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Fresh Water Institute

Lake George, New York
Adirondack Field Station at Bolton Landing

Aquatic Vegetation of Lake Iroquois
Chittenden County, Vermont

Prepared By

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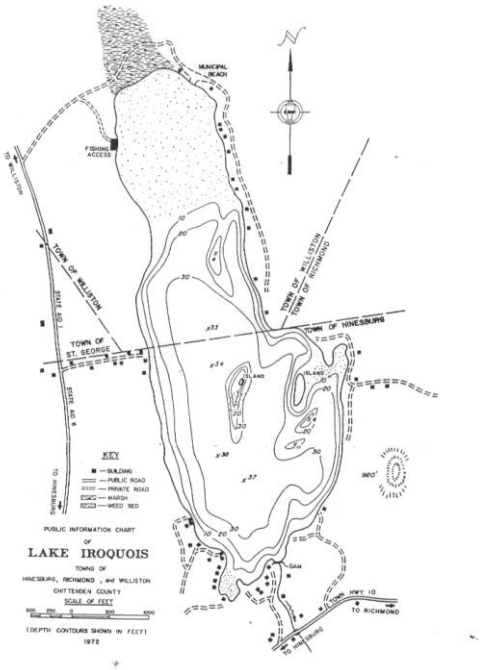
Background.

At the request of Mr. Chris Conant of the Lake Iroquois Association, Spring and Fall quantitative aquatic plant surveys were undertaken for Lake Iroquois, Vermont. The surveys occurred pre- and post-treatment following aquatic plant management efforts employing the herbicide ProcellaCOR EC in 2021 for Eurasian watermilfoil control. The Spring survey focused on a subset of survey points in the proposed treatment area at the north end of the lake. The September component of the survey duplicated the 2017 survey conducted by the author (Eichler 2017). The surveys consisted of frequency of occurrence and relative abundance data for all aquatic plant species present in points distributed throughout the lake. The Point-Intercept Rake Toss method presently used by the US Army Corps of Engineers and others was employed. The assessment includes the distribution and density of existing aquatic plant communities, the extent of exotic species infestation and a review of ongoing management efforts to control Eurasian watermilfoil (*Myriophyllum spicatum*).

Methods

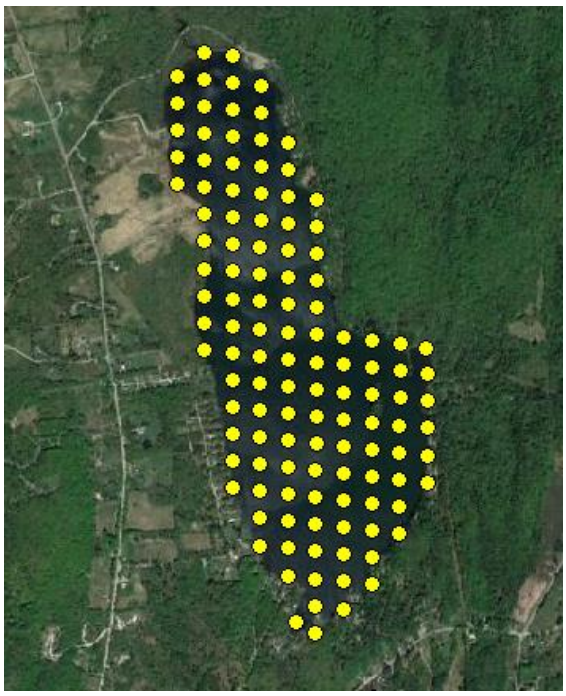
Survey Sites



Lake Iroquois. Lake Iroquis is located in Chittenden County, in the towns of Hinesburg, Richmond and Williston. The lake has a surface area of approximately 244 acres with a watershed area of 2198 acres. Lake Iroquois has a single outlet with a control structure to maintain lake level. Maximum water depth is reported to be 37 ft with average water depth of 19 feet (VTDEC 2016a). Secchi disk transparency in 2015 averaged 12 ft (3.8 m; VT DEC 2015). Lake Iroquois is classified as eutrophic based on phosphorous and chlorophyll concentrations, indicating that nutrient levels are sufficient to support dense growth of planktonic algae and aquatic plants. Two invasive aquatic plant species are reported for Lake Iroquois, Eurasian watermilfoil (*Myriophyllum spicatum*) and Curly-leaf Pondweed (*Potamogeton crispus*) (VT DEC 2016b). VT DEC records indicate that Eurasian watermilfoil was first confirmed in 1991 while curly-leaf pondweed was present in 1984. An aquatic plant survey of Lake Iroquois in September of 2014 reported over 70 acres of dense Eurasian watermilfoil growth (Knoecklein 2015). A total of 45 aquatic plant species have been reported for Lake Iroquois in multiple surveys since 1984, however a 2014 survey only reported 23 species. Loss of native species is a commonly reported phenomenon in lakes with severe infestation by Eurasian watermilfoil and/or other invasive aquatic plant species (Madsen et al. 1991). Hand harvesting efforts began on Lake Iroquois during 2008 to control the dense growth of Eurasian watermilfoil. The aquatic weevil (*Euhrychiopsis lecontei*) population

in Lake Iroquois was supplemented in 2008 and 2009 in an effort to provide a biocontrol agent for Eurasian watermilfoil. The extensive growth of Eurasian watermilfoil reported in 2014 spurred more intensive management effort based on hand and suction harvesting. The management effort was expanded in 2021 to include herbicides, with 40 acres at the north end of Lake Iroquois treated with ProcellaCOR EC.

Figure 1. Map of Lake Iroquois with potential point intercept survey locations .



Species List and Herbarium Specimens. As the lake was surveyed, the occurrence of each aquatic plant species observed in the lake was recorded and herbarium specimens collected where necessary. Herbarium specimens were pressed, dried, and mounted (Hellquist 1993); and became part of the permanent collection at the Darrin Fresh Water Institute in Bolton Landing, NY. All taxonomy is based on Crow & Hellquist, 2000.

Point Intercept Surveys. The frequency and richness of aquatic plant species were evaluated using a point intercept method (Madsen 1999). At each grid point intersection, all species located at that point were recorded, as well as water depth. Species were located by a visual inspection of the point and by deploying a rake to the bottom, and examining the plants retrieved. A total of 66 points were surveyed in the Spring, and 77 points were surveyed in the Fall for Lake Iroquois, based on a 100 m grid. Point intercept plant frequencies were surveyed on May 21, 2021 and September 13, 2021 to provide pre- and post-treatment data. A global positioning system (GPS) was used to navigate to each point for the survey observation.

Relative abundance in the Point Intercept surveys. To characterize relative abundance of each of the species identified in the point intercept survey, a scale developed by Cornell University and the US Army Corps of Engineers was employed. For each rake toss, the relative abundance of each plant species collected was recorded based on this rating scale. Maps of the distribution of each species by its relative abundance is included in Appendix A.

Relative abundance scale based on US Army Corp/Cornell methods.

Code	Rating	Abundance
0	no plants	
1	trace growth of plants	fingerful on rake
2	sparse growth of plants	handful on rake
3	medium growth of plants	rakeful of plants
4	dense growth of plants	difficult to bring into boat

Results and Discussion

In September of 2021, the aquatic plant community of Lake Iroquois included twenty-three submersed species, two floating-leaved species, and six emergent species (Table 1), including some species observed but not collected in the point intercept survey. Twenty-six species were present in the point intercept portion of the 2021 survey, slightly more than the 19 and 23 species reported in 2017 and 2014, even though a greater number of survey points were included in 2014. Combining the results of all surveys, a total of 45 aquatic plant species have been reported for Lake Iroquois, however many of these are classified as wetland species not typically captured by the current survey technique. This number of species greatly exceeds the 15 species typically reported for moderately productive lakes in our region and indicates good water quality and a variety of habitat types. Eurasian watermilfoil (*Myriophyllum spicatum)* and curly-leaf pondweed (*Potamogeton crispus*) were the only exotic species reported in Lake Iroquois. Species richness was quite high, with a number of species occurring in more than 5% of survey points (Table 2).

Table 1. Species list for Lake Iroquois.
Species in red are invasive.

Species Name	Common Name	Lake Iroquois
Brasenia schreberi	Water shield	fl
Ceratophyllum demersum L.	coontail	s
Chara sp.	muskgrass, chara	s
Eleocharis acicularis (L.) Roemer & Schultes	needle spike-rush	e
Elodea canadensis Michx.	elodea	s
Isoetes echinospora Dur.	quillwort	e
Lemna trisulca L.	duckweed	s
Megalodonta (Bidens) beckii Torr.	water marigold	s
Myriophyllum spicatum L.	Eurasian watermilfoil	s
Najas flexilis (Willd.) Rostk. & Schmidt.	bushy pondweed	s
Najas guadalupensis L.	southern naiad	s
Nymphaea odorata Ait.	white waterlily	fl
Polygonum amphibium	smartweed	e
Pontederia cordata L.	pickerelweed	e
Potamogeton amplifolius Tuckerm.	largeleaf pondweed	s
Potamogeton crispus L.	curlyleaf pondweed	s
Potamogeton foliosus Raf.	pondweed	s
Potamogeton natans L.	floating-leaf pondweed	s
Potamogeton perfoliatus L.	clasping-leaf pondweed	s
Potamogeton praelongus Wulfen	white-stem pondweed	s
Potamogeton pusillus L.	small pondweed	s
Potamogeton richardsonii Oakes	Richardsons' pondweed	s
Potamogeton spirillus Tuckerm.	pondweed	s
Potamogeton zosteriformis Fern.	flat-stem pondweed	s

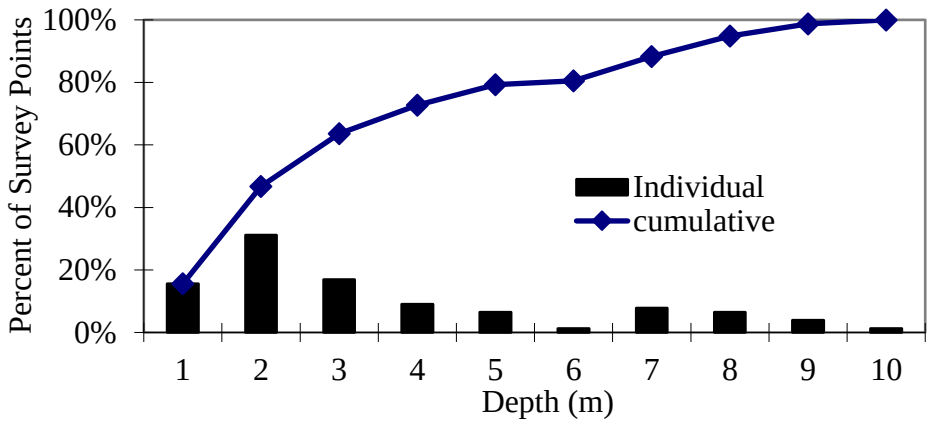
Species Name	Common Name	Lake Iroquois
Ranunculus longirostris Godron	white watercrowfoot	s
Sparganium sp.	burreed	e
Typha sp.	cattail	e
Utricularia gibba L.	humped bladderwort	s
Utricularia vulgaris L.	great bladderwort	s
Vallisneria americana L.	wild celery	s
Zosterella dubia (Jacq.) Small	water stargrass	s

f=floating fl=floating leaved e=emergent s=submersed

Maximum Depth of Colonization

Maximum depth of rooted aquatic plant growth, termed the littoral zone, extended to a depth of approximately 5.0 meters (16 feet) in Lake Iroquois. The majority of survey points were in the littoral zone (Figure 2), providing a reasonable representation of the aquatic plant population of Lake Iroquois.

