DARRIN
Fresh Water Institute

Lake George, New York
Adirondack Field Station at Bolton Landing

An Assessment of Aquatic Plant Growth in Galway Lake, Saratoga County, New York

Prepared for the

Galway Lake Campers Association

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TABLE OF CONTENTS

List of Tables

List of Figures

Executive Summary

A quantitative aquatic plant survey was conducted for Galway Lake, Galway, New York as part of a cooperative effort between the Darrin Fresh Water Institute (DFWI) and the Galway Lake Campers' Association. The aquatic plant survey was designed to provide data on aquatic plant distribution and to evaluate a treatment program based on lake level drawdown and benthic barrier installation to control Eurasian watermilfoil (*Myriophyllum spicatum*). The Point-Intercept Rake Toss method presently required by NYS DEC for Tier III Lakes was employed. The assessment generated information necessary to: 1) review effectiveness of aquatic plant management efforts, 2) meet selected permit requirements and 3) provide data for comparison of post-treatment conditions to prior survey information.

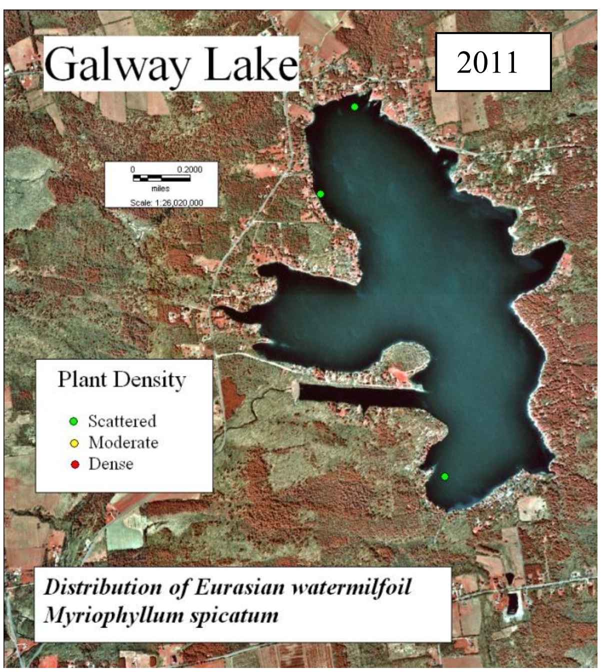
The aquatic plant community of Galway Lake in August of 2011 included one group of macroscopic alga, or charophytes (*Chara/Nitella*), two floating-leafed species (*Nuphar* and *Nymphaea*), four emergent species (*Sparganium, Scirpus, Typha* and *Pontederia*) and 18 submersed species. A total of 19 aquatic plant species were collected in the point intercept survey, a species richness which compares favorably with the New York State average of 15 species reported for lakes of moderate productivity statewide. Lake-wide aquatic plants were found to occur in 99% of all survey points in the littoral zone. The large number of points supporting native plant species suggests that Galway Lake is a prime candidate for recovery of its native plant population following management of Eurasian watermilfoil. These results also suggest that lake level drawdown is not having a particularly negative impact on native aquatic plant species.

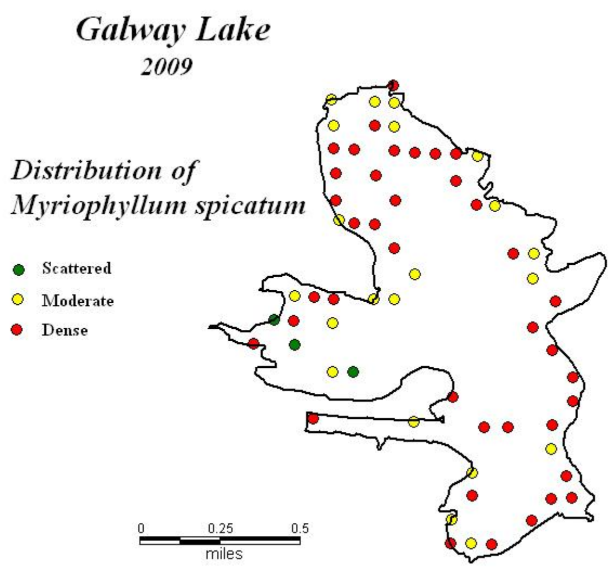
Macroalgae (*Chara* sp. and *Nitella* sp.) were the most common plants, present in 83% of survey points. Water naiad (*Najas flexilis*), a common native species was the most widely distributed rooted plant (38% of points), followed closely by narrow-leaf pondweed (*Potamogeton pusillus*) at 29% of points. Brittle naiad (*Najas minor*) was the most abundant invasive species, found in 30% of points. Eurasian watermilfoil declined substantially, reported in 5% of points, down from 34% in 2009. Common native macrophytes species included *Potamogeton zosteriformis* (26%), *Ceratophyllum demersum* (24%), *Vallisneria americana* (21%), *Potamogeton perfoliatus* (20%), and *Elodea canadensis* (17%).

In 2011, species richness was 3.44 ± 0.18 species per survey point, nearly identical to the 3.44 ± 0.15 species per sample reported in 2009. These results are comparable to other low elevation mesotrophic (moderately productive) lakes within our region. 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 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 littoral zone and its shallow fringe was higher than whole lake species richness, an indication that lake level drawdown has not had a substantial impact on species richness.

Eurasian watermilfoil (*Myriophyllum spicatum*) expanded rapidly in Galway Lake, after an initial invasion in the mid 1980's. Eurasian watermilfoil populations were first confirmed in 1989, and dominated the aquatic plant community. Annual lake level drawdowns of 3 to 5 feet were initiated in 1990 as an aquatic plant management technique, with deeper drawdowns conducted periodically. Reduced Eurasian watermilfoil growth in the shallow, shoreline areas may be attributed to drawdown. By 2009, Eurasian watermilfoil had declined to the third most common plant species, present in 34 percent of survey points. Two other exotic aquatic plant species were reported, Waterchestnut (*Trapa natans)* and Curly-leaf Pondweed (*Potamogeton crispus*). Waterchestnut was first reported as scattered individuals in the northeastern cove in 2009. All visible specimens were removed by hand harvesting. Curly-leaf Pondweed was reported in 1989 at a number of locations. The lack of Curly-leaf Pondweed in the 2009 survey may be attributed to the timing of that survey (August), rather than an actual decline in the abundance of this species. Curly-leaf Pondweed generally reaches peak abundance in June and July, and then undergoes senescence. A small number of Curly-leaf Pondweed plants were observed in 2011.

Exotic species, dominated by Eurasian watermilfoil, were clearly abundant lake-wide in 2009. Following a deep drawdown in 2010 – 11, Eurasian watermilfoil abundance declined to 5% of survey points. A new invasive species, Brittle Naiad (*Najas minor*) was the most abundant exotic species in 2011. This species is known to be expanding its' range northward and is particularly efficient at invading disturbed locations, including bottom areas exposed by lake level drawdown. With the diversity and distribution of native species present in Galway Lake, native plant restoration in areas formerly inhabited by Eurasian watermilfoil appears to be rapid following management efforts.





Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) growth in Galway Lake in 2011 and 2009.

The current aquatic plant management program has two components: annual drawdowns to control Eurasian watermilfoil and limited use of benthic barrier in high traffic areas to provide access and limit fragmentation of Eurasian watermilfoil. In 2010 – 11, a deep drawdown to 12 feet below mean high water was conducted to expose the majority of the littoral zone. Ice scour, which occurs when ice scrapes the lake bottom during Spring 'ice-out', further extends the effective depth of deep drawdowns, sometime by as much as 3 feet depending on the severity of the Winter. Results from the current survey indicate that Eurasian watermilfoil growth has been limited lake-wide as a result of this practice. While deep drawdowns are not recommended on an annual basis, they may be used periodically (every 3 to 5 years) to reduce the deep water growth of invasive species.

Lake level drawdowns can be conducted in a number of ways based on the hydrology of the lake system and the structure of the lake outlet devices, however as a general guideline, we recommend that the water level be drawn down during the middle of September, and no later than mid-October. The water level should be drawn down at a rate of approximately one-to-two inches per day. Drawing the water level down at this rate and time of year allows mobile aquatic organisms such as fresh water mussels, crayfish, turtles and amphibians to migrate to deeper water. The lowered water level should be maintained for 6 to 8 weeks (November and December) until there is a prolonged period of temperatures below 15° F (one week or more), or other conditions (e.g. hydrology budget or weather conditions) dictate refilling. Multiple freeze/thaw cycles are necessary to break up the root masses of species such as Eurasian watermilfoil and provide effective control. The water body should be refilled (April or May), before the following growing season to prevent terrestrial plants from growing on the exposed sediment.

Background

Quantitative aquatic plant surveys were undertaken for Galway Lake, New York as part of a cooperative effort between the Darrin Fresh Water Institute and the Galway Lake Campers Association. The aquatic plant survey was designed to provide data on aquatic plant distribution and to evaluate a treatment program based on lake level drawdown to control Eurasian watermilfoil (*Myriophyllum spicatum*). The Point-Intercept Rake Toss method presently required by NYS DEC for Tier III Lakes was employed. The project was designed to obtain data to evaluate current aquatic plant management efforts and review potential new strategies. The assessment will generate the information necessary to: 1) review effectiveness of aquatic plant management efforts, 2) meet all permit requirements and 3) provide data for comparison of post-treatment conditions to prior survey information.

Introduction

Galway Lake is located on the western edge of Saratoga County in the Town of Galway. The lake's watershed is part of the Mohawk River drainage system. Included within the watershed is a smaller lake, Lake Butterfield, along with various streams and wetlands. Elevations within the watershed range from 259 meters at the surface of the lake to 390 meters above sea level (Table 1).

Table 1. Physical Features of Galway Lake.

GALWAY LAKE – Galway, Saratoga County, New York	
Latitude	43 degrees 01 minutes
Longitude	74 degrees 05 minutes
Topographic Quad. Map	Galway
Watershed	Mohawk River
Maximum Depth	7.1 meters (23 feet)
Surface Area	209.8 hectares (518.2 acres)
Watershed Area	2236 hectares (5523 acres)
Shoreline Length	12.6 kilometers (7.8 miles)
Elevation Above Sea Level	259 meters (857 feet)
Annual Precipitation	40-50 inches
Water Quality Classification	B

The lake has a surface area of 518 acres and a rolling watershed of 5523 acres. A maximum depth of 7.1 meters (23 ft.) is reported. Typical of lakes in the temperate region, it is dimictic, exhibiting both summer and winter thermal stratification. The shallow nature of this lake may lead to frequent breakdown and reformation of thermal stratification during the summer and fall of the year.

Based on water quality data collected by lake association volunteers and analyzed thru the Citizens Statewide Lake Assessment Program (Kishbaugh 2009), Galway Lake is best described as a soft water, alkaline lake of moderate productivity (i.e. mesotrophic). The lake is weakly colored as a result of dissolved tannins from leaf litter both within the lake and its' watershed. Galway Lake water also has low levels of nitrate, ammonia and total nitrogen readings. Conductivity, a measure of total dissolved minerals, has not varied significantly since 1990.

Calcium levels are probably not high enough to support zebra mussels, and these exotic animals have not been reported at the lake.

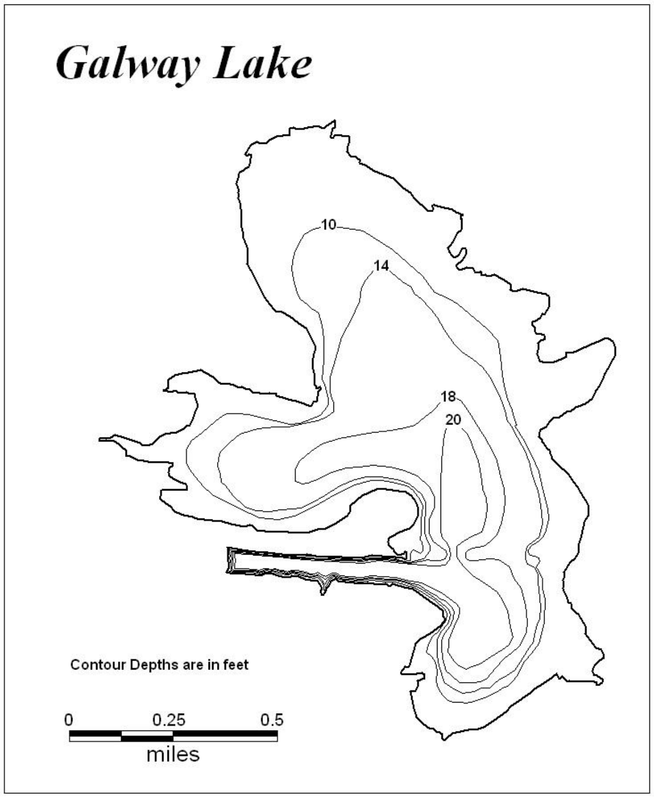


Figure 1. Depth map of Galway Lake.

Galway Lake is largely man-made, originally formed by a dam constructed in 1855 to provide a reservoir. The lake was enlarged 1865 and again in 1875 to its current size. The waters of the lake were impounded to provide water power and a supply of clean water to the textile mills in Galway and Amsterdam. The dams were built by a group of mill owners headed by State Senator Steven Sanford. In 1980, the owner of the dam, Mohasco Industries, turned the dam and control of the water level of the lake over to the Galway Lake Campers Association. The dam is located on the western margin of the lake and is the only outlet. Winter drawdown of the lake, averaging 4 to 5 feet, is conducted on an annual basis to prevent spring flooding, protect docks from ice damage, facilitate inspection and maintenance of the dam and to control excessive weed growth. In the winter of 1989-90, the lake was drawn down to the base of the dam, approximately 18 feet below mean water level, in order to replace the control tower. Periodic deep drawdowns to a maximum of 10 feet have also been employed for weed management.

