Maryland Department of Natural Resources

Tidewater Ecosystem Assessment

Deep Creek Lake
Submerged Aquatic Vegetation Survey
Year 2

Report of Survey Activity and Results

October 14, 2011

Prepared For

Maryland Department of Natural Resources

Maryland Park Service

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 produces 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 turbulence which allows suspended solids to settle to the bottom and get incorporated into the plants root systems, reduces 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 water milfoil (*Myriophyllum spicatum*).

Maryland Department of Natural Resources (DNR) Resource Assessment Service (RAS) staff conducted a second season of Submerged Aquatic Vegetation (SAV) monitoring in Deep Creek Lake (DCL), Garrett County, Md, during summer 2011 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 sampling six areas throughout the lake using globally accepted methodology. The areas were selected based on spatial distribution and the presence of SAV. 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 2011.**

- There is a highly 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.,* (Water milfoil), 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 annual changes occurring rarely.

- In 2010, *Myriophyllum spp*. (Water milfoil) density was higher at Honi Honi than at any other survey site. However, in 2011 there were no differences among sites as

Myriophyllum spp. density values decreased. Although we observed an increase in frequency of occurrence of *Myriophyllum spp*. at Red Run Cove from 2010 to2011, density did not change over time. There is no evidence that *Myriophyllum spp.* has increased from 2010 to 2011 based on the six study areas under this assessment.

- Though not specifically identified during the survey, *Myriophyllum spicatum,* or Eurasian Water milfoil, 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 *Myriophyllum ssp*. in DCL, DNR recommends evaluating options for implementing a species-specific SAV survey to determine the spatial extent, density and change over time of *Myriophyllum ssp.*

- 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.

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INTRODUCTION

In 2010, the Maryland Department of Natural Resources initiated a survey of submerged aquatic vegetation (SAV) in Deep Creek Lake. Despite its inherent ecological benefits, SAV may be viewed as an impediment to recreation and boat traffic in shallow areas, or in areas with fluctuating water levels. Due to complaints and concerns raised by some residents of Deep Creek Lake regarding the density of SAV during the late summer season, DNR's Resource Assessment Service (RAS) staff implemented an SAV survey in summer 2010 and repeated the survey in summer 2011. The goal of the SAV survey was to define the distribution and relative abundance of SAV species present by sampling six representative areas throughout the lake. This survey is a component of the comprehensive water quality and habitat monitoring program in DCL which began in April 2009. This program is a seasonal, spatially diverse monitoring plan that aims to define the lake's water quality conditions, spatial and seasonal variations, and to define a baseline for future trend analyses. This plan identified 7 monitoring sites in the mainstem-lake between the dam and Turkey Neck and additional sites in 9 significant embayments. At each site, field water quality measures are recorded (temperature, dissolved oxygen, pH, conductivity) and water samples collected for laboratory analysis of nitrogen and phosphorus, suspended particulates and chlorophyll (a measure of algae). Starting in April 2009, data and water samples have been collected from each site monthly in the summer (May – Sep) and, weather permitting, in the fall (Nov), winter (Jan) and spring (Mar). To assess stream loads of nutrients and sediment flowing into the lake, DNR also collects water quality samples for analysis of nutrients and sediments each month and during storm flows at two USGS stream gages on Cherry Creek and Poland Run. Additional water samples have been collected and analyzed after reported fish kills or algal blooms or to assess complaints.

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 65 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 the lake's shore is 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.

Because the coves are all stream fed, they are first in line to receive nutrient and sediment run-off from the surrounding watershed. Beginning in late spring and fueled by the incoming nutrients and increased water temperatures, submerged aquatic vegetation (SAV) begins growing in these coves and throughout the lake's photic zone. 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 produces 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 turbulence which allows suspended solids to settle to the bottom and get incorporated into the plants root systems, reduces 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 water milfoil (*Myriophyllum spicatum*).

METHODS

In June 2010, RAS staff, accompanied by local SAV experts, identified six areas to survey throughout 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, listed clockwise from north, include an area near the town of McHenry (-79.35787, 39.55087), Meadow Mountain Run Cove (-79.30334, 39.51182), Green Glade Cove (-79.26206, 39.47844), Deep Creek Cove (-79.30904, 39.45368), an area near the Honi Honi Bar and Restaurant in Thayersville (-79.32091, 39.50485), and Red Run Cove (-79.3711, 39.49977). See Figure 1 for a map of locations and Table 1 for a list of site abbreviations.

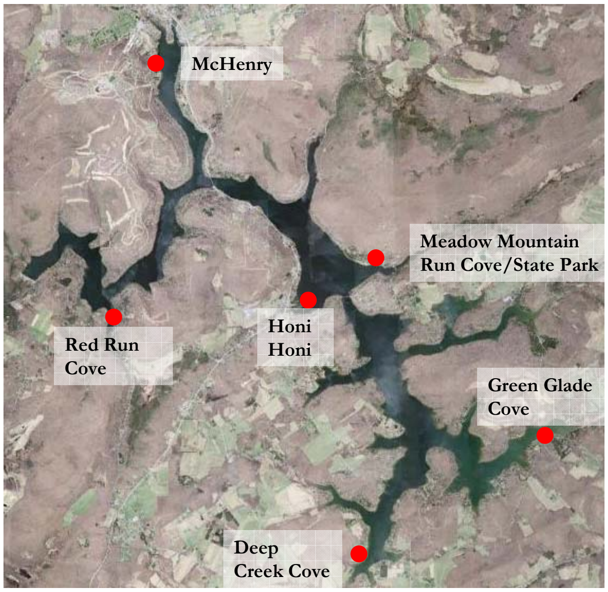


Figure 1. Aerial map of Deep Creek lake with MD DNR SAV survey transect locations indicated by red dots.

