THE PLANT COMMUNITY OF WEBSTER LAKE IN 2012

PREPARED FOR THE WEBSTER LAKE ASSOCIATION

BY WATER RESOURCE SERVICES, INC.

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Background

Webster Lake, also known as Lake Chargoggagoggmanchaugagoggchaubunagungamaugg, is located just north of the Connecticut border in Webster, MA. It covers roughly 1270 acres in three main basins with a highly irregular shoreline and many coves (Figure 1). Maximum water depth is about 45 ft while average depth is about 13 feet. The north basin is the deepest, while the south basin is the shallowest. The Webster Lake Association has been active in monitoring and managing the lake since at least 2003, Water Resource Services, Inc. (WRS) issued a report on water quality and plant data from 2003 into 2011 in late 2011. One recommendation from that report was to conduct a more detailed plant survey as a decadal baseline for the lake, to both assess the success of past management efforts and to help plan for future efforts. This report provides that baseline assessment.

Figure 1. Webster Lake aerial view.

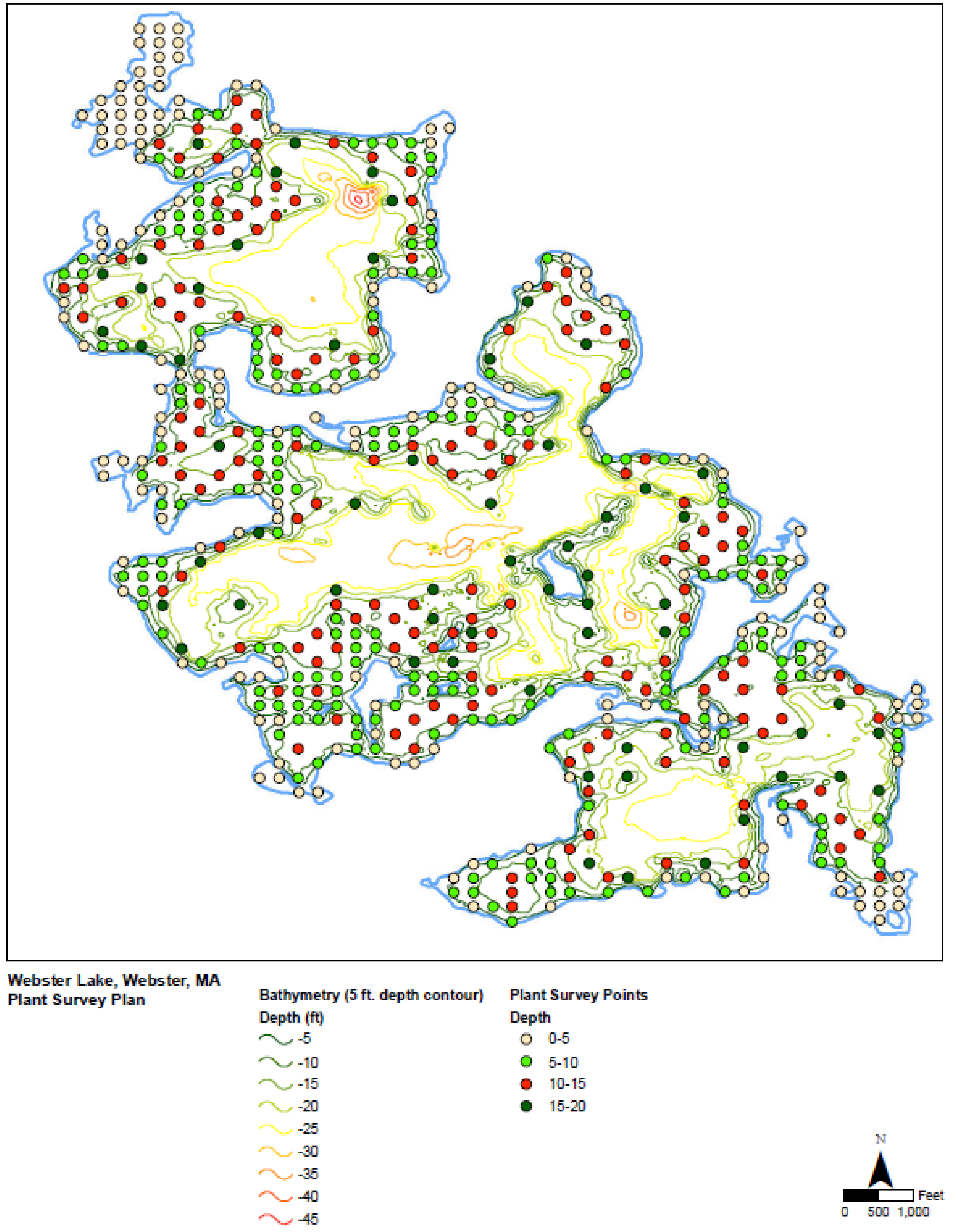
Methods

In order to adequately assess the plant community of such a large lake, we applied a grid system that allowed selection of intersections of the grid lines (nodes) to act as possible sampling points. Iterative applications and consideration of point density, differential water depth, historical knowledge of the plant community, and available funding resulted in the following approach.

1. Set up a GPS grid that provides about one “block” per acre. Establish possible sampling stations at each node.
2. Using a bathymetric map, denote which stations (nodes) are in water deeper than plants are known to occur. Confirm this in the field at the start of the survey.
3. For all accessible nodes at water depths <10 ft (365 points, see Figures 2-6), use an underwater viewing system to examine the plant community at each node. Follow steps 6 to 8 below for each of the accessible points.
4. For one half of the nodes in water 10-15 ft deep (1/2 of 319 points = 160 points), repeat the assessment process from #3 above and #6-8 below.
5. For one third of the nodes in water 15-20 ft deep (1/3 of 183 points = 61 points), repeat the assessment process from #3 above and #6-8 below.
6. At each node, record the water depth and visible sediment type (muck, sand, gravel, cobble, rock).
7. At each node, record the total cover (two dimensions) and biovolume (3 dimensions) by plants, using a scale of 0-4 (0 = no plants, 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%).
8. At each node, record the plant species present as trace, sparse, moderate or dense (trace=<1 specimen/m^2, sparse=1-3 specimens/m^2, moderate=4-10 specimens/m^2, dense=>10 specimens/m^2).
9. Once all data have been collected, analyze it spatially and in terms of relative abundance of plant species. Map the overall community density and distribution for each species by density classification. Calculate the frequency for each species. Focus on plants which are most abundant, particularly invasive species and native plants with nuisance potential.

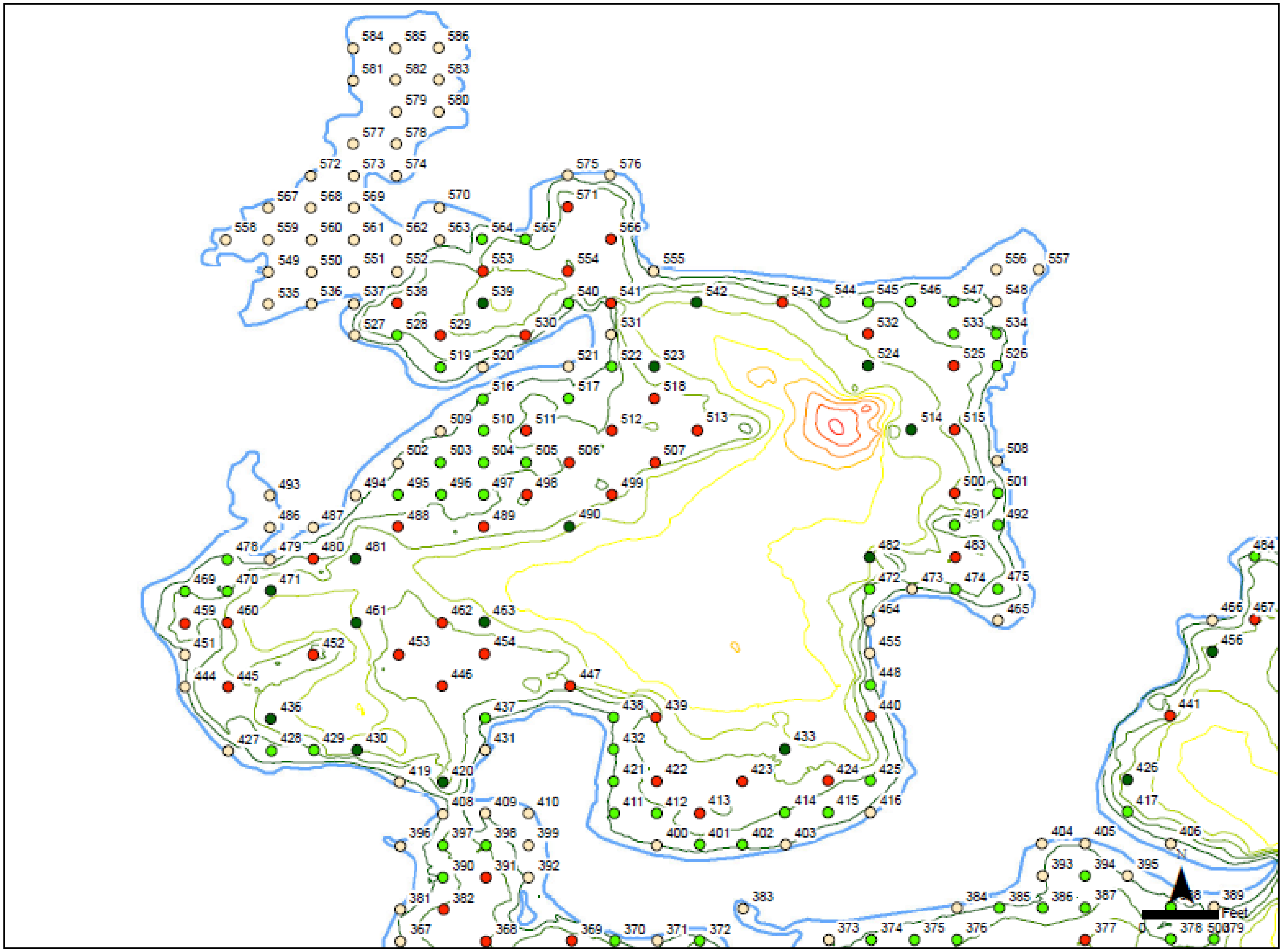
Survey work was conducted in late August and early September on four different good weather days. All but two selected points were assessed, leading to a total of 584 assessment locations, slightly more than expected. The assistance of the Webster Lake Association is acknowledged, especially aid from Al Huefner, who provided boat and equipment storage and useful insights. Collected data were organized in Excel spreadsheets and analyzed spatially with a geographic information system (GIS).

Figure 2. Webster Lake plant assessment points: whole lake without point labels.



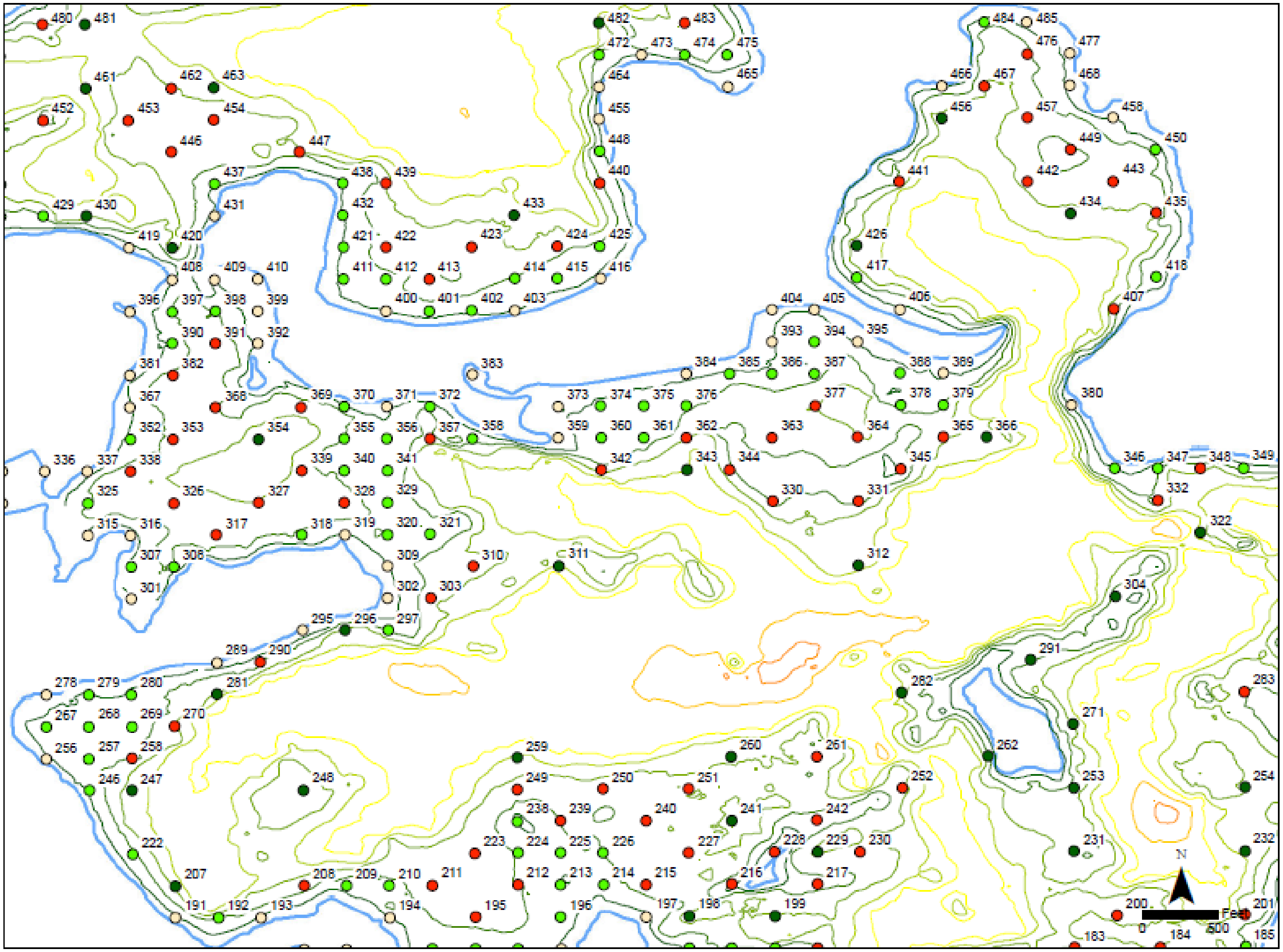
Bathymetry Information from CR Environmental Inc. Date: 7/12/2012 Name: WebsterLake_PlantSurvey Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 3. Webster Lake plant assessment points: North Basin.



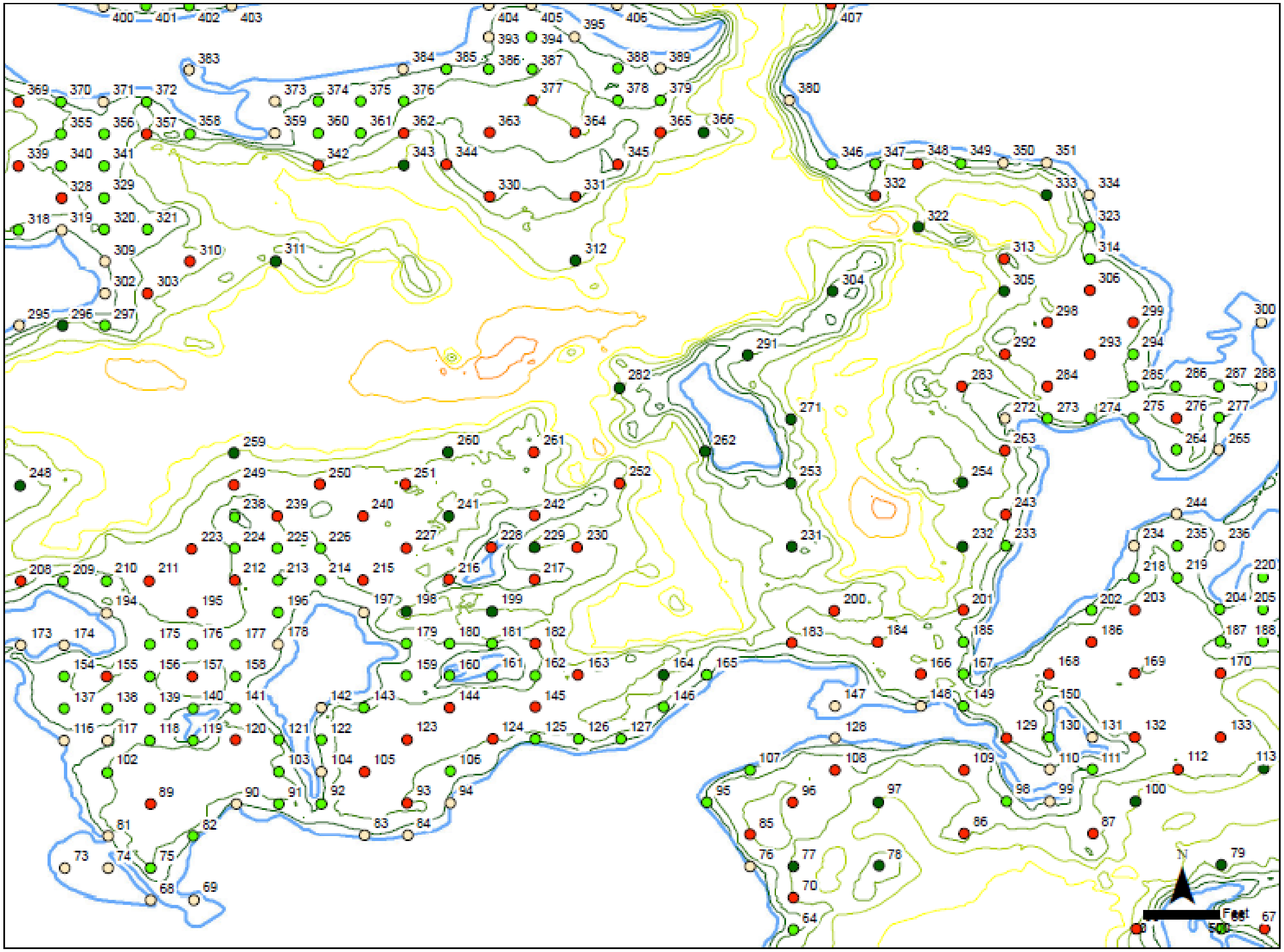
Bathymetry Information from CR Environmental Inc. Date: 7/12/2012 Name: WebsterLake_PlantSurvey Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 4. Webster Lake plant assessment points: Upper Middle Basin.



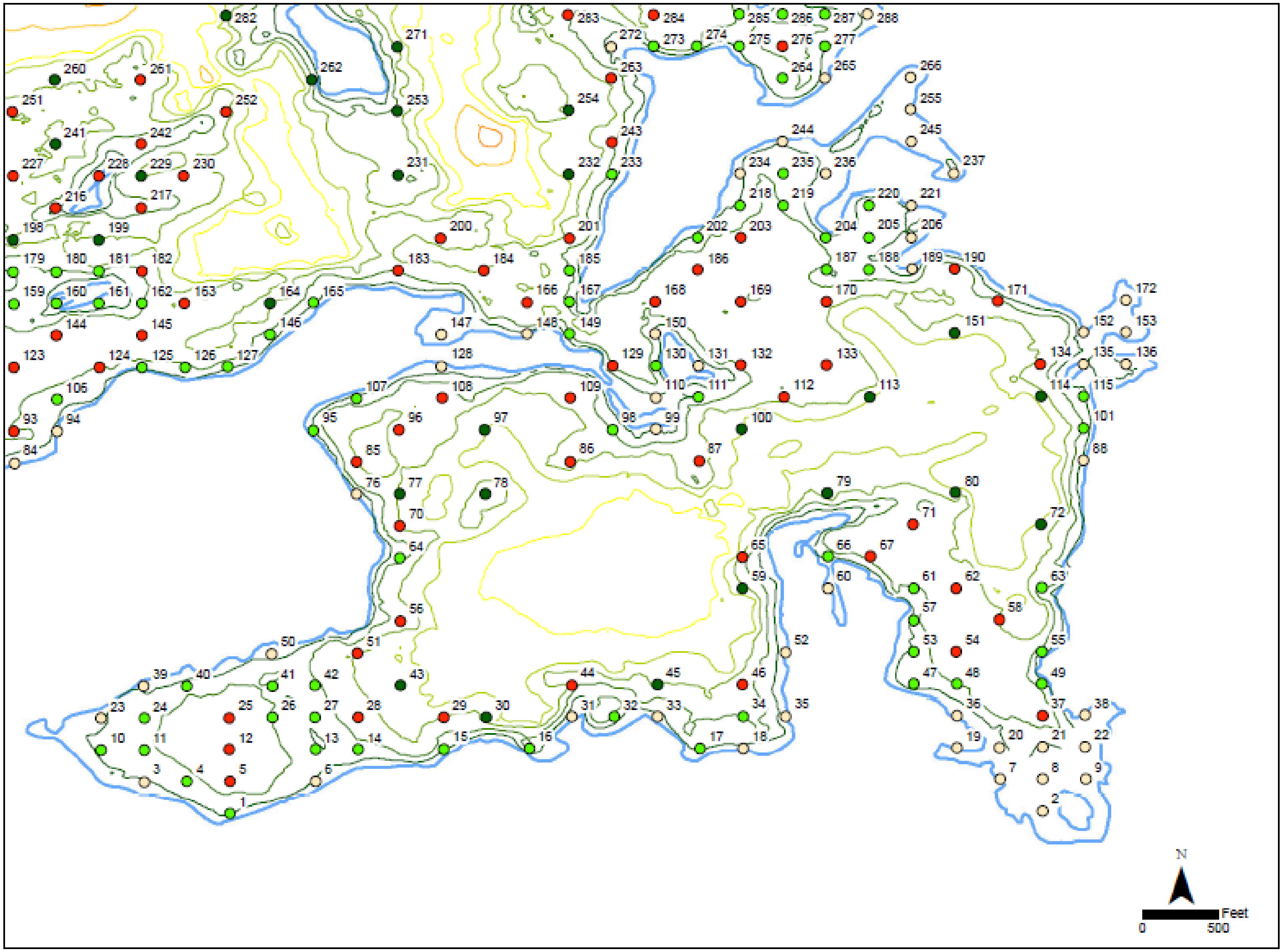
Bathymetry Information from CR Environmental Inc. Date: 7/12/2012 Name: WebsterLake_PlantSurvey Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 5. Webster Lake plant assessment points: Lower Middle Basin.



Bathymetry Information from CR Environmental Inc. Date: 7/12/2012 Name: WebsterLake_PlantSurvey Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 6. Webster Lake plant assessment points: South Basin.



Bathymetry Information from CR Environmental Inc. Date: 7/12/2012 Name: WebsterLake_PlantSurvey Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Aquatic Plants Taxonomic Composition: What Species are Present?

The plant survey of Webster Lake in 2012 yielded a total of 32 species (Table 1), although only 26 species were actually found during assessments at established points; the remaining 6 species were found during the course of examination of other areas, mainly as an initial survey to determine what plants might be found in Webster Lake. In comparison, the 2003 survey by GeoSyntec found 35 species, but stonewort and bladderwort species were lumped by genus, so only 32 taxa were reported. The overlap in species was not complete; a total of 44 species were found between the two surveys.

Only two species found in more than trace amounts in 2003 were not found in 2012: waterweed and Eurasian watermilfoil. It did seem odd that no waterweed was encountered in the 2012 survey, as this is a very common plant in many lakes, but it was not extremely common even in 2003. It is also unusual that Eurasian watermilfoil would be present and disappear; it was also not very abundant in 2003, but one would expect this species to expand. Taxa found in 2012 but not in 2003 included blue-green (cyanophyte) and filamentous green algae mats, which are not higher plants and may simply not have been recorded in the 2003 survey. Also present in 2012 but not in 2003 were several pondweed species and one bladderwort species, but both these genera are commonly represented by multiple species and identification is not always easy. The only apparently new addition of concern in 2012 is purple loosestrife, which is an invasive species, but was not common in 2012.

