Maryland Department of Natural Resources

Tidewater Ecosystem Assessment

Deep Creek Lake
Submerged Aquatic Vegetation Survey
Year 3

Report of Survey Activity and Results

December 2012

Prepared For

Maryland Department of Natural Resources

Maryland Park Service

Prepared by Landry, J.B., R.R. Raves, M.J. Lewandowski, and L. Karrh

EXECUTIVE SUMMARY

Submerged aquatic vegetation can be found in a variety of aquatic habitats and forms the foundation of a healthy lake ecosystem. Similar to their terrestrial counterparts, SAV are underwater grasses which provide a myriad of important ecological functions. Through the process of photosynthesis, SAV produce oxygen which is vital to the survival of all lake organisms. It provides food, habitat and nursery grounds for many species of fish and invertebrates, absorbs nutrients which decreases the likelihood of algal blooms, improves water clarity by reducing turbidity, diminishes shoreline erosion by reducing the effects of waves and currents, and is a major food source for waterfowl. Healthy native aquatic plant communities also help prevent the establishment of invasive plants like Eurasian Watermilfoil (*Myriophyllum spicatum*).

Maryland Department of Natural Resources (DNR) Resource Assessment Service (RAS) biologists conducted a third season of Submerged Aquatic Vegetation (SAV) monitoring in Deep Creek Lake (DCL), Garrett County, Md, during summer 2012 as part of the lake's expanding water quality and aquatic habitat monitoring program. The project's goal was to define the distribution and relative abundance of SAV species present by surveying transects in six areas throughout the lake using globally accepted methodology. The areas were selected based on spatial distribution and the presence of SAV. The 2012 summer survey was expanded to include a comprehensive shoreline survey of *Myriophyllum* (including the invasive Eurasian Watermilfoil). Monitoring objectives were to define the distribution and relative abundance of all SAV species present in the lake and to record their change over time via the study of representative transects, and to identify the location and extent of *Myriophyllum* via the shoreline survey. Survey results are as follows:

- **The majority of observed species, as well as the physical characteristics of each survey site, showed no significant change in density or distribution from 2010 to 2012 .**

- There is a diverse population of SAV growing throughout the lake with densities ranging from sparse to 100% cover where present.

- Nine genera of vascular plants (sixteen species) and two genera of macroalgae were observed.

- *Sagittaria cristata,* (Crested arrowhead), *Vallisneria americana,* (Wild celery), *Elodea canadensis,* (Canadian waterweed), *Ceratophyllum demersum,* (Coontail), *Myriophyllum spp.,* (Watermilfoil), and *Nitella flexilis* (Nitella) were dominant species observed throughout the lake.

- Species zonation is apparent at every site with *Sagittaria cristata* dominating the shallows; *Potamogeton spp., Vallisneria americana,* and *Ceratophyllum demersum* dominating the mid depths; and *Elodea canadensis, Myriophyllum spp.*, and macroalgae most commonly observed at greater depths.

- The distribution and abundance of these species differ primarily by site, with significant annual changes occurring rarely.
-
- *Potamogeton amplifolius* and *P. robinssii* were observed during the surveys. Both of these species are rare and thought to be extirpated from Maryland waters.

- In 2010, *Myriophyllum* density was higher at Honi Honi than at any other survey site. However, in 2011 there were no differences among sites as *Myriophyllum* density values decreased. Although we observed an increase in frequency of occurrence of *Myriophyllum* at Red Run Cove from 2010 to2012, density did not change over time. There is no evidence that *Myriophyllum* density has increased from 2010 to 2012 based on the six study areas under this assessment.

- Though not specifically identified during the transect surveys, *Myriophyllum spicatum*, or Eurasian Watermilfoil, is present in DCL. This plant is considered an Aquatic Invasive Species. Invasive species are non-native plants or animals that adversely affect the habitats they invade economically and/or ecologically. They disrupt by dominating a region and oftentimes displacing native populations. Over the past 300 years, approximately 50,000 non-native species have become established in the United States; 200 introduced species have viable, wild populations in the Chesapeake Bay watershed.

- In response to concern about Eurasian Watermilfoil in DCL, DNR biologists conducted a comprehensive shoreline survey in July 2012 and will conduct another comprehensive survey for Watermilfoil in late June 2013. Results of the survey indicate that Watermilfoil is present at 130 locations throughout the Lake, but occupies less than 6% (~86 acres) of available benthic habitat. Because 94% of available habitat is free of Watermilfoil, and because it does not occur in monoculture stands to the exclusion of native species, no systemic control measures are recommended at this time.

- The high density and diversity of SAV in DCL is promoting water clarity throughout the lake and providing habitat for a healthy population of fish and invertebrates.

Like most any ecosystem, Deep Creek Lake has a fluctuating environment. Because of its role as a hydroelectric utility, the water level in the lake fluctuates often, which affects the distribution of SAV growing in the lake. There are also periods of heavy precipitation, drought conditions, and record high and low temperatures. Because of its fluctuating environment, it is necessary to maintain a long-term SAV monitoring program in DCL in order to track changes over time.

TABLE OF CONTENTS

INTRODUCTION

During the summer 2012 field season, Maryland Department of Natural Resources (DNR) Resource Assessment Service (RAS) biologists conducted a third year of submerged aquatic vegetation (SAV) monitoring in Deep Creek Lake (DCL). Despite its inherent ecological benefits, SAV can be an impediment to recreation and boat traffic in shallow areas, or in areas with fluctuating water levels. Due to concerns raised by some DCL residents regarding the density of SAV during the summer season, RAS biologists implemented an SAV transect monitoring plan in summer 2010 and repeated the survey in summers 2011 and 2012. The 2012 summer survey was expanded to include a comprehensive shoreline survey of *Myriophyllum* species (including Eurasian Watermilfoil, an invasive species). Our monitoring objectives were to define the distribution and relative abundance of SAV species present in the lake and to record their change over time via the study of representative transects, and to identify the location and extent of *Myriophyllum* via the shoreline survey. This work is a component of the comprehensive water quality and habitat monitoring program in DCL which began in April 2009.

Background

Located in the Allegheny Highlands of western Maryland, in Garrett County, Deep Creek Lake was formed in 1925 when Deep Creek was impounded for hydro-electric power generation. With a surface area of 3,900 acres and 68 miles of shoreline, it is Maryland's largest reservoir. The lake is composed of a mainstem, branches, and multiple small, shallow coves. Because it is a reservoir, the water level fluctuates seasonally due to managed releases (water level draw-downs) and hydrographic conditions, resulting at times in very shallow coves.

In 2000, the State of Maryland purchased the lake bottom and shoreline buffer zone from General Public Utility to be managed as public lands by the Department of Natural Resources (DNR). The acquisition of Deep Creek Lake by Maryland's DNR has presented many unique and challenging management issues to DNR's Park Service.

Since the lake was created in 1925, it has become a four-season travel destination. Towns have grown up around the lake, and much of the lake's shore is now lined with hotels, condominiums, and private homes along the mainstem, branches, and shallow coves. The northern portion of the lake watershed is primarily composed of towns, residential areas, and forested land. The southern portion of the lake watershed is dominated by agricultural land.

Beginning in late spring when temperatures increase, SAV begin growing throughout the lake's photic zone, particularly in the shallower coves, which are the first to receive runoff containing nutrients needed by SAV, and are warmer due to shallower depths. Submerged aquatic vegetation can be found in a variety of aquatic habitats and form the foundation of healthy lake ecosystems. Similar to their terrestrial counterparts, SAV are underwater grasses which provide a myriad of important ecological functions. Through the process of photosynthesis, SAV produce oxygen which is vital to the survival of all lake organisms. It provides food, habitat and nursery grounds for many species of fish and invertebrates, absorbs nutrients which decreases the likelihood of algal blooms, and improves water clarity. It diminishes shoreline erosion by reducing the effects of currents and waves (generated by wind as well as heavy boat wakes), and it is a major food source for waterfowl. Healthy native aquatic plant communities also help prevent the establishment and spread of invasive plants like Eurasian Watermilfoil (*Myriophyllum spicatum*).

There are approximately 70 species of *Myriophyllum*, submersed aquatic plants that are most commonly recognized for their long stems and whorled leaves that are finely, pinnately divided. The name *Myriophyllum* comes from Latin, “myrio” meaning “too many to count”, and “phyllum” meaning “leaf”. Watermilfoil fruits and leaves are an important food source for waterfowl, which are thought to play an important role in seed and clonal dispersal. *Myriophyllum spicatum*, or Eurasian Watermilfoil, is one of three species of *Myriophyllum* found in Deep Creek Lake, but it is the only invasive variety.

METHODS

In June 2010, RAS biologists, accompanied by local SAV experts from Frostburg State University, identified six areas to survey in Deep Creek Lake. These areas were selected based on spatial distribution (two north-western, two central, and two south-eastern) and the presence of SAV. These locations are as follows: Red Run Cove (-79.3711, 39.49977), an area near the town of McHenry (-79.35787, 39.55087), an area near the Honi Honi Bar and Restaurant in Oakland (-79.32091, 39.50485), Meadow Mountain Run Cove (-79.30334, 39.51182), Deep Creek Cove (-79.30904, 39.45368), and Green Glade Cove (-79.26206, 39.47844). See Figure 1 for a map of locations and Table 1 for a list of site abbreviations.

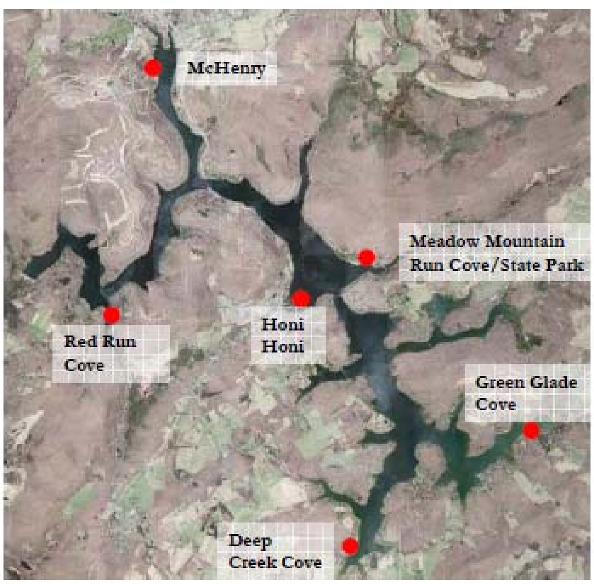


Figure 1. Aerial map of Deep Creek lake with MD DNR SAV survey transect locations indicated by red dots.

Table 1. Transect locations and abbreviations.

Site	Abbreviation
McHenry	McH
Meadow Moutain Run Cove	MMR
Green Glades Cove	GGC
Deep Creek Cove	DCC
Honi Honi Oakland	HHO
Red Run Cove	RRC

At the time each transect location was established in June 2010, the extent of the SAV bed was identified by dive-certified SAV biologists using SCUBA. Along the shoreward edge of the bed, a spot was randomly selected to begin a transect. Rebar was used to mark each point and secure a transect tape. A biologist then swam the tape out, perpendicular to shore, to the deep edge of the

SAV bed where a weighted buoy was placed to mark the point and secure the opposite end of the tape. If conditions were considered unsafe due to heavy boat traffic, transects were terminated prior to the edge of bed. If the SAV bed extended farther than 200 meters from shore, transects were terminated at 200 meters. Both ends of the transect were recorded using a handheld Garmin Global Positioning System (GPS) device so that all future surveys could be repeated in the same location. If the SAV beds expanded or contracted from 2010 to 2011 to 2012, a new point was recorded and the transect was terminated at the current edge of bed.

During each sampling event, SAV biologists sampled eleven $0.25m^2$ quadrats per transect. To establish the sampling positions, the transect lengths were divided by 10 for a total of 11 quadrats per transect. For example, if a transect was 100 meters long, quadrats were sampled at 0m, 10m, 20m, 30m, 40m, 50m, 60m, 70m, 80m, 90, and 100m from the shoreward edge of bed. Within each quadrat, the percent cover of both underwater grasses and macroalgae (MA) were visually quantified for each species present. A total SAV percent cover was also estimated, as well as a total macroalgae percent cover. In this case, SAV is any vascular plant present, whereas macroalgae is any non-vascular plant present. The two groups are quantified and recorded separately because of their differing responses to water quality dynamics. [Note: SAV and MA were not originally separated, so results in this report regarding previous years may vary from results in past reports]. Canopy height for each species present was recorded when possible, as well as water depth at each quadrat. Shoot counts for each species were completed within a smaller square in the bottom right corner of the quadrat when feasible. If the plant could not be identified to the species level, only the genus was recorded.

Transects were surveyed on August 5th and September 16th, 2010, on June 14th, August 9th and September 12th, 2011, and on June 27th, August 22nd, and September 19th, 2012.

On July 9-10, 2012, an additional survey was conducted of the entire 68-mile shoreline to determine the location and extent of *Myriophyllum*. The survey was conducted over a two-day period using three boats. Each boat was equipped with a driver and one to two on-board "observers", as well as Lowrance HDS echo-sounders (with side and down-scan functionality) and hand-held Garmin GPS units. The Lowrance echo-sounders display unique signatures for different species of SAV; that functionality combined with the on-board observers provided the ability to locate and geographically mark all Watermilfoil using the hand-held GPS. Although there are three species of *Myriophyllum* present in DCL, only one, *Myriophyllum spicatum*, is invasive. Because it is physically similar to and difficult to differentiate from other species of Watermilfoil, all Watermilfoil observations were recorded.

