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BLACKSTONE RIVER WATERSHED 2003 BIOLOGICAL ASSESSMENT

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CONTENTS

Tables and Figures

INTRODUCTION

Biological monitoring is a useful means of detecting anthropogenic impacts to the aquatic community. Resident biota (e.g., benthic macroinvertebrates, fish, periphyton) in a water body are natural monitors of environmental quality and can reveal the effects of episodic and cumulative pollution and habitat alteration (Barbour et al. 1999, Barbour et al. 1995). Biological surveys and assessments are the primary approaches to biomonitoring.

As part of the Massachusetts Department of Environmental Protection/Division of Watershed Management (MassDEP/DWM) 2003 Blackstone River watershed assessments, aquatic benthic macroinvertebrate biomonitoring was conducted to evaluate the biological health of portions of the Blackstone and Mumford rivers. Four biomonitoring stations were sampled to investigate the effects of nonpoint and point source stressors—both historical and current—on the aquatic communities of the watershed. These stations—sampled most recently in 1993 and/or 1997 (MassDEP 2001)—were reevaluated to determine if water quality and habitat conditions have improved or worsened over time. To minimize the effects of temporal (seasonal and year-to-year) variability, sampling was conducted at approximately the same time of the month as previous biosurveys. Sampling locations, along with station identification numbers and sampling dates, are noted in Table 1. Sampling locations are also shown in Figure 1.

For point source investigations in the Mumford River, a site-specific sampling approach was implemented, in which the aquatic community and habitat downstream from the perceived stressor (downstream study site) were compared to an upstream reference station (control site) representative of "least disturbed" biological conditions for that waterbody. While the alternative to this site-specific approach is to compare the study site to a regional or watershed reference station (i.e., "best attainable" condition), the site-specific approach is more appropriate for an assessment of a known or suspected stressor, provided that the stations being compared share basically similar instream and riparian habitat characteristics (Barbour et al. 1999). Since both the quality and quantity of available habitat affect the structure and composition of resident biological communities, effects of such features can be minimized by sampling similar habitats at stations being compared, providing a more direct comparison of water quality conditions (Barbour et al. 1999). Sampling highly similar habitats also reduces metric variability, attributable to factors such as current speed and substrate type. The upstream-downstream sampling approach was utilized in the Mumford River to assess potential impacts of the Douglas Municipal Wastewater Treatment Facility discharge.

To provide additional information necessary for making basin-wide *Aquatic Life Use* determinations required by Section 305(b) of the Clean Water Act, macroinvertebrate biomonitoring stations were compared to a regional reference station most representative of the "best attainable" conditions in the watershed. Use of a watershed reference station is particularly useful in assessing nonpoint source pollution originating from multiple and/or unknown sources in a watershed (Hughes 1989). The Mumford River reference station (BLK09-8A) served as the reference condition for the entire Blackstone River watershed. BLK09-8A has historically been used as a reference condition by MassDEP for bioassessment purposes (MassDEP 2001)—it is situated upstream from all known point sources of water pollution, and is also assumed (based on historical MassDEP water quality data, topographic map examinations, and field reconnaissance) to be minimally impacted (relative to other portions of the watershed) by nonpoint sources.

During "year 1" of its "5-Year Basin Cycle", problem areas within the Blackstone River watershed were better defined through such processes as coordination with appropriate groups, assessing existing data, conducting site visits, and reviewing NPDES permits. Following these activities, the 2003 biomonitoring plan was more closely focused and the study objectives better defined. Table 2 includes a summary of the important current and historical conditions and perceived problems identified prior to the 2003 Blackstone River watershed biomonitoring survey.

The main objectives of 2003 biomonitoring in the Blackstone River watershed were: (a) to determine the biological health of rivers within the watershed by conducting assessments based on aquatic macroinvertebrate communities; and (b) to identify problem stream segments so that efforts can be focused on developing NPDES permits, Water Management Act (WMA) permits, stormwater management, and control of other nonpoint source (NPS) pollution. Specific tasks were:

1. Conduct benthic macroinvertebrate sampling and habitat assessments at locations in the Blackstone and Mumford rivers;

2. Based upon the macroinvertebrate data, identify river segments within the watershed with existing and/or potential point/nonpoint source pollution problems; and

3. Using the benthic macroinvertebrate data and supporting water chemistry and field/habitat data:

- Assess the types of water quality problems that are present, and
- if possible, make recommendations for remedial actions or additional monitoring and assessment.
- Provide macroinvertebrate and habitat data to MassDEP/DWM's Environmental Monitoring and Assessment Program for assessments of *Aquatic Life Use* support status required by Section 305(b) of the Federal Clean Water Act (CWA).
- Provide macroinvertebrate and habitat data for other informational needs of Massachusetts regulatory and resource agencies.

Table 1. List of biomonitoring stations sampled during the 2003 Blackstone River watershed survey, including station identification number, mile point, site description, and sampling date.

Station ID	River Mile	Blackstone River Watershed Site description	Sampling Date
BLK09-8A	10.0	Mumford River, 125 m downstream from Manchaug St., Douglas, MA	15 Sept. 2003
MF03B	9.0	Mumford River, 260 m downstream from North St., below Douglas WWTP, Douglas, MA	15 Sept. 2003
BLK02	46.0	Blackstone River, at Old McCracken Road, below UBWPAD, Millbury, MA	15 Sept. 2003
BLK12A	24.5	Blackstone River, 30 m upstream from Central St., Millville, MA	15 Sept. 2003

Table 2. Existing conditions and perceived problems identified prior to the 2003 Blackstone River watershed survey.

Blackstone River Watershed Stations	Conditions
BLK09-8A	-reference (i.e., minimally impacted) condition[1]
BLK02; BLK12A; MF03B	-urban runoff/miscellaneous NPS pollution (includes road runoff)[1]
BLK02; BLK12A; MF03B	-point source discharges – WWTPs (UBWPAD and Douglas WWTP)[1,2]
BLK02	-CSO contributions (Worcester CSO Treatment Facility via Mill Brook)[1]
BLK02	-illicit sewer connections
BLK02; BLK12A; MF03B	-303d listed for nutrients, organic enrichment/low D.O., metals, unknown toxicity[1,3]
MF03B	-"not assessed" for Aquatic Life by DEP[1]

