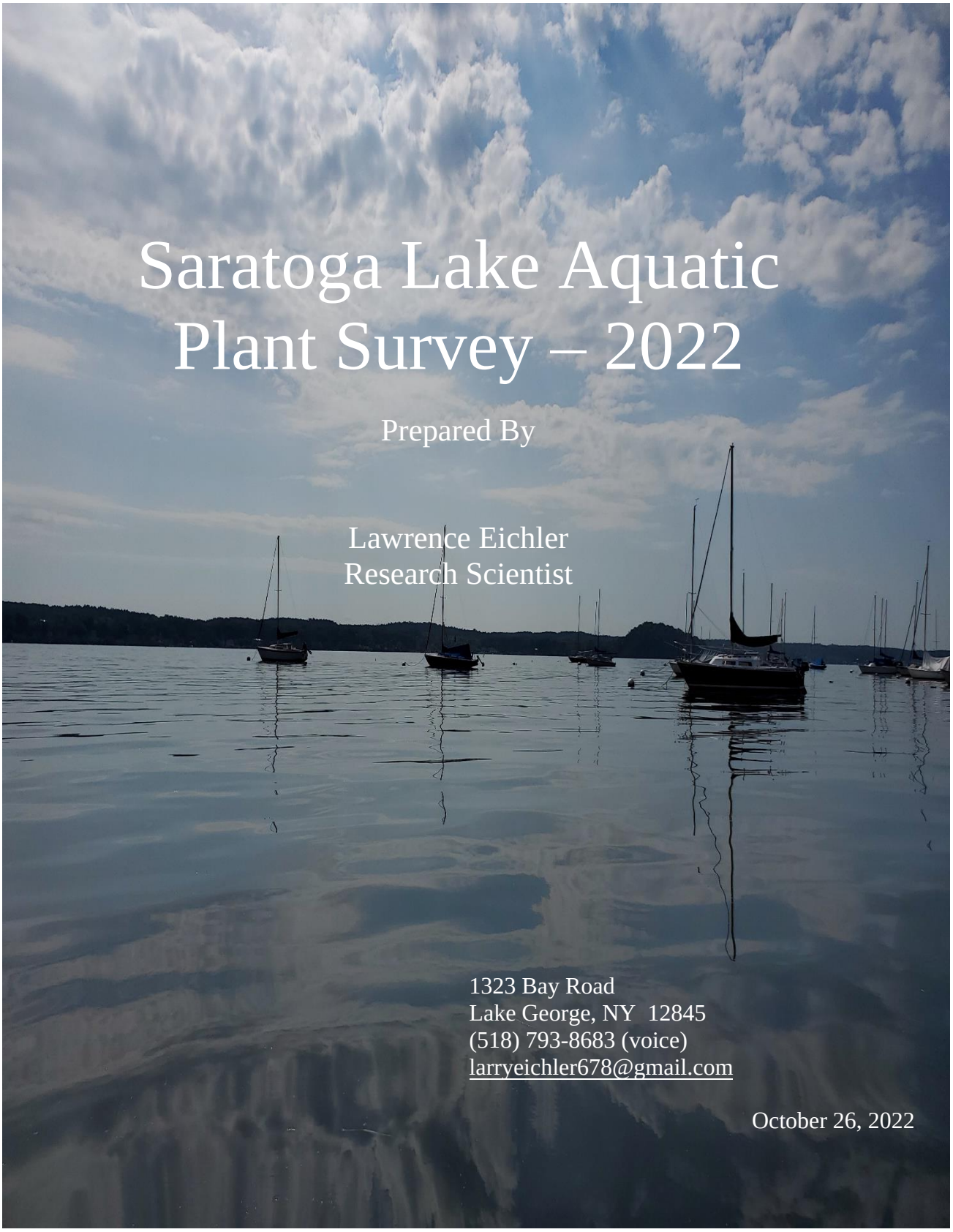

Saratoga Lake Aquatic Plant Survey – 2022

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Background

Quantitative aquatic plant surveys were undertaken for Saratoga Lake, New York as part of a cooperative effort between Solitude, the author, and the Saratoga Lake Protection and Improvement District (SLPID). The aquatic plant survey was designed to be comparable to pre-treatment and post-treatment data collected by the author in 2004, and 2007 thru 2021 (Eichler 2021). The 2022 plant management effort was based on lake drawdown, mechanical harvesting, and hand pulling. Hand harvesting for Waterchestnut (*Trapa natans*) and European Frogbit (*Hydrocharis morsus ranae*) control has occurred annually near the mouth of the Kayadeross Creek and at the Fish Creek boat launch. Prior management efforts included the herbicide fluridone (SONAR^{TM}) in 2015 and the herbicide triclopyr (Renovate) in 2008 thru 2015 and again in 2018, supplemented with endothall (Aquathol K) in 2014, 2017 and 2018. No herbicide application occurred in 2016. In 2011, hand harvesting of Eurasian watermilfoil by SCUBA divers was also conducted by Adirondack Invasives Management (AIM) in an area south of Mannings Cove. Clearcast (imazimox) was employed in 2012, 2014, 2018 and 2019 for Waterchestnut management. The Point-Intercept Rake Toss aquatic plant survey method presently required by NYS DEC for Tier III Lakes was employed.

The survey area encompassed the entire littoral zone of Saratoga Lake. The assessment was designed to generate the information necessary to review effectiveness of aquatic plant management efforts, meet all permit requirements and provide data for comparison of post-treatment conditions to prior survey information. The project consisted of three components: 1) collection of herbarium specimens throughout the lake for compilation of a species list, 2) point-intercept frequency and depth data for points distributed within the treatment areas, when warranted and 3) point-intercept frequency and depth data for points distributed within an untreated (control) area of the lake.

Introduction

Survey Site

Saratoga Lake is located in Saratoga County, New York in the towns of Saratoga, Stillwater, Malta and the City of Saratoga Springs. The lake has a surface area of approximately 3765 acres and a surface elevation of 203 ft amsl. Saratoga Lake has a single outlet, Fish Creek, draining to the Hudson River. Average water depth is reported to be 25 ft, with a maximum depth of 95 ft (Mikol and Polsinelli 1985). Hydraulic retention time is reported to be 0.4 years and lake volume is 381,000,000 m^3. Transparency via secchi disk in 2003 was reported to be 4.1 m (SLPID 2003). More recently the NYS DEC has reported secchi transparency values of 4.0 m and 3.6 m in 2009 and 2010, respectively (CSLAP 2010). The 2018 CSLAP (CSLAP 2018) reports long-term average secchi transparency of 3.2 meters.

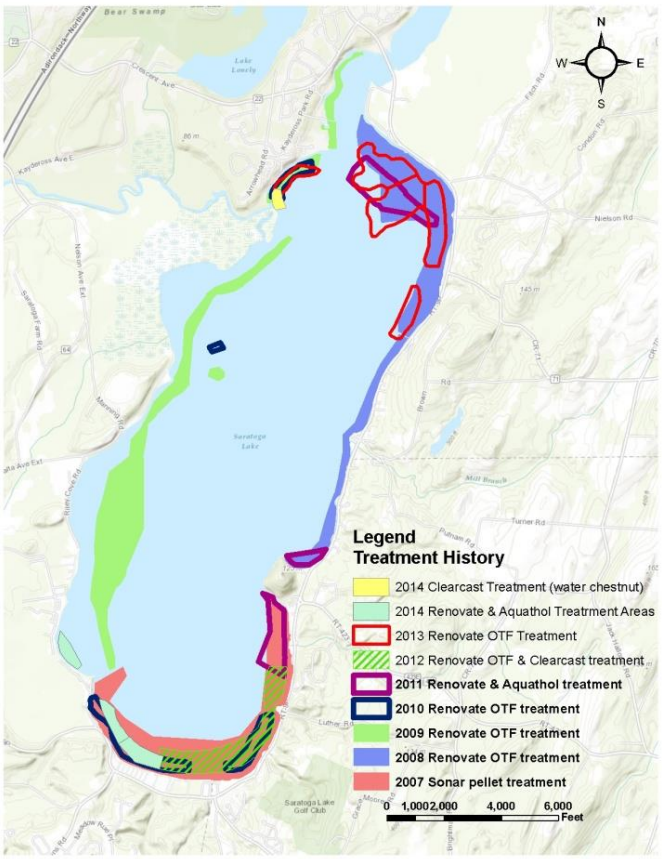
An aquatic plant survey of Saratoga Lake in 1932 (NYS DEC 1932) indicated that the lake was quite free of "weeds" except in a few protected bays, primarily along the south and west shores.

Common species included *Ceratophyllum demersum, Elodea canadensis, Vallisneria americana* and the pondweeds; *Potamogeton amplifolius, P. praelongus, P. nodosus,* and *P. friesii*. One exotic species, *Potamogeton crispus* was reported. In 1969, the NYS DEC pesticides unit did a more extensive mapping of aquatic plants in Saratoga Lake. They reported a healthy native plant community with 13 submersed species, 2 native rooted floating-leaf species, 3 native emergent species and 3 free floating species (Dean 1969). *Myriophyllum spicatum* populations were first confirmed in the mid-1970's and reported to be the dominant aquatic plant species in the lake by the early-1980's (Hardt et al. 1983). Additional data collections by the US EPA Clean Lakes Program reported 14 submersed species, 2 floating-leaved species, 2 emergent species and 3 free floating species in 1981-82 (Hardt et al. 1983). Both *Myriophyllum spicatum* and *Potamogeton crispus* were reported as occurring as dense growth. By 1994, the Saratoga Lake aquatic plant community included 23 submersed species, 3 native rooted floating-leaf species, 2 native emergent species and 1 free floating species (Eichler and Boylen 1995). *Myriophyllum spicatum* was the most common plant species, present in 68 percent of survey points. Two other exotic aquatic plant species were reported, *Potamogeton crispus* and *Trapa natans*.

Nuisance aquatic plant growth has posed problems for Saratoga Lake for the past several decades. Excessive aquatic plant growth is reported to impact water-based recreation, aesthetic quality, environmental issues related to loss of habitat diversity, exclusion of native plant and animal species, and hydrodynamics. Nuisance growth of aquatic plants in Saratoga Lake is mainly attributable to three non-native species: Eurasian watermilfoil (*Myriophyllum spicatum),* Curly-leaf Pondweed (*Potamogeton crispus),* and Waterchestnut (*Trapa natans),* with the majority of effort devoted to the management of Eurasian watermilfoil.

In 1994, an aquatic plant survey of Saratoga Lake was conducted by the Darrin Fresh Water Institute to evaluate ongoing aquatic plant harvesting and lake level drawdown programs for the control of *Myriophyllum spicatum* and *Potamogeton crispus*. Volunteer efforts were also employed to hand harvest scattered growth of *Trapa natans*. These aquatic plant management efforts were instituted in 1984 and continue on an annual basis. Results of the 1994 survey indicated a diverse population of native aquatic plants dominated by the exotic invasive *Myriophyllum spicatum*. While mechanical harvesting provided access to the open waters of the lake for recreational use, this technology was not having an appreciable long-term effect on the density of growth of *Myriophyllum spicatum*. Winter draw-down and the resultant ice scour in shallow waters (depth less than 1 meter) was negatively affecting the growth of *Myriophyllum spicatum*. In 2000 and 2003, two additional aquatic plant management tools were evaluated on an experimental basis, biological control agents (weevils) and herbicide (SONAR) application. Biocontrol agents, while promising, continue to be experimental. Surveys conducted in 2004 (Eichler and Boylen 2004) indicated that native species richness in the herbicide treated areas had increased, however Eurasian watermilfoil was still dominant. A three-year herbicide cycle was initiated in 2007 with fluridone (Sonar) treatment of the southern margin of the lake in the area of Browns Beach. Triclopyr (Renovate) herbicide was applied in 2008 and 2009 on the eastern and western margins of the lake, respectively. In 2010, four discrete areas were treated with triclopyr; the sunken islands on the west side of the lake, the area just north of the Kayadeross Creek, and two plots at the southern end of the lake. In a post-treatment survey, 28

species were observed lake-wide in 2010 (Eichler and Boylen 2010). Eurasian watermilfoil was the seventh most widely distributed plant (22% of survey points), an increase from ninth in 2009. Common native species included *Ceratophyllum demersum* (62% of survey points), *Najas guadalupensis* (48%), *Elodea canadensis* (46%), *Vallisneria americana* (43%), *Zosterella dubia* (30%), *Potamogeton zosteriformis* (23%), *Potamogeton perfoliatus* (16%) and *Najas flexilis* (8%). Average number of species per sample point was greater in 2010 (3.47 ± 0.12) than in 2009 (2.74 ± 0.12) or 2008 (2.47 ± 0.12). Exclusion of survey points outside the littoral zone may have accounted for this change.



In 2011, three areas were treated with a combination of triclopyr and endothall, with the objective to control both *Myriophyllum spicatum* and *Potamogeton crispus*. Two of the sites were bays adjacent to Snake Hill, one to the north of about 10 acres and the other to the south including about 35 acres were treated. The remaining site centered on the shoal area off Franklins Beach, encompassing about 55 acres. In August of 2011, the aquatic plant community of Saratoga Lake included 23 submersed species, 3 floating-leaved species, 2 floating species and 3 emergent species for a total of 31 species. Native species were dominant in 2011. Common native species in the untreated or control areas included *Ceratophyllum demersum* (61% of survey points), *Najas guadalupensis* (50%), *Vallisneria americana* (46%), *Elodea canadensis* (42%), *Zosterella dubia* (31%), *Potamogeton zosteriformis* (21%), *Potamogeton perfoliatus* (16%), *Chara/Nitella* (13%), *Najas flexilis* (9%), *Potamogeton illinoensis* (6%) and *Potamogeton pusillus* (6%). Eurasian watermilfoil showed some signs of decline in the previously treated portions of the survey, reported for 18% of survey points a decrease from 21% of survey points reported for 2010.

In 2012, a 100 acre area at the southeastern margin of the lake near Browns Beach was treated with triclopyr (Renovate OTF) and imazamox (Clearcast 2.7G) was applied in a 50 acre sub-area to control both *Myriophyllum spicatum* and *Potamogeton crispus*. Eurasian watermilfoil declined to 26% of survey points lake-wide and 7% of survey points in the treated areas.
In 2013, a total of 172 acres at the northern margins of the lake were treated with triclopyr

(Renovate OTF). The treatment areas were adjacent to Franklins Beach, the northern margin of the Kayadeross Creek delta and along the northeastern shoreline

In 2014, 42 acres in Rileys Cove and at the south end of the lake were treated with Aquathol K and a combination of Renovate OTF and Aquathol K. In addition, an area of 5 acres was treated near the mouth of the Kayadeross Creek with Clearcast to control waterchestnut.

