SARATOGA LAKE
AQUATIC VEGETATION MANAGEMENT PROGRAM
2013 ANNUAL HERBICIDE TREATMENT REPORT

November 2013

Prepared for:
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INTRODUCTION

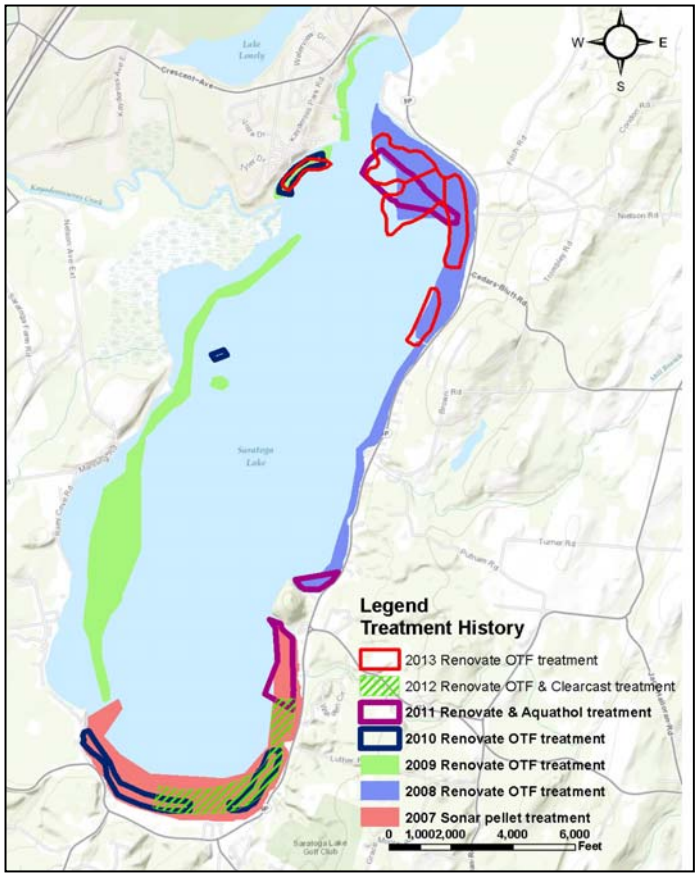
An integrated aquatic plant management program was performed at Saratoga Lake for the seventh consecutive year in 2013. The current program includes the use of aquatic herbicides to control invasive Eurasian watermilfoil (*Myriophyllum spicatum*) and curlyleaf pondweed (*Potamogeton crispus*), the use of mechanical harvesting equipment owned and operated by the Saratoga Lake Protection and Improvement District (SLPID) to manage nuisance plant growth along developed shoreline areas, and limited winter drawdown. This integrated management approach (IMP) approach was developed after nearly a decade of investigations and studies and is detailed in the following documents: Watershed Management Plan prepared by The LA Group in 2002, the Long-Term Aquatic Vegetation Management Plan prepared by Aquatic Control Technology in 2005, and the EIS prepared by The LA Group in 2007. The balance of this report details the herbicide treatment program that was performed at Saratoga Lake during the 2013 season.

SUMMARY OF RECENT HERBICIDE TREATMENTS

Herbicide treatments were initially considered to control the dense beds of Eurasian watermilfoil that were documented to cover between 700 and 800 acres by the Darrin Fresh Water Institute (DFWI) in 2004. The considerable Eurasian watermilfoil biomass was overwhelming SLPID's harvesting program and was severely impacting recreational use of the lake. A phased herbicide treatment program was initiated in 2007 to target all of the dense beds of Eurasian watermilfoil over a three-year period. It was then hoped that drawdown and harvesting could be used to keep nuisance plant growth at manageable levels, and herbicides would be used as a complimentary maintenance strategy to control invasive species.

Since 2007, the following herbicide treatments have been performed at Saratoga Lake:

Year	*acres treated*	*location*	*herbicide applied*
2007	158	south end	Sonar PR & Q (fluridone pellets)
2008	292	northeast and east shore	Renovate OTF (triclopyr granular)
2009	285	northwest and west shore	Renovate OTF
2010	50	various locations	Renovate OTF
2011	100	northeast & southeast shore	Renovate 3 (triclopyr liquid) & Aquathol K (endothall liquid)
2012	100	southeast shore	Renovate OTF & Clearcast 2.7G (imazamox granular)
2013	172	northeast & northwest shore	Renovate OTF



The three-year treatment program performed during the 2007, 2008 and 2009 seasons was very effective at reducing the distribution and biomass of Eurasian watermilfoil lake-wide. Spot-treatment of recovering Eurasian watermilfoil was performed in 2010. Maintenance level treatments were continued in 2011, 2012 and 2013 and were expanded to also target curlyleaf pondweed in 2011 and 2012.

HERBICIDE TREATMENT PROGRAM - 2013

Herbicide treatment efforts were focused on the northeast and northwest shorelines in 2013. Despite reduced densities from what was documented in 2008 and 2009 in these areas, milfoil growth was widespread and abundant from 4-10 feet in depth.

Contact Exposure Time (CET) has been difficult to maintain in small treatment areas is past years, so larger treatment blocks were intentionally selected to increase the potential for success. Granular triclopyr (Renovate OTF) was again used for treatment. Granular herbicide formulations were selected to limit mixing and dilution caused by wind and wave action and to help improve CET. Renovate OTF was used successfully at Saratoga Lake in previous years and provided selective and effective milfoil control.

Program Chronology

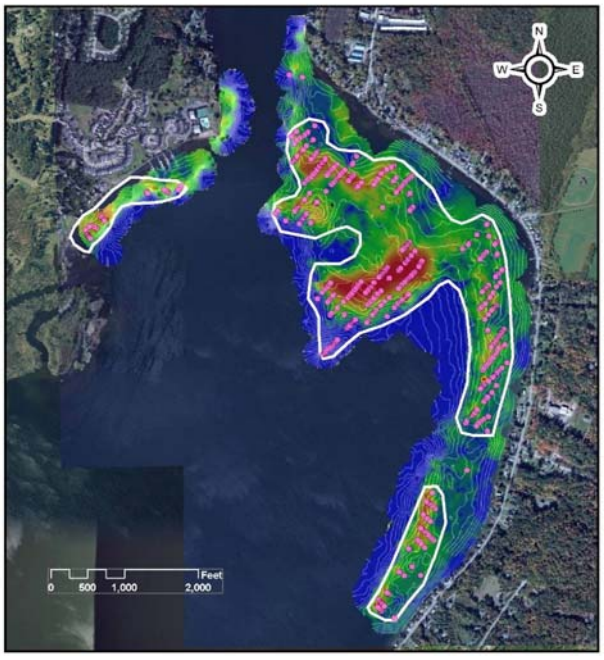
A chronology of the 2013 treatment program is provided below:

- Pre-treatment inspection and finalize treatment areas.....(Oct-Nov 2012)
- Submission of permit application to DEC.....January 17
- DEC permit issuance ID 5-4199-00002/00008 & 11..... May 27
- Treatment of approximately 172 acres with Renovate OTF for EWM control..... June 5 & 6
- Post-treatment inspections..... July 3
- Comprehensive aquatic plant survey (DFWI).....Aug 28 & 29
- Late season inspection.....Oct 15

Pre-Treatment Inspection

On 12 November 2012 the littoral zone on the northeast and northwest portions of Saratoga Lake was surveyed with a hydro acoustic mapping system to determine the size and density of the milfoil infestation in this area of the lake. Areas of dense milfoil growth were also confirmed by visual observation.

Areas identified for treatment in 2013 were dictated by the density and distribution of milfoil observed during the November survey. A map generated from the hydro acoustic survey including manually entered GPS points denoting dense milfoil growth (pictured to the right).

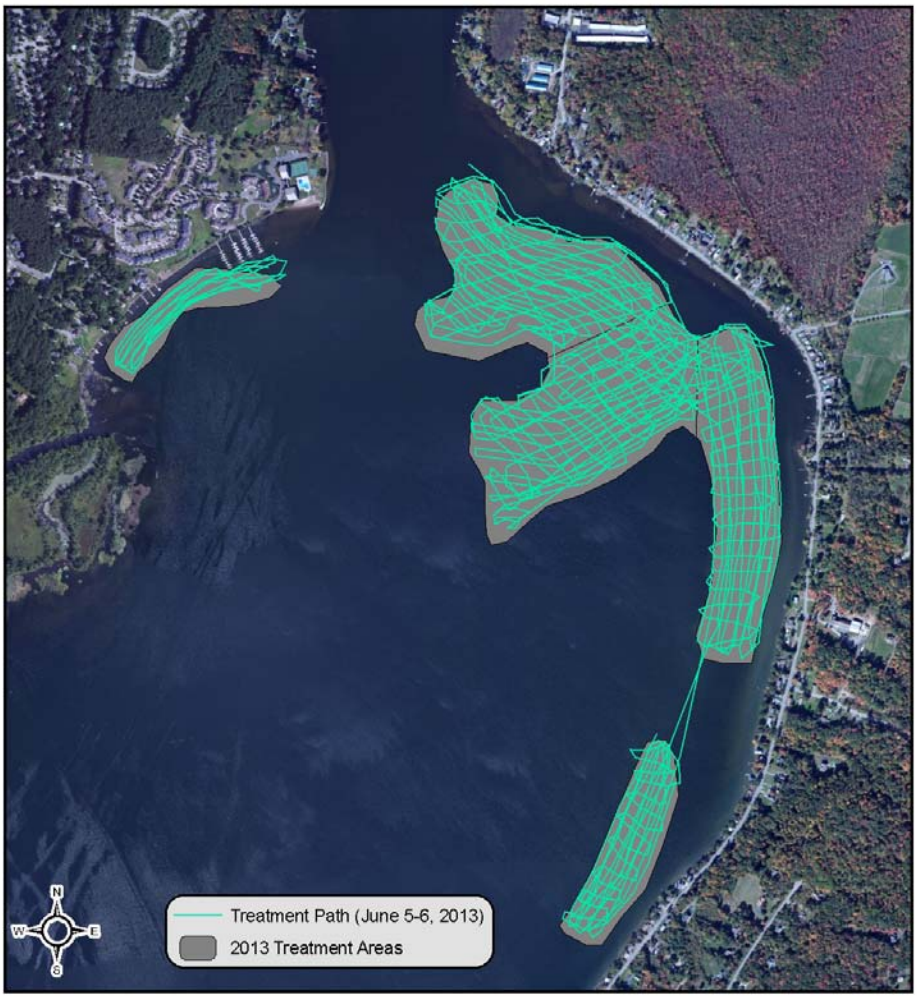


Summary of 2013 Treatment

Treatment dates of Wednesday, 5 June and Thursday 6 June 2013 were selected so that the one-day swimming restriction would not be imposed over a weekend. Weather conditions on both days were ideal with an air temperature of 75°F, sunny/partly cloudy conditions and light winds (<5mph) out of the W/SW. The surface water temperature was approximately 20.4° C and the dissolved oxygen concentration was 9.4 mg/L.

The treatment was conducted using a 24-foot fiberglass work skiff outfitted with two calibrated, cyclone seeder/ spreaders mounted in the stern. This produced an approximate 30-foot swath during the application. Renovate OTF (EPA Reg. No. 67690-42; SLN NY-070004) granules were loaded into the spreaders and evenly applied throughout pre-determined treatment sectors.

The treatment boat was equipped with a WAAS GPS unit that had the treatment areas pre-loaded and was used for real-time navigation an to insure that even applications were made within the designated treatment areas. The Fitch Road access point on the NE shoreline of the lake used as the base of operations. Crop Production Services (CPS) delivered the Renovate OTF herbicide directly to the lake.



Treatment was performed as a split application whereby roughly 70% of the herbicide was applied to each of the designated areas initially and then the remaining 30% was applied on the following day. There was approximately 16-20 hours between the two applications. This split application approach was used to increase CET and treatment efficacy.

Renovate OTF herbicide was applied at a target dose of 1.3-1.5 ppm in the bottom 5-feet of the water column. It was expected that the majority of the targeted milfoil growth would be found in the lower 5 feet of the water column at the time of treatment. This application rate was consistent with previous treatments performed at Saratoga Lake. A total of 30,700 pounds of Renovate OTF (granular) was applied to the three distinct treatment areas. The herbicide application took two full work days to complete.

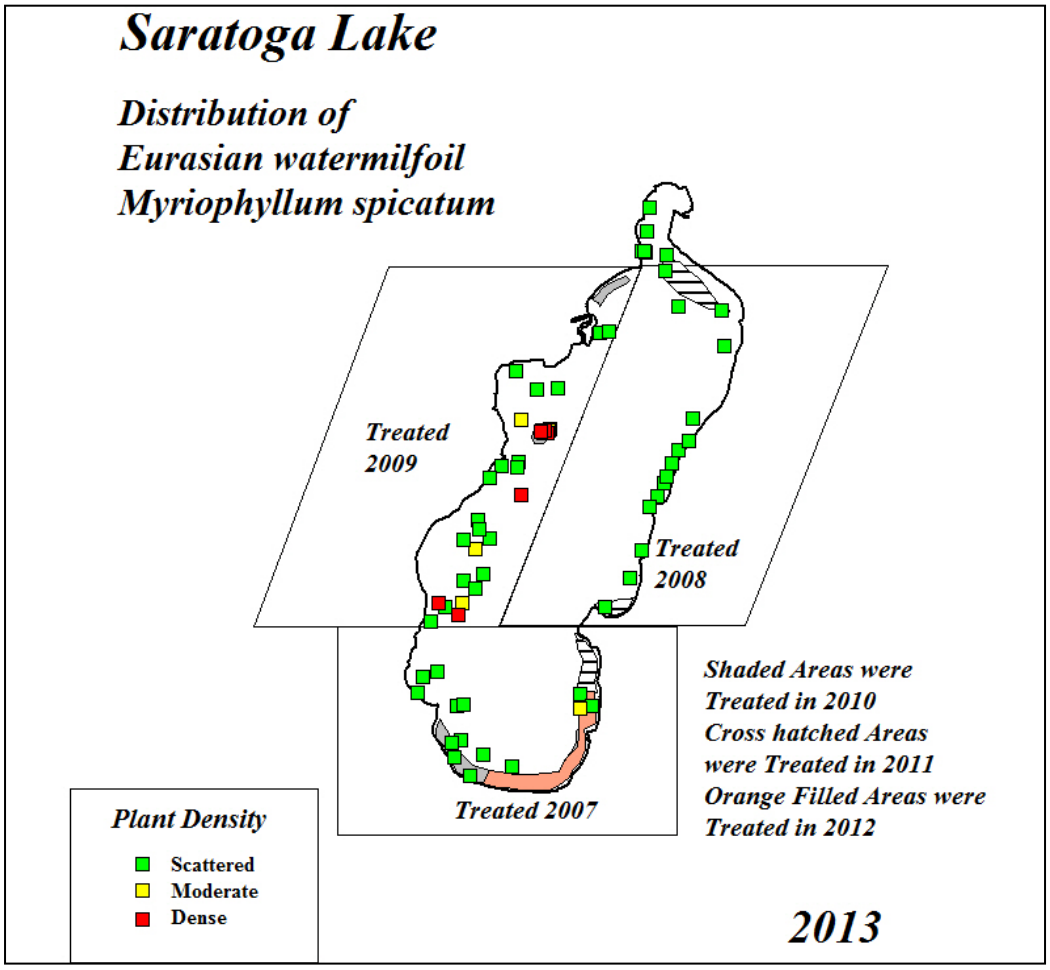
Post-Treatment Inspections

Approximately four weeks post-treatment (7/3/13) ACT conducted a visual inspection of the treatment area and found that most of the targeted milfoil plants were dead and decomposing on the bottom. Low-density EWM remained erect in water column in some of the treated areas but most of the observed plants were showing signs of treatment impact. The 19 acre treatment area along the eastern shore had the most remaining milfoil but overall cover of milfoil was less than 10%. Healthy growth of native plant species observed growing in the treatment area included: *Potmogeton richardonii, Zosterella dubia, Stuckenia pectinatus, Elodea canadensis, Ceratophyllum demersum & Potamogeton zosteriformis.*

2013 LATE SEASON COMPREHENSIVE AQUATIC VEGETATION SURVEY

The annual comprehensive aquatic plant survey was conducted by DFWI in late August. A copy of their interim report is provided in Attachment B. A point-intercept vegetation survey was performed throughout the littoral zone of the lake consistent with their survey efforts in prior years.

Map from DFWI 2013 final report



Within the treatment area there was an obvious reduction in EWM between the 2012 and 2013 surveys. Only 5 instances of low-density milfoil recorded among the 50-60 data points located in the treatment areas. According to the DFWI Final Report (Appendix A), EWM frequency within treated areas was reduced from 42% in 2012 to 9% in 2013.

Frequency of Occurrence data from DFWI surveys

Year	*2004*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Treatment performed	*Pre-treatment*	*South end Sonar 158 acres*	*East and northeast shore Renovate OTF 292 acres*	*West shore Renovate OTF 285 acres*	*Spot-treatment Renovate OTF 50 acres*	*Spot-treatment Renovate & Aquathol liquid 100 acres*	*Spot-treatment Renovate OTF & Clearcast 2.7G granular 100 acres*	*Spot-treatment Renovate OTF granular 172 acres*
Eurasian watermilfoil	54.2%	49.7%	13.0%	6.8%	22.1%	29.3%	25.6%	23.1%
Curlyleaf pondweed	5.6%	5.6%	5.6%	3.1%	9.4%	0.7%	2.3%	2.3%

In reviewing the survey data for the entire lake produced by DFWI, there appeared to be slight decline in frequency of occurrence of EWM between 2012 and 2013 from 26% to 23%. The frequency of occurrence of CLP remained low at just 2.3%; indices for CLP have be comparably low over the past three years. The maintenance treatments performed over the past four years appear to be maintaining the lake-wide populations of EWM and CLP at relatively low levels.

Native species continue to dominate the aquatic plant community in Saratoga Lake. Quantitative measures of frequency of occurrence and species richness were consistent with prior years. Twenty-nine species were encountered during the 2013 survey, which is the same number that was found in 2009 and remains comparable with prior years. Slight changes in the frequency of occurrence values of native species are seen from year to year, but this is attributable to annual variation in growth and limitations of the survey methodology that is being employed. The only noteworthy difference seen in 2013 was the continued expansion in the frequency of occurrence of Richardsons' Pondweed (*Potamogeton richardonii)*, which increased from 0.3% in 2011 to 22% in 2012 and 33% in 2013. Increased densities of this plant were also reported at other area waterbodies, which suggests that the increased growth may be due to weather or other factors that are influencing the entire region and not simply Saratoga lake. Indices for all other recorded plant species were consistent with results from prior years.

SUMMARY AND DISCUSSION

By all measures, the 2013 herbicide treatment at Saratoga Lake provided reasonably effective control of Eurasian watermilfoil. Only low densities occurrences of milfoil were found in the treatment areas during post -treatment inspections and late season surveys, while the treated areas supported diverse and abundant growth of numerous native plant species. As has been the case in prior years, the smallest treatment areas with the greatest edge to area ratio appear to be subject to the most dilution with untreated water. This reduces the herbicide CET and results in reduced treatment efficacy.

The most significant challenge encountered during the 2013 treatment program was the numerous significant rainfall events that began approximately one-week after the treatment. This caused elevated water levels in the lake and accelerated outflow that carried triclopyr residues further downstream than predicted. This necessitated

additional sampling and notification to downstream riparian owners of the temporary restrictions on the use of treated lake water for irrigation purposes.

Saratoga Lake is a productive system and it will continue to support growth of invasive Eurasian watermilfoil and curlyleaf pondweed for the foreseeable future. Herbicide treatment programs performed since 2007 have controlled dense beds of Eurasian watermilfoil and have allowed for recovery of a diverse native plant assemblage. However, the treatments do not provide complete control and recovery of Eurasian watermilfoil will occur at accelerated rates if ongoing management is not continued. Future herbicide treatments should continue to be "fine-tuned" based on the recent experiences at Saratoga Lake and at other lakes in the Northeast.

RECOMMENDATIONS FOR 2014 SEASON

The results of the DFWI August 2013 survey and observations made during late season inspections suggest that the southern end, especially the southwest shoreline will support the most robust Eurasian watermilfoil growth on the lake during the 2014 season and is expected to be the focus of management efforts.

We will work with SLPID to prioritized potential treatment areas based on the available data and will attempt to finalize the 2014 treatment areas and treatment protocol over the winter, so permits can be submitted to NYSDEC early next year to allow ample time for review.

Based on the positive results from previous treatments we anticipate the use of Renovate (triclopyr) herbicide will be considered in 2014, but we will evaluate all available herbicide treatment options to achieve selective control of the nuisance Eurasian watermilfoil and curlyleaf pondweed growth. We will work closely with all of the involved parties to develop treatment protocols that will provide the desired level of control, while minimizing impact to lake riparian owners and downstream riparian owners that use water for domestic purposes and for irrigation. We will also try to develop and propose a sampling protocol that will allow for assessment of the treatment effectiveness and provide the necessary protection for downstream water users. Treatment timing will likely stay similar to recent years, targeting a treatment date between mid-May and early-June. The objective will be to schedule treatment when there is at least 3 or more feet of active Eurasian watermilfoil growth, and when there is still a temperature gradient in the water column that will help limit herbicide dissipation. The herbicides, formulations and application approaches used will ultimately depend on treatment area configuration. It will also be necessary to maintain some flexibility in the treatment date should there be adverse weather conditions, such as heavy rainfall or high winds that could accelerate dilution and mixing.