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 each location, the extent of the SAV bed was identified by visual observations of SCUBA divers. 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 diver 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 device so that all surveys could be repeated in the same location. If the SAV beds expanded or contracted from 2010 to 2011, a new point was recorded and the transect was terminated at the current edge of bed.

Using SCUBA, divers 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 macroalgal were visually quantified for each species present. A total SAV percent cover was also estimated. 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 and on June 14th, August 9th and September 12th, 2011.

Data Analysis

Raw data were entered into a Microsoft Excel spreadsheet. A species diversity index was defined for each transect and sampling event as the number of species observed per transect. 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% or 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 year 2011, in which three sampling events took place, a species/genus had to be found dominant during two of the three sampling events.

To identify differences in our observations among sites and over time, a number of statistical analyses were performed using the statistical software package SAS version 9.1 (SAS Institute Incorporated, Cary, NC). Site-specific characteristics (transect length, maximum water depth and slope) were compared using 2-Way ANOVAs to identify significant differences among sites and changes at each site over time. Species diversity, total mean SAV percent cover, individual species mean percent cover and species frequency of occurrence were also compared using 2-Way ANOVAs in order to determine differences over space and time. Homogeneity of variances was assessed using Levene's test. Following a significant ANOVA, post hoc multiple comparisons were performed using Tukey's test.

RESULTS

We observed nine genera of vascular aquatic plants and two species of macroalgae during our 2010 and 2011 SAV surveys. These plants include *Vallisneria americana* (Wild celery), *Sagittaria cristata* (Crested arrowhead), *Elodea canadensis* (Canadian waterweed), *Myriophyllum spp.* (Water milfoil, including *M. sibiricum*, *M. heterophyllum*, and *M. spicatum*, or Eurasian water milfoil, an Aquatic Invasive Species in North America), *Ceratophyllum demersum* (Coontail), *Najas flexilis* (Slender naiad), *Najas guadalupensis* (Southern naiad), *Utricularia vulgaris* (Common bladderwort), *Isoetes spp*. (Quillwort), 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*. The two macroalgae observed include *Nitella flexilis* and *Chara vulgaris.* Common names and abbreviations for these species can be found in Table 2. Information about each species is given in Appendix A.

Table 2. List of SAV observed in Deep Creek Lake during summer 2010 and summer 2011 SAV study 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	Water millfoil
Najas flexilis	Nf	Slender 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 Water milfoil to the species level, particularly underwater while diving, *Myriophyllum* was only identified and recorded at the genus level for the SAV 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.

A compilation of sampling results, including transect length, maximum water depth, slope from onshore to offshore edge of SAV bed, total SAV mean percent cover, diversity index, and density and frequency of occurrence for each SAV species observed during each survey is given in Appendix B.

Most species that we observed were seen throughout the lake, but each site was dominated by just one or two species (Table 3). The SAV bed transect surveyed near McHenry (transect length from 60-90m and max depth of 5.3m) was dominated by *V. americana* in 2010 and changed to a macroalgal (*Nitella flexilis)* dominated bed in 2011. Moving clockwise around the lake, the SAV bed surveyed in Meadow Mountain Run Cove, offshore of the State Park, was dominated by *S. cristata* and *V. americana* during both summers. This transect ranged from 55-63m with a max depth of 4.1m. Green Glade Cove, with a transect length ranging from 55-70m and a max depth of 5m, is in the southeastern portion of the lake. This SAV bed was dominated by *S. cristata*, *E. canadensis*, and *Nitella flexilis* in 2010. In 2011, the dominant plant observed was *S. cristata*. Moving south and west, Deep Creek Cove was one of the longest transects (length of 200m and max depth of 3m). This expansive bed was dominated by *E. canadensis* in 2010, but in 2011 *C. demersum* was also found to be dominant. Continuing clockwise, the SAV bed surveyed near the Honi Honi in Oakland was also a long transect (ranging from 150-200m) with the greatest maximum depth (5.8m). This SAV bed was dominated by *Myriophyllum spp*. in 2010 and again in 2011, though the density of *Myriophyllum* decreased substantially and was co-dominant with *Nitella flexilis*, a macroalgae in 2011. Finally, survey results for the SAV bed in Red Run Cove (transect length from 100-127m and max depth of 4.1m), in the northwestern portion of the lake near the dam, indicate that *Nitella flexilis* and *E. canadensis* dominated this bed in 2010. In 2011, *E. canadensis* maintained dominance, but *S. cristata* replaced *Nitella flexilis*. See Appendix C for a map of the lake with dominant species for 2010 and 2011, as well as color-coded transect models.

