Northeast Aquatic Research

2021 Monitoring Report

Article 409 Nuisance Plant Monitoring of Lakes; Candlewood, Lillinonah, and Zoar

Prepared for FirstLight Power
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Executive Summary

Northeast Aquatic Research, LLC (NEAR) conducted the Article 409 Nuisance Plant Monitoring Surveys of Candlewood Lake, Squantz Pond, and Lake Lillinonah in 2021. Surveys of Lake Lillinonah and Lake Zoar are conducted every other year. A survey of Lake Zoar was conducted in 2020.
Three invasive aquatic plant species were found during the Candlewood/Squantz Pond survey in 2021: Eurasian milfoil (*Myriophyllum spicatum*), Brittle naiad/spiny naiad (*Najas minor*), and Mudmat (*Glossostigma cleistanthum*). The following invasive plants specified in the 409 Survey Plan were not found in Candlewood Lake in 2021:

- Flowering rush (*Butomus umbellatus*)
- Fanwort (*Cabomba caroliniana*)
- Brazilian water-weed (*Egeria densa*)
- European waterclover (*Marsilea quadrifolia*)
- Variable-leaf watermilfoil (*Myriophyllum heterophyllum*)
- Curly-leaved pondweed (*Potamogeton crispus*)
- Watercress (*Rorippa nasturtium-aquaticum*)
- Water chestnut (*Trapa natans*)

The 2021 Candlewood Lake survey found Eurasian milfoil covering ~408 acres within the lake's littoral zone. This is a lesser amount than was found in 2020, when milfoil covered ~469 acres.

Eurasian milfoil growth was relatively consistent along shoreline areas that are conducive to plant growth, though it was present to a lesser extent in the lake's coves. The species was present at varying densities in bands located between approximately 5 feet and 16 feet of water depth. However, milfoil was found growing in 18-19 feet of water at ~3 percent of the waypoints, and out to a maximum 20 feet in one location. Generally, variations in bed width followed the lake's bathymetric contours.

Mudmat was found at 16 locations in the lake in 2021. This is a notable increase compared to 2020, when Mudmat was found in just one location. Mudmat was also present at the northern end of Squantz Pond.

Brittle naiad was present at 25 locations in Candlewood Lake, mainly in the two northern arms and the central basin.

Eurasian milfoil and Brittle naiad were not found in Squantz Pond in 2021.

Each winter, Candlewood Lake is drawn down to varying depths ranging from ~4 feet to ~9.5 feet. A deep drawdown was conducted in the winter of 2020-2021, when the lake reached a maximum drawdown depth of -9.4 feet. This is the deepest drawdown in at least the past six years.

2015-16 = max depth of -4.18 ft
2016-17 = max depth of -5.6 ft
2017-18 = max depth of -7.68 ft
2018-19 = max depth of -8.7 ft
2019-20 = max depth of -5.3 ft
2020-21 = max depth of -9.4 ft

21 native plant species were found in Candlewood Lake during the 2021 survey, along with Filamentous green algae and the filamentous cyanobacteria *Lyngbya wollei*. This is notably more species than found in any prior survey, in part due to extra time spent searching for native species in the lakes' shallow water coves.

- *Callitriche* sp.
- *Ceratophyllum demersum*
- *Chara sp.*
- *Elatine minima*
- *Eleocharis acicularis*
- *Fontinalis sp.*
- *Lemna sp.*
- *Ludwigia sp.*
- *Najas flexilis*
- *Nymphaea odorata*
- *Pontederia cordata*
- *Potamogeton berchtoldii*
- *Potamogeton bicupulatus*
- *Potamogeton illinoensis*
- *Sparganium fluctuans*
- *Spirodela polyrhiza*
- *Stuckenia pectinata*
- *Vallisneria americana*
- *Wolffia sp.*
- *Zannichellia palustris*
- *Zosterella dubia*

Only one species, the invasive Mudmat, was found in Squantz Pond in 2021 and at only two locations in the northern end of the lake. No native species were found in the Squantz Pond in 2021.

- *Glossostigma cleistanthum*

During the survey of Lake Lillinonah, ~142 acres of invasive Eurasian milfoil was growing in the lake, along with ~4 acres of invasive Brittle naiad, ~0.1 acres of invasive Curly-leaf pondweed, and ~0.1 acres of invasive Mudmat. Invasive Water Chestnut was found at 34 waypoints.

22 native plant species were found in Lake Lillinonah, along with Filamentous green algae and the filamentous cyanobacteria *Lyngbya wollei*:

- *Ceratophyllum demersum*
- *Elatine sp.*
- *Eleocharis acicularis*
- *Elodea nuttallii*
- *Fontinalis sp.*
- *Lemna sp.*
- *Ludwigia sp.*
- *Nitella sp.*
- *Nymphaea odorata*
- *Pontederia cordata*
- *Potamogeton nodosus*
- *Potamogeton perfoliatus*
- *Potamogeton pusillus*
- *Sagittaria graminea*
- *Spirodela sp.*
- *Stuckenia pectinata*

- *Utricularia geminiscapa*
- *Utricularia minor*
- *Vallisneria americana*
- *Wolffia sp.*
- *Zannichellia palustris*
- *Zosterella dubia*

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Article 409 Survey Background

On February 3, 2006, the Federal Energy Regulatory Commission (FERC) approved methodology for the licensee to conduct Article 409-Nuisance Plant Monitoring at Candlewood Lake, Lake Lillinonah and Lake Zoar (Rocky River, Shepaug, and Stevenson Developments). The licensee at the time of this report is FirstLight Power. Nuisance plant monitoring involves conducting annual surveys at Candlewood Lake and Squantz Pond and biannual surveys at Lake Lillinonah and Lake Zoar to determine presence and extent of invasive aquatic plant species.

The Connecticut Agricultural Experiment Station (CAES) conducted the Article 409 Survey under contract with the licensee for 11 years (2007-2017). NEAR first performed the Article 409 Survey in 2018. The number of days and months of each survey are recorded in **Table 1**.

Table 1. *Prior Nuisance Aquatic Plant Surveys of Candlewood Lake, 2007 - 2021.*

Year	Acres of Milfoil	Number of Survey Days Each Month						Total Days
		May	June	July	Aug	Sept	Oct	
2021	408		1	4	8			13
2020	469	2		2	10			14
2019	477				4	5		9
2018	512				7	2		9
2017	498		3	2	12			17
2016	506		4		12	2		17
2015	441		1	1	10	1		13
2014	477		4	1	11	4		20
2013	259		3		14	2	1	20
2012	505		5		16			21
2011	331				17	4	2	23
2010	461			1	14	1		15
2009	373				13	2		15
2008	451		1	5	9	3		18
2007 (all 3 lakes)	221		2	7	8			17

*Yellow shading indicates Lake Lillinonah survey years

*Blue shading indicates Lake Zoar survey years

*Green shading indicates Curly-leaf pondweed surveys in Candlewood

2021 Article 409 Survey Methods

Northeast Aquatic Research (NEAR) conducted the Article 409 Nuisance Plant Monitoring Plan Survey (Article 409 survey) in 2021. Candlewood Lake was surveyed for Curly-leaf pondweed in June, in locations where the species has historical records of existence. The full-lake survey of Candlewood Lake was conducted over twelve days between July 23rd and August 11th. Squantz Pond was surveyed on July 28th. Lake Lillinonah was surveyed over five days between August 12th and August 20th.

The dates of the Candlewood Lake and Squantz Pond surveys are presented in **Table 2**, along with the number of waypoints made each survey day. The number of waypoints made each day varied due to differences in the amount of littoral zone in each location and daily time spent on the water.

Table 2. *Dates of NEAR 2021 aquatic plant surveys in Candlewood Lake and Squantz Pond.*

Date	Location	Number of Waypoints
July 23	Lattin's Cove	116
July 26	Squantz Cove	106
July 29	Spear Point and Skeleton Island	99
July 30	Western shore of Sherman and Deer Island	98
August 2	North end of Sherman	111
August 3	Eastern shore of Sherman	196
August 4	Echo Bay	85
August 5	Central Basin	150
August 6	Danbury Bay	223
August 9	New Fairfield Bay	113
August 10	Eastern shore of New Milford	172
August 11	Western shore of New Milford	144
	Sub-Total	**1,613**
July 28	Squantz Pond	84
	Candlewood + Squantz Total	**1,697**

General Methodology

Surveys were conducted using high resolution down-imaging SONAR devices (Humminbird 688ciHD and/or Garmin Echo Map 74cv) transfixed to a survey boat. Both SONAR devices have imaging power of 455 and 800 kHz and scrolling images of resolved features in the water column, with water depth contours at 5-foot intervals. Scroll speed was set to 0.5 feet/sec.

A Garmin GPSMAP 78 was used to record waypoints and tracks during the survey. GPS waypoints were made when the boat was stopped to improve location accuracy. Waypoints provide geographical sampling units to estimate community species richness, diversity, abundance, and density. Waypoints were typically made at intervals of 300 feet throughout the littoral zone. Additional waypoints were made when water depth changed rapidly, species composition or density changed, or when new species were found. Extra waypoints were taken when necessary to improve mapping accuracy. Regular 300-foot spaced waypoints were made at the inner and outer edges of Eurasian milfoil beds. Detailed field notes documented the depth of the inner and outer edge of Eurasian milfoil stands, as shown by the depth soundings in **Image 1**, as well as between waypoints to document the continuous nature of the milfoil bands. Samples of plants were collected with a pole rake and throw rake at each waypoint where aquatic plants were not entirely visible from the surface. Aquatic plants were identified

according to Crow and Hellquist 2000. In addition to waypoints, the GPS continuous survey track from each day recorded the continuous position of the boat.

As a supplement to the survey methods, NEAR also recorded sonar logs throughout the entire survey. These sonar logs were then uploaded to a third-party software program called CI BioBase, which creates heat maps using the recorded information. The heat maps represent both lake depth and plant biovolume, which is a measure of the percentage of the water column occupied by plants. This helps to establish the true boundaries of the littoral zone and accurately delineate the presence/absence of plant beds.

The sonar logs were saved to an external SD card using the .sl2 file extension. Settings for the sonar recording were compliant with CI BioBase recommended standards:

- Fishing Mode = Shallow Water if less than 60 ft, Freshwater if less than 400 ft, General Use if less than 1000 ft
- Ping Rate = 15-20
- Range = Auto, unless mapping shallow ponds, then set range 2x the max depth
- Noise Rejection = Low
- Surface Clarity = Off
- Frequency = 200 kHz
- Speed = 1-7 mph

Image 1. *Down-imaging SONAR images showing edge of milfoil coverage and the height of milfoil plants.*

NEAR Survey Methods

The central purpose of the Article 409 Survey is to census the population of Eurasian milfoil and to search for new invasive species in the three lakes. The plant surveys aim to report the surface coverage, location, and qualitative density of each invasive and native species found. Annual locations and acreages are to be compared against data from previous years. This type of census survey requires a diligent search for target plants in the littoral zone. New or rarely present species are more likely found with this "meander" survey technique than with transect-based surveys, or surveys with pre-determined waypoints.

A "meander" survey was performed by driving the boat in a zig-zag pattern, crossing the inner and outer edges of the Eurasian milfoil beds. In areas where the littoral zone was very narrow, the boat was driven in a straight line along the outer edge of the plant bed, rather than the zig-zag pattern. The outer edge of plant growth, which was located in deep water and therefore not visible from the water's surface, was found using SONAR images, which showed a flat featureless line where plants stopped growing (**Image 1**). The lack of plant cover was verified with at least two throws of the rake. The edge of plant growth was marked with a waypoint and water depth was recorded. The outer edge of plant growth can be considered the boundary between the littoral zone and water too deep to support rooted aquatic plants. SONAR imaging was used continuously throughout the survey and noted for mapping purposes between waypoints.

Survey Track and Waypoints

Survey boat speed was maintained between 0.1 and 0.4 miles/hour. Surveyors continuously observed plants off the front and sides of the boat, as well as on the depth sounder. Continuous visual assessment allows for detection of rare and potentially new invasive species.

The boat was driven in a zig-zag pattern along the shoreline, as described in the above section (**Map 1**). The boat was driven away from shore until reaching the outer edge of the milfoil as could be seen on the depth sounder and verified by the throw rake. The boat was then turned and driven towards shore until reaching the inner edge of the milfoil bed. As previously mentioned, in areas where the littoral zone was very narrow, the boat was driven in a straight line rather than a zig zag pattern.

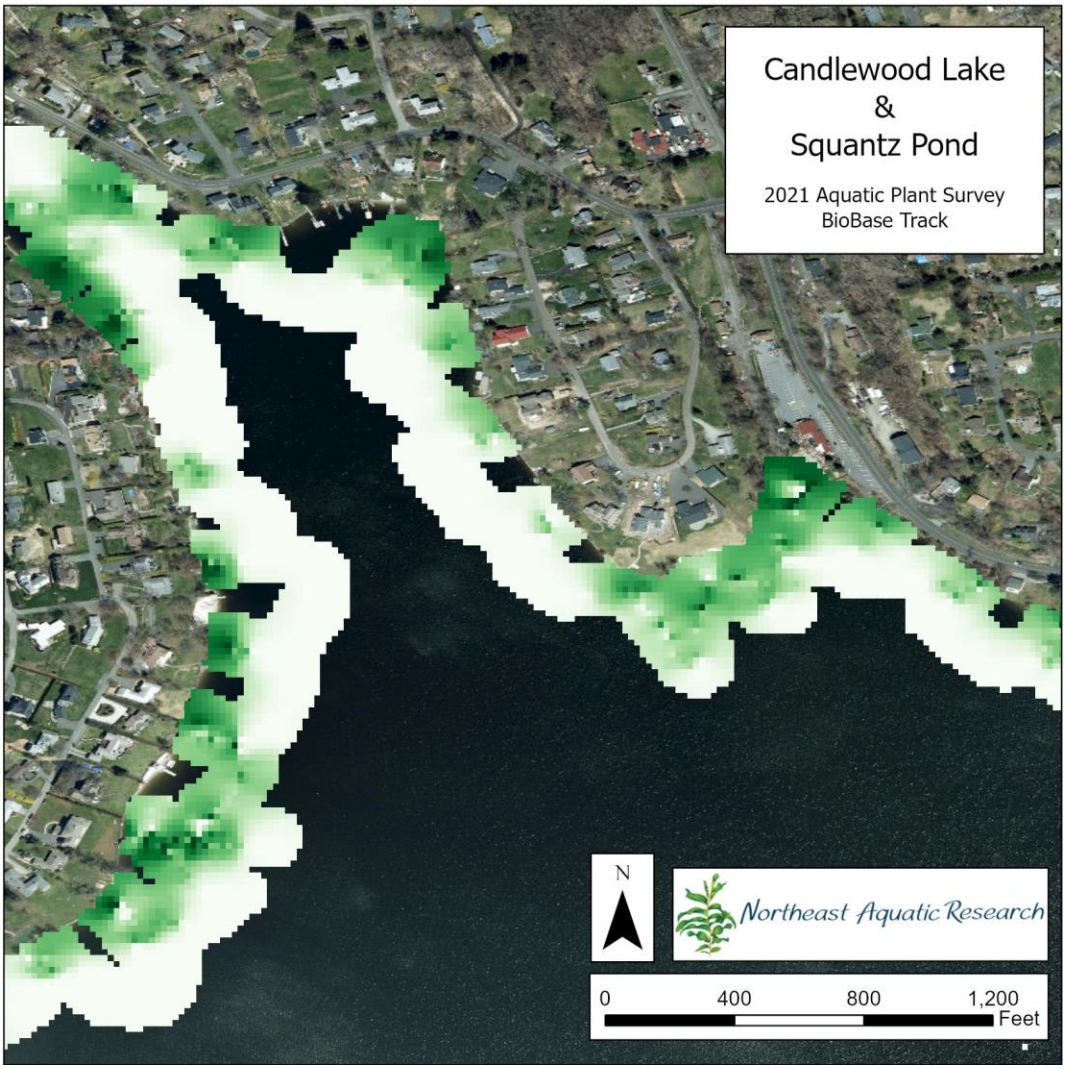
As a pilot program, BioBase was used for seven of the twelve Candlewood Lake survey days to collect continuous plant growth data. The program collects a grid of waypoints with associated water depth and plant height. This waypoint data was loaded into ArcGIS Pro and converted into a raster layer. The water depth and plant height data allowed for more accurate mapping of the milfoil beds compared to prior years (**Map 2**). BioBase will be used for the entirety of the Candlewood Lake survey in 2022.

Waypoints were created every ~300 feet along the lake's shoreline and around all the islands. At each waypoint, the depths of the inner and outer edges of the milfoil bed were recorded, along with the density and growth form of all species present at the waypoint. Any changes in bed density perpendicular to shore were also recorded, as well as the water depths at which those density changes occurred.

