Data Scorecard and Action Plan

1000 New York Avenue, Suite B ● Huntington Station, NY 11746 ● 631.760.9300

To:	Ms. Jacqueline Annabi
From:	Alejandro Reyes, CLM and Project Manager
cc:	Luke Gervase, CLM
Date:	January 2025
Re:	Roaring Brook Lake Data Scorecard Town of Putnam Valley Putnam Valley, New York
Project No.:	2405201

GEI Consultants Inc. (GEI) is pleased to present this summary of 2024 monitoring and data scorecard to the Town of Putnam Valley (TOPV) and the Roaring Brook Lake Property Owners Association (RBLPOA).

Summary of Monitoring Events

Building off the previous years' sampling and action plan for Roaring Brook Lake, the lake was monitored for water quality at one station from June to October 2024. Although no tributary monitoring occurred this season, aquatic plant sampling was conducted.

In-Lake Water Quality Monitoring

Methodology

In-lake monitoring in 2024 consisted of five monitoring trips from June to October (once per month except in September which was conducted in early October instead) sampling the south lake main station (Station 1).

At the monitoring station, water clarity data was collected using a viewscope and Secchi disk. Both clarity readings with and without the viewscope are taken to stay consistent with past Citizen Statewide Lake Assessment Program (CSLAP) methodology (without scope) and to provide a more accurate reading (with scope). Temperature and oxygen profiles were taken at 0.5-meter increments from the surface to the bottom of the lake using a Aquatroll 500 multiparameter probe with sensors calibrated according to manufacturer's specifications.

During the August sampling, anomalous dissolved oxygen readings were detected. GEI investigated the issue and found an issue with the dissolved oxygen sensor. GEI rectified the issue; however the August profile may not be accurate. GEI has decided to present the data with the caveat of the issues with the dissolved oxygen sensor, as we still feel that the overall trend of the profile is accurate even though the absolute DO concentration values may be inaccurate.

Nutrient samples at Station 1 were taken at three depths (0.5 meters, 2.5 meters, and 4.5 meters) and were analyzed for total phosphorus (TP), total nitrogen (TN), and ammonia. Cyanobacteria samples were taken using a 3-meter integrated hose sampler.

Evaluating Lake Water Quality Status

While state standards for TP and Secchi disk readings exist, these standards represent the worst case, do not exceed values, and are not directly relevant to Roaring Brook Lake. The lake does not come close to exceeding each value throughout the season, so a more conservative evaluation system specific to Roaring Brook Lake is needed.

GEI is proposing a three-part water quality evaluation system for each key parameter. This is intended to take advantage of all the past data collected in the lake and to examine long-term trends, not only single values. The proposed system is as follows:

- Each parameter receives a score out of three at the end of the field season. One point is awarded if the seasonal average does not exceed the established upper threshold value. When parameters exceed the threshold value, lakes are at risk for high algal abundance and frequent desired use impairments such as swimming closures, etc.
- One point is awarded if the seasonal average for the parameter exceeds, or is at, the optimal value, which is a value that we would ideally like to see the lake maintain. These optimal values are indicative of extremely low algae favorable conditions, where harmful algae blooms (HABs) are not expected to be present at all.
- One point is awarded if the trend is not increasing over a 5-year period. This is intended to capture declines in water quality that do not reach to the level of the upper threshold. Declines in water quality parameters are not good signs for the lake, even if the values themselves are not of concern individually. A 5-year timeframe is used to account for yearly differences in precipitation and weather. For cyanobacteria cell counts, we used the average of total cyanobacteria cell counts (collected throughout the season to determine if a point is awarded for the long-term trend).
- For example, for a given year if water clarity averages 2.5 meters over the summer season, and the values have not been decreasing over a 5-year period, the water clarity year's score would be a 2/3. One point was awarded because the seasonal average was greater than 2 meters and one point was awarded because there was no decrease in values over the 5-year period. Since the value was not greater than the optimal value, a third point was not awarded.

The parameters included in this measure include:

Table 1. Parameters included in the Optimal and Threshold Value Matrix for Evaluating Lake Status

Parameter	Optimal Value	Threshold Limit
Water Clarity	>3 meters	<2 meters
Surface Total Phosphorus	<10 µg/L	>20 µg/L
Surface Total Nitrogen	<200 µg/L	>600 µg/L
Cyanobacteria Cell Counts	<2,000 cells/mL	>20,000 cells/mL

Scores across all parameters can be summed to give the lake an overall score for the year. This score can be tracked over time to evaluate how the lake has been faring in terms of water quality. The TOPV and RBLPOA monitoring scheme for future years should aim to continue to adequately sample for all these parameters at least monthly or on a more frequent basis.

Results

Data Scorecard

Table 2. Data Scorecard for Roaring Brook Lake in 2024

Parameter	Seasonal Average at or Better than Optimal Value	Seasonal Average Not Above Threshold Value	Long Term Trend	2024 Score
Water Clarity (m)	0	1	1	**2**
Surface Total Phosphorus (µg/L)	0	0	1	**1**
Surface Total Nitrogen (µg/L)	0	1	1	**2**
Cyanobacteria Cell Counts (cells/mL)	0	1	1	**2**
Total	**0/4**	**¾**	**2/4**	**7/12**

The 2024 score matches the score from 2023, however there is a difference in the parameter scores. Namely, the TP seasonal average did not meet the threshold value in 2024, and the cyanobacteria cell counts did. This is likely a result of two higher than normal TP values recorded in June and October of 2024. Nuisance conditions of algae such as blooms or significant water discoloration were not reported, so GEI feels that recreation was not significantly impeded.

Water Clarity

Water clarity in 2024 was desirable throughout the recreational season (Fig. 1), with the greatest clarity measured in early August (3.9 meters). Clarity values worsened (water became less clear) as the season continued, but did not drop below the 2-meter threshold this season. Mean clarity in 2024 was slightly improved compared to 2023, but for the most part has stayed similar for the past 5 years (Fig. 2).

Figure 1. Water Clarity Measurements (without a viewscope) from 2024 Provided by GEI (CSLAP data for 2023 not yet released at time of report). Red dashed line indicates the New York State narrative limit for eutrophic waterbodies at 2 meters. Blue line indicates the optimal value of 3 or more meters.

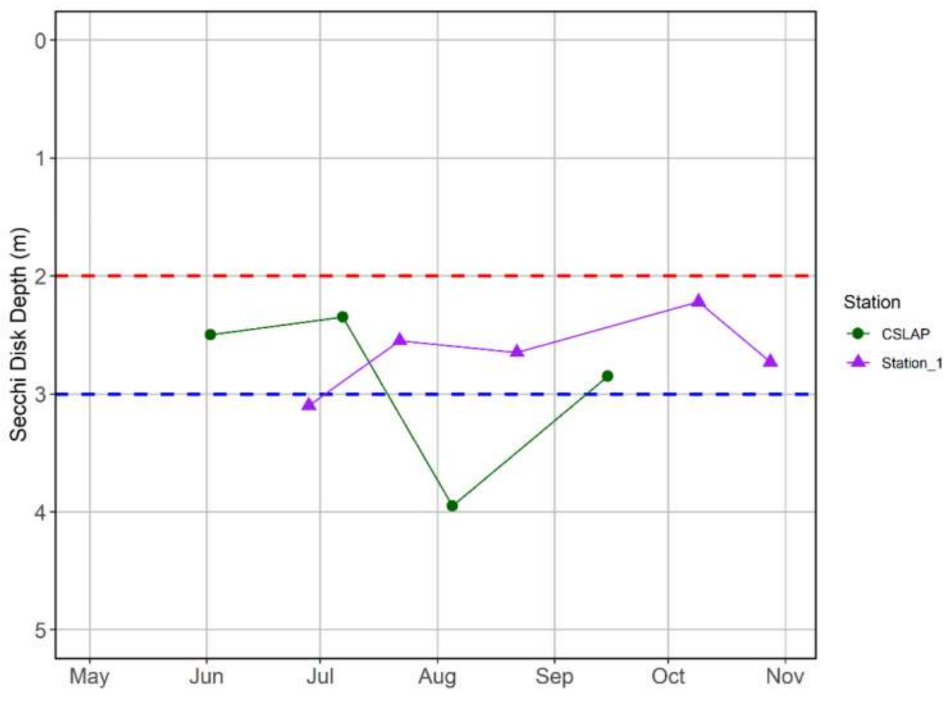
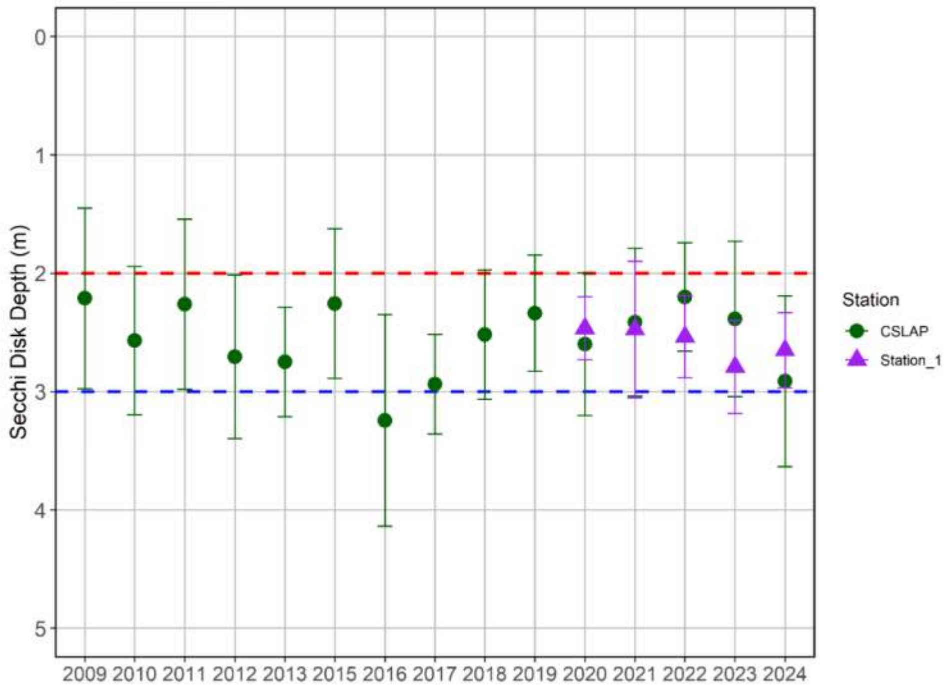


Figure 2. Water Clarity Measurements (without a viewscope) for all historical data collected on Roaring Brook Lake. Data sources include CSLAP data (green circles) and NEAR/GEI monitoring Station 1 (purple triangle). Red dashed line indicates the threshold limit (2 m), and the blue line indicates the optimal value (3 m). Error bars represent one standard deviation.

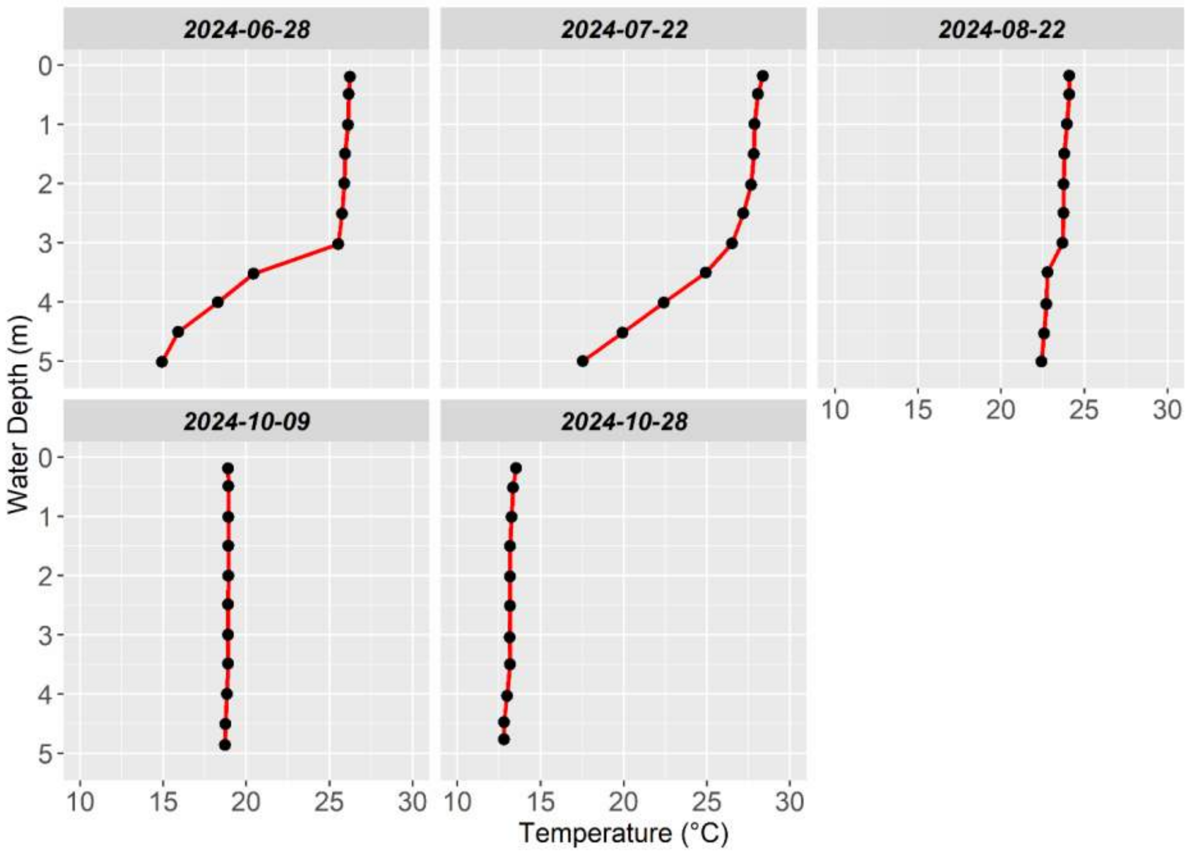


Temperature

Lake temperature profiles followed a typical seasonal pattern. Thermal stratification is strong in June and July with a mixed epilimnion stretching from the surface to about 3 meters deep (a general rule of thumb is that the larger the difference between the surface and bottom temperature values on temperature plots, the stronger the stratification; Fig. 3). In August, the lake appears to have undergone recent mixing with relatively uniform temperatures throughout the water column and slightly cooler temperatures at the bottom. This is likely a result of the heavy rain that happened a few days prior to sampling (2.12 inches on August 19, 2024; CLIMOD2 Station: SHRUB OAK) and the cold front that occurred the day before and day of. October shows a significant drop in water temperature and continued mixing throughout the water column.

Compared to last year's temperature data, the temperature patterns of the lake in 2024 were different than observed in the water column in 2023. This is likely a result of the relatively unusual year that was 2023 in which most months had relatively uniform, temperature throughout the water column caused by rainfall and temperature patterns. In 2024, there is clear thermal stratification with a metalimnion extending from 3 meters to the bottom. There were similarities between the two years as well, including when the lake appears to reach uniform temperature approximately the same time (mid-August), and the evident cooling temperature pattern observed in the month of October. The year 2024 was more similar to previous years temperature data such as 2022, in which thermal stratification was strong in the summer, with the metalimnion beginning about 3 meters deep.

Figure 3. Water Temperature Profiles from Station 1 in 2024.



Roaring Brook Lake's average thermocline depth, epilimnion depth, and hypolimnion thickness was calculated for each year from 2019 to 2024. The thermocline in a lake is the depth at which the greatest change in temperature occurs. The average thermocline depth ranged from 2.8 to 4.4 meters with an average of 3.6 meters across all years (Table 3). The epilimnion, or the upper layer of the lake in which every meter is within 1°C, ranged from 2.1 to 3.0 meters in depth averaging 2.6 meters across all years. The hypolimnion, or the lower layer of the lake in which every meter is within 1°C, ranged from 0.0 to 1.0 meters. Typically, the hypolimnion was 0.0 meters thick, or nonexistent, because the metalimnion extended to the bottom of the lake or the lake was fully mixed (meaning no distinct layers). However, a few years had instances in which a hypolimnion was present on one or multiple dates, leading to an average thickness greater than zero. 2024 represented an average year in terms of thermal structure. Due to the shallow depth of Roaring Brook, it is expected that the thermal structure would shift year to year, based on temperature, precipitation and wind patterns.

