GREEN RIVER WATERSHED
2005 MACROINVERTEBRATE ASSESSMENT
(Franklin County, Massachusetts and Windham County, Vermont)

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EXECUTIVE SUMMARY

- As part of the Deerfield River Watershed Association's (DRWA) commitment to protecting the watershed's resources, the DRWA has performed water quality monitoring to supplement the efforts of regulatory agencies to monitor the watershed's condition. In recognizing the need to more thoroughly assess biological conditions in the Deerfield River watershed, the DRWA implemented in 2005 a long-term macroinvertebrate monitoring program. The objectives of the program are to 1) augment MA DEP/DWM biomonitoring efforts to assess surface waters in the watershed with respect to their aquatic-life-use status and 2) familiarize citizens of the watershed with biological monitoring to increase support for and participation in watershed enhancement and protection activities. The Green River was the watershed of choice for the program's first year of sampling for several reasons, primarily a need for comprehensive baseline information describing the river's current biological condition as development pressures in and around the town of Greenfield increase.

- Twelve river and stream reaches were selected in the Green River watershed for sampling in 2005. Four sites were selected on the Green River. The uppermost site was located in the Vermont portion of the river, while the three lower sites occurred in Massachusetts. The Cold River, a major tributary to the upper Deerfield River, was selected as the reference site against which to compare conditions in the Green River. The lower reaches of eight tributaries to the Green River were also sampled. Two of the eight tributaries sampled for this study, Roaring Brook and Hinesburg Brook, occur in Vermont. The Roaring Brook reach was selected as the reference reach for the tributaries in this assessment, as it occurs in a largely forested, undisturbed drainage. Six tributaries were located in the Massachusetts portion of the watershed.

- Macroinvertebrate samples were collected between September 23 and October 2, 2005 using methods employed by the Massachusetts Department of Environmental Protection for assessing the condition of macroinvertebrate communities in Massachusetts streams. Macroinvertebrates were collected from each site using kick-sampling collection methods. Macroinvertebrate taxonomic data were analyzed using DWM's modification of EPA's Rapid Bioassessment Protocol III multimetric scoring and analysis to determine the condition of macroinvertebrate communities.

- Among the Green River sample reaches, the lowest reach, GRM1, was the most influenced by human activities and development encroachment; consequently, this reach received the lowest rapid habitat score of 112 of a possible 200 points. The other three Green River reaches were similar in instream, bank, and riparian conditions, with total rapid habitat scores ranging between 165 and 177. Riparian zones were generally intact; however, Green River road occurs within 10-20 m of the right bank of GRM6 and a maintained field occurs within 20 m of the left bank of GRM7. Stream banks in each of these reaches were stable and well vegetated. Substrate composition was similar among the three reaches, with co-dominance of boulder and cobble substrate with relatively low embeddedness.

- Habitat conditions ranged widely among Green River tributary reaches. The Roaring Brook (RBM1) reference reach and Hinesburg Brook (HGBM1) received the highest rapid habitat scores of 179 and 162, respectively. Johnson Brook received a total rapid habitat score of 141, while Katley Brook scored 125/200. Hinsdale and Wheeler brooks, two tributaries that enter the Green River in or near the town of Greenfield, are paralleled by roads for much of their lengths. Consequently, riparian zone and streambank conditions have been degraded and result in rapid habitat assessment scores of 125 and 111, respectively. The extent of sediment deposition in Hinsdale Brook was particularly noteworthy, as depositional areas were completely covered and some even filled in with recently-deposited fine sediment. Cherry Rum Brook and Mill Brook, the two tributaries flowing through the north end of Greenfield, received the 1st and 3rd-lowest rapid habitat scores.

- Macroinvertebrate communities sampled from the four Green River sample sites ranged from slightly impacted at GRM1 to non-impacted at the other three Green River sites relative to the Cold River reference reach. Multimetric scores ranged from 32 at GRM1 to 42 at the other three Green River. The lower score at the lowest Green River site is largely attributable to the lower EPT taxonomic richness sampled from this reach. Our 2005 mainstem results are similar to those of the 2004 study and the 2000 DWM assessment of the Green River and differ only in the lower GRM1a score relative to 2000 DWM and 2004 DRWA metric scores. The difference between 2005 and 2004 appears to be related primarily to fewer taxa having been sampled in 2005. It is likely that the 2005 slightly impaired score more accurately characterizes this reach's condition than the 2004 score, as the reach clearly shows community composition attributes that differ from all of the other mainstem sites sampled.