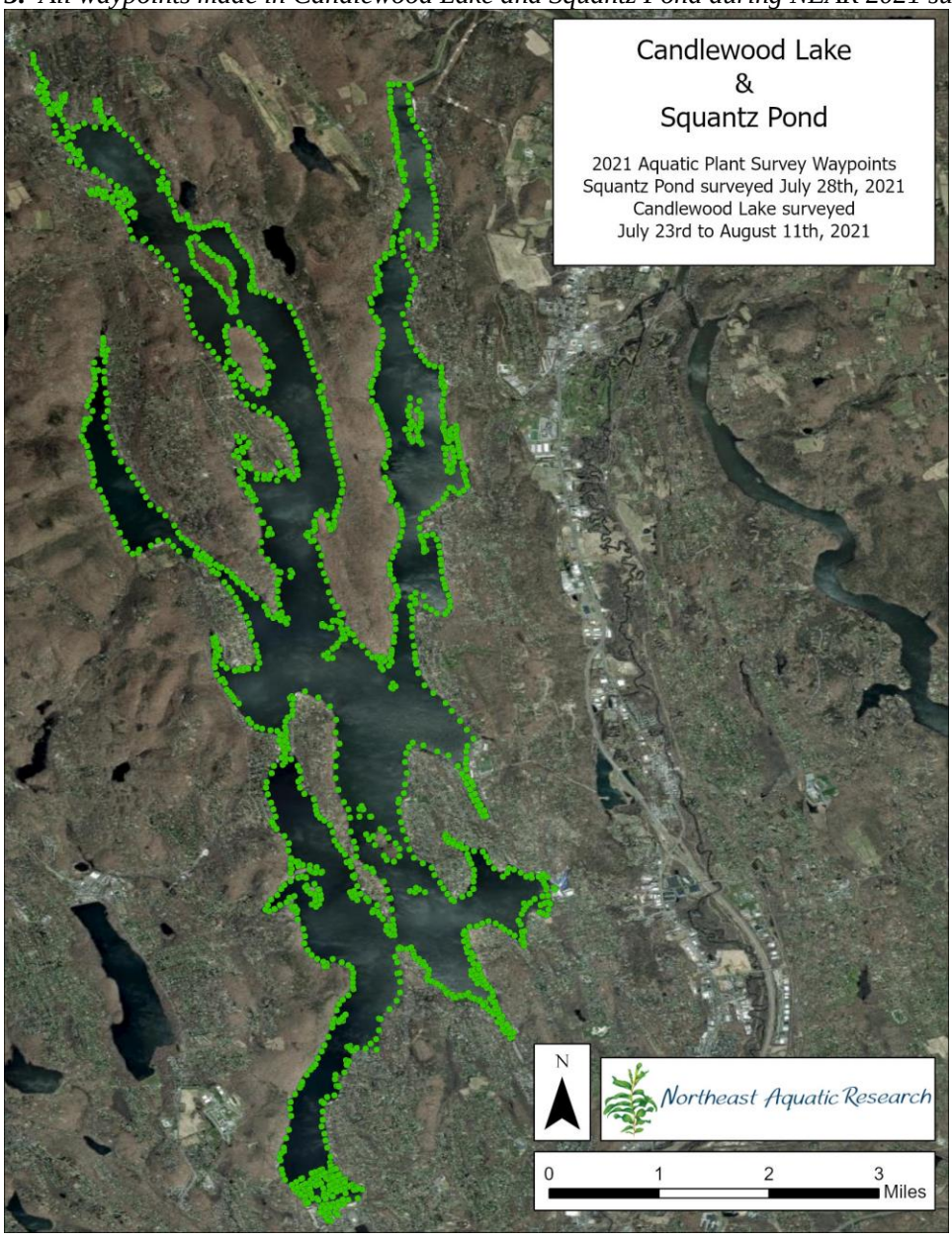
Outer limits of plant growth were often governed by changes in landscape and slope. Consistency of milfoil beds was visually assessed between waypoints and indicated on the data sheets as notes to improve GIS mapping accuracy. These notes add more data to the survey and diminish the amount of interpolation between waypoints. Infrequent invasive species were also marked with GPS waypoints when identified, which is one reason why some waypoints occur closer together than the typical 300 feet. Waypoints were also made to indicate the beginning and end of milfoil beds when they occurred. A total array of 1,613 waypoints were created in Candlewood Lake and 84 waypoints were created in Squantz Pond (**Map 3**).

Map 1. *Zoomed section of 2021 survey track and waypoints.*

Map 2. *Zoomed section of 2021 BioBase track White indicates no plant growth. Dark green indicates abundant biomass.*



Map 3. *All waypoints made in Candlewood Lake and Squantz Pond during NEAR 2021 survey.*



Waypoint Data: Density & Plant Height

Plant density was determined using a combination of three methods. The first method, visual density determination, is based solely on what is seen from the surface within 10 feet of the boat. This method involves a scaled-up version of quadrat vegetation percent cover assessments. In this method, one visually assesses how much area is covered by the plant in question. **Image 2** below demonstrates approximate ranges in visual percent cover of aquatic plants as seen from the surface. Yet, using an actual quadrat in the field is not appropriate for the large scale of aquatic plant surveys. For that reason, surveyors visualize a hypothetical quadrat, approximately 10ft in length, and then estimate coverage accordingly within the plant beds.

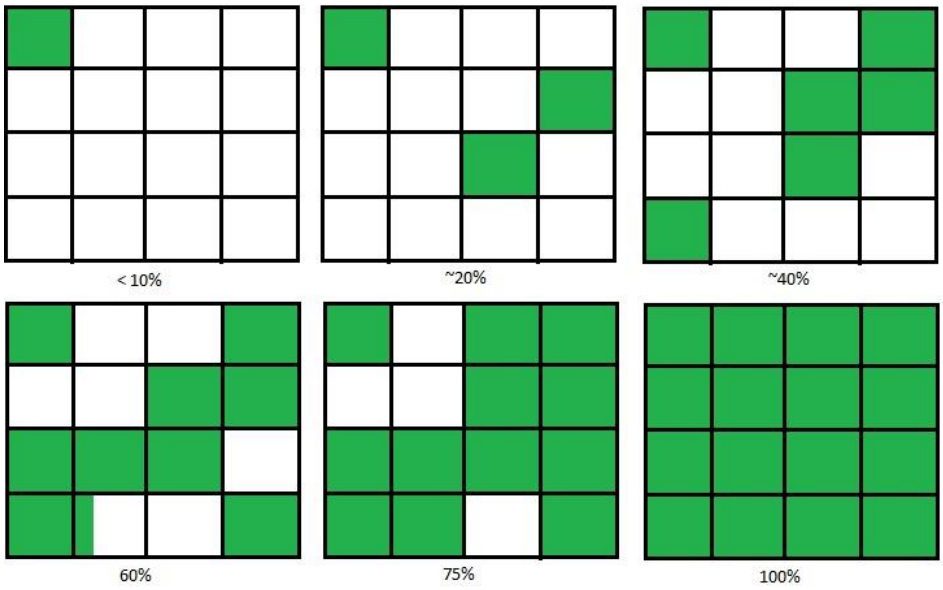


Image 2. *Visual Percent Cover Estimate Guides - Hypothetical Field Quadrats ~10ft across.*

Visual estimates are made by a single person throughout the survey, but survey team members do input their perceived percent coverage estimates if the primary surveyor's estimate seems too low or too high. Team collaboration encourages objectivity and more accurate estimates.

The second method used to estimate percent cover of vegetation is to use down-imaging SONAR, which shows a detailed image of the plants as the boat passes above (**Image 1**). In this photo, milfoil is shown reaching to about 3 feet from the surface in both images. Plants in the first image begin growing at 7.5ft deep, while milfoil plants in the second image are very sparse in shallow water and dense starting at 8ft. The boat is at far right at time of depth readout in both images.

SONAR imaging is used to corroborate visual percent cover estimates in areas where plants can be seen from the surface. In areas where plants cannot be seen from the surface, the SONAR image becomes the primary way to 'see' coverage. SONAR and visual estimates are then corroborated by weed-rake tosses. Rake tosses involve stopping the boat and throwing a 30ft line to tow through plant beds. Plants retrieved by the rake are estimated semi quantitatively as a percent cover:

- Sparse (1-19%, handful of plants)
- Moderate (20-59%, plants covering about half of the rake tines)
- Dense (60-100%, plants covering significantly more than half to all rake tines)

When possible, all three methods of estimating percent cover are used at each waypoint, and the resulting estimate is recorded on the datasheet. Raking in shallow water, however, yields limited results due to sandy and rocky substrates, so visual assessment was the primary density determination method for waters shallower than 3ft.

Coverage percentages are used to distinguish between Sparse, Moderate, and Dense plant beds for the purposes of GIS mapping. The numeric percent cover at each individual waypoint is only semi-quantitative. Though, across all waypoints together, the data can be used more quantitatively over time if users recognize the inherent limitations in percent cover estimates per species at individual waypoints.

The down-imaging SONAR device is also used to estimate plant height in the water column, as well as the water depth. In almost all cases in Candlewood Lake, Eurasian milfoil reached to only 1-2 feet from the surface. Survey methods involve a number scale of 1 to 5 in estimating plant height (also known as "growth form") in the water column.

1 = Plants low to the lake bottom, not more than a few inches tall.
2 = Plants reach about 1/3 of water depth tall.
3 = Plants reach about 2/3 of water depth tall, typically 1-2ft below the surface in milfoil depth-ranges.
4 = Plants just beneath the surface, < 1ft from surface.
5 = Plants "topped out" and breaking the surface, likely flowering.

GIS Mapping

All waypoints created during the survey were imported into ArcGIS Pro and used to create the maps of invasive species. In ArcGIS, the project's coordinate system was set to *CT State Plane NAD83*. The GPS tracks and waypoints were uploaded as .gbd files and converted to .gpx files using GPSBabel, and then converted to ESRI 2D shapefiles (.shp), using DNRGarmin. Both are simple file formatting computer programs designed to transfer GPS data between various types of mapping programs.

The three density categories for milfoil – Sparse, Moderate and Dense – taken from waypoint percent cover data, were mapped by using the GPS track, waypoints, survey notes, and BioBase raster files as guides to accurately draw polygons.

The CT Lake Bathymetry GIS layer, produced by the Connecticut Department of Energy and Environmental Protection (DEEP), was used as an aid in mapping the milfoil beds, but to a lesser extent than in prior years due to the introduction of the more accurate BioBase water depth data. On days when the BioBase program was not utilized, the bathymetric contours were used in conjunction with the survey waypoints to determine the edges of polygons based on notes indicating the water depths of the inner and outer edges of milfoil beds or changes in plant density.

The total acreage of all polygons within each density category was calculated within each layer's attribute table.

Candlewood Lake Results

INVASIVE AQUATIC PLANTS

Three invasive aquatic plant species were found in Candlewood Lake during the 2021 survey: Eurasian milfoil *(Myriophyllum spicatum*), Brittle naiad (*Najas minor*), and Mudmat (*Glossostigma cleistanthum*). This is consistent with findings from the three prior years (**Table 3**).

Eurasian milfoil was the most abundant, covering a total of ~408 acres (**Table 4**, **Map 4** – **Map 13**). Of this total, there were ~263 acres of dense growth, ~104 acres of moderate density growth, and ~42 acres of sparse growth.

Brittle naiad was found at 23 waypoints in Candlewood Lake in 2021 (**Map 14**).

Mudmat was found at 17 waypoints in Candlewood Lake and Squantz Pond. Mudmat is a very small plant, with leaves less than 1/4 inch. It is found only in very shallow water, typically <6 inches, with sandy sediment.

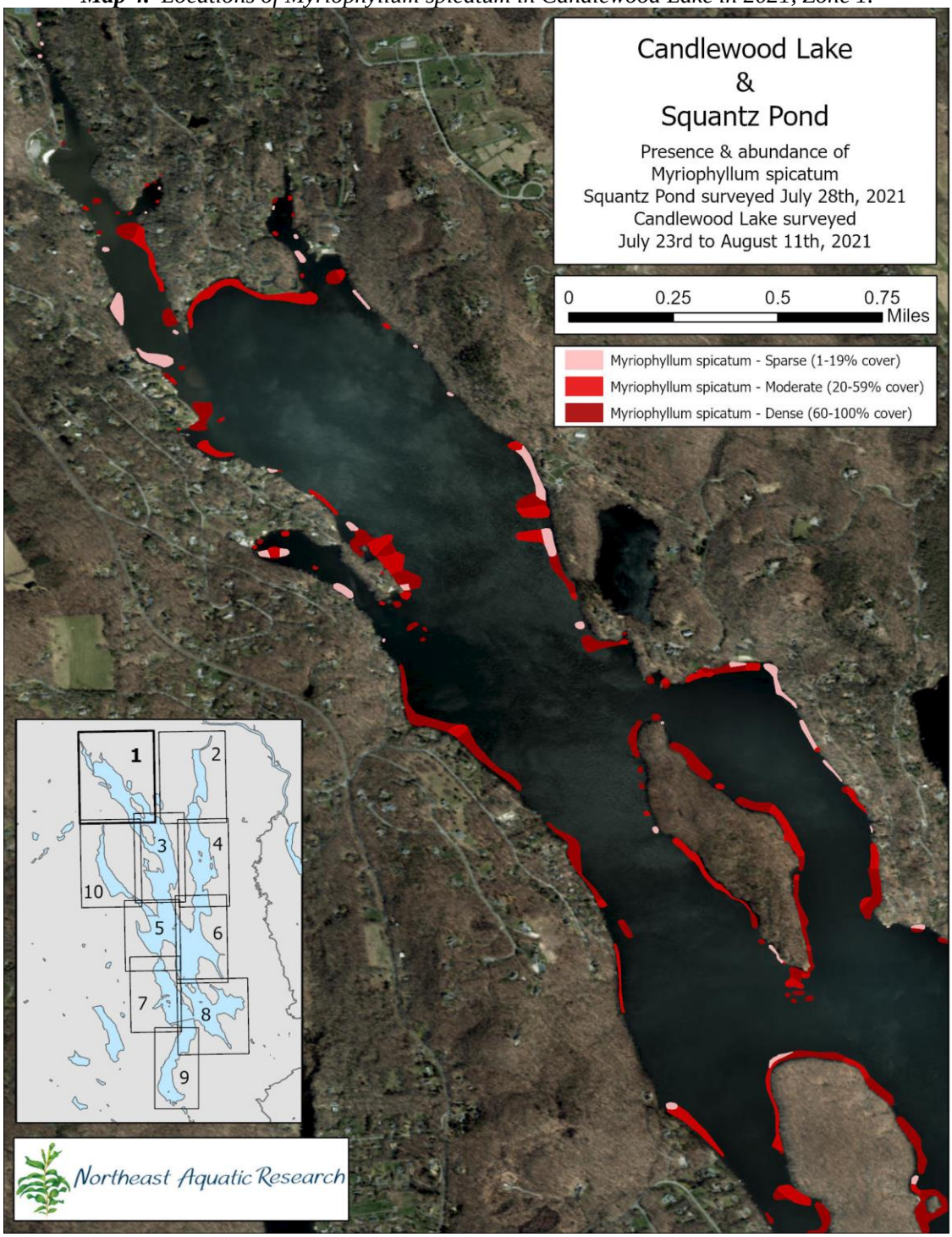
Table 3. *Invasive aquatic plant species found in Candlewood Lake by NEAR, 2018-2021.*

Invasive Species	% Frequency 2021	% Frequency 2020	% Frequency 2019	% Frequency 2018
Eurasian Milfoil	75%	76%	74.5%	83.10%
Brittle Naiad	1.4% / 23 points	3% / 45 points	0.5% / 10 points	1.6% / 27 points
Mudmat	1.1% / 17 points	0.4% / 6 points	1.1% / 22 points	1% / 17 points