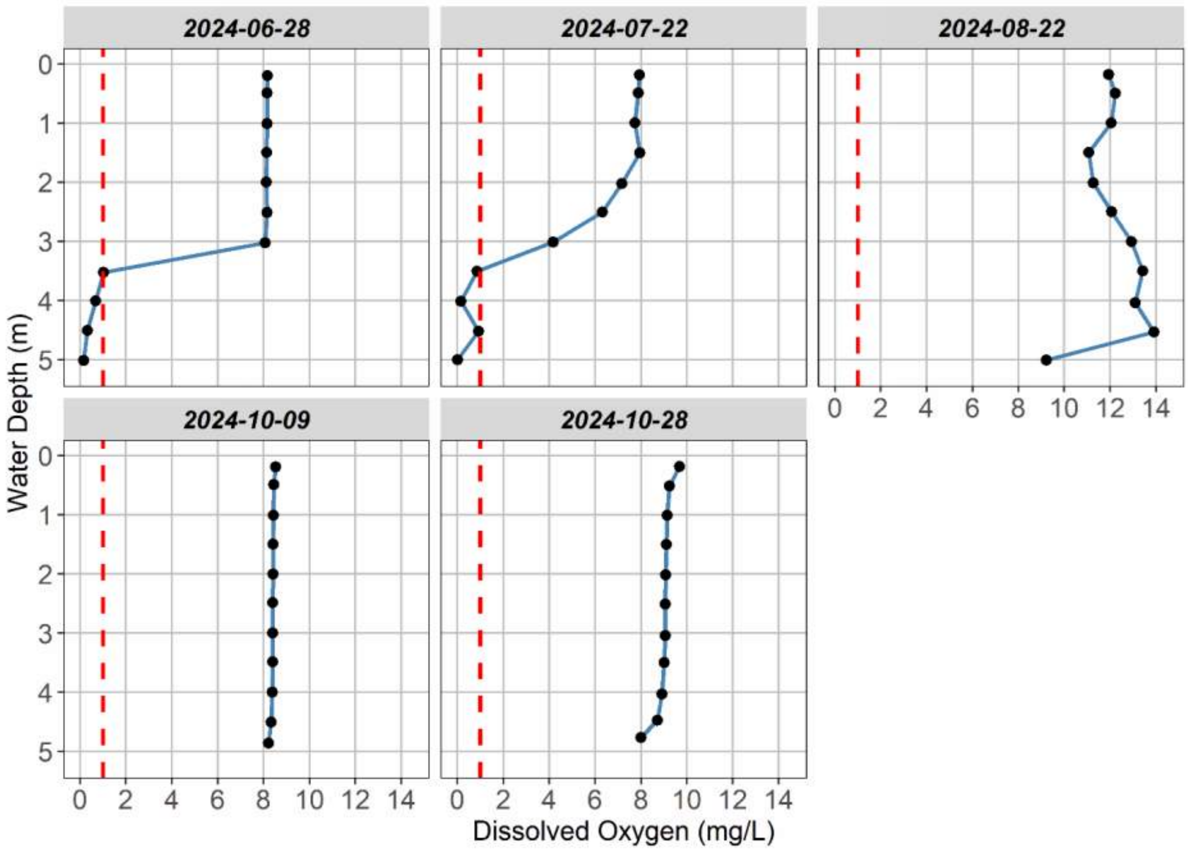
Table 3. Average Thermocline Depth, Epilimnion Depth, and Hypolimnion Depth for 2019 to 2024 at Station 1

Year	Average Thermocline Depth (m)	Average Epilimnion Depth (m)	Average Hypolimnion Thickness (m)
2019	3.6	3.0	0.0
2020	3.5	2.3	202
2021	3.8	2.8	0.2
2022	4.4	2.4	0.0
2023	2.8	2.1	1.0
2024	3.5	2.8	0.5

Dissolved Oxygen

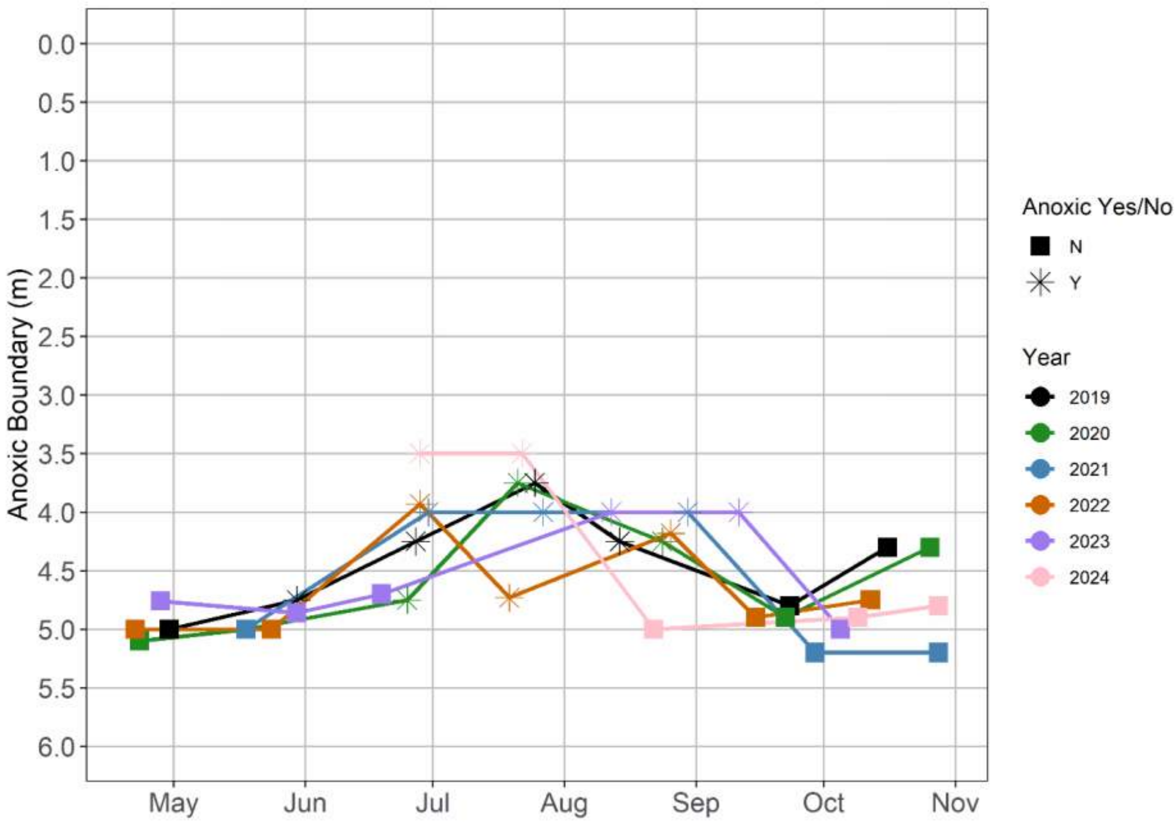
In 2024, the average surface and bottom dissolved oxygen concentrations at Station 1 were the highest observed concentrations (9.3 and 5.1 mg/L respectively) than any previously sampled year (2019 to 2023). All surface concentrations were higher than the 5.0 mg/L minimum daily average standard set by the New York State Department of Environmental Conservation (NYSDEC; Fig. 4). Bottom DO concentrations in 2024 were anoxic (less than 1 mg/L), in the months of June and July as is the usual pattern for Roaring Brook Lake. August did not have anoxia as is typical in previous years, which could be a result of the later August sampling date, or an artifact of the DO sensor issues (Methodology Section) during the month of August which could have produced inaccurate readings.

Figure 4. DO Profiles from Station 1 in 2024. Values left of the red dashed line indicate anoxic (less than 1 mg/L) conditions. Please note that on the August 22nd visit, the DO probe was broken and although the absolute numbers may be off, the trend of DO loss is probably correct. The rest of the probes were functioning properly which is why this does not affect any other data.



The anoxic boundary in 2024 showed a slightly different pattern than previous years (Fig. 5). The anoxic boundary present in June and July of 2024 was shallower than any previous year. Additionally, unlike previous years, anoxic water was not present in August. Although data for months prior to June is not present, the anoxic boundary tracked with previous years. It is important to track the anoxic boundary over time as this is an indicator of the severity of the internal nutrient load. The higher the boundary in the water column, the more sediment area is exposed to anoxic conditions, increasing the area that can release phosphorus and nitrogen into the water column. The anoxic boundary this year was only shallower by a quarter meter from historic values so it is not alarming, but it should continue to be monitored.

Figure 5. Anoxic Boundary at Station 1 in 2019 to 2024. Star and square point shapes indicate either anoxic (star) or oxic (DO concentrations greater than 1 mg/L; square) sampoling dates. For example, for the sampling on July 22, 2024, there was anoxic water present at an estimated depth of 3.5 meters, while on October 28, 2024, all DO values were above 1 mg/L, hence no anoxic water (only squares).



Total Phosphorus

In 2024, surface TP concentrations were the highest recorded compared to historical concentrations, averaging 23.0 µg/L (Fig. 6). The high average is likely due to two dates of high concentration TP, one in June (34.1 µg/L) and one in October (48.9 µg/L). Despite the high concentration of TP in June, the water clarity on that date did not decrease, in fact it was the best clarity value of the season reaching just deeper than 3 meters. The disjointed water clarity and TP concentration, suggests that the high TP concentration values did not translate into algae growth that influenced clarity. In October, the high TP concentration correlated with the worst water clarity of the season, but still was deeper than the 2 meter threshold value. Once a year, the bottom TP concentrations tend to spike. This year, the spike in bottom TP occurred on October 9th, which exhibited mixing temperature conditions. This could explain the elevated surface TP concentrations on that date. Surface TP concentrations over time have varied between 10 and 20 µg/L with recent years having concentrations over 30 µg/L. The low TP concentrations observed over the past few years makes it difficult for the lake to sustain thick, lake wide algae blooms as seen in other local lakes. Cyanobacteria can still grow and proliferate in Roaring Brook Lake, as evident by the infrequent shoreline algae scums that are reported. Low phosphorus concentrations in the surface waters are likely the difference between the scum showing up and going away in a few hours versus sustained, lake-wide blooms that will close swimming for the entire season.

Bottom phosphorus concentrations resembled previous years, exhibiting a spike a bit later than usual in early October, but low concentrations in the rest of the months (Fig. 7). Surface and middle phosphorous concentrations were low all year with little to no evidence of spiking, matching previous years monitored.

Figure 6. Surface TP for all historical data collected on Roaring Brook Lake during the summer season (June through September). Data sources include CSLAP data (green circles) and NEAR/GEI monitoring Station 1 (purple triangle). Red dashed line indicates the threshold limit (20 µg/L), and the blue dashed line indicates the optimal value (10 µg/L). Error bars represent one standard deviation.

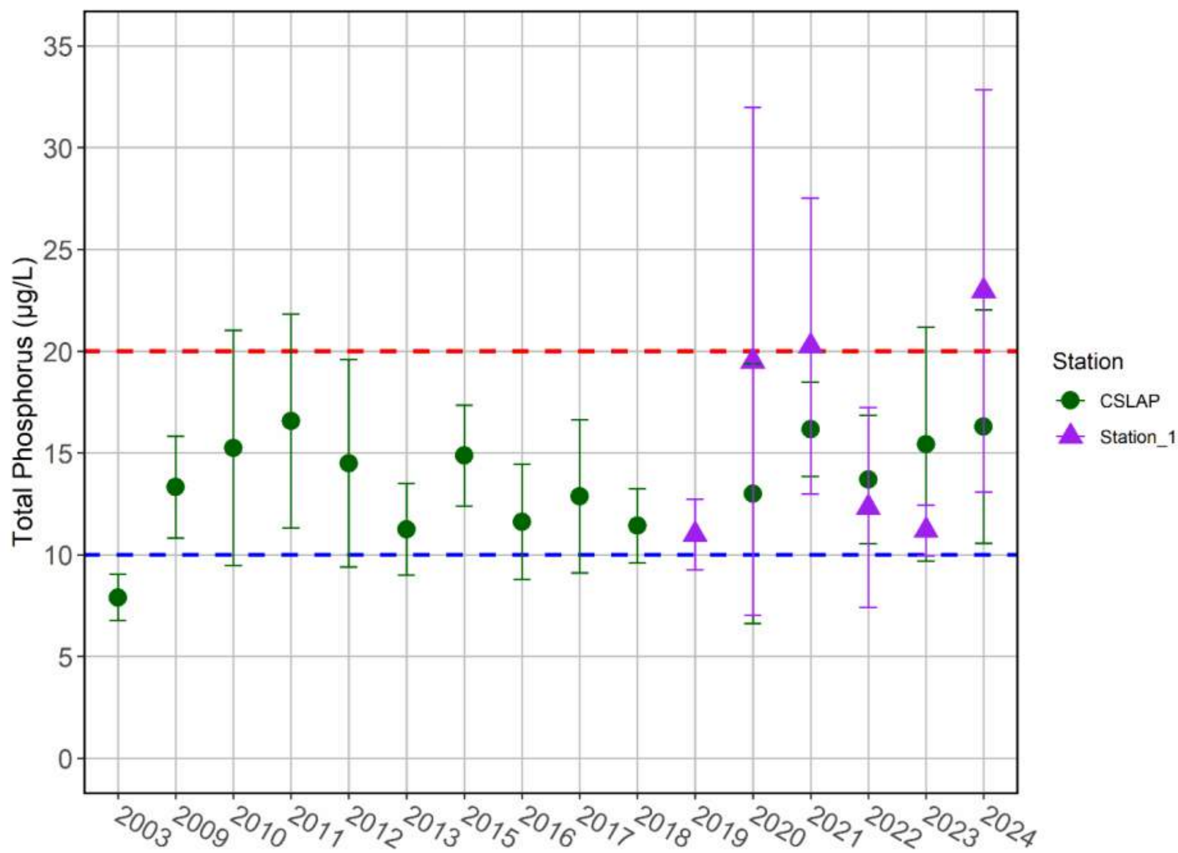
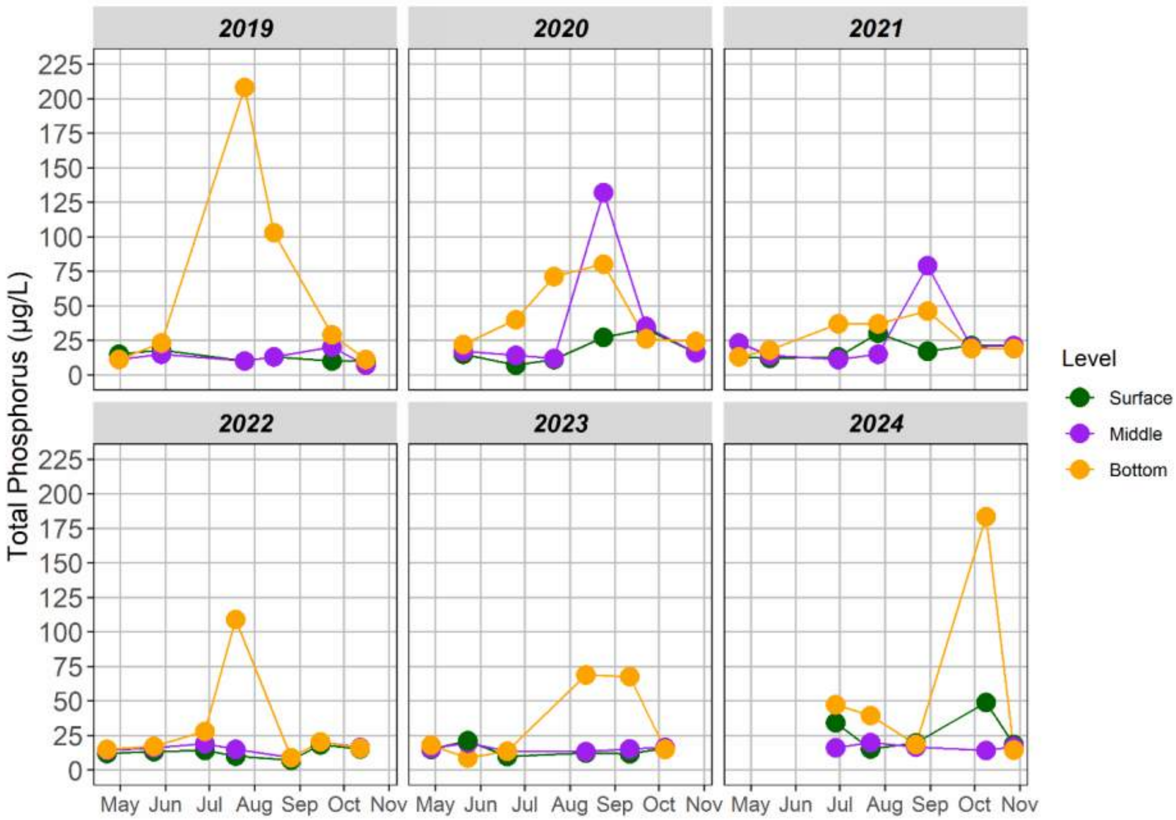


