Northeast Aquatic Research

2022 Monitoring Report

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

Prepared for FirstLight Power
November 2022

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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 Zoar in 2022. Surveys of Lake Lillinonah and Lake Zoar are conducted every other year. A survey of Lake Lillinonah was conducted in 2021.

Three invasive aquatic plant species were found during the Candlewood Lake/Squantz Pond survey in 2022: 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 2022:

- 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 coverage of Eurasian milfoil in Candlewood Lake was drastically reduced in 2022. The 2022 survey documented less than one acre of milfoil throughout the entire lake. In 2021, milfoil covered ~408 acres.

Mudmat was found in just one location in the lake in 2022. In 2021, Mudmat was found in 16 locations. Mudmat was also found in one location in Squantz Pond in 2022.

Brittle naiad was present at three locations in Candlewood Lake, all in the two northern arms.

Eurasian milfoil and Brittle naiad were not found in Squantz Pond in 2022.

Each winter, Candlewood Lake is drawn down to varying depths ranging from ~4 feet to ~9.5 feet. In the winter of 2021-2022, the lake reached a maximum drawdown depth of -7.4 feet.

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
2021-22 = max depth of –7.4ft

14 native plant species were found in Candlewood Lake during the 2022 survey, along with Filamentous green algae.

- *Callitriche* sp.
- *Ceratophyllum demersum*
- *Elatine minima*
- *Eleocharis acicularis*
- *Ludwigia sp.*
- *Nymphaea odorata*
- *Potamogeton bicupulatus*

- *Potamogeton illinoensis*
- *Potamogeton pusillus*
- *Stuckenia pectinata*
- *Vallisneria americana*
- *Zannichellia palustris*

Four native species were found in Squantz Pond in 2022, along with Filamentous algae.

- *Chara*
- *Eleocharis acicularis*
- *Elatine*
- *Potamogeton bicupulatus*

Eurasian milfoil was also notably reduced in Lake Zoar in 2022, totaling just 23 acres. Brittle naiad covered a total of ~21.5 acres, while Curly-leaf pondweed covered ~3.1 acres. Invasive Water chestnut was not found in the lake during the 2022 survey.

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

- *Ceratophyllum demersum*
- *Elodea nuttallii*
- *Emergent sparganium*
- *Fontinalis sp.*
- *Lemna sp.*
- *Marsilea quadrifolia*
- *Nymphaea odorata*
- *Potamogeton nodosus*
- *Potamogeton perfoliatus*
- *Potamogeton pusillus*
- *Potamogeton zosteriformis*
- *Stuckenia pectinata*
- *Vallisneria americana*
- *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 - 2022.*

Year	Acres of Milfoil	Number of Survey Days Each Month						Total Days
		May	June	July	Aug	Sept	Oct	
2022	<1			6	1			7
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 Lake

2021 Article 409 Survey Methods

Northeast Aquatic Research (NEAR) conducted the Article 409 Nuisance Plant Monitoring Plan Survey (Article 409 survey) in 2022. The full-lake survey of Candlewood Lake was conducted over seven days between July 21st and August 3rd. Squantz Pond was surveyed on July 20th. Lake Zoar was surveyed on September 7th and 8th.

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 2022 aquatic plant surveys in Candlewood Lake and Squantz Pond.*

Date	Location	Number of Waypoints
7-21-22	Squantz Cove and eastern shore of Sherman	220
7-22-22	North end of Sherman	222
7-25-22	Lattin's Cove and Echo Bay	150
7-27-22	Danbury Bay	309
7-28-22	Central Basin	160
7-29-22	New Fairfield Bay and south end of New Milford	219
8-3-22	North end of New Milford	171
	Sub-Total	**1,451**
7-20-22	Squantz Pond	173
	Candlewood + Squantz Total	**1,624**

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 (**Image 1)**.

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. 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. Photos taken during 2019 Candlewood Lake survey.*

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.

In areas where the littoral zone was wide, 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.

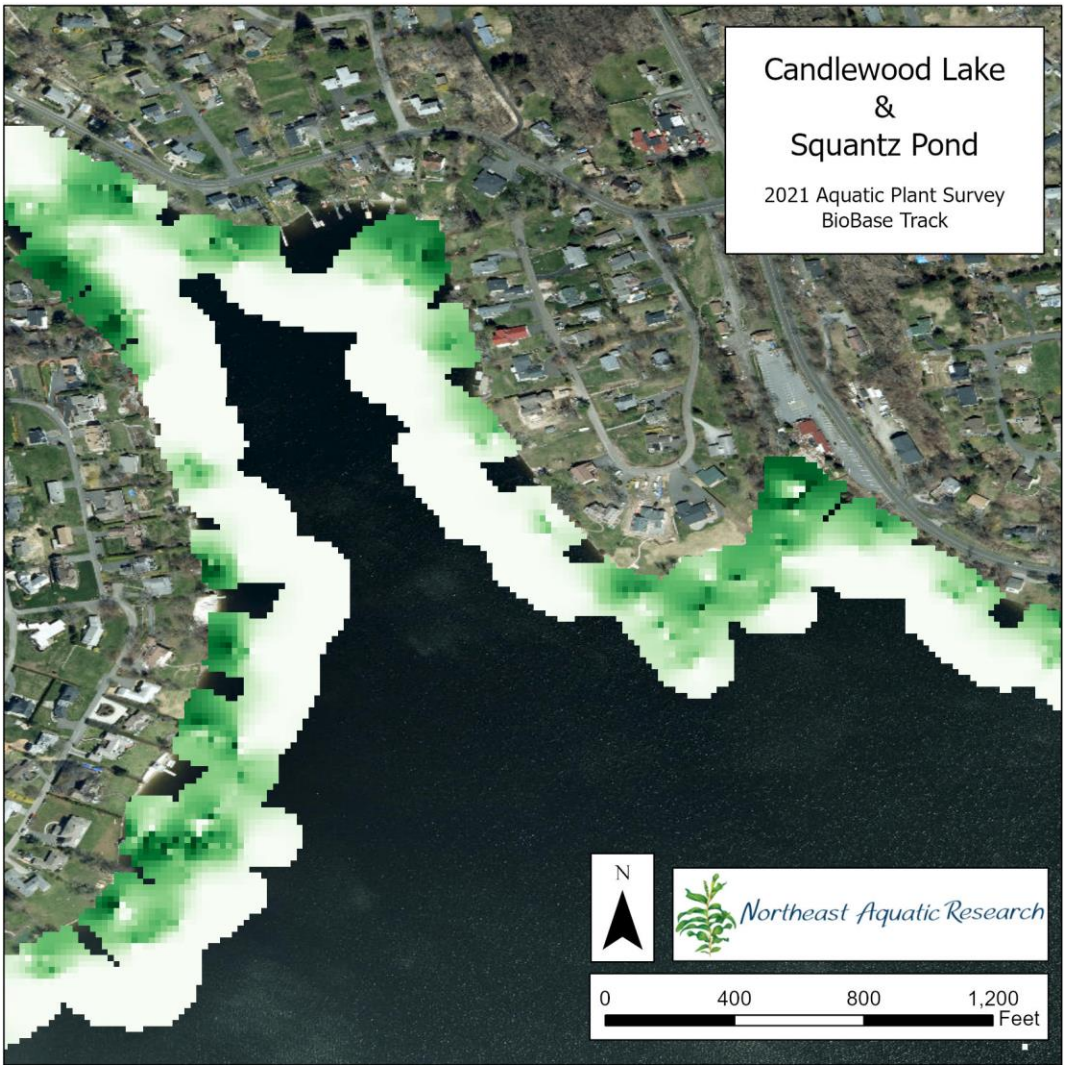
BioBase was used for the entirety of the survey to collect continuous water depth and plant growth data. The program collects a grid of waypoints with associated water depth and plant height. This waypoint data was loaded into ArcGIS Pro and converted into a raster layer. Because of the lack of milfoil and the overall lack of plant beds, BioBase was not needed to supplement the mapping, but the data will be saved and may be useful for future analyses (**Map 2**).

Waypoints were created every ~300 feet throughout the lake's littoral zone, including around the islands. At each waypoint, all plant species (if any) that were present at the waypoint were recorded, along with associated density of each species.

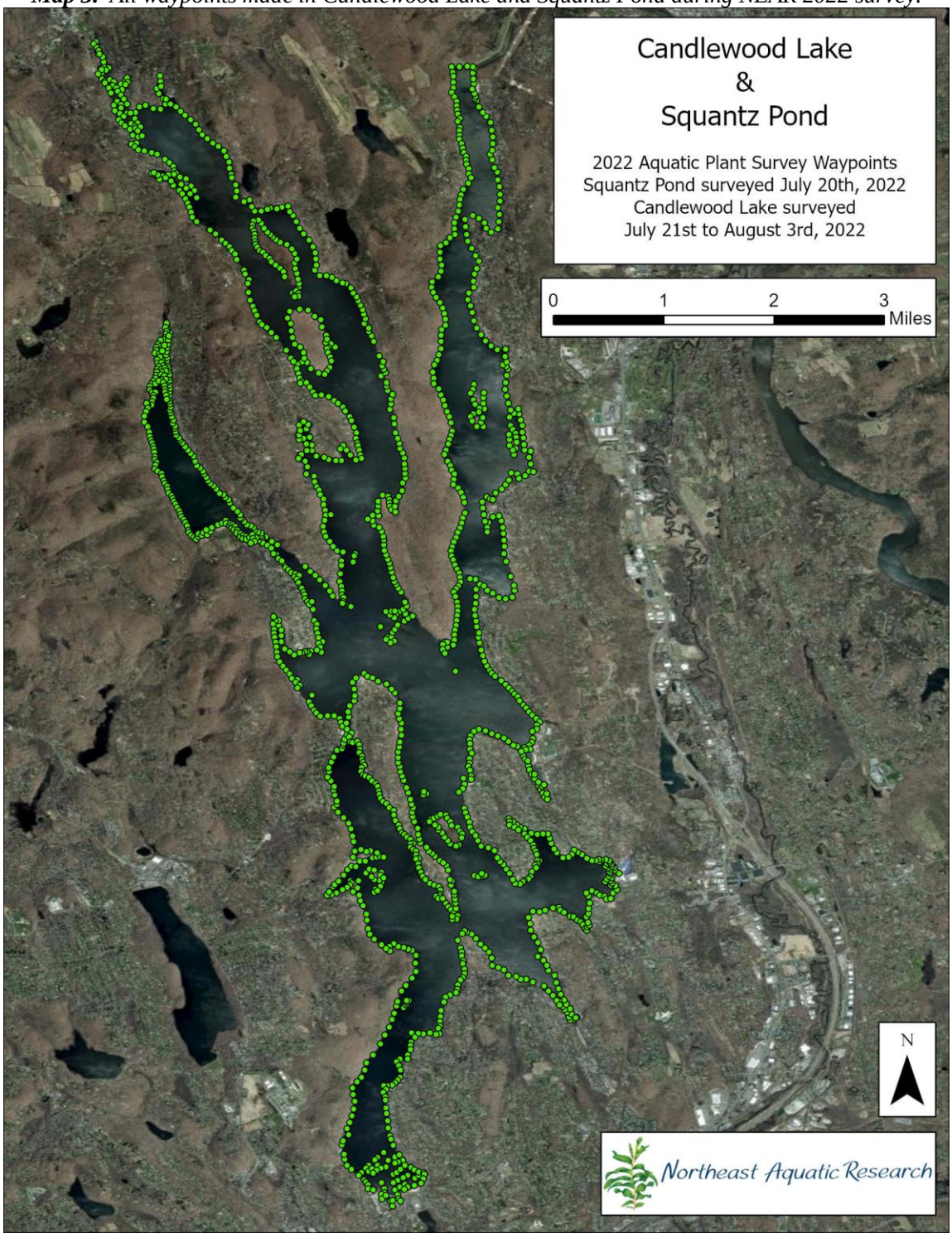
A total array of 1,451 waypoints were created in Candlewood Lake and 173 waypoints were created in Squantz Pond (**Map 3**).

Map 1. *Zoomed section of 2022 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 2022 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.