The lake is classified by NYSDEC as class B, which indicates that its best use is for contact recreation and other recreational uses, but not as a water supply for drinking or food preparation. Galway Lake is a residential/recreational lake with boating, fishing and swimming the primary uses. No public access exists. The watershed is sparsely populated, however areas of undeveloped shoreline with potential for residential use are almost non-existent. There is no commercial land use on the shore of the lake. Agricultural activities are present within the drainage basin and constitute a major land use in the region. Dense growth of aquatic plants, "weeds", has been a concern of lake residents for an extended period of time. Long time residents indicate that heavy weed growth, particularly in the north end of the lake, has been observed for several decades (R. Otto, pers. comm.). The introduction of Eurasian watermilfoil sometime during the 1980’s however, spurred camper association members to seek professional assistance in managing aquatic plant growth in the lake.

The fisheries resources of Galway Lake are characteristic of a warm-water temperate zone fishery (Table 2). Stocking of game species has been conducted with walleye pike the most recent, however both largemouth and smallmouth bass have been stocked in the past. The species present indicate average water quality.

A bathymetric (depth) map of the lake was found in the Amsterdam Water Department Office and updated in 1989 by Mr. Lewis Denton and Mr. D. Swann of the Campers Association. A composite map of these is included as Figure 1.

Table 2. A partial list of fish indigenous to Galway Lake.

Common Name	Classification
Largemouth Bass[1]	*Micropterus salmoides*
Smallmouth Bass[1]	*Micropterus dolomieu*
Rock Bass	*Ambloplites rupestris*
Chain Pickerel	*Esox niger*
Brown Bullhead	*Ictalurus nebulosus*
Pumpkinseed Sunfish	*Lepomis gibbosus*
Yellow Perch	*Perca flavescens*
Walleye Pike[1]	*Stizostedium vitreum*

[1] These species have been stocked.
Species listing provided by Mr. Lewis Denton, Galway Lake resident.

A total of 19 submersed aquatic plant species were reported for Galway Lake in 1989, not including benthic algae (Eichler and Madsen 1990). Filamentous green algae were also present and while not specifically part of the survey were reported to be predominantly of the genera *Spirogyra* and *Mougeotia*. Of the 19 submersed species, seven are in the genus Potamogeton, commonly called pondweeds. Pondweeds are a common component of many littoral zone communities, serving a valuable function as the base of numerous aquatic food webs, providing habitat for fish and invertebrates and stabilizing lake-bottom sediments. Seventeen of the 19 species present were native to North America, however two exotic species were reported. These two are the most common nuisance plants of temperate North American lakes: Eurasian watermilfoil (*Myriophyllum spicatum*) and Curly-leaf Pondweed (*Potamogeton crispus*). In 2007 and again in 2008, lake residents experienced excessive algal growth with floating algal mats interfering with lake access in the northern portion of Galway Lake. Extensive algal growth provided an impetus for an aquatic plant survey in 2009.

A total of 28 species were observed in open lake surveys of Galway Lake in 2009, with 19 present in the point intercept portion of the survey. These results are comparable to a previous survey in 1989 (23 species with 19 in the survey areas; Eichler and Madsen 1990). The limited occurrence of *Potamogeton crispus* in 1989 and absence in 2009 may be due to the timing of the surveys (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. Grass-like species such as *Isoetes (macrospora) lacustris* or *Eleocharis acicularis* are not well sampled by the 'rake toss' methodology and thus may de under-represented in the 2009 survey. Other species absent from the 2009 survey but present in prior surveys were generally relatively uncommon in prior surveys (<5% of survey points).

In 2009, Coontail (*Ceratophyllum demersum*) was the most widely distributed plant (38% of survey points), followed closely by white stem pondweed (*Potamogeton praelongus*) present at 36% of survey points. Eurasian watermilfoil was the most abundant invasive species, present in 34% of survey points. A second invasive species of concern, waterchestnut (*Trapa natans*) was observed for the first time in less than 1% of survey points. Macroalgae including *Chara* sp. and *Nitella* sp. were the fourth most common plants, present in 33% of survey points. Other common native macrophyte species included *Potamogeton zosteriformis* (30%), *Najas flexilis* (24%), *Elodea canadensis* (21%), *Vallisneria americana* (10%) and *Potamogeton pusillus* (14%). Extensive growth of Eurasian watermilfoil, particularly at the deep margins of the littoral zone spurred the Campers Association to conduct a deep drawdown in the winter of 2010 – 2011. The current survey was conducted to evaluate that deep drawdown.

Methods – Aquatic Plant Assessment

The frequency and diversity of aquatic plant species was evaluated using a point intercept method (Madsen 1999). The vegetation survey is designed to duplicate surveys conducted by the Darrin Fresh Water Institute for a number of regional lakes including Galway Lake. Three components form the basis for the surveys: herbarium records of all species encountered, point intercept data collections to characterize aquatic plant abundance by frequency of occurrence, and relative abundance values to estimate dominance of the total plant population by selected species. Point intercept survey methods are designed to meet with NYS DEC Tier III Survey requirements.

Species List and Herbarium Specimens. As the lake was surveyed, the occurrence of each aquatic plant species observed in the lake 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. Digital photographs of each species was archived.

Point Intercept. The frequency and richness of aquatic plant species was 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 and by deploying a rake to the bottom, and examining the plants retrieved. A differential global positioning system was used to navigate to each point for the survey observation. Point intercept plant frequencies were surveyed on August 31, 2011, at the time of maximum aquatic plant abundance. Based on a 100 meter grid and excluding all points outside the littoral zone, we surveyed a total of 66 points (Figure 2) which represent a subset of the 2009 survey points. The point intercept method allows a large number of discrete observations in a short period of time facilitating statistical analysis and comparisons.

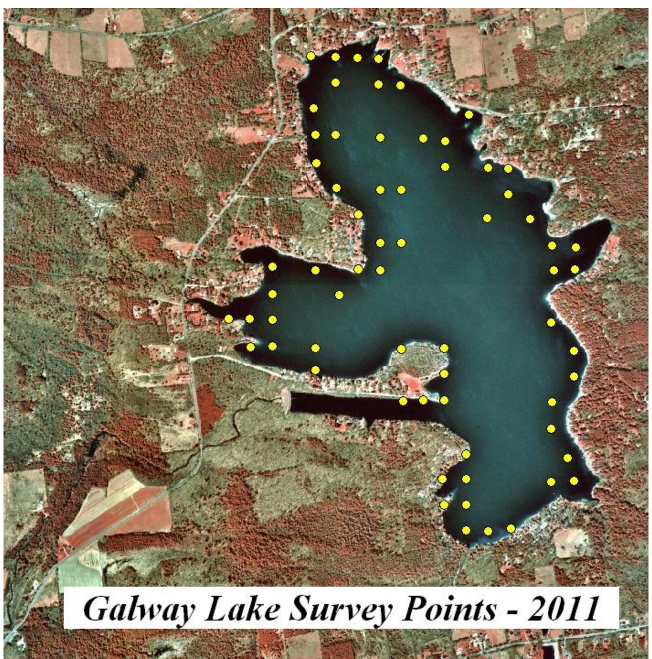


Figure 2. Survey points for Galway Lake

Relative abundance of species in the Point Intercept survey. To characterize relative abundance of each of the species identified in the point intercept survey, a scale developed by Cornell University and the US Army Corps of Engineers was employed. For each rake toss, the relative abundance of each plant species collected was recorded based on a rating scale (Table 3). Maps of the distribution of each species by its relative abundance was produced (Appendix A).

Table 3. Relative abundance scale based on US Army Corp/Cornell methods adopted by NYS DEC for their Tier Survey System

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

Results & Discussion - Aquatic Plant Assessment

A list of species observed for Galway Lake is provided in Table 4. A total of 34 species have been reported from Galway Lake when all survey results are combined. Of these, one group are macroscopic alga, or charophytes (*Chara/Nitella*), three are floating-leaved species (*Nuphar, Nymphaea* and *Trapa*), six are emergent species (*Eleocharis, Eriocaulon, Sparganium, Scirpus, Typha* and *Pontederia*) and the remaining 23 are submersed. In 2011, a total of 24 species were observed, with 19 collected in the point intercept survey. This high species richness suggests a healthy aquatic plant population at the present time. None of these species is on the New York State Rare Plant list (Young, 2010).

Aquatic plants were present from the waters' edge to a depth of 6.2 meters (20 feet) defining the littoral zone of Galway Lake. The current survey found very limited numbers of Eurasian watermilfoil (*Myriophyllum spicatum* L.) plants, present in less than 5% of survey points within the littoral zone. Two other invasive species, curly-leaf pondweed (*Potamogeton crispus* L.) and brittle naiad (*Najas minor* All.) were observed in the 2011 survey, with brittle naiad reported for the first time. Unlike 2009, no waterchestnut (*Trapa natans* L.) was observed in 2011.

Table 4. Aquatic plant species present in Galway Lake in 1989, 2009 and 2011.

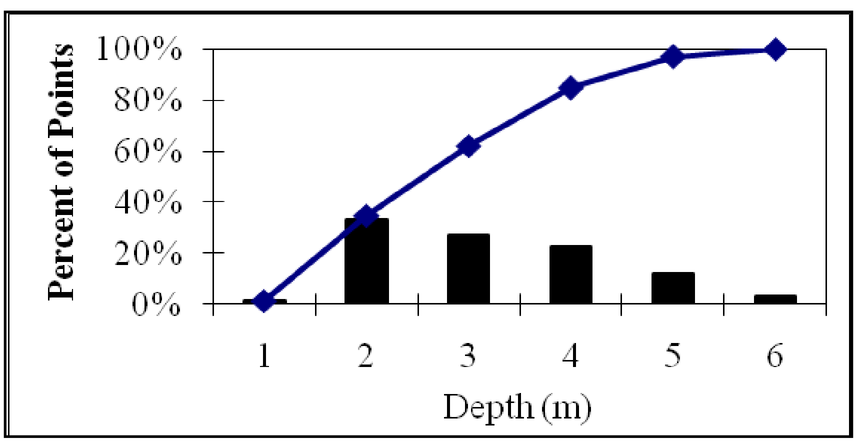
Species	**Common Name**	**2011**	**2009**	**1989**
Benthic/Filamentous algae	algae	x	x	x
Ceratophyllum demersum L.	coontail	x	x	x
Chara/Nitella sp.	muskgrass, chara	x	x	x
Eleocharis acicularis (L.) Roemer & Schultes	needle spike-rush			x
Elodea canadensis Michx.	elodea	x	x	x
Eriocaulon septangulare With.	pipewort		x	
Fontinalis sp.	moss		x	
Isoetes lacustris L.	large spore quillwort			x
Lemna minor L.	duckweed		x	
Myriophyllum spicatum L.	Eurasian watermilfoil	x	x	x
Myriophyllum tenellum Bigel.	leafless watermilfoil			x
Najas flexilis (Willd.) Rostk. & Schmidt.	bushy pondweed	x	x	x
Najas minor All.	brittle naiad	x		
Nuphar luteum (Ait.) Ait. f.	yellow pondlily	x	x	x
Nymphaea odorata Ait.	white pondlily	x	x	x
Polygonum amphibium L.	smartweed		x	
Pontederia cordata L.	pickerelweed	x	x	x
Potamogeton crispus L.	curly-leaf pondweed	x		x
Potamogeton epihydrus Raf.	ribbon-leaf pondweed		x	
Potamogeton gramineus L.	variable-leaf pondweed	x	x	x
Potamogeton natans L.	pondweed		x	
Potamogeton obtusifolius Mert. & Koch	pondweed			x

Species	Common Name	2011	2009	1989
Potamogeton perfoliatus L	clasping-leaved Pondweed	x	x	x
Potamogeton praelongus Wulfen	white-stem pondweed	x	x	x
Potamogeton pusillus L.	small pondweed	x	x	
Potamogeton robbinsii Oakes	Robbins' pondweed	x	x	
Potamogeton vaseyii Robbins	Narrowleaf pondweed	x	x	x
Potamogeton zosteriformis Fern.	flat-stem pondweed	x	x	x
Sagittaria graminea Michx.	arrowhead			x
Scirpus sp.	rush	x	x	x
Sparganium sp.	burreed	x	x	x
Stuckenia pectinata L.	sago pondweed	x	x	
Trapa natans L.	waterchestnut		x	
Typha sp.	cattail	x	x	x
Vallisneria americana L.	duck celery	x	x	x
Zosterella dubia Jacq.	water stargrass	x	x	x

Maximum Depth of Colonization

Maximum depth of colonization by rooted aquatic plant growth extended to a depth of 6.2 meters in 2011. Specimens of *Ceratophyllum demersum* were found beyond 6 meters depth, however this weakly rooted species may have drifted to this location and may not be able to survive. Several native species, including pondweeds (*Potamogeton* sp.) were found in water depths to 6 meters. Based on the definition of the littoral zone as the zone of rooted aquatic plant growth, 6 meters was classified as the maximum extent of the littoral zone. This depth represents an increase of approximately 0.5 meters in depth from 1989 estimates (Eichler and Madsen 1990) and is comparable to the 6.4 meters reported in 2009. Depth distribution of sampling points (Figure 3) was equitable throughout the littoral zone.

Figure 3. Depth Distribution of sampling points in 1 meter depth classes.



