Northeast Aquatic Research

Tuxedo Lake, Wee Wah and Little Wee Wah Aquatic Plant Sampling Report

Prepared for the Village of Tuxedo Park
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Executive Summary

Summary of 2019 Survey Results:

- Tuxedo Lake, Little Wee Wah, and Wee Wah were sampled for aquatic plants on multiple dates during the 2019 field season. The target plant was Eurasian watermilfoil, which has increased in Tuxedo and Little Wee Wah in recent years.
- In Tuxedo lake, Eurasian watermilfoil was abundant and widespread throughout, with 'topped-out' growth, meaning plants reached the lake's surface.
- In Little Wee Wah, the herbicide 2-4D was used to treat Eurasian watermilfoil in 2018. Our 2019 survey showed rebounding plants suggesting the success of the 2018 treatment may have been compromised by flushing and re-inoculation from Tuxedo Lake.
- Aquatic plant community in Wee Wah was found to be almost entirely composed of Coontail, which is a native, but at times a serious nuisance (aggressive) plant. There were a few small patches of milfoil present in the lake during the September survey.

Management Recommendations:

- Preventing the spread of Eurasian watermilfoil between lakes via a fragment barrier at Little Wee Wah and Wee Wah outlets is advisable.
- For Tuxedo Lake, we recommend the use of EPA registered herbicides to reduce the Eurasian Watermilfoil population to a level where DASH (Diver Assisted Suction Harvesting) may be used as a follow-up management technique in subsequent years. The Eurasian Watermilfoil population is large, which precludes cost-effective management through DASH operations of done on a lake-wide scale.
- We recommend dive crews wade into the shallow delta area at Little Wee Wah and physically remove Eurasian watermilfoil shoots. Eurasian milfoil beds in the rest of the waterbody will be managed with herbicides.
- Wee Wah lake milfoil should be managed using DASH operations focusing on the small patches found during the September survey. Coontail should be controlled using DASH.

Site Descriptions

Tuxedo Lake, Little Wee Wah Pond and Wee Wah Lake are three connected waterbodies in the village of Tuxedo Park (Orange County, NY). Water flows from Tuxedo lake northward into Little Wee Wah and then into Wee Wah before emptying out into the Indian Kill, then the Ramapo River.

Table 1. Select morphometric parameters for Tuxedo Lake, Wee Wah Lake, and Little Wee Wah. Note: the watershed acreage was calculated including the waterbodies acreage. Data sources include Kilson (2019), CSLAP (2019) and Princeton Hydro (2009).

Parameter	Tuxedo Lake	Wee Wah Lake	Little Wee Wah Pond
Surface Area	295 acres	54 acres	12 acres
Shoreline Length	4.4 miles	1.8 miles	0.6 miles
Watershed Area	2,029 acres	5,274 acres	2,133 acres
Watershed to Lake Area Ratio	6.8:1	97.0:1	172.6:1
Maximum Depth	66 feet (20 meters)	20 feet (6 meters)	13 feet (4 meters)
Mean Depth	27.6 feet (8.4 meters)	8.25 feet (2.5 meters)	8.25 feet (2.5 meters)

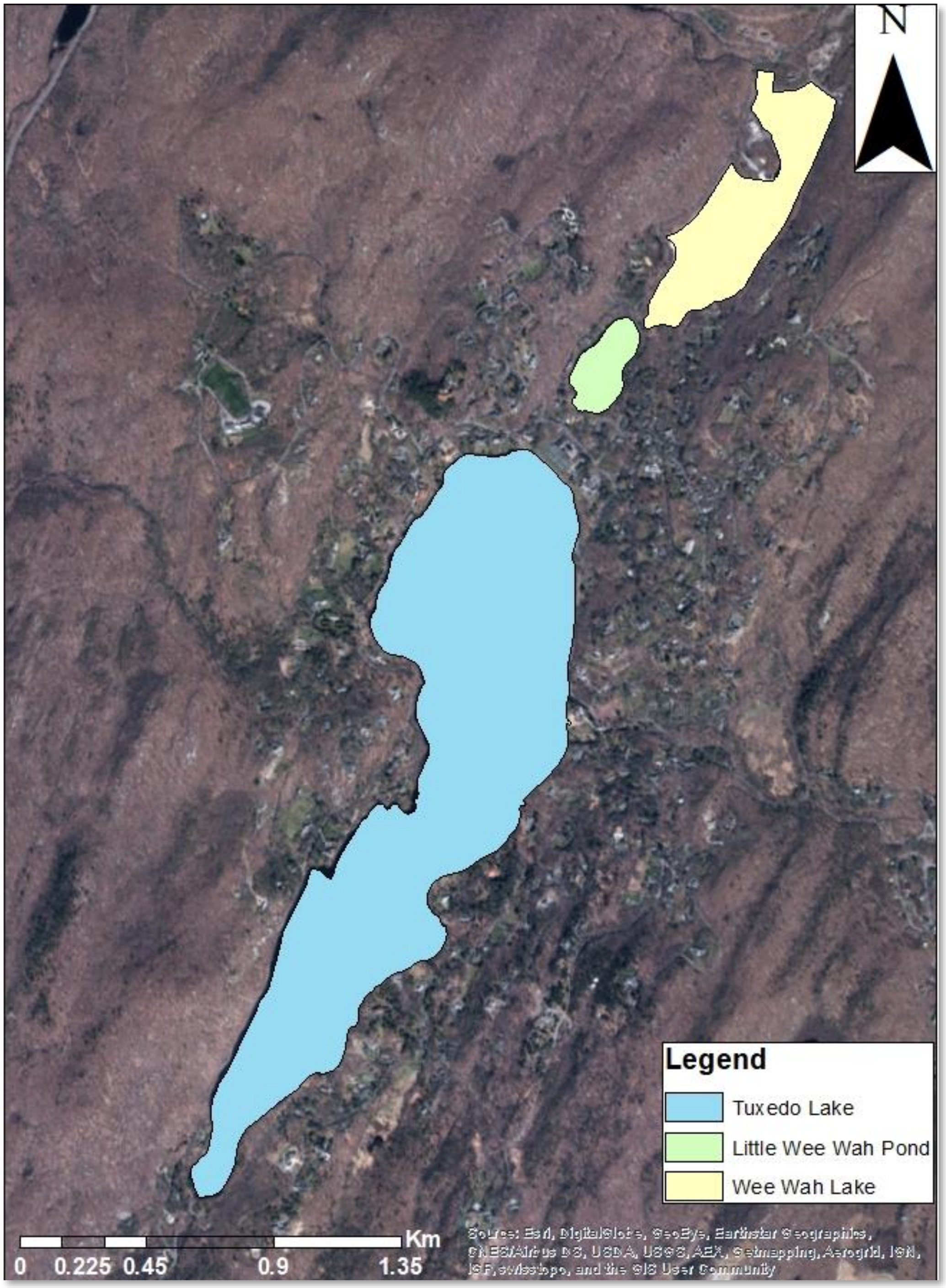

Figure 1. Map of Tuxedo Lake, Wee Wah Lake, and Little Wee Wah Pond.

Aquatic Plants

Tuxedo Lake

Historical Data

Aquatic plant surveys were conducted in Tuxedo Lake on October 21, 2011, September 13, 2012, August 28, 2017 and September 21, 2018 by Solitude Lake Management (formerly Allied Biological) (Mayer 2018, 2019b). The 2018 SOLitude survey is used to compare against findings from our 2019 survey results. During the 2011 and 2012 surveys, EWM was only found at 5.7 and 4.8% abundance, respectively (Table 2). At that time EWM was 5^{th} and 7^{th} in ranking of abundance. By 2017, EWM had become the most abundant plant in the lake increasing to 74.0%, and 85.0% in 2018, with a larger proportion of dense EWM than in previous years. This is typical rapid growth of EWM populations once established in a lake.

Table 2. Percent occurrence data from past surveys on Tuxedo Lake (October 21^{st}, 2011; September 13^{th}, 2012; August 28^{th}, 2017; September 21^{st}, 2018 and September 9-10, 2019). 2019 data present in this table is just from SOLitude points.

		Percent Occurrence (%)				
Common Name	**Scientific Name**	**2011**	**2012**	**2017**	**2018**	**2019**
Eurasian Watermilfoil	*Myriophyllum spicatum*	5.7	4.8	74.0	85.0	89.4
Eel-grass/ Wild celery	*Vallisneria americana*	29.8	35.5	28.8	27.0	32.7
Large-leaf pondweed	*Potamogeton amplifolius*	5.7	5.7	9.6	17.3	15.4
Southern Naiad	*Najas guadalupensis*	--	--	7.6	--	--
Leafy pondweed	*Potamgeton foliosus*	--	5.7	4.8	5.0	--
Ribbon-leaf Pondweed	*Potamogeton epihydrus*	--	--	--	--	1.0
Robbin's Pondweed	*Potamogeton robbinsii*	17.3	13.5	2.8	13.0	23.1
Arrowhead (Rosettes)	*Sagittaria sp.*	4.8	13.5	1.9	2.0	9.6
Benthic Filamentous Algae	--	4.8	4.8	1.0	--	1.0
Watermoss	*Fontinalis sp.*	2.8	3.8	1.0	--	5.8
Small Pondweed	*Potamogeton pusillus*	8.6	1.0	1.0	--	27.9
Floating Filamentous Algae	--	--	--	1.0	2.0	22.1
Slender Naiad	*Najas flexilis*	17.3	11.5	--	5.0	--
Stonewort	*Nitella sp.*	1.0	1.0	--	--	--
Pipewort	*Eriocaulon aquaticum*	--	1.0	--	--	--
Spikerush	*Eleocharis sp.*	--	1.0	--	--	--
Spiral-fruited Pondweed	*Potamogeton spirillus*	--	1.0	--	--	--
Small Duckweed	*Lemna minor*	--	--	--	1.0	--
Great Duckweed	*Polyrhiza spirodela*	--	--	--	1.0	--
Brittle Naiad	*Najas minor*	--	--	--	1.0	3.8
Muskgrass	*Chara sp.*	--	--	--	1.0	--
TOTAL TAXA		**10**	**14**	**11**	**12**	**10**

Over the four years of study, the number of native plant species (species richness) has been low between 7 and 12 species. Species composition changed between 2011-2012 and 2017-2018, with 5 new species added to the record after EWM became dominant (Filamentous floating algae, Small Duckweed, Great Duckweed, Invasive Brittle Naiad and Muskgrass) and four species becoming absent after EWM dominance (Stonewort, Pipewort, Spikerush, and Spiral-fruited Pondweed). The majority of these species were found only at 1% when present, so their absence in either previous or subsequent years may be more due to annual variation and sampling limitations than direct competition with EWM. Large-leaf pondweed and southern naiad were the only species that showed increases after EWM dominance, with the latter being first discovered in 2017, then absent in 2018. Wild Celery (alternate common name Eel-grass), Arrowhead, Robbin's Pondweed, Slender Naiad, and Watermoss all experienced declines after EWM dominance. Overall, the dominance of EWM in 2017 and 2018 seems to have impacted aquatic plants, by shifting species composition and reducing the percent occurrence of a few taxa.

2019 NEAR Survey

The survey was conducted between September 9th and 10th, 2019. A total of 295 (104 SOLitude) waypoints were made throughout the lake (Figure 2). Nineteen points were made to pinpoint the location of the outer edge of the littoral zone. Our study established the outer edge of the littoral zone by the maximum depth at which aquatic plants were found to grow. This depth was consistently approximately 14 feet deep (4.3 meters). Of the remaining 276 points, 71 points or 25 % were devoid of plants.

