Aquatic Plant Biomass Assessment of the Large Impoundments of the Assabet River in Eastern Massachusetts[1]

Suzanne Flint[2]

February 2, 2006

Abstract:

An assessment of the nature and extent of aquatic plant biomass in four of the major impoundments of the Assabet River was conducted using a boat-based visual survey. The field data was mapped in ArcGIS 9.x and interpolated to raster files to calculate the total biomass for each impoundment. For two of the impoundments, Ben Smith and Gleasondale, the co-occurrence of plant growth, water depth, and sediment accumulation was examined. Throughout the four impoundments assessed, the dominant floating plants were duckweed, watermeal, and filamentous green algae; the dominant submerged plants were coontail and waterweed. Several limited patches of the invasive species water chestnut were found. Differences in the total biomass per impoundment measured in 1999, 2000 and 2005 suggest that annual variation in total biomass is relatively high, and that a long-term baseline of measurements will be needed to be able to detect future changes in biomass attributable to changes in watershed management. This analysis provides a basis for revising the study's methods, both field and analytical, for future years.

Introduction:

The Assabet River, a federally designated Wild and Scenic River, flows for 31 miles from its headwaters in Westborough through nine towns to the town of Concord, where it joins the Sudbury River to form the Concord River. Beloved of Hawthorne and Thoreau, the Assabet is a lovely, scenic river, and its popularity among recreational boaters has grown in recent years. The Assabet should be a tremendous asset to its region. Unfortunately, the river suffers from nutrient pollution, becoming severely eutrophic most summers. A heavy green "lawn" of algae and duckweed covers much of the river, making it difficult for fish to breathe and harming river recreation. When these plants die at the end of the summer, their decay results in a sewage-like odor that can be detected in downtown Maynard and Hudson. The primary cause of this eutrophication is nutrient-rich sewage effluent discharged to the river by four wastewater treatment plants (WWTPs) serving the communities of Westborough, Marlborough, Shrewsbury, Northborough, Hudson, and Maynard.

In 2004, after a six-year Total Maximum Daily Loading (TMDL) study of the river, the Massachusetts Department of Environmental Protection issued a final TMDL for the Assabet River (DEP, 2004), proposing to achieve water quality goals in the Assabet River through an innovative adaptive management strategy. The state determined that a combination of stringent point source phosphorus controls and sediment remediation is needed to reduce eutrophication. In a two phased approach, the four municipal WWTPs that discharge to the Assabet River will be required to meet a limit of 0.1 mg/L total phosphorus by the end of the NPDES permit period (2005 - 2010). During the permit period the feasibility of remediating sediments to reduce phosphorus flux by 90% will be investigated. In the spring of 2009, DEP and EPA will jointly develop the second phase implementation strategy to decide if, when, and to what level additional WWTP upgrades will be needed based on the results and recommendations of the sediment evaluation.

---

[1] This work was supported, in part, by a grant from the Massachusetts Environmental Trust.

[2] Organization for the Assabet River, 9 Damonmill Square Suite 1E, Concord, MA

Long-term monitoring of the Assabet River will be essential to determine the efficacy of the adaptive management controls and ensure that the time, money, and effort spent restoring the Assabet is effective. One of the goals of the TMDL[3] is a 50% reduction in plant biomass (the mass of aquatic macrophytes and mat-forming algae) in the river. Because biomass production varies annually with flow and weather conditions, it is necessary to establish baseline conditions over the four year period before control strategies are implemented to be able to measure real changes in the river's condition above natural variation. Therefore, the Organization for the Assabet River (OAR), working with the MA DEP, started a biomass monitoring assessment of the major impoundments of the river. In August 2005, the pilot year of the assessment, field estimates of floating and rooted biomass were made on four impoundments. From these field estimates, total biomass for each impoundment was calculated using ArcGIS. Total biomass calculations were compared with measurements taken in 1999 and 2000. Finally, for two of the impoundments, the co-occurrence of plant growth, water depth, and sediment accumulation was examined.

Field methods:

Briefly, the biomass assessment was based on visual examination from a boat of the major river impoundments to assess the nature and extent of aquatic plant biomass in the impoundments. In each impoundment, a series of transects perpendicular to the perceived stream channel were established and observations were made at multiple points along each of the transects. Transects and observation points were spaced appropriately to the size and plant coverage of the impoundment to adequately map the distribution of aquatic plants in the whole impoundment. All assessments were conducted between August 12th and September 1st, 2005.