<u>Data Analysis</u>

Raw transect data were entered into a Microsoft Excel spreadsheet. Using color-blocking, Total SAV and Total Macroalgae data were used to create color-coded representations of the transects which were geographically overlaid onto a map of Deep Creek Lake. Species richness was defined for each transect and sampling event as the number of species observed per transect. Species diversity, which is a measure of both the number of species (richness) and the relative contribution of each of these species to the total number of individuals in a community, was also calculated and analyzed. Frequency of occurrence and density for each species or genera at each site were calculated using the following formulas:

Frequency of Occurrence = # of quadrats where observed /total # of quadrats

Density = sum of % cover values/ total # of quadrats.

Density and frequency of occurrence were used to determine which species were dominant at each site during each sampling event. Dominance was defined as density being equal to or greater than 10% <u>or</u> frequency of occurrence being equal to or greater than 50%. To determine dominance for sampling year 2010, a species/genus had to be found dominant during both sampling events that took place that year. For sampling years 2011 and 2012, in which three sampling events took place, a species/genus had to be found dominant during two of the three sampling events.

To graphically display observed changes in Total SAV and Total Macroalgae over time, density data were entered into Sigma Plot graphing software and bar charts were created. To show observed changes in *Myriophyllum* specifically, frequency of occurrence and density data for this genus were also entered into Sigma Plot graphing software. Bar graphs were created to show change in *Myriophyllum* density while point/line graphs were created and overlaid on density graphs to simultaneously show changes in frequency of occurrence over time.

To identify any significant differences in SAV among sites and changes over time, statistical analyses were performed using the SAS statistical software package (Enterprise Guide 4, SAS Institute Incorporated, Cary, NC). Species richness and diversity, Total SAV density and Total Macroalgae density were compared over time and among sites using 1-Way ANOVAs. Individual species density and frequency of occurrence were also assessed in order to determine differences over space and time using 1-Way ANOVAs. Homogeneity of variances was assessed using Levene's test. Following a significant ANOVA ($p \leq 0.05$), pairwise comparisons were performed using Bonferroni's test.

Data collected during the Watermilfoil shoreline survey were transferred from hand-held Garmin GPS units into ArcGIS for mapping and analysis (ArcGIS Desktop 9.3. Redlands, CA: Environmental Systems Research Institute). To determine the area affected by Watermilfoil, polygons were drawn based on GPS points and notes from the field and were merged to create one map of Watermilfoil distribution, both native and invasive species.

RESULTS

We observed nine genera of vascular aquatic plants and two species of macroalgae during our 2010, 2011, and 2012 SAV surveys. These plants include *Vallisneria Americana, Sagittaria cristata, Elodea canadensis*, *Myriophyllum spp.* (including *M. sibiricum, M. heterophyllum,* and *M. spicatum,* or Eurasian watermilfoil, an Aquatic Invasive Species in North America), *Ceratophyllum demersum*, *Najas flexilis*, *Najas guadalupensis*, *Utricularia vulgaris*, *Isoetes spp*., and five species of *Potamogeton*, including *Potamogeton robbinsii*, a species thought to be extirpated from Maryland waters, *P. pusillus, P. vaseyii, P. spirillus,* and *P. diversifolius. Potamogeton amplifolius* (also believed to be extirpated from Maryland waters) and *P. nodosus* were also observed in DCL, but because they were not on any of our transects, they were not included in the analyses. The two macroalgae observed include *Nitella flexilis* and *Chara* *vulgaris.* Common names and abbreviations for these species can be found in Table 2. Pictures and a brief description of each species are given in Appendix A. .

Table 2. List of SAV species/genera observed in Deep Creek Lake during summers 2010-2012 SAV surveys. Also given are the abbreviations used in this report and the plant's common name.

Species	**Abbreviation**	**Common name**
Sagittaria cristata	Sc	Crested arrowhead
Vallisneria americana	Va	Wild celery
Elodea canadensis	Ec	Canadian waterweed
Ceratophyllum demersum	Cd	Coontail
Myriophyllum spp.	Myr	Watermilfoil
Najas flexilis	Nf	Slender/nodding naiad
Najas guadalupensis	Ng	Southern naiad
Utricularia vulgaris	Uv	Common bladderwort
Isoetes spp.	Iso	Quillwort
Potamogeton pusillus	Pp	Slender pondweed
Potamogeton robbinsii	Pr	Robbin's pondweed
Potamogeton vaseyii	Pv	Vasey's pondweed
Potamogeton spirillus	Ps	Spiral pondweed
Potamogeton diversifolius	Pd	Waterthread pondweed
Chara vulgaris	Cv	Chara
Nitella flexilis	Nit	Nitella

Due to the difficulty in accurately identifying Watermilfoil to the species level, particularly underwater while diving, *Myriophyllum spp*. were only identified and recorded at the genus level for the SAV transect survey. Samples collected later throughout the lake, stored, and examined for species level identification in the lab confirmed that *M. spicatum*, *M. sibiricum*, and *M. heterophyllum* were all present in DCL.

Table 3 includes a summary of sampling results, including transect length, maximum water depth, Total SAV density, Total Macroalgae density, species richness, and density and frequency of occurrence for each SAV and macroalgae species observed during each survey. Table 4 gives the dominant species observed during each sampling event and for the year. Figure 2 shows Total SAV and Total Macroalgae density graphed over time for each transect, with corresponding trendlines showing overall increasing, decreasing, or no-change trends. Maps of Deep Creek Lake with color-coded Total SAV and Total Macroalgae survey data, found in Appendix B, compliment the bar charts in Figure 2 but more clearly display the quadrat by quadrat relationship between SAV and macroalgae. In most cases, there was an inverse relationship between SAV and macroalgae; where SAV was dense, macroalgae was sparse, and

Table 3. Summary of sampling results, including date, transect length, maximum water depth, Total SAV density, Total Macroalgae density, species richness, and density and frequency of occurrence (in parentheses) for each SAV and macroalgae species observed during each survey.

Date	Transect ID	Transect Length (m)	Max Water Depth (m)	Total SAV Density	Total Algae Density	Species Richness	*Sagittaria cristata*	*Vallisneria americana*	*Elodea canadensis*	*Ceratophyllum demersum*	*Myriophyllum spp.*	*Najas flexilis*	*Najas guadalupensis*	*Utricularia vulgaris*	*Isoetes sp.*	*Potamogeton pusillus*	*Potamogeton robinsii*	*Potamogeton vaseyi*	*Potamogeton spirillus*	*Potamogeton diversifolius*	*Chara vulgaris*	*Nitella flexilis*
8/4/10	RRC	127	3.3	35	28	10	6(18)	0(0)	5(55)	0(0)	3(9)	<1(18)	0(0)	<1(9)	<1(9)	10(18)	0(0)	9(45)	0(0)	0(0)	12(45)	16(36)
9/15/10	RRC	125	3.7	33	40	7	9(18)	0(0)	10(55)	0(0)	<1(18)	0(0)	0(0)	<1(9)	0(0)	<1(9)	0(0)	11(27)	0(0)	0(0)	0(0)	40(64)
6/14/11	RRC	100	4.1	48	13	5	2(18)	0(0)	9(55)	0(0)	5(36)	0(0)	0(0)	0(0)	0(0)	32(82)	0(0)	0(0)	0(0)	0(0)	13(27)	0(0)
8/9/11	RRC	110	3.7	71	2	7	13(27)	0(0)	17(64)	0(0)	4(55)	<1(18)	0(0)	0(0)	0(0)	5(45)	0(0)	32(100)	0(0)	0(0)	0(0)	2(18)
9/12/11	RRC	100	3.3	41	0	6	13(27)	0(0)	20(73)	0(0)	3(45)	2(9)	0(0)	0(0)	0(0)	3(45)	0(0)	<1(9)	0(0)	0(0)	0(0)	0(0)
6/27/12	RRC	100	3.6	58	34	7	13(27)	0(0)	23(64)	0(0)	6(55)	0(0)	0(0)	<1(9)	0(0)	14(55)	0(0)	0(0)	0(0)	2(27)	0(0)	34(45)
8/22/12	RRC	110		42	15	7	9(18)	0(0)	27(55)	0(0)	5(64)	<1(9)	0(0)	<1(9)	0(0)	<1(9)	0(0)	0(0)	0(0)	0(0)	0(0)	15(27)
9/19/12	RRC	100		39	18	7	7(18)	0(0)	22(64)	0(0)	4(55)	0(0)	<1(9)	0(0)	0(0)	4(9)	0(0)	2(18)	0(0)	0(0)	0(0)	18(36)
8/4/10	McH	80	4.0	34	4	6	2(18)	9.5(18)	12(55)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	9(45)	0(0)	0(0)	0(0)	0(0)	3(18)	1(9)
9/15/10	McH	90	4.0	14	5	7	<1(18)	9.5(18)	2(36)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	<1(18)	0(0)	<1(9)	<1(9)	0(0)	0(0)	5(18)
6/14/11	McH	77	5.3	4	53	4	<1(9)	3(9)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	<1(9)	0(0)	0(0)	0(0)	0(0)	53(82)	0(0)
8/9/11	McH	90	4.8	10	32	8	<1(18)	7(18)	<1(27)	0(0)	<1(9)	0(0)	0(0)	<1(9)	0(0)	<1(36)	0(0)	<1(9)	0(0)	0(0)	0(0)	32(82)
9/12/11	McH	60	4.0	16	8	7	<1(9)	10(27)	<1(27)	0(0)	<1(27)	0(0)	0(0)	<1(18)	0(0)	3(45)	0(0)	0(0)	0(0)	0(0)	0(0)	8(64)
6/27/12	McH	100	5.4	12	55	7	0(0)	8(18)	3(27)	0(0)	<1(9)	<1(9)	0(0)	0(0)	0(0)	<1(9)	<1(9)	0(0)	0(0)	0(0)	0(0)	45(64)
8/22/12	McH	90		30	26	6	<1(9)	5(9)	13(73)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	3(36)	0(0)	0(0)	0(0)	0(0)	8(18)	18(45)
9/19/12	McH	75		30	18	8	7(18)	14(18)	<1(36)	0(0)	<1(18)	0(0)	0(0)	0(0)	0(0)	<1(36)	0(0)	<1(9)	0(0)	0(0)	9(18)	9(45)
8/5/10	HHO	195	5.8	38	30	7	15(36)	0(0)	1(27)	0(0)	21(64)	<1(18)	0(0)	0(0)	0(0)	<1(18)	0(0)	0(0)	0(0)	0(0)	16(45)	14(45)
9/15/10	HHO	200	3.0	46	8	5	6(27)	0(0)	2(18)	0(0)	31(55)	0(0)	0(0)	0(0)	0(0)	0(0)	8(9)	0(0)	0(0)	0(0)	8(36)	0(0)
6/14/11	HHO	150	5.6	40	20	8	7(45)	0(0)	14(18)	<1(9)	16(36)	0(0)	0(0)	0(0)	0(0)	<1(18)	0(0)	0(0)	<1(9)	0(0)	19(36)	1(27)
8/9/11	HHO	180	5.0	44	25	9	15(45)	0(0)	3(18)	0(0)	5(18)	<1(27)	2(18)	15(45)	0(0)	<1(9)	0(0)	2(18)	0(0)	0(0)	0(0)	25(64)
9/12/11	HHO	162	4.1	29	15	8	7(36)	0(0)	6(27)	0(0)	6(45)	3(18)	0(0)	3(9)	0(0)	11(27)	<1(9)	0(0)	0(0)	0(0)	0(0)	15(18)
6/27/12	HHO	180	6.3	37	41	7	15(36)	0(0)	4(36)	0(0)	3(45)	0(0)	0(0)	6(27)	0(0)	5(36)	4(27)	0(0)	0(0)	0(0)	0(0)	41(45)
8/22/12	HHO	180		36	34	7	15(36)	0(0)	6(27)	0(0)	12(45)	0(0)	0(0)	<1(27)	0(0)	3(18)	0(0)	0(0)	0(0)	0(0)	2(9)	31(45)
9/19/12	HHO	190		72	7	6	17(36)	0(0)	27(64)	0(0)	27(73)	0(0)	0(0)	0(0)	0(0)	2(27)	0(0)	<1(9)	0(0)	0(0)	0(0)	7(18)
8/5/10	MMR	63	3.0	51	0	6	30(82)	21(55)	0(0)	0(0)	0(0)	<1(9)	0(0)	0(0)	<1(9)	<1(9)	0(0)	<1(9)	0(0)	0(0)	0(0)	0(0)
9/15/10	MMR	60	3.9	51	0	3	34(64)	17(55)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	<1(9)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
6/14/11	MMR	55	4.1	35	0	4	29(82)	6(73)	0(0)	0(0)	0(0)	<1(36)	0(0)	0(0)	0(0)	<1(18)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
8/9/11	MMR	55	2.9	46	<1	8	37(91)	5(18)	<1(9)	0(0)	0(0)	2(36)	0(0)	2(82)	0(0)	<1(18)	0(0)	<1(45)	0(0)	0(0)	0(0)	<1(9)
9/12/11	MMR	60	4.0	51	0	4	34(73)	17(55)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	<1(9)	<1(9)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
6/27/12	MMR	55	4.2	46	2	7	34(82)	11(64)	1(9)	0(0)	0(0)	<1(9)	0(0)	0(0)	<1(18)	<1(9)	0(0)	0(0)	0(0)	0(0)	0(0)	2(9)
8/22/12	MMR	60		54	5	8	35(73)	16(45)	<1(9)	0(0)	0(0)	0(0)	0(0)	4(18)	1(9)	0(0)	0(0)	0(0)	2(18)	0(0)	<1(9)	5(18)
9/19/12	MMR	60		65	3	6	40(73)	23(64)	<1(9)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(18)	0(0)	0(0)	0(0)	3(18)
8/5/10	DCC	200	2.5	87	13	7	<1(18)	0(0)	60(82)	<1(18)	7(9)	0(0)	0(0)	0(0)	0(0)	11(27)	0(0)	9(36)	0(0)	0(0)	13(18)	0(0)
9/16/10	DCC	200	2.3	68	7	7	2(27)	0(0)	44(73)	17(36)	0(0)	0(0)	0(0)	0(0)	<1(9)	3(18)	0(0)	<1(9)	0(0)	0(0)	7(18)	0(0)
6/14/11	DCC	200	3.0	70	0	4	7(27)	0(0)	36(82)	14(45)	0(0)	0(0)	0(0)	0(0)	0(0)	13(36)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
8/9/11	DCC	200	2.7	58	0	8	5(9)	0(0)	24(64)	3(27)	8(9)	0(0)	0(0)	0(0)	0(0)	1(9)	0(0)	1(9)	<1(9)	13(27)	0(0)	0(0)
9/12/11	DCC	200	3.7	54	2	6	7(18)	0(0)	31(64)	14(45)	0(0)	0(0)	0(0)	0(0)	0(0)	<1(9)	0(0)	<1(9)	0(0)	0(0)	0(0)	2(9)
6/27/12	DCC	200	3.0	29	30	6	4(27)	0(0)	18(73)	2(55)	<1(9)	0(0)	0(0)	0(0)	0(0)	4(36)	0(0)	0(0)	0(0)	0(0)	0(0)	30(55)
8/22/12	DCC	200		52	22	4	6(18)	0(0)	43(73)	2(18)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	22(55)
9/19/12	DCC	200		68	7	6	12(18)	0(0)	54(73)	<1(9)	<1(18)	<1(9)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	7(27)
8/5/10	GGC	70	3.0	49	11	6	20(55)	0(0)	27(36)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2(27)	0(0)	<1(18)	0(0)	0(0)	<1(9)	11(64)
9/15/10	GGC	70	3.5	31	30	5	20(36)	0(0)	13(27)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(18)	0(0)	0(0)	0(0)	0(0)	14(27)	13(27)
6/14/11	GGC	65	3.4	26	4	5	13(36)	0(0)	6(45)	0(0)	<1(9)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	7(82)	0(0)	0(0)	0(0)	4(27)
8/9/11	GGC	55	3.6	68	2	8	21(45)	0(0)	9(36)	0(0)	6(9)	0(0)	0(0)	11(73)	0(0)	15(55)	0(0)	6(36)	0(0)	0(0)	<1(9)	1(18)
9/12/11	GGC	54	4.0	36	8	5	20(36)	0(0)	4(9)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	8(18)	0(0)	5(18)	0(0)	0(0)	0(0)	8(45)
6/27/12	GGC	65	3.4	48	7	4	14(45)	0(0)	23(45)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	11(27)	0(0)	0(0)	0(0)	0(0)	0(0)	7(18)
8/22/12	GGC	66		31	5	7	20(45)	0(0)	11(45)	0(0)	<1(9)	0(0)	0(0)	0(0)	<1(9)	0(0)	0(0)	0(0)	<1(9)	0(0)	<1(9)	5(27)
9/19/12	GGC	80		48	7	6	25(36)	0(0)	22(55)	0(0)	<1(9)	0(0)	0(0)	0(0)	0(0)	<1(18)	0(0)	<1(9)	0(0)	0(0)	0(0)	7(9)