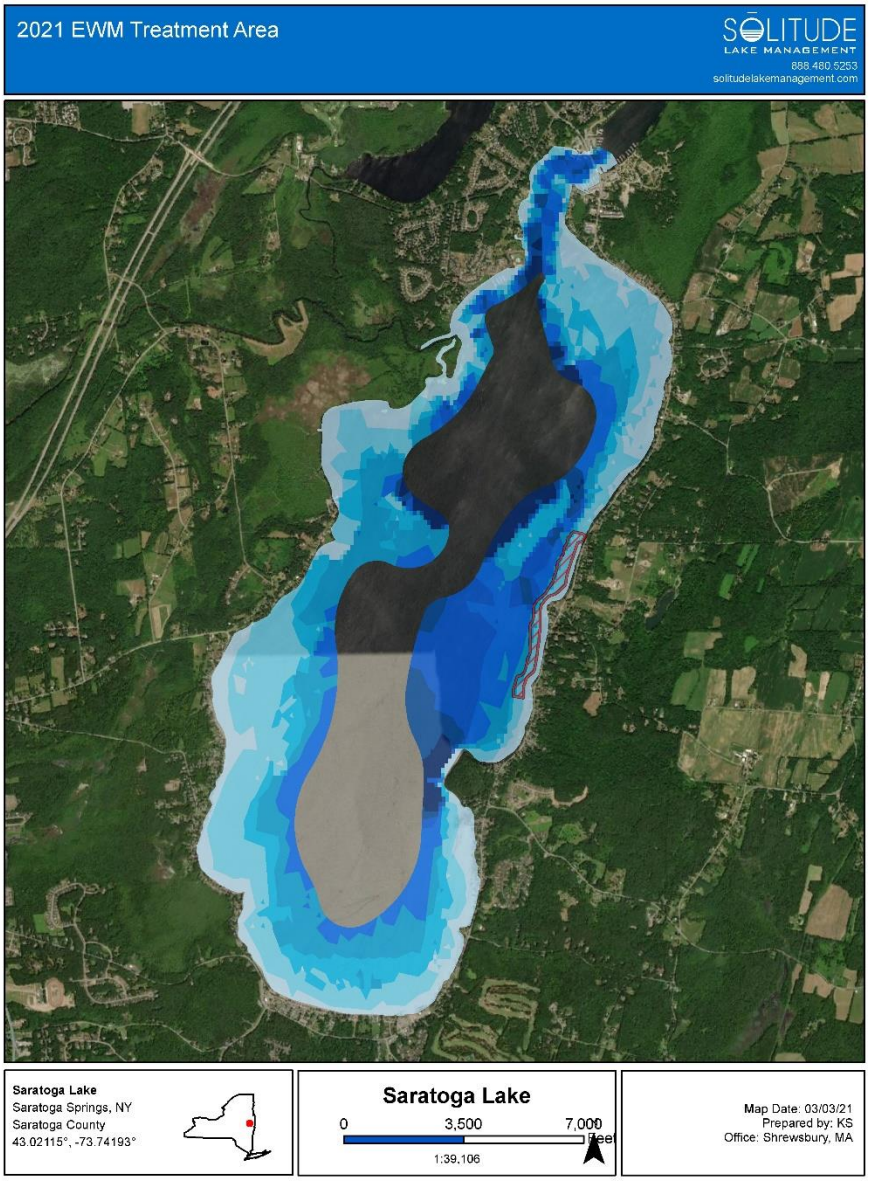
In 2015, fluridone (Sonar) was used to treat the area south from Snake Hill to Browns Beach. Native species continued to be dominant in 2015. Common native species in untreated or control areas included *Vallisneria americana* (45% of survey points), *Ceratophyllum demersum* (36%), *Potamogeton richardsonii* (33%), *Najas guadalupensis* (33%), *Myriophyllum spicatum* (28%), *Zosterella dubia* (26%), *Elodea canadensis* (13%), *Chara/Nitella* (12%), *Najas flexilis* (9%), and *Potamogeton illinoensis* (5%). Eurasian watermilfoil declined to 27% of survey points from 2014 levels (36% of survey points), but relatively unchanged from the 29% of survey points reported in 2011 and 2012.

In 2016, lake level drawdown, mechanical harvesting and hand harvesting of *Trapa natans* were the exclusive management efforts. No herbicide application was conducted. Native species continued to be dominant. Common native species included *Vallisneria americana* (41% of survey points), *Ceratophyllum demersum* (33%), *Potamogeton richardsonii* (31%), *Najas guadalupensis* (24%), *Zosterella dubia* (29%), *Elodea canadensis* (10%), and *Najas flexilis* (8%). Eurasian watermilfoil frequency of occurrence declined to 26% of survey points.

In 2017, hand harvesting for Waterchestnut and European Frogbit control was implemented. Waterchestnut control was instituted at the northern margin of the delta of the Kayadeross Creek. European frogbit management was conducted at the northern margin of the Fish Creek Boat Launch area. At the south end of the lake, 67 acres were treated with Aquathol K and 28 acres were treated with Navigate (2,4-D). Eurasian watermilfoil was the fourth most widely distributed plant (29% of survey points). Native plant species distribution was similar to prior years. Common native species included *Vallisneria americana* (41%), *Ceratophyllum demersum* (46%), *Potamogeton richardsonii* (21%), *Najas guadalupensis* (26%), *Zosterella dubia* (31%), *Elodea canadensis* (11%), and *Najas flexilis* (9%).

In 2018, hand harvesting for Waterchestnut and European Frogbit control was continued. European frogbit management occurred at the northern margin of the Fish Creek Boat Launch area. Waterchestnut control was instituted at the northern margin of the delta of the Kayadeross Creek with Aquathol K (3.9 acres) and 7.5 acres were treated with Navigate (2,4-D). At the Franklins' Beach area of the lake, 43.1 acres were treated with Renovate OTF for Eurasian watermilfoil control.

Hand harvesting for Waterchestnut and European Frogbit control was continued in 2019 as were lake level drawdown and mechanical harvesting. European frogbit management occurred at the



northern margin of the Fish Creek Boat Launch area. Waterchestnut at the southern margin of the delta of the Kayadeross Creek was treated with Clearcast (imazimox).

The 2020 effort was based on lake drawdown, mechanical harvesting and application of the herbicides Procella COR (Renovate) and endothall (Aquathol K). Procella COR was applied for Eurasian watermilfoil control on the Franklins Beach area while endothall was employed at the southern margin on the lake to Browns Beach.

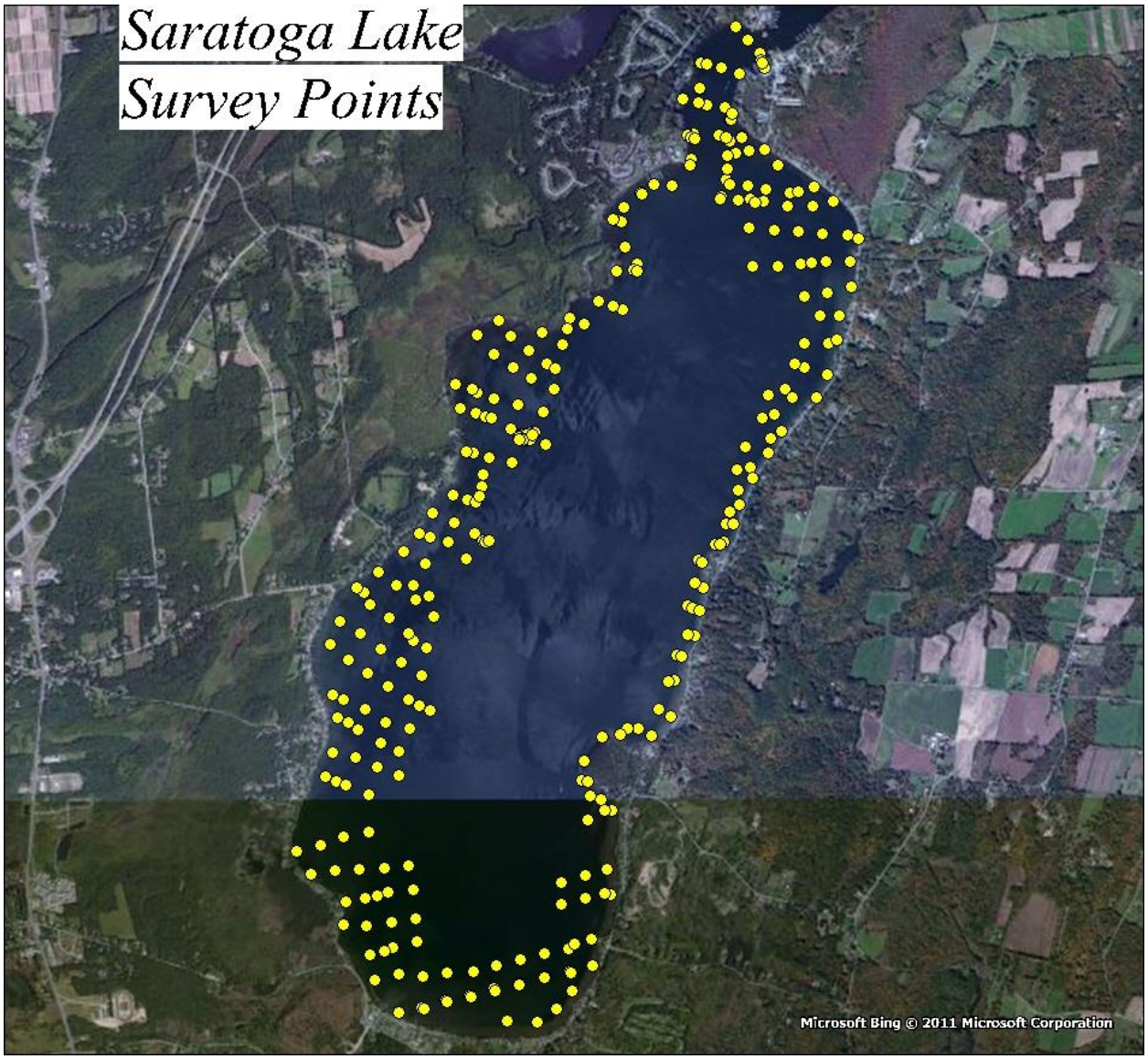
In 2021, Procella COR was applied to an area on the east side of the lake north of Snake Hill, complementing the annual lake level drawdown, hand and mechanical harvesting effort.

Aquatic plant management in 2022 employed lake level drawdown, hand and mechanical harvesting.

Methods

Species List and Herbarium Specimens. As the lake was surveyed, the occurrence of each aquatic plant species was recorded and adequate herbarium specimens collected. The herbarium specimens were pressed, dried, and mounted (Hellquist 1993) at the Darrin Fresh Water Institute Laboratory in Bolton Landing, NY, where they became part of the permanent collection.

Figure 1. Distribution of point intercept survey points for Saratoga Lake aquatic plant survey.



Point Intercept Survey. The frequency and diversity 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 differential global positioning system (Garmin GPSmap 168) was used to navigate to each point for the survey observation. Point intercept plant frequencies were surveyed on August 25 and 26 of 2022, at the time of maximum aquatic plant abundance. Based on an 80 m grid and excluding most points outside the littoral zone, a total of 310 points on Saratoga Lake were surveyed (Figure 2). The point intercept method allows a large number of discrete observations in a short period of time facilitating statistical analysis and comparisons. Point intercept methods also allow for production of distribution maps for all species listed (Figure 1).

Results and Discussion

In August of 2022, the aquatic plant community of Saratoga Lake included 25 submersed species, 4 floating-leaved species, 3 floating species and 3 emergent species for a total of 35 species (Table 1). Five exotic species, *Myriophyllum spicatum, Najas minor, Potamogeton*

Table 1. Aquatic plant species present in Saratoga Lake in recent surveys.

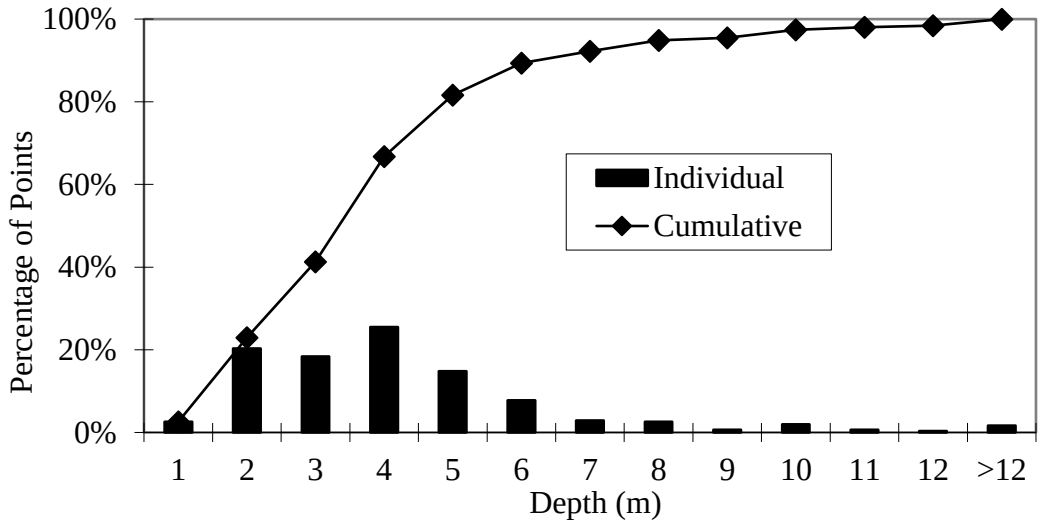
Species	**Common Name**	**2018**	**2019**	**2020**	**2021**	**2022**
Ceratophyllum demersum L.	coontail	**x**	**x**	**x**	**x**	**x**
Chara/Nitella sp.	muskgrass, chara	**x**	**x**	**x**	**x**	**x**
Elodea canadensis Michx.	waterweed	**x**	**x**	**x**	**x**	**x**
Fontinalis sp.	moss		**x**	**x**		**x**
Hydrocharis morsus-ranae	European frogbit	**x**	**x**	**x**		**x**
Lemna minor L.	duckweed	**x**	**x**	**x**	**x**	**x**
Lemna trisulca L.	duckweed	**x**	**x**	**x**	**x**	**x**
Megalodonta beckii Torr.	water marigold	**x**	**x**	**x**	**x**	**x**
Myriophyllum spicatum L.	Eurasian watermilfoil	**x**	**x**	**x**	**x**	**x**
Najas flexilis (Willd.) Rostk. & Schmidt.	bushy pondweed	**x**	**x**	**x**	**x**	**x**
Najas minor All.	brittle naiad	**x**	**x**	**x**	**x**	**x**
Najas guadalupensis (Spreng.) Magnus	southern naiad	**x**	**x**	**x**	**x**	**x**
Nuphar variegata Engelm. ex Durand	yellow pondlily	**x**	**x**	**x**	**x**	**x**
Nymphaea odorata Ait.	white pondlily	**x**	**x**	**x**	**x**	**x**
Pontederia cordata L.	pickerelweed	**x**	**x**	**x**	**x**	**x**
Potamogeton amplifolius Tuckerm.	largeleaf pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton crispus L.	curly-leaf pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton gramineus L.	variable-leaf pondweed	**x**			**x**	**x**
Potamogeton illinoensis L.	Illinois pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton natans L.	floating-leaf pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton perfoliatus L	clasping-leaf pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton praelongus Wulfen	white-stem pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton pusillus L.	small pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton richardsonii (Ar. Benn.) Rydb.	Richardsons' pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton robbinsii Oakes	Robbins' pondweed	**x**	**x**	**x**	**x**	**x**
Potamogeton vaseyi Robbins	Vasey's pondweed		**x**			
Potamogeton zosteriformis Fern.	flat-stem pondweed	**x**	**x**	**x**	**x**	**x**
Ranunculus longirostris Godron	white watercrowfoot	**x**	**x**	**x**	**x**	**x**
Sagittaria graminea Michx.	arrowhead	**x**	**x**		**x**	
Sparganium sp.	burreed	**x**	**x**	**x**	**x**	**x**
Spirodela polyrhiza (L.) Schlieden	giant duckweed	**x**		**x**	**x**	
Stuckenia pectinata L.	sago pondweed	**x**	**x**	**x**	**x**	**x**
Trapa natans L.	waterchestnut	**x**	**x**	**x**	**x**	**x**
Typha	cattail	**x**	**x**	**x**	**x**	**x**
Utricularia vulgaris L.	great bladderwort	**x**	**x**	**x**		**x**
Vallisneria americana L.	wild celery	**x**	**x**	**x**	**x**	**x**
Wolffia sp.	water meal	**x**	**x**	**x**	**x**	**x**
Zosterella dubia Jacq.	water stargrass	**x**	**x**	**x**	**x**	**x**

crispus, *Trapa natans* and *Hydrocharis morsus-ranae* were reported. Species richness was quite high, with a large number of species occurring in more than 10% of survey points (Table 2). Eurasian watermilfoil was the ninth most widely distributed plant (8% of survey points) in 2022, down from eighth in 2021, seventh in 2020, sixth in 2019 and unchanged from 2018; a declining from fourth in 2017 and fifth in 2016.

