The Connecticut

Agricultural

Experiment

Station

123 Huntington Street

New Haven, CT 06511

Pachaug Pond

Griswold, CT

Aquatic vegetation survey

Water chemistry

Aquatic plant management options

2017

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CAES

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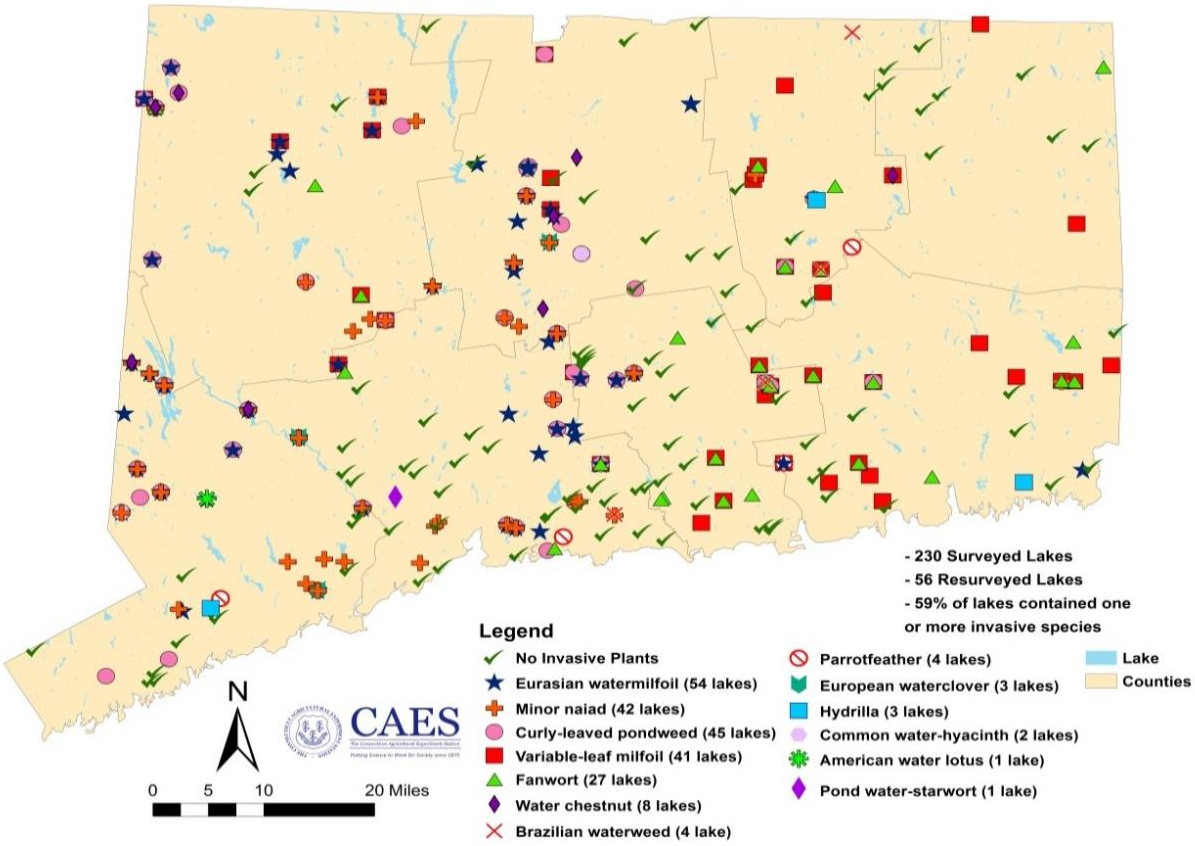

Figure 1. Locations of invasive aquatic plants found by CAES IAPP from 2004 to 2016.

Introduction

Since 2004, the Connecticut Agricultural Experiment Station (CAES) Invasive Aquatic Plant Program (IAPP has surveyed or resurveyed aquatic vegetation and monitored water chemistry in over 300 Connecticut lakes and ponds (Figure 1). Approximately 60% of the lakes and ponds contain invasive (non-native) plant species that are capable of causing rapid deterioration of aquatic ecosystems and recreation value. The presence of invasive species appears related to water chemistry, public boat launches and random events. The CAES IAPP information is databased on the website www.ct.gov/caes/iapp where interested parties can view digitized vegetation maps, detailed transect data, temperature and dissolved oxygen profiles as well as water tests for clarity, pH, alkalinity, conductivity, and total phosphorus. This information allows citizens, government officials and scientists to view past conditions compare them with current conditions and make educated management decisions. The work described in this report adds Pachaug Pond to the CAES IAPP database.

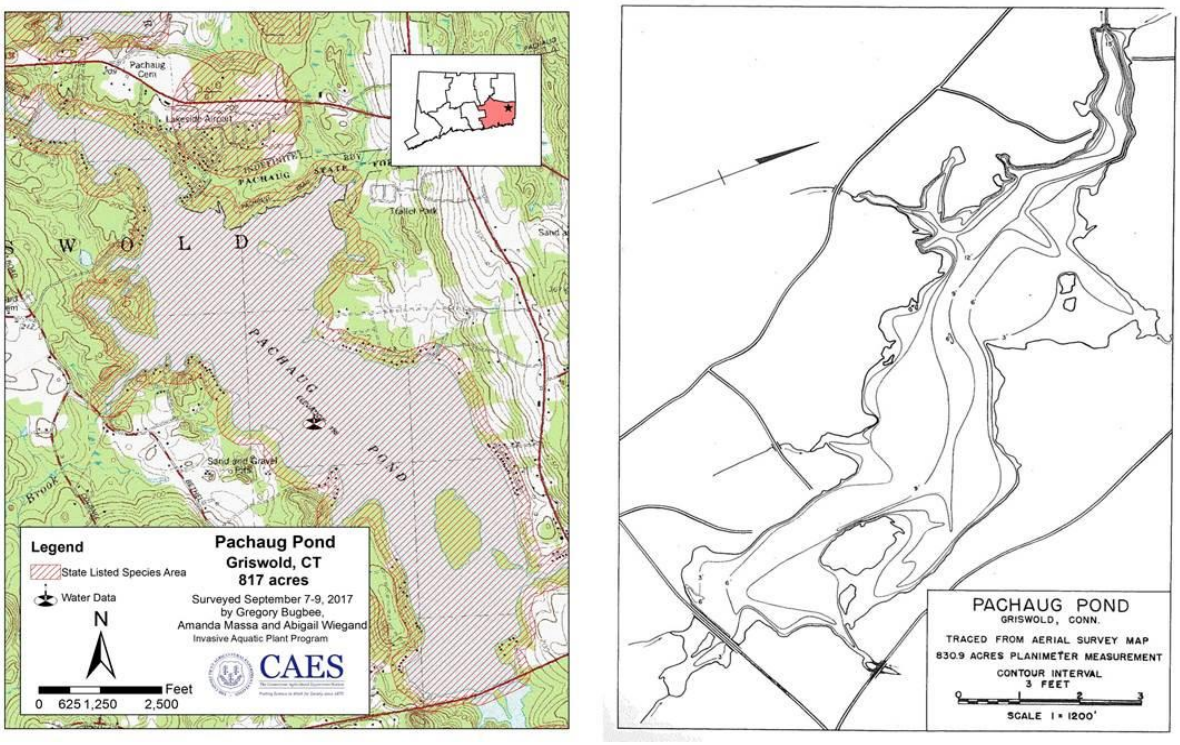

Figure 2. Topographic map of Pachaug Pond including location of State listed species (Natural Diversity Area) and CAES IAPP water sampling site (left) and bathymetry map circa 1959 (right).

This is the first CAES IAPP survey of Pachaug Pond for aquatic vegetation and water chemistry. Pachaug Pond is an 817 acre waterbody located in Griswold, CT (Figure 2). It has a maximum depth of approximately 16 feet and an average depth of about six feet. The shallow nature of the lake allows a large littoral zone where aquatic plant growth is favored. State listed species may be present throughout the entire lake (Figure 2, left)(CTDEEP, 2017). Protection of these species requires withholding details from the public without the special request forms. Public access is via a state boat launch on the southern shore. There are no motor restrictions. Previous work on Pachaug Pond dates back to the 1950's when the State Board of Fisheries and Game (1959) described the lake as being shallow and fertile (Figure 2, right) with abundant emergent and submergent vegetation (see appendix for full description). The specific plant species were not mentioned but the bottom was described as being mud, swampy ooze and sand. A dense algal bloom was observed that reduced the water clarity to two feet. Bass fishing was described as excellent with fish over five pounds common. The 1959 information mentioned frequent severe summer drawdowns that may be controlling aquatic vegetation. These drawdowns were stated as being due to utilization of the water

Figure 3. Aquatic plants along the western shoreline of Pachaug Pond in 2017.

for "industrial" purposes which was likely power generation (personnel communication) . Apparently, drawdowns were lessening as of 1959 and aquatic vegetation was increasing. CAES studied Pachaug Pond in 1979 as part of a statewide investigation into changes in lake water chemistry (Frink and Norvell, 1984). In addition to detailed water chemistry, the study mentions Pachaug Pond as having moderately dense aquatic weeds in shallow areas and watermilfoil (species not identified) near the boat launch. Interestingly, pioneer infestations of invasive species might first be noticed at the boat launches if the plant arrived on a boat or trailer. Native plants that occurred at depths of less than three feet were bushy pondweed (*Najas flexilis*), spatterdock (*Nuphar varigata*) and pipewort (*Eriocaulon sp.*). The 1979 CAES water tests found a water clarity of 3.5 m (12 feet), an alkalinity of 15 mg/L $CaCO_3$ and a total phosphorus concentration of 16 µg/l at the surface and 13 µg/L at the bottom. These results suggest an oligo-mesotrophic condition where nutrients are not excessive.

Objectives:

- Survey Pachaug Pond for aquatic vegetation and test water to quantify water chemistry.
- Add Pachaug Pond vegetation maps and water chemistry information to the CAES IAPP website.
- Provide aquatic plant management options.

Materials and Methods:

Aquatic plant surveys and mapping:

We surveyed Pachaug Pond for aquatic vegetation from September 7 - 9, 2017. Our aquatic vegetation survey utilized methods established by CAES IAPP with the exception that fewer transects and less detail were possible due to funding restrictions. Surveys were conducted from a 16 and an 18 foot motorized boat traveling over areas shallow enough to support aquatic plants. Plant species were recorded based on visual observation or collections with a long-handled rake or grapple. A Lowrance HDS® sonar system, with structure scan technology, was used to determine vegetated areas in deep water and eliminate the need for time-consuming grapple tosses. In some cases we circumnavigated the plant patches with Trimble® global positioning systems to form georeferenced polygons. Quantitative information on plant abundance was obtained from 10 transects that were positioned perpendicular to the shoreline. Transects were set using a Trimble® global positioning systems with sub-meter accuracy. Transect locations represented the variety of habitats occurring in the lake. Sampling locations were along each transect at points 0, 5, 10, 20, 30, 40, 50, 60, 70, and 80 m from the shore. We measured depth with a rake handle, drop line or digital depth finder and sediment type was estimated. Plant samples were obtained in shallow water with a rake and in deeper water with a grapple. Abundances of species present at each point were ranked on a scale of 1 – 5 (1 = very sparse, 2 = sparse, 3 = moderately abundant, 4 = abundant; 5 = extremely abundant). When field identifications of plants were questionable, we brought samples back to the lab for review using the taxonomy of Crow and Hellquist (2000*a*, 2000*b*). One specimen of each species collected in the lake were dried, and mounted in the CAES aquatic plant herbarium and digitized mounts can be viewed online (www.ct.gov/caes/iapp). We post-processed the GPS data in Pathfinder® 5.85 (Trimble Navigation Limited, Sunnyvale, CA) and then imported it into ArcGIS® 10.5.1 (ESRI, Redlands, CA), where it was geo-corrected. Data were then overlaid onto 2010 United States Department of Agriculture - National Agricultural Inventory Program aerial imagery with 1 m resolution.