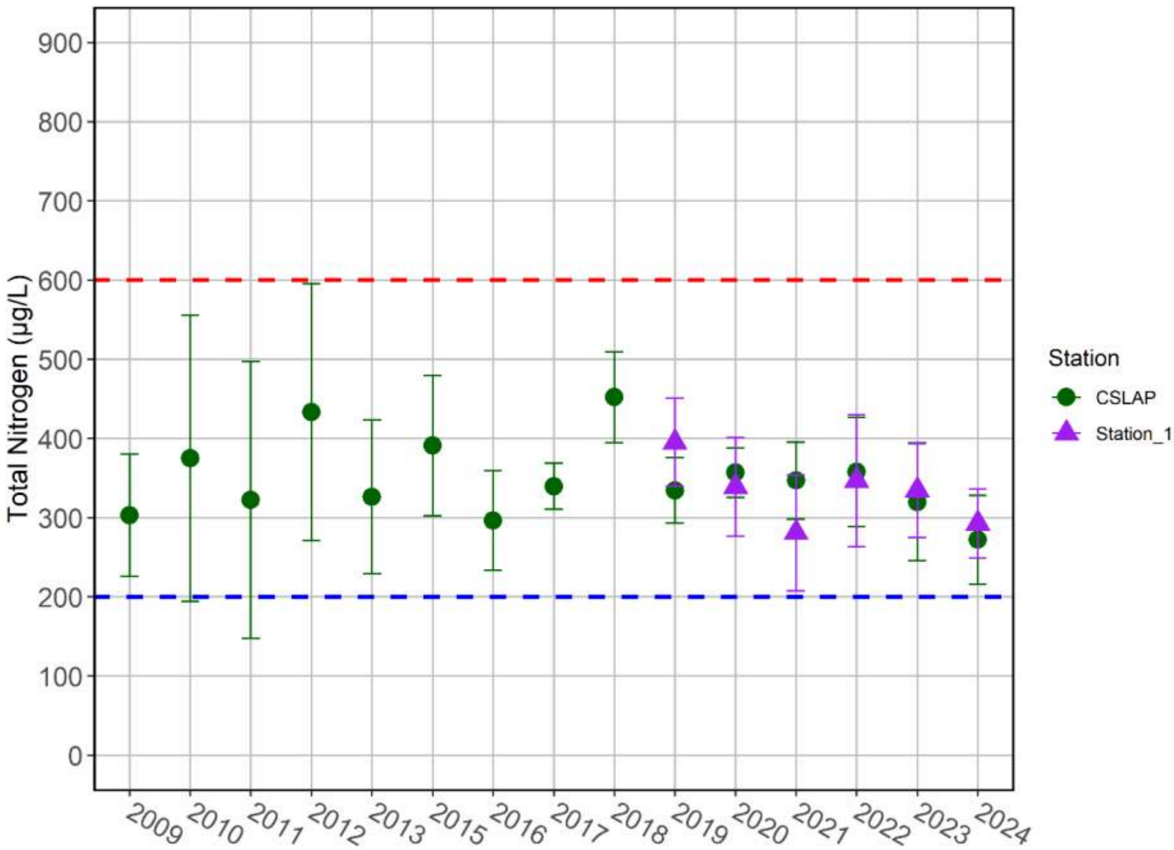
Figure 7. Surface, middle, and bottom TP concentrations on Roaring Brook Lake from 2019 to 2024



Total Nitrogen

The TN concentrations in 2024 at Station 1 averaged 293 µg/L which is slightly lower than the average concentrations in the past 5 years (Fig. 8). Historically, TN has varied between 300 and 500 µg/L and there has not been any consistent increase or decrease in TN trends over the entire sampling period, but there does seem to be a decrease in concentration from 2018 to 2024 . Lakes with high TN concentrations have excessive growth of filamentous algae and floating aquatic plants like duckweed (*Lemna minor*). Fortunately, this has not been documented on Roaring Brook Lake.

Figure 8. Surface TN for all Historical Data Collected on Roaring Brook Lake during the Summer Season (June through September). Data sources include CSLAP Data (green circles) and NEAR Station 1 (purple triangle). Red dashed line indicates the threshold limit (600 µg/L) and the blue line indicates the optimal value (200 µg/L). Error bars represent one standard deviation. Please note that an outlier value from the 2020 CSLAP data set was removed in the data above.



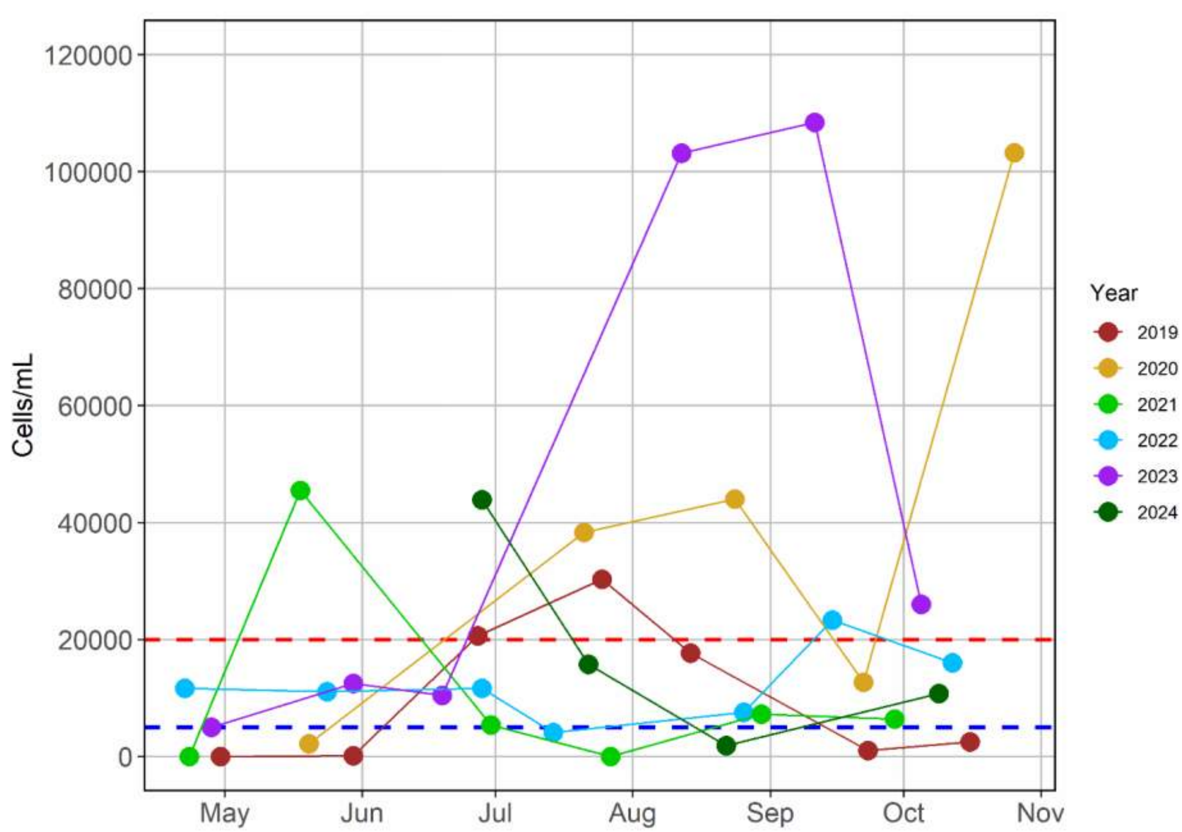
Cyanobacteria Cell Counts

The June sampling had the highest cyanobacteria density, followed by July and then October (Table 4). *Cyanodictyon* was the dominant genera in June as well as October. Common toxin producers such as *Dolichospermum* and *Microcystis* were present during all sample periods, but in low abundances. The total cell counts in 2024 were generally lower than previous years, except for June (Fig. 9).

Table 4. Cyanobacteria Genera Cell Counts for Samples During the 2024 Season.

	6/28/2024	7/22/2024	8/22/2024	10/9/2024
Anathece	0	0	0	1200
Cyanodictyon	40045	376	0	8505
Cyanogranis	0	14835	0	97
Dolichospermum	1481	270	1732	421
Limnococcus	11	1	0	33
Merismopedia	30	0	0	0
Microcystis	496	9	77	427
Oscillitoria	0	0	0	2
Planktothrix	0	0	7	0
Pseudanabaena	0	46	0	0
Synechococcus	121	0	0	0
Unidentified Cyanobacteria	0	194	0	48
Woronichinia	1	0	0	29
Totals	43865	15762	1816	10765

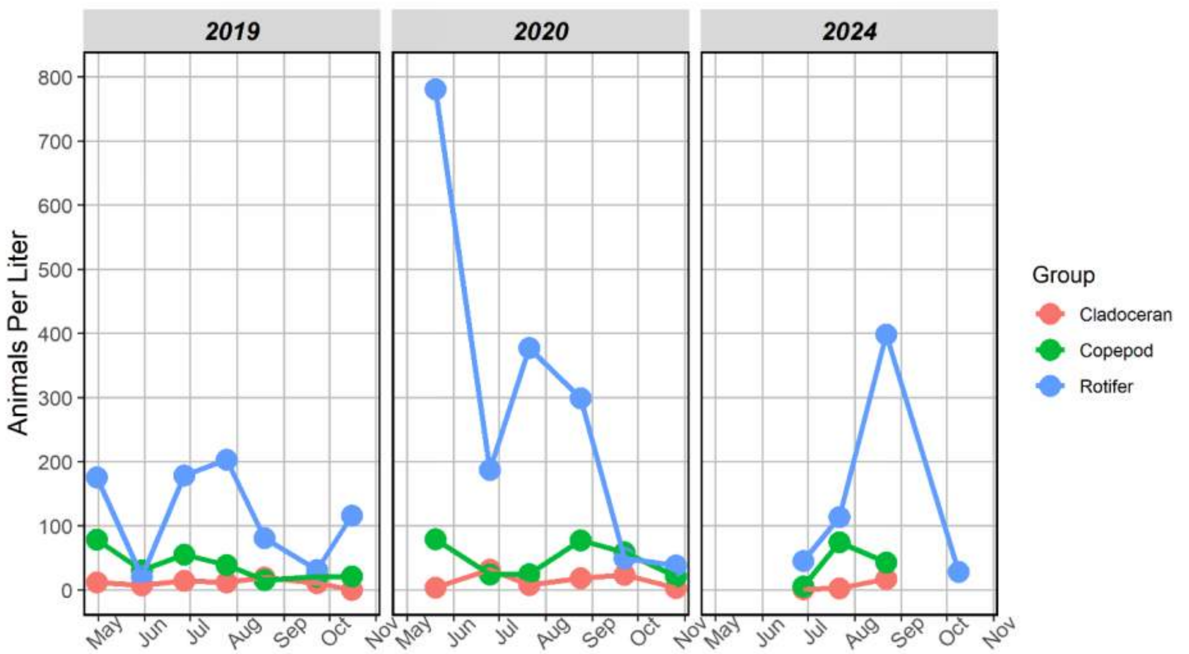
Figure 9. Cyanobacteria Cell Counts all Historical Data Collected on Roaring Brook Lake during the Summer Season (June through October). Red deashed line indicates the threshold limit (2,000 cells/mL) and the blue line indicates the optimal value (5,000 cells/mL).



Zooplankton

Total zooplankton abundance was lower in 2024 as compared to 2020 but was generally in line with 2019 results (Fig. 10). Rotifers dominated the community numerically in 2024 followed by copepods, then cladocerans. The dominant cladocerans in 2024 were *Daphnia sp*., which was similar to past years (Northeast Aquatic Research 2020; 2021). Cyclopoids dominated the copepod assemblage in 2024 as seen in previous years, however calanoids were present each year (Fig. 11). Ratio of calanoids to cyclopoids in lakes has been proposed as an indicator of eutrophication, as calanoids are considered sensitive to increase in nutrient concentrations (Min et al. 2021).

Figure 10. Zooplankton Group Abundance in 2019, 2020, and 2024.



Length distributions of cladocerans and copepods in 2024 were similar to previous years, with most sizes falling in the 0.4 to 0.6 range. The dashed lines in Figs. 11 and 12 indicate the fish predation threshold for lakes. If most of the zooplankton lengths are below 0.6mm, fish predation (planktivory) is presumed to be significant for the ecosystem, as larger plankton would have been removed, reducing the filtering capacity (Brooks and Dodson 1965). If most zooplankton lengths are above 0.6mm, planktivory is not significant for the ecosystem. Fish herbivory is size selective, meaning that fish usually feed on the larger individuals, with smaller zooplankton being prey to only larval fish and other zooplankton/invertebrates. Mean zooplankton lengths in 2024 were similar to 2020, but slightly lower than in 2019 (Fig. 12). The zooplankton length data indicates that the population is relativly unaffected by fish herbivory, with mean lengths close to 0.6mm in all years. The dominance of *Daphnia sp.* Instead of a smaller bodied cladoceran such as *Bosmina sp*. or *Ceriodaphnia sp.* is an indication that fish herbivory is not dominant. This is supported by the most recent fisheries survey (Northeast Aquatic Research 2021), which did not show any large planktivorous fish populations such as alewife or white perch.

Figure 11. Length Frequency Distribution of Copepods and Cladocerans in Roaring Brook Lake in 2019, 2020, and 2024. The vertical dashed line indicates the threshold size for significant fish predation.

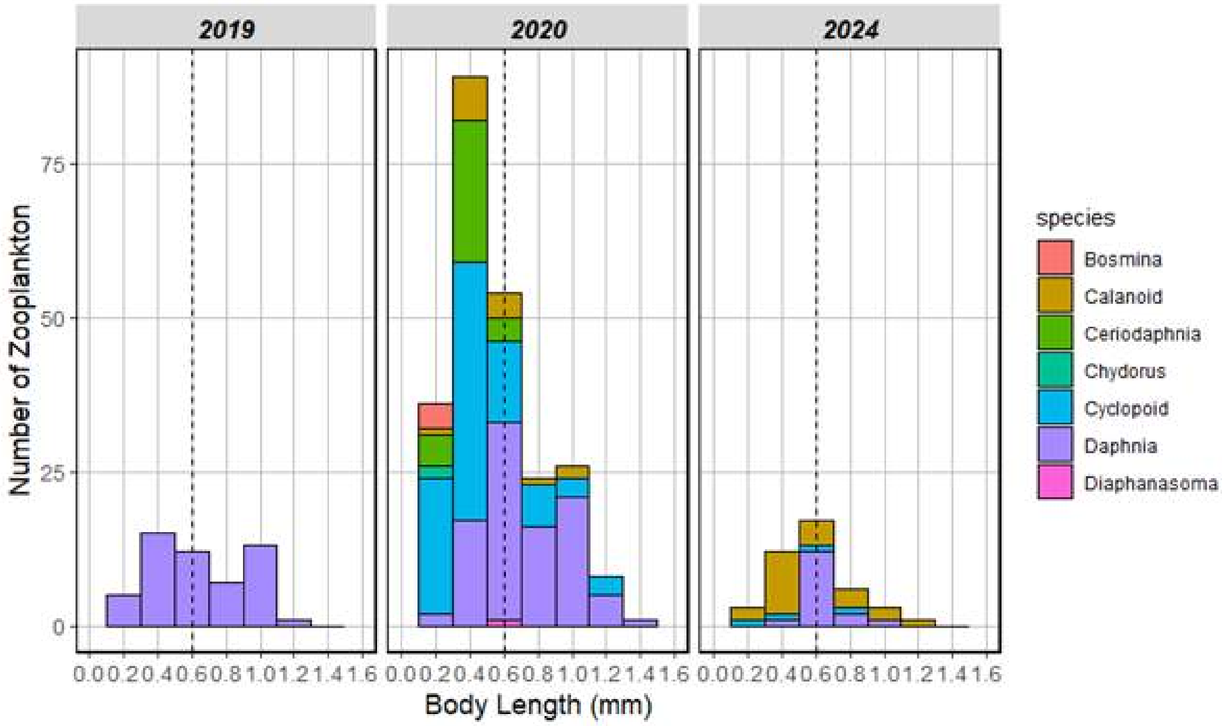
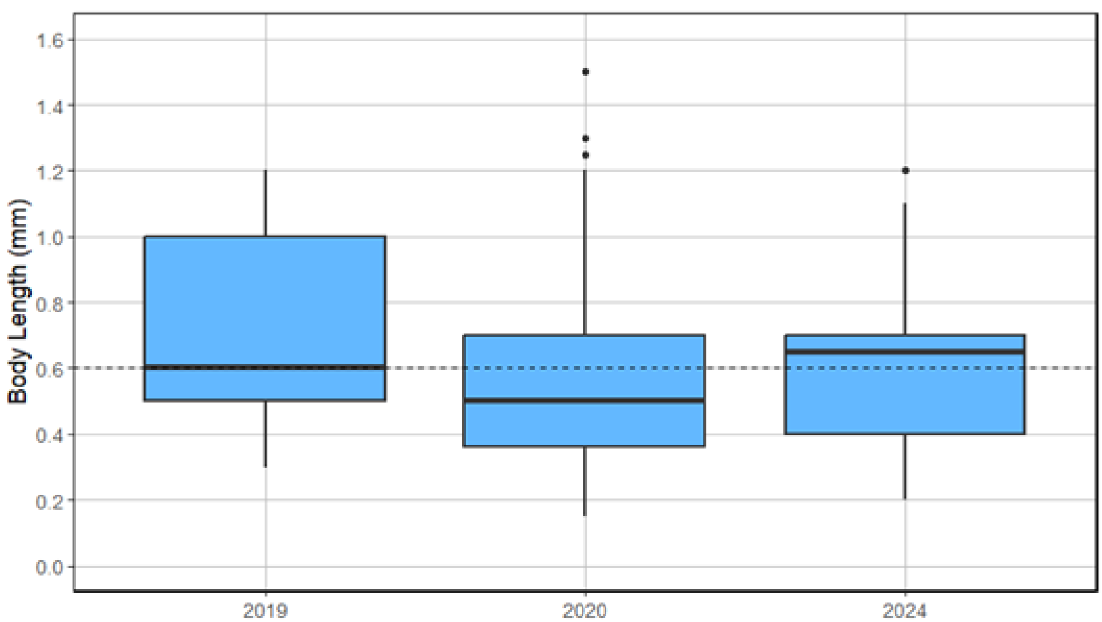


Figure 12. Mean Body Length of Copepods and Cladocerans in Roaring Brook Lake in 2019, 2020, and 2024. The vertical dashed line indicates the threshold size for significant fish predation.