Figure 2. Depth Distribution of Lake Iroquois Sampling Points in 1 meter depth classes.



Species Lists

Maps of the distribution of aquatic plant species for Lake Iroquois are included in Appendix A. Frequency of occurrence results are presented in Table 2. For the May, pre-treatment survey, waterweed (*Elodea canadensis*) was the most common plant (27% of survey points). Eurasian watermilfoil (*Myriophyllum spicatum*) was present in 24% of survey points, comparable to the Fall 2017 results. Other common native species in the May survey for Lake Iroquois included *Zosterella dubia* (25% of survey points), *Potamogeton crispus* (19%), *Chara/Nitella* (18%), *Potamogeton amplifolius* (12%), *Nymphaea odorata* (8%), *Potamogeton praelongus* (8%) and *Ceratophyllum demersum* (6%). While the Spring survey provides a confirmation of the distribution of Eurasian watermilfoil, a perennial species, the timing of the survey precludes determination of the distribution and relative abundance of most native species that have not started growing this early in the season. The remainder of this report will focus on comparison of the Fall 2017 and Fall 2021 survey results.

Table 2. Lake Iroquois percent frequency of occurrence data.

Species Name	Common Name	Fall 2017	Fall 2021	Spring 2021
Ceratophyllum demersum L.	coontail	27.5%	6.5%	6.0%
Chara sp.	muskgrass, chara	19.6%	33.8%	17.9%
Eleocharis acicularis (L.) Roemer & Schultes	needle spike-rush	4.9%	2.6%	1.5%
Elodea canadensis Michx.	elodea	22.5%	44.2%	26.9%
Isoetes echinospora Dur.	quillwort	1.0%		
Lemna trisulca L.	duckweed	2.9%	5.2%	3.0%
Myriophyllum spicatum L.	Eurasian watermilfoil	23.5%		23.9%
Najas flexilis (Willd.) Rostk. & Schmidt.	bushy pondweed	14.7%	5.2%	
Najas guadalupensis L.	southern naiad	1.0%		
Nymphaea odorata Ait.	white waterlily	11.8%	15.6%	7.5%
Polygonum amphibium	smartweed	1.0%	1.3%	
Potamogeton amplifolius Tuckerm.	largeleaf pondweed	5.9%	22.1%	11.9%
Potamogeton crispus L.	curlyleaf pondweed	2.0%	9.1%	19.4%
Potamogeton foliosus Raf.	pondweed	6.9%	13.0%	1.5%
Potamogeton natans L.	floating-leaf pondweed		1.3%	
Potamogeton perfoliatus L.	clasping-leaf pondweed	2.9%	6.5%	
Potamogeton praelongus Wulfen	white-stem pondweed	9.8%	9.1%	7.5%
Potamogeton pusillus L.	small pondweed	6.9%	6.5%	
Potamogeton richardsonii Oakes	Richardsons' pondweed	4.9%	3.9%	
Potamogeton spirillus Tuckerm.	pondweed	1.0%		
Potamogeton zosteriformis Fern.	flat-stem pondweed	6.9%	13.0%	1.5%
Ranunculus longirostris Godron	white watercrowfoot	5.9%	2.6%	1.5%
Sparganium sp.	burreed	1.0%	2.6%	4.5%
Typha sp.	cattail	1.0%	1.3%	1.5%
Utricularia gibba L.	humped bladderwort	2.0%	1.3%	
Utricularia vulgaris L.	great bladderwort	3.9%	6.5%	4.5%
Vallisneria americana L.	wild celery	28.4%	40.3%	1.5%
Zosterella dubia (Jacq.) Small	water stargrass	20.6%	18.2%	25.4%

For the September post-treatment sample, waterweed (*Elodea canadensis)* was the most common species, present in 44% of survey points. Eurasian watermilfoil (*Myriophyllum spicatum*) was absent at all survey sites. Common native species included *Vallisneria americana* (40% of survey points), *Zosterella dubia* (18%), *Nymphaea odorata* (16%), *Potamogeton zosteriformis* (13%), *Potamogeton foliosus* (13%), *Potamogeton cispus* (9%), *Potamogeton praelongus* (9%), *Ceratophyllum demersum* (7%), *Potamogeton perfoliatus* (7%), *Potamogeton pusillus* (7%), *Utricularia vulgaris* (7%), *Lemna trisulca* (5%), and *Najas flexilis* (5%). Native species results were generally comparable to those reported in 2017 with a few exceptions. A common native species, *Ceratophyllum demersum*, was dominant in Lake Iroquois in 2017 but was observed at a

lower frequency of occurrence in 2021. Pondweed species (*Potamogeton amplifolius, P. foliosus and P. zosteriformis*) were generally more abundant in September post-treatment surveys, particularly Broad-leaf Pondweed. Declines in most native species are observed as a result of invasion and canopy formation by Eurasian watermilfoil, with recovery generally fairly rapid after removal of the canopy.

Seventy-five percent of whole lake sampling points were vegetated by at least one native plant species (Figure 3), 93% of survey points with depths less than 5 m (Figure 4) and 100% of survey points with depths less than 2 meters depth yielded native aquatic plants in Fall of 2021. For 2017, fifty-four percent of whole lake sampling points were vegetated by at least one native plant species, 92% of survey points with depths less than 5 m and 98% of survey points with depths less than 2 meters depth yielded native aquatic plants. Absent in 2021, Eurasian watermilfoil was present in 24% of whole lake survey points, and 42% of survey points less than 5 m water depth in 2017, representing the littoral zone or zone of aquatic plant growth.

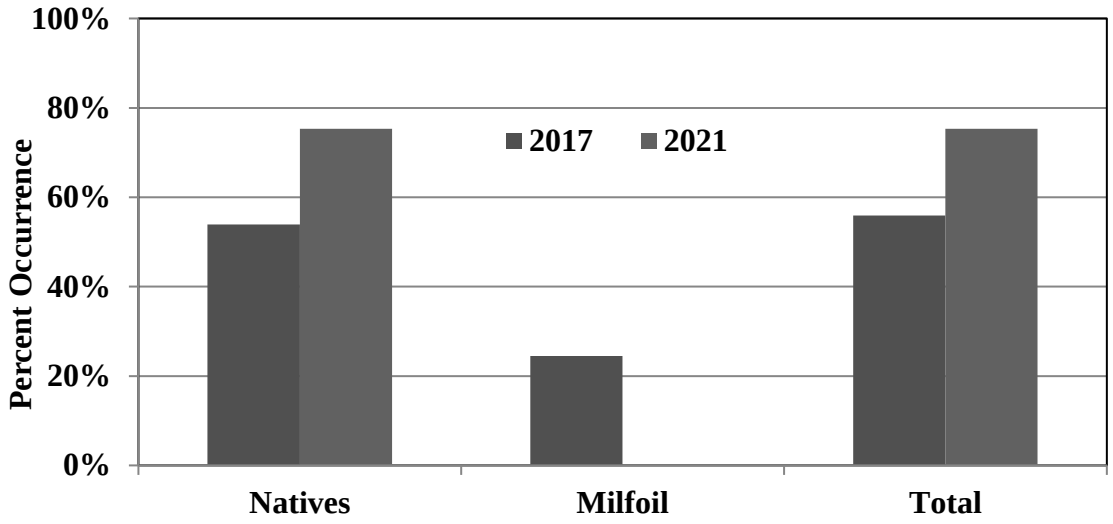


Figure 3. Lake Iroquois frequency of occurrence summaries.

For survey points within the littoral zone, water depth less than 5 m, results similar to whole lake surveys are reported. The expected relationship of greater frequency of occurrence of aquatic plants with shallower water depth is consistent with that reported by other regional studies. Littoral zone frequency of occurrence values for both survey years were dominated by native species (Figure 3) and similar to nearby lakes (Getsinger et al. 2002).

Species richness results are presented in Table 3 and Figure 4. Whole lake native species richness in 2021 was 2.65 species per sample point exceeding the 2.13 species per sample point reported in 2017. Species richness in this range is comparable to other nearby lakes (Eichler 2016). For survey points exclusively within the littoral zone (depths less than 5 meters), native species richness was 3.33 and 3.62 species per survey point (Figure 6) for 2021 and 2017, respectively. As expected, species richness in the littoral zone and its shallow fringe was higher than whole lake species richness and native species richness increased with the removal of Eurasian watermilfoil.

Table 3. Lake Iroquois species richness comparison.