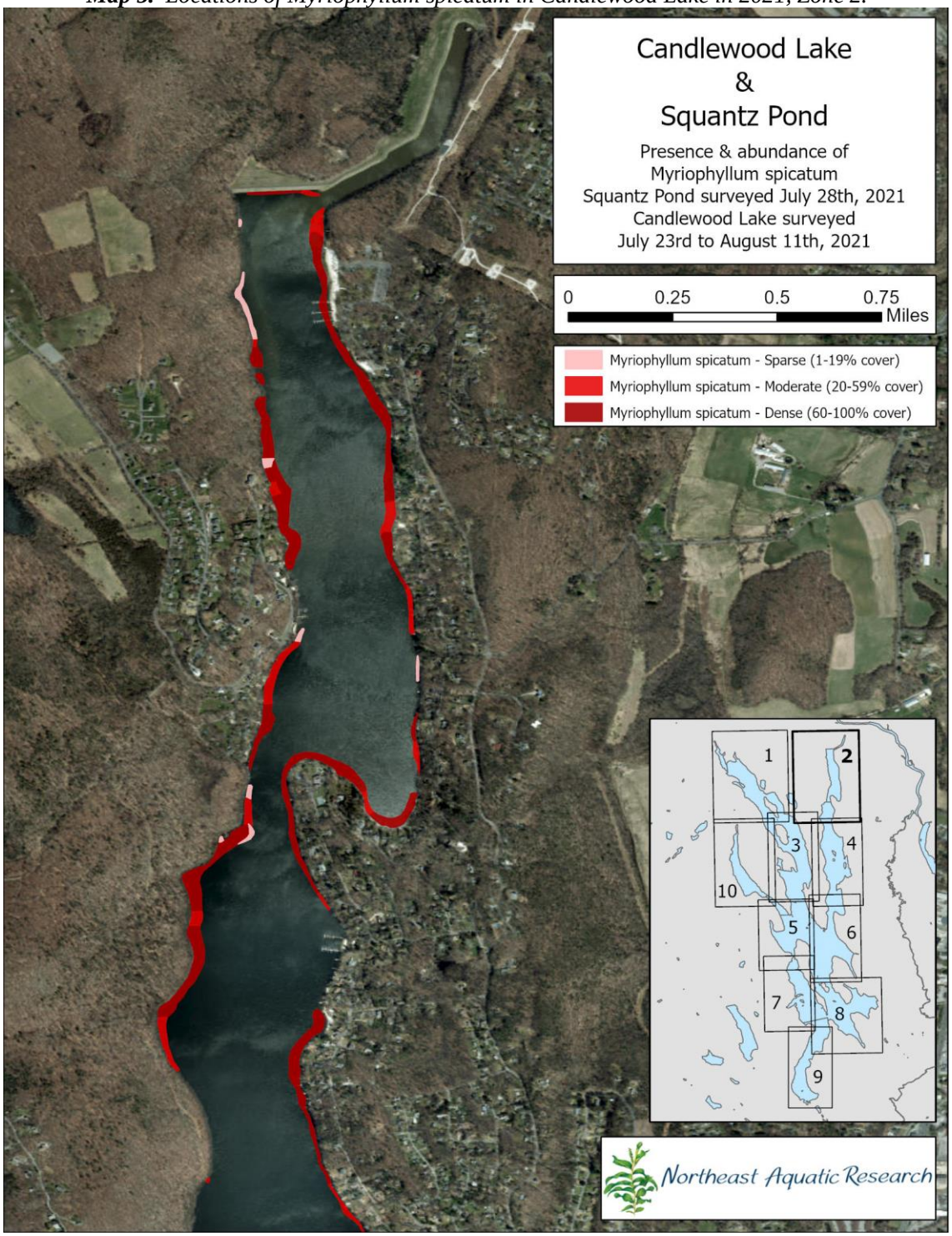
Table 4. *Acreages of milfoil density categories, 2018-2021. Acreage values are approximations.*

Density Category	2021		2020		2019		2018	
	Acres	% of Total Acres	Acres	% of Total Acres	Acres	% of Total Acres	Acres	% of Total Acres
Dense	262.5	64.3	352.6	75.2	262.2	55.0	418.1	81.7
Moderate	103.8	25.4	61.0	13.0	112.8	23.6	61.7	12.1
Sparse	42.1	10.3	55.2	11.8	102.1	21.4	31.8	6.2
Total	408.4		468.8		477.0		511.6	

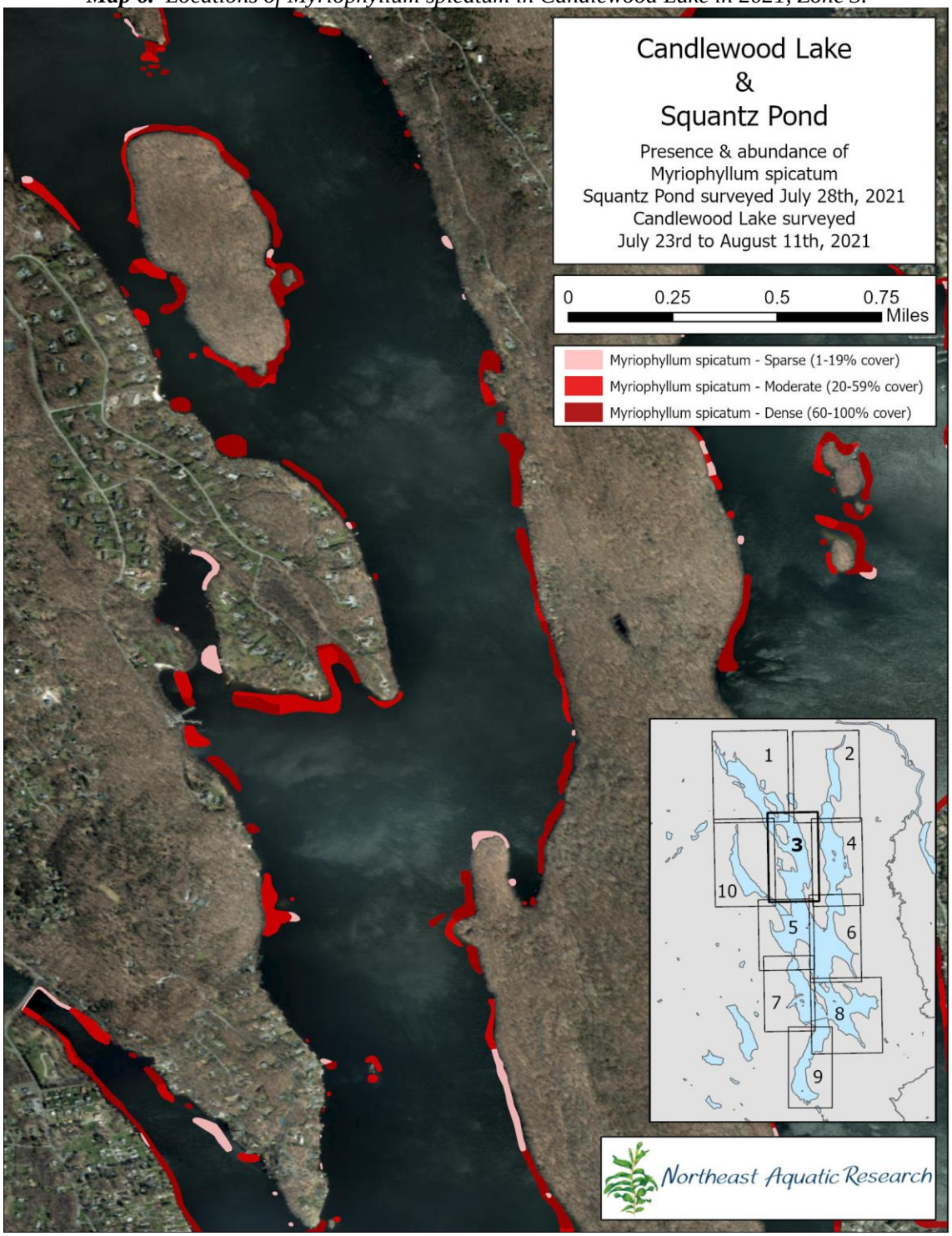
Map 4. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 1.*



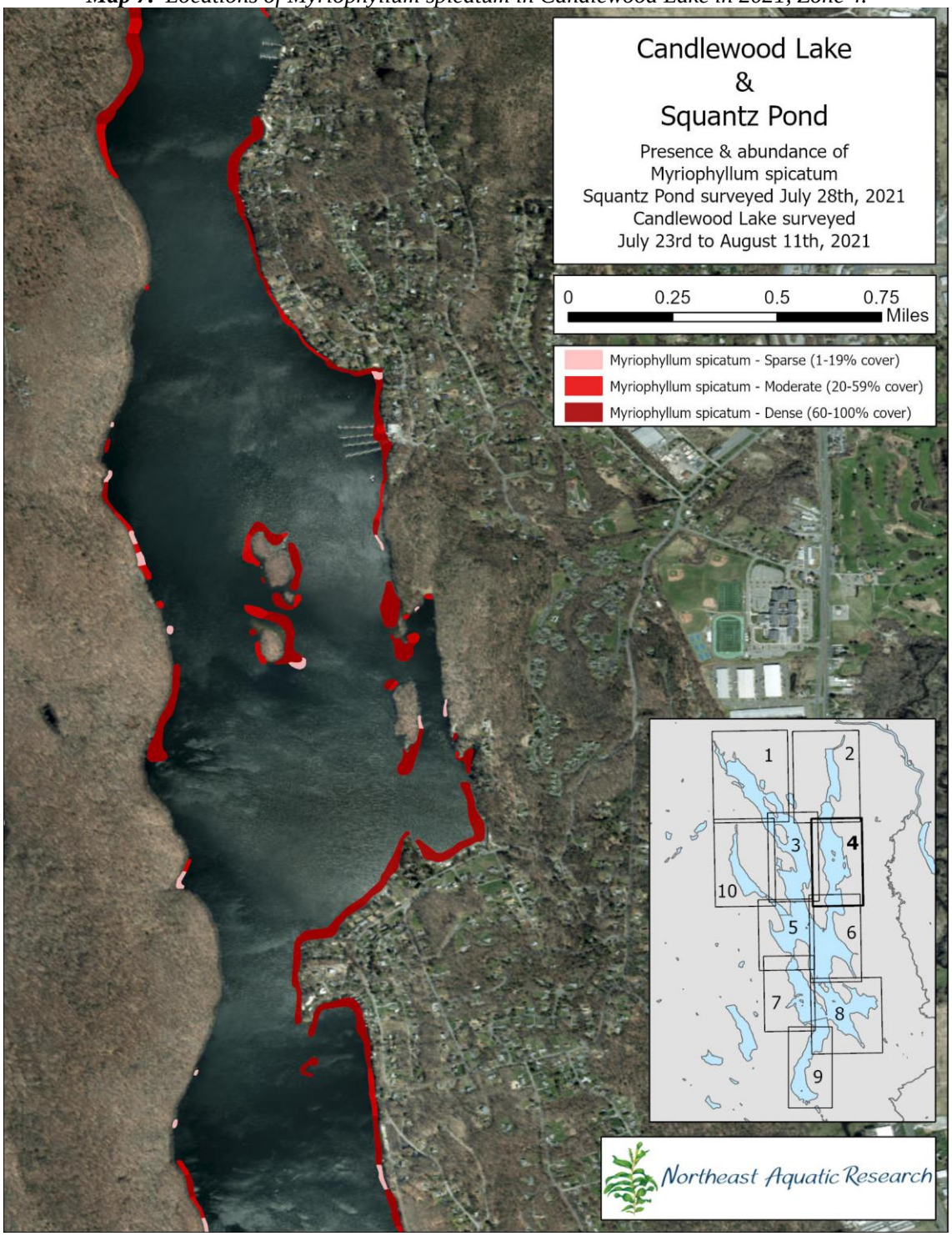
Map 5. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 2.*



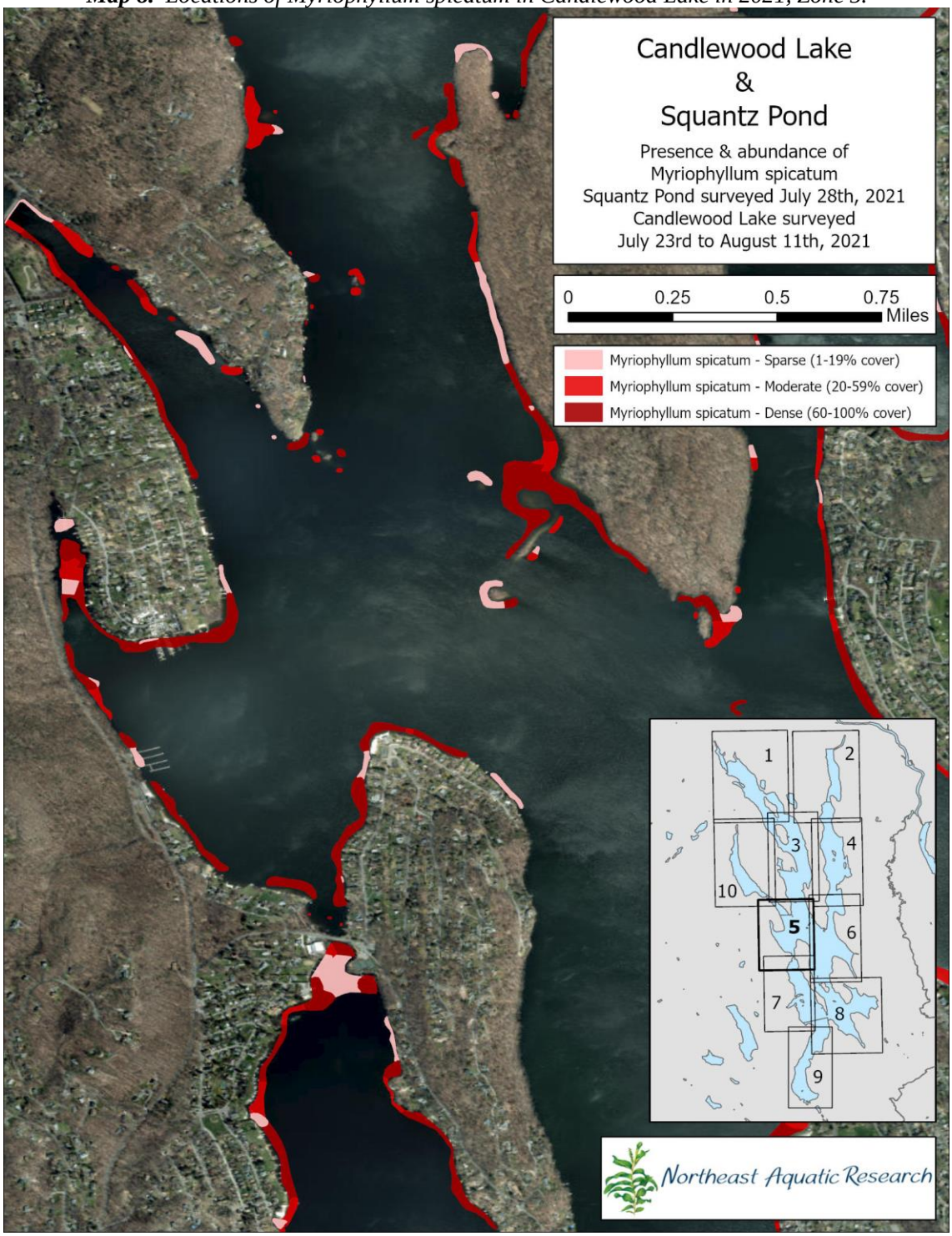
Map 6. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 3.*



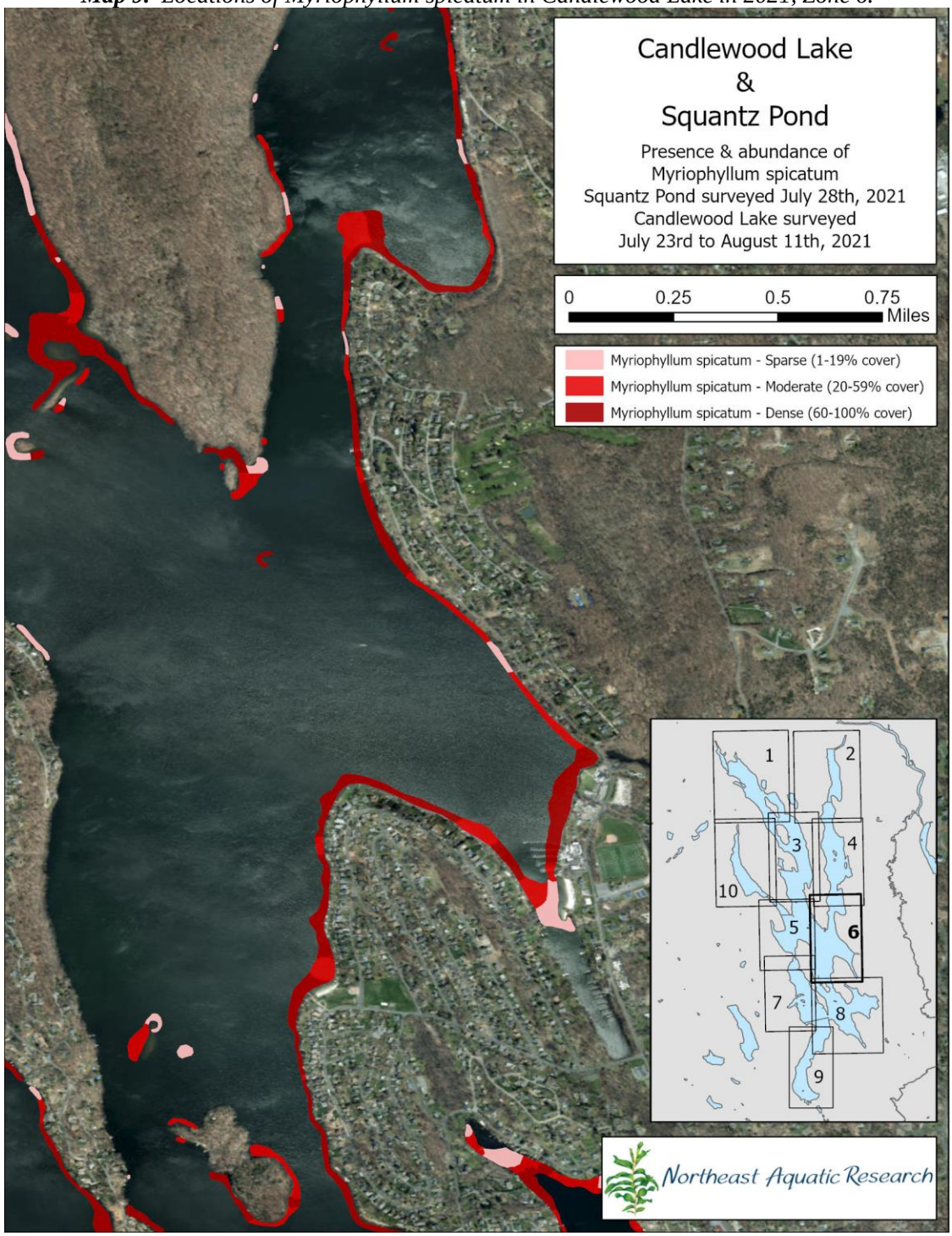
Map 7. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 4.*