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. It was observed at its highest densities along the shallowest 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, *S. cristata* was generally replaced by *Potamogeton spp.*, *Vallisneria americana*, or *Ceratophyllum demersum*. Along the deeper edge of SAV beds is where we found more *C. demersum*, *Elodea canadensis*, *Myriophyllum spp.*, and the two species of macroalgae (which have lower light requirements), *C. vulgaris* and *Nitella flexilis*.

Statistical analyses indicated that *S. cristata*, *V. americana*, *E. canadensis*, *C. demersum,* and *Myriophyllum spp*. were the most common species at our survey sites in 2010 and 2011. There was a significant difference ($p < 0.0001$) in species density and frequency of occurrence for all

Table 3. Dominant SAV species for each sampling event, survey site, and year, where Dominance = Density > or = 10%, or Frequency of Occurrence > = 50%

2010

Site	Date	Dominant spp. For Event	Dominant spp. For Year
McH	8/5/10	**Va,** Ec	***Vallisneria americana***
	9/16/10	**Va**	
MMR	8/5/10	**Sc, Va**	***Sagittaria cristata, Vallisneria americana***
	9/16/10	**Sc, Va**	
GGC	8/5/10	**Sc, Ec**, **Nit**	***Sagittaria cristata, Elodea canadensis, Nitella flexilis***
	9/16/10	**Sc, Ec**, Cv, **Nit**	
DCC	8/5/10	**Ec**, Pp, Cv	***Elodea canadensis***
	9/16/10	**Ec**, Cd	
HHO	8/5/10	Sc, **Myr**, Cv, Nit	***Myriophyllum spp.***
	9/16/10	**Myr**	
RRC	8/5/10	**Ec**, Pp, Cv, **Nit**	***Elodea canadensis, Nitella flexilis***
	9/16/10	**Ec,** Pv, **Nit**	

2011

Site	Date	Dominant spp. For Event	Dominant spp. For Year
McH	6/14/11	Cv	***Nitella flexilis***
	8/9/11	**Nit**	
	9/12/11	Va, **Nit**	
MMR	6/14/11	**Sc, Va**	***Sagittaria cristata, Vallisneria americana***
	8/9/11	**Sc,** Uv	
	9/12/11	**Sc, Va**	
GGC	6/14/11	**Sc**	***Sagittaria cristata***
	8/9/11	**Sc**, Uv, Pp	
	9/12/11	**Sc**	
DCC	6/14/11	**Ec**, **Cd**, Pp	***Elodea canadensis, Ceratophyllum demersum***
	8/9/11	**Ec**, Pd	
	9/12/11	**Ec, Cd**	
HHO	6/14/11	Ec, **Myr**, Cv	***Nitella flexilis, Myriophyllum spp.***
	8/9/11	Sc, Uv, **Nit**	
	9/12/11	Pp, **Nit, Myr**	
RRC	6/14/11	**Ec**, Pp, Cv	***Sagittaria cristata, Elodea canadensis***
	8/9/11	**Sc, Ec**, Myr, Pv	
	9/12/11	**Sc, Ec**	

five of these species among the six survey areas. We observed the highest densities of *S. cristata* and *V. americana* most frequently at Meadow Mountain Run. *Vallisneria americana* was also observed at higher densities at McHenry compared to the other survey sites. Deep Creek Cove had the highest densities and frequencies of occurrence of *E. canadensis* and *C. demersum* in both 2010 and 2011. *Elodea canadensis* was also observed at higher densities at Red Run Cove. While not statistically significant ($p = 0.05$), *Nitella flexilis* was observed most frequently at Green Glade Cove, McHenry, Honi Honi and Red Run Cove compared to Deep Creek Cove and Meadow Mountain Run. At Red Run Cove, the annual mean density of *Nitella flexilis* decreased from 28% in 2010 to <1% in 2011, although not significantly ($p = 0.05$).

In 2010, *Myriophyllum spp*. density was significantly higher at Honi Honi than at any other survey site. However, in 2011 there were no significant differences among sites as *Myriophyllum spp*. density values decreased (density decreased at Honi Honi from 31% in September 2010 to 6% in September 2011). Although we observed a statistically significant increase in frequency of occurrence of *Myriophyllum spp*. at Red Run Cove from 2010 to 2011 (values went from 18% frequency of occurrence in September 2010 to 45% frequency of occurrence in September 2011), density did not change over time (values ranged from <1% to 5%).

Total mean SAV percent cover and species diversity also varied significantly ($p < 0.02$) among survey sites. The highest total percent covers and diversity values were observed at Deep Creek

Cove, Red Run Cove and Honi Honi, while transects at Green Glade Cove, Meadow Mountain Run and McHenry had lower total percent covers and species diversity. Table 4 (lower left portion) summarizes the post-hoc comparisons and denotes if each site is statistically different from the other five. No significant changes in species diversity or overall total SAV percent cover were observed between 2010 and 2011.

Table 4. Summary of post-hoc comparisons. Letters representing physical or biological characteristic, defined below, denote if each site is statistically different from the others.