- Relative to the Roaring Brook reference site, four tributary reaches scored as non-impacted, one scored as slightly impacted, and two scored as moderately impacted. Among those scoring as non-impacted, only Hinesburg Brook scored at least 40 total metric points. Hinesburg Brook richness metrics outperformed those from the Roaring Brook reference site, as Hinesburg Brook supported the second-highest total taxa richness and EPT richness sampled from any Green River tributaries. Hinsdale Brook scored an average total metric score of 38, despite the large quantity of sediment that has recently been deposited in the reach. Johnson Brook also scored as non-impacted relative to the Roaring Brook reference reach, with the second-highest total taxa richness among all tributaries sampled and the lowest HBI score. Among tributaries, only Katley Brook scored as slightly impaired. A low EPT richness of 13 and low scraper-to-filterer ratio of 0.4 relative to Roaring Brook reference conditions were largely responsible for the slightly impaired score at this reach. The two tributaries that flow, in part, through the north end of the town Greenfield each scored in the moderately impaired range. Mill Brook scored a total of 18 metric points, only 43% of the reference site score of 42. Cherry Rum Brook scored the lowest of all of the Green River tributaries with a total score of 12 which equates to 29% of the reference site metric score. Only eight EPT taxa were sampled from this reach, the lowest EPT richness sampled from any reach in this assessment. Cherry Rum Brook received the highest HBI score of 5.2, indicative of a community with a high collective tolerance to organic enrichment pollution.

- This study is the first known to assess the biological condition of Green River tributaries. Our data suggest that tributaries occurring within developed areas in the town of Greenfield tend to support moderately impaired macroinvertebrate communities. Those tributaries occurring further up in the watershed, where the valley walls converge and tributaries flow through steeper, forested hillslopes for their entire length to the Green River, generally support unimpaired communities. Katley Brook represents an exception to this observation, as it was the only tributary outside the town of Greenfield that scored as slightly impaired or worse.

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INTRODUCTION

The Massachusetts Department of Environmental Protection, Division of Watershed Management (DWM) currently assesses the biological health in each of the Deerfield River's major tributaries every five years in partial fulfillment of their federal mandate to report on the status of the Commonwealth's waters under the Clean Water Act. DWM suggests that an ideal monitoring plan for the Deerfield River Watershed would include 35-40 biomonitoring stations (MA DWM 2005) to adequately assess the watershed's rivers and streams with respect to assessing attainment of the aquatic-life-use water quality standard. Owing to budgetary and staffing limitations, assessment efforts fall well short of these recommendations. In 2005, for example, DWM sampled from approximately 20 sites distributed throughout the entire Massachusetts portion of the watershed.

As part of the Deerfield River Watershed Association's (DRWA) commitment to protecting the watershed's resources, the DRWA has performed water quality monitoring to supplement the efforts of regulatory agencies to monitor the watershed's condition. In recognizing the need to more thoroughly assess biological conditions in the Deerfield River watershed, the DRWA implemented in 2005 a long-term macroinvertebrate monitoring program for the watershed. The objectives of the program are to 1) augment DEP biomonitoring efforts to assess surface waters in the watershed with respect to their aquatic-life-use status and 2) familiarize citizens of the watershed with biological monitoring to increase support for and participation in watershed enhancement and protection activities.

The program includes elements of both professional and volunteer monitoring programs. In could be called, in a sense, a "hybrid" program. In order to provide useful data to the state, the program uses DWM's professional field and laboratory biomonitoring protocols. Volunteers are trained by the program lead, Dr. Michael Cole, to collect field data and to assist with sample sorting. All field sampling and sample processing is overseen by Dr. Cole. Macroinvertebrate identification is performed exclusively by Dr. Cole who uses the same levels of taxonomic resolution employed by the state. The program sampling design is designed to emulate the sampling program of the DWM in that sampling is rotated through subwatersheds from one year to the next, as DWM rotates through major watersheds of the state on an annual basis. Using this design, DRWA plans to survey from five subwatersheds during the first five years of the program: the Green River, South River, Chickley River, North River, and Cold River. Smaller tributaries draining directly to the Deerfield River, such as Pelham and Clesson brooks, will be sampled as well, likely in the same year that neighboring larger drainages are sampled. Under this program, the DRWA will assess biological conditions in 60 to 70 stream and river reaches in these first five years.