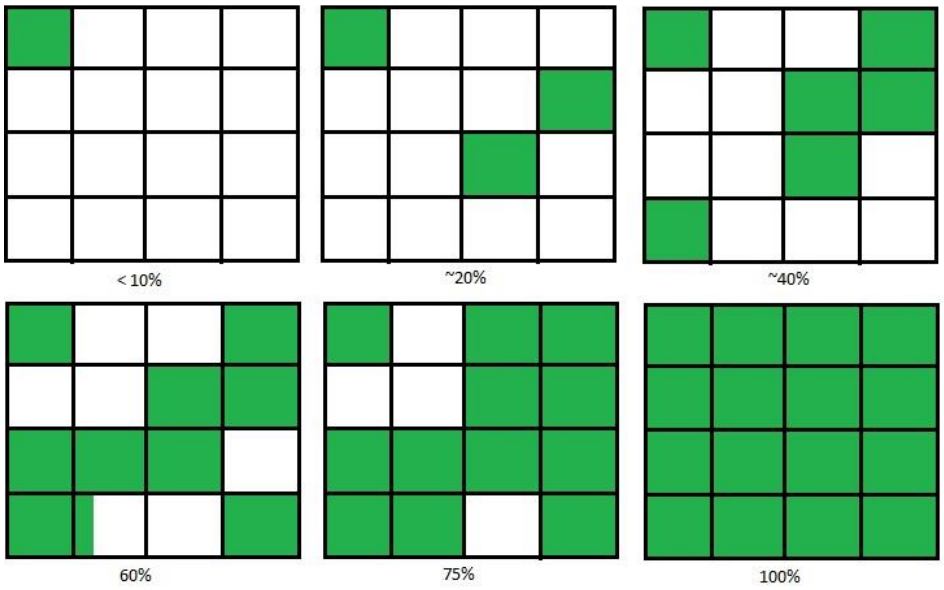


Image 2. *Visual Percent Cover Estimate Guides - Hypothetical Field Quadrats ~10ft across.*

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 waypoints at which milfoil was present are depicted on the map, with color denoting the density category. Unlike prior years, the milfoil beds were not drawn as polygons. This is because all milfoil was either growing as single plants or beds typically made up of less than ten plants in each area and were too small to accurately map.

Candlewood Lake Results

INVASIVE AQUATIC PLANTS

Three invasive aquatic plant species were found in Candlewood Lake during the 2022 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 drastically reduced in 2022, totaling less than one acre (**Table 4**, **Map 4** – **Map 13**). In all locations where milfoil was found, the beds were small and sparse.

Brittle naiad was found at 3 waypoints in Candlewood Lake in 2022 (**Map 14**).

Mudmat was found at 1 waypoint in Candlewood Lake and two waypoints in 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.

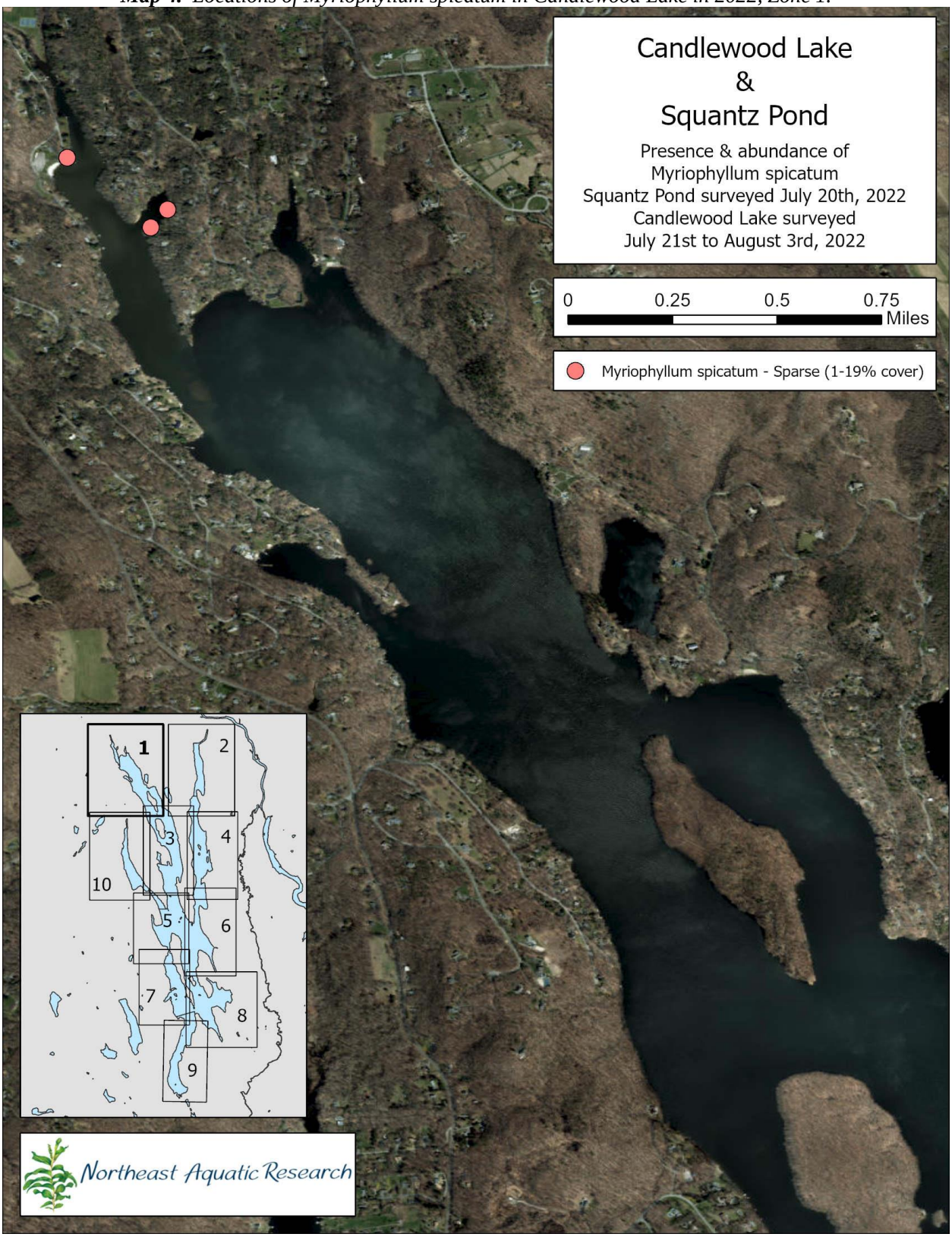
Table 3. *Invasive aquatic plant species found in Candlewood Lake by NEAR, 2018-2022.*

Invasive Species	% Frequency 2022	% Frequency 2021	% Frequency 2020	% Frequency 2019	% Frequency 2018
Eurasian Milfoil	1.2%	75%	76%	74.5%	83.10%
Brittle Naiad	0.2% / 3 points	1.4% / 23 points	3% / 45 points	0.5% / 10 points	1.6% / 27 points
Mudmat	0.1% / 1 point	1.1% / 17 points	0.4% / 6 points	1.1% / 22 points	1% / 17 points

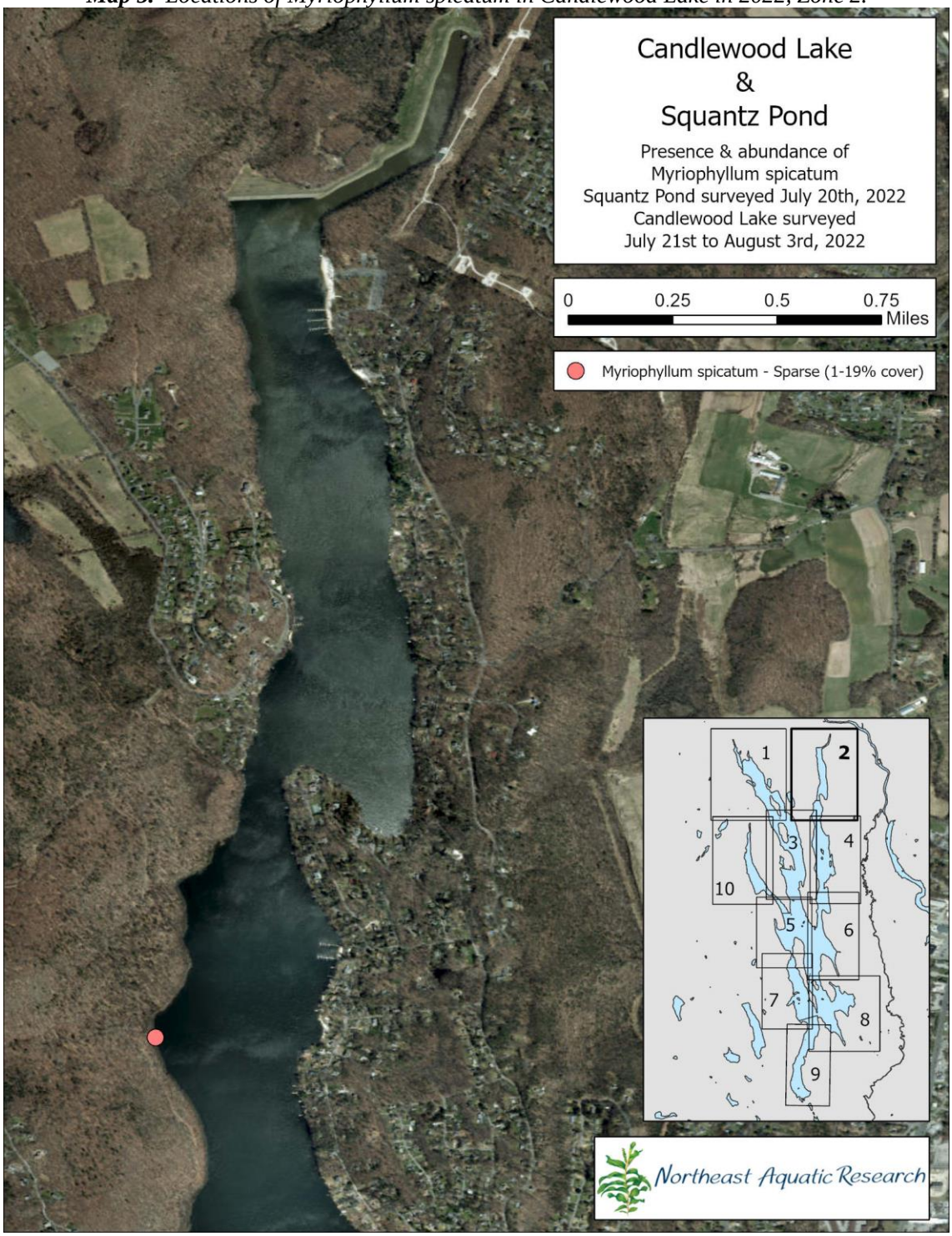
Table 4. *Acreages of Eurasian milfoil density categories, 2018-2022. Acreage values are approximations.*

Density Category	2022		2021		2020		2019		2018	
	Acres	% of Total Acres	Acres	% of Total Acres	Acres	% of Total Acres	Acres	% of Total Acres	Acres	% of Total Acres
Dense	0	0	262.5	64.3	352.6	75.2	262.2	55	418.1	81.7
Moderate	0	0	103.8	25.4	61	13	112.8	23.6	61.7	12.1
Sparse	<1	100	42.1	10.3	55.2	11.8	102.1	21.4	31.8	6.2
Total	<1		408.4		468.8		477		511.6	

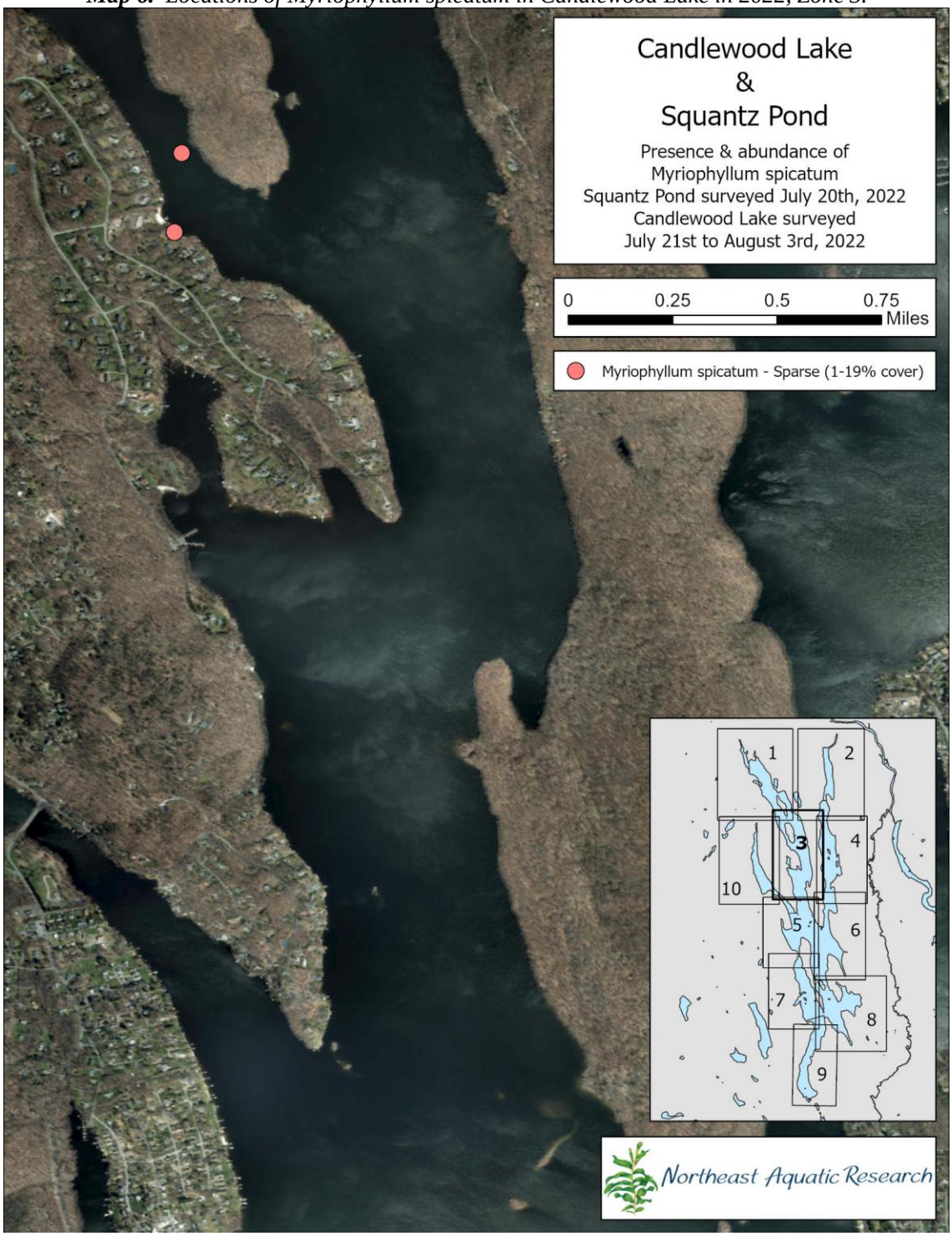
Map 4. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 1.*