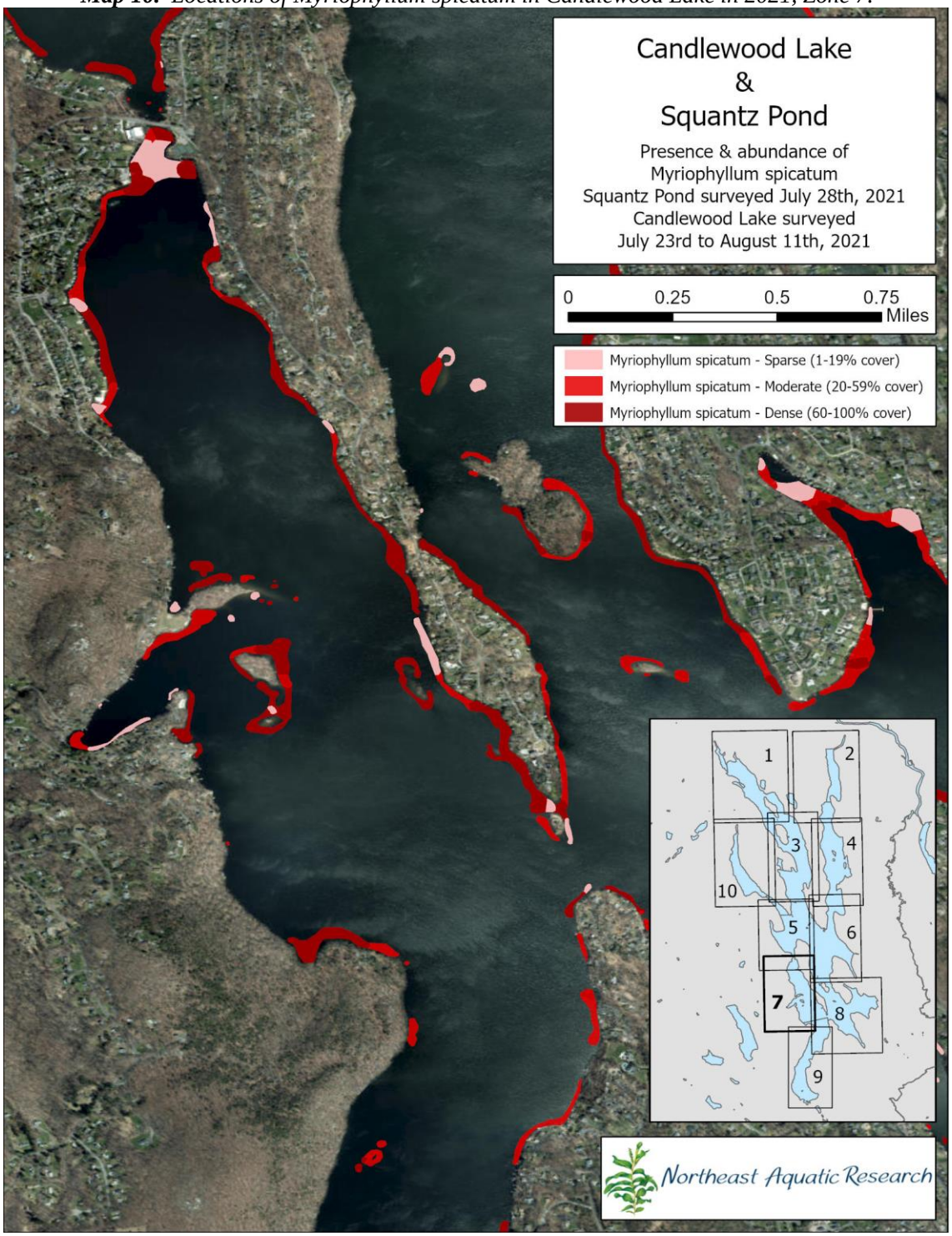
Map 8. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 5.*



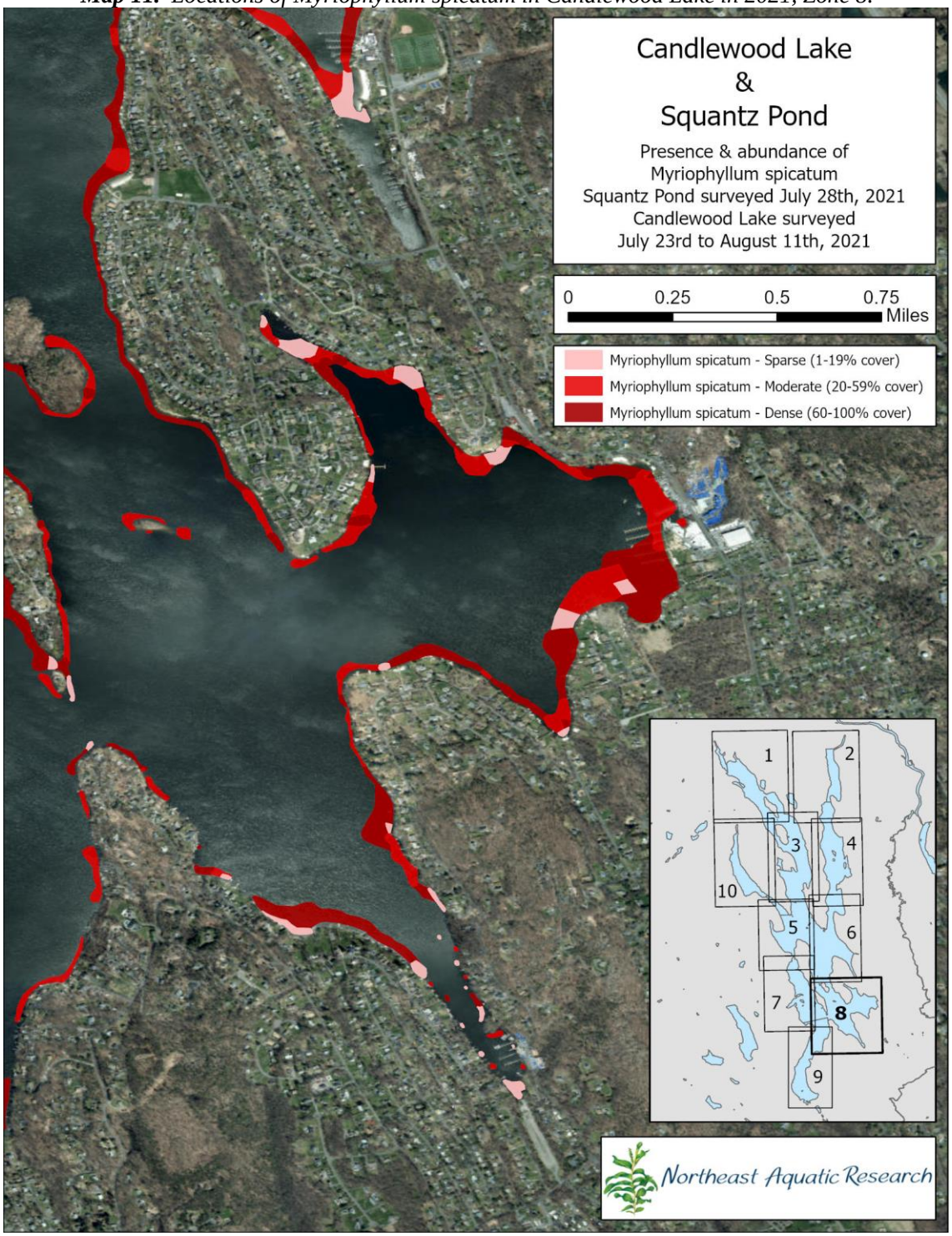
Map 9. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 6.*



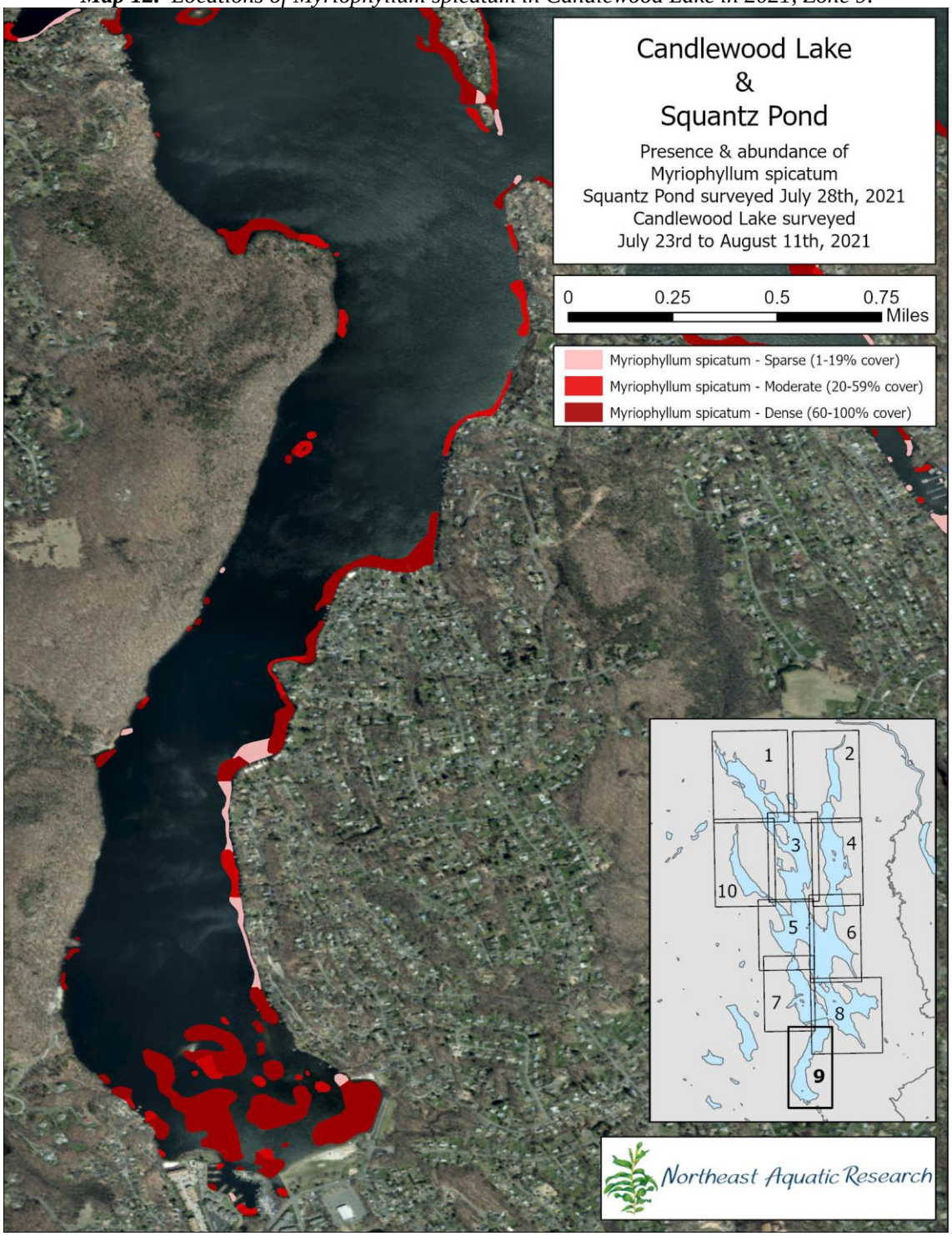
Map 10. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 7.*



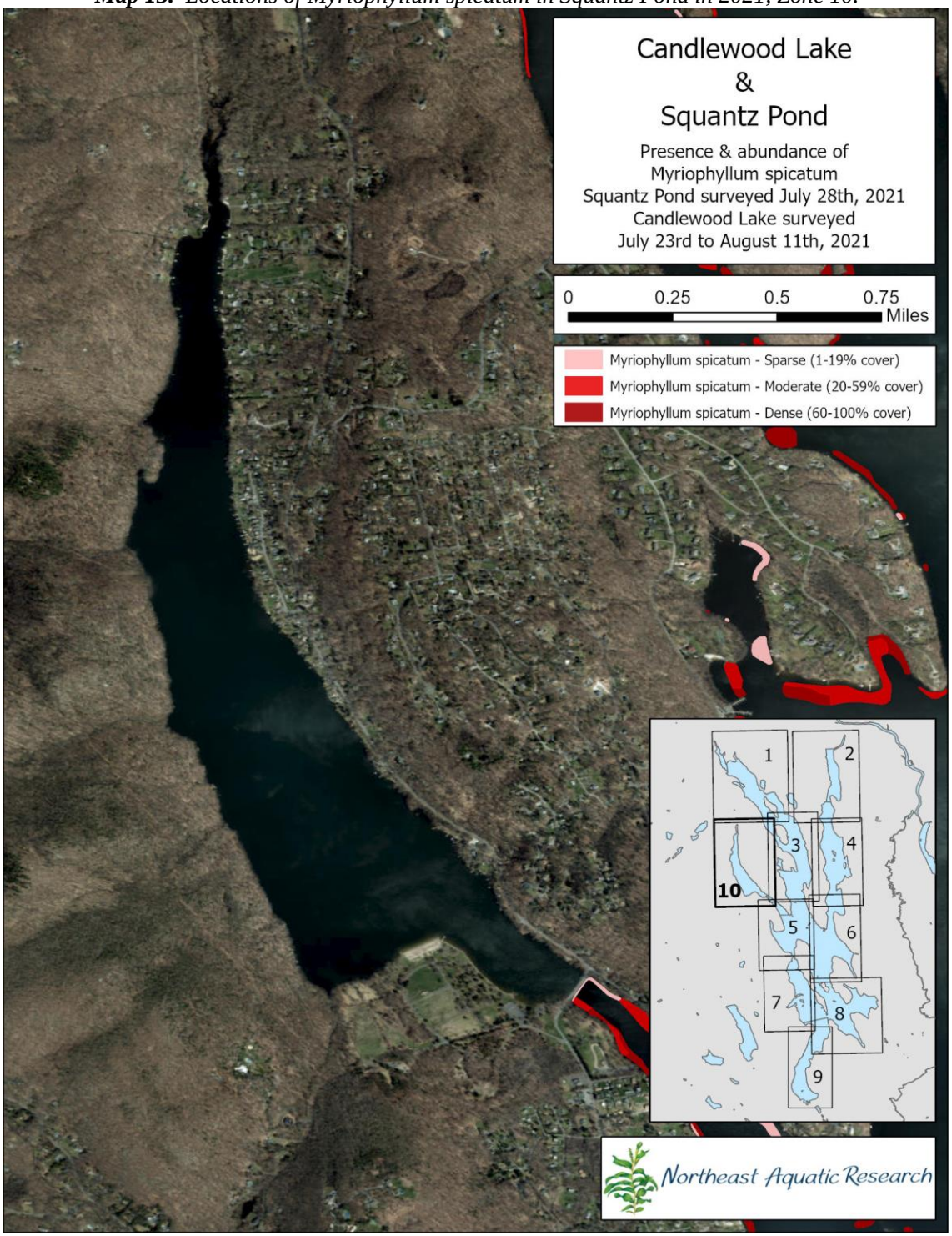
Map 11. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 8.*