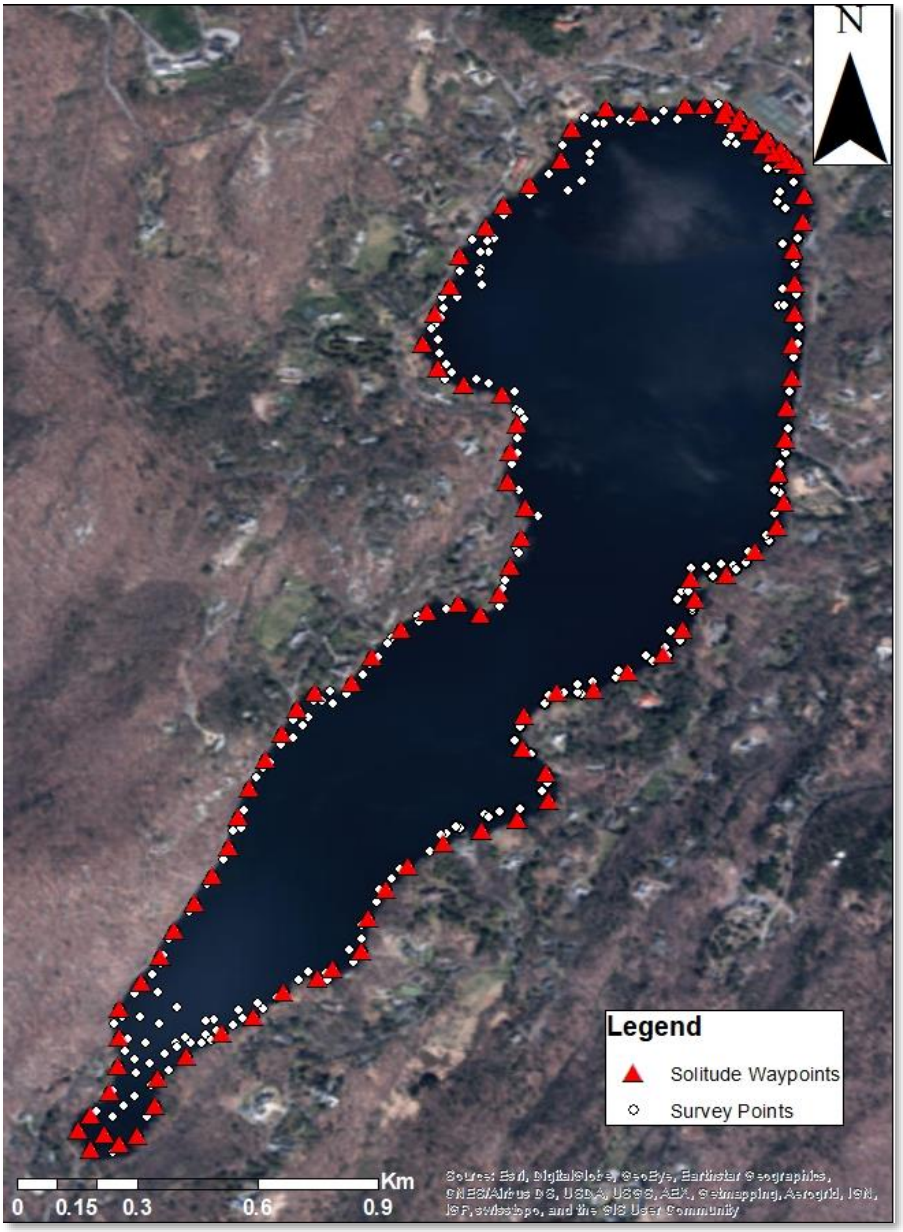

Figure 2. NEAR field survey waypoints and SOLitude waypoints that were sampled during the September survey.

A total of 12 different taxa were recorded. Two invasive species, EWM and Brittle naiad, were found in the lake. (Table 3). Brittle naiad was found at 6 locations, with a mean percent cover of 10% (Figure 5). EWM was observed at 223 locations spread across the entire lake in dense patches with a mean percent cover of 54% (Figure 3). Total surface area coverage of EWM was 39 acres (13% total lake surface area, Figure 4), most heavily concentrated in the northwestern and the southern sections both north and south of the barrier. Other native species noted included Tapegrass (Figure 6), Largeleaf pondweed (Figure 7), Small pondweed, and Robbin's pondweed.

Table 3. Aquatic plant species found in Tuxedo Lake during our 2019 survey ranked by mean percent cover, frequency of occurrence (N) also given. Data includes both Solitude and NEAR waypoints.

Tuxedo Lake	September	
Scientific Name	**Mean Percent Cover (%)**	**N**
Filamentous algae	62	34
Vallisneria americana	53	56
Myriophyllum spicatum	52	223
Potamogeton robbinsii	49	38
Potamogeton pusillus	35	54
Potamogeton amplifolius	32	24
Sagittaria gramenia	32	23
Potamogeton epihydrus	30	1
***Fontinalis* sp.**	28	*6*
Elatine minima	10	1
Lyngbya wolleii	10	2
Najas minor	10	6

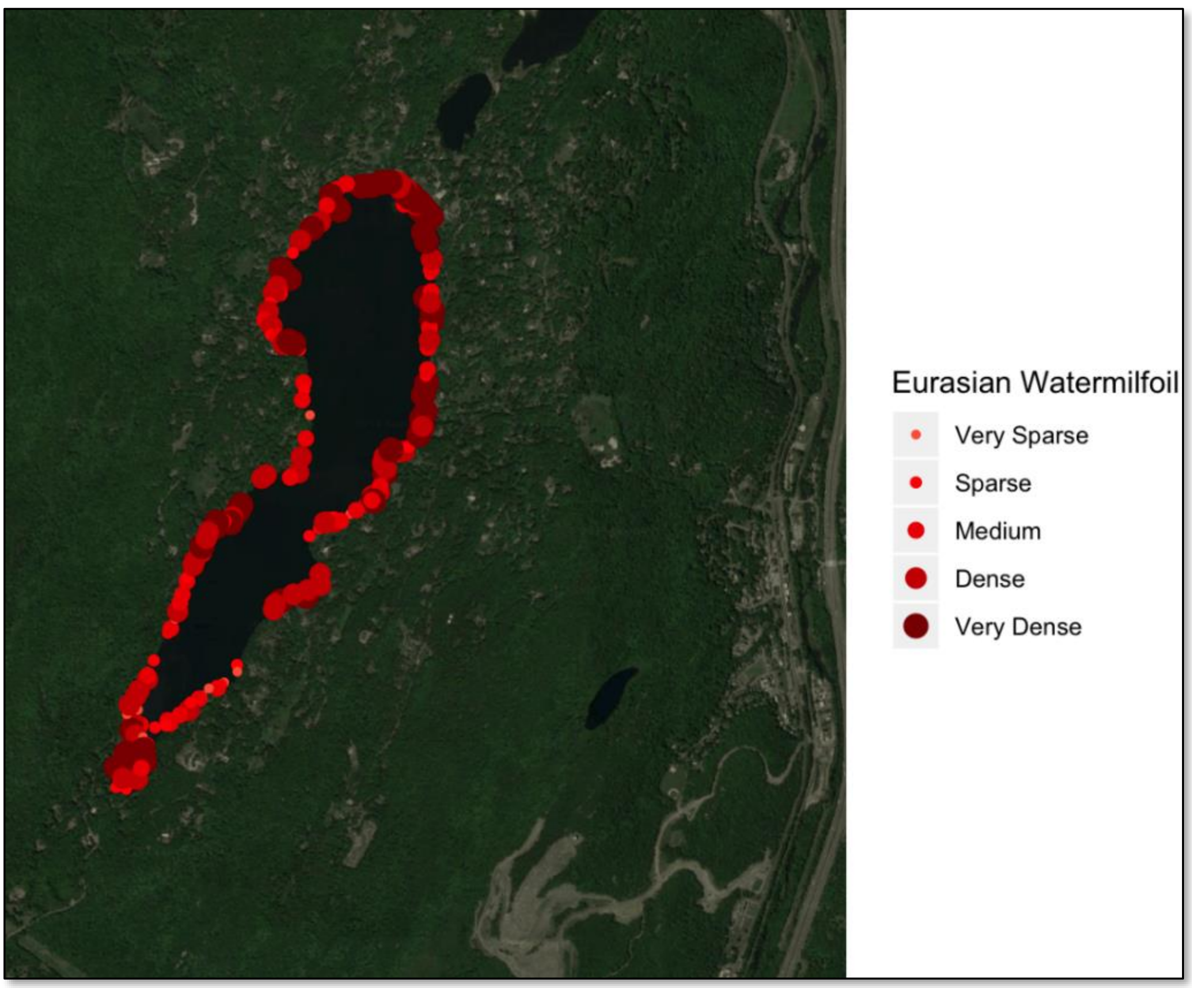

Figure 3. Distribution and percent cover of EWM in Tuxedo Lake during the September survey. Percent cover categories are as follows: <10 = Very Sparse, 10-19 = Sparse, 20-49 = Medium, 50-79 = Dense, 80-100 = Very Dense

Figure 4. EWM acreage estimation from September NEAR survey.

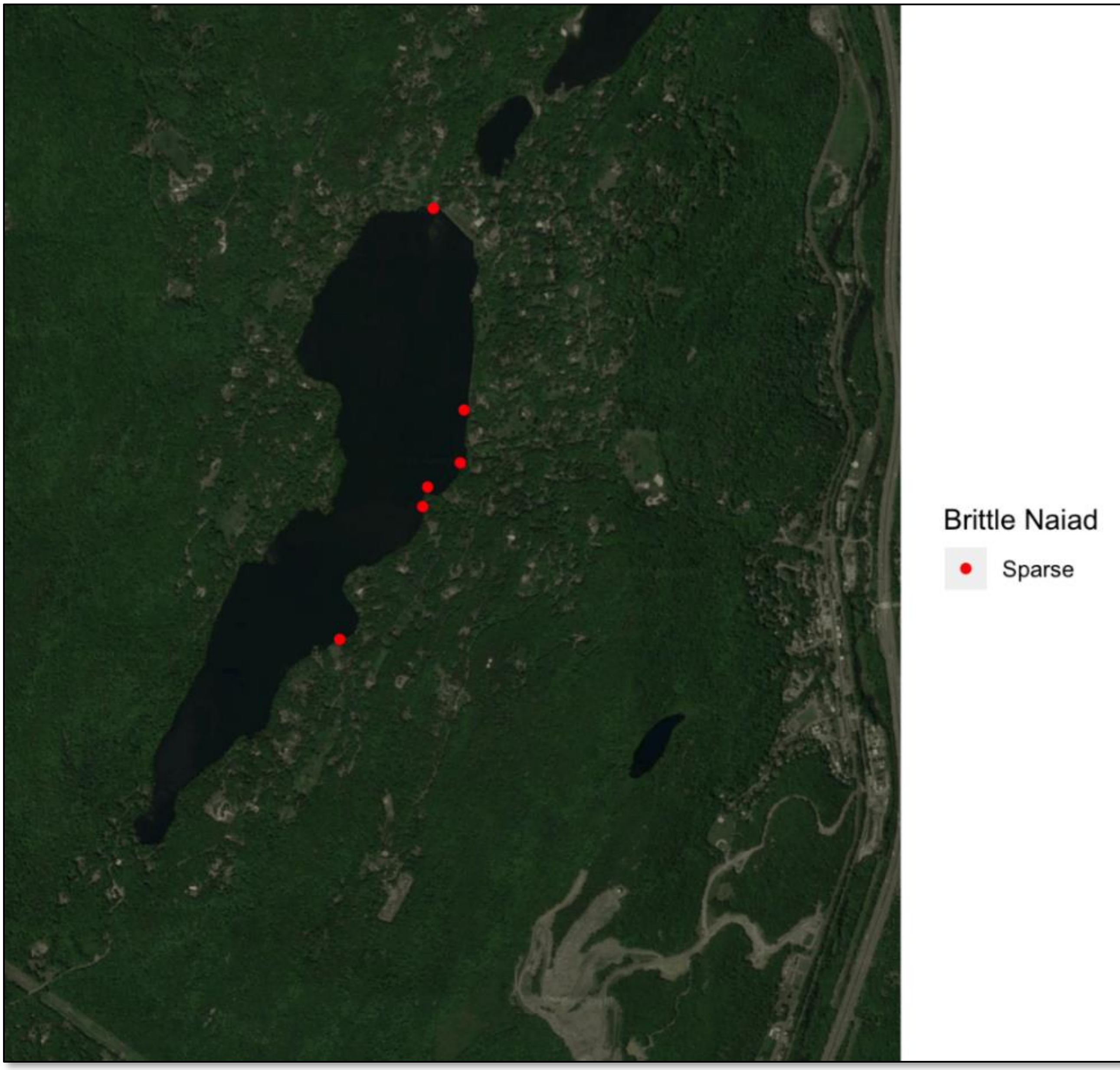

Figure 5. Distribution and percent cover of Brittle Naiad in Tuxedo Lake during the September survey. Percent cover categories are as follows: 10-19 = Sparse.