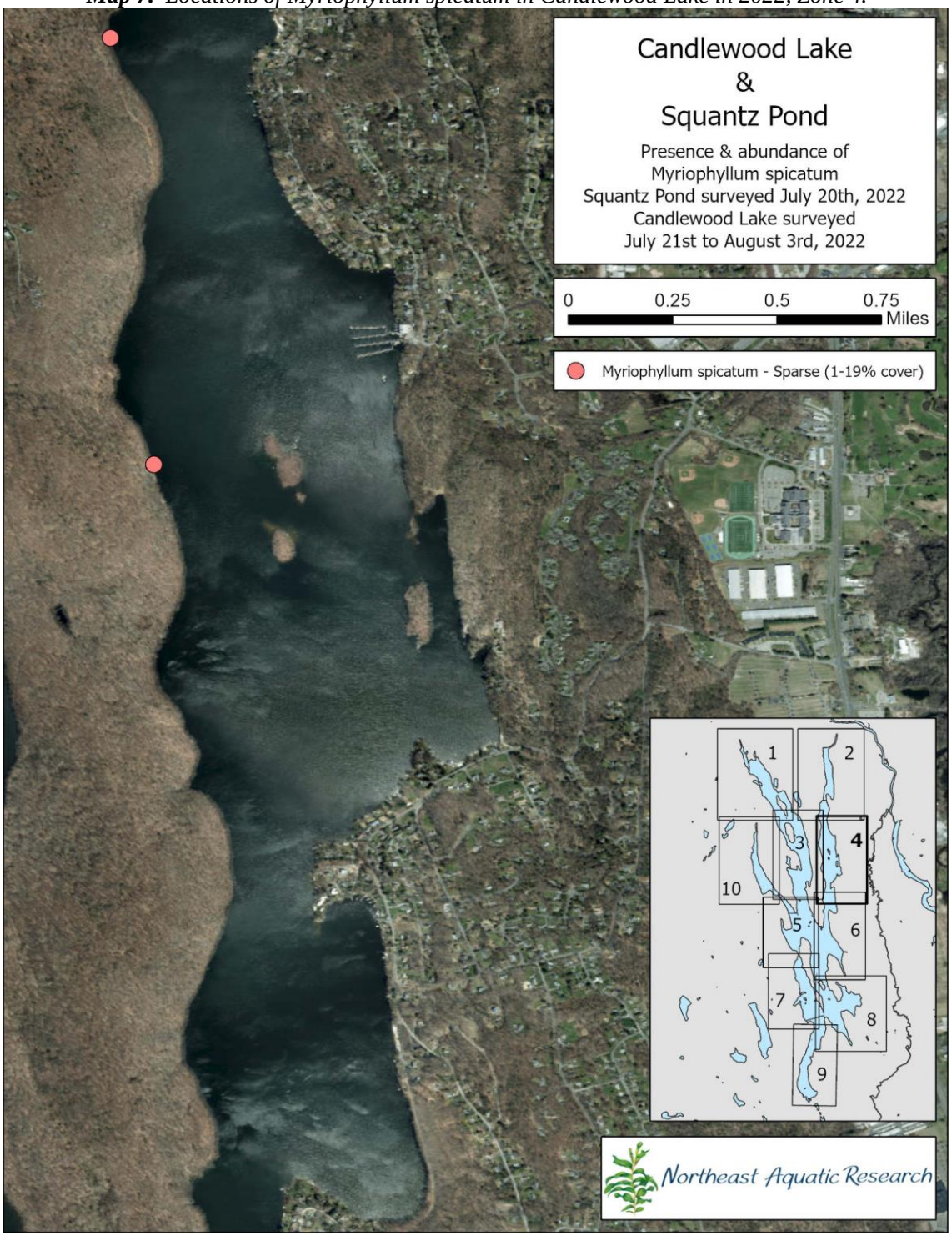
Map 5. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 2.*



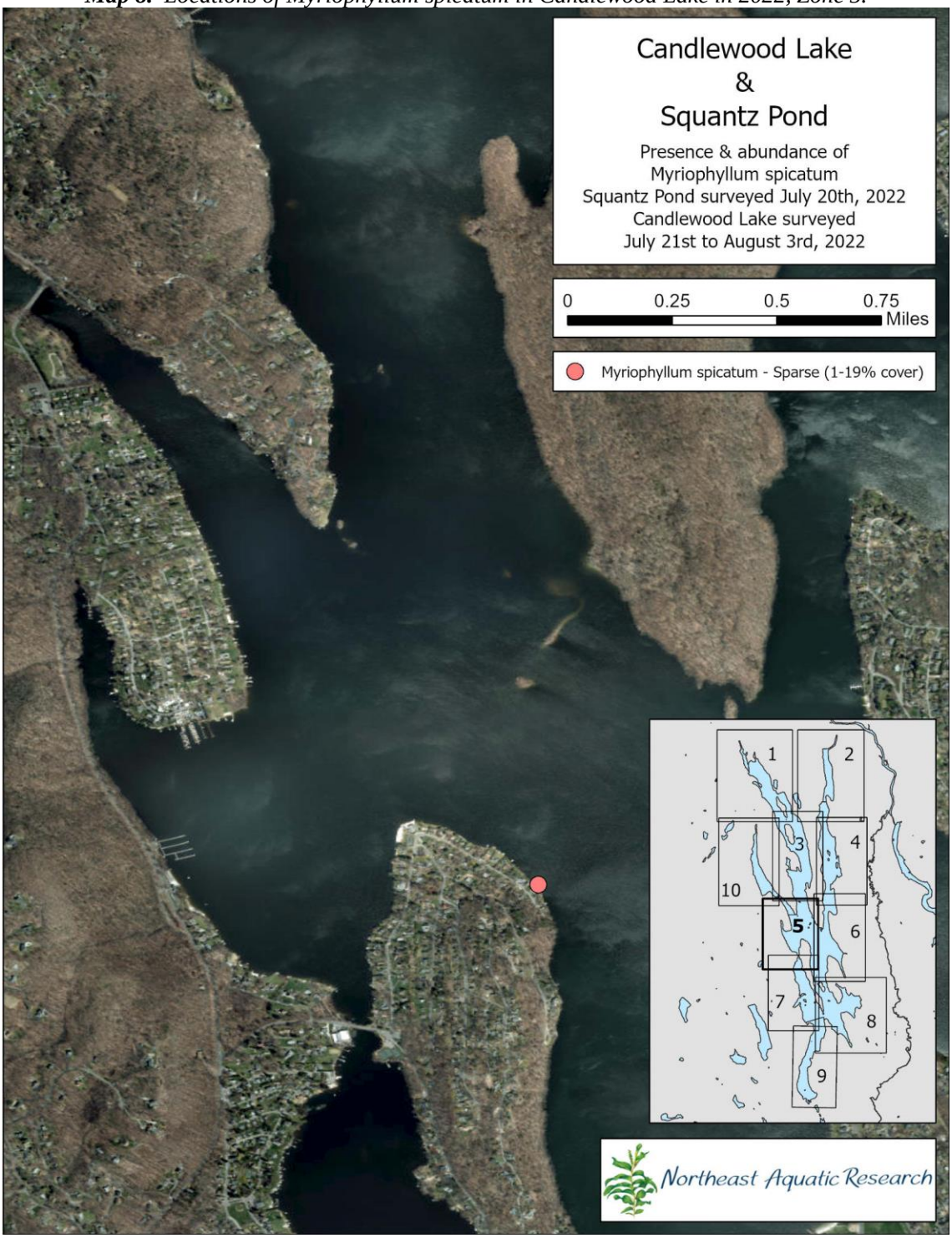
Map 6. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 3.*



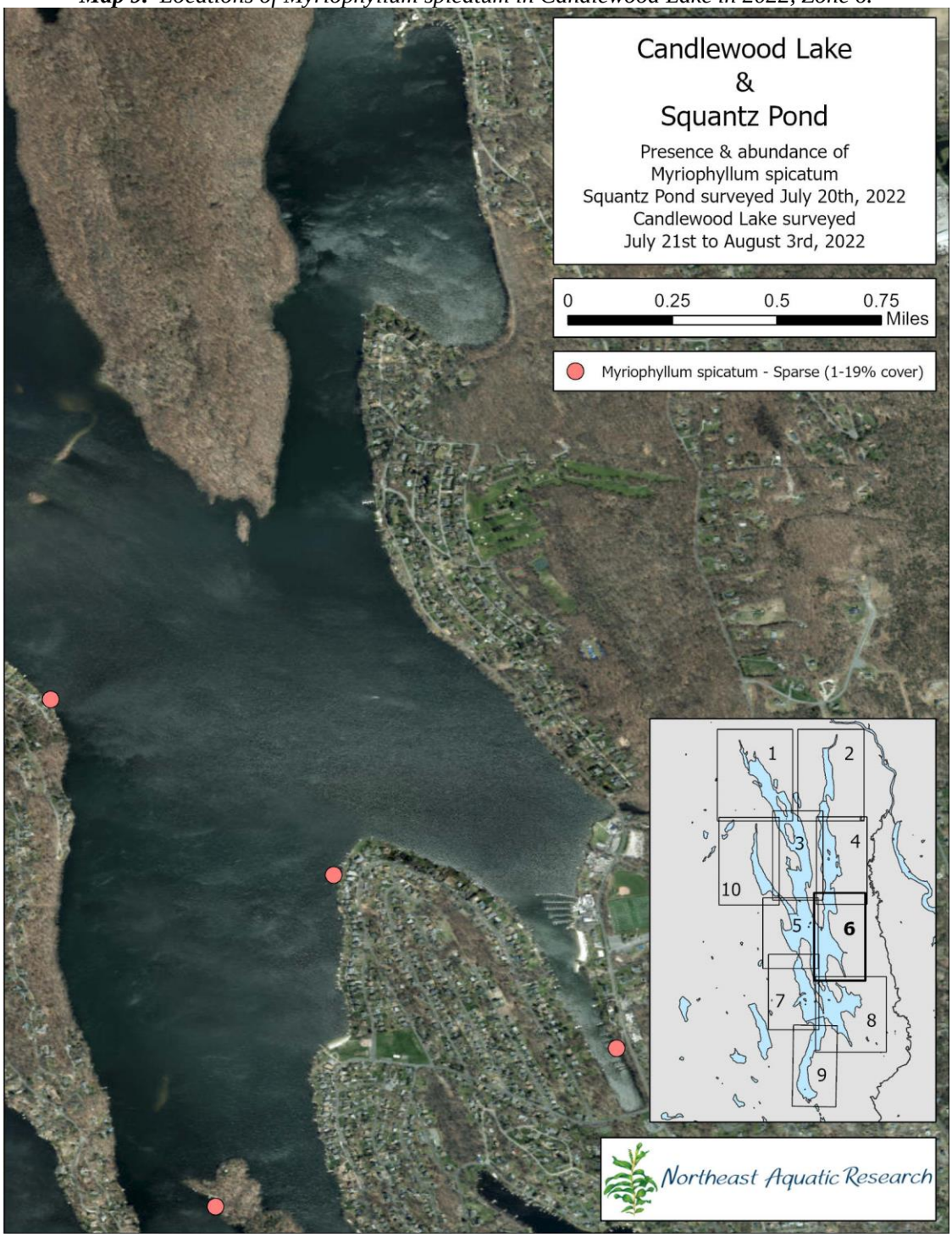
Map 7. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 4.*