Aquatic Plant Species Richness and Distribution

Species richness in Galway Lake was high, with a large number of species occurring in more than 5% of survey points (Table 5). Macroalgae (*Chara* sp. and *Nitella* sp.) were the most common plants, present in 83% of survey points. Water naiad (*Najas flexilis*), a common native species was the most widely distributed rooted plant (38% of points), followed closely by narrow-leaf pondweed (*Potamogeton pusillus*) at 29% of points. Brittle naiad (*Najas minor*) was the most abundant invasive species, found in 30% of points. Eurasian watermilfoil declined substantially, reported in 5% of points, down from 34% in 2009. Common native macrophytes species included *Potamogeton zosteriformis* (26%), *Ceratophyllum demersum* (24%), *Vallisneria americana* (21%), *Potamogeton perfoliatus* (20%), and *Elodea canadensis* (17%).

Table 5. Percent frequency of occurrence of aquatic plant species in Galway Lake.

Species	Common Name	1989	2009	2011
Ceratophyllum demersum	coontail	71.4%	37.6%	24.2%
Chara/Nitella	muskgrass, chara	37.1%	32.6%	83.3%
Eleocharis acicularis	needle spike-rush	5.7%		
Elodea canadensis	waterweed	65.7%	20.8%	16.7%
Isoetes (macrospora) lacustris	large-spored quillwort	11.4%		
Myriophyllum spicatum	Eurasian watermilfoil	68.6%	34.3%	4.5%
Myriophyllum tenellum	leafless milfoil	2.9%		
Najas flexilis	water naiad	31.4%	24.2%	37.9%
Najas minor	Brittle naiad			30.3%
Potamogeton crispus	curly-leaf pondweed	2.9%		3.0%
Potamogeton epihydrus	bushy pondweed		0.6%	
Potamogeton gramineus	variable-leaf pondweed	14.3%	4.5%	6.1%
Potamogeton illinoensis	Illinois pondweed		1.1%	
Potamogeton obtusifolius	pondweed	5.7%		
Potamogeton perfoliatus	clasping pondweed	5.7%	3.4%	19.7%
Potamogeton praelongus	white-stem pondweed	40.0%	36.0%	10.6%
Potamogeton pusillus	small pondweed		13.5%	28.8%
Potamogeton robbinsii	Robbins' pondweed		1.1%	
Potamogeton vaseyii	narrow-leaf pondweed	5.7%	9.0%	13.6%
Potamogeton zosteriformes	flat-stem pondweed	28.6%	30.3%	25.8%
Sagittaria graminea	arrowhead	2.9%		
Sparganium sp.	Robbins' pondweed	8.6%	1.1%	
Stuckenia pectinata	sago pondweed		5.1%	9.1%
Trapa natans	waterchestnut		0.6%	
Vallisneria americana	wild celery	20.0%	10.1%	21.2%
Zosterella dubia	water stargrass	20.0%	2.8%	9.1%

Shaded species are invasives

A total of 24 species were observed in open lake surveys of Galway Lake in 2011, with 19 present in the point intercept portion of the survey (Table 5). These results are comparable to previous surveys in 2009 (28 species, Eichler 2009) and 1989 (23 species with 19 in the survey areas; Eichler and Madsen 1990). The limited occurrence of *Potamogeton crispus* in 1989 and absence in 2009 may be due to the timing of the surveys (August), rather than an actual decline. *Potamogeton crispus* reaches peak abundance in June and July, and then undergoes senescence. Grass-like species such as *Isoetes lacustris* or *Eleocharis acicularis* are not well sampled by the 'rake toss' methodology and thus may be under-represented in the 2009 survey. Other species absent from the 2009 survey but present in prior surveys were generally relatively uncommon in prior surveys (<5% of survey points).

Maps of the distribution of aquatic plant species for Galway Lake are included in Appendix A. While the frequency of occurrence of most species has remained stable since the 1989 survey given the differences in survey techniques, there were some exceptions. Eurasian watermilfoil remains a member of the aquatic plant community, however it continued its' decline in frequency of occurrence. In 2011, Eurasian watermilfoil was present in 5% of survey points, down from 34% of survey points in 2009 and 69% of survey areas in 1989. The most recent decline was lake-wide while much of the earlier declines were in water depths less than 2 meters, the shallow end of the depth range for Eurasian watermilfoil and the area most impacted by annual lake level drawdowns. Three native species increased in abundance between 2009 and 2011, *Chara/Nitella, Potamogeton perfoliatus* and *Potamogeton pusillus*. All of these species are resistant to drawdown. Coontail, *Ceratophyllum demersum,* continued to decline, reported in only 24% of survey points in 2011. Coontail was the most widespread aquatic plant in 2009, present in 38% of survey points but down considerably from the 71% of survey areas reported in 1989. Two other native species to show declines were *Elodea canadensis* and *Zosterella (Heteranthera) dubia,* species which were present in limited numbers in 2009 but much more abundant in 1989. *Elodea canadensis* continued to decline in 2011, but *Zosterella (Heteranthera) dubia* increased in abundance. With the possible exception of *Zosterella (Heteranthera) dubia*, all of these species are known to be susceptible to lake level drawdown. All other differences were in the less common species.

Ninety-nine percent of whole lake sampling points were vegetated by at least one native plant species (Figure 4), 99% of survey points with depths less than 6 m and 100% of survey points less than 2 meters depth (Figure 5) yielded native aquatic plants. Eurasian watermilfoil was present in 5% of whole lake survey points, and 11% of survey points less than 2 m water depth, representing the shallow end of the littoral zone. Native species frequency on a whole lake basis declined slightly between 1989 (98% of survey points) and 2009 (79% of survey points), however it recovered in 2011 to 99% of survey points. Eurasian watermilfoil frequency of occurrence declined between 1989 (73% of survey points), 2009 (34%) and 2011 (5%), possibly as a result of annual winter lake level drawdown since the 1989 survey.

Figure 4. Galway Lake frequency of occurrence summaries for sampling points of all water depths.

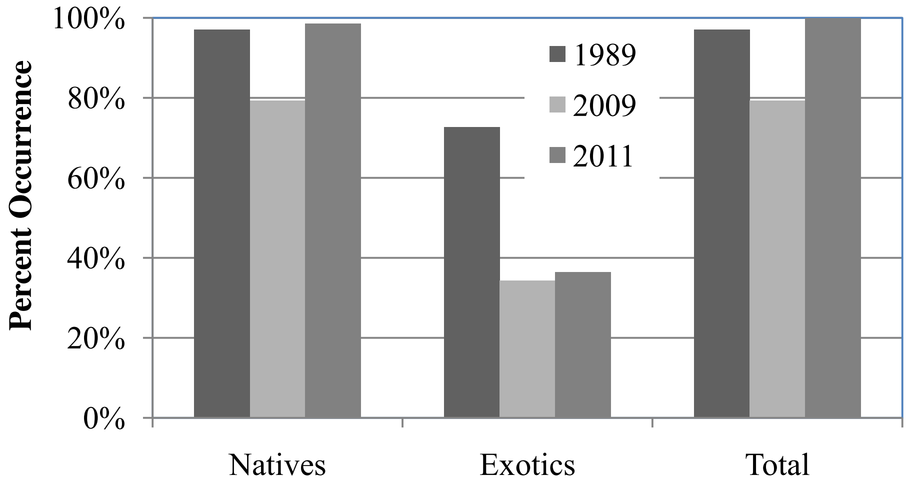
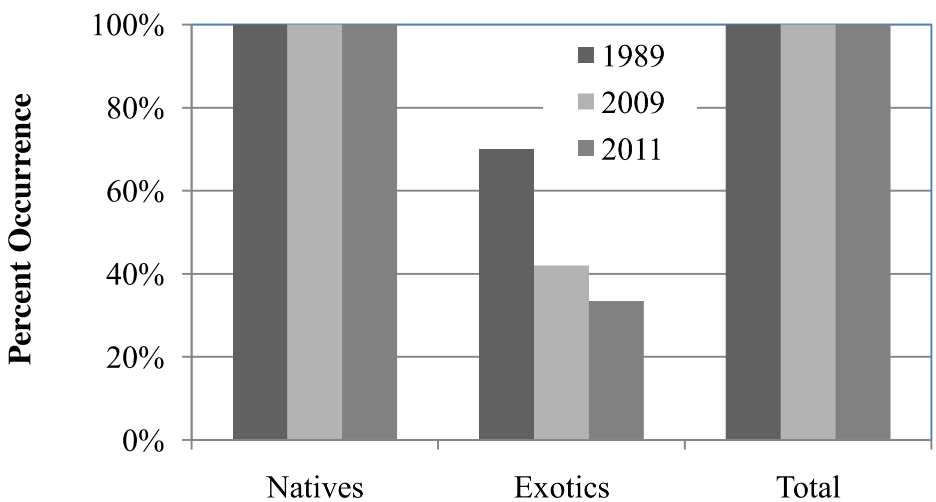


Figure 5. Galway Lake frequency of occurrence summaries for sampling points less than 2 meters water depth.



For the shallow end of the littoral zone, depth less than 2 meters, exotic species frequency of occurrence declined from 70% of survey points in 1989 to 42% of survey points in 2009 and 36% of survey points in 2011. The appearance of brittle naiad (*Najas minor*) in 2011 accounted for the majority of exotic species, since Eurasian watermilfoil frequency of occurrence declined to 5% of survey points in 2011. This annual species is known to colonize areas following lake level drawdowns and has been expanding northward over the last few decades. Native plants were present in all survey points less than 2 meters depth. The expected relationship of greater frequency of occurrence of aquatic plants with shallower water depth is consistent with that reported in most regional lakes, where frequency of occurrence values in the littoral zone range from 80 to 100% of survey points.

Species richness results for all survey years are presented in Table 3 and Figure 6. Whole lake native species richness has ranged from 1.74 species in 1989 to 3.06 species per sample point in 2011. This increase is coincident with a decline in the abundance of Eurasian watermilfoil. For

Table 6. Galway Lake species richness comparison between the current open-lake survey and surveys conducted in 1989 (Eichler and Madsen, 1990).

Plant Grouping	Water Depth Class	Summary Statistic	1989	2009	2011
Native plant species	Whole Lake (all depths)	Mean	1.74	2.38	3.06
		N	34	178	66
		Std. Error	0.24	0.14	0.17
	Points with depths <6m	Mean	1.87	3.04	3.06
		N	30	137	66
		Std. Error	0.25	0.14	0.17
	Points with depths <2m	Mean	2.80	4.04	3.11
		N	10	26	18
		Std. Error	0.40	0.30	0.24
All plant species	Whole Lake (all depths)	Mean	1.97	2.69	3.44
		N	34	178	66
		Std. Error	0.24	0.15	0.18
	Points with depths <6m	Mean	2.13	3.44	3.44
		N	30	137	66
		Std. Error	0.26	0.15	0.18
	Points with depths <2m	Mean	3.00	4.31	3.50
		N	10	26	18
		Std. Error	0.40	0.30	0.31

survey points exclusively within the littoral zone, an increase in native species richness was observed between the 1989 pretreatment survey (1.87 species per sample) and post-treatment surveys in 2009 and 2011 (3.04 and 3.06 species per sample, respectively). The increase in species richness from 1989 to 2011 may be the result of changes in the frequency of occurrence of Eurasian watermilfoil. In the shallow portion of the littoral zone, depths less than 2 meters, species richness in 1989 (3.00 species per sample) was similar to the results for the entire littoral zone in 2009 and 2011 (3.44 species per sample), but less than the approximately 4.31 species per survey point reported in shallow portion of the littoral zone in 2009. 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 littoral zone and its shallow fringe was higher than whole lake species richness, an indication that lake level drawdown has not had a substantial impact on species richness.

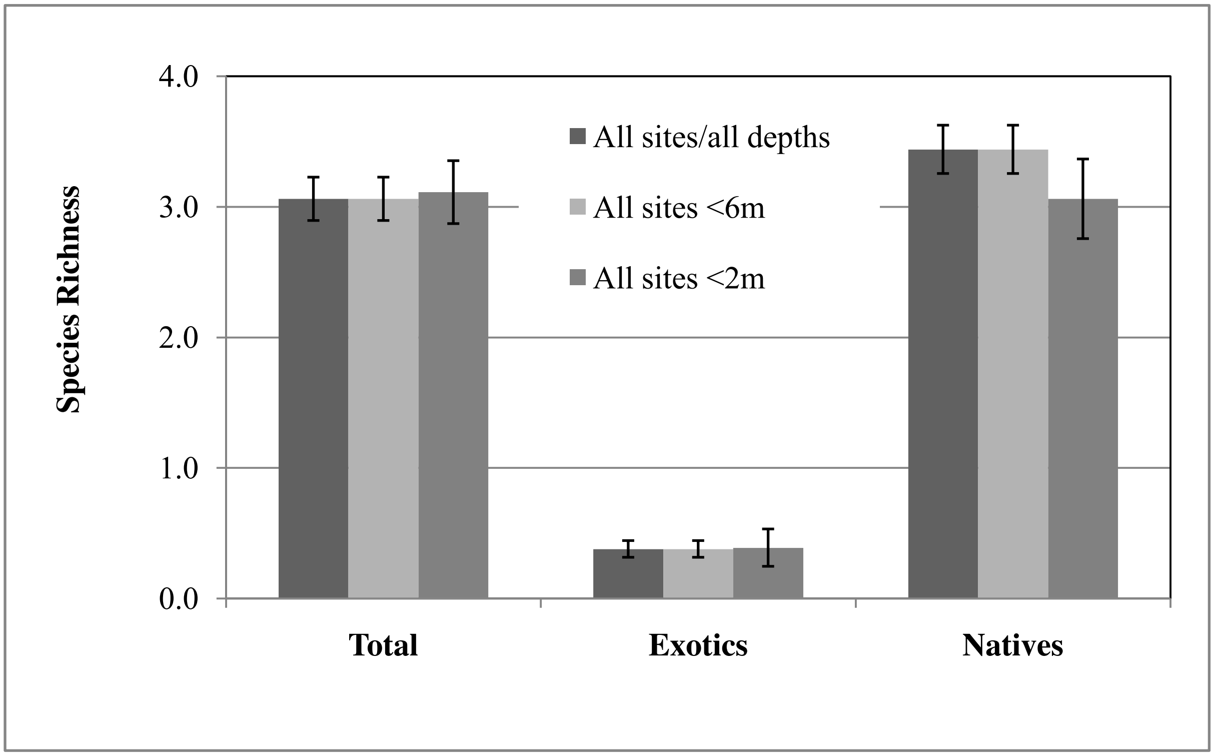


Figure 6. Galway Lake species richness. Error bars are standard error of the mean.