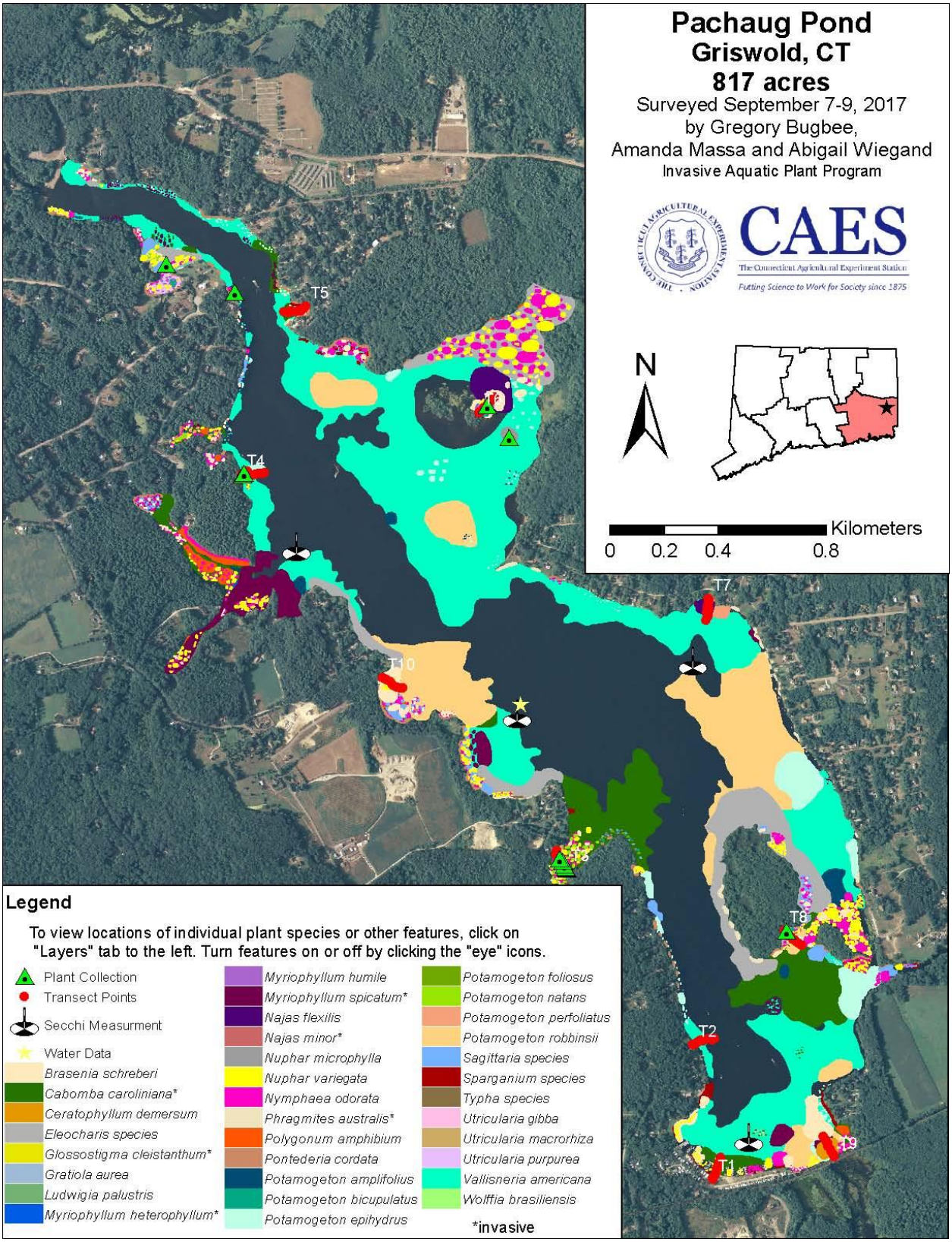

Figure 4. CAES IAPP 2017 aquatic plant survey of Pachaug Pond (Full Map).

Table 1. Plants present in Pachaug Pond in 2017

Pachaug Pond			
Species (*invasives in bold)		**Transects 2017**	
Scientific Name	**Common Name**	**Found**	**Frequency of Occurrence** (%/point)
Brasenia schreberi	watershield	X	31
Cabomba caroliniana	fanwort	X	48
Ceratophyllum demersum	coontail	X	17
Eleocharis species	spikerush	X	8
Glossostigma cleistanthum*	**mudmat**	**X**	**1**
Gratiola aurea	golden hedge-hyssop	X	5
Ludwigia palustris	marsh primrose-willow	X	2
Myriophyllum heterophyllum	**variable-leaf watermilfoil**	**X**	**8**
Myriophyllum humile	low watermilfoil	X	8
Myriophyllum spicatum	**Eurasian watermilfoil**	**X**	**31**
Najas flexilis	nodding waternymph	X	11
Najas minor*	**brittle waternymph**	**X**	**4**
Nuphar microphylla	small-leaved pond-lily		0
Nuphar variegata	yellow water lily	X	13
Nymphaea odorata	white water lily	X	18
Phragmites australis*	**common reed**	**X**	1
Polygonum amphibium	water smartweed	X	4
Pontederia cordata	pickerelweed	X	12
Potamogeton amplifolius	large-leaf pondweed	X	9
Potamogeton bicupulatus	snailseed pondweed	X	10
Potamogeton epihydrus	ribbon-leaf pondweed	X	35
Potamogeton foliosus	leafy pondweed	X	1
Potamogeton natans	floating-leaf pondweed	X	3
Potamogeton perfoliatus	clasping-leaf pondweed	X	2
Potamogeton robbinsii	Robbins pondweed	X	35
Sagittaria species	arrowhead	X	9
Sparganium species	bur-reed	X	12
Typha species	cattail		0
Utricularia gibba	humped bladderwort	X	1
Utricularia macrorhiza	common bladderwort	X	8
Utricularia purpurea	purple bladderwort	X	1
Utricularia radiata	floating bladderwort	X	48
Vallisneria americana	tapegrass	X	65
Wolffia brasiliensis	Brazilian watermeal	X	1
Total Species Richness	34	32	
Total native Species Richness	29	27	
Total Invasive Species Richness	**5**	**5**	

Water Analysis:

Water was analyzed from the deepest part of the lake (Figure 4). Water temperature and dissolved oxygen were measured 0.5 m beneath the surface at 1 m intervals to the bottom. Water sample (250 mL) for pH, alkalinity, conductivity, and total phosphorus testing were obtained from 0.5 m beneath the surface and 0.5 m above the bottom. All samples were stored at 38°C until testing. A Fisher AR20® meter was used to determine pH and conductivity and alkalinity (expressed as mg/l $CaCO_3$) was quantified by titration with 0.016 N H_2SO_4 to an end point of pH 4.5. We determined total phosphorus using the ascorbic acid method preceded by digestion with potassium

Figure 5. Invasive fanwort (left) and native water smartweed (right) in shallow cove of Pachaug Pond in 2017.

persulfate (APHA, 1995). Phosphorus was quantified using a Milton Roy Spectronic 20D® spectrometer with a light path of 2 cm and a wave length of 880 nm. Water was tested for temperature and dissolved oxygen using an YSI 58® meter. Water clarity was measured by lowering a six inch diameter black and white Secchi disk into the water and determining to what depth it could be viewed (Figure 12, top left).

Results and Discussion

General Aquatic Plant Surveys and Transects

Our 2017 survey of Pachaug Pond (Figures 4, 6-10) found from 34 plant species of which 29 were native and five were invasive (Table 1). The invasive species were mudmat, variable-leaf watermilfoil, Eurasian watermilfoil, brittle waternymph and phragmites are invasive while the native species represent a wide diversity of emergent and submergent macrophytes. Pachaug Pond contains among the greatest number of plant species found in any CAES IAPP survey with only Gardner Lake (38 species) and Upper Moodus Reservoir (37 species) supporting more. Descriptions of the invasive species are in the appendix of this report while information on the native species can be found at the USDA "About PLANTS" website (https://plants.usda.gov/about_plants.html). Although monostands of invasive species covered areas of the lake, areas covered by native species or invasive species mixed with native species were more common. Many of the shallow coves contained nuisance