vice versa. Figure 3 shows *Myriophyllum* density and frequency of occurrence graphed over time for each transect.

Most species that we observed were seen throughout the lake, but each site was dominated by just one, two, or three species. The survey results for the SAV bed in Red Run Cove (transect length from 100-127m and max depth of 4.1m, Table 3), in the northwestern portion of the lake near the dam, indicate that *Nitella flexilis* and *E. canadensis* dominated this bed in 2010 (Table 4). In 2011, *E. canadensis* maintained dominance, but *S. cristata* replaced *Nitella flexilis*. *Elodea canadensis* co-dominated with *Myriophyllum* and *Nitella flexilis* in 2012. Total SAV in Red Run Cove showed a slightly increasing though statistically insignificant trend over the 2010-2012 time period (Figure 2), while Total Macroalgae showed a decreasing trend. Though there was a significant decrease in macroalgae between 2010 and 2011, by 2012 macroalgae had increased in density again to the extent that there was no overall change during the survey time period. *Myriophyllum* was observed at low densities in Red Run Cove during every sampling event, but its density did not change over time. Frequency of occurrence, however, increased significantly, as seen in Figure 3.

Table 4. Dominance by site and year, where dominance is defined as density being equal to or greater than 10% <u>or</u> frequency of occurrence being equal to or greater than 50%. To determine dominance for 2010, a species/genus had to be found dominant during both sampling events that took place that year. For years 2011 and 2012, in which three sampling events took place, a species/genus had to be found dominant during two of the three sampling events.

	2010			**2011**			**2012**		
	Date	Dominant Species for Event	Dominant Species for Year	Date	Dominant Species for Event	Dominant Species for Year	Date	Dominant Species for Event	Dominant Species for Year
RRC			*Elodea canadensis, Nitella flexilis*	6/14/11	Ec, Pp, Cv	*Sagittaria cristata, Elodea canadensis*	6/27/12	Sc, Ec, Myr, Pp, Nit	*Elodea canadensis, Myriophyllum, Nitella flexilis*
	8/5/10	Ec, Pp, Cv, Nit		8/9/11	Sc, Ec, Myr, Pv		8/22/12	Ec, Myr, Nit	
	9/16/10	Ec, Pv, Nit		9/12/11	Sc, Ec		9/19/12	Ec, Myr, Nit	
McH			no dominant for year	6/14/11	Cv	*Nitella flexilis*	6/27/12	Nit	*Nitella flexilis*
	8/5/10	Ec		8/9/11	Nit		8/22/12	Ec, Nit	
	9/16/10	none		9/12/11	Va, Nit		9/19/12	Va	
HHO			*Myriophyllum*	6/14/11	Ec, Myr, Cv	*Nitella flexilis*	6/27/12	Sc, Nit	*Sagittaria cristata, Myriophyllum, Nitella flexilis*
	8/5/10	Sc, Myr, Cv, Nit		8/9/11	Sc, Uv, Nit		8/22/12	Sc, Myr, Nit	
	9/16/10	Myr		9/12/11	Pp, Nit		9/19/12	Sc, Ec, Myr	
MMR			*Sagittaria cristata, Vallisneria americana*	6/14/11	Sc, Va	*Sagittaria cristata, Vallisneria americana*	6/27/12	Sc, Va	*Sagittaria cristata, Vallisneria americana*
	8/5/10	Sc, Va		8/9/11	Sc, Uv		8/22/12	Sc, Va	
	9/16/10	Sc, Va		9/12/11	Sc, Va		9/19/12	Sc, Va	
DCC			*Elodea canadensis*	6/14/11	Ec, Cd, Pp	*Elodea canadensis, Ceratophyllum demersum*	6/27/12	Ec, Cd, Nit	*Elodea canadensis, Nitella flexilis*
	8/5/10	Ec, Pp, Cv		8/9/11	Ec, Pd		8/22/12	Ec, Nit	
	9/16/10	Ec, Cd		9/12/11	Ec, Cd		9/19/12	Sc, Ec	
GGC			*Sagittaria cristata, Elodea canadensis, Nitella flexilis*	6/14/11	Sc, Pv	*Sagittaria cristata*	6/27/12	Sc, Ec, Pp	*Sagittaria cristata, Elodea canadensis*
	8/5/10	Sc, Ec, Nit		8/9/11	Sc, Uv, Pp		8/22/12	Sc, Ec	
	9/16/10	Sc, Ec, Cv, Nit		9/12/11	Sc		9/19/12	Sc, Ec	

The SAV bed surveyed near McHenry (transect length from 60-100m and max depth of 5.4m, Table 3), also in the northern portion of the lake but in the eastern arm, showed no true dominant in 2010, although *E. canadensis* dominated in August (Table 4). The macroalgae *Nitella flexilis* dominated the bed in 2011, and again in 2012. Both Total SAV and Total Macroalgae showed increasing trendlines at this location, but statistical analyses of the data indicate that only macroalgae density increased significantly between 2010 and 2012 (Figure 2). *Myriophyllum* was only observed in trace amounts and low frequencies during four of the eight sampling events (Figure 3), and it did not change significantly over time.

The SAV bed surveyed near the Honi Honi in Oakland, on the western shore of the central lake area, was a long transect (ranging from 150-200m) with the greatest maximum depth (6.3m) (Table 3). This SAV bed was dominated by *Myriophyllum* in 2010, by *Nitella flexilis* in 2011, and by *S. cristata, Myriophyllum,* and *Nitella flexilis* in 2012 (Table 4). Both Total SAV and Total Macroalgae density graphs show slightly increasing trendlines at this location, but statistical analyses indicate that the change was not significant (Figure 2). *Myriophyllum* was commonly observed at this transect, but it did not change significantly over time either in density or frequency of occurrence either (Figure 3).

Across the lake from Honi Honi, the SAV bed surveyed offshore of the State Park in Meadow Mountain Run Cove was dominated by *S. cristata* and *V. americana* during all three summers (Table 4). This transect ranged from 55-63m with a max depth of 4.2m (Table 3). Both Total SAV and Total Macroalgae showed increasing trends at this location, but neither increased significantly. Macroalgae was only present in very low densities during the more recent sampling events (Figure 2). *Myriophyllum* was never observed at this transect.

In the southern portion of the lake, Deep Creek Cove had one of the longest transects (length of 200m and max depth of 3.7m, Table 3). This expansive bed was dominated by *E. canadensis* in 2010, but in 2011, *C. demersum* was found to be co-dominant with *E. canadensis* (Table 4). In 2012, *E. canadensis* co-dominated with the macroalgae *Nitella flexilis*. Total SAV in Deep Creek Cove showed a statistically significant decrease, while Total Macroalgae increased significantly (Figure 2). *Myriophyllum* was present in low densities and frequencies of occurrence during four of eight sampling events, but it did not change significantly over time (Figure 3).

Green Glade Cove, east of Deep Creek Cove in the southeastern portion of the lake, had transect lengths ranging from 55-80m and a max depth of 4m (Table 3). This SAV bed was dominated by *S. cristata*, *E. canadensis*, and *Nitella flexilis* in 2010. In 2011, the dominant plant observed was *S. cristata* and in 2012, *S. cristata* and *E. canadensis* co-dominated (Table 4). Total SAV in Green Glade Cove oscillated over time, but did not change overall, while Total Macroalgae decreased significantly between 2010 and 2012 (Figure 2). *Myriophyllum* was present in low densities and frequencies of occurrence during four of eight sampling events, but it did not change significantly over time (Figure 3).

In general, species zonation was apparent at all sites. *Sagittaria cristata*, a plant with low canopy height, was observed at all sites during every sampling event, with the exception of the transect at McHenry during the June 2012 sampling. In all cases, it was observed at its highest densities along the shallow edge of the SAV beds. Along transects with little slope and minimal depth, *S. cristata* maintained high densities father from shore. As transects moved offshore and got deeper, *S. cristata* was generally replaced by *Potamogeton spp., Vallisneria americana*, *Ceratophyllum demersum,* or a combination thereof. Along the deeper edges of the SAV beds,

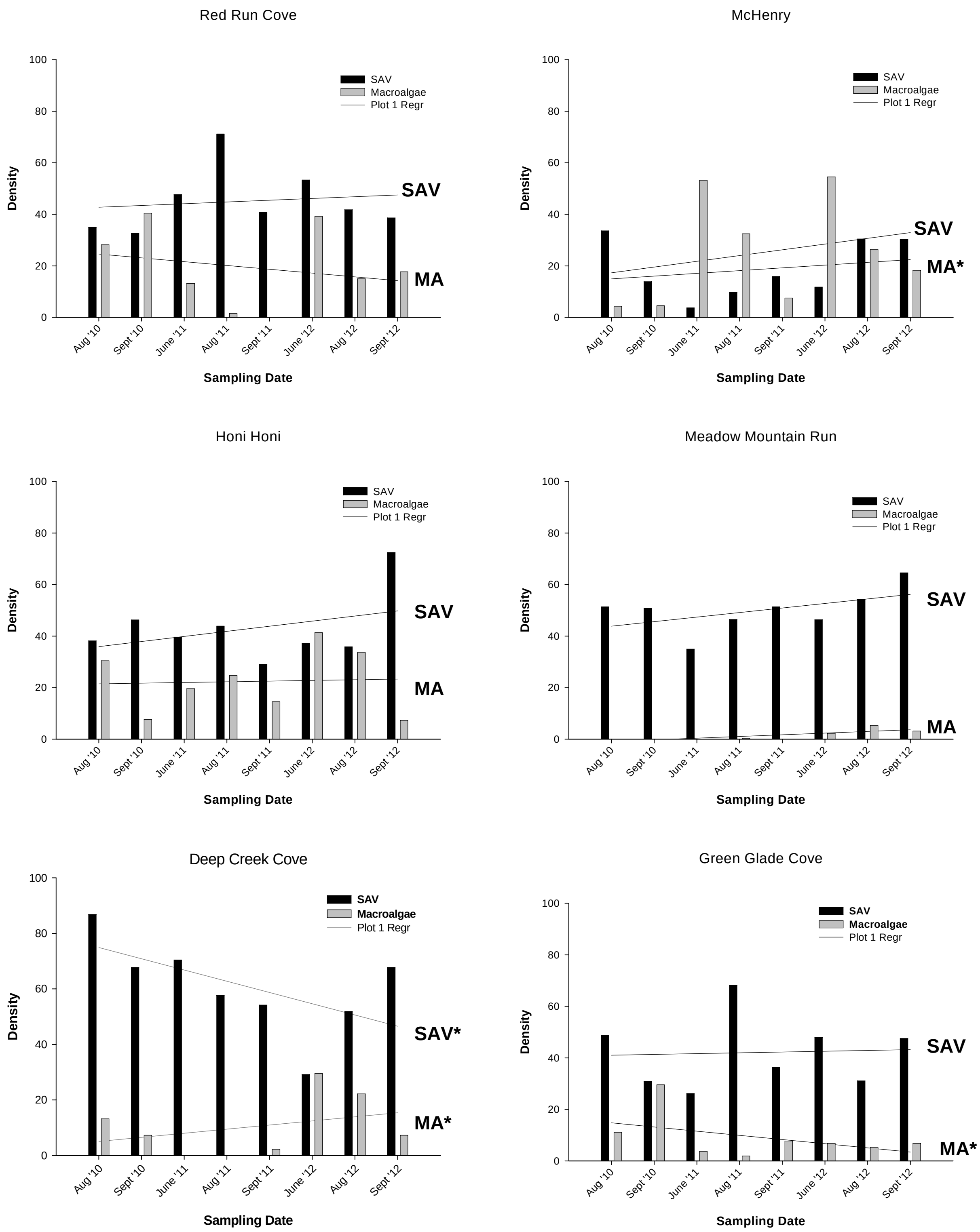


Figure 2. Total SAV and Total Macroalgae Density (where Density = sum of % cover values/total # of quadrats) graphed over time for each transect, with corresponding trendlines showing overall increasing, decreasing, or no-change trends. Asterisks (*) indicate significant ($p \leq 0.05$) change from 2010 to 2012.