Maximum Depth of Colonization

Maximum depth of colonization by rooted aquatic plant growth extended to a depth of 6 meters. Calculated maximum depth of colonization (MDOC) by macrophytes ranged from 4.3 to 4.9 meters in 2004 (Eichler and Boylen 2004), comparable to 1994 records (Eichler and Boylen 1995). Specimens of *Ceratophyllum demersum*, *Najas guadalupensis* and *Myriophyllum spicatum* were found between 5 and 6 meters depth in most years. Thus, 6 meters is the maximum extent of the littoral zone, representing an increase of approximately 1 meter in depth from 1994 estimates (Eichler and Boylen 1995) and comparable to depth records for 2004 (Eichler and Boylen 2004) and 2007 (Eichler and Boylen 2008). Depth distribution of sampling points (Figure 2) was equitable throughout the littoral zone in 2007 thru 2022.

Figure 2. Depth Distribution of Saratoga Lake sampling points in 1 meter depth classes.



Species Richness and Distribution

A total of 29 species were collected in the point intercept portion of the survey and 35 species were observed in Saratoga Lake in 2022 (Table 1). These results are comparable to previous surveys, where 35 species were observed in 2021, 34 species in 2019 and 2017, 30 species in 2014 and 2015, 29 species in 2013 and 2009, 28 species in 2020 and 2018, 25 species in 2007 and 2008, 24 species in 2012, 22 species in 1995 and 2010, 21 species in 1982 and 2004 (Hardt et al., 1983) and 20 species in 1969 (Dean 1969). The limited occurrence of *Potamogeton*

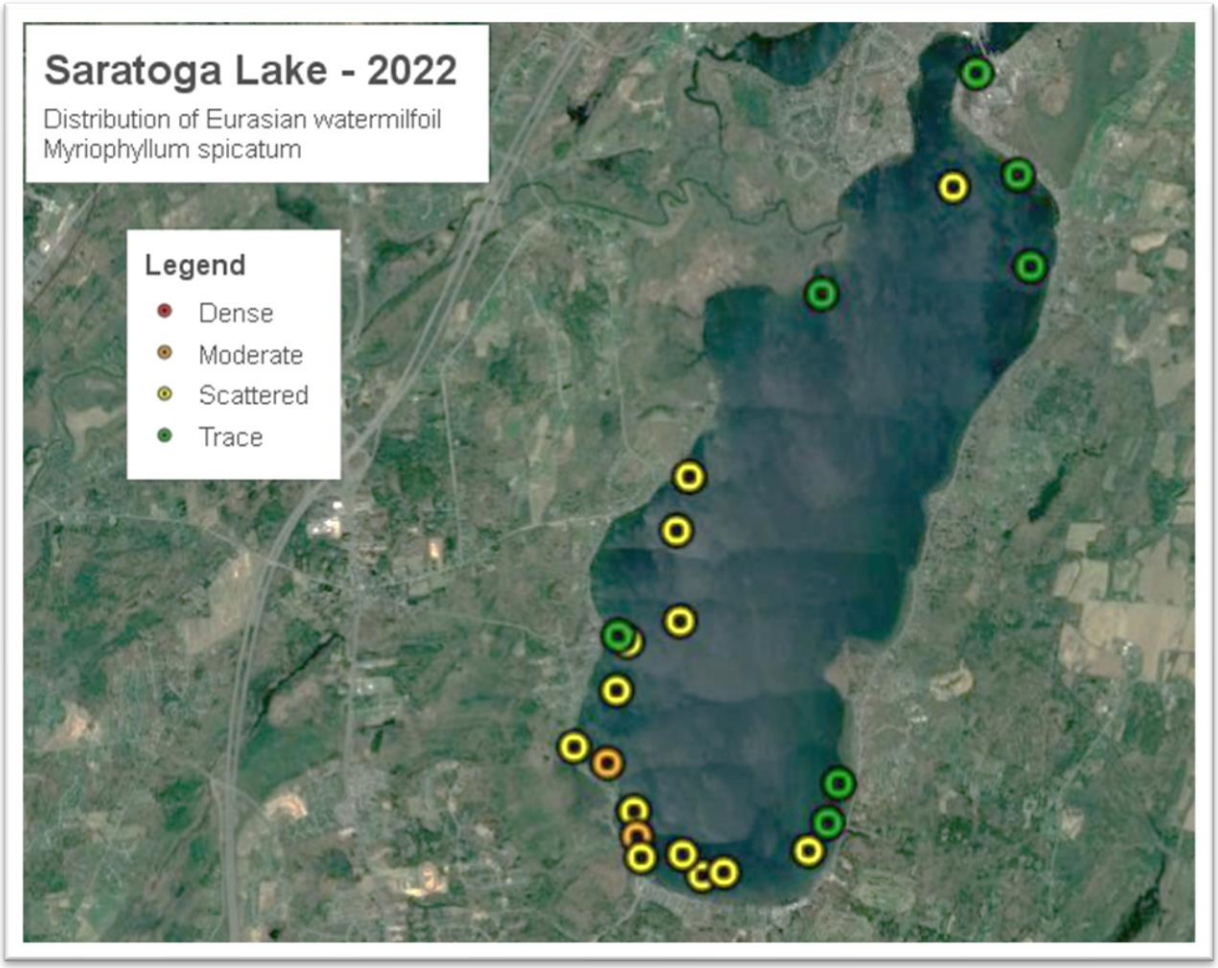
crispus can be attributed to the timing of the current survey (August), rather than an actual decline in the abundance of this species. *Potamogeton crispus* generally reaches peak abundance in June and July, and then undergoes senescence. *Trapa natans* was observed to cover large areas near the delta of the Kayadeross Creek in 2013. Following herbicide treatments in 2014, a reduced area of coverage remained which persisted in 2015 and 2016. Hand harvesting effort supplemented with herbicides in 2017 thru 2022 reduced the *Trapa natans* to scattered plants. Brittle Naiad (*Najas minor*) was reported for the first time in 2011, absent in 2012, but present in 3 locations in 2022, 4 locations in 2018, 3 locations in 2016 and 2017, and up from 2 locations in 2013 and 2015 and 1 location in 2014 and 2019 through 2021. Brittle naiad is an annual species spreading primarily by seeds, and has been expanding its range northward over the last decade, particularly in the Upper Hudson Valley. Species absent from the 2022 survey but present in prior surveys were generally either present in only a single survey year or relatively uncommon in prior surveys (<1% of survey points).

Maps of the distribution of aquatic plant species for Saratoga Lake are included in Appendix A. Eurasian watermilfoil was present in 8% of survey points in 2022, a slight increase from the 7% of sites in 2021, but a decline from the 10%, 13%, 20%, 29%, 26% and 27% of survey points in 2020 through 2015, respectively, and continuing a decline from 37% of survey points in 2014, 23% of survey points in 2013, 26% of survey points in 2012, 29% in 2011, and 22% of survey points in 2010. Common native species included *Vallisneria americana* (46% of survey points), *Ceratophyllum demersum* (46%), *Zosterella dubia* (30%), *Najas guadalupensis* (27%), *Potamogeton richardsonii* (23%), *Elodea canadensis* (11%), *Chara* sp. (9%), *Potamogeton illinoensis* (8%), and *Najas flexilis* (5%). A list of frequency of occurrence results for all species observed is provided in Table 2. While the frequency of occurrence of most native species has remained stable since the pre-treatment survey of 2004, there were some exceptions. Two exceptions were *Najas guadalupensis* and *Elodea canadensis*, species present in limited numbers in 2004 prior to treatment but much more abundant in post-treatment surveys in 2007 thru 2010. Frequency of occurrence for *Elodea canadensis* has declined since 2010. A related species, *Najas flexilis*, declined in 2007 but returned to pre-treatment levels in 2008, increased in abundance in 2009 and stabilized at 2008 levels since that time. Getsinger et al. (2002) reported declines in *Najas flexilis* and *Elodea canadensis* in the year following fluridone treatment in two Vermont lakes, however these species returned to levels comparable to pretreatment in the following year. Eichler and Boylen (2008) reported similar increases in frequency of occurrence of *Najas flexilis* and *Elodea canadensis* in two Vermont lakes following triclopyr treatments. *Potamogeton crispus* increased in abundance between the pre-treatment survey in 2004 and subsequent post-treatment surveys in 2007 and 2008, but still remained a minor component of the overall population. Frequency of occurrence of *Potamogeton crispus* increased in 2010 to the highest levels recorded in recent surveys. Many of the survey points reporting *Potamogeton crispus* in 2010 were in areas treated in 2011. In 2011 through 2022, *Potamogeton crispus* remained in limited abundance, however the late summer surveys tend to underestimate this species. *Potamogeton richardsonii* has greatly expanded its' coverage in a number of regional lakes, however the reason for this expansion is unknown as the current time. All other differences were in the less common species.

Table 2. Percent frequency of occurrence of aquatic plant species in Saratoga Lake. Species in bold are known to be invasive.

Species	Common Name	2018	2019	2020	2021	2022
Ceratophyllum demersum	coontail	51.3%	43.2%	43.4%	47.1%	45.8%
Chara/Nitella	muskgrass, chara	9.4%	6.8%	7.1%	8.8%	9.0%
Elodea canadensis	waterweed	7.7%	10.3%	12.6%	11.0%	10.6%
Hydrocharis morsus-ranae	**European frogbit**	**0.3%**	**0.3%**	**0.3%**		**0.3%**
Lemna minor	duckweed		1.3%	0.3%	0.3%	
Lemna trisulca	duckweed	0.6%	0.6%	0.3%	0.6%	0.6%
Megalodonta beckii	water marigold	0.3%	1.9%	1.0%	1.0%	1.9%
Myriophyllum spicatum	**Eurasian watermilfoil**	**20.3%**	**12.6%**	**10.0%**	**6.8%**	**8.1%**
Najas flexilis	bushy pondweed	9.0%	8.4%	8.4%	5.8%	4.8%
Najas guadalupensis	Southern naiad	28.7%	26.8%	24.9%	19.2%	26.8%
Najas minor	**brittle naiad**	**1.3%**	**0.3%**	**0.3%**	**0.6%**	**1.0%**
Nuphar variegata	yellow pondlily	1.3%	1.3%	0.6%	1.0%	1.3%
Nymphaea odorata	white pondlily	0.3%	1.6%	1.3%	0.6%	0.3%
Potamogeton amplifolius	large-leaf pondweed	1.3%	1.6%	0.3%	1.6%	0.6%
Potamogeton crispus	**curly-leaf pondweed**	**1.6%**	**1.0%**	**1.0%**	**1.0%**	**0.3%**
Potamogeton illinoensis	Illinois pondweed	7.4%	7.1%	6.5%	6.5%	8.4%
Potamogeton perfoliatus	clasping-leaf Pondweed	1.3%	0.6%	0.6%		0.3%
Potamogeton praelongus	white-stem pondweed	3.2%	2.3%	2.3%	0.6%	4.2%
Potamogeton pusillus	small pondweed	0.6%	2.6%	0.6%	1.0%	0.3%
Potamogeton richardsonii	Richardsons' Pondweed	29.4%	28.7%	18.4%	16.9%	23.2%
Potamogeton robbinsii	Robbins' pondweed				5.5%	0.6%
Potamogeton zosteriformes	flat-stem pondweed	1.9%	3.5%	0.6%	1.0%	1.3%
Ranunculus longirostris	white watercrowfoot	0.3%	1.0%	1.6%	1.0%	0.6%
Stuckenia pectinata	sago pondweed	1.9%	2.3%	1.9%	1.6%	2.3%
Trapa natans	**waterchestnut**	**1.0%**	**1.6%**	**0.6%**	**0.3%**	**0.6%**
Utricularia vulgaris	giant bladderwort	0.3%	0.3%	0.3%		0.3%
Vallisneria americana	wild celery	41.3%	41.9%	46.6%	47.4%	45.8%
Wolffia sp.	water meal				0.6%	0.6%
Zosterella dubia	water stargrass	28.7%	26.5%	33.7%	28.9%	30.3%

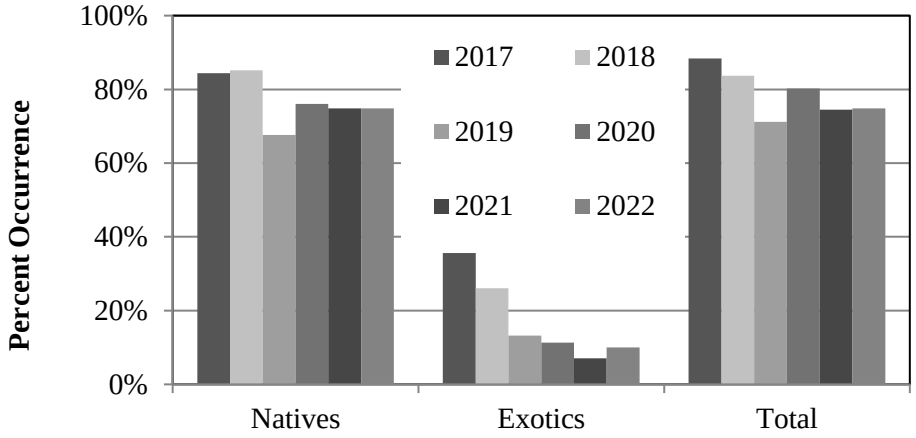
Figure 3. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) in surveyed areas of Saratoga Lake in 2022.



Eighty-nine percent of whole lake points were vegetated by native plant species in 2010, 80% in 2011, 79% in 2012, 72% in 2013, 79% in 2014, 70% in 2015, 71% in 2016 and 76% in both 2017 and 2018, 73% in 2019, 80% in 2020, 75% in 2021 and 2022 (Figure 4). In depths less than 6 m, representing the littoral zone, 84% of survey points contained native species and 92% of survey points less than 2 meters depth yielded native aquatic plants in 2022. Eurasian watermilfoil was present in 8% of whole lake survey points, and 11% of survey points within the littoral zone or zone of aquatic plant growth. Exotic species, dominated by Eurasian watermilfoil, were more abundant lake-wide in 2004, 2007 & 2008 (56%, 53% and 18% of survey points, respectively) than in 2009 (10% of survey points). With only 'spot' treatments conducted in 2010 and 2011, Eurasian watermilfoil recovery to 29% and 33% of survey points was reported. With a larger treatment area in 2012 and 2013, Eurasian watermilfoil declined to 26% and 23% of survey points, respectively. In 2014, Eurasian watermilfoil increased to 37% of survey points, declined to 27% of survey points in 2015 and remained at that level in 2016 thru

2018 at 26%, 29% and 20% of survey points, respectively. A steady decline in Eurasian watermilfoil frequency of occurrence occurred between 2018 and 2021, with 19%, 10% and 7% reported in 2019, 2020 and 2021, respectively. A 1% increase in Eurasian watermilfoil abundance occurred between 2021 and 2022.

Figure 4. Saratoga Lake frequency of occurrence summaries for all sampling points.



