2009 Survey of Aquatic Plants in Martins Pond

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Acknowledgements

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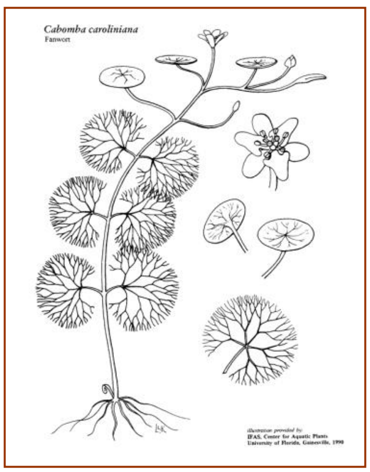
Section A. Overview

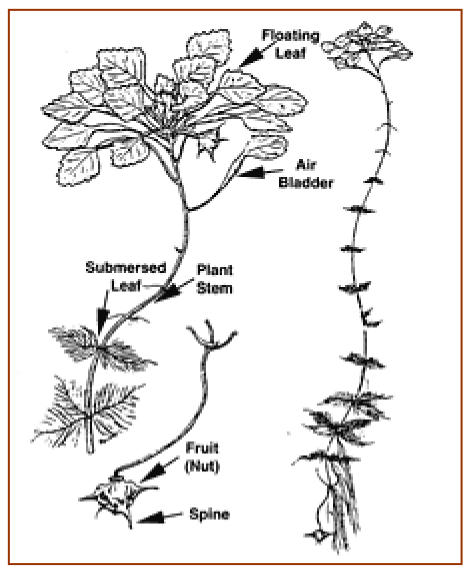
Freshwater aquatic macrophytes are the large macroscopic aquatic plants found in lakes and ponds as opposed to the smaller and microphytic algae or phytoplankton. Macrophytes have historically been classified into four classes based on their location: emergent, submersed, floating-leaved or free floating. Each group has unique characteristics and can have unique distributions in ponds and lakes. The distribution of macrophytes in the littoral zone (the extent of aquatic plant cover in a pond or lake) can be influenced by numerous factors including sediments, wind, water clarity and trophic status. A recent Diagnostic/Feasibility Study on Martins Pond describes these conditions in some detail (Lyon, 2007).

Exotic and invasive macrophyte species invasions have exerted a strong influence on shallow pond and lake systems. In New England, several invasive species have proliferated throughout freshwater bodies in the region (Hellquist 1998). Given the ecological importance of freshwater systems, there is keen interest in characterizing the influence of nuisance, non-native species such as fanwort on the distribution of both native and non-native macrophytes. In addition, there is great interest in developing and pursuing effective control measures for these nuisance species. Unfortunately, there are often limited data available for pre- and post-control measure comparisons or to predict the impacts of various control measures on target species abundance and distribution. There are two critical invasive species currently impacting Martins Pond: **Fanwort** (*Cabomba caroliniana* Gray) and **Water Chestnut** (*Trapa napans* L.).



Fanwort is an aquatic plant originating in the neotropics and other southern temperate climates that has spread from incidental release from aquariums. Once established, fanwort is an extremely persistent and competitive plant. It is a submersed, floating perennial that may surface in late summer, producing tiny white flowers with oval floating leaves. Below the waterline, fanwort has distinct fan shaped leaves that vary in color from grass green to olive green, or sometimes even reddish-brown (see illustration on left).

Water chestnut is native to Europe and Asia. It is a rooted, floating plant that invades shallow to deep, fresh water habitats. It typically forms dense, floating mats. Leaves on the surface of the water are alternate, triangular in shape, strongly toothed. The submerged leaves are feathery and either opposite or alternate (see illustration on right).



This report summarizes aquatic plant survey results from Martins Pond in 2009, four years after mechanical harvesting was performed to reduce the abundance and spatial distribution of fanwort. This report also provides a broader analysis of all aquatic plant species found in Martins Pond and their abundance since 2002. Long-term monitoring results are the best way to assess the impacts of mechanical harvesting on the entire aquatic plant community.

Light, Turbidity and Color in Martins Pond

Light is arguably the most important limiting factor regulating macrophyte and algae growth in Martins Pond. One of the most critical aspects of the current study is the impact of the relatively high water color levels in Martins Pond (and in the Skug River, its tributaries and several other ponds in the watershed) on light attenuation through the water column. Color alone, at median levels found in Martin Pond, can reduce available light by $1/3^{rd}$ at depths of only 0.4 m. Light attenuation is further exacerbated by the relatively high turbidity levels consistently observed in the pond. Combined, these factors are effectively limiting macrophyte growth, the extent of the littoral zone and the spatial and temporal scale of algal blooms. In addition, low water clarity is creating conditions unfavorable for swimming.

A summary of the interconnections and feedbacks between turbidity, color, nutrients and other critical components of shallow eutrophic lakes (such as Martins Pond) are shown in Figure 1. Management efforts that alter turbidity, nutrients, macrophyte or other components shown in the Figure, will have repercussions on the entire system. For example, any significant reductions in turbidity will likely result in increased macrophyte growth, expansion of the littoral zone and increased susceptibility to algal blooms. Such a result might ultimately be counter to the objective of improving the recreational potential of Martins Pond.