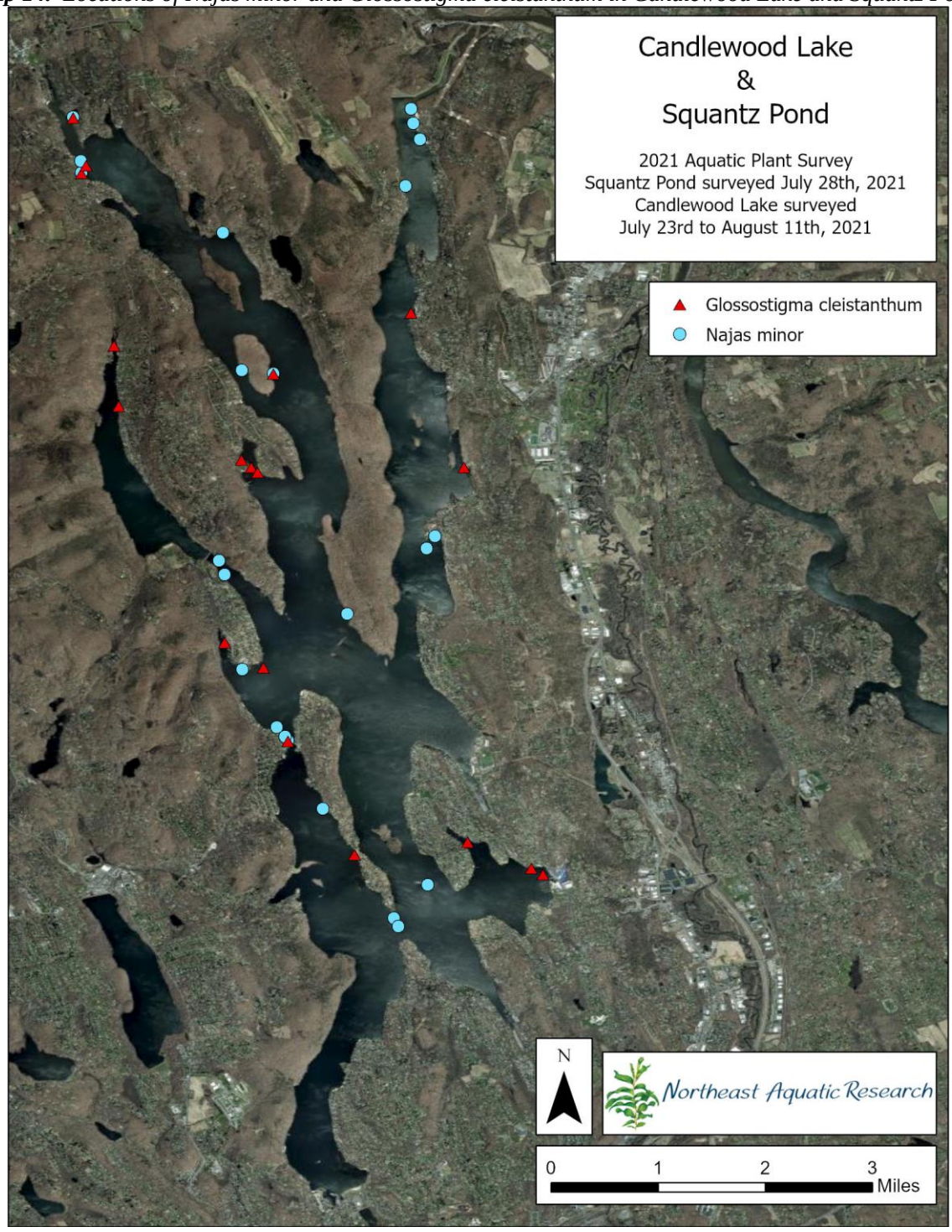
Map 12. *Locations of Myriophyllum spicatum in Candlewood Lake in 2021, Zone 9.*



Map 13. *Locations of Myriophyllum spicatum in Squantz Pond in 2021, Zone 10.*



Map 14. *Locations of Najas minor and Glossostigma cleistanthum in Candlewood Lake and Squantz Pond.*



The overall milfoil acreage in 2021 was lower than in recent years. There are a few possible causes for the decrease. First, the inner (shoreline) edge of the milfoil appears regulated by exposure during winter drawdown, along with wind and wave action. Milfoil is consistently reduced in the summer following a deep winter drawdown (**Figure 1**). In the winter 2020/2021 the lake was drawn down to -9.4 feet, which is the deepest drawdown in at least seven years (**Figure 2**). The inner edge of the milfoil beds regularly ended in ~5-7 feet of water in 2021, compared to 2020 when the inner edge typically ended in ~4-5 feet of water, meaning plant beds were often narrower in 2021. Additionally, Candlewood Lake contained fewer high-density and sparse milfoil beds in 2021 compared to 2020, but more moderate-density beds. It is likely that some of the milfoil beds that were dense in 2020 decreased in density following the deep drawdown.

Second, the introduction of the BioBase software drastically improved the accuracy of mapping the milfoil beds. Comparison between the BioBase water level data and the CT Lake Bathymetry layer revealed that the bathymetric contour lines were frequently drawn slightly deeper than was accurate. This means that in past years, when mapping was more reliant on the bathymetry, the outer edges of milfoil beds may have been drawn out into water that was deeper than the bathymetry suggested.

It is important to note that the acreage calculations should be used as a guide rather than exact values. In 2020, in an attempt to estimate the potential mapping acreage error range for the Eurasian milfoil in Candlewood Lake, one-foot and two-foot buffers were added to the outside edges of the total milfoil polygons as a sensitivity test. A one-foot buffer added ~13 acres to the total, while a two-foot buffer added ~26 acres. It is important to acknowledge this type of inevitable GIS mapping error when evaluating the impacts of plant management methods over time.

The outer edge of the milfoil is limited by the loss of available light in deep water. The outer edge of milfoil was typically located between 15 and 16 feet but was occasionally found out to 18-20 feet.

Along some shorelines, the slope was very steep, meaning that the water reached depths of greater than 20 feet very close to shore. Many areas also had exposed bedrock and large boulders, which are a hindrance to plant growth and account for the gaps in shoreline milfoil bands**.**

The inner ends of many of the coves had very little milfoil, even less than in 2020, likely due to the grass carp. Based on observations noted during the past three years of surveying, it seems that the grass carp prefer the coves, and are therefore consuming milfoil at a faster rate in these areas of the lake.

During the 2021 survey, approximately 20% of the milfoil was at a growth form of 4, meaning the plants were less than one foot from the water surface (**Figure 3**). Approximately 6% of the milfoil was "topped out" (**Map 15**). Topped-out is a term used to describe growth conditions where plant shoots break the water's surface and produce aerial flowers. There was notably less topped out milfoil in 2021 compared to 2020. The decrease is likely caused by impacts of the deep winter drawdown, though it is also possible that grass carp were feeding on the plant tips.

Coontail (*Ceratophyllum demersum*) was often found in deeper water than the Eurasian milfoil. However, the two species were differentiated with the use of the down-imaging SONAR in conjunction with the throw rake. Eurasian milfoil and Coontail have distinct structural forms that can be easily differentiated on the down-imaging SONAR. The throw rake was used to pull up plants to confirm the species that were present.

Figure 1. *Acres of Eurasian Milfoil in Candlewood Lake 2006 - 2021, deep drawdowns indicated with orange vertical lines.*

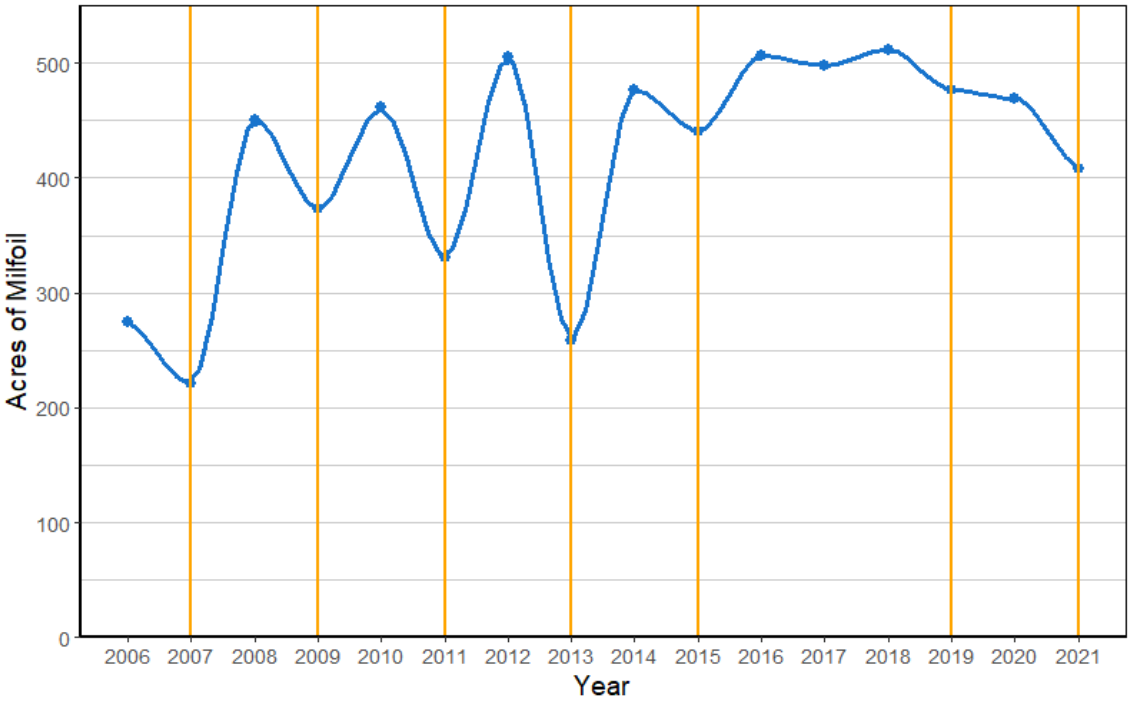


Figure 2. *Water levels at Candlewood Lake between Jan. 1, 2015 and November 16, 2021. Average summer elevation indicated with orange vertical dashed line. (DATA Provisional).*

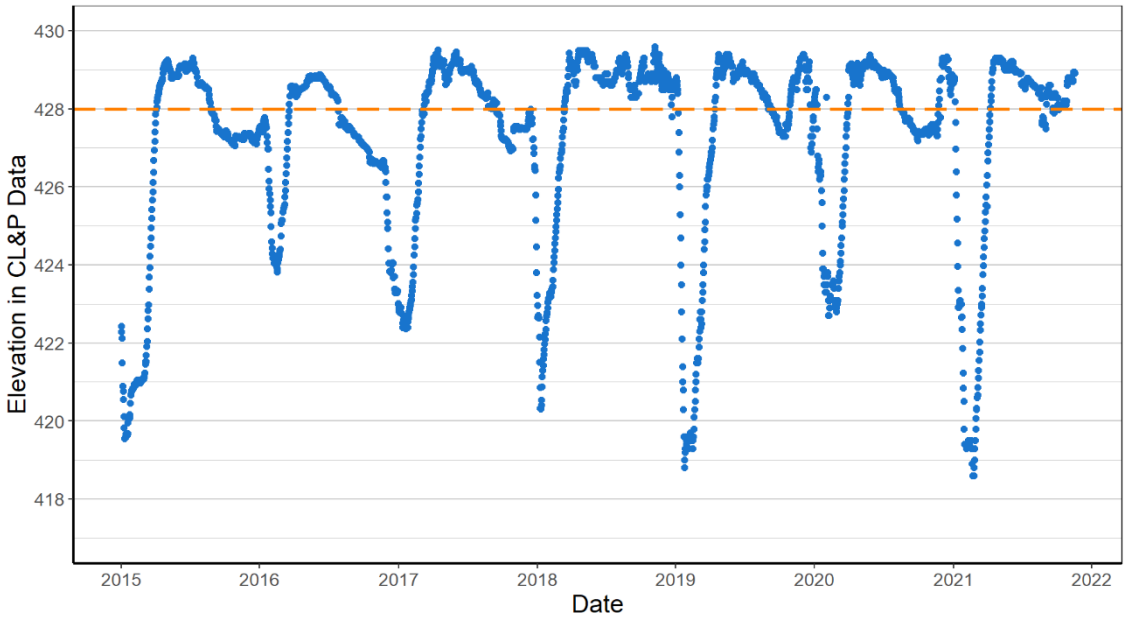
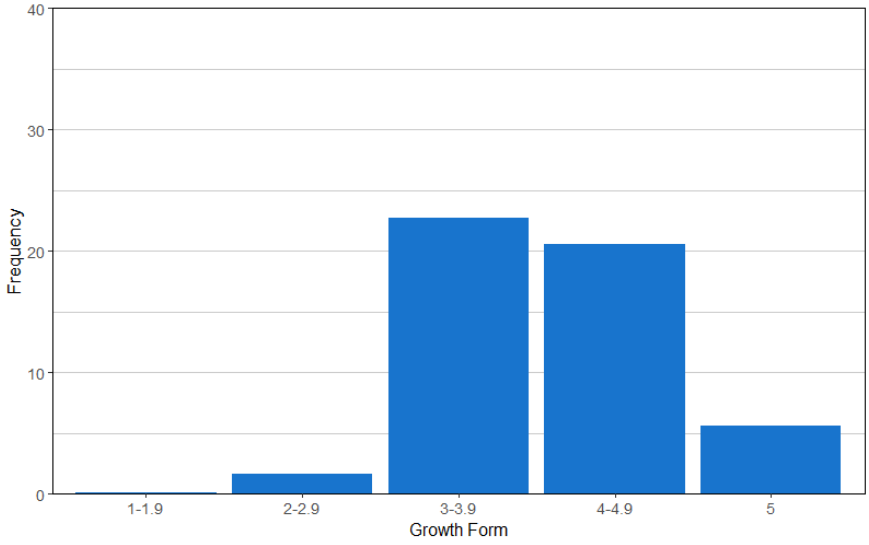
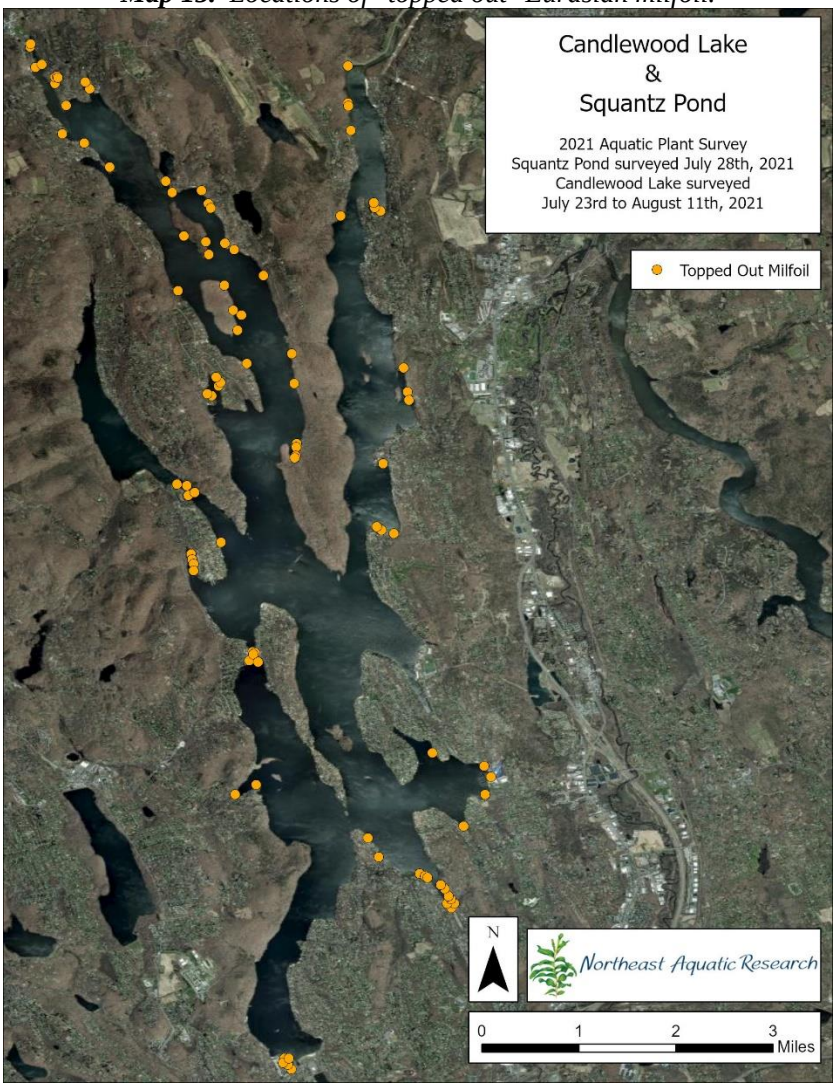


Figure 3. *Myriophyllum spicatum growth form frequencies in Candlewood Lake in 2021.*



Map 15. *Locations of "topped out" Eurasian milfoil.*



NATIVE PLANTS IN CANDLEWOOD LAKE

21 native vascular aquatic plant species were found in Candlewood Lake during the 2021 survey, which is the highest species richness so far to be documented in the lake (**Table 5**, **Table 6)**. Filamentous cyanobacteria (*Lyngbya wollei*) and Filamentous green algae (*Spirogyra sp.*) are not categorized as plants but are included in the species list to provide information about their abundances in the lake.

Coontail (*Ceratophyllum demersum*) was the most abundant native plant, which is consistent with findings from the prior three years. It was present at ~16% of waypoints. This species is generally found in deep water outside of the milfoil beds.

Spike rush (*Eleocharis acicularis*) and Horned pondweed (*Zannichellia palustris*) were found at 33 waypoints and 16 waypoints respectively. The remaining native species were each found at very few locations and all species other than Coontail and Tape grass (*Vallisneria americana*) were small, generally less than three inches in height.