Noticeably absent from both surveys was coontail (*Ceratophyllum demersum*), a common native species. Also absent was curlyleaf pondweed (*Potamogeton crispus*), a common invasive species, but one that dies off in early summer and may not have been detected by later summer surveys. There are probably more pondweeds (*Potamogeton* spp.) and bladderworts (*Utricularia* spp.) than either survey reported, but we are comfortable that no abundant species have been missed or misidentified.

There were some differences in the dominance pattern between 2003 and 2012; the 2003 study reported eleven plant species that had a frequency of at least 20% and were dominant in multiple locations, although some were dominant in only a few locations. The 2003 survey lumped all bladderworts for the purpose of frequency and dominance, and at least two of those bladderwort species were common in 2012. Of the more abundant species from 2003, waterweed and Eurasian watermilfoil were not found in 2012, and bigleaf pondweed was not abundant in 2012. For some of the less abundant species, it is possible that they were missed in the 2012 survey, as use of the underwater video system does not provide specimens for careful identification, as does the rake toss method. Of greatest importance, however, was that the invasive fanwort was not considered common in 2003, yet was one of the three most abundant plant species in 2012. Water celery was not listed as a dominant plant in 2003, but was among the most common plants in 2012; this may have more to do with survey methods (water celery is much harder to collect with throw rakes) or an apparent focus of the 2003 survey on shallow areas (water celery achieved greatest abundant in water >10 ft deep). Also, purple loosestrife was not listed in 2003, but was found in 2012; it is a peripheral invasive species that is still not abundant and may have been present but not recorded in 2003.

Overall, most differences between the 2003 and 2012 plant surveys may be explained by differences in survey coverage of the lake and different methods of assessment, but several differences may be due to actual shifts in plant community features, most notably the increase in fanwort.

Table 1. Plant species found in Webster Lake.

X indicates presence at survey stations. P indicates presence in the lake, but not at surveyed points.

Scientific Name	Abbreviation	Common Name	WRS 2012	GeoSyntec 2003
Brasenia schreberi	B schreb	Watershield	X	X
Cabomba caroliniana	Cab car	Fanwort	X	X
Callitriche palustris	Cal pal	Water starwort		X
Chara sp.	Chara	Muskgrass		X
Chlorophyta mats	Fil green	Filamentous green algae	X	
Cyanophyta mats	BG	Filamentous blue-green algae	X	
Decodon verticillatus	Dec vert	Swamp loosestrife	X	X
Elatine minima	Ela min	Waterwort		X
Eleocharis acicularis	Eleo acic	Spikerush	X	X
Elodea nuttalii	El can	Waterweed		X
Eriocaulon septangulare	Erio aq	Pipewort	X	X
Gratiola neglecta	Grat neg	Hedge hyssop	X	
Isoetes sp.	Iso	Quillwort	P	X
Juncus sp.	Junc	Rush		X
Lemna minor	Lem min	Duckweed		X
Lythrum salicaria	Ly sal	Purple loosestrife	X	
Myriophyllum alterniflorum	My alt	Alternating watermilfoil		X
Myriophyllum heterophyllum	My het	Variable watermilfoil	X	X
Myriophyllum humile	My hum	Low watermilfoil		X
Myriophyllum spicatum	My spic	Eurasian watermilfoil		X
Naja flexilis	N flex	Common naiad	X	X
Nitella flexilis	Nitella	Nitella, stonewort	X	X
Nitella species 1	Nit sp1	Shallow water nitella, stonewort	X	X
Nuphar variegata	N var	Yellow water lily	X	X
Nymphaea odorata	N odor	White water lily	X	X
Nymphoides cordata	N cord	Little floating heart	P	X
Peltandra virginica	Pelt virg	Arrow arum	P	X
Pontederia cordata	Pont cord	Pickerelweed	X	X
Potamogeton amplifiolius	Pot ampli	Bigleaf pondweed	X	X
Potamogeton confervoides	Pot con	Algae-like pondweed		X
Potamogeton epihydrus	Pot epi	Bronze pondweed	X	
Potamogeton gramineus	Pot gram	Graminoid pondweed		X
Potamogeton natans	Pot nat	Floatingleaf pondweed	P	X
Potamogeton pusillus	Pot pus	Thinleaf pondweed	X	
Potamogeton robbinsii	Pot rob	Robbins pondweed	X	X
Potamogeton spirillus	Pot spir	Spiral seed pondweed	X	
Sagittaria graminea	Sag gram	Submerged arrowhead	X	
Sagittaria latifolia	Sag lat	Emergent arrowhead	P	X
Sparganium sp.	Sparg	Burreed	P	X
Utricularia gibba	Ut gib	Fine bladderwort	X	
Utricularia purpurea	Ut purp	Purple bladderwort	X	X
Utricularia radiata	Ut infl	Inflated bract bladderwort		X
Utricularia vulgaris	Ut vulg	Coarse bladderwort	X	X
Vallisneria americana	V am	Water celery	X	X
Total Species			32	35

Distribution of Aquatic Plants: What Species are Found Where?

The distribution of all species found at surveyed points in 2012 was mapped by individual species, and those maps will be provided electronically. However, as many species are present in only a few locations and their low abundance limits the value of any comparison over space or time, we will focus here on the most common plants observed (Figures 7-19). These maps are supported by the tabular data, provided as an electronic appendix.

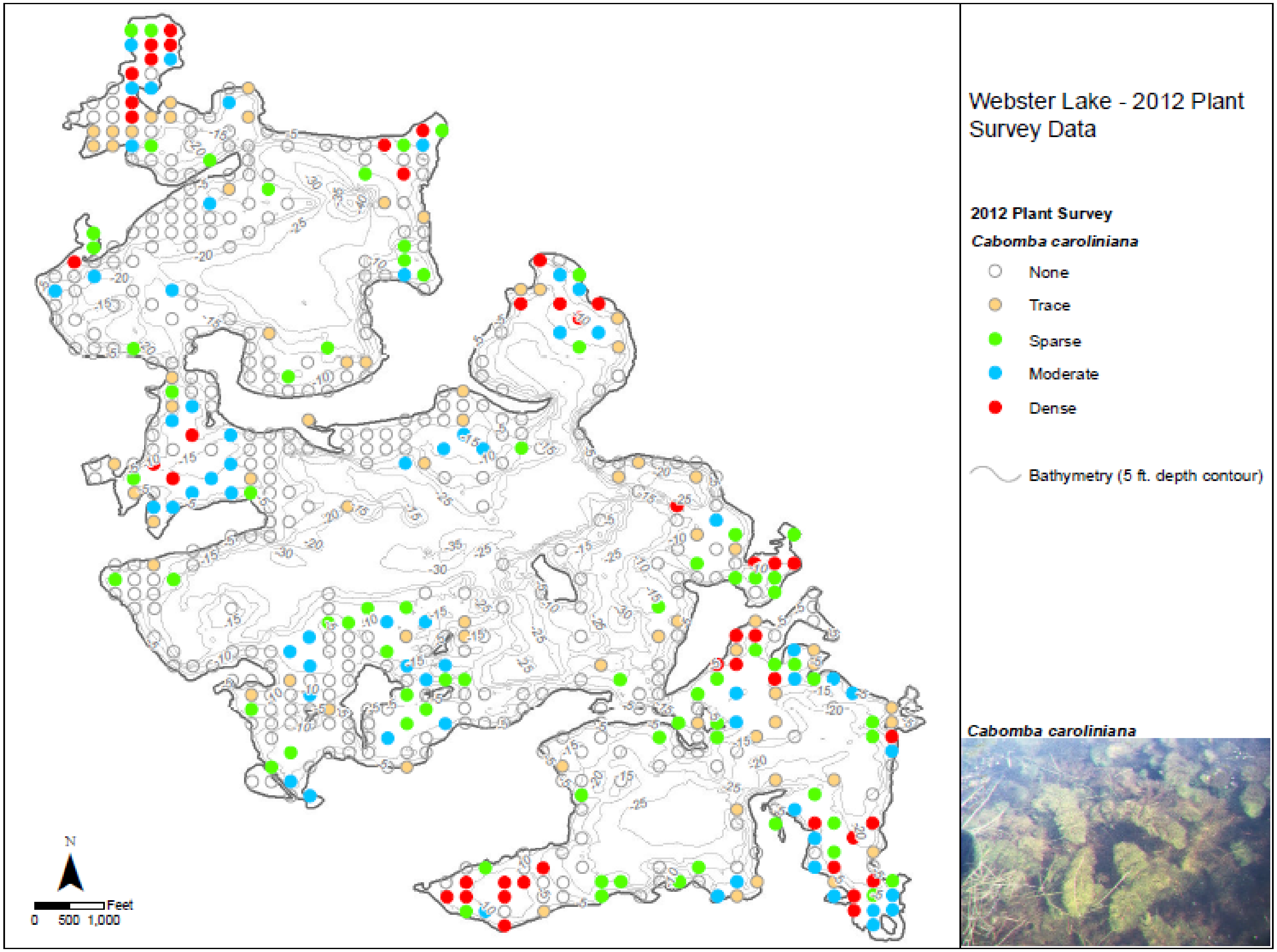
No plant species was found at even 50% of the 584 sites visited; the most commonly encountered species were fine bladderwort (46% of all sites), fanwort (42%) and water celery (42%), and of these species, only fanwort attains densities that would constitute a nuisance. Other potential nuisance species include the invasive variable watermilfoil, present at 29% of sites, filamentous green algae (30%), white water lily (14%), yellow water lily (8%), watershield (7%), and sometimes purple or coarse bladderwort (36 and 15% of all sites, respectively). However, only variable watermilfoil and the water lilies generate apparent nuisances in Webster Lake at this time.

It should be noted that the design of this survey favors shallower water, with one point per acre in water <10 ft deep, one point per two acres in water 10-15 ft deep, one point per three acres in water 15-20 ft deep, and no points in water >20 ft, although there are very few plants in such deep water. This means that the frequencies listed would actually be lower if the entire lake area was considered, and species that increase in abundance at water depths >10 ft are probably more frequent than suggested by these values. However, as most nuisance conditions occur in water <10 ft deep and most plant interactions with people occur in shallow water, this reporting format does provide a representative approach that is relevant to lake users and plant management.

The distribution of the more abundant species can be summarized largely as a function of water depth and substrate, two important plant ecology variables. The lateral distribution within each pond is also affected by wind and any treatment activities, but depth (which is partly a surrogate for light quantity and quality) and substrate (which affects anchoring and nutrient supply) are the master variables. Some species tolerate less light and the shift in dominant wavelength better than others. Most species are getting most nutrition through their roots, so some finer particles are necessary, but the ability to extract nutrients from available substrates varies and the ability to anchor in various substrates also varies. Slope also matters, with most plants preferring flatter areas. Light change over depth in Webster Lake is relatively predictable, with the possible exception of some cove areas that experience algal blooms and have less light in shallow water than might otherwise be expected.

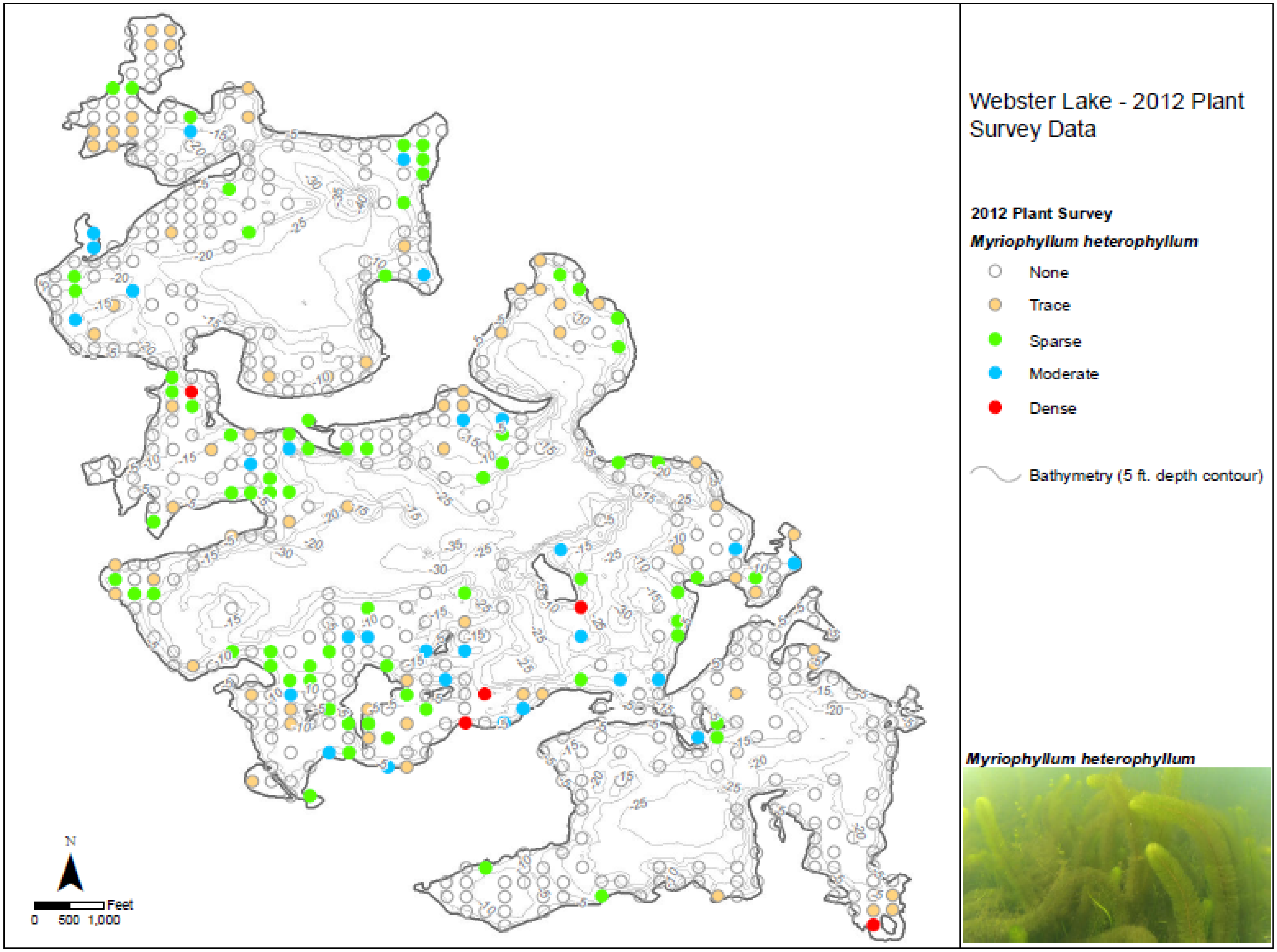
However, sediment features are less predictable. In general, the coarsest material is closest to shore in area lakes, grading into muck or silt in deep water, but in Webster Lake the substrate is a seemingly more random mix over space. The shoreline can be mucky in certain cove areas and sandy along some shoreline reaches, but tends to be rocky to gravelly in most areas. Moving away from shore and into deeper water, muck does become more common, but the transition can be gradual or abrupt, and many deeper areas of Webster Lake have cobble fields and sand spits that are remnants of the lake's glacial history. This creates more of a mosaic plant community than in many other area lakes.

Figure 7. Distribution of fanwort in Webster Lake, late summer 2012.



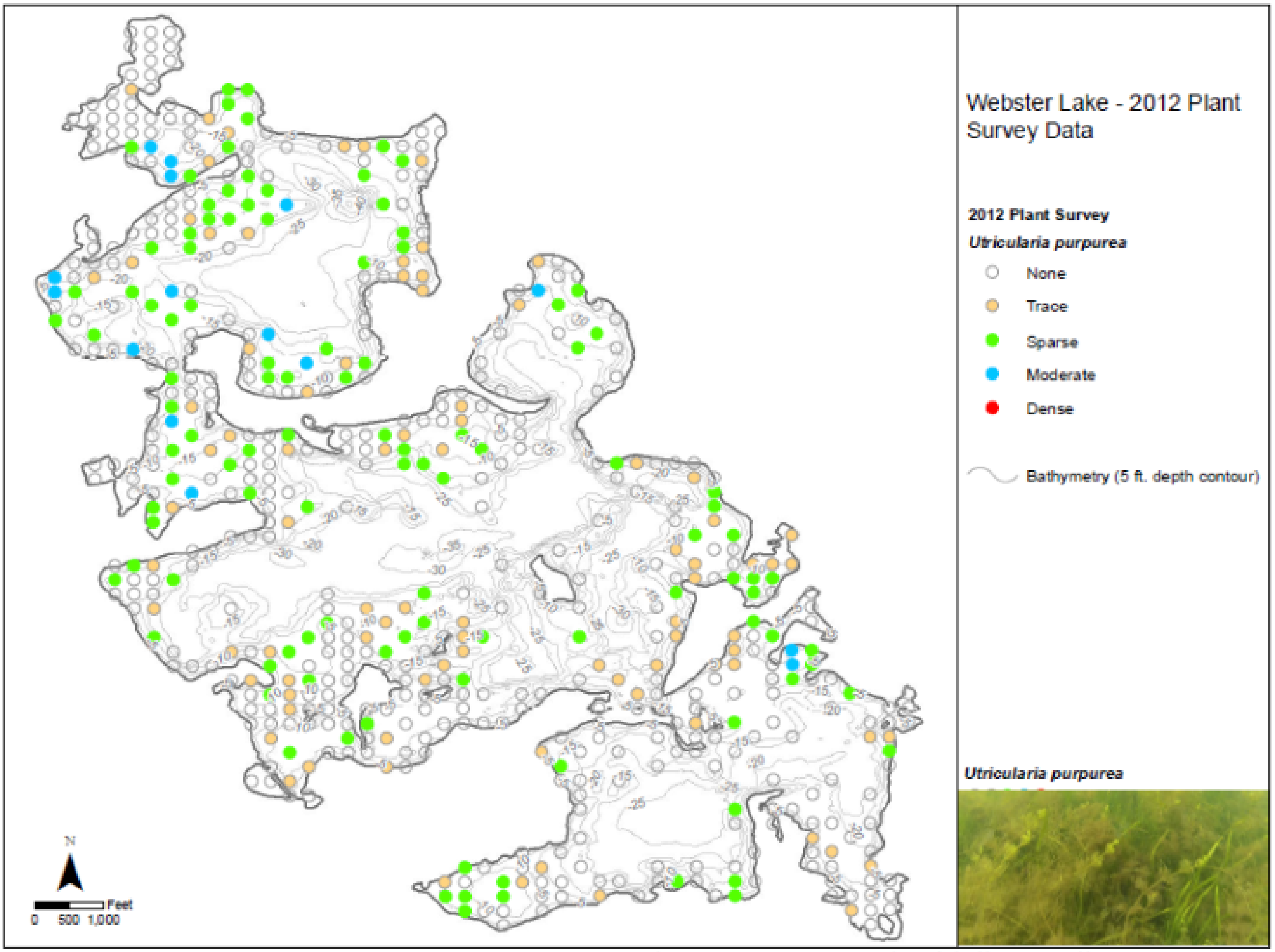
Bathymetry information from CR Environmental Inc. Date: 10/2/2012 Name: WebsterLake_PlantSurvey_CCaroliniana Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 8. Distribution of variable watermilfoil in Webster Lake, late summer 2012.



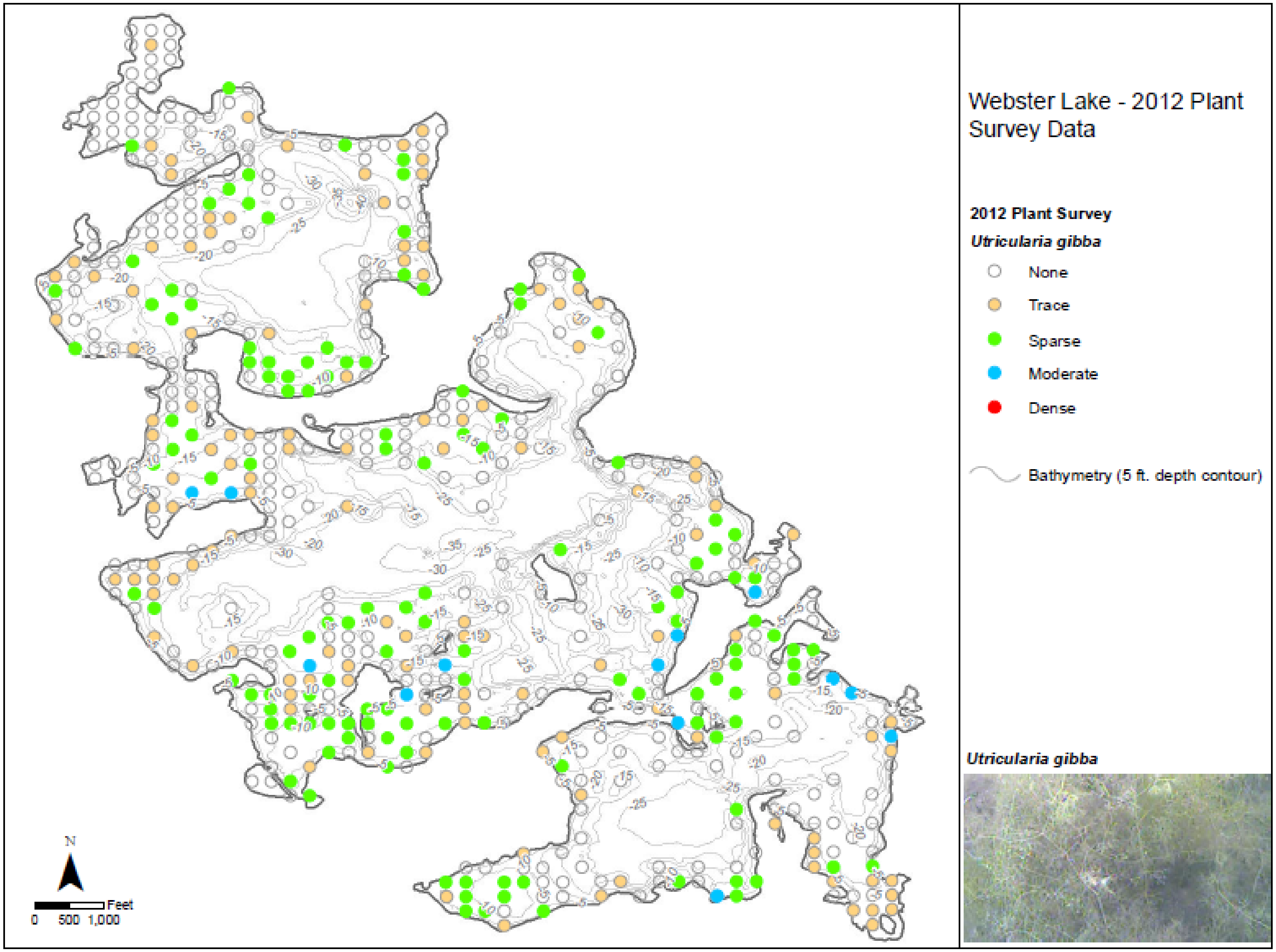
Bathymetry Information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_MHeterophyllum Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 9. Distribution of purple bladderwort in Webster Lake, late summer 2012.