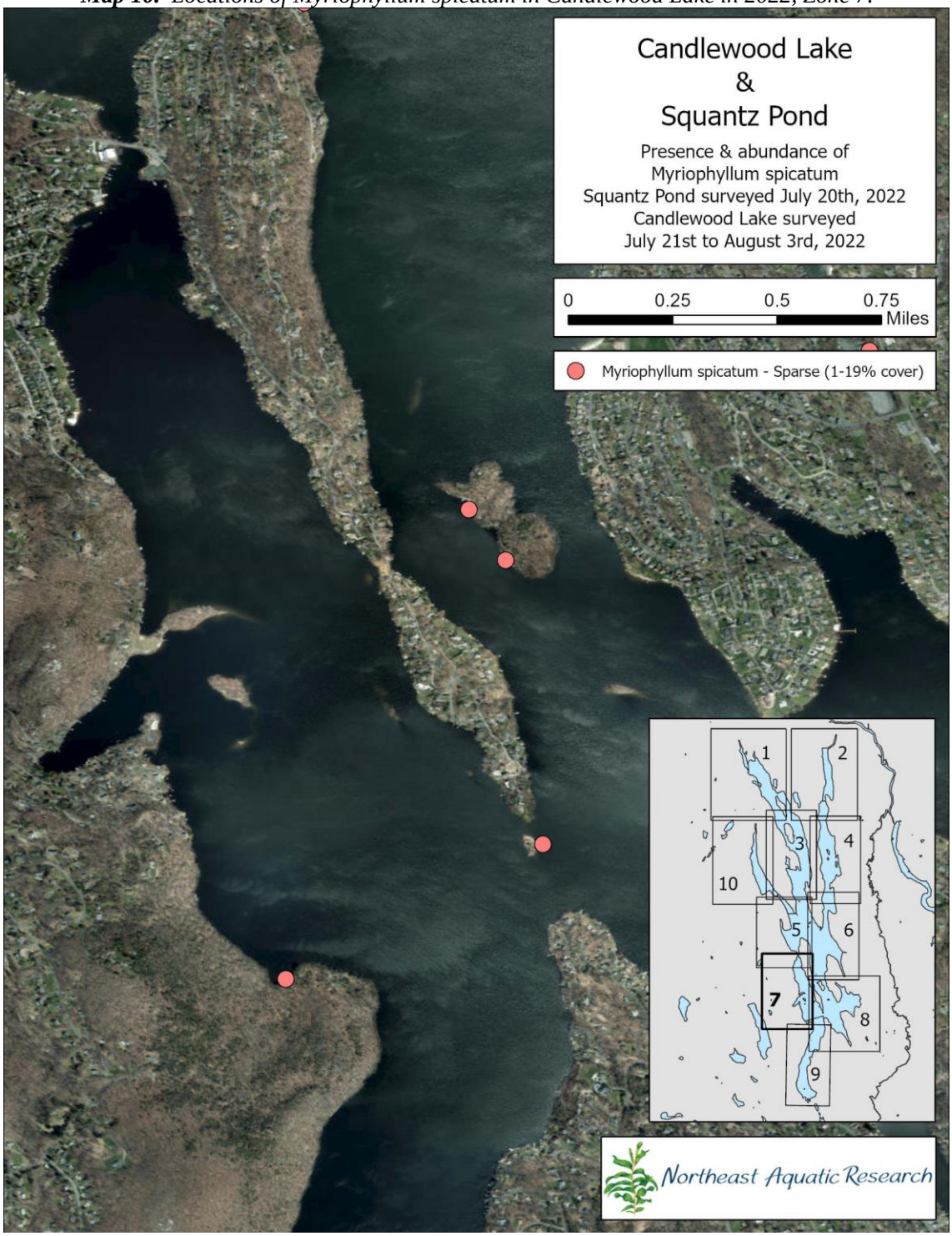
Map 8. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 5.*



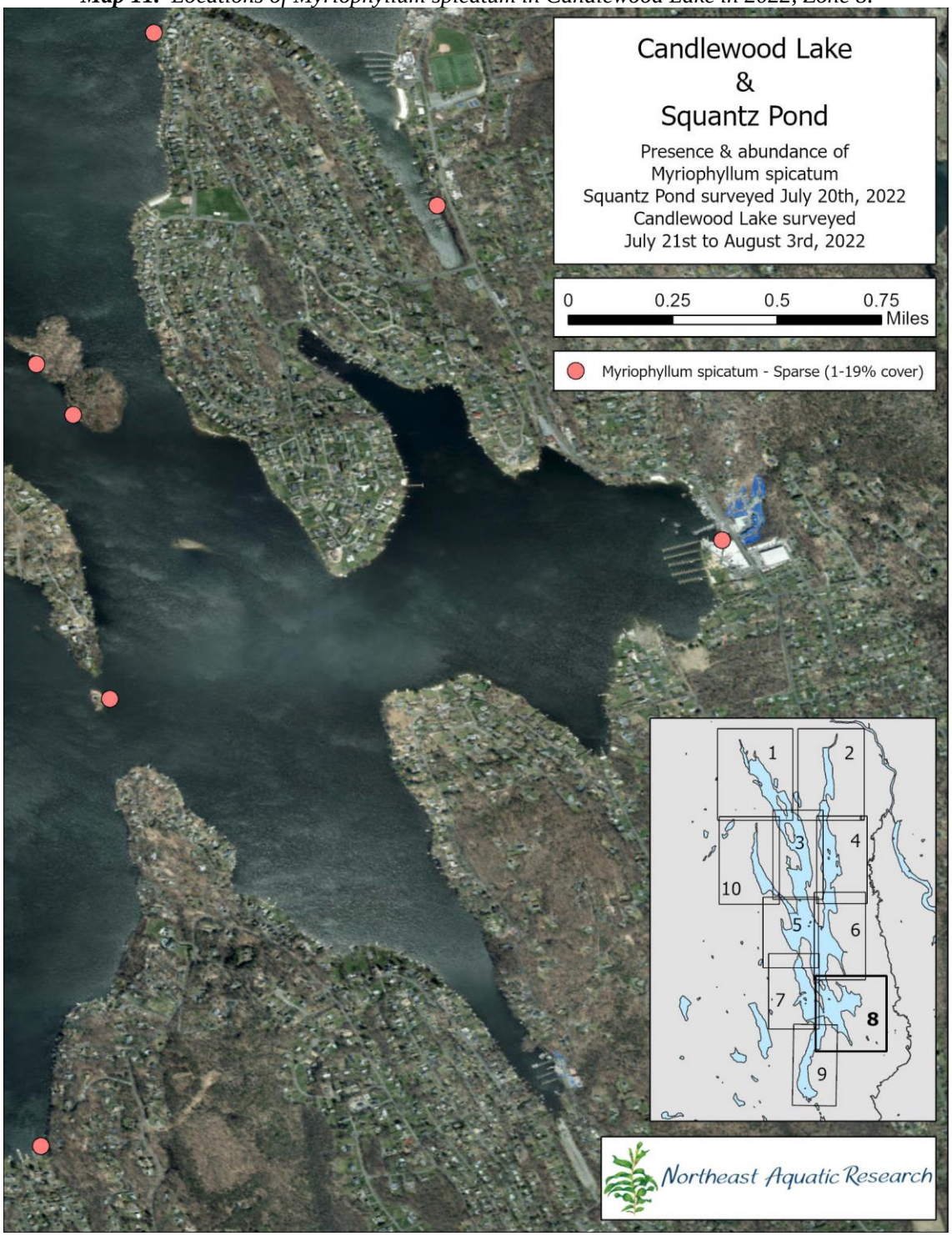
Map 9. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 6.*



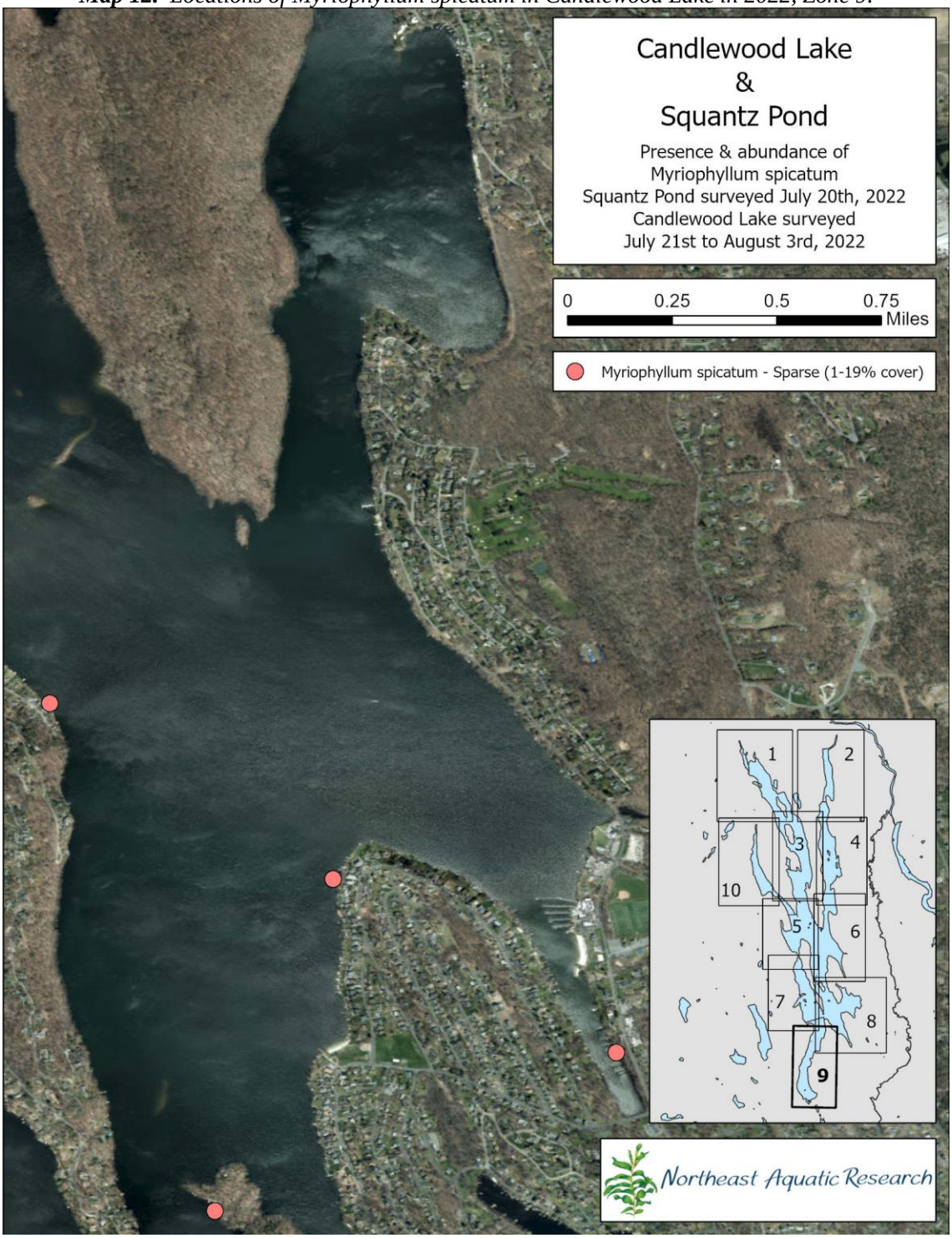
Map 10. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 7.*