[1]MassDEP 2001; [2]MassDEP 2006; [3]MassDEP 2002

BLACKSTONE RIVER WATERSHED
2003 BIOMONITORING STATIONS

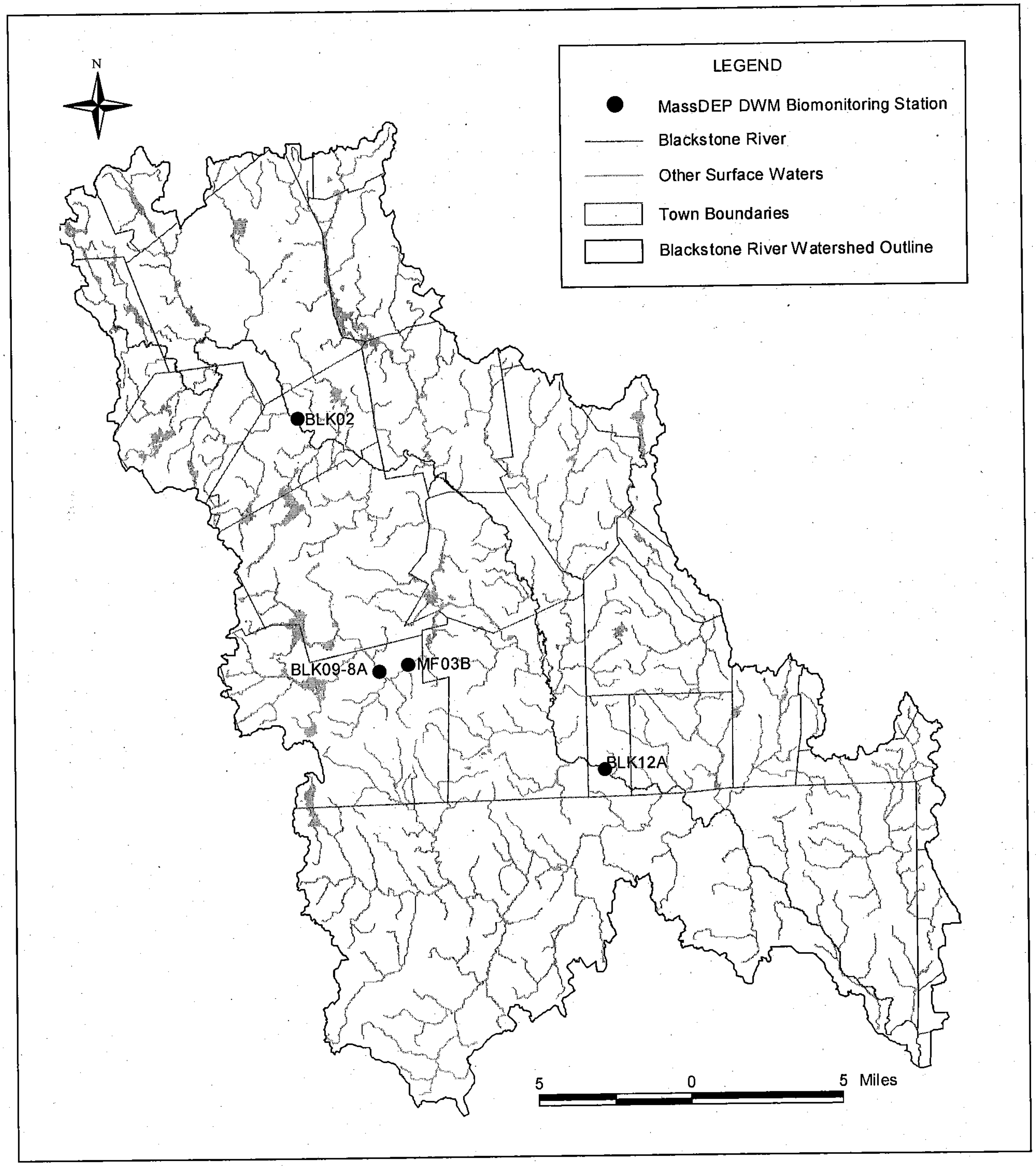

Figure 1. Location of MassDEP/DWM biomonitoring stations for the 2003 Blackstone River Watershed survey

BASIN DESCRIPTION

The Blackstone River is formed in the City of Worcester by the confluence of the Middle River and Mill Brook. The mainstem flows generally southeast through Worcester, Millbury, Sutton, and Grafton to Fisherville Pond, where it converges with the Quinsigamond River. Below Fisherville Pond, the Blackstone River flows in a southerly direction through Northbridge, Uxbridge, Millville, and Blackstone and crosses for the first time into Rhode Island. Just south of the RI border, it is joined by the Branch River, turns north and re-enters Massachusetts for a short distance, then turns south again and enters Woonsocket, RI. The Blackstone River Basin is bordered by the Chicopee River Basin to the northwest, the French River Basin to the southwest, the Concord River Basin to the northeast and by the Charles River Basin to the southeast. The north and south portions of the basin are bordered by the Nashua River Basin and the state of Rhode Island, respectively. Major tributaries that discharge to the Blackstone River in Massachusetts include the Quinsigamond, West, and Mumford rivers. The Mill and Peters rivers join the Blackstone River in Rhode Island. There are 188 lakes in the Massachusetts portion of the basin which cover approximately 7,087 acres.

The mainstem Blackstone River is characterized by numerous impoundments formed by the remains of old mill-dams used historically for water power. In Massachusetts, two of these are still used at varying levels to generate power: Riverdale and Synergics (Tupperware). Water levels in the river fluctuate rapidly over short periods of time due to a combination of storm impacts and water flow regulations. The flow impacts during storm events are compounded by the predominance of impervious surfaces and the scarcity of wetlands. A decrease in impervious surfaces and an increase in wetlands would moderate flows through absorbing and releasing the water over larger time events.

The drainage area of the Blackstone River Basin encompasses a total of 540 square miles of which approximately 335 square miles lie in Massachusetts including portions of Bristol, Middlesex, Norfolk, and Worcester counties. The communities of Attleboro, Auburn, Bellingham, Blackstone, Boylston, Douglas, Franklin, Grafton, Holden, Hopedale, Hopkinton, Leicester, Milford, Millbury, Millville, Northbridge, Mendon, North Attleborough, Oxford, Paxton, Plainville, Shrewsbury, Sutton, Upton, Uxbridge, Webster, Westborough, West Boylston, Worcester, and Wrentham lie wholly or in part within the watershed boundaries.

The Blackstone River has a long history of water pollution. The Blackstone Valley was the birthplace of the American textile industry. The construction of the Blackstone Canal, which extended from Narragansett Bay to Worcester, was finished in 1828. It was used through 1848, when the railroad became a quicker and cheaper method of transporting goods. A detailed description of the canal and its history can be found in the Blackstone River Valley Cultural Heritage and Land Management Plan (BRVNHCC 1989). The Blackstone River and its tributaries were the first to be polluted by waste discharges from textile mills. The river has been described as "the world's busiest river" and "industrial stream" during the nineteenth and twentieth centuries (Tennant et al. 1975). Gross sediment contamination also resulted from the discharges of heavy metals from plating operations, oil and grease from machine shops, dyes and prints from textile plants, organics and metals from tanneries, and other sources (McGinn 1981). Resuspension of contaminated sediments located behind many of the dams along the Blackstone River, however, remains a major concern.

The industrial pollution has declined but domestic wastes being discharged into the river have increased with the growing population of the valley. According to Tennant et al. (1975), the city of Worcester is the single most important factor in the pollution of the Blackstone River. Not only is the flow of the Blackstone River adversely affected by extensive impervious surfaces (altered natural hydrology resulting in higher high flows and lower low flows) which contribute pollutants from nonpoint sources, the river also provides limited dilution for municipal and industrial wastewater discharges. Since 1963, thirty-six National Pollutant Discharge Elimination System (NPDES) discharges, representing both municipal and industrial operations in 11 towns, have ceased to discharge to the Blackstone River Basin (Paul Hogan, MassDEP, personal communication, 2006).

Today, major municipal wastewater treatment plants are located in Millbury (Upper Blackstone Water Pollution Abatement District - UBWPAD), Northbridge, Upton, Douglas, Hopedale, Grafton and Uxbridge.

Nonpoint source pollution associated with urban and agricultural runoff, contaminated sediments, runoff and/or leachate from dumps, junkyards, gravel pits, and automobile graveyards also contributes to the basin's water quality problems.

With the exception of Worcester, all communities in the Blackstone River Basin rely on groundwater as their primary source of public supply (Izbicki 2000). By the year 2020, demand for water in the basin is expected to be 52 MGD, one-third greater than the demand in 1980. Most of this increase is expected to be supplied by increased groundwater withdrawals from aquifers in the eastern and northern parts of the basin.

METHODS

Macroinvertebrate Sampling

The macroinvertebrate sampling procedures employed during the 2003 Blackstone River watershed biomonitoring survey are described in the standard operating procedures *Water Quality Monitoring In Streams Using Aquatic Macroinvertebrates* (Nuzzo 2002), and are based on US EPA Rapid Bioassessment Protocols (RBPs) for wadeable streams and rivers (Barbour et al. 1999). The macroinvertebrate collection procedure utilized kick-sampling, a method of sampling benthic organisms by kicking or disturbing bottom sediments and catching the dislodged organisms in a net as the current carries them downstream (Figure 2). Sampling activities were conducted in accordance with the Quality Assurance Project Plan (QAPP) for benthic macroinvertebrate biomonitoring (MassDEP 2003). Sampling was conducted at each station by MassDEP/DWM biologists throughout a 100 m reach, in riffle/run areas with fast currents and rocky (cobble, pebble, and gravel) substrates—generally the most productive habitats, supporting the most diverse communities in the stream system. Ten kicks in squares approximately 0.46 m x 0.46 m were composited for a total sample area of about 2 m^2. Samples were labeled and preserved in the field with denatured 95% ethanol, then brought to the MassDEP/DWM lab for further processing.