ATTACHMENT A

- Comprehensive Aquatic Plant Survey – 2013 Interim Report (prepared by Darrin Fresh Water Institute)

DARRIN
Fresh Water Institute

Lake George, New York
Adirondack Field Station at Bolton Landing

Saratoga Lake Aquatic Plant Survey – 2013

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DFWI Technical Report 2013-10

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Background

Quantitative aquatic plant surveys were undertaken for Saratoga Lake, New York as part of a cooperative effort between Aquatic Control Technologies (ACT) and the Darrin Fresh Water Institute, and supported by 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 2012 (Eichler & Boylen 2012) to evaluate a treatment program based on application of the herbicide fluridone (SONAR^{TM}) in 2007 and the herbicide triclopyr (Renovate) in 2008 thru 2013 (Figure 1) to control Eurasian watermilfoil (*Myriophyllum spicatum*). 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. The Point-Intercept Rake Toss 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 area, 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).

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

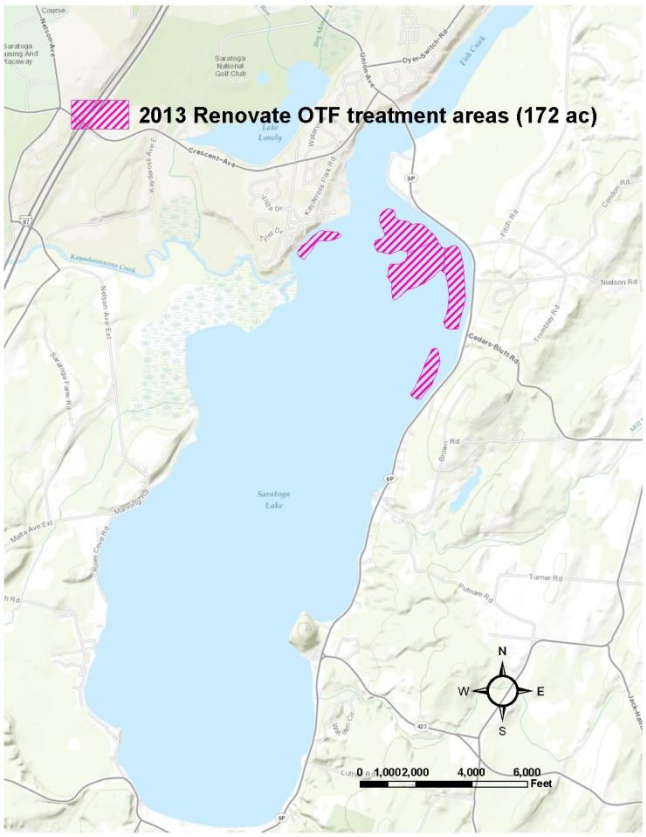
community with 13 submersed species, 2 native rooted floating-leaf species, 3 native emergent species and 3 free floating species (Dean 1969). *Myriophyllum spicatum* populations were first confirmed in the mid-1970's and reported to be the dominant aquatic plant species in the lake by the early-1980's (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 two 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 determined to be negatively effecting 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 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 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.



Treatment area map courtesy of ACT, Inc., Sutton, MA.

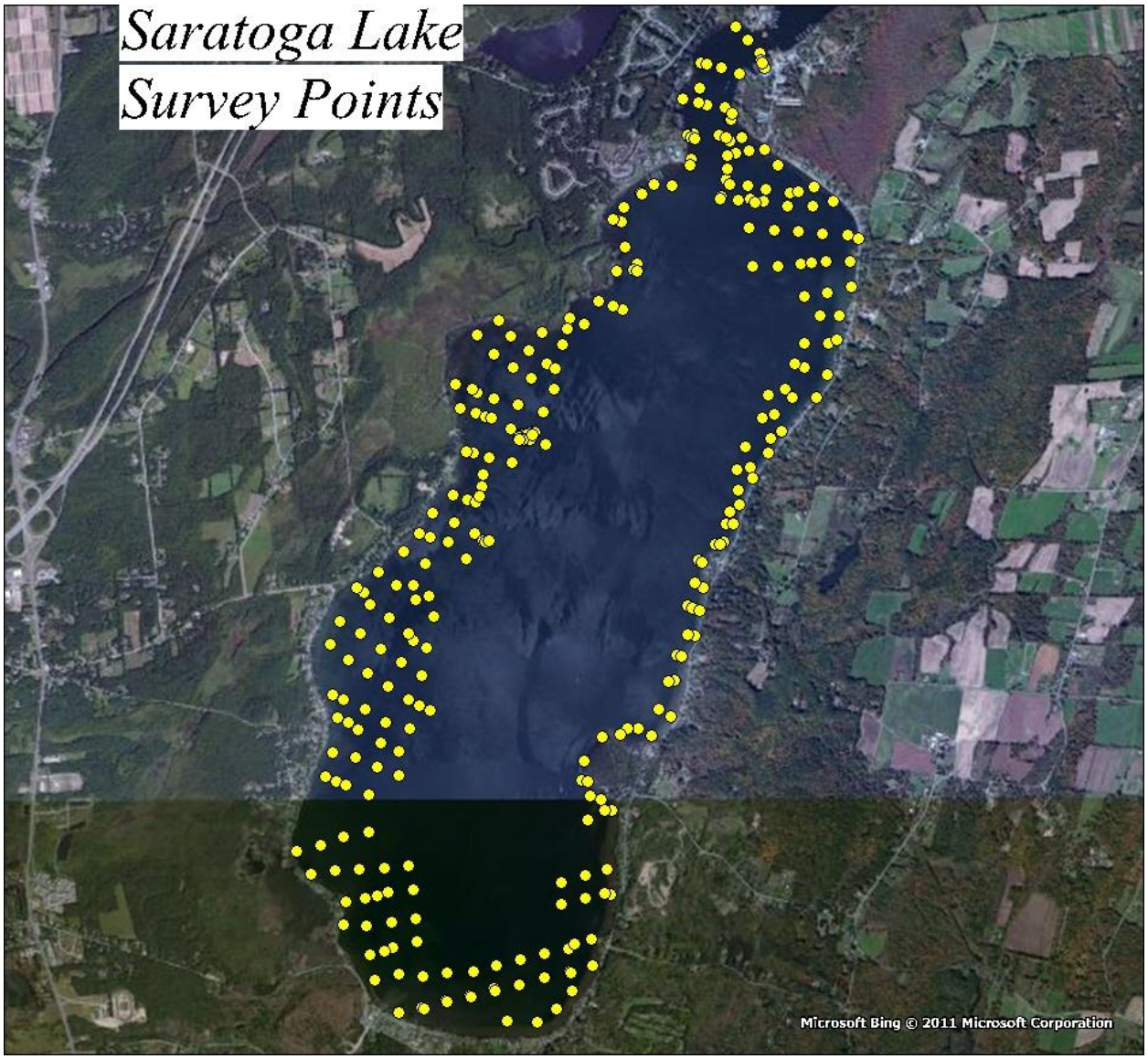
In 2012, a 100 acre area at the southeastern margin of the lake in the area of Browns Beach was treated with triclopyr (Renovate OTF) and imazamox (Clearcast 2.7G) was applied in a 50 acre sub-area. Eurasian watermilfoil declined to 26% of survey points lakewide and 7% of survey points in the treated 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 (see insert).

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 28-29 of 2013, at the time of maximum aquatic plant abundance. Based on an 80 m grid and excluding nearly all points outside the littoral zone, a total of 313 points were surveyed for Saratoga Lake in 2013. 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 2013, the aquatic plant community of Saratoga Lake included 22 submersed species, 3 floating-leaved species, 3 floating species and 1 emergent species for a total of 29 species (Table 1). Four exotic species, *Myriophyllum spicatum, Najas minor, Potamogeton crispus* and *Trapa natans* 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 fifth most widely distributed plant (23% of survey points), ranked the same as 2011 and 2012 but an increase from seventh in 2010 and ninth in 2009.

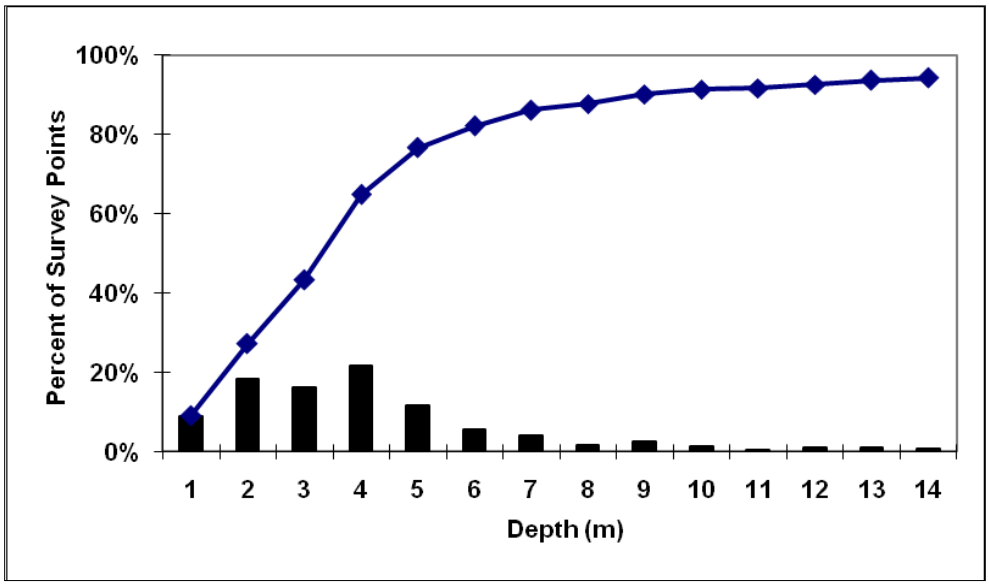
Table 1. Aquatic plant species present in Saratoga Lake in recent surveys.

Species	**Common Name**	**2010**	**2011**	**2012**	**2013**
Ceratophyllum demersum L.	coontail	**x**	**x**	**x**	**x**
Chara/Nitella sp.	muskgrass, chara	**x**	**x**	**x**	**x**
Elodea canadensis Michx.	elodea	**x**	**x**	**x**	**x**
Lemna minor L.	duckweed	**x**	**x**	**x**	**x**
Lemna trisulca L.	duckweed	**x**	**x**	**x**	**x**
Megalodonta beckii Torr.	water marigold	**x**	**x**	**x**	**x**
Myriophyllum spicatum L.	Eurasian watermilfoil	**x**	**x**	**x**	**x**
Najas flexilis (Willd.) Rostk. & Schmidt.	bushy pondweed	**x**	**x**	**x**	**x**
Najas minor All.	Minor Naiad		**x**		**x**
Najas guadalupensis (Spreng.) Magnus	Southern naiad	**x**	**x**	**x**	**x**
Nuphar variegata Engelm. ex Durand	yellow pondlily	**x**	**x**	**x**	**x**
Nymphaea odorata Ait.	white pondlily	**x**	**x**	**x**	**x**
Pontederia cordata L.	pickerelweed	**x**	**x**	**x**	**x**
Potamogeton amplifolius Tuckerm.	largeleaf pondweed	**x**	**x**	**x**	**x**
Potamogeton crispus L.	curlyleaf pondweed	**x**	**x**	**x**	**x**
Potamogeton foliosus Raf.	leafy pondweed				**x**
Potamogeton gramineus L.	variable-leaf pondweed	**x**	**x**	**x**	**x**
Potamogeton illinoensis L.	Illinois pondweed	**x**	**x**	**x**	**x**
Potamogeton perfoliatus L	clasping-leaved Pondweed	**x**	**x**	**x**	**x**
Potamogeton praelongus Wulfen	white-stem pondweed	**x**	**x**	**x**	**x**
Potamogeton pusillus L.	small pondweed	**x**	**x**	**x**	
Potamogeton richardsonii (Ar. Benn.) Rydb.	Richardsons' pondweed		**x**	**x**	**x**
Potamogeton robbinsii Oakes	Robbins' pondweed	**x**	**x**	**x**	**x**
Potamogeton vaseyi Robbins	Vasey's pondweed				**x**
Potamogeton zosteriformis Fern.	flat-stem pondweed	**x**	**x**	**x**	**x**
Ranunculus longirostris Godron	white watercrowfoot	**x**	**x**		**x**
Sparganium sp.	burreed		**x**	**x**	**x**
Spirodela sp.	great duckweed				**x**
Stuckenia pectinata L.	sago pondweed	**x**	**x**	**x**	**x**
Trapa natans L.	waterchestnut	**x**	**x**	**x**	**x**
Typha	cattail	**x**	**x**	**x**	**x**
Utricularia vulgaris L.	great bladderwort	**x**	**x**		**x**
Vallisneria americana L.	wild celery	**x**	**x**	**x**	**x**
Zosterella dubia Jacq.	water stargrass	**x**	**x**	**x**	**x**

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), and was 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 2013.

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



Species Richness and Distribution

A total of 28 species were collected in the point intercept portion of the survey and 29 species were observed in Saratoga Lake in 2013 (Table 1). These results are comparable to previous surveys, where 29 species were observed in 2009, 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, and as moderate growth adjacent to the Fish Creek Boat Launch area. Brittle Naiad (*Najas minor*) was reported for the first time in 2011, absent in 2012, but present in 2 locations in 2013. Brittle naiad is an annual species which spreads primarily by seeds, and has been expanding its range northward over the last decade, particularly in the Upper Hudson Valley. Species absent from the 2013 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 and groups of species (i.e. Broad-leaf Pondweeds) for Saratoga Lake are included in Appendix A. Eurasian watermilfoil decreased in frequency of occurrence (23% of survey points in 2013, down from 26% of survey points in 2012 and 29% in 2011, but up from 22% of survey points in 2010, 7% of survey points in 2009, 13% of survey points in 2008). *Ceratophyllum demersum* remains the most widespread native plant, present in 54% of survey points. A number of other native species were also commonly observed, including *Vallisneria americana* (35%), *Potamogeton richardsonii* (33%), *Najas guadalupensis* (30%), *Zosterella dubia* (18% of survey points), *Elodea canadensis* (15%), *Chara* (12%), *Potamogeton zosteriformis* (10%), *Najas flexilis* (7%), and *Potamogeton illinoensis* (7%). 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 afterward. 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 2013, *Potamogeton crispus* remained in very limited abundance. *Potamogeton richardsonii* has greatly expanded its' coverage in a number of regional lakes in 2012 and 2013, 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	2009	2010	2011	2012	2013
Ceratophyllum demersum	coontail	61.4%	62.3%	62.9%	54.1%	53.5%
Chara/Nitella	muskgrass, chara	10.5%	11.9%	8.5%	9.5%	11.6%
Elodea canadensis	elodea	40.7%	46.3%	26.2%	22.3%	14.5%
Lemna trisulca	duckweed	2.5%	2.5%	2.4%	1.0%	3.3%
Lemna minor	duckweed					0.3%
Megalodonta beckii	water marigold	0.9%	2.0%	0.3%	0.3%	1.0%
Myriophyllum spicatum	**Eurasian watermilfoil**	**6.8%**	**22.1%**	**29.3%**	**25.6%**	**23.1%**
Najas flexilis	bushy pondweed	13.6%	7.8%	9.2%	3.0%	6.9%
Najas guadalupensis	Southern naiad	38.3%	48.0%	41.8%	32.8%	30.0%
Najas minor	**brittle naiad**			**0.3%**		**0.7%**
Nuphar variegata	yellow pondlily	0.3%	0.4%	0.3%	0.3%	0.7%
Nymphaea odorata	white pondlily	0.3%	0.8%	0.3%	0.3%	0.7%
Nymphoides cordata	floating heart					0.7%
Potamogeton amplifolius	largeleaf pondweed	1.2%	2.5%	1.7%	1.6%	1.3%
Potamogeton crispus	**curlyleaf pondweed**	**3.1%**	**9.4%**	**0.7%**	**2.3%**	**2.3%**
Potamogeton foliosus	pondweed					1.7%
Potamogeton gramineus	variable-leaf pondweed	1.9%		0.3%	0.7%	0.3%
Potamogeton illinoensis	Illinois pondweed	4.6%	6.6%	3.1%	4.3%	6.9%
Potamogeton perfoliatus	Clasping-leaved Pondweed	8.0%	15.6%	11.6%	5.9%	0.3%
Potamogeton praelongus	white-stem pondweed	3.1%	4.1%	3.4%	4.6%	2.3%
Potamogeton pusillus	small pondweed	6.5%	5.7%	2.3%	0.7%	
Potamogeton richardsonii	Richardsons' Pondweed			0.3%	22.0%	33.3%
Potamogeton robbinsii	Robbins' pondweed	0.9%	0.4%		0.3%	
Potamogeton vaseyii	Vaseys' pondweed					1.0%
Potamogeton zosteriformes	flat-stem pondweed	17.3%	22.5%	6.5%	2.6%	9.9%
Ranunculus longirostris	white watercrowfoot	0.3%	1.6%	0.3%		1.0%
Spirodela	water meal					0.3%
Stuckenia pectinata	sago pondweed	0.3%	0.4%	1.4%	1.0%	2.0%
Trapa natans	**waterchestnut**				**0.3%**	**0.3%**
Utricularia vulgaris	great bladderwort	0.3%				
Vallisneria americana	wild celery	31.2%	43.4%	33.0%	33.1%	35.3%
Zosterella dubia	water stargrass	20.4%	30.3%	35.4%	36.1%	17.5%

In 2013, *Myriophyllum spicatum* was the fifth most abundant species, present in 26% of all samples collected in the untreated (control) area and 9% of all samples collected in the treated areas (Table 3, Figure 3). In the treated portion of the survey, Eurasian watermilfoil declined sharply in the year of treatment (9% of survey points, Figure 4) when compared to the 42% frequency of occurrence reported in 2012. A number of native species were commonly observed in the treated area, including *Ceratophyllum demersum* (82%), *Potamogeton richardsonii* (51%), *Vallisneria americana* (40%), *Najas guadalupensis* (27%), *Zosterella dubia* (18%), *Potamogeton*

Table 3. Percent frequency of occurrence of aquatic plant species in Saratoga Lake.

	All	Control	Treated
Ceratophyllum demersum	53.5%	48.4%	82.2%
Chara/Nitella	11.6%	12.4%	6.7%
Elodea canadensis	14.5%	15.5%	8.9%
Lemna trisulca	3.3%	3.5%	2.2%
Lemna minor	0.3%	0.4%	
Megalodonta beckii	1.0%	1.2%	
Myriophyllum spicatum	23.1%	25.6%	8.9%
Najas flexilis	6.9%	8.1%	
Najas guadalupensis	30.0%	30.6%	26.7%
Najas minor	0.7%	0.8%	
Nuphar variegata	0.7%	0.8%	
Nymphaea odorata	0.7%	0.8%	
Nymphoides cordata	0.7%	0.8%	
Potamogeton amplifolius	1.3%	1.6%	
Potamogeton crispus	2.3%	1.6%	6.7%
Potamogeton foliosus	1.7%	1.9%	
Potamogeton gramineus	0.3%		2.2%
Potamogeton illinoensis	6.9%	7.8%	2.2%
Potamogeton perfoliatus	0.3%	0.4%	
Potamogeton praelongus	2.3%	1.9%	4.4%
Potamogeton richardsonii	33.3%	30.2%	51.1%
Potamogeton vaseyii	1.0%	1.2%	
Potamogeton zosteriformes	9.9%	10.1%	8.9%
Ranunculus longirostris	1.0%	1.2%	
Spirodela	0.3%	0.4%	
Stuckenia pectinata	2.0%	1.9%	2.2%
Trapa natans	0.3%	0.4%	
Vallisneria americana	35.3%	34.5%	40.0%
Zosterella dubia	17.5%	17.4%	17.8%

praelongus (14%), *Elodea canadensis* (9%), *Potamogeton zosteriformis* (9%), *Potamogeton crispus* (7%), and *Chara* sp. (7%). With this diversity and distribution of native species, the test for selectivity should be sensitive to a number of species, and the probability of native plant restoration in areas formerly inhabited by Eurasian watermilfoil should be high following management efforts. Common native species in untreated areas included *Ceratophyllum demersum* (48% of survey points), *Vallisneria americana* (35%), *Najas guadalupensis* (31%), *Potamogeton richardsonii* (30%), *Zosterella dubia* (17%), *Elodea canadensis* (16%), *Chara/Nitella* (12%), and *Potamogeton zosteriformis* (10%).

Figure 3. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) in surveyed areas of Saratoga Lake in 2013.