Filamentous green algae (*Spirogyra sp.* and *Zygnema sp.*) was relatively abundant, present at 13% of waypoints spread throughout the lake. Filamentous algae is indicative of elevated nutrient concentrations.

Table 5. *Native aquatic plant species, found in Candlewood Lake by NEAR during the surveys 2018 - 2021.*

Scientific Name	Common Name	# of sites **** 2021	# of sites *** 2020	# of sites ** 2019	# of sites * 2018
Callitriche palustris	Water starwort	1	0	0	0
Ceratophyllum demersum	Coontail	259	152	53	110
Chara	Muskgrass	1	0	0	0
Elatine minima	Waterwort	5	28	23	0
Eleocharis acicularis	Spike rush - submersed	33	49	27	19
Spirogyra sp.	Filamentous green algae	211	42	3	6
Fontinalis	Aquatic moss	6	2	0	0
Lemna	Duckweed	3	0	0	0
Ludwigia palustris	Marsh purslane	1	1	0	0
Lyngbya wollei	Cyanomat	4	8	0	4
Najas flexilis	Slender naiad	1	0	1	0
Nymphaea odorata	White water-lily	2	2	1	4
Pontederia cordata	Pickerelweed	1	0	0	0
Potamogeton amplifolius	Large-leaf pondweed	0	0	0	1
Potamogeton berchtoldii	Slender pondweed	1	0	0	0
Potamogeton bicupulatus	Snail-seed pondweed	2	0	0	0
Potamogeton foliosus	Leafy pondweed	0	2	0	0
Potamogeton illinoensis	Illinois pondweed	1	0	0	0
Potamogeton pusillus	Slender pondweed	0	0	3	0
Potamogeton spirillus	Spiral pondweed	0	8	0	0
Sparganium fluctuans	Floating bur-reed	1	0	0	0
Spirodela polyrhiza	Greater duckweed	1	0	0	0

Spirogyra typical - green	Filamentous algae	0	0	3	6
Stuckenia pectinata	Sago pondweed	5	2	0	0
Vallisneria americana	Tape-grass	9	6	12	5
Wolffia	Watermeal/Duckweed	4	1	5	1
Zannichellia palustris	Horned pondweed	16	20	0	0
Zosterella dubia	Water stargrass	4	3	5	1

* Out of a total of 1,988 sites

** Out of a total of 1,686 sites

*** Out of a total of 1,491 sites

**** Out of a total of 1,613 sites

Table 6. *Percent frequency of aquatic plant species observed in Candlewood Lake by CAES and NEAR. Red text indicates invasive species.*

Scientific Name	Common Name	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Callitriche sp.	Water starwort	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Ceratophyllum demersum	Coontail	31	33	11.3	22.7	29.9	27.7	21.7	27	27	39	39	6.6	2.8	10.2	16.4
Chara	Muskgrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Elatine minima	Waterwort	0	1	3	2	0	4	0	1	2	1	0	0	1.2	1.9	0.3
Eleocharis acicularis	Spikerush	0	0	0	0	0	0	0	0	0	0	0	1.1	1.5	3.3	2.1
Elodea nuttallii	Water weed	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontinalis sp.	Aquatic moss	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.4
Glossostigma cleistanthum	Mudmat	0	0	0	0	0	0	0	0	0	0	0	1	1.2	0.4	1.1
Lemna minor	Duckweed	0	2.1	6.3	1	4.2	7.2	4.1	0	3	0	0	0	0	0	0.2
Ludwigia palustris	Marsh purslane	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1
Myriophyllum spicatum	Eurasian milfoil	51	79	65	71	78.4	29.4	42.3	76	68	77	57	77.8	76.8	76.4	85.3
Najas flexilis	Bushy Pondweed	7.3	1	1	0	2	0	0	0	0	0	0	0	0.1	0	0.1
Najas minor	Brittle naiad	12.5	6.3	8.2	11.5	15.5	12.4	19.6	24	16	10	10	1.6	0.5	3	1.7
Nymphaea odorata	White water lily	1	1	1	1	1	1	1	2	1	1	1	0.2	0.1	0.1	0.1
P. amplifolius	Large-leaf pondweed	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0
Pontederia cordata	Pickerelweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
P. berchtoldii	Small pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1

P. bicupulatus	Snail-seed pondweed	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.1
P. crispus	Curly-leaf pondweed	13.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
P. foliosus	Pondweed	3.1	0	0	0	2.1	1	5.2	1	0	0	0	0	0	0	0
P. illinoensis	Illinois pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
P. perfoliatus	Clasping-leaf pondweed	1	2.1	1	0	0	2.1	0	1	1	0	0	0	0	0	0
P. pusillus	Slender pondweed	3.1	1	0	0	0	0	0	0	0	0	0	0	<0.01	0	0
P. foliosus	Leafy pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0
P. gramineus	Grassy pondweed	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P. spirillus	Spiral pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Sparganium fluctuans	Floating bur-reed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Spirodela polyrhiza	Giant duckweed	0	1	0	0	1	5.2	0	0	0	1	0	0.1	0	0	0.1
Stuckenia pectinata	Sago pondweed	6.3	1	0	4.1	0	3.1	2.1	2	1	11	0	0	0	0.1	0.3
Vallisneria americana	Tape-grass	2.1	2.1	4.1	4.1	3	4	4.1	6	4	3	5	0.3	0.5	0.4	0.6
Wolffia sp.	Watermeal	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.1	0.3
Zannichellia palustris	Horned pondweed	11.5	3.1	0	0	0	0	0	0	0	0	0	0	0	1.3	1
Zosterella dubia	Water stargrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.3
Number of species		**12**	**12**	**7**	**6**	**7**	**8**	**6**	**7**	**7**	**6**	**3**	**6**	**8**	**13**	**21**

*2007-2017 frequency based on the same 96 points spaced over 10 fixed location transects, 2018 frequency based on 1,669 points, 2019 frequency based on 1,988 points, 2020 frequency based on 1,491 points, 2021 frequency based on 1,613 points.

Squantz Pond Results

INVASIVE AQUATIC PLANTS

The aquatic invasive species Mudmat (*Glossostigma cleistanthum*) was found in Squantz Pond in 2021 (**Map 14, Pg 26**). Eurasian milfoil (*Myriophyllum spicatum*) and Brittle naiad (*Najas minor*) were not present in 2021. Eurasian milfoil was also not found in Squantz Pond in 2019 or 2020, but in 2018 milfoil covered a total of 22.6 acres, with 13.5 acres of high-density beds (**Table 6**). This reduction, and possible eradication of milfoil from Squantz Pond is likely due to the stocking of grass carp.

Table 7. *Invasive aquatic plant species found in Squantz Pond by NEAR during 2019 survey.*

Invasive Species	Common Name	# of Sites 2021	# of Sites 2020	# of Sites 2019	# of Sites 2018
Myriophyllum spicatum	Eurasian milfoil	0	0	0	99
Najas minor	Brittle naiad	0	0	10	24
Glossostigma cleistanthum	Mudmat	2	6	1	3

NATIVE PLANTS

No native plants were found in Squantz pond during the 2021 survey (**Table 8**). 98% of the waypoints had no plant presence.

Table 8. *Native aquatic plant species found by NEAR in Squantz Pond during the 2020, 2019 & 2018 surveys. The table also shows frequency of green filamentous algae (Spirogyra).*

Scientific Name	Common Name	# of sites **** 2021	# of sites *** 2020	# of sites ** 2019	# of sites * 2018
Ceratophyllum demersum	Coontail	0	0	2	15
Elatine minima	Waterwort	0	6	1	0
Eleocharis acicularis	Spike rush - submersed	0	1	3	0
Elodea canadensis	Water weed	0	0	0	2
Spirogyra sp.	Filamentous Green Algae	0	0	2	4
Fontinalis	Aquatic moss	0	1	0	1
Lemna	Duckweed/Giant Duckweed	0	0	0	1
Najas flexilis	Bushy Pondweed	0	0	0	3
Potamogeton amplifolius	Large-leaf pondweed	0	0	1	0
Potamogeton pusillus	Narrow-leaf pondweed	0	0	0	1

**** Out of a total of 84 sites

*** Out of a total of 216 sites

** Out of a total of 203 sites

* Out of a total of 182 sites

Lake Lillinonah Results

Lake Lillinonah was surveyed over five days between August 12th and August 20th. Waypoints were created every ~200 feet along the shoreline (**Map 16**). Additional points were created if an invasive species was spotted in between the 200-foot intervals.

During the survey, the invasive species Eurasian milfoil, Curly-leaf pondweed, Brittle naiad, Water chestnut, and Mudmat were found in the lake (**Table 9**). In addition, 22 native aquatic plant species were present in the lake, along with Filamentous algae and *Lyngbya wollei* (**Table 10**).

Eurasian milfoil totaled ~142 acres, of which approximately ~65% was dense. The species was most abundant in the western portion of the lake (**Map 17**, **Map 18**). Patches were typically smaller in the eastern portion of the lake, though many patches were high density (**Map 19**, **Map 20**). Milfoil abundance in 2021 was similar to that in 2019, when milfoil covered ~134 acres.

Brittle naiad was present in small patches along the lake's shoreline, totaling ~4 acres (**Map 21** to **Map 24**). There was less Brittle naiad in 2021 compared to 2019, when the species covered ~15 acres.

Curly-leaf pondweed was only found in two locations in the lake, both at a low density

The invasive species water chestnut, which is not present in Candlewood Lake or Squantz Pond, was found at 34 waypoints in Lake Lillinonah, but only at the lake's the northwest end (**Map 25**). Many water chestnut plants above Lovers' Leap were not rooted, have been recently washed into the lake from the Housatonic River upstream.

Map 16. *Waypoints (green dots) made in Lake Lillinonah during 2021 survey.*

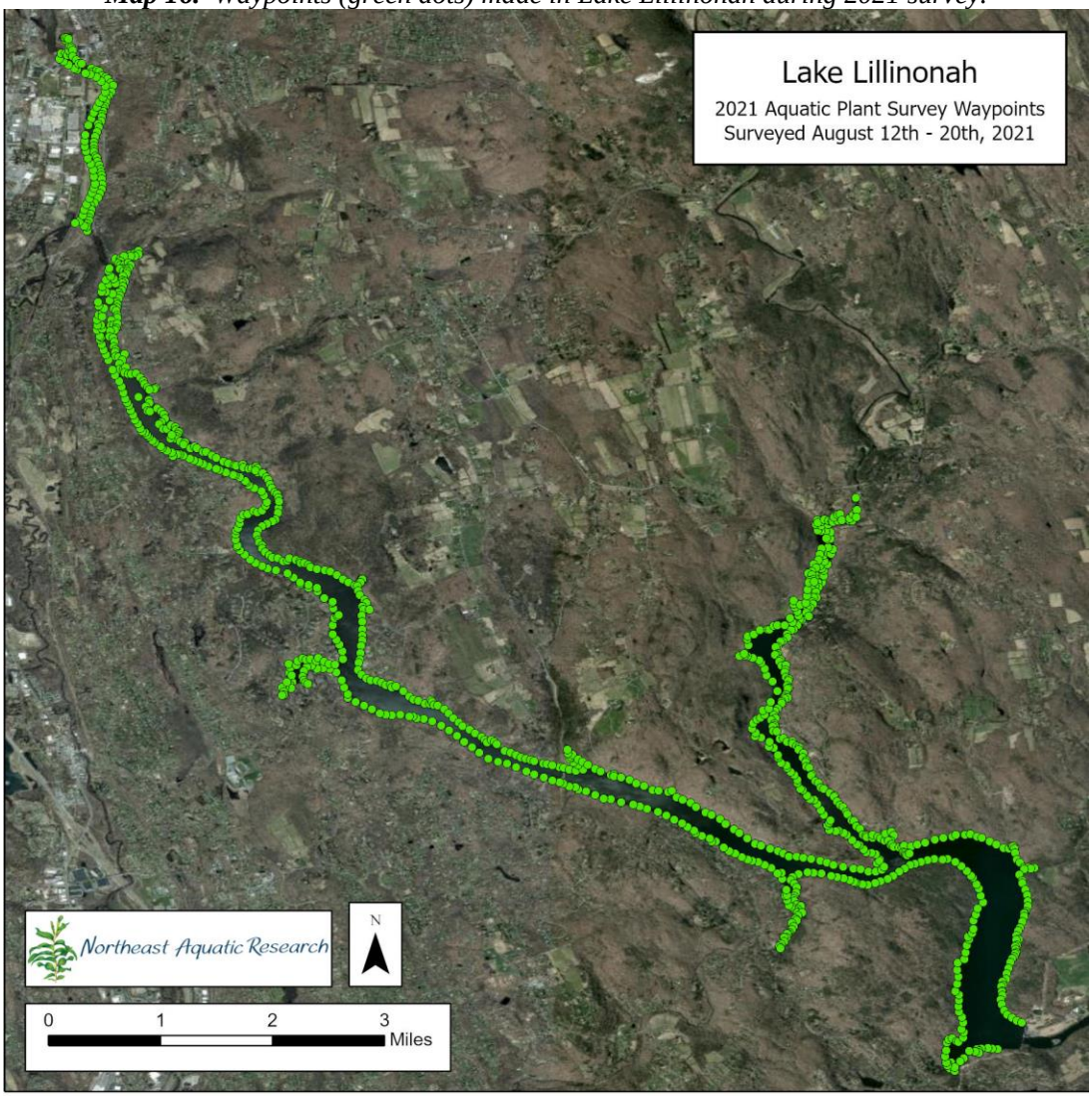


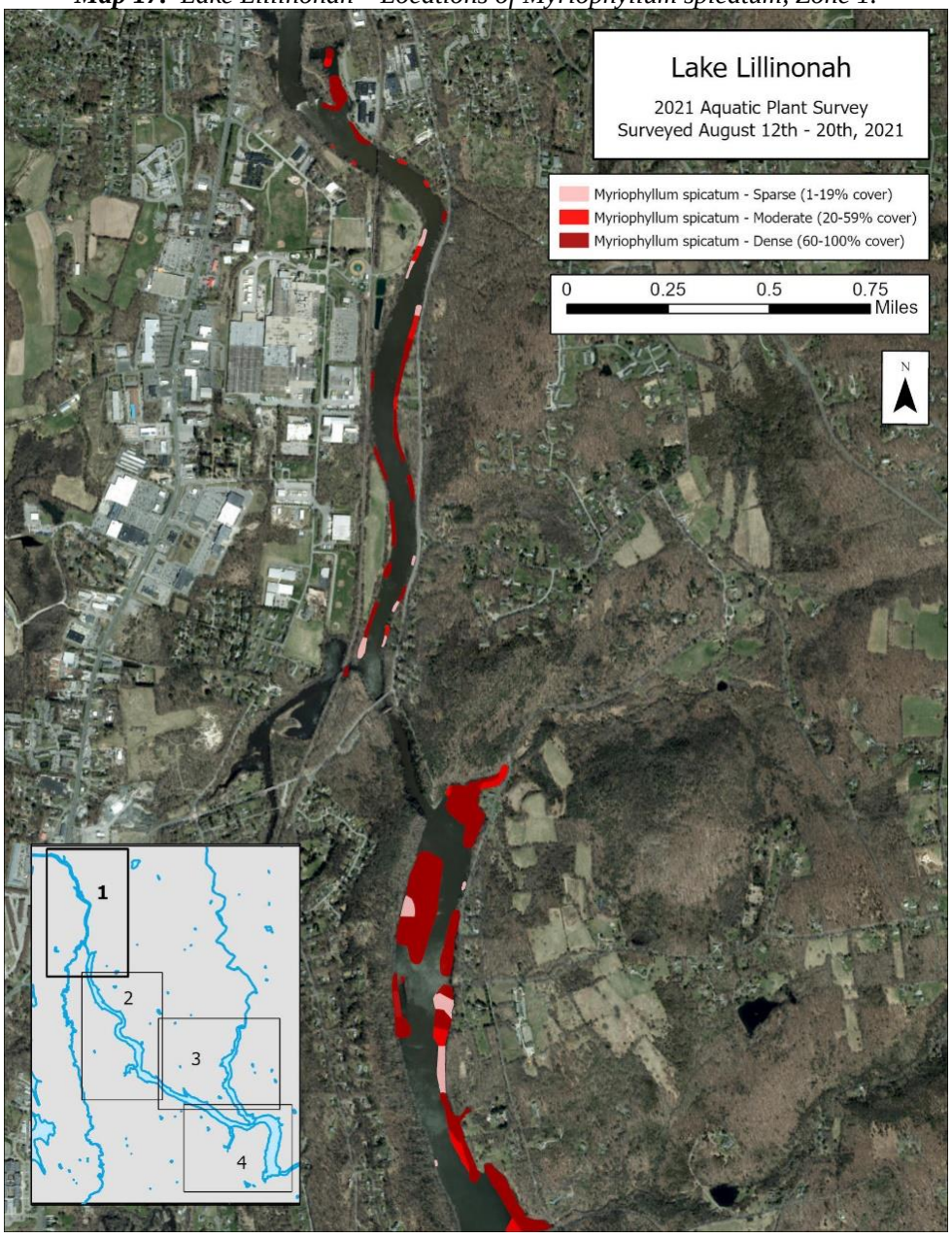
Table 9. *Acres of invasive plants found in Lake Lillinonah in 2021.*