	DCC	**GGC**	**HHO**	**MMR**	**RRC**	**McH**
DCC		L,S	L,D	L,S	L,S	L,D,S
GGC			L,S		L,S	L
HHO				L,S	L	L,S
MMR			D		L,S	L
RRC				D		L,S
McH	%					

Top: L = transect length, S = slope and D = maximum water depth
Bottom: % = mean total percent cover and D = species diversity

Results of the 2-Way ANOVAs indicate that the six survey sites differed significantly ($p < 0.01$) based on physical characteristics (transect length, maximum water depth and slope). Deep Creek Cove was the longest and shallowest transect, while Meadow Mountain Run was the shortest and steepest site. The transect near Honi Honi was the deepest. Table 4 (upper right portion) summarizes the post-hoc comparisons and denotes if each site is statistically different from the other five. Only the transect at Red Run Cove was significantly shorter ($p = 0.04$) in 2011 than in 2010. There was no significant change in transect length, maximum water depth or slope over time at any other site.

DISCUSSION

The goal of the SAV survey was to define the distribution and abundance of the SAV community at several 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 survey methodology is a globally accepted method to identify changes in a SAV community; it does not focus on any one species over another. Our results indicate that DCL supports a healthy and diverse population of SAV, including 9 genera of vascular plants and 2 species of macroalgae. The distribution and abundance of these species differ primarily by site, with annual changes occurring within a few sites. 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 2011.

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

SAV. *Sagittaria cristata,* commonly known as Crested arrowhead, was observed at each site during 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 spp*., and macroalgae. *Elodea canadensis* and *Myriophyllum spp.* 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 spp*. and macroalgae (both *Nitella flexilis* and *Chara vulgaris*).

In 2010, *Myriophyllum spp*. density was significantly higher at Honi Honi than at any other survey site. However, in 2011 there were no significant differences among sites as *Myriophyllum spp*. density values decreased. Although we observed a statistically significant increase in frequency of occurrence of *Myriophyllum spp*. at Red Run Cove from 2010 to2011, density did not change over time. Neither *Myriophyllumm spp*. density nor frequency of occurrence changed over time in any of the other surveyed coves.

Fish were observed in all of the SAV beds surveyed, using the SAV shoots and blades as habitat and refuge. In general, the more diverse a habitat, the more species of both fish and invertebrates will be supported. With such a diverse collection of plants in Deep Creek Lake, one can conclude that overall biodiversity in the Lake is relatively high.

CONCLUSIONS

Like many ecosystems, Deep Creek Lake has a fluctuating environment. Because of its role as a hydroelectric utility, the water level in the lake can change often, which affects the distribution of SAV growing in the lake. There have also been periods of heavy precipitation, drought, and record high and low temperatures. Because of its fluctuating environment, it is recommended that a long-term SAV monitoring program is maintained in DCL in order to characterize existing conditions and assess potential changes over time due to water quality improvements or declines related to population and land use changes.

In addition to maintaining the existing SAV monitoring program, DNR recommends implementing a species-specific SAV survey to determine the spatial extent, density and change over time of *Myriophyllum ssp.* We are currently developing several monitoring options that will be presented and discussed over the November 2011 – February 2012 time frame to specifically address this issue. These monitoring options will be aimed at characterizing the extent of *Myriophyllum ssp.* in DCL and determining if this species is a threat to other SAV species, a healthy ecosystem and recreational activities. The selected survey methodology will be ready for implementation by April 1, 2012. If *Myriophyllum ssp.* is found to be a severe problem and/or out-competing other more desirable species, management options will be evaluated. Because poor or irresponsible activities designed to control aquatic plants may have unanticipated and adverse effects on all of the organisms that need and use the lake ecosystem, including humans, we will make recommendations on how to control and manage this species in context of preserving a healthy lake and diverse SAV population.

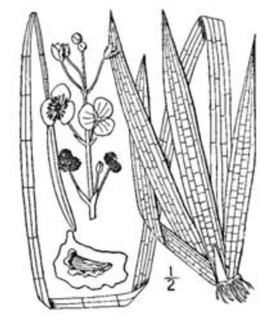
APPENDIX A

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 summer 2010 and summer 2011 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).

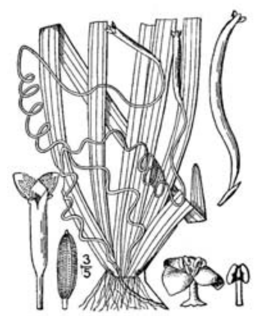
Crested arrowhead grows along the margins and bottoms of shallow lakes, ponds, and swamps. It may grow up to 75 cm tall, though in DCL it hasn't been observed more than 10 cm high. Flowering occurs July through August.



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)

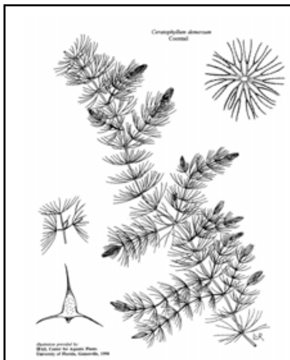
Monocot. Perennial. Native to the continental US and Canada, but considered Invasive in Puerto Rico. Distributed in all but three continental US states: TX, LA, and GA.

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.

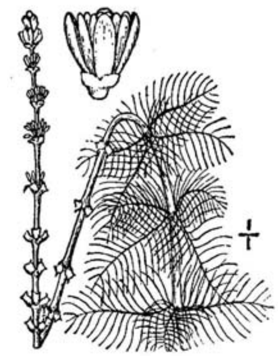
Coontail's leaves grow in crowded whorls which make it resemble a raccoon's tail underwater. Each leaf is forked into segments with fine teeth on one side of the leaf margin. Leaves are brittle and keep their shape out of water. Coontail may float in dense mats beneath the surface and its base is only 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.