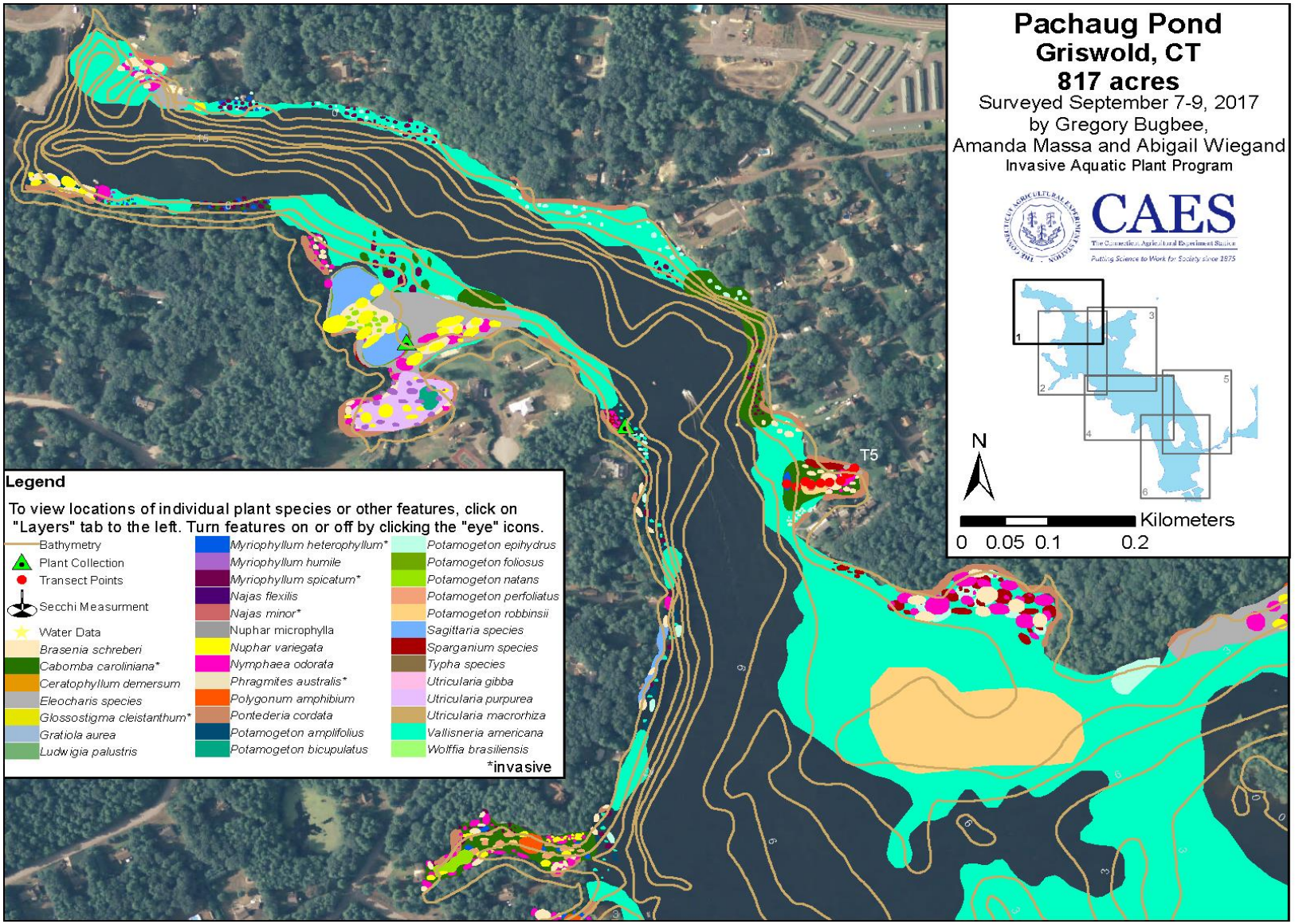

Figure 6. 2017 survey of Pachaug Pond (Section 1).

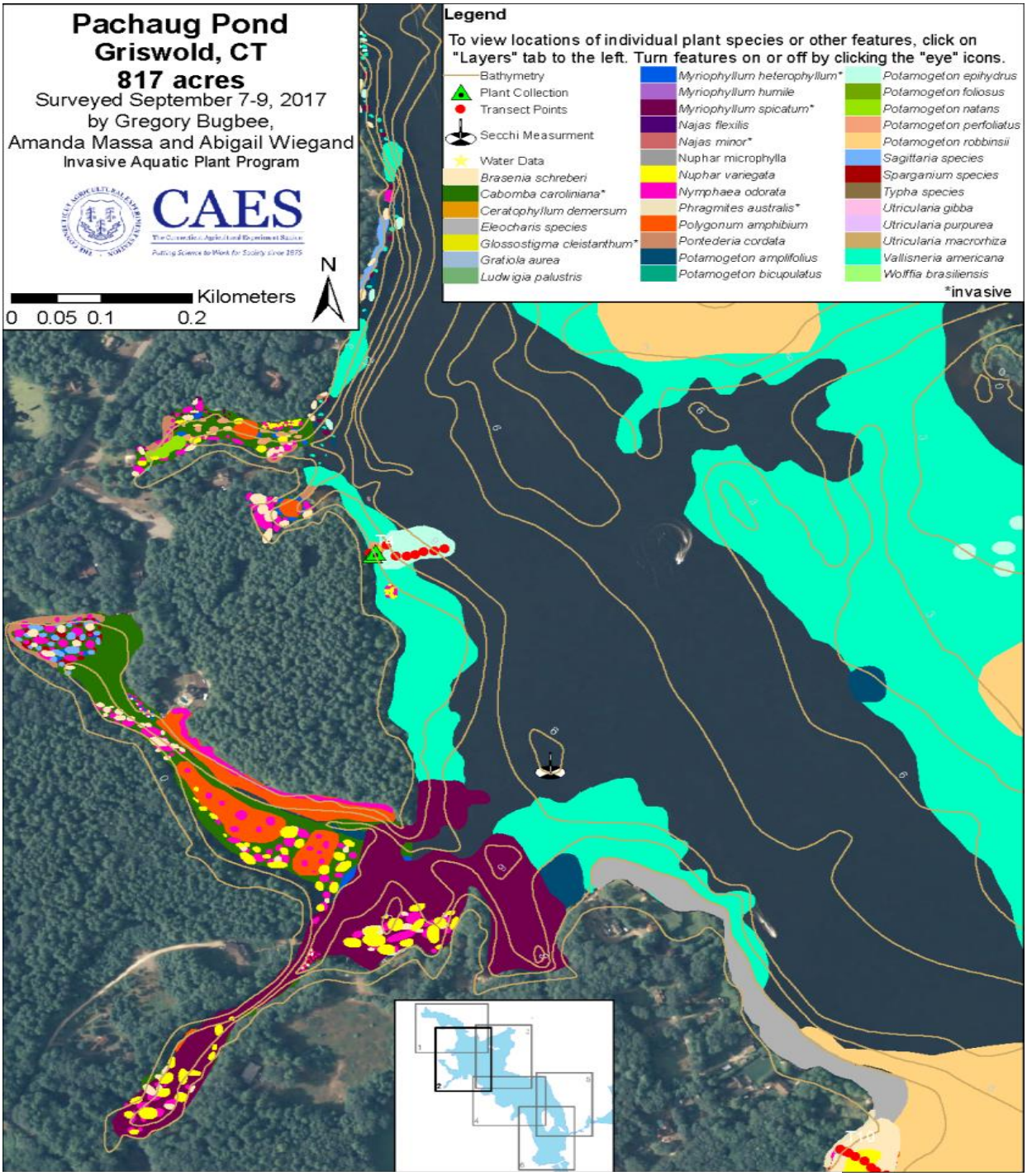

Figure 7. 2017 survey of Pachaug Pond (Section 2).

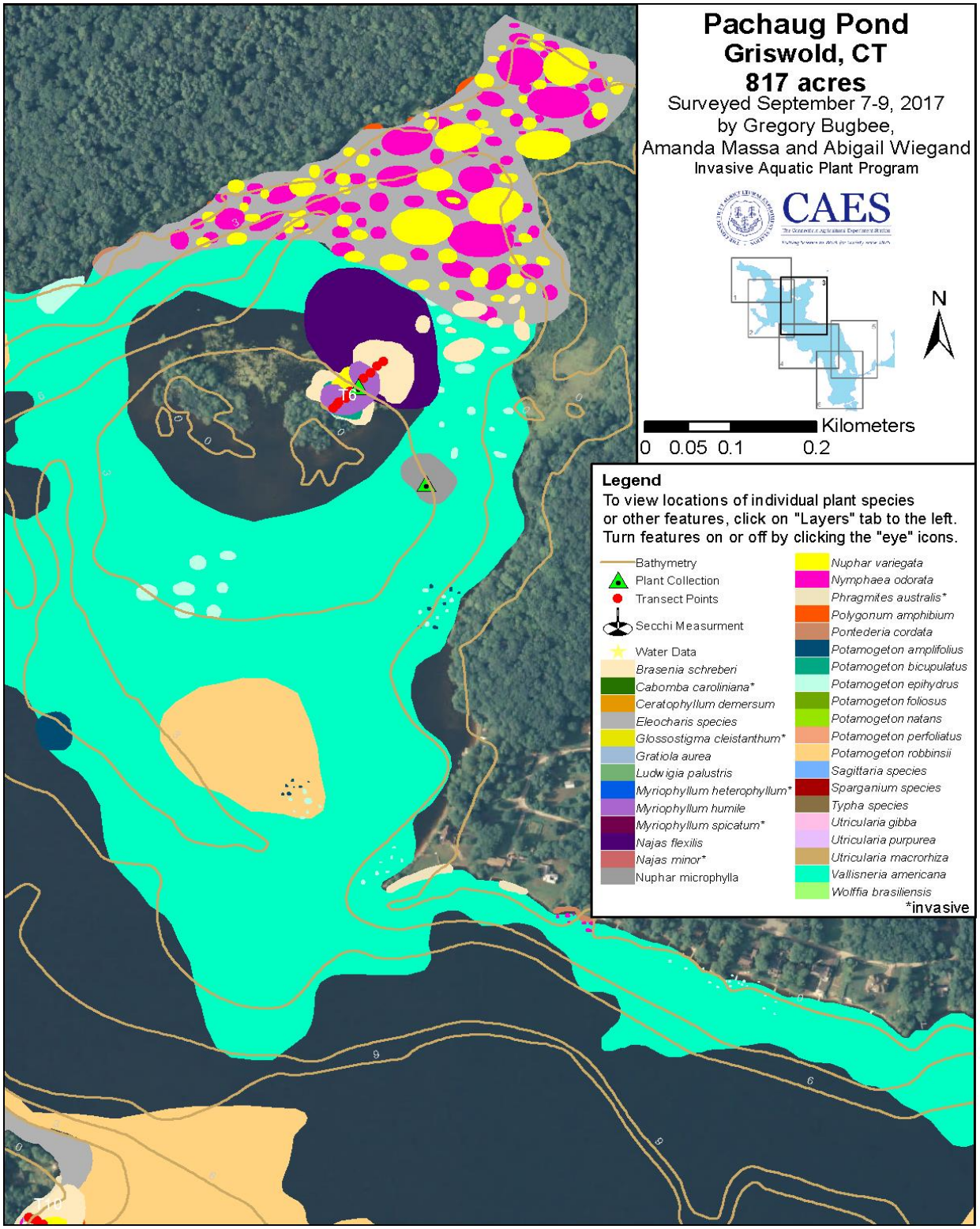

Figure 8. 2017 survey of Pachaug Pond (Section 3).

