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CONCORD RIVER WATERSHED
2006 BENTHIC MACROINVERTEBRATE BIOASSESSMENT

Division of Watershed Management
Watershed Planning Program
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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 (Plafkin et al. 1989, Barbour et al. 1995).

As part of the Massachusetts Department of Environmental Protection/Division of Watershed Management's (MassDEP/DWM) 2006 Concord River Watershed assessments, aquatic benthic macroinvertebrate monitoring was conducted to evaluate the biological health of the Assabet River and River Meadow Brook and to investigate the effects of potential point and nonpoint sources of pollution—both historical and current—on the aquatic communities in those streams. A total of four stations on the Assabet River and one site on River Meadow Brook were sampled. Table 1 presents the sampling locations, along with station identification numbers and sampling dates.

Nuzzo (2004) reported on the results of the previous MassDEP/DWM biomonitoring survey of the Concord Watershed performed in 2001. That survey focused on the main stem Assabet and Sudbury rivers as well as several tributary streams. As part of the study, four monitoring stations were positioned along the Assabet River to ascertain the effects, if any, of the effluent from publicly-owned treatment works (POTWs) in Westborough, Marlborough and Hudson. Using a regional reference site on North Brook in Berlin for comparison, stations both upstream and downstream from the Westborough-Shrewsbury POTW were determined to be "slightly impacted", while stations downstream from the Marlborough Westerly and Hudson POTWs were "moderately impacted". Nuzzo (2004) concluded that the macroinvertebrate community structure was indicative of organic enrichment at all of the sites on the Assabet River.

The 2001 reference site on North Brook was deemed appropriate for defining the best attainable conditions throughout the Concord Watershed, and its use in the previous analysis resulted in the determination of some impairment even at the site farthest upstream on the Assabet River. Nonetheless, in 2006, a reference site (AS01A) was established on the Assabet River near its source in the Assabet River Reservoir (A-1 Site) to more closely focus this assessment on the effects of downstream discharges on the biota of the Assabet River. This site was approximately 350 meters downstream from the farthest upstream Assabet River station assessed in 2001. While not likely representative of "least disturbed" conditions in the watershed taken as a whole, the macroinvertebrate community at AS01A was indicative of the "background" condition of the main stem Assabet River upstream from the POTWs and other potential sources of pollution. Macroinvertebrate communities at downstream sites along the Assabet River and in River Meadow Brook were compared with the community near the headwaters to isolate potential causes of downstream impairments. Impacts to the benthic community may be revealed 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 total taxa richness; or other shifts in community composition relative to the reference station (Plafkin et al. 1989).

METHODS

Macroinvertebrate Sampling - RBPIII

Macroinvertebrate sampling activities employed for the 2006 Concord River Watershed survey were conducted in accordance with the Sampling & Analysis Plan (SAP) for the Concord River Watershed (MassDEP 2006). The sampling procedures are described in the standard operating procedures *Water Quality Monitoring in Streams Using Aquatic Macroinvertebrates* (Nuzzo 2003), and are based on US EPA Rapid Bioassessment Protocols (RBPs) for wadeable streams and rivers (Plafkin et al. 1989). 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. Sampling was conducted by MassDEP/DWM biologists throughout a 100 m reach, in 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.

Table 1. List of biomonitoring stations sampled during the 2006 Concord River watershed survey, including station and unique identification numbers, drainage areas, sampling site descriptions, and sampling dates.

Station ID	Unique ID	Drainage area (mi^2)	Concord River Watershed Site description	Sampling Date
AS01A[1]	B0358	7.2	Assabet River – Upstream / South from Maynard Street, Westborough, MA	6-Jul-2006
AS04	B0359	18.7	Assabet River – Downstream / South from School Street, Northborough, MA	5-Jul-2006
AS15A	B0389	77.4	Assabet River – Upstream / North from Route 62, Stow, MA	5-Jul-2006
AS20	B0586	117	Assabet River – Approx. 60 meters downstream from Route 62, Acton, MA	5-Jul-2006
RM10A	B0587	26.9	River Meadow Brook – Upstream at Lawrence Street, Lowell, MA	10-Jul-2006

[1] Reference Station

Macroinvertebrate Sample Processing and Data Analysis

The macroinvertebrate sample processing and analysis procedures employed for the 2006 Concord River watershed biomonitoring samples are described in the standard operating procedures (Nuzzo 2003). Macroinvertebrate sample processing entailed distributing whole samples in pans, randomly selecting grids within the pans, 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.