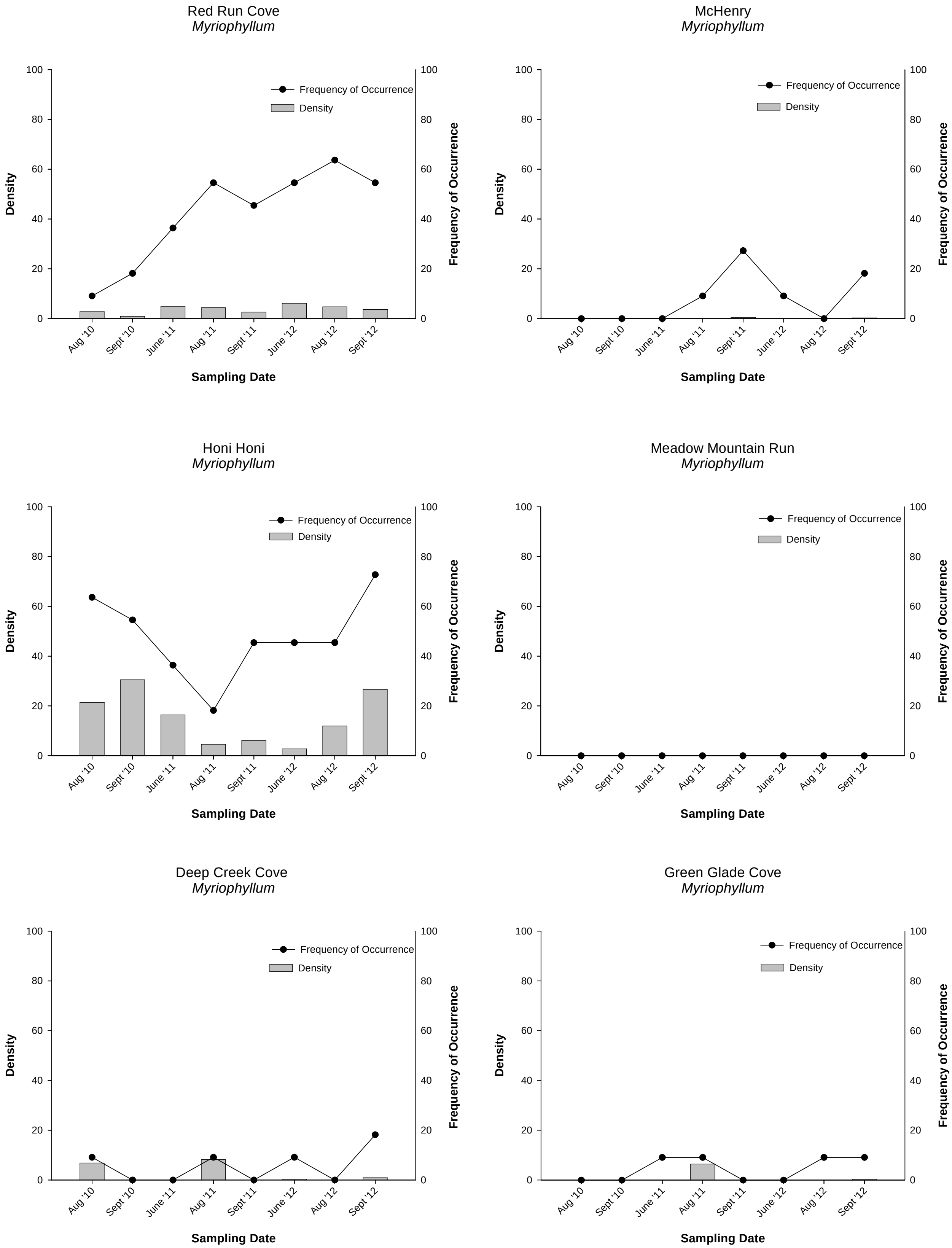


Figure 3. *Myriophyllum D*ensity (bars, where Density = sum of % cover values/total # of quadrats) and Frequency of Occurrence (point and line, where Frequency = # of quadrats where observed/total # quadrats) graphed over time for each transect.

we observed more *C. demersum, E. canadensis, Myriophyllum,* and the two species of macroalgae (which have lower light requirements), *C. vulgaris* and *Nitella flexilis*.

Statistical analyses confirmed that *Sagittaria cristata*, *Elodea canadensis* and the macroalgae *Nitella flexilis* were the dominant species observed at our sites during the three year monitoring period (2010-2012). *Potamogeton pusillus*, *P. vaseyii* and the macroalgae *Chara vulgaris* were observed at least once at all six sites, but at very low densities. The greatest densities and highest frequencies of occurrence of *S. cristata* and *V. americana* were observed at Meadow Mountain Run. *Elodea canadensis* and *C. demersum* densities and frequencies of occurrence were significantly higher at Deep Creek Cove than at the other sites. *Myriophyllum* density was significantly higher at Honi Honi (15) than other sites (0-3.7), and *Myriophyllum* was also observed more frequently at Honi Honi (48% of quadrats) and Red Run Cove (42%) than at other sites (0-8%).

Total SAV density, Total Macroalgae density, species richness and species diversity were all significantly different among sites. Deep Creek Cove contained the highest SAV coverage and greatest species diversity. Meadow Mountain Run also had significantly higher SAV coverage and the lowest percent cover of algae. Observed macroalgae cover was significantly higher at Honi Honi, McHenry and Red Run Cove compared to the other sites. Red Run Cove also had the highest species richness, while McHenry had the fewest species observed. SAV cover and species diversity were significantly lower at McHenry than any other site.

Analyzing the data by year (data averaged across all sites) indicated that *Nitella flexilis* was the only species that displayed significant differences in lake-wide density between sampling dates (observations were higher in June 2012 than in June 2011). There were no significant changes over time for any other species, including *Myriophyllum* when data were averaged across the six sites.

While the SAV transects surveyed throughout the Lake represent the Lake as a whole, the comprehensive shoreline survey allowed us to map the lake-wide spatial extent of Watermilfoil specifically. With this sampling design, we identified 130 locations with Watermilfoil, totaling approximately 86 acres where Watermilfoil was present at varying densities. Using bathymetry data collected by the Maryland Geological Survey, 86 acres represents approximately 2.3% of the lake surface and 5.8% of the waters less than six meters deep, the photic zone in which plants may grow in Deep Creek Lake. The remaining 94.2% of habitat within the photic zone was free of Watermilfoil. Appendix C, Figure C1 shows Watermilfoil locations throughout the lake with symbol size proportional to Watermilfoil patch size. The majority of Watermilfoil, particularly the larger patches, was observed in the southern portion of the lake (Figure C1, C5-C7).

DISCUSSION and CONCLUSION

The goal of the SAV transect survey was to define the distribution and density of the SAV community at several representative sites throughout Deep Creek Lake. As such, the results of the survey provide a comprehensive analysis of the Lake's SAV community as a whole and how this community changes in space and time. The transect survey methodology is a globally accepted method to identify changes in an SAV community; it does not focus on any one species over another, as did our Watermilfoil shoreline survey. Our results indicate that DCL supports a healthy and diverse population of SAV, including 9 genera of vascular plants and 2 species of macroalgae. These SAV observations include two rare species of *Potamogetons* thought to be extirpated from Maryland waters. The distribution and density of these species differ primarily by site, with annual variations occurring occasionally. The majority of observed species, as well as the physical characteristics of each survey site, showed no significant change in density or distribution from 2010 to 2012.

Aside from some shallow water areas, the water in Deep Creek Lake is clear and allows light to penetrate to impressive depths. SAV and macroalgae were observed growing as deep as 5-6 m on some transects with species zonation apparent at every site. Zonation is an inherent characteristic of any SAV bed, but could be particularly exaggerated in Deep Creek Lake as a direct result of the winter water level draw-down, which limits the shoreward expansion of canopy forming species. *Sagittaria cristata*, commonly known as Crested arrowhead, was observed at each site during almost every sampling event. This plant, which is short in stature and can withstand extensive periods of exposure during lake level draw down, was most prevalent along the shallow edges of the SAV beds. *Potamogeton spp.* (also present to some extent in the shallows), *Vallisneria americana,* and/or *Ceratophyllum demersum* replaced *S. cristata* as the transects extended into deeper water. All of these species can form canopies from 0.5-2m or more. *Potamogeton spp.* were seen reaching the surface at shallow to mid-depths during the August and September sampling events due to their reproductive strategy. During late summer/early fall, the *Potamogetons* send their reproductive structures to the surface to take advantage of its two dimensional aspect. Along the deeper edge of the transects and SAV beds, we were more likely to observe *Elodea canadensis, Myriophyllum*, and macroalgae. *Elodea canadensis* and *Myriophyllum* can form canopies greater than 2m in clear water. One of the most notable observations made was an SAV bed extending into greater than 5m of water at the transect site near the Honi Honi in Oakland. Submerged aquatic vegetation observed here included *Myriophyllum* that grew nearly to the surface, and macroalgae (both *Nitella flexilis* and *Chara vulgaris*).

Myriophyllum density and frequency of occurrence was higher at Honi Honi than at the other sites. Although we observed a statistically significant increase in frequency of occurrence of *Myriophyllum* at Red Run Cove from 2010 to 2012, density did not change over time in that cove. Neither *Myriophyllum* density nor frequency of occurrence changed over time in any of the other surveyed coves. The Watermilfoil-specific shoreline survey indicated that this nuisance plant is present at varying densities in 86 acres of the lake and occupies less than 6% of available benthic space for vegetative growth. The remaining 94% of available benthic habitat is free of Watermilfoil. While conducting the survey, SAV biologists also noted that other species of plants were found with Watermilfoil, indicating that at this time, *Myriophyllum* species are not forming monoculture stands to the exclusion of native species.

It is the opinion of DNR SAV biologists that at this time, *Myriophyllum* is not a problem in Deep Creek Lake, but that it should be monitored carefully. As is the case with most species considered "invasive", *Myriophyllum spicatum* has the capacity to establish and spread in an unbalanced ecosystem. Even carefully designed efforts to control aquatic plants may have unanticipated and adverse impacts on the lake ecosystem, as well as the humans using the lake. Therefore, it is advisable to allow the ecosystem itself to achieve balance without attempting large-scale Watermilfoil control measures. The best possible way to prevent further expansion of this invasive plant is to promote the growth of native species, to boat responsibly in areas where Watermilfoil is growing, and to develop ways to prevent further introduction or spread of any invasive species. If at any time *Myriophyllum* is found to be a severe problem and/or out-competing other more desirable native species, appropriate and localized management actions will be evaluated and implemented at the State's discretion, and with input from various stakeholders.

<u>APPENDIX A</u>

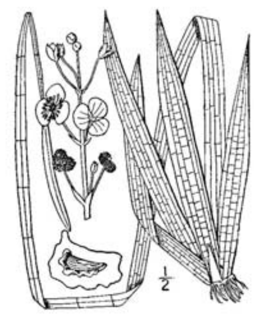
Deep Creek Lake Plant Guide

This appendix provides drawings, pictures, distribution maps, and a brief description of each species of submerged aquatic vegetation observed in Deep Creek Lake during the summers 2010 - 2012 SAV surveys.

Sagittaria cristata (Crested arrowhead)

Monocot, Perennial, Native to the continental US and Canada. Distribution includes IA, IL, MI, MN, NE, and WI. It has not been previously documented in MD according to the USDA Plant Database (http://plants.usda.gov/java).

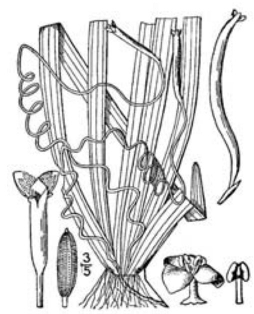
Crested arrowhead grows along the margins and bottoms of shallow lakes, ponds, and swamps. It may grow up to 75 cm tall, though in DCL it hasn't been observed more than 10 cm high. Flowering occurs July through August.



Vallisneria americana (Wild celery)

Monocot, Perennial, Native to continental US and Canada. Distribution in all but seven states and most of Canada.