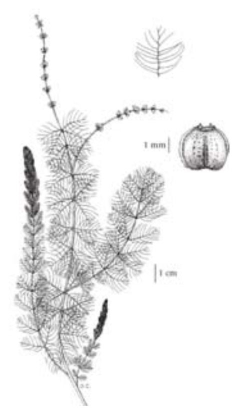
Eurasian watermilfoil can grow in ponds, lakes, reservoirs, and slow flowing rivers and streams. It will grow in shallow or deep water, fresh or brackish water, and within a wide temperature range. It tends to do well in waters that have had some sort of disturbance like intense plant management, overabundance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

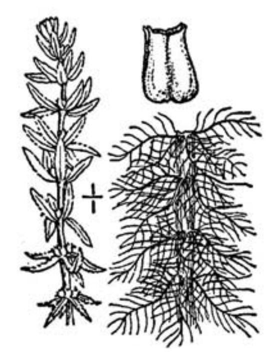
Myriophyllum sibiricum (Northern water milfoil)
Dicot, Perennial. Native to the continental US, Alaska, Canada, and elsewhere. Distribution throughout Canada and the US with the exception of southeastern states from TX east to FL.

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.

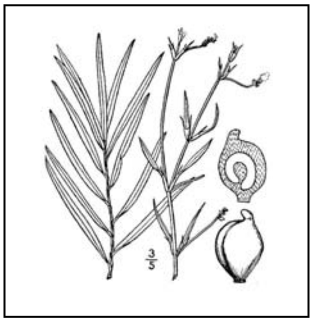


Myriophyllum heterophyllum (Two-leafed water milfoil)
Dicot, Perennial. Native to the continental US and Canada with distribution throughout the eastern US and Canada.

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*

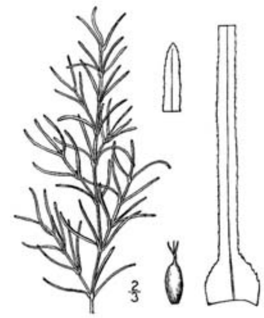


***Najas flexilis* (Slender naiad)**
Monocot. Annual. Native to the continental US, Alaska, and Canada. Found in most northern states and Canada.

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.

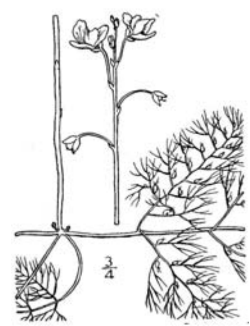
***Najas guadalupensis* (Southern naiad)**
Monocot. Annual. Native to the continental US, Puerto Rico, and Canada. Invasive to Hawaii. Distributed throughout US.

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



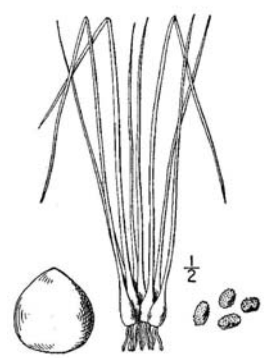
***Utricularia vulgaris* (Common bladderwort)**
Dicot. Perennial. Native to the continental US, Alaska, and Canada.

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.

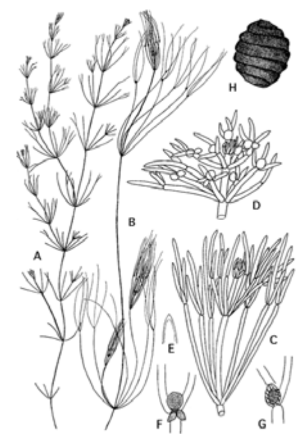


Chara vulgaris (macroalgae – Chara, Common stonewort)

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.