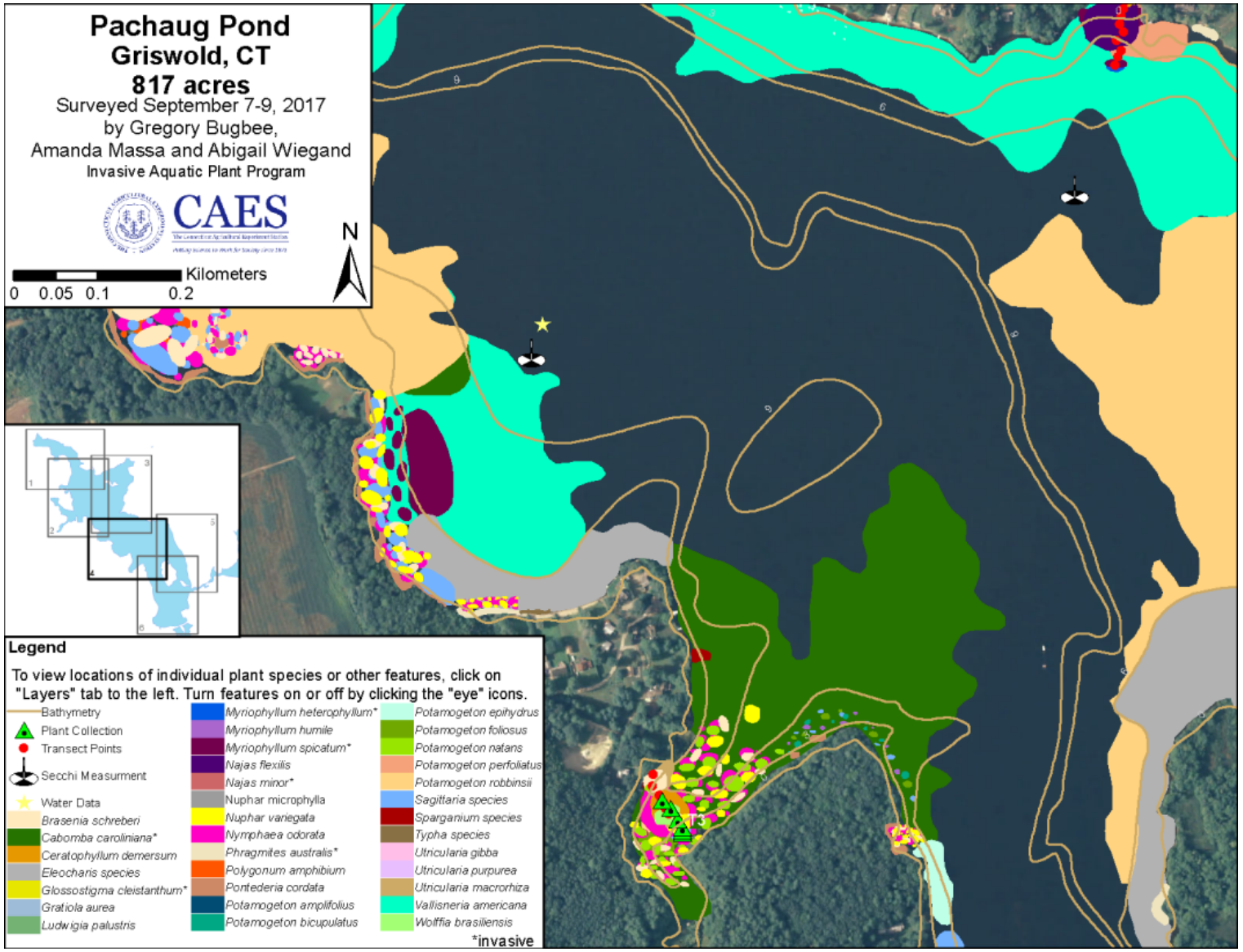

Figure 9. 2017 survey of Pachaug Pond (Section 4).

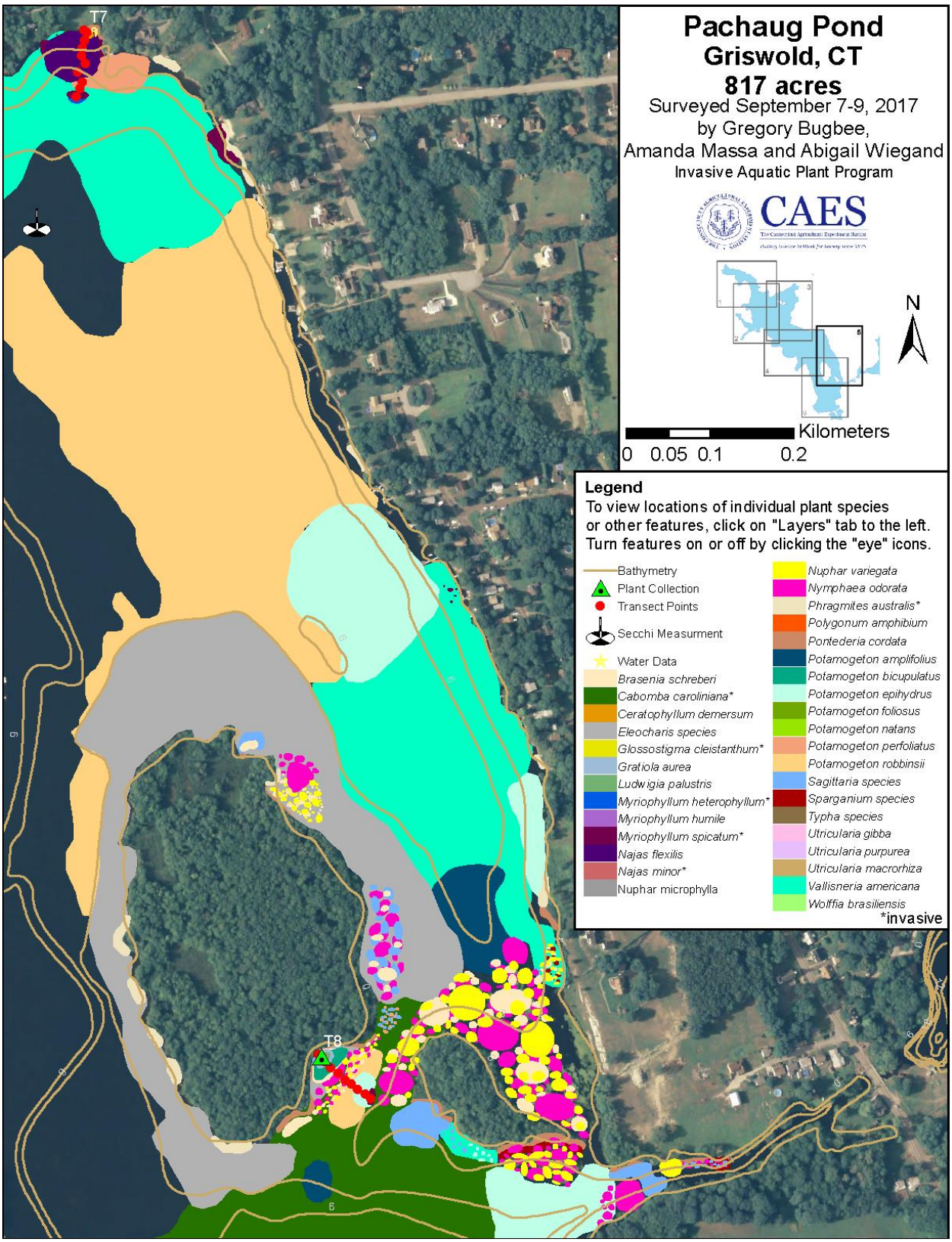

Figure 10. 2017 survey of Pachaug Pond (Section 5).

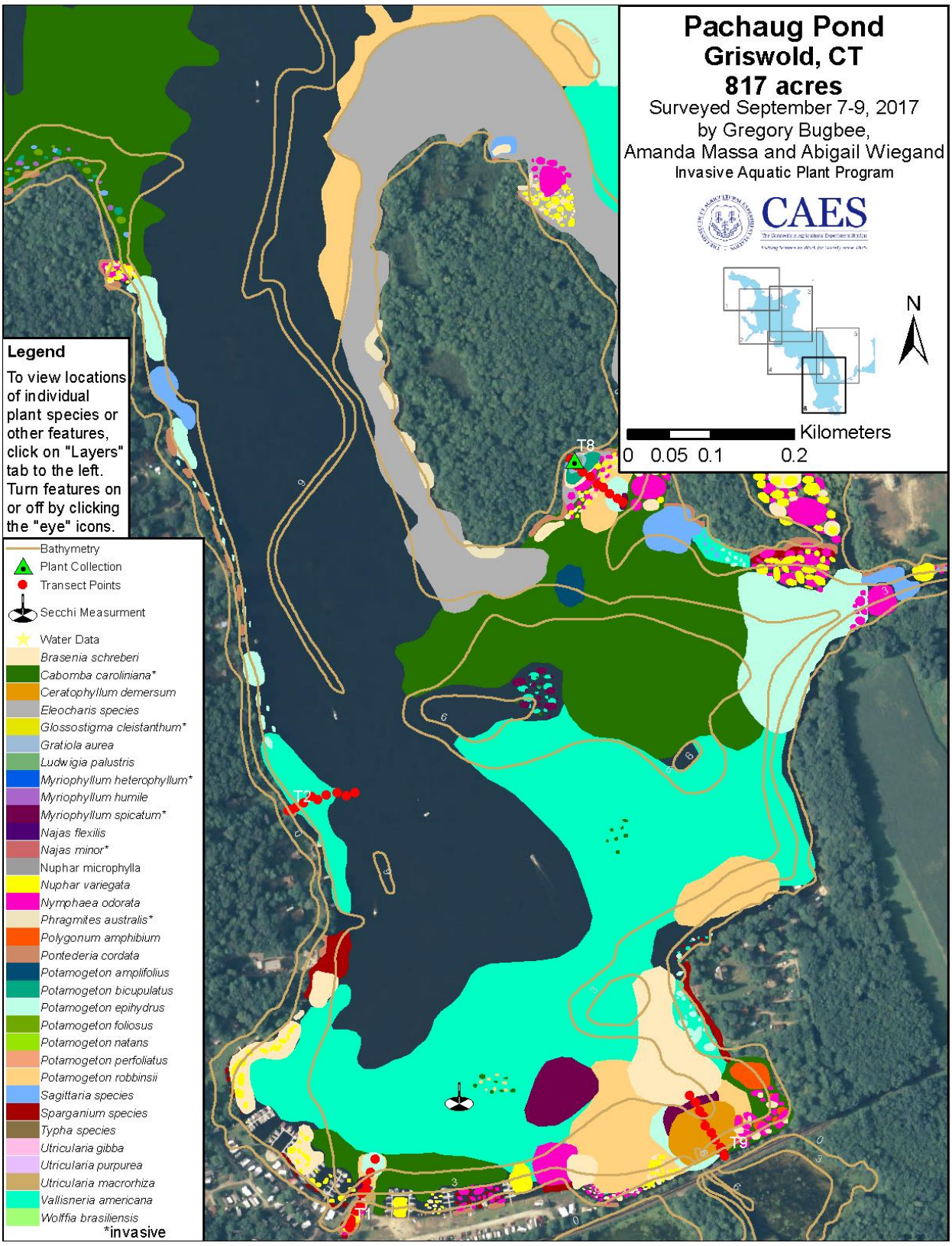

Figure 11. 2017 survey of Pachaug Pond (Section 6).