Wild celery is primarily a freshwater species, although it is occasionally found in brackish waters (up to 12-15 ppt). Wild celery seems to prefer coarse silty to sandy soil, and is fairly tolerant of murky waters and high nutrient loading. It can tolerate wave action better than some other grass species.



Elodea canadensis (Canadian waterweed)

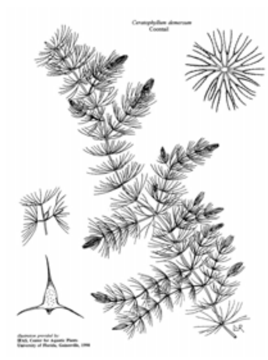
Monocot. Perennial. Native to the continental US and Canada, but considered Invasive in Puerto Rico. Distributed in all but three continental US states: TX, LA, and GA.

This waterweed is primarily a freshwater species. It prefers loamy soil and slow-moving water with high nitrogen and phosphorous concentrations. It will grow in a wide range of conditions, from very shallow to deep water, and in many sediment types. It can even continue to grow unrooted, as floating fragments.

Ceratophyllum demersum (Coontail)

Dicot. Perennial. Native to the continental US and Alaska, Canada, Puerto Rico, and the US Virgin Islands. Invasive in Hawaii. Distribution is ubiquitous throughout the US.

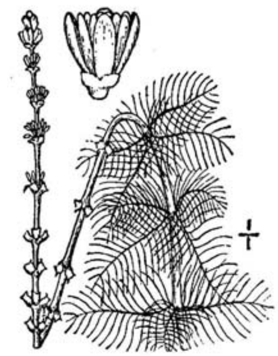
Coontail's leaves grow in crowded whorls which make it resemble a raccoon's tail underwater. Each leaf is forked into segments with fine teeth on one side of the leaf margin. Leaves are brittle and keep their shape out of water. Coontail may float in dense mats beneath the surface and its base is only occasionally attached to the sediment. It may also be found near the bottom in deep water – in creek channels, for example.



***Myriophyllum spicatum* (Eurasian water milfoil)**
Dicot, Perennial. Invasive to the continental US, Alaska, and Canada. Native to Europe, Asia, and northern Africa. Invasive distribution throughout the US.

This plant has a long stem that branches profusely when it reaches the surface of the water. Leaves are finely divided and feather-like in appearance. There are usually 12 to 21 pairs of leaflets.

Eurasian watermilfoil can grow in ponds, lakes, reservoirs, and slow flowing rivers and streams. It will grow in shallow or deep water, fresh or brackish water, and within a wide temperature range. It tends to do well in waters that have had some sort of disturbance like intense plant management, overabundance of nutrients, or extensive motorboat use.



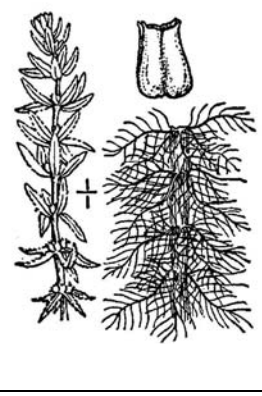
Dispersal through vegetative means is Eurasian watermilfoil's main reproductive strategy. The plant goes through autofragmentation during the growing season, where roots will develop at the nodes and the plant will break off at these nodes on its own. Fragments can also be produced by wind, waves, and human activity. These fragments will set root and grow into a new plant. New shoots begin to grow from the overwintering root crowns when water temperature reaches about 60^{o} F in the spring. Flowering generally occurs in July. Autofragmentation usually occurs after flowering. Plants die back to the roots in the fall. These roots store carbohydrates in order to initiate the rapid growth in the spring.

***Myriophyllum sibiricum* (Northern water milfoil)**
Dicot, Perennial. Native to the continental US, Alaska, Canada, and elsewhere. Distribution throughout Canada and the US with the exception of southeastern states from TX east to FL.

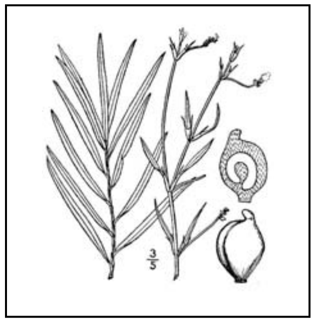
This plant is distinguished from the Eurasian water milfoil by its less finely divided leaves and larger floral bracts. It typically has 5-10 thread-like segments on each side of the midrib whereas Eurasian water milfoil has 12-24 segments. It is found in shallow to deep water of lakes, ponds, marshes, where its presence significantly increases the abundance of macroinvertebrates, although the value of milfoil is likely due more to its value as habitat than as food.

***Myriophyllum heterophyllum* (Two-leafed water milfoil)**
Dicot, Perennial. Native to the continental US and Canada with distribution throughout the eastern US and Canada.

Two-leafed water milfoil has fine densely packed, featherlike leaves whorled around a main stem. It can grow up to 15 feet and may exhibit a three to six inch green spike-like flower above the waterline in late June or in July. A cross-section of the stem will reveal "pie-shaped" air chambers.



***Potamogeton robbinsii* (Robbin's pondweed)**
Monocot. Perennial. Native to the continental US, Alaska, and Canada. Distribution limited to ~ half US states and most of Canada.
This pondweed is found in deep to shallow, often muddy waters of lakes, ponds, and rivers. It is the only *Potamogeton* that has branching inflorescences, though it rarely flowers. This plant is believed extirpated from Maryland and is threatened or endangered in several of its native states.



***Potamogeton pusillus* (Slender pondweed)**
Monocot. Perennial. Native to the continental US, Alaska, and Canada. Distributed throughout native range.

Slender pondweed grows in soft, fertile mud substrates and quiet to gently flowing water. Leaf blades of slender pondweed are entire and have pointed tips and can have a purplish tint. Like all other pondweeds, slender pondweed is considered an important food for waterfowl.

***Potamogeton diversifolius* (Waterthread pondweed)**
Monocot. Perennial. Native to the continental US and distributed throughout with the exception of far northeast.

This pondweed produces a very narrow, compressed stem branching to around 35 cm. It has thin, pointed linear leaves a few cm long spirally arranged about the thin stem. Flowers emerge from the water surface.

Pota*mogeton vaseyi* (Vasey's pondweed)
Monocot. Perennial. Native to the continental US and Canada. Distribution limited to the northeastern US and eastern Canada.

Not previously documented in Maryland, Vasey's pondweed is considered threatened, endangered, or of special concern where found in northeastern US states. It grows in quiet waters and has dimorphic leaves: very narrow, flaccid, submersed leaves and wider, thicker floating leaves.

***Potamogeton spirillus* (Spiral pondweed)**
Monocot. Perennial. Native to the continental US and Canada, but distributed only throughout the northeast US and northern mid-west, and eastern Canada.

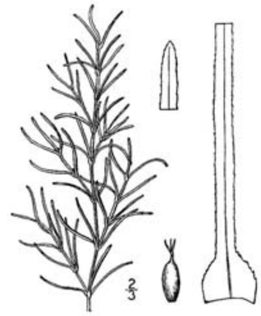
Spiral pondweed usually grows in shallow water: lakes, ponds, wet swales, and rarely quiet river borders. The submersed leaves are often curved, giving the whole bushy plant the aspect of a broad-leaved *Najas*

***Najas flexilis* (Slender or nodding naiad)**
Monocot. Annual. Native to the continental US, Alaska, and Canada. Found in most northern states and Canada.

Naiads grow in small freshwater streams. They prefer sandy substrates and tolerate relatively low light. Naiads vary in size from inch-high tufts on sandy bottoms to highly branched plants two or three feet high. *Najas flexilis* is considered to be excellent food sources for waterfowl.

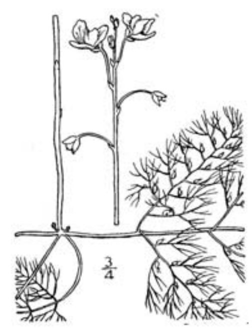
***Najas guadalupensis* (Southern naiad)**
Monocot. Annual. Native to the continental US, Puerto Rico, and Canada. Invasive to Hawaii. Distributed throughout US.

This plant grows in ponds, ditches, and streams. It produces a slender, branching stem up to 60 to 90 centimeters in maximum length. The thin, somewhat transparent, flexible leaves are up to 3 cm long and just 1-2 mm wide. They are edged with minute, unicellular teeth. Tiny flowers occur in the leaf axils; staminate flowers grow toward the end of the plant and pistillate closer to the base



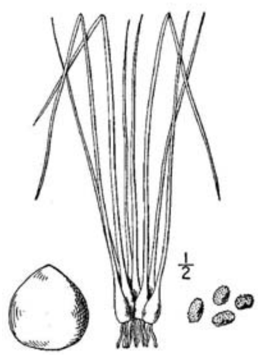
***Utricularia vulgaris* (Common bladderwort)**
Dicot. Perennial. Native to the continental US, Alaska, and Canada.

Several species of bladderwort occur in the Chesapeake Bay region, primarily in the quiet freshwater of ponds and ditches. They can also be found on moist soils associated with wetlands. Bladderworts are considered carnivorous because minute animals can be trapped and digested in the bladders that occur on the underwater leaves.



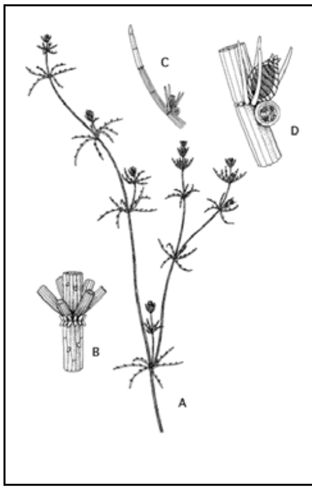
***Isoetes spp.* (Quillwort)**
Lycopod. Perennial. Native to the continental US, Alaska, and Canada. Distributed throughout.

Quillwort leaves are hollow. Each leaf is narrow (2–20 cm long and 0.5–3 mm wide). They broaden to a swollen base up to 5 mm wide where they attach in clusters to a bulb-like, underground rhizome. This base also contains male and female sporangia, protected by a thin velum. Quillwort species are very difficult to distinguish by general appearance.



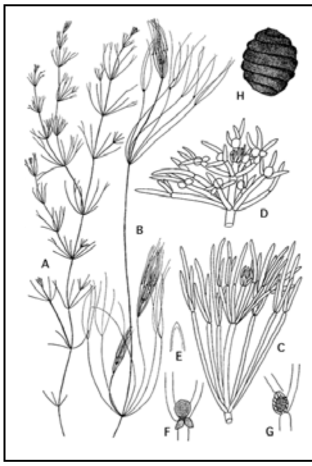
Chara vulgaris (macroalgae – Chara, Common stonewort)

Chara is a green alga belonging to the Charales, a lineage that may have given rise to all land plants. It is a modern lime-secreting alga, which grows in fresh water. The stoneworts (class Charophyceae) are a very distinctive group of green algae that are sometimes treated as a separate division (the Charophyta). These algae can occur in fresh or brackish waters, and they have cell walls that contain large concentrations of calcium carbonate. Charophytes have relatively complex growth forms, with whorls of "branches" developing at their tissue nodes. Charophytes are also the only algae that develop multicellular sex organs, although these are not comparable to those of the higher plants.



Nitella flexilis (macroalgae – Nitella, Smooth stonewort)

Nitella flexilis is closely related to *Chara vulgaris* in the Stonewort family, a group of complex algae that superficially resemble vascular plants more than they do other groups of algae. *Nitella* is a green, freshwater algae; a robust species growing up to a meter long with axes up to 1mm wide. Branches in whorls once or twice divided.



Most plant drawings were obtained from Britton and Brown (1913) via the USDA Plant Database.
USDA-NRCS PLANTS Database / Britton, N.L., and A. Brown. 1913. *An illustrated flora of the northern United States, Canada and the British Possessions. 3 vols.* Charles Scribner's Sons, New York.

Distribution maps were obtained from the USDA Plant Database.
USDA, NRCS. 2011. The PLANTS Database (http://plants.usda.gov, 10 November 2011). National Plant Data Team, Greensboro, NC 27401-4901 USA.