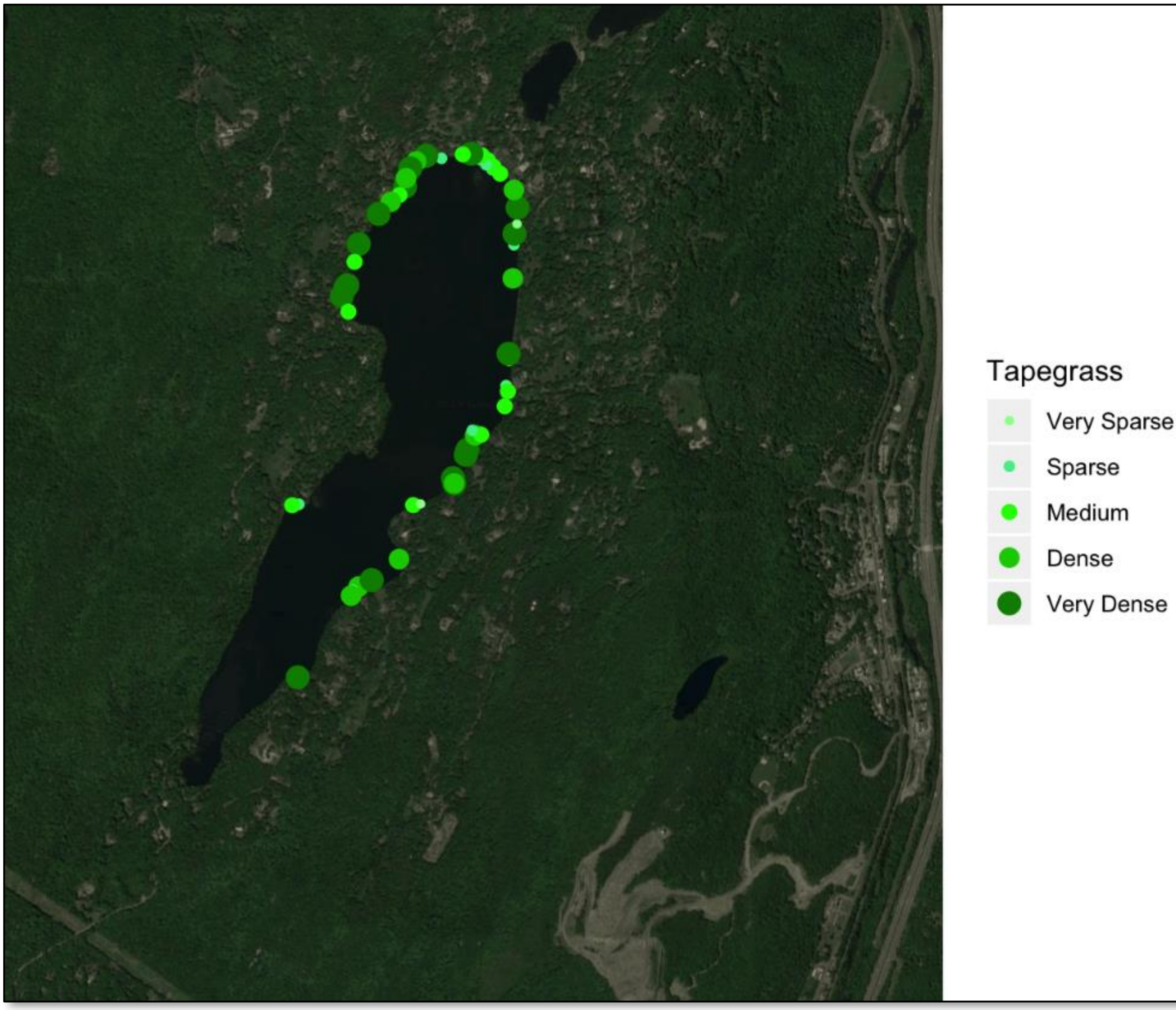

Figure 6. Distribution and percent cover of Tapegrass in Tuxedo Lake during the September survey. Percent cover categories are as follows: <10 = Very Sparse, 10-19 = Sparse, 20-49 = Medium, 50-79 = Dense, 80-100 = Very Dense

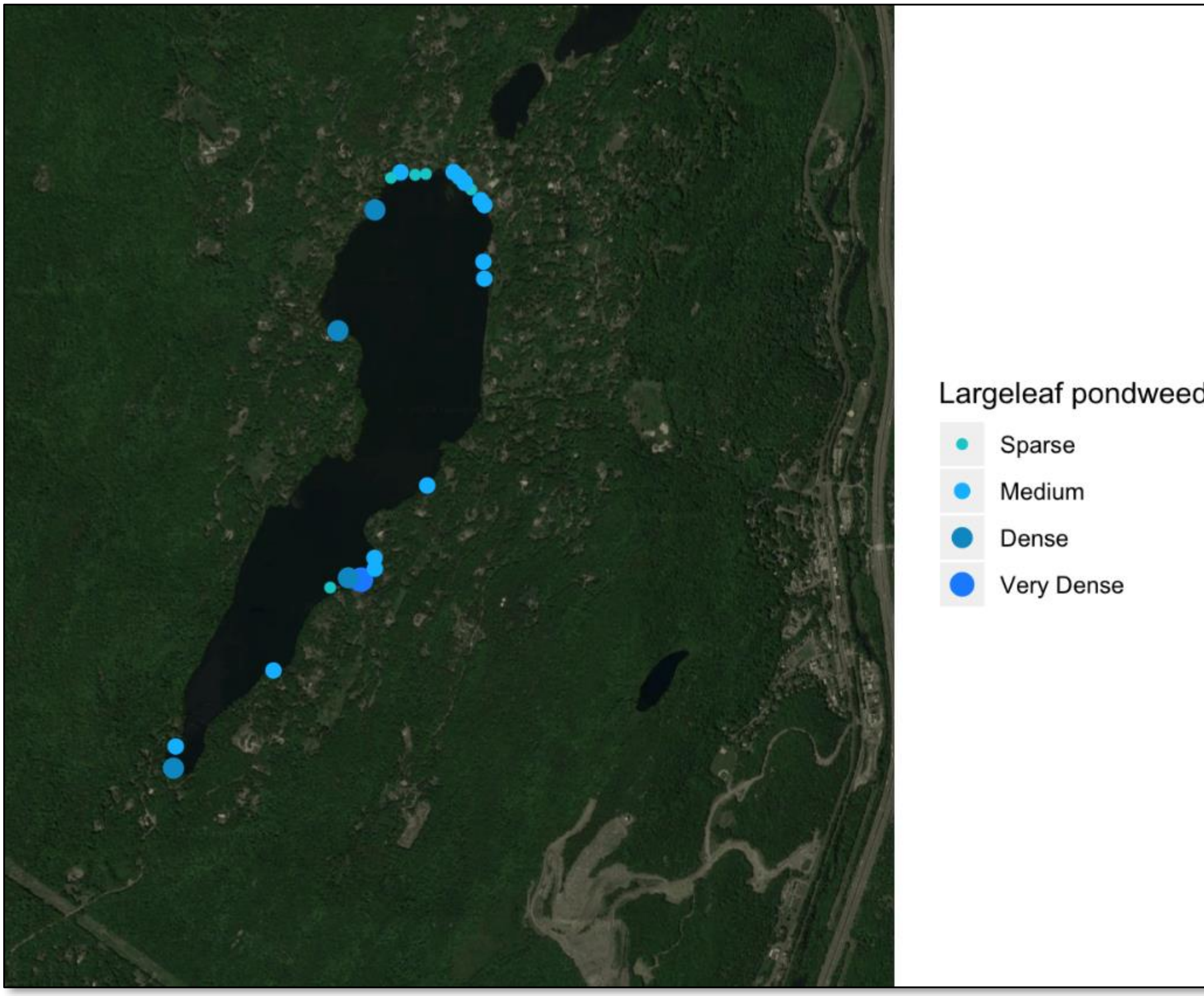

Figure 7. Distribution and percent cover of Large leaf pondweed in Tuxedo Lake during the September survey. Percent cover categories are as follows: 10-19 = Sparse, 20-49 = Medium, 50-79 = Dense, 80-100 = Very Dense.

Comparison of 2019 survey results against 2018 points sampled by SOLitude, EWM percent occurrence has increase slightly from 85.0% to 89.4% (Table 2). Thirteen different species were found at these waypoints, with one new species identified: (Ribbon-leaf pondweed). Five species were not found during the survey (Muskgrass, Great Duckweed, Small Duckweed, Slender Naiad, and Leafy Pondweed. As mentioned previously, changes in the presence-absence of species that are at low abundance are most likely due to difficulty of detection from year to year.

Little Wee Wah

Historical Data

Little Wee Wah was surveyed in 2012 and on September 28, 2018 by SOLitude Lake Management (Mayer 2019a), using 25 historically referenced points. Combining results from both surveys, only eight species of aquatic plants and two types of filamentous algae have been found in Little Wee Wah (Table 4.). In 2012, EWM was the dominant plant, found at 64% of the sites sampled. In 2018, after a 2,4-D treatment, milfoil was reduced to 12 % of the sites sampled. Bassweed became the dominant plant, present at 64% of sites sampled. There was also a large increase in benthic cyanobacteria from 2012 to 2018.

Table 4. Percent occurrence data from past surveys on Little Wee Wah (2012 and 2018).

Common name	Scientific Name	Occurrence (%)	
		2012	2018
Eurasian Watermilfoil	*Myriophyllum spicatum*	64.0	12.0
Robbin's Pondweed	*Potamogeton robbinsii*	32.0	0.0
Slender Naiad	*Najas flexilis*	28.0	0.0
Benthic Filamentous Algae	--	20.0	72.0
Bassweed	*Potamogeton amplifolius*	16.0	64.0
Spikerush	*Eleocharis sp.*	4.0	0.0
Small Duckweed	*Lemna minor*	0.0	56.0
Brittle Naiad	*Najas minor*	0.0	16.0
Wild Celery	*Vallisneria americana*	0.0	16.0
Floating Filamentous Algae	--	0.0	4.0

We surveyed Little Wee Wah twice, once in spring in May and once in the fall in September. Together 57 waypoints made were vegetation data was collected (Figure 8). There were a few more made in September because plant growth was near maximum as compared to early growth we found in May. Both surveys showed EWM to be the most frequently encountered aquatic plant in the lake. Our data show more EWM was found in September than was found in May.

It appears the 2,4-D treatment in the summer of 2018 was able to suppress EWM abundance for about a year, with the plant rebounding after that. Most of the EWM found in September was located at the south-western end of the lake, near the tuxedo outflow. This may be due to the fact that the outflow diluted herbicide concentrations, making control in this area less effective. Fragments also can flow downstream from Tuxedo Lake, and there was EWM observed growing in the slower-flowing sections of the inflow. This could have also aided in the establishment and growth of EWM in the southwestern section of Little Wee Wah.

Figure 8. NEAR field survey waypoints sampled at Little Wee Wah during the May and September survey.

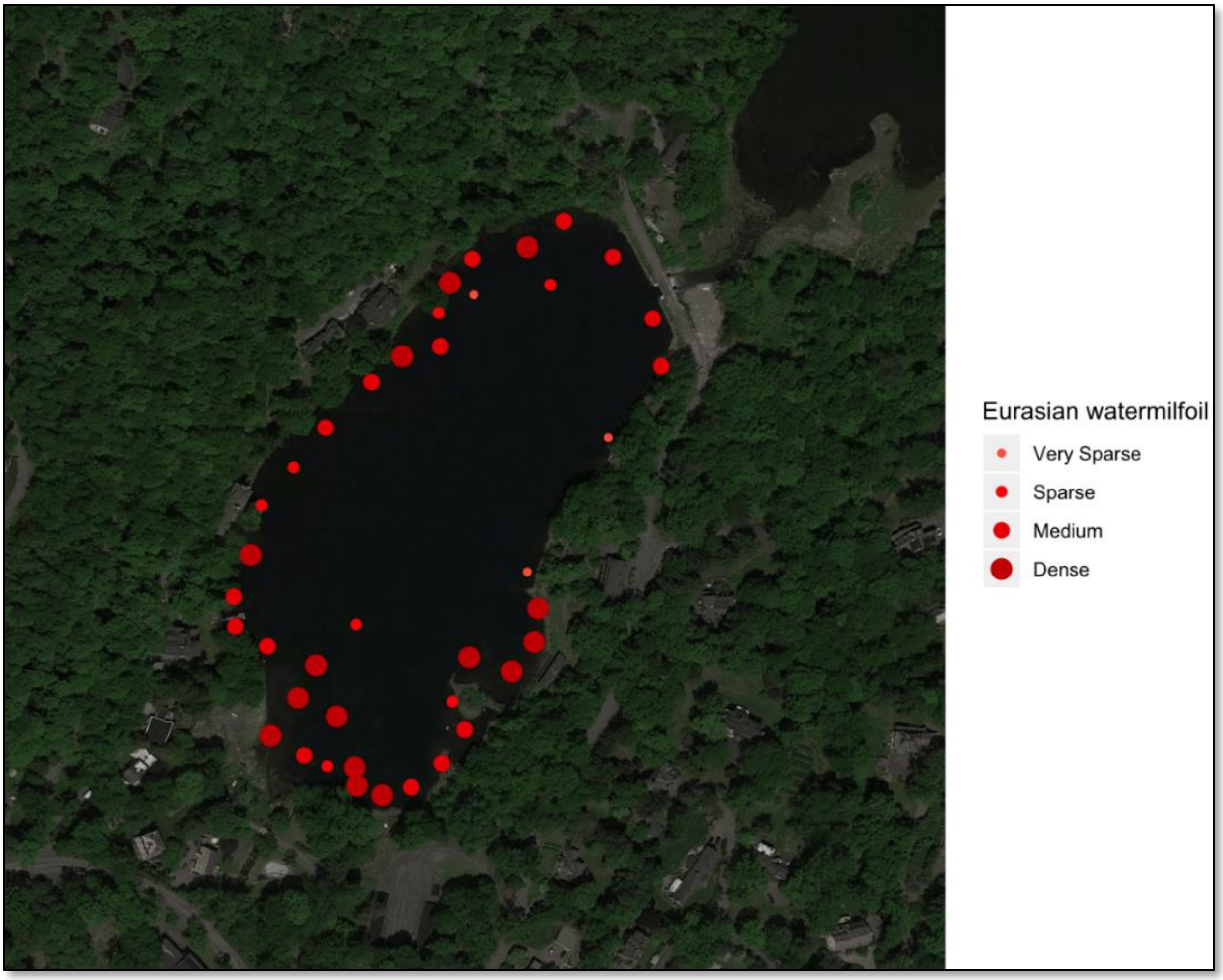

Figure 9. Distribution and percent cover of Eurasian watermilfoil in Little Wee Wah during the September survey. Percent cover categories are as follows: <10 = Very Sparse, 10-19 = Sparse, 20-49 = Medium, 50-79 = Dense.

