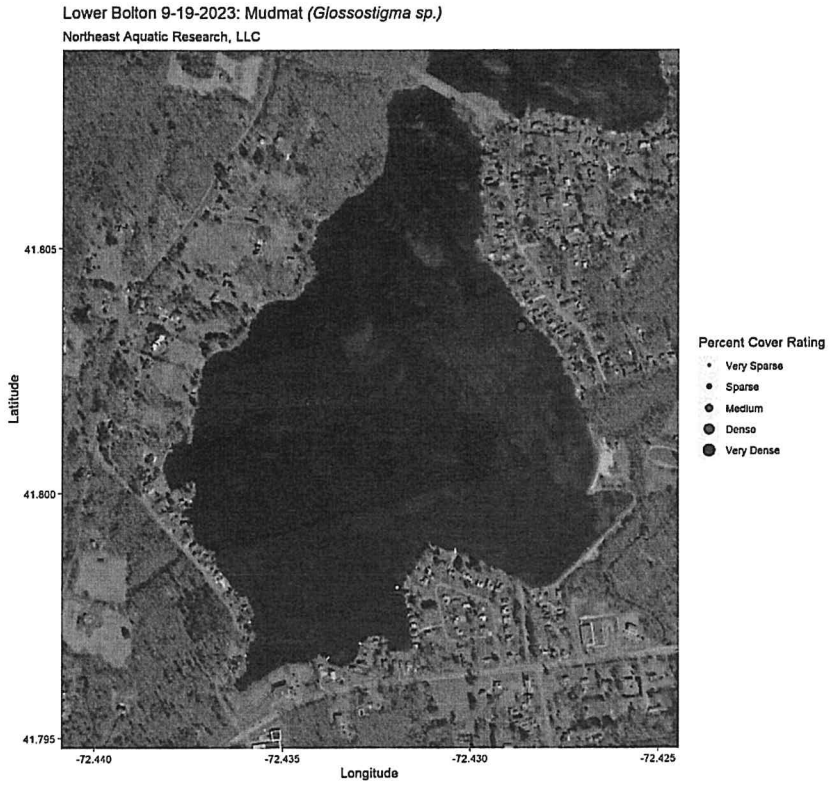
Map 4. Locations of Curly-leaf Pondweed (Potamogeton crispus) in Lower Bolton Lake during June 2023 survey.



Map 5. Locations of Filamentous Algae in Lower Bolton Lake during June 2023 survey.



Map 6. Locations of Mudmat in Lower Bolton Lake during September 2023 survey.



Conclusions / Recommendations

Volunteer monitors should conduct monthly water quality monitoring at Station 1 (the deep spot) from March through November in 2024. Water temperature and dissolved oxygen should be measured to the very bottom of the deep spot. For example, if the water is 6 meters deep, the last two profiles measurements should be taken at 5 meters and 5.9 meters.

We recommend NEAR host a volunteer monitor training at the beginning of the 2024 monitoring season as a refresher and to ensure that all data is collected accurately.

In addition to analyzing the water samples for total phosphorus and total nitrogen, we recommend also testing the bottom water samples for ammonia concentration in June, July, August, and September 2024.

A survey should be conducted in early May to search for the invasive species Curly-leaf Pondweed. If any Curly-leaf Pondweed plants are found, the plants should be hand-pulled or removed via Diver Assisted Suction Harvesting, depending on how many plants are found. Hydrilla will also be looked for, but from experience, May is too early in the season to find Hydrilla.

A second survey should be conducted in August. This survey should be comprehensive, covering the entire littoral zone and documenting the presence and density of all plants in the lake. Special attention should be given to searching for the invasive species *Hydrilla verticillata*, which was found upstream in Middle Bolton Lake in 2023. If any Hydrilla is found, a permit needs to be secured from the state for a whole lake fluridone treatment.

Southern Naiad was abundant in the lake in both June and September 2023. This species can grow in deeper water than many other aquatic plant species, so far being found out to 7 feet of water. A survey to document the overall growth of Southern Naiad would be best conducted in September. This survey should include searching for Southern Naiad in deep water ~10 of water depth. Following this survey, we will be able to estimate the total coverage of Southern Naiad in the lake and determine whether treatment of the species is necessary.

A full analysis of the water quality data, specifically the nutrients phosphorus and nitrogen, should be conducted after the 2024 season to ascertain if sanitary sewers around Lower and Middle Bolton Lakes has led to a decrease in nutrient concentrations in the lake.