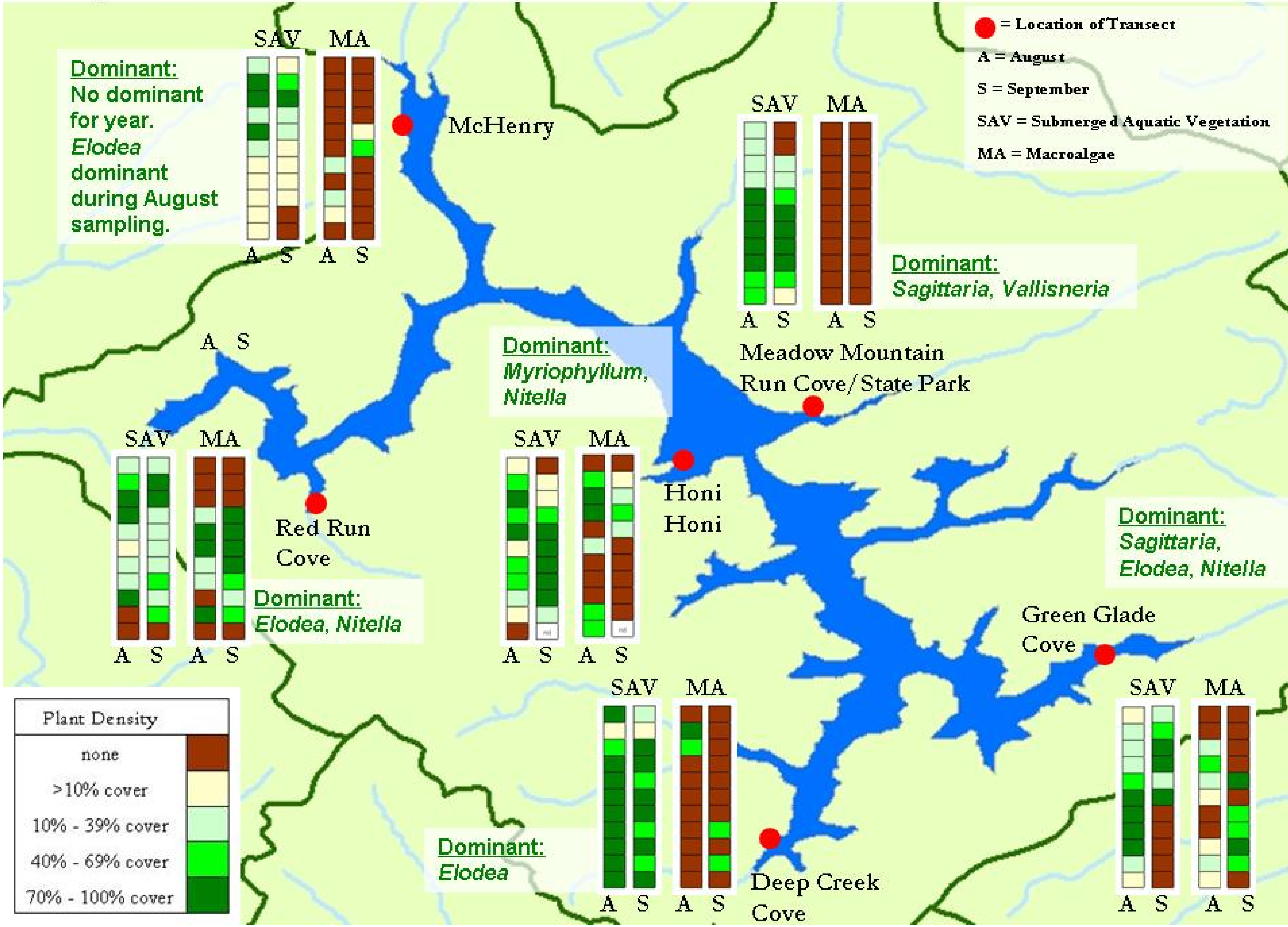
Images were obtained from the following:
Sagittaria cristata: www.uwgb.edu/biodiversity/herbarium/wetland_plants
Vallisneria Americana: www.dnr.state.md.us/bay/sav/key
Elodea Canadensis: www.dnr.state.md.us/bay/sav/key/
Ceratophyllum demersum: www.dnr.state.md.us/bay/sav/key/
Myriophyllum spicatum: www.dnr.state.md.us/bay/sav/key/
Myriophyllum sibiricum: www.mainevolunteerlakemonitors.org
Myriophyllum heterophyllum: www.missouriplants.com
Potamogeton robbinsii: www.yankee-lake.org
Potamogeton pusillus: http://flora.nhm-wien.ac.at/Seiten-Arten/Potamogeton-pusillus.htm
Potamogeton diversifolius: www.dcnr.state.al.us
Potamogeton vaseyi: www.botany.wisc.edu
Potamogeton spirillus: www.uwgb.edu/biodiversity/herbarium/wetland_plants
Najas flexilis: www.vilaslandandwater.org
Najas guadalupensis: www.aquahobby.com
Utricularia vulgaris: www.dnr.state.md.us/bay/sav/key
Isoetes spp.: www.nybg.org
Chara vulgaris: http://en.wikipedia.org/wiki/File:Chara_vulgaris.jpeg; www.aquaticus.biz
Nitella flexilis: www.diszhal.info

APPENDIX B

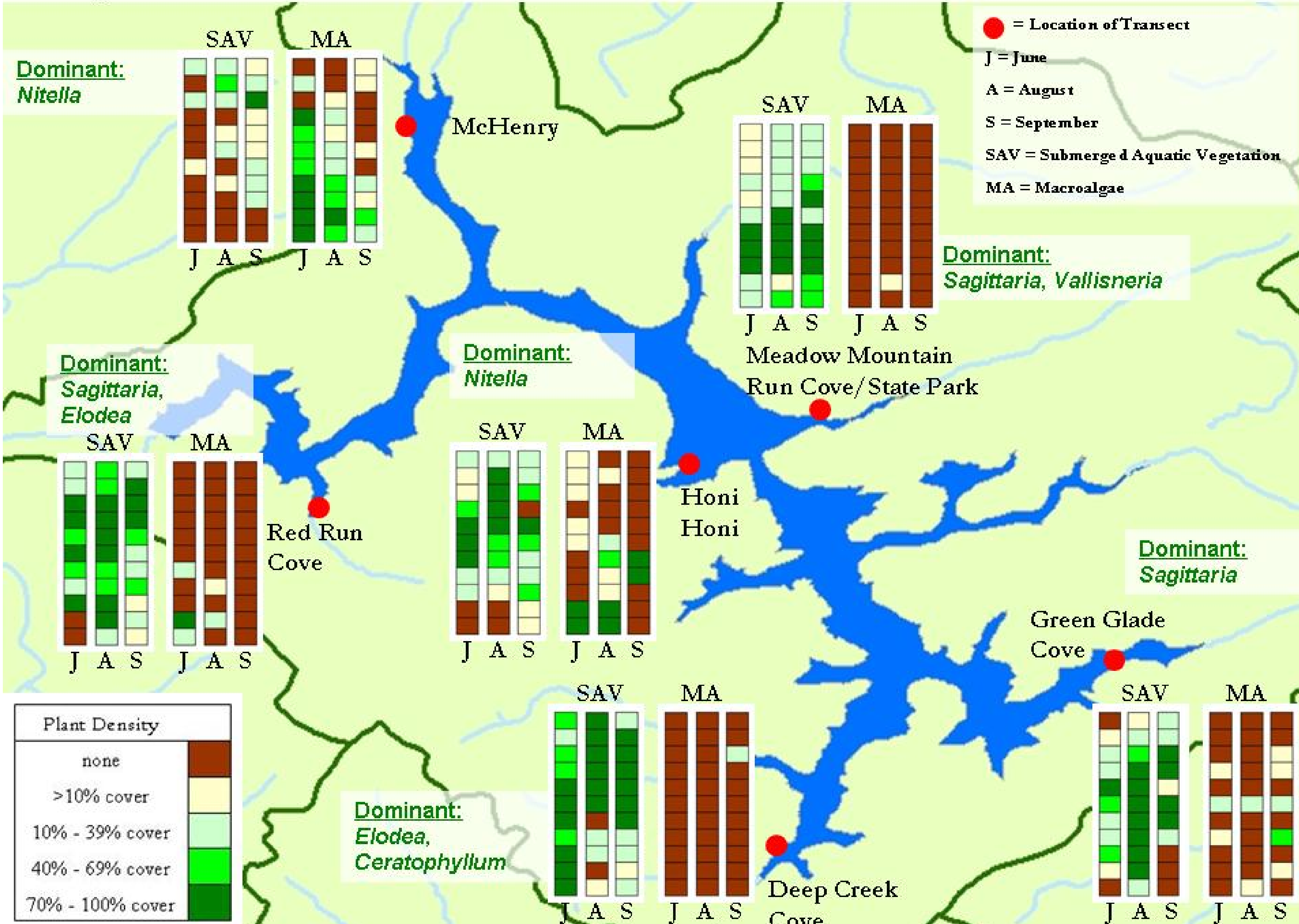
Deep Creek Lake
Submerged Aquatic Vegetation and Macroalgae Transect Results

