Technical Memorandum

Blackstone River Algal Biomass Measured as Chlorophyll a at Selected Main Stem and Impoundment Stations - 2008

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Worcester, MA

December 2009

CN: 325.4

INTRODUCTION

The Blackstone River, located in central Massachusetts, was sampled during the summer of 2008 by personnel from the Massachusetts Department of Environmental Protection (MassDEP). Algal biomass is not well documented in the Blackstone River, and the objective of this study was to provide information to aid in the calibration of the Blackstone River HSPF model, by locating areas of algal and macrophyte production in the main stem of the river, and quantifying their biomass. The Blackstone River reach of primary interest extends from the Upper Blackstone Water Pollution Abatement District's (UBWPAD) advanced wastewater treatment facility outfall in Millbury down to the outlet of the Singing Dam Impoundment in Sutton. MassDEP sampling extended downstream as far as Depot St., Sutton. Algal biomass in this segment of the river was studied by sampling the chlorophyll a content of the attached algae or periphyton. Water column samples of the phytoplankton were also collected and analyzed for chlorophyll a. Since chlorophyll a is found in all plants, including algae, chlorophyll measurements were used to locate river areas where primary production is occurring. The algae samples collected from the Blackstone River benthos and water column were also examined under a microscope to determine the dominant genera composing the algal community. The algae genera, along with their densities, can be indicative of elevated nutrient conditions.

At the impoundments, estimates were made of macrophyte plant densities and biovolumes (e.g., the amount of the water column occupied by plants). Although the impoundment plant density results will be reported separately, phytoplankton chlorophyll a results from the impoundments are included in this report.

Conditions that are conducive to algal growth depend on a variety or physical and chemical variables including nutrient concentrations, sunlight, temperature, residence time and habitat. Before sampling occurred, reconnaissance of selected segments of the river was conducted to observe where algal growth was prevalent or where the habitat was suitable for periphyton or phytoplankton growth (i.e., wadeable areas with an open or partially open canopy allowing light to penetrate to the bottom and substrates that included cobble or boulders). Observations of habitat conditions are included where applicable (see Table 4). The sampling plan initially specified monthly sampling during periods of low flow (July, August and September) since summer months result in the critical conditions when algal blooms are typically most severe and have the greatest impact on designated uses. However, the summer of 2008 turned out to be an unusually rainy and high flows following significant rainstorms on several dates in July resulted in river flows that remained high for most of August. These wet weather conditions ultimately led to the cancellation of the August sampling.

MATERIALS AND METHODS

A list of the sampling locations, dates, and the variables measured is summarized in Table 1. The methods for sample collection are described in more detail below and follow DWM draft Standard Operating Procedures for micro and macro identifications and biomass determinations (Mass DEP, DWM CN 060.0 2002).

Water Column Chlorophyll a from Phytoplankton

Samples for water column chlorophyll a were collected at ten stations (see Table 1). Samples were either collected from the shore by attaching a sample bottle to a pole or from a boat in the case of the impoundments. A plastic bottle was inverted below the water surface and brought back up through the water column to provide a grab sample. Samples were kept on ice until they could be brought back to the MassDEP's biological laboratory in Worcester for analysis. Chlorophyll a analysis was performed on a Turner-Design TD-700 lab fluorometer.

Periphyton Collection Methods

On July 1 and September 2, periphyton samples were collected for chlorophyll a analysis from substrata at three sites along the Blackstone River (Table 1) to examine the benthic algal production compared to the water column production. Riffle/run areas were chosen for the establishment of four transects at each site. An effort was made to sample in areas with a canopy ≥50% open and with a cobble bottom. Percent canopy cover was determined by standing midstream and estimating the amount of bottom that is shaded by vegetation (MassDEP 2002).

Four transects, approximately 10 meters (m) apart, were established perpendicular to the river flow starting at the downstream end of a riffle/run reach. Using a tape measure, the river's width was subdivided into five equidistant sites along each transect. At each predetermined site the sampler picked up the first cobble that he or she touched without looking at the surrounding substrata. The color, thickness, and percent cover of microalgae and macroalgae on all cobbles collected were noted on the field sheets. A discrete sample for chlorophyll analysis was obtained from each of two transects as follows. Cobbles from Transect 1 were conveyed to the stream bank where a soft plastic ring (2.5 in. diameter) was placed on the cobble surface and its perimeter inscribed with a knife. The outlined surface was cleaned of attached algae using a wire pot scrubber, a knife and a soft toothbrush. The cobbles were cleaned into a pan containing approximately 100 ml of filtered ambient water. A hand pump with a 0.5 polymicron filter was used to filter instream water for use in diluting the composited material and cleaning the tray and toothbrush. The composited material was rinsed from the plastic tray into a sample container to yield one chlorophyll a sample. This process was repeated at Transect 3. Lab duplicates were run on these samples. Substrates collected along transects 2 and 4 were examined for their percent cover of microalgae and macroalgae but were not used for chlorophyll analyses. After processing, all cobbles were returned to the stream bottom.