The Green River was the watershed of choice for the program's first year of sampling primarily from a need for comprehensive baseline information describing the river's current biological condition as development pressures in and around the town of Greenfield increase. The Green River, one of the largest tributaries to the Deerfield River in northwest Massachusetts, originates in southeastern Vermont, just west of the town of Marlboro. From its headwaters the river first flows east through predominantly forested lands for approximately eight miles before turning south towards Massachusetts.

Through the remaining five miles in Vermont and through its entire length of approximately 16 miles in Massachusetts, the Green River flows south before entering the Deerfield River on the south end of the town of Greenfield.

Throughout its length in Massachusetts, the river flows through forested and agricultural lands before reaching the town of Greenfield. This length of the river is typified by a relatively low gradient (<2% throughout most of its length in Massachusetts) with shallow riffles interspersed by long, often shallow pools and glides. Substrate is predominantly cobble and gravel in erosional habitats with larger proportions of fine substrates occurring in pools and other slow-water habitats.

Four small dams occurring between river miles one and seven create several reaches of impounded water in the lower river and present barriers to upstream fish passage. At least one of these dams, the Wiley & Russell Dam, is at risk of failing and poses considerable liability concerns to the town of Greenfield. Consequently, the Army Corps of Engineers has recently completed a draft analysis of alternatives for remedying the unsafe conditions and barriers to fish passage these dams present. The possibility that one or more of these dams could be removed in the near future served as further impetus to focus this year's efforts on the Green River.

The river flows through the town of Greenfield, the only population center in the Green River watershed. Concerns over water-quality impairment from urban runoff and industrial activities in the town have focused monitoring water quality, physical habitat, and biological conditions in the lower river (MA DEP 1989, Fiorentino 1997, MA DEP 1997, MA DEP 1999, Fiorentino and Maietta 2002). Biological assessments of macroinvertebrate communities in the lower river (downstream of downtown Greenfield) in 1988 and 1995 indicated that biological conditions were slightly to moderately impaired. Results of physical habitat surveys indicated that the impairment was likely resulting from degraded water quality.

In 2000, the DWM again sampled the lower Green River to continue to monitor biological health in relation to potential stressors associated with urban settings. Results of the study indicated significant improvement in the condition of macroinvertebrate communities downriver of downtown Greenfield. Results of the 2000 study suggested that macroinvertebrate communities in this portion of the Green River were non-impacted in comparison to conditions measured at a regional reference site (Fiorentino and Maietta 2002). Improvements to Greenfield's stormwater management in recent years has been suggested, at least in part, to be responsible for the improved biological condition in the lower river.

Most recently, renewed interest in the current condition of macroinvertebrate communities has resulted from a cleanup of a decommissioned gas station site on Rt. 5/10 in Greenfield. In 2004, the Deerfield River Watershed Association led a volunteer-based assessment of the potential effects of contaminants from the site on macroinvertebrate communities in the lower river. Also in 2004, a macroinvertebrate study was performed in six reaches of the Green River to assess the condition of macroinvertebrate communities in the river above and below the town of Greenfield, as a pilot study, in part, to the development of the DRWA macroinvertebrate monitoring program (Cole 2004). Results of the 2004 study were in agreement with those of the 2000 DWM assessment.

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METHODS

SAMPLE SITE SELECTION

Sample sites for this study were selected to provide adequate coverage of the Green River and its major tributaries in Massachusetts and Vermont. Twelve river and stream reaches were selected for sampling in 2005. Four sites were selected on the mainstem Green River. Three of these sites (GRM1a, GRM4, and GRM6) overlap with last year's pilot assessment as well as with prior DWM assessments (Table 1). The uppermost site, GRM7, was located in the Vermont portion of the river. The Cold River, a major tributary to the upper Deerfield River, was selected as the reference site against which to compare conditions in the Green River. This site was also sampled by DWM in 2005 as the reference condition for their biological assessment of the Deerfield River watershed.

The lower reaches of most of the larger tributaries to the Green River were also sampled (Table 1). Two of the eight tributaries sampled for this study, Roaring Brook and Hinesburg Brook, occur in Vermont. The Roaring Brook reach was selected as the reference reach for tributaries for this assessment, as it occurs in a largely forested, undisturbed drainage. Six tributaries are located in the Massachusetts portion of the watershed. Cherry Rum Brook flows through the north end of the town of Greenfield, where it confluents with Mill Brook; both were sampled near this confluence point for this study. Wheeler Brook and Hinsdale Brook each also occur in the lower end of the Green River watershed, as both drain the eastern slopes of the hills to the west of Greenfield. Wheeler Brook enters the Green River in the southwest corner of Greenfield after flowing parallel to Route 2 and several commercial developments for a short distance. Wheeler Brook was sampled upstream of this heavy commercial development. Hinsdale Brook joins the Green River approximately one mile northwest of Greenfield after emerging from the hills and traversing the valley floor for approximately ¾ miles. Hinsdale Brook was sampled well out onto the valley floor near its confluence with the Green River. Two of the eight tributaries drain into the mid-reaches of the Green River. Katley Brook enters the Green River from the east approximately 2.6 miles upriver along Green River Road. Johnson Brook enters the Green River from the west approximately 3.5 miles upriver along Green River road.