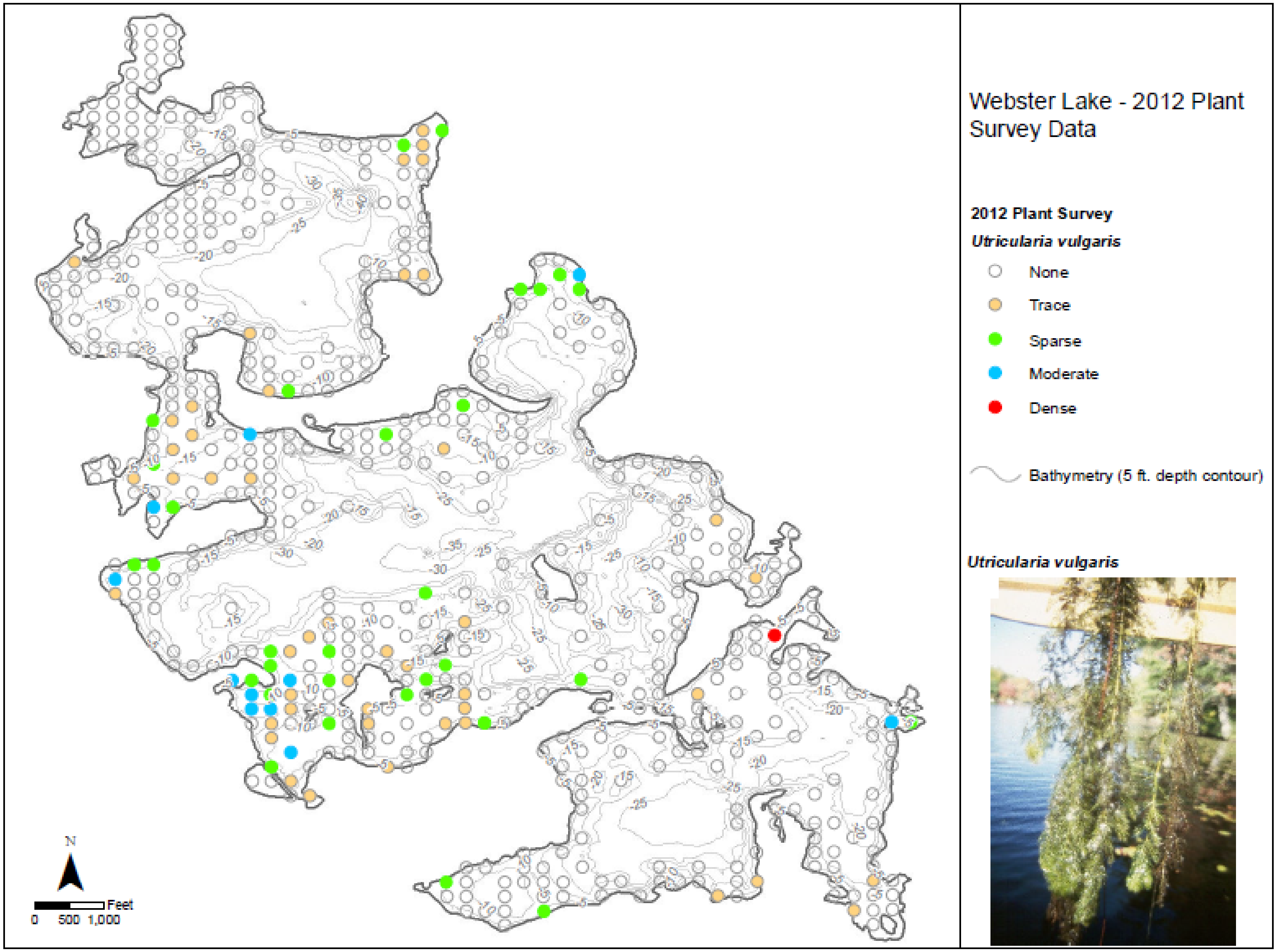
Bathymetry information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_UPurpurea Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 10. Distribution of fine bladderwort in Webster Lake, late summer 2012.



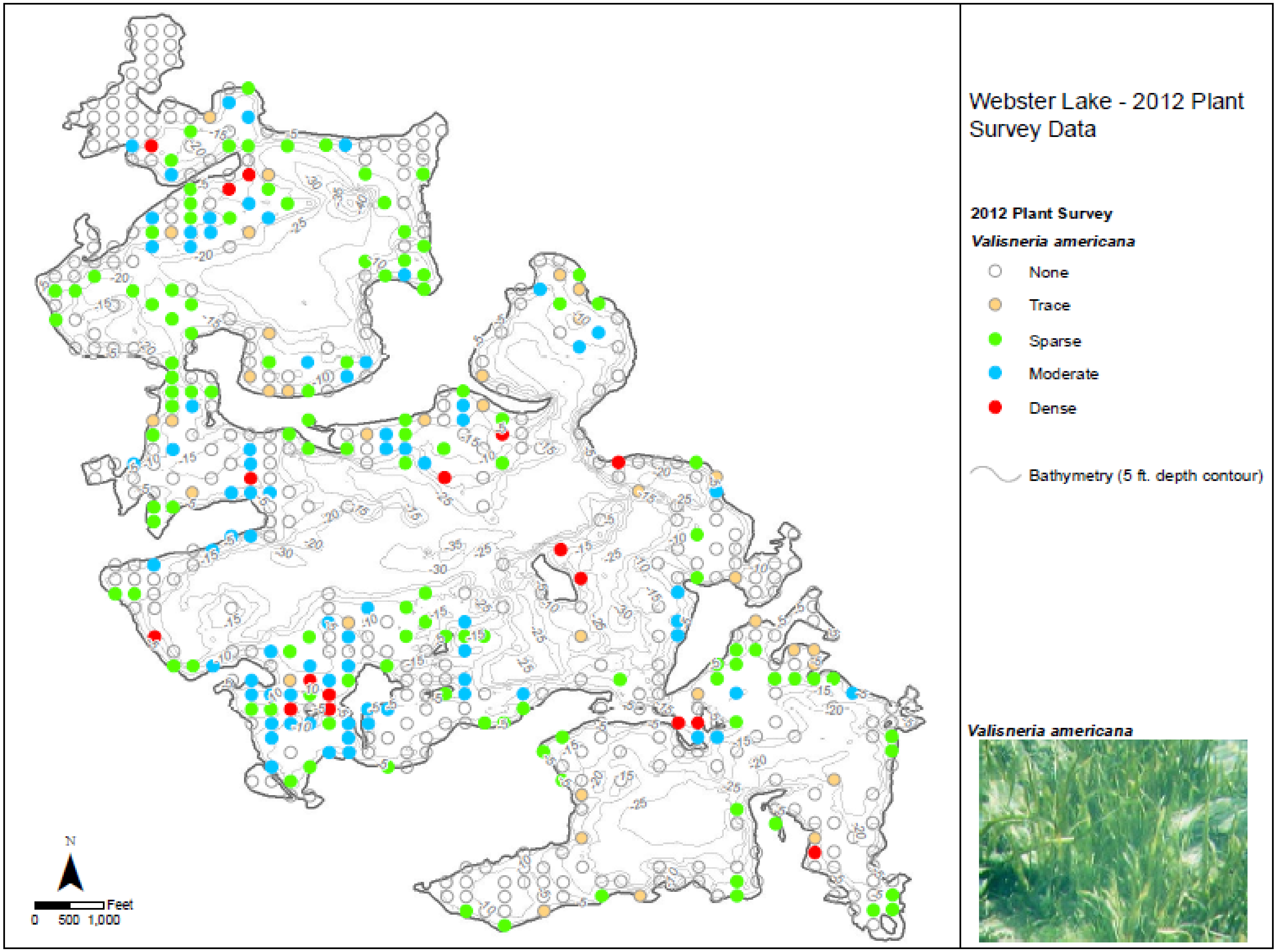
Bathymetry information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_UGibba Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 11. Distribution of coarse bladderwort in Webster Lake, late summer 2012.



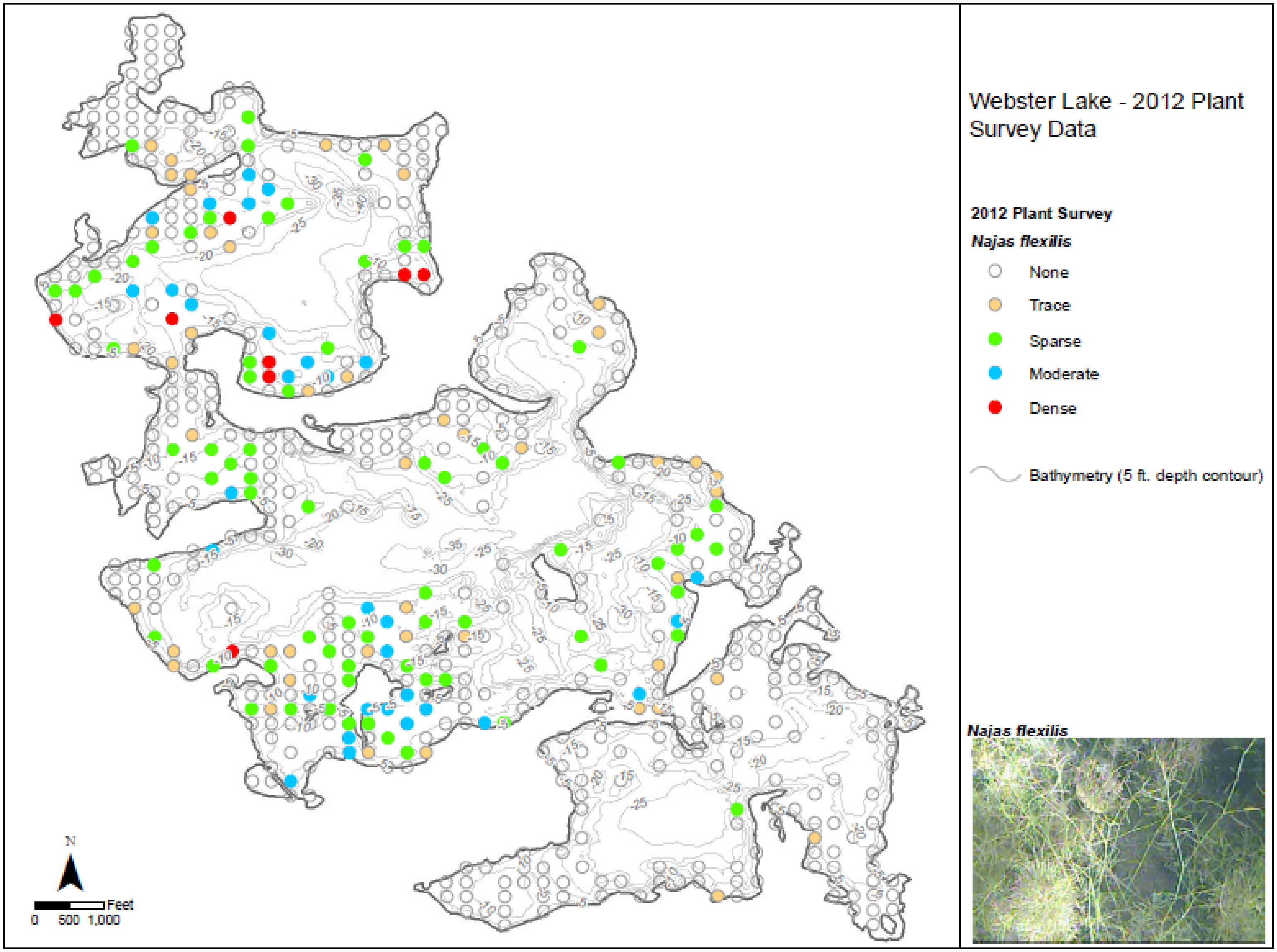
Bathymetry information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_UVulgaris Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 12. Distribution of water celery in Webster Lake, late summer 2012.



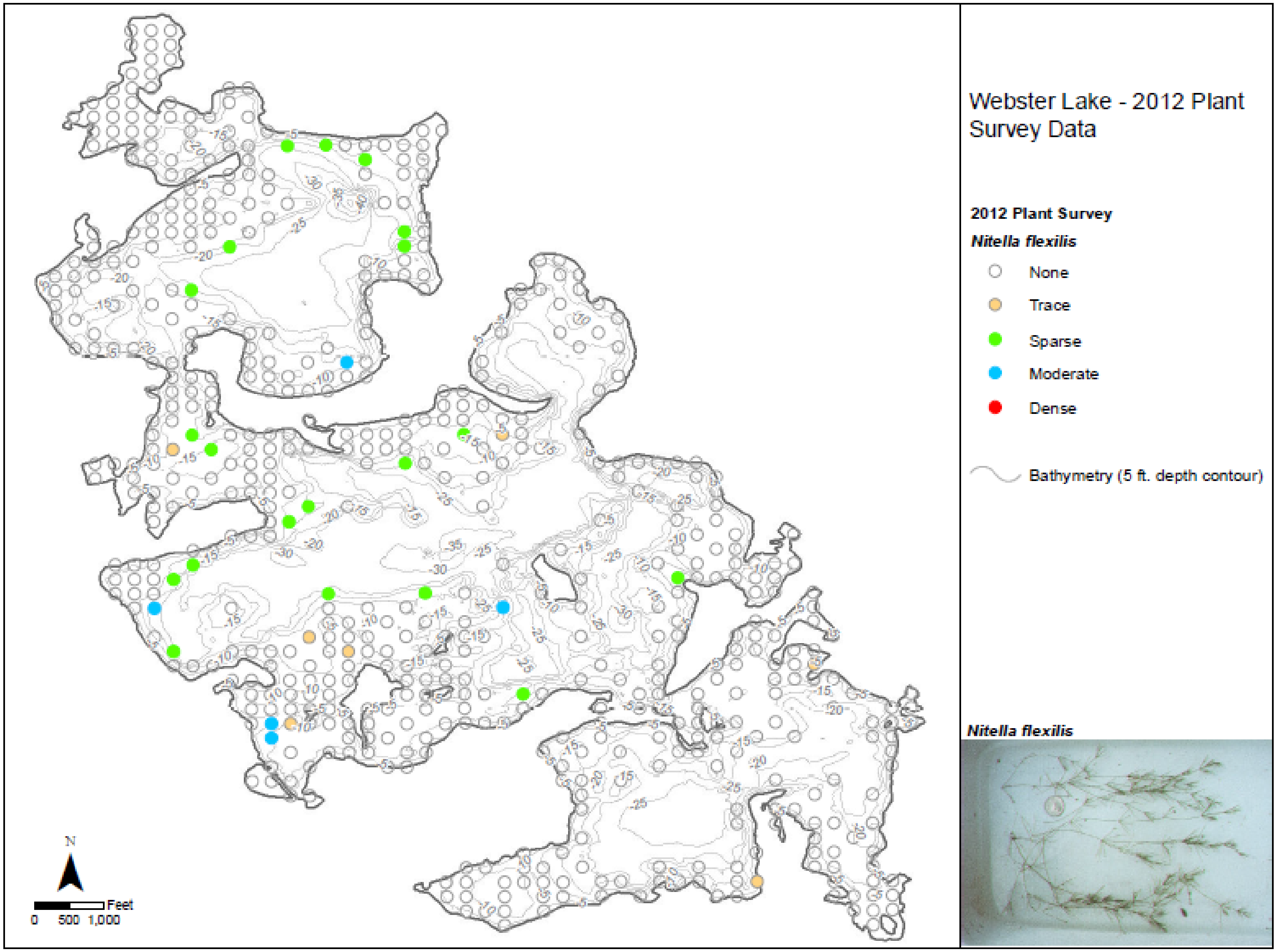
Bathymetry information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_VAmericana Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 13. Distribution of bushy naiad in Webster Lake, late summer 2012.



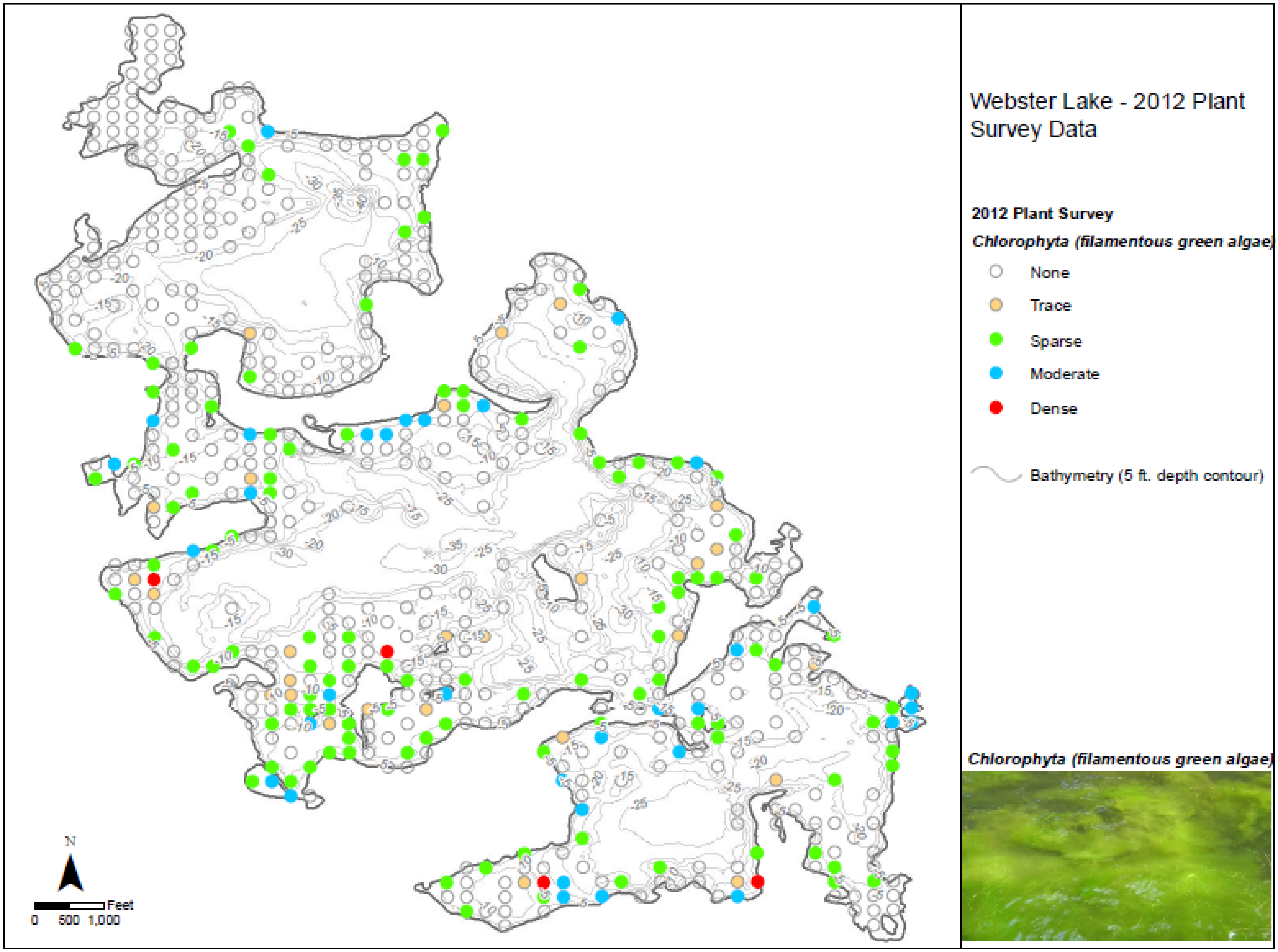
Bathymetry information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_NFlexilis Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 14. Distribution of flexible stonewort in Webster Lake, late summer 2012.



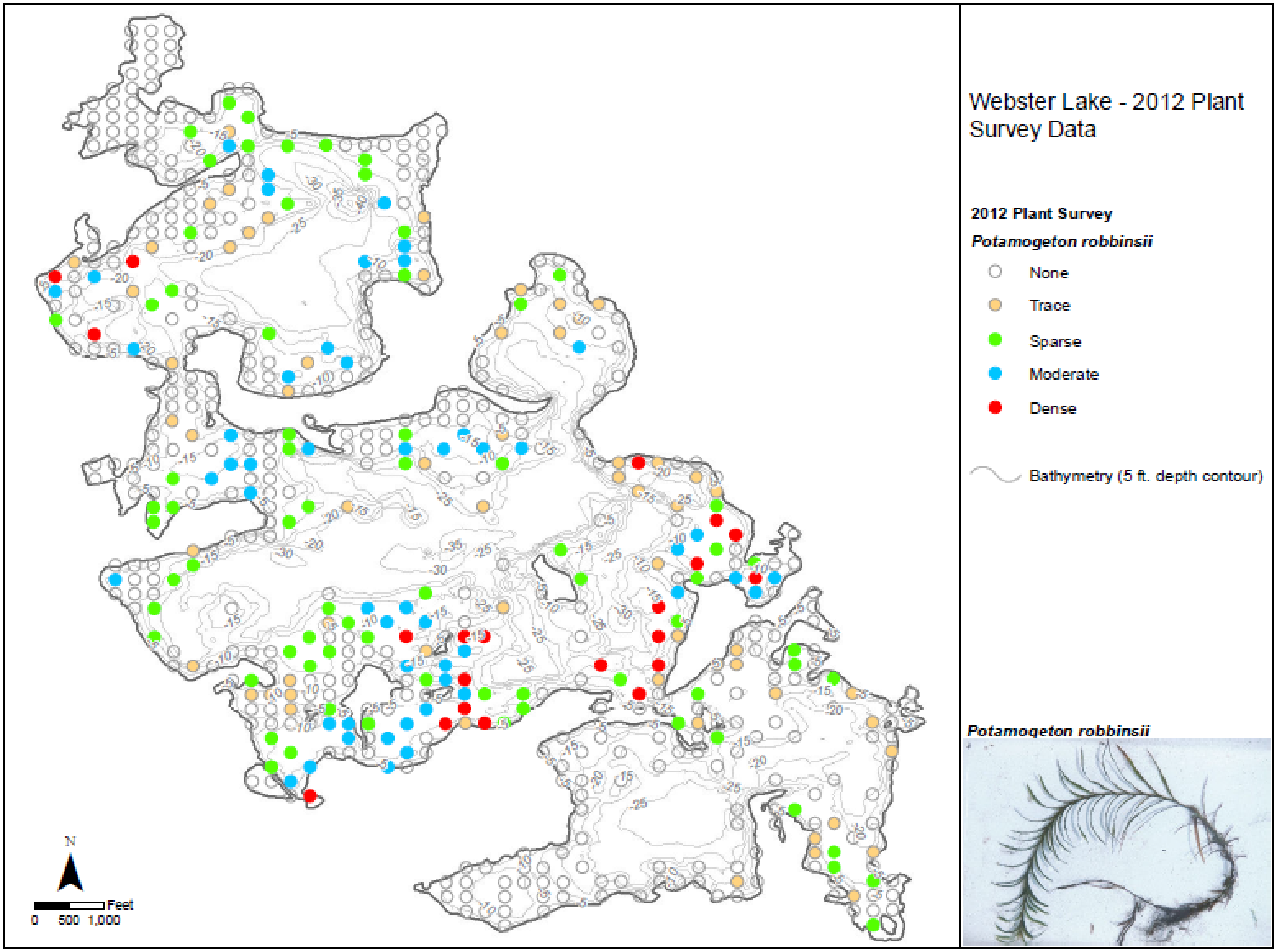
Bathymetry Information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_NitellaF Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 15. Distribution of filamentous green algae in Webster Lake, late summer 2012.