The chlorophyll samples were transported to the laboratory, logged in and refrigerated until they were processed. Within 24 hours, +/- 2 hours, the samples were taken from the refrigerator, the contents of the first sample were emptied into the 1 liter plastic graduated cylinder and the volume brought up to 500 mls. The sample was then poured into a flask, stirred and an aliquot of 5 mls removed. The aliquot was filtered through a glass fiber filter, placed in a plastic petri dish, labeled, covered with aluminum foil and put in the freezer until they were ground using a tissue homogenizer to break up cells to release the chlorophyll a. A holding period of 21 days was observed for all samples (MassDEP 2008). The samples were analyzed on a Turner TD-700 fluorometer for chlorophyll a.

Table 1: Blackstone River Periphyton and Water Column Chlorophyll a Sampling Stations.

Location	Station No.	Periphyton		Water column chlorophyll a (river stations)			Water column chlorophyll a (impoundments)		
		July 1	Sep 2	Jun 30	Sep 2	Sep 4	Sep 11	Sep 15	Sep 16
Blackstone Bikeway below Rte 146, Millbury	BP-1			X					
Approx. 60 ft. upstream from confluence UBWPAD discharge and Blackstone River, Millbury	W1240					X			
Below confluence UBWPAD and Blackstone River, Millbury	UBWPAD	X	X		X				
Kettle Brook, bypass upstream of bike path, Millbury	none					X			
Upstream McCracken Rd. Millbury	W0505			X		X			
Singing Dam Impoundment, Sutton	none			X		X		X	
Singing Dam, along right hand	W1017			X		X			

Location	Station No.	Periphyton		Water column chlorophyll a (river stations)			Water column chlorophyll a (impoundments)		
		July 1	Sep 2	Jun 30	Sep 2	Sep 4	Sep 11	Sep 15	Sep 16
shore, Sutton									
Central Cemetery, downstream Waters St., Millbury	BLK02A	X	X	X	X	X			
Depot St., Sutton	Depot	X	X		X				
Rice City Impoundment, Uxbridge	none						X		
Farnumsville Dam, Sutton	none							X	
Fisherville Impoundment, Grafton	none								X
Riverdale Impoundment, Northbridge	none								X

RESULTS

Phytoplankton-chlorophyll and algae

Chlorophyll a results from the water column samples are presented in Table 2. The chlorophyll a values for the main stem stations were all low and ranged from 1 to 3.7 mg/m^3. One station on the Kettle Brook bypass, a tributary below the UBWPAD, exhibited 1.3 mg/m^3 chlorophyll, but had abundant macrophyte growth.

Appendix A includes a list of the algal genera found in the water column samples from the main stem and impoundments. Very few algal cells were recovered from any of the samples. This may be a result of the elevated flows, but it can not be determined from this data. The one impoundment (Fisherville) that exhibited an elevated chlorophyll a value did not have an associated algae sample collected on that date (Sept. 16). An earlier sample collected from Fisherville Impoundment on July 31 had primarily green filamentous algae *Rhizoclonium* sp. and *Spirogyra* sp. present. These species may also have been present in September and contributed to the chlorophyll value, but this can not be verified.

Table 2: Blackstone River chlorophyll a data (mg/m^3) from grab samples collected from water column main stem stations and impoundments - June and September 2008.

OWM ID	Sampling Location	Collection Date	Chlorophyll a (mg/m^3)
	Main stem River Stations		
W1240	Approx. 60 ft. upstream from confluence UBWPAD discharge and Blackstone River, Millbury	Sept. 4	2.7
UBWPAD	Confluence UBWPAD discharge and Blackstone River, Millbury	Sept. 2	3
BP-1	Blackstone Bikeway, Millbury	June 30	3.7
BLK-02A	Central Cemetery, downstream Waters Street, Millbury	June 30 Sept. 2 Sept. 4	3.2 3 2.4
--	Kettle Brook bypass, Millbury	Sept. 4	1.3
W-0505	Upstream McCracken Rd. Millbury	June 30	2.8