EutroSORB Field Trial

To enhance watershed nutrient uptake, GEI staff piloted a novel technology to filter incoming dissolved phosphorus from Roaring Brook Proper (Inlet 5). The technology (EutroSORB F) is a proprietary blend of minerals such as lanthanum, iron, and aluminum inside of a clay bentonite matrix. These minerals have a high affinity to bind and retain soluble phosphorus, preventing release downstream. This technology has potential applications in multiple areas of lake and watershed management including in-lake applications, catch basins, stormwater retrofits, stream installations, etc. However, before recommending the technology for the entire lake and watershed-wide area, a pilot study was conducted to determine best deployment methods, maintenance needs, and effectiveness of phosphorus filtration.

Results

Results presented in this report represent pre installation conditions, 1 month after installation or treatment (1 MAT), 3 months after installation (3 MAT), 6 months after installment (6 MAT), and 12 months after installation (12 MAT). This section of the report will primarily focus on the new data which is the now available: 12 MAT data.

Impact on Phosphorus

There was little difference in TP and SRP concentrations above and below the bag placement area (Table 5). Concentrations of both TP and SRP were highest during the July sampling, which corresponded with the significant rains a few weeks earlier. Average inflow (above bag samples) TP and SRP concentrations across the study period was 30 µg/L and 13.2 µg/L respectively.

Table 5. Above Bag and Below Bag TP and SRP Concentrations in Roaring Brook Lake

Date	Timing	Sample	SRP (µg/L)	TP(µg/L)
4/28/2023	Pre	Inlet 5 Above Bags	3.4	17.4
		Inlet 5 Below Bags	3.5	17.8
5/23/2021	1 MAT	Inlet 5 Above Bags	13.2	14.6
		Inlet 5 Below Bags	14.7	9.3
7/24/2023	3 MAT	Inlet 5 Above Bags	23.2	44.1
		Inlet 5 Below Bags	20.9	52.4
10/25/2023	6 MAT	Inlet 5 Above Bags	14.7	27.9
		Inlet 5 Below Bags	14.0	34.96
4/30/2024	12 MAT	Inlet 5 Above Bags	11.5	46.1
		Inlet 5 Below Bags	10.2	38.1

Testing of the filter media shows accumulation of phosphorus over the 12-month trial period (Fig. 13, Table 6). One sample was significantly higher than the others during the 6 MAT sample period, which the reasoning behind is unknown at the moment. If the extraneous TP concentration from the 6 MAT period is removed, the average TP concentration from the sample period is 25.74 mg/kg and each month showed an average increase in TP concentration. However, the 12 MAT sampling period also has one concentration that is higher than the others, which could also be dragging the average for that time period up (average without high value = 24.08 mg/kg). Thus, there is an argument that the bags are not significantly binding more TP at the 12 MAT time period. It is important to note that it is not guaranteed that the same bags are sampled each time, as biofouling and high flows which jumble locations has made bag ID nearly impossible.

Figure 13. Total Phosphorus Accumulation on Filter Media from Pre-Treatment to 12 MAT

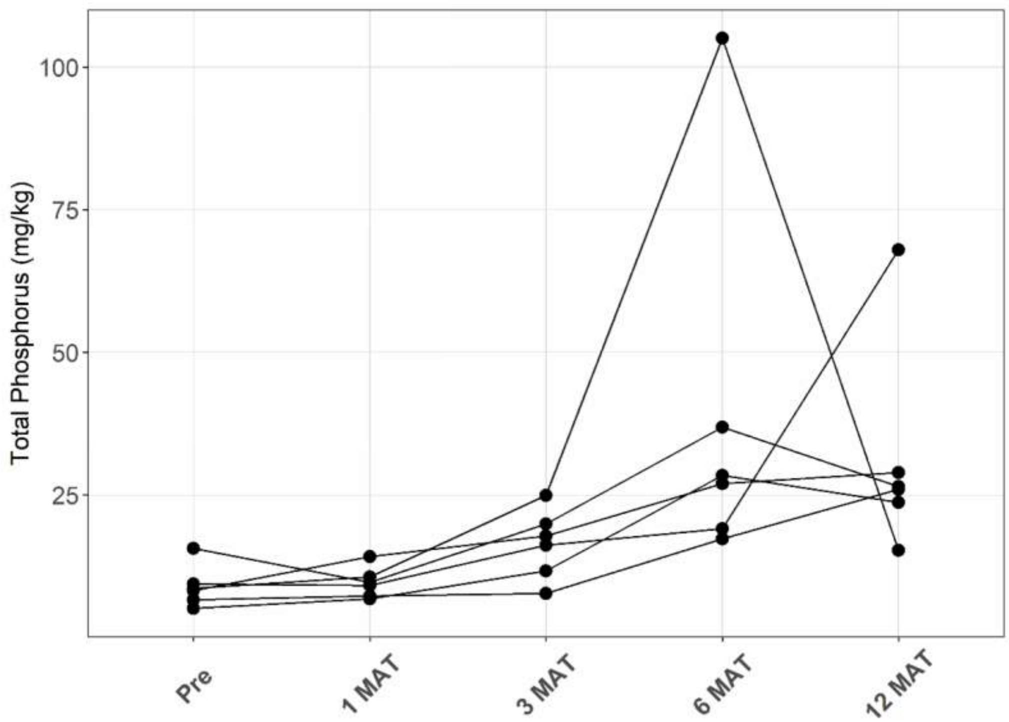


Table 6. Average Phosphorus Concentration in Media Over Time

Average Media P Concentration	Pre	1 MAT	3 MAT	6 MAT	12 MAT
TP (mg/kg)	8.92	9.62	16.37	25.74*	31.4

*Please note that the extraneous concentration was removed in this table. If included in the average, the 6 MAT average TP concentration is 38.97 mg/kg.

While the increase in phosphorus bound to the media is an indication that the media is working, there is still a long way to go to meet the manufacturer's stated P binding limit for the bags (Table 6). This can be interpreted in two different ways. First, this suggests that the bags have not removed a large amount of phosphorus from the stream. Without mass measurements comparing the total amount of phosphorus to pass over the bags versus the total amount of uptake, the relative effectiveness of the bags are unknown. Lower phosphorus streams, such as Roaring Brook may not be as conducive to rapid uptake as there is just not as much phosphorus in the water to interact with the media. On the other hand, this means that replacement of the bags is not needed after even 12 months of deployment. With the cost of purchasing the bags plus installation being ~$3,000, the media is still binding phosphorus. Fig. 13 shows that the phosphorus binding has not leveled out but has kept increasing. This means that the initial investment into the bags is still yet to run out. The 12 MAT sample period continues to show modest increase in the TP bound to the bags. Given the bags still have 99% of their media still available for binding, it suggests these bags should not be used for efficient TP binding in low TP concentration streams. However, the bags can be deployed for long periods of time and not need replacement, although biofouling should be managed regularly to ensure water contact with the bag media.

Table 7. Total Amount of Phosphorus Removed Compared to Manufacturers Recommendations

Metric	Value
Mean P Uptake Per Bag (mg/kg)	30.05
Total Uptake per bag (mg)	340.47
Total Uptake per bag (lbs)	0.0008
Manufacturer Target Uptake (lbs)	0.25
Percent of Media Still Available for Binding	99.70%
Total Uptake Across all Bags (lbs)	0.01

Water Quality Discussion and Recommendations

Water quality in Roaring Brook Lake in 2024 was generally similar to 2023 with the exception of the higher TP concentrations. TP concentrations while elevated, were driven more by the two high samples seen in June and October. There continued to be a lack of beach closures and HAB reports on the lake further support the notion of desirable water quality, despite the high TP data. GEI also did not see a worsening in Secchi disk depth readings and in Chlorophyll a concentrations in the 2024 CSLAP data, supporting the notion that higher TP readings did not translate into detrimental algae conditions. Based on the DEC HAB archive page for 2024, Roaring Brook Lake had only six reported HABs from August 24th to October 14th, which is earlier than the higher cell counts seen in the in-lake data. Turnover in bottom waters after August could have contributed to the increased the chance of HAB’s occurring.

There is a decline in TN concentrations from 2018 to 2024 seen in both the CSLAP data and the GEI/NEAR collected data. During the previous time period, the variance in the mean TN concentrations was higher than the recent data (2018 to 2024). The TOPV implemented a septic system maintenance law in 2016, which drastically increased the number of systems that were pumped out on an annual basis. Nitrogen is more mobile in shallow sediments than phosphorus, so it is reasonable to expect that declines in TN concentrations would be seen in-lake before declines in TP. Decreases in the variance of the TN concentrations can also be potentially explained by the septic system pumpout program. It is reasonable to assume that the more systems are pumped out and function effectively, large pulses due to heightened groundwater via rainfall may not occur as frequently.

The EutroSORB trial on Roaring Brook Lake continues to provide numerous insights into the functioning of the bags and the potential for use in future years and applications. The general consensus from the 2024 monitoring report that the bags while up taking phosphorus were still not nearly at capacity. The recommendations to continue to try the bags out in different areas is still valid, with more years of information needed to truly elucidate the effectiveness. Since the bags are a lost cost strategy, the TOPV and RBLPOA should continue to invest in them.

General Lake Management Recommendations for Homeowners

Rainfall Management

For rainfall that hits the roof and runs off, it is important to have gutters installed and maintained correctly, as well as ensuring that once that water leaves the gutter, it does not flow onto an impervious surface. This can be done by either directing gutters into a natural wooded or vegetated area, installing a rain barrel to capture water and re-use for gardening/general irrigation, or install a rain garden and plant saturation-tolerant vegetation.

Driveways and roadways are one of the largest sources of impervious surface in the Roaring Brook Lake watershed. Residents should be encouraged to consult the RBLPOA on new driveway repair/construction to ensure that stormwater runoff is properly treated before entering the roadways and catch basins. This involves proper curbing and diversion of water into wooded areas and when possible, using sensible grading and/or drain placement.

Lawn Care

For lawn care, using little to no fertilizer is suggested, especially in areas directly next to the road or the lake. Storms can flush the fertilizer into the drain system. If fertilizer is desired, use of slow-release nitrogen fertilizer is suggested, as this allows the vegetation to uptake nutrients in a fashion that minimizes wash off. Grass clippings and leaves should never be blown onto roads or into drainpipes. These clippings can decay in the lake and drain system, adding more organic material and nutrients. Only phosphorus-free fertilizers should be used.

Landscape Practices

Reducing the number of short grasses and increasing shrubbery and mulch will also help keep nutrients on site. The idea of a beautiful landscape is not restricted to short grass extending directly to the shoreline. A mosaic of tall-growing grass, low growing native plants, mulched shrubbery, and trees can provide both an aesthetically pleasing view and protection against stormwater runoff.

Construction on Property

New or ongoing construction should adhere to all proper protocols for stormwater prevention, especially the use of silt fences and other erosion control devices. If a new driveway or patio is being planned, using alternatives to impervious materials such as pavers or porous pavement will help reduce runoff. These materials infiltrate the rainwater into the ground instead, rather than allowing the water to run directly into the lake. It is also important to mention stormwater prevention and mitigation practices to the contractors prior to construction and before the design phase. It is much easier to build proper drainage and stormwater practices into the design of a project, than to adapt after the fact.

Septic System Maintenance

All septic systems should be pumped out and inspected on a rotating 3-year basis. The TOPV already has a 5-year septic system pump-out regulation in effect for Roaring Brook Lake, which is a great starting point. GEI suggests that pump outs be conducted on a 3-year basis by homeowners, as more frequent inspections will assist in catching problems with the tank earlier on. It is also a good idea to ask the septic contractor to inspect the leach field for any signs of capacity issues or ponding of water. Most inspections only involve the integrity of the tank, which can only catch a portion of the issues.

Aquatic Plant Survey

Background

GEI staff visited Roaring Brook Lake on September 4th and 5th to perform a full lake aquatic plant survey. The survey was designed to take a representative sample of all plants growing in the lake. Residents have started to notice increased aquatic plant growth and have expressed interest in management strategies to reduce growth. In 2011, the TOPV decided to stock 500 grass carp in Roaring Brook Lake for to control excess vegetation. From 2011 to 2017, there were no aquatic plant surveys done to track and document declines in vegetation. Princeton Hydro did document plants within the lake in 2017, noting that while there appeared to be declines in vegetation as compared to a 2007 study (Note: GEI could not find the study Princeton Hydro was referencing), where vegetation biomass was moderate to dense around the shoreline. While the methodology between the different surveyors are not directly comparable, observations from the 2019 aquatic plant survey indicate that vegetation did decline from 2016, as observers did not document “moderate to dense” aquatic vegetation in areas around the shoreline.

Methodology

Aquatic plant survey methods involved a point intercept style survey. Pre-determined waypoints from previous survey efforts were re-visited. A total of 212 waypoints were visited. At each waypoint, depth was recorded along with all species observable in a 10 X 10 ft quadrat alongside the boat.

Plant coverage was determined using a combination of three methods. The first method was at each waypoint, a 14-tine double-sided garden rake attached to a 10m rope was tossed or a long-handled garden rake was used to rake the lake bottom to collect specimens of all species at that point. This method involves stopping the boat and throwing the 10m tow line and rake head and/or raking the bottom with the long-handled rake through the plant bed. The second method is the visual density determination method which is based solely on what is visible from the surface. This method involves using a hypothetical quadrat. The surveyor visually estimates how much area is covered by the plant in question. Surveyors visualized a hypothetical quadrat approximately 10 ft X 10 ft around the boat, then estimated coverage accordingly. Visual estimates are made by a single person during the survey, but the entire team has input on the final estimate to ensure accuracy.

The final method used to estimate the percent coverage of vegetation is to use the down-imaging SONAR images from a Lowrance Hook Reveal of the plants as the boat passes above. In areas where plants cannot be seen from the surface, the SONAR images become extremely useful for percent coverage estimations, along with rake tosses. SONAR and visual estimates are corroborated by rake tosses. When possible, all three ways of estimating the percent cover are used at each waypoint, and the resulting estimate is recorded on the datasheet. Using those three measurements in conjunction achieves the most accurate estimate of plant coverage possible during surveying. In the field, plant survey data was entered into ESRI's Survey123 application and was later processed where quality control and data cleaning took place prior to analysis. A few different metrics were derived used to describe the aquatic plant community which are as follows:

Growth Habit: Describes the dominant habit of growth for the specific species. The three main growth habits are submersed, meaning the plants grow from the lake bottom and their leaves mostly occupy the water column (e.g. pondweeds), emergent, where the plant's growth habit is to grow from the sediments out of the water column and into the air (e.g. cattails) and floating, where the leaves are on top of the water's surface (e.g. lilies). There are some subclasses to each of these growth habits, such as floating plant (e.g. duckweed) and floating rooted (e.g. lilies) and algae (including cyanobacteria).