A higher number of aquatic plant species were encountered during the September survey versus the May survey (Table 5). This fact may be partially attributed to the increase in sampling points in September, but more likely a result of natural plant growth increases later in the season. Many aquatic plant species do not grow as early as May. Brittle Naiad was observed at three different locations during the September survey (Figure 10).

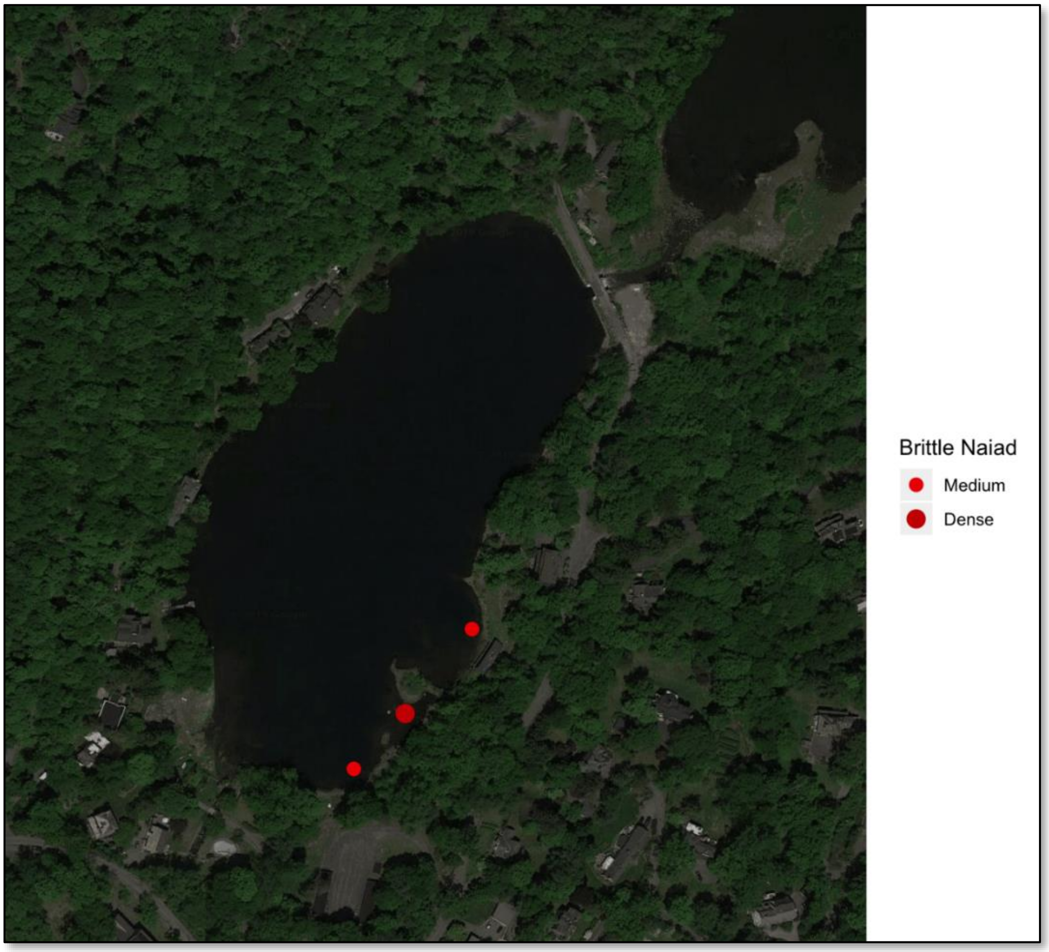

Figure 10. Distribution and percent cover of Brittle Naiad in Little Wee Wah during the September survey. Percent cover categories are as follows: 20-49% = Medium, 50-79% = Dense.

Table 5. Mean percent cover and frequency of occurrence (N) of species found during the May and September Little Wee Wah survey.

Little Wee Wah	May		September	
Scientific Name	**Mean Percent Cover (%)**	**N**	**Mean Percent Cover (%)**	**N**
Filamentous algae	17	8	--	--
Filamentous brown algae	31	5	45	3
Ludwigia sp.	60	1	--	--
Lyngbya wolleii	--	0	65	4
Myriophyllum spicatum	22	12	38	40
Najas flexillis	--	0	15	2
Najas minor	--	0	43	3
Potamogeton amplifolius	43	8	42	22
Potamogeton pusillus	--	0	24	4
Potamogeton robbinsii	--	0	8	2
Vallisneria americana	--	0	25	4

Wee Wah

A total of 112 points were sampled over the two months in 2019, with 85 points visited in May and an additional 27 points added in September (Figure 11). In May, EWM was found at only two locations, close to the Warwick Brook outflow (Table 8). Due to the drawdown that occurred in 2018, we would expect that most of the milfoil present in the shallow sections of the lake would be desiccated, except for areas with continuous year-round water flows, such as the inlet. During the September survey, milfoil was present at 29 different locations lake-wide, mostly at low abundance (Figure 12). We believe that milfoil increased in Wee Wah because 1) The survey was later in the growing season, meaning the plants were larger and therefore more easily detectable and 2) there were additional areas less affected by the drawdown such as the southwestern Little Wee Wah outlet section and 3) fragments from Little Wee Wah may have floated into the lake from Tuxedo and established new plants.

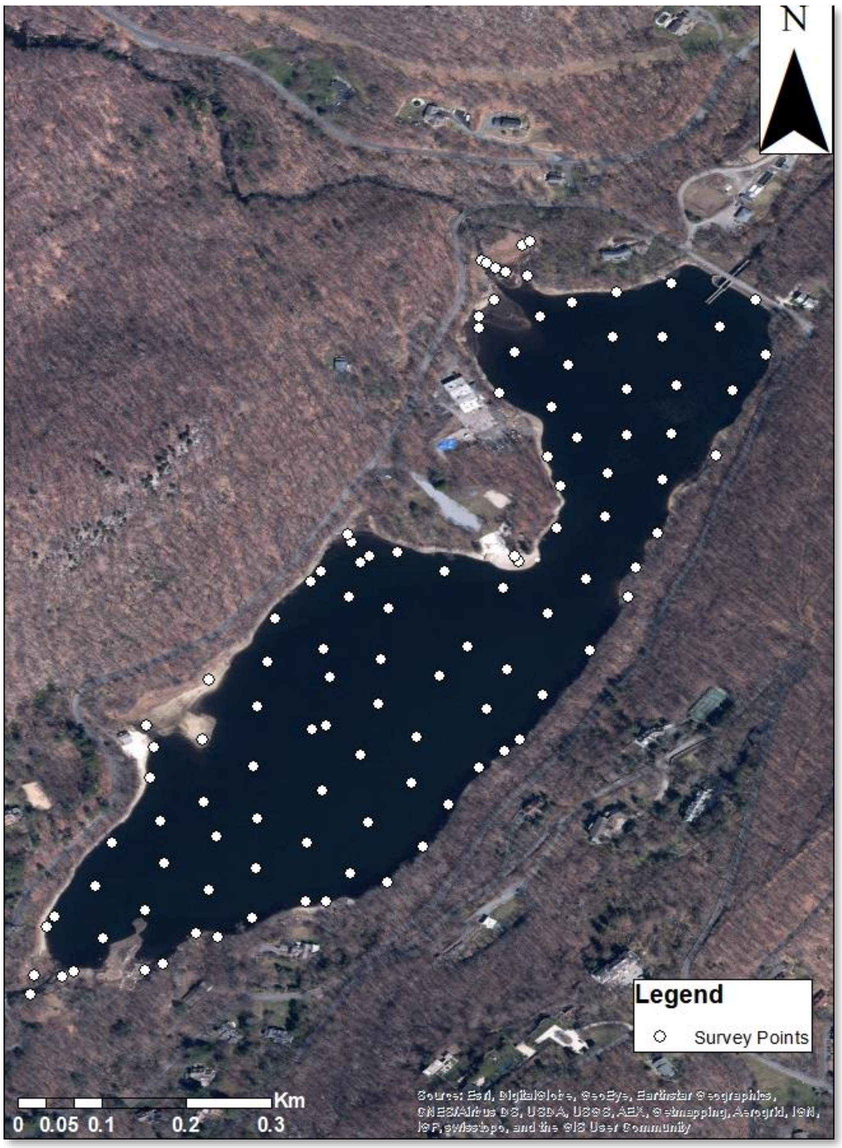

Figure 11. NEAR field survey waypoints sampled at Little Wee Wah during the May and September survey.

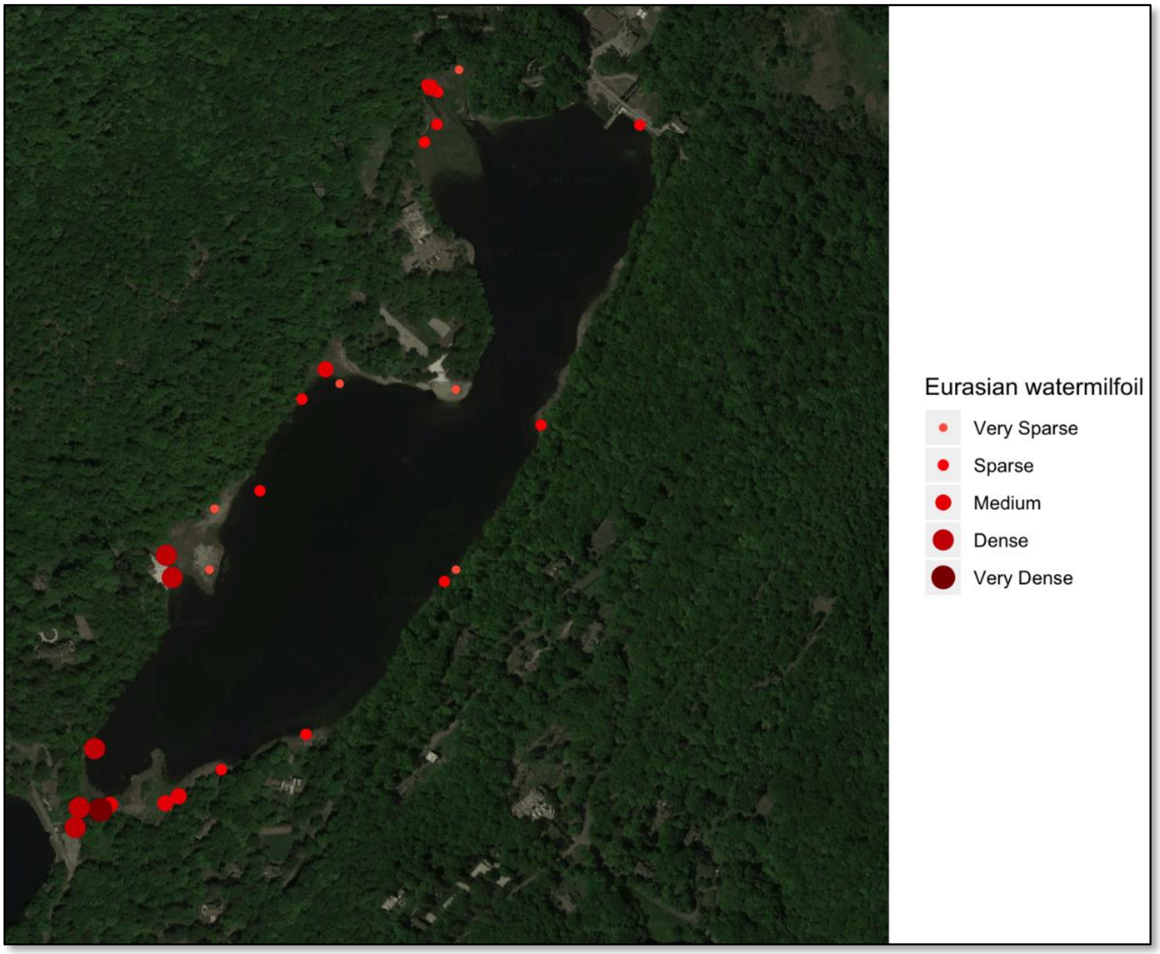

Figure 12. Distribution and percent cover of EWM in Wee Wah during the September survey. Percent cover categories are as follows: <10 = Very Sparse, 10-19 = Sparse, 20-49 = Medium, 50-79 = Dense, 80-100 = Very Dense.