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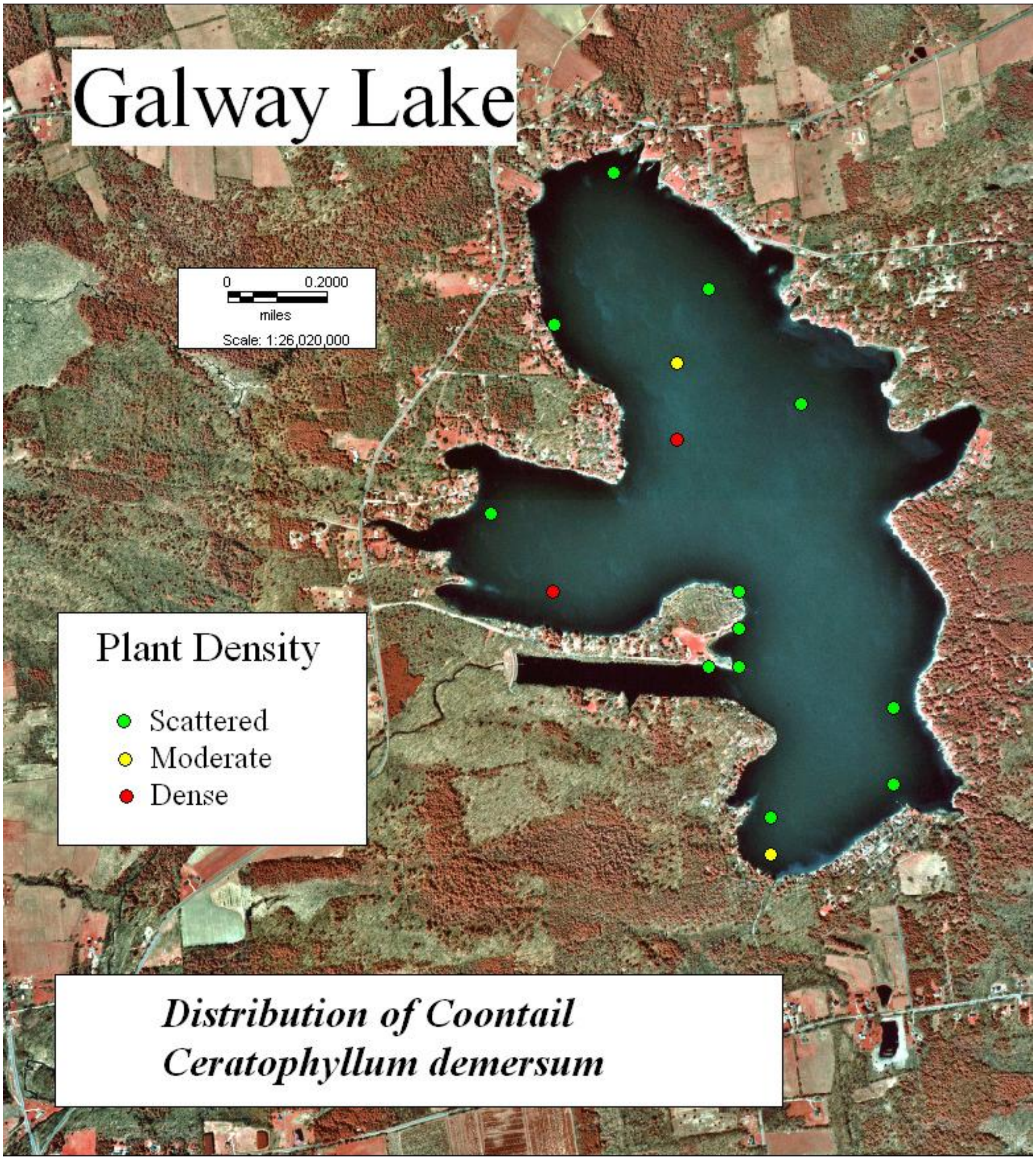
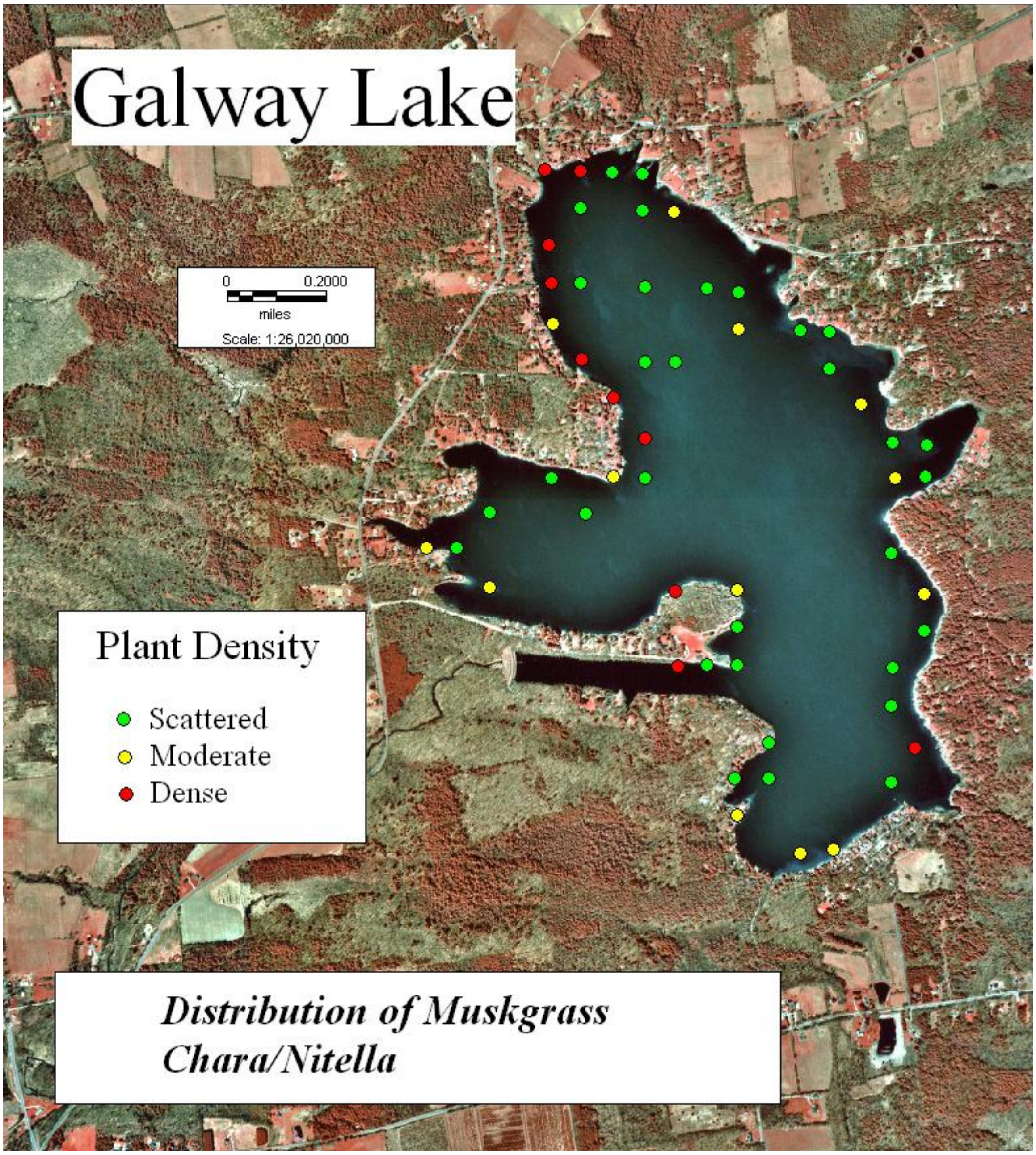
Appendix A