Frequency of Occurrence: Measure of the total amount of observations of a particular species divided by the total amount of points that were surveyed. Can also be represented as Percent Occurrence.

Mean Water Depth: Measure of the average water depth in which species observed during the survey.

Growth Form: Categorical measure of plant height in the water column. The rating scale is from 1 to 5. A species with a growth rating of 1 is growing right along the lake bottom, while a species with a growth rating of 5 is growing all the way to the water's surface or toping and growing horizontally.

Nuisance Index: Metric that describes how problematic a particular species is at a particular location in terms of recreational and ecological impact. The index is calculated by multiplying the percent cover (as a proportion) by the growth form. The theoretical densest a patch of plants can be is if the plant occupies 100% of the lake bottom and grows all the way to the surface. This dense patch would have a nuisance index score of 5. Plants that both cover the bottom completely and grow to the surface negatively impact recreational and ecological uses. Plants that cover the bottom, but are low growing may crowd out native species, but will most likely have little impact on recreational uses. Conversely tall growing plants (such as curly leaf pondweed) may be unsightly if it grows to the surface, but if there are only a few stems in the area and percent cover is low, it would be expected that most ecological and recreational uses would be unaffected.

Analysis to determine frequency of occurrence, mean percent cover, mean water depth, and mean nuisance index was performed within R studio utilizing the tidyr and dplyr packages. Maps were made utilizing ArcMap. For ease of interpretation, percent cover values were binned into different density categories (Very Sparse <10%, Sparse 11-25%, Moderate 26-50%, Dense 51-75%, Very Dense 76-100%).

Aquatic Plant Community

A total of 29 different aquatic taxa were documented at Roaring Brook Lake in 2024, with four of the taxa being algae (either macroalgae, filamentous algae and cyanobacteria), 20 being submersed species, two floating leaved, six non-rooted and one emergent. The most commonly occurring species was Eurasian watermilfoil which was observed at a total of 126 points or 59.4% of all survey points. The next most abundant species were stonewort, inflated bladderwort, and brittle naiad. Duckweed had the highest mean nuisance index, however, this index does not account for the frequency of occurrence, given that this species was present at only one location. When accounting for the frequency of occurrence, Eurasian watermilfoil is the most recreationally impeding species of 2024. When accounting for the survey points that did not have any plants likely due to depth, Eurasian watermilfoil was present at 75% of the points that did have plants and on average at a low density, with individual plants spotting the lake.

Table 8. Frequency of Occurrence for all Species Observed During the 2019, 2022, and 2024

			2019	2022	2024
Scientific Name	**Common Name**	**Growth Form**	**Frequency of Occurrence**		
Brasenia schreberi	Water Shield	Floating Leaved	0	1	0.9
Cabomba caroliniana	Fanwort	Submersed	21.4	1	14.2
Callitriche stagnalis	Pond Water-Starwort	Submersed	21	12.4	9
Ceratophyllum demersum	Hornwort	Non-Rooted	5.7	1	14.2
Chara sp.	Muckgrass	Algae	0	0	9.9
Elatine sp.	Waterwort	Submersed	0	4.3	2.8
Eleocharis acicularis	Least Spikerush	Submersed	0	0.5	0
Elodea nuttallii	Western Waterweed	Submersed	0	0	0.9
Filamentous algae	Filamentous algae	Algae	4.8	1.4	12.7
Isoetes sp.	Quillwort	Submersed	0	0.5	0
Fontinalis sp.	Water Moss	Submersed	0	0	1.4
Lemna minor	Common Duckweed	Non-Rooted	0	0	0.5
Lyngbya wolleii	Horsehair Algae	Algae	0.5	15.3	1.9
Myriophyllum spicatum	Eurasian Watermilfoil	Submersed	12.9	29.2	59.4
Najas flexilis	Nodding Naiad	Submersed	0	0.5	2.4
Najas gracillima	Slender Naiad	Submersed	0.5	2.9	16.5
Najas guadalupensis	Southern Naiad	Submersed	0	0	7.5
Najas minor	Brittle Naiad	Submersed	3.8	2.9	25
Nitella sp.	Stonewort	Algae	29.5	24.9	42.5
Nothing present			31	39.7	21.2
Nymphaea odorata	White Water Lily	Floating Leaved	0	0	0.9
Phragmites australis	Common Reed	Emergent	0.5	1.4	0.5
Potamogeton amplifolius	Largeleaf Pondweed	Submersed	4.3	10.5	18.4
Potamogeton bicupulatus	Snail-Seed Pondweed	Submersed	0	0	2.8
Potamogeton epihydrus	Ribbon-Leaf Pondweed	Submersed	0.5	0	2.4
Potamogeton perfoliatus	Clasping-Leaf Pondweed	Submersed	0	0	0.5
Potamogeton pusillus	Small Pondweed	Submersed	0.5	0	13.7
Potamogeton spirillus	Northern Snail-Seed Pondweed	Submersed	0	0	0.5
Sparganium angustifolium	Narrow-Leaved Bur-Reed	Emergent/Submersed	0	0	0.9
Spirodela polyrhiza	Greater Duckweed	Non-Rooted	0	0	0.5
Typha sp.	Cattail	Emergent	0	0.5	0
Utricularia geminiscapa	Hidden Fruit Bladderwort	Non-Rooted	0	0	0.9
Utricularia gibba	Humped Bladderwort	Non-Rooted	1.9	0	0
Utricularia inflata	Inflated Bladderwort	Non-Rooted	46.7	23.4	32.5
Vallesneria americana	Eel Grass	Submersed	0	5.7	0

Comparison Between Past Surveys

Overall species richness and richness per waypoint increased each year from 2019 to 2024 (Table 9), supporting the notion of recovery from grass carp stocking impacts. The increases in species richness were most evident in the cove areas (Appendix A, Map 26). The number of species that exhibited increases in frequency of occurrence from 2022 to 2024 and from 2019 to 2024 was 25 and 26 species respectively (Table 10). This indicates that an increasing number of species are becoming more well distributed across the lake since 2019.

Table 9. Species Richness at Whole-Lake Scale and Mean Richness per Sampling Location

	2019	2022	2024
Species Richness	16	20	30
Richness per Site	0.9	0.8	2.2

Table 10. Changes in the Number of Species that Showed Increases in Frequency of Occurrence from 2019, 2022, and 2024

Frequency of Occurrence Changes	2019-2022	2022-2024	2019-2024
Increased	13	25	26
Decreased	11	11	6
Remained the Same	13	1	5

Percent cover of the highest frequency of occurrence (Top 10) species generally increased from 2019 to 2024, with all species except for inflated bladderwort and fanwort (Fig. 14). Mean growth form for the same species showed the opposite pattern, where the highest plant height values were documented in 2022 except for Eurasian watermilfoil (Fig. 15). The contrasting percent cover and growth form results indicate that while total density at each site increased in 2024, plant height decreased. The mean nuisance index values in 2024, which accounts for both percent cover and growth form were either the highest or tied with the highest values for six of the top 10 species (Fig. 16). Overall nuisance index values still show low overall lake impact of aquatic vegetation, as a nuisance index of 5 would indicate that all waypoints that a particular species occurred at had 100% coverage and were growing all the way to the lake surface. No mean nuisance index value was above 2.

Figure 14. Mean Percent Cover of Select Species in Roaring Brook Lake from 2019, 2022, and 2024

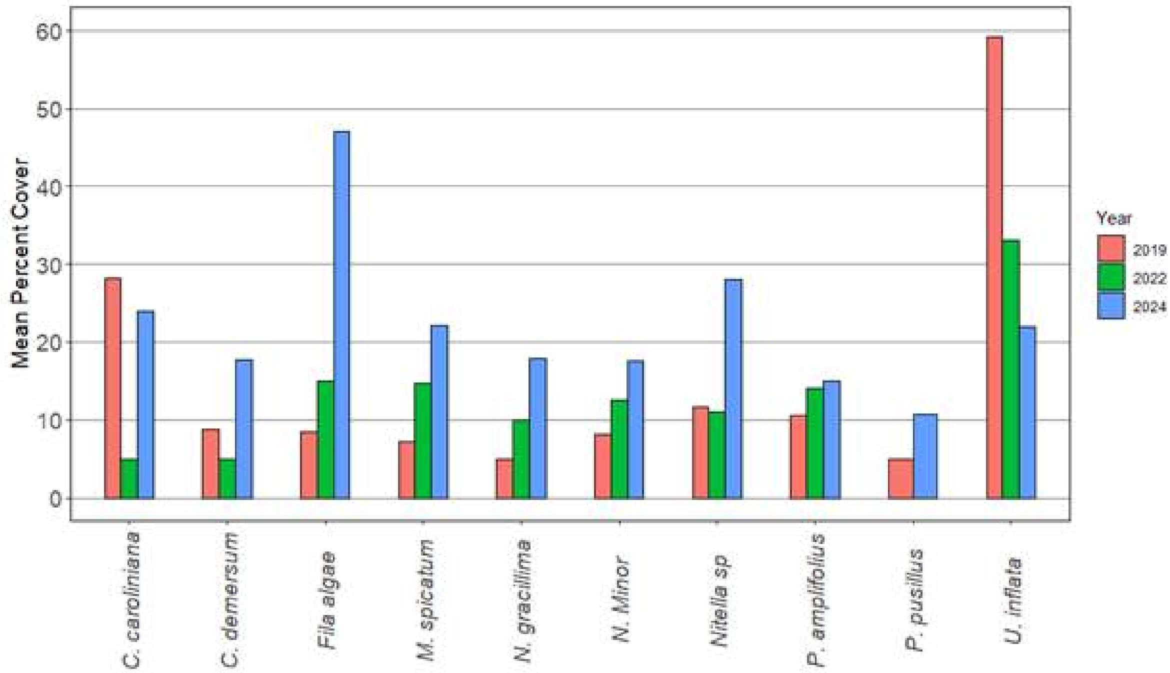


Figure 15. Mean Growth Form of Select Species in Roaring Brook Lake from 2019, 2022, and 2024

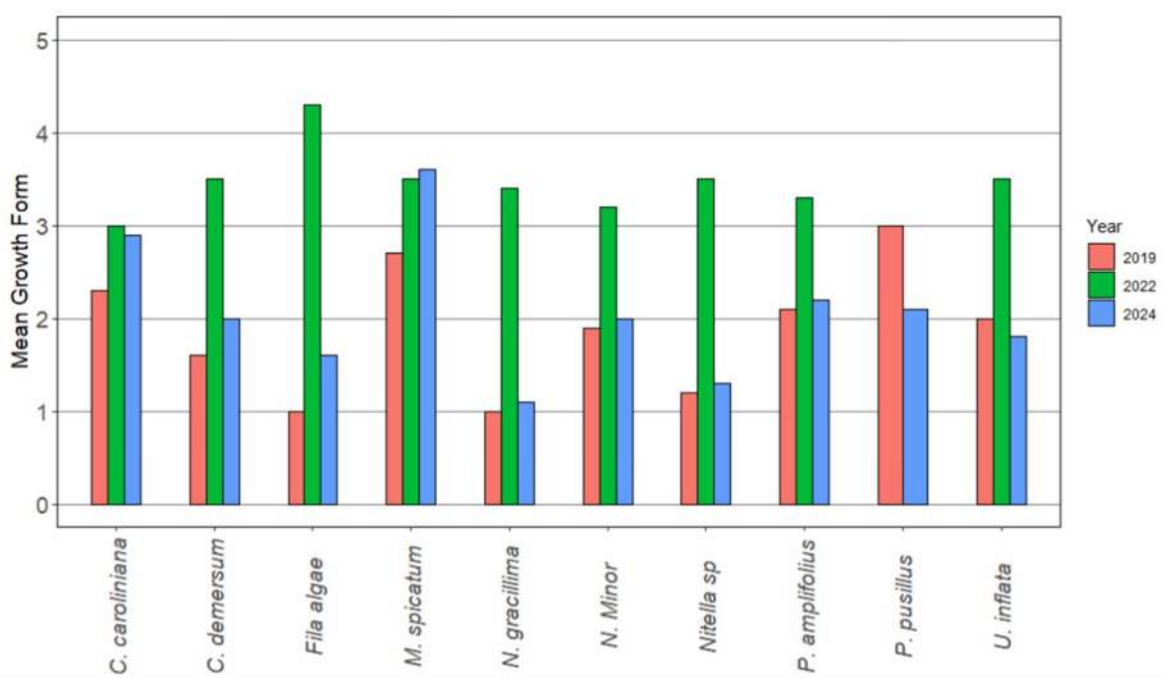
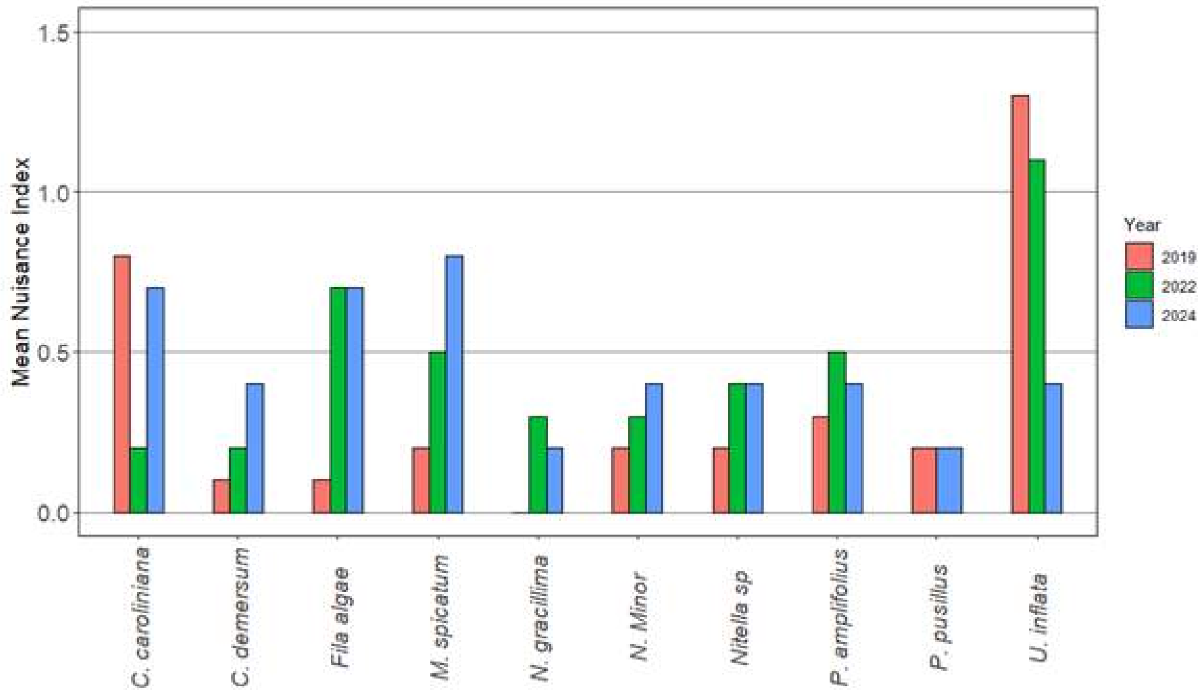


Figure 16. Mean Nuisance Index of Select Species in Roaring Brook Lake from 2019, 2022, and 2024



Individual Species

Maps for individual species distributions in Roaring Brook Lake are present in Appendix A.

Eurasian watermilfoil showed the largest increase from the 2022 to 2024 season and has been increasing in frequency of occurrence since 2019 (Table 8). Eurasian watermilfoil was distributed throughout the entire lake, with denser patches seen in the northern basin above Park Beach. Dense patches were also seen on sections of the western shoreline and near Moon Beach. The increase in Eurasian watermilfoil over the past 5 years is also happening in slightly deeper waters, with the middle of the northern basin (~8 feet) and the area directly north of Spur Beach.

Brittle naiad was abundant in shoreline areas and in cove areas and stonewort was abundant throughout the lake at all most depths. Fanwort has seen a curious decline in 2022 as compared to 2019. Anecdotally, fanwort in 2019 was found in deeper waters than in 2024, where fanwort was abundant in the 4-to-6-foot depth range . Inflated bladderwort, which was likely the bladderwort responsible for the large growth increase in 2016 that severely impeded lake use is still abundant throughout the lake in deeper water. No nuisance floating mats of bladderwort were noted for all surveys.