The most abundant plant in Wee Wah during our 2019 surveys was Coontail, found at 70 locations (Figure 13). Coontail is distributed throughout the entire lake, with the most abundant sections located in the middle of the lake. During the summer, floating rafts of Coontail were observed in this middle section causing nuisance conditions to recreation. Coontail may inhibit oxygen transfer from water of higher DO coming from outside the beds leading to reduced oxygen levels and locally increased nutrients from sediment release. Similar to Little Wee Wah, more species were observed during the September survey compared to the May survey. Brittle Naiad was observed at four different locations, and was fairly dense when found (Table 8).

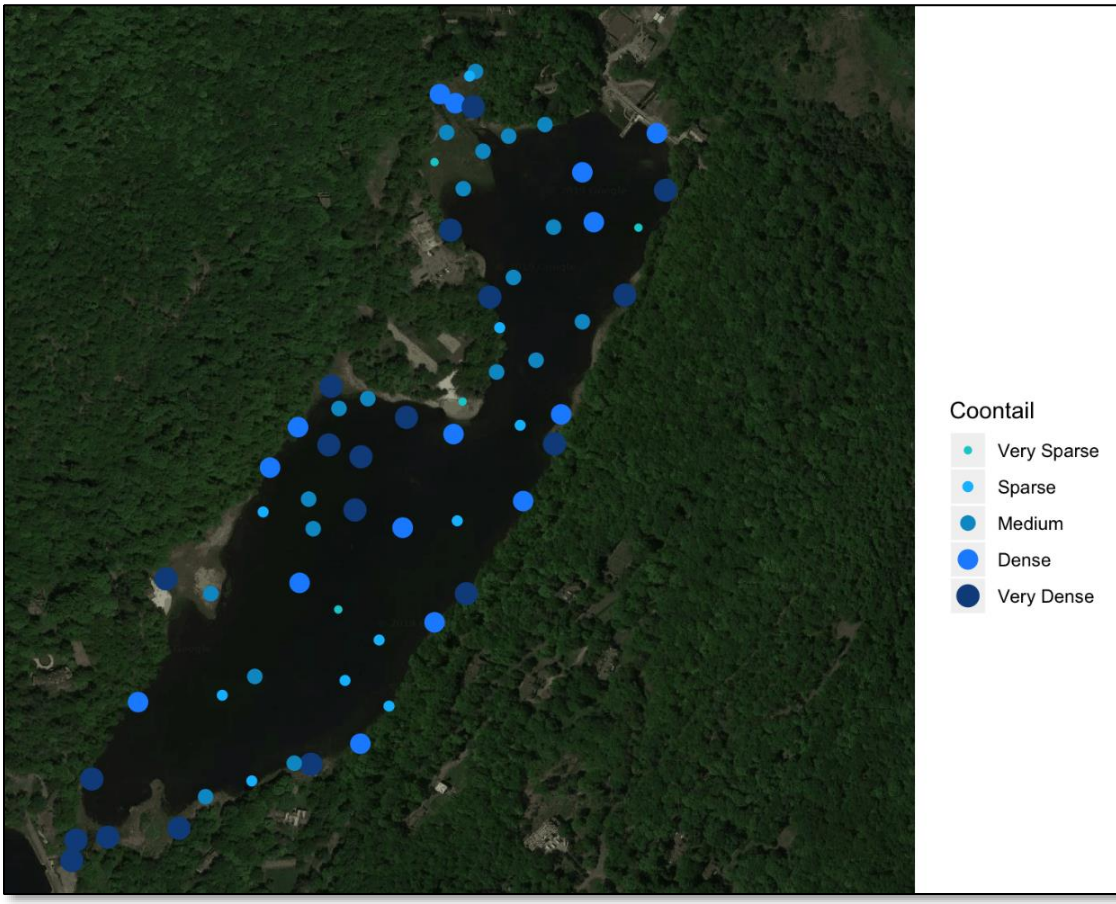

Figure 13. Distribution and percent cover of Coontail in Wee Wah during the September survey. Percent cover categories are as follows: <10 = Very Sparse, 10-19 = Sparse, 20-49 = Medium, 50-79 = Dense, 80-100 = Very Dense

Table 6. Mean percent cover and frequency of occurrence (N) of species found during the May and September Wee Wah survey.

Wee Wah	May		September	
Scientific Name	Mean Percent Cover (%)	N	Mean Percent Cover (%)	N
Ceratophyllum demersum	56	70	50	70
Elodea nuttallii	9	5	5	1
Emergent plants	15	2	26	7
Filamentous brown algae	13	10	--	--
Ludwigia sp.	25	4	65	3
Lythrum salicaria	--	--	20	2
Myriophyllum spicatum	25	2	25	29
Najas flexillis	--	--	30	1
Najas minor	--	--	50	4
Polygonum sp.	--	--	43	2
Potamogeton pusillus	--	--	20	1
Sparganium sp.	--	--	10	1

Feasibility of Aquatic Plant Management Techniques

There are only a few management options for effectively controlling invasive aquatic plants, however those that have proven useful are typically focused toward specific plant species or groups of species. Each of the few methods has strengths and weaknesses making the decision of the most suitable control option dependent of the specifics of each case.

Aquatic plant management methods fall into three categories: physical, biological and chemical. No panacea for aquatic plant management exists, as each lake's specific ecological, recreational and regulatory conditions are different. For successful management, it is essential to identify appropriate techniques and look for integration when possible.

For Tuxedo, Wee Wah and Little Wee Wah, we deemed the most appropriate methods warranting further consideration are physical and chemical alternatives. Mechanical and biological controls are not appropriate for management in these systems, so discussions or those methods is provided in the appendix.

Recommendations for Aquatic Plant Management

Management Goals

Management of aquatic invasive plants that have become established is an annual (iterative), and indefinite process because eradication is rarely achieved, although the proscribed end point of the management plan is to eliminate the invasive from the lake.

EWM control is much more effective if conducted under an overlying suite of specific annual objectives and goals. By defining specific goals and objectives for the management of EWM, the village of Tuxedo Park will be able to maximize the efficiency of management, and drastically reduce the cost of management over the course of decades. In addition, having clearly stated goals and objectives in the plan will make the village more competitive for grants related to aquatic plant management, which could further reduce financial costs.

Goals for invasive species management include 1) accurate and comprehensive identification of any new infestation of non-native aquatic plants into the three lakes. This includes inoculation of one lake by one of the other sister lakes. 2) Early detection and rapid response for any new infestation that focuses on finding and removing all new plants. 3) A long-term management plan to control established EWM in lakes where the plant is compromising recreational and ecological values.

Eurasian milfoil has very rarely been removed permanently from a lake once established. The species has several growth advantages that o colonize new habitats through fragmentation, combined with the size of Tuxedo Lake, it is unlikely that the population will ever be eradicated. Therefore, setting a goal of eradication would not be wise; the goal may not be met without exorbitant capital investment. Little Wee Wah and Wee Wah have smaller populations in smaller water bodies, so eradication is more feasible, but still not guaranteed. If control is the goal, the village of Tuxedo Park, in conjunction with the lake users, must determine what level of control is acceptable. It will be important to recognize that different stakeholders will view plant control differently based on what they find most important, so consideration must be given to potential conflicts between various uses of the lakes during this process. The goals stated in the latter sections are meant as a starting off point and should be subject to discussion within stakeholder groups and the Village of tuxedo to deem appropriateness with desired uses.

Tuxedo Lake

Goal: Reduce Eurasian Watermilfoil to ~20% of original coverage

EWM in Tuxedo Lake should be managed on a lake-wide scale, as plants, even in uninhabited areas, have negative impacts on the entire water body. The most viable, cost-effective, whole-lake strategy to combat milfoil is the use of EPA-registered herbicides. While DASH can be effective at very small scales, using this technique over a large area is very cost-inefficient. Comparing prices for DASH operations and herbicide treatments reveal the large disparity in pricing as the treatment area increases. For example, if you had a 20-acre plot of EWM to manage, estimated DASH efforts can cost anywhere from $56,000 to $336,000 based on the density of the plants, number of divers and individual companies' labor prices. For that same 20-acre plot, an estimated herbicide treatment would cost anywhere from $5,000 to $20,000 depending on the particular product used and if the application needs to take place over multiple days. DASH efforts on an acre-scale cost anywhere from 3-18 times as much as herbicide treatments with the larger differences seen when the treatment plot acreage increases The biggest difference in price is how much labor adds up; it is much more expensive to have divers physically swim an entire treatment area that’s 20 to 100 acres than it is to have a boat drive across the same distance.

There are also other scalability issues with DASH. Considering there are two divers working in the water, harvesting a 20-acre area would take a minimum of 40 days (8 work weeks) to complete with a conservative estimate of 2 days per acre. Over that long of a period, averaging 7-8 hours a day for 5 days, diving crews can get exhausted quickly. Exhausted crews tend to let their quality of work slip, not thoroughly checking areas on a second pass, and not pulling all plants by the root crowns. This can be remedied by adding additional DASH boats, however, that will result in a net increase in cost. In a scenario with unlimited funds, using DASH to manage the infestation on a lake-wide scale can be done, however with the estimated cost of DASH being exorbitantly higher than the cost of herbicide treatments, we cannot recommend DASH for lake-wide management at this stage.

Our recommendation is that the Village of Tuxedo considers the use of ProcellaCOR for the control of EWM lake-wide. While fluridone is highly effective on EWM and has been around for decades, there are a few logistical issues that need to be considered for Tuxedo Lake. Fluridone treatments in drinking water supply reservoirs cannot be within ¼ of a mile from the potable water intake if the treatment is applied over 20 ppb. If the treatment is within 4-20 ppb, the liquid formulation may be applied within ¼ mile of the intake provided that the potable water use is delayed by 24 hours. If bump applications are needed, then there will be additional days with 24-hour water use restrictions. ProcellaCOR does not have any drinking water restrictions, so areas of high EWM growth near the potable water intake can be treated.

One of the downsides of ProcellaCOR in our opinion is the lack of peer-reviewed, published field trials, which is due to the relatively recent national registration (2018). To this end, we would recommend that the Village of Tuxedo Park conduct a small scale field trial in the southernmost section of Tuxedo Lake. This would allow the village to evaluate the product on a small scale and collect data on target and non-target impacts along with herbicide dilution rates. If the field trials are received favorably by the public and have demonstrated quantifiable results, then we would recommend moving forward with a full-lake treatment. Concurrent with the field trials, the Village of Tuxedo should hold public information sessions concerning the use of herbicides for EWM management. This would allow the public to ask questions and be involved in the process throughout. The use of herbicides is controversial, so a strong public outreach campaign will go a long way to increase public support and dispel myths concerning treatment.

During the first year of herbicide trials, DASH operations can still be used to keep the high-use areas (the Tuxedo Club and the Village boat house) clear of milfoil. We suggest allocating at least 5 days for each area based on 2019 effort, provided the boats at both locations can be moved out of the slips. The contractor in 2019 noted that the presence of the boats in the slips prevented efficient harvesting. This should be done earlier in the year (June/July) to maximize clarity.

After this full-lake treatment, we recommend following up with intensive surveys and DASH operations to harvest any plants that may have survived the treatment. This follow-up survey should be done the year of the treatment and in the years to follow. If DASH is done combined with detailed aquatic plant mapping, EWM should be suppressed lake wide. This also allows the DASH efforts to be targeted and reducing costs. DASH can also be used to manage the Brittle Naiad present at a few locations. Care should be taken when managing this plant physically as it can break apart easily.