Galway Lake Aquatic Plant Distribution Maps


Galway Lake
0
0.2000
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Coontail
Ceratophyllum demersum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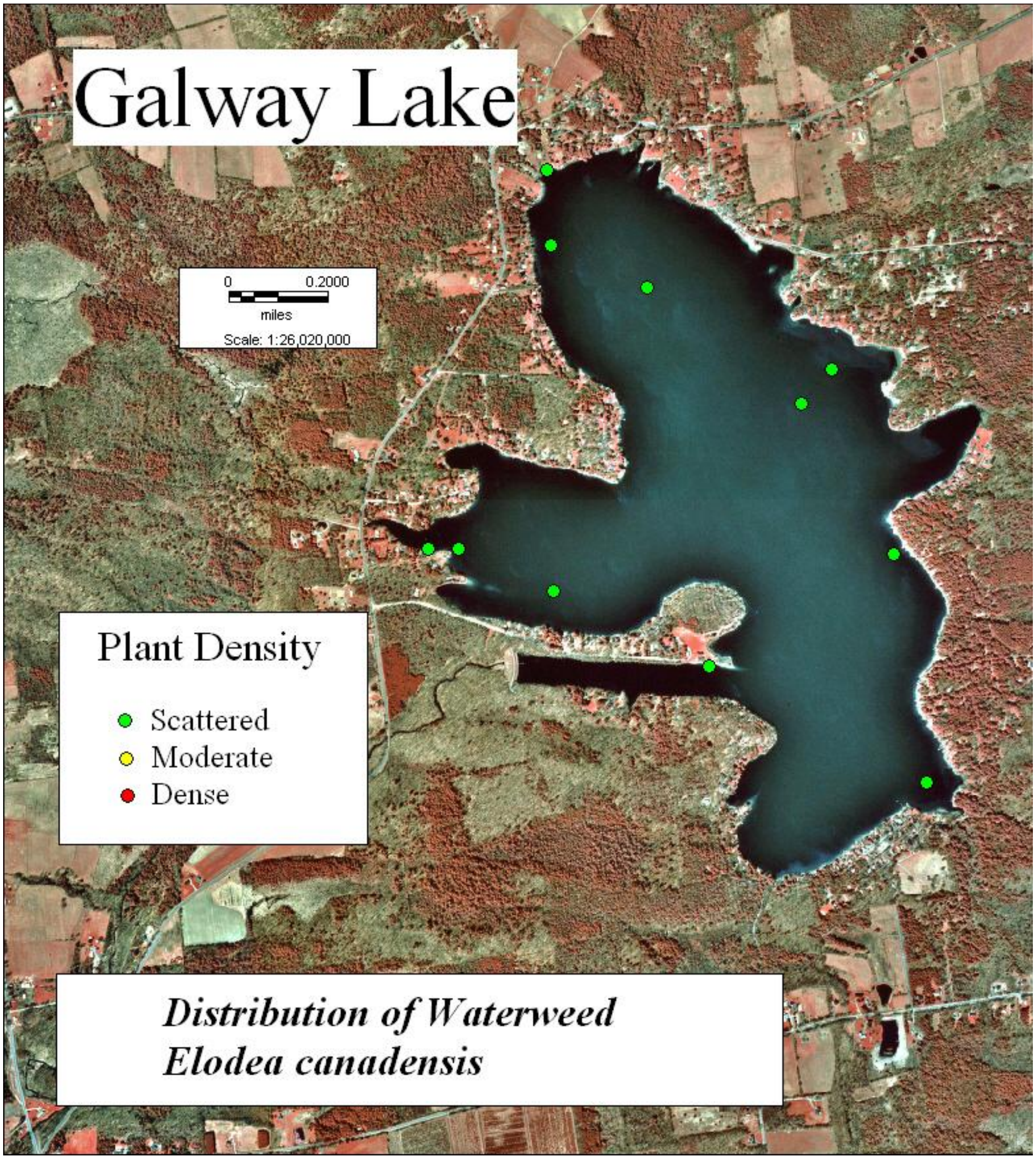
0.2000
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Muskgrass
Chara/Nitella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miles
Scale: 1:26,020,000
Plant Density
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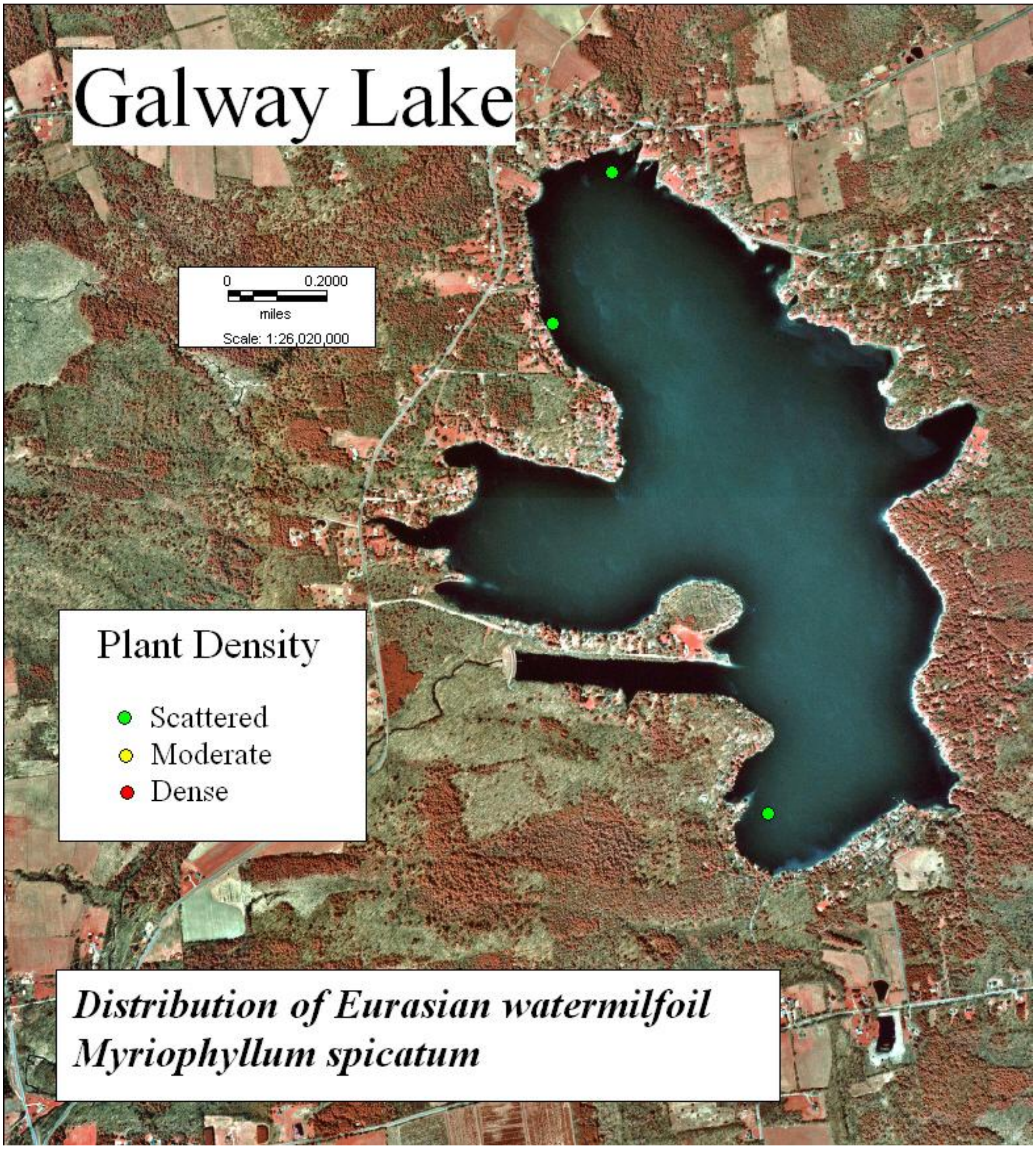
Moderate
Dense
Distribution of Waterweed
Elodea canadensis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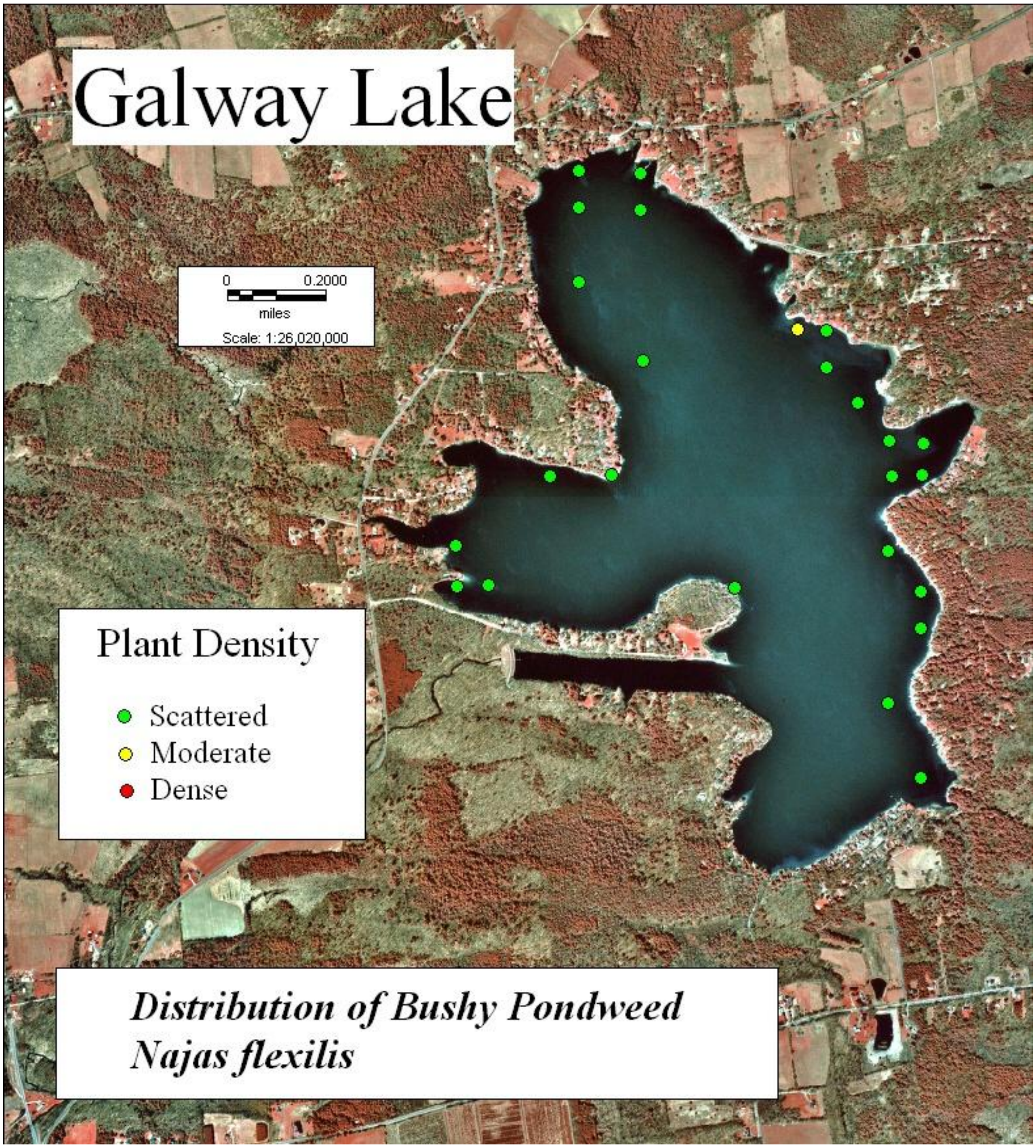
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Eurasian watermilfoil
Myriophyllum spicatum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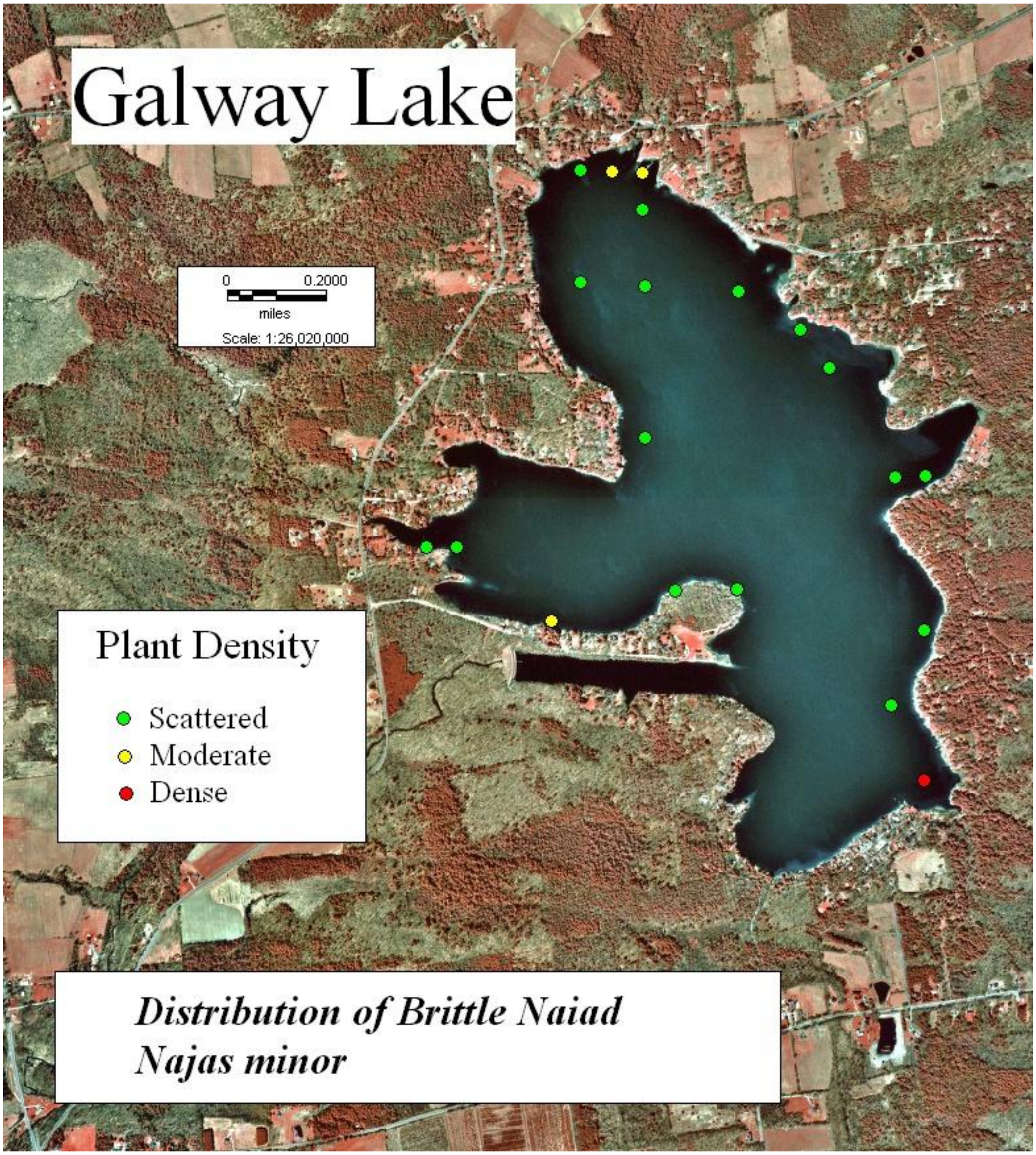
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Bushy Pondweed
Najas flexilis


Galway Lake
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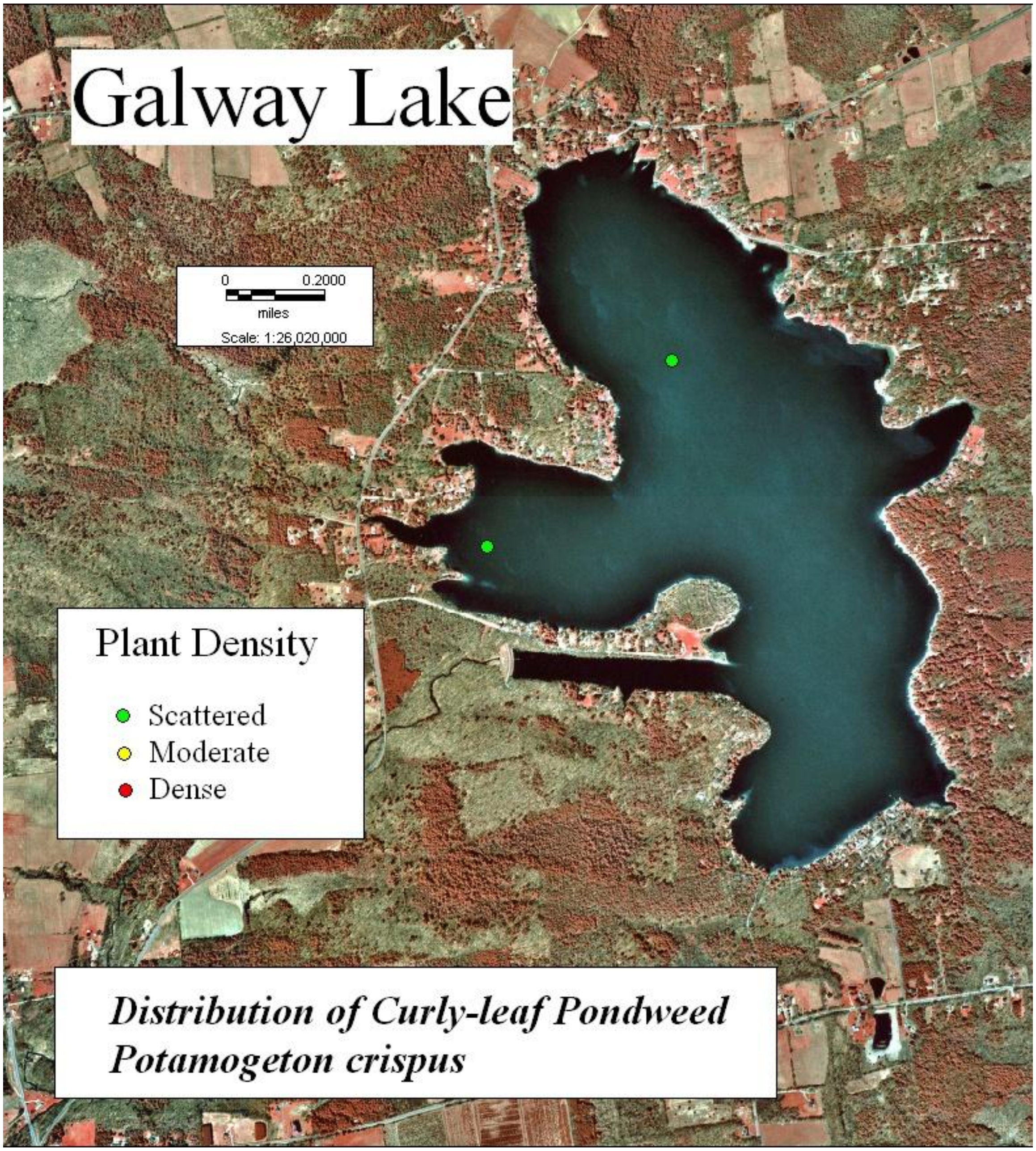
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Brittle Naiad
Najas minor