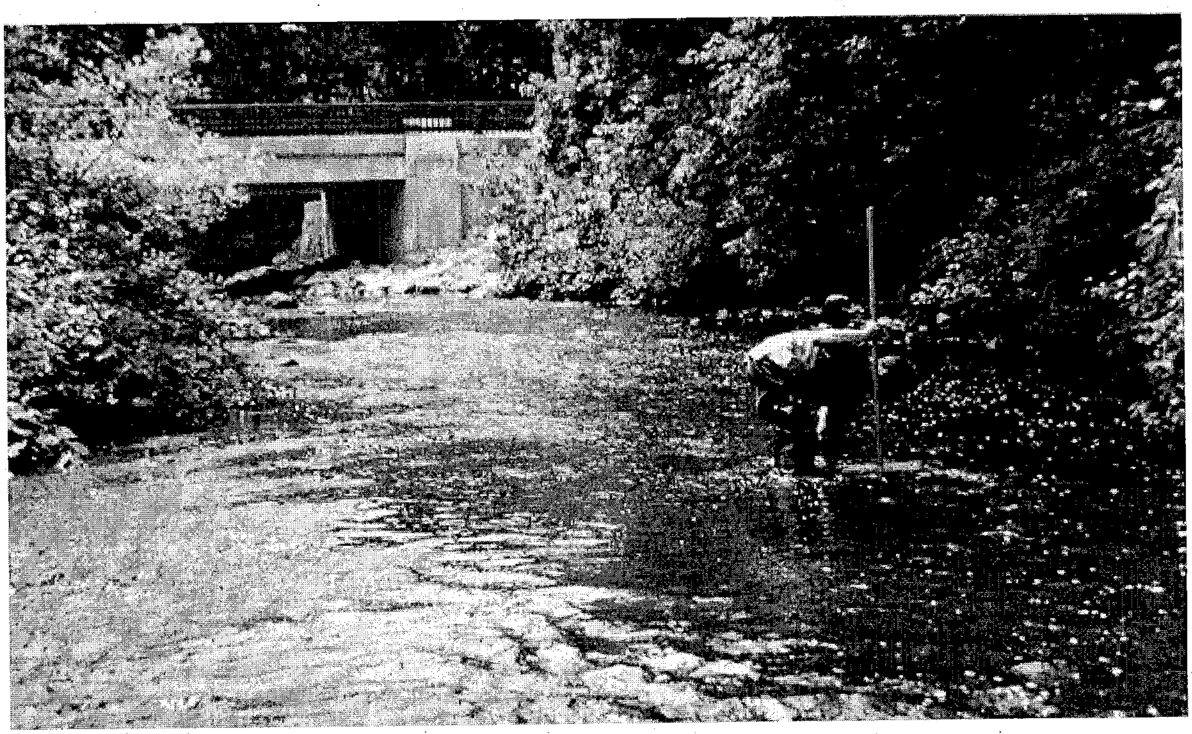

Figure 2. MassDEP/DWM biologist collecting macroinvertebrates using the "kick" sampling technique.

Macroinvertebrate Sample Processing and Analysis

The macroinvertebrate sample processing and analysis procedures employed for the 2003 Blackstone River watershed biomonitoring samples are described in the standard operating procedures (Nuzzo 2002) and were conducted in accordance with the Quality Assurance Project Plan (QAPP) for benthic macroinvertebrate biomonitoring (MassDEP 2003). Macroinvertebrate sample processing entailed distributing whole samples in pans, selecting grids within the pans at random, and sorting specimens from the other materials in the sample until approximately 100 organisms (±10%) were extracted. Specimens were identified to genus or species as allowed by available keys, specimen condition, and specimen maturity. Taxonomic data were analyzed using a modification of Rapid Bioassessment Protocol III (RBP III) metrics and scores (Plafkin et al. 1989). Based on the taxonomy, various community, population, and functional parameters, or "metrics", were calculated which allow measurement of important aspects of the biological integrity of the community. This integrated approach provides more assurance of a valid assessment because a variety of biological parameters are evaluated. Deficiency of any one metric should not invalidate the entire approach (Barbour et al. 1999). Metric values for each station were scored based on comparability to the reference station, and scores were totaled. The percent comparability of total metric scores for each study site to those for a selected "least-impacted" reference station yields an impairment score for each site. The analysis separates sites into four categories: non-impacted, slightly impacted, moderately impacted, and severely impacted. Each impact category corresponds to a specific *Aquatic Life Use* support determination used in the CWA Section 305(b) water quality reporting process—non-impacted and slightly impacted communities are assessed as "support" in the 305(b) report; moderately impacted and severely impacted communities are assessed as "impaired." A definition of the *Aquatic Life Use* designation is provided in the *Massachusetts Surface Water Quality Standards* (SWQS) (MassDEP 1996). Impacts to the benthic community may be indicated by the absence of generally pollution-sensitive macroinvertebrate taxa such as Ephemeroptera, Plecoptera, and Trichoptera (EPT); dominance of a particular taxon, especially the pollution-tolerant Chironomidae and Oligochaeta taxa; low taxa richness; or shifts in community composition relative to the reference station (Barbour et al. 1999). Those biological metrics calculated and used in the analysis of 2003 Blackstone River watershed macroinvertebrate data are listed and defined below [For a more detailed description of metrics used to evaluate benthos data, and the predicted response of these metrics to increasing perturbation, see Barbour et al. (1999)]:

1. Taxa Richness—a measure based on the number of taxa present. Generally greater with better water quality, habitat diversity, and habitat suitability. The lowest possible taxonomic level is assumed to be genus or species.

2. EPT Index—a count of the number of genera/species from the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). As a group these are considered three of the more sensitive aquatic insect orders. Therefore, the greater the contribution to total richness from these three orders, the healthier the community.

3. Biotic Index—Based on the Hilsenhoff Biotic Index (HBI), this is an index designed to produce a numerical value to indicate the level of organic pollution (Hilsenhoff 1982). Organisms have been assigned a value ranging from zero to ten based on their tolerance to organic pollution. Tolerance values currently used by MassDEP/DWM biologists were originally developed by Hilsenhoff and have since been supplemented by Bode et al. (1991) and Lenat (1993). A value of zero indicates the taxon is highly intolerant of pollution and is likely to be found only in pollution-free waters. A value of ten indicates the taxon is tolerant of pollution and may be found in highly polluted waters. The number of organisms and the individually assigned values are used in a mathematical formula that describes the degree of organic pollution at the study site. The formula for calculating HBI is:

$$HBI = \sum \frac{x_i t_i}{n}$$

where:

x_i = number of individuals within a taxon
t_i = tolerance value of the taxon
n = total number of organisms in the sample

4. Ratio of EPT and Chironomidae Abundance—The EPT and Chironomidae abundance ratio uses relative abundance of these indicator groups as a measure of community balance. Skewed populations having a disproportionate number of the generally tolerant Chironomidae ("midges") relative to the more sensitive insect groups may indicate environmental stress.

5. Percent Contribution Dominant Taxon—is the percent contribution of the numerically dominant taxon (genus or species) to the total number of organisms. A community dominated by few species indicates environmental stress. Conversely, more balance among species indicates a healthier community.

6. Ratio of Scraper and Filtering Collector Functional Feeding Groups—This ratio reflects the community food base. The proportion of the two feeding groups is important because predominance of a particular feeding type may indicate an unbalanced community responding to an overabundance of a particular food source (Barbour et al. 1999). Scrapers predominate when diatoms are the dominant food resource, and decrease in abundance when filamentous algae and mosses prevail. Filtering collectors thrive where filamentous algae and mosses are prevalent and where Fine Particulate Organic Material (FPOM) levels are high.