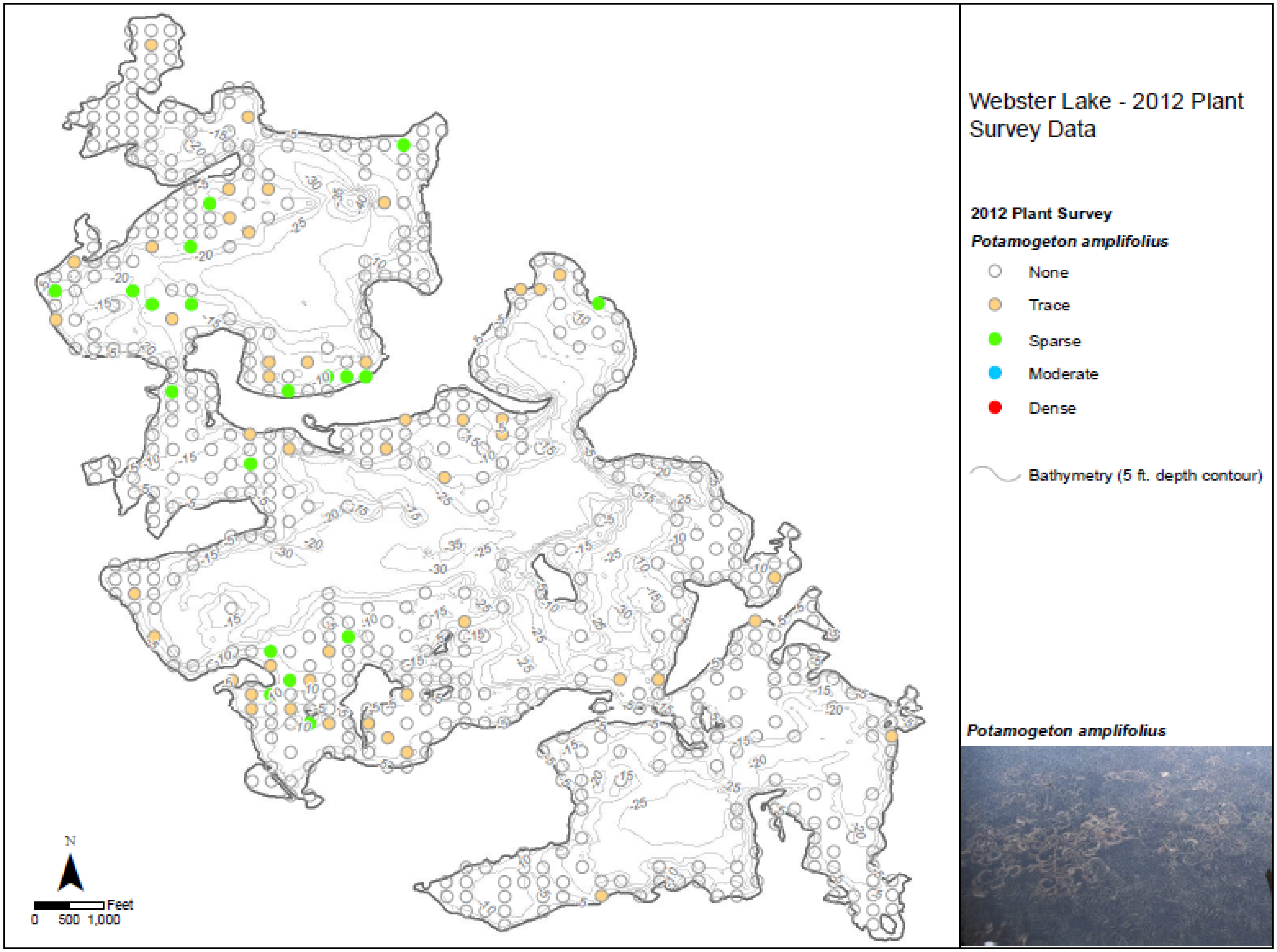
Bathymetry information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_Chlorophyta Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 16. Distribution of Robbins' pondweed in Webster Lake, late summer 2012.



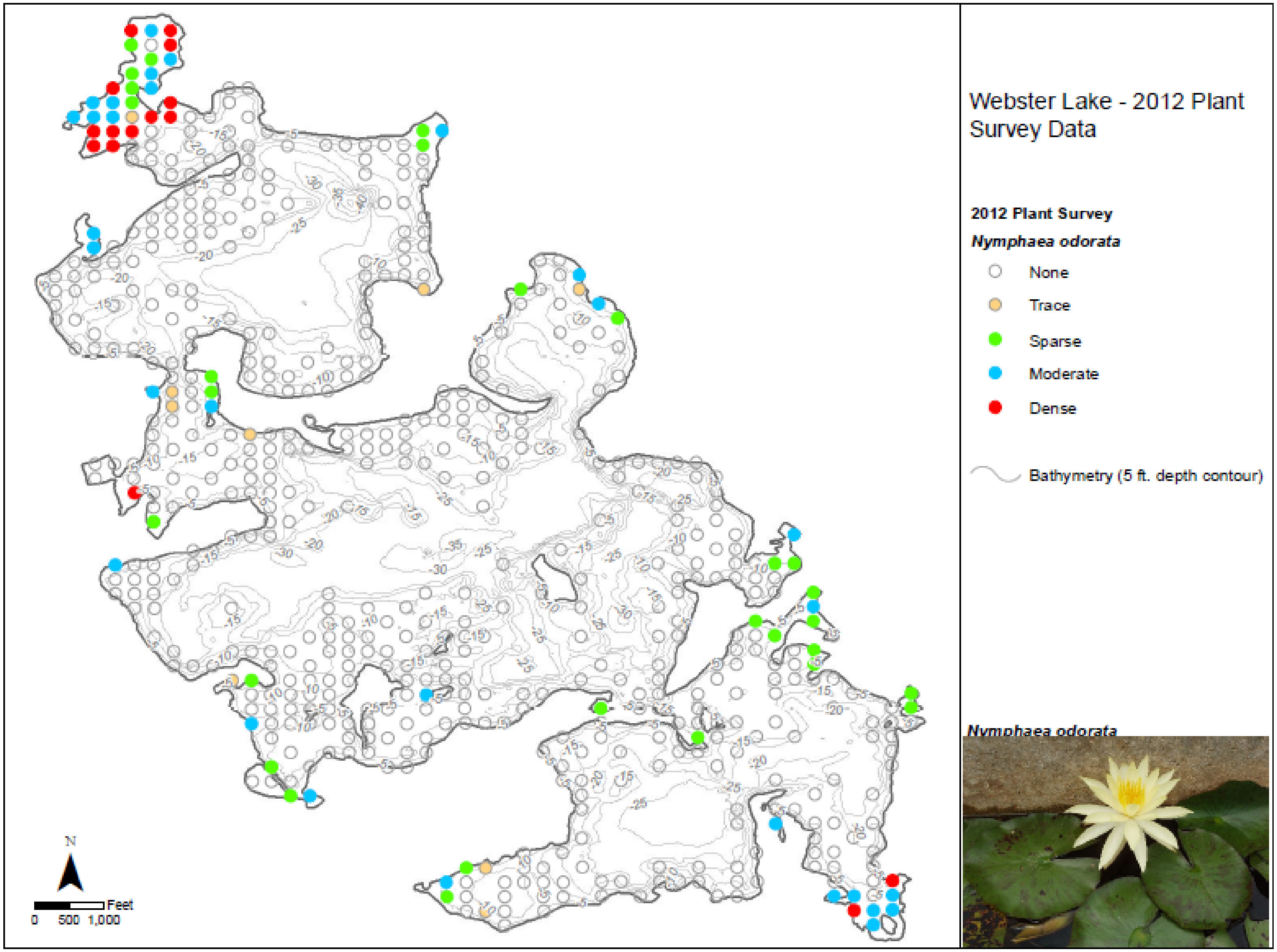
Bathymetry Information from CR Environmental Inc. Date: 10/3/2012 Name: WebsterLake_PlantSurvey_PRobbinsii Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 17. Distribution of bigleaf pondweed in Webster Lake, late summer 2012.



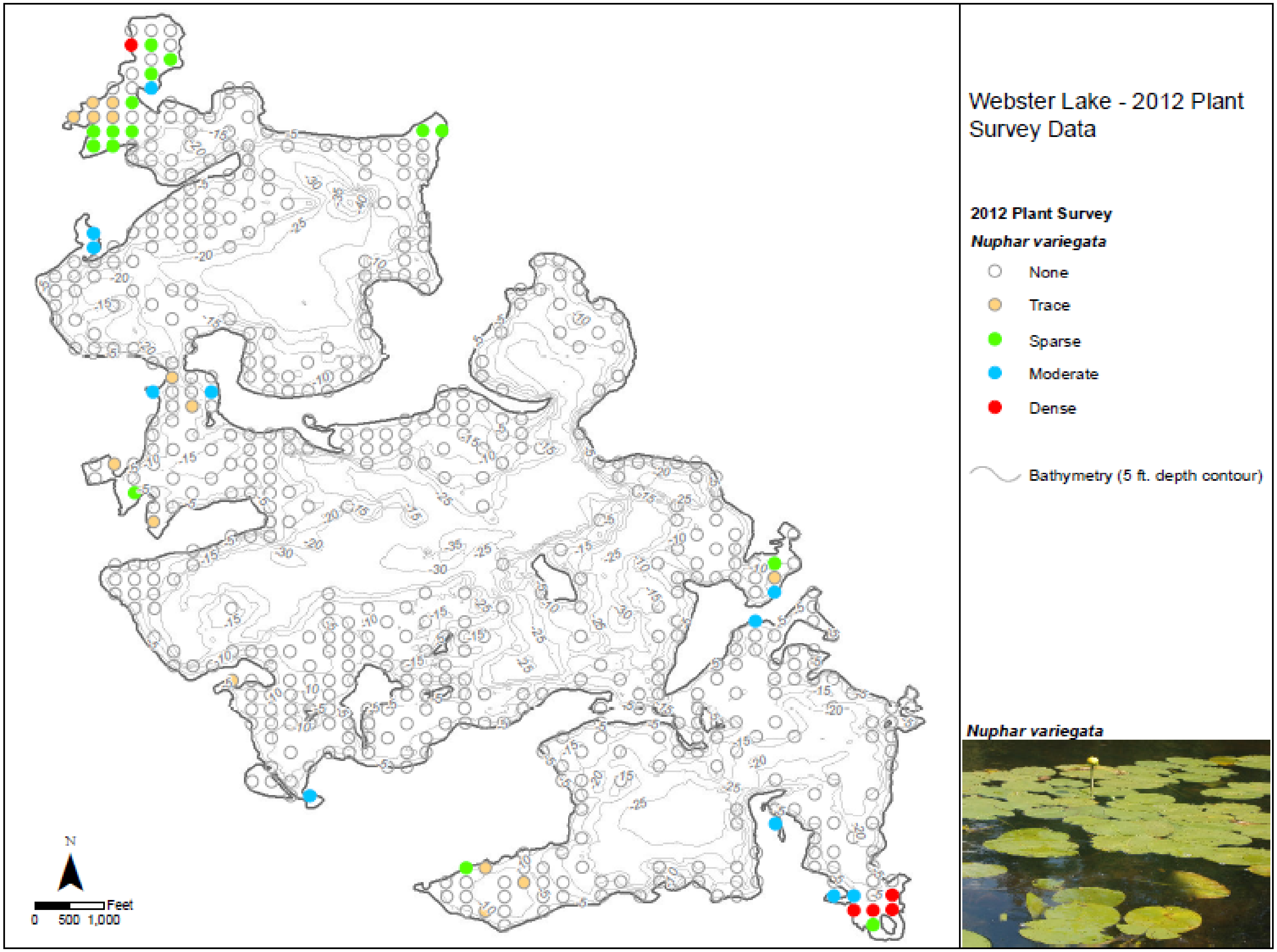
Bathymetry information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_PAmplifolius Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 18. Distribution of white water lily in Webster Lake, late summer 2012.



Bathymetry information from CR Environmental Inc. Date: 10/4/2012 Name: WebsterLake_PlantSurvey_NOdorata Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Figure 19. Distribution of yellow water lily in Webster Lake, late summer 2012.



Bathymetry information from CR Environmental Inc. Date: 10/2/2012 Name: WebsterLake_PlantSurvey_NVariegata Coordinate System: GCS WGS 1984 Datum: WGS 1984 Units: Degree

Population features of the more abundant species are provided here. In addition to the preceding distribution and density maps, graphs of distribution over depth and substrate type are provided for plants that are encountered at more than 20% of sites. Water depths are given in feet in those graphs, and substrate types include muck (m), sand (s), gravel (g) and cobble (c).

Fanwort – This invasive plant is common throughout the lake, but is proportionally more common in the south basin and is more often dense in that part of the lake (Figure 7). Fanwort achieves maximum density in somewhat deeper water (10-15 ft), but can be found at any depth up to almost 20 ft (Figure 20). It is most abundant on muck and sandy substrates (Figure 21); this would translate into maximum abundance in deeper water overall (where there is more muck), but fanwort can also be abundant in mucky to sandy coves around the lake where it has been targeted for treatment.

Figure 20. Distribution of fanwort over water depth.

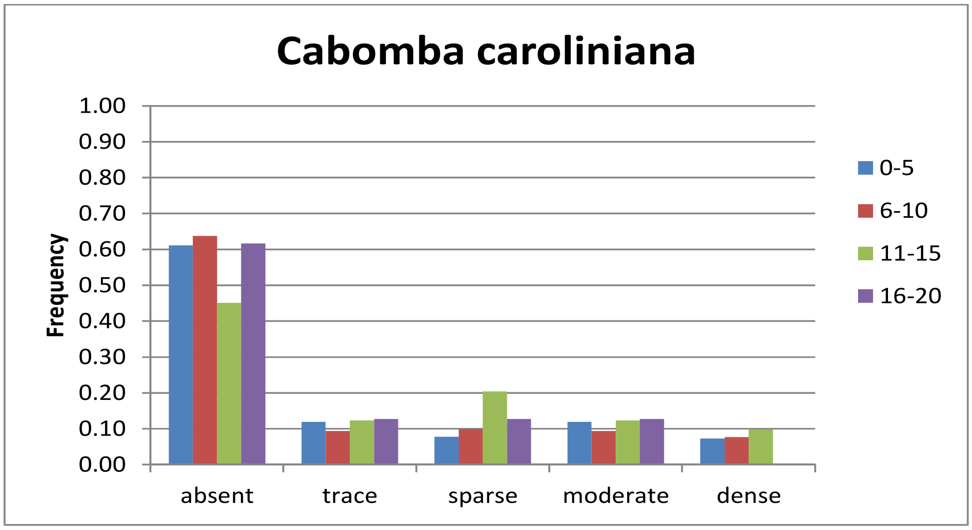
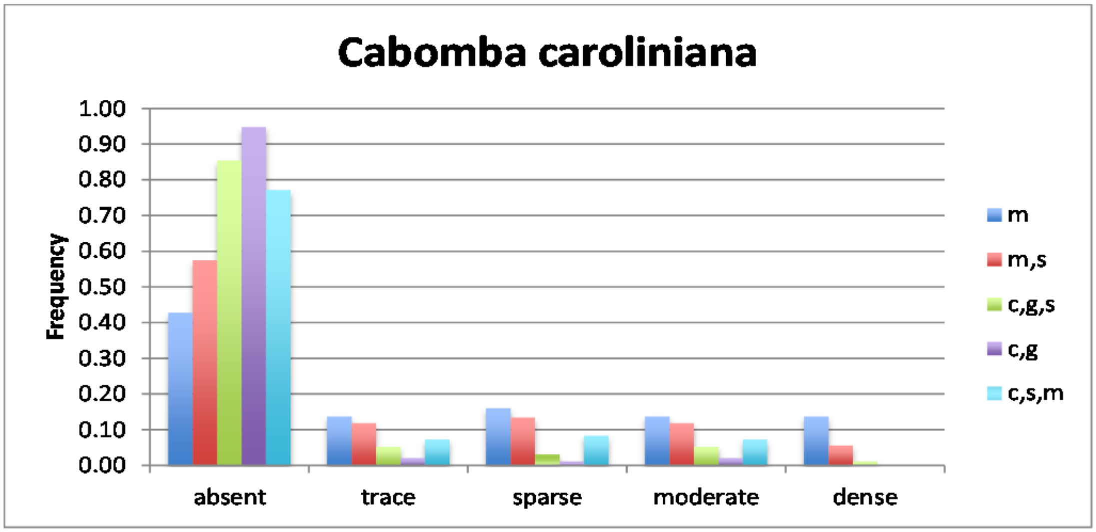


Figure 21. Distribution of fanwort over substrate type.



Variable watermilfoil – This invasive plant is common around the north and middle basins, but is less common in the south basin (Figure 8). It is rarely found in expansive, dense beds, as is often the case in other lakes, but can be very dense in small patches. It is rarely found in water deeper than 15 ft, is most common and dense in water 6-10 ft deep, but can be found in up to moderate densities in shallower water (Figure 22). It can be found on all substrates in Webster Lake (Figure 23), including cobble, where it is often the only plant observed and can form small, dense patches.

Figure 22. Distribution of variable watermilfoil over water depth.

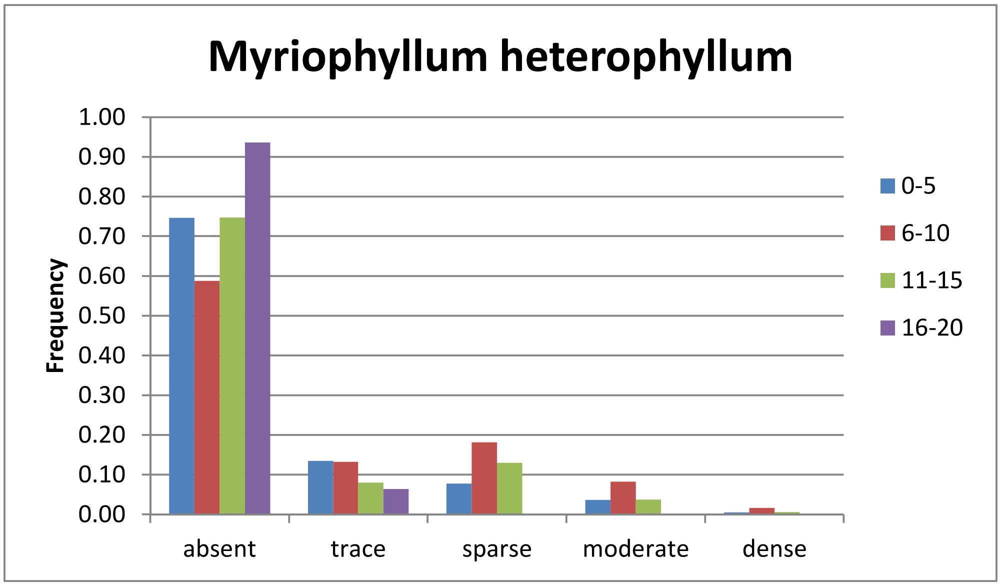
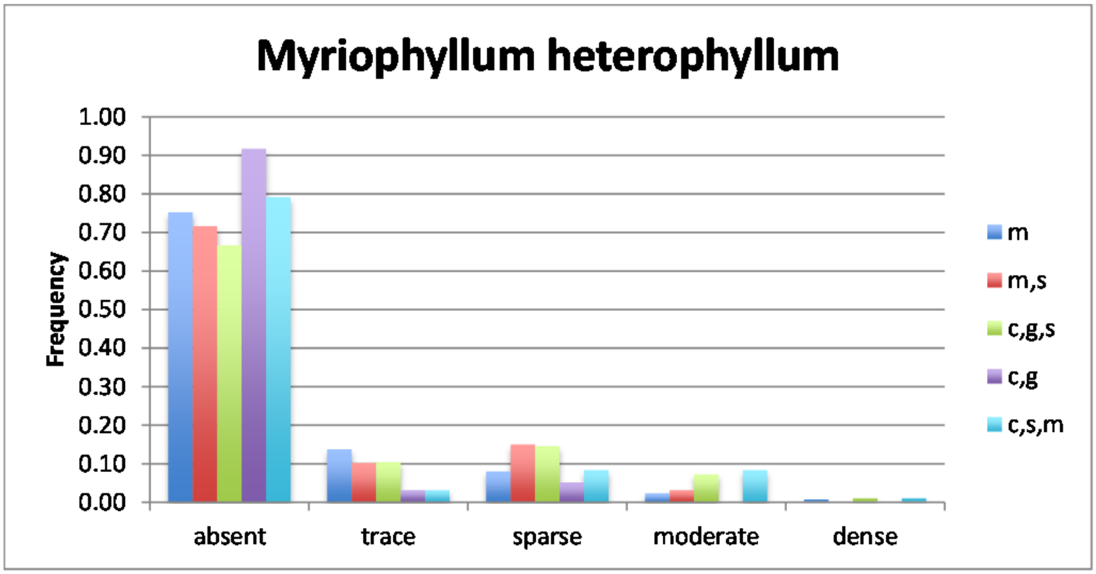


Figure 23. Distribution of variable watermilfoil over substrate type.



Purple bladderwort – This common native species can become a nuisance if it grows densely and floats to the surface. No evidence of such growths was observed in Webster Lake, and most of these plants were in water deeper than 5 ft (Figure 24) where they were anchored to the mucky bottom (Figure 25). Early summer flowering could mean greater surface presence for the flowers, Growths were not observed to be dense, and this plant was typically mixed in with other native species.

Figure 24. Distribution of purple bladderwort over water depth.

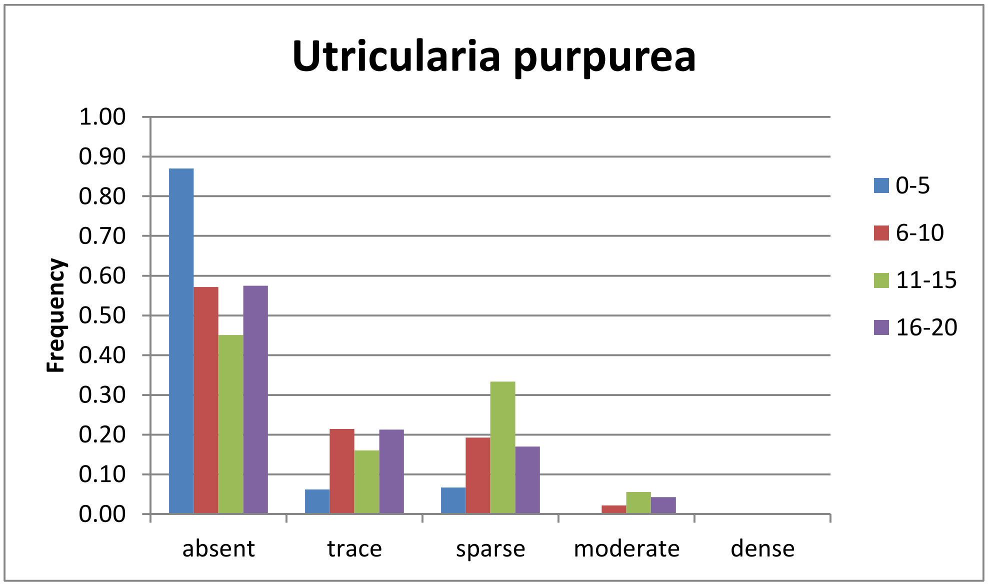
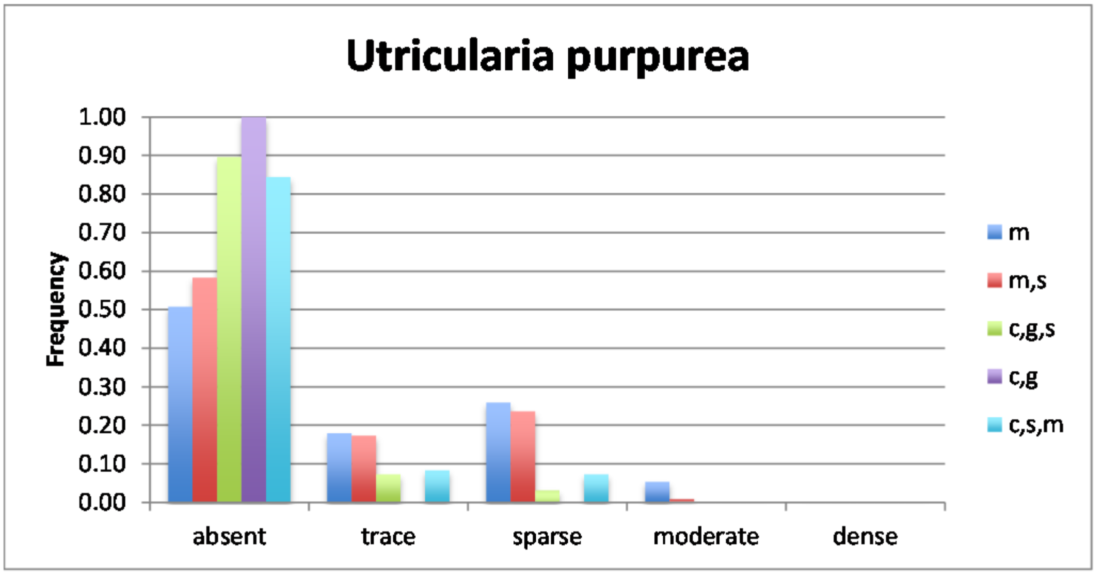


Figure 25. Distribution of purple bladderwort over substrate type.