Plant Grouping	Water Depth Class	Summary Statistic	Survey Result	
			2017	2021
Native plant species	Whole Lake (all depths)	Mean	2.13	2.65
		N	102	77
		Std. Error	0.25	0.26
	Points with depths <5m	Mean	3.62	3.33
		N	60	61
		Std. Error	0.30	0.26
	Points with depths <2m	Mean	4.50	4.11
		N	50	36
		Std. Error	0.31	0.32
All plant species	Whole Lake (all depths)	Mean	2.40	2.74
		N	102	77
		Std. Error	0.27	0.26
	Points with depths <4m	Mean	4.08	3.44
		N	60	61
		Std. Error	0.30	0.27
	Points with depths <2m	Mean	4.90	4.25
		N	50	36
		Std. Error	0.31	0.33

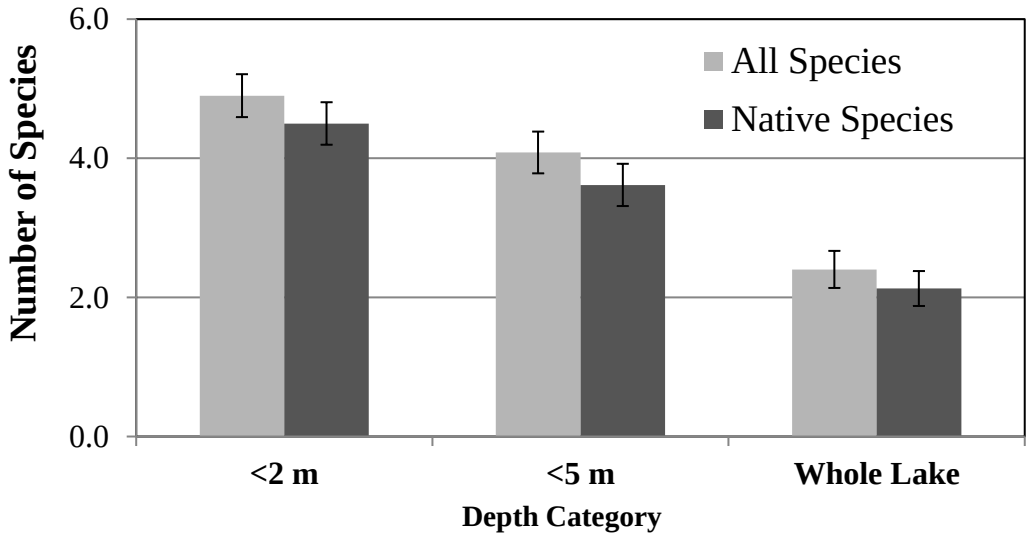


Figure 4. Lake Iroquois species richness.
Error bars are standard error of the mean.

Summary

Spring and Fall quantitative aquatic plant surveys were undertaken for Lake Iroquois, Vermont in May and September 2021. The surveys occurred pre- and post-treatment following aquatic plant management efforts employing the herbicide ProcellaCOR EC in 2021 for Eurasian watermilfoil control. The September component of the survey duplicated the 2017 survey conducted by the author (Eichler 2017). The surveys consisted of frequency of occurrence and relative abundance data for all aquatic plant species present in points distributed throughout the lake. The Point-Intercept Rake Toss method presently used by the US Army Corps of Engineers and others was employed. The assessment generated the information necessary to: 1) evaluate the effectiveness of the aquatic plant management efforts, 2) determine the impact of the management efforts on non-target aquatic plant species, and 3) provide data for comparison of post-treatment conditions to prior survey information.

Eurasian watermilfoil (*Myriophyllum spicatum*) populations were first reported in 1990 in Lake Iroquois and confirmed in 1991. Hand harvesting by skin and SCUBA divers has been the basis of the program for most years since the formation of the lake association in 2007. The aquatic weevil (*Euhrychiopsis lecontei*) population of the lake was supplemented in 2008 and 2009 in an effort to provide a biocontrol agent for Eurasian watermilfoil. However, by 2014 approximately 70 acres of Lake Iroquois was reported to support dense growth of Eurasian watermilfoil. A more extensive management effort based on hand and suction harvesting was initiated, with an herbicide treatment included in the Spring of 2021.

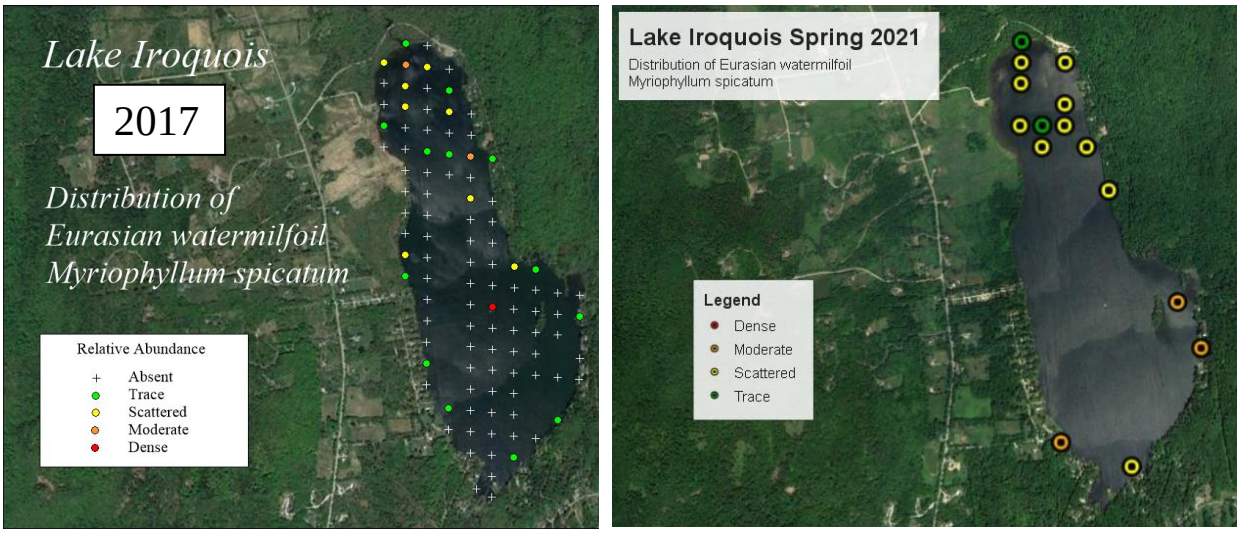
The aquatic plant community of Lake Iroquois in 2021 includes twenty-three submersed species, two floating-leaved species, and six emergent species, slightly greater than the 19 and 23 species reported in 2017 and 2014, respectively. This number of species greatly exceeds the 15 species typically reported for moderately productive lakes in our region and indicates good water quality and a variety of habitat types. One of the species present in Lake Iroquois, Humped Bladderwort (*Utricularia gibba*) is found on Vermont's rare plant list (VT DEC 2012). Eurasian watermilfoil was absent in the Fall, post-treatment survey in 2021. Eurasian watermilfoil was present in 24% of survey points in the Spring of 2021 and Fall of 2017 (Figure 5), representing a decline from the dense growth reported for over 67% of the littoral zone in 2014. The density of Eurasian watermilfoil growth has also declined, with most points described as dense growth in 2014 reduced to scattered or moderate growth in 2017 and absent in the Fall 2021 survey.

Species richness in Lake Iroquois was quite high, with a number of species occurring in more than 5% of survey points. Seventy-five percent of sampling points were vegetated by at least one native plant species in the Fall 2021 survey. The large number of points supporting native plant species suggests that Lake Iroquois is a prime candidate for recovery of its native plant population following management of Eurasian watermilfoil. Native species richness in the littoral zone was 3.33 and 3.62 species per sample in 2021 and 2017, respectively; and at the high end of species richness values for other regional lakes, which ranged from 1.79 to 4.00 species per sample.

Common native species for Lake Iroquois in the Fall 2021 survey included waterweed (*Elodea canadensis,* 44% of survey points), wild celery (*Vallisneria americana,* 40%), muskgrass

(*Chara/Nitella*, 34%), water stargrass (*Zosterella dubia*, 18%), white waterlily (*Nymphaea odorata*, 16%), white-stem pondweed *(Potamogeton praelongus*, 9%), coontail (*Ceratophyllum demersum*, 7%), and bushy pondweed (*Najas flexilis*, 5%). Native species results are generally comparable to those reported in 2017 with a few exceptions. A common native species, *Ceratophyllum demersum*, remains dominant in Lake Iroquois but at lower frequency of occurrence in 2021. Pondweed species (*Potamogeton amplifolius, P. foliosus and P. zosteriformis*) were generally more abundant in September post-treatment surveys, particularly Broad-leaf Pondweed. Declines in most native species are observed as a result of invasion and canopy formation by Eurasian watermilfoil, with recovery generally fairly rapid after removal of the canopy. Shifts in plant growth from year to year are common, particularly with new invaders like Eurasian watermilfoil. These shifts are often attributed to changing weather patterns, plant disease outbreaks or differences in the abundance of plant predators.

Figure 5. Distribution of Eurasian watermilfoil in Lake Iroquois. Eurasian watermilfoil was absent in Fall 2021 surveys.



Eurasian watermilfoil growth in Lake Iroquois was present primarily as scattered and moderate density growth in September of 2017 and May of 2021 (Figure 5), while native plant populations were robust and similar to other regional lakes. Eurasian watermilfoil was most abundant at the north end of the lake, the area chosen for treatment with the herbicide Procella COR EC in 2021. Eurasian watermilfoil was absent in post-treatment surveys in September of 2021, most likely attributable to the use of the herbicide (Procella COR), in conjunction with a hand and suction harvesting program.