7. Community Similarity—is a comparison of a study site community to a reference site community. Similarity is often based on indices that compare community composition. Most Community Similarity indices stress richness and/or richness and abundance. Generally speaking, communities with comparable habitat will become more dissimilar as stress increases. In the case of the Blackstone River watershed bioassessment, an index of macroinvertebrate community composition was calculated based on similarity (i.e., affinity) to the reference community, expressed as percent composition of the following organism groups: Oligochaeta, Ephemeroptera, Plecoptera, Coleoptera, Trichoptera, Chironomidae, and Other. This reference site affinity (RSA) approach is based on a modification of the Percent Model Affinity (Novak and Bode 1992). The RSA metric is calculated as:

   $$100 - (\Sigma\, \delta \times 0.5)$$

   where δ is the difference between the reference percentage and the sample percentage for each taxonomic grouping. RSA percentages convert to RBPIII scores as follows: <35% receives 0 points; 2 points in the range from 35 to 49%; 4 points for 50 to 64%; and 6 points for ≥65%.

Habitat Assessment

An evaluation of physical and biological habitat quality is critical to any assessment of ecological integrity (Karr et al. 1986; Barbour et al. 1999). Habitat assessment supports understanding of the relationship between physical habitat quality and biological conditions, identifies obvious constraints on the attainable potential of a site, assists in the selection of appropriate sampling stations, and provides basic information for interpreting biosurvey results (US EPA 1995). Before leaving the sample reach during the 2003 Blackstone River watershed biosurveys, habitat qualities were scored using a modification of the evaluation procedure in Barbour et al. (1999). The matrix used to assess habitat quality is based on key physical characteristics of the water body and related streamside features. Most parameters evaluated are instream physical attributes often related to overall land-use and are potential sources of limitation to the aquatic biota (Barbour et al. 1999). The ten habitat parameters are as follows: instream cover, epifaunal substrate, embeddedness, sediment deposition, channel alteration, velocity/depth combinations, channel flow status, right and left (when facing downstream) bank vegetative protection, right and left bank stability, right and left bank riparian vegetative zone width. Habitat parameters are scored, totaled, and compared to a reference station to provide a final habitat ranking.

QUALITY CONTROL

Field and laboratory Quality Control (QC) activities were conducted in accordance with the Quality Assurance Project Plan (QAPP) for benthic macroinvertebrate biomonitoring (MassDEP 2003). Quality Control procedures included collection of a duplicate sample in the field, taxonomic "checks" in the lab, and review of all data entry and analysis. These procedures are further detailed in the standard operating procedures (Nuzzo 2002).

RESULTS AND DISCUSSION

The biological and habitat data collected at each sampling station during the 2003 biomonitoring survey are attached as an Appendix (Tables A1 – A3). Table A1 is the macroinvertebrates taxa list for each station and includes organism counts, the functional feeding group designation (FG) for each macroinvertebrate taxon, and the tolerance value (TV) of each taxon.

A summary table of the macroinvertebrate data analysis, including biological metric calculations, metric scores, and impairment designations, is also included in the Appendix (Table A2). Habitat assessment scores for each station are included in the summary table, while a more detailed summary of habitat parameters is shown in Table A3.

The 2003 biomonitoring data for this watershed generally indicate various degrees of nonpoint source-related problems in all of the streams examined—urban runoff, habitat degradation, and other forms of NPS pollution compromise water quality and biological integrity throughout the watershed. Serious water quality and biological impairment were also evident at BLK02 and BLK12A, most likely the result of upstream wastewater treatment discharges or other sources of organic loadings. That said, some portions of the Mumford River were found to remain relatively non-impacted and are indicative of the "best attainable" conditions in the watershed. It is imperative that anthropogenic perturbations be kept to a minimum here.

Mumford River

The Mumford River is a major tributary of the Blackstone River, encompassing approximately 57 square miles of land area in the Blackstone River basin in south central Massachusetts. The majority of the Mumford River watershed lies within four communities—Douglas, Northbridge, Sutton and Uxbridge. Two towns, Oxford and Webster, have a small amount (approximately one square mile) of land area in the Mumford River watershed (Dorlester 1994). Two major storage reservoirs (Whiten and Manchaug reservoirs) were constructed in the early 1800s in the headwaters of the Mumford River watershed to provide storage of spring runoff for release during the dry seasons of the year (Acheron 1985). These releases were initially used to power hydromechanical equipment in numerous mills along the river, and later powered hydroelectic turbines in many of the mills. The effect on streamflow was clearly documented by USGS gaging station records during the period from 1940 - 1951. By the early 1950s all of the hydromechanical and hydroelectric installations on the river were abandoned. The two reservoirs, however, were still operated with a shift in emphasis to flood control and low-flow augmentation. Residential development around the reservoirs also led to maintenance of the reservoir level for recreational purposes.

The Mumford River originates at the confluence of two unnamed tributaries flowing from the outlets of Tuckers and Stevens ponds in Sutton. In the upper segment, the Mumford River is designated a Class B Warm Water Fishery, High Quality Water (MADEP and US EPA 1995). Downstream from the Douglas WWTP the Mumford River is designated as a Class B Warm Water Fishery (MADEP and US EPA 1995). It flows through the Gilboa Pond impoundment after which it receives the treated wastewater discharge from Guilford of Maine, Inc. before entering Lackey Pond. It continues its journey through four more impoundments (Meadow Pond, Linwood Pond, Whitin Pond and Caprons Pond) before joining the mainstem Blackstone River south of Route 16 in Uxbridge.

BLK09-8A—Mumford River, mile point 10.0, 125 m downstream from Manchaug Street, Douglas, MA

Habitat

The BLK09-8A macroinvertebrate sampling reach began approximately 125 m downstream from Manchaug Street in Douglas. This portion of the river was mostly (80% canopy cover) shaded and with a width of about 4 m. Fast-water areas (i.e., "riffles") of varying (0.5 – 1.0 m) depths dominated the reach, and coupled with an abundance of boulder-dominated rocky substrates, provided excellent epifaunal habitat for macroinvertebrates. Fish habitat was also considered optimal, with boulders, overhanging and instream (bur-reed, *Sparganium* sp.) vegetation, and submerged woody debris offering stable cover in both riffle and deep (1 m) run/pool areas. Channel flow status was optimal, with water reaching the base of both banks and leaving no substrates exposed. Both stream banks were well-vegetated and stable, with a fairly wide and undisturbed riparian zone along the left (north) bank. The riparian zone along the right (south) bank, however, was reduced due to the close proximity of a cemetery. Due to the narrow buffer between the cemetery driveway and river, NPS inputs in the form of grass clippings and discarded flowers that were dumped along the bank posed a threat to the stream. In addition, the Manchaug Street road crossing offered a potential source of NPS pollution. Instream sediment deposition, observed here during the 1998 DEP biosurvey and originating from piles of excavated materials (sand and gravel) associated with the cemetery along the right bank, was not observed during the 2003 survey. Riparian vegetation was dominated by red maple (*Acer rubrum*) with occasional red oak (*Quercus rubra*) and white pine (*Pinus strobus*). Vines (riverbank grape, *Vitis riparia*) and herbaceous (Joe-Pye weed, *Eupatorium* sp.) growth occupied both banks as well. Instream algae, though minimal, consisted mainly of matted forms of brown-colored algae.

BLK09-8A received a composite habitat score of 164/200 (Table A3). This station was the watershed reference station for all biomonitoring stations in the 2003 Blackstone River watershed survey. The designation as reference station was based on the habitat evaluation conducted there, historical bioassessments, surrounding land use (the Mumford River subwatershed is 76% forested), and good overall water quality relative to other segments of the Blackstone River watershed (MassDEP 2001 and 2005). The upper segment of the Mumford River—from its headwaters to the Douglas WWTP—is designated a Class B Warm Water Fishery, High Quality Water (MassDEP and US EPA 1995).