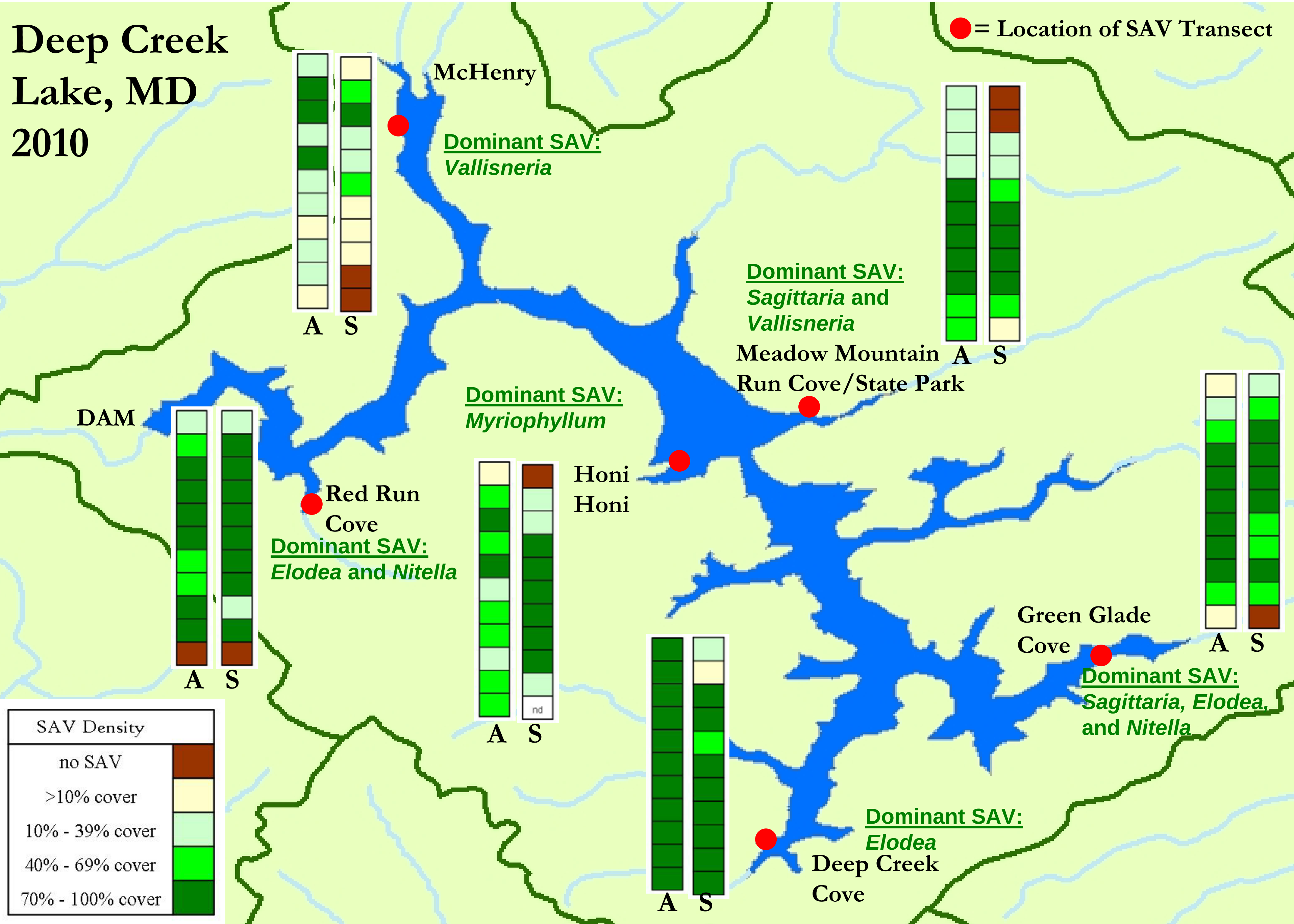
Images were obtained from the following:
Sagittaria cristata: www.uwgb.edu/biodiversity/herbarium/wetland_plants
Vallisneria Americana: www.dnr.state.md.us/bay/sav/key
Elodea Canadensis: www.dnr.state.md.us/bay/sav/key/
Ceratophyllum demersum: www.dnr.state.md.us/bay/sav/key/
Myriophyllum spicatum: www.dnr.state.md.us/bay/sav/key/
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