Fine bladderwort – The very diminutive Utricularia gibba was actually the most frequently encountered plant in Webster Lake, but was never dense and rarely moderately abundant. It was found at all depths and over all substrates, but seems to prefer deeper water (Figure 26) and mucky substrates (Figure 27), although this species is generally a floating form. The bladders on these plants capture zooplankton to supplement their nutrition, especially as a source of nitrogen. This species has minimal nuisance potential, being much smaller than the other bladderwort species present in Webster Lake.

Figure 26. Distribution of fine bladderwort over water depth.

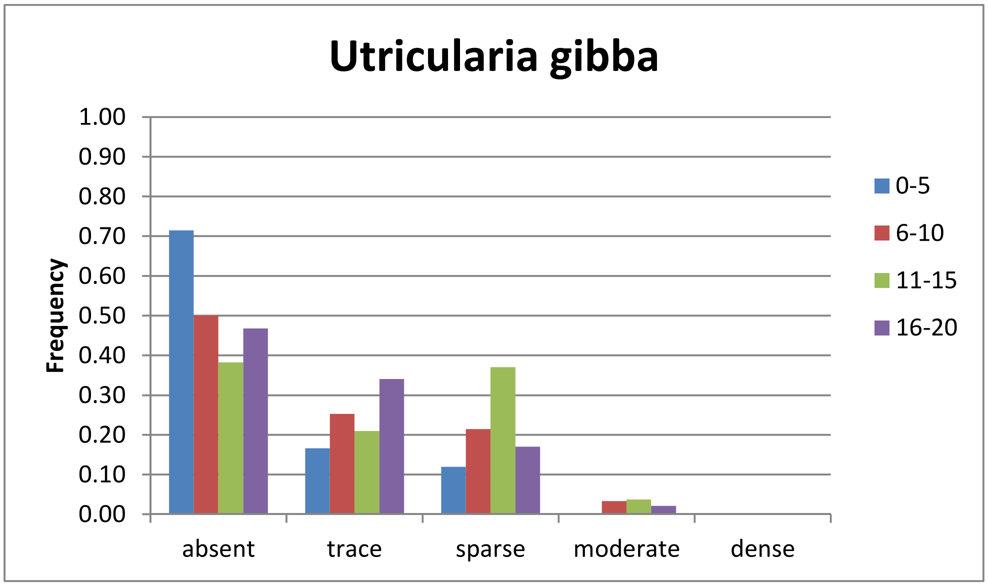
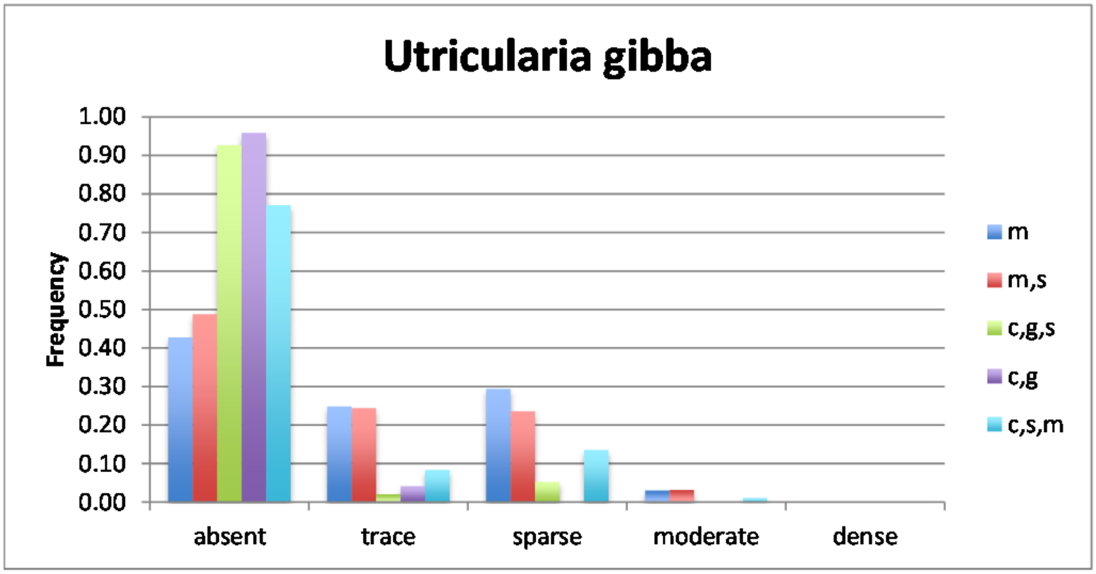


Figure 27. Distribution of fine bladderwort over substrate type.



Coarse bladderwort – This species is among the largest bladderworts, and can create nuisance conditions, although abundance in Webster Lake was not elevated; only one site had this plant at a high density. It was found at low to moderate frequencies (13-18%) at depths <15 ft and was less frequent (6%) at greater depths.

Water celery – This low growing plant does send up reproductive shoots (flowers on flexible stems) that can sometimes be annoying to boaters and swimmers, but not all populations or plants send up those shoots, and deep populations tend to spread more by lateral root runners. This plant was one of the most commonly encountered forms in Webster Lake, but with its low growth habit, it never filled more than a small fraction of the water column and did not create nuisance conditions. It grows best in water >5 ft deep (Figure 28) and with moderate sand content (Figure 29).

Figure 28. Distribution of water celery over water depth.

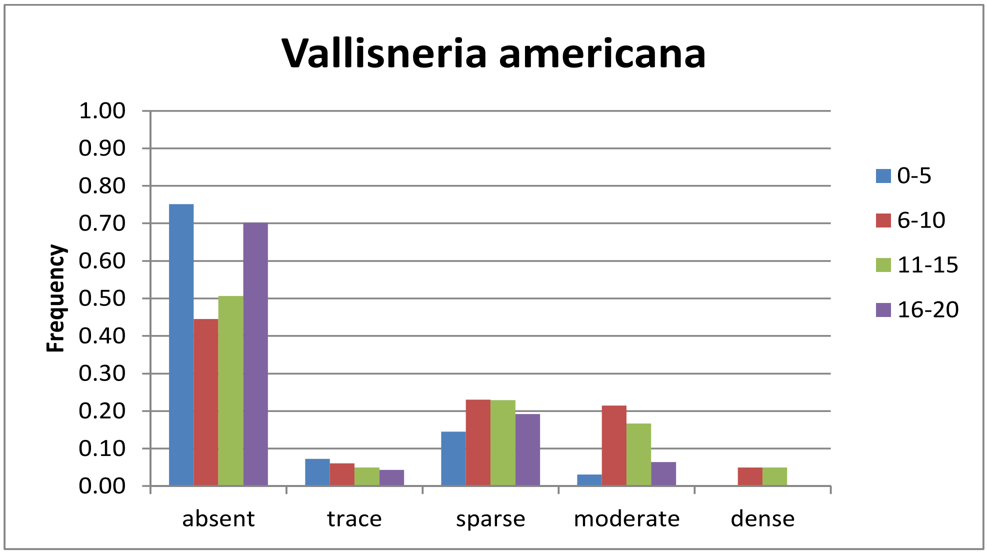
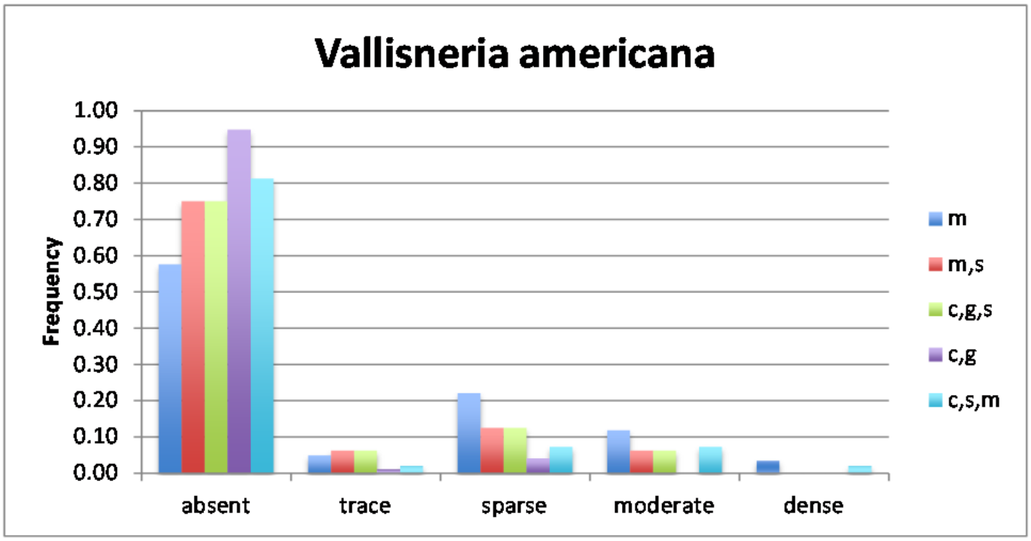


Figure 29. Distribution of water celery over substrate type.



Bushy naiad – This plant can achieve nuisance densities when older growths break fee and float, but is generally a desirable submergent species. In Webster Lake it tends to be found in deeper water (Figure 30) over mucky sediment (Figure 31) at lower densities. It is one of the last remaining species at 20 ft of water depth.

Figure 30. Distribution of bushy naiad over water depth.

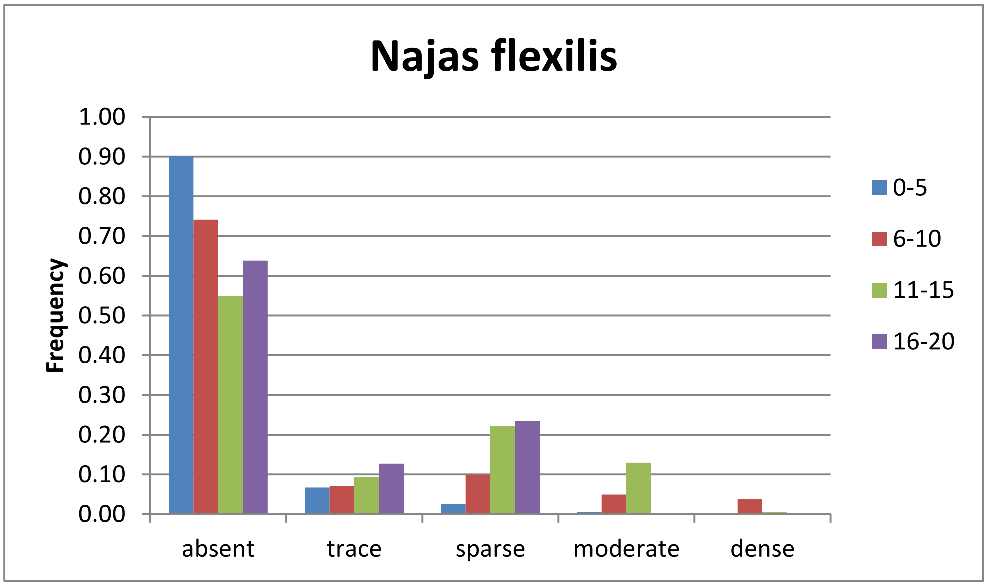
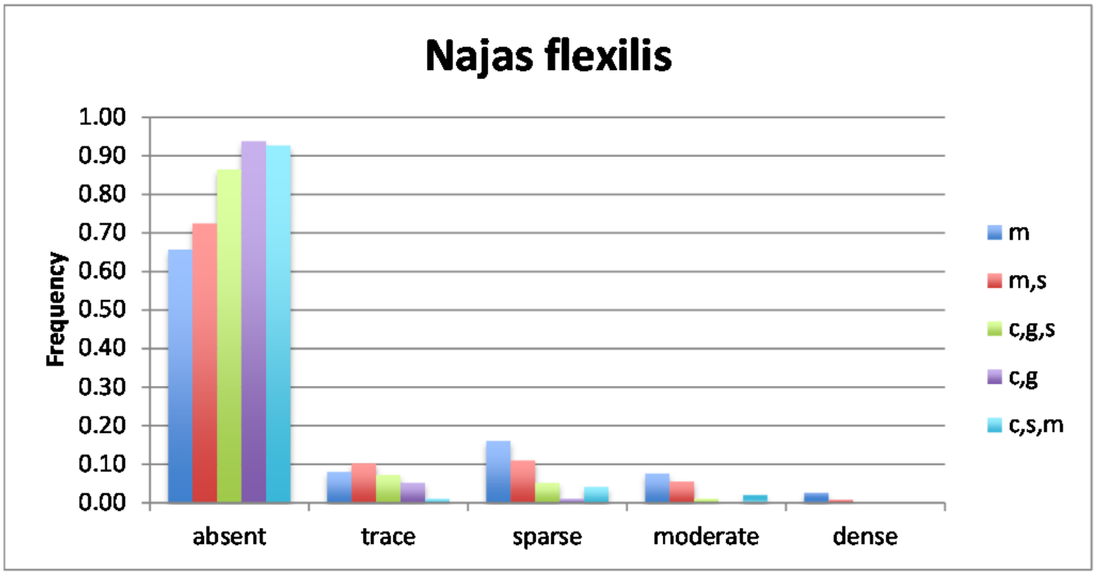


Figure 31. Distribution of bushy naiad over substrate type.



Stonewort – There are two species of Nitella in Webster Lake, a shallow water species that sometimes forms a dense carpet and a deeper water form (*Nitella flexilis*). The shallow water species is found on sandy sediment with some muck, while the deeper water species prefers muck sediment and tolerates low light, so it is among the last species to disappear at greater depth in Webster Lake.

Filamentous Green Algae – While not vascular plants, these large algae are visible to the naked eye and are included as "macrophytes" (visible plants) in most surveys. They do not have true roots, but may attach to higher plants, rocks or other structures. Even the floating forms tend to start as growths on the bottom, usually in water <15 ft deep (Figure 32). Because nutrition is drawn from the water, they occur on any substrate (Figure 33). Filamentous greens can float to the surface and cause nuisance conditions, and this could be an issue in treated coves with muck sediments.

Figure 32. Distribution of filamentous green algae over water depth.

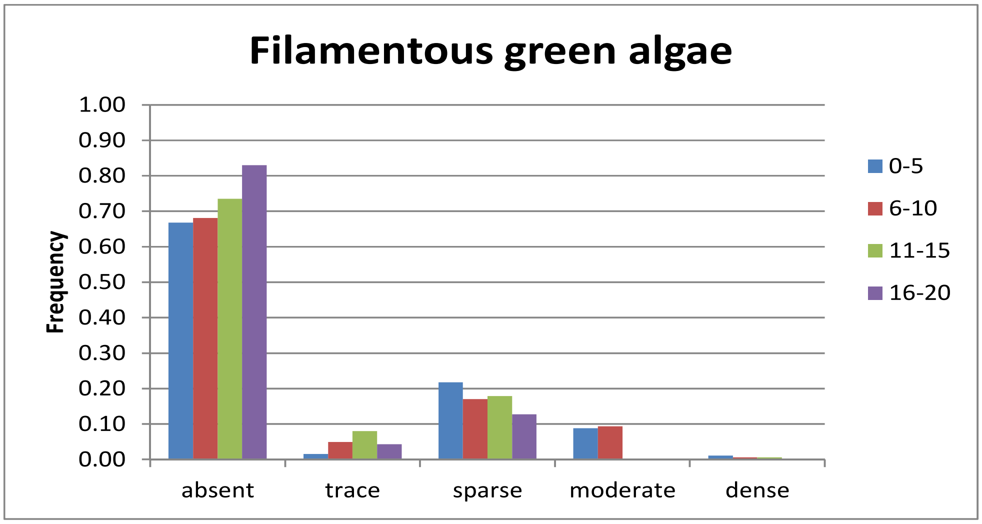
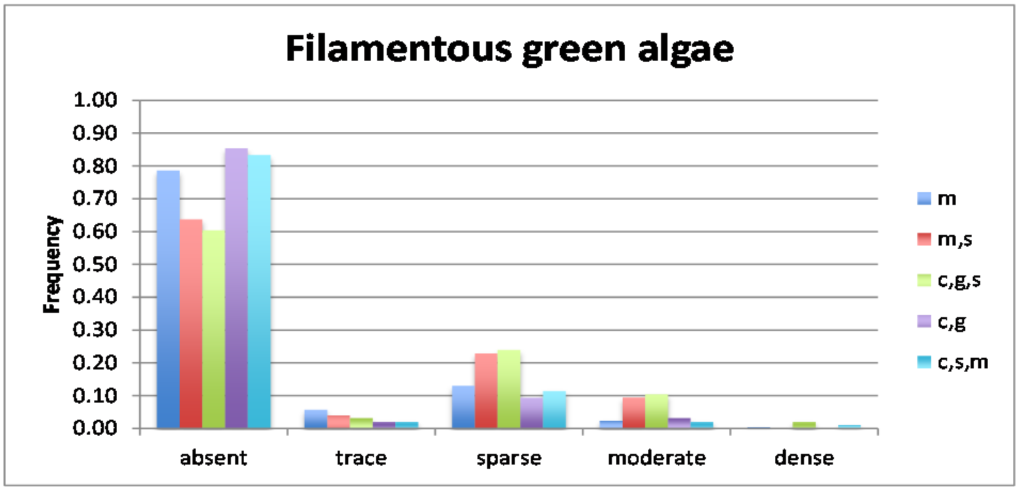


Figure 33. Distribution of filamentous green algae over substrate type.



Robbins' Pondweed – This desirable native species tends to grow close to the bottom, spreading fern-like leaves over the substrate and expanding mainly by root runners. It creates expansive carpets in many lakes that minimize invasion potential for species like milfoil and fanwort. It can grow at any depth where light is adequate, tolerating low light and being among the last plants to disappear as depth increases in Webster Lake (Figure 34); it is actually found at greater density with increasing depth in Webster Lake, to about 20 ft, probably as a function of sediment type and less competition with invasive species that can form a canopy over it. It prefers muck to sand for a substrate (Figure 35), with density increasing as sediment particle size declines.

Figure 34. Distribution of Robbins' pondweed over water depth.

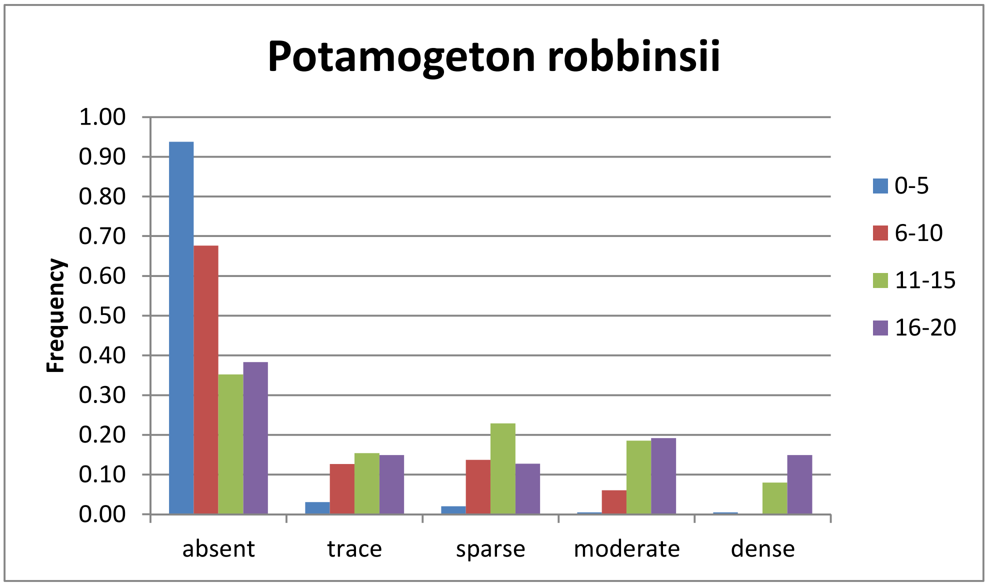
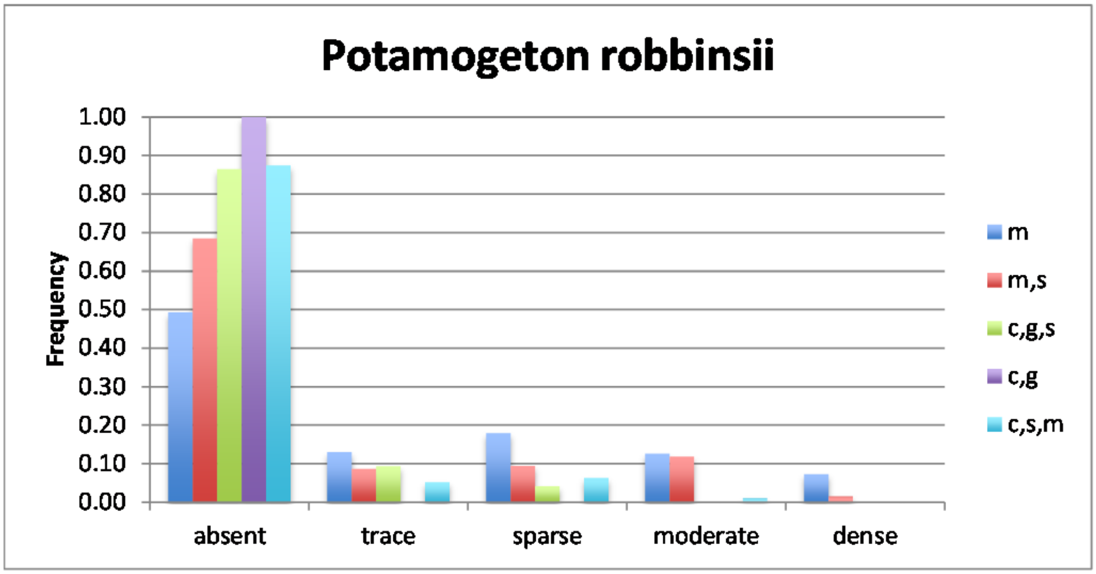


Figure 35. Distribution of Robbins' pondweed over substrate type.



Bigleaf pondweed – This native plant is listed as a dominant species in the 2003 survey, but was never observed at even a moderate density in 2012. This is somewhat unusual, as this plant can form dense stands that have been considered nuisances in shallow portions of some lakes, but in Webster Lake this pondweed is found in just trace or sparse quantities mixed among other species. It was found at 5% of the sites <5 ft deep, 20% of the sites 6-10 ft deep, and 13% of the sites 11-15 ft deep; it was not found in water >15 ft deep. It was always found on substrates with some muck content in Webster Lake.

White water lily – This native species can form a dense canopy of floating leaves in shallow areas with substantial muck deposits, and is one cause of poor boating and swimming conditions in some cove areas of Webster Lake. Yet it makes excellent fish and wildlife habitat, and some areas have been left untreated for this reason. It is a shallow water species, found in 38% of sites <5 ft deep, 4% of sites 6-10 ft deep, 1% of sites 11-15 ft deep, and really not at depths much greater than 11 ft. It is found only in muck and sand substrates. When present, density was almost always at least moderate.

Yellow water lily – This native species can form a dense canopy of floating leaves in shallow areas with substantial muck deposits, and along with white water lily, is a cause of poor boating and swimming conditions in some cove areas of Webster Lake. It makes excellent fish and wildlife habitat, however, and some areas have been left untreated for this reason. It is a shallow water species, found in 20% of sites <5 ft deep, 3% of sites 6-10 ft deep, 1% of sites 11-15 ft deep, and not at depths greater than 11 ft. It is found only in muck and sand substrates. Density varied considerably, with everything from trace amounts to dense growths and a roughly even distribution among the occurrences of each density rating.