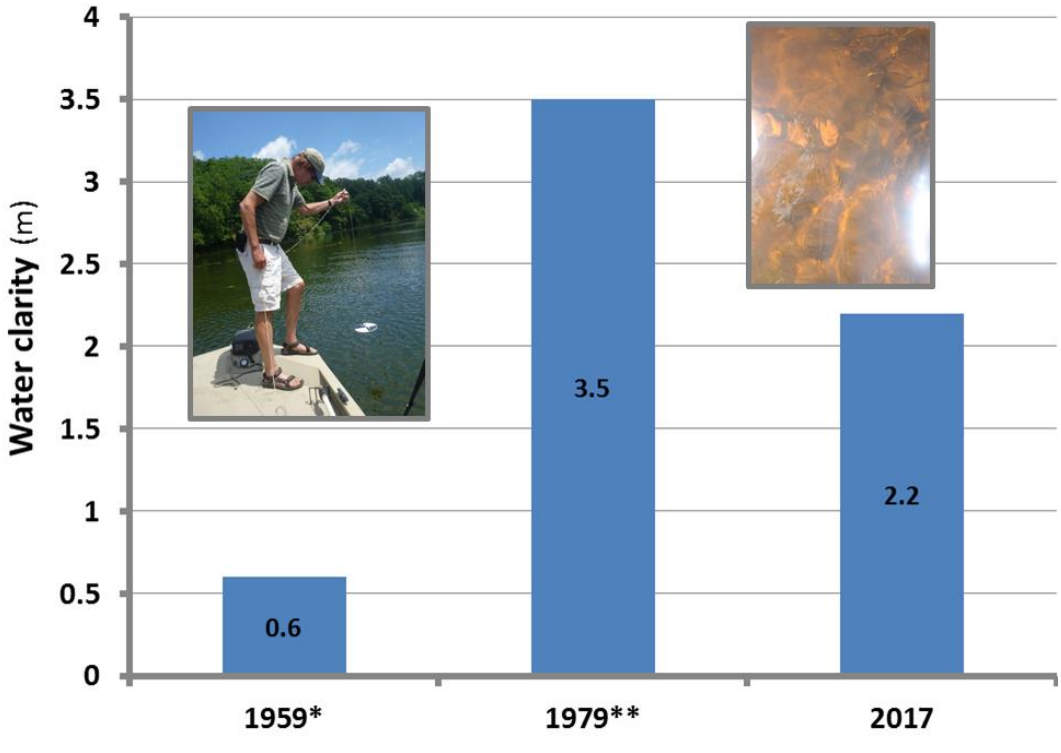

Figure 12. Water clarity in Pachaug Pond in 1959(*State Board of Fisheries and Game), 1979 (**CAES) and 2017(CAES IAPP).

vegetation such as fanwort , water smartweed and water lilies that reached the surface (Figure 5). Most of the lake, however, did not have problematic vegetation reaching the surface even though it was shallow enough to support luxuriant growth. In these areas the bottom was often covered with non-nuisance eel grass and Robbin's pondweed. Reasons for this may include the brown water coloration that limits light, infertile substrate and previous drawdowns.

Our frequency of occurrence data, taken from our transects points (Table1), found the most common invasive plants were fanwort (48%), Eurasian watermilfoil (31%) and variable-leaf watermilfoil (8%) and the most commonly native plants were eel grass (65%), floating bladderwort (48%), Robbin's pondweed (35%), ribbonleaf pondweed (35%) and watershield (31%). Our survey found a few instances where stands of aquatic plants were covered with filamentous algae but no planktonic algal blooms were observed. When there are a large number of species present with many in high abundance, ecosystem diversity is considered optimal. Pachaug Pond exhibits this characteristic; however, areas of abundant vegetation can be a nuisance if in a place where recreation is inhibited. Management options for these areas will be discussed later in this report.

Water Chemistry

Pachaug Pond had water clarity as measured with a Secchi disk (Figure 12, top left) of 2.2 m (7 feet) in our 2017 survey. Measurements 1979 found clarity to be 3.5 m (12 feet)(Frink and Norvell, 1984) while in the 1950's it was only 0.6 m (2 feet)(State Board of Fisheries and Game, 1959). The poor water clarity in the 1950's was attributed to an algal bloom. This could have been due to the reported industrial use of the water but these historical uses are beyond the scope of this report. Our 2017 observation was that water clarity was most limited by its brown coloration from naturally occurring organic derivatives (Figure 12, top right). Water clarities in Connecticut's lakes ranged from 0.3 - 10 m (1-33 feet) with an average of 2.3 m (7 feet) (CAES IAPP, 2017). Thus, the current water clarity of Pachaug Pond is near average.

The shallow nature of Pachaug pond resulted in little stratification during our late summer measurements (Figure 13). Thus only minor changes in the tested water parameters occurred with depth. Dissolved oxygen concentrations were high throughout the water column and the pH was near neutral. The ponds alkalinity of near 13 mg/L $CaCO_3$ was low for Connecticut lakes which range from near 0 to >170 (CAES IAPP, 2017). Low alkalinity waterbodies are more prone to pH change due to outside influences such as watershed activities and acid rain. Conductivity is an indicator of dissolved ions that come from natural and man-made sources (mineral weathering, organic matter decomposition, fertilizers, septic systems, road salts, etc.). Connecticut waterbodies have conductivities that range from 50 -250 µS/cm. Pachaug Pond's conductivity of near 63 µS/cm ranks it among the lowest.

A key parameter used to categorize a lake's trophic state is the concentration of phosphorus (P) in the water column. High levels of P can lead to nuisance or toxic algal blooms (Frink and Norvell 1984, Wetzel 2001). Rooted macrophytes are considered to be less dependent on P from the water column as they obtain a majority of their nutrients from the hydrosoil (Bristow and Whitcombe, 1971). Lakes with P levels from 0 - 10 µg/L are considered nutrient-poor or oligotrophic. When P concentrations reach 15 - 25 µg/L, lakes are classified as moderately fertile or mesotrophic and when

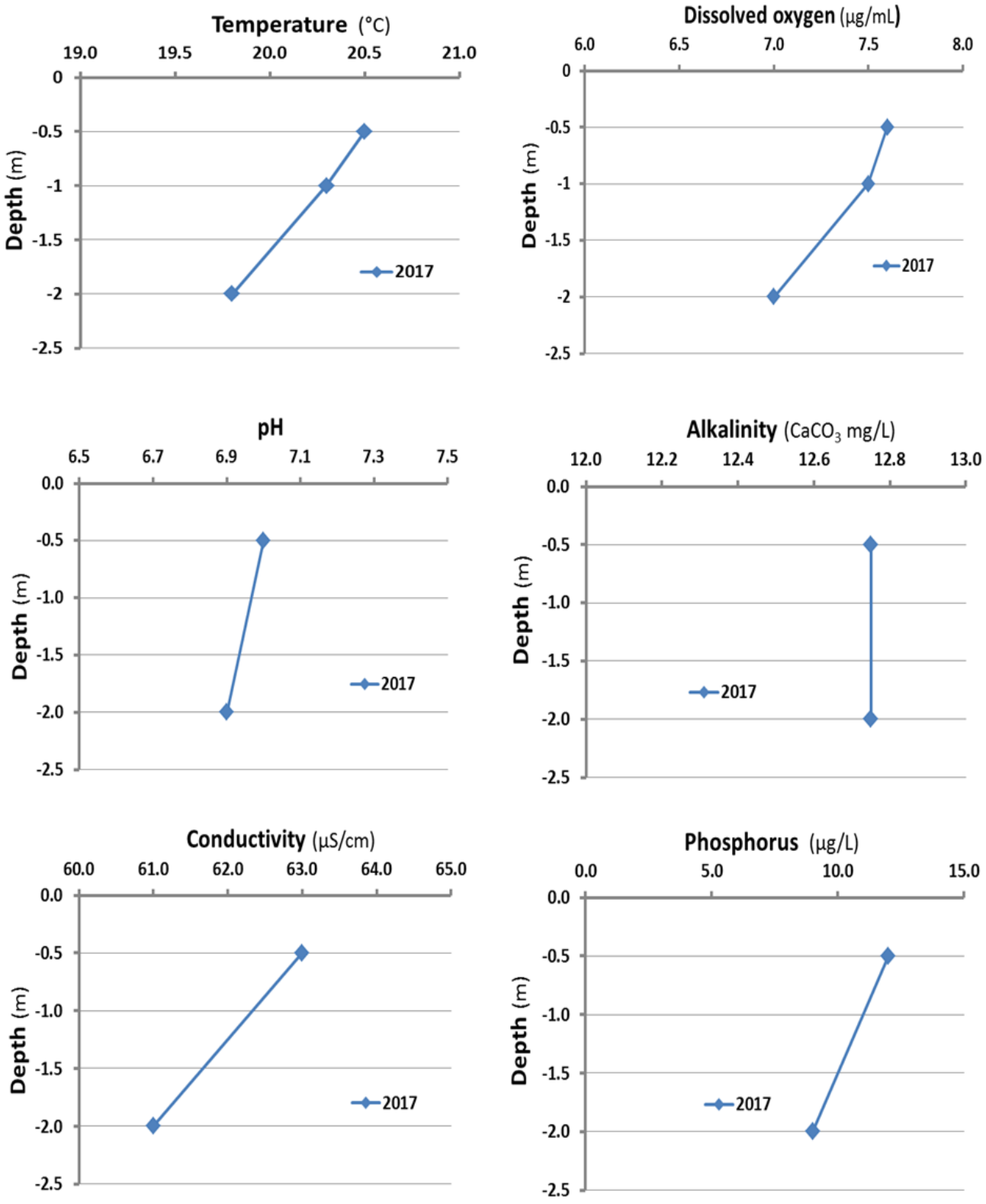

Figure 13. Water chemistry in Pachaug Pond in 2017.

Table 2. Water chemistry preferences of invasive plants in Connecticut lakes (June-Wells et al. 2013).

Group	Species	Alkalinity mg/L $CaCO_3$	Conductivity µS/cm	pH	Phosphorus µg/L
1	Fanwort Variable watermilfoil	0 - 28	39 - 107	5.6 - 7.0	1 - 27
2	Curlyleaf pondweed Euarasian watermilfoil Minor naiad	17 - 77	108 - 232	6.3 - 8.1	0 - 85

P reaches 30 - 50 µg/L they are considered fertile or eutrophic (Frink and Norvell, 1984). Lakes with P concentrations >50 µg/L are categorized as extremely fertile or hyper eutrophic. Pachaug Pond's P concentration was 13 µg/L at surface and 9 µg/L near the bottom which classifies the lake as oligo-mesotrophic conditions. Some of the P may have been depleted from the water column during the summer by actively growing plants. Analysis of the water in by CAES 1979 (Frink and Norvell, 1984) found similar P concentrations of 16 µg/L at surface and 13 µg/L near the bottom.

CAES IAPP has found that the occurrence of invasive plants in lakes can be attributed to specific water chemistries (June-Wells et al. 2013). For instance, lakes with higher alkalinities and conductivities are more likely to support Eurasian watermilfoil, minor naiad and curlyleaf pondweed while lakes with lower values support fanwort (*Cabomba caroliniana*) and variable watermilfoil (*Myriophyllum heterophyllum*) (Table 2). Invasive zebra mussels (*Dreissena polymorpha*), are becoming a problem in several lakes in in western Connecticut and have similar preferences.

Aquatic vegetation management options:

Managing nuisance aquatic vegetation in Pachaug Pond will be challenging because the lake has extensive areas of desirable native vegetation and state listed species may need protection. In addition, large numbers of residents utilize the lake for recreational activities, particularly fishing, boating and swimming. Options include: harvesting, herbicides, biological controls, bottom barriers and wa-

ter level drawdown (Cooke et al., 2005). Dredging may also be employed but is usually impractical for large lakes like Pachaug.