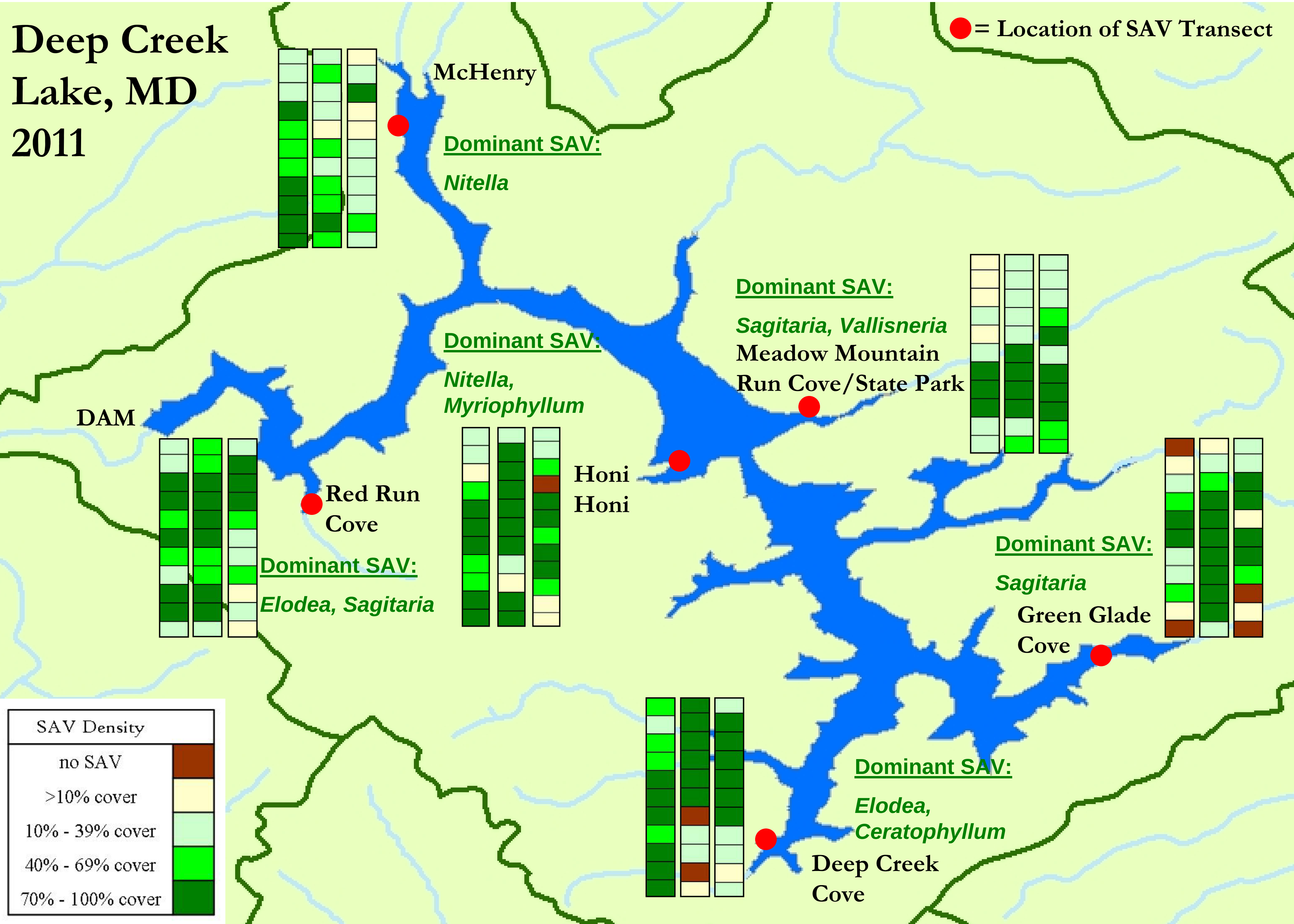
APPENDIX B

Summary of Deep Creek Lake SAV survey results. For each cove surveyed, Transect Length, Maximum Water Depth, Mean Total SAV % Cover, Diversity Index, and Mean % Cover and Frequency of Occurrence for each type of SAV observed along the transect are given. Frequency of Occurrence values are in parentheses. DCC = Deep Creek Cove, GGC = Green Glades Cove, HHO = Honi Honi in Oakland, MMR = Meadow Mountain Run Cove, RRC = Red Run Cove, and McH = McHenry.