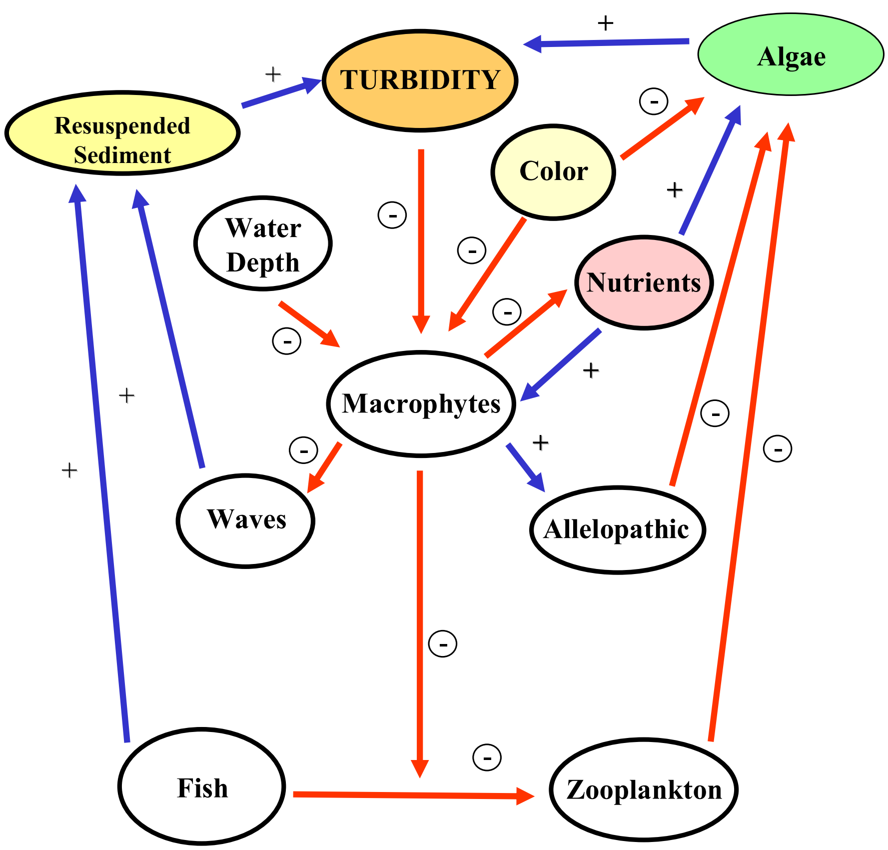


Figure 1. A summary of interrelationships between aquatic plants (macrophytes) and other factors in shallow eutrophic systems such as Martins Pond.

Section B. Martins Pond

Martins Pond (segment MA92038-2004) is a Great Pond in the Commonwealth of Massachusetts and covers some 92 acres. It is a Class B water body meaning that is designated for supporting aquatic life and recreational uses. Martins Pond is listed under the Year 2004 Integrated List of Waters (303[d] list) as an impaired water body due to turbidity, **noxious aquatic plants**, exotic species and metals (Lyon, 2007).

The area surrounding Martins Pond is highly congested, with a few Town owned parcels in a matrix of small, private landholdings. The area was historically a summer camp vacation spot that evolved into year round residences during the Depression. Some of the basic limnological characteristics of Martins Pond summarized from the 2007 Diagnostic/Feasibility Study are noted below in Table 1.

Table 1. Basic Limnological Characteristics of Martins Pond

Pond surface area	37.2 ha	(91.9 ac)
Maximum depth	2.47 m	(8.1 ft)
Mean depth	1.25 m	(4.1 ft)
Volume	638,764 m^3	(517.85 ac-ft)
Length of shoreline[1]	3002 m	(9847 ft)
Osgood Ratio[2]	2.03	
Shoreline Development Index[3]	1.38	
Watershed area	1994 ha	(4927 acres)
Watershed area/Lake area ratio	~54:1	
Hydraulic residence time	10.1 days	

[1] Based on a pond elevation of 74.5 feet based on Burroughs Road Gauge

[2] Osgood ratio = mean depth / sqrt of surface area (Osgood 1988)

[3] Shoreline Development Index (SDI) = length of shoreline / 2(sqrt[πA])

The pond is obviously shallow with a mean depth of 4.1 ft and a maximum depth of 8.1 ft. Based on this 2005 re-mapping of the bathymetry of the pond, the volume was estimated to be approximately 638,764 m^3 (518 acre-feet or some 168.744 million gallons). This was determined by calculating the volume of water of a frustrum of a circular cone based on the surface area of the top and bottom of 1-ft section of pond depth. The volume of the pond was previously reported to be between 414 acre-feet (Anderson-Nichols and Lycott 1985) and 500 acre-feet (Eco-Control 1972). That corresponds to between some 135 and 163 million gallons of surface water. The newer estimate is much closer to the Eco-Control estimate. Of course, the elevation of the pond will change its volume (see FEMA Flood Study: USACE 2004).

Recent History of Aquatic Plant Surveys in Martins Pond

Previous Sampling - To assess the diversity of native macrophyte species, their extent and the presence of nuisance exotic species in Martins Pond, existing macrophyte data for the pond were reviewed and all quantitative data from previous studies were compiled, including intensive macrophyte surveys in 2002 and 2004 and key results from these studies are presented in this report. In addition, in an effort to control fanwort in Martins Pond, mechanical harvesting was undertaken in July 2005. To assess the impacts of the harvesting on fanwort and other macrophyte species, an intensive survey was conducted first conducted in late July 2006 (Lyon, 2006). Similar surveys were conducted in late August of 2007 (Lyon, 2007) and August 2008 (Lyon, 2008) and this report summarizes the findings of the latest survey conducted in late July and early August of 2009.

Overall, in 2005 (pre-harvest) and in 2006, 2007, 2008 and 2009, one, two, three and four years after harvesting, respectively, the aquatic plant surveys centered on quantifying the composition and spatial distribution of all species in Martins Pond and not just fanwort.