Aquatic Plant Recommendations

The most striking result of the 2024 aquatic plant monitoring is the increase in species found and frequency of occurrence of those species. Normally, increases in species richness in lakes is a good sign, as this shows ecological diversity which helps increase resilience to disturbances. However, many of the species that showed market increases are either invasive (Eurasian watermilfoil, fanwort, brittle naiad) or nuisances to recreation (largeleaf pondweed, small pondweed, filamentous algae). The cove areas exhibited high species richness, where multiple pondweed species that have not been seen in the lake since before 2019 started to appear. The recovery of species is to be expected as a result of the decline of grass carp numbers.

The recovery of the aquatic plant community does mean that the TOPV and the RBLPOA need to make decisions on management. Many areas of the lake, especially the northern cove and area by moon beach have significant aquatic plant growth, particularly of Eurasian watermilfoil and fanwort. Based on the increase in nuisance plant populations, GEI is recommending the following actions take place.

1. **Establish a Goal for Future Vegetation Management**: It is important to set a goal that the TOPV and the RBLPOA agree will reduce nuisance levels of vegetation, while also maintaining strong ecological function. A goal can be both narrative and quantitative such as “reduce vegetation to a point where recreation is not impeded, but ecological integrity is kept intact” or “reduce Eurasian watermilfoil frequency of occurrence by 70 percent,” for example. Any goal set should be clear and unambiguous which will allow for evaluations of success.
2. **Selection of Management Technique(s):** Based on the established goals, management techniques should be selected that best align with the vision for Roaring Brook Lake. There is no silver bullet for management of aquatic plants, therefore, multiple strategies may be needed. This is due to each technique having clear strengths and weaknesses. For example, drawdown only affects the areas which have sufficient exposure to dry conditions during winter.
3. **Independent Monitoring of Management Action:** Monitoring the effectiveness of the chosen management strategy allows evaluation of successes and failures and sets the TPOV and the RBLPOA up for more scientifically sound management decisions moving forward. The monitoring should be done by an entity that is not the same as the entity implementing the management. Monitoring of the aquatic plant community should take place yearly at least within the management zones, but preferable within the entire lake to document large scale changes. Water quality is already being monitored through the CSLAP program and GEI’s work.
    a. A fisheries study should be conducted either in 2025 or 2026 that documents any changes in the fish populations as a result of the recovering aquatic plant community. The 2020 fish study showed that the largemouth bass population was stunted with most individuals between 11 and 13 inches. There was an absence of small fish as well. In 2024, GEI staff observed small schools of fish in the cove areas and residents have mentioned that there are now larger bass present. A repeat of the 2020 fish study would be instrumental in understanding how the recovery of vegetation within Roaring Brook Lake has affected the fishery. There may also be effects of a different fisheries structure on zooplankton, which should be closely monitored.

Literature Cited

Brooks, J. L., & Dodson, S. I. (1965). Predation, Body Size, and Composition of Plankton. *Science*, *150*(3692), 28–35. https://doi.org/10.1126/science.150.3692.28

Ecosystem Consulting Services. (1991). *Roaring Brook Lake Supplemental Diagnostic-Feasibility Study*.

Min, C., Johansson, L. S., Søndergaard, M., Lauridsen, T. L., Chen, F., Sh, T., & Jeppesen, E. (2021). Copepods as environmental indicator in lakes: Special focus on changes in the proportion of calanoids along nutrient and pH gradients. *Aquatic Ecology*, *55*(4), 1241–1252. https://doi.org/10.1007/s10452-021-09877-y

Northeast Aquatic Research. (2020). *Roaring Brook Lake Water Quality and Aquatic Plant Monitoring Report 2019*. Northeast Aquatic Research.

Northeast Aquatic Research. (2021). *Roaring Brook Lake 2020 Water Quality Monitoring & Fisheries Report*. Northeast Aquatic Research.

Northeast Aquatic Research. (2022). *Roaring Brook Lake 2021 Monitoring Report*. Northeast Aquatic Research.

Pearce NJT, Parsons CT, Pomfret SM, Yates AG. Periphyton Phosphorus Uptake in Response to Dynamic Concentrations in Streams: Assimilation and Changes to Intracellular Speciation. Environ Sci Technol. 2023 Mar 21;57(11):4643-4655. doi: 10.1021/acs.est.2c06285. Epub 2023 Mar 10. PMID: 36897624; PMCID: PMC10035032.

Reyes, A. (2023). *Roaring Brook Lake 2022 Data Scorecard and Action Plan*. GEI Consultants Inc. PC.

Reyes, A. (2024). *Roaring Brook Lake 2023 Data Scorecard and Action Plan*. GEI Consultants Inc. PC.

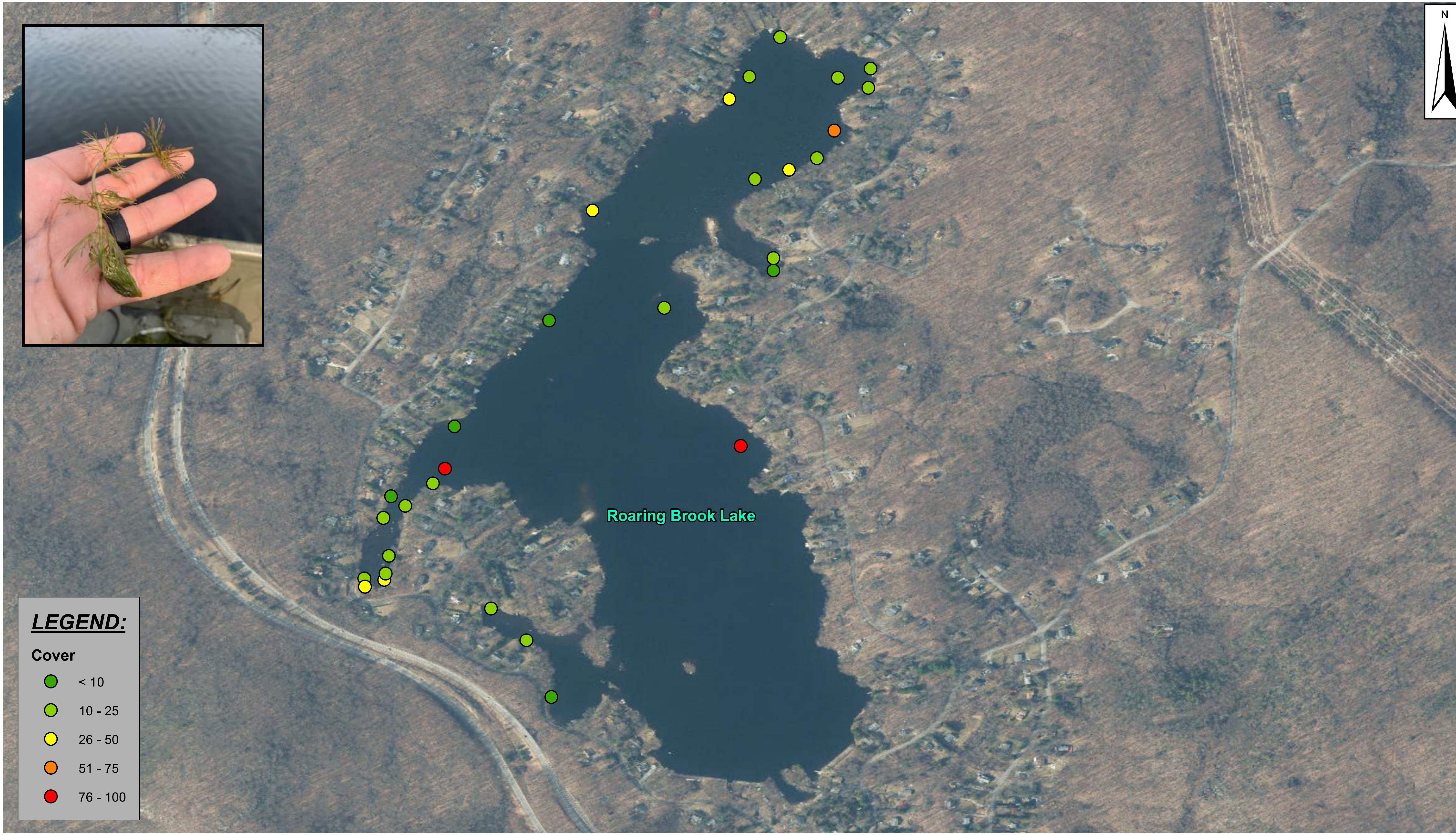
AR/LG/LK:ag
B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\08_Report\GEI_2024 Data Scorecard and Roaring Brook Lake 2025-02-05.docx

Appendix A Maps

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Brasenia schreberi*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 1 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

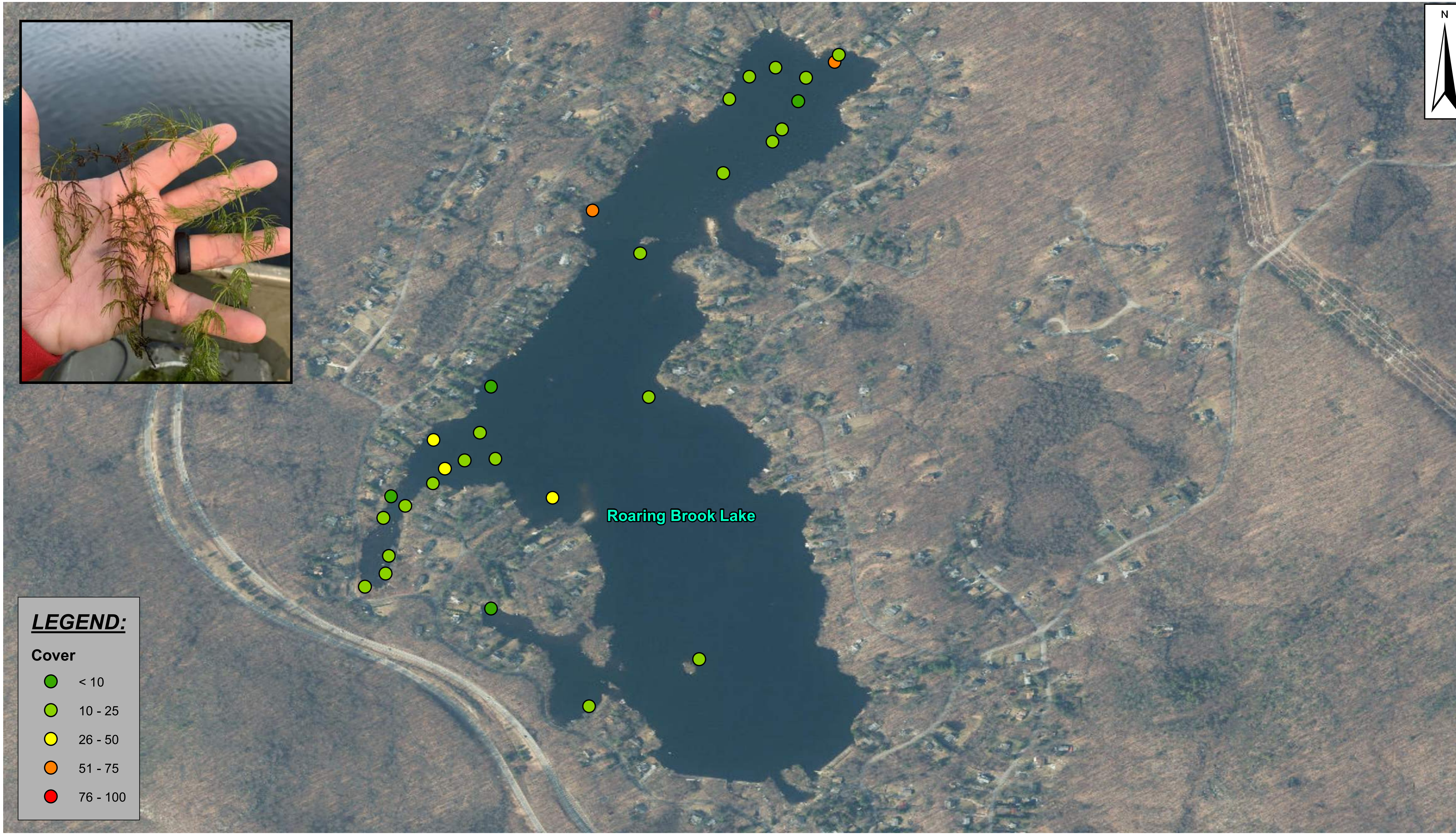
B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Brasenia_schreberi.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Cabomba caroliniana*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 2 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

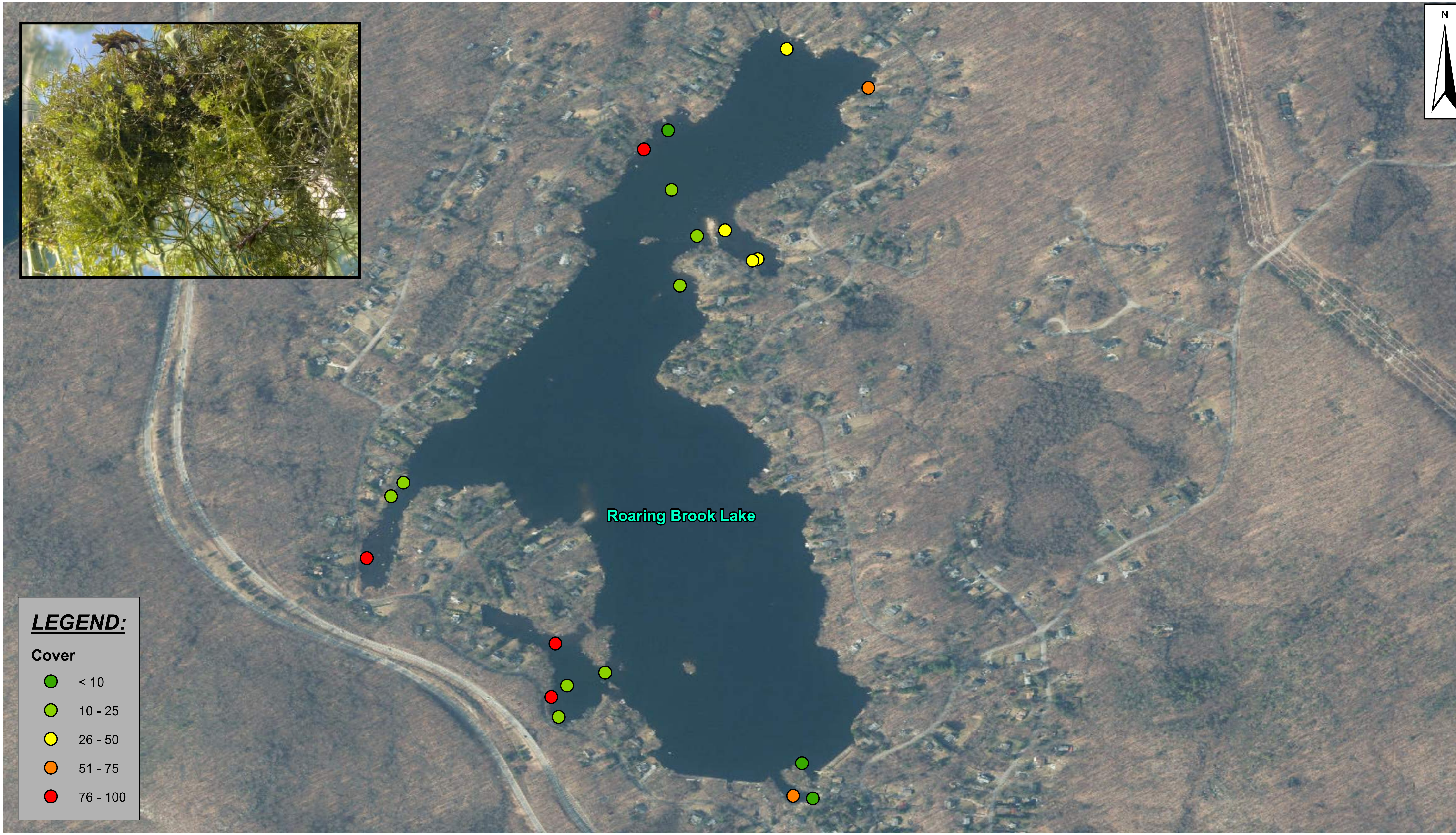
B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Brasenia_schreberi - Copy.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Ceratophyllum demersum*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 3 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_C.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Chara sp.*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 4 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_C.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Elatine sp.*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 5 Survey September 2024 Project 2405201 October 2024