There are some differences among the three major basins of Webster Lake, as evidenced by the distributional maps (Figures 7-19). There seems to be more dense growths of fanwort in the south basin and more variable watermilfoil in the middle basin, followed by the north basin, followed by the south basin. These differences appear to be a function of depth and substrate distribution, but we can't rule out where these plants were introduced as a factor in their current distribution. It is possible that fanwort entered the south basin first and variable watermilfoil entered the middle basin first. Also, treatment history and establishment of untreated preserve areas may influence invasive species distribution; this will be addressed separately in this report.

The bladderworts appear to be slightly less common in the south basin, but there is no clear reason for this; conditions are suitable for these species throughout Webster Lake. Water celery attains moderate to high densities in the middle basin more often than in the other two basins, but this is not a problem species; expansive growths of this plant should be welcomed. Likewise, Robbins' pondweed attains higher densities in the middle basin, particularly along the south side, and is a desirable species. This plant is replaced by milfoil and fanwort in most lakes invaded by those species; the greater abundance of fanwort in the south basin may be linked to the lesser abundance of Robbins' pondweed there. Bushy naiad, stonewort (nitella) and bigleaf pondweed are all also less common in the south basin. It would appear that species diversity is depressed in the south basin overall, and this may be related to depth and substrate distribution, invasion history, and repeated treatment activities.

Quantitative Plant Community Assessment: How Abundant Are Plants?

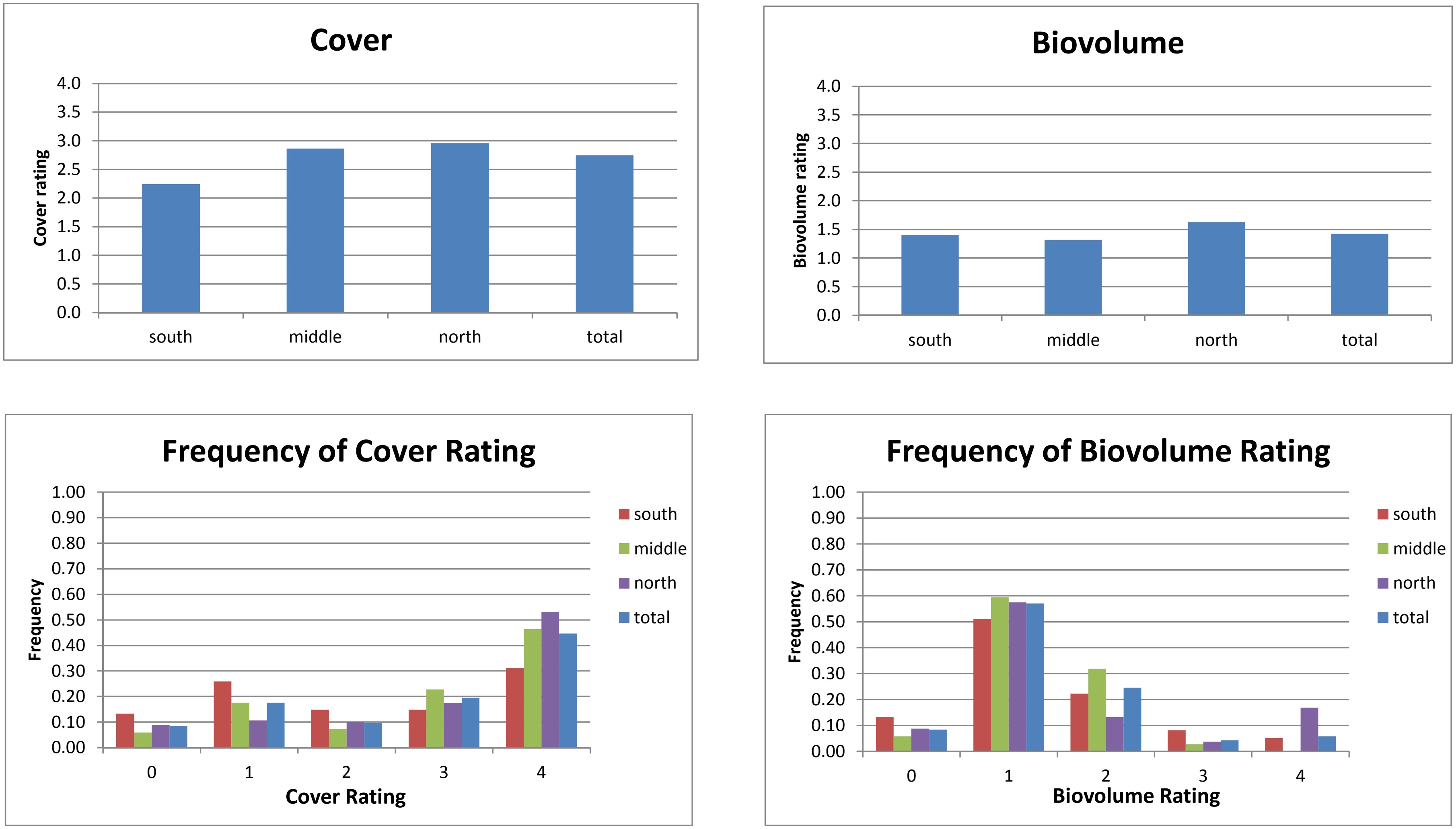
There are certainly areas of Webster Lake with dense plant growths, most notably shallow coves where such growths impact use by people and habitat for some aquatic organisms. However, overall plant abundance in areas <20 ft deep is not extremely high in the lake. Overall average ratings for cover (the portion of the bottom covered by plants in two dimensions when one is looking down from above) and biovolume (the portion of the water column filled by plants) (Figure 36, top two panels) are of limited use in a management context, however. Most lakes have open water areas and a range of plant densities, and it is the distribution that is more important (Figure 36, bottom two panels).

In terms of overall average, Webster Lake in its entirety and each of the 3 basins exhibit cover ratings in the 2-3 range, suggesting that around 50% of the lake bottom under <20 ft of water has plant cover. Cover values are slightly higher in the north and middle basins than in the south basin. For biovolume, the ratings average between 1 and 2, suggesting that around 25% of the water column is filled with plants on average. Biovolume ratings for the north basin are slightly higher than those for the middle and south basins. So based on average values, the north basin has more plants and more potential for plant nuisance issues. However, as noted, the distribution of rating values over the five abundance categories applied in this survey provides better insight.

The distribution of values for cover (Figure 36, bottom left panel) indicates that there are more places in the south basin with no plant cover; this could be due to treatment, which was most extensive in the south basin, or substrate features. All surveyed sites are in <20 ft of water, so light should not eliminate plant growths, although the clarity of water in the south basin does tend to be lower than for the other two basins. The south basin also has a higher frequency of values of 1 or 2 (1-25% and 26-50% cover, respectively), and lower frequencies of values of 3 or 4 (51-75% and 76-100% cover, respectively). The north and middle basins are more similar, although not identical in terms of cover rating distribution, but there is no clear trend (sometimes the middle is higher than the north and vice versa). All basins have more high cover sites than any other category, so while the average is in the mid-range, there are many locations where most or all of the lake bottom is covered by plants. This by itself is not a problem; in fact, plant cover is a stabilizing influence on sediments and provides habitat. It is only when the biovolume is large that we get nuisance conditions. Biovolume ratings can’t be larger than cover ratings, so low cover will translate into low biovolume, but cover can be high with biovolume still being low.

The distribution of values for biovolume (Figure 36, bottom right panel) has the same pattern as cover for sites without plants, which has to be the case (no cover = no biovolume), but that is where the similarity ends. All basins had between 50 and 60% of their values equal to 1, indicating that more than half the surveyed sites had no more than 25% of the water column filled with plants. A 25% biovolume will not cause nuisance conditions unless it is all floating leaved plants, like water lilies. The middle basin had the most biovolume values of 2, followed by the south basin, followed by the north basin, with enough difference to suggest that the volume of water filled 26-50% by plants was actually different among the basins. Well under 10% of all sites had biovolume values of 3, but there were twice as many in the south basin as in either the north or the middle basins. There were no biovolume ratings of 4 in the middle basin, a few in the south basin, and quite a few in the north basin.

Figure 36. Cover and biovolume ratings for Webster Lake and its basins.

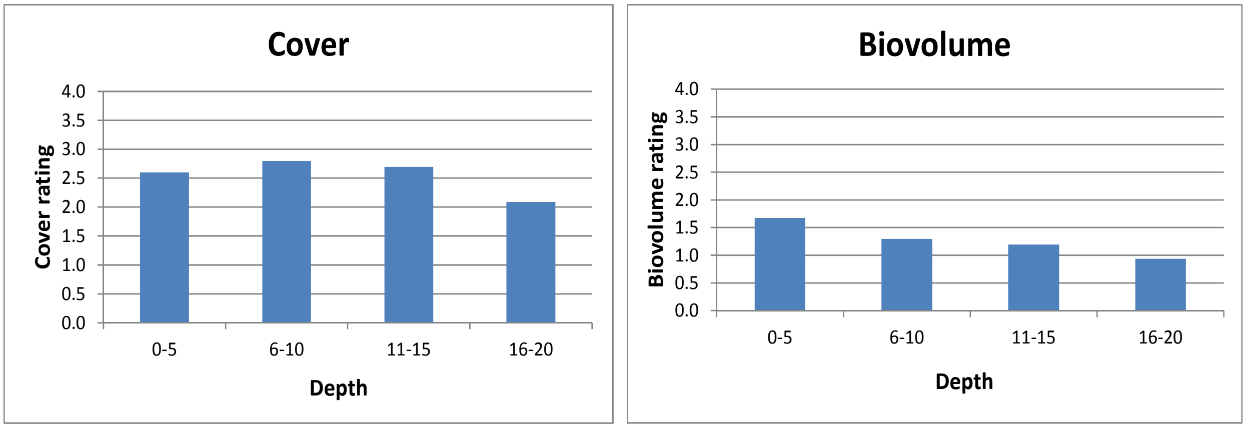


The distribution of biovolume values suggests that the vast majority of each lake will not experience nuisance conditions, but areas where plant growths are dense will be scarce in the middle basin, slightly more abundant in the south basin (5% of sites), and quite a bit more abundant in the north basin (16% of sites). This does not preclude and occasional small patch of dense growth in the middle basin, and at least one area of expansive dense growth (the northeastern cove, where two major brooks enter) was not surveyed, as growths were too dense to allow boat traffic. The reason for lower density growths in other areas may well be treatment activities, but it does suggest that in late summer of 2012 conditions were generally desirable in Webster Lake, while there are small differences in plant density among the basins and localized areas of dense growths that may impair lake use. Exactly where those areas are located can be inferred from the plant distribution maps (Figures 7-19).

The Impact of Water Depth

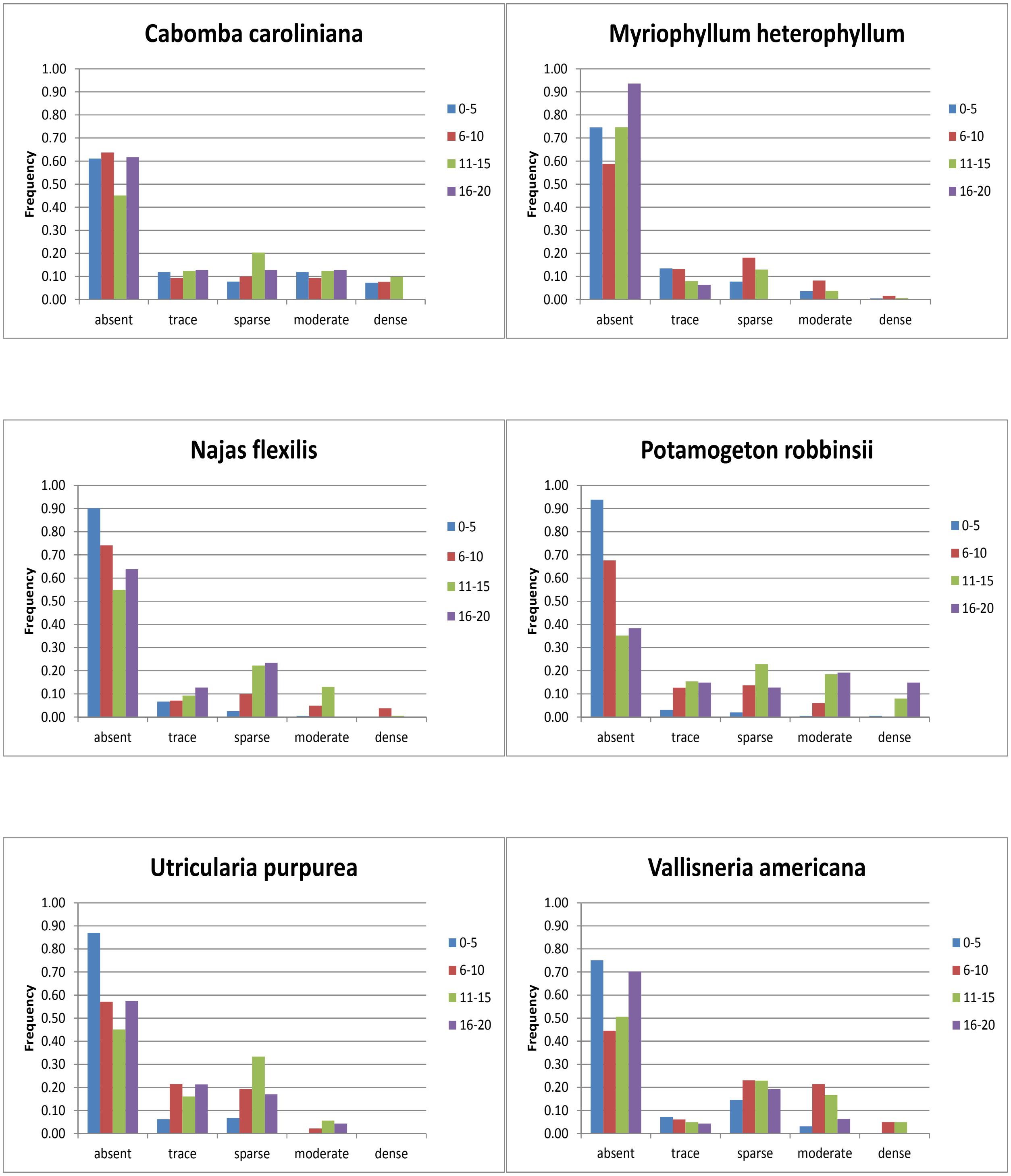
The pattern of plant cover over depth (Figure 37) shows only slight change, with slightly higher values for the 6-10 and 11-15 ft water depths. Light and substrate limit growths in shallower and deeper water, and this is a common observation in many area lakes. Mean cover values are all greater than 2, indicating that at least 26-50% of the bottom is covered on average. Biovolume exhibits a decline with increasing depth, which is partly related to there being more water column to fill as the water gets deeper. Values in shallow water are still <2, suggesting that about 25% of the water column is filled, and the values for deeper water are lower, indicating no extensive filling of the water column on average. This does not preclude smaller areas of high biovolume in any of the water depth categories, and we know that there are nuisance growths in some area. Yet on average, cover and biovolume do not indicate serious problems for lake users.

Figure 37. Cover and biovolume ratings in relation to water depth.



Looking at representative individual species (Figure 38), there are differences based on the ecology of each species. Fanwort (Cabomba Carolinian) has a similar distribution of density across all four depth

Figure 38. Plant biovolume in relation to water depth for six species.



categories, while variable watermilfoil (*Myriophyllum heterophyllum*) is rare in water >15 ft deep and attains greatest density in water 6-10 ft deep. Bushy naiad (*Najas flexilis*) and Robbins' pondweed (*Potamogeton robbinsii*) can be found at any depth, but are more common as the water becomes deeper, up to about 20 ft. Purple bladderwort (*Utricularia purpurea*) is rare in water <5 ft deep, but has a fairly even distribution in water 6-20 ft deep. Water celery (*Vallisneria americana*) is more common at intermediate depths (6-15 ft). Some of the species not shown, such as watershield and both white and yellow water lilies, are distinctly shallow water species, rarely found in water >10 ft deep. As with most lakes, there is a zonation of plant assemblages as water depth changes. In Webster Lake, however, that zonation is not as distinct as in many other lakes, as a consequence of more variable substrate distribution and its effect on which plants thrive where.

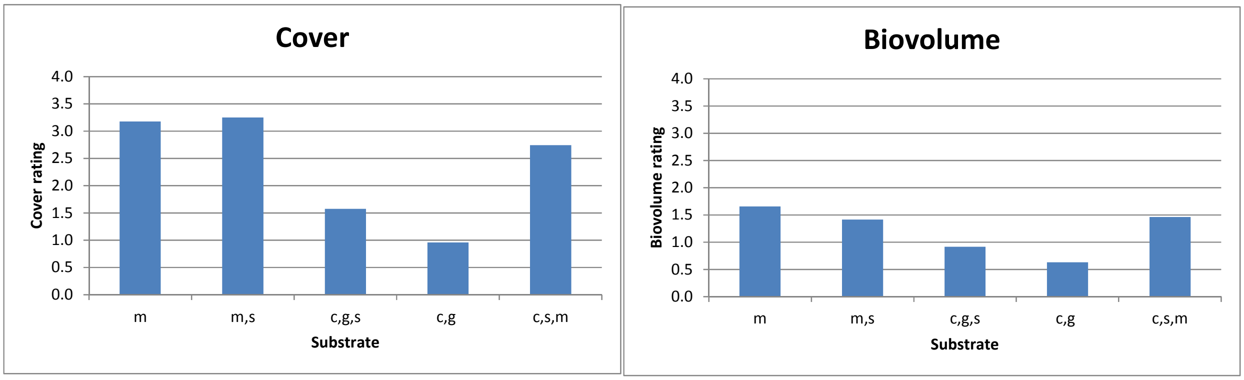
The Impact of Substrate

The primary substrates in Webster Lake include muck (m), sand (s), gravel (g) and cobble (c). Few plants grow on bare rock, but some will root through gravel and most grow well on sand or muck. As the muck gets finer, however, water and gas exchange become more difficult, so pure muck is not necessarily a desirable plant medium. A mix of sand and muck usually optimizes plant growth, and is common in the deeper areas of most lakes. In Webster Lake, however, areas of cobble and/or gravel can occur almost anywhere; distance from shore is not as useful a predictor of sediment features as in most lakes.

Cover is similar for muck and sand substrates (Figure 39) and only slightly smaller for the combination of cobble, sand and muck. The combination of cobble and gravel produced the lowest average cover rating, followed by the cobble, gravel and sand mix. Cover in muck and sand substrates exceeded 3, which translates into at least 50-75% cover. Cover on cobble/gravel substrate averaged just under 1, indicating <25% cover, so substrate clearly plays a major role in determining plant abundance.

Biovolume ratings displayed a similar but more muted pattern. Muck, sand, and the combination of cobble, sand and muck exhibited average biovolume values close to 1.5, suggesting average biovolumes near 25%. The cobble and gravel combination yielded the lowest biovolume at 0.6, which translates into about 10-15% cover. The cobble/gravel/sand combination was intermediate to the others in terms of biovolume rating.

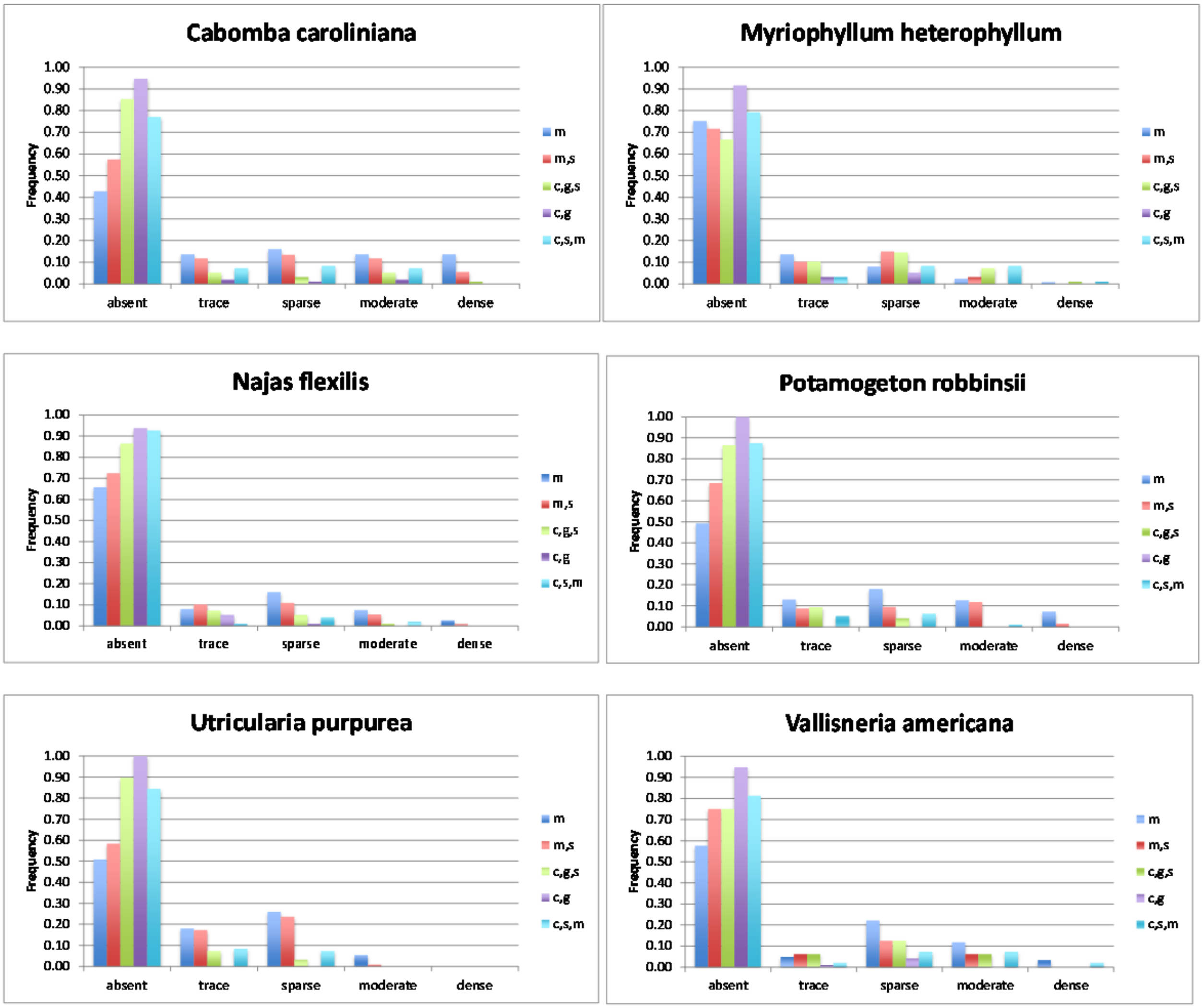
Figure 39. Cover and biovolume ratings in relation to substrate.



Considering representative individual species (Figure 40), fanwort becomes scare on substrates where muck and/or sand are not the dominant components, while variable watermilfoil seems to grow almost independently of substrate type. It appears to grow less well on cobble/gravel or cobble/gravel/muck, but is sometimes the only plant present on those substrates, so it appears to be very hardy. The other four species in Figure 40 exhibit a preference for muck over sand over any of the substrates with cobble and gravel as dominant components.

The presence of muck or sand as a dominant component of the substrate favors dense plant growths, while cobble and gravel as dominant components tend to depress plant abundance. In most lakes, the cobble and gravel substrates are close to shore, with substrate grading to sand and then muck (organic or inorganic) with increasing water depth. In Webster Lake, while this pattern can be found, it is not unusual to find areas of cobble or gravel in water >10 ft deep. This alters the pattern of plant assemblages and introduces more spatial variation than we are used to seeing in area lakes.