However, due to the importance of fanwort as a nuisance species in Martins Pond and its targeting for management, Merrimack College specifically mapped and analyzed the spatial distribution of fanwort in 2002, 2005, 2006, 2007 and 2008 using a Geographical Information System (GIS). Linking the aquatic plant surveys with GIS allowed us to simultaneously quantify both fanwort abundance and spatial extent in an effort to better assess the long-term impacts of mechanical harvesting on fanwort in Martins Pond.

It is critical to note that in late July and early August 2009, the first water chestnut plants were identified on Martins Pond. This is a critical new threat that will require immediate management.

Section C. Macrophyte Sampling and Analysis Methods

Macrophyte (aquatic plant) sampling in 2009 was conducted by Merrimack College personnel from 29 July to 1 August 2009. These sampling dates were chosen to correspond with peak biomass levels of macrophytes in the pond. In addition to the 2009 survey, this report also summarizes the results from previous pond-wide macrophyte sampling conducted by Merrimack College in July and August of 2002, 2004, 2005, 2006, 2007 and 2008. Sampling in 2005 was conducted in late June to match the timeline for mechanical harvesting (in July 2005).

In each year prior to harvesting (2002, 2004, 2005) and in each year after harvesting (2006, 2007, 2008, 2009), the same sampling procedures were followed. Aquatic plant sampling was conducted at varying depth intervals, using some 30-36 transects that covered the entire littoral zone of the pond. Transects were spaced at regular intervals along the shoreline and extended from the shoreline towards the pond center and traversed the littoral zone into the limnetic zone. In 2007, 2008 and 2009, some additional sampling points were added outside existing transects to ensure full spatial coverage of the littoral zone, including verifying there was no plant cover in the limnetic zone. In 2009 the entire shoreline was traversed by canoe to locate water chestnut. For each sample point, we used the following methods:

- The depths of all sample locations were recorded to the nearest 0.1 ft
- A rake sampling method was used to assess macrophyte abundance and frequency of occurrence at each sampling site (Deppe and Lathrop 1993; Weaver et al. 1997; Yin et al. 2000)
- Four replicate samples were taken at each sampling point. Aquatic plants (floating and submerged) recovered from the sampling device were assigned an abundance rating ranging from 0 (not present) to 5 (very abundant)
- Both average species abundance and percent occurrence at each sampling point were calculated based on the four replicates
- In 2009, a total of 179 sample points were sampled and 122 had macrophytes present; high turbidity made quadrat and/or biomass sampling highly impractical
- Percent occurrence of each species was determined by dividing the number of sample points were each species was found by the total number of sample points; Total abundance for species was determined by summing the abundance values over all sampling points
- Taxonomy follows Crow and Hellquist (2000a; 2000b); non-native species designations follow Sorrie and Somers (1999)

The sediment layer at the bottom of the Pond takes up some 70-75% of the potential volume of the pond. The IEP Study in 1977 reported a sediment depths ranging from 14 to 20+ ft. The 1985 D/F Study (Anderson-Nichols and Lycott 1985) reported a mean sediment depth of some 8 ft and depths ranging from 0 ft at sandy shorelines to 15+ ft in the northern half of the pond. Regardless of the exact percentage of the basin that is currently occupied by organic rich sediments, Martins Pond is clearly ‘filling in’ as is typical of shallow, eutrophic pond systems. The depth to bedrock beneath the pond was estimated to be some 40 ft (Anderson-Nichols and Lycott 1985).

With respect to the organic content of sediments in Martins Pond, the Eco-Control Study (1972) reported that 2-ft surface sediment cores had between 32-49% organic matter (mean = 40.5%). In the current study, 128 sediments samples were collected at sites chosen all around the Pond and the mean organic matter content was 40.6% (SE = 1.7).

Figure 2 shows the location of all the sample points for the 2009 macrophyte survey. A similar distribution of aquatic plant sample points was used in all the previous aquatic plant surveys conducted by Merrimack College.