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Acknowledgements

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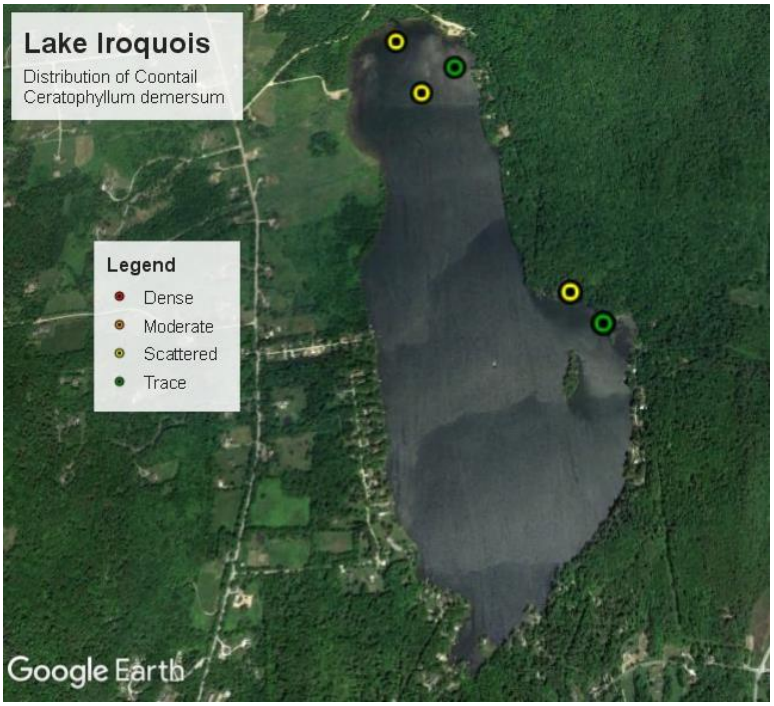
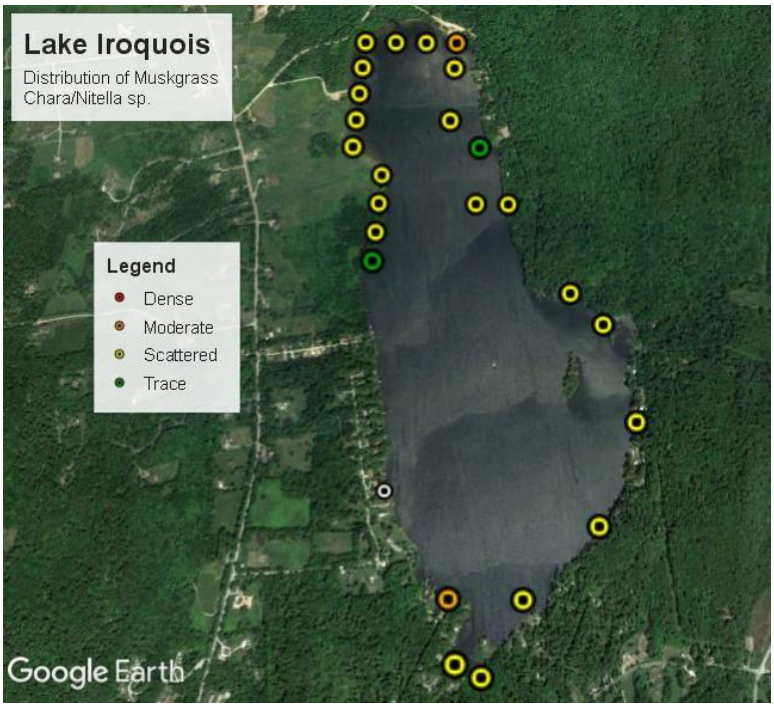
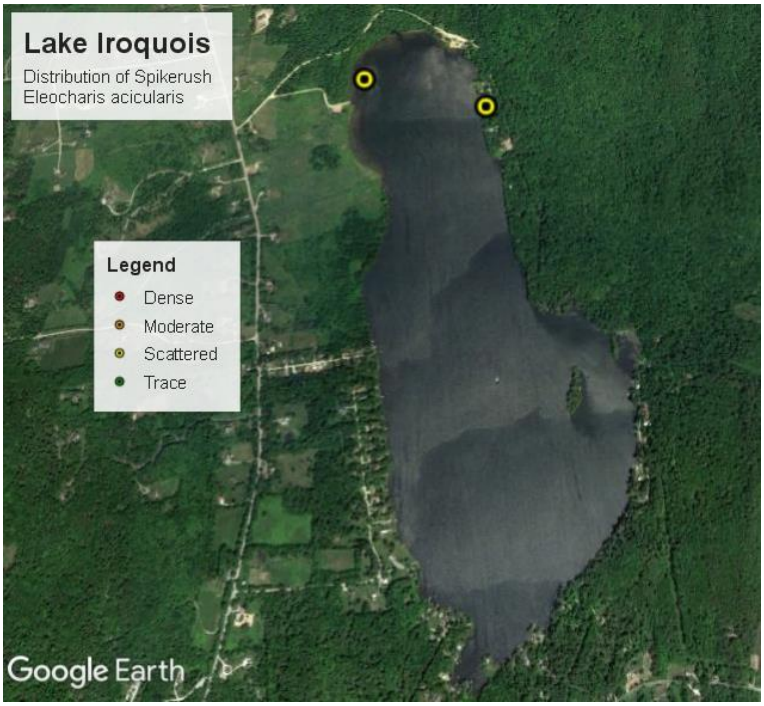
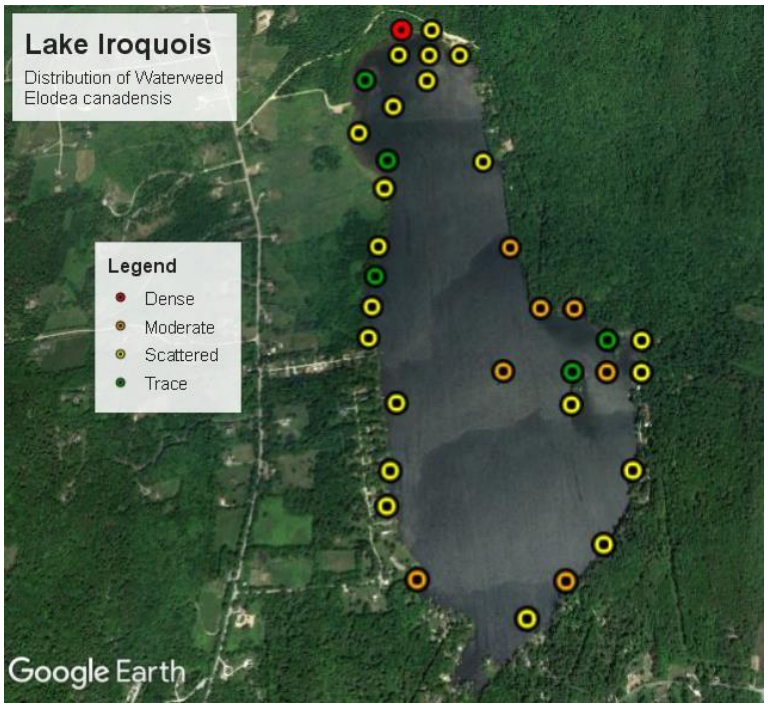
Appendix A

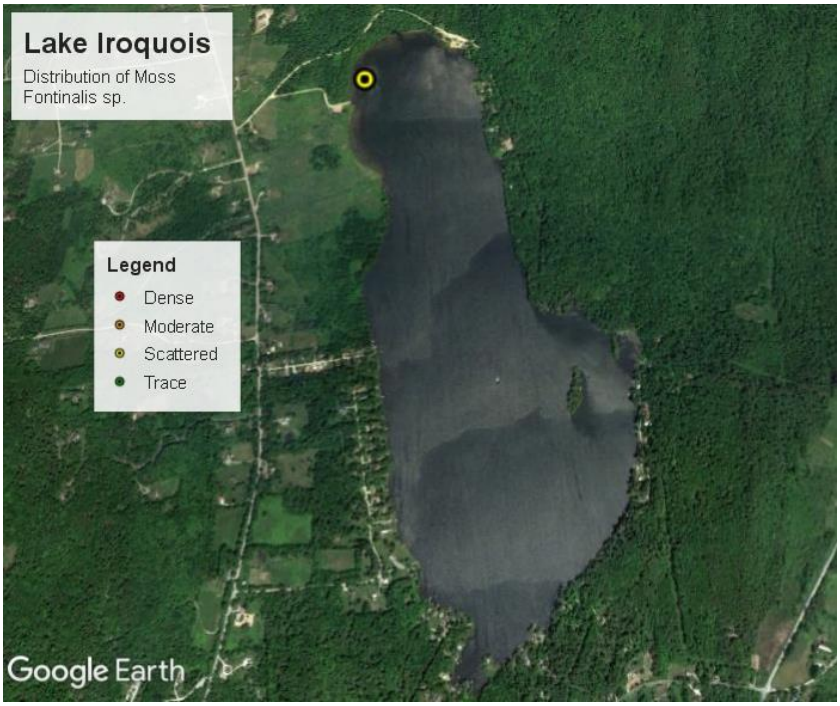
Lake Iroquois Aquatic Plant Distribution Maps

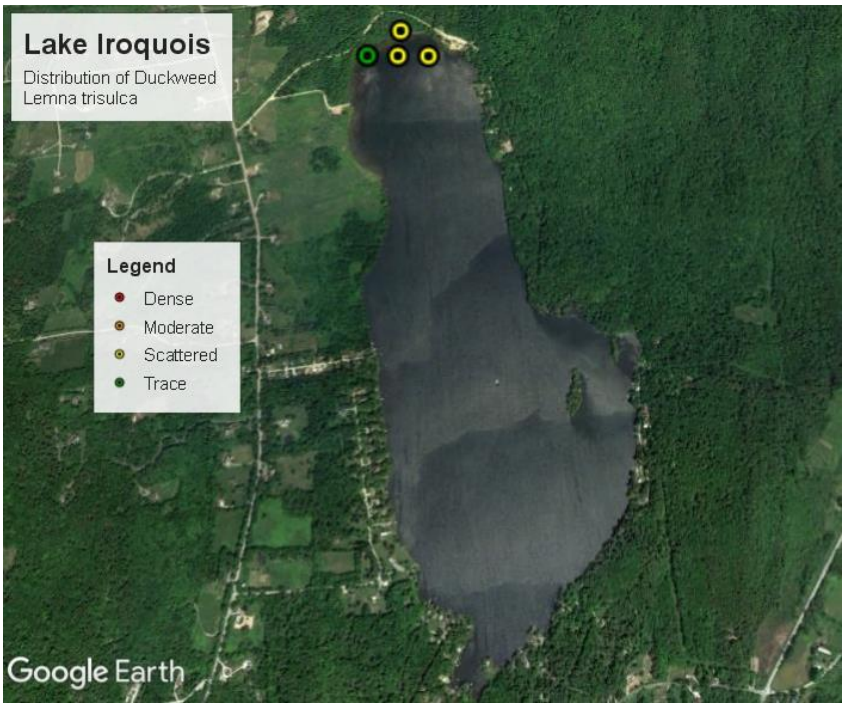

Lake Iroquois
Distribution of Coontail
Ceratophyllum demersum
Legend
Dense
Moderate
Scattered
Trace
Google Earth