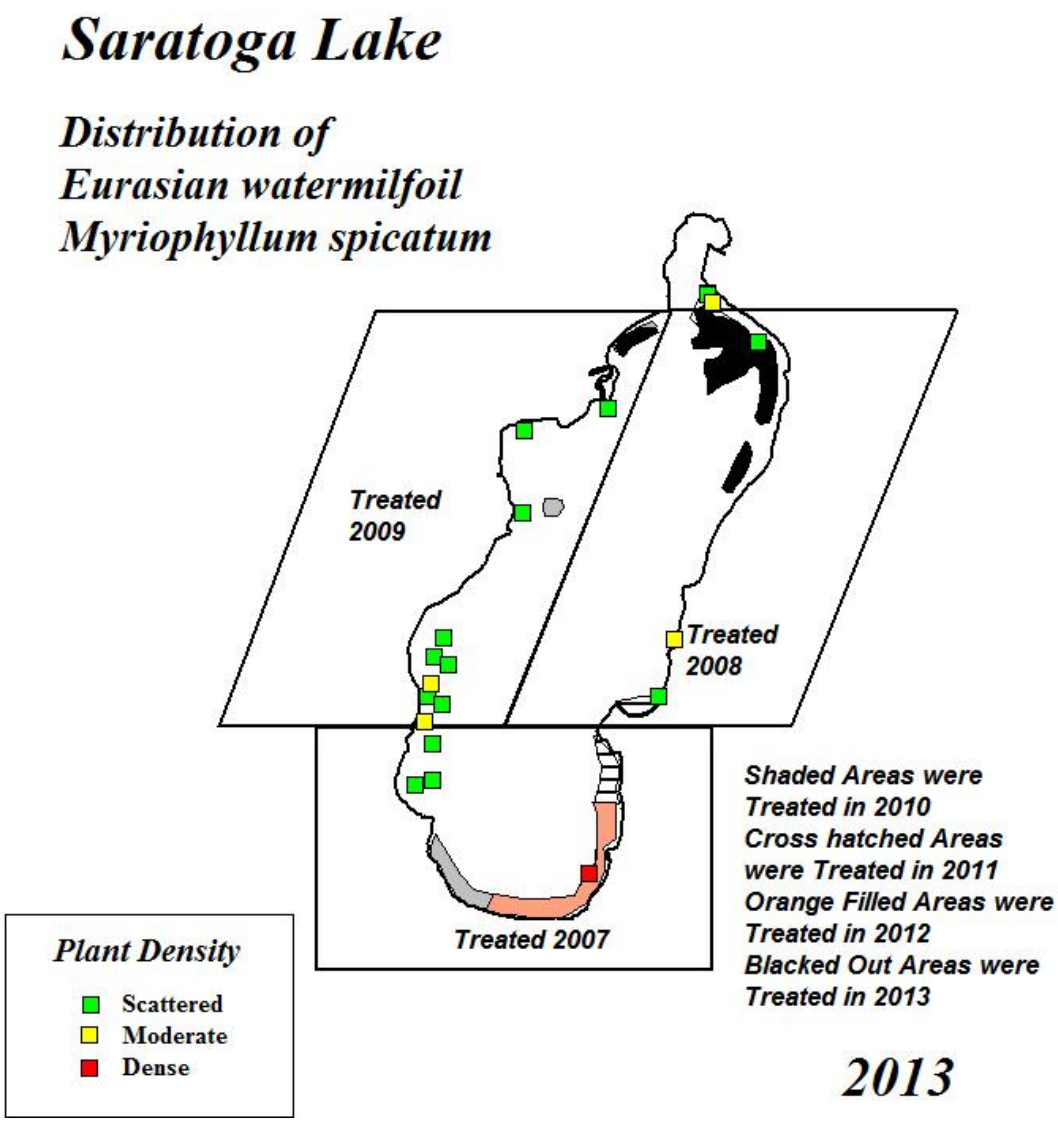
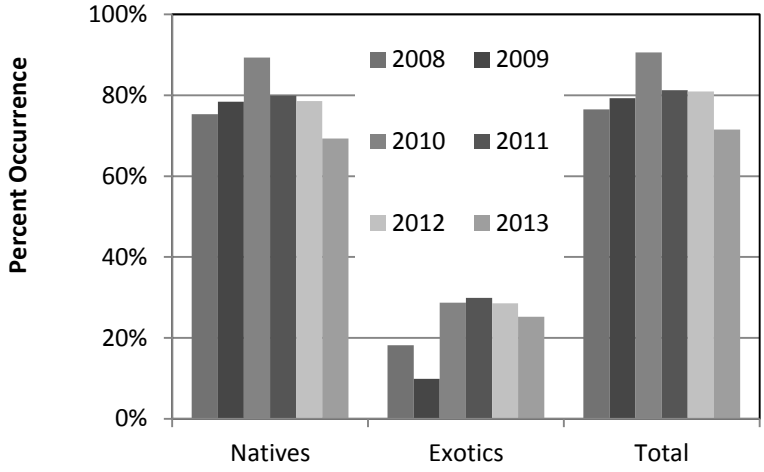


Figure 4. Saratoga Lake frequency of occurrence summaries for all sampling points.



In 2013, 69% of survey points in the control area and 87% in the treated area supported native species. Seventy-five percent of whole lake points were vegetated by native plant species in 2008, 78% in 2009, 89% in 2010, 80% in 2011, 79% in 2012 and 72% in 2013 (Figure 4). In depths less than 6 m, representing the littoral zone, 79% of survey points contained native species and 84% of survey points less than 2 meters depth yielded native aquatic plants in 2013. Eurasian watermilfoil was present in 23% of whole lake survey points, and 26% of survey points within the littoral zone or zone of aquatic plant growth. It is apparent that exotic species, dominated by Eurasian watermilfoil, were clearly more abundant lakewide 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.

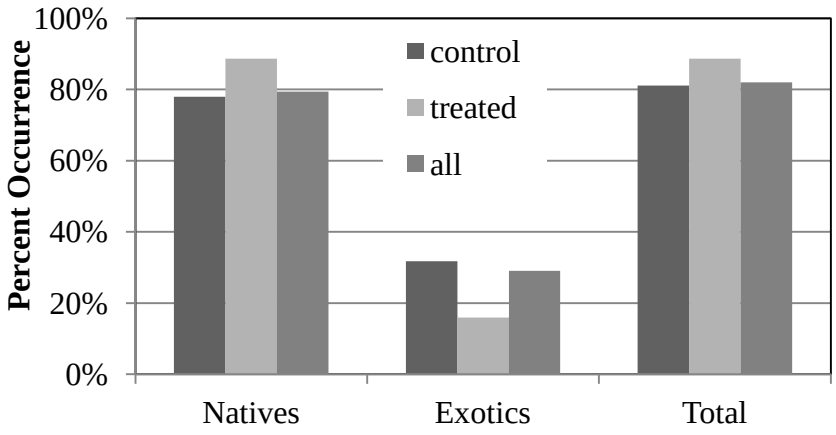


Figure 5. Saratoga Lake frequency of occurrence summaries for sampling points less than 6 meters water depth.

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 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. 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 remained at or below moderate levels in 2011 thru 2013. 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.

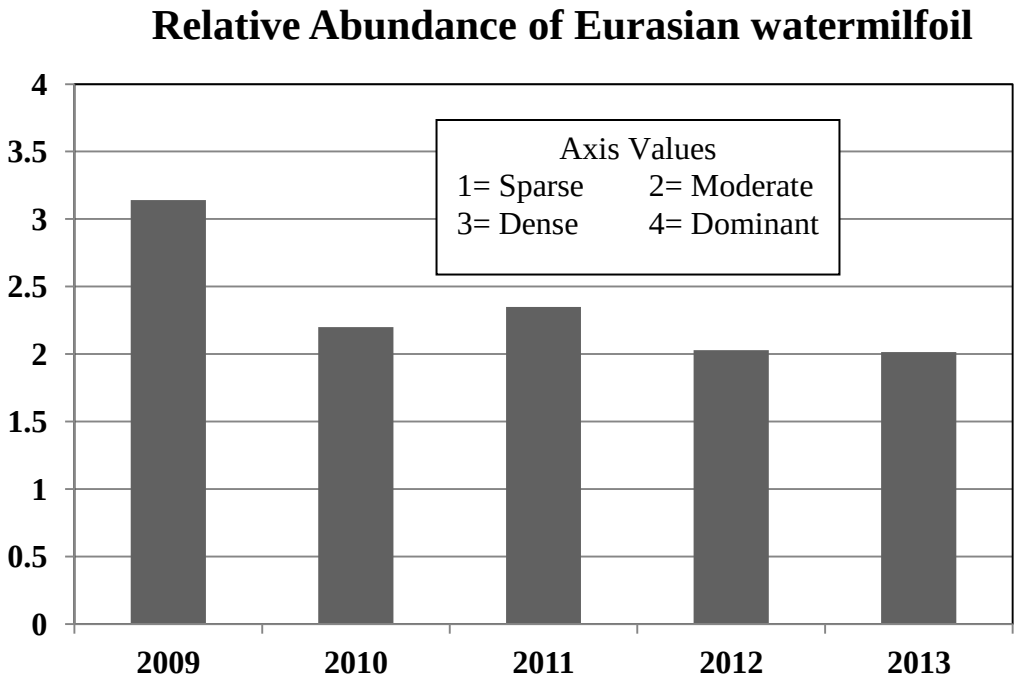


Figure 6. Lake-wide relative abundance of Eurasian watermilfoil in Saratoga Lake.

Species richness results for the point intercept survey are presented in Table 4 and Figure 6. 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. Depths less than 2 meters yielded 3.72 ± 0.21 and 3.69 ± 0.25 species per sample point in 2011 and 2012. In comparison, littoral (<6m depth) species richness in 2007 was 2.74 ± 0.20, and peaked at 3.17 ± 0.12 species per sample point in 2009. 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). The shallow fringe (<2m depth) species richness also peaked in 2009 at 4.25 ± 0.23, however 2013 was nearly identical at 4.24 ± 0.32. Total species richness appears to be closely linked to the relative abundance of Eurasian watermilfoil.

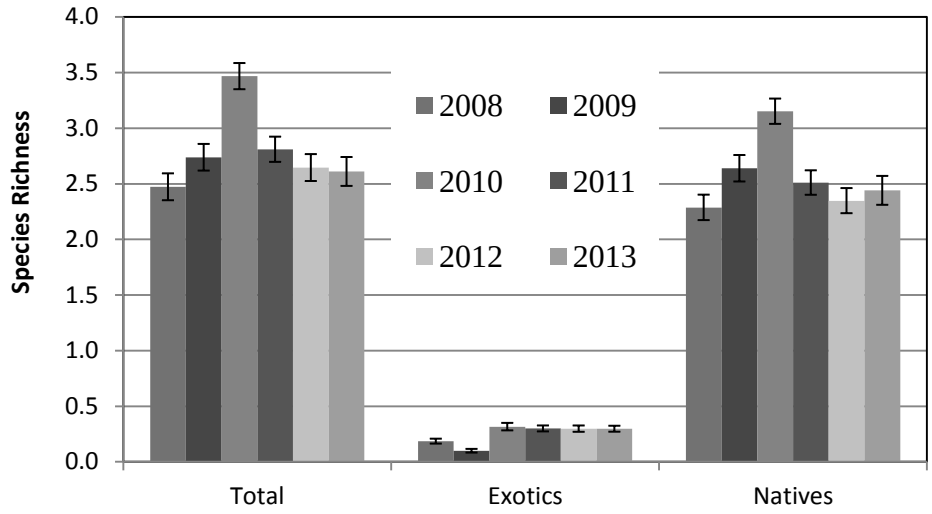
Native species richness was 2.07 ± 0.18 species per survey point in 2007 for the entire littoral zone (depths less than 6 meters), exceeding the 2004 littoral, native species richness of 1.65 ± 0.09 species per survey point, but still less than the 2.66 ± 0.12 species per survey point in 2008 and 3.05 ± 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). Whole lake native species richness was 1.43 ± 0.08 species per sample in 2004, 1.74 ± 0.19

species per sample in 2007, 2.29 ± 0.11 species per sample in 2008, 2.64 ± 0.12 species per sample in 2009, 3.15 ± 0.11 species per sample in 2010 and 2.51 ± 0.11 species per sample in 2011. 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). One again, species richness in 2013 was greater than prior years (4.02 ± 0.31), but within the range of values for Saratoga Lake. 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. 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

Table 4. Saratoga Lake species richness for the point intercept survey.

Plant Grouping	Water Depth Class	Statistic	2008	2009	2010	2011	2012	2013
Native plant species	Whole Lake (all depths)	Mean	2.29	2.64	3.15	2.51	2.35	2.44
		N	324	324	244	294	279	279
		Std. Error	0.11	0.12	0.11	0.11	0.11	0.13
	Points with depths <6m	Mean	2.66	3.05	2.77	2.78	2.57	2.68
		N	278	278	241	265	272	272
		Std. Error	0.12	0.12	0.13	0.11	0.11	0.13
	Points with depths <2m	Mean	3.84	4.22	3.72	3.57	3.46	4.02
		N	76	76	65	79	74	74
		Std. Error	0.22	0.24	0.24	0.21	0.23	0.31
All plant Species	Whole Lake (all depths)	Mean	2.47	2.74	3.47	2.81	2.65	2.61
		N	324	324	244	294	279	279
		Std. Error	0.12	0.12	0.12	0.11	0.12	0.13
	Points with depths <6m	Mean	2.88	3.17	3.04	3.11	2.89	3.00
		N	278	278	241	265	272	272
		Std. Error	0.13	0.12	0.13	0.11	0.12	0.14
	Points with depths <2m	Mean	3.99	4.25	3.89	3.72	3.69	4.24
		N	76	76	65	79	74	74
		Std. Error	0.22	0.23	0.25	0.21	0.25	0.32

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



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 occurred in conjunction with a slight decline in total and native species richness. Species richness has remained stable since that time.

Summary

Quantitative aquatic plant surveys were undertaken in 2013 for Saratoga Lake, New York as part of a cooperative effort between Aquatic Control Technologies (ACT) and the Darrin Fresh Water Institute, and supported by 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. The project included three components: 1) collection of specimens for compilation of a species list, 2) point-intercept frequency and depth data for points distributed in previously treated areas, and 3) point-intercept frequency and depth data for points distributed in herbicide treated areas (southwest end and north of the Kayadeross).

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 percent 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, however it was absent from the 2008 and 2009 surveys, but returned in 2011 and 2012. A number of *Trapa natans* plants have 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 southest corner of the lake, and imazimox to 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 August of 2013, the aquatic plant community of Saratoga Lake included 22 submersed species, 3 floating-leaved species, 3 floating species and 1 emergent species for a total of 29 species. Twenty-four of these species were found in the point intercept survey of 2001 and 2013.

These results are comparable to previous surveys in 2012 (28 species, Eichler and Boylen 2012), 2009 (26 species, Eichler and Boylen 2009), 2007 and 2008 (25 species, Eichler and Boylen 2007), 2004 (21 species, Eichler and Boylen 2004), 1994 (22 species, Eichler and Boylen 1994), 1982 (21 species, Hardt et al. 1983) and 1969 (20 species, Dean 1969). Eleven species were found in samples from the treated area and 22 species were reported in the control samples, however very limited areas were treated in 2011.

Exotic species, dominated by Eurasian watermilfoil, were clearly 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 exotics species abundance (22% and 29% of survey points) was observed in 2010 and 2011, respectively which stabilized in 2012 (26% of survey points) and 2013 (23% of survey points). 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 and fifth most abundant species in 2011 thru 2013.

Native species were dominant in 2013. Common native species in untreated or control areas included *Ceratophyllum demersum* (48% of survey points), *Vallisneria americana* (35%), *Najas guadalupensis* (31%), *Potamogeton richardsonii* (30%), *Zosterella dubia* (17%), *Elodea canadensis* (16%), *Chara/Nitella* (12%), and *Potamogeton zosteriformis* (10%). Eurasian watermilfoil showed some signs of decline in the previously treated portions of the survey, reported for 28% of survey points, relatively unchanged from the 29% of survey points reported in 2011 and 2012.

In the treated areas of Saratoga Lake, Eurasian watermilfoil was present in 9% of survey points in 2013. Common native species in the treated areas included *Ceratophyllum demersum* (82%), *Potamogeton richardsonii* (51%), *Vallisneria americana* (40%), *Najas guadalupensis* (27%), *Zosterella dubia* (18%), *Potamogeton praelongus* (14%), *Elodea canadensis* (9%), *Potamogeton zosteriformis* (9%), and *Chara* sp. (7%). With this diversity and distribution of native species, the test for selectivity should be sensitive to a number of species, and native plant restoration in areas formerly inhabited by Eurasian watermilfoil appears to be rapid following management efforts.

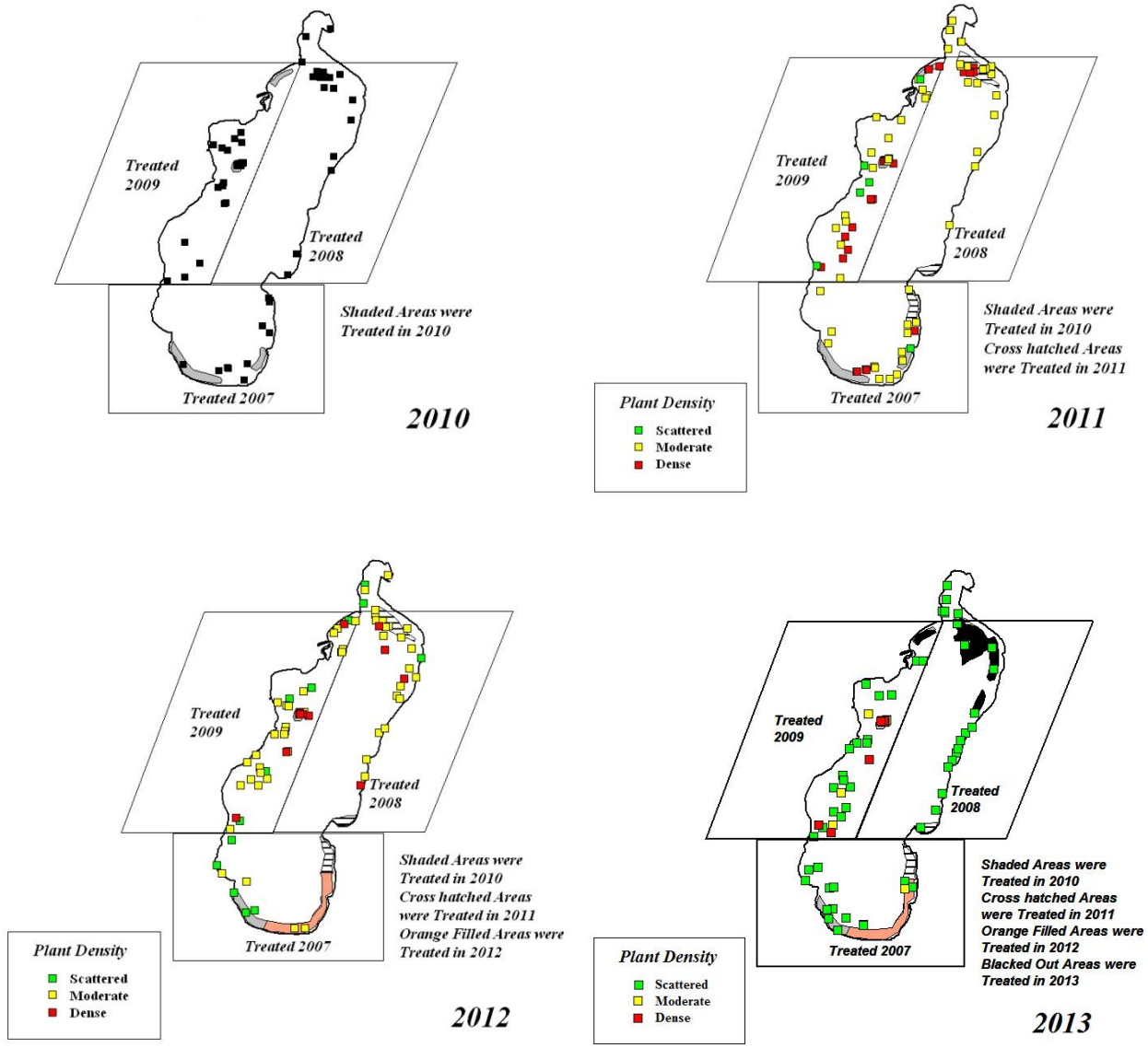
Estimates of relative abundance for each species surveyed were incorporated into the sampling protocol in 2009 (Figure 7). A four point scale, ranging from one which indicated a trace amount of a particular species to four indicating clear dominance of the species in a particular sample was employed. 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 2013. While frequency of occurrence results provide a statistically reliable way to represent aquatic plant populations, combining relative abundance with frequency of occurrence may provide a better way to characterize the impact of an invasive species on a native plant population.

In 2004 whole lake species richness was 2.00 ± 0.10 species per survey point. Whole lake species richness has increased steadily since that time to 3.47 ± 0.12 by 2010. 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. Whole lake species richness in 2012 and 2013 remained comparable to 2011. 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 aboe 4 species per survey point (4.02 ± 0.31). 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 and 2013, native species richness and the abundance of invasive species were nearly unchanged from 2011.

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 (Figure 6). 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 lakewide 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 lakewide 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. Eurasian watermilfoil remains as persistent growth in the mouth of Mannings Cove and along the west shore.

Lakewide aquatic plants were found to occur in 82% of survey points in the littoral zone, comparable to prior surveys (range of 87 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

Figure 8. A comparison of the distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) growth in selected areas of Saratoga Lake in 2009 through 2012.



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. The fact that Eurasian watermilfoil is only slowly recovering after treatment suggests the durability of treatment regimes from 2007 thru 2010. 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.