Benthos

Because BLK09-8A is a reference station, the biological attributes of the macroinvertebrate assemblage sampled do not yield a final impairment score for the resident aquatic community. However, the metric values calculated as part of the RBP III analysis reflect a healthy benthic community one would expect to find in a "least impacted" stream (Table A2). Metric values for Biotic Index and EPT Index—parameters known to display low inherent variability (Resh 1988)—scored well and corroborate the designation as a reference station based on an assemblage composed of pollution sensitive taxa. The Percent Dominant Taxon (19%) metric also performed well relative to other stations in the survey, indicating good overall balance in the BLK09-8A benthic community. BLK09-8A received a total metric score of 42 out of a possible 42 (Table A2). Water quality monitoring data collected near BLK09-8A by MassDEP (2005) during the months of May through October 2003 corroborate the overall good water quality reflected in the aquatic community in this portion of the Mumford River.

MF03B—Mumford River, mile point 9.0, 260 m downstream from North Street (below the Douglas WWTP discharge), Douglas, MA

Habitat

The MF03B biomonitoring station began approximately 260 m downstream from North Street and just below the discharge of the Douglas WWTP (NPDES permit no. MA0101095). This segment (i.e., from the WWTP outfall to its confluence with the Blackstone River) of the river is currently listed as a "Category 5 Water" (i.e., reported to Congress and EPA as 303(d)-listed) for organic enrichment/low dissolved oxygen, metals, and pathogens (MassDEP 2002). Since the last DEP biomonitoring survey in this segment—conducted in 1993

(MassDEP 2001)—the Douglas WWTP's NPDES permit was reissued in 1995 with new effluent limits, in 2003, and again in 2005 following facility expansion and upgrades (MassDEP 2006; Kathleen Keohane, MassDEP, personal communication, 2006).

The MF03B sampling reach was 4 m wide and of uniform depth (about 1 m), with minimal canopy cover (20% shaded) despite the forested nature of the surrounding area. Long riffle/runs with boulder-dominated substrates provided excellent macroinvertebrate habitat throughout the reach. Fish habitat was also considered optimal, with boulder, undercut banks, and submerged logs providing stable cover. Instream algae and macrophytes were not observed; however, the turbid nature (the water color was grey-brown) of this portion of the river made it difficult to see the stream bottom. Channel flow status was optimal, as water easily reached the base of both banks. Bank and riparian habitat parameters rated excellent. Both stream banks were well vegetated and stabilized with a profusion of grasses, vines (greenbrier, *Smilax* sp.), and herbaceous growth (jewelweed, *Impatiens capensis*; purple loosestrife, *Lythrum salicaria*). Bank vegetation gave way to a wide and undisturbed riparian zone composed of white pine (*Pinus strobus*) and red maple (*Acer rubrum*) along both sides of the channel. Instream sediment deposition affected a little over 5% of the stream bottom in the sampling reach, although sources of sedimentation were unknown.

MF03B received a total habitat assessment score of 174/200—the highest habitat score in the entire 2003 Blackstone River watershed survey (Table A3). That habitat quality was highly comparable to the reference station, BLK09-8A allowed for a direct comparison of biological conditions above and below the Douglas WWTP discharge.

Benthos

The MF03B benthic community received a total metric score of 32, representing 76% comparability to reference conditions at BLK09-8A and resulting in a bioassessment of "slightly impacted" for biological condition (Tables A2). That habitat quality is similar at both the upstream (BLK09-8A) and downstream (MF03B) stations implies that detected impacts at MF03B can be attributed to water quality factors. However, the current bioassessment of MF03B appears considerably better than the one received following the 1993 biomonitoring survey here, when worms and midges (Chironomidae) highly tolerant of conventional organic wastes hyperdominated (n=105) the benthos assemblage and indicated severely impacted conditions (MassDEP 2001). Though still present in the 2003 benthos sample, worms and midge densities were much reduced compared to the sample collected in 1993. In addition, metric values for Taxa Richness and EPT Index were highly comparable to the reference assemblage, indicating a fairly diverse macroinvertebrate community that includes numerous pollution sensitive taxa. Furthermore, high scoring metric values for Percent Dominant Taxon and Scrapers/Filterers at MF03B suggest well balanced trophic and community structure relative to the reference station.

The apparent improvement in water quality and biological integrity at MF03B may be the result of improvements in effluent quality at the Douglas WWTP. Prior to the 2003 biosurvey, the plant historically had problems with insufficient sludge/solids disposal, non-functioning chlorination, failure to meet discharge limits for flow, and exceedences of DO/BOD limits—resulting in multiple Notices of Non-Compliance for operating deficiencies (MassDEP 2006). With the most recent facility upgrades—which include more stringent phosphorus, ammonia, and BOD/TSS limits (MassDEP 2006; Kathleen Keohane, MassDEP, personal communication, 2006)—now online, it is anticipated that aquatic health will continue to improve in this portion of the Mumford River.

Blackstone River

From its origin in Worcester, the Blackstone River, a Class B Warm Water Fishery (O'Shea 1991), flows southeastward and through numerous impoundments for a distance of approximately 29 miles to the corporate boundary between Massachusetts and Rhode Island, and then on to Providence and Narragansett Bay. The 540 square mile total drainage area of the Blackstone River includes 335 square miles within the Massachusetts counties of Bristol, Middlesex, Norfolk, and Worcester. Major tributary catchment areas of the Blackstone River include those of the Quinsigamond (38 square miles), West (30 square miles), Mumford (57 square miles), and Mill (33 square miles) rivers (Johnson et al. 1992).

BLK02—Blackstone River, mile point 46.0, at Old McCracken Rd., below UBWPAD, Millbury, MA

Habitat

The BLK02 sampling reach was located near an abandoned bridge that was formerly the river crossing of McCracken Road (since relocated a short distance downstream) in Millbury, where the river is crossed by high-tension power lines. Wide (16 m) and unshaded (<5% canopy cover), the reach was somewhat run and pool-dominated, with occasional deep (0.75 m) riffle areas. Since riffles were concentrated in the area near the bridge abutment of Old McCracken Road, kick sampling was limited to a fairly short stretch immediately above and below the bridge crossing. Cobble and gravel substrates were common here and provided optimal benthos habitat, although some instream sedimentation and associated substrate embeddedness were noted. Despite good channel depth (pool depth >1 m; optimal channel flow status), cover for fish was suboptimal due to lack of stable habitat and moderate deposition of sand in pool areas. Both banks were fairly well-vegetated, save for the lower portion of the reach where vegetation has obviously been cleared for the existing power lines. Stability was good along both banks, with stone "rip-rap" providing additional reinforcement. The riparian zone was reduced along both sides of the river due to the adjacent dirt roads and railroad bed. Riparian vegetation was dominated by shrubs (sumac, *Rhus* sp.) and herbaceous growth (false bamboo, *Polygonum cuspidatum*; jewelweed, *Impatiens capensis*; purple loosestrife, *Lythrum salicaria*), with occasional scattered trees (white pine, *Pinus strobus*; maple, *Acer* spp.). Instream aquatic vegetation was extremely abundant, covering virtually the entire river bottom and dominated by rooted submergent macrophytes (coontail, *Ceratophyllum* sp.; waterweed, *Elodea* sp.; pondweed, *Potamogeton crispus*). Slight turbidity in the water column was noted during sampling. A luxuriant algal community was also observed, with green filamentous algae attached to submergent vegetation and a brown flock covering much of the rocky substrates.

NPS pollution consisted mainly of debris associated with the adjacent railroad tracks along the right (west) bank. And while instream sedimentation was observed in the BLK02 sampling reach during the 2003 biomonitoring survey, it appeared much less severe than during the 1998 biosurvey. At that time a massive public works project (highway interchange construction--now complete) just upstream from the sampling reach resulted in large deposits of excavated materials adjacent to the river and was the most likely cause of sediment inputs to this portion of the Blackstone River. BLK02 received a total habitat assessment score of 153/200 during the 2003 survey (Table A3).