For survey points within the littoral zone, water depth less than 6 m (Figure 5), results are similar to whole lake surveys. The impact of the herbicide treatment for 2009 was less apparent on the relative abundance of exotic species when comparing treated (11% of survey points) and control sites (12%), most likely due to the fact 2009 is the final year of a 3 year program to treat the whole lake. Eurasian watermilfoil declined from 31% of littoral zone survey points within the treatment area in 2008 to 11% of comparable survey points post-treatment in 2009. In 2010, an

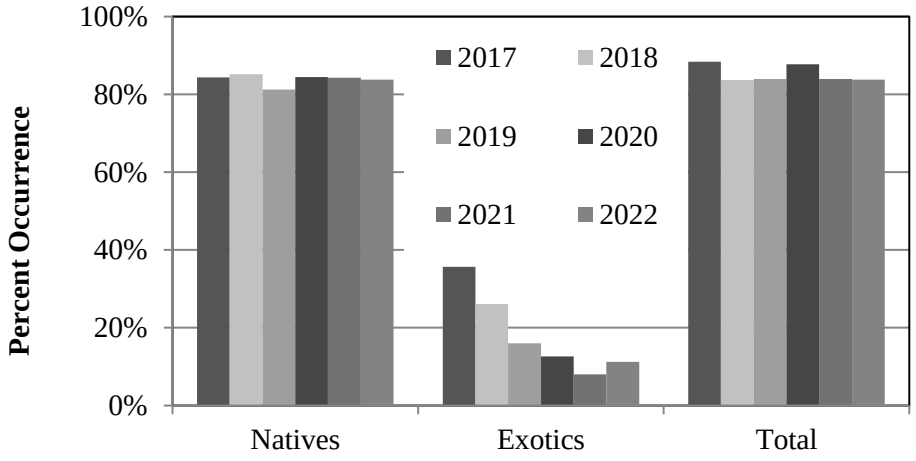


Figure 5. Saratoga Lake frequency of occurrence summaries for sampling points less than 6 meters water depth.

increase in the frequency of occurrence of Eurasian watermilfoil, to levels comparable to 2008, was observed. Eurasian watermilfoil declined from 40% of survey points in 2010 to 33% of survey points in 2011 as areas supporting the heaviest growth of Eurasian watermilfoil were treated. The decline continued in 2012 and 2013, with 31% and 26% of littoral survey points supporting Eurasian watermilfoil. In 2014, an increase to 40% of littoral zone survey points was observed, followed by a decline to 34% in 2015, 31% in 2016, 33% in 2017, 26% in 2018, 17% in 2019, 11% in 2020 and 8% in 2021. The expected relationship of greater frequency of occurrence of aquatic plants with shallower water depth is consistent with that reported by Eichler and Boylen (1995) where frequency of occurrence values in the littoral zone ranged from 78 to 90% of survey points.

In 2009, relative abundance of each species was incorporated into the survey effort. All species recorded for each sample point were ranked by relative abundance on a 4 point scale, ranging from present as a trace amount to entirely dominating the sample. Maps of relative abundance for each species are provided in Appendix A. Relative abundance provides a different picture of the abundance of Eurasian watermilfoil (Figure 6). Lake-wide Eurasian watermilfoil was present as dense growth in 2009, but declined to moderate levels in 2010 and continued with gradual declines in 2011 thru 2015. A slight increase was observed in 2016, perhaps due to the lack of an herbicide treatment. Results for 2017 thru 2022 remained very similar to 2016, however abundance appears to be increasing slightly over the long-term. While frequency of occurrence provides a statistically reliable measure of the aquatic plant population of a lake, combining frequency with relative abundance may provide a clearer picture of the impact of an individual species on the overall population.

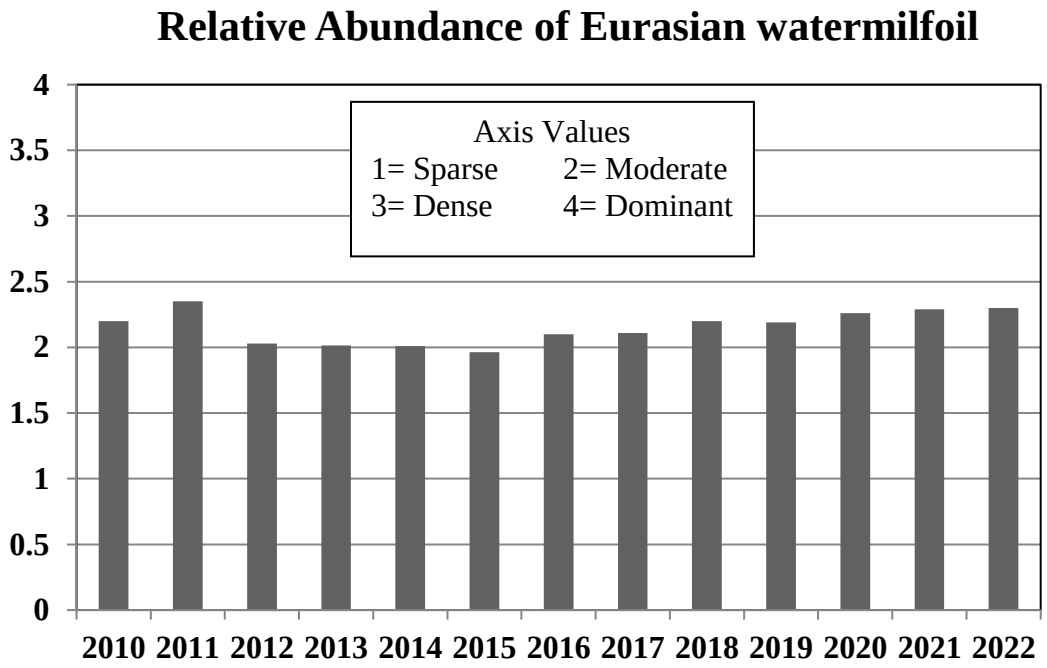


Figure 6. Lake-wide relative abundance of Eurasian watermilfoil in Saratoga Lake.

Species richness results for the point intercept survey are presented in Table 3 and Figure 7. In 2004 whole lake species richness was 2.00 ± 0.10 species per survey point. Whole lake species richness increased steadily from 2.31 ± 0.17 in 2007 to 3.47 ± 0.12 in 2010. In 2011, species richness lake-wide was comparable to 2009 at 2.81 ± 0.11 species per sample and slightly greater than the 2.65 ± 0.12 and 2.61 ± 0.13 reported in 2013. Species richness in 2014 once again stabilized at 2.89 ± 0.12 species per sample. Species richness declined in 2015 and 2016 to 2.46 ± 0.11 and 2.35 ± 0.11 species per sample, respectively, and recovered slightly in 2017 (2.48 ± 0.10) where it remained in 2018 (2.50 ± 0.11). Species richness in 2019 (2.38 ± 0.11), 2020 (2.27 ± 0.10), 2021 (2.17 ± 0.10) and 2022 (2.30 ± 0.11) remain similar to prior years and within the relative error of the mean. Depths less than 2 meters yielded 3.72 ± 0.21 and 3.69 ± 0.25 species per sample point in 2011 and 2012, increased to greater than 4 species per sample point in 2013 and 2014, but declined to 3.41 ± 0.23 and 3.28 ± 0.23 species per sample in 2015 and 2016, respectively. In comparison, littoral (<6m depth) species richness in 2007 was 2.74 ± 0.20, peaked at 3.31 ± 0.12 species per sample point in 2014 and declined back to 2.63 ± 0.11 species per sample point in 2016 and 2.76 ± 0.10 in 2017. Species richness in both the littoral and shallow depths remained in this range between 2017 and 2021. In 2011 littoral zone species richness was slightly lower at 3.11 ± 0.11 and this decline continued into 2012 (2.89 ± 0.12). A slight recovery occurred in 2013 (3.00 ± 0.14). Total species richness appears to be closely linked to the relative abundance of Eurasian watermilfoil.

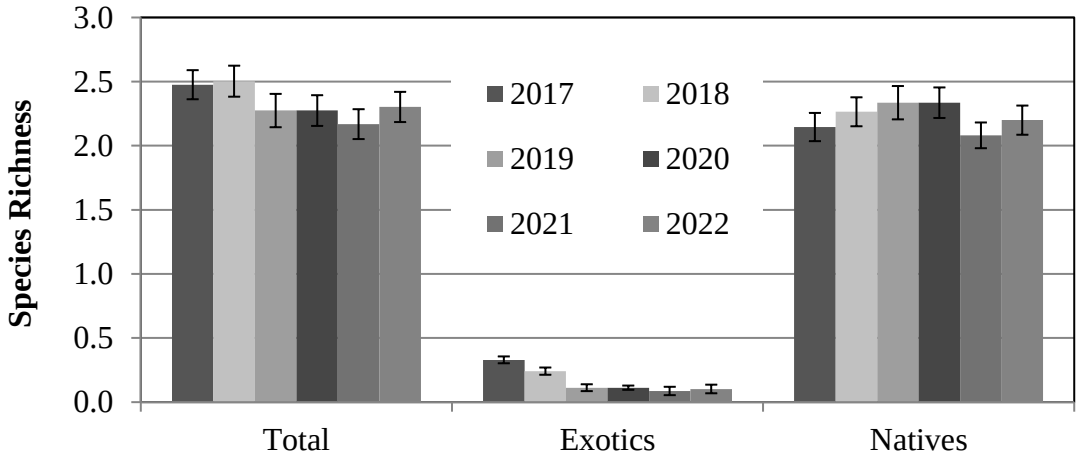
Table 3. Saratoga Lake species richness for the point intercept survey.

Plant Grouping	Water Depth Class	Statistic	2017	2018	2019	2020	2021	2022
Native plant species	Whole Lake (all depths)	Mean	2.14	2.25	2.22	2.34	2.08	2.20
		N	309	310	310	310	310	310
		Std. Error	0.10	0.10	0.11	0.10	0.10	0.10
	Points with depths <6m	Mean	2.39	2.22	2.46	2.59	2.32	2.47
		N	276	276	280	276	277	277
		Std. Error	0.10	0.11	0.11	0.10	0.10	0.10
	Points with depths <2m	Mean	2.30	3.30	3.53	3.33	3.23	3.10
		N	91	91	74	91	70	71
		Std. Error	0.15	0.20	0.23	0.18	0.23	0.19
All plant Species	Whole Lake (all depths)	Mean	2.48	2.50	2.38	2.27	2.17	2.30
		N	309	310	310	310	310	310
		Std. Error	0.10	0.11	0.11	0.10	0.10	0.11
	Points with depths <6m	Mean	2.76	2.79	2.63	2.61	2.42	2.58
		N	276	276	280	276	277	277
		Std. Error	0.10	0.11	0.11	0.11	0.11	0.11
	Points with depths <2m	Mean	3.34	3.48	3.66	3.29	3.41	3.25
		N	91	91	74	91	70	71
		Std. Error	0.16	0.20	0.23	0.18	0.25	0.20

Native species richness was 2.07 ± 0.18 species per survey point in 2007 for the entire littoral zone (depths less than 6 meters), exceeding the 2004 littoral, native species richness of 1.65 ± 0.09 species per survey point, but still less than the 2.66 ± 0.12 species per survey point in 2008

and 3.05 ± 0.12 species per survey point in 2009. Native species richness stabilized in 2010 and 2011 at 2.77± 0.13 and 2.78± 0.11 species per survey point, respectively. A slight decline in native species richness was observed in 2012 (2.57± 0.11) with recovery in 2013 (2.68± 0.13) and 2014 (2.83± 0.11). A decline to 2.47 ± 0.11 species per sample was reported in 2015 which continued in 2016 to a low of 2.29 ± 0.11 species per sample. A slight recovery was observed in 2017 (2.39 ± 0.10), but declined back to 2.22 ± 0.11 in 2018. Whole lake native species richness ranged from was 3.15 ± 0.11 species per sample in 2010 to 2.05 ± 0.10 species per sample in 2016. The increase in 2010 may have been a sampling artifact since the majority of sampling points outside the littoral zone were eliminated from the 2010 sampling. In the shallow portion of the littoral zone, depths less than 2 meters, species richness was 2.47 ± 0.18 native species per sample in 2004; and rose steadily to peak at 4.22 ± 0.24 native species per sample in 2009. A slight decline to 3.72 ± 0.24 native species per sample was observed in 2010 and continued in 2011 (3.57 ± 0.21) and 2012 (3.46 ± 0.23). Species richness in 2013 and 2014 was greater than prior years (4.02 ± 0.31 and 3.75 ± 0.22, respectively), but within the range of values for Saratoga Lake. Species richness in 2016 and 2017 declined to 3.08 ± 0.20 and 2.30 ± 0.15 species per sample but recovered to previous levels in 2018 (3.30 ± 0.20), 2019 (3.53 ± 0.23), 2020 (3.33 ± 0.18), 2021 (3.23 ± 0.23) and 2022 (3.10 ± 0.19). As expected, species richness in the littoral zone and its shallow fringe was higher than whole lake species richness. Lack of a

Figure 7. Saratoga Lake species richness.
Error bars are standard error of the mean.



Eurasian watermilfoil canopy in water depths less than 2 meters may also allow for greater species richness. The negative impact of a canopy of Eurasian watermilfoil on species richness of native plants has been well documented (Madsen et al. 1989; 1991). Conversely, species richness increases in areas where Eurasian watermilfoil growth is reduced (Boylen et al. 1996). Species richness in the control area exceeded that in the treated area, but generally by less than 1 species per survey point. The elimination of Eurasian watermilfoil from many of the survey points in the treated area accounts for the majority of the difference. A sharp decline in exotic species richness was observed following herbicide treatments in 2007, 2008 and 2009 while total

and native species richness increased. A slight increase in the lake-wide abundance of exotic species in 2010 and 2014-2015 occurred in conjunction with a slight increase followed by a decrease in total and native species richness. While native species richness varied over the past 6 survey years, results have remained within relative error between years, with the exception of 2014.

Summary

Quantitative aquatic plant surveys were undertaken in 2022 for Saratoga Lake, New York as part of a cooperative effort between Solitude LLC, the author, and the Saratoga Lake Protection and Improvement District (SLPID). The project was designed to obtain data to evaluate aquatic plant management efforts and review potential new strategies.