Mechanical or suction harvesting has the benefit of providing immediate control but problems include rapid regrowth, finding suitable disposal sites and spreading of weeds by fragmentation. Weeds like milfoil (Madsen, et al, 1988) and fanwort spread by the rooting of broken pieces. Harvesting practices can distribute the weed throughout a lake. These weeds also have strong root systems that will cause regrowth. Usually, harvesting has to be done every year. Some lakes have purchased mechanical harvesters. Suction harvesting is better for small areas but costs for divers and equipment can be expensive.

Herbicides can be effective in controlling unwanted aquatic vegetation. Aquatic herbicide use requires permits from the Connecticut Department of Energy and Environmental Protection (CTDEEP). The fee for a permit is currently $200. Some of the most widely used aquatic herbicides in Connecticut are fluridone (Sonar™, Avast™), diquat (Reward™), 2,4-D (Navigate™, AquaKlean™) and glyphosate (Rodeo™). In recent years, several new products have emerged such as Flumioxazin (Clipper™), imazamox (Clearcast™) and triclopyr (Renovate™). Fluridone, 2,4-D, glyphosate, imazamox and triclopyr are translocated throughout the entire plant, causing dieback of the roots and shoots. Diquat, and flumioxazin destroys only foliage, and regrowth from the roots is likely. Fluridone and flumioxazin are the only herbicides that are currently considered effective against fanwort. Because whole lake herbicide treatments would cause damage to non-target organisms and be cost prohibitive, spot treatments would be needed. Fluridone requires many weeks of contact time and therefore a granular formulation would likely be needed. Glyphosate is sprayed directly on plants and is effective only on weeds like water lily and water shield that have large areas of foliage above the surface Pachaug Pond is inhabited by state listed species (Figure 1) and this could affect the use of aquatic herbicides. Aquatic herbicides can be expensive and often have associated water use restrictions (Table 4). Annual treatments are common. Specifics on the use of aquatic herbicides in Connecticut are found in the CTDEEP (2005) publication entitled “Nuisance Aquatic Vegetation Management: A Guidebook” (CTDEP, 2005).

Figure 14. Benthic barrier being installed in Lake Quonnipaug, Guilford, Connecticut.

Although efforts are underway to find biological controls for nuisance aquatic vegetation, breakthroughs have been limited. Plant eating fish, called grass carp (*Ctenopharyngodon idella*), can effectively reduce the populations of certain aquatic weeds. Often it is an "all or nothing" procedure where too few are introduced to have much of an effect or too many are introduced and both nuisance and desirable vegetation is eliminated. The introduction of grass carp into Connecticut lakes requires approval by the CTDEEP. Often these fish are considered inappropriate because their feeding is not selective and desirable plants can be eliminated. In Connecticut, only sterile grass carp (triploid) are permitted. They are usually 10-12 inches in length when introduced (Figure 12, left) and can grow to over 30 inches. Typically 10-20 fish per vegetated acre are used at a cost of $10-$15 per fish. All lake inlets and outlets must be screened to prevent movement of the fish (Figure 12, middle). These screens must be CTDEEP approved and cannot interfere with the flow of water or the integrity of the dam. The screen must be kept free of debris to prevent flooding. Written approval by lakefront landowners may be necessary. Introducing grass carp in Pachaug Pond could cause damage to non-target plants necessary to maintain the current fishery. CAES has worked with officials from the United Sates Department of Agriculture to find new plant pathogens and insects that control nuisance aquatic plants with little success.

Benthic barriers or "bottom blankets" are effective at eliminating nuisance vegetation in small areas such as swim zones and around docks. CAES IAPP tested installing the barriers in late April and

Figure 15. Winter drawdown in Candlewood Lake, Connecticut.

removing them after 30 days at the Lake Quonnipaug town beach (Figure 14). Season long control for Eurasian watermilfoil and fanwort was achieved. Thus, although labor intensive, benthic barriers may be able to be moved from place to place during a season.

Water level drawdown can be an effective and economical means of controlling nuisance vegetation in large shallow lakes like Pachaug Pond. Fortunately the lake has a dam with an outlet suitable for the technique and in fact it has been employed with possibly some success. If weeds are allowed to freeze or dry, but this has an adverse effect on non-target aquatic organisms. Winter drawdown is preferable because of its lessened impact on ecosystems and recreation. Some weeds, like water milfoil, have root systems and other plant parts that can survive substantial drying (Standifer and Madsen, 1997) and temperatures near freezing. CAES has been monitoring the yearly drawdowns in Candlewood Lake and has observed rapid regrowth of vegetation in drawn down areas (Figure 15). Thus the practice usually needs to be done regularly. This has a benefit of allowing lake management to optimize the aquatic plant community if regular surveys are employed to document changes.

Conclusions

The shallow nature and fertile sediment of Pachaug Pond makes it prime habitat for aquatic vegetation. Thirty-four plant species were present in the lake in 2017 with five being invasive. Although the invasive species covered large areas of the pond, areas covered by native species or where the invasive and native species cohabitated were greater. Many of the shallow coves contained nuisance vegetation such as fanwort and water smartweed that reached the surface (Figure 5). Most of the lake, however, did not have problematic vegetation reaching the surface even though it was shallow enough to support it. In these areas the bottom was often covered with non-nuisance eel grass and Robbin's pondweed. Reasons for this may include brown coloration to the water that limits light, infertile substrate and previous drawdowns. Our water tests found Pachaug Pond to be relatively low in alkalinity and phosphorus. Water clarity was limited by the waters brown coloration. Many aquatic plant management options are available, including harvesting, herbicides, biological controls, bottom barriers and water level drawdown. Usually a combination of these options, in conjunction with regular vegetation monitoring, provides the best results.

Acknowledgments

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Appendix

Narrative from State Board of Fisheries and Game Lake and Pond Survey Unit – 1959

Pachaug Pond

Pachaug Pond is a large, artificial impoundment located in New London County in the township of Griswold. This shallow, fertile pond was formed by impounding the Pachaug River. It has a surface area of 830.9 acres, a maximum depth of 18 feet and an average depth of 6.1 feet. Much of the well-wooded shoreline is in the Pachaug State Forest. Submerged and emergent vegetation is abundant, particularly in the shoal areas and shallow areas. The pond bottom is of mud, swampy ooze and sand. A dense algal bloom reduces transparency to two feet. The waters of this pond are not thermally stratified.

Shoreline development is very light and there are only a few cottages present. Boats are available for rental at a livery at the southern end of the pond. There is a state-owned right-of-way present, but this is poorly developed and is unuseable.

Pachaug Pond has been stocked with smallmouth bass and yellow perch.

Largemouth bass are common in abundance and exhibit excellent growth. Yellow perch are common in abundance. This species grows at a rate equal to the state average. Bluegill sunfish are abundant and grow at a rate well above the state average. Chain pickerel are scarce and exhibit an above-average growth rate. Calico bass are common in abundance. The growth rate of this species is equal to the state average. Bullheads are common in abundance and golden shiners are abundant.

This pond has the reputation of producing excellent bass fishing. Bass over five pounds are relatively common. Fishing for panfish such as perch, bluegill sunfish, calico bass and bullheads should be excellent.

In the past, this body of water was subject to severe drawdown during late June, July and August. This drawdown took place after the game species had reproduced and did not destroy their nests or young. As a result of the drawdown, the game fish and panfish were crowded into a smaller area and the panfish were more readily available to the game fish as forage. The resultant increase in predation aided in controlling the numbers of panfish and helped to keep these fish within the limits of the food supply and, at the same time, helped to provide numerous fast-growing game fish. The drawdown process also helped to control aquatic vegetation and this resulted in considerable open water relatively free from water weeds. For the past several years, the water has not been used for industrial purposes and, as a result, the water level has remained fairly stable. Aquatic vegetation is becoming more abundant and the amount of open water more restricted. This increase in the abundance of "water weeds" may provide excessive escape cover for panfish and can well result in stunted populations of yellow perch and bluegill sunfish.

The drawdown and exposure of considerable areas of the pond bottom also allowed smartweed and other semi-terrestrial plants to grow on the exposed shoals. These terrestrial plants furnished excellent food for waterfowl and attracted large numbers of ducks during the fall shooting season.

It is recommended that a control structure be installed in the dam so that the pond can be lowered three to four feet every summer. Such a drawdown should be started in June and the reduced water level should be held until the end of August.

No special regulations are recommended at this time.

Invasive Plant Descriptions

Cabomba caroliniana


Photo by CAES IAPP

Common names:
Fanwort
Carolina fanwort

Origin:
Southeast United States
South America

Key features:
Plants are submersed

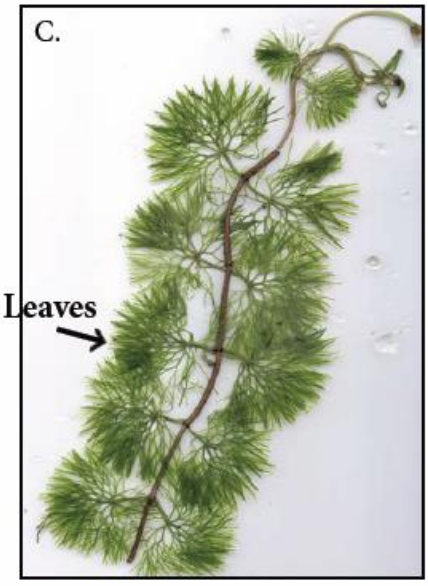
Stems: Can be 6 feet (2 m) long

Leaves: Dissected, opposite leaves 0.8-2 inches (2-5 cm) are fan-like and made up of forked leaflets attached to the stem by a petiole. Floating leaves 0.2-0.8 inches (6-20 mm) wide are oblong and produced on flower shoots

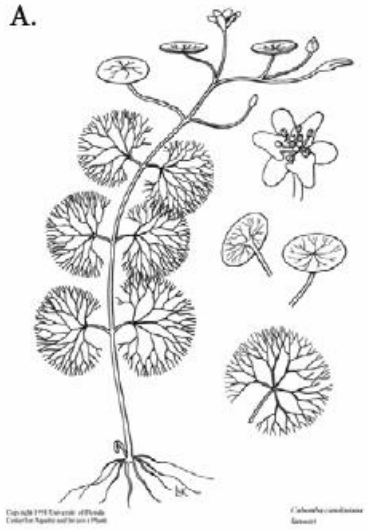
Flowers: Small, solitary flowers are usually white to pinkish

Fruits/Seeds: Flask shaped

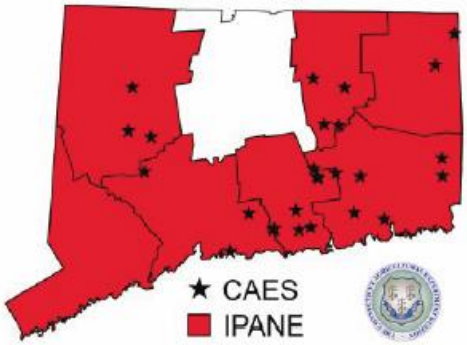
Reproduction: Seed and fragmentation



Easily confused species:
Watermilfoils: *Myriophyllum* spp.
White water crowfoot: *Ranunculus longirostris*
Water marigold: *Megalodonta beckii*