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 macroinvertebrate community. This integrated approach provides more assurance of a valid assessment because a variety of biological parameters are evaluated, and the deficiency of any one metric should not invalidate the entire approach (Plafkin et al. 1989). Taxonomic data were analyzed using a modification of Rapid Bioassessment Protocol III (RBP III) metrics and scores (Plafkin et al. 1989). The modifications were: substitution of "reference site affinity" (RSA) for the Community Loss Index and elimination of the shredder/total ratio (no separate leaf-pack material was collected). The reference site affinity metric is a modification of Percent Model Affinity (Novak and Bode 1992). Instead of using the model's percentages for Oligochaeta, Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Chironomidae, and "other," these percentages were taken from the reference site data. The RSA score is then 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 RBP III scores as follows: 0 points for <35%; 2 points in the range from 35 to 49%; 4 points for 50 to 64%; and 6 points if ≥65%. The entire suite of metrics used for the analysis was:

- Richness—the total number of different species present in the subsample plus those detected from a "large/rare" search of the whole sample (those taxa missed in subsampling);

- HBI—Hilsenhoff Biotic Index (Hilsenhoff 1982), as modified in Nuzzo (2003); the HBI is the sum of the products of each taxon's abundance and its corresponding pollution tolerance value, divided by the total count in the subsample;

- EPT—sum of richness among the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) as determined from the specimens in the subsample plus those detected in a "large/rare" search of the whole sample; these orders tend to be dominated by species generally considered to be pollution sensitive;

- $EPT_a/Chiro_a$—ratio of total abundance among EPT taxa to total abundance among Chironomidae taxa;

- SC/FC—ratio of the proportion of sample that is represented by individuals that predominantly feed by scraping to those that are primarily filter-feeders;

- % Dominant—most abundant taxon as a percent of the assemblage; >20% is generally considered hyperdominant and indicative of a stressor impact;

- RSA—reference site affinity (described above).

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 the selected "least-impacted" reference station yielded an impairment score for each site. RBP III analysis separates sites into four categories: "non-impaired", "slightly impaired", "moderately impaired", and "severely impaired". Each impairment category corresponds to a specific *Aquatic Life* use-support determination used in the CWA Section 305(b) water quality reporting process—non-impaired and slightly impaired benthic invertebrate communities are generally indicative of conditions supporting the *Aquatic Life* use, whereas water bodies exhibiting moderately or severely impaired communities are generally assessed as "non-support."

Habitat Assessment

Habitat qualities were scored for each sampling reach using the assessment procedure in Plafkin et al. (1989), as modified in Barbour et al. (1999). An evaluation of physical and biological habitat quality is critical to any assessment of ecological integrity (Karr et al. 1986; Plafkin et al. 1989). 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). The matrix used to assess habitat quality is based on key physical characteristics of the water body and the immediate riverfront area. Most parameters evaluated are instream physical attributes that are potential sources of limitation to the aquatic biota (Plafkin et al. 1989). 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 the reference station to infer the extent to which the condition of the habitat, rather than water quality effects, may account for differences in macroinvertebrate community structure at the study sites.

RESULTS AND DISCUSSION

The quality of the habitat encountered at the biomonitoring stations along the main stem Assabet River was generally fair (Table 2), with only one site (i.e., AS04) scoring higher than 80% of the maximum attainable value. Nonetheless, habitat scores of the downstream sites on the Assabet River were found to compare favorably with the reference site (AS01A). Station RM10A on River Meadow Brook exhibited poor habitat conditions that were considered less than fully comparable with the reference condition.

A taxonomic list of the macroinvertebrate organisms collected at each sampling station during the 2006 biomonitoring survey is attached as an Appendix. Included in the list are total organism counts, the functional feeding group designation (FG) for each macroinvertebrate taxon, and the tolerance value (TV) of each taxon. Table 3 presents a summary of the RBP III macroinvertebrate data analyses, including biological metric calculations, metric scores, and impairment designations.

Table 2. Habitat assessment summary for biomonitoring stations sampled during the 2006 Concord River Watershed survey. For within-reach parameters, scores ranging from 16-20 = optimal; 11-15 = suboptimal; 6-10 = marginal; 0-5 = poor. For riparian parameters, scores ranging from 9-10 = optimal; 6-8 = suboptimal; 3-5 = marginal; 0-2 = poor. Maximum habitat score for any site = 200. Refer to Table 1 for a listing and description of sampling stations.