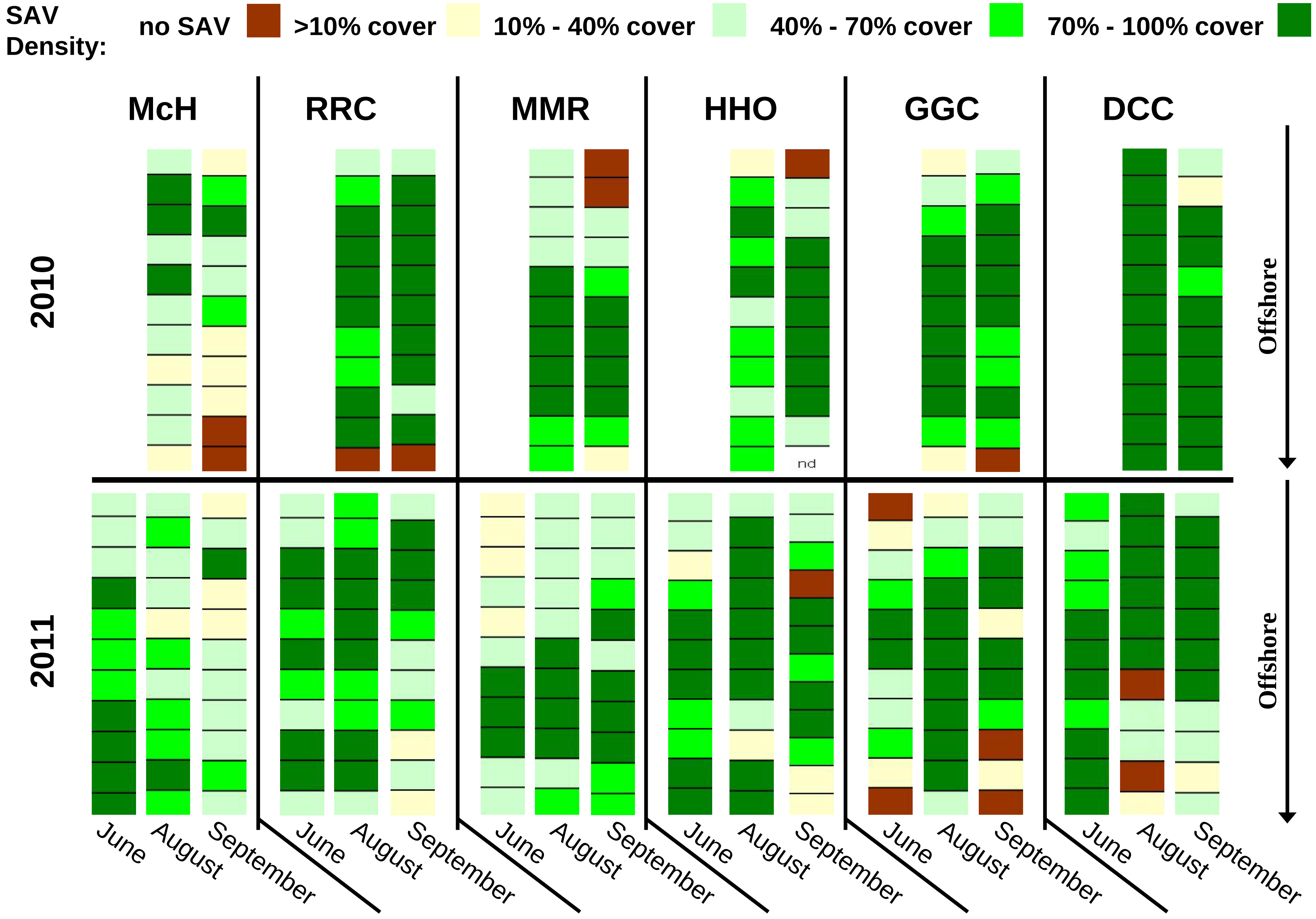
Date	Transect ID	Transect length (m)	Max Water Depth (cm)	Slope (cm/m)	Mean Total SAV % cover	Diversity Index	Sagittaria cristata	Vallisneria americana	Elodea canadensis	Ceratophyllum demersum	Myriophyllum spp.	Najas flexilis	Najas guadalupensis	Utricularia vulgaris	Isoetes spp.	Potamogeton pusillus	Potamogeton robbinsii	Potamogeton vaseyi	Potamogeton spirillus	Potamogeton diversifolius	Chara vulgaris (algae)	Nitella flexilis (algae)
8/4/10	McH	80	400	4.69	38	6	2 (18)	10(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	400	4.33	18	7	<1 (18)	10(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	530	4.97	57	3	<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	480	4.67	42	5	<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)	33(82)
9/12/11	McH	60	400	5.75	23	5	<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)
8/5/10	MMR	63	300	4.73	51	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	390	6.50	51	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	410	6.00	35	3	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	290	4.45	47	5	37 (91)	5(18)	<1(9)	0(0)	0(0)	2(36)	0(0)	2(82)	0(0)	<1(9)	0(0)	<1(45)	0(0)	0(0)	0(0)	<1(9)
9/12/11	MMR	60	400	6.58	51	2	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)
8/5/10	GGC	70	300	3.21	60	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	350	5.00	60	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	500	4.00	30	4	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	360	5.27	70	8	21 (45)	0(0)	9(36)	0(0)	6(9)	0(0)	0(0)	11(73)	0(0)	15(55)	0(0)	6(27)	0(0)	0(0)	<1(18)	1(18)
9/12/11	GGC	60	400	5.50	44	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)
8/5/10	DCC	200	250	1.23	100	7	<1(18)	0(0)	60(82)	<1(18)	7(9)	0(0)	0(0)	0(0)	0(18)	11(18)	0(0)	9(27)	0(0)	0(0)	13(18)	0(0)
9/16/10	DCC	200	230	1.15	75	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	300	1.25	70	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	295	1.25	58	7	5 (9)	0(0)	24(64)	3(27)	8(9)	0(0)	0(0)	0(0)	0(0)	1(36)	0(0)	1(9)	<1(9)	13(27)	0(0)	0(0)
9/12/11	DCC	200	370	1.75	56	5	7 (5)	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)
8/5/10	HHO	195	580	2.56	48	7	15 (36)	0(0)	1(27)	0(0)	22(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	300	1.50	54	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	560	2.87	59	7	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	500	2.50	69	8	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	410	2.10	48	7	7 (36)	0(0)	6(27)	0(0)	6(55)	3(18)	0(0)	3(9)	0(0)	10(27)	<1(9)	0(0)	0(0)	0(0)	0(0)	13(18)
8/4/10	RRC	127	325	2.55	63	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	370	2.80	73	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	410	3.10	61	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	370	2.73	73	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	330	3.04	41	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)

APPENDIX C


Deep Creek
Lake, MD
2010
= Location of SAV Transect
McHenry
Dominant SAV:
Vallisneria
A S
Dominant SAV:
Sagittaria and
Vallisneria
Meadow Mountain
Run Cove/State Park
A S
DAM
Dominant SAV:
Myriophyllum
Red Run
Cove
Dominant SAV:
Elodea and Nitella
A S
Honi
Honi
nd
A S
Green Glade
Cove
A S
Dominant SAV:
Sagittaria, Elodea,
and Nitella
Dominant SAV:
Elodea
Deep Creek
Cove
A S
SAV Density
no SAV
>10% cover
10% - 39% cover
40% - 69% cover
70% - 100% cover



Deep Creek Lake, MD 2011
= Location of SAV Transect
McHenry
Dominant SAV:
Nitella
Dominant SAV:
Nitella, Myriophyllum
DAM
Red Run Cove
Dominant SAV:
Elodea, Sagitaria
Honi Honi
Dominant SAV:
Sagitaria, Vallisneria
Meadow Mountain Run Cove/State Park
Dominant SAV:
Sagitaria
Green Glade Cove
Dominant SAV:
Elodea, Ceratophyllum
Deep Creek Cove
SAV Density
no SAV
>10% cover
10% - 39% cover
40% - 69% cover
70% - 100% cover


SAV Density:
no SAV
>10% cover
10% - 40% cover
40% - 70% cover
70% - 100% cover
McH
RRC
MMR
HHO
GGC
DCC
2010
2011
Offshore
Offshore
nd
June
August
September