Scientific Name	Common Name	Acres			
		Sparse	Moderate	Dense	Total
Myriophyllum spicatum	Eurasian milfoil	19.8	30.3	91.7	141.8
Najas minor	Brittle naiad	2.8	0.6	0.5	3.9
Potamogeton crispus	Curly-leaf pondweed	0.1	0	0	0.1
Glossostigma cleistanthum	Mudmat	0.1	0	0	0.1
Trapa natans	Water chestnut	NA	NA	NA	34 wpts

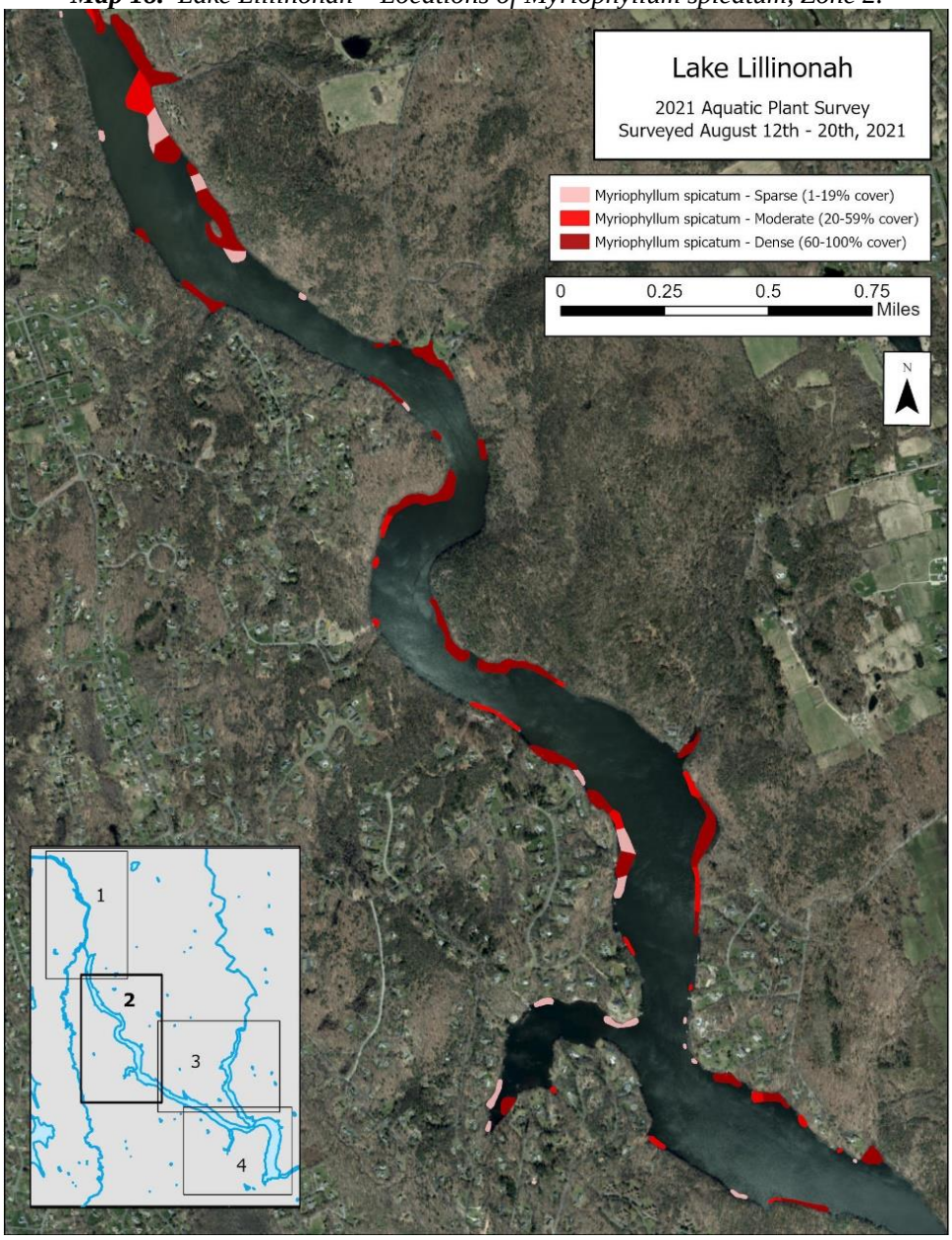
Table 10. *Aquatic plant species in Lake Lillinonah during the 2021 aquatic plant survey, with associated percent frequencies and average densities. Red text indicates invasive species.*

Scientific Name	Common Name	% Frequency	Average Density %
Ceratophyllum demersum	Coontail	39.3	42.1
Elatine sp	Waterwort	0.1	10
Eleocharis acicularis	Spikerush	0.3	15
Elodea nuttallii	Waterweed	0.4	17.5
Spirogyra sp.	Filamentous Algae	15.0	47.9
Fontinalis sp.	Aquatic moss	0.1	NA
Glossostigma sp	Mudmat	0.1	5
Lemna minor	Duckweed	6.1	24.7
Ludwigia palustris	Marsh purslane	0.5	11.25
Lyngbya wollei	Cyanomat	2.6	37.1
Myriophyllum spicatum	Eurasian milfoil	43.7	58.1
Najas minor	Spiny naiad	2.8	24.4
Nitella sp	Stonewort	0.1	10
Nymphaea odorata	White water lily	0.1	10
Pontederia cordata	Pickerelweed	0.1	5
Potamogeton crispus	Curly-leaf pondweed	0.2	10
Potamogeton nodosus	Long-leaf pondweed	1.2	44.5
Potamogeton perfoliatus	Clasping-leaf pondweed	1.2	17.7
Potamogeton pusillus	Small pondweed	1.7	12.8
Sagittaria graminea	Grassy arrowhead	0.5	13
Spirodela polyrhiza	Giant duckweed	1.0	8.5
Stuckenia pectinata	Sago pondweed	0.1	15
Trapa natans	Water chestnut	3.6	9.9
Utricularia geminiscapa	Hidden-fruit bladderwort	4.0	10.7
Utricularia minor	Lesser bladderwort	0.1	NA
Vallisneria americana	Tape grass	0.6	36.7
Wolffia sp	Watermeal	0.1	20
Zannichellia palustris	Horned pondweed	0.4	8.3
Zosterella dubia	Water stargrass	6.4	23.2

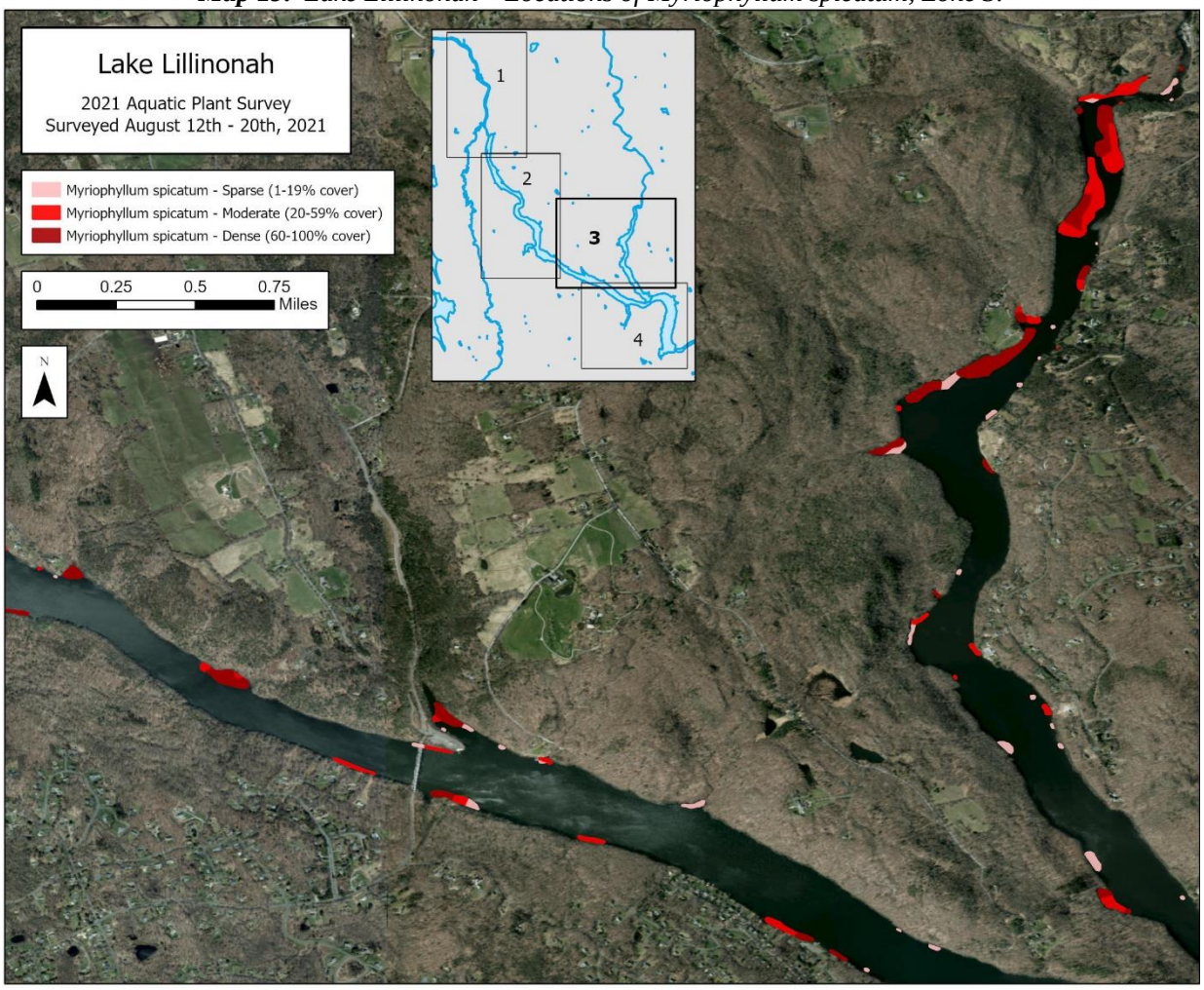
Map 17. *Lake Lillinonah – Locations of Myriophyllum spicatum, Zone 1.*



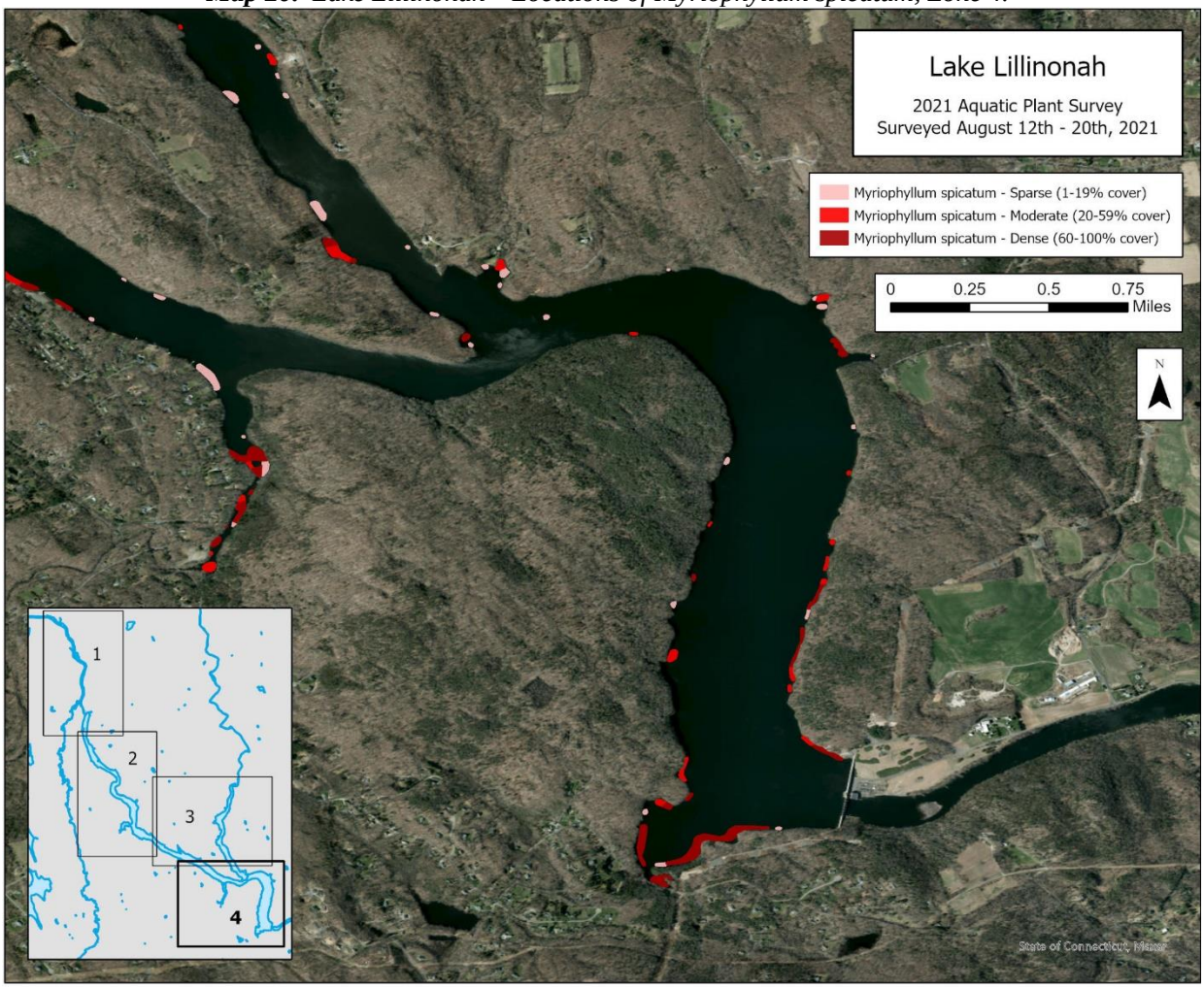
Map 18. *Lake Lillinonah – Locations of Myriophyllum spicatum, Zone 2.*



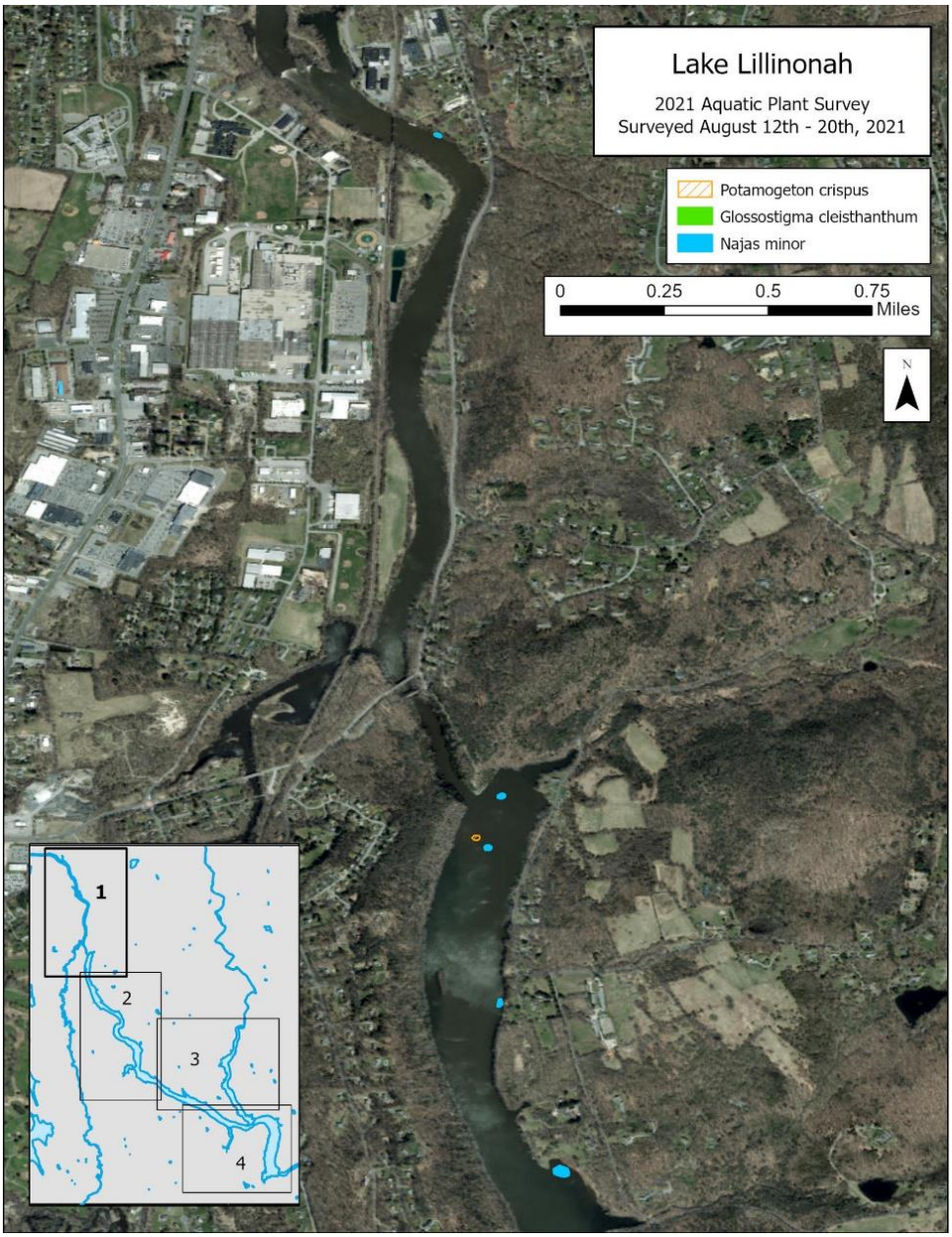
Map 19. *Lake Lillinonah – Locations of Myriophyllum spicatum, Zone 3.*