In Saratoga Lake, Eurasian watermilfoil (*Myriophyllum spicatum*) expanded rapidly after an initial invasion in the 1970's. *Myriophyllum spicatum* populations were first confirmed in the mid-1970's and reported to be the dominant aquatic plant species in the lake by the early-1980's (Hardt et al. 1983). In 1994, the Saratoga Lake aquatic plant community contained 23 submersed species, 3 native rooted floating-leaf species, 2 native emergent species and 1 free floating species (Eichler and Boylen 1995). *Myriophyllum spicatum* was the most common plant species, present in 68% of survey points. Two other exotic aquatic plant species were reported, *Potamogeton crispus* and *Trapa natans*. *Potamogeton crispus* is seasonally abundant, forming a dense band at the deep margins of Eurasian watermilfoil growth in the spring and early summer. *Trapa natans* has been reported as scattered individuals on the delta of Kayadeross Creek and in Mannings Cove. Waterchestnut was absent from the 2008 and 2009 surveys, but returned and expanded its coverage in 2011 and 2012. A number of *Trapa natans* plants have also been observed in the area of the Fish Creek boat launch ramp annually since 2010. Herbicide treatments were incorporated into the aquatic plant management program in 2007 to supplement previously employed lake level drawdown and mechanical harvesting. A three year herbicide treatment effort was initiated with fluridone (Sonar) treatment of the southern margin of the lake in the area of Browns Beach in 2007. Triclopyr (Renovate) herbicide was applied in 2008 and 2009 on the eastern and western margins of the lake, respectively. In 2010, three small area treatments with triclopyr were conducted, two at the south end of the lake and one around the sunken islands in the mouth of Mannings Cove. In 2011, three areas were treated with triclopyr. Two of the sites were bays adjacent to Snake Hill, one to the north encompassing about 10 acres and the other to the south including about 35 acres were treated. The remaining site centered on the shoal area off Franklins Beach, encompassing about 55 acres. In 2012, triclopyr was applied to a 100 acre area at the southeast corner of the lake, and imazimox was applied to a 50 acre sub-area. In 2013, triclopyr was applied to 172 acres at the north end of the lake, with the majority in the Franklins Beach area and two smaller areas, one at the northern margin of the Kayadeross Creek delta and the other along the northeast shoreline. In 2014, 42 acres in Rileys Cove and at the south end of the lake were treated with a combination of endothall and triclopyr. In addition, an area of 5 acres was treated near the mouth of the Kayadeross Creek with imazimox to control waterchestnut. In 2015, fluridone (Sonar) was applied to an area from Snake Hill south to Browns Beach. There were no herbicide applications in 2016, however annual mechanical harvesting and lake level drawdown continued as in past seasons. In 2017, a total of 67 acres at the south end of the lake were treated with Aquathol K and 28 acres were treated with Navigate (2,4-D). In 2018, the northern margin of the delta of Kayadeross Creek was treated with Aquathol K (3.9 acres) and Navigate (2,4-D; 7.5 acres). Additionally, in the Franklins' Beach area, 43.1 acres were treated with Renovate OTF. In 2019, the southern margin of the

Kayadeross Creek delta was treated with imazimox for waterchestnut control. The 2020 effort was based on lake drawdown, mechanical harvesting and application of the herbicides Procella COR (Renovate) and endothall (Aquathol K). Procella COR was applied to 54 acres for Eurasian watermilfoil control in the Franklins Beach area while endothall was employed for management of 147 acres at the southern margin of the lake extending to Browns Beach. In 2021, Procella COR was applied to an area on the east side of the lake north of Snake Hill, complementing annual lake level drawdown, hand and mechanical harvesting. Lake level drawdown, hand and mechanical harvesting were the basis of the 2022 management program.

In August of 2022, the aquatic plant community of Saratoga Lake included 25 submersed species, 4 floating-leaved species, 3 floating species and 3 emergent species for a total of 35 species. Twenty-nine of these species were found in the point intercept survey. These results are comparable to previous surveys in 2012, 2018 and 2020 (28 species), 2015 and 2019 (27 species), 2009, 2016, 2017 and 2021 (26 species), 2007 and 2008 (25 species), 2004 (21 species), 1994 (22 species), 1982 (21 species) and 1969 (20 species).

Exotic species, dominated by Eurasian watermilfoil, were more abundant lake-wide in 2004 (56% of survey points), prior to the herbicide treatments of 2007 through 2009 (53%, 18% and 10% of survey points, respectively). A slight increase in exotic species abundance (22% and 29% of survey points) was observed in 2010 and 2011, which stabilized in 2012 (26% of survey points) and 2013 (23% of survey points). An increase in frequency of occurrence was observed in 2014 (37% of survey points) while relative abundance declined slightly. In 2015, Eurasian watermilfoil frequency of occurrence declined to 27% of survey points with similar levels reported in 2016 (26% of survey points), 2017 (29% of survey points), and 2018 (20% of survey points). Invasive species frequency of occurrence declined to 13% of survey points in 2019, 10% of survey points in 2020 and 7% of survey points in 2021. A slight increase (8% of survey points) was observed in 2022. Eurasian watermilfoil remains a common member of the plant community, but at greatly reduced numbers when compared to previous surveys. Eurasian watermilfoil declined from first to tenth most abundant species by frequency of occurrence between 2007 and 2009, however an increase was reported to seventh in 2010, fifth most abundant species in 2011 thru 2013, third most abundant species in 2014, fourth in 2015, fifth in 2016, fourth in 2017, sixth in 2018 and 2019, seventh in 2020, eighth in 2021 and ninth in 2022.

As in prior surveys, native species continued to be dominant in 2022. Common native species included *Vallisneria americana* (46% of survey points), *Ceratophyllum demersum* (46%), *Zosterella dubia* (30%), *Najas guadalupensis* (27%), *Potamogeton richardsonii* (23%), *Elodea canadensis* (11%), *Chara* sp. (9%), *Potamogeton illinoensis* (8%), and *Najas flexilis* (5%). These results resemble 2021 when native species included *Vallisneria americana* (47%), *Ceratophyllum demersum* (47%), *Zosterella dubia* (30%), *Najas guadalupensis* (19%), *Potamogeton richardsonii* (17%), *Elodea canadensis* (11%), *Chara* sp. (9%), and *Najas flexilis* (6%).

Estimates of relative abundance for each species surveyed were incorporated into the sampling protocol in 2009. A four point scale, ranging from one which indicated a trace amount of a

particular species to four indicating clear dominance of the species in a particular sample was employed. On a lake-wide basis, dense growth of Eurasian watermilfoil was reported for 2009, declining to moderate levels in 2010 and remaining at or below moderate levels in 2011 thru 2022. While frequency of occurrence results provide a statistically reliable way to represent plant populations, combining relative abundance with frequency of occurrence may provide a better way to characterize the impact of an invasive species on native plant populations.

In 2004, whole lake species richness was 2.00 ± 0.10 species per survey point. Whole lake species richness increased steadily through 2010, reaching to 3.47 ± 0.12. The increase in 2010 may have been a sampling artifact since the majority of sampling points outside the littoral zone were eliminated from the 2010 sampling. In 2011, whole lake species richness was 2.81 ± 0.11 species per survey point, a decline associated with an increase in the relative abundance of invasive species. Species richness in 2014 once again stabilized at 2.89 ± 0.12 species per sample. Species richness declined in 2015 and 2016 to 2.46 ± 0.11 and 2.35 ± 0.11 species per sample, respectively, and recovered slightly in 2017 (2.48 ± 0.10) where it remained in 2018. Slight declines were observed in 2019 thru 2021 (2.30 ± 0.11). In the shallow portion of the littoral zone, depths less than 2 meters, species richness was 2.47 ± 0.18 native species per sample in 2004; and rose steadily to peak at 4.22 ± 0.24 native species per sample in 2009. A slight decline to 3.57 ± 0.21 and 3.46 ± 0.23 native species per sample was observed in 2011 and 2012, however 2013 results were once again above 4 species per survey point (4.02 ± 0.31). Species richness in 2015 (3.23 ± 0.22 native species per sample) was at the low end of the range of values observed in prior surveys, a trend which continued into 2016 and 2017, rebounded in 2018 through 2020 and stabilized in 2021 and 2022. As expected, species richness in the littoral zone and its shallow fringe was higher than whole lake species richness. Lack of a Eurasian watermilfoil canopy in water depths less than 2 meters may also allow for greater species richness. Native species richness lake-wide and in the treatment zone was higher post-treatment in 2007, 2008 and 2009 than during 2004 (pre-treatment). A slight increase in the lake-wide abundance of exotic species in 2010 and 2011 occurred in conjunction with a slight decline in total and native species richness. In 2012 thru 2022, total species richness was nearly unchanged from 2011 levels.

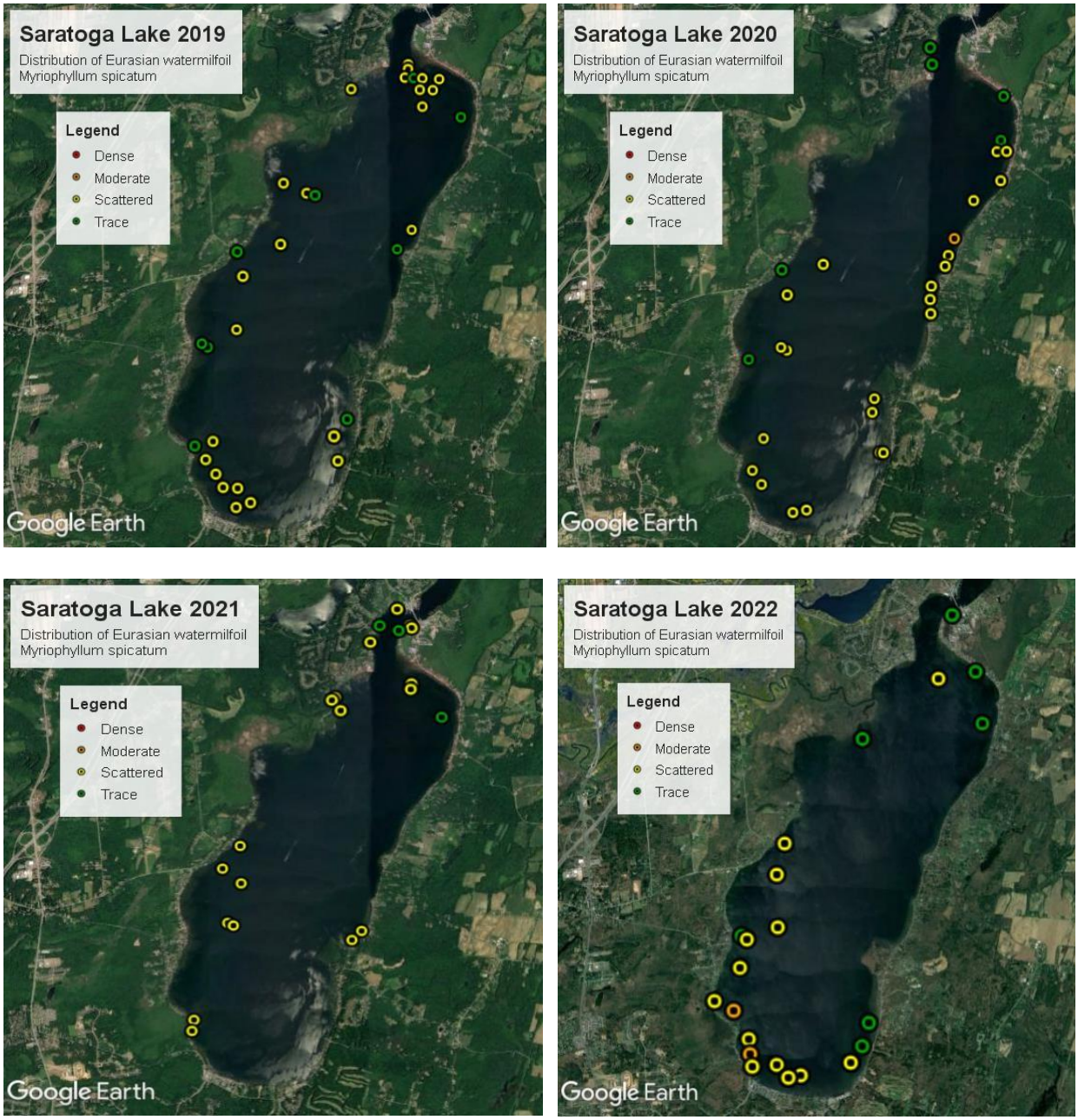
Principal areas of Eurasian watermilfoil expansion in 2004 were reported in the northeast at Franklins Beach and the southwest in the area of Rileys Cove. Franklins Beach was selected as the control (untreated) area for 2007 while the south end of the lake and Browns Beach area were treated with herbicide. In 2008, the Franklins Beach area was selected for treatment, the west shore including Mannings Cove served as the control, and Browns Beach west across the south end of the lake was assessed 1 year post-treatment. In 2009, the west shore and Mannings Cove areas were treated, the Franklins Beach area was assessed 1 year post-treatment and Browns Beach west across the south end of the lake was assessed 2 years post-treatment. In 2010, spot treatments were conducted at the southern end of the lake and north of the mouth of the Kayadeross Creek. In 2011, spot treatments were conducted to the north and south of Snake Hill and adjacent to Franklins Beach. Substantial reduction in Eurasian watermilfoil frequency of occurrence was observed in the treated area between 2008 (pre-treatment) and 2009 (post-treatment) while the previously treated control areas increased from 2% to 5%. Eurasian

watermilfoil declined from 26% of littoral zone survey points within the treatment area in 2008 to 9% of comparable survey points post-treatment in 2009. Eurasian watermilfoil increased in frequency of occurrence lake-wide in 2010 (22% of survey points), with principal areas of growth in Mannings Cove and the shoal area offshore from Franklins Beach. In 2011, Eurasian watermilfoil continued to increase in lake-wide occurrence (29% of survey points), with persistent growth in the mouth of Mannings Cove and the Franklins Beach area. Eurasian watermilfoil growth was also observed at the deep margin of the littoral zone along the western shoreline and south end of the lake. In 2012 and 2013, larger areas were treated and Eurasian watermilfoil declined to 26% and 23% of survey points. In 2014, Eurasian watermilfoil was treated at the south end of the lake and while frequency of occurrence remained high, relative abundance was reported as primarily scattered plants. Lake-wide relative abundance of Eurasian watermilfoil declined in 2015 and 2016 (Figure 8), however Eurasian watermilfoil remained as persistent growth in the mouth of Mannings Cove, and along the shoal area off Franklins Beach. A slight increase in abundance of Eurasian watermilfoil was observed in 2017, with dense growth areas similar to 2016. In 2018, the herbicide treatment in the Franklins Beach area greatly reduced the Eurasian watermilfoil growth, from 41% of survey points in 2017 to 19% of survey points in 2018. In 2019, Eurasian watermilfoil continued to decline with scattered growth present lakewide. The decline continued into 2020 and 2021 with Eurasian watermilfoil present primarily along the eastern shore in 2020 and sparsely scattered in the outlet area and west shore in 2021. A slight increase in frequency of occurrence, primarily at the south end of the lake, was reported in 2022.

Lake-wide aquatic plants were found to occur in 84% of survey points in the littoral zone, comparable to prior surveys (range of 84 to 91%), and not indicative of any major change in the aquatic plant population. Eurasian watermilfoil abundance declined from 66% of littoral zone survey points in 2004 to 59% of survey points in 2007, 21% in 2008 and 8% in 2009. With selective treatments in 2010, Eurasian watermilfoil increased to 22% of whole lake survey points, and 29% of survey points less than 6 m water depth, representing the littoral zone or zone of aquatic plant growth. Following additional small area treatments in 2011, Eurasian watermilfoil abundance increased to 29% of lake-wide survey points. The distribution of exotic species, dominated by Eurasian watermilfoil, in the previously treated areas (29% of survey points) was less than the treated area (40%). A larger treatment area (100 acres) in 2012 produced a decline in Eurasian watermilfoil to 26% of survey points lake-wide, and 7% of survey points within the treatment area. In 2013, a total of 172 acres were treated and Eurasian watermilfoil declined to 23% of survey points lake-wide, and 9% of survey points within the treatment area. In 2014, a total of 42 acres were treated and Eurasian watermilfoil increased to 37% of survey points lake-wide, and 53% of survey points within the treatment area. In 2015, Eurasian watermilfoil decreased to 27% of survey points lake-wide, and 10% of survey points within the treatment area. Herbicide treatments were suspended in 2016, and Eurasian watermilfoil abundance remained static at 26% of survey points. In 2017, 95 acres at the south end of the lake were treated, however Eurasian watermilfoil frequency increased slightly to 29% of survey points. Eurasian watermilfoil abundance in 2018 (20% of survey points) was lower than the three prior years, a trend that continued into 2019 (13% of survey points), 2020 (10% of survey points) and 2021 (7% of survey points). A slight increase to 8% of survey points was

observed in 2022. The fact that Eurasian watermilfoil only slowly recovers after treatment suggests the durability of treatment regimes from 2007 thru 2022. The difficulty of treating certain areas, particularly small isolated plots such as the sunken islands in the mouth of Mannings Cove, is demonstrated by the resilience of Eurasian watermilfoil at these sites even after repeated treatments.

Figure 8. A comparison of the distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) growth in selected areas of Saratoga Lake in 2019 through 2022.