		Sept. 4	1.7
--	Depot St. Sutton	Sept. 2	2.6
W-1017	Singing Dam, along right hand shore, Sutton	June 30	4
		Sept. 4	1
	Impoundment Stations		
--	Singing Dam Impoundment, Sutton	Sept. 15	3.6
--	Fisherville Impoundment, Grafton	Sept. 16	20.3
--	Farnumsville Impoundment, Sutton	Sept. 15	5.1
--	Riverdale Impoundment, Northbridge	Sept. 16	4.9
--	Rice City Pond, Uxbridge	Sept. 11	2.8

Periphyton-chlorophyll and Algae

The chlorophyll a results from the periphyton sampling are presented in Table 3. The average results from July (range 25.9 to 65.3 mg/m^2) were all lower than in September (range 104.7-138.3 mg/m^2). T-tests showed no significant difference between stations for their chlorophyll a results from September.

Table 3: Blackstone River Periphyton Chlorophyll a (mg/m^2) for July and September – 2008.

Sampling Location	**Average chlorophyll (mg/m^2) n=2**	
	July	**Sept**
Below confluence UBWPAD and Blackstone River, Millbury	65.3	138.3
Central Cemetery, Millbury	50.9	104.7
Depot St, Sutton	25.9	109.7

The percent micro and macroalgal cover was estimated for each cobble that was "picked" along the transects. The July samples were examined microscopically. A green/black film, composed primarily of green coccoid algae, covered all of the cobbles examined. Table 4 provides a description of the algae observed.

Table 4: Blackstone River Periphyton (attached algae) description of algae present - July 1, 2008.

Sampling Location	**Description of attached algae**
Approximately 30 m below confluence UBWPAD and Blackstone River, Millbury	Most cobbles covered with green/black film of green coccoid algae, green parenchymatous *Coleochaete* sp.
Approximately 50 m downstream Central Cemetery - Waters St., Millbury	Most cobbles covered by attached cyanobacteria filaments, pennate diatoms and filaments of green filamentous *Stigeoclonium* sp.
Approximately 30 m downstream Depot St., Sutton	Most cobbles covered with green/black film of green coccoid algae, also few filaments of red algae *Audouinella* sp.

Precipitation and Flow Data

Table 5 shows precipitation data for 6 days leading up to and including the sampling date. The June 30 sampling date was not affected by precipitation, nor was September 4, but later that month, on the 9th, 12th and 14th, significant amounts of precipitation fell which may have adversely affected the attached and suspended algal population by scouring from increased runoff and turbidity.

Because the precipitation data reported is not from a town in the watershed, flow data from a Blackstone River main stem station was examined to see if any storms represented in the precipitation data had impacted the river flows (Table 6). Flow data gathered by the USGS (http://waterdata.usgs.gov/nwis/sw) at the Blackstone River gage at West Main St., Millbury declined in June prior to the sampling date. Recorded flows ranged from a high of 182 cfs on June 25 to a low of 94 cfs on June 28. In early September, low flows were observed in the Blackstone River at Millbury with a low of 63 cfs on September 3, the day before sampling, to a high of 86 cfs on August 30.

A significant rain event (3.01 inches) occurred outside of the selected antecedent time period, on September 6. This led to an increase in stream flow that ranged between 244 cfs on September 6 to 1650 cfs on September 7. Subsequently, stream flow diminished steadily to 273 cfs on September 14 and 216 cfs on September 15, prior to sampling on these dates. While, the impact of flushing of the planktonic algal population caused by the flow increase is not known, it is likely to be considerable since many taxa depend on currents to live in the photic zone and it is anticipated that the supply of nutrients would be considerably diluted by the rain.

Table 5: Precipitation data for Blackstone Watershed sampling dates in 2008 and five days prior as measured at National Climatic Data Center in Taunton, MA.

Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)
June 25	0.01	August 30	0.01	Sept. 9	0.36
				Sept. 10	0.01
June 26	T**	August 31	0.01	Sept. 11	0.0
June 27	0.01	Sept. 1	0.0	Sept. 12	0.47
June 28	T**	Sept. 2	0.0	Sept. 13	0.03
June 29	T**	Sept. 3	0.0	Sept. 14	0.61
June 30*	0.05	Sept. 4*	0.0	Sept. 15, 16*	0.0

*sampling date; **T trace amounts precipitation
Source: http://www.erh.noaa.gov/box/dailystns.shtml

Table 6: Flow data (cfs) for Blackstone Watershed sampling dates in 2008 and five days prior as measured at Millbury, MA.