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 and 2012 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 2013. 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 2013, while still quite abundant, the frequency of occurrence of this species has declined. 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. The growth habit of this species may be a consideration in future management efforts. One 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 33% in 2013. Richardsons Pondweed (*Potamogeton richardsonii*) has been present in Saratoga Lake for many years, but always as a minor component of the aquatic plant population. 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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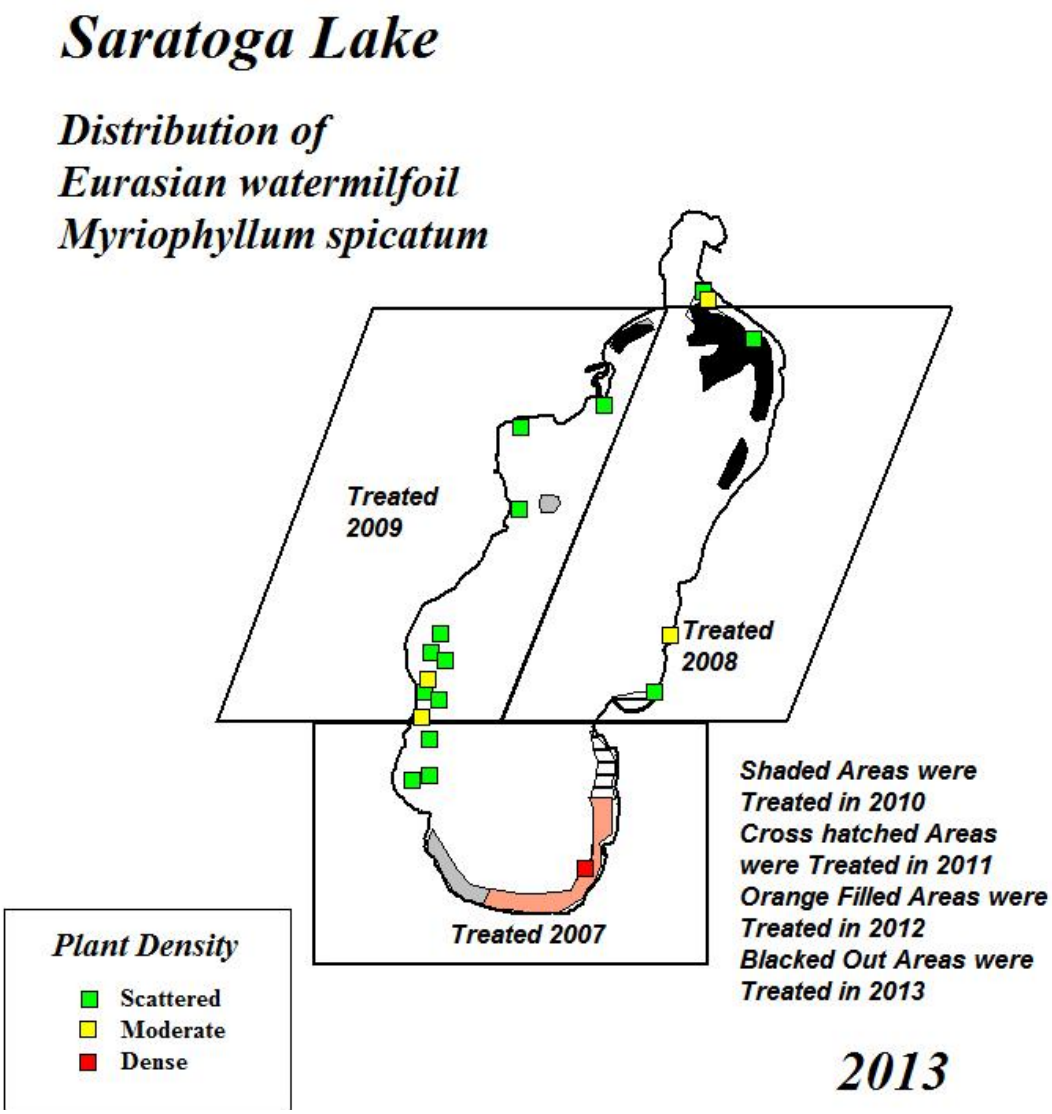
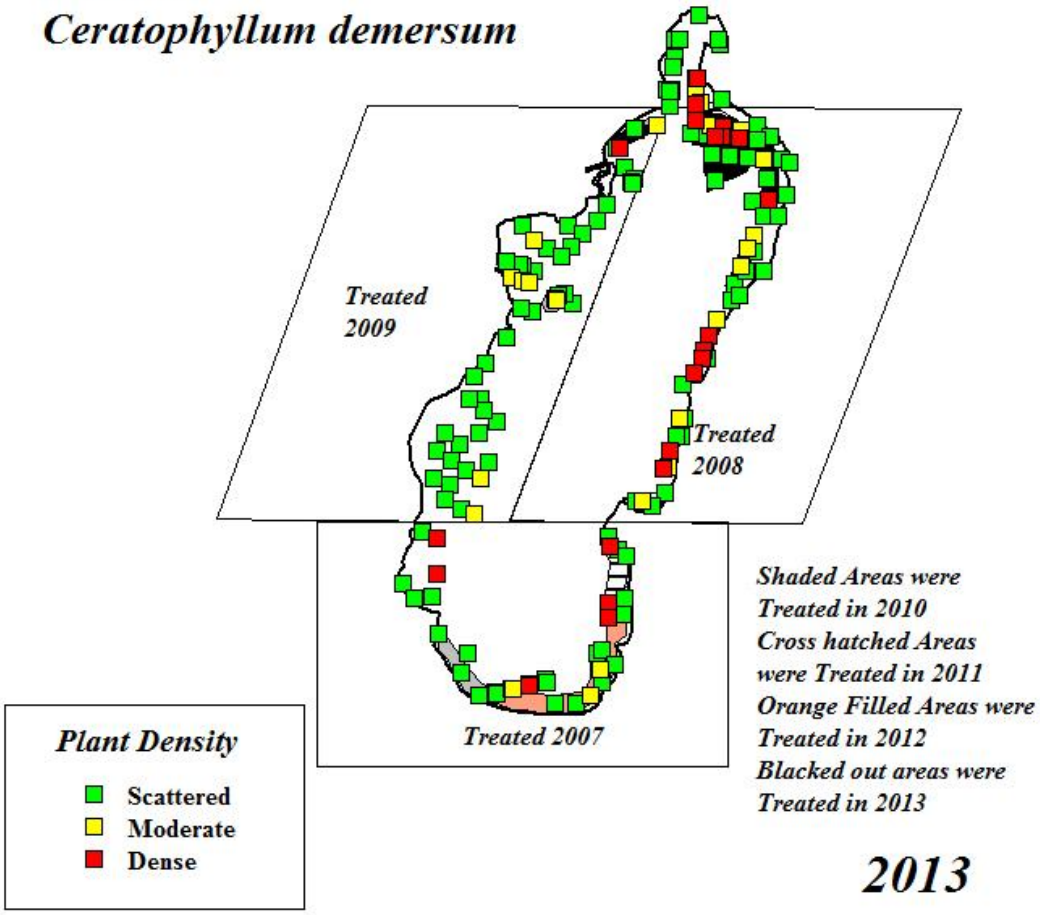
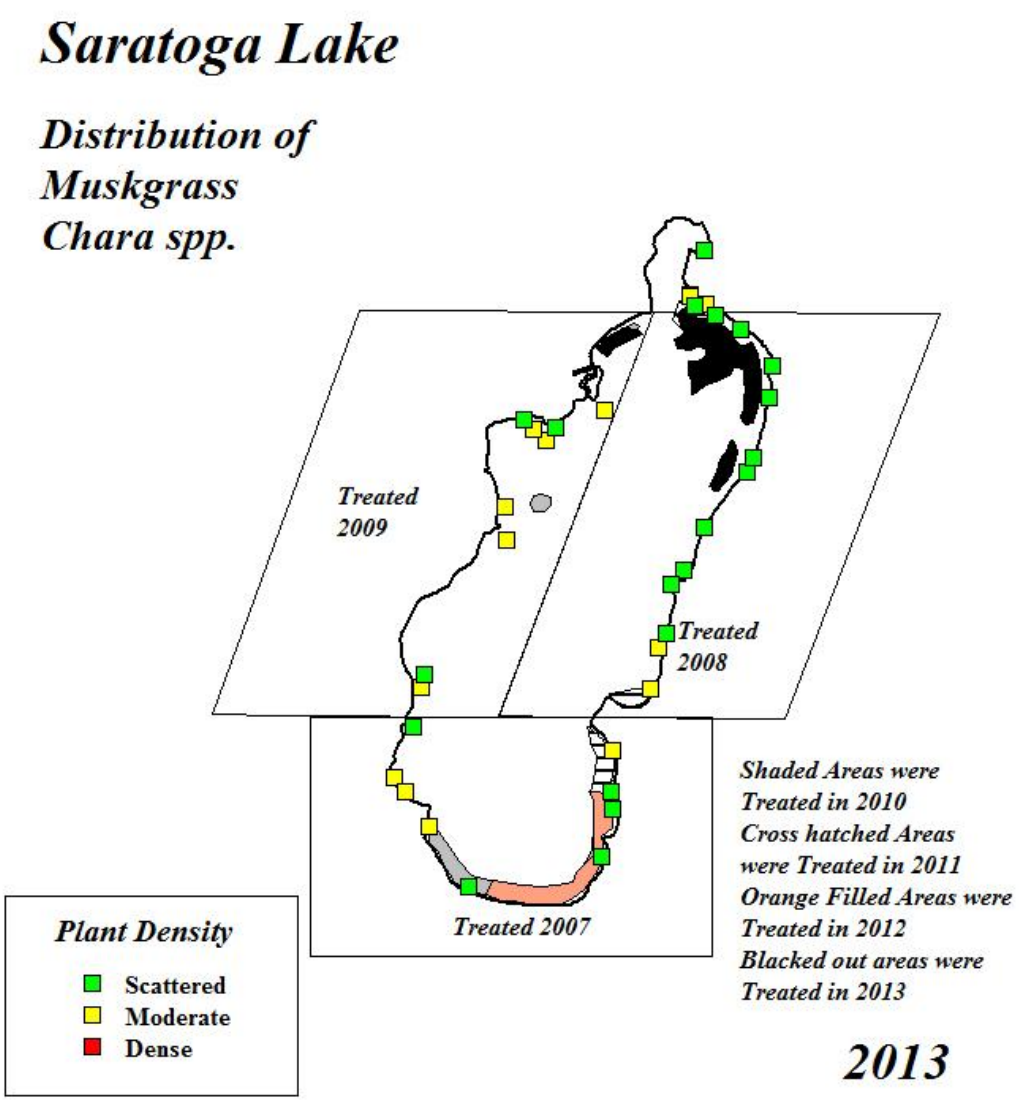
Appendix A. Saratoga Lake aquatic plant distribution maps

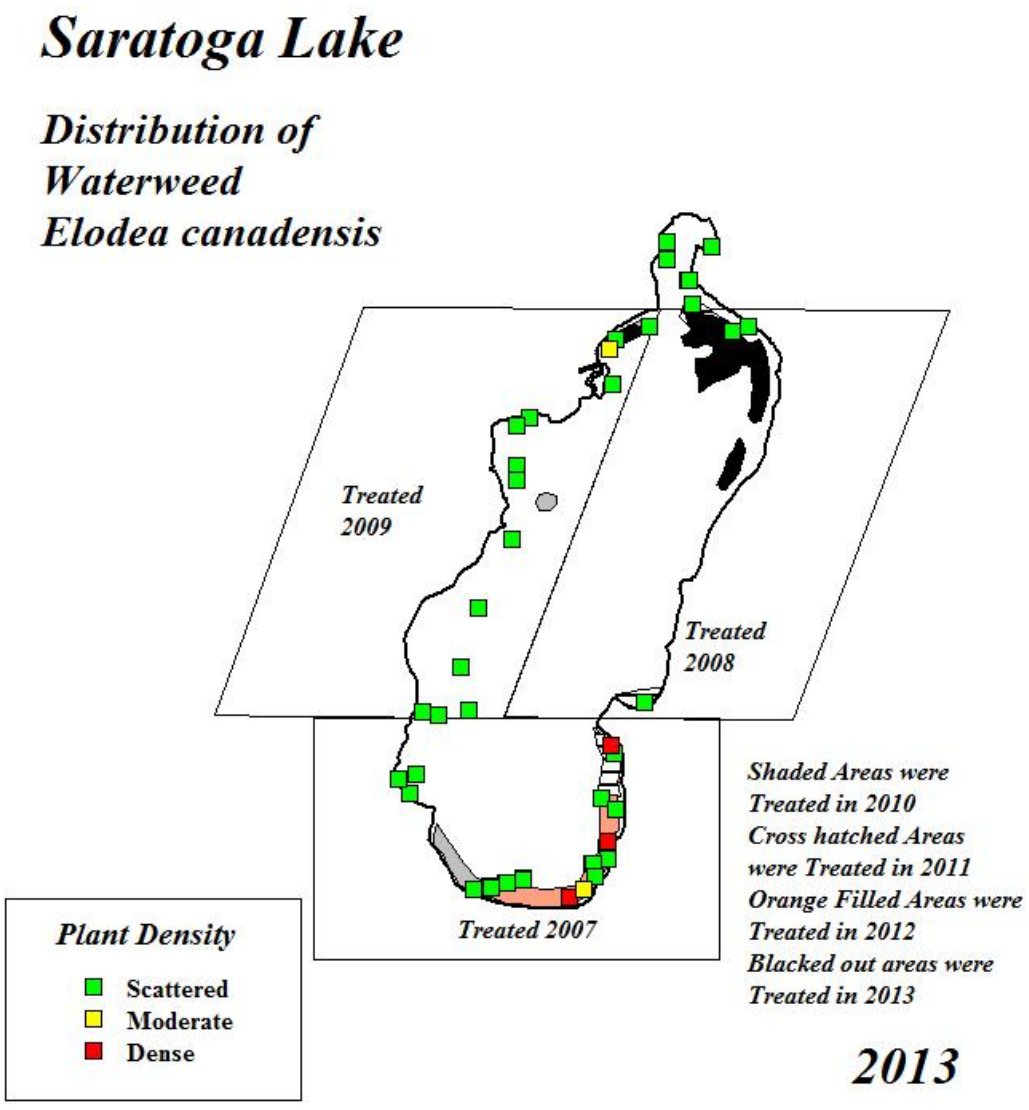

Saratoga Lake
Distribution of
Eurasian watermilfoil
Myriophyllum spicatum
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
Plant Density
Scattered
Moderate
Dense
2013

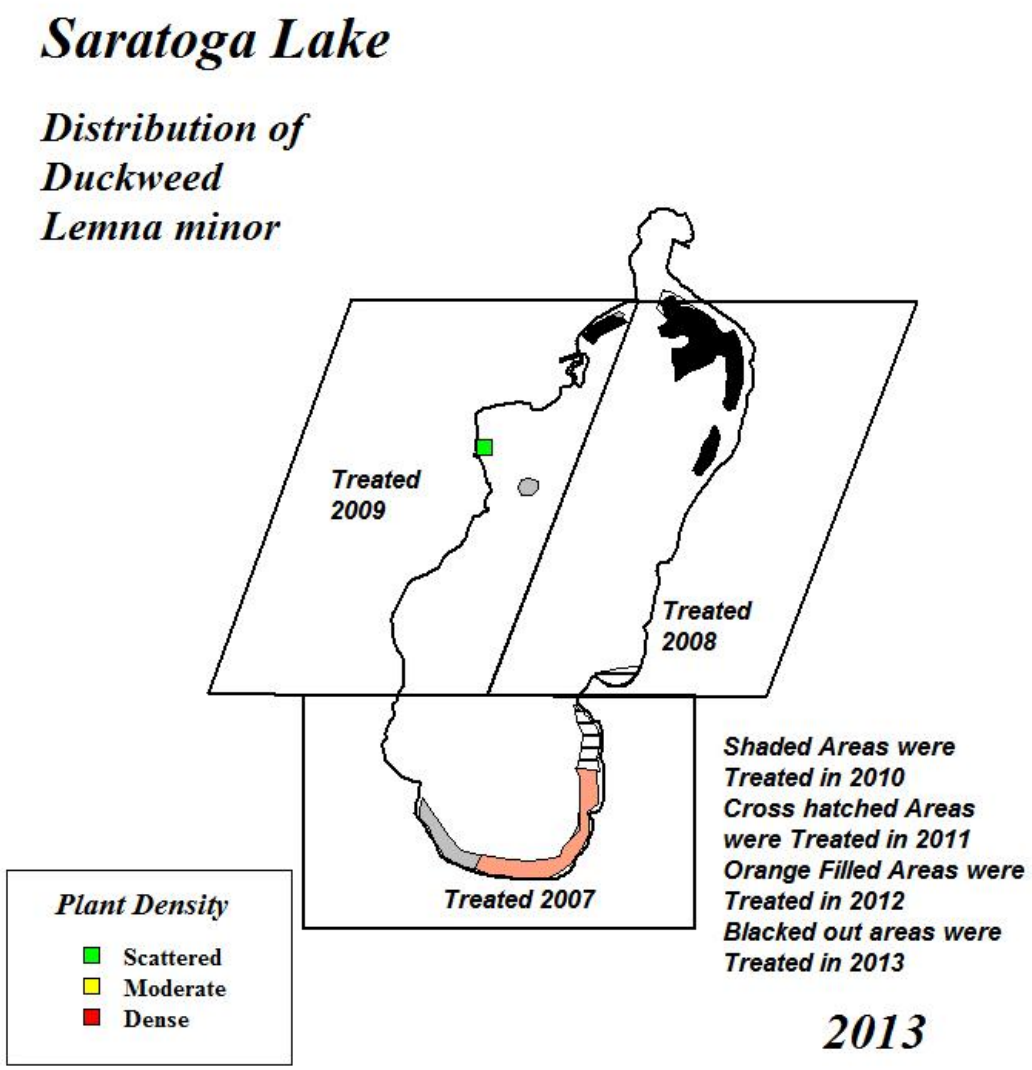
Saratoga Lake

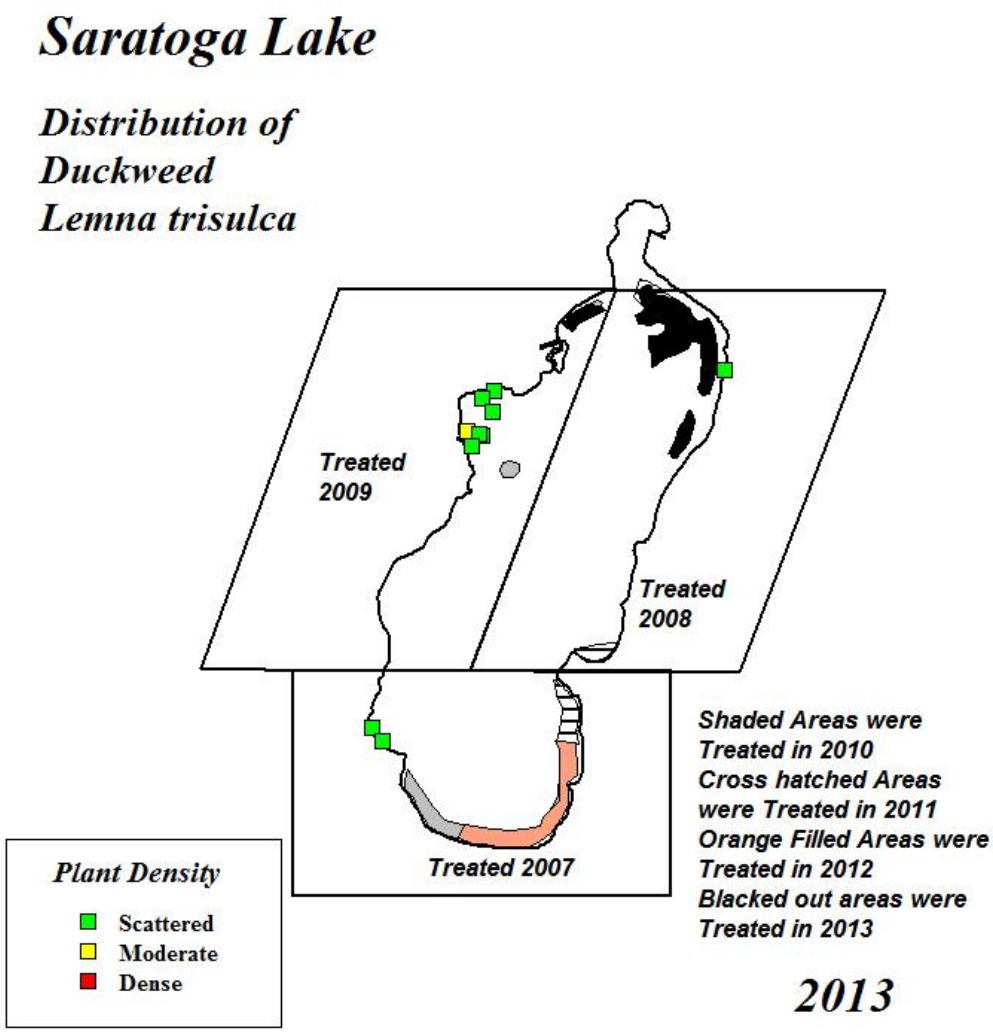
Distribution of Coontail Ceratophyllum demersum