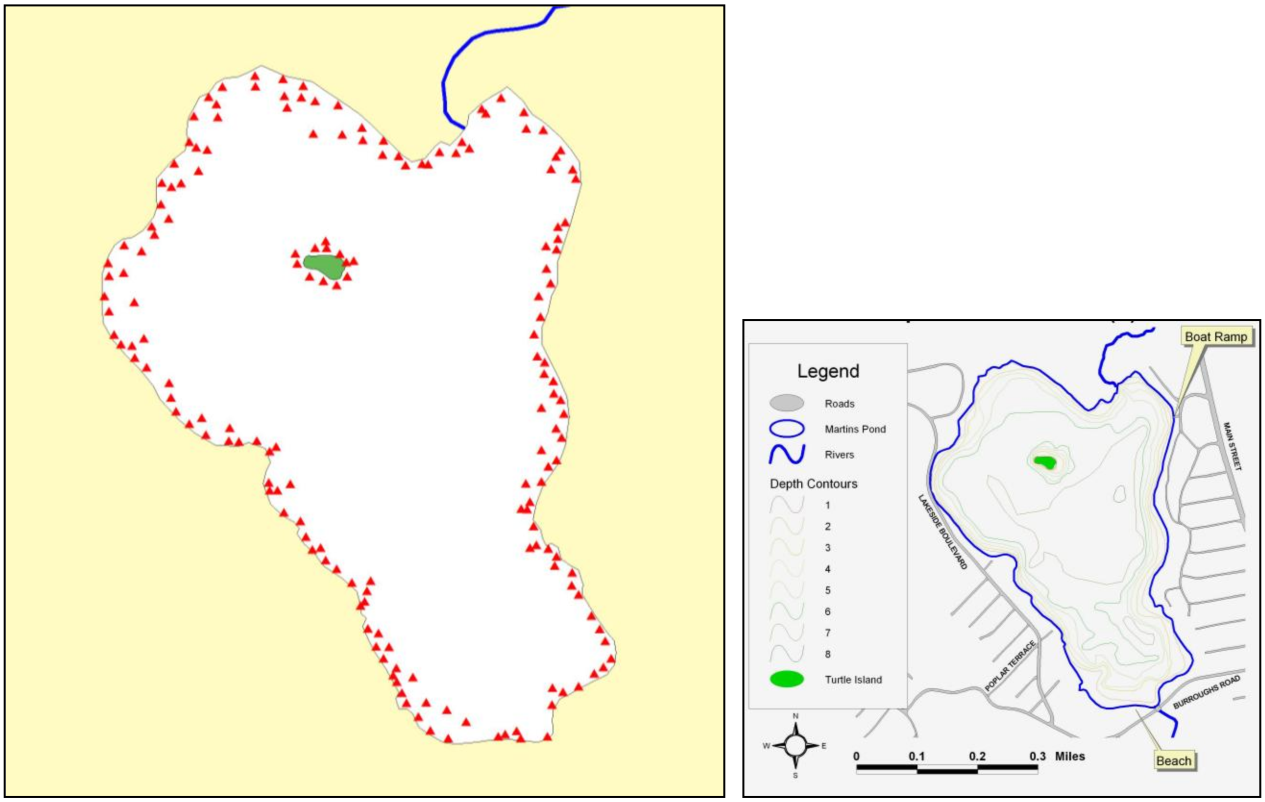


Figure 2. The location of aquatic plant sample points (red triangles) for the 2009, 4-year-post-harvest survey are noted in the larger figure on the left. Data from a total of 179 sample points was collected, with 122 sample points having at least some macrophytes present. The smaller figure on the right is a bathymetric map of Martins Pond generated in 2007.

Section D. Pre-Harvesting Fanwort Distribution and Abundance in Martins Pond

Cabomba caroliniana (fanwort) is a problematic non-native invasive species found in Martins Pond and throughout portions of the northeastern US (Hellquist 1998). Understanding its spatial distribution, occupancy of the littoral zone and relationship with depth are important variables that require quantification in developing and implementing effective management plans.

Fanwort abundance has exhibited a pattern of changing abundance and distribution from year to year in Martins Pond. Figure 3 provides a comparison of the abundance and distribution of fanwort in 2002 and in 2005 in Martins Pond. The original impetus for the 2005 harvesting program was the high density of fanwort observed in 2002 (Lyon and Eastman, 2006). However, by 2005 both the distribution and abundance of fanwort had decreased substantially (see Table 2). Similar short-term changes in fanwort abundance were noted in the IEP (1977) study. They cited pond surveys in 1968 and 1969 by the Department of Environmental Quality Engineering. The 1968 and 1969 surveys indicated high density and widespread distribution of fanwort in the littoral zone. However, by 1976, fanwort density was substantially lower.