STATION	AS01A[1]	AS04	AS15A	AS20	RM10A
WITHIN-REACH PARAMETERS (range is 0-20)	**SCORE**				
INSTREAM COVER	10	13	2	10	13
EPIFAUNAL SUBSTRATE	16	17	17	18	14
EMBEDDEDNESS	11	13	12	17	18
CHANNEL ALTERATION	16	15	10	16	16
SEDIMENT DEPOSITION	17	16	18	19	8
VELOCITY-DEPTH COMBINATIONS	10	14	15	17	12
CHANNEL FLOW STATUS	18	19	19	20	16
RIPARIAN PARAMETERS (range is 0-10 for each bank)	**SCORE**				
BANK VEGETATIVE PROTECTION left	6	10	9	5	3
BANK VEGETATIVE PROTECTION right	10	10	10	7	1
BANK STABILITY left	9	10	10	8	3
BANK STABILITY right	9	10	10	8	1
RIPARIAN VEGETATIVE ZONE WIDTH left	2	8	3	2	3
RIPARIAN VEGETATIVE ZONE WIDTH right	10	6	1	9	1
TOTAL SCORE	**144**	**161**	**136**	**156**	**109**

[1] Reference site

The benthic macroinvertebrate community at AS01A, while serving as the reference condition for downstream biomonitoring stations, appeared compromised by its location downstream from the A-1 Site. Consistent with findings from 2001, the assemblage of organisms near the headwaters of the Assabet River exhibited low total and EPT taxa richness and high HBI values indicative of nutrient-rich water quality conditions. In addition, filter-feeding caddisflies from the Family Hydropsychidae comprised 40% of the total sample suggesting that the benthic invertebrate community was structured in response to the

availability of detrital organic matter exported from the upstream reservoir. Baseline lake sampling of the Assabet River Reservoir by MassDEP/DWM in 2001 revealed oxygen depletion below 2.5 m, evidence of phosphorus release resulting from the anoxic conditions, and supersaturation at shallower depths, all indicators of a highly productive waterbody (O'Brien-Clayton 2005).

Table 3. Summary of RBP III analysis of macroinvertebrate communities sampled during the Concord River Watershed survey between 5 and 10 July 2006. Shown are the calculated metric values, metric scores (in italics) based on comparability to the reference station (AS01A), and the corresponding assessment designation for each biomonitoring station. Refer to Table 1 for a listing and description of sampling stations.

SAMPLING STATION	**AS01A**[1]		**AS04**		**AS15A**		**AS20**		**RM10A**	
STREAM	Assabet River		Assabet River		Assabet River		Assabet River		River Meadow Brook	
HABITAT SCORE	144		161		136		156		109	
TAXA RICHNESS	18	*6*	18	*6*	29	*6*	18	*6*	22	*6*
BIOTIC INDEX	5.10	*6*	5.64	*6*	5.66	*6*	5.23	*6*	5.18	*6*
EPT INDEX	8	*6*	5	*0*	6	*2*	6	*2*	4	*0*
EPT/CHIRONOMIDAE	13.80	*6*	2.56	*0*	2.55	*0*	5.69	*2*	1.90	*0*
SCRAPER/FILTERER	0.62	*6*	0.30	*4*	0.08	*0*	0.08	*0*	0.17	*2*
REFERENCE AFFINITY	100%	*6*	78%	*6*	70%	*6*	66%	*6*	63%	*4*
% DOMINANT TAXON	32%	*2*	23%	*4*	24%	*4*	22%	*4*	15%	*6*
TOTAL METRIC SCORE	*38*		*26*		*24*		*26*		*24*	
% COMPARABILITY TO REFERENCE	*100%*		*68%*		*63%*		*68%*		*63%*	
BIOLOGICAL CONDITION (DEGREE IMPAIRED)	Reference		Slightly Impaired		Slightly Impaired		Slightly Impaired		Slightly Impaired	

[1]Reference site

The macroinvertebrate communities at the four test stations – AS04, AS15A, AS20, and RM10A – were all less than 70% comparable to the reference site community and were judged "slightly-impaired". Filtering Collector taxa, primarily Hydropsychid caddisflies, predominated the invertebrate assemblage at all of these sites. The high HBI values and low Scraper/Filterer ratios imply some increase in nutrient concentrations above background levels, yet typify the invertebrate communities of many low-gradient, impounded streams of eastern Massachusetts. Habitat conditions also may have limited the potential to support macroinvertebrate communities throughout the watershed, as stations AS15A and AS20 were situated just downstream from dams, and the immediate contributing watershed to RM10A was heavily urbanized. River Meadow Brook flows through industrial portions of downtown Lowell and underground

before “day-lighting” immediately upstream of the sampled reach. The habitat score at RM10A was the lowest of the sites sampled in 2006 and was affected most notably by limitations in riparian parameters.