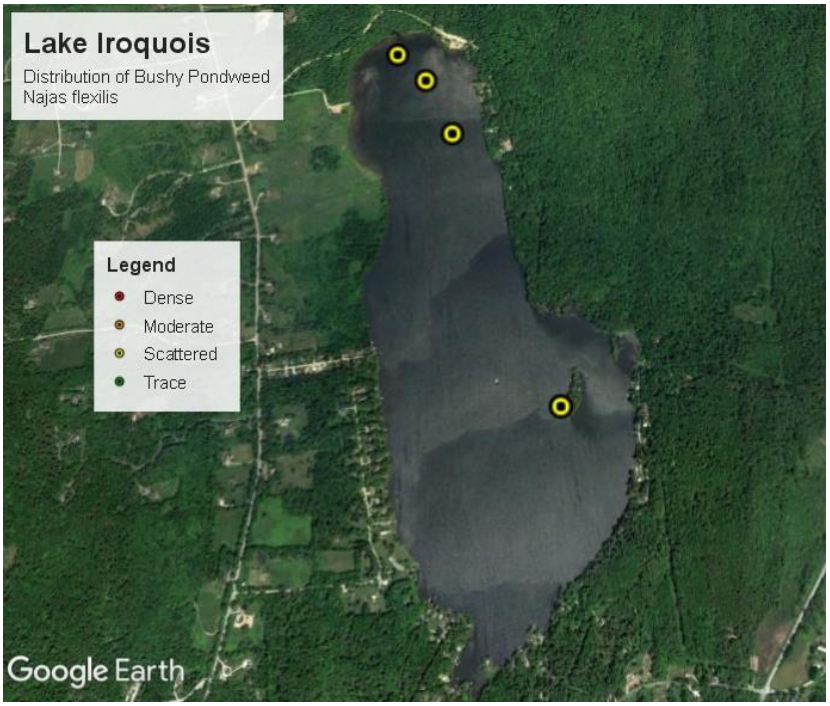

Lake Iroquois
Distribution of Muskgrass
Chara/Nitella sp.
Legend
Dense
Moderate
Scattered
Trace
Google Earth

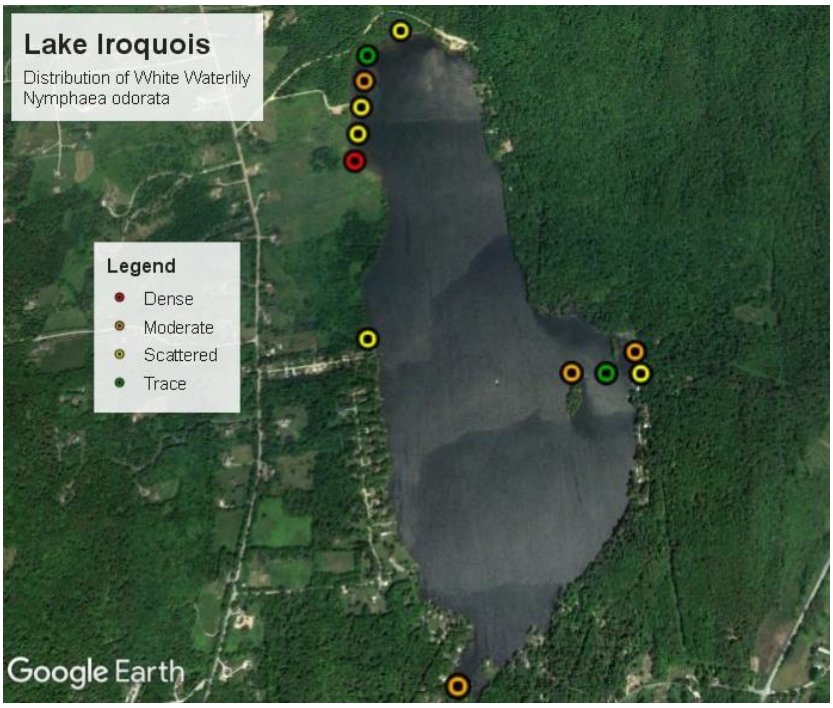

Lake Iroquois
Distribution of Spikerush
Eleocharis acicularis
Legend
Dense
Moderate
Scattered
Trace
Google Earth

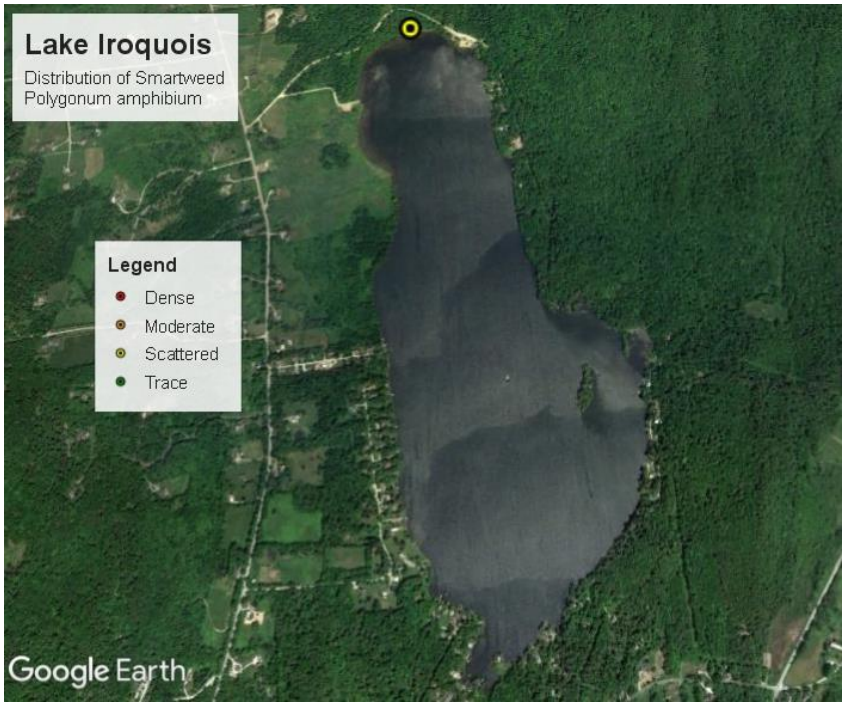

Lake Iroquois
Distribution of Waterweed
Elodea canadensis
Legend
Dense
Moderate
Scattered
Trace
Google Earth

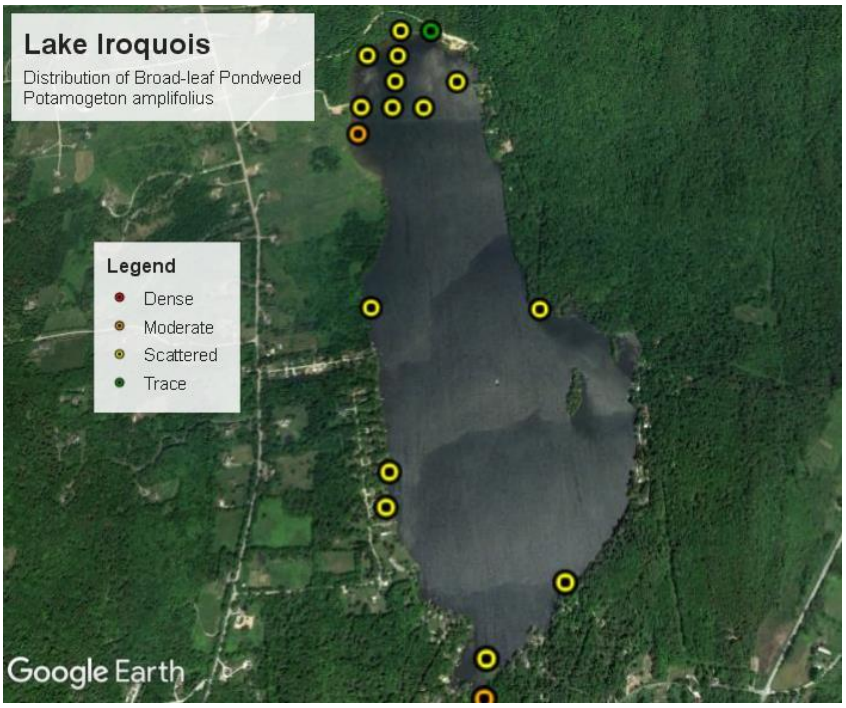

Lake Iroquois
Distribution of Moss
Fontinalis sp.
Legend
Dense
Moderate
Scattered
Trace
Google Earth

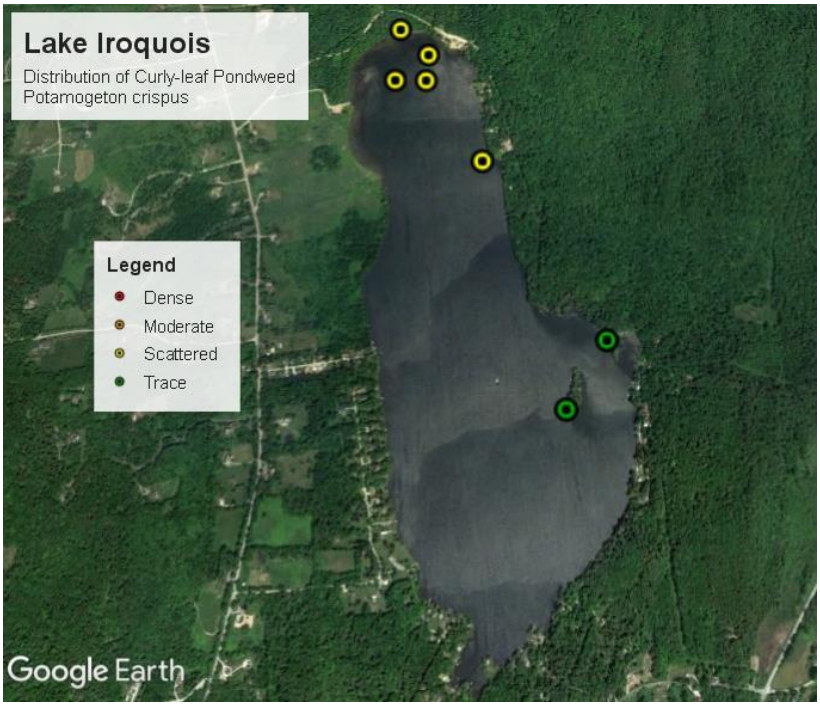

Lake Iroquois
Distribution of Duckweed
Lemna trisulca
Legend
Dense
Moderate
Scattered
Trace
Google Earth