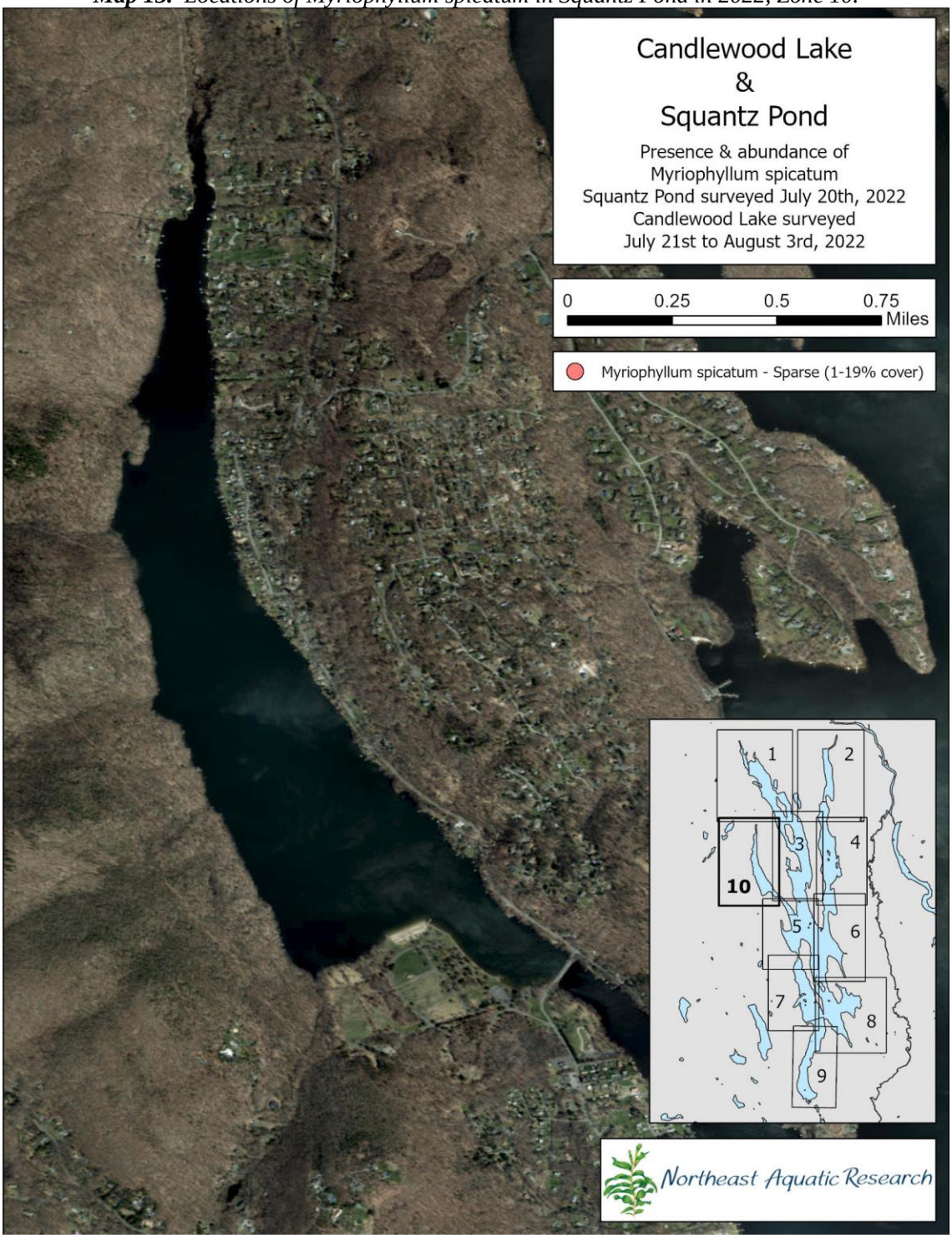
Map 11. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 8.*



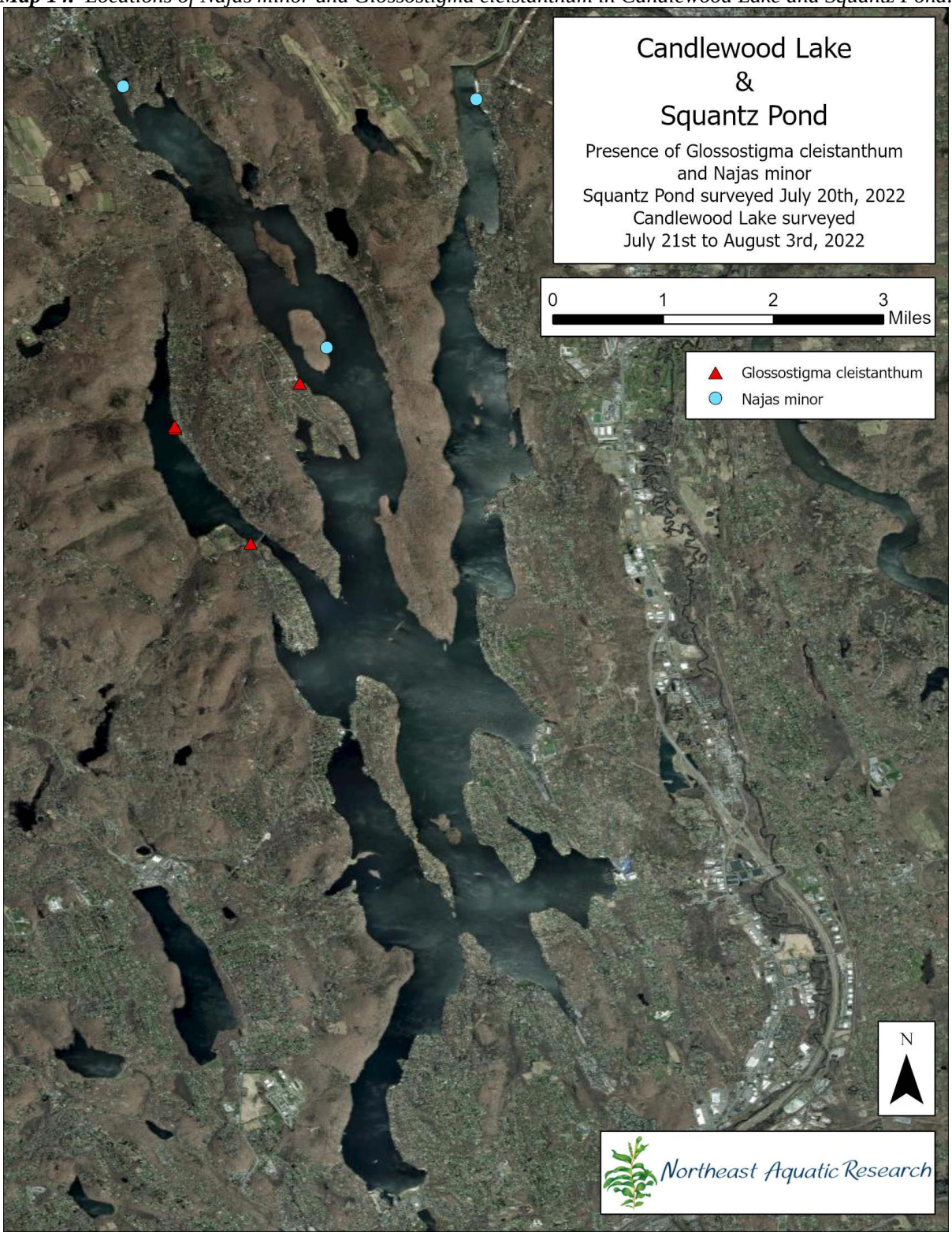
Map 12. *Locations of Myriophyllum spicatum in Candlewood Lake in 2022, Zone 9.*



Map 13. *Locations of Myriophyllum spicatum in Squantz Pond in 2022, Zone 10.*



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



Eurasian milfoil was found at just 17 waypoints in 2022, or 1.2% of all waypoints. Of these, 10 of the locations were in less than 5 feet of water. Plants were found in greater than 10 feet of water at just two locations, with a maximum depth of 14.6 feet. These plants were very small, at a growth form of '1'.

Milfoil was "topped-out" at just one waypoint in 2022, on the western shore of New Milford Bay. "Topped-out" refers to growth conditions where plant shoots break the water's surface and produce aerial flowers.

In total, milfoil covered less than 1 acre in 2022, down from 408 acres in 2021. The cause of this astounding decline can be attributed to grass carp finally reaching an age and size where their consumption rate exceeded the standing crop of milfoil. The biomass, as total kg of Eurasian milfoil in the lake, has been declining in two ways since NEAR began the monitoring in 2018. First - the surface area coverage declined from 512 acres in 2018 to 408 acres in 2021. The severely topped-out beds of milfoil, as shown in **Image 3** are now rare, occurring only within sheltered coves, if at all. Second - the beds have experienced changes in average shoot height in the last few years. The charts of growth form for 2020 and 2021 (**Figure 1**) show a shift wherein the majority of plants in 2020 had a growth form of 4.0-4.9 (growing a foot below, to just below the surface) to 2021, when the most frequent growth form was 3.0-3.9 (shoots reach about the middle of the water column).

If there is about 4000 kilograms of milfoil biomass per acre[1], the loss of 104 acres of milfoil between 2018 and 2021 represents 416,000 kgs of biomass, with the total biomass of milfoil in the lake decreasing from 2.0 million kgs at 512 acres to 1.6 million kgs at 408 acres. **Figure 2** shows an apparent increasing rate of decline in milfoil acreage. From 2018 to 2019, milfoil coverage declined by 35 acres, from 2019 to 2020 the decline was only 8 acres, but between 2020 and 2021, coverage declined by 61 acres. The loss of shoot height between 2020 and 2021 represents a loss of biomass of about 500,000 kgs. This, coupled with the loss of 61 acres of milfoil, or about 250,000 kgs, suggests that between 2020 and 2021, the lake lost 750,000 kgs of milfoil. It is possible that the lake had less than 1 million kgs of milfoil at the end of 2021, which is within range of total consumption for 2022.

Image 3. *Topped out milfoil in Candlewood Lake in 2018.*

[1] Kalff, J. (2003). *Limnology: Inland Water Ecosystems*. Prentice Hall.

Figure 1. *Myriophyllum spicatum growth form frequencies in Candlewood Lake in 2020 (left) and 2021 (right).*

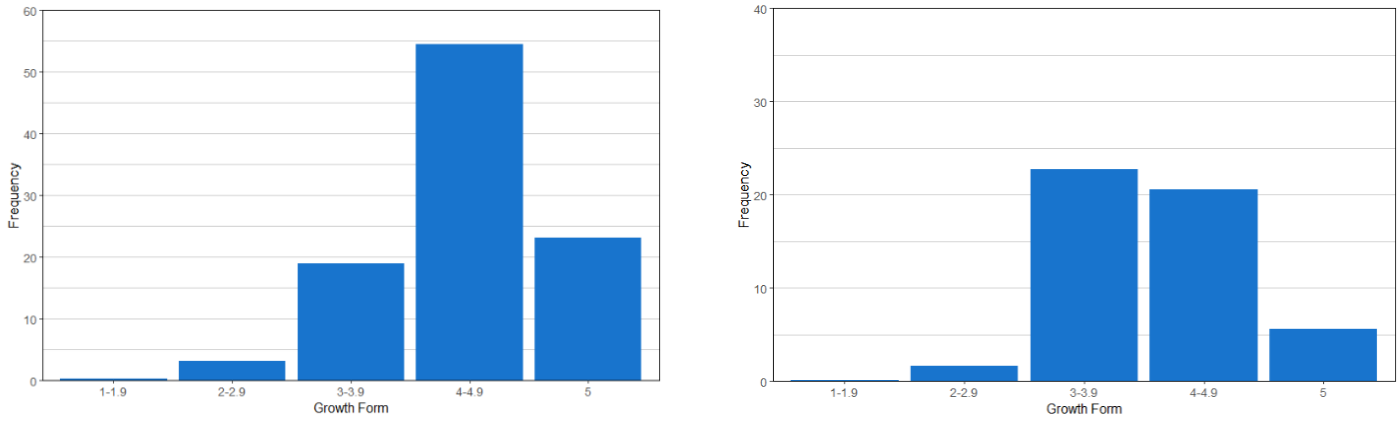
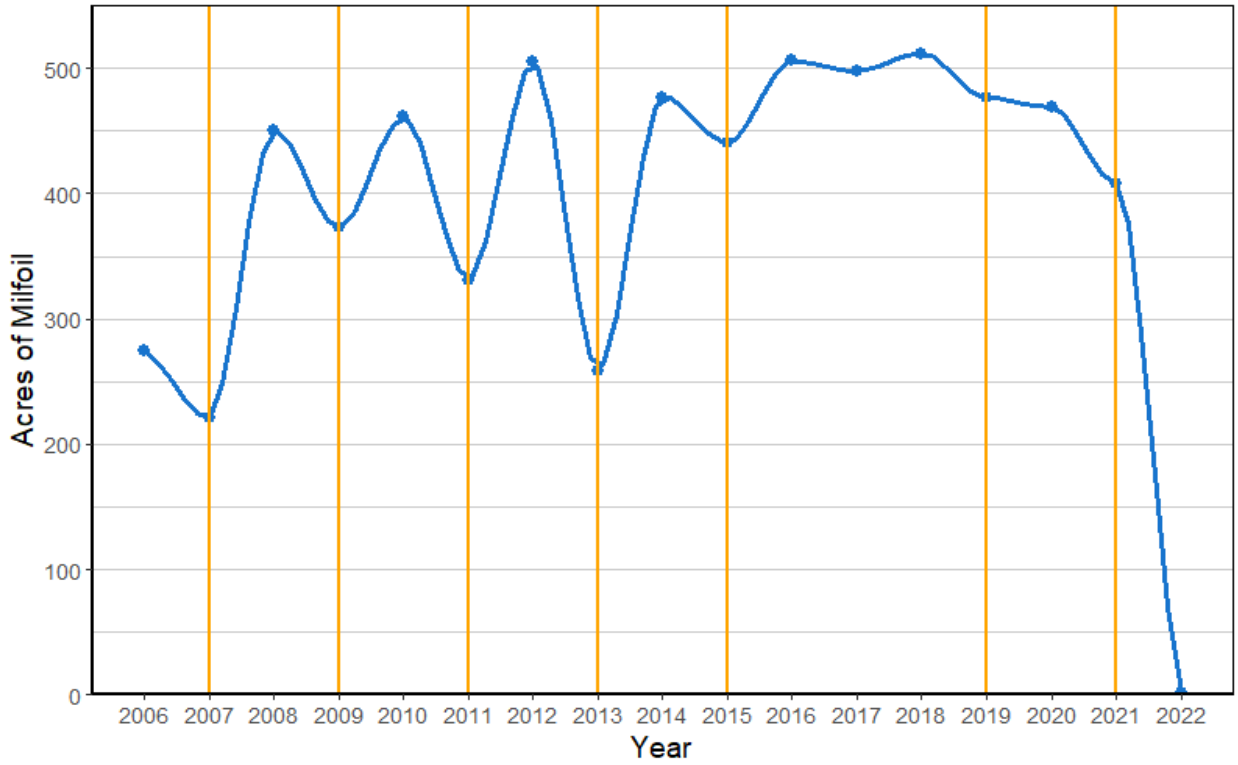


Figure 2. *Acres of Eurasian Milfoil in Candlewood Lake 2006 – 2022, deep drawdowns indicated with orange vertical lines.*



NATIVE PLANTS IN CANDLEWOOD LAKE

12 native vascular aquatic plant species were found in Candlewood Lake during the 2022 survey (**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.