One goal of the 2006 biomonitoring effort in the Concord Watershed was to determine whether existing wastewater discharges were adversely affecting the biological condition of the receiving streams. This appears unlikely in the Assabet River, given that the invertebrate community structure at the downstream sites differed only slightly from that of the reference site. The documented water quality problems at station AS01A and the presence of several man-made impoundments along the course of the river also probably affect water quality conditions in the river. Likewise, the macroinvertebrate community in River Meadow Brook was only “slightly impaired” when compared with the reference condition, despite obvious habitat limitations at station RM10A. Further study is needed to distinguish wastewater discharge impacts from habitat effects in this stream.

Although specific wastewater discharges were not implicated in the slight impairment identified during this investigation, results were inconclusive with respect to the *Aquatic Life Use* support status of the Assabet River and River Meadow Brook. Generally, waters assessed as non- or slightly impaired are considered to be in support of the *Aquatic Life Use* for purposes of reporting pursuant to Section 305(b) of the CWA. However, the validity of this approach rests with the selection of a suitable reference site that is representative of the best achievable conditions in the watershed. As discussed earlier, the applicability of the benthic invertebrate community at AS01A to characterize the best attainable condition for the Assabet River and other streams in the Concord River Watershed was limited. Without benefit of a regional reference site, such as that used in 2001, a determination of the *Aquatic Life* use support status should not rely, solely, on the results of the 2006 invertebrate bioassessment. Rather, water quality data and other biological information should be reviewed in an effort to provide a holistic assessment of the conditions prevailing at all of the sites investigated.

Monitoring stations on the Assabet River in Northborough and Stow were sampled in both 2001 and 2006, and the upstream-most sites in Westborough, although not exactly the same each year, were in close enough proximity to allow for year-to-year comparisons to be made (Table 4). Habitat scores and invertebrate community attributes at each site were quite consistent over the five years separating the two surveys. The 2001 results from North Brook are presented to illustrate deficiencies in the macroinvertebrate community in the Assabet River in Westborough that limit its use as the reference condition for making *Aquatic Life Use* support determinations from the 2006 data.

Table 4. Comparison of macroinvertebrate community attributes in 2001 with those for the same or nearby[1] sampling sites in 2006. Also included are community metrics, for 2001 only, from North Brook in Berlin, MA. This site served as a regional reference site for the 2001 bioassessment of the Concord River Watershed, whereas the Assabet River in Westborough was used for reference in 2006. Refer to Table 1 for a listing and description of the 2006 sampling stations. The 2001 habitat score and invertebrate community metrics are from Nuzzo (2004).

	Assabet River						North Brook
	Westborough		Northborough		Stow		
Community Attributes	**2001**	**2006**	**2001**	**2006**	**2001**	**2006**	**2001**
TAXA RICHNESS	12	18	15	18	17	29	34
EPT Index	7	8	3	5	7	6	13
BIOTIC INDEX	4.97	5.10	5.35	5.64	5.56	5.66	3.86
EPT/CHIRONOMIDAE	4.42	13.80	4.25	2.56	17.00	2.55	1.63
SCRAPER/FILTERER	0.89	0.62	0.40	0.30	0.05	0.08	0.50
% DOMINANT TAXON	20%	32%	27%	23%	33%	24%	16%
HABITAT SCORE	138	144	154	161	150	136	180

[1] The Assabet River in Westborough was sampled approximately 350 meters farther downstream in 2006 than in 2001.

SUMMARY AND RECOMMENDATIONS

During July 5-10, 2006, MassDEP/DWM performed sampling of the aquatic macroinvertebrate community at four sites along the Assabet River and one station on River Meadow Brook to evaluate the biological health of these streams and to investigate the effects of point and nonpoint sources of pollution—both historical and current—on their resident aquatic communities. Station AS01A on the Assabet River in Westborough was deemed a suitable reference site for assessing the impacts from downstream discharges, but results from an earlier biosurvey in 2001 suggest that a more suitable regional reference site should be used to make *Aquatic Life Use* support determinations for reporting under Section 305(b) of the Clean Water Act. The invertebrate community at all of the sites sampled in 2006 exhibited low total and EPT taxa richness and high HBI values, indicating nutrient-rich water quality conditions. Habitat factors also compromised invertebrate community structure, particularly in River Meadow Brook.