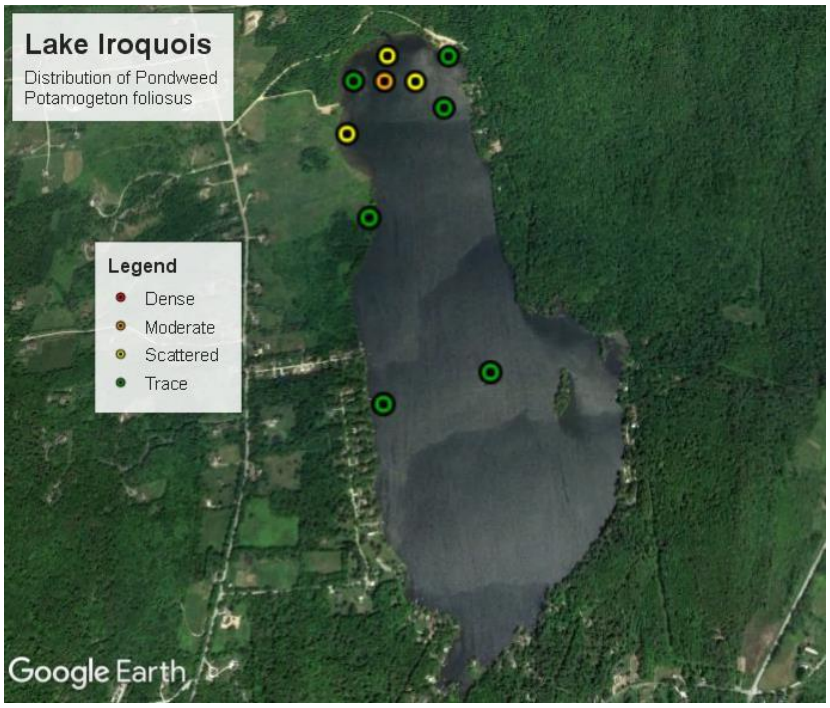

Lake Iroquois
Distribution of Bushy Pondweed
Najas flexilis
Legend
Dense
Moderate
Scattered
Trace
Google Earth

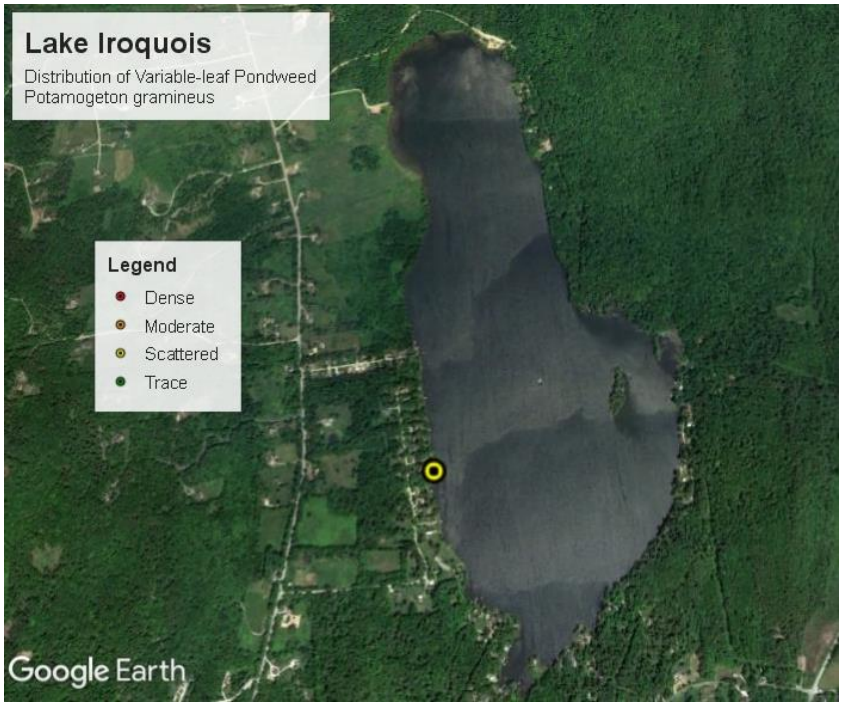

Lake Iroquois
Distribution of White Waterlily
Nymphaea odorata
Legend
Dense
Moderate
Scattered
Trace
Google Earth

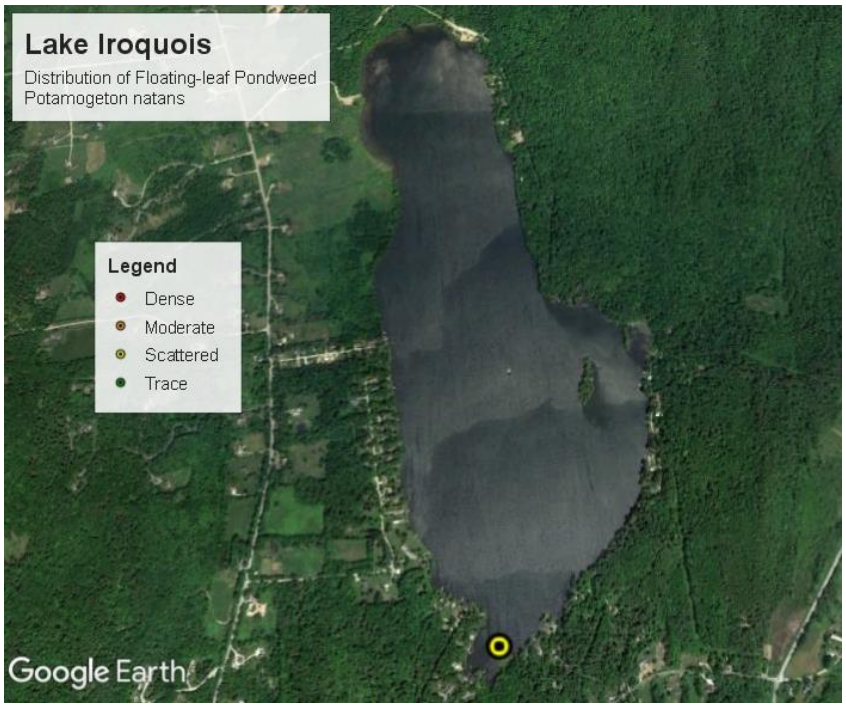

Lake Iroquois
Distribution of Smartweed
Polygonum amphibium
Legend
Dense
Moderate
Scattered
Trace
Google Earth

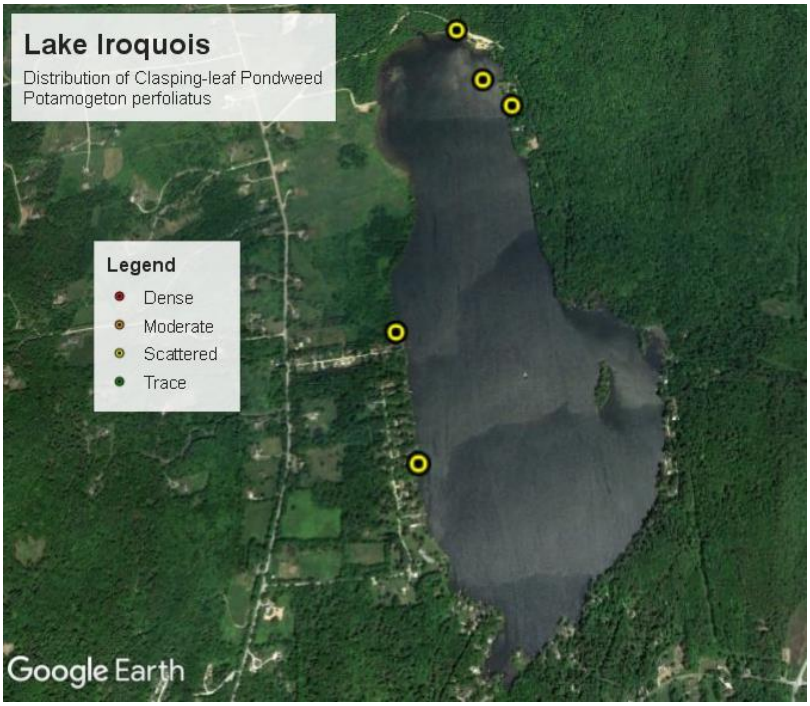

Lake Iroquois
Distribution of Broad-leaf Pondweed
Potamogeton amplifolius
Legend
Dense
Moderate
Scattered
Trace
Google Earth

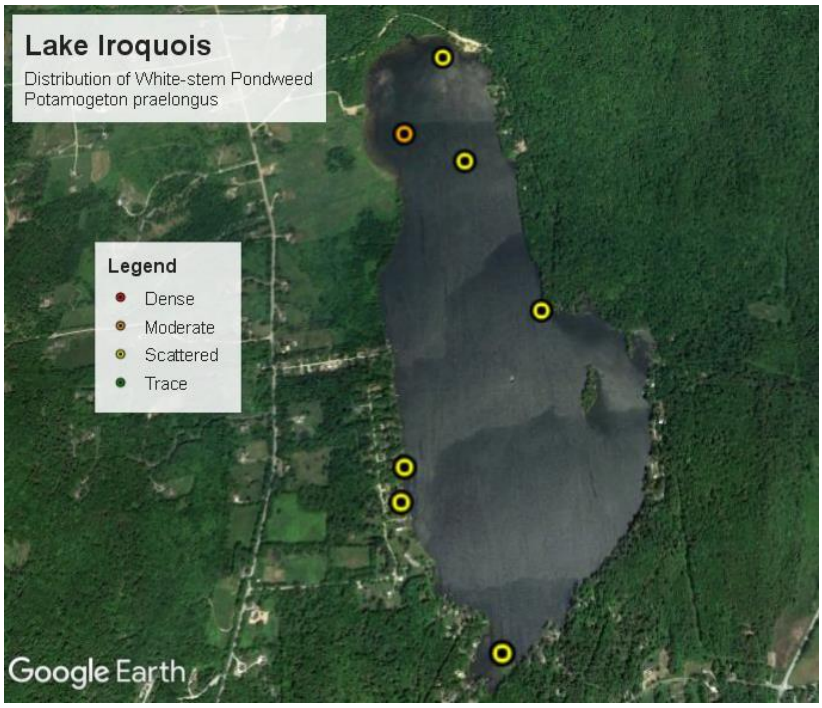

Lake Iroquois
Distribution of Curly-leaf Pondweed
Potamogeton crispus
Legend
Dense
Moderate
Scattered
Trace
Google Earth