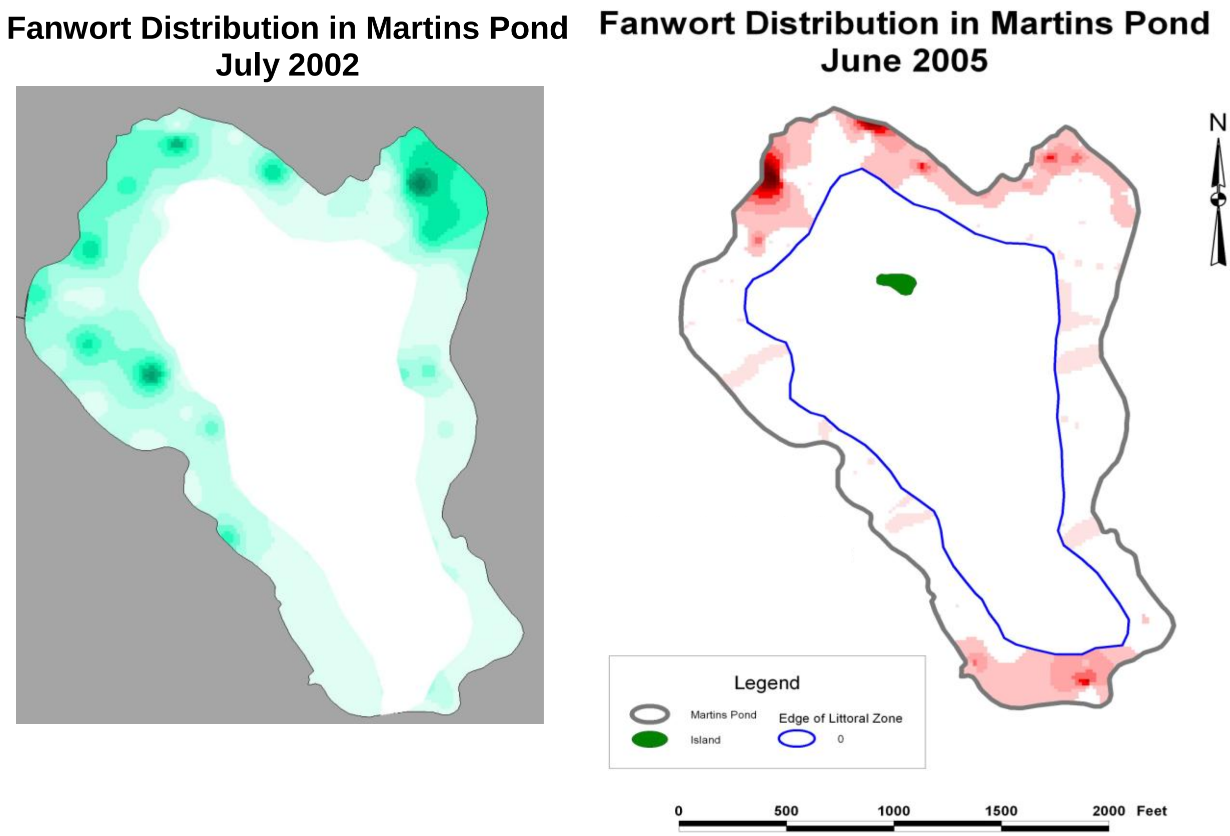


Figure 3. A comparison of fanwort distribution and abundance in Martins Pond in 2002 (left) and 2005 (right). Darker shades of green (2002) and red (2005), represent higher densities of fanwort. The 2005 distribution represents conditions prior to mechanical harvesting.

Section E. Post-Harvesting Macrophyte Survey Results

Figure 4 shows the 2005 mechanical harvesting map for Martins Pond. All Areas with the exception of Area A (2.2 acres) were harvested in 2005.

2005 Mechanical Harvesting Areas

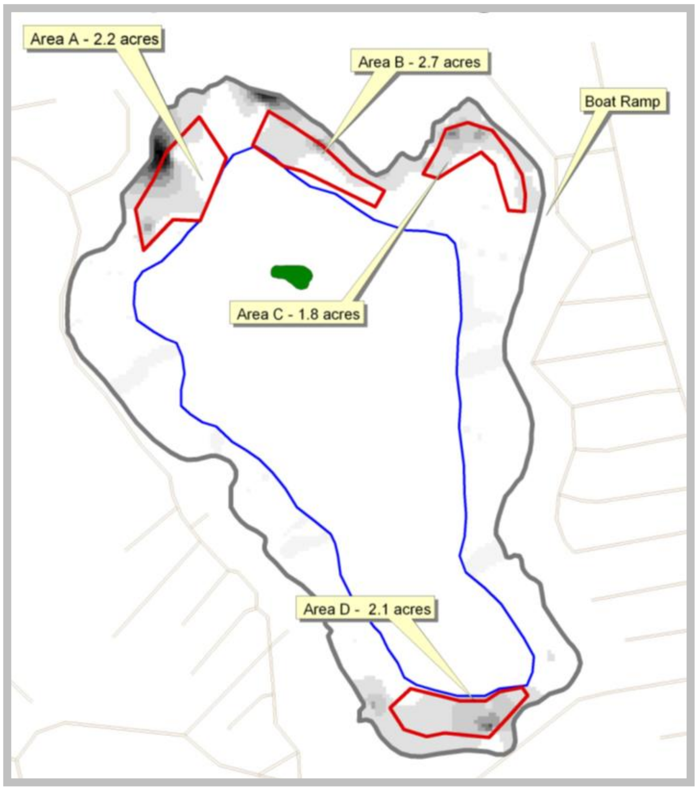


Figure 4. The harvesting map created for Aquatic Control Technology Inc., to guide their mechanical harvesting in July 2005. A total of four harvesting areas (in red) were proposed. The total proposed harvesting area was approximately 8.8 acres (9.4% of the pond's area). The extent of the littoral zone is shown by the blue line. All Areas except Area A were harvested in 2005.

Table 2 provides both an overview of the recent macrophyte abundance in Martins Pond. Data are presented that are prior to harvesting as well as the most recent post-harvesting survey results for 2009. Variability in species abundance of both fanwort and other species was clearly evident between years, even over relatively short periods of time (e.g., 2002 to 2005) and prior to any harvesting or management activities. The abundance of fanwort has been variable between years, showing a decline prior to the mechanical harvesting in 2005 and low levels in 2006, 2007 and 2008. In 2009, fanwort occurrence decreased only slightly from 2008.

Fanwort cover was similar in 2009 relative to 2008, and was higher than the low, post-harvesting levels observed in 2006 and 2007. In 2009, fanwort still remained considerably lower than pre-harvest levels. All other species sampled in 2009 were very similar in occurrence to those in 2008. In addition, the total number of species found in 2009 was only 14. While this finding may be influenced in part by sampling error, it does suggest that the number of species found with similar sampling effort is variable from year to year.

Table 2. A comparison of the density and occurrence of macrophytes from previous quantitative studies on Martins Pond. All values presented from 2002 to 2009 are percent (%) occurrences of each species based on the number of sample points were each species was found divided by the total number of sample points.