BLK02 is located approximately 700 m downstream from the UBWPAD (NPDES permit no. MA0102369) discharge outfall, and an additional 2 km from Mill Brook, which is the receiving water for the City of Worcester's Combined Sewer Overflow (CSO) Treatment Facility (NPDES permit no. MA0102997) discharge.

Benthos

The BLK02 benthic community received a total metric score of only 8, representing 19% comparability to the watershed reference station, BLK09-8A, and resulting in a bioassessment of "moderately/severely impacted" for biological condition (Tables A2). This was easily the worst benthic community assessment received by a biomonitoring station in the 2003 Blackstone River watershed survey, and a similar assessment to the one received following the 1997 biomonitoring survey here (MassDEP 2001).

The codominance (n=67) of the blackfly *Simulium vittatum* cpl. and the chironomid *Polypedilum flavum*—taxa highly tolerant of conventional organic pollutants and often associated with municipal wastewater discharges (Adler and Kim 1986; Bode and Novak 1998)—and virtually 100% cover of instream substrates by aquatic vegetation and filamentous algae, suggest the effects of nutrient loads and excessive organic enrichment one might associate with a wastewater discharge. Indeed, water quality monitoring conducted here by MassDEP from May through October 2003 found consistently elevated (>0.05 mg/L) phosphorus levels and occasionally elevated (>2.0) ammonia-nitrogen levels, as well as frequent violations (<5.0 mg/L; <60% saturation) of the dissolved oxygen criteria on numerous occasions and during both dry and wet weather surveys (MassDEP 2005). Interestingly, *Polypedilum flavum* was absent from the benthos sample collected here in 1998, yet it was a numerically dominant taxon in the sample collected during the 1991 DEP biomonitoring survey (MassDEP 1992). On the other hand, the chironomid *Cricotopus bicinctus*—a taxon that has been shown to display resistance to contamination by heavy metals and chlorine (Beckett and Keyes 1983; Simpson and Bode 1980)—abundant during both the 1991 and 1998 biosurveys at BLK02 and highly suggestive of toxic impacts suspected to originate from UBWPAD or other upstream sources (e.g., New England Plating Company; Worcester CSO Treatment Facility - both via Mill Brook) (MassDEP 1992; MassDEP 2001), was absent from the 2003 benthos assemblage. This suggests that water quality degradation associated with organic enrichment, rather than the presence of toxicants, now limits biological integrity in this portion of the river. It is worth mentioning that the New England Plating Company (NPDES permit no. MA0005088) is no longer in business, having ceased operations in 2003 (Paul Hogan, MassDEP, personal communication, 2006). Additionally, since the 1998 DEP biomonitoring efforts at BLK02 the City of Worcester DPW Storm Water Management Program, Illicit Connections Program has made progress in identifying and repairing illicit sanitary sewage discharges to Mill Brook (MassDEP 2001).

Other BLK02 benthos metric values, including Taxa Richness and an extremely reduced EPT Taxa Index (1), a high Biotic Index (6.81—the highest of all the biomonitoring stations in the 2003 survey), and a high (34%) Dominant Taxon percentage, indicate an unbalanced and unhealthy benthic community structured in response to organic pollution or other types of water quality degradation. In addition, the complete absence of scraping forms (i.e., algal grazers) of macroinvertebrates, generally considered sensitive to pollution and known to decline in numbers with increased perturbation (Barbour et al. 1995; Fore et al. 1996), corroborates the trophic imbalance resulting from water quality impairment at BLK02. Scrapers were also absent from the benthos sample collected here in 1998.

Due to the lack of a suitable biomonitoring reference condition (i.e., upstream control) immediately upstream from the UBWPAD discharge it is difficult to isolate the exact sources of anthropogenic impacts to BLK02. While the UBWPAD is a likely cause of impairment to the BLK02 aquatic community, biological degradation may be exacerbated by additional upstream sources of pollutant loadings (e.g., Worcester CSO Treatment Facility, stormwater runoff, illicit sewer connections, etc.). It is worth noting that MassDEP conducting water quality monitoring upstream from BLK02 in the Middle River (the Middle River becomes the mainstem Blackstone River at its confluence with Mill Brook)–upstream from both the UBWPAD and CSO discharge outfalls. Nutrient levels (ammonia and phosphorus) were considerably lower there than at the McCracken Road water quality station, and pre-dawn dissolved oxygen levels appeared normal (MassDEP 2005). This suggests that these upstream point sources (i.e., UBWPAD and the Worcester CSO) of pollution are probably the primary contributors of organic inputs and BOD loads to the upper Blackstone River, resulting in a highly taxed waste assimilative capacity in this portion of the river.

In addition to water quality degradation, habitat degradation—specifically, instream sediment deposition—continues to threaten biological potential in this portion of the Blackstone River (though perhaps not to the degree observed during the 1998 survey). Sand and other fine sediments drastically reduce macroinvertebrate microhabitat by filling the interstitial spaces of epifaunal substrates (Minshall 1984). In addition, the filling of pools with sediment reduces fish cover and may be detrimental to fish egg incubation and survival. Sediment inputs may originate from multiple sources in this highly urbanized portion of the watershed—upstream road crossings and road/building construction sites, parking lots and other impervious surfaces, and a nearby sand/gravel operation all may contribute to the instream deposition historically and currently observed in the BLK02 sampling reach.

BLK12A—Blackstone River, mile point 24.5, 30 m upstream from Central St., Millville, MA

Habitat

The BLK12A sampling reach began immediately upstream from Central Street in Millville, where a small island splits the river into two channels of high-velocity water. Sampling was conducted in the partially shaded (50% canopy cover) and narrower (3 m wide) southern-most channel, as it offered easier access for kick-sampling and better benthic habitat than the opposite channel. Riffle areas of varying (0.25 – 0.30 m) depth dominated each end of the reach, while slower water (i.e., runs/pools up to 1 m deep) comprised the middle. Boulder and cobble substrates were found throughout the entire reach, and with an abundance of aquatic mosses, offered optimal epifaunal habitat. Snags, submerged logs, and large boulders provided fish with some stable cover; however, overall fish habitat was less than optimal due to marginal channel flow status (water filled less than 75% of channel) that resulted in much exposed/unavailable debris. Luxuriant algal growth—comprised of thin green film, brown floc, and brown mats—covered most (70%) of the stream bottom throughout the reach. Both banks were well-vegetated and fairly stable. Riparian vegetation was undisturbed and wooded along the left (north) bank, with red maple (*Acer rubrum*), oaks (*Quercus* spp), sycamore (*Platanus occidentalis*), and willows (*Salix* sp.) extending from the shrub-dominated (willow, *Salix* sp.; elderberry, *Sambucus canadensis*) bank. Riparian zone width was slightly reduced along the right (south) bank due to a nearby parking lot that offered a potential source of NPS pollution. Vines (riverbank grape, *Vitis riparia*) and herbaceous growth (false bamboo, *Polygonum cuspidate*; purple loosestrife, *Lythrum salicaria*; goldenrod, *Solidago* sp.; cardinal flower, *Lobelia cardinalis*) comprised the majority of the riparian vegetation along the right bank.

BLK12A received a total habitat assessment score of 144/200 (Table A3). Habitat rated better during the 1998 biosurvey here, mainly due to more optimal (score=19) Channel Flow Status and its effect on available fish habitat.