Little Wee Wah

Goal: Reduce Eurasian Watermilfoil to ~10% of original coverage

Following the 2,4-D treatment in 2018, EWM has started to recover, especially near the south end by the Tuxedo lake inlet. DASH efforts aimed at curbing this recovery has not been successful to date due to a combination of factors, primarily being limited harvesting time and very low visibility. Overall, efforts to curb the EWM introduction will continue to be compromised unless there is something done about fragments floating down from Tuxedo lake and small plants living within the inlet stream. NEAR recommends that there be a fragment barrier placed at the mouth of the outlet on Tuxedo Lake to prevent movement of EWM 6 -12 inches under the surface. A barrier similar to the one in the southern section of Tuxedo Lake would suffice. These barriers would need to be inspected regularly to In addition to the barrier, NEAR recommends that the inlet stream between Tuxedo Lake and Little Wee Wah be surveyed and hand-harvested for strands of milfoil. NEAR staff has observed small single stem plants growing in slower flow areas within the inlet, and these plants have the potential to break off and float into Little Wee Wah.

The inflow of the Tuxedo Lake into Little Wee Wah complicates the use of herbicides due to the flowing water diluting the product. Conversely, DASH in these very shallow areas next to and to the right of the inlet is not feasible as well. These areas are less than 1 foot deep and not enough room to get a diver in. Having crews wade in these very shallow areas and hand-pull plants is probably the most effective option for those shallow zones. Our primary recommendation is to manage the rest of the lake with ProcellaCOR with pre-treatment and post-treatment monitoring and can serve as another field test study. DASH can be used lake wide, but we believe that a ProcellaCOR treatment would be more effective strategy based on cost and control outcomes. It is also important to remember that ProcellaCOR is much more effective for milfoil control than 2,4-D, which was previously used in 2018. If DASH is preferred by the Village, we recommend at least two weeks of harvesting, with any additional days being rolled over to Tuxedo Lake or Wee Wah if the entire lake is covered twice in that time. DASH can be used to manage the brittle naiad, but with the caveats presented in the Tuxedo Lake subsection of the “Recommendations for Aquatic Plant Management” section.

Wee Wah

Goal: Reduce EWM to ~10% of original coverage.

While EWM was largely absent from Wee Wah at the beginning of the year save the Warwick Brook section, September's survey showed an increase in milfoil around the entire lake. None of the milfoil stands were particularly large, but their wide distribution is concerning. There are most likely fragments entering the lake from upstream and allowing for the recolonization, which would explain the distribution in the southern part of the lake. As suggested for the Tuxedo outlet, we believe that a fragment barrier at the outlet of Little Wee Wah would be a great option to reduce the chance of downstream movement of milfoil and the establishment of new subpopulations.

Since the population is still small, DASH harvesting is a viable option for Wee Wah. Divers should be provided with GPS points of past milfoil areas and harvest in a targeted approach. One or two extra days should be added on to the diving effort to harvest any additional milfoil areas found during the initial effort. As with Little Wee Wah and Tuxedo lake, pre and post milfoil monitoring should take place to assess the effectiveness of the technique and to spot additional milfoil. As previously mentioned, DASH can be used to manage brittle naiad locations as well. We recommend at least one week of work on Wee Wah to sufficiently cover all EWM areas.

The most abundant plant in the lake, Coontail is in need of management as well. Large mats of Coontail can negatively affect oxygen conditions from decomposition, especially under the mats. This low oxygen could provide conditions for phosphorus and ammonia release into the water column, further increasing Coontail growth or aiding in green algae and cyanobacteria growth. While some Coontail is good for Wee Wah because it provides habitat for fish and invertebrates and takes up nutrients that would otherwise be used by less desirable cyanobacteria, large mats that are decomposing are an issue.

Removing the Coontail from the system using DASH harvesting would be preferable over using an herbicide. Herbicide treatments can clear large mats of aquatic plants but would accelerate decomposition and depress oxygen levels. Furthermore, herbicide treatments would change the timing of decomposition, and the release of dissolved nitrogen and phosphorus would be coupled with favorable light and temperature regimes for algal growth, therefore, we do not recommend herbicide treatments for the control of Coontail in Wee Wah.

Removal should be done towards the end of the summer, when Coontail biomass will likely be at its maximum growth. This would allow the Coontail to take up a large portion of nitrogen and phosphorus throughout the summer, but would not release those nutrients back to the sediments after decomposition. DASH operations aimed at controlling the large Coontail mats may work but would be cost-intensive. Such large beds of Coontail would take divers multiple days to clear out. Ideally, with this level of biomass, mechanical harvesting would be a good option. Because the plant is not rooted, a large amount of plant material can be harvested without significant disturbance to the bottom sediments. Access for the harvesters would be an issue, as there are no well-defined access points for large boats to enter Wee Wah. Similarly, there needs to be a defined off-shore area for harvested material to be deposited and a plan in place for disposal. The village DPW makes the most sense for access and initial disposal area, however, those logistics would need to be further explored. We reccoemnd DASH for small mats of coontail, but logistics for mechanical harvesting should be explored to handle larger plots.

In order to evaluate the success of this harvesting, the total amount of nitrogen and phosphorus in the lake needs to be known, along with the percentage removed related to the total amount of nutrients in the lake. Literature values can be used to estimate the content of N and P in the plant tissue, but data collected from Wee Wah plants would be preferable. This would allow the village of Tuxedo Park to gauge how much Coontail needs to be removed to make a measurable difference in the in-lake nutrient concentrations.

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Conclusions

The 2019 aquatic plant surveys conducted on all three lakes documented EWM growth at varying degrees. Eurasian watermilfoil was abundant throughout Tuxedo Lake, with 'topped-out' growth (plants reaching the surface water) common throughout the northern and eastern lake shores. Little Wee Wah had an herbicide treatment in 2018, which resulted in EWM reduction, but the 2019 survey results indicate this species has since recovered. Wee Wah is almost entirely composed of Coontail, which is a native species, but at times can grow and spread aggressively. There were a few small patches of EWM present in Wee Wah, documented during the September survey.

Since the three lakes are hydrologically connected, preventing the spread of Eurasian watermilfoil via fragment barriers on the Tuxedo outlet and the Little Wee Wah outlet is advisable. The Tuxedo Eurasian watermilfoil population is large, which precludes cost-effective management through DASH (Diver Assisted Suction Harvesting) operations. Instead, we recommend the use of EPA registered herbicides to reduce the EWM population to a level where DASH operations may be used as a follow-up management technique in subsequent years.

The outlet of Tuxedo Lake flows into Little Wee Wah, which presents logistical issues with herbicide treatments and DASH operations. We recommend dive crews wade into the shallow delta area and physically remove EWM shoots while managing the rest of the waterbody with herbicides. Wee Wah lake EWM should be managed using DASH operations focusing on the small patches found during the September survey. Coontail may have detrimental impacts on the lake's water quality, so removal via DASH is recommended.

In closing, while EWM is present in all three lakes, cost-effective management guided by scientifically-based monitoring can help reduce EWM to a level where it is not impacting ecological and recreational uses. Successful aquatic plant management also requires effective communication between all stakeholders, which should be kept in mind when implementation takes place.

Goals and Objective for Tuxedo, Little Wee Wah and Wee Wah

GOAL Tuxedo Lake: Reduce EWM in lake to ~20% of original coverage.

- Conduct a small-scale field trial for a ProcellaCOR treatment to test product effectivness non-target impacts.
- If trial results are positive, move forward with full-lake ProcellaCOR treatment with intensive pre-post monitoring and herbicide residue testing.
- Follow up treatment with DASH operations in succesive years aimed at harvesting any plants that have regrown or were unaffected during the treatment.
- Additional DASH to target brittle naiad locations and keep plant from spreading further in lake.

GOAL Little Wee Wah: Reduce EWM in lake to ~10% of original coverage.

- Install a fragment barrier at the outlet of Tuxedo Lake that will limit movement of plants between waterbodies.
- Survey for and hand-harvest EWM in the inlet stream between Tuxedo and little wee wah.
- Use ProcellaCOR to control EWM throughout the entire pond. DASH can be used, with a minimum of two weeks of harvesting suggested.
- Follow up treatment with DASH operations in succesive years aimed at harvesting any plants that have regrown or were unaffected during the treatment.
- Additional DASH to target brittle naiad locations and keep plant from spreading further in lake.

GOAL Wee Wah: Reduce EWM in lake to ~10% of original coverage.

- Use DASH, supported by pre and post monitoring to mamage small patches of EWM throughout Wee Wah.
- Install a fragment barrier on the outlet of little wee wah to limit movement of plants between waterbodies.
- Additional DASH to target brittle naiad locations and keep plant from spreading further in lake.

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Appendix A

Invasive Aquatic Plant Biology and Ecology

Aquatic plants serve a variety of ecological functions within lake systems. They provide habitat for aquatic organisms such as fish, invertebrates, amphibians, and waterfowl to forage and reproduce. Plants also play a critical role in maintaining good water quality by holding sediment in place and limiting particulate and nutrient re-suspension from winds and bottom-feeding fish (Madsen et al. 2001). Dense stands may also help dampen wave action (Losee and Wetzel 1988), reducing the amount of shoreline erosion in highly windswept areas.

While a certain amount of aquatic plant growth is beneficial, an overabundance can have detrimental impacts on a lake. Most often, invasive species, defined as species introduced from outside of a basin that causes harm to the environment, economy or human health (NYSDEC 2019), cause the most detriment to lakes. Invasive plants are often ecological engineers that change the environment and disrupt lake functions. In high abundance, invasive plants create dense canopies that shade out native species and interfere with fish habitat, dissolved oxygen levels, and nutrient concentrations. Invasive species are also a detriment to human recreation, including boating, swimming, and angling. A large portion of this aquatic plant management plan focuses on the invasive species Eurasian watermilfoil (*Myriophyllum spicatum*).

Eurasian watermilfoil (Hereafter referred to as EWM) is a submersed, perennial aquatic plant native to Europe, Asia, and northern Africa (Couch and Nelson 1985). It was first introduced to North America around 1950, and by 1985 that plant was found in 33 US states and parts of Canada (Couch and Nelson 1985). EWM has whorls of 4 leaves per node with 14-20 pairs of thin leaflets (Borman et al. 1997). It can occur in 1- to 10-meters water depth in clear waters but is more often found in the 1- to 4-meter water depth zone (Smith and Barko 1990). Growth from shoots begins in spring when water temperatures reach approximately 15°C (Smith and Barko 1990). Maximum biomass often occurs in late July/early August in northeastern lakes. Canopies of EWM can alter the ecology of a lake system by reducing native plant diversity (Madsen et al. 1991; Boylen et al. 1999) and influencing water chemistry (Unmuth et al. 2000).

There are a few different ways EWM gains a competitive advantage over native plants. The vegetative spread of EWM via root structures and fragments is thought to be the major mechanism for in-lake dispersal (Smith and Barko 1990). Root structures can spread EWM over short distances, usually less than a few meters. Auto-fragmentation, which involves the natural detachment of shoots and the induced breakage of shoots due to disturbance, is the primary method of long-range dispersals (Madsen 1988). These detached shoots grow new roots at stem nodes (called adventitious roots) and can start new colonies of plants if they land on a suitable substrate. Madsen and Smith (1997) found that 46% of fragments that settled on substrates in outdoor ponds successfully established. Considering there can be hundreds of fragments floating on a lake at any one time (Reyes, personal observation), this is a significant source of population colony establishment in lakes.

EWM's varied growth form also gives it a competitive advantage. The plant can grow rapidly to the surface and branch horizontally (Titus and Adams 1979), shading out competitors that grow near the lake bottom. The root crowns and shoots of EWM have the ability to overwinter, in part due to the fact that the species can photosynthesize at temperatures as low as 10°C (Stanley and Naylor 1972). This overwintering allows for early and accelerated growth in the spring (Smith and Barko 1990).

Appendix B

Survey Methods

The aquatic plant surveys of the three waterbodies were conducted using a 12ft Jon-boat transfixed with one high-resolution down-imaging SONAR device (Garmin Echo Map 74cv). The SONAR has an imaging power of 455 and 800 kHz, and target separation of 6 cm. The depth-sounder provides scrolling images of bottom features as well as water depth and plant features (Figure 2).