2010-2012

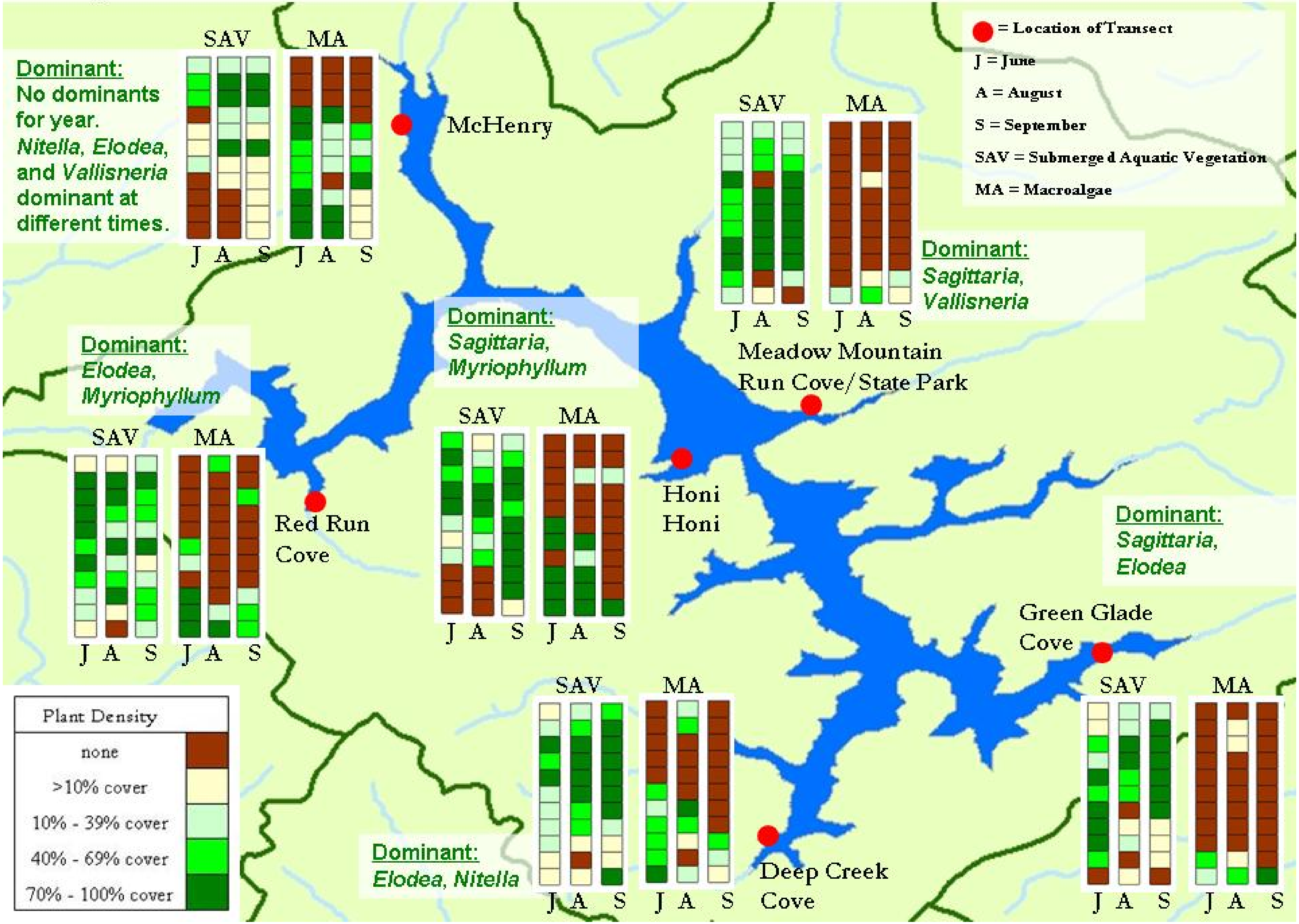
Deep Creek Lake, MD 2010



Deep Creek Lake, MD 2011



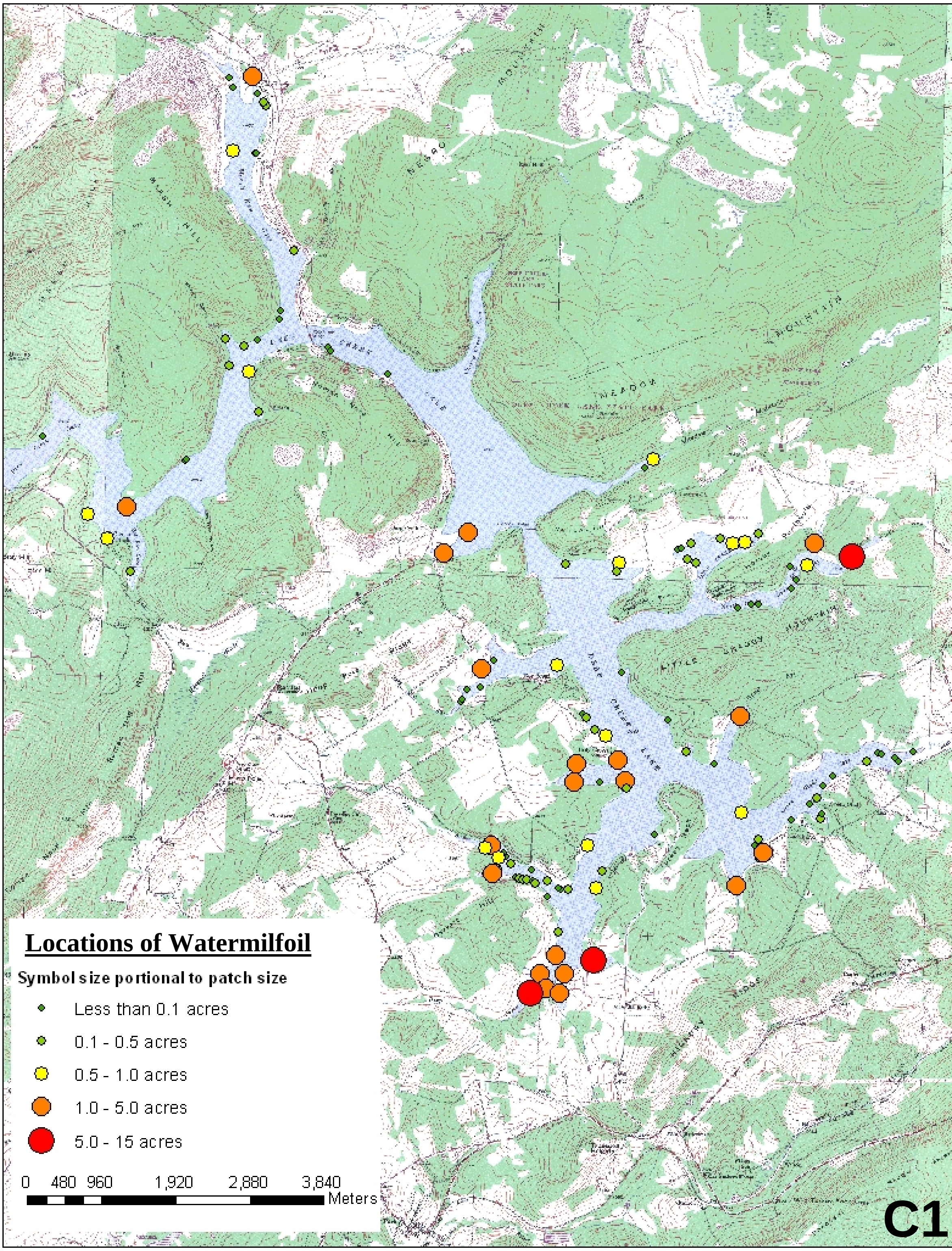
Deep Creek Lake, MD 2012

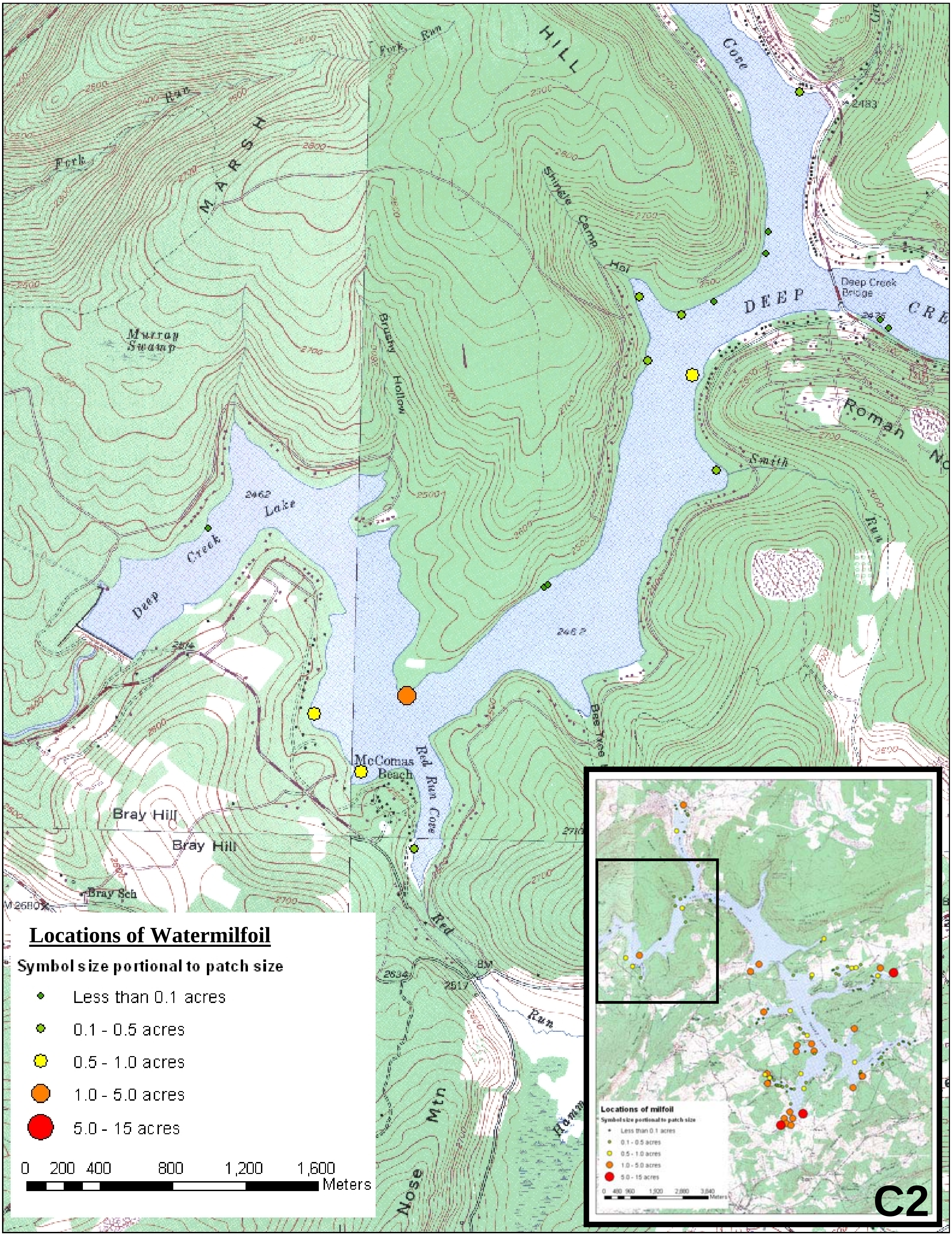


APPENDIX C

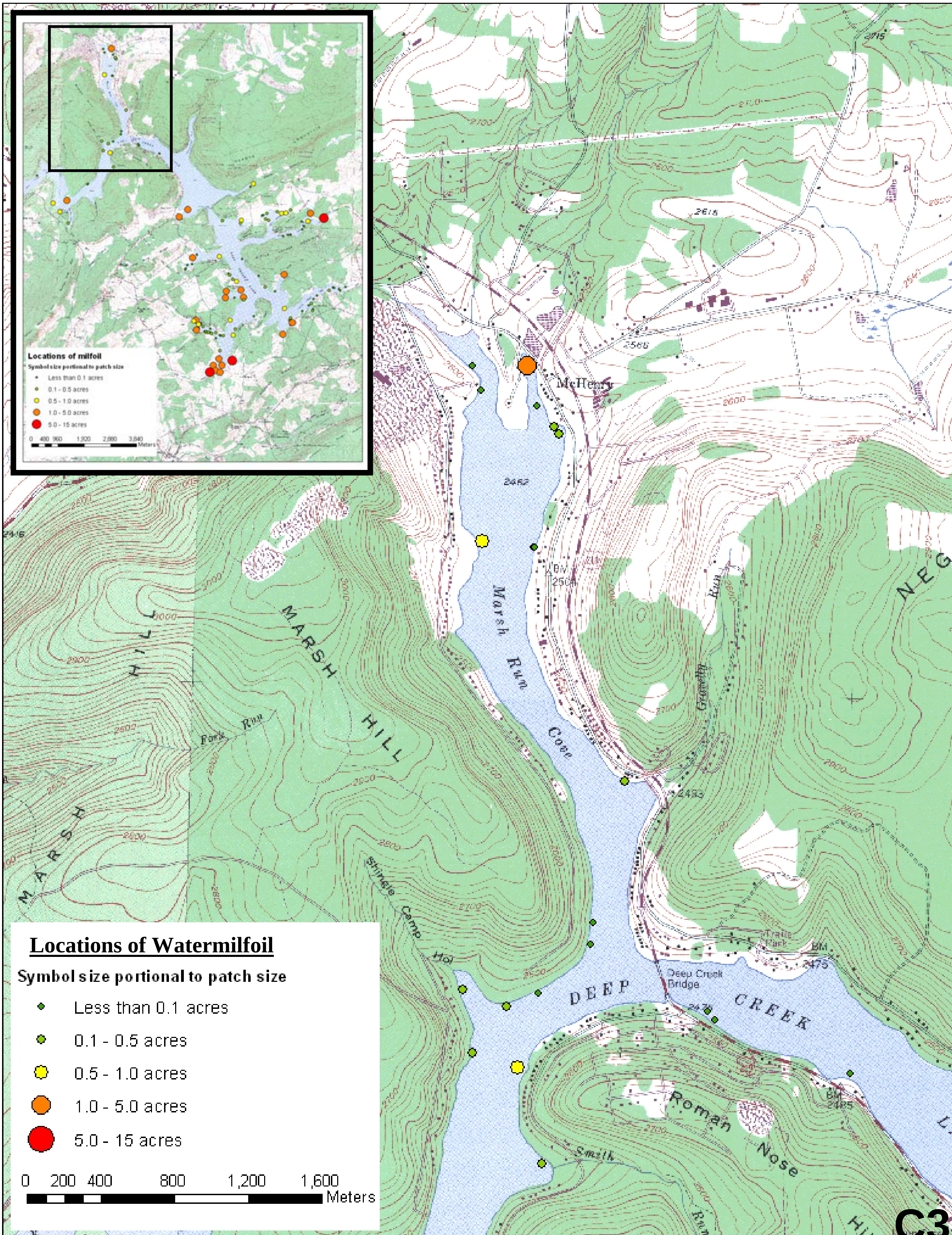
Deep Creek Lake *Myriophyllum* Survey Results 2012

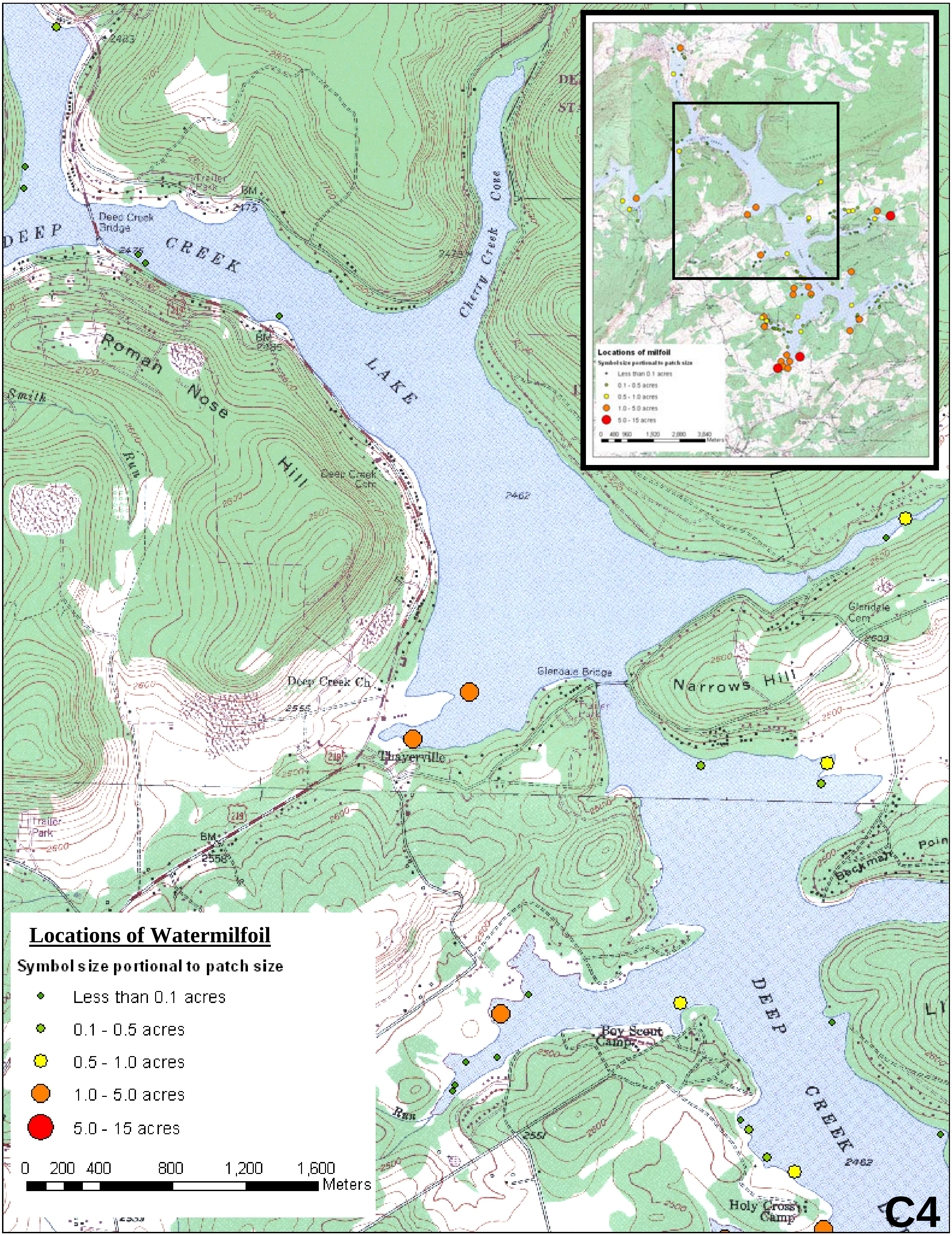
Deep Creek Lake *Myriophyllum* Survey Results 2012