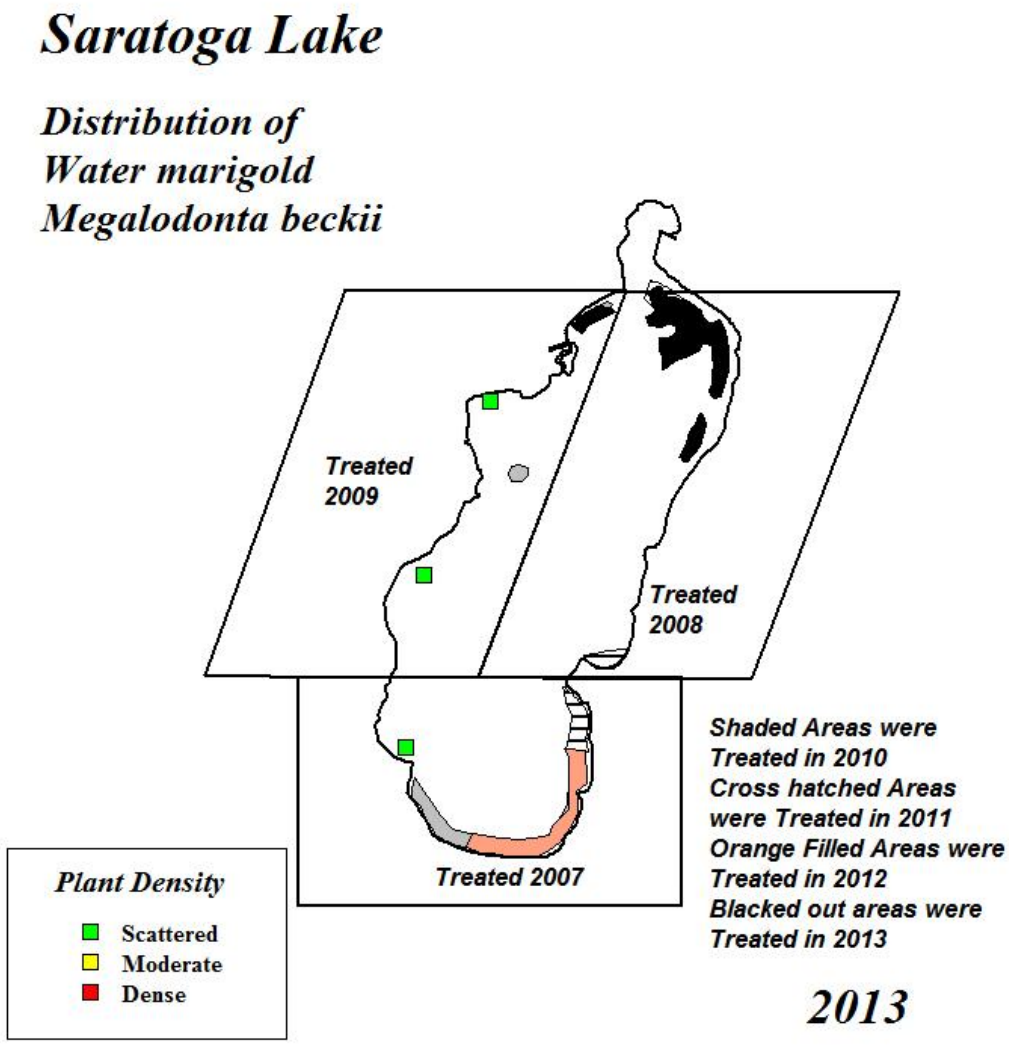


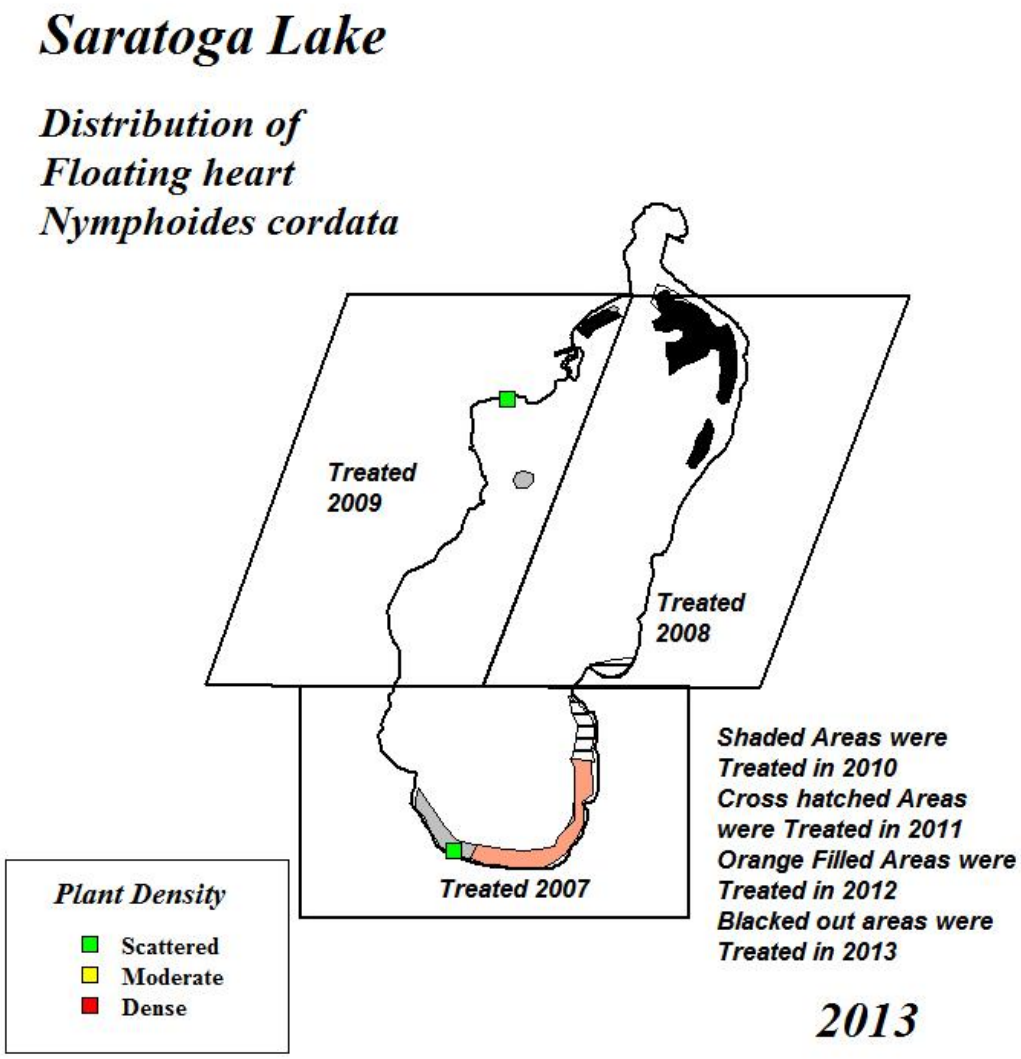

Saratoga Lake
Distribution of
Muskgrass
Chara spp.
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

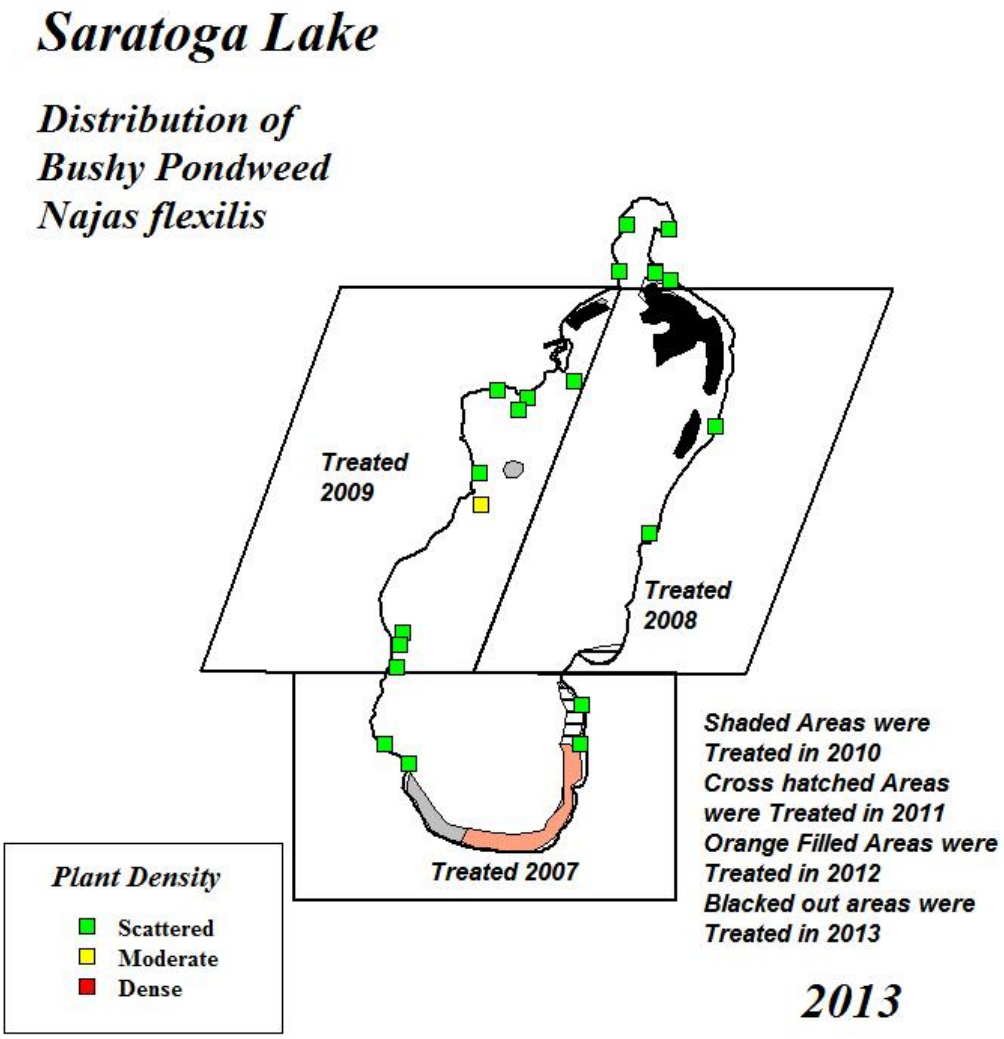

Saratoga Lake
Distribution of
Waterweed
Elodea canadensis
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

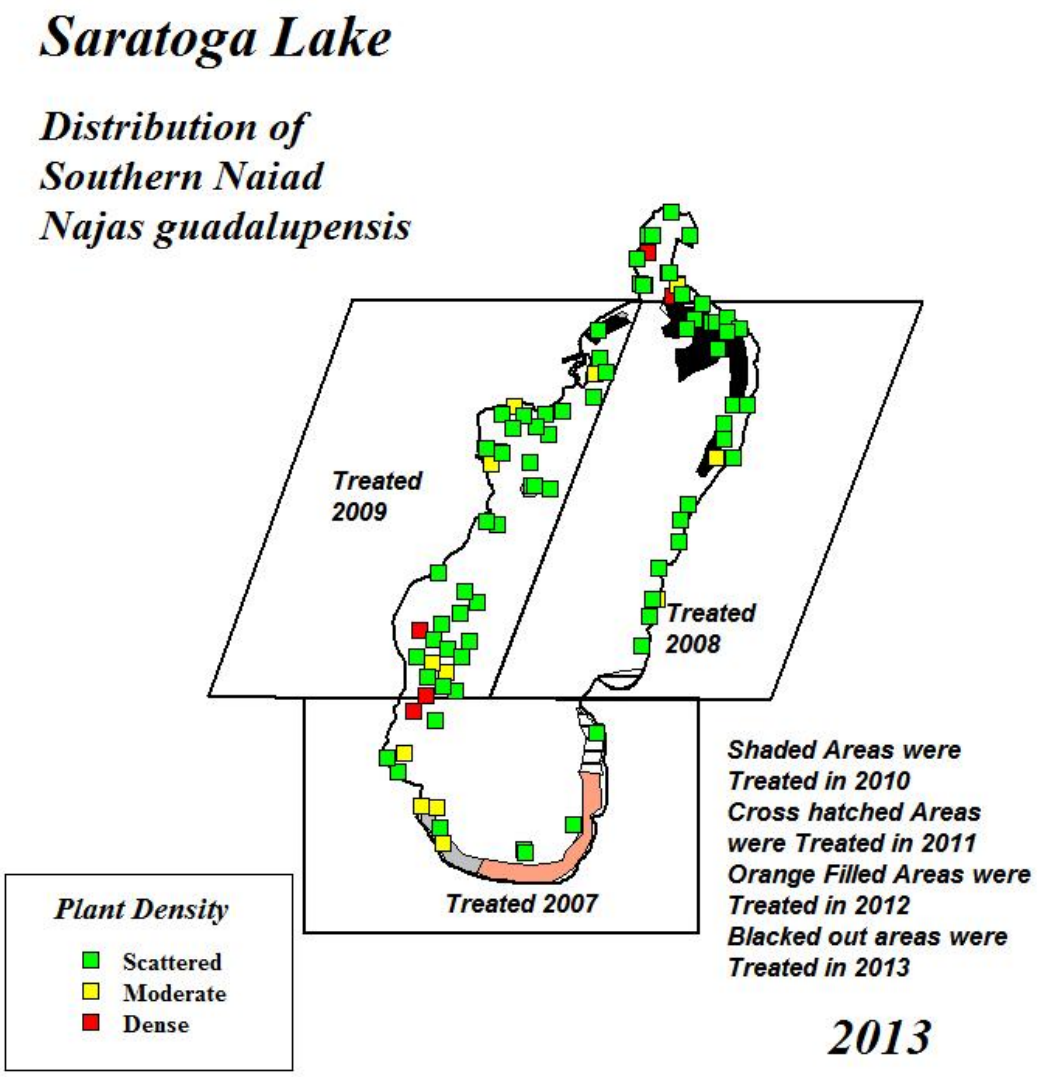

Saratoga Lake
Distribution of
Duckweed
Lemna minor
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

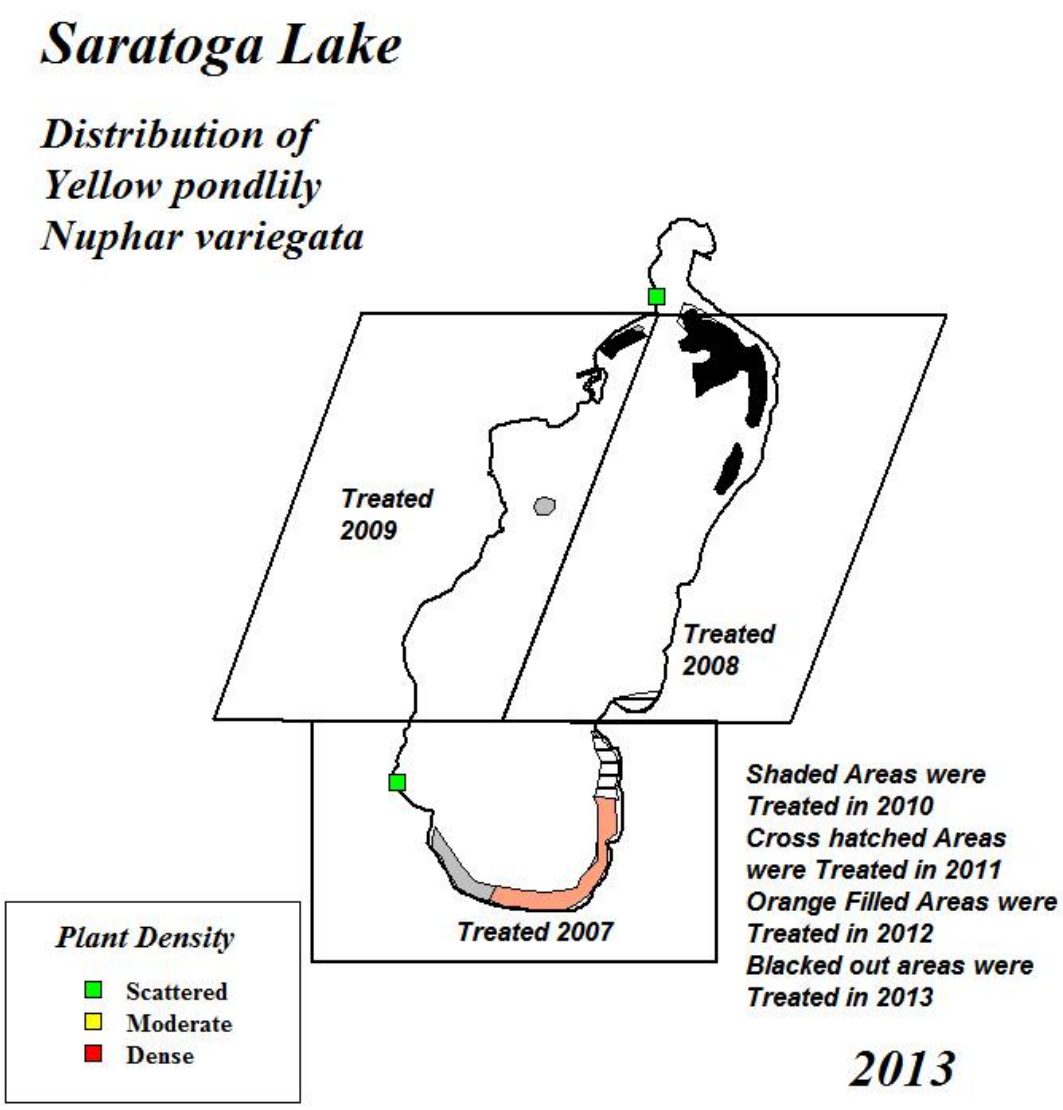

Saratoga Lake
Distribution of
Duckweed
Lemna trisulca
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

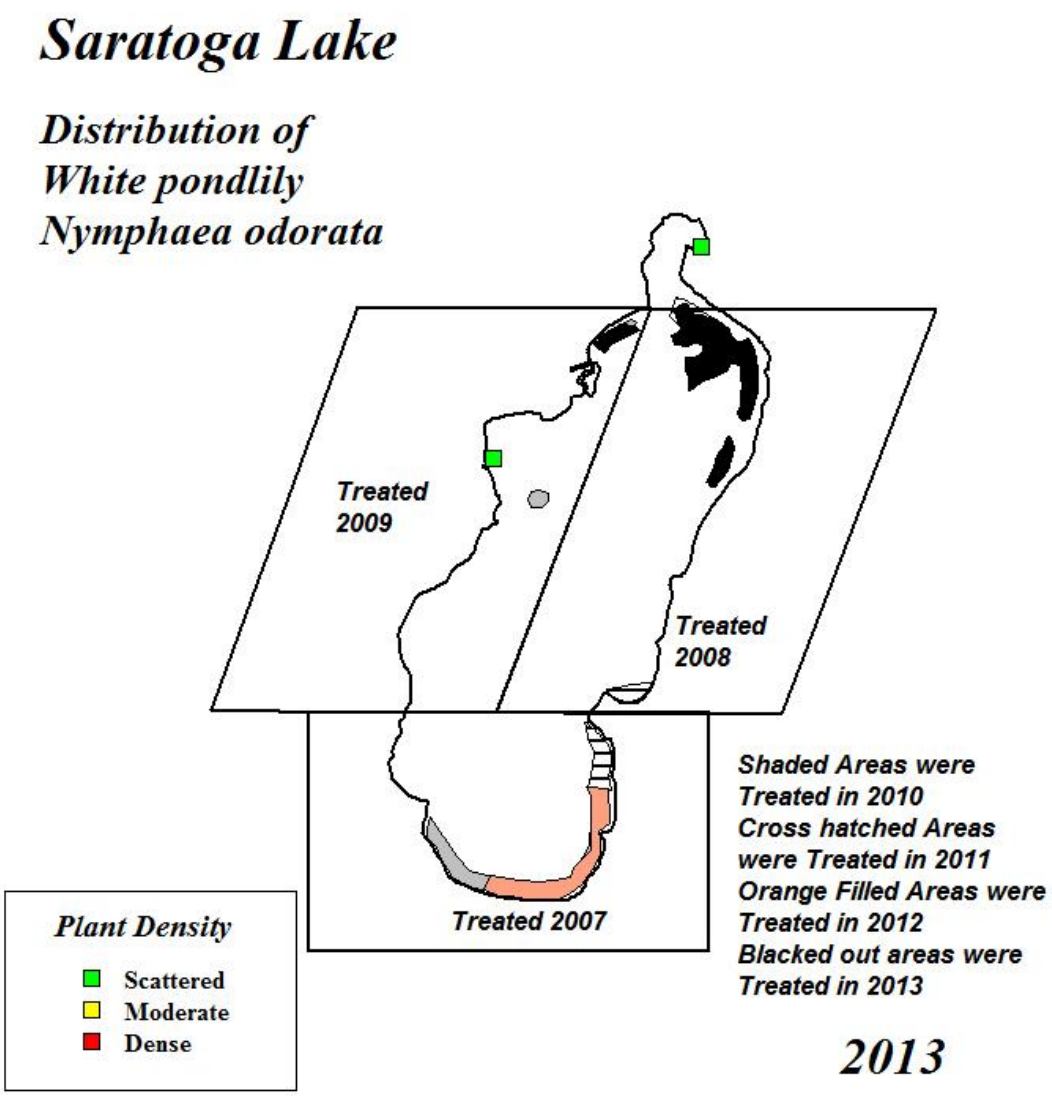

Saratoga Lake
Distribution of
Water marigold
Megalodonta beckii
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