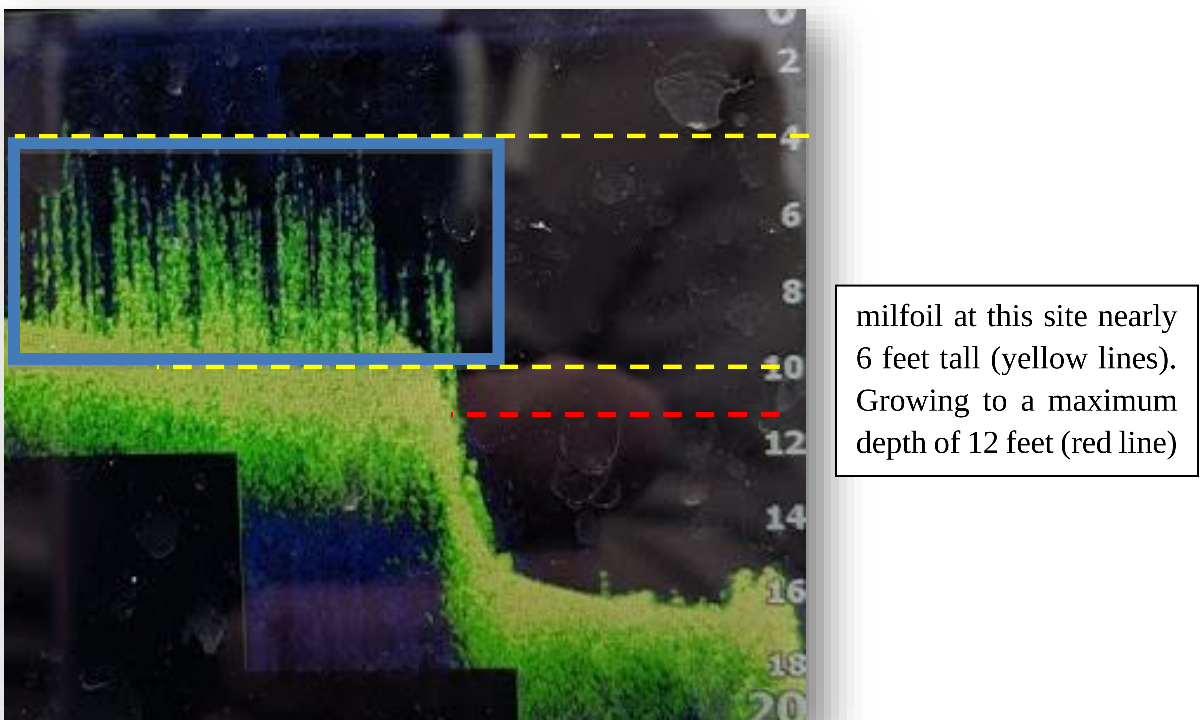

Figure 14. Down-imaging SONAR showing Eurasian watermilfoil (blue box).

The most effective survey method for mapping Eurasian milfoil is a meander survey. The meander survey method is also the best technique for searching for sparse native and new invasive species. This method involves traveling along the shoreline at slow speeds of between 0.1 and 0.4 miles/hour, in search of all plants that inhabit the littoral zone of the lake. Unlike a point-intercept style survey where all waypoints are predetermined at fixed intervals throughout the littoral zone, the meander survey method allows for waypoint creation at exact locations where invasive species are found. Accurate area mapping of target species uses a combination of GPS tracks, waypoints, and field notes. During the survey, waypoints were made approximately 50-200ft feet apart along aquatic plant beds. When the topography or plant composition changed rapidly over small distances, GPS waypoints were made closer together. If plant composition remained constant, waypoints were made a maximum of 200ft apart.

In the case of EWM beds, GPS waypoints were made along the inner and outer edges of the bed to adequately map acreage. Waypoints were also made to indicate the beginning and end of milfoil beds when they occurred. The continuous GPS track, waypoints, and additional field notes allow for accurate post-survey polygon creation in a Geographic Information Systems (GIS) software. An example of a field note critical to mapping is: "Milfoil continuous band approximately 5ft wide from waypoints 50-70" or "Milfoil band wider (2x) between waypoints 55-58." Quick shorthand notes in the field add more data and diminish the amount of interpolation between waypoints.

At each waypoint, either a long-handled (16ft) rake or a 14-tine double-sided garden rake attached to a 10m rope was used to collect specimens of all species present at that point. The water depth and plant density were recorded at each waypoint. Plant density was determined using a combination of three methods. The visual density determination method is based solely on what is visible from the surface. This method involves using a hypothetical quadrat. In this method, one visually assesses an estimate of how much area is covered by the plant in question. The use of actual survey quadrats in the field is not appropriate for the large scale of most aquatic plant surveys. For that reason, surveyors visualized a hypothetical quadrat, approximately 10-15ft in length, then estimated coverage accordingly. Surveyors used the long-handled rake to assist in delineating the hypothetical quadrat, as the rake is marked at 10 feet and 16 feet. The rake was positioned perpendicular to the boat, giving the surveyors a visual guide as to the extent of the sampling quadrat.

The second method for estimating the percent coverage of vegetation is to use the down-imaging SONAR, which shows a detailed image of the plants as the boat passes above. The SONAR image is used to corroborate the visual percent cover estimate in areas where plants can be seen from the surface. In areas where plants cannot be seen from the surface, the SONAR image becomes extremely useful for percent coverage estimations, along with weed-rake tosses. Rake tosses involve stopping the boat and throwing a 10m tow line and rake through the plant bed. Percent cover of collected plants is estimated semi-quantitatively. When possible, all three ways of estimating percent cover are used at each waypoint, with the resulting estimate recorded on the datasheet.

In order to maintain consistency with previous SOLitude surveys (Mayer 2017, 2018), 104 waypoints were sampled using past protocols. Solitude sampling involved throwing a weed-rake attached to a 10-meter rope off one random side of the boat and slowly retrieving the rake. Density categories used are based on the Point Intercept Rake Toss Relative Abundance method (PIRTRAM, Lord and Johnson 2005). The densities are presented in Table 7.

Table 7. Density categories for PIRTRAM sampling

Density Category	Description
No plants	Empty Rake
Trace	One or two stems per rake; can be held by two fingers
Sparse	Three to ten stems, about a handful
Medium	More than 10 stems, covering all the tines of the rake
Dense	Entire rake full of stems; has trouble getting rake into the boat.

The computer programs ArcGIS and R were used to map plant locations and density. Percent cover values were organized into five different, but equal categories (see figure legends in the results section).

Appendix C

Discussion of Physical and Chemical Control Methods

Physical Methods

Hand Harvesting

Hand harvesting is a very common plant management technique in New York State, and particularly the Adirondacks (NYSFOLA 2009). Hand harvesting can be performed through a variety of methods, such as by boat, snorkeling, SCUBA, or wading. Generally, harvesters fill dive bags with pulled plants. One of the more common hand-harvesting techniques is diver assisted suction harvesting (DASH). With DASH, divers hand-pull aquatic plants, including the root system, then insert the plants into a suction hose suspended above the lake bottom. The hose then pulls the plants up to a catchment area on a boat (Eichler et al. 1993). Suction hoses allow divers to spend less time traveling to and from the boat with traditional dive bags filled with plants. The hose also pulls away some of the sediment that is disturbed during the hand-removal process, making it easier for divers to continue working in an area because visibility is not completely obstructed.

The main advantage of this aquatic plant management technique is its selectiveness, as divers can target small invasive plant clumps, resulting in less collateral damage to native plants in the same area. DASH is best suited for areas where EWM reaches moderate to high-density infestation levels and plant density is too high for hand harvesting using individual diver bags (Eichler et al. 1993). In 1990 on Lake George, DASH was used as the primary management technique to control EWM at seven sites (Eichler et al. 1993). This method reduced both the biomass and the percent cover of EWM in the lake (Eichler et al. 1993). Approximately 93% of the dry weight of EWM, on average, was removed from each site by suction harvesting (Eichler et al. 1993). One year after the harvest, the impact of harvesting on the native plant community included a greater number of species per unit area, but reduced biomass and percent cover at those sites (Eichler et al. 1993).

Intensive hand-harvesting was undertaken to achieve whole-lake control of milfoil in Upper Saranac Lake (Kelting et al. 2010). For three consecutive years, beginning in 2004, six crews of divers hand harvested the entire littoral zone (~ 485 hectares) of the lake twice per summer. Milfoil coverage was reduced to less than 5% from more than 90% of the littoral zone, and plant biomass in need of removal decreased from 16,640 kg in 2004 to 460 kg in 2006. The cost/kg of milfoil removal increased with each year of management, starting at $23/kg during the first year and eventually reaching $485/kg in 2008, in which the harvesting effort was scaled down to a maintenance configuration.

Upper Saranac Lake is a great example of both the strengths and weaknesses of DASH. The lake was able to achieve control of milfoil over a large littoral zone, but the cost was nearly $1.5 million, spent from 1999 to 2008, plus over $100,000 spent annually from 2009 to 2017. A conservative total cost estimate is roughly $2.4 million dollars since 1999. This estimate does not include monitoring costs by the Adirondack Watershed Institute and salary for the Upper Saranac lake manager. While DASH can be an effective management technique for milfoil, it is very expensive, especially when used for lake-wide control.

The cost of DASH efforts varies based on the number of divers in the water, site terrain, and density of the target plants. Some contractors wrap the entire cost into one hourly rate, while others separate mobilization and housing costs from actual on the water labor. Typically, for all-included pricing, DASH contractors charge anywhere from $250-350 per hour for two divers. The amount of area a DASH crew can get done in one day also varies. In our experience, two divers can removal an acre of sparse milfoil in two days, while it takes an average of four days to clear a moderately dense acre of milfoil, and up to six days to clear an acre of dense milfoil. There is also some amount of hourly cost reduction possible for large DASH projects, where contractors may bill at the lower end of expected hourly rates in return for a greater number of days of work.

Recommended Approach to DASH Operations

The pricing for DASH, as mentioned above, varies greatly with the density of milfoil and the type of terrain. Soft sediments are problematic due to the propensity to be disturbed and interfere with clarity, while roots in rocky sediments are difficult to pull. Potential contractors should be given detailed site descriptions and, if possible, volunteer-facilitated site visits to determine the most accurate cost estimate prior to any contract initiation. It is common that divers set out to remove plants over a given acreage but fall short due to logistical difficulties that consume the available budget. Divers are paid hourly, not by acreage.

After an initial clearing of a site, divers should allow the sediment to settle and move on to another area. Only after sediment settles from the water column should divers revisit the same sites. At least two "passes" should be required for each site to ensure adequate milfoil root removal.

While DASH does not produce the same amount of fragmentation as mechanical harvesting, steps should be taken to minimize excess plant material from leaving the worksite. Volunteers with pool skimmers can trail the harvesters in kayaks or canoes, or the contracting company can provide additional staff to collect fragments. Similarly, cove areas may require the use of a plant fragment or sediment curtain. There should also be a clear plan as to how to dispose of milfoil biomass once harvested.

Reporting of harvesting effort should be consistent as well. There is considerable variation in how progress is reported with DASH operations, which hinders the ability to compare results over time and between lakes. This becomes especially problematic if the lake association has to switch contractors in the middle of management, potentially losing critical data collection consistency.

Reports of harvesting effort should include the following:

- Amount of milfoil removed via wet weight
    - Extrapolations based on the standard weight of milfoil-full bags or buckets are sufficient due to logistical problems with weighing each bag.
- Area harvested or searched
    - Documentation of both where the DASH team harvested plants and where they looked for plants but did not find any.
    - Can use GPS tracks or polygons to indicate area managed.
- Time spent harvesting
    - An estimate of set-up and breakdown time along with time in the water and a consistent record of the number of divers in the water at a time.
- Detailed notes on each site including but not limited to:
    - Weather
    - Visibility
    - Native plants
    - Comparisons to past harvesting efforts (if applicable)
    - Logistical instances that may have hindered or helped harvesting efficiency

The use of volunteer and professionally collected data to guide DASH efforts is critical to the success of the technique. DASH operations are expensive and dive contractors should not waste their time searching for target plants, they should be equipped with a Google Maps document of exact sites to work at. The waypoint data from the 2019 survey can be used by DASH harvesters in the field if they have cell phone internet access. The contractor selected should be provided with the most up to date milfoil distribution information for the lake, generated by volunteer and professional surveys.

Benthic Barriers

Benthic barriers are mats that prevent plant growth by blocking out light (Wittmann et al. 2012). Barriers are most often used around docks, in swimming areas, or to open and maintain boat-access channels (NYSFOLA 2009). A permit is required in New York State to install benthic barriers (APA General Permit 2015G-2). The advantage of using benthic barriers is that they can be installed from the shore in shallow water, particularly in those areas of recreational activities. However, in waters deeper than six feet, divers are needed, which increases labor costs. Costs of material and labor vary depending on screening material and whether the application involves an initial or repeat installation (NYSFOLA 2009).