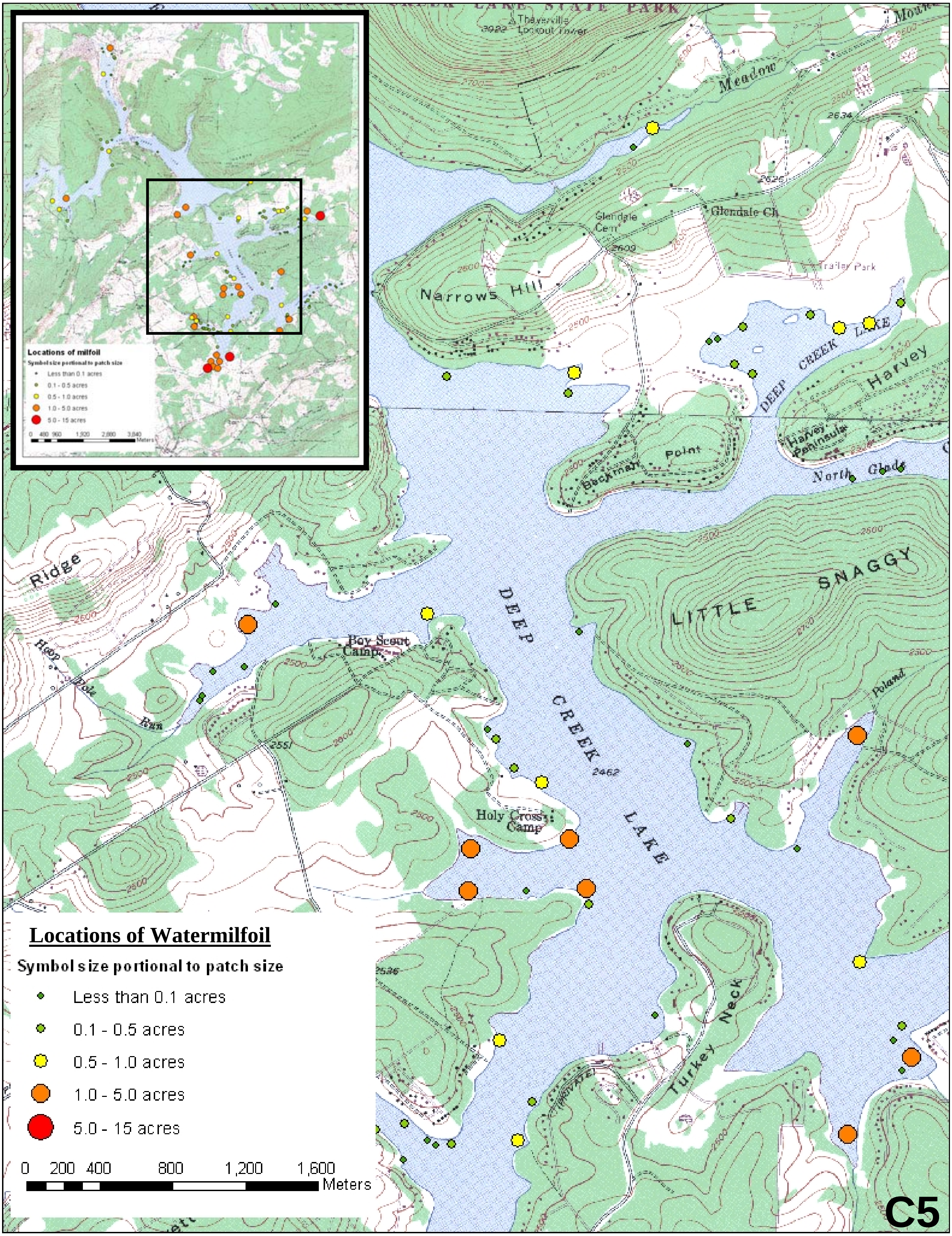




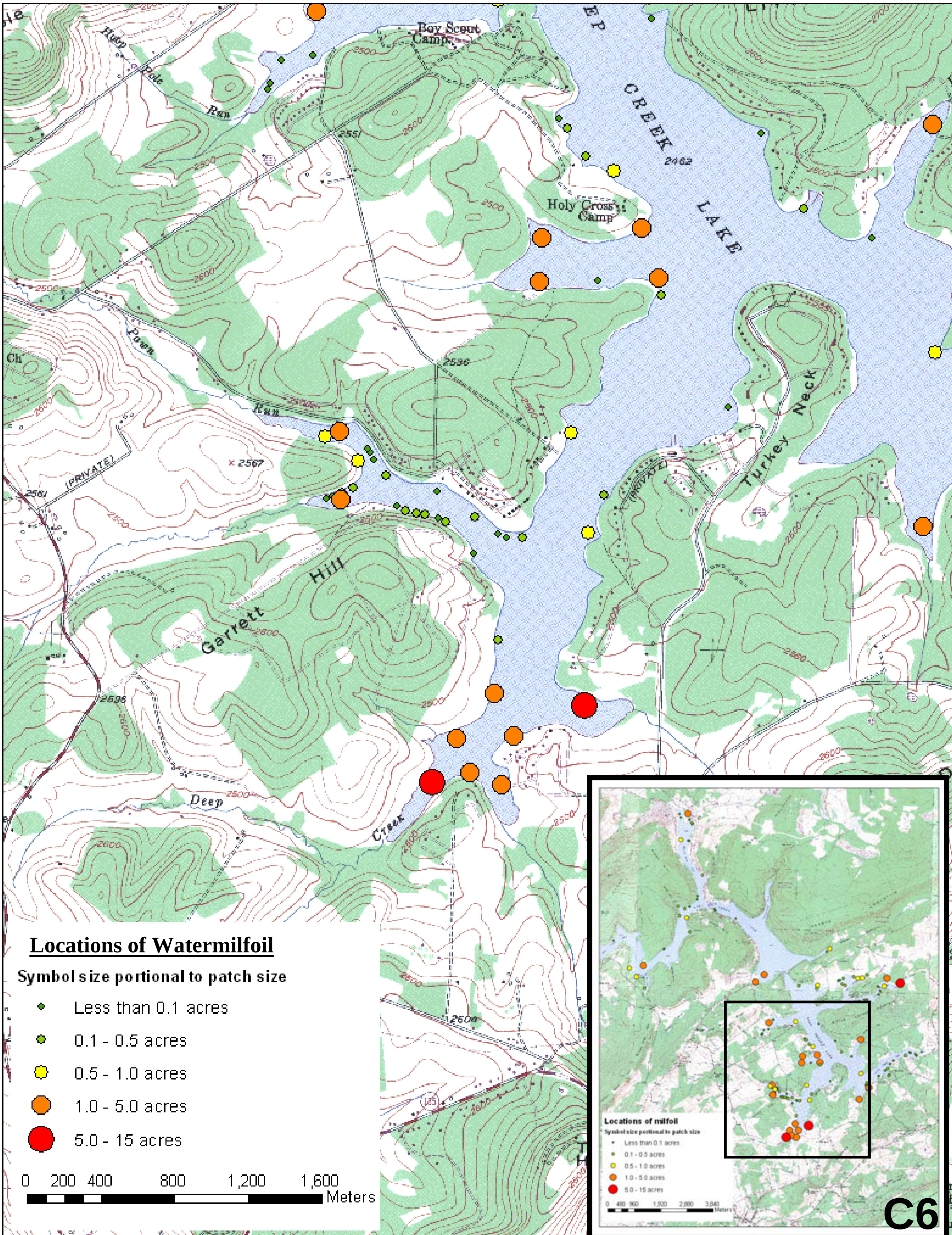
Locations of Watermilfoil
Symbol size portional to patch size
Less than 0.1 acres
0.1 - 0.5 acres
0.5 - 1.0 acres
1.0 - 5.0 acres
5.0 - 15 acres
0 200 400 800 1,200 1,600
Meters
Deep Creek Lake
MARSH
HILL
Murray Swamp
Brushy Hollow
Shingle Camp Hol
Cove
DEEP CREEK
Deep Creek Bridge
Roman
Smith Run
McComas Beach
Red Run Cove
Bray Hill
Bray Sch
Fork Run
Nose Mtn
Locations of milfoil
C2

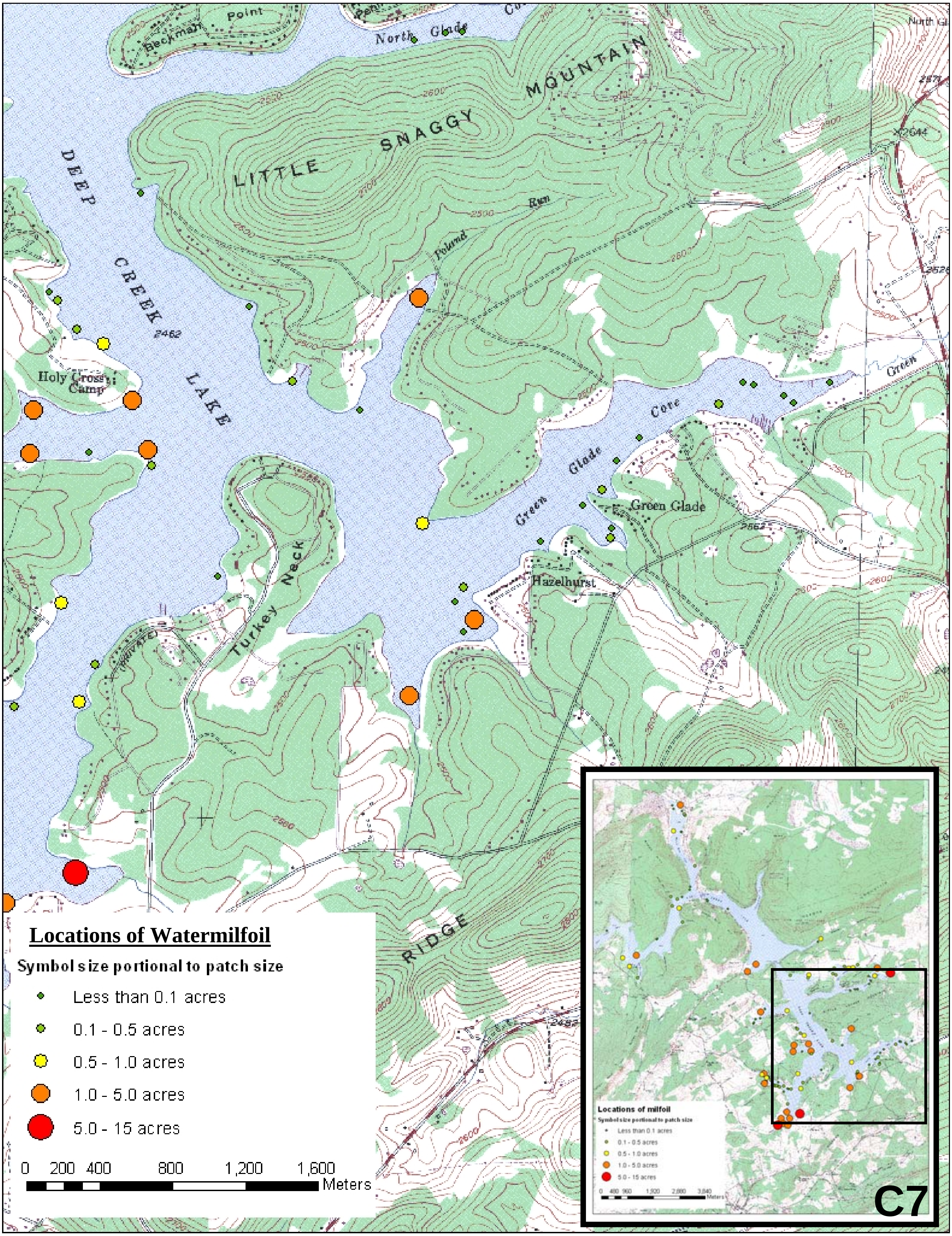

Locations of Watermilfoil
Symbol size portional to patch size
Less than 0.1 acres
0.1 - 0.5 acres
0.5 - 1.0 acres
1.0 - 5.0 acres
5.0 - 15 acres
0 200 400 800 1,200 1,600
Meters
Locations of milfoil
McHenry
Marsh Run Cove
MARSH HILL
DEEP CREEK
Roman Nose
Deep Creek Bridge
Trailer Park
Shingle Camp Hol
Fork Run
Smith
Gravelly Run
C3


Locations of Watermilfoil
Symbol size portional to patch size
Less than 0.1 acres
0.1 - 0.5 acres
0.5 - 1.0 acres
1.0 - 5.0 acres
5.0 - 15 acres
0 200 400 800 1,200 1,600
Meters
Locations of milfoil
DEEP CREEK LAKE
Deep Creek Bridge
Trailer Park
Roman Nose Hill
Smith Run
Deep Creek Cem
Cherry Creek Cove
Deep Creek Ch
Thayerville
Glendale Bridge
Narrows Hill
Glendale Cem
Boy Scout Camp
Holy Cross Camp
DEEP CREEK
C4



Locations of Watermilfoil
Symbol size portional to patch size
Less than 0.1 acres
0.1 - 0.5 acres
0.5 - 1.0 acres
1.0 - 5.0 acres
5.0 - 15 acres
0 200 400 800 1,200 1,600
Meters
Locations of milfoil
Narrows Hill
Meadow
Glendale Cem
Glendale Ch
Trailer Park
DEEP CREEK LAKE
Harvey
Harvey Peninsula
North Glade
Beckman Point
LITTLE SNAGGY
Ridge
Boy Scout Camp
Holy Cross Camp
DEEP CREEK LAKE
Turkey Neck
Poland
Thayerville Lookout Tower
C5


Locations of Watermilfoil
Symbol size portional to patch size
Less than 0.1 acres
0.1 - 0.5 acres
0.5 - 1.0 acres
1.0 - 5.0 acres
5.0 - 15 acres
0 200 400 800 1,200 1,600
Meters
Boy Scout Camp
Holy Cross Camp
CREEK LAKE
Turkey Neck
Garrett Hill
Deep Creek
Locations of milfoil
C6



Locations of Watermilfoil
Symbol size portional to patch size
Less than 0.1 acres
0.1 - 0.5 acres
0.5 - 1.0 acres
1.0 - 5.0 acres
5.0 - 15 acres
0 200 400 800 1,200 1,600
Meters
DEEP CREEK LAKE
LITTLE SNAGGY MOUNTAIN
Beckman Point
North Glade
Poland Run
Holy Cross Camp
Turkey Neck
Green Glade Cove
Green Glade
Hazelhurst
RIDGE
Locations of milfoil
C7