Figure 40. Plant biovolume in relation to substrate for six species.



The interaction of water depth (affecting light quality and quantity) and substrate yields the following general plant associations in Webster Lake. The boundaries are not distinct, and assemblages grade into each other, but these groupings define most of what is observed in the lake.

Shallow, mucky area assemblage – dominated by any of fanwort, white water lily, yellow water lily, and/or watershield, sometimes with abundant bronze pondweed, spikerush or burreed under and around lilies. Near the shoreline of such areas, where there will be more sand, swamp loosestrife, purple loosestrife, pickerelweed, emergent arrowhead, or arrow arum may form an emergent fringe. Bladderwort species may be mixed in as well.

Shallow, sandy area assemblage – shallow water nitella, filamentous green algae mats, pipewort, submergent arrowhead, possibly with waterwort, quillwort, and/or hedge hyssop also present. Depending on the depth and mix of other substrates, a wide variety of other plants may be present, including multiple pondweed and bladderwort species, sometimes at elevated densities. The emergent fringe noted above for shallow, mucky areas, may also be present.

Shallow, cobble/gravel area assemblage – may be devoid of plants, but low densities of variable watermilfoil, bushy naiad, water celery, and possibly a few pondweeds and bladderworts may be found.

Intermediate depth (6-15 ft) mucky area assemblage – dominated by fanwort, bladderworts, deep water nitella, bushy naiad and Robbins' pondweed, with other species present at lower densities. Distribution tends to be patchy, with individual species at high density over small areas. Bladderwort tends to be mixed into most areas. Biovolume is highest when fanwort is dominant.

Very deep (>15 ft) mucky area assemblage – usually low densities of deep water nitella, bushy naiad, and Robbins' pondweed are usually encountered. Cyanophyte (blue-green algae) mats may be present or even abundant.

Deep, sandy area assemblage – dominated by a mix of fanwort, variable watermilfoil, water celery, bladderworts and pondweeds, most notably Robbins' pondweed with some bigleaf pondweed mixed in. A wide variety of other species may be present. Density tends to be highest when variable watermilfoil is dominant, but fanwort, pondweeds and bladderwort can fill about half the water column on average.

Deep cobble/gravel area assemblage – usually low plant densities overall, but may have small dense patches or scattered growths of variable watermilfoil, occasional bladderwort or water celery plants, and some filamentous green algae.

The Impact of Herbicide Treatment

A program of organized, scientific plant control has been conducted at Webster Lake for about a decade. The approach and treatment areas into 2011 are discussed in the 2011 WRS data review report. The general focus has been on cove areas and selected shoreline stretches, of which there are many, where growths of fanwort, variable watermilfoil, white and yellow water lilies, and watershield can cause nuisance conditions. Reward (with diquat as its active ingredient) has been most often applied. This is a contact herbicide that requires limited contact time and produces results within a week or two. As a contact herbicide, it only kills the parts of the plant with which it comes into contact, so regrowth from roots, seeds, or unimpacted vegetative parts is likely within a year or two. With repeated treatment, species that depend on vegetative reproduction may decline, and some control over seed producers may be achieved if treatment precedes seed production over multiple years (often 5 or more).

The primary alternative to Reward is Sonar (with fluridone as the active ingredient), a systemic herbicide that kills the entire plant of susceptible species. This is the herbicide of choice for fanwort control, but does not consistently control variable watermilfoil, and is much more expensive than Reward per unit area treated. More problematic is its high diffusivity; while only a low concentration (<20 ppb) is needed to control most susceptible species, contact must be maintained for at least two months and preferably 3-4 months for best results. Except in isolated coves or areas where curtains can be installed, repeated treatment is necessary during the intended contact period to achieve desirable results. Consequently, Reward is used more in Webster Lake than Sonar.

The 2012 treatment program involved treatment of some areas with Reward (Figure 41) and others with Sonar (Figure 42). Only a small area treated with Sonar was not also treated with Reward in 2012. As in past years, areas that are treated are chosen based on plant surveys, with resultant apparent need assessed and priorities established. Budget dictates the total extent of treatment, which does not cover all areas that might be perceived as appropriate for treatment. Additionally, some coves with limited human access are left untreated as “preserve” areas. The concept is to protect at least some weedy habitat, but this also serves to protect population of invasive species, a difficult tradeoff.

As different coves have been treated over the years at different frequencies, and systematic plant surveys have been rare, it is difficult to compare specific areas over space or time with any reliability. We set up comparisons between treated areas and all untreated areas, then reduced the untreated areas to those with depths similar to treated areas, then eliminated cobbly to gravelly substrates that would not be expected to support nuisance growths in untreated areas, and finally restricted the comparison to treated areas vs. areas held as preserves or only rarely treated over the last decade, and not in the last few years, based on the available record.

For treated vs. all untreated sites, there was no discernible difference in cover or biomass (Figure 43), and no species distributions appeared to be appreciably altered (electronic appendix). This is undoubtedly related to the inclusion of many sites in the untreated group that are deeper or have substrate not conducive to nuisance growths, and probably to inclusion of sites that were in fact

Figure 41. Areas of Webster Lake treated with Reward (Diquat) in 2012.

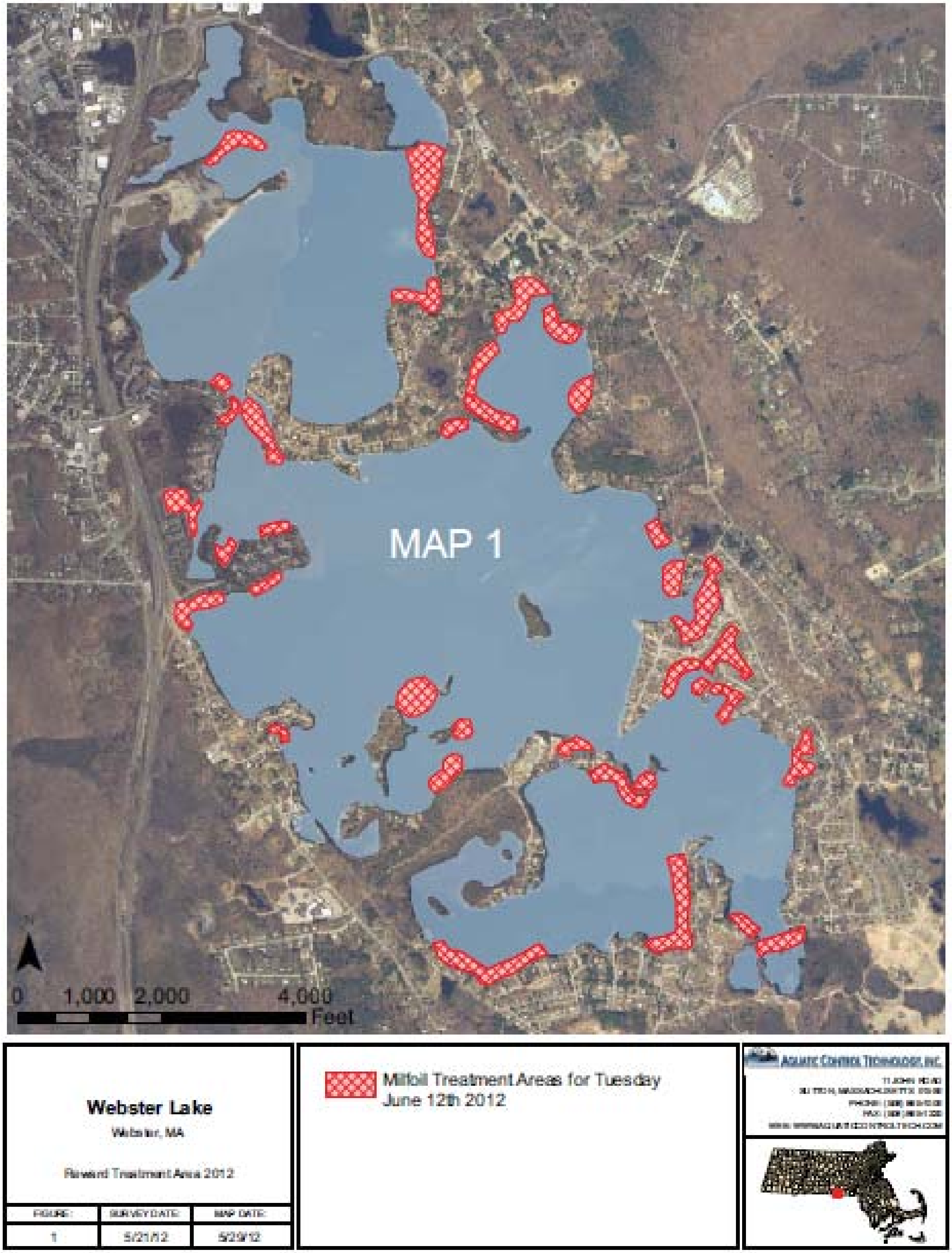


Figure 42. Areas of Webster Lake treated with Sonar (Fluridone) in 2012.

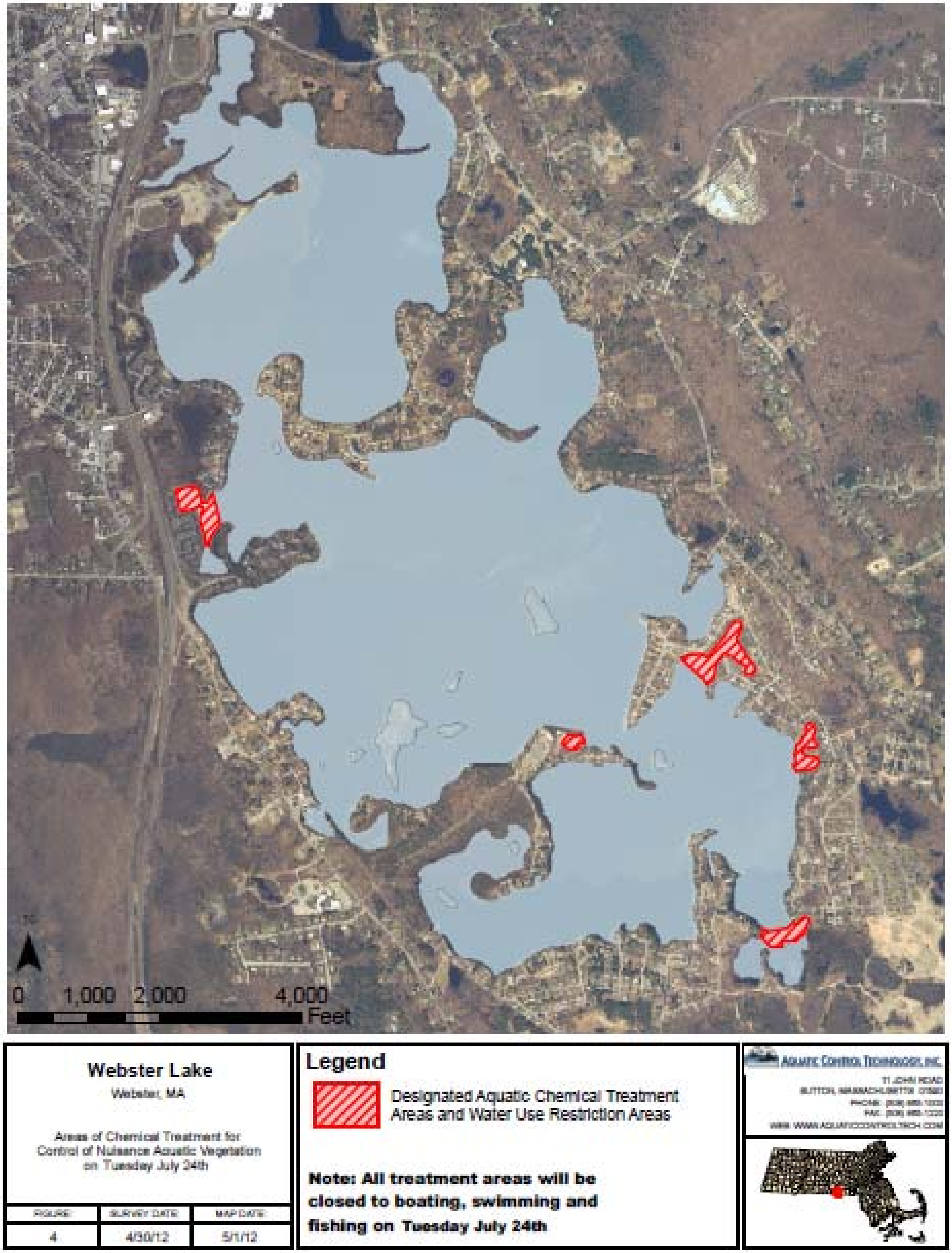
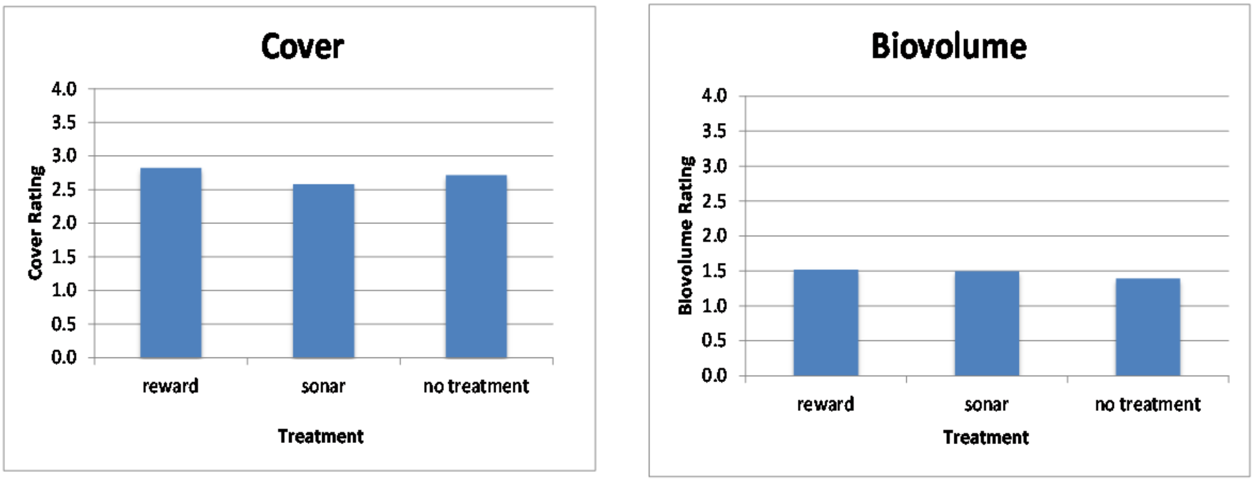


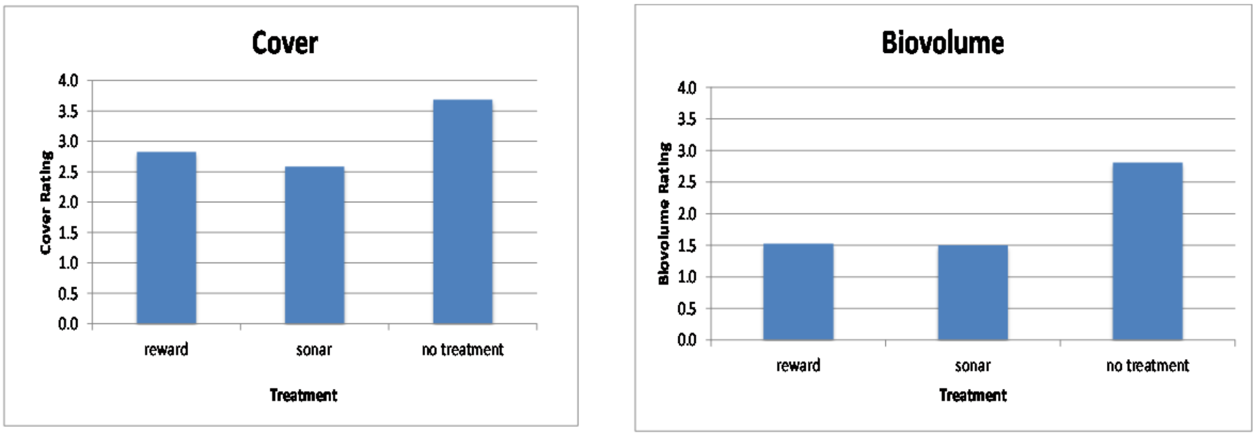
Figure 43. Cover and biovolume for areas treated in 2012 vs. all sites in untreated areas.



treated, just not in 2012. Eliminating deeper sites, where treatment would not typically occur, did not reveal any differences, nor did eliminating both deeper sites and those with gravel or cobble as the dominant substrate. The problem may indeed lie with a decade of treatment history (see the 2011 WRS review report) that has facilitated treatment of any area in need; comparing areas treated in 2012 with any subset of areas not treated in that year ignores this history.

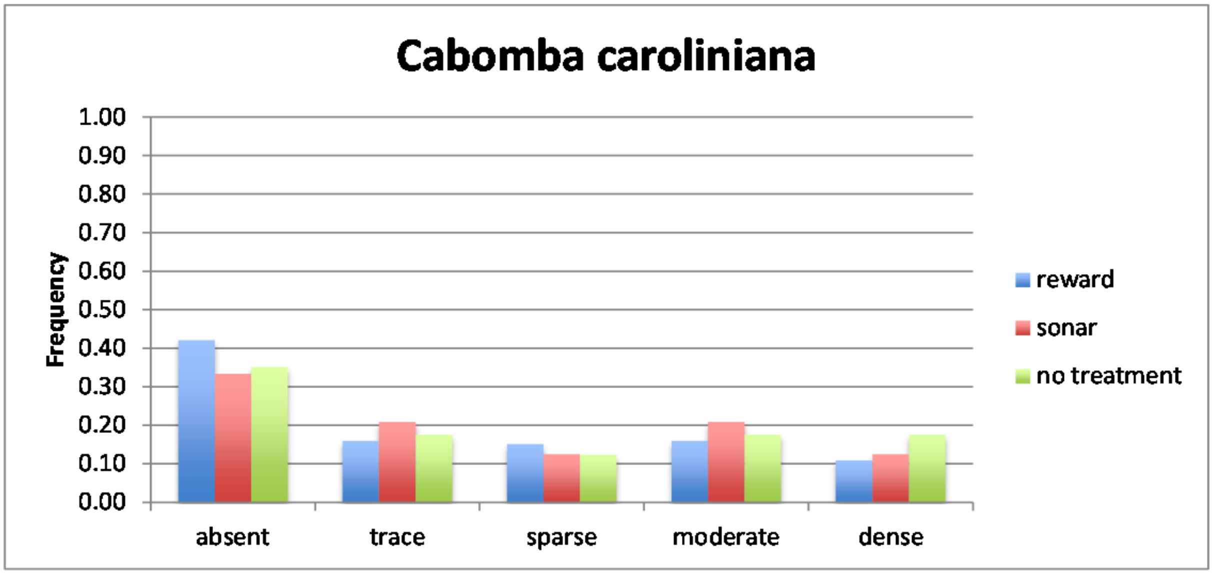
To resolve this issue, we compared the data for sites treated in 2012 with areas not known to have been treated in at least 5 years, focusing mainly on the areas set aside as habitat preserves (Figure 44). This represents a comparison of sites that were considered to need treatment in 2012 due to dense plant growths to sites that have been known to harbor dense plant growths but have not been treated ever or in many years. The result is more striking, with cover in the untreated areas about 25% greater than in treated areas and biovolume almost twice as high in the untreated areas. This is a more reliable estimate of the impact of treatment on overall plant community features.

Figure 44. Cover and biovolume for areas treated in 2012 vs. sites in rarely or never treated coves.



With regard to the two invasive plant species of greatest concern, fanwort (*Cabomba caroliniana*) and variable watermilfoil (*Myriophyllum heterophyllum*), the change in abundance in response to treatment is variable. Fanwort exhibits slight reduction except for the densest growths, but the average reduction for areas treated with Sonar, the herbicide expected to yield the greatest impact on fanwort, are minimal (Figure 45). The portion of sites without fanwort is not substantially different, but there is a slight decrease in the portion of sites with dense fanwort growths. This is consistent with the overall increase in fanwort in the lake over the last decade; treatment with Sonar may have slowed the expansion and reduced fanwort in some areas, but overall it has not produced any lasting reduction.

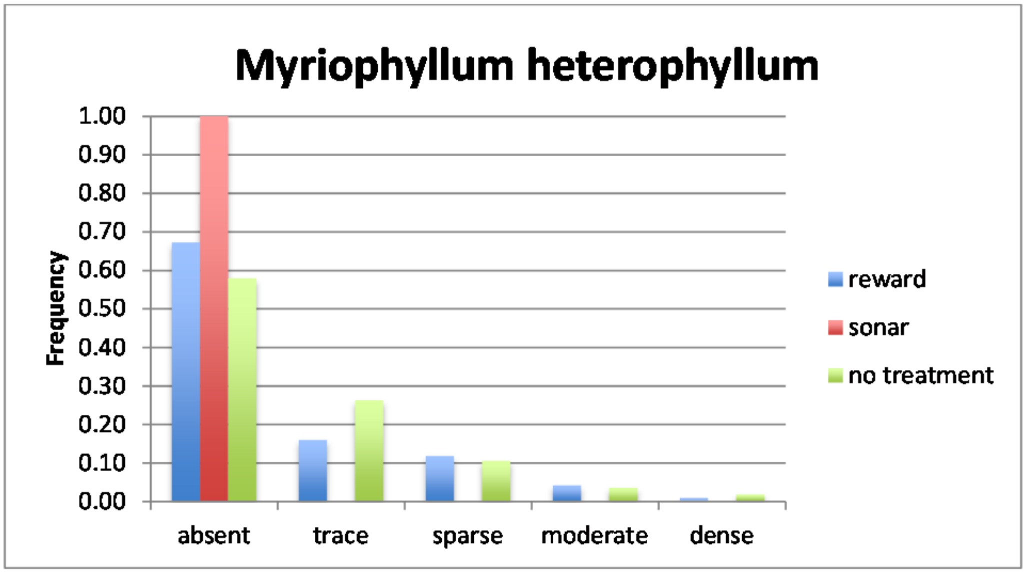
Figure 45. Frequency of fanwort density categories for treated and untreated areas of Webster Lake in 2012.



For variable watermilfoil, there are no sites treated with Sonar that have variable watermilfoil (Figure 46). This suggests a much greater effectiveness of Sonar on milfoil than expected, and may be more a consequence of not treating milfoil-infested areas with Sonar. Sonar is applied to Webster Lake mainly for the control of fanwort, and while fanwort and milfoil can co-occur, areas of dense fanwort growth that would be targeted for Sonar treatment would not be expected to have much milfoil present.

For areas treated with Reward, there are more sites where variable watermilfoil is absent, and fewer sites where it is found in trace amounts, but there is no appreciable difference with untreated sites with regard to sparse, moderate or dense growths of milfoil. The number of sites with moderate or dense growths is very small, suggesting that treatment has been successful where applied and that treatment has not been conducted where it is not needed to control nuisance growths. It does appear that the preserve areas are not heavily infested with milfoil, something that cannot be said about fanwort.

Figure 46. Frequency of variable watermilfoil density categories for treated and untreated areas of Webster Lake in 2012.



Overall, it appears that treatment of Webster Lake with herbicides lowers plant coverage and density and facilitates human uses, but it does not result in long-term elimination of the target nuisance species from the lake. Rather, it keeps infested areas at a low enough plant density to facilitate uses, and is not used on the large scale necessary to attempt complete control throughout the lake. Treatment in Webster Lake is a maintenance activity, and has not been represented as anything else in the available reports.