Aquatic Plant Species (Macrophytes)		**Sample Year**							
Scientific	common	**1976**	**'02**	**'04**	**'05**	**'06**	**'07**	**'08**	**'09**
Cabomba caroliniana	**fanwort**	**S-M**	**57.6**	**65.6**	**38.9**	**6.5**	**4.3**	**17.7**	**16.1**
Ceratophyllum demersum	coontail		34.7	42.6	35.8	11.1	6.2	20.2	21.6
Aquatic moss	moss	M-D	61.5	59.0	76.8	67.6	46.5	48.3	51.3
Nuphar variegate	yellow water lily	S	2.5	3.3	9.5	13.9	12.6	11.8	102
Nymphaea odorata	white water lily	S	27.1	21.3	27.4	37.0	32.5	34.6	33.2
Brasenia schreberi	watershield	S	19.5	19.7	30.5	35.2	34.8	33.0	29.3
Utricularia intermedia	flatleaf bladderwort		28.0	23.0			0.9	2.3	
Utricularia vulgaris	common bladderwort		8.5	6.6				2.1	
Utricularia purpurea	purple bladderwort		11.0	8.2	3.2	0.9		1.1	
Utricularia radiate	floating bladderwort			3.3	4.2				
Filamentous algae			29.7	3.3	4.2	10.2	2.6	11.3	24.5
Najas flexilis	bushy pondweed		17.8	14.8					
Najas gracillima	bushy pondweed		0.8	1.6					
Najas guadalupensis	bushy pondweed		0.8	8.2					
Elodea Canadensis	Canadian waterweed		8.4	13.1	1.1				2.3
Nitella sp	stonewart		5.3	11.5	1.1	0.9		1.3	
Potamogeton epihydrus	ribbonleaf pondweed		4.2	6.6		1.9		2.0	
Potamogeton amplifolius	big-leaf pondweed		0.8	8.2					
Potamogeton crispus	curly pondweed			1.6	2.1			0.9	
Potamogeton pectinatus	sago pondweed		0.8	6.6	2.1			0.8	
Potamogeton robbinsii	fern pondweed			4.9	1.1				
Pontederia cordata	pickeralweed	S	6.8	3.3	3.2	4.6	3.5	4.2	3.2
Myriophyllum heterophyllum	variable milfoil				3.2	0.9			
Scirpus spp	bullrush		0.8	3.3	1.1	1.9	1.1	2.1	2.1
Lemna	duckweed		0.8	1.6	4.2			3.2	2.6
Trapa natans	**water chestnut**								**0.7**
Typha latifolia	cattail	S	0.8	1.6	1.1	1.9	0.9	1.3	1.0
Lythrum salicaria	purple loosestrife	S	0.8	1.6	3.2	1.9	1.1	1.9	1.1
Total Species Found		**8**	**23**	**26**	**20**	**15**	**12**	**19**	**14**
Total Sample Points		*?*	*118*	*91*	*95*	*108*	*116*	*174*	*179*

[1] 1976 data from IEP (1977); abundance categories are: S= Sparse; M=Medium; D=Dense; 2002, 2004, 2005, 2006, 2007, 2008 and 2009 data are from Merrimack College. Percent occurrences of each species are based on the number of sample points were each species was found divided by the total number of sample points. Fanwort and water chestnut are both highlighted.

2009 Fanwort Occurrence Results – The mean percent occurrence of fanwort in Martins Pond in 2006, the year after mechanical harvesting, was only 6.5%, compared to 38.9% occurrence in 2005 (pre-harvest), strongly suggesting that harvesting was successful in reducing the overall level of occurrence of fanwort in Martins Pond. The mean percent occurrence remained low in 2007 (4.3%). However, fanwort decreased in all portions of the pond, even Area A (see Figure 4) that was not harvested. This result suggests that fanwort cover may have naturally decreased in the pond in 2006 and 2007 even without harvesting. In 2008, fanwort occurrence increased to 17.7% of sample points sampled. This was a solid increase from 2007 and suggested that the extent of fanwort increased, the first time since harvesting operations in 2005. However, in 2009, fanwort abundance was slightly less than in 2008 indicating that it had stabilized at near 2008 levels, at least for this year.

Section F. Post Harvesting Fanwort Distribution and New Discovery of Water Chestnut

Post-Harvesting Fanwort Distribution – Figure 5 shows the abundance and distribution of fanwort based on the 2007, 2008 and 2009 survey results. Overall, there was an increase in both the extent and abundance of fanwort in Martins Pond relative to 2007 levels (and 2006), but still lower than the pre-harvest levels observed in 2005. The abundance of fanwort in the non-harvested Area A (see Figure 4 for location) in 2008 and 2009 also showed increased abundance despite not being harvested. This suggests that fanwort abundance may be increasing cyclically independent of any harvesting effect. In any event, the extent and abundance of fanwort was very similar to that observed in 2008.