At each transect point water depth was measured in feet to the tenth using a secci disk to help locate the top of the soft sediment. Observations of biomass were made viewing an area covering a ~ 10 ft diameter circle. A viewing tube, held over the side of the boat, was used to help estimate biovolume and a plant rake was used where samples were needed for confirmatory identification. Aquatic plants at each point were identified using a field guide (Kelly, 1999) and the dominant plants (floating and submerged) were noted. Less effort was made to identify emergent plants along the edges of the impoudments. Plant cover was rated into classes on a scale of 0 – 5 (0 = no plants to 5 = 100% cover). Plant biovolume was rated into classes on a scale of 0 – 5 (0 = no plants to 5 = water column completely filled with plants). The presence of algal mats on the bottom or in association with plants (visible periphytic growths) was noted. Transect locations and observation points were recorded on a topographic map in the field; data was recorded directly into a field notebook.

At a subset of the sampling locations, a 0.5-m^2 sample was harvested, drained, and transported to shore for weighing. The mean of the wet weights for each biovolume field rating were used to calculate the factor to convert the field ratings of biovolume to biomass (wet weight in g/m2).

GIS analysis methods:

The field data was entered into ESRI's ArcGIS 9.x and interpolated to raster files to calculate the total biomass for each impoundment. In general, areas of emergent vegetation were not included in the analysis. Raster provides a method of (1) interpolating point data across the whole area of analysis, and

---

[3] TMDL goals: a 50% reduction in aquatic biomass relative to the levels measured in the assessment phase of the TMDL in the summer of 1999; meeting the state's minimum DO standard of 5.0 mg/L and 60% DO saturation; and reducing the percent hours of dissolved oxygen super-saturation. (DEP, 2004)

(2) calculating total biomass on a cell-by-cell basis. Rasters were then re-converted to shape files and intersected to analyze the co-occurrence of plant growth, water depth, and sediment accumulations. Finally the attribute data from the intersection of the biomass, water depth, and sediment thickness layers were exported for analysis. The steps involved were as follows.

The field data were transferred to a spreadsheet and imported to GIS as a database file. For each impoundment the sampling transects and sites were entered visually from the field notes as shape files. For two impoundments, Gleasondale and Allen Street, additional transects and sampling points were interpolated from the field notes to improve the accuracy of the raster analysis. The extent of the analysis for each impoundment was defined as a "river banks" shapefile created from 1:5,000 (1/2 meter) color ortho-photos from Mass GIS (NAD 83). Field data (plant cover, biovolume, and water depth) and biovolume/biomass conversion factors were joined as attributes to the sampling site point layer. Using the Inverse Density Weighted (IDW) interpolation method, rasters were created from the point layer attributes for biovolume, biomass (the biovolume/biomass conversion factor for each point), and water depth. (IDW settings: power = 6, search radius = 36, analysis mask = river banks shapefile, output = 1-meter cell size.) Total biomass (g/m^2) per cell was calculated as the product of the biomass (g/m^3) and water depth (m) rasters using Spatial Analysts' Raster Calculator. The total biomass (g) per impoundment was calculated from the resulting raster using Spatial Analysts' Zonal Statistics with the river banks defining the zone.

For two of the impoundments, Ben Smith and Gleasondale, the co-occurrence of plant growth, water depth, and sediment accumulation was examined. The rasters for biovolume and water depth were converted to shape files and overlayed as an intersection. The resulting biovolume/water depth intersection was then intersected with a sediment thickness shapefile developed by USGS (Zimmerman and Sorenson, 2005) and the attribute data was exported to MS Excel for analysis.

Results and Discussion:

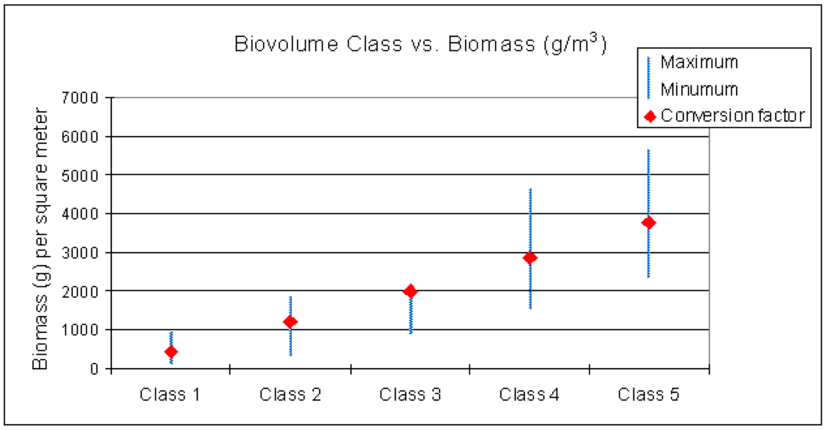
Plant species: In the Ben Smith impoundment, assessed on August 12th and 16th, the dominant floating plants were filamentous green algae and duckweed (*Lemna*); the dominant submerged plants were coontail (*Ceratophyllum demersum*) and waterweed (*Elodia* sp.); along the edges were several patches of emergent pickerel weed. In the Gleasondale impoundment, assessed on August 24th and 25th, the main channel of the impoundment tended to be clear while the backwater areas were heavily overgrown. The dominant floating plants were watermeal (*Wollfia*) and duckweed; the dominant submerged plants were coontail and waterweed; there were wide sections of emergent grass species along the edges of the impoundment (not included in the biomass assessment) and a large backwater section of emergent arrowhead (*Sagittaria*), arrow arrum (*Peltandar virginica*) and pickerelweed (*Pontederia cordata*). Several patches of water chestnut (*Trapa natans*) were found. In the Hudson impoundment, assessed on August 18th and 19th, the dominant floating plants were duckweed and watermeal; the dominant submerged plants were coontail and waterweed; there were wide sections of emergent grass species along the upstream right edge and surrounding the island. In the Allen Street impoundment, assessed on September 1st, the dominant floating species were, again, duckweed and watermeal; the dominant submerged species were coontail and waterweed; there were emergent patches of burreed (*Sparganium*) and grass species. Coontail and waterweed were the most common dominant plants, and it is interesting to note that coontail is a rootless plant, weakly attached to the sediments by modified leaves.

Biovolume/biomass conversion factors: Table 1 and Figure 1 show the biovolume/biomass conversion factors calculated from field measurements of wet weight. The conversion factor for each biovolume class, except Class 3, was calculated as the mean of the wet weight measurements for that class (Figure 1). Because Class 3 had only four wet weight measurements and the mean appeared out of line with the other measurements, the conversion factor for the class was adjusted upward based on the trend line of Classes 1, 2, 4, and 5.

Table 1: Biovolume/biomass conversion factor

Biovolume class	Biomass (g/m3)
0	0
1	427
2	1186
3	2000
4	2855
5	3782

Figure 1: Biovolume class vs. biomass



Mapping: Attached are figures for four impoundments, Ben Smith, Gleasondale, Hudson, and Allen Street, showing: (1) transects, sampling points, and river banks, (2) water depth, (3) total plant biomass, and (4) sediment thickness (USGS data). While the raster interpolation method used tended to create an artifactual series of deeper (or denser) spots in the impoundments, in general the distribution of biomass and water depths appeared reasonable. Ground-truthing a random selection of measurements would give a measure of the accuracy of the interpolation. The largest sources of error in this assessment are likely the distribution of sampling sites, the biovolume /biomass conversion factor calculated, and the interpolation methods used.

Total biomass: Sampling area, mean biomass, and total biomass were calculated for each impoundment from the GIS rasters (Table 2). Total biomass per impoundment from this study was compared (Table 3) with total biomass calculated as part of the Assabet River TMDL study in 1999 and 2000 (ENSR, 2001). For this comparison, the biomass for the Ben Smith impoundment reported in 1999 and 2000 was recalculated to compare similar assessment areas.

Table 2: Calculations (2005)

	Total biomass per impoundment (August 2005)			
	Sampling area (m2)	Mean biomass (g/m2)	Total biomass (g)	Total biomass (kg)
Ben Smith	75703	474	35874800	35875
Gleasondale	40304	1255	50563500	50564
Hudson	56126	1299	72884600	72885
Allen	9761	328	3211360	3211

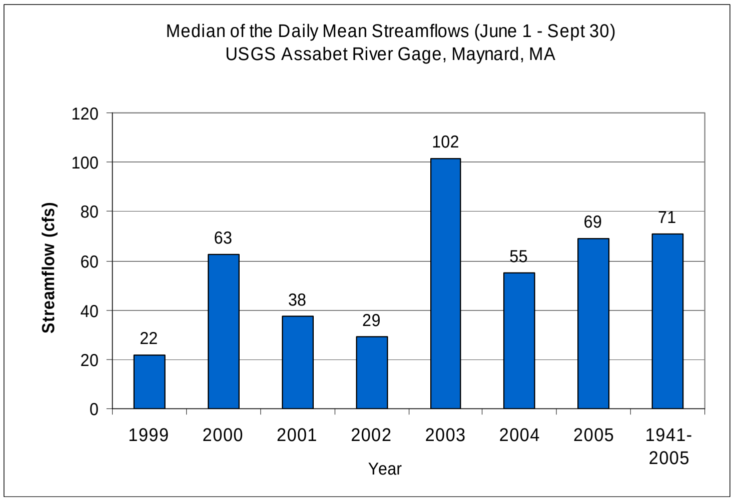
Table 3: Total biomass comparison (1999, 2000, 2005)