Comparison between 2003 and 2012 Surveys

Plant composition aspects of the 2003 and 2012 have already been discussed; here we examine more quantitative comparison. The 2003 and 2012 surveys involved different points and different survey methods, so comparison involves some adjustments and interpretation, but is a worthwhile exercise. The 2003 survey used visual assessment in shallow water and throw rakes in deeper water, but emphasized mostly shallow locations, of which there were 84. The 2012 survey used visual assessment by underwater video system at 584 points, extending into water up to 20 ft deep. Throw rakes will miss some species that one might see visually, and do not allow direct cover or biovolume ratings, although a similar system of abundance based on what comes up with the rake can be applied. Visual surveys may not afford the collection of plant material for more detailed taxonomic assessment, and may miss low density growths of one species hidden among more dense growths of other species.

The most direct and defensible comparison is to use the frequency of plant occurrence, with consideration of abundance ratings after some conversion to get values from different surveys on the same scale. We have done this using all 2003 points vs. all 2012 points, and again after selecting the 2012 point that most closely matches each 2003 point, to adjust for possible differences in the depth and substrate variation induced by using all 584 of the 2012 points (Table 2). In Table 2, shaded areas indicate differences between shaded cells. We compare the 2003 data to the 2012 data for the matched points and those matched point data with the larger 2012 data set.

For cover, there appear to be more low cover (0-2) ratings and fewer high cover ratings (3-4) in 2003 than in 2012. This suggests that there is more plant cover now than back in 2003, and the comparison of the complete and reduced 2012 data sets indicates that this is not an artifact of sample site selection.

For biovolume, there are differences among the data sets, but nothing substantial enough to conclude that there is a major difference between 2003 and either the reduced or complete 2012 data sets. The full 2012 data set and the 2003 data set agree on portion of sites with a biovolume rating of 1, but the reduced 2012 data set exhibits a lower value. The portion of sites with a rating of 2 is lower in 2003, accounting for the difference in portions with a rating of 1. The 2003 and reduced 2012 data sets roughly agree on the portion of sites with dense growths (biovolume = 4), but the full 2012 data set exhibits a lower value. This is probably a result of 2003 and reduced 2012 data sets reflecting more shallow water stations, where biovolume tends to be greater, and indicates the importance of determining the purpose of a survey ahead of time and designing it accordingly. If the overall condition of the lake is the focus, overemphasis on shallow water sites will affect condition assessment. If the survey is to assess treatment needs and effectiveness, a focus on shallow water sites may be justified.

When we look at the frequency of occurrence of individual plant species that are considered more abundant in Webster Lake, we do find numerous differences. The frequency of variable watermilfoil, Eurasian watermilfoil, bigleaf pondweed, bushy naiad, watershield, nitella, and waterweed are all lower in 2012 than in 2003, most by substantial amounts. Of those species, only bushy naiad shows a difference between the reduced and complete 2012 data sets that suggests that much of the apparent decrease could be related to site selection, but even then, the 2003 frequency is still larger than that of the complete 2012 data set. The frequency of fanwort in 2012 is markedly increased over the 2003 value, consistent with general observations over the intervening years by herbicide applicators in their annual reports.

When we look at the reduced and complete data sets for 2012, we find that the reduced data set yields substantially different values for bushy naiad (as noted above), bladderwort, and both white and yellow water lily. So even though the combined bladderwort frequency and that of the lilies was not different between 2003 and the reduced 2012 data sets, the 2012 reduced data set may not be representative of the whole lake. This pertains to extrapolating to the whole lake from a relatively small number of sites, and is why we surveyed so many sites in 2012. The potential for a reduced number of sites to provide adequate data will be examined separately.

Considering only the number of sites where a potentially abundant plant is dominant, we find that variable watermilfoil, bladderwort, and bigleaf pondweed are less often dominant in 2012 than in 2003. Fanwort and water celery are more often dominant in 2012 than in 2003. Fanwort surely is more abundant and has greater dominance now than in 2003, but the change in water celery may relate more to methods; water celery was never found to be a dominant in 2003, but throw rakes will not catch much water celery and this plant achieves maximum density in deeper water. Only white water lily shows any discrepancy between dominance in the reduced and complete 2012 data sets, and the 2003 value is intermediate to the two 2012 values.

Table 2. Comparison of 2003 and 2012 data.

	2003 Sites	2003 Sites	2012 Sites
	2003 data	2012 data	2012 data
Mean Cover Rating	2.0	2.8	2.7
Cover 0-25% (0-1)	42.9%	25.0%	26.0%
Cover 26-50% (2)	32.1%	6.0%	9.8%
Cover 51-75% (3)	9.5%	20.5%	19.5%
Cover 76-100% (4)	15.5%	48.2%	44.7%
Mean Biovolume Rating	1.7	1.7	1.4
Biovolume 0-25% (0-1)	65.5%	56.0%	65.4%
Biovolume 26-50% (2)	13.1%	22.9%	24.5%
Biovolume 51-75% (3)	9.5%	7.2%	4.3%
Biovolume 76-100% (4)	11.9%	13.3%	5.8%
Bladderwort frequency	74.1%	77.0%	97.9%
Variable watermilfoil frequency	52.9%	33.7%	28.8%
White water lily frequency	41.2%	34.9%	14.2%
Robbin’s pondweed frequency	35.3%	24.1%	35.1%
Bigleaf pondweed frequency	49.4%	8.4%	11.3%
Bushy naiad frequency	35.3%	16.9%	26.7%
Watershield frequency	27.1%	12.0%	7.4%
Yellow water lily frequency	23.5%	22.9%	7.7%
Nitella frequency	30.6%	2.4%	5.5%
Waterweed frequency	23.5%	0.0%	0.0%
Eurasian watermilfoil frequency	18.8%	0.0%	0.0%
Fanwort frequency	10.6%	47.0%	41.6%
Water celery frequency	32.9%	36.1%	41.6%
Dominant sites: bladderwort	21.2%	8.0%	6.8%
Dominant sites: variable milfoil	16.5%	4.8%	5.7%
Dominant sites: white water lily	12.9%	21.7%	7.7%
Dominant sites: Robbin's pondwee	10.6%	8.4%	12.3%
Dominant sites: bigleaf pondweed	9.4%	0.0%	0.0%
Dominant sites: bushy naiad	8.2%	6.0%	6.7%
Dominant sites: watershield	7.1%	1.2%	2.7%
Dominant sites: yellow water lily	5.9%	8.4%	2.7%
Dominant sites: nitella	4.7%	1.2%	0.9%
Dominant sites: waterweed	3.5%	0.0%	0.0%
Dominant sites: Eurasian milfoil	3.5%	0.0%	0.0%
Dominant sites: fanwort	0.0%	27.7%	18.8%
Dominant sites: water celery	0.0%	9.6%	15.8%

Implications for Future Surveys

The 2012 survey serves as an important baseline for past and future comparisons. However, the primary question for a lake as large as Webster Lake relates to how few sites can be surveyed and still acquire enough data for reliable assessment of conditions. Comparison of the 84 site data from 2003 to the full 2012 data for 584 sites (Table 2) suggests some differences that may relate to number and placement of sites, but comparison between all 2012 sites and just those that match 2003 sites suggests that many differences represent real changes in the plant community. Where there are differences that seem to relate to reduced number of survey sites, they appear to be a function of reduced survey sites being more often shallow sites, and therefore favoring higher biovolume measurements and shallow water species such as water lilies.

To address the question of minimum sites for a valid survey more scientifically, we compared the full 2012 data set to data sets obtained by reducing the number of points by half, two thirds and three quarters (Table 3). Somewhat surprisingly, the frequency of species occurrence or the frequency of any density category (trace, sparse, moderate and dense) is only minimally impacted by reducing the number of site assessed by up to three quarters (from 584 to 146 sites). The reduction was done by deleting every other point, two points out of every three, or three out of every four, so this does not address what happens if selected sampling sites favor shallower water, which is how most annual surveys are conducted. Yet it appears that a reasonable impression of the overall plant community can be obtained with measurements at as few as 146 sites, a survey that could be accomplished in one field day at reasonable cost.

Considering surveys that focus on shallow water, either 0-5 ft (Table 4) or 6-10 ft (Table 5), there is no major difference in the results for the full data set and a reduction by 50%. This changes the number of points from 193 to 97 for the 0-5 ft depth interval and 182 to 91 for the 6-10 ft depth interval. This suggests that surveys focusing on the areas where treatments have most often been conducted can be based on few enough points to make this a cost effective exercise. It may be completely acceptable to simply cruise the coves looking for nuisance growths when deciding where to treat, but more regimented surveys are advised if treatment results are to be properly documented.

Table 3. Comparison of full and reduced 2012 data sets.

Total frequency

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	584	2.7	1.4	0.02	0.07	0.42	0.01	0.13	0.08	0.30	0.01	0.29	0.27	0.05	0.10	0.08	0.14	0.03	0.01	0.11	0.05	0.03	0.10	0.35	0.00	0.36	0.15	0.46	0.42
Half	293	2.8	1.4	0.03	0.07	0.43	0.02	0.13	0.08	0.29	0.01	0.31	0.28	0.05	0.09	0.08	0.13	0.03	0.00	0.11	0.05	0.03	0.10	0.36	0.00	0.35	0.15	0.47	0.43
Third	195	2.7	1.4	0.03	0.08	0.44	0.02	0.11	0.11	0.27	0.01	0.32	0.27	0.05	0.09	0.07	0.14	0.05	0.01	0.10	0.05	0.04	0.09	0.34	0.01	0.38	0.17	0.46	0.43
Quarter	146	2.8	1.4	0.03	0.08	0.40	0.03	0.13	0.06	0.28	0.01	0.32	0.27	0.03	0.10	0.07	0.13	0.03	0.01	0.12	0.04	0.03	0.10	0.36	0.01	0.31	0.12	0.47	0.40

Frequency of trace values

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	584	2.7	1.4	0.00	0.01	0.11	0.01	0.02	0.02	0.05	0.01	0.11	0.08	0.01	0.01	0.02	0.02	0.00	0.01	0.08	0.02	0.03	0.07	0.10	0.00	0.15	0.08	0.22	0.06
Half	293	2.8	1.4	0.00	0.01	0.10	0.02	0.01	0.01	0.04	0.01	0.10	0.09	0.01	0.01	0.02	0.01	0.00	0.00	0.06	0.02	0.02	0.06	0.11	0.00	0.14	0.07	0.20	0.06
Third	195	2.7	1.4	0.00	0.02	0.11	0.02	0.02	0.02	0.04	0.01	0.11	0.09	0.01	0.02	0.02	0.02	0.01	0.01	0.07	0.02	0.03	0.07	0.07	0.01	0.21	0.08	0.21	0.04
Quarter	146	2.8	1.4	0.00	0.02	0.08	0.03	0.01	0.02	0.03	0.01	0.10	0.08	0.01	0.01	0.02	0.03	0.01	0.01	0.08	0.01	0.02	0.08	0.11	0.01	0.11	0.06	0.18	0.06

Frequency of sparse values

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	584	2.7	1.4	0.02	0.03	0.12	0.00	0.07	0.05	0.18	0.00	0.12	0.12	0.03	0.05	0.03	0.05	0.02	0.00	0.03	0.03	0.01	0.03	0.12	0.00	0.19	0.05	0.22	0.20
Half	293	2.8	1.4	0.02	0.03	0.14	0.00	0.08	0.05	0.18	0.00	0.14	0.14	0.03	0.03	0.03	0.05	0.03	0.00	0.04	0.02	0.01	0.04	0.12	0.00	0.18	0.05	0.24	0.20
Third	195	2.7	1.4	0.03	0.04	0.14	0.00	0.06	0.07	0.15	0.00	0.15	0.11	0.03	0.05	0.02	0.05	0.03	0.00	0.03	0.04	0.01	0.02	0.14	0.00	0.15	0.07	0.22	0.23
Quarter	146	2.8	1.4	0.03	0.03	0.14	0.00	0.07	0.03	0.20	0.00	0.13	0.16	0.01	0.05	0.02	0.05	0.03	0.00	0.04	0.03	0.01	0.03	0.12	0.00	0.16	0.03	0.25	0.19

Frequency of moderate values

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	584	2.7	1.4	0.00	0.03	0.11	0.00	0.01	0.01	0.06	0.00	0.05	0.05	0.01	0.03	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.03	0.02	0.02	0.13
Half	293	2.8	1.4	0.00	0.02	0.10	0.00	0.01	0.01	0.05	0.00	0.05	0.05	0.01	0.03	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.03	0.03	0.03	0.14
Third	195	2.7	1.4	0.00	0.03	0.11	0.00	0.02	0.01	0.07	0.00	0.06	0.07	0.02	0.02	0.03	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.03	0.02	0.04	0.12
Quarter	146	2.8	1.4	0.00	0.03	0.08	0.00	0.01	0.01	0.04	0.00	0.07	0.03	0.01	0.03	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.03	0.03	0.03	0.12

Frequency of dense values

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	584	2.7	1.4	0.00	0.00	0.08	0.00	0.03	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.03
Half	293	2.8	1.4	0.00	0.00	0.07	0.00	0.03	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.03
Third	195	2.7	1.4	0.00	0.00	0.07	0.00	0.03	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.04
Quarter	146	2.8	1.4	0.01	0.00	0.08	0.00	0.03	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.03

Table 4. Comparison of 2012 total and half data sets for sites 0 to 5 feet deep.

Total frequency at 0-5 ft

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	193	2.6	1.7	0.01	0.19	0.34	0.04	0.32	0.17	0.33	0.03	0.25	0.10	0.02	0.22	0.20	0.38	0.05	0.02	0.05	0.13	0.05	0.19	0.06	0.01	0.13	0.13	0.28	0.25
Half	97	2.5	1.7	0.01	0.20	0.33	0.04	0.29	0.15	0.29	0.05	0.25	0.10	0.02	0.25	0.20	0.40	0.06	0.01	0.04	0.07	0.03	0.20	0.05	0.00	0.11	0.09	0.25	0.22

Frequency of trace values (0-5 ft)

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	193	2.6	1.7	0.00	0.03	0.12	0.04	0.04	0.02	0.02	0.03	0.13	0.07	0.01	0.02	0.04	0.03	0.01	0.02	0.03	0.05	0.03	0.11	0.03	0.01	0.06	0.06	0.17	0.07
Half	97	2.5	1.7	0.00	0.03	0.09	0.04	0.04	0.02	0.03	0.05	0.15	0.07	0.01	0.02	0.03	0.01	0.01	0.01	0.01	0.04	0.03	0.12	0.02	0.00	0.07	0.03	0.15	0.04

Frequency of sparse values (0-5 ft)

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	193	2.6	1.7	0.01	0.08	0.08	0.00	0.15	0.11	0.22	0.00	0.08	0.03	0.01	0.10	0.07	0.13	0.04	0.00	0.02	0.08	0.02	0.07	0.02	0.00	0.07	0.05	0.12	0.15
Half	97	2.5	1.7	0.00	0.08	0.10	0.00	0.13	0.12	0.19	0.00	0.05	0.02	0.00	0.10	0.06	0.12	0.05	0.00	0.03	0.03	0.00	0.07	0.02	0.00	0.04	0.03	0.09	0.13

Frequency of moderate values (0-5 ft)

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	193	2.6	1.7	0.00	0.07	0.12	0.00	0.04	0.02	0.09	0.00	0.04	0.01	0.01	0.08	0.06	0.15	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.02	0.00	0.03
Half	97	2.5	1.7	0.00	0.08	0.09	0.00	0.02	0.00	0.07	0.00	0.04	0.01	0.01	0.12	0.07	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.04

Frequency of dense values (0-5 ft)

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	193	2.6	1.7	0.01	0.08	0.08	0.00	0.15	0.11	0.22	0.00	0.08	0.03	0.01	0.10	0.07	0.13	0.04	0.00	0.02	0.08	0.02	0.07	0.02	0.00	0.07	0.05	0.12	0.15
Half	97	2.5	1.7	0.00	0.08	0.10	0.00	0.13	0.12	0.19	0.00	0.05	0.02	0.00	0.10	0.06	0.12	0.05	0.00	0.03	0.03	0.00	0.07	0.02	0.00	0.04	0.03	0.09	0.13

Table 5. Comparison of 2012 total and half data sets for sites 6 to 10 feet deep.

Total frequency at 6-10 ft

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	182	2.8	1.3	0.01	0.03	0.34	0.00	0.07	0.08	0.32	0.00	0.41	0.26	0.03	0.09	0.03	0.04	0.02	0.00	0.20	0.02	0.03	0.11	0.32	0.00	0.43	0.18	0.50	0.55
Half	91	2.7	1.3	0.01	0.02	0.36	0.00	0.04	0.10	0.31	0.00	0.42	0.24	0.02	0.09	0.05	0.04	0.03	0.00	0.22	0.03	0.03	0.11	0.36	0.00	0.40	0.14	0.46	0.49

Frequency of trace values (6-10 ft)

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	182	2.8	1.3	0.00	0.00	0.09	0.00	0.02	0.07	0.05	0.00	0.15	0.04	0.02	0.01	0.05	0.01	0.01	0.00	0.18	0.01	0.02	0.09	0.15	0.00	0.20	0.09	0.22	0.05
Half	91	2.7	1.3	0.00	0.00	0.09	0.00	0.02	0.03	0.05	0.00	0.13	0.07	0.02	0.01	0.03	0.02	0.01	0.00	0.15	0.01	0.02	0.09	0.13	0.00	0.21	0.08	0.25	0.06

Frequency of sparse values (6-10 ft)

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	182	2.8	1.3	0.01	0.01	0.12	0.00	0.02	0.03	0.18	0.00	0.15	0.13	0.00	0.07	0.00	0.02	0.01	0.00	0.04	0.02	0.01	0.02	0.13	0.00	0.18	0.02	0.19	0.18
Half	91	2.7	1.3	0.01	0.02	0.10	0.00	0.05	0.04	0.17	0.00	0.18	0.10	0.00	0.05	0.01	0.02	0.01	0.00	0.04	0.01	0.01	0.02	0.14	0.00	0.19	0.06	0.21	0.23

Frequency of moderate values (6-10 ft)

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	182	2.8	1.3	0.00	0.00	0.09	0.00	0.00	0.00	0.08	0.00	0.09	0.03	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.02	0.03	0.05	0.20
Half	91	2.7	1.3	0.00	0.00	0.09	0.00	0.00	0.01	0.09	0.00	0.08	0.05	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.02	0.04	0.03	0.21

Frequency of dense values (6-10 ft)

Points	# points	Cover	Biovol	BG	B schreb	Cab car	Dec vert	Eleo acic	Erio sep	Fil green	Ly sal	My het	Naj flex	Nit flex	Nit spl	N var	N odor	Sag gram	Pont cord	Pot ampli	Pot epi	Pot pus	Pot spir	Pot rob	T lat	Ut purp	Ut vulg	Ut gib	Val am
Total	182	2.8	1.3	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Half	91	2.7	1.3	0.00	0.00	0.08	0.00	0.01	0.00	0.01	0.00	0.02	0.04	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05

Implications for Future Management

The 2012 plant survey suggests that there has been an overall increase in plant cover since 2003 but no major increase in the portion of the water column filled. This may relate to differences in survey locations and methods, but may also be a result of treatment, which has opened up coves that would otherwise be choked with weeds. With the irregular shape of Webster Lake, there are more cove and distinct shoreline areas than in many other lakes, so these areas represent a substantial portion of the lake, and many have homes on them and are expected to provide access to the main body of each basin. However, with the large area of the lake overall, these coves and nearshore areas do not represent the majority of lake area. Discussion of "average" conditions within each basin or in Webster Lake overall may be misleading in terms of satisfaction with conditions over the range of locations where people interact with the lake. Consideration of coves and shoreline areas only, however, can also be misleading in terms of overall quality of the lake use experience. Management planning should take this dichotomy into consideration and be clear on goals and the approach to be taken to assess achievement of objectives.

Plant management tends to focus on peripheral areas, and there is no reason to be concerned about areas deeper than about 20 ft, but the intermediate areas do support plant life. While the potential for nuisance conditions in water deeper than about 10 ft is limited, the area between 10 and 20 ft deep represents a possible source of invasive species to nearshore areas. This survey has determined that both fanwort and variable watermilfoil, the two invasive species of greatest concern at this time, are present in water up to 20 ft deep and can be abundant in water up to 15 ft deep. Lack of management of deeper populations of invasive species will allow colonization of shallower, peripheral areas and necessitate repeat management of plant nuisances in those areas.

The area over which invasive species can occur is very large in Webster Lake, and management options for dealing with such an area cost effectively are very limited. Different herbicides are required for each of the two primary invasive species (fanwort and variable milfoil), and have been applied with some success over the last decade. Treatment of all infested areas would seem to be cost prohibitive, however, without even considering the likely need for re-application every few years. Application of follow up physical methods such as hand harvesting or benthic barriers would be inefficient on the necessary scale, and not inexpensive either. Settling for control in coves considered to need relief from plant nuisances seems to be a rational decision in this case. While growths in other areas represent future threats, in at least deeper water there are no nuisances to human users and aquatic habitat is not substantially impaired. If money and permits were not obstacles, attacking all invasive growths would be worth considering, but costs and regulatory restrictions are indeed factors and play a role in lake management decisions.

This project does not seek to perform a detailed analysis of all available options, but some simple observations are possible. Other means to control the primary invasive species over large areas include drawdown and dredging. Drawdown is possible up to a few feet, but not to depth necessary to impact even a majority of invasive populations. Even if such capability could be built into the outlet structure, refilling the lake from a drawdown in excess of 5 ft would probably not be possible over the course of winter and spring, creating habitat and user issues possibly worse than plant nuisances. Dredging is an extremely expensive endeavor, and disposal options and cost are strongly influenced by sediment quality. No testing of Webster Lake sediments has been performed recently, but as the average values for some contaminants in Massachusetts lake exceeds the standards for simple, least cost disposal, it can be assumed that the cost of removing sediment and controlling plant growth by light or substrate limitation will be very, very costly. Dredging might be considered for a few mucky coves that require frequent retreatment, but does not represent a viable option for much of Webster Lake.

There are no biological agents that would be likely to control either fanwort or variable watermilfoil and are legal in Massachusetts; there is some potential for grass carp to achieve control, but these are not legal in this state and can have undesirable side effects (e.g., loss of other vegetation, increase in algae) that make this approach questionable even if it was legal. Other physical controls may be applicable on a localized basis, but are not suitable for widespread control. Alternative herbicides are available, but may not be approved for use in this case. 2,4-D is very effective on variable watermilfoil, but is not approved for use in lakes with sandy soils and nearby wells; use in Webster Lake would be very unlikely to be approved. Some newer formulations may be worth trying, and any systemic herbicide that can be applied in a cost effective manner is worth considering. Alternative contact herbicides, such as Clipper (with flumioxazin as its active ingredient) for variable watermilfoil may be worth testing, just to avoid potential development of resistance in species in areas that are repeatedly treated. Other herbicides might be considered as our experience with them increases and they are approved for use in Massachusetts.

There is evidence that variable milfoil is declining in Webster Lake. This may be a function of treatment or competition, particularly with fanwort, which has been increasing. And as the only herbicide used on fanwort (Sonar) requires extended contact time and diffuses readily, fanwort will be very difficult to control in Webster Lake. Even if sufficient funds to perform major treatments and appropriate follow up were available, fanwort is present in areas where treatment has been avoided to maintain high density plant growths as habitat for certain forms of aquatic life. Re-infestation of many areas would therefore be expected unless a lakewide campaign against fanwort was conducted, and this may not be possible on both cost and regulatory grounds.

It is not clear how much more dominant fanwort will become in Webster Lake. It has increased in frequency from about 10% to 45% over ten years, but is at moderate or high densities in only about 20% of the sites where it occurs. This represents a substantial area in terms of potential use impairment and control cost, but not an especially large area of the lake overall. More effective control in targeted areas would be desirable, but it is not certain how this can be achieved without substantial increase in cost and/or user inconvenience. Use of curtains to maintain Sonar levels in target areas increases cost and inconvenience. Alternative herbicides with high specificity and strong success against fanwort are not known. The current approach of maintenance treatments on an as needed basis may be the most cost effective management approach, but the association should remain vigilant and open to new ideas and options.