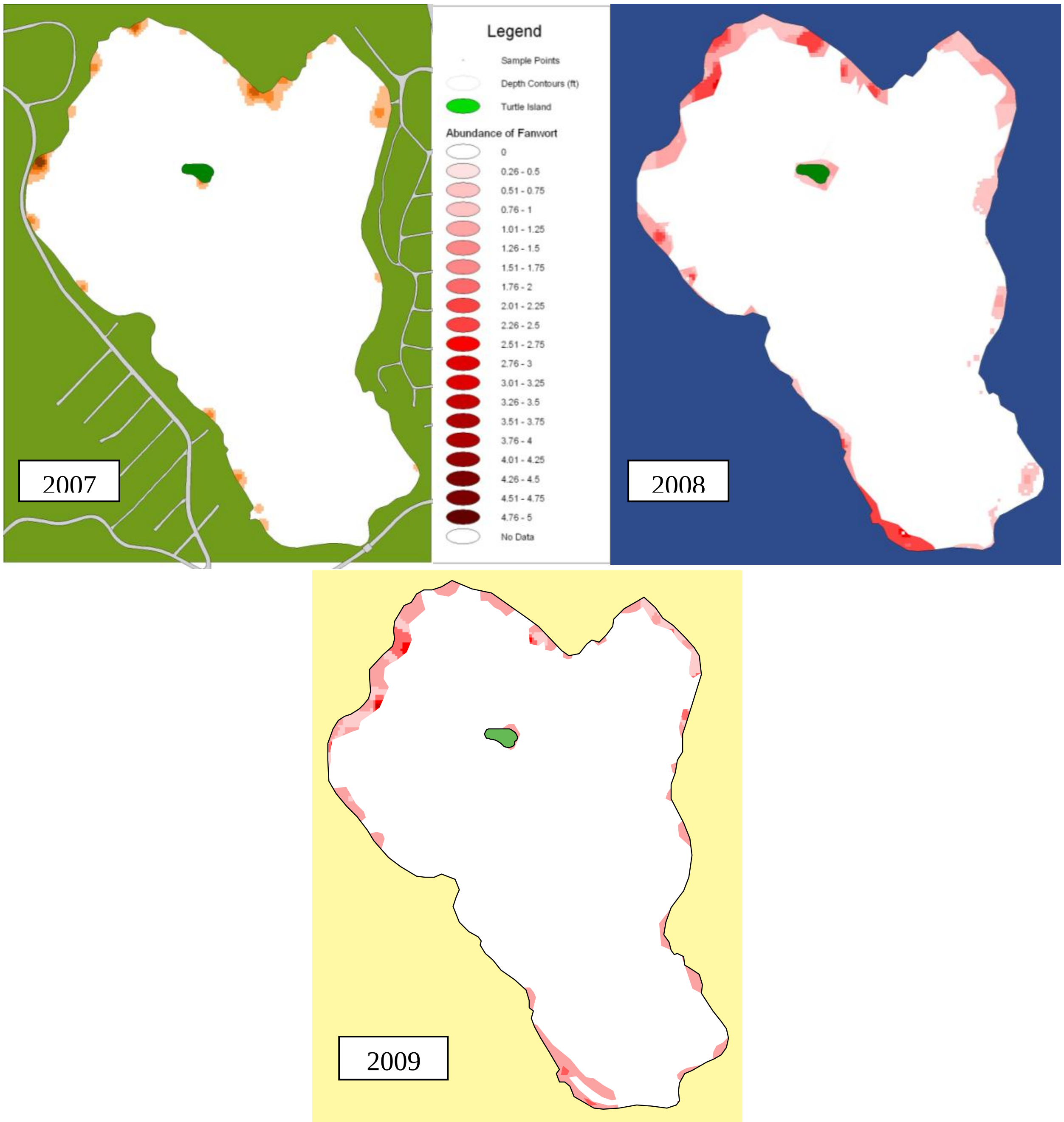


Figure 5. The abundance and distribution of fanwort (*Cabomba caroliniana*) based on the 2007 (upper left), 2008 (upper right) and 2009 (lower center) survey results. Fanwort abundance is based on a 0 to 5 abundance scale with increased density correlated with darker red colors. It is clearly evident that the abundance and spatial distribution of fanwort increased in 2008 relative to 2007. However, 2009 abundance was very similar to the 2008 both in relative density and distribution. In all three sample years, fanwort exhibited a patchy distribution with a higher density of fanwort along the shorelines, particularly in the northern half of Martins Pond.

New Discovery of Water Chestnut

Two new small patches of water chestnut were found in Martins Pond for the first time in 2009. Figure 6 below shows the locations of the two confirmed patches of water chestnut. The species is currently restricted to only these two areas. A detailed canoe survey was conducted along the entire shoreline of the pond to ensure that any water chestnut plants were observed and mapped.

It is **highly recommended that immediate action** be taken to carefully harvest all the existing plants and that there be continued monitoring to track any occurrences and locations of this new invasive species.

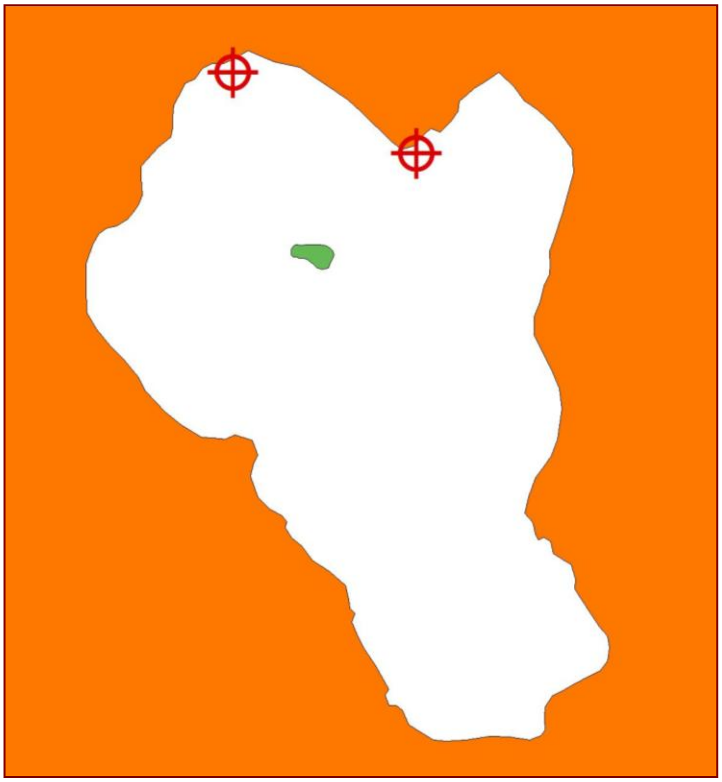


Figure 6. The locations of the two isolated patches of water chestnut found in the 2009 survey are noted by the red circle-crosses. The plants, while currently limited in population size in two regions in the northern shoreline of the pond, are mature and reproductive.