FIELD DATA COLLECTION

Macroinvertebrate samples were collected between September 23 and October 2, 2005 using methods employed by the DWM for assessing the condition of macroinvertebrate communities in Massachusetts streams (Nuzzo 2003). These methods are based on the US EPA Rapid Bioassessment Protocols (RBPs) for wadeable streams and rivers (Barbour et al. 1999). Macroinvertebrates were collected from each site using kick-sampling, a method by which organisms are sampled by disturbing streambed substrates and catching dislodged organisms in a net. At each sample site, ten kick samples of approximately 0.46 m x 0.46 m were collected and composited for a total

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Table 1. Stream reaches sampled for macroinvertebrates in the Green River watershed, Franklin and Berkshire counties, Massachusetts and Windham County, Vermont in fall 2005.

Site	River	Location
GRM1a	Green River	~50 m downstream of foot bridge crossing Green River at Green River Park (~400 m downstream of Meridian St. bridge in Greenfield).
GRM4	Green River	100 m below Pumping Station Covered Bridge on Eunice Williams Drive
GRM6	Green River	200 m above New County Road
GRM7	Green River	~50 m downstream of Green River Road crossing upstream of confluence with Hinesburg Brook
CRM1*	Cold River	~1 mile upriver of Mohawk Trail State Forest campground (Berkshire County).
RBM1	Roaring Brook	Upstream of Green River Road crossing
HGBM1	Hinesburg Brook	Upstream of Hinesburg Road crossing
HDBM1	Hinsdale Brook	Downstream of Road Crossing immediately north of the Polish picnic area on Plains Road.
CRBM1	Cherry Rum Brook	~75 m upstream of confluence with Mill Brook
JBM1	Johnson Brook	Upstream of Green River Road crossing
KBM1	Katley Brook	~25 m upstream of confluence with Green River
MBM1	Mill Brook	~25 m upstream of HWY 91 underpass (~100 m upstream of confluence with Cherry Rum Brook)
WBM1	Wheeler Brook	Along Shelburne Road approximately 50 m upstream of Route 2 underpass.

*Reference reach located outside of the Green River watershed

sampled area of approximately 2 m^2. Samples were labeled and preserved in the field with 70% isopropyl alcohol for later processing and identification in a laboratory. Sampling targeted fast-water areas with coarse substrate within each of the sample sites (collected samples in this habitat type throughout a 100-m reach, if habitat availability allowed).

SAMPLE SORTING AND MACROINVERTEBRATE IDENTIFICATION

Samples were sorted to remove a 100-organism subsample from the original sample using procedures described in Nuzzo (2003). Samples were first distributed in gridded pans. Macroinvertebrates were sorted from randomly selected grids until 100 organisms (±10%) were removed. The remainder of unsorted grids were then scanned for large/rare organisms that were not encountered during the 100-organism subsampling. These organisms were then removed and placed in a separate "large/rare" organism vial.

Specimens were identified to the lowest practical taxonomic level (generally genus or species and following the same level of resolution used for the 2000 DWM assessment of the lower Green River) as allowed by specimen condition and maturity. Taxonomic keys used included Merritt and Cummins 1996, Wiggins 1996, Stewart and Stark 2002, Peckarsky et al. 1990, and Weiderholm 1983.

DATA ANALYSIS

Macroinvertebrate taxonomic data were analyzed using DWM's modification (Nuzzo 2003) of EPA's Rapid Bioassessment Protocol III multimetric scoring and analysis (Barbour et al. 1999) to determine the condition of macroinvertebrate communities. Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that is known to be responsive to one or more types of pollution or habitat degradation. Because a number of biological attributes are simultaneously evaluated, the multimetric approach is a robust assessment tool and a deficiency in any one metric should not invalidate assessment results (Barbour et al. 1999). Each attribute value is first calculated from the taxonomic data and then converted to a standardized score by comparison with the reference site score (Table 2). Standardized scores of all metrics are then summed to produce a single multimetric score that is a numeric measure of overall biological integrity. DWM currently employs a 7-metric set for use with fast-water samples from streams (Table 2).