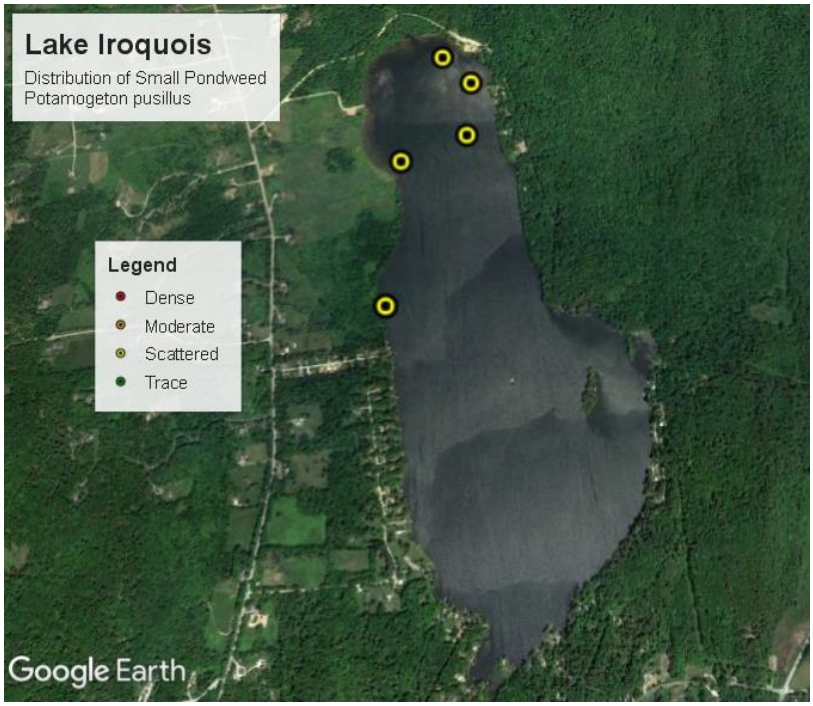

Lake Iroquois
Distribution of Pondweed
Potamogeton foliosus
Legend
Dense
Moderate
Scattered
Trace
Google Earth

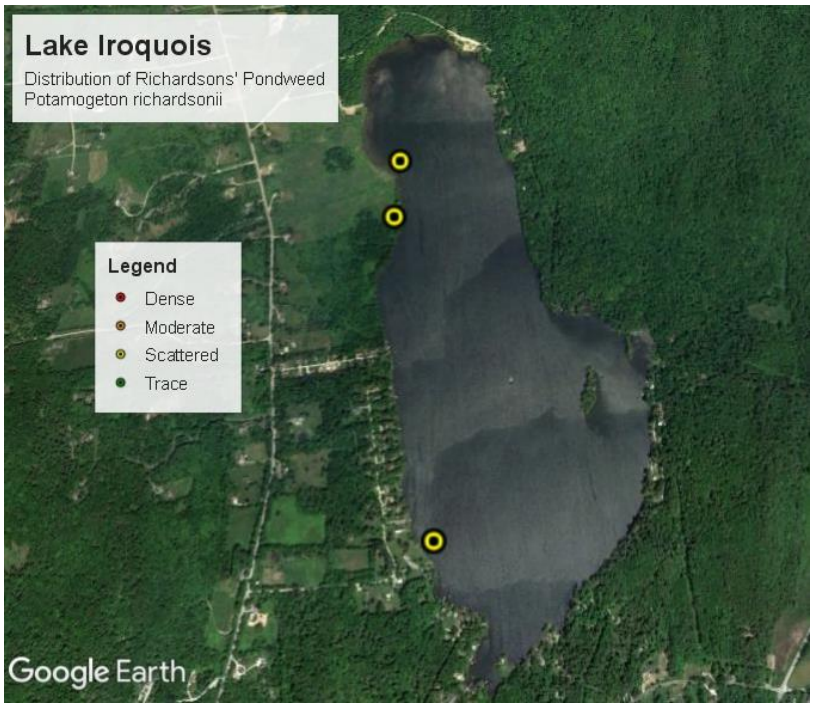

Lake Iroquois
Distribution of Variable-leaf Pondweed
Potamogeton gramineus
Legend
Dense
Moderate
Scattered
Trace
Google Earth

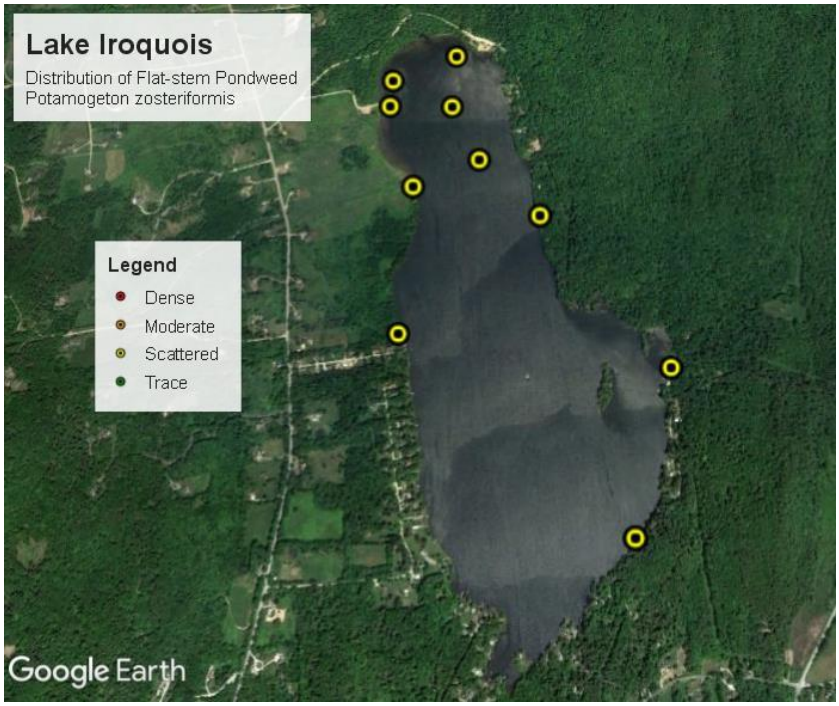

Lake Iroquois
Distribution of Floating-leaf Pondweed
Potamogeton natans
Legend
Dense
Moderate
Scattered
Trace
Google Earth

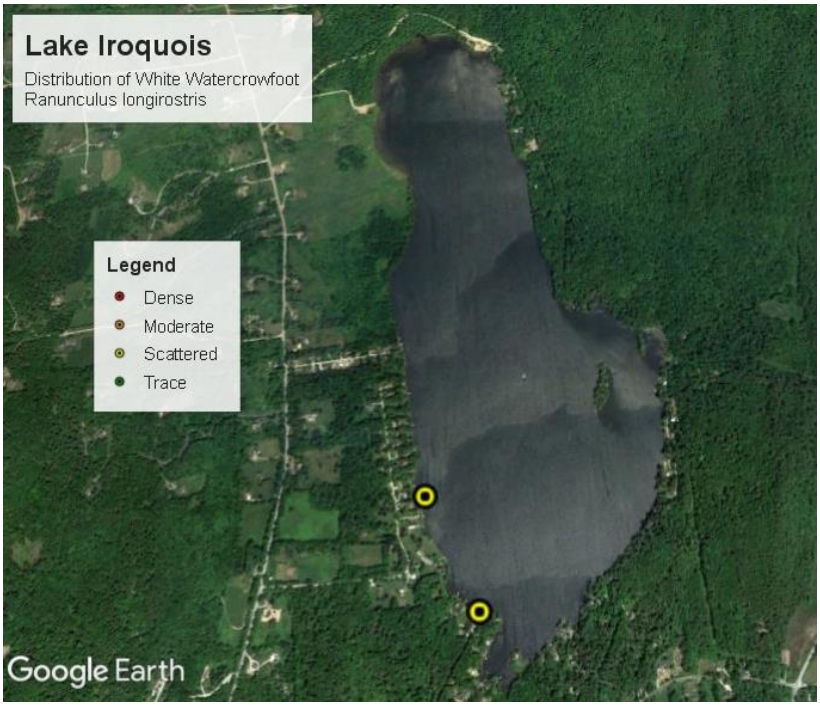

Lake Iroquois
Distribution of Clasping-leaf Pondweed
Potamogeton perfoliatus
Legend
Dense
Moderate
Scattered
Trace
Google Earth

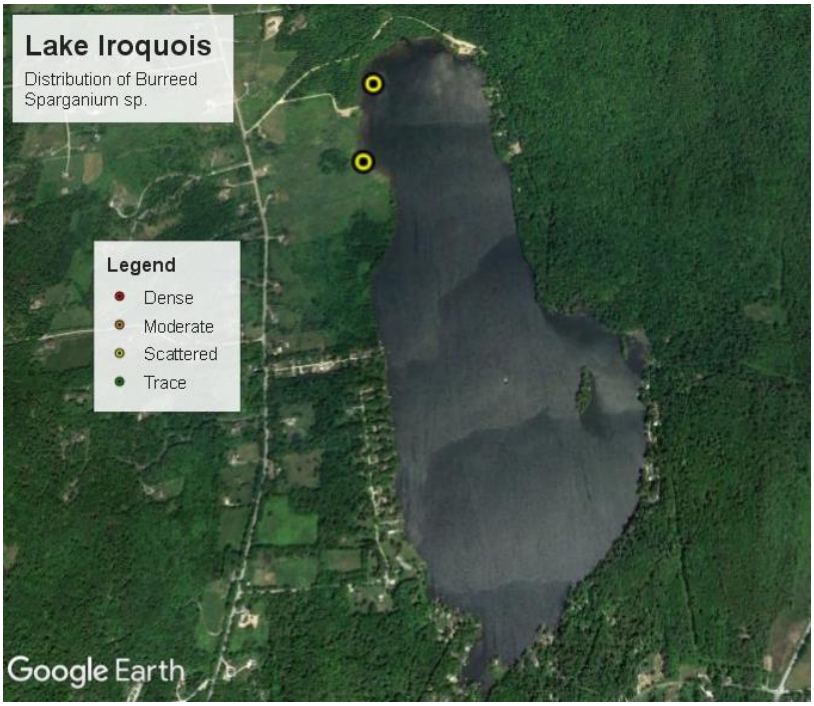

Lake Iroquois
Distribution of White-stem Pondweed
Potamogeton praelongus
Legend
Dense
Moderate
Scattered
Trace
Google Earth