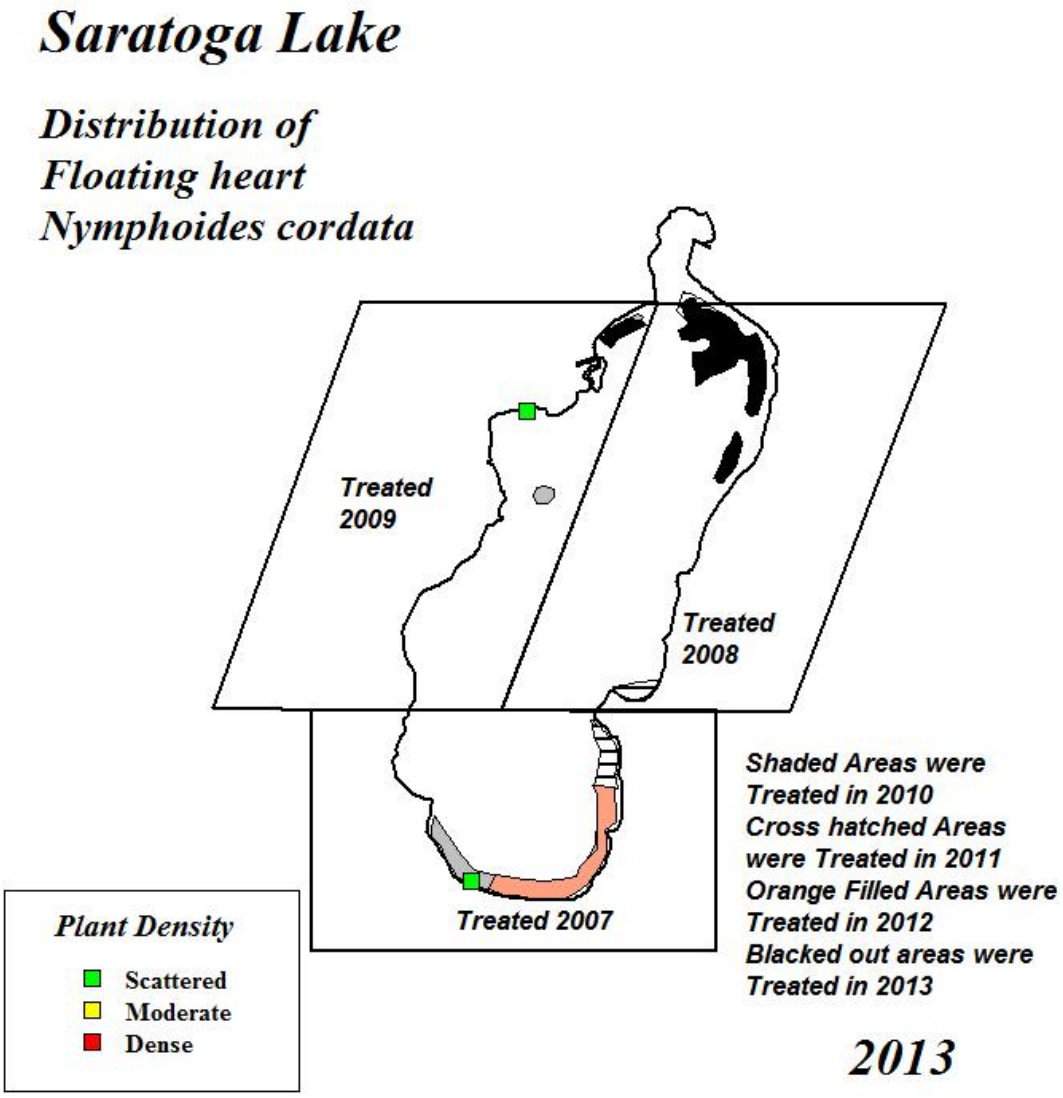

Saratoga Lake
Distribution of
Floating heart
Nymphoides cordata
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

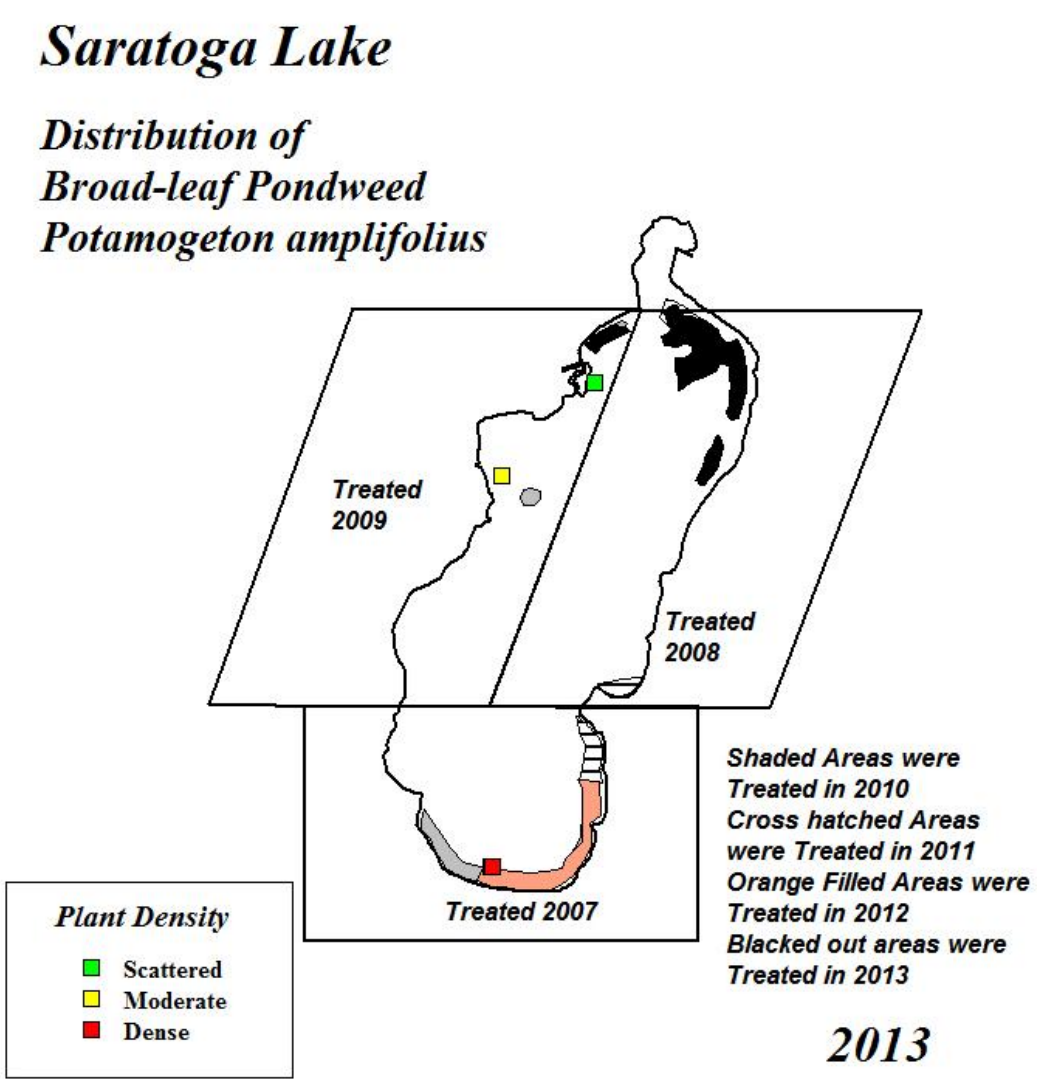

Saratoga Lake
Distribution of
Bushy Pondweed
Najas flexilis
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

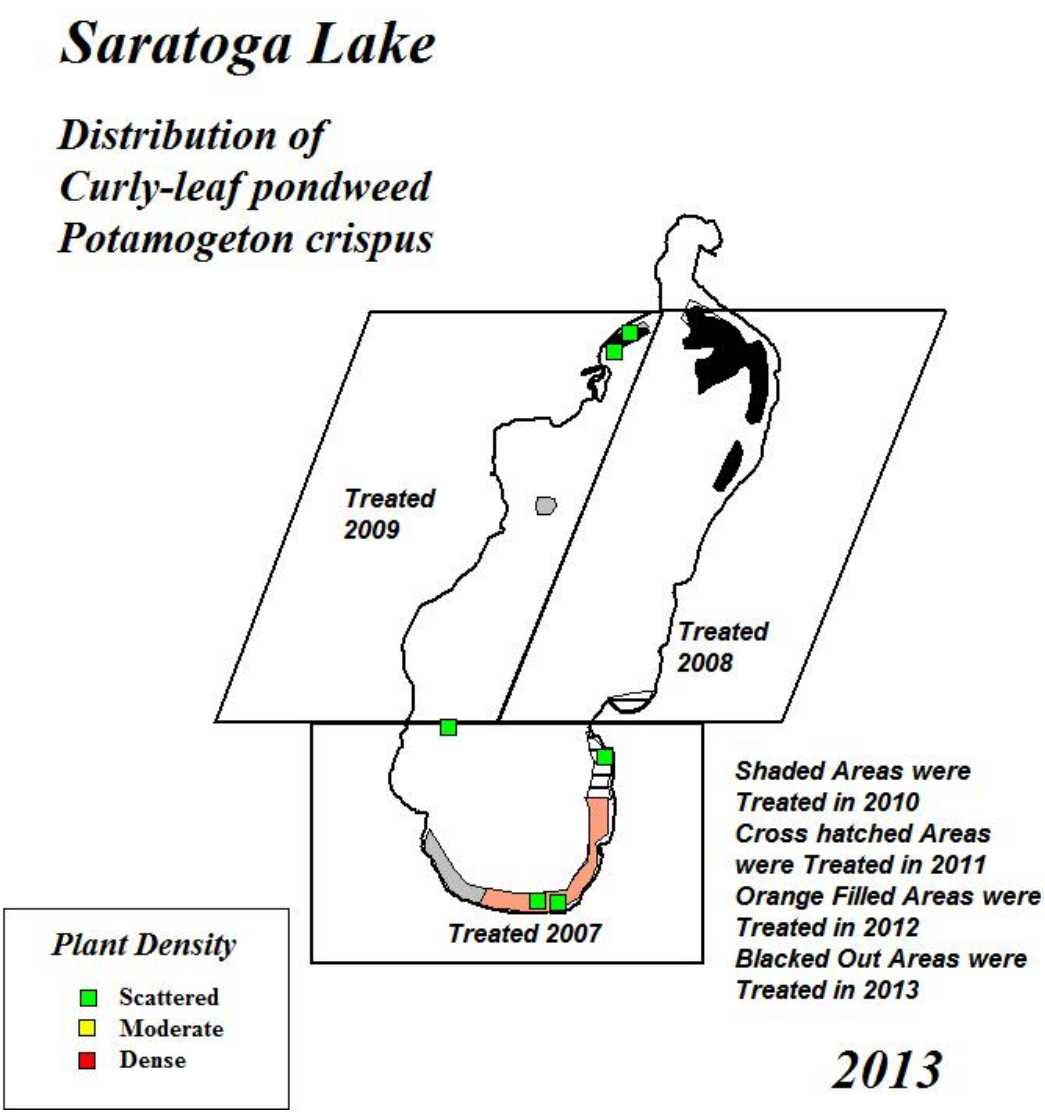

Saratoga Lake
Distribution of
Southern Naiad
Najas guadalupensis
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

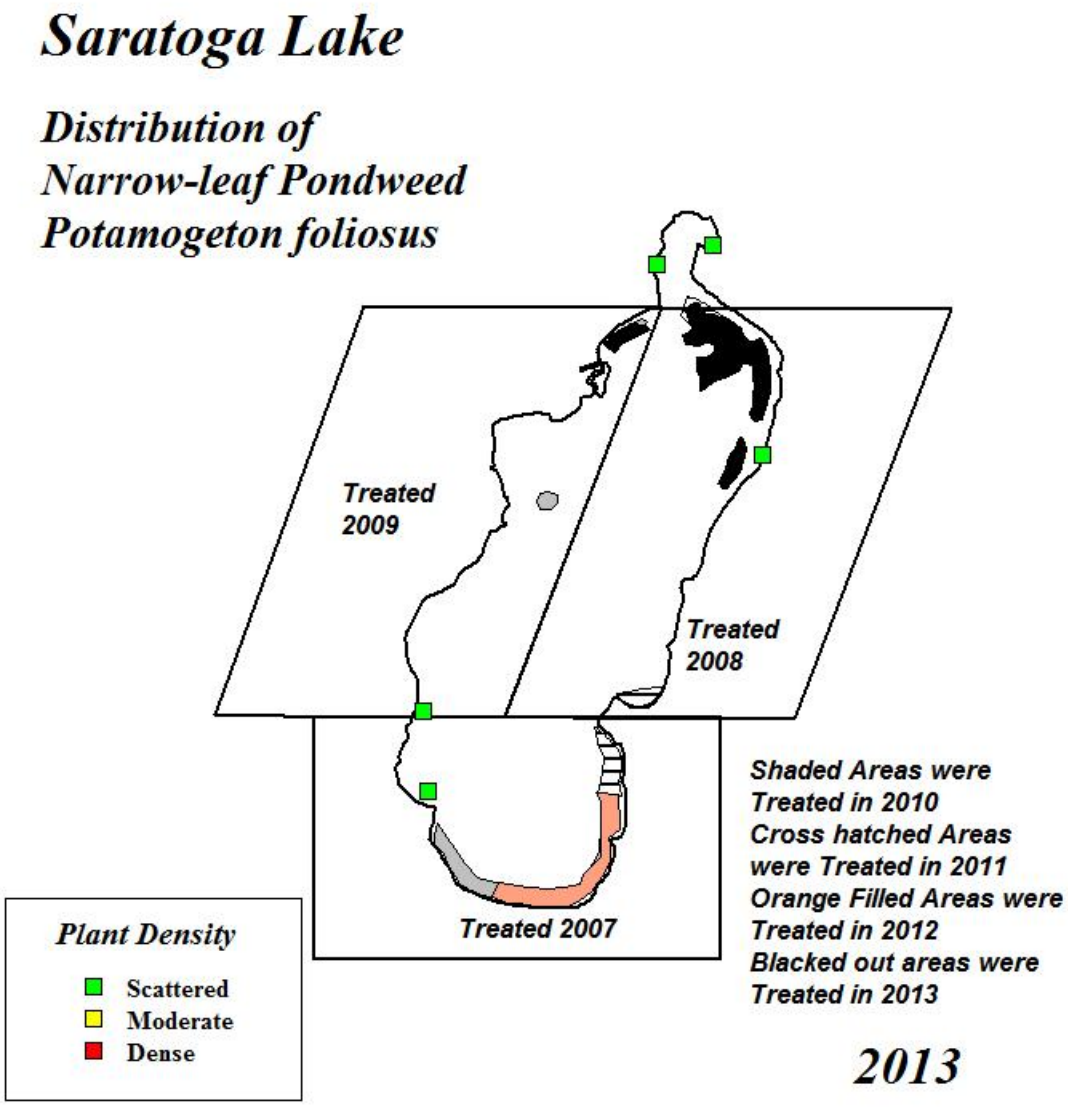

Saratoga Lake
Distribution of
Yellow pondlily
Nuphar variegata
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

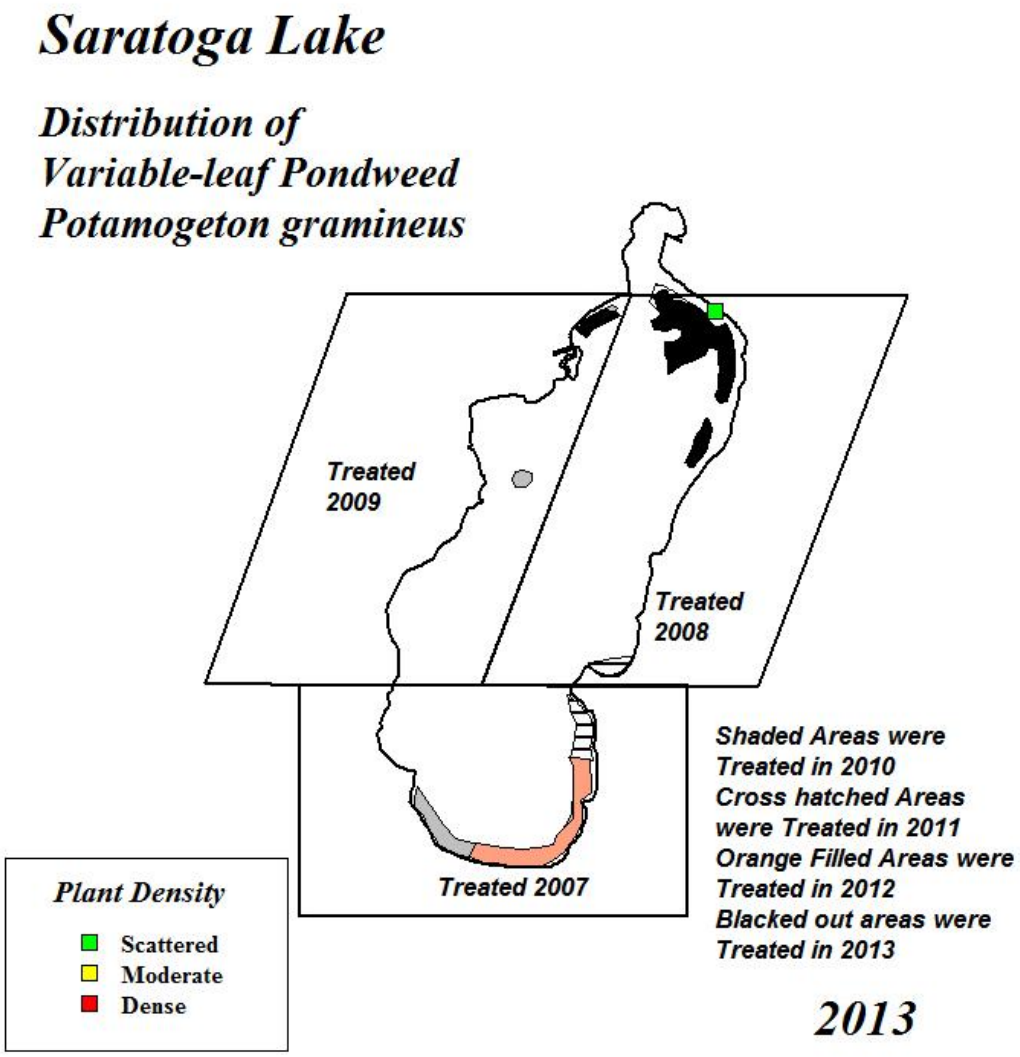

Saratoga Lake
Distribution of
White pondlily
Nymphaea odorata
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

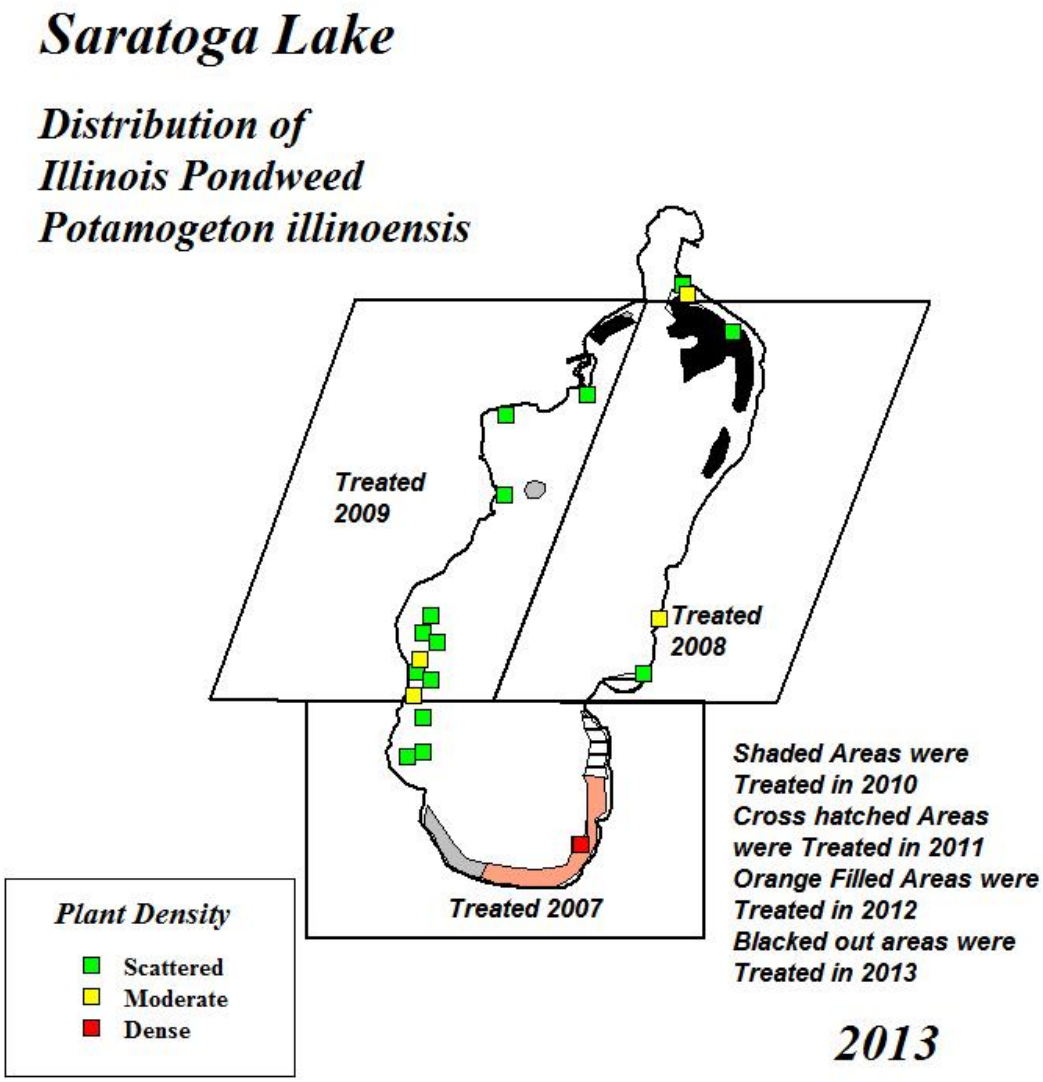

Saratoga Lake
Distribution of
Floating heart
Nymphoides cordata
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