In prior years, Coontail (*Ceratophyllum demersum*) has consistently been the most abundant native plant species. In 2022, Coontail was found at just 6 locations. It is likely that whatever caused the decline in Milfoil also impacted the Coontail population.

Spike rush (*Eleocharis acicularis*) and Horned pondweed (*Zannichellia palustris*) were found at 11 waypoints and 3 waypoints respectively. The remaining native species were each found at only one or two waypoints.

Filamentous green algae (*Spirogyra sp.* and *Zygnema sp.*) were found at 13 waypoints spread throughout the lake. This, too, is notably less than the amount found in 2021.

Table 5. *Native aquatic plant species, found in Candlewood Lake by NEAR during the surveys 2018 - 2022.*

Scientific Name	Common Name	# of sites ***** 2022	# of sites **** 2021	# of sites *** 2020	# of sites ** 2019	# of sites * 2018
Callitriche palustris	Water starwort	1	1	0	0	0
Ceratophyllum demersum	Coontail	6	259	152	53	110
Chara	Muskgrass	0	1	0	0	0
Elatine minima	Waterwort	3	5	28	23	0
Eleocharis acicularis	Spike rush - submersed	11	33	49	27	19
Fontinalis	Aquatic moss	0	6	2	0	0
Lemna	Duckweed	0	3	0	0	0
Ludwigia palustris	Marsh purslane	1	1	1	0	0
Lyngbya wollei	Cyanobacteria mat	0	4	8	0	4
Najas flexilis	Slender naiad	0	1	0	1	0
Nymphaea odorata	White water-lily	1	2	2	1	4
Pontederia cordata	Pickerelweed	0	1	0	0	0
Potamogeton amplifolius	Large-leaf pondweed	0	0	0	0	1
Potamogeton berchtoldii	Slender pondweed	0	1	0	0	0
Potamogeton bicupulatus	Snail-seed pondweed	1	2	0	0	0
Potamogeton foliosus	Leafy pondweed	0	0	2	0	0
Potamogeton illinoensis	Illinois pondweed	1	1	0	0	0
Potamogeton pusillus	Slender pondweed	1	0	0	3	0
Potamogeton spirillus	Spiral pondweed	0	0	8	0	0
Sparganium sp.	Floating bur-reed	0	1	0	0	0
Spirodela polyrhiza	Greater duckweed	0	1	0	0	0
Spirogyra typical - green	Filamentous algae	0	0	0	3	6
Stuckenia pectinata	Sago pondweed	2	5	2	0	0
Vallisneria americana	Tape-grass	1	9	6	12	5

Wolffia	Watermeal/Duckweed	0	4	1	5	1
Zannichellia palustris	Horned pondweed	3	16	20	0	0
Zosterella dubia	Water stargrass	0	4	3	5	1
	Species Richness	**12**	**21**	**14**	**9**	**9**

* 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
***** Out of a total of 1,451 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	2022
Callitriche sp.	Water starwort	1	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1
Ceratophyllum demersum	Coontail	31	33	11	23	30	28	22	27	27	39	39	7	3	10	16	<1
Chara	Muskgrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0
Elatine minima	Waterwort	0	1	3	2	0	4	0	1	2	1	0	0	1	2	<1	<1
Eleocharis acicularis	Spikerush	0	0	0	0	0	0	0	0	0	0	0	1	2	3	2	<1
Elodea nuttallii	Water weed	4	0	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	<1	<1	0
Glossostigma cleistanthum	Mudmat	0	0	0	0	0	0	0	0	0	0	0	1	1	<1	1	<1
Lemna minor	Duckweed	0	2	6	1	4	7	4	0	3	0	0	0	0	0	<1	0
Ludwigia palustris	Marsh purslane	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	<1
Myriophyllum spicatum	Eurasian milfoil	51	79	65	71	78	29	42	76	68	77	57	78	77	76	85	1
Najas flexilis	Bushy Pondweed	7.3	1	1	0	2	0	0	0	0	0	0	0	<1	0	<1	0
Najas minor	Brittle naiad	13	6	8	12	16	12	20	24	16	10	10	2	<1	3	2	<1
Nymphaea odorata	White water lily	1	1	1	1	1	1	1	2	1	1	1	<1	<1	<1	<1	<1
P. amplifolius	Large-leaf pondweed	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0
Pontederia cordata	Pickerelweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0
P. berchtoldii	Small pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0

P. bicupulatus	Snail-seed pondweed	0	1	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1
P. crispus	Curly-leaf pondweed	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P. foliosus	Pondweed	3	0	0	0	2	1	5	1	0	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	<1	<1
P. perfoliatus	Clasping-leaf pondweed	1	2	1	0	0	2	0	1	1	0	0	0	0	0	0	0
P. pusillus	Slender pondweed	3	1	0	0	0	0	0	0	0	0	0	0	<1	0	0	<1
P. foliosus	Leafy pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0
P. gramineus	Grassy pondweed	2	0	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	<1	0	0
Sparganium fluctuans	Floating bur-reed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0
Spirodela polyrhiza	Giant duckweed	0	1	0	0	1	5	0	0	0	1	0	<1	0	0	<1	0
Stuckenia pectinata	Sago pondweed	6	1	0	4	0	3	2	2	1	11	0	0	0	<1	<1	<1
Vallisneria americana	Tape-grass	2	2	4	4	3	4	4	6	4	3	5	<1	<1	<1	<1	<1
Wolffia sp.	Watermeal	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	<1	0
Zannichellia palustris	Horned pondweed	12	3	0	0	0	0	0	0	0	0	0	0	0	1	1	<1
Zosterella dubia	Water stargrass	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0
Number of species		**12**	**12**	**7**	**6**	**7**	**8**	**6**	**7**	**7**	**6**	**3**	**6**	**8**	**13**	**21**	**15**

*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, 2022 frequency based on 1,451 points.

Squantz Pond Results

INVASIVE AQUATIC PLANTS

The aquatic invasive species Mudmat (*Glossostigma cleistanthum*) was found at two locations in Squantz Pond in 2022 (**Map 14**). Eurasian milfoil (*Myriophyllum spicatum*) and Brittle naiad (*Najas minor*) were not present in 2022. Eurasian milfoil was last found in Squantz Pond in 2018, at which time it covered a total of 22.6 acres, with 13.5 acres of high-density beds (**Table 7**). 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 2022 survey.*

Invasive Species	Common Name	# of Sites 2022	# of Sites 2021	# of Sites 2020	# of Sites 2019	# of Sites 2018
Myriophyllum spicatum	Eurasian milfoil	0	0	0	0	99
Najas minor	Brittle naiad	0	0	0	10	24
Glossostigma cleistanthum	Mudmat	2	2	6	1	3

NATIVE PLANTS

Two native plants (*Elatine minima* and *Eleocharis acicularis*) were found in Squantz pond during the 2022 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 2018 – 2022 surveys.*

Scientific Name	Common Name	# of sites ***** 2022	# of sites **** 2021	# of sites *** 2020	# of sites ** 2019	# of sites * 2018
Ceratophyllum demersum	Coontail	0	0	0	2	15
Elatine minima	Waterwort	2	0	6	1	0
Eleocharis acicularis	Spike rush - submersed	2	0	1	3	0
Elodea canadensis	Water weed	0	0	0	0	2
Spirogyra sp.	Filamentous Green Algae	0	0	0	2	4
Fontinalis	Aquatic moss	0	0	1	0	1
Lemna minor	Duckweed	0	0	0	0	1
Najas flexilis	Bushy Pondweed	0	0	0	0	3
Potamogeton amplifolius	Large-leaf pondweed	0	0	0	1	0
Potamogeton pusillus	Narrow-leaf pondweed	0	0	0	0	1

***** Out of a total of 169 sites
**** 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 Zoar Results

Lake Zoar was surveyed on September 7th and 8th, 2022. Waypoints were created every ~200 feet along the shoreline (**Map 15**). 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, and Brittle naiad were found in the lake (**Table 9**). In addition, 20 native aquatic plant species were present in the lake (**Table 10**).

Eurasian milfoil totaled ~23 acres, of which approximately half was sparse. The species was most abundant at the northern and southern ends of the lake (**Map 16**, **Map 17**, **Map 18**).

Milfoil abundance has decreased in Lake Zoar over the past three Article 401 surveys. In 2020, milfoil covered ~64 acres and in 2018, milfoil covered ~114 acres.

Brittle naiad totaled just over 20 acres and was most abundant at the two ends of the lake. The majority of the plant beds were sparse (**Map 19**, **Map 20**, **Map 21**).

Curly-leaf pondweed totaled approximately 3 acres, made up of small, sparse patches.

Water chestnut was not found in the lake.