Benthos

The BLK12A macroinvertebrate assemblage received a total metric score of 20, representing 48% comparability to reference conditions at BLK09-8A (Table A2). While some recovery of the aquatic community was evident in this portion of the Blackstone River compared to conditions farther upstream, the benthos assemblage remained in the "moderately impacted" category for biological condition. The BLK12A assemblage received a somewhat similar bioassessment (24% comparable to BLK09-8A; moderately impaired) following the 1998 biomonitoring survey (MassDEP 2001). Most metric values performed better than the benthos assemblage observed upstream at BLK02—the exception being the Percent Dominant Taxon metric, which scored a 0 due to the hyperdominance of net-spinning caddisflies (i.e., Hydropsychidae; n=78). The preponderance of filter-feeding hydropsychids, which use silken "nets" to capture suspended forms of Fine Particulate Organic Material (FPOM), is not unlike the assemblage observed during both the 1991 and 1998 biosurveys at BLK12A (MassDEP 1992; MassDEP 2001). The hyperdominace of filter-feeders is probably most directly related to the productive nature of this portion of the watershed. The entire length of the Blackstone River from its source waters to BLK12A (and extending downstream to the MA/RI border) is classified as an impaired, Category 5 Water due to nutrients, organic enrichment, and associated low dissolved oxygen, among other pollutants (MassDEP 2002). The effects of nutrient enrichment are also reflected in other types of resident biota at BLK12A. As mentioned above, algae (brown flock and mats; thin green film) covered most available surfaces in the BLK12A sampling reach. Water quality data collected at Central Street by MassDEP (2005) from May through October 2003, which found consistently elevated (0.11 – 0.37 mg/L) phosphorus levels, corroborates the productive conditions at BLK12A.

Only one metric value for the BLK12A benthos assemblage scored comparably (score=6) to the watershed reference community—EPT/Chironomidae (Table A2). This was the result of the numerous hydropsychids mentioned above, combined with reduced densities (n=4) of chironomids. Interestingly, chironomid densities were considerably higher (n=31) in the 1998 benthos sample collected here, and probably contributed to lower overall comparability to reference conditions in 1998 (metric scores were 24% comparable to BLK09-8A; Reference Affinity=18%) than in 2003 (metric scores were 48% comparable to BLK09-8A; Reference Affinity=59%).

The combined effects of municipal point source discharges immediately upstream (Northbridge WWTP, Uxbridge WWTP) and/or other point sources farther upstream probably contribute most to water quality degradation at BKL12A. In addition, the impounded nature of much of the mainstem Blackstone River may exacerbate the effects of water quality impairment (e.g., organic enrichment; nutrient loadings) on downstream biota.

SUMMARY AND RECOMMENDATIONS

Most biomonitoring stations investigated during the 2003 survey indicated various degrees of impairment. Impacts to the resident biota at these sites were generally a result of point source water quality effects, and to a lesser degree, habitat degradation and/or nonpoint source-related water quality impairment.

The schematic below (Figure 3) is based on a proposed conceptual model that predicts the response of aquatic communities to increasing human disturbance. It incorporates both the biological condition impact categories (non-, slightly, moderately, severely impacted) outlined in the RBPIII biological assessment methodology currently used by MassDEP and the Tiered Aquatic Life Use (TALU) conceptual model developed by the US EPA and refined by various state environmental agencies (US EPA 2003). The model summarizes the main attributes of an aquatic community that can be expected at each level of the biological condition category, and how these metric-based bioassessments can then be used to make *Aquatic Life Use* determinations as part of the 305(b) reporting process. Non-impacted and slightly impacted aquatic communities—such as those encountered at BLK09-8A and MF03B—support the Massachusetts SWQS designated *Aquatic Life Use* in addition to meeting the objective of the Clean Water Act (CWA), which is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters (Environmental Law Reporter 1988). Moderately and/or severely impacted communities observed at BLK02 and BLK12A do not support the *Aquatic Life Use* and fail to meet the goals of the CWA. It should be mentioned that MassDEP will continue to refine the TALU classifications for Massachusetts surface waters as new biological data become available. This in turn may affect future *Aquatic Life Use* determinations (e.g., support, impaired) as they relate to the biological condition categories (non-, slightly, moderately, severely impacted).

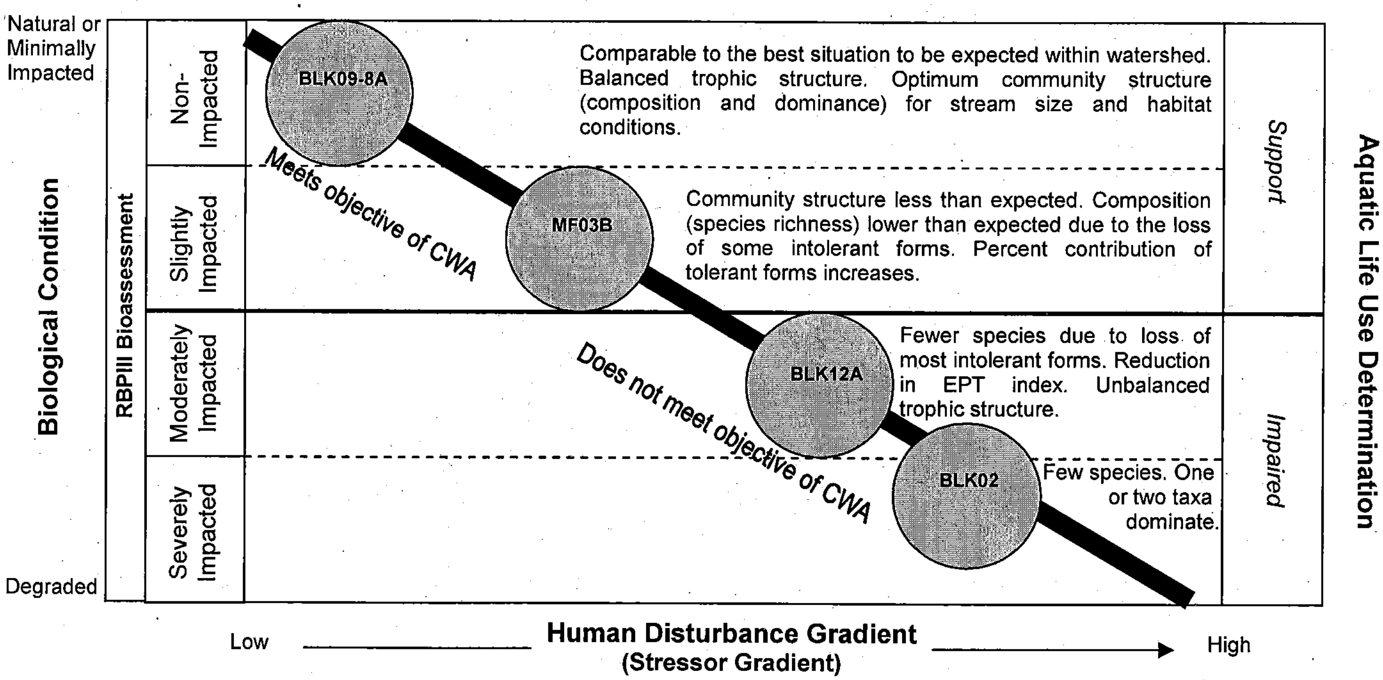

Figure 3. A schematic of results of the RBPIII analysis of the 2003 Blackstone River watershed biomonitoring stations as they relate to Tiered Aquatic Life Use.

While the RBP analysis of benthic macroinvertebrate communities is an effective means of determining severity of water quality impacts, it is less effective in determining what kinds of pollution are causing the impact (i.e., ascertaining cause and effect relationships between potential stressors and affected biota). Nevertheless, in some situations a close examination of individual metric performance, taxon absence or presence, habitat evaluations, or other supporting field data can lead to inferences of potential anthropogenic causes of perturbation. The table below (Table 3) lists the potential causes of benthic community impairment, where applicable, observed at each biomonitoring station. The table also includes recommendations addressing the various types of impairment and general conditions observed. The list is by no means exhaustive, but rather a summary of suggestions for additional monitoring efforts, BMP implementation, and other recommendations for follow-up activities while still working within the framework of the "5-Year Basin Cycle".

Table 3. A summary of potential causes of benthos and habitat impairment observed at each biomonitoring station during the 2003 Blackstone River watershed survey. Where applicable, recommendations have been made.