A. Copyright 1991 Univ. of Florida, Center for Aquatic and Invasive Plants
B. Copyright 2002 Univ. of Florida, Photo by A. Murray
C. Photo by A. Smagula



Myriophyllum heterophyllum

Common names:
Variable-leaf watermilfoil
Variable watermilfoil
Two-leaf watermilfoil

Origin:
Southern United States

Key features:
Plants are submersed

Stems: Dark brown stems extend to the water's surface and spread to form large mats

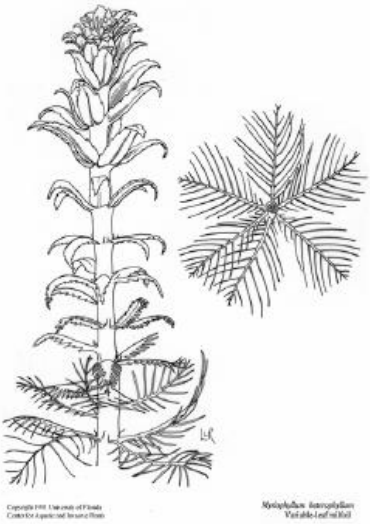
Leaves: Triangular with ≤ 11 pairs of leaflets. Leaves are dissected and whorled (4-6 leaves/whorl) resulting in a feathery appearance with leaf whorls < 1 inch apart giving it a ropy appearance

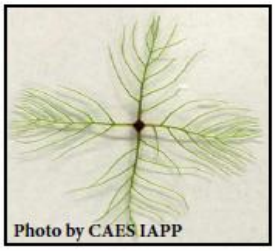
Flowers: Inflorescence spike 2-14 inches (5-35 cm) long extend beyond the water's surface with flowers in whorls of four with reddish petals

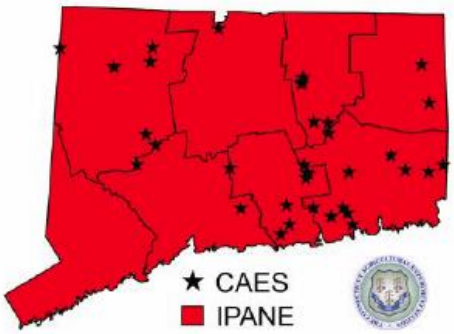
Fruits/Seeds: Fruits are almost round, with a rough surface

Reproduction: Fragmentation and seeds

Easily confused species:
Eurasian watermilfoil: *Myriophyllum spicatum*
Low watermilfoil: *Myriophyllum humile*







Myriophyllum spicatum

Common name:
Eurasian watermilfoil

Origin:
Europe and Asia

Key features:
Plants are submersed

Stems: Stem diameter below the inflorescence is greater with reddish stem tips

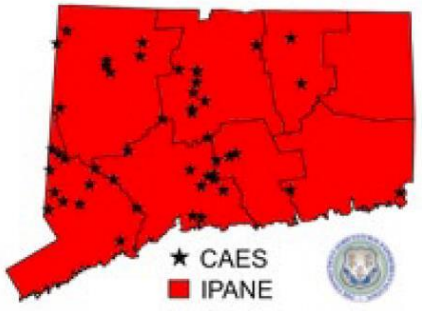
Leaves: Leaves are rectangular with ≥ 12 pairs of leaflets per leaf and are dissected giving a feathery appearance, arranged in a whorl, whorls are 1 inch (2.5 cm) apart

Flowers: Small pinkish male flowers that occur on reddish spikes, female flowers lack petals and sepals and have 4 lobed pistil

Fruits/Seeds: Fruit are round 0.08-0.12 inches (2-3 mm) and contain 4 seeds

Reproduction: Fragmentation and seeds

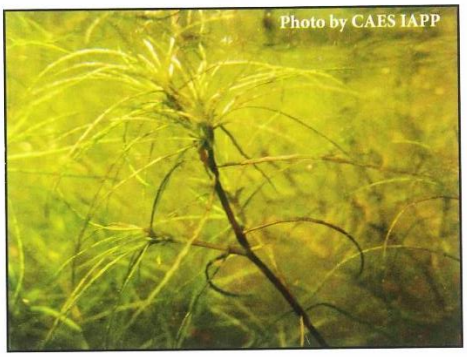
Easily confused species:
Variable-leaf watermilfoil: *Myriophyllum heterophyllum*
Low watermilfoil: *Myriophyllum humile*
Northern watermilfoil: *Myriophyllum sibiricum*
Whorled watermilfoil: *Myriophyllum verticillatum*



Najas minor

Common names:
Minor naiad
Brittle waternymph
Spiny leaf naiad
Eutrophic waternymph

Origin:
Europe



Key features:
Plants are submersed

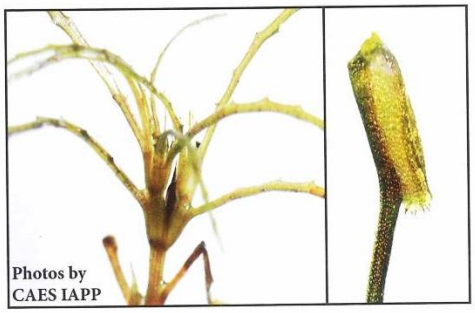
Stems: Branched stems can grow up to 4-8 inches (10-20 cm) long

Leaves: Opposite and lance shaped on branched stems with easily visible toothed leaf edges and leaves appear curled under, basal lobes of leaf are also serrated, 0.01-0.02 inches (0.3-0.5 mm)

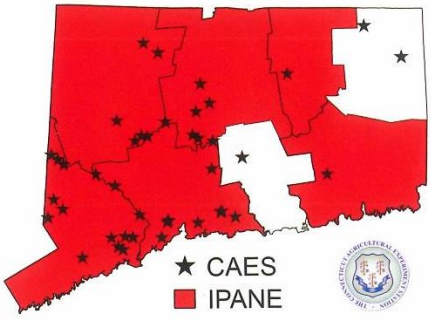
Flowers: Monoecious (male and female flowers on same plant)

Fruits/Seeds: Fruits are purple-tinged and seeds measure 0.03-0.06 inches (1.5-3 mm)

Reproduction: Seeds and fragmentation



Easily confused species:
Other naiads (native): *Najas* spp.



Transect Data

Surveyor	Depth (m)	Substrate	Transect	Points	Distance from shore (m)	Notes	*Brasenia schreberi*	*Cabomba caroliniana*	*Ceratophyllum demersum*	*Eleocharis* species	*Glossostigma cleistanthum*	*Gratiola aurea*	*Ludwigia palustris*	*Myriophyllum heterophyllum*	*Myriophyllum humile*	*Myriophyllum spicatum*	*Najas flexilis*	*Najas minor*	*Nuphar variegata*	*Nymphaea odorata*	*Polygonum amphibium*	*Pontederia cordata*	*Potamogeton amplifolius*	*Potamogeton bicupulatus*	*Potamogeton epihydrus*	*Potamogeton foliosus*	*Potamogeton natans*	*Potamogeton perfoliatus*	*Potamogeton robbinsii*	*Sagittaria* species	*Sparganium* species	*Utricularia gibba*	*Utricularia macrorhiza*	*Utricularia purpurea*	*Utricularia radiata*	*Vallisneria americana*	*Wolffia* species	Date	Latitude	Longitude
Bugbee	0.2	Gravel	1	1	0.5																	2																9/7/2017	41.54866	-71.90053
Bugbee	0.9	Muck	1	2	5.0		2	3	2													2							2				2			2		9/7/2017	41.54869	-71.90051
Bugbee	1.2	Muck	1	3	10.0			3	2													2							2				2	2		2		9/7/2017	41.54875	-71.90051
Bugbee	1.4	Muck	1	4	20.0		2	2								2				1															2		9/7/2017	41.54884	-71.90043
Bugbee	1.6	Muck	1	5	30.0			2								2									2							2			2	2		9/7/2017	41.54889	-71.90037
Bugbee	1.8	Muck	1	6	40.0			2								2			2										2		2		2		2	2		9/7/2017	41.54903	-71.90036
Bugbee	1.9	Muck	1	7	50.0			2						2					2										2		2				2	2		9/7/2017	41.54907	-71.90028
Bugbee	1.6	Muck	1	8	60.0			2								2													2						2			9/7/2017	41.54915	-71.90028
Bugbee	1.6	Muck	1	9	70.0			2						2											2				2						3			9/7/2017	41.54925	-71.90022
Bugbee	2.0	Muck	1	10	80.0			2																	2				2						2			9/7/2017	41.54939	-71.90016
Bugbee	0.2	Sand	2	1	0.5	Fontanella sp.																																	9/7/2017	41.55317	-71.90136
Bugbee	1.0	Sand	2	2	5.0																	2														3			9/7/2017	41.55317	-71.90131
Bugbee	1.2	Sand	2	3	10.0	many zebra mussels																														2			9/7/2017	41.55320	-71.90124
Bugbee	2.0	Sand	2	4	20.0											2																				2			9/7/2017	41.55325	-71.90114
Bugbee	2.2	Muck	2	5	30.0																															2			9/7/2017	41.55332	-71.90102
Bugbee	2.3	Muck	2	6	40.0																														2	2			9/7/2017	41.55328	-71.90093
Bugbee	2.3	Muck	2	7	50.0	Charaphyte																																	9/7/2017	41.55333	-71.90080
Bugbee	2.5	Muck	2	8	60.0	nothing																																	9/7/2017	41.55335	-71.90065
Bugbee	2.6	Muck	2	9	70.0	nothing																																	9/7/2017	41.55332	-71.90052
Bugbee	2.7	Muck	2	10	80.0	nothing																																	9/7/2017	41.55336	-71.90040
Bugbee	0.3	Gravel	3	1	0.5		2					1			2	2								2		2			1	2					2			9/7/2017	41.55905	-71.90693
Bugbee	1.0	Gravel	3	2	5.0			2	2					1					1	2																		9/7/2017	41.55908	-71.90693
Bugbee	1.0	Gravel	3	3	10.0		2	2						2		2			2	2			2	2	2		2		2										9/7/2017	41.55911	-71.90693
Bugbee	1.5	Muck	3	4	20.0		2	3	3					2		2			2	3							2		2				3			2		9/7/2017	41.55920	-71.90699
Bugbee	1.0	Muck	3	5	30.0	fil. algae mat		3	3					2							3		2						2						2		2	9/7/2017	41.55927	-71.90712
Bugbee	1.2	Muck	3	6	40.0	fil. algae mat		3	3											2	3		2						3						2			9/7/2017	41.55932	-71.90716
Bugbee	1.4	Muck	3	7	50.0			2	3											4	3				2				2									9/7/2017	41.55941	-71.90722
Bugbee	1.2	Muck	3	8	60.0			2	3											4	2																	9/7/2017	41.55946	-71.90725
Bugbee	1.0	Muck	3	9	70.0		3	2												3					2		2				2		3			2		9/7/2017	41.55957	-71.90735
Bugbee	0.2	Muck	3	10	80.0		2	2												3		2			2					2	2		2					9/7/2017	41.55969	-71.90733
Bugbee	0.2	Sand	4	1	0.5	nothing																																	9/8/2017	41.57234	-71.92113
Bugbee	0.4	Sand	4	2	5.0						2							1										2								3		9/8/2017	41.57235	-71.92107
Bugbee	0.6	Sand	4	3	10.0																				3											3		9/8/2017	41.57232	-71.92103
Bugbee	0.6	Sand	4	4	20.0																				2											3		9/8/2017	41.57243	-71.92091
Bugbee	0.6	Sand	4	5	30.0	Charaphyte																			2											3		9/8/2017	41.57230	-71.92079
Bugbee	0.6	Sand	4	6	40.0	Charaphyte																			2													9/8/2017	41.57230	-71.92065
Bugbee	3.0	Sand	4	7	50.0	nothing																																	9/8/2017	41.57232	-71.92054
Bugbee	4.0	Sand	4	8	60.0	nothing																																	9/8/2017	41.57235	-71.92042
Bugbee	4.0	Sand	4	9	70.0	nothing																																	9/8/2017	41.57235	-71.92027
Bugbee	4.0	Sand	4	10	80.0	nothing																																	9/8/2017	41.57238	-71.92014
Bugbee	0.2	Gravel	5	1	0.5		2			2												3			3					2								9/8/2017	41.57790	-71.91824
Bugbee	1.0	Organic	5	2	5.0			3								2				1		1																9/8/2017	41.57785	-71.91829
Bugbee	1.4	Organic	5	3	10.0		2	3								2				3					2										3	2		9/8/2017	41.57783	-71.91835
Bugbee	1.4	Organic	5	4	20.0			2												3															2	3		9/8/2017	41.57776	-71.91844
Bugbee	1.4	Organic	5	5	30.0		2	2																					2				2		2	4		9/8/2017	41.57774	-71.91858