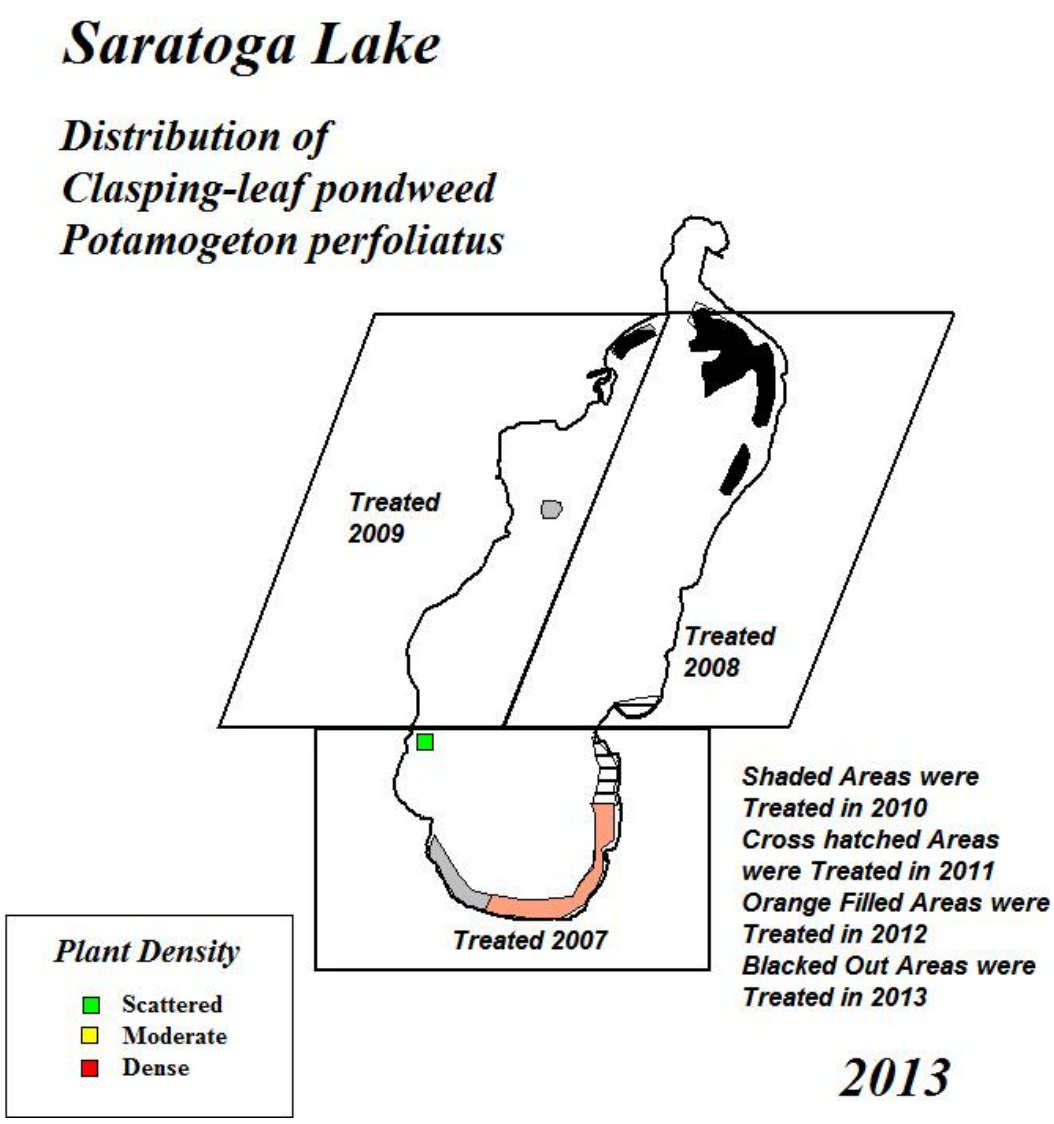

Saratoga Lake
Distribution of
Broad-leaf Pondweed
Potamogeton amplifolius
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

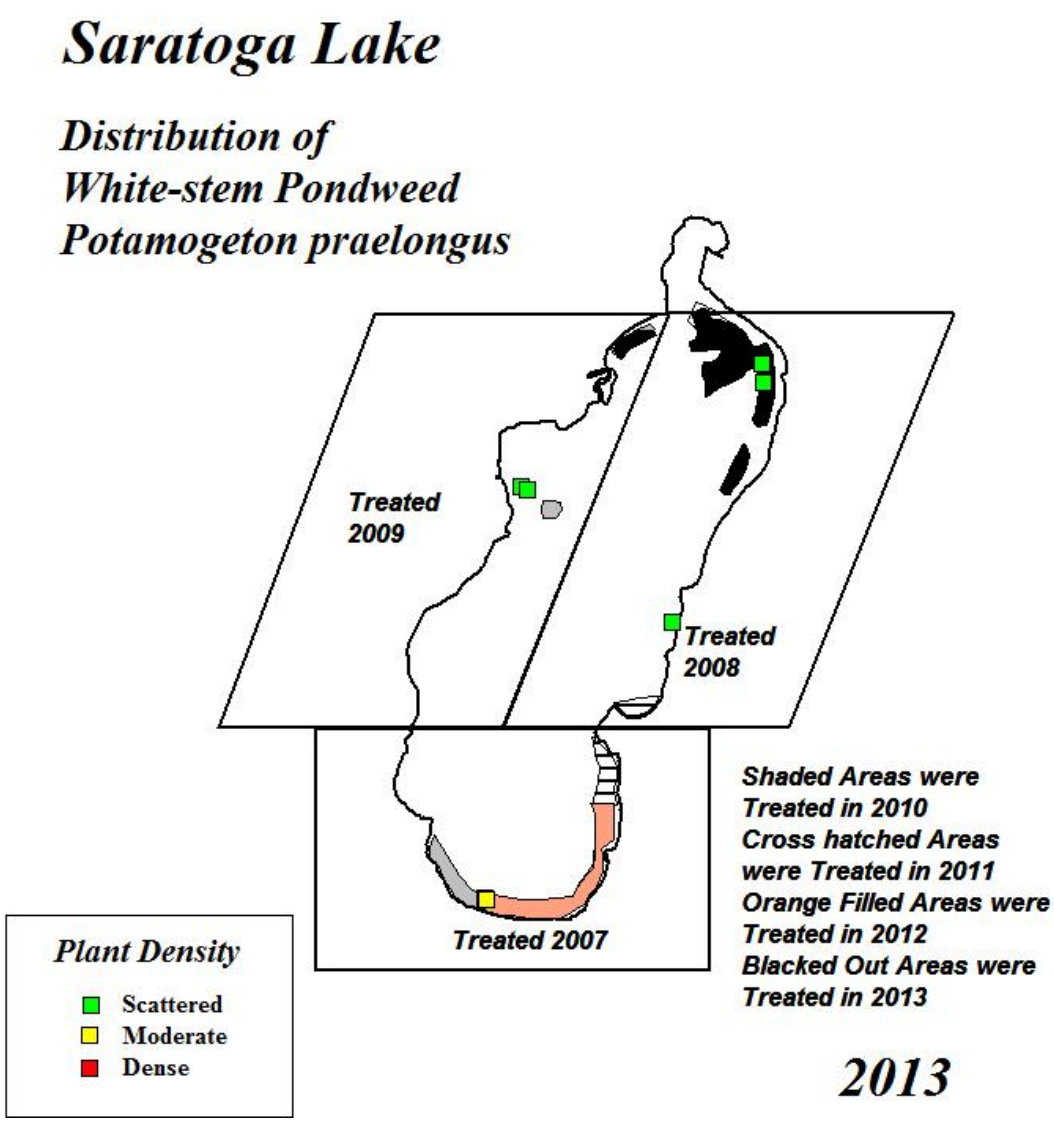

Saratoga Lake
Distribution of
Curly-leaf pondweed
Potamogeton crispus
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
Plant Density
Scattered
Moderate
Dense
2013

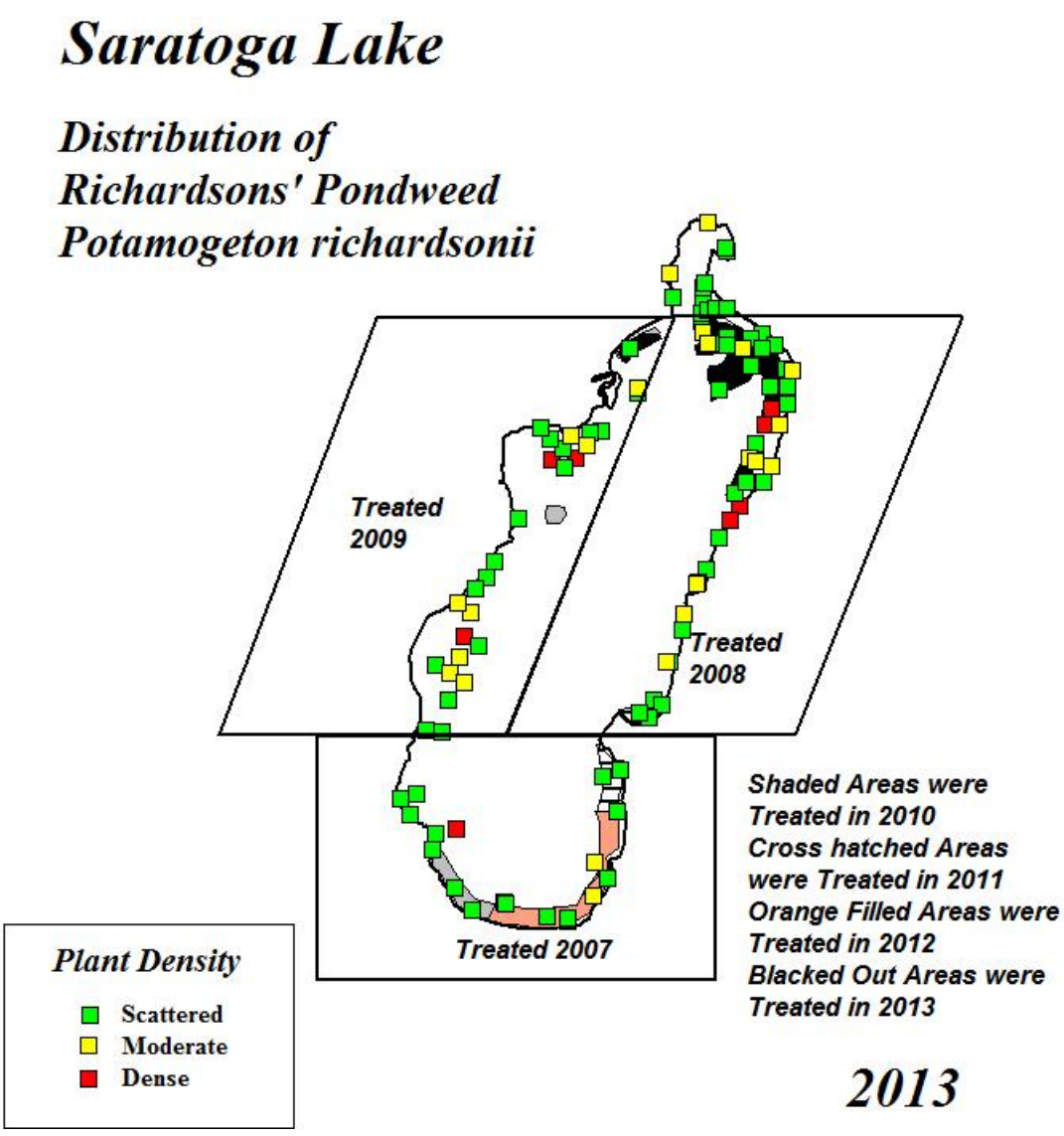

Saratoga Lake
Distribution of
Narrow-leaf Pondweed
Potamogeton foliosus
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

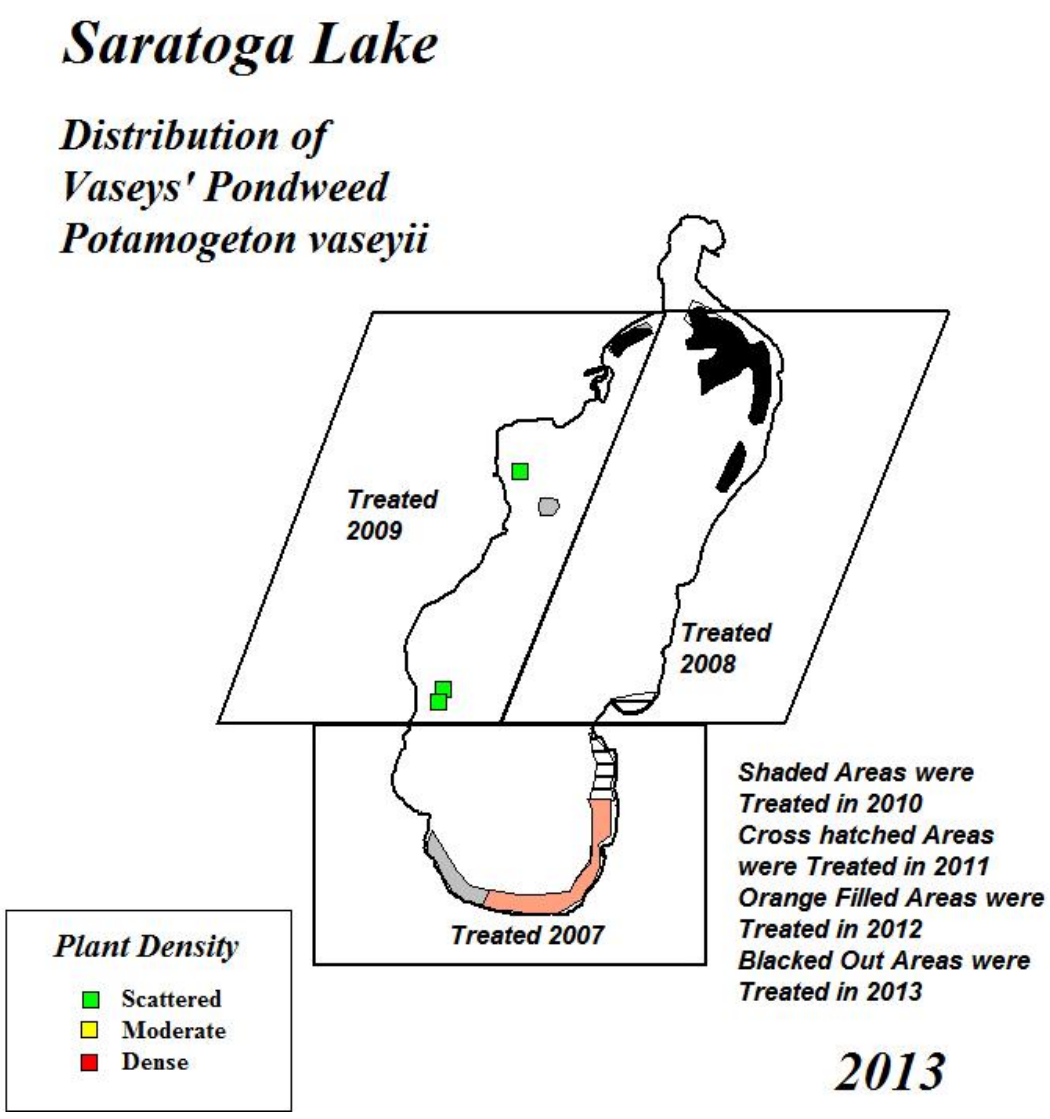

Saratoga Lake
Distribution of
Variable-leaf Pondweed
Potamogeton gramineus
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

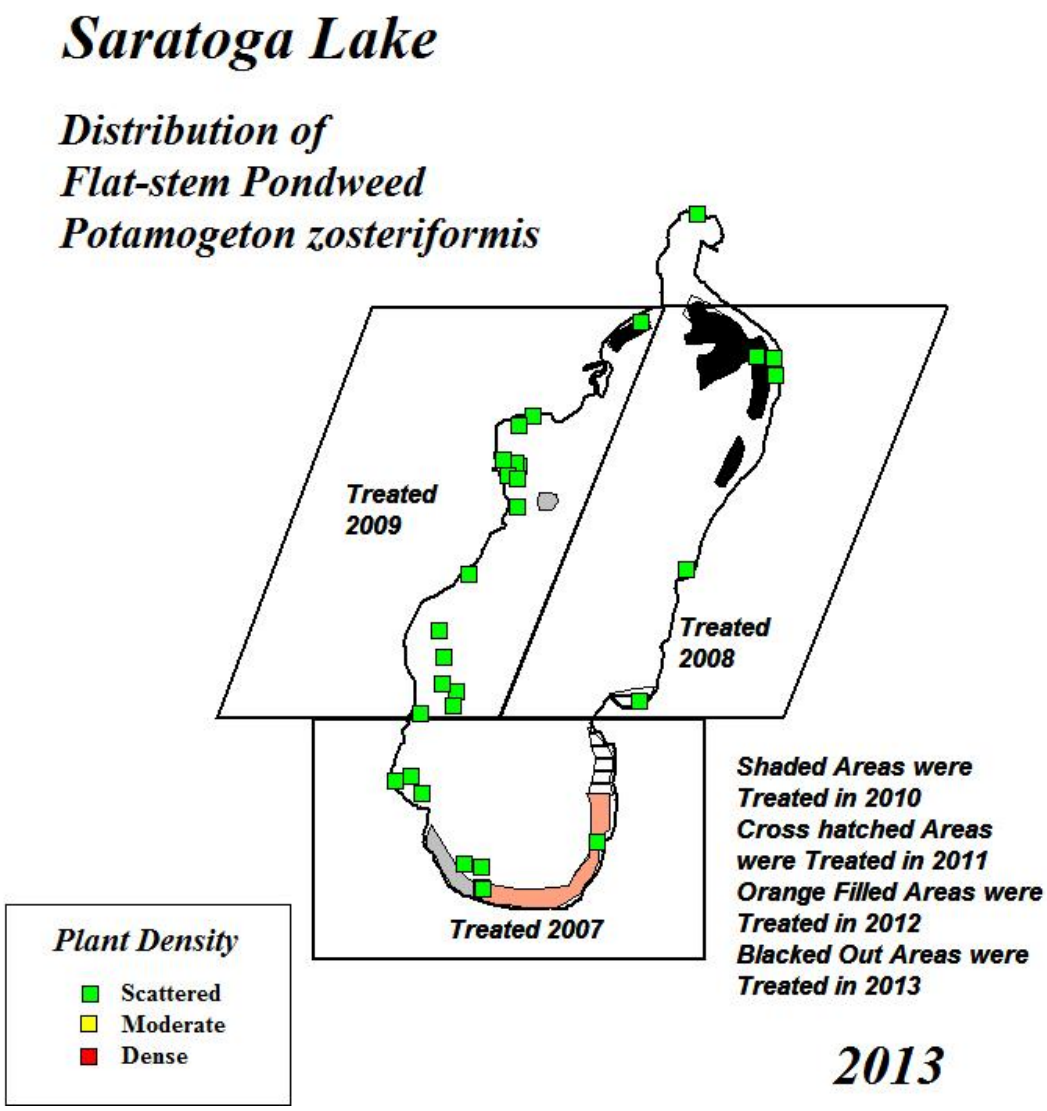

Saratoga Lake
Distribution of
Illinois Pondweed
Potamogeton illinoensis
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked out areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

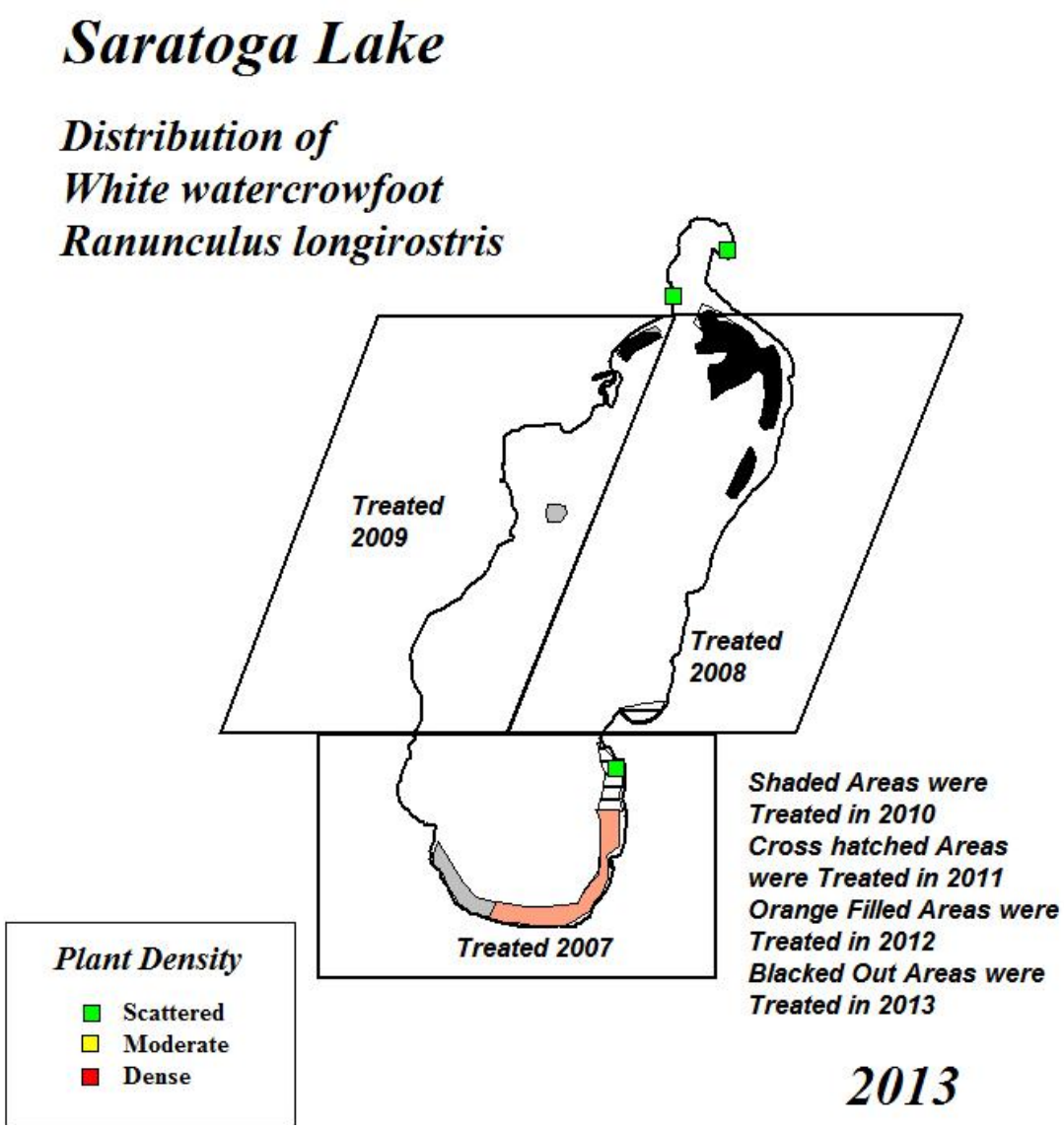

Saratoga Lake
Distribution of
Clasping-leaf pondweed
Potamogeton perfoliatus
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