Eurasian watermilfoil abundance declined from 58% of littoral zone survey points within the treatment area in 2004 to 25% of comparable survey points post-treatment in 2007. In 2008, Eurasian watermilfoil abundance continued to decline to 3% of littoral zone survey points within the treatment area. In the control area, Eurasian watermilfoil abundance increased from 74% of survey points in 2004 to 80% of comparable survey points in 2007. In 2008, Eurasian watermilfoil abundance declined to 26% of survey points in untreated areas. In 2009, the decline in Eurasian watermilfoil abundance continued, with lake-wide frequency of occurrence at 7% of survey points. This decline coupled with what appeared to be sub-lethal effects of the herbicide in the untreated areas, suggest efficacy of the herbicide over a much greater area than anticipated. An increase in Eurasian watermilfoil abundance was observed in 2010 and again in 2011, primarily in areas not treated for 2 years and certain problem sites. Even with the increase, Eurasian watermilfoil abundance in 2011 thru 2017 remains at less than half of pre-treatment levels. Lake-wide relative abundance values for Eurasian watermilfoil also declined from dense to moderate levels between 2009 and 2010, and remained at moderate to low levels through 2022. While frequency of occurrence provides a statistically reliable measure of the aquatic plant population of a lake, combining frequency with relative abundance may provide a clearer picture of the impact of an individual species on the overall population.

The littoral zone or maximum depth of colonization (MDOC) by aquatic plants was calculated to extend to a depth of 4.9 meters based on transparency data. *Ceratophyllum demersum* and *Najas guadalupensis*, however were commonly found between 5 and 6 meters depth, with occasional *Myriophyllum spicatum* specimens also encountered, suggesting a littoral zone maximum depth of approximately 6 meters, 1.0 meter greater than reported in 1994. Suppression of canopy formation through mechanical harvesting may allow for light penetration and thus the survival of native plant species in areas of dense Eurasian watermilfoil growth. Changing water clarity may also be a by-product of the invasion of Saratoga Lake by zebra mussels (*Dreissena polymorpha*) in the mid-1990's. Improved water clarity is frequently reported following zebra mussel invasions due to their ability to filter large volumes of phytoplankton from the water column. Reduced Eurasian watermilfoil density in shallow waters as a result of winter draw-down and ice scouring has also provided areas for colonization of native species resistant to winter draw-down. Evidence continues to suggest that a native species, Water Stargrass (*Zosterella dubia*) is replacing Eurasian watermilfoil at the shallow end of its range. The frequency of occurrence of *Zosterella dubia* has increased substantially, reported in 19% of samples in 1994, 47% of samples in 2004 and 44% of samples in 2007 in the control area. In 2008 through 2021, while still quite abundant, the frequency of occurrence of this species has stabilized between 25% and 34% of survey points. The operators of the mechanical harvesters continue to report that *Zosterella dubia* has become a prevalent species in their harvested materials. Survey results indicate that this species is found growing densely in waters of 1 to 1.5 meters depth at the inner margins of dense Eurasian watermilfoil growth. Richardsons Pondweed (*Potamogeton richardsonii*) has been present in Saratoga Lake for many years, but always as a minor component of the aquatic plant population. This native pondweed species dramatically expanded its frequency of occurrence from less than 1% of survey points in 2011 to 22% of survey points in 2012 and 34% in 2014. Richardsons' Pondweed then stabilized at approximately 30% of survey points through 2019, but has declined in the past 2 years to approximately 20% of survey

points. A similar rapid growth of Richardsons Pondweed was observed in other regional lakes, including Hadlock Pond in Washington County and Loon Lake in Warren County. The extremely mild winters of 2011 – 2013 may be responsible for the expansion of this species.