Galway Lake
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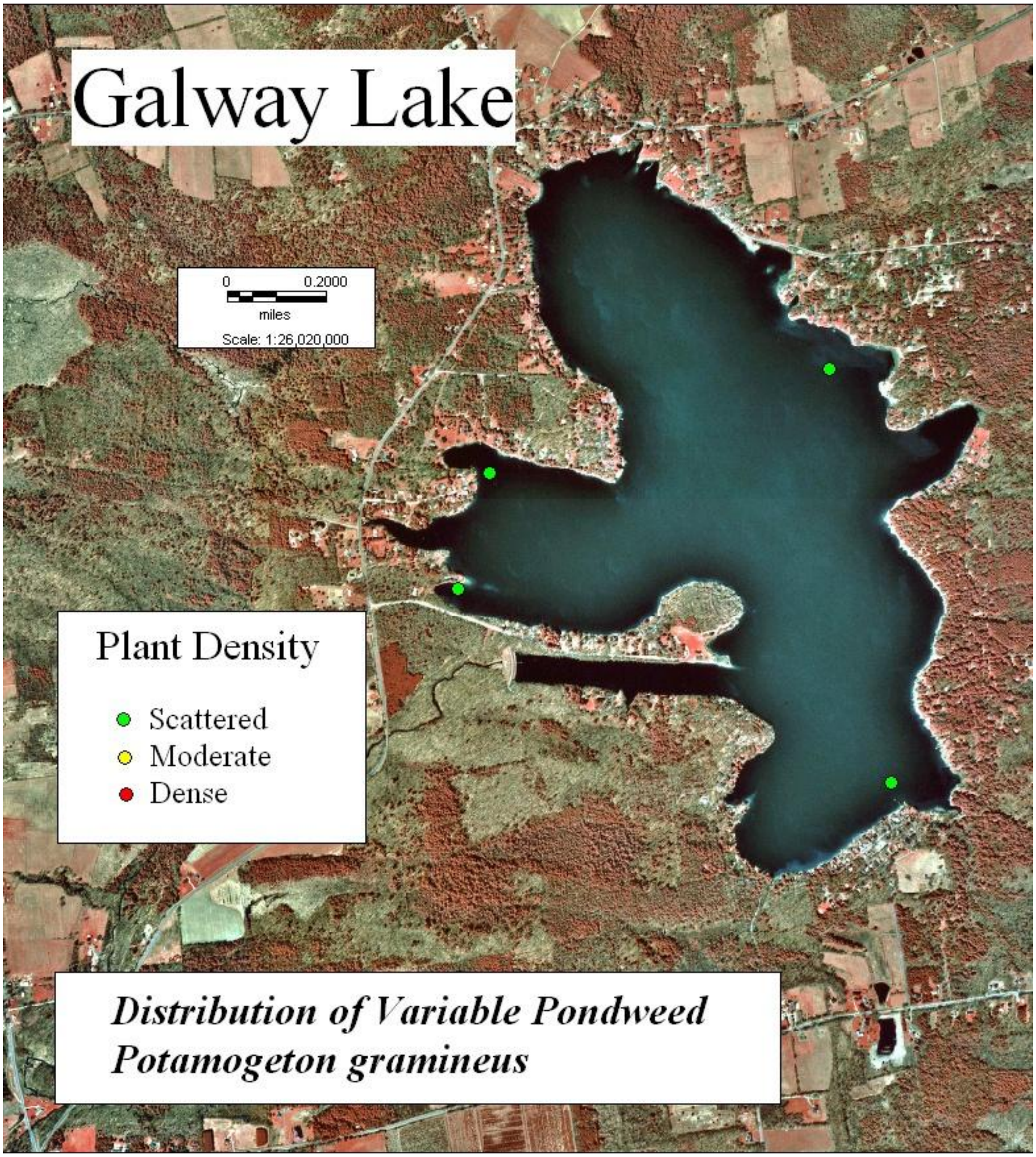
0.2000
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Curly-leaf Pondweed
Potamogeton crispus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miles
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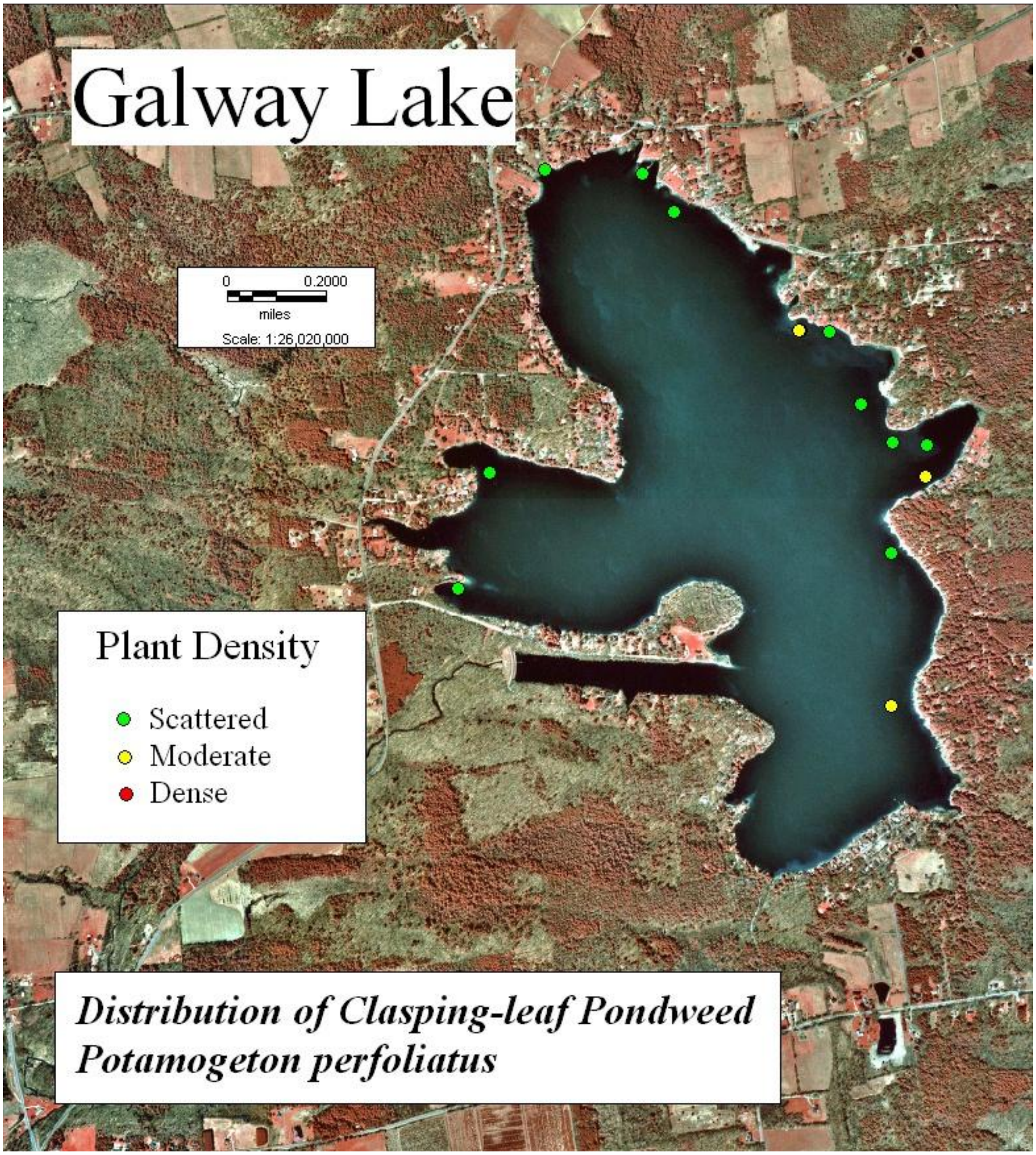
Plant Density
Scattered
Moderate
Dense
Distribution of Variable Pondweed
Potamogeton gramineus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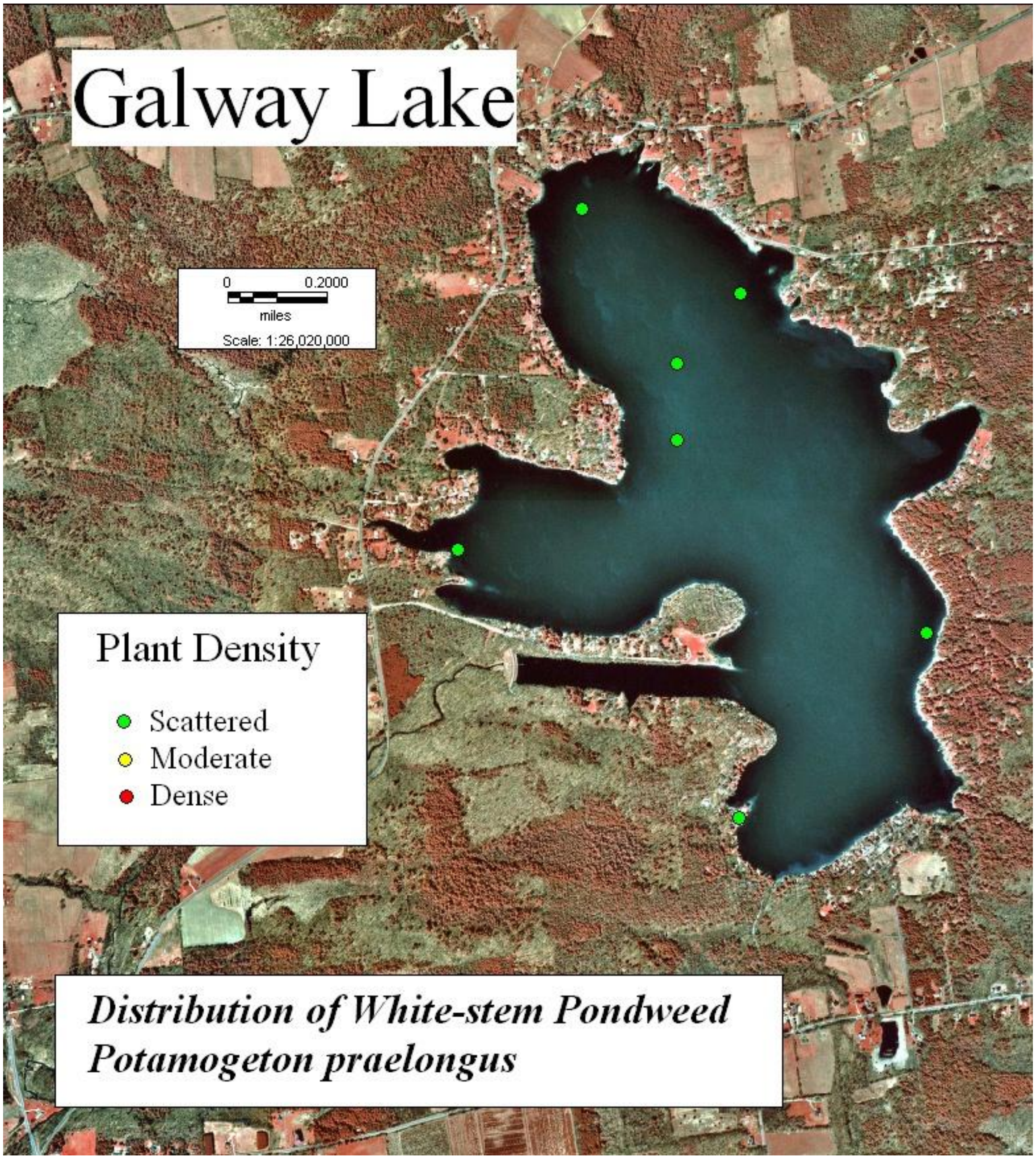
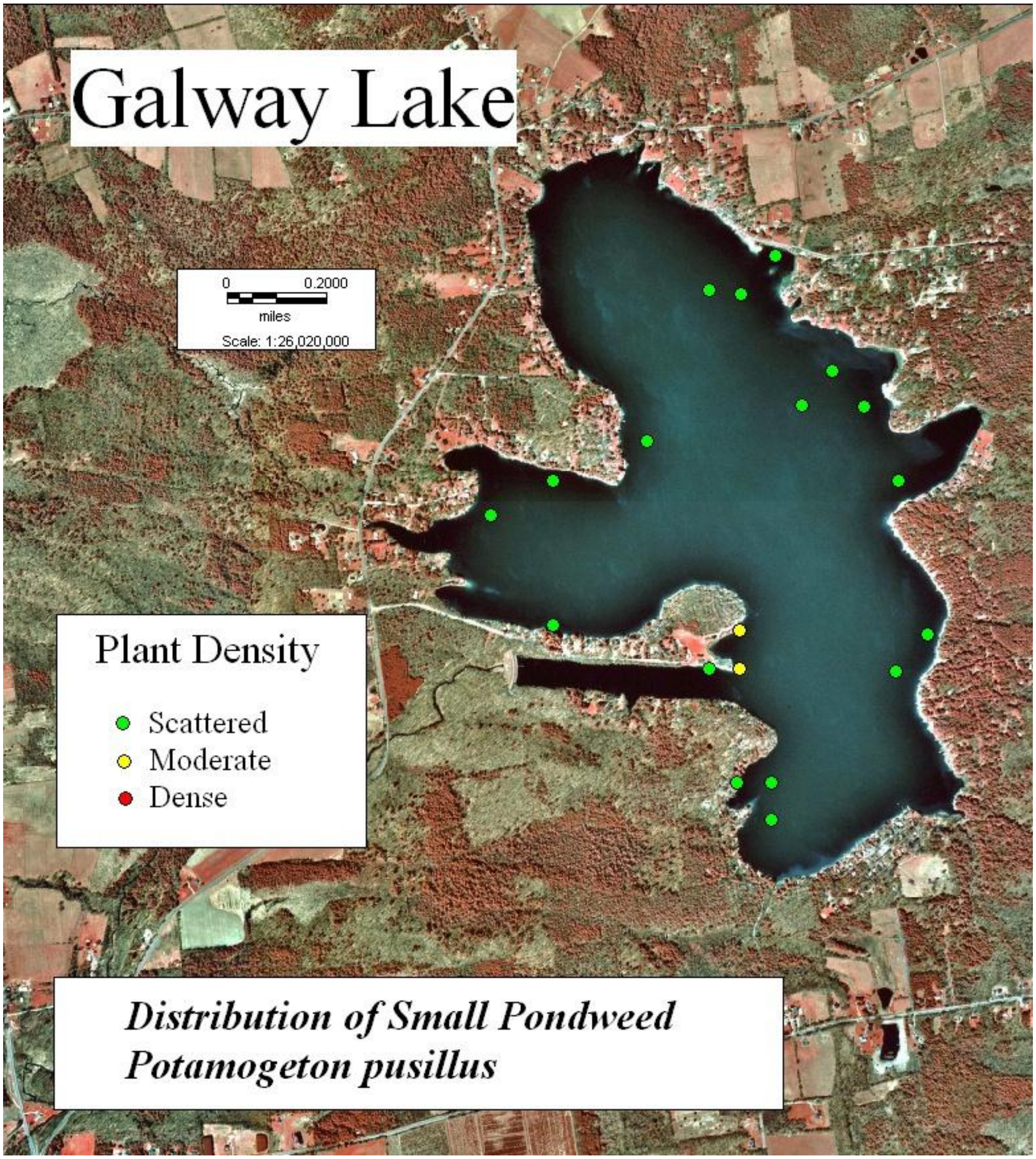
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Clasping-leaf Pondweed
Potamogeton perfoliatus