Date	Mean discharge (cfs)	Date	Mean discharge (cfs)	Date	Mean discharge (cfs)
June 25	182	August 30	86	Sept. 9	302
June 26	133	August 31	73	Sept. 10	245
June 27	112	Sept. 1	63	Sept. 11	194
June 28	94	Sept. 2	66	Sept. 12	166
June 29	112	Sept. 3	63	Sept. 13	173
June 30*	122	Sept. 4*	72	Sept. 14	273
				Sept. 15*, 16*	216/173

*sampling date
Source: http://waterdata.usgs.gov/ma/nwis

DISCUSSION

Phytoplankton Assemblage and Chlorophyll a

Measured values of water column chlorophyll collected from both free flowing and impounded reaches along the Blackstone River were low which could indicate oligotrophic conditions, however, the elevated discharge values and lack of steady state, low flow conditions also suggests that wash out of the algae in the impoundments had occurred.. The one exception was Fisherville Impoundment where a measurement of 20.3 mg/m^3 was recorded. Wetzel (2001) found that chlorophyll a values of >10 mg/m^3 are indicative of eutrophic conditions, while Forsberg and Ryding (1980) describe lakes with phytoplankton chlorophyll concentrations between 7 and 40 mg/m^3 as eutrophic. Even here, the algae could have been washed in from areas that are typically out of the main channel.

Phytoplankton cells were also sparse in water column samples collected from a few sites along the river, as well as from the impoundments. Large river systems may have a resident population of phytoplankton, but velocities and algal regeneration times usually result in algae being carried in-stream that have been “flushed” out of side pools. Other factors that may have reduced the algal population include runoff, which may “flush” or scour substrates, and the highly colored water in the Blackstone River that may reduce available light so that production is limited.

Attached algae and Chlorophyll a

Observations of the substrates and algae were made along the main stem of the Blackstone River. Following rainstorms the river appeared black with turbidity contributed by stormwater. This suspended material persisted for several days and eventually settled out on the substrates creating a floc. The turbidity contributed by stormwater limited the amount of light available for plant growth. Other areas of interest along the river exhibited sandy substrates that are typically not good habitat for attached algae. It was hoped that a comparative station could be established upsteam of the UBWPAD along the Blackstone Bikeway, but because of the non-wadeable depth, no sites were found. Rather, water column samples were collected upstream from the UBWPAD using the pole sampler, and phytoplankton were sampled instead of periphyton.

Below the UBWPAD discharge, at the confluence with the main stem Blackstone River, there was a limited reach with approximately 150 feet of good substrate encompassing an area approximately two thirds across the river that had an open or partially open canopy. Downstream from that zone the river bottom became sandy again, until cobble/ boulder substrates were found approximately 30 m upstream from the McCracken Road Bridge.

Below the confluence of the UBWPAD discharge channel with the river, approximately 80% of the cobble substrata were covered by a green/black film, especially in the sunlit areas. This growth occurred over approximately 30 m of the benthos. On the east side of the river, shade and organic enrichment led to the development of long filaments of “sewage fungus”. Below this area the canopy became more closed, further limiting light availability. The bottom was predominantly sandy which limited available habitat for periphyton. Where the canopy opened up (e.g. at road crossings) and suitable substrates were available, growth of the green algae appeared to dominate. Still, the appearance of the algal cover had not caused any aesthetic problem since long filamentous forms were not present.

Downstream from McCracken Road., Millbury, the river was too deep for wading. Likewise, the impounded condition of the station at Central Cemetery, Millbury, upstream of Waters St., was too deep for wading. However, the flow at the downstream side was somewhat braided with a main channel and a side channel. For a distance of approximately 100 m the main channel was a wadeable waterbody with an open canopy and a cobble bottom and was included in the periphyton sampling.

The limited available habitat for attached algal growth in the Blackstone River has likely reduced the spatial coverage of this population. Little temporal data are available on attached algal growth, and although chlorophyll a values had increased from July, it is not known if peak values were captured by the September sampling event. Significant rainfall on September 12 and 14 may have actually affected the biomass that was recovered on the substrates on September 15/16. The areas supporting attached algae did not visually appear to be impaired, since nuisance type filamentous green algae were not recovered; however, chlorophyll a values were indicative of enrichment based on the work of other researchers.

Biggs (1996) examined chlorophyll a values for different enrichment levels from 16 stream sites in New Zealand. Enriched streams in watersheds with agricultural use predominating exhibited high chlorophyll a values (i.e., >100 mg/m^2) approximately 40 % of the year. Actual values ranged from a low of 25 mg/m^2 to a high of 260 mg/m^2. The average Blackstone River chlorophyll a values ranged from 25.9-65.3 mg/m^2, in July, and 109.7-138.3 mg/m^2, in September. The Blackstone River chlorophyll a values in September provide evidence of nutrient enriched conditions in the Blackstone.