	Total biomass (kg)			% Difference		
	1999**	2000**	2005	1999/ 2000	1999/ 2005	2000/2005
Ben Smith*	73,008	71,994	35,875	-1%	-51%	-50%
Gleasondale	83,000	50,400	50,564	-39%	-39%	0%
Hudson	118,000	85,400	72,885	-28%	-38%	-15%
Allen Street	5960	3720	3211	-38%	-46%	-14%

* 1999 & 2000 Ben Smith biomass measurements were adjusted account for differences in sampling areas between 1999/2000 and 2005 measurements.
** ENSR, 2001.

Total biomass per impoundment calculated in 2005 was from 38% to 51% less than reported in 1999. Because different sampling and analysis methods may have been used in 1999/2000 than in 2005, the measurements from 1999 and 2000 were also compared; biomass per impoundment in 2000 was from 1% to 39% less than in 1999. From these comparisons it appears that total biomass varies considerably from year to year. The variability is likely due to differences in climate and differences in nutrient availability. Since streamflow is an indicator of climate conditions, it is useful to compare summertime streamflows measured at the USGS gage on the Assabet River. Compared with the period of record, the median of the daily mean streamflows for the summer (June 1 to Sept 30) in 1999 was about 30% of normal (as defined as the median of the daily mean streamflows for the period of record 1941 – 2005) (Figure 2). Summer streamflows in 2000 and 2005 were 88% and 97% of normal respectively. As more data is collected it will be possible to better analyze the co-variance of biomass, streamflow, rainfall, temperature, and water column nutrient concentrations.

Figure 2: Median of daily mean streamflows (June 1 - Sept 30)



Plant growth/water depth/sediment thickness: For two of the impoundments, Ben Smith and Gleasondale, the co-occurrence of plant growth, water depth, and sediment accumulation was examined by analysing attribute data from the intersection of the biovolume, water depth, and sediment thickness GIS shape files. Figures 3 - 5 show the comparison of biovolume (as a measure of plant occurrence without regard to water column depth) vs. water depth, biovolume vs. sediment thickness, and sediment thickness vs. water depth. There appears to be some relationship between biovolume and water depth, and between sediment thickness and water depth. The relationship between macrophyte presence (biovolume) and water depth could be a result of light limitation (although most sites were less than 10 ft deep) or could related to higher flow rates and thinner sediments in the deeper sections of the impoundments. The deepest sites in each impoundment tended to be in a distinct, cobbly or sandy-bottomed thalweg through the impoundment. Similarly, sediment thickness greater than six feet appear to be in shallower, off-channel areas. From this analysis there appeared to be no relationship between macrophyte presence and sediment depth, but, note that sediment thickness was reported in one-foot increments, so it is possible that a relationship would be apparent at thicknesses less than one foot.