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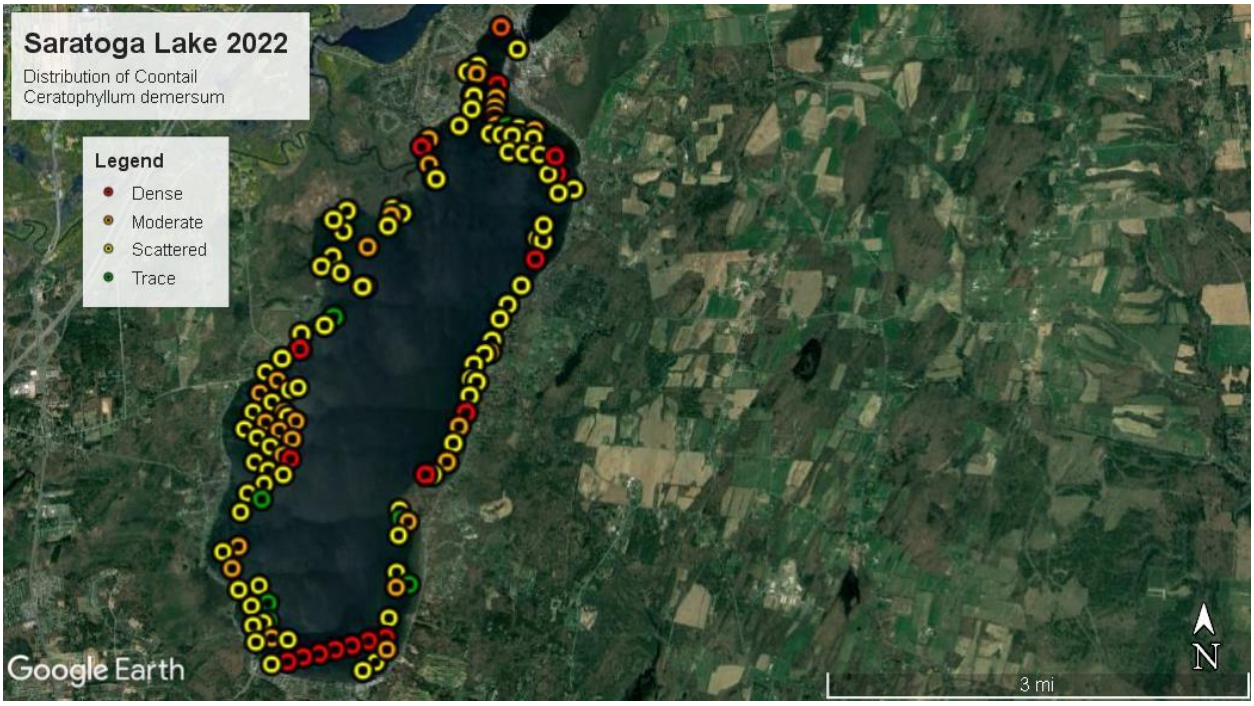
Appendix A. Saratoga Lake aquatic plant distribution maps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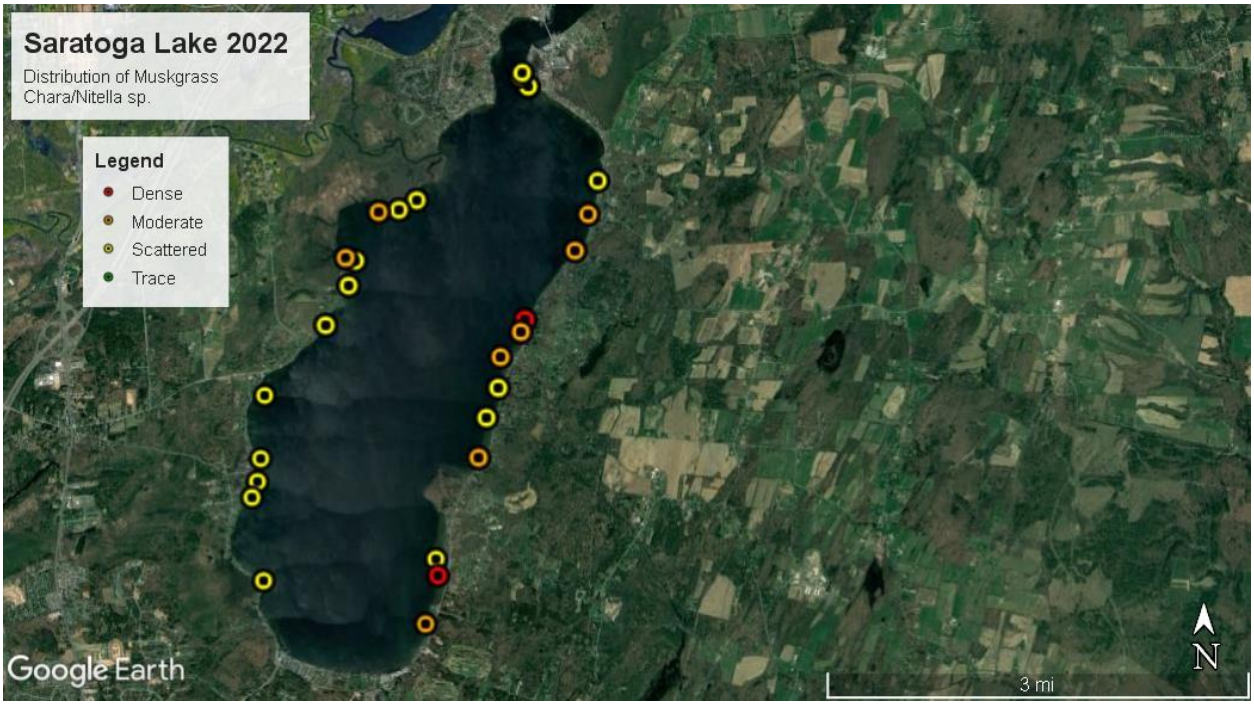
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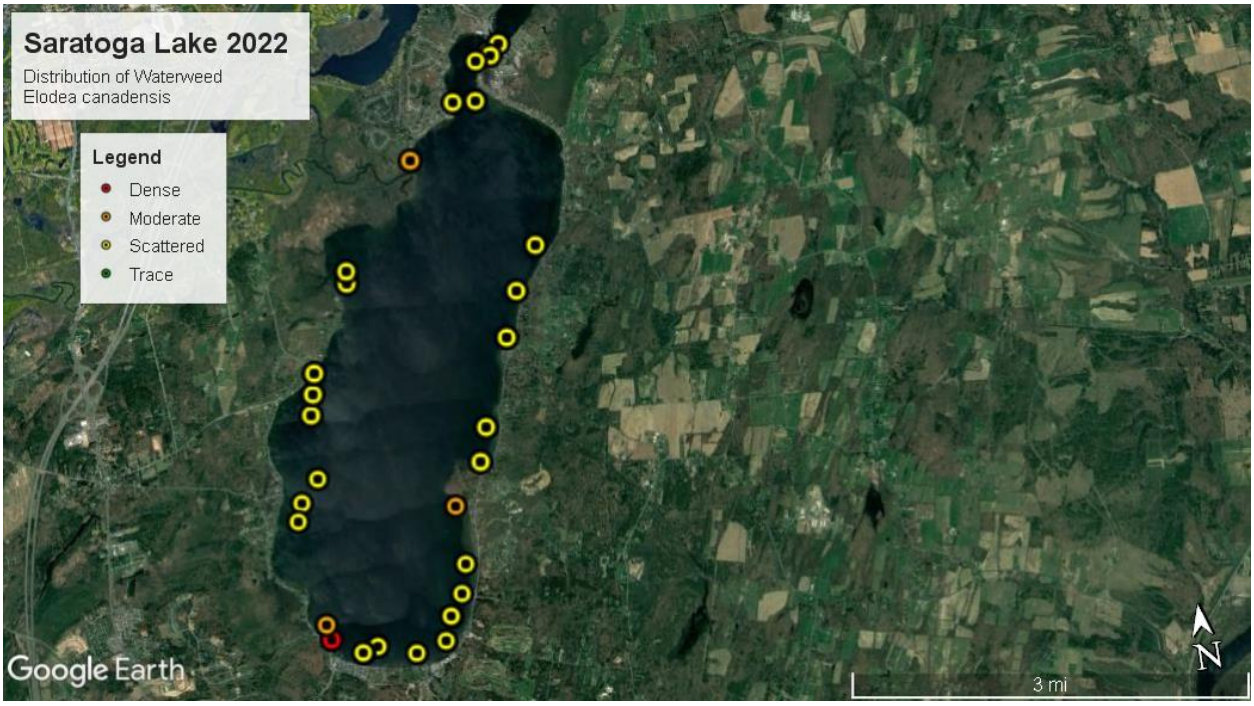
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Distribution of Moss
Fontinalis sp.
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Saratoga Lake 2022
Distribution of European Frogbit
Hydrocharis morsus-ranae
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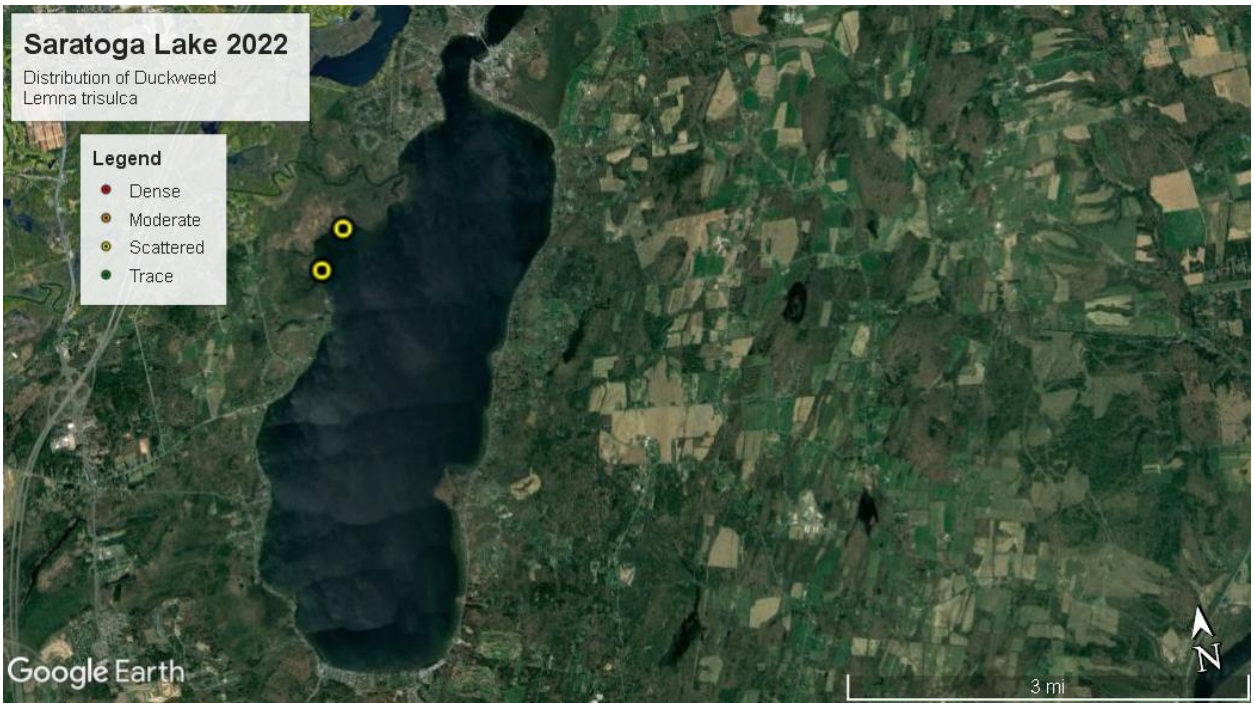
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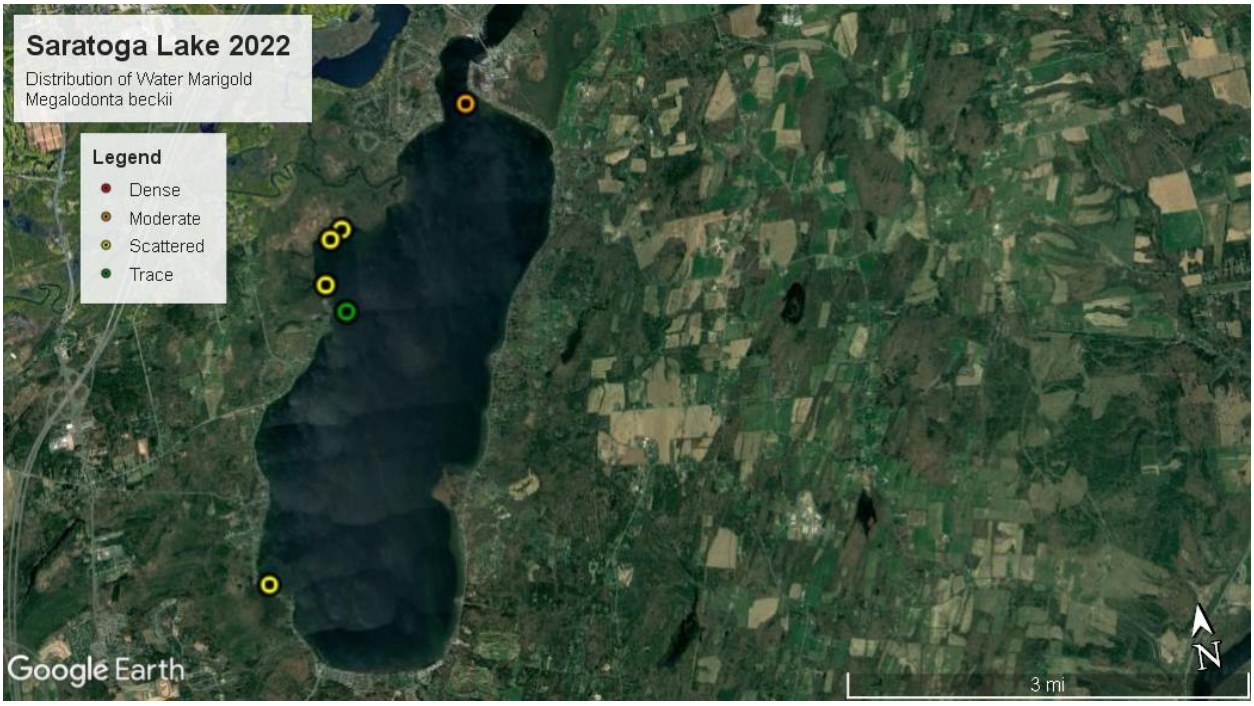
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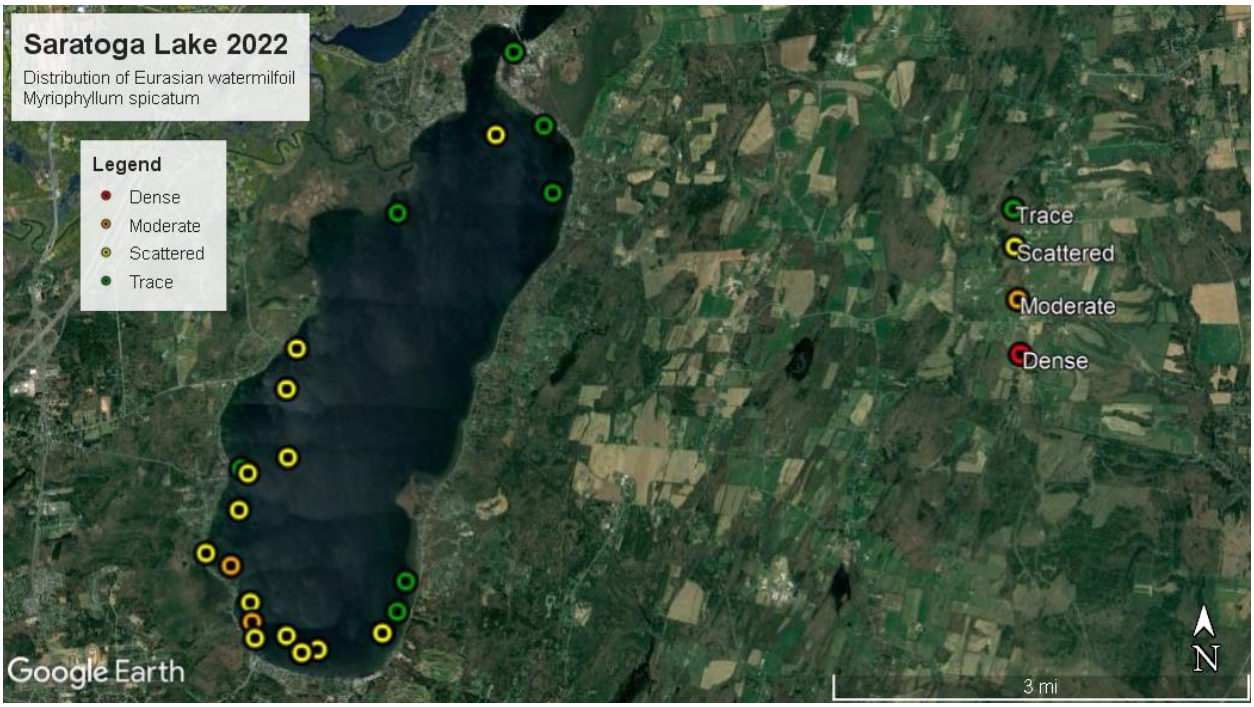
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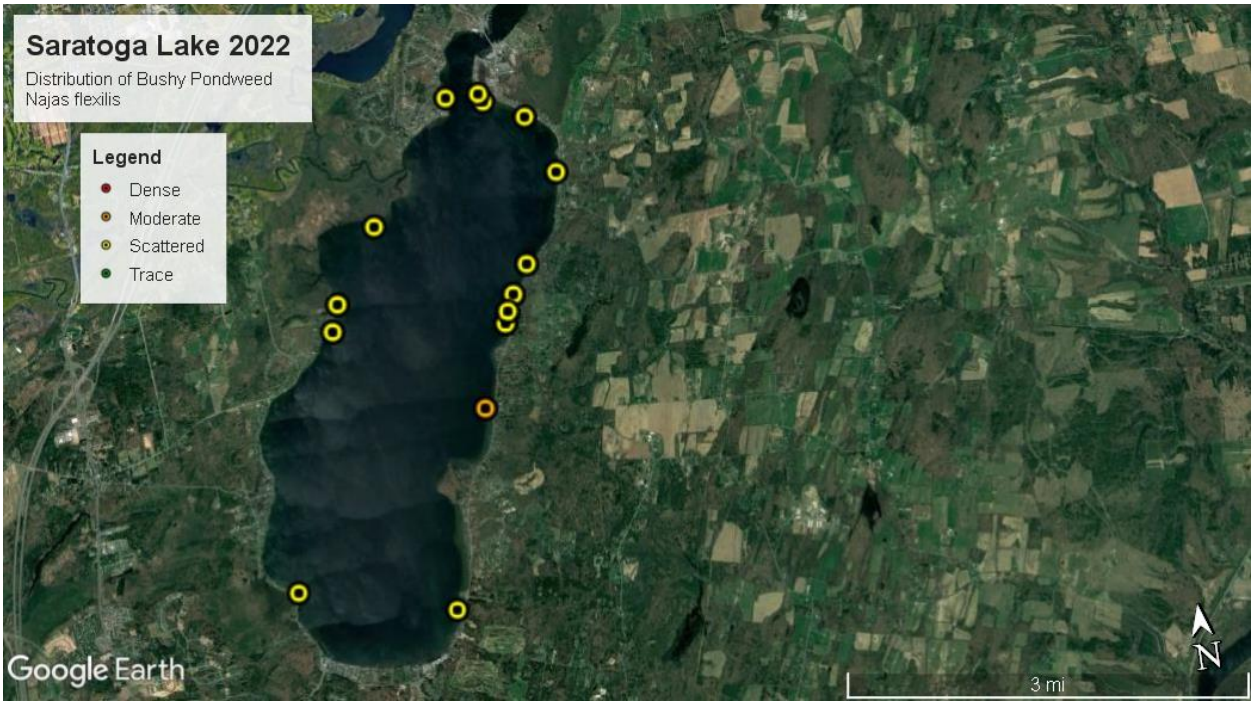
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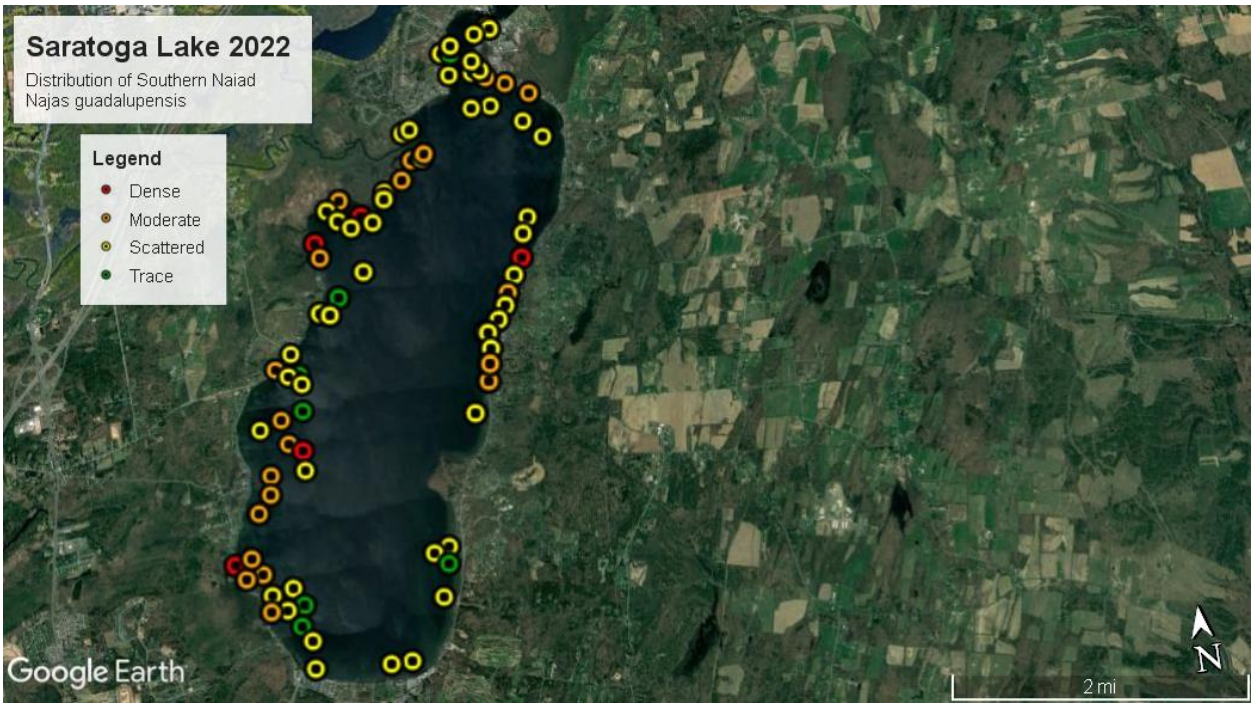