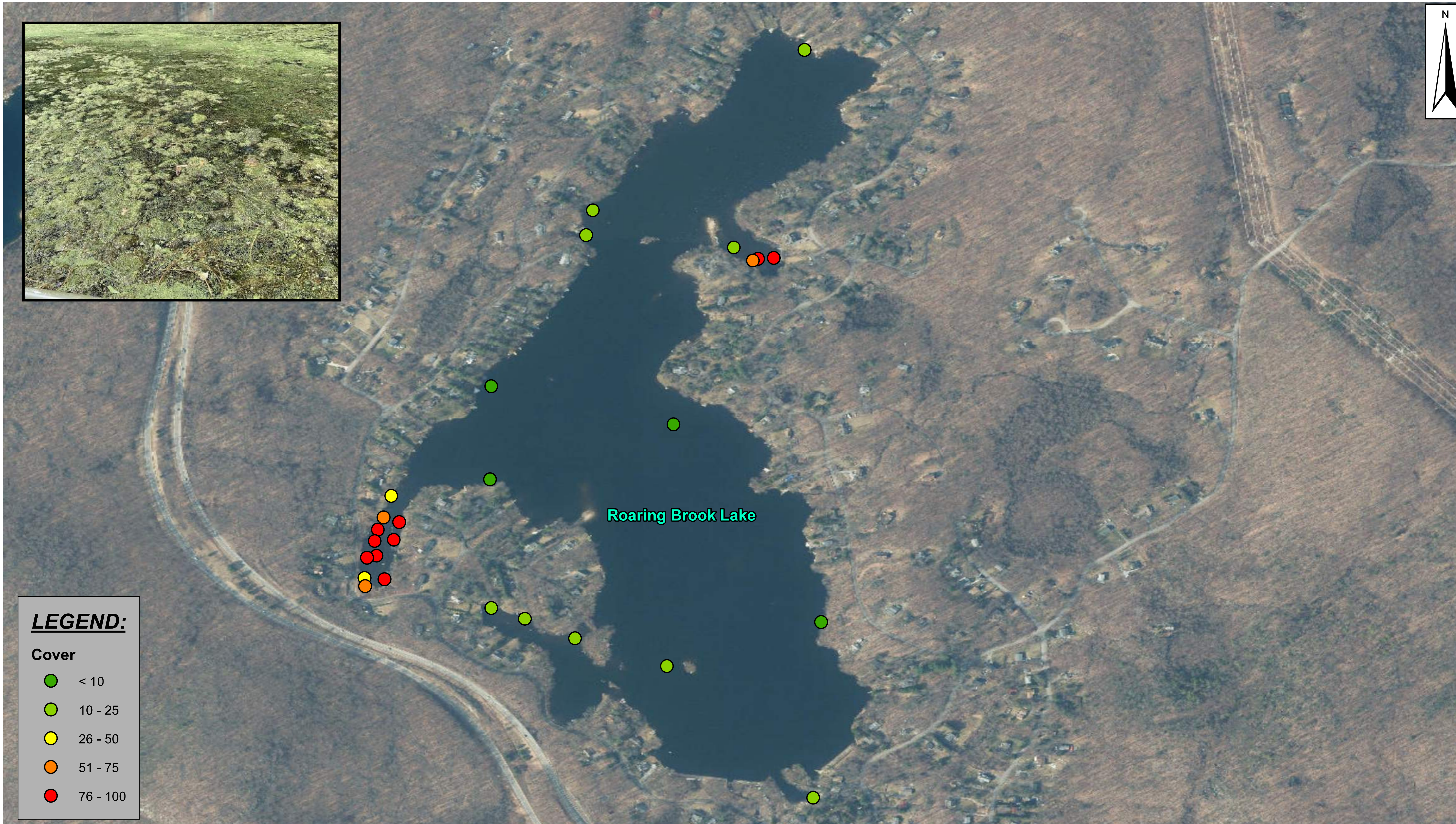
SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Chara_sp. - Copy.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Elodea nuttallii*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 6 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Elatine_sp. - Copy.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	Filamentous algae	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 7 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Elatine_sp. - Copy.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Lemma minor*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 8 Survey September 2024 Project 2405201 October 2024

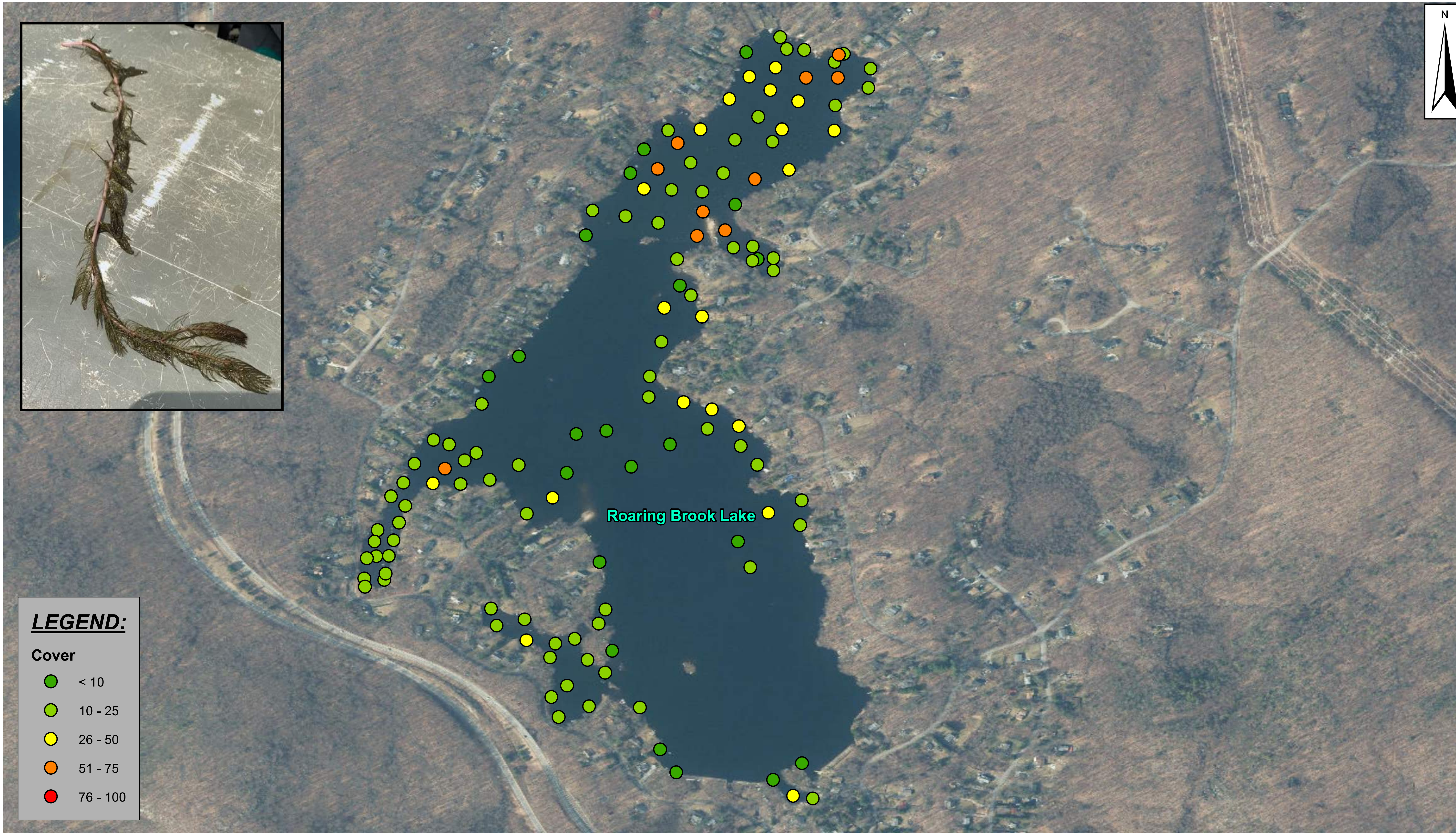
SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_F.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Lyngbya wolleii*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 9 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Lyngbya_wolleii_NEEDS IMAGE.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Myriophyllum spicatum*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 10 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Lyngbya_wolleii_NEEDS IMAGE - Copy.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Najas flexilis*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 11 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Najas_flexilis_NEEDS IMAGE.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Najas gracillima*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 12 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Najas_gracillima_NEEDS IMAGE.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Najas guadalupensis*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 13 Survey September 2024 Project 2405201 October 2024

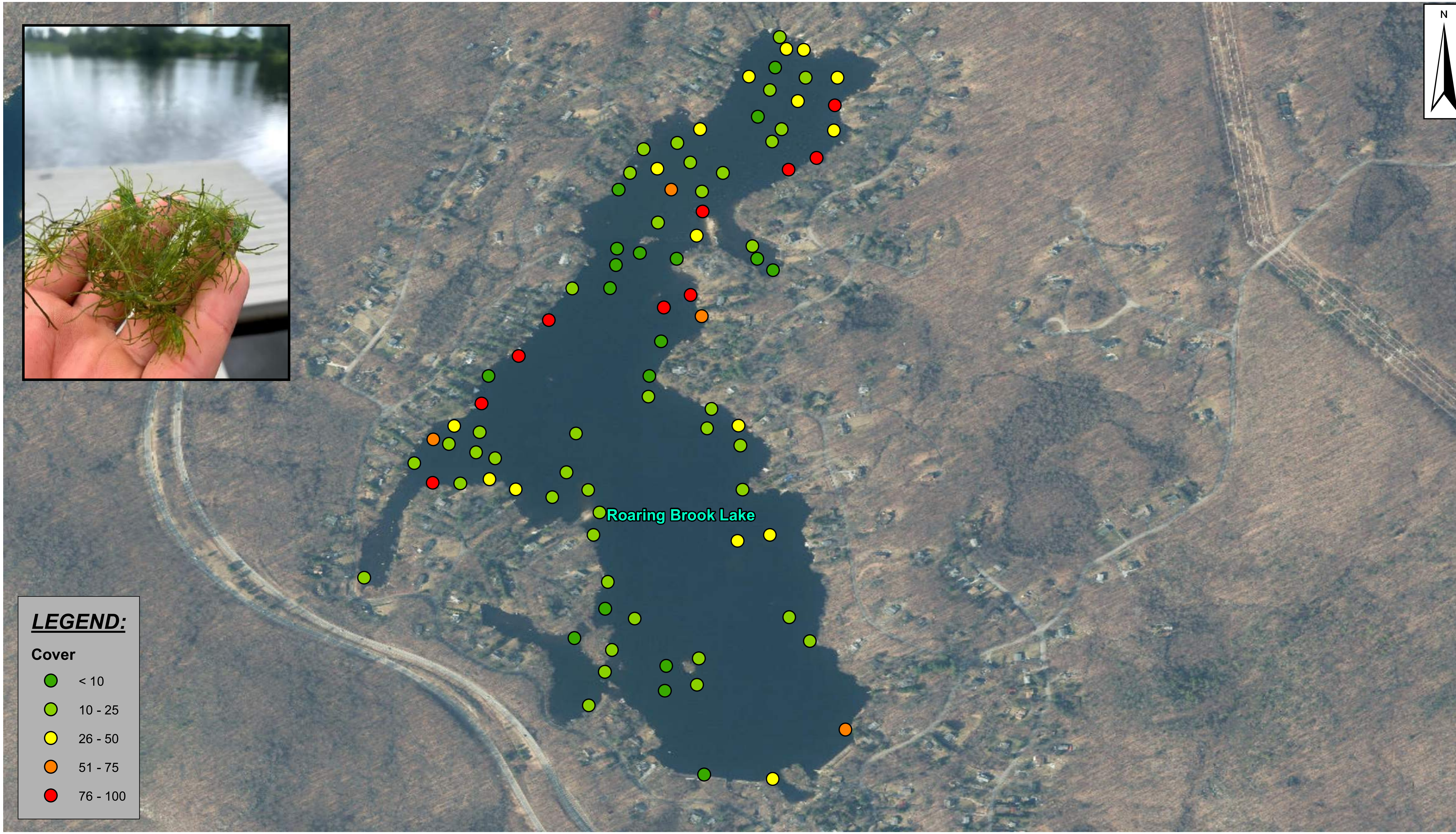
SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Najas.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Najas minor*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 14 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Najas_minor.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Nitella sp.*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 15 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_N.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Nymphaea odorata*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 16 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_M.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Phragmites australis*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 17 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_M.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Potamogeton amplifolius*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 18 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_P.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Potamogeton epihydrus*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 19 Survey September 2024 Project 2405201 October 2024

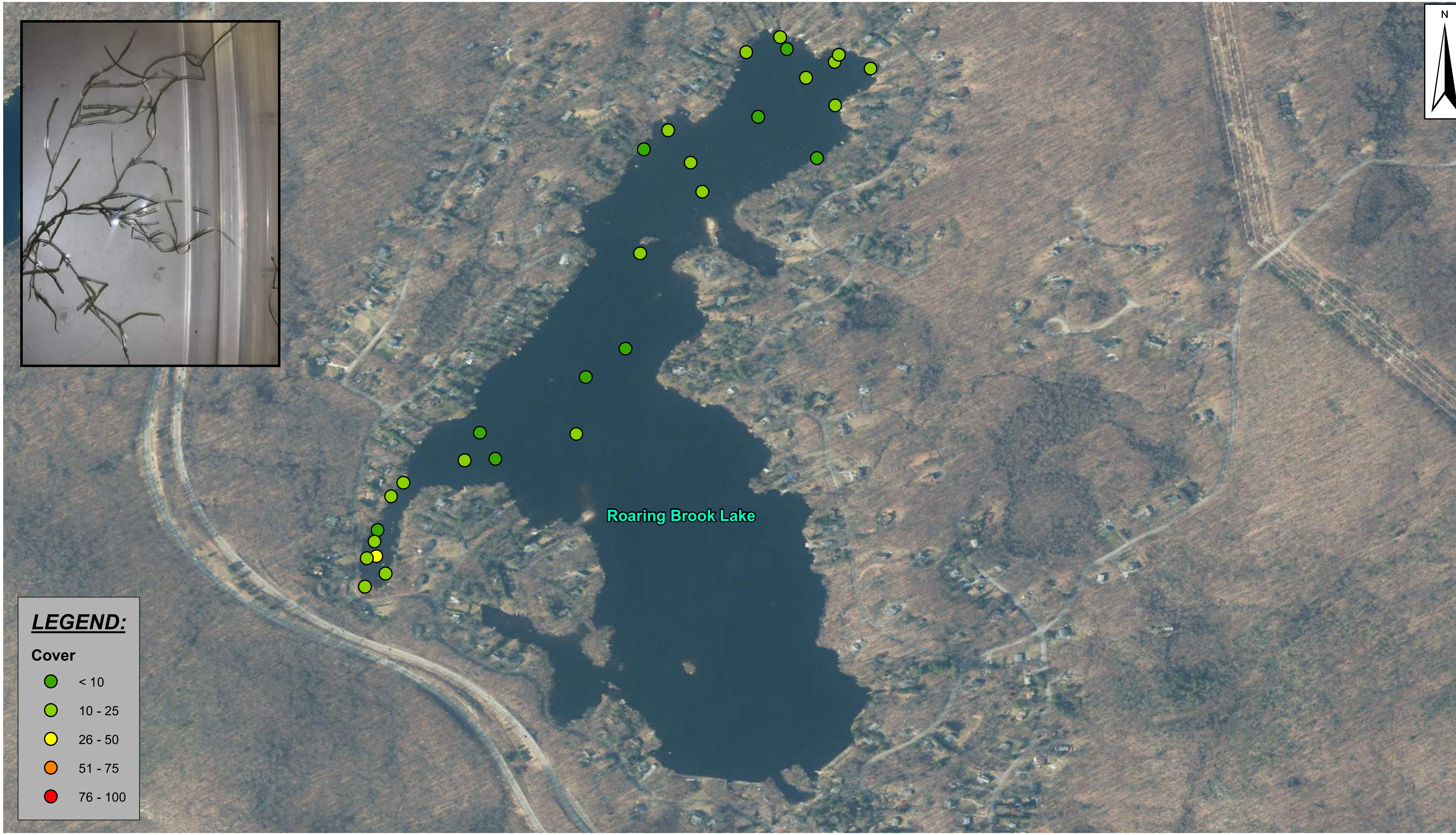
SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Potamogeton_.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Potamogeton perfoliatus*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 20 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Potamogeton_perfoliatus IMAGE BEING ANNOYING.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Potamogeton pusillus*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 21 Survey September 2024 Project 2405201 October 2024