Specific wastewater discharges were not implicated in the slight impairment of the benthic invertebrate community identified during this investigation. The predominance of filter-feeding caddisflies at sites both upstream and downstream of the POTWs pointed to an abundance of detrital organic matter originating in the many impoundments throughout the Concord River Watershed. Nonetheless, the Concord River Watershed is highly developed and wastewater discharges, water withdrawals, and stormwater run-off do have the potential to impair instream aquatic life. Continued efforts to reduce nutrient inputs and to increase instream base flows will improve both the water quality and the health of the aquatic communities. Over time, the application of the Assabet River TMDL for total phosphorus (MassDEP 2004) will reduce nutrient loadings to this river. Future biomonitoring efforts should be aimed at documenting anticipated improvements.

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APPENDIX

Species-level taxa list and counts, functional feeding groups (FG), and tolerance values (TV) for macroinvertebrates collected from stream sites in the Concord River Watershed between 5 and 10 July 2006. Refer to Table 1 for a listing and description of sampling stations.

Taxon	FFG[1]	TV[2]	Sampling Site				
			AS01A[3]	AS04	AS15A	AS20	RM10A
Pisidiidae	FC	6			6		1
Lumbricina	GC	8			1		
Enchytraeidae	GC	10				1	
Naididae	GC	9			6		
Nais communis	GC	8				2	2
Tubificidae	GC	10			1		
Tubificidae IWB	GC	10				1	
Tubificidae IWP	GC	10					2
Lumbriculidae	GC	7			1		1
Caecidotea sp.	GC	8					1
Caecidotea communis	GC	8		4	1		
Crangonyx sp.	GC	6		8	3		
Gammarus sp.	GC	6				3	3
Baetis pluto	GC	6	6				
Plauditus sp.	GC	4		1	4	1	
Maccaffertium sp.	SC	3	13				
Tricorythodes sp.	GC	4				2	
Argia sp.	PR	6			1		
Capniidae	SH	1					1
Nigronia serricornis	PR	0	1				
Brachycentrus sp.	FC	1			1		
Hydropsychidae	FC	4					4
Cheumatopsyche sp.	FC	5	5	20	9	21	13
Hydropsyche sp.	FC	4	3		6	4	14
Hydropsyche betteni	FC	7	32	23	5	6	3
Hydropsyche sparna	FC	6			25	18	
Hydroptila sp.	GC	6		1			
Lepidostoma sp.	SH	1	1				
Chimarra aterrima	FC	4	4				
Chimarra obscura	FC	4	1	1	1	22	3
Neophylax oligius	SC	3	4				
Ancyronyx variegata	GC	5			1		
Microcylloepus pusillus	GC	3		2	1		
Optioservus sp.	SC	4			1		2
Oulimnius latiusculus	SC	4	8				
Promoresia tardella	SC	2		1	1		
Stenelmis sp.	SC	5			2	4	
Stenelmis crenata	SC	5	4	16			7
Dineutus sp.	PR	4	1				
Psephenus herricki	SC	4	5	1	1	2	
Microtendipes pedellus gr.	FC	6				1	4
Polypedilum sp.	SH	6					1
Polypedilum flavum	SH	6		2	2	5	1
Rheotanytarsus exiguus gr.	FC	6	3	7	2	2	1
Rheotanytarsus pellucidus	FC	5		6			

Tanytarsus sp.	FC	6			5		
Diamesa sp.	GC	5				2	3
Potthastia longimana gr.	GC	2		1		1	
Cardiocladius obscurus	PR	5					1
Cricotopus bicinctus	GC	7			1		5
Cricotopus/Orthocladius sp.	GC	7			1		2
Eukiefferiella claripennis gr.	GC	8					1
Orthocladius sp.	GC	6			1		1
Rheocricotopus sp.	GC	6	1	1			
Thienemanniella sp.	GC	6			3		
Tvetenia paucunca	GC	5	1				
Tvetenia vitracies	GC	5		1	5	2	
Hemerodromia sp.	PR	6	1				
Simulium sp.	FC	5	7	4	2		10
Antocha sp.	GC	3			4		6
TOTAL			**101**	**100**	**104**	**100**	**93**

[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.

[3] Reference Station