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Distribution of White Waterlily
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Distribution of Broad-leaf Pondweed
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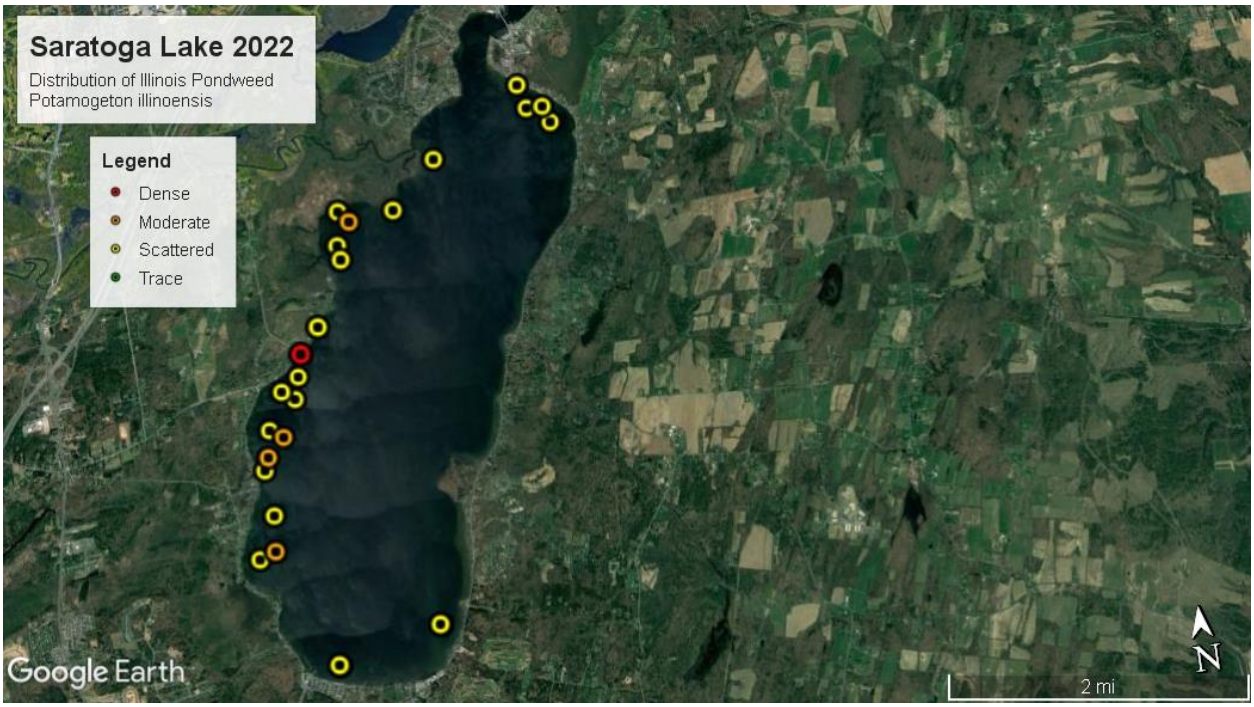
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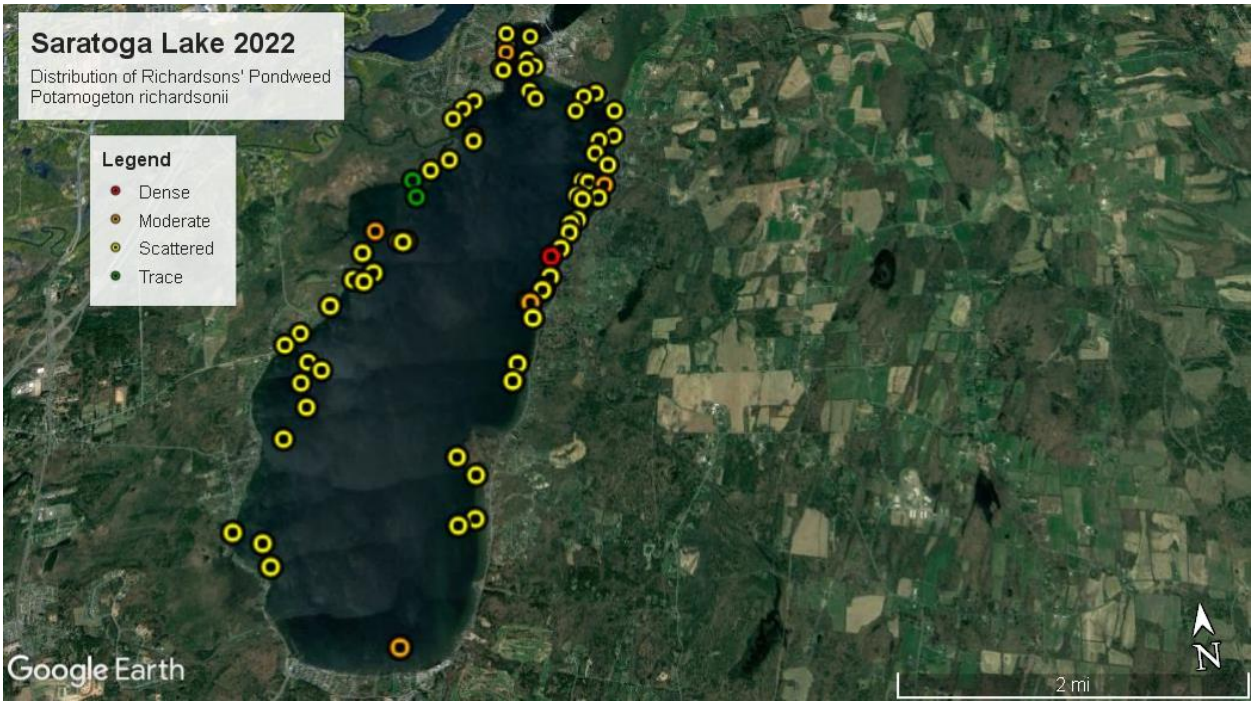
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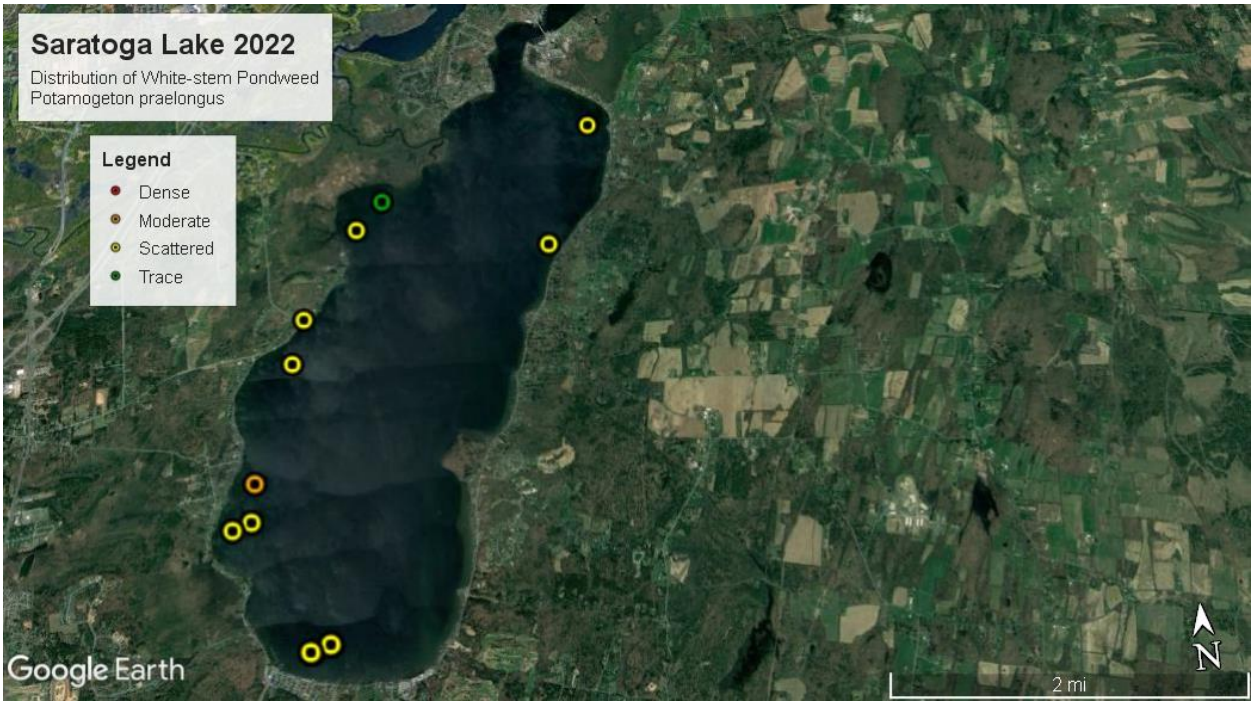
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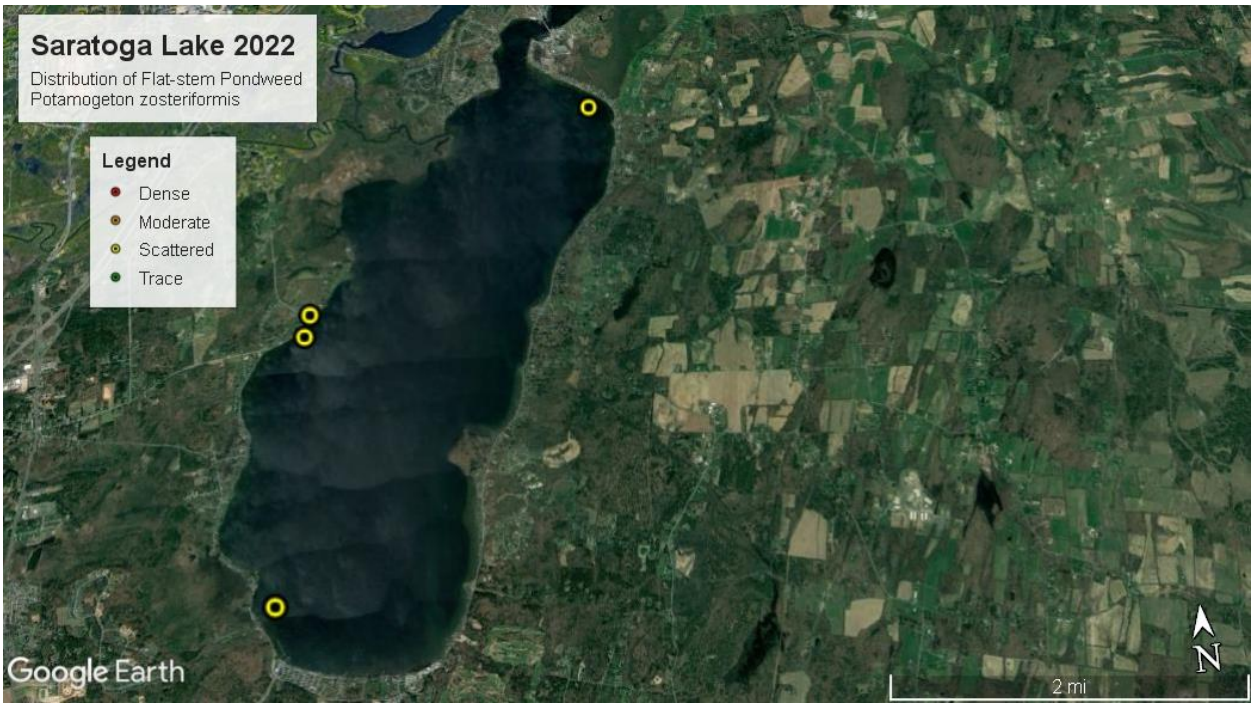
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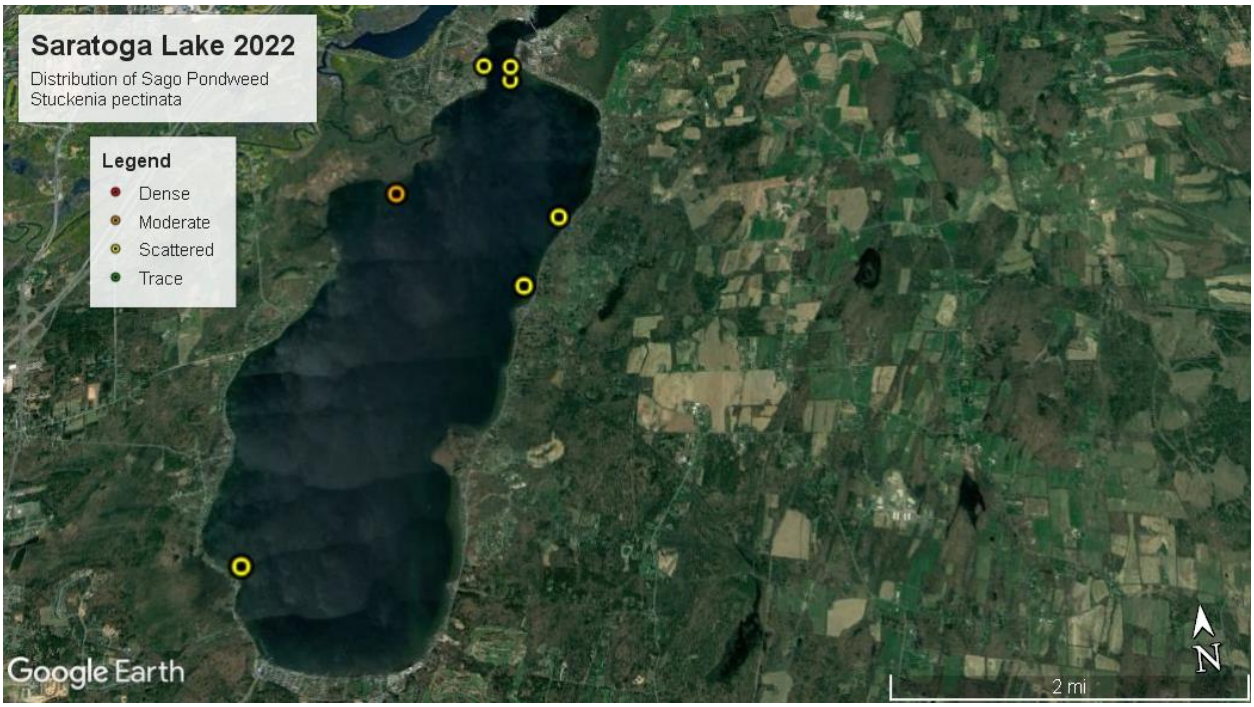
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Distribution of Giant Bladderwort
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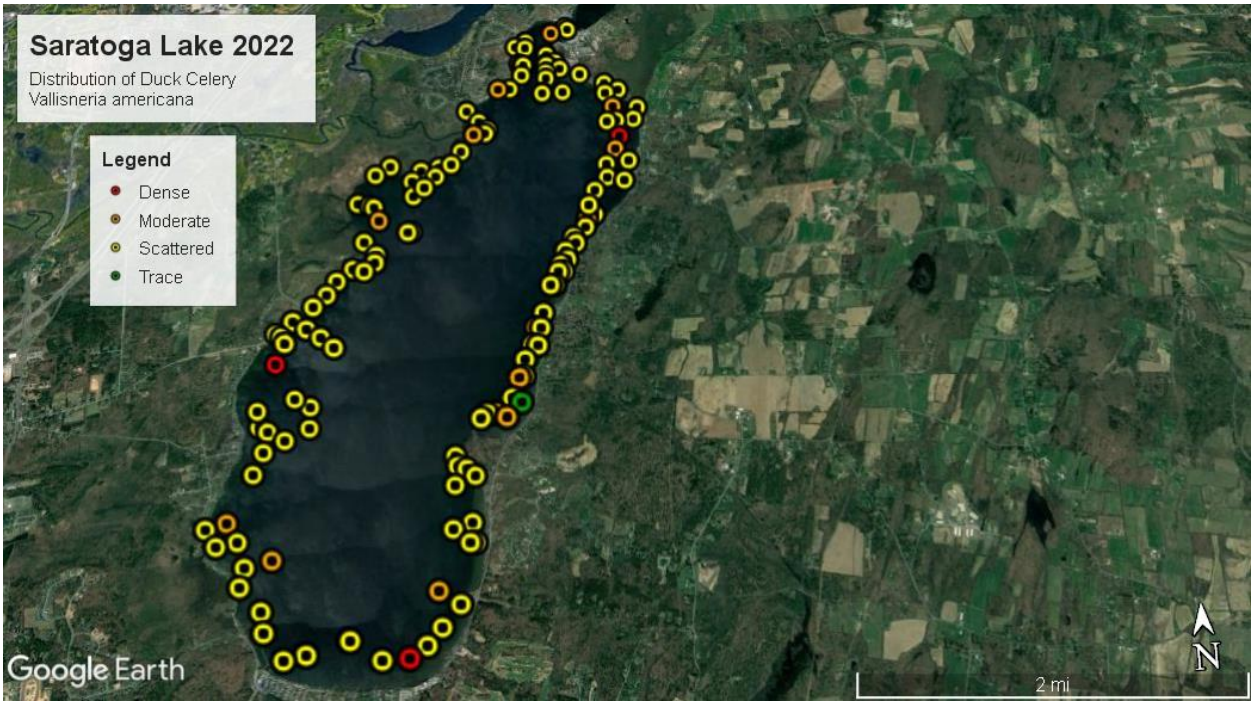
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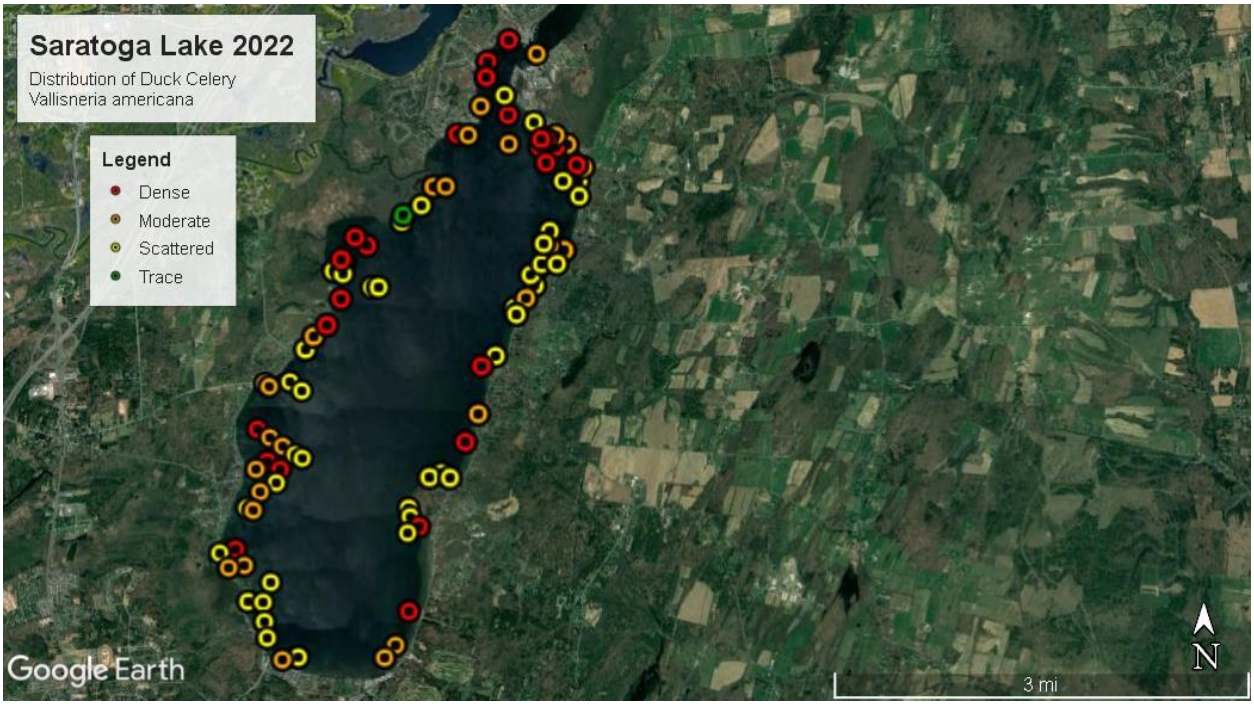
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