Galway Lake
0
0.2000
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of White-stem Pondweed
Potamogeton praelongus


Galway Lake
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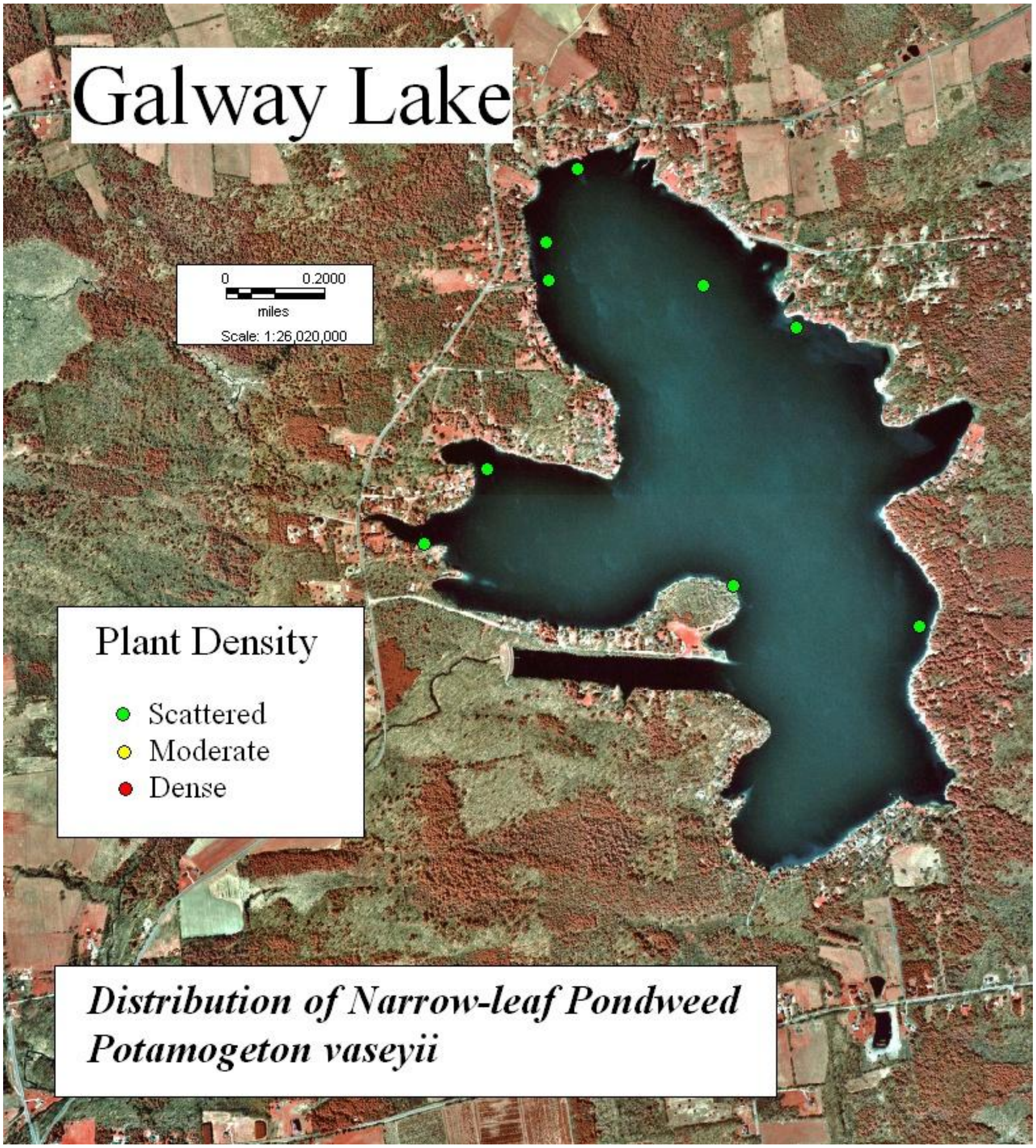
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Small Pondweed
Potamogeton pusillus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miles
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Plant Density
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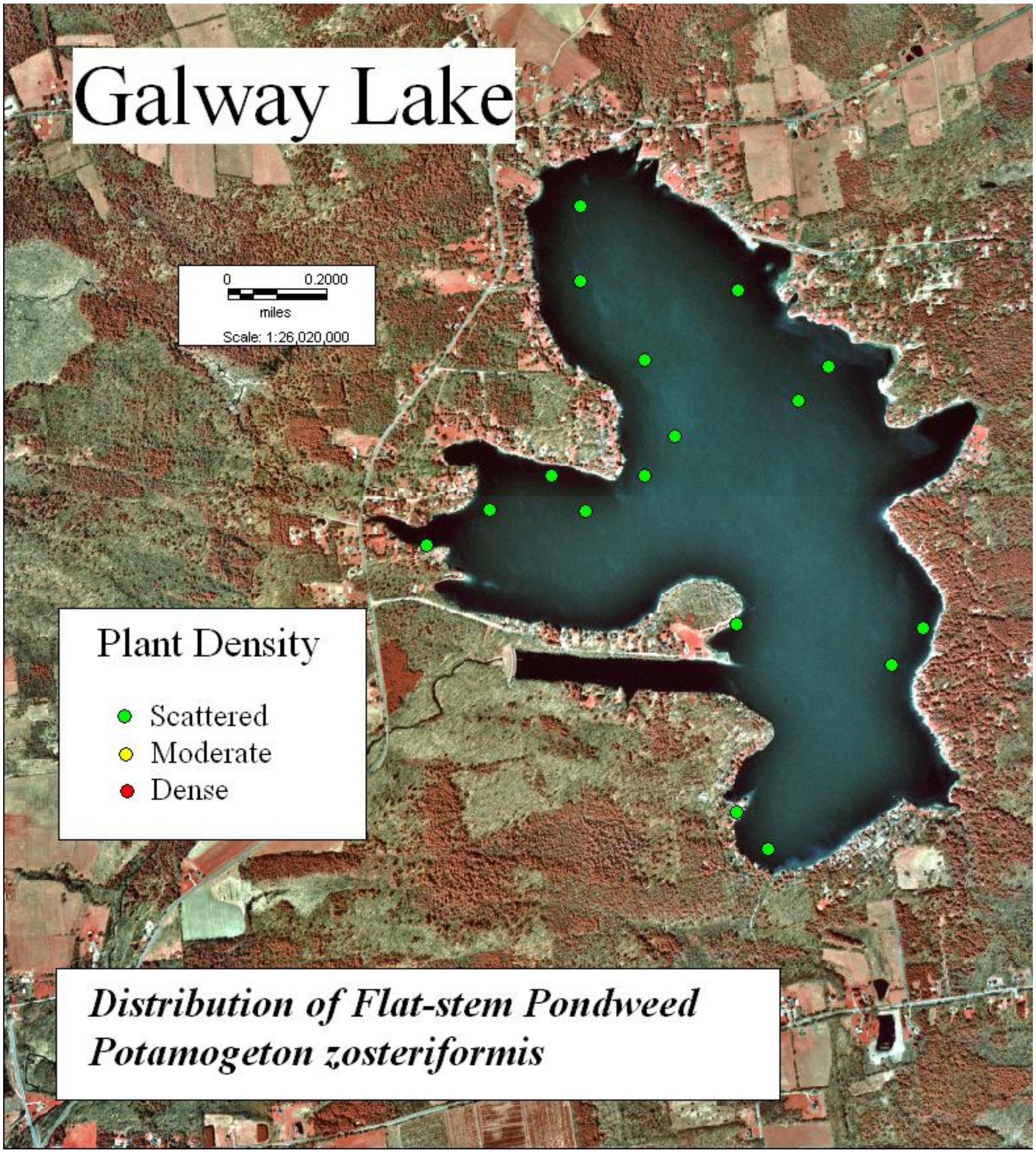
Moderate
Dense
Distribution of Narrow-leaf Pondweed
Potamogeton vaseyii


Galway Lake
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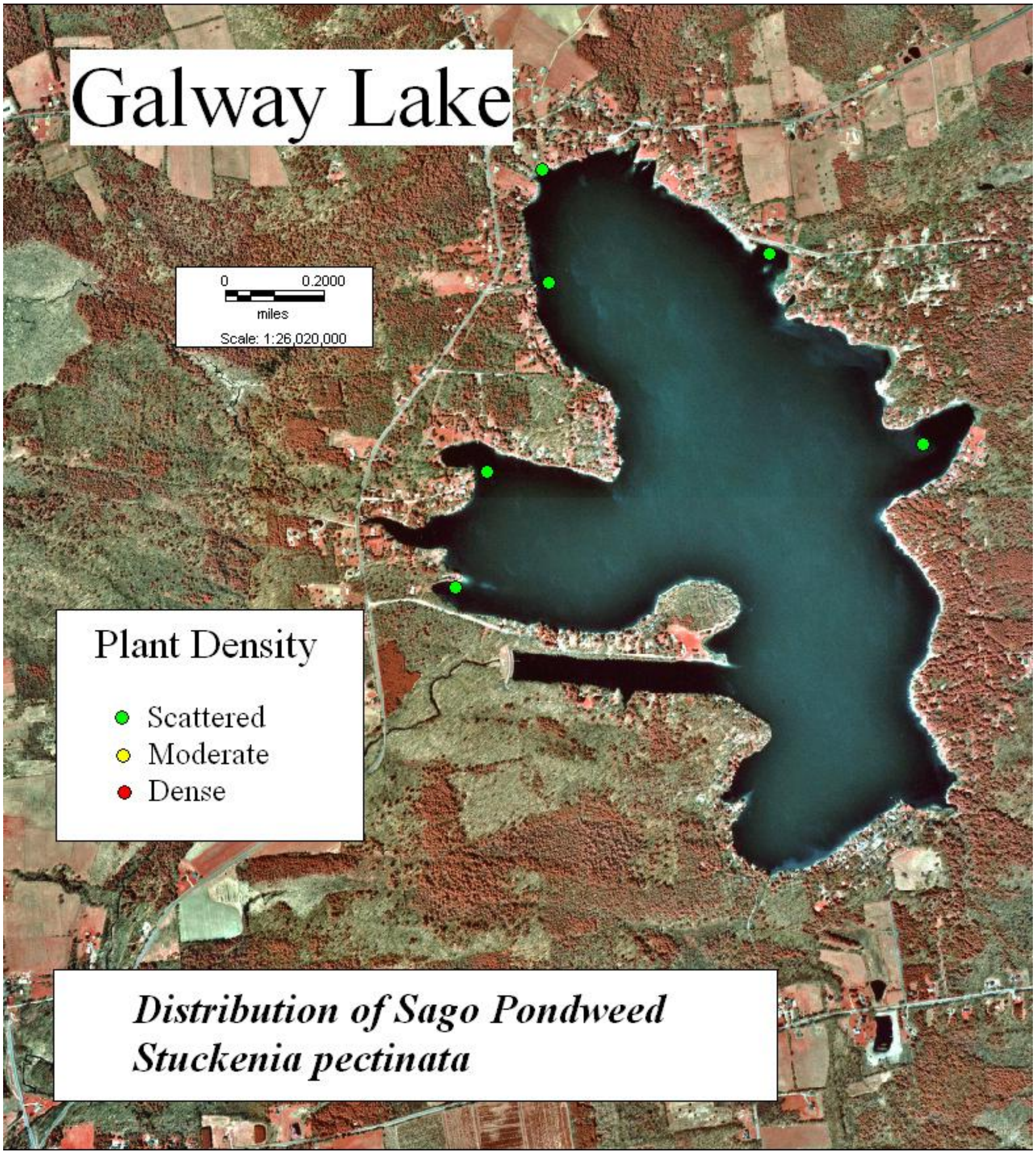
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Flat-stem Pondweed
Potamogeton zosteriformis