SITE	POSSIBLE CAUSES OF IMPAIRMENT	RECOMMENDATIONS
BLK09-8A	-Riparian habitat degradation	-Biomonitoring during next (2008) MassDEP Blackstone River watershed survey; -Water quality monitoring during 2008 MassDEP Blackstone River watershed survey; -Outreach to address NPS inputs from adjacent cemetery (St. Denis); -Improve vegetative buffer along south bank; Implement BMPs as needed
MF03B	-Organic/nutrient enrichment; -Other water quality degradation; -Sedimentation	-Biomonitoring during next MassDEP Blackstone River watershed survey; -Water quality monitoring (nutrients, DO) during next MassDEP Blackstone River watershed survey; -Review Douglas WWTP DMR data as they become available; -Investigate possible sources (e.g., road crossings, nearstream sand/gravel operations) of sediment inputs—implement BMPs as needed
BLK02	-Point source-related organic/nutrient enrichment; -Other water quality degradation; -Riparian habitat degradation; -Sedimentation	-Biomonitoring during next MassDEP Blackstone River watershed survey; -Water quality monitoring (nutrients, DO) during next MassDEP Blackstone River watershed survey to isolate major sources of nutrient and/or organic inputs; -Review of UBWPAD NPDES permit and DMR data as they become available; -Continue to assist the City of Worcester where needed in addressing the repairs of illicit sewer connections; Monitor and review the effectiveness of the City of Worcester DPW Storm Water Management Program, Illicit Connections Program; -Evaluate (e.g., wet weather water quality monitoring) the effectiveness of the Worcester CSO Treatment Facility; -Improve vegetative buffer along both banks; -Investigate possible sources of sediment inputs—implement BMPs as needed
BLK12A	-Organic/nutrient enrichment (point source and NPS); -Other water quality degradation	-Biomonitoring during next (2008) MassDEP Blackstone River watershed survey; -Water quality monitoring (here and at multiple historical sampling stations upstream) during 2008 MassDEP Blackstone River watershed survey; -Review Northbridge and Uxbridge WWTP NPDES permits and DMR data as they become available. Consider stricter effluent limits at these and other upstream WWTPs when NPDES permits are scheduled for reissuance.

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APPENDIX

Macroinvertebrate taxa list, RBPIII benthos analysis, and Habitat evaluations

Table A1. Species-level taxa list and counts, functional feeding groups (FG), and tolerance values (TV) for macroinvertebrates collected from stream sites during the 2003 Blackstone River watershed biomonitoring survey on 15 August 2003. Refer to Table 1 for a listing and description of sampling stations.

TAXON	FG	TV	BLK09-8A	BLK02	BLK12A	MF03B
Pisidiidae	FC	6		1	2	
Tubificidae (immature, bifid chaetae)	GC	10				4
Lumbriculidae	GC	7	4			
Eclipidrilus sp.	GC	5				4
Caecidotea communis	GC	8		4	1	1
Crangonyx sp.	GC	6		1		
Gammarus sp.	GC	6			1	
Hydrachnidia	PR	6	2			
Baetidae	GC	4	1		4	3
Baetis (subequal terminal filament) sp.	GC	6	1			
Heptageniidae	SC	4	6		3	4
Maccaffertium ithaca	SC	3	6			5
Isonychia sp.	GC	2	12			
Corydalus cornutus	PR	4	1			
Cheumatopsyche sp.	FC	5	10	25	19	6
Hydropsyche betteni	FC	6	20		59	5
Hydroptila sp.	GC	6	1			
Leucotrichia sp.	SC	6			1	
Oecetis sp.	PR	5	3			5
Apatania sp.	SC	3				3
Chimarra sp.	FC	4	10		9	2
Psychomyia sp.	GC	2				1
Microcylloepus sp.	GC	3	1			
Optioservus sp.	SC	4	3			
Oulimnius latiusculus	SC	4	2			
Promoresia sp.	SC	2	6			1
Stenelmis sp.	SC	5	1			
Chironomidae	GC	6				2
Chironomus riparius	GC	10				15
Glyptotendipes sp.	SH	10		1		
Microtendipes pedellus gr.	FC	6				5
Polypedilum flavum	SH	6	2	35		
Tribelos/Phaenopsectra sp.	GC	7				11
Rheotanytarsus exiguus gr.	FC	6		4	4	2
Cricotopus annulator	SH	7				1
Cricotopus bicinctus	GC	7				3
Orthocladius sp.	GC	6				3
Tvetenia paucunca	GC	5				1
Tvetenia vitracies	GC	5	5			
Conchapelopia sp.	PR	6				1
Simulium sp.	FC	5	7		1	
Simulium vittatum cpl.	FC	9		32		
Antocha sp.	GC	3			2	2
TOTAL			104	103	106	90

[1]Functional Feeding Group (FG) lists the primary feeding habit of each species and follows the abbreviations: SH-Shredder; GC-Gathering Collector; FC-Filtering Collector; SC-Scraper; PR-Predator.
[2]Tolerance Value (TV) is an assigned value used in the calculation of the biotic index. Tolerance values range from 0 for organisms very intolerant of organic wastes to 10 for very tolerant organisms.

Table A2. Summary of RBP III data analysis for macroinvertebrate communities sampled in the Blackstone River watershed on 15 August 2003. Shown are the calculated metric values, metric scores (in italics) based on comparability to the reference station (BLK09-8A), and the corresponding assessment designation for each biomonitoring station. Refer to Table 1 for a listing and description of sampling stations.

STATION	BLK09-8A		MF03B		BLK02		BLK12A	
STREAM	Mumford River		Mumford River		Blackstone River		Blackstone River	
HABITAT SCORE	164		174		153		144	
TAXA RICHNESS	19	*6*	21	*6*	8	*2*	12	*4*
BIOTIC INDEX	4.45	*6*	6.23	*4*	6.81	*2*	5.47	*4*
EPT INDEX	8	*6*	8	*6*	1	*0*	6	*2*
EPT/CHIRONOMIDAE	10.0	*6*	0.77	*0*	0.63	*0*	23.75	*6*
SCRAPERS/FILTERERS	0.51	*6*	0.65	*6*	0	*0*	0.04	*0*
% DOMINANT TAXON	19%	*6*	17%	*6*	34%	*2*	56%	*0*
COMMUNITY SIMILARITY (REFERENCE AFFINITY)	100%	*6*	53%	*4*	41%	*2*	59%	*4*
TOTAL METRIC SCORE		*42*		*32*		*8*		*20*
% COMPARABILITY TO REFERENCE STATION			76%		19%		48%	
BIOLOGICAL CONDITION (DEGREE OF IMPACT)	**REFERENCE Non-impacted**		**Slightly Impacted**		**Moderately/ Severely Impacted***		**Moderately Impacted**	

* percent comparability value was intermediate to the ranges for the moderately impacted and severely impacted biological condition categories

Table A3. Habitat assessment summary for biomonitoring stations sampled during the 2003 Blackstone River watershed survey. For primary parameters, scores ranging from 16-20 = optimal; 11-15 = suboptimal; 6-10 = marginal; 0-5 = poor. For secondary parameters, scores ranging from 9-10 = optimal; 6-8 = suboptimal; 3-5 = marginal; 0-2 = poor. Refer to Table 1 for a listing and description of sampling stations.

Station	BLK09-8A	MF03B	BLK02	BLK12A
Primary Habitat Parameters	**Score (0-20)**			
INSTREAM COVER	18	17	13	11
EPIFAUNAL SUBSTRATE	19	17	17	17
EMBEDDEDNESS	18	15	14	13
CHANNEL ALTERATION	16	20	15	15
SEDIMENT DEPOSITION	18	15	15	17
VELOCITY-DEPTH COMBINATIONS	14	10	14	15
CHANNEL FLOW STATUS	20	20	19	10
Secondary Habitat Parameters	**Score (0-10)**			
BANK VEGETATIVE PROTECTION left	10	10	10	9
BANK VEGETATIVE PROTECTION right	5	10	10	6
BANK STABILITY left	10	10	10	8
BANK STABILITY right	5	10	10	8
RIPARIAN VEGETATIVE ZONE WIDTH left	8	10	3	10
RIPARIAN VEGETATIVE ZONE WIDTH right	3	10	3	5
Total Score	**164**	**174**	**153**	**144**