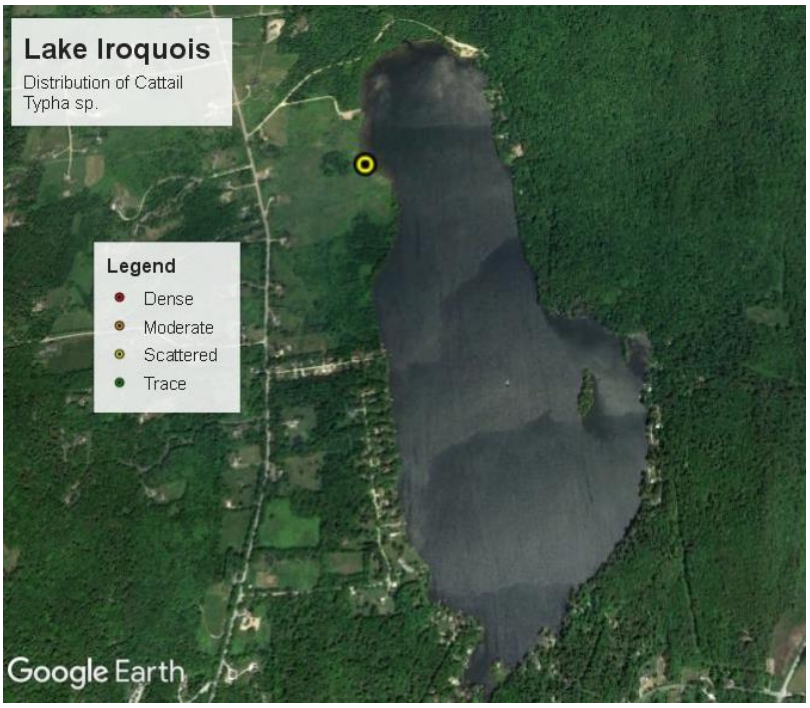

Lake Iroquois
Distribution of Small Pondweed
Potamogeton pusillus
Legend
Dense
Moderate
Scattered
Trace
Google Earth

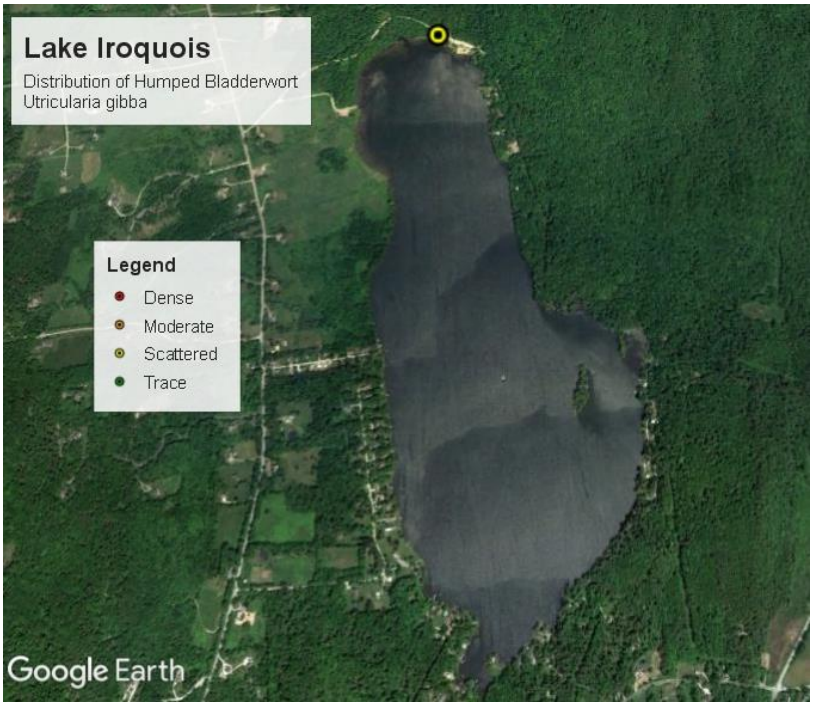

Lake Iroquois
Distribution of Richardsons' Pondweed
Potamogeton richardsonii
Legend
Dense
Moderate
Scattered
Trace
Google Earth

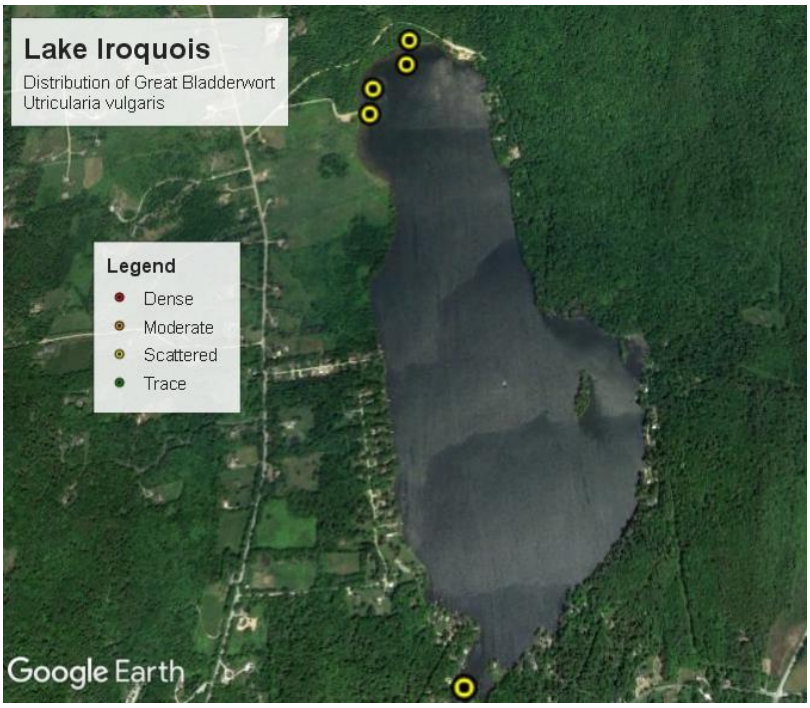

Lake Iroquois
Distribution of Flat-stem Pondweed
Potamogeton zosteriformis
Legend
Dense
Moderate
Scattered
Trace
Google Earth

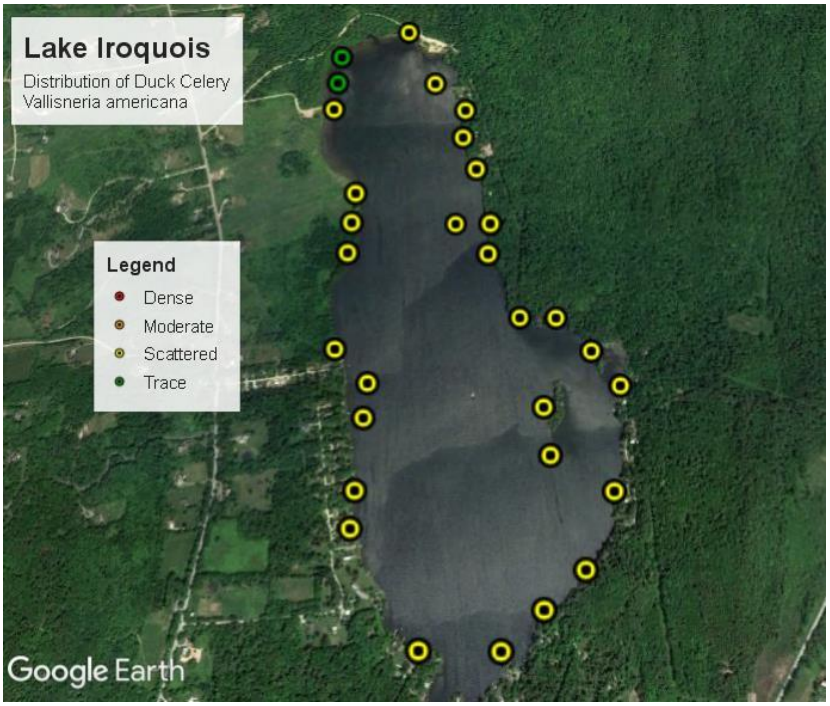

Lake Iroquois
Distribution of White Watercrowfoot
Ranunculus longirostris
Legend
Dense
Moderate
Scattered
Trace
Google Earth

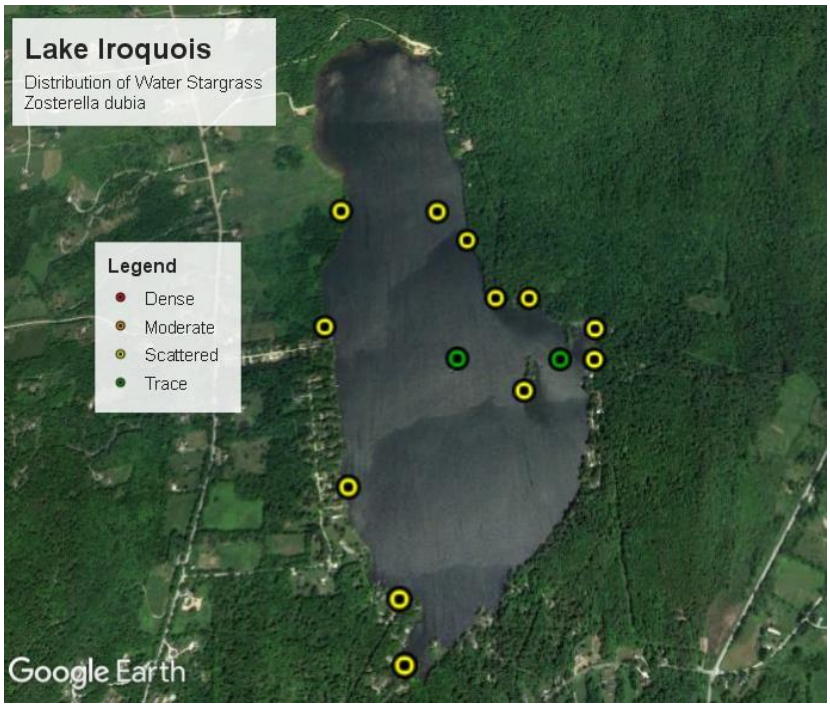

Lake Iroquois
Distribution of Burreed
Sparganium sp.
Legend
Dense
Moderate
Scattered
Trace
Google Earth


Lake Iroquois
Distribution of Cattail
Typha sp.
Legend
Dense
Moderate
Scattered
Trace
Google Earth


Lake Iroquois
Distribution of Humped Bladderwort
Utricularia gibba
Legend
Dense
Moderate
Scattered
Trace
Google Earth


Lake Iroquois
Distribution of Great Bladderwort
Utricularia vulgaris
Legend
Dense
Moderate
Scattered
Trace
Google Earth


Lake Iroquois
Distribution of Duck Celery
Vallisneria americana
Legend
Dense
Moderate
Scattered
Trace
Google Earth


Lake Iroquois
Distribution of Water Stargrass
Zosterella dubia
Legend
Dense
Moderate
Scattered
Trace
Google Earth