Galway Lake
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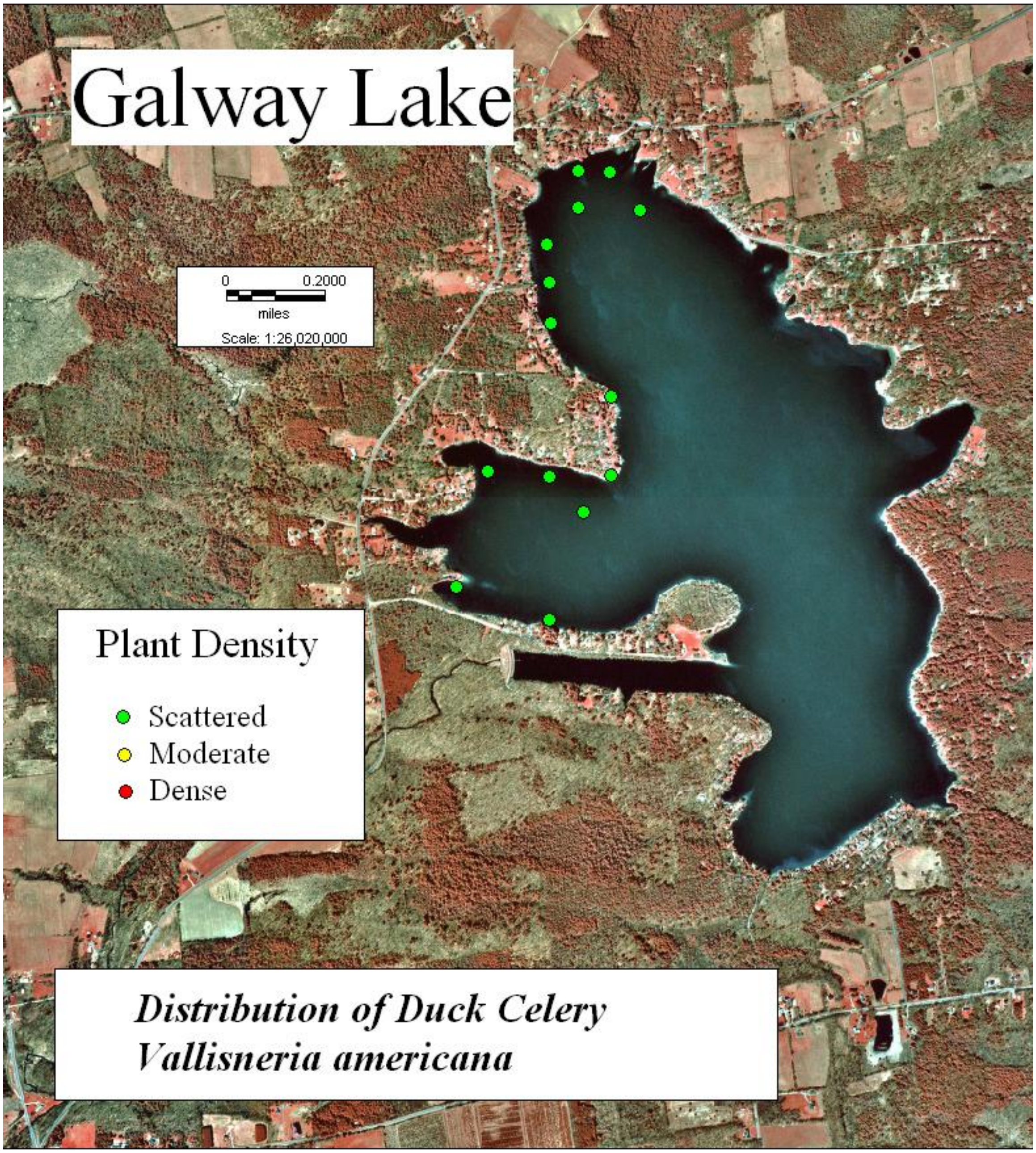
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Sago Pondweed
Stuckenia pectinata


Galway Lake
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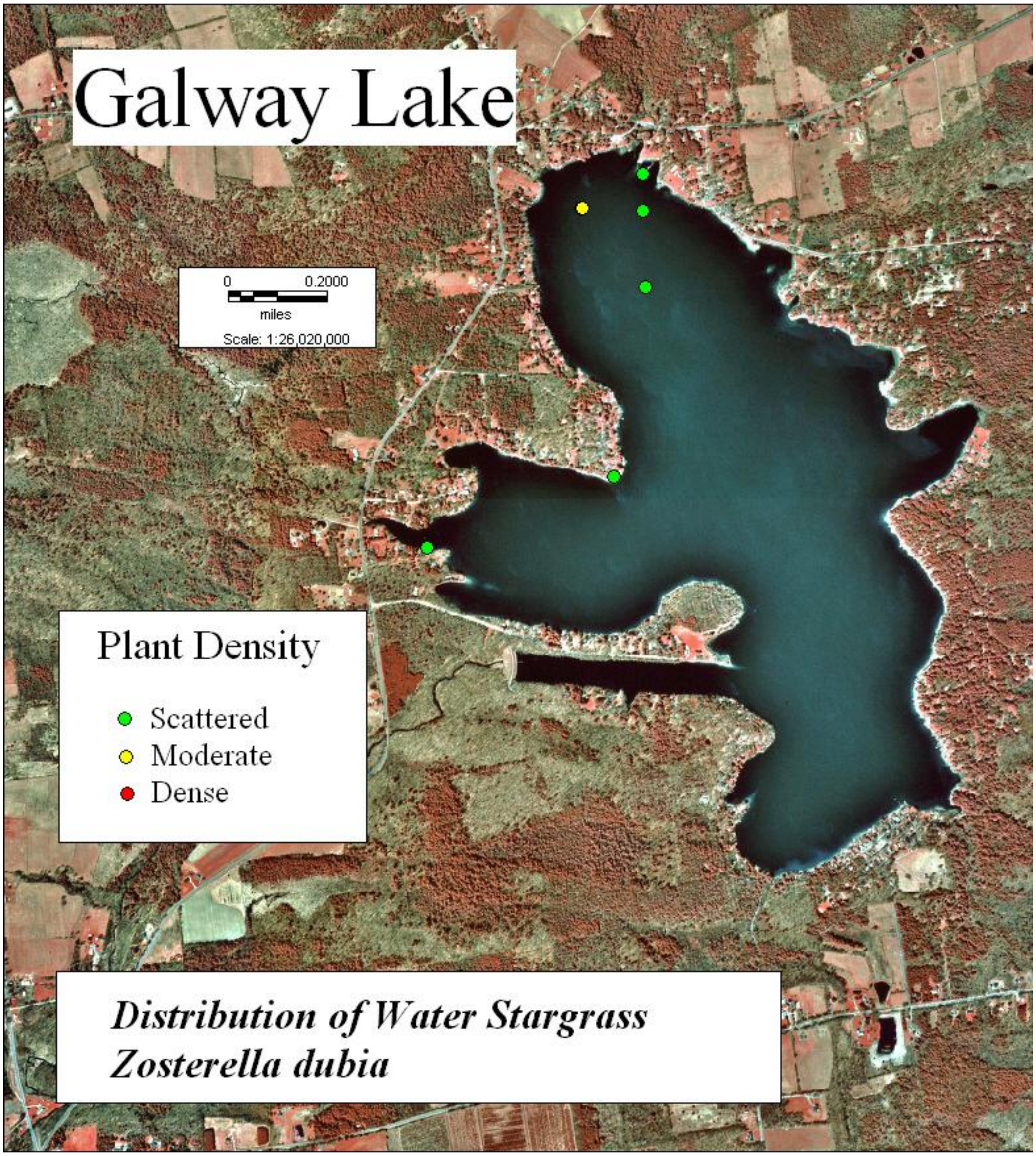
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Duck Celery
Vallisneria americana


Galway Lake
0
0.2000
miles
Scale: 1:26,020,000
Plant Density
Scattered
Moderate
Dense
Distribution of Water Stargrass
Zosterella dubia

Appendix B. Galway Lake Aquatic Plant Survey Results for 2011

Abundance Codes:

1 = trace, fingerful on rake
2 = sparse growth, handful on rake
3 = moderate growth, rake full of plants
4 = dense growth, difficult to bring into boat

Species Codes:

Code	*Species*	Common Name	Code	*Species*	Common Name
CD	*Ceratophyllum demersum*	Coontail	PV	*Potamogeton vaseyii*	Vasey's Pondweed
CH	*Chara species*	Musk Grass	PW	*Potamogeton praelongus*	White stem Pondweed
EC	*Elodea canadensis*	Waterweed	PZ	*Potamogeton zosteriformis*	Flat stem Pondweed
MS	*Myriophyllum spicatum*	Eurasian watermilfoil	SP	*Stuckenia pectinata*	Sago Pondweed
NF	*Najas flexilis*	Water Naiad	VA	*Vallisneria americana*	Duck Celery
NM	*Najas minor*	Brittle Naiad	ZD	*Zosterella dubia*	Water stargrass
PC	*Potamogeton crispus*	Curly-leaf Pondweed			
PG	*Potamogeton gramineus*	Variable Pondweed			
PP	*Potamogeton perfoliatus*	Clasping Pondweed			
PU	*Potamogeton pusillus*	Narrow-leaf Pondweed			

Survey Pt	Latitude	Longitude	Depth (m)	CD	CH	EC	NF	NM	PC	PG	PP	PU	PV	PW	PZ	SP	VA	ZD	MS	Algae
422	-74.082	43.041	0.9		4	2					2					2				
423	-74.080	43.041	1.4		4		2	1					1				2			
424	-74.079	43.040	1.6	2	2			3									2		1	
425	-74.078	43.040	1.1		2		2	3			2							2		2
427	-74.080	43.039	2.4		2		2							2	2		2	3		
429	-74.078	43.039	2.0		2		2	2									2	2		
430	-74.076	43.039	1.3		3						2									
432	-74.081	43.038	1.9		4	2							1				2			
439	-74.072	43.038	1.6									1				1				
440	-74.081	43.037	2.0		4								1			2	2			
441	-74.080	43.037	3.1		2		2	2							2					
443	-74.078	43.037	3.4		2	2		2										2		
445	-74.075	43.037	4.0	2	2							2	1							
446	-74.074	43.037	3.4		2			2				1		2	2					
447	-74.081	43.036	1.5	2	3												2		1	
453	-74.074	43.036	2.8		3															
455	-74.071	43.036	1.3		2		3	2			3		1							
456	-74.070	43.036	1.1		2		2				2									
458	-74.080	43.035	1.5		4															
460	-74.078	43.035	4.0		2		2								2					
461	-74.076	43.035	4.4	3	2				2					2						
466	-74.070	43.035	2.9		2	2	2	2		2		2			2					
468	-74.079	43.034	1.9		4												2			
474	-74.071	43.034	4.2	2		2						2			2					
476	-74.069	43.034	3.0		3		2				2	1								
478	-74.078	43.033	3.9		4			2				1								
479	-74.076	43.033	4.9	4										2	2					
486	-74.068	43.033	1.2		2		2				2									
487	-74.066	43.032	1.4		2		2				2					2				
490	-74.084	43.032	1.9							2	2		2			2	2			2

Survey Pt	Latitude	Longitude	Depth (m)	CD	CH	EC	NF	NM	PC	PG	PP	PU	PV	PW	PZ	SP	VA	ZD	MS	Algae
492	-74.081	43.032	3.0		2		2					1			2		2			
493	-74.079	43.032	3.2		3		2										2	2		
494	-74.078	43.032	5.2		1										1					
505	-74.084	43.031	3.4	2	2							2			2					
508	-74.080	43.031	3.8		2										2		2			
519	-74.086	43.030	2.2		3	2		2					2		2			2		
520	-74.085	43.030	2.6		2	2	2	2						2						
521	-74.084	43.030	4.2						1											
534	-74.068	43.029	2.7		2	2	2				2									
535	-74.085	43.028	2.0				2			2	2					1	2			
536	-74.084	43.028	1.2		3		2													
540	-74.068	43.031	1.9		3		2	2				2								
541	-74.066	43.031	2.0		2		2	2			3									
542	-74.081	43.028	4.9	4		2														
546	-74.076	43.028	2.9		4			2												
547	-74.074	43.028	2.0	2	3		2	2					1							
553	-74.067	43.028	2.4		3		2													
556	-74.081	43.027	3.8					3				2					2			
559	-74.074	43.027	2.7	2	2							3			2					
565	-74.067	43.027	2.9		2		2	2				2	1	1	2					
571	-74.076	43.026	4.0		4															
572	-74.075	43.026	4.6	2	2	2						2								
573	-74.074	43.026	3.6	2	2							3								
578	-74.068	43.026	3.8		2							2			2					
584	-74.068	43.025	2.7	2	2		2	2			3									
585	-74.073	43.024	5.9		2															
591	-74.074	43.023	3.5		2							2								
592	-74.073	43.023	3.2		2							2								
596	-74.068	43.023	1.7	2	2					2										
597	-74.067	43.023	2.9			2	2	4												

Survey Pt	Latitude	Longitude	Depth (m)	CD	CH	EC	NF	NM	PC	PG	PP	PU	PV	PW	PZ	SP	VA	ZD	MS	Algae
598	-74.074	43.022	2.9		3									2	2					
599	-74.073	43.022	5.0	2								2							1	
605	-74.073	43.021	4.2	3											2					
606	-74.072	43.021	2.9		3															
607	-74.070	43.021	2.1		3															
609	-74.067	43.024	2.1		4															