Figure 3: Biovolume vs. water depth

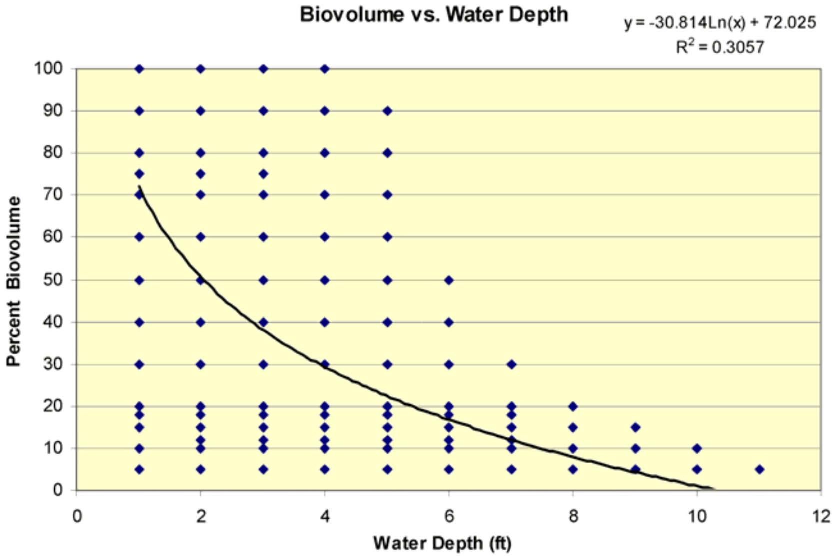


Figure 4: Biovolume vs. sediment thickness

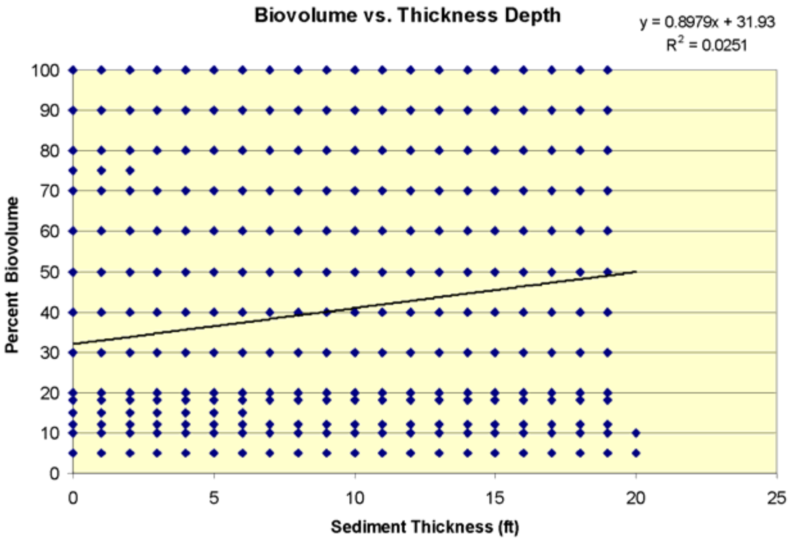
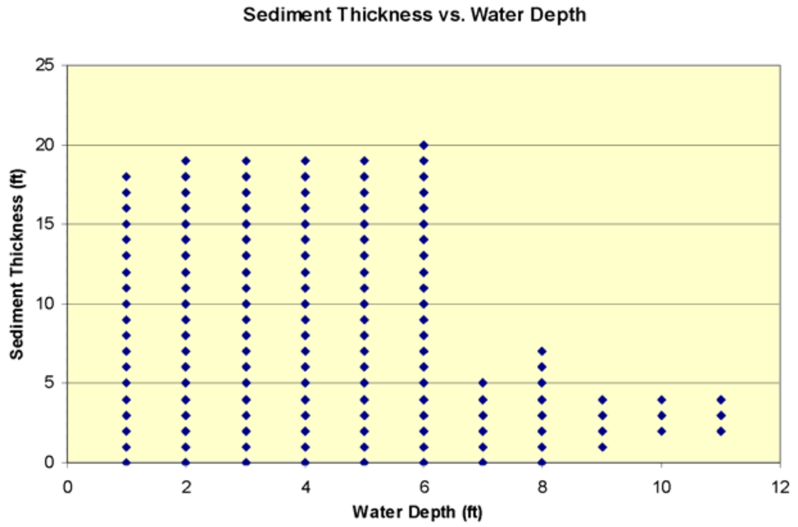


Figure 5: Sediment thickness vs. water depth



Conclusions:

This analysis provides a basis for revising the biomass assessment's methods, both field and analytical. Throughout the four impoundments assessed, the dominant floating plants were duckweed, watermeal, and filamentous green algae; the dominant submerged plants were coontail and waterweed. There were limited patches of the invasive species water chestnut in the Gleasondale impoundment which could, at this stage, be controled by hand-pulling the plants. The differences in total biomass calculated per impoundment suggest that annual variation in biomass is relatively high, and that a long-term baseline of measurements will be needed to be able to detect future changes in biomass attributable to changes in watershed management.

References:

DEP, 2004. Assabet River Total Maximum Daily Load for Total Phosphorus, Report # MA82B-01-2004-01

ENSR, 2001. SuAsCo Watershed Assabet River TMDL Study Phase One: Assessment Final Report. ENSR International, November 2001. 9000-259-100.

Kelly, Wanda, 1999. A Guide to Aquatic Plants in Massachusetts. New England Aquarium, Boston, MA, and Massachusetts Department of Environmental Management, Lakes and Ponds Program, Boston, MA.

Zimmerman, M. J., and J. R. Sorenson, 2005, Sediment Studies in the Assabet River, Central Massachusetts, 2003; US Geologic Survey Scientific Investigations Report 2005-5131, 87p.