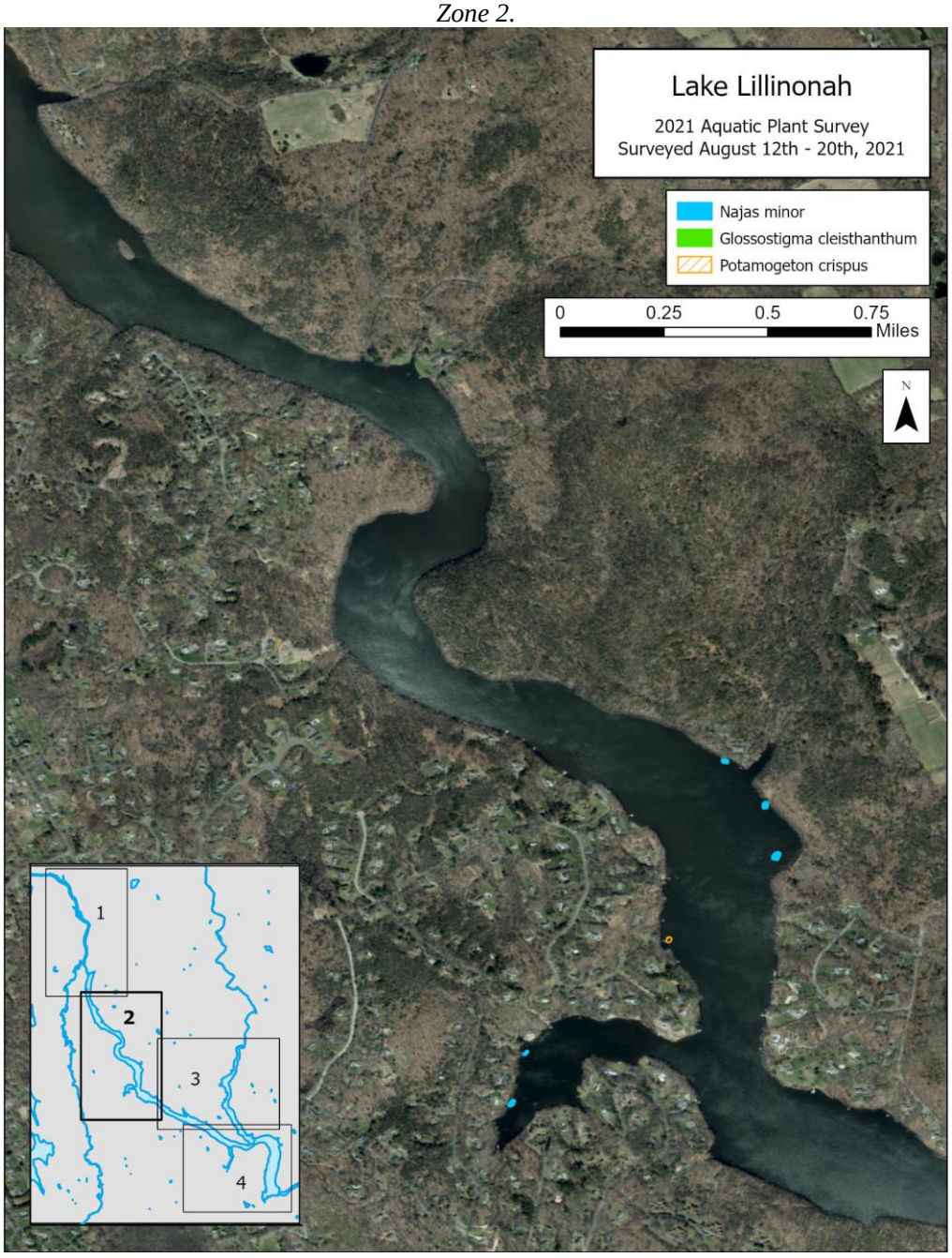
Map 20. *Lake Lillinonah – Locations of Myriophyllum spicatum, Zone 4.*



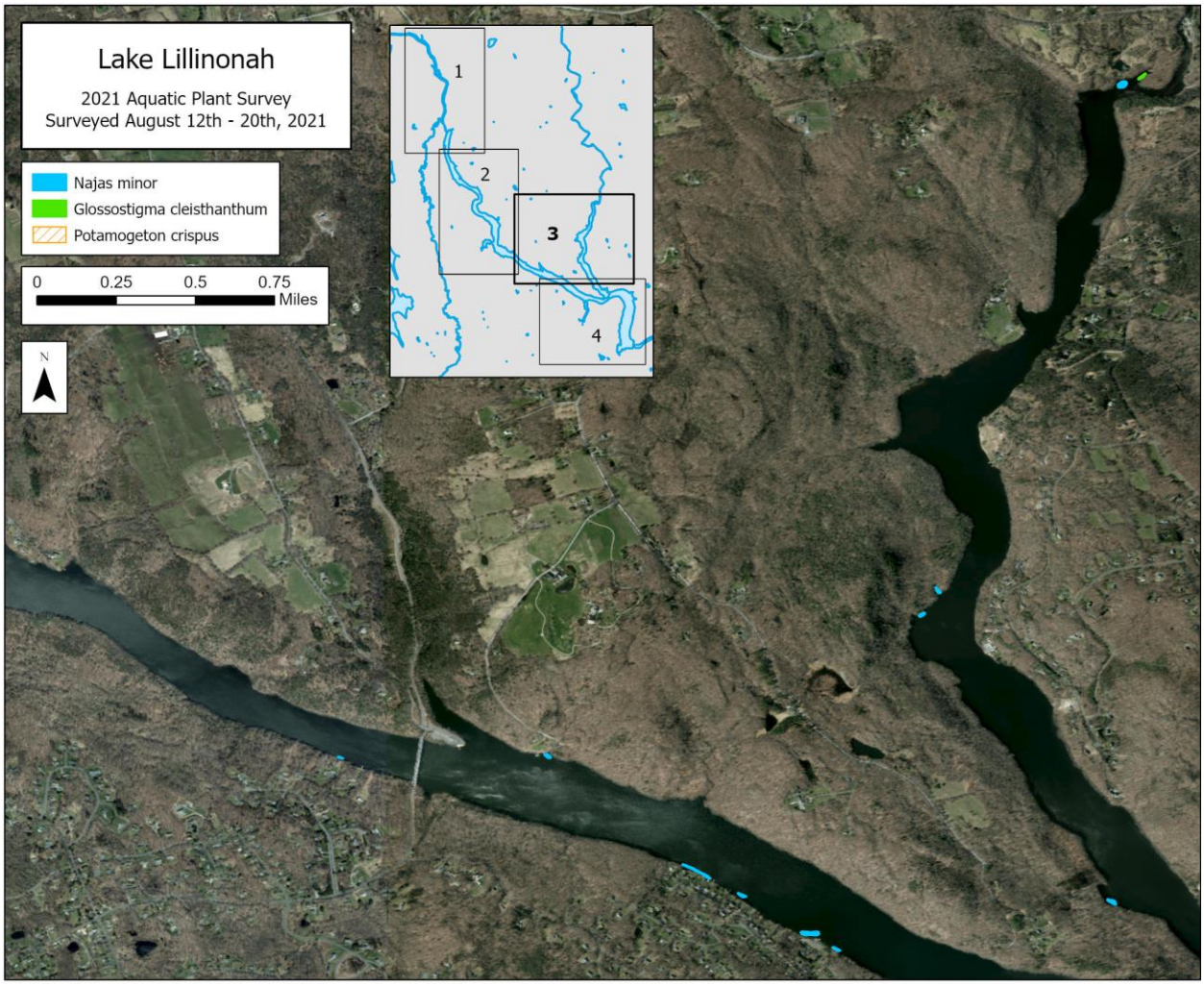
Map 21. *Lake Lillinonah – Locations of Najas minor, Potamogeton crispus and Glossostigma cleistanthum, Zone 1.*



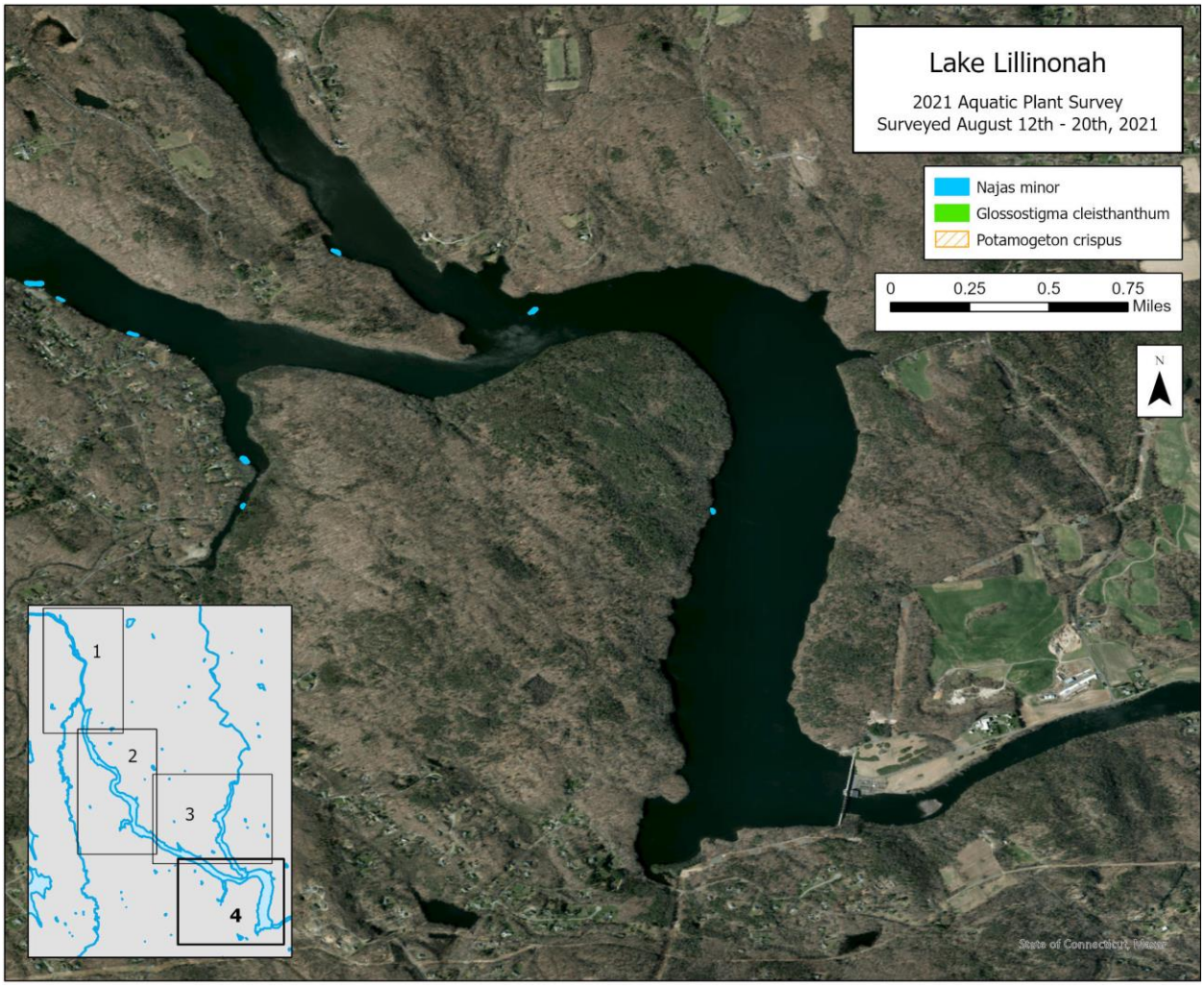
Map 22. *Lake Lillinonah – Locations of Najas minor, Potamogeton crispus and Glossostigma cleistanthum, Zone 2.*



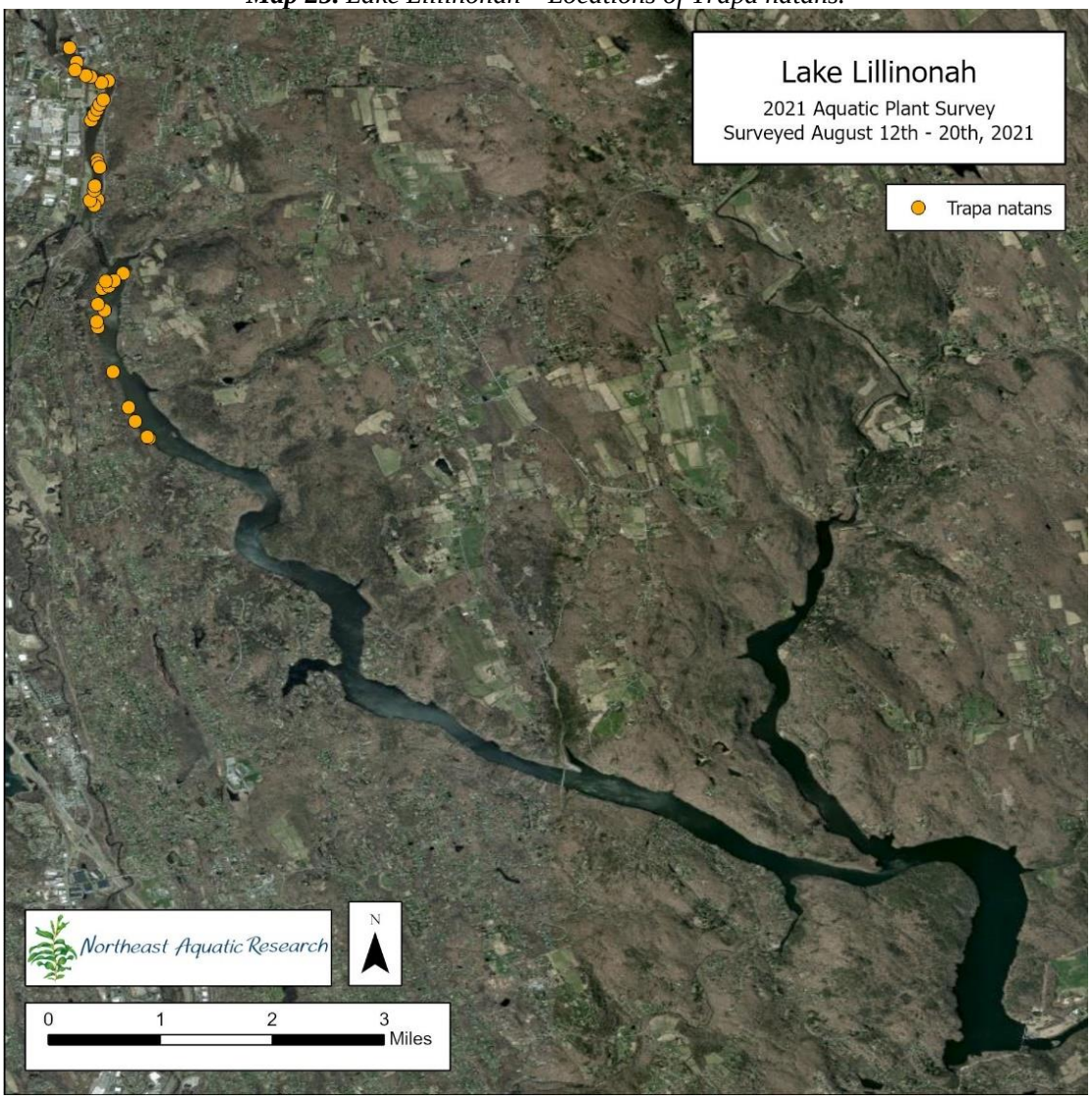
Map 23. *Lake Lillinonah – Locations of Najas minor, Potamogeton crispus and Glossostigma cleistanthum, Zone 3.*



Map 24. *Lake Lillinonah – Locations of Najas minor, Potamogeton crispus and Glossostigma cleistanthum, Zone 4.*



Map 25. *Lake Lillinonah – Locations of Trapa natans.*



Appendix 1: Raw Lake Survey Data

Raw waypoint data is included as a separate pdf document.