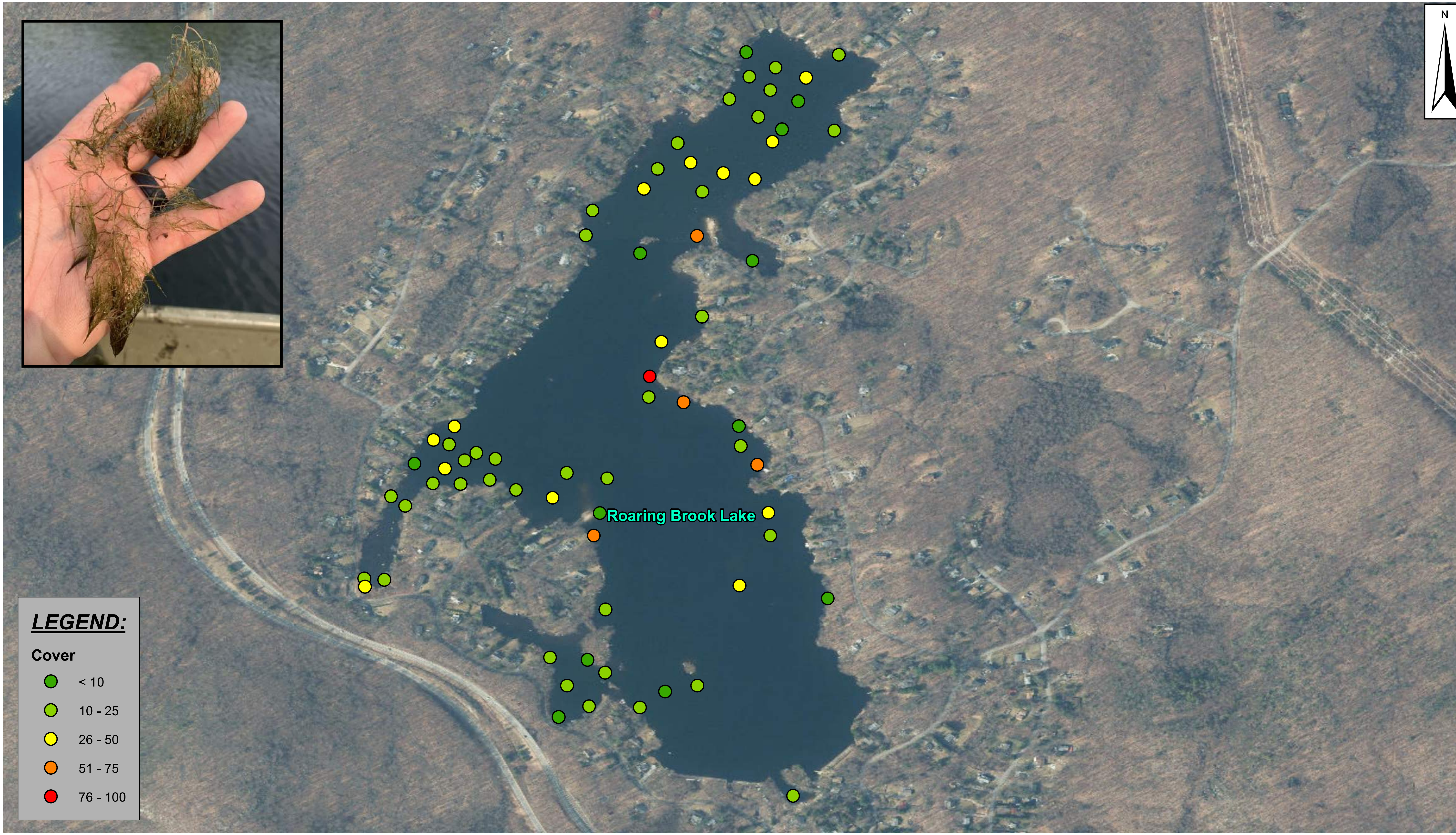
SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Potamogeton_.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Potamogeton spirillus*	0 600 1,200 SCALE: 1" = 600'	GEI Consultants	Plant Distribution Map 22 Survey September 2024 Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Potamogeton_spirillus_NEEDS IMAGE.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake
Town of Putnam Valley
Putnam County, New York

Utricularia inflata

0 600 1,200
SCALE: 1" = 600'

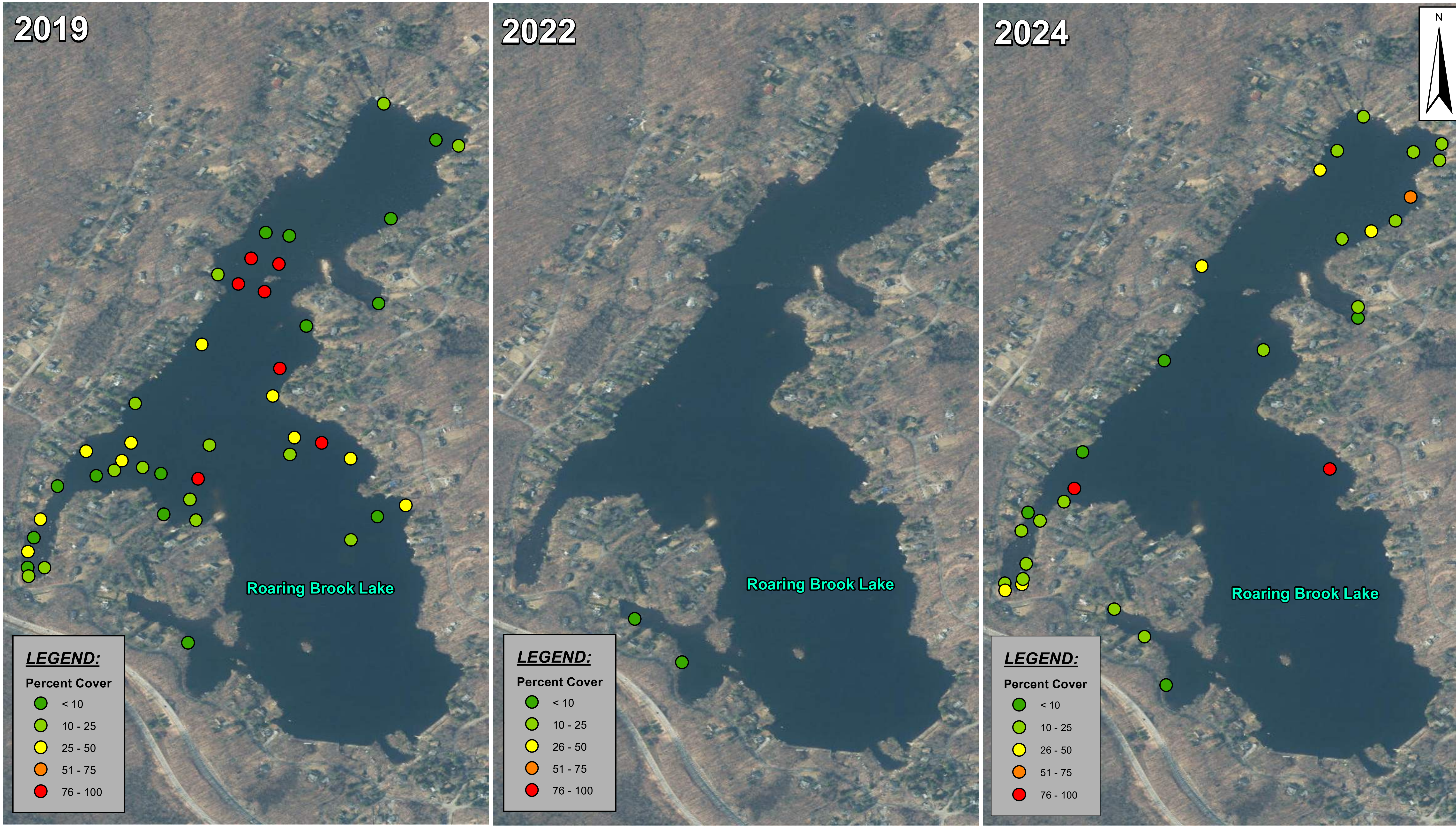
GEI Consultants

Plant Distribution Map 23
Survey September 2024

Project 2405201 October 2024

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

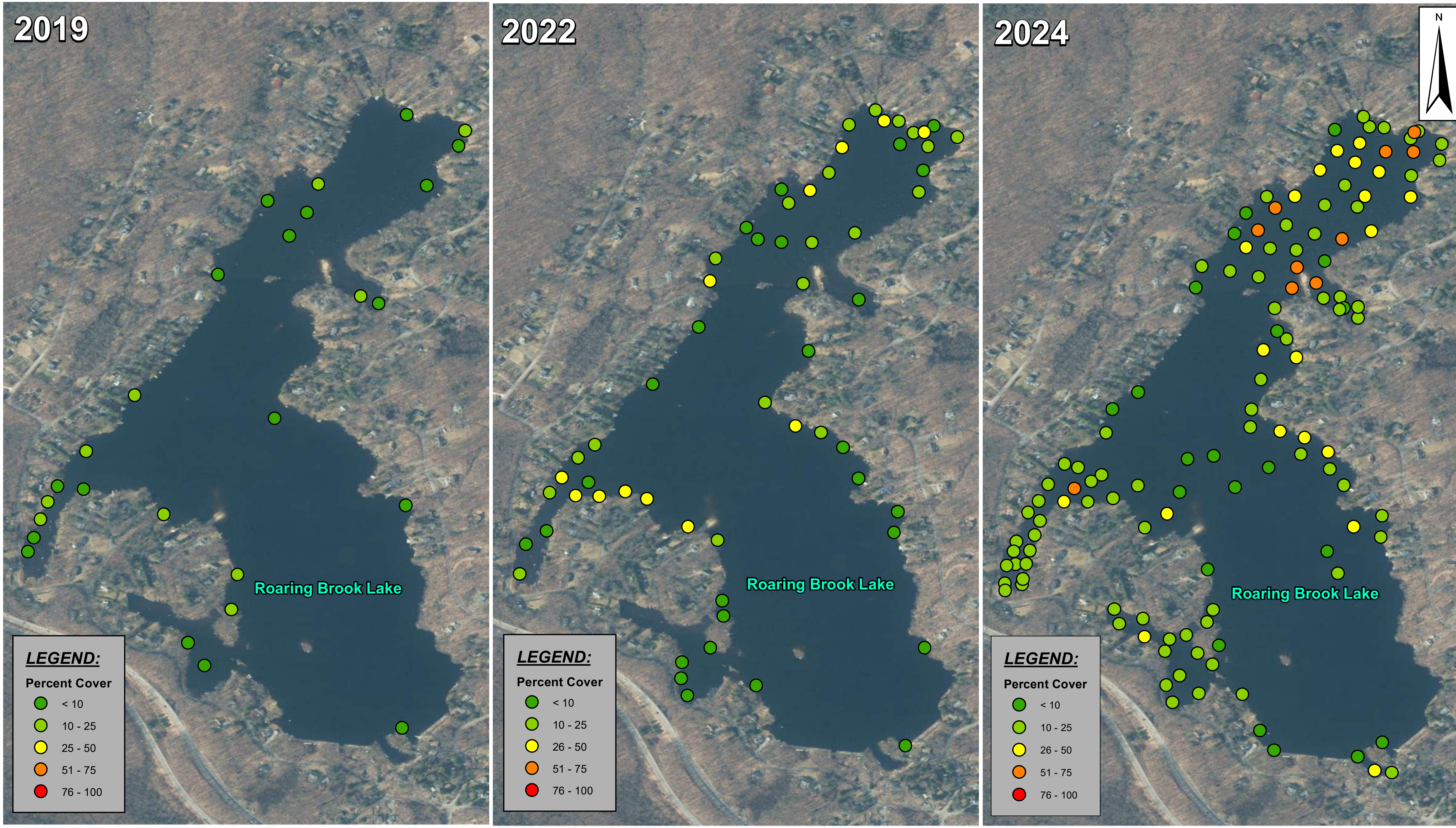
B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake 09-2024_Aquatic Plant Maps_Utricularia_inflata.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Cabomba caroliniana*	0 690 1,380 SCALE: 1" = 690'	GEI Consultants	Plant Distribution Map Surveys 2019, 2022, & 2024 Project 2405201 January 2025

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

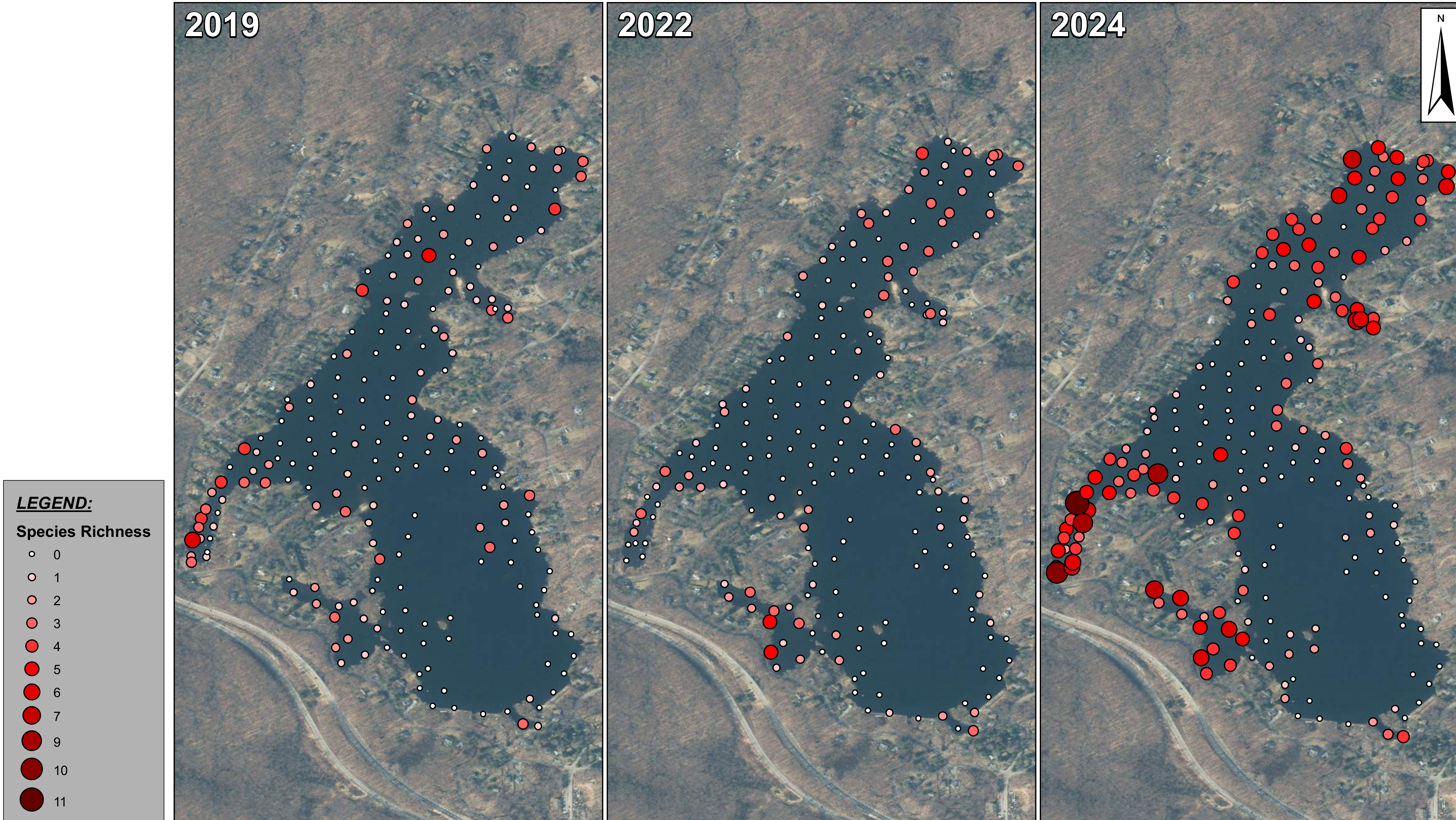
B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake_Aquatic Plant Maps_Cabomba_caroliniana_2019, 2022, 2024.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	*Myriophyllum spicatum*	0 690 1,380 SCALE: 1" = 690'	GEI Consultants	Plant Distribution Map Surveys 2019, 2022, & 2024 Project 2405201 January 2025

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake_Aquatic Plant Maps_Myriophyllum_spicatum_2019, 2022, 2024.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Roaring Brook Lake Town of Putnam Valley Putnam County, New York	Species richness at each site	0 770 1,540 SCALE: 1" = 770'	GEI Consultants	Plant Distribution Map Surveys 2019, 2022, & 2024 Project 2405201 January 2025

SOURCE:
1.2022 WORLD IMAGERY ACCESSED VIA ESRI ARCMAP

B:\Working\PUTNAM VALLEY, TOWN OF\2405201 Roaring Brook 2024 Mgmt Svcs\05_GIS\Roaring Brook Lake_Aquatic Plant Maps_Species Richness Per Site_2019, 2022, 2024_edits.mxdService Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community