Map 15. *Waypoints (green dots) made in Lake Zoar during NEAR 2022 survey.*

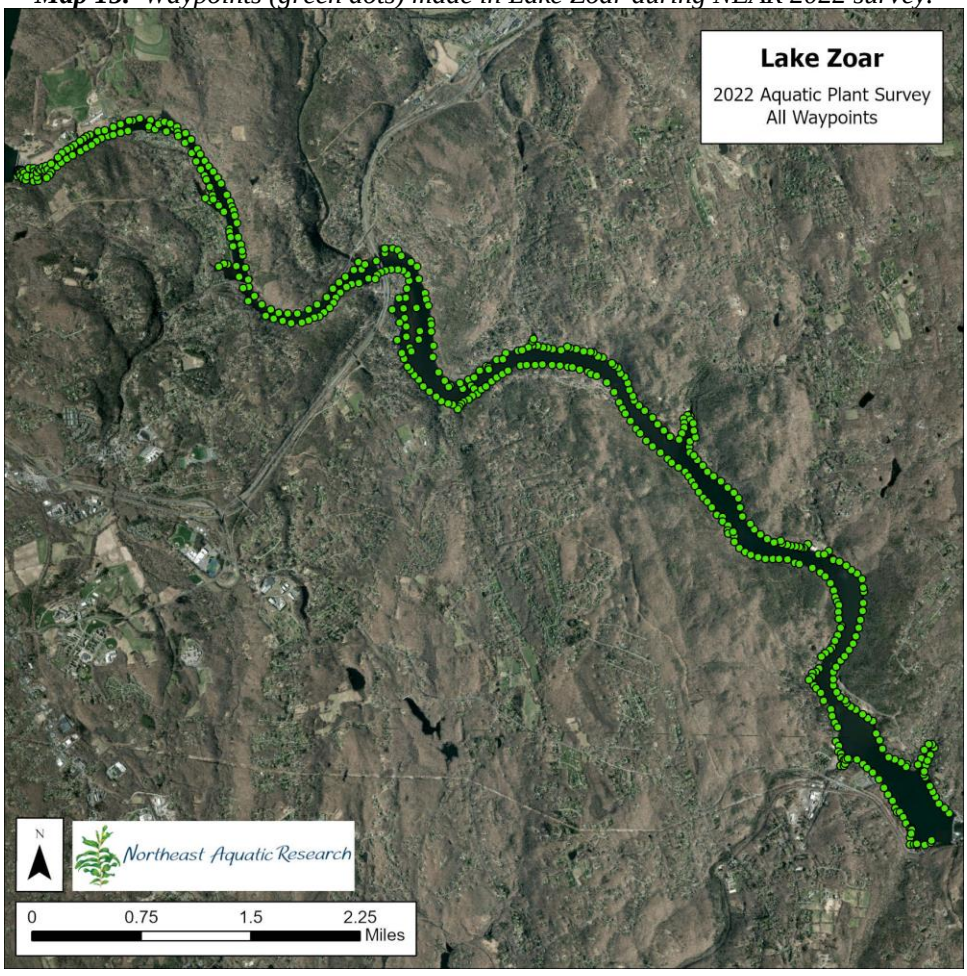


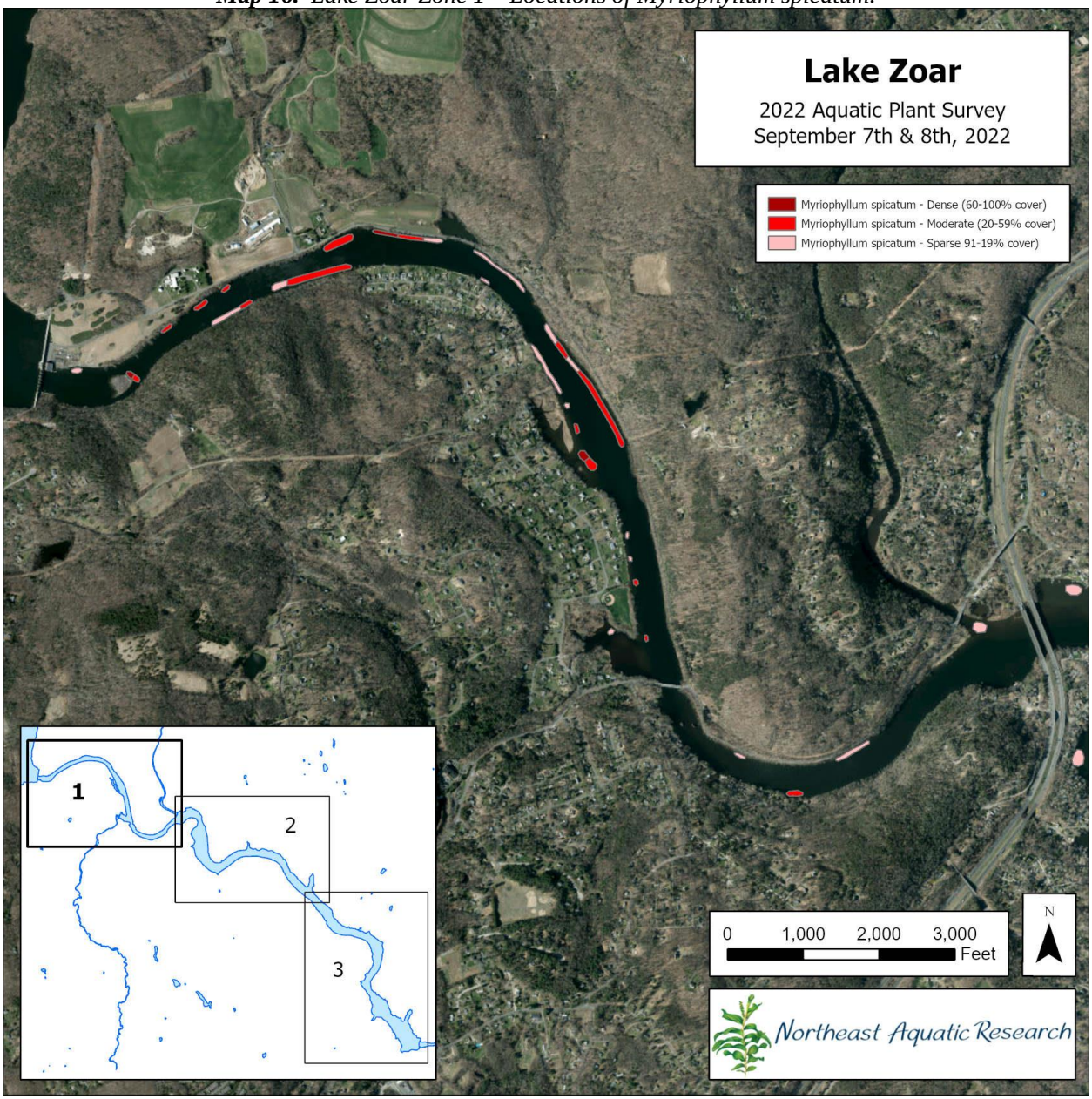
Table 9. *Acres of invasive plants found in Lake Zoar in 2022.*

Scientific Name	Common Name	Acres			
		Sparse	Moderate	Dense	Total
Myriophyllum spicatum	Eurasian milfoil	12.6	8.9	1.5	23
Najas minor	Brittle naiad	14.4	4.0	3.1	21.5
Potamogeton crispus	Curly-leaf pondweed	2.6	0.5	0	3.1

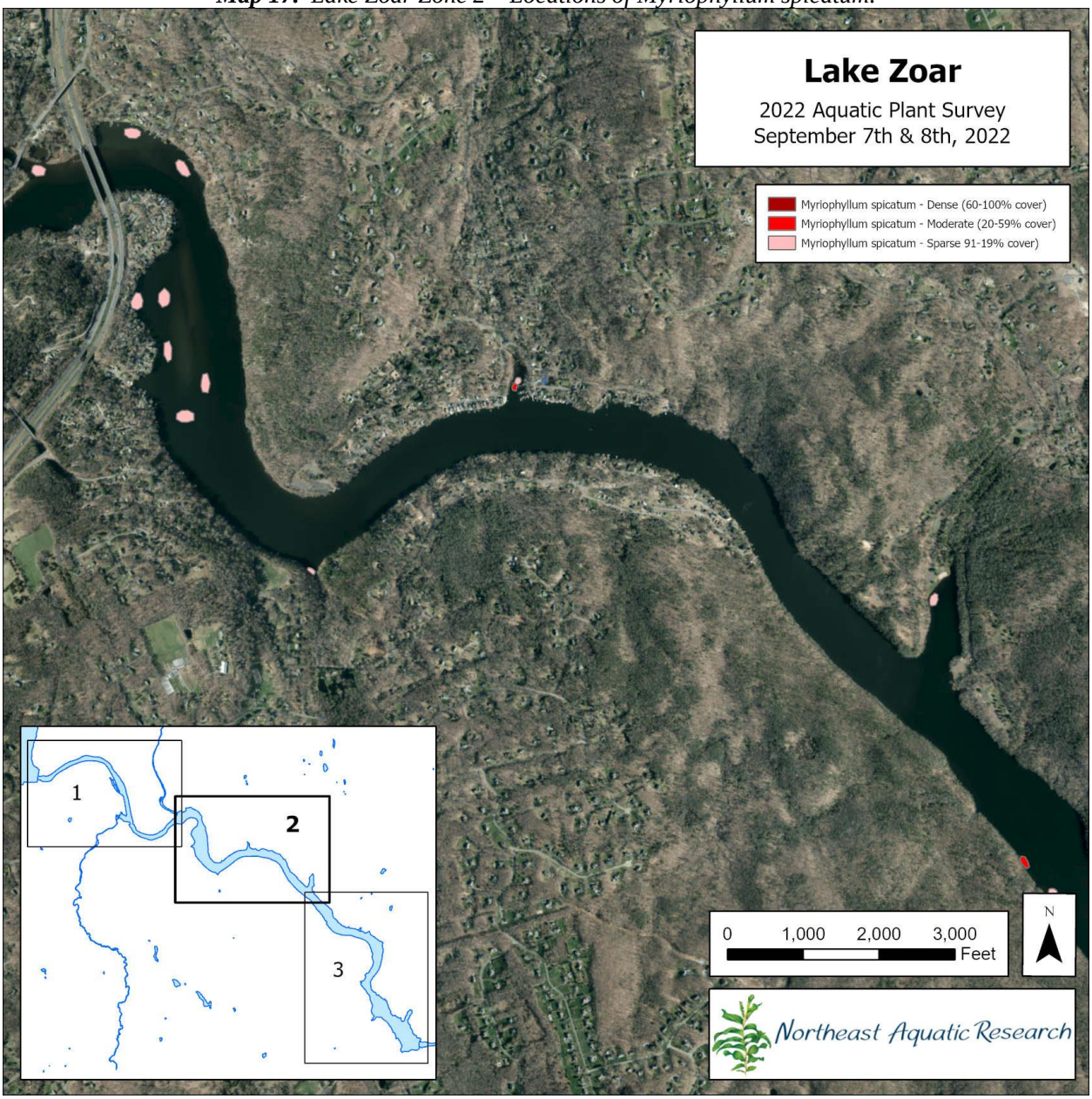
Table 10. *Aquatic plant species in Lake Zoar during the 2022 aquatic plant survey, with associated percent frequencies and average densities. Red text indicates invasive species.*

Scientific Name	Common Name	% Frequency	Average Density %
Ceratophyllum demersum	Coontail	8	29
Elodea nuttallii	Western waterweed	6	35
Sparganium sp.	Emergent sparganium	<1	80
Filamentous algae	Filamentous algae	3	29
Fontinalis sp	Aquatic moss	<1	20
Lemna sp	Duckweed	<1	30
Lyngbya	Slender naiad	6	45
Marsilea quadrifolia	Water clover	<1	70
Myriophyllum spicatum	Eurasian milfoil	20	24
Najas minor	Brittle naiad	11	33
Nymphaea odorata	White water lily	<1	5
Potamogeton crispus	Curly-leaf pondweed	4	12
Potamogeton nodosus	Long-leaf pondweed	11	35
Potamogeton perfoliatus	Clasping-leaf pondweed	1	20
Potamogeton pusillus	Slender pondweed	7	20
Potamogeton zosteriformis	Flat-stem pondweed	3	23
Stuckenia pectinata	Sago pondweed	<1	10
Vallisneria americana	Tape-grass	20	46
Zosterella dubia	Water stargrass	11	32

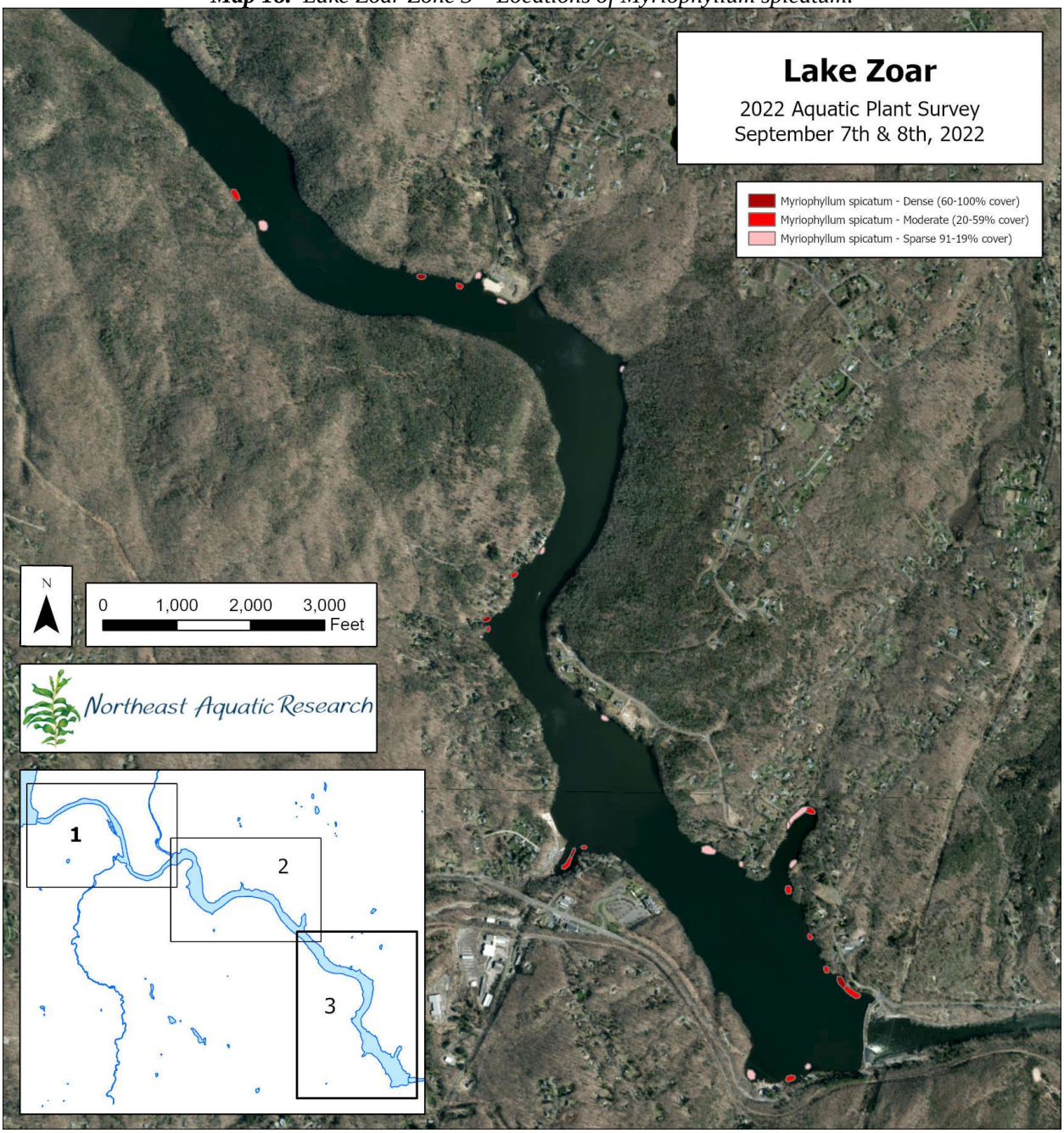
Map 16. *Lake Zoar Zone 1 – Locations of Myriophyllum spicatum.*