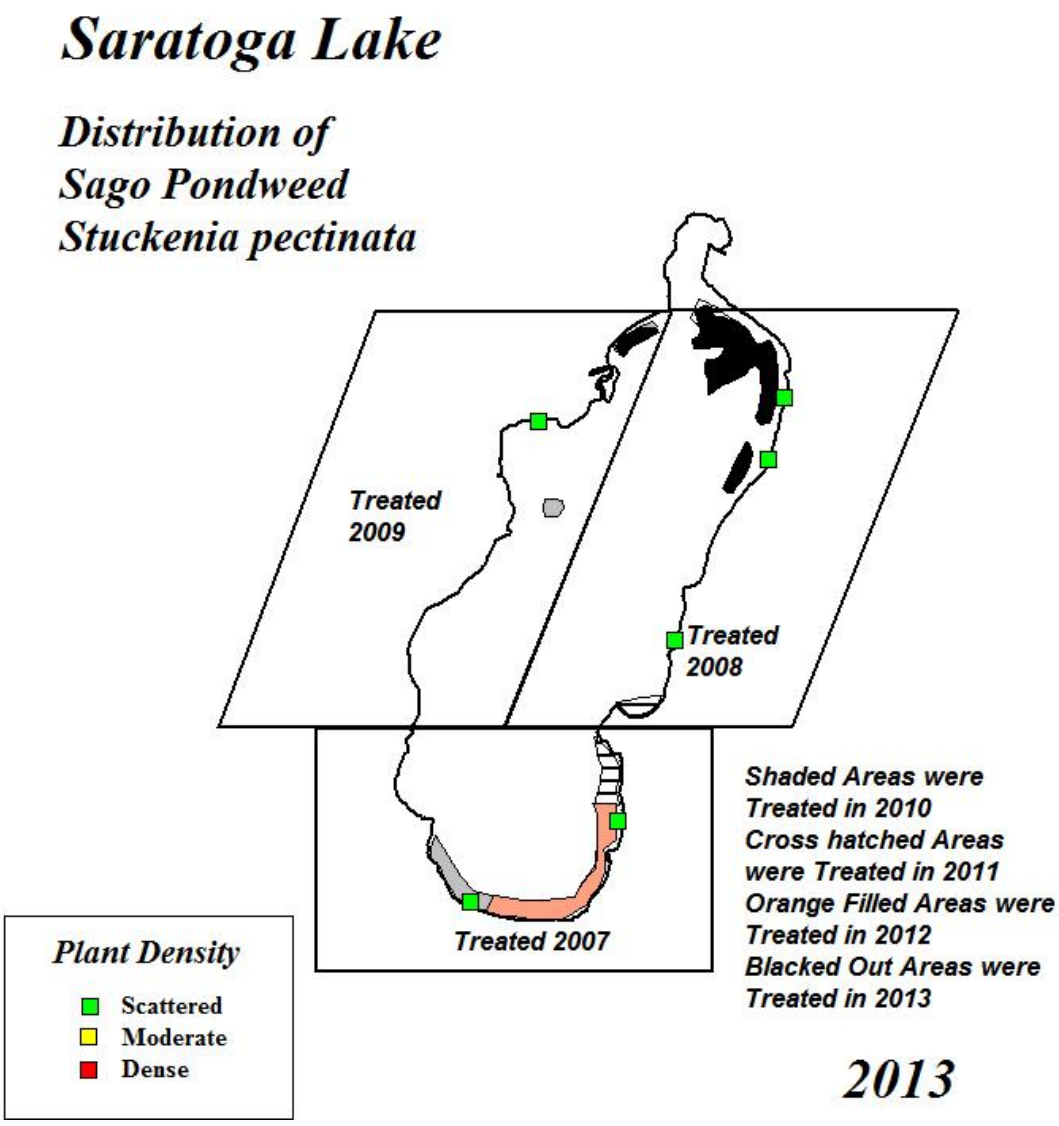

Saratoga Lake
Distribution of
White-stem Pondweed
Potamogeton praelongus
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

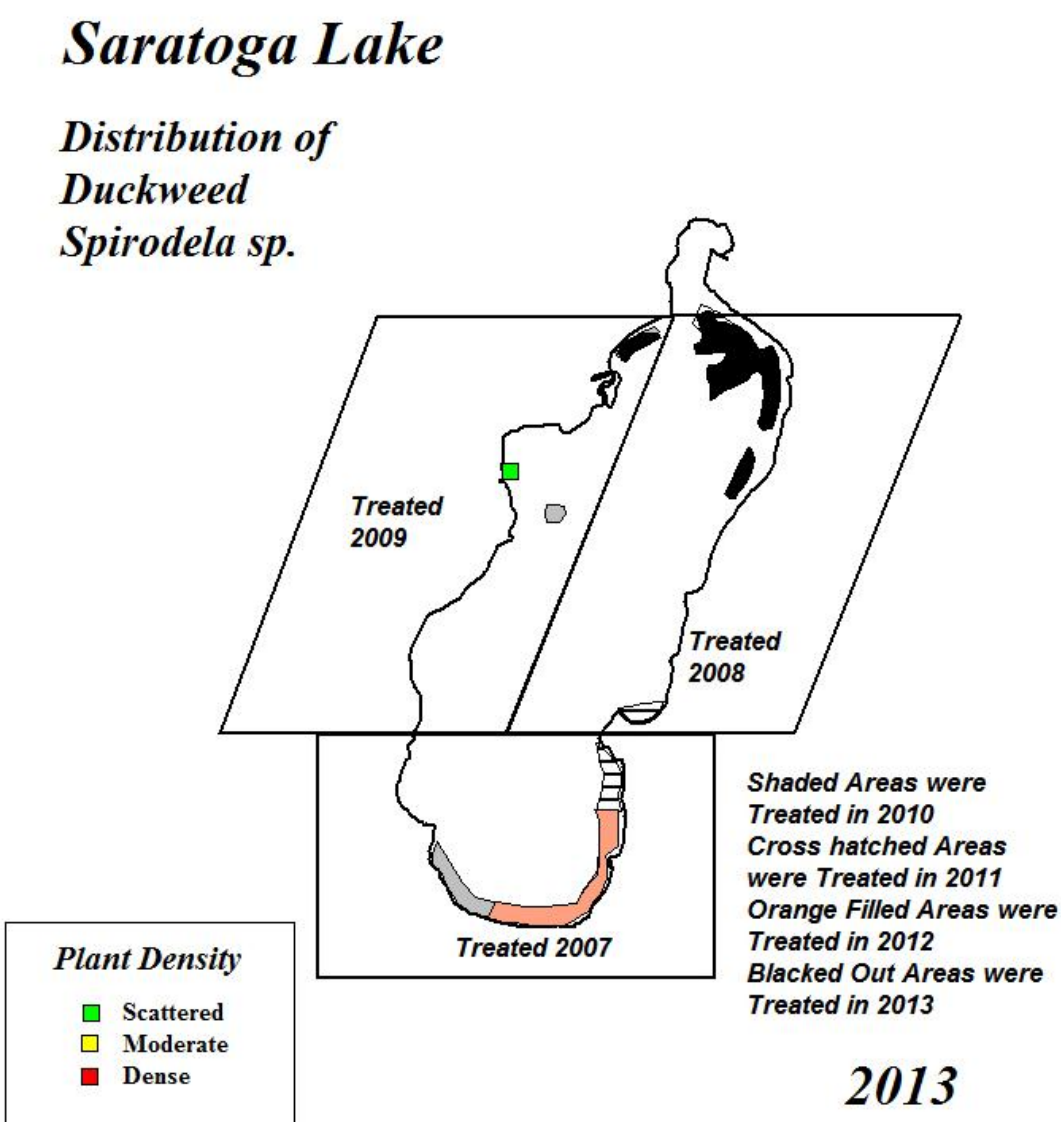

Saratoga Lake
Distribution of
Richardsons' Pondweed
Potamogeton richardsonii
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
Plant Density
Scattered
Moderate
Dense
2013

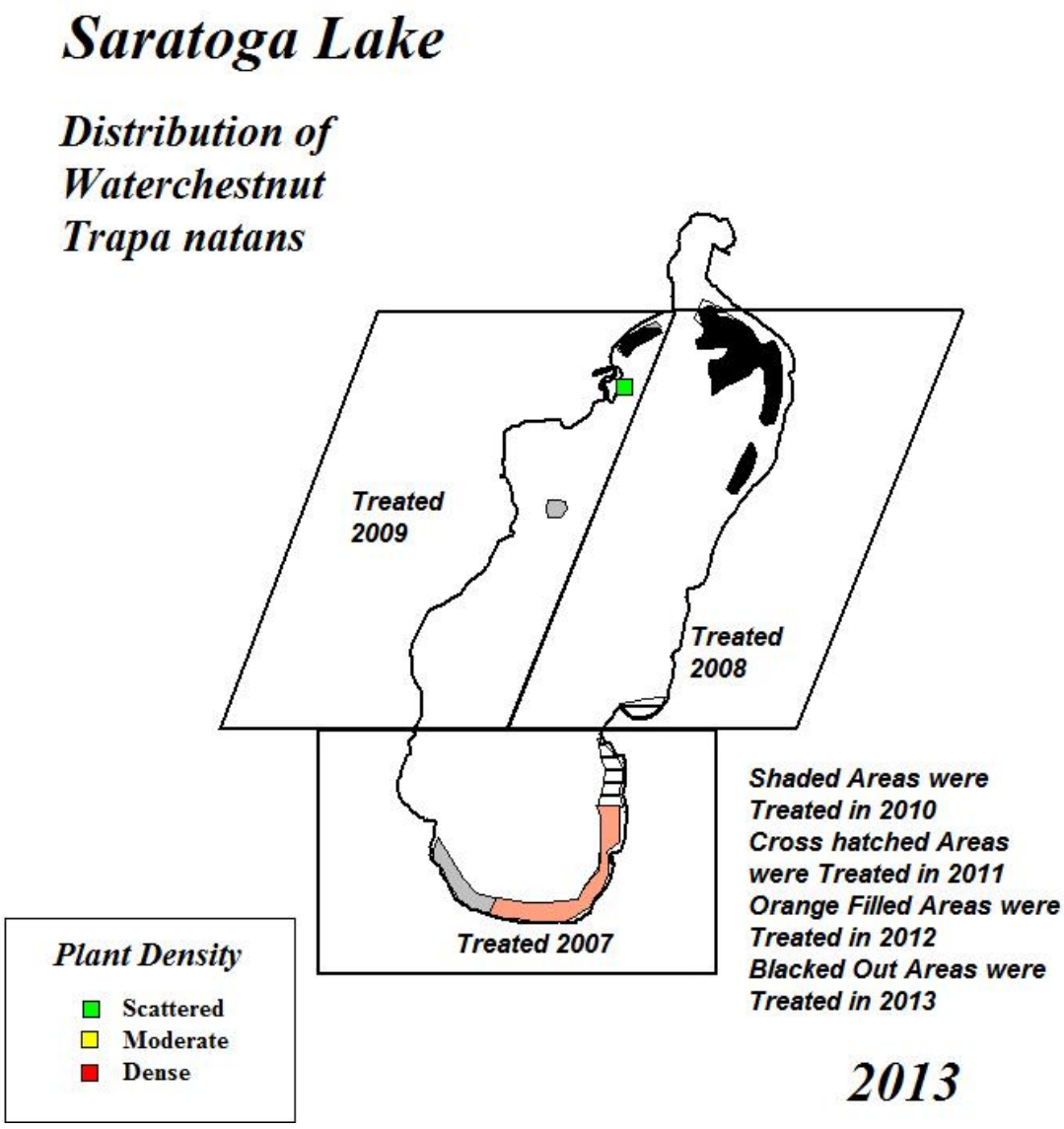

Saratoga Lake
Distribution of
Vaseys' Pondweed
Potamogeton vaseyii
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense

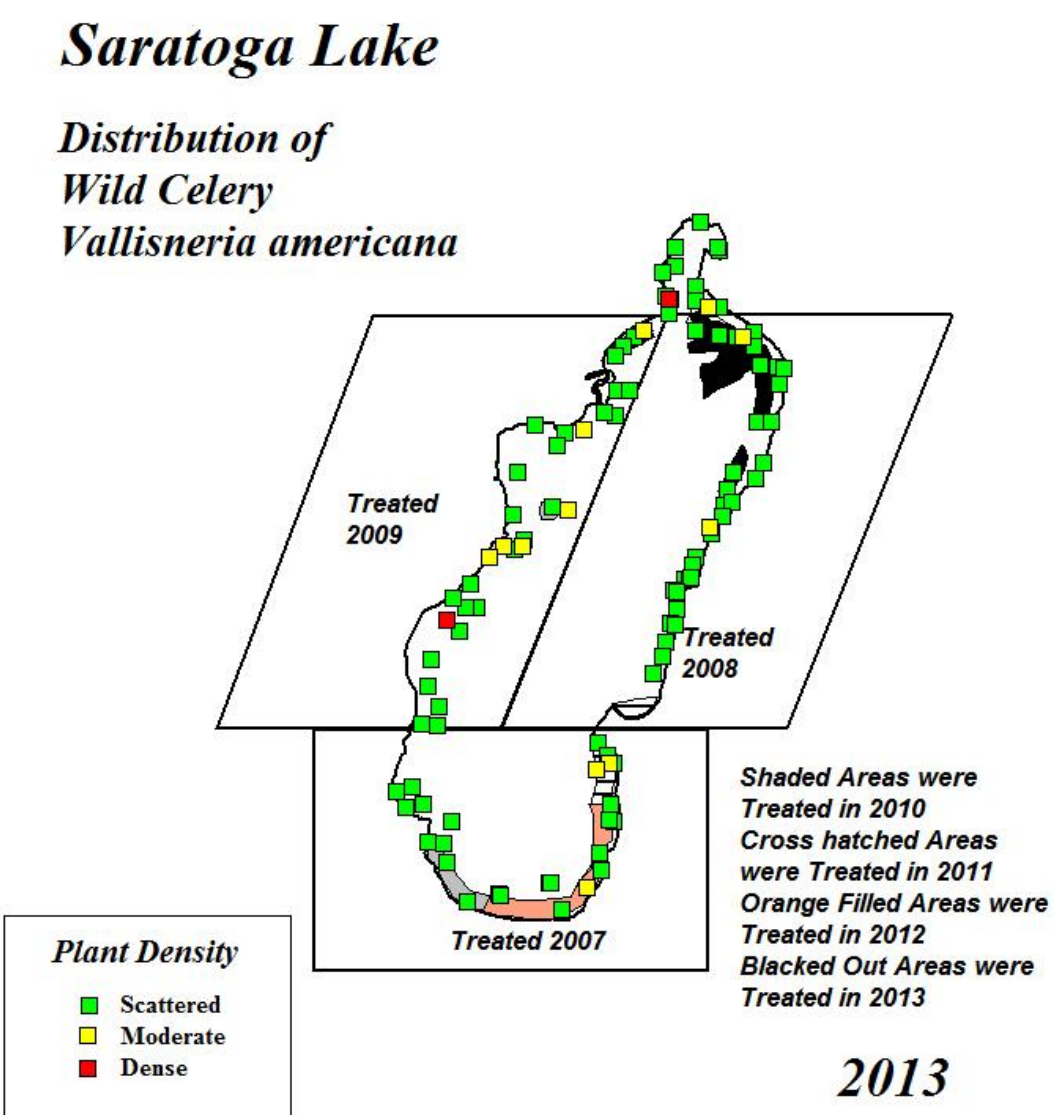

Saratoga Lake
Distribution of
Flat-stem Pondweed
Potamogeton zosteriformis
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense


Saratoga Lake
Distribution of
White watercrowfoot
Ranunculus longirostris
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense


Saratoga Lake
Distribution of
Sago Pondweed
Stuckenia pectinata
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense


Saratoga Lake
Distribution of
Duckweed
Spirodela sp.
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
Plant Density
Scattered
Moderate
Dense
2013


Saratoga Lake
Distribution of
Waterchestnut
Trapa natans
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
Treated in 2013
2013
Plant Density
Scattered
Moderate
Dense


Saratoga Lake
Distribution of
Wild Celery
Vallisneria americana
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
Blacked Out Areas were
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Plant Density
Scattered
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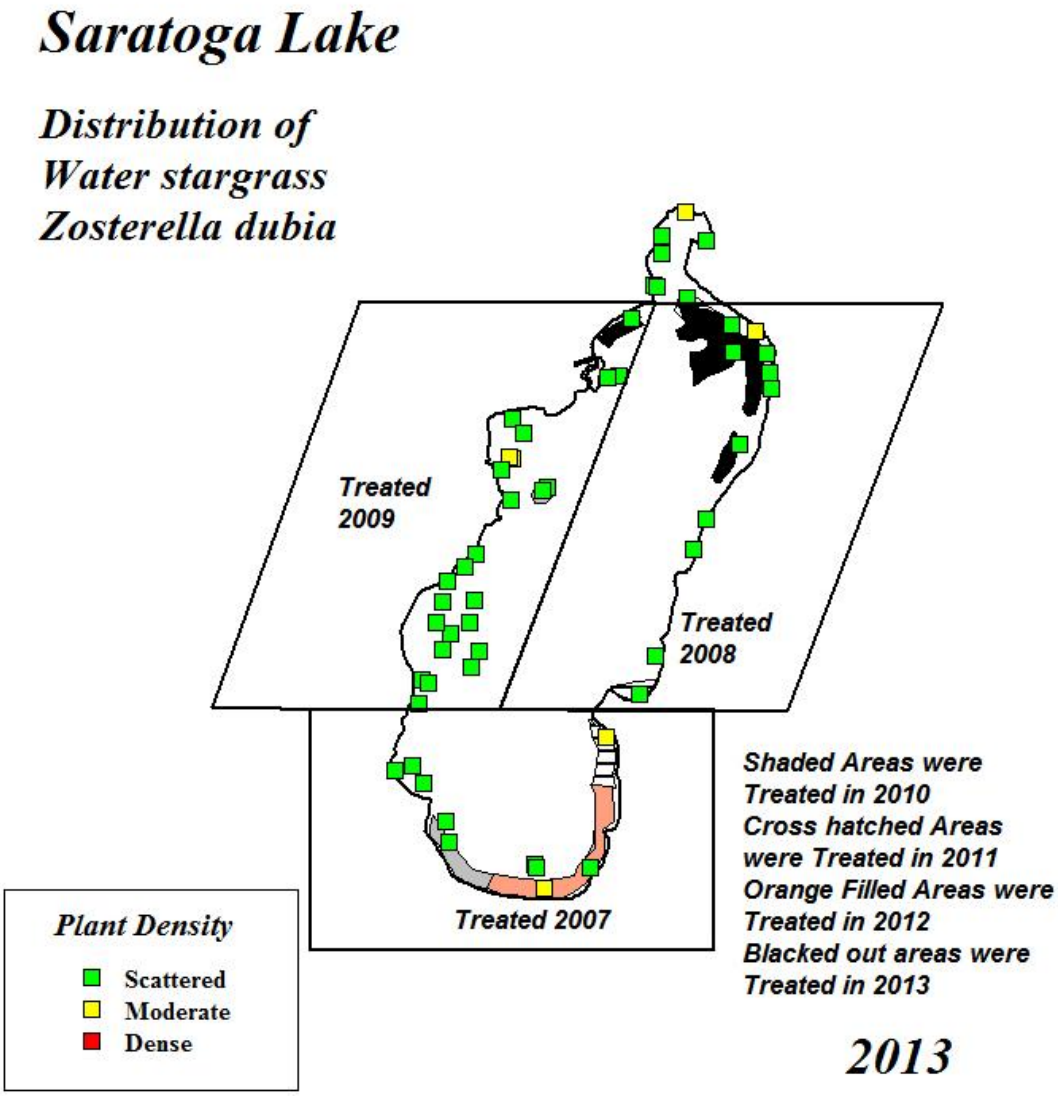
Dense
2013


Saratoga Lake
Distribution of
Water stargrass
Zosterella dubia
Treated
2009
Treated
2008
Treated 2007
Shaded Areas were
Treated in 2010
Cross hatched Areas
were Treated in 2011
Orange Filled Areas were
Treated in 2012
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