Barriers are most effective when installed early in the growing season and maintenance is critical in order to minimize plant regrowth due to sediment or silt deposits on top of the mats (CT DEP 1996). Benthic barriers require a relatively flat bottom with no obstructions such as rocks or stumps for best results. There are many types of benthic barriers; most are comprised of synthetic fabrics like polypropylene, polyethylene terephthalate (PET), Typar, Hypalon, or polyvinyl chloride (PVC) coated fiberglass, (Wittmann et al. 2012). Most barriers used in macrophyte control are made of gas-permeable materials to prevent the buildup of decomposition gases underneath the barriers. Barriers that are not permeable or properly vented cause billowing and may rise to the surface negating its use.

On Tuxedo Lake, benthic barriers can be used around both the village boathouse and the Tuxedo boat club to reduce EWM growth locally. Barriers can be either professionally installed or installed by trained volunteers in shallow waters. Installation in deeper requires divers. Because of frequent maintenance requirements and depth restrictions, benthic mats should be applied sparingly and restricted to small areas with dense milfoil growth. Resources to build benthic mats are available from the Wayne County soil and water conservation district and the Diet for a Small Lake (NYSFOLA 2009).

https://waynecountynysoilandwater.org/wp-content/uploads/Benthic-Mat.pdf

Using DASH and benthic barriers in tandem can be a helpful way to keep re-infestation to a minimum. Once the benthic mat is laid down and has suppressed plant growth, divers may be able to harvest milfoil along the edges of the mat. This should help prolong control and allow natives a chance to re-establish in the matted area. In NY, however, mats are required to be removed and reinstalled annually.

Mechanical Harvesting/Cutting

Aquatic plant control with power-driven (mechanical) equipment has been used for decades in aquatic plant management. Mechanical control is most used to clear high-use areas such as beaches and navigation channels. There are two main types of mechanical harvesters used in plant management: cutting-based harvesters and hydro-rakes (Figure 8). Cutting harvesters cut and rip plant stems at between 3 and 6 feet below the water surface. A conveyor belt then brings cut plant fragments from the water to the harvester for collection. Periodically plants are off-loaded onshore. Hydro-rakes, on the other hand, use metal prongs to dig into the mud. Hydro-rakes are not suitable for milfoil control and are best used for waterlilies and plants with thick rhizomes instead of very fine root structures.

Mechanical weed-harvesting/cutting has been used for milfoil management at many lakes, but it is not a sustainable option. Weed-harvesters create huge numbers of fragments and increase the spread of milfoil to new areas of the lake. Similarly cutting of plants can stimulate re-growth (Crowell et al. 1994) and may cause milfoil to grow more densely, like trimming bushes. Mechanical harvesting is not at all species selective, and there have been many case studies where mechanical weed-harvesting caused increases lake turbidity as operation in shallow areas will consequently disturb sediments. Because of the potential for extensive fragmentation and non-selectivity of this technique, we do not recommend any mechanical harvesting techniques for Tuxedo Lake.

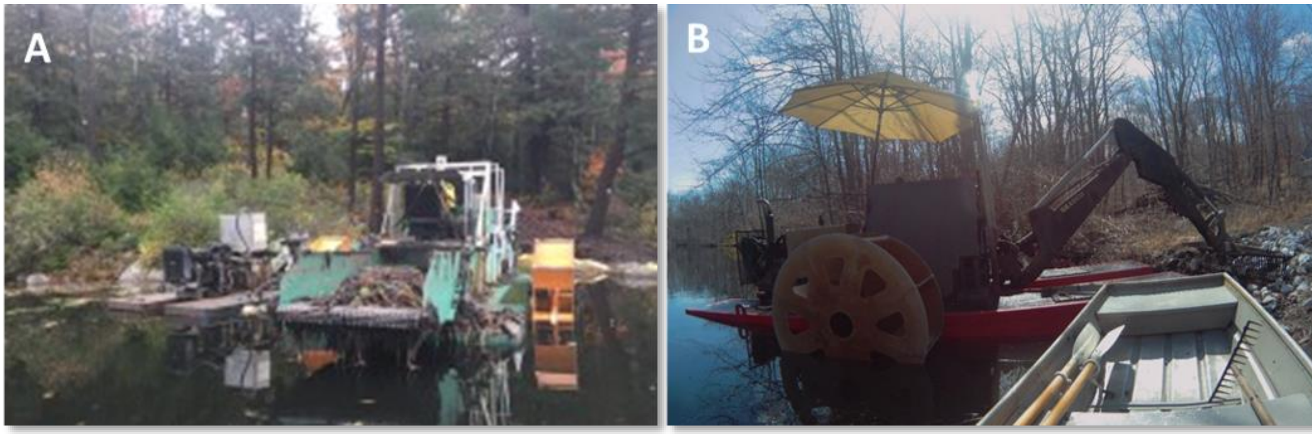

Figure 15. Examples of mechanical harvesting equipment. A) cutting-harvester, B) hydro-rake

Chemical Methods

Chemical management involves the use of EPA-registered aquatic herbicides to control invasive and/or nuisance aquatic plants. Herbicides must be applied by licensed applicators and permits must be issued before a treatment can be conducted. There are two main categories of aquatic herbicides, based on the chemical activity on the plant:

Contact Herbicides

- Generally only affect the area of the plant where the chemical is applied
- Not formulated to kill plant root systems
- Regrowth in following seasons can be expected

Systemic Herbicides

- Affect the plant's metabolic or growing processes
- Products move through plant tissues to affect the entire plant
- Longer control times and better chances of eradication.

Table 8.Aquatic herbicides with known activity on EWM.

Trade name	Chemical Name	Activity on Plant
Tribune/Reward	Diquat Dibromide	Contact
Aquathol K/Hydrothol 191	Endothall	Contact
Clipper	Flumioxazin	Contact
Stingray	Carfentrazone	Contact
Sonar	Fluridone	Systemic
Navigate	2,4-D	Systemic
Renovate	Triclopyr	Systemic
ProcellaCOR	Florpyrauxifen-benzyl	Systemic

There are a variety of systemic and contact herbicides that can control EWM. Based on reputation and potential for long term control, the following discussion will focus on two herbicides in particular. Florpyrauxifen-benzyl (trade name: ProcellaCOR) and fluridone (trade name: SONAR) are two EPA-registered herbicides that are very effective in controlling EWM.

Fluridone is a systemic herbicide that has been widely used in lakes across the country for over 30 years. Fluridone inhibits the formation of carotenoids in plants, leading to the rapid degradation of chlorophyll by sunlight which stops the plant from being able to produce carbohydrates (Bartels and Watson 1978). EWM is highly susceptible to fluridone (Hall et al. 1984; Slade et al. 2007) with some lakes showing control for multiple seasons (Smith and Pullman 1997; Madsen et al. 2002; Crowell et al. 2006; Valley et al. 2006).

Typical effective concentrations range from 4-10 ppb, with the lower dose of fluridone allowing for species selectivity to decrease impacts on non-target species. One of the downsides of fluridone treatments is the extended contact times, which range from 45 to 90 days. To achieve the desired contact time, additional, smaller treatments termed "bump applications" are done 1-2 times after the initial treatment. Fluridone is a safe choice for drinking water supply reservoirs, with the EPA setting a 150 ppb maximum allowable application rate and the NYSDEC setting a 50 ppb threshold for acceptable organic compound concentration (which includes fluridone).

In 2018, ProcellaCOR (active ingredient: Florpyrauxifen-benzyl), a new herbicide formulation was labeled and licensed for use (NH DES 2019). Originally developed for control of weeds in rice fields, ProcellaCOR is a synthetic auxin mimic similar to 2,4-D and Triclopyr. Auxin mimics are synthetic growth hormones that affect biochemical processes. These hormones artificially and rapidly heighten plant activity resulting in abnormal growth leading to reduced physic logical responses and cell and plant tissue death.

ProcellaCOR, though a relatively new product, has already shown promising results on EWM (Netherland and Richardson 2016) and other species in the milfoil genera (Richardson et al. 2016). Beets et al. (2019) tested Procellacor on EWM and Hybrid watermilfoil (*M. spicatum* X *M. sibiricum*) along with seven native plants, using concentrations of 3 µg/l, 9 µg/l and 27 µg/l for 6 and 24-hour exposures along with a static exposure for 30 and 60 days. EWM was significantly reduced in all exposure and concentration scenarios, while native responses were variable, but overall, not reduced using the same exposure/use rates. Typical use rates for EWM are around 3.17 fl oz. of product to 12.68 fl oz. dependent on the percent of the waterbody treated.

ProcellaCOR has an excellent environmental profile, with the EPA designating it a Reduced Risk Pesticide (https://www.epa.gov/pesticide-registration/conventional-reduced-risk-pesticide-program). This designation means that the EPA considers ProcellaCOR to have a low impact on human health, low toxicity to fish and wildlife, low potential for groundwater contamination, low use rates and low pestresistant potential relative to other alternatives on the market. There are no use restrictions on swimming, fishing and animal consumption while there are some for non-agricultural irrigation.

Costs of herbicides are based on a variety of factors such as treatment area and volume, product, formulation, and permitting. Usually, there is a base cost associated with permitting, herbicide treatment equipment mobilization, and required public notifications. Base costs vary from ~$600 to $1,200 per acre, with herbicide product and application costs varying from ~$200 to $900 per acre.

Recommended Approach to Herbicide Treatments

Effective herbicide treatment planning lies in public education and outreach. Herbicides are a controversial topic for many people, and there are stories in the news concerning their use and misuse. While safety and precaution are necessary for any herbicide treatment, there are a few things to keep in mind when evaluating these techniques. Primarily, herbicide use is the most regulated plant management technique available. Products are not allowed to be sold in the US unless they go through a multi-year, stringent EPA-review process, and are subject to follow up reviews in subsequent years. The product then goes through a secondary review by the NYSDEC. Even then, herbicides can only be applied in NY by certified pesticide applicators with significant training approved by the NYSDEC. There is more scientific peer-reviewed literature on herbicide uses in the US than there is on any other aquatic plant management technique combined. This base of literature means there is a much better understanding of how these products work and how to safely apply them than any other management technique available today. Based on the scientific literature and registration process, these listed herbicides were determined to be safe and effective.

The NYSDEC will have herbicide treatment requirements, but in general, it is a good idea to have a pre-treatment and post-treatment survey done through an independent professional third party to determine how well the treatment controlled milfoil and where non-target plant species impacts may have occurred. If a systemic product is used, herbicide residue testing is also advised. Testing for the herbicide concentrations at different intervals after treatment in different areas can help explain treatment effects such as dilution and drift from the initial area.

Biological Methods

Biological strategies for aquatic vegetation control involve the use of organisms that consume plant matter to reduce abundance and growth. Biological techniques generally are received favorably in communities because these techniques are marketed as organic practices, rather than chemical applications. Yet, the effectiveness and unintended consequences of certain biological control methods are not nearly as well researched as other techniques. Particularly in NY, there seems to be less government oversight in the use of biological aquatic plant control methods.

Grass Carp

Sterile grass carp (*Ctenopharyngodon idella*) are herbivorous fish that provide relatively inexpensive control of aquatic plants. Carp will selectively feed on particular plants, but their choice of plants is unpredictable and varies from lake to lake. Grass carp prefer certain aquatic plant species and are known for selecting native species over milfoil (Pine and Anderson 1991). Many emergent and floating-leaved plants are not considered palatable to grass carp because they have fibrous or woody tissue (Hanlon et al. 2000). Grass carp most often prefer soft and succulent submersed plants (Hanlon et al. 2000), such as waterweed (*Elodea nuttallii*) and longleaf pondweed (*Potamogeton nodosus*) (Pine and Anderson 1991). Because the carp have a moderate to low feeding preference for milfoil, they may only begin to consume milfoil after other plants in the lake are gone.

In Tuxedo, while there are a few monoculture beds of dense milfoil, this species is also mixed in with many native plants. Grass carp would likely eat the native plants and there would be little milfoil control mixed plant communities. There is also no way to control where the Grass carp feed in the lake. Carp are often seen feeding in calm uninhabited locations, away from human activity, which is counter-productive to attempts to manage milfoil in places of recreational importance.

There are many unknowns with grass carp stocking that also affect success. The principal among these unknowns is the fish stocking rate. Aquatic plant management should never set out to eliminate all aquatic plants from a waterbody. Instead, the goal is to manage the unwanted invasive species while maintaining beneficial native plants at non-nuisance levels. Based on case studies in NY and other southern states, it is near impossible to achieve a stocking rate of grass carp that is high enough to affect milfoil without negatively impacting native plants. This issue is confounded by the fact that crucial information regarding grass carp population dynamics (mortality rate, growth estimates, feeding preferences) are either absent or poorly understood in northeastern lakes. Because of the lack of information on grass carp population dynamics combined with their unpredictable feeding patterns, we do not recommend grass carp for Tuxedo Lake.