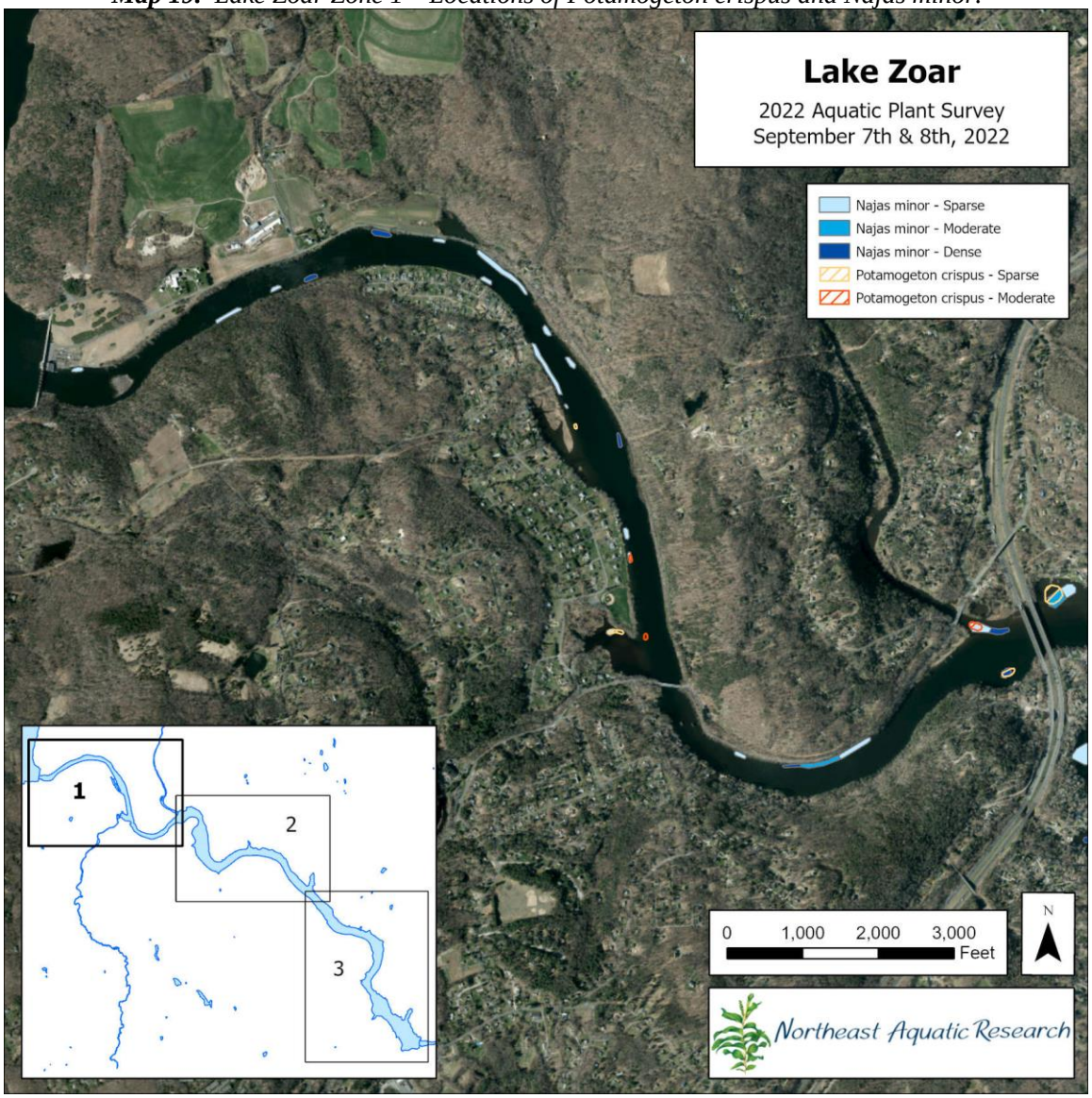
Map 17. *Lake Zoar Zone 2 – Locations of Myriophyllum spicatum.*



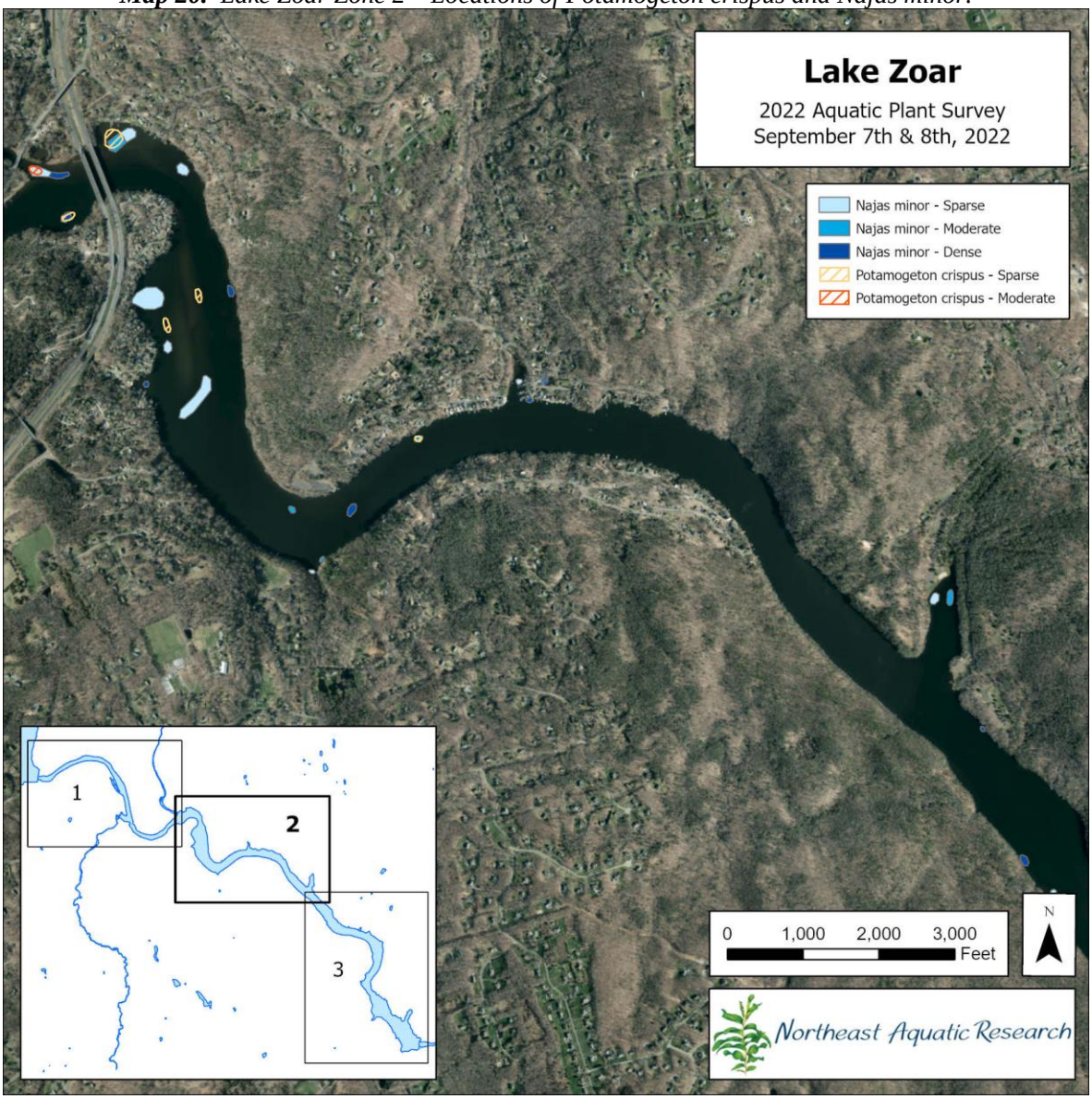
Map 18. *Lake Zoar Zone 3 – Locations of Myriophyllum spicatum.*



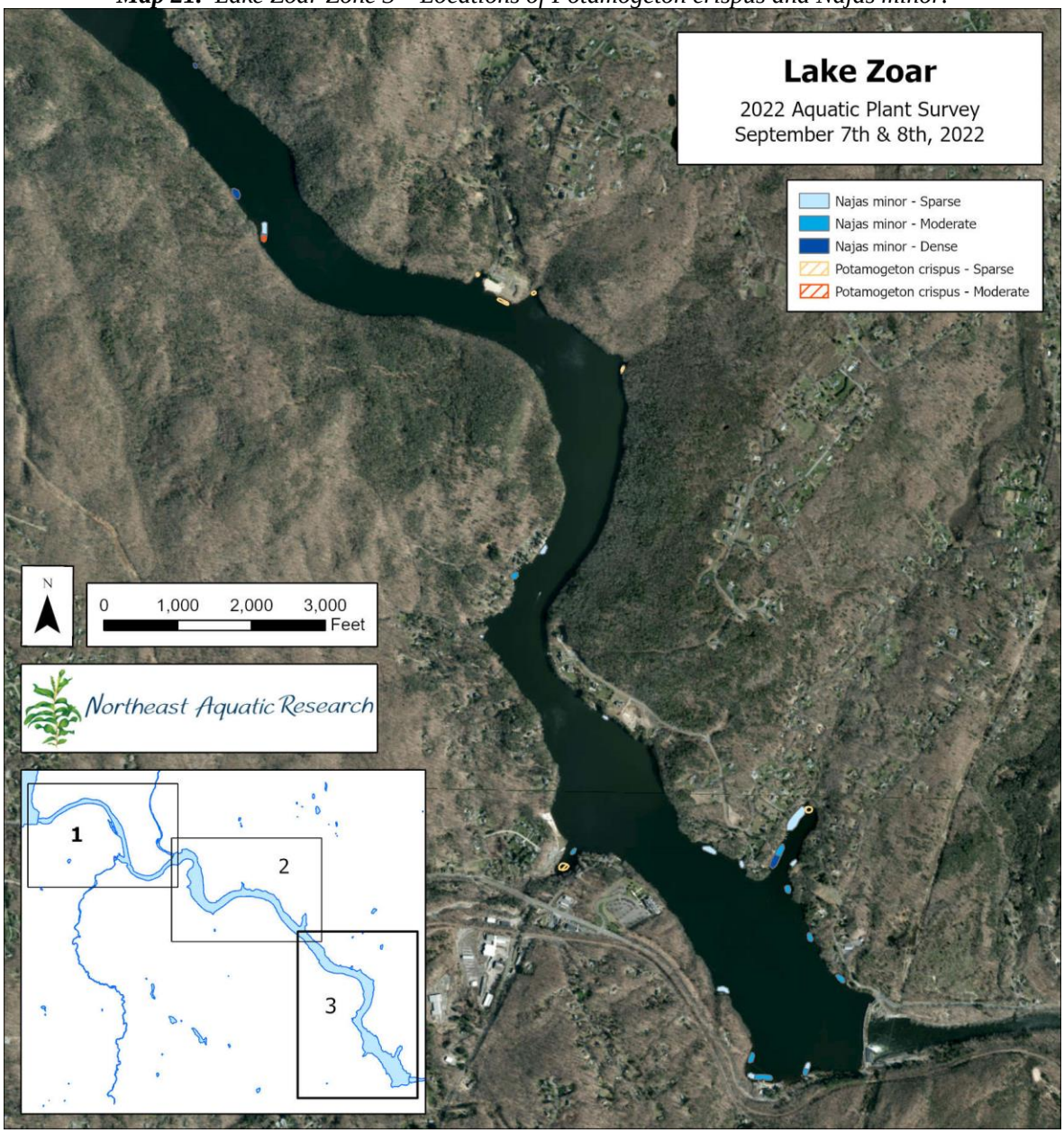
Map 19. *Lake Zoar Zone 1 – Locations of Potamogeton crispus and Najas minor.*



Map 20. *Lake Zoar Zone 2 – Locations of Potamogeton crispus and Najas minor.*



Map 21. *Lake Zoar Zone 3 – Locations of Potamogeton crispus and Najas minor.*



Appendix 1: Raw Lake Survey Data

Raw waypoint data is included as a separate pdf document.