Surveyor	Depth (m)	Substrate	Transect	Points	Distance from shore (m)	Notes	*Brasenia schreberi*	*Cabomba caroliniana*	*Ceratophyllum demersum*	*Eleocharis* species	*Glossostigma diandrum*	*Gratiola aurea*	*Ludwigia palustris*	*Myriophyllum heterophyllum*	*Myriophyllum humile*	*Myriophyllum spicatum*	*Najas flexilis*	*Najas minor*	*Nuphar variegata*	*Nymphaea odorata*	*Polygonum amphibium*	*Pontederia cordata*	*Potamogeton amplifolius*	*Potamogeton bicupulatus*	*Potamogeton epihydrus*	*Potamogeton foliosus*	*Potamogeton natans*	*Potamogeton perfoliatus*	*Potamogeton robbinsii*	*Sagittaria* species	*Sparganium* species	*Utricularia gibba*	*Utricularia macrorhiza*	*Utricularia purpurea*	*Utricularia radiata*	*Vallisneria americana*	*Wolffia* species	Date	Latitude	Longitude
Bugbee	1.4	Organic	5	6	40.0			2																										2	4		9/8/2017	41.57773	-71.91871
Bugbee	1.4	Organic	5	7	50.0	Charaphyte		2										2											2						2	4		9/8/2017	41.57771	-71.91885
Bugbee	1.6	Organic	5	8	60.0	Charaphyte		2																					2						2	4		9/8/2017	41.57776	-71.91893
Bugbee	1.7	Organic	5	9	70.0	Charaphyte		2																											3	4		9/8/2017	41.57769	-71.91904
Bugbee	1.6	Sand	5	10	80.0	Charaphyte		2						2																					3	4		9/8/2017	41.57773	-71.91918
Bugbee	0.2	Muck	6	1	0.5		3								3					2				2	2					2	2		1		3			9/8/2017	41.57429	-71.91058
Bugbee	0.4	Muck	6	2	5.0		3	2							3									2	2										3			9/8/2017	41.57433	-71.91053
Bugbee	0.4	Muck	6	3	10.0		4								3				2					2	2										2	3		9/8/2017	41.57436	-71.91050
Bugbee	0.7	Muck	6	4	20.0		2								2				2					2	2										2	3		9/8/2017	41.57440	-71.91040
Bugbee	0.7	Muck	6	5	30.0		3									1			2					2	2										2	3		9/8/2017	41.57448	-71.91035
Bugbee	0.7	Muck	6	6	40.0										2		2		2											2					2			9/8/2017	41.57453	-71.91022
Bugbee	0.9	Muck	6	7	50.0		3								2	1	2		2			2													2	3		9/8/2017	41.57462	-71.91015
Bugbee	0.9	Muck	6	8	60.0		3								2	1	3																		2	3		9/8/2017	41.57467	-71.91005
Bugbee	1.0	Muck	6	9	70.0		3										3					2													2	3		9/8/2017	41.57475	-71.90997
Bugbee	1.2	Muck	6	10	80.0		3										2					2													2	3		9/8/2017	41.57480	-71.90987
Bugbee	0.2	Gravel	7	1	0.5																									3								9/8/2017	41.56803	-71.90048
Bugbee	0.7	Sand	7	2	5.0	Charaphyte		1	2								2																				3	9/8/2017	41.56801	-71.90043
Bugbee	0.8	Sand	7	3	10.0	Charaphyte		1									2								2										2	3		9/8/2017	41.56792	-71.90047
Bugbee	0.8	Sand	7	4	20.0	Charaphyte											2																		2	3		9/8/2017	41.56783	-71.90050
Bugbee	1.0	Sand	7	5	30.0	Charaphyte										2	2																			2		9/8/2017	41.56775	-71.90052
Bugbee	1.2	Sand	7	6	40.0	Charaphyte										2	2																			2		9/8/2017	41.56767	-71.90046
Bugbee	1.5	Sand	7	7	50.0	Charaphyte		2									2																			2		9/8/2017	41.56757	-71.90057
Bugbee	1.6	Sand	7	8	60.0	Charaphyte																						2	2						2	2		9/8/2017	41.56747	-71.90050
Bugbee	1.9	Sand	7	9	70.0	Charaphyte																													2	2		9/8/2017	41.56740	-71.90054
Bugbee	1.9	Sand	7	10	80.0	Charaphyte								2		2																			2	2		9/8/2017	41.56731	-71.90060
Bugbee	0.2	Sand	8	1	0.5		2	2		2		2				2						2								2	2				3			9/9/2017	41.55693	-71.89724
Bugbee	0.3	Sand	8	2	5.0		2	2		2		2	2											2	2					2					3	2		9/9/2017	41.55691	-71.89720
Bugbee	0.3	Sand	8	3	10.0		2	2		2		2	2											2	2					2					3	2		9/9/2017	41.55686	-71.89716
Bugbee	0.5	Muck	8	4	20.0		2	2		2						2				4				2	2					2		2			3	2		9/9/2017	41.55679	-71.89708
Bugbee	1.0	Muck	8	5	30.0			2												4															3			9/9/2017	41.55673	-71.89697
Bugbee	1.2	Muck	8	6	40.0			3																					2							2		9/9/2017	41.55665	-71.89686
Bugbee	1.5	Muck	8	7	50.0			3																					2							2		9/9/2017	41.55661	-71.89678
Bugbee	1.5	Muck	8	8	60.0			3																	2				2							2		9/9/2017	41.55655	-71.89669
Bugbee	1.5	Muck	8	9	70.0			3																	2				2						2	3		9/9/2017	41.55650	-71.89658
Bugbee	1.2	Muck	8	10	80.0			2								1									2										3	3		9/9/2017	41.55645	-71.89650
Bugbee	0.2	Bedrock	9	1	0.5	Fontanella sp.																																	9/9/2017	41.54939	-71.89513
Bugbee	1.6	Muck	9	2	5.0			3	2							2							2		2				3							3		9/9/2017	41.54946	-71.89517
Bugbee	1.8	Muck	9	3	10.0			3	2							2							2		2				4							2		9/9/2017	41.54948	-71.89519
Bugbee	1.8	Muck	9	4	20.0			3	2							2							2		2				4							2		9/9/2017	41.54956	-71.89526
Bugbee	1.8	Muck	9	6	40.0				3							2													4							2		9/9/2017	41.54972	-71.89540
Bugbee	1.8	Muck	9	5	30.0			3	2							2							2		2				4							2		9/9/2017	41.54964	-71.89532
Bugbee	1.8	Muck	9	7	50.0			3	2							2									2				4							2		9/9/2017	41.54982	-71.89542
Bugbee	1.8	Muck	9	8	60.0			3	2							2									2				4							2		9/9/2017	41.54988	-71.89548
Bugbee	1.8	Muck	9	9	70.0				2							2									2				4							2		9/9/2017	41.54997	-71.89554
Bugbee	1.8	Muck	9	10	80.0											2							2		2				4							2		9/9/2017	41.55005	-71.89563

Surveyor	Depth (m)	Substrate	Transect	Points	Distance from shore (m)	Notes	*Brasenia schreberi*	*Cabomba caroliniana*	*Ceratophyllum demersum*	*Eleocharis* species	*Glossostigma cleistanthum*	*Gratiola aurea*	*Ludwigia palustris*	*Myriophyllum heterophyllum*	*Myriophyllum humile*	*Myriophyllum spicatum*	*Najas flexilis*	*Najas minor*	*Nuphar variegata*	*Nymphaea odorata*	*Polygonum amphibium*	*Pontederia cordata*	*Potamogeton amplifolius*	*Potamogeton bicupulatus*	*Potamogeton epihydrus*	*Potamogeton foliosus*	*Potamogeton natans*	*Potamogeton perfoliatus*	*Potamogeton robbinsii*	*Sagittaria* species	*Sparganium* species	*Utricularia gibba*	*Utricularia macrorhiza*	*Utricularia purpurea*	*Utricularia radiata*	*Vallisneria americana*	*Wolffia* species	Date	Latitude	Longitude
Bugbee	0.2	Sand	10	1	0.5	Phr aus (abd = 2)	2	2		3		2								2		2								2				3			9/9/2017	41.56548	-71.91496
Bugbee	0.5	Sand	10	2	5.0		2			2										2														2	2		9/9/2017	41.56546	-71.91490
Bugbee	0.6	Sand	10	3	10.0		2			2						1									2									2	2		9/9/2017	41.56544	-71.91485
Bugbee	0.7	Sand	10	4	20.0		2												2						3					3				2	2		9/9/2017	41.56540	-71.91476
Bugbee	0.9	Sand	10	5	30.0		2											2	2											2				2	2		9/9/2017	41.56535	-71.91464
Bugbee	1.0	Sand	10	6	40.0		2											2	2											2				2	2		9/9/2017	41.56528	-71.91455
Bugbee	1.0	Sand	10	7	50.0		2									2				2			2						3		2				2	2		9/9/2017	41.56523	-71.91449
Bugbee	1.2	Muck	10	8	60.0		1									1													4						2	2		9/9/2017	41.56519	-71.91435
Bugbee	1.2	Muck	10	9	70.0																								4									9/9/2017	41.56516	-71.91422
Bugbee	1.3	Muck	10	10	80.0																								4									9/9/2017	41.56514	-71.91409