According to Barbour et al. (1999), chlorophyll measurements >100 mg/m^2 indicate nuisance levels of algae and nutrient or organic enrichment. However, some researchers have found a higher chlorophyll a threshold to be indicative of enriched conditions. Dodds et al. (1998) found values above 200 mg/m^2 chlorophyll a to be indicative of eutrophic conditions based upon temperate streams and rivers around the world. Suplee et al. (2009) found in Montana that the public perceives ≥200 mg/m^2 chlorophyll a as undesirable for recreation.

Although the segments of the Blackstone River in the study area exhibited organic or nutrient enrichment according to some schemes (Barbour et al. 1999), they were not characterized by having large areas of the bottom covered by nuisance algal species (e.g. long streamers of filamentous algae). Rather, the cobbles were covered by a close film. This may be an indication of high disturbance levels which result in reduced biomass and with algal communities dominated by low-growing “highly shear-resistant” taxa (Biggs 1996).

Algal production in the Blackstone River increased from July to September with the highest value measured just below the confluence of the UBWPAD discharge channel with the river. No site was available for an upstream comparison above this confluence, but it is likely because of depth issues that periphyton production is low. Algal production, as shown by chlorophyll a values, remained high down to Depot St., Sutton. Water column productivity was found to be low in the river reach upstream from the confluence.

Many factors influenced algal production in the Blackstone River in 2008. Higher water depths and flows in 2008 contributed to scouring of substrates and lack of light for the periphyton (USGS 2009(a)). Statistics of monthly mean data for water years 2002-2008 (USGS 2009(a)) indicate that July, Aug and Sept. of 2008 had the maximum discharge values (cfs) as recorded at the Millbury gage as compared to the other years during this period. Dilution or wash-out may have reduced the phytoplankton population throughout the river. There also are restrictions governing the periphyton habitat that are present year to year. In particular, the reach of the river from the confluence of the UBWPAD channel and the main stem down to McCracken Rd. had a closed canopy and sandy substrates, except for a small area at the confluence (approximately 30 meters) and approximately 20 meters above the McCracken Rd bridge where cobble substrates and open canopy conditions were the best areas for periphyton to grow. The lack of suitable substrate is an important factor controlling attached algal growth in the Blackstone River.

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Appendix A: Listing of phytoplankton from various sites along the Blackstone River (2008) including the main stem and impoundments

Location	Date	Class	Genus
Fisherville Impoundment, Grafton	31-Jul	Chlorophyceae	*Spirogyra* sp.
Fisherville Impoundment, floating algal mat	31-Jul	Chlorophyceae	*Rhizoclonium* sp.
Blackstone, channel diversion site W-1893	26-Aug	Chlorophyceae	*Spirogyra* sp.
Upstream confluence UBWPAD discharge and Blackstone River, Millbury	4-Sep	Bacillariophyceae	*Melosira* sp.
		Chlorophyceae	*Closteriopsis* sp.
		Cryptophyceae	*Cryptomonas* sp.
		Cyanophyceae	*Phormidium* sp.
Central Cemetery, Waters St., Millbury	4-Sep	Cyanophyceae	*Anabaena* sp.
		Cyanophyceae	*Crucigenia* sp.
Rice City Pond, Uxbridge	11-Sep	Bacillariophyceae	*Navicula* sp.
		Bacillariophyceae	pennate diatoms
		Chlorophyceae	coccoid green
		Chlorophyceae	*Scenedesmus* sp.
		Cryptophyceae	*Cryptomonas* sp.
		Cyanophyceae	*Anabaena* sp.
		Cyanophyceae	*Oscillatoria* sp.
		Cyanophyceae	*Phormidium* sp.
		Euglenophyceae	*Trachelomonas* sp.
Farnumsville Impoundment, Sutton	15-Sep	Bacillariophyceae	*Asterionella* sp.
		Bacillariophyceae	ui pennate diatoms
		Chlorophyceae	*Sphaerocystis* sp.
		Chlorophyceae	ui green flagellate
		Cyanophyceae	*Anabaena* sp.
		Cyanophyceae	*Coelosphaerium* sp.
		Cyanophyceae	*Phormidium* sp.
		Euglenophyceae	*Trachelomonas* sp.
Singing Dam, Sutton	15-Sep	Bacillariophyceae	ui pennate diatom
		Chlorophyceae	*Sphaerocystis* sp.
		Chlorophyceae	ui green flagellate
		Cyanophyceae	b-g coccoid
		Dinophyceae	ui dinoflagellate