Impacts of Harvesting on Other Aquatic Species – As noted earlier, there was relatively similar fanwort abundance and distribution in 2009 as in 2008. However, a complete assessment of all the species found in the pond in 2009 showed a decrease in both the number of species found and various measures of plant diversity relative to pre-harvest conditions. Table 4 summarizes some of the measures of species diversity in Martins Pond from 2002 to 2009.

While species richness remained relatively constant prior to harvesting, there were drops in species richness, Shannon diversity and mean number of species per plot in 2005 prior to any harvesting activities These results and those presented in Table 2 reflect the relatively high levels of seasonal variability in aquatic plant abundance often observed in shallow eutrophic water bodies (Scheffer 1998). The 2009 survey results showed decreases in all three measures of diversity relative to all other year results (except for species richness in 2007). The decrease in species richness may in part, be due to sampling error and chance due to limited sample locations. However, these results do indicate that macrophyte diversity is still not as high as before mechanical harvesting.

Table 4. A comparison of macrophyte species richness and diversity in Martins Pond from 2002 to 2008.

Parameter	**2002**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Species Richness(Entire Pond)	24	26	20	15	12	19	14
Shannon Diversity	0.878	0.923	0.537	0.417	0.301	0.499	0.298
Mean Number of Species Per Sample Point	3.3	3.4	2.6	1.9	1.3	2.0	1.2

Floating mats of *Nymphaea* rhizomes with attached shoots were observed at 7 locations in 2009, compared to 2 locations in August 2008, 7 locations in the pond in 2007 and 18 locations in the pond during the 2006 survey. The cause of these floating mats remains unknown. The impacts of harvesting activities and the high spring and/or late summer water levels may, in part, explain these occurrences. No floating mats were observed in the 2002, 2004 and 2005 surveys.

As noted in previous reports, the introduction of this report and the 2007 Diagnostic/Feasibility Study, given the exceptionally high turbidity and color in Martins Pond, many of the patterns observed in the 2002 to 2009 macrophyte surveys need to be interpreted in the context of the severe turbidity constraints on macrophyte growth and littoral zone extension (see Figure 1). Given the shallow and colored nature of Martins Pond, turbidity via sediment resuspension is a crucial factor in maintaining littoral zone coverage. These factors may also explain, in part, the year-to-year variation in aquatic plant abundance and distribution in the pond. In addition, the very high water levels in Martins Pond in the spring of 2006, 2007 and 2009 may have contributed to the overall decrease in aquatic plant growth in the pond observed in 2006, 2007 and 2009, and increased water clarity in 2008, may help explain the overall increase in macrophyte growth, distribution and diversity.

Overall, understanding the relative influences of natural processes versus management techniques on the spatial and compositional patterns of aquatic plant species in Martins Pond is essential prior to making any future management decisions regarding fanwort. A crucial consideration in any future management effort should be to maintain the aquatic plant diversity in Martins Pond, especially in a system with a high proportion of uncommon species, complex and in many cases non-overlapping spatial distributions of species and a system with inherently high levels of temporal variability in species diversity and abundance.

The discovery of water chestnut should be of great concern and this species needs to be controlled immediately before it spreads beyond its present very narrow distribution.

Section G. Conclusions and Recommendations

- The new outbreak of water chestnut in the northern region of Martins Pond needs to be dealt with immediately. Hand harvesting of all plants should occur as soon as possible.

- It is strongly advised that the Town of North Reading continue to fund the monitoring of aquatic plant species in Martins Pond (and other water bodies in the Town) to deal with emerging invasive plant threats.

- Given the exceptionally high turbidity and color in Martins Pond, many of the patterns observed during the entire study period (2002 to 2009) need to be interpreted in the context of the severe turbidity/light constraints on macrophyte growth and littoral zone extension.

- Overall, there was only a slight decrease in both the extent and abundance of fanwort in Martins Pond in 2009 relative to the 2008 sample.

- The percent occurrence of fanwort on all sample points in 2009 was 16.1%, compared to 17.7% in 2008, 4.3% in 2007, 6.5% in 2006 and 38.9% in 2005. This indicates that fanwort stabilized in 2008 and 2009, but it remains only about half the extent it was prior to harvesting and at much lower abundances.

- The abundance of fanwort in the non-harvested Area A (see Figure 4 for location) during the entire study period suggests that fanwort abundance may be increasing cyclically, independent of the impact of harvesting. The low levels of fanwort in 2006 and 2007 in Area A and the increase in fanwort in 2008 and 2009, point to factors other than harvesting that are contributing to both fanwort decline and increase.

- Variability in species abundance of both fanwort and other species was clearly evident between years, even over relatively short periods of time (e.g., 2002 to 2005; 2007 to 2009) and prior to any harvesting or management activities. Martins Pond is a dynamic system and the compilation of the yearly survey results needs to continue.

- There were decreases in all three of the 2009 plant diversity measures relative to 2008, suggesting that macrophyte diversity may be still fluctuating. The reduction in species richness observed in 2006 and 2007 was of concern; the increase in diversity in 2008 was a positive indicator of the ecological integrity of the pond. The decrease in 2009 is of concern and fanwort control must be balanced with full consideration of the ecological integrity of the native aquatic plant communities in Martins Pond.

- Given both the relatively low abundance and extent of fanwort in Martins Pond in the summer of 2009, especially given its relative similarity to the 2008 survey, no additional harvesting or management activities to control fanwort are recommended at this time.

Section H. References

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