Table 2. MA DEP metric set and scoring criteria (relative to reference station) used to assess the condition of macroinvertebrate communities in the Green River, Franklin County, Massachusetts in fall 2004.

	Scoring Criteria			
Metric	**6**	**4**	**2**	**0**
Taxa Richness	>80%	60-80%	40-59%	<40%
EPT	>90%	80-90%	70-79%	<70%
EPT/Chironomidae (abundance ratio)	>75%	50-75%	25-49%	<25%
HBI (modified)	>85%	70-85%	50-69%	<50%
Scraper/Filtering collector Ratio	>50%	35-50%	20-34%	<20%
% Contribution of Dominant Taxon	<20%	20-29%	30-40%	>40%
Similarity Index: % Reference Affinity	>64%	50-64%	35-49%	<35%

Metric Descriptions (from Fiorentino and Miaetta 2002)

1. Taxa Richness—A count of the number of taxa present. Taxa richness generally increases with increasing water quality and habitat quality.

2. EPT Index—The number of taxa 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. 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 a taxon
   n = total number of organisms in the sample

4. Ratio of EPT and Chironomidae Abundance—Uses the ratio of EPT to Chironomidae abundance as a measure of community balance. Macroinvertebrate communities with a disproportionately large number of the generally tolerant Chironomidae relative to the more sensitive insect groups may indicate a stressed community.

5. Percent Contribution Dominant Taxon—The percent contribution of the numerically dominant taxon (genus or species) to the total numbers of organisms. A community dominated by few species indicates environmental stress.

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 matter (FPOM) levels are high.

7. Community Similarity—Compares study site community data 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 Deerfield 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 approach is based on a modification of the Percent Model Affinity (Novak and Bode 1992). The reference site affinity (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%.

Metric values for each study site were scored based on comparability to a "least impacted" reference station, and scores were totaled. The percent comparability of total metric scores for each study site to those for the reference site is then used to assign a biological condition or impact class to the site. RBP III utilizes four categories in its impact classification of non-impacted (>83% reference comparability), slightly impacted (54-79% reference comparability), moderately impacted (21-50% reference comparability), and severely impacted (<17% reference comparability). For this study, the Cold River, another large tributary to the Deerfield River, was used as the reference site. Data from the Cold River collected during DWM's 2000 biological assessment (site CR01) were used as regional reference data to determine comparability of the Green River macroinvertebrate communities to reference conditions.

QUALITY CONTROL

A Quality Assurance Project Plan (QAPP) was developed and written for this project (Cole and Walk 2005). The QAPP included all required state and federal elements and was approved by MA DEP and the US Environmental Protection Agency prior to the beginning of this assessment. Elements of the QAPP included the project background, site selection rationale, measurement quality objectives, training, documentation, sampling design, protocols, quality control requirements, instrument/equipment testing and maintenance, data management, data review, and data validation. Although the details of the QAPP are too lengthy to present in the context of this report, several of the critical elements of the QAPP are as follows.

Volunteers collecting field samples and data were trained on the day they assisted in the field and worked closely at all times in the field with Dr. Michael Cole. All macroinvertebrate identifications were performed by Michael Cole, a professional aquatic entomologist. Representative specimens of each taxon encountered were labeled and saved as vouchers for later reference and verification, as needed. Sorted macroinvertebrate samples were preserved in 80% ethyl alcohol and archived. Voucher specimens and two 100-organism sub-samples were verified by an independent professional taxonomist. Unsorted fractions of all samples were also preserved and will be archived for two years following project completion. All data entered into spreadsheets were checked for transcription errors and outliers before analyses were performed. Analyses were also checked for errors in formulae used and results.

RESULTS & DISCUSSION

PHYSICAL CONDITIONS

Among the Green River sample reaches, the lowest reach, GRM1, was the most influenced by human activities and development encroachment; consequently, this reach received the lowest rapid habitat score of 112 of a possible 200 points. Residential development occurs within 10 m of the right bank throughout this reach, while a park with a narrow riparian zone occurs on the left bank. Among the four Green River sample sites and the Cold River reference site, GRM1 scored, by far, the lowest with respect to bank stability and riparian zone conditions (Table 3). Substrate composition also differed in GRM1 from the other Green River reaches, with a larger proportion of cobble (rather than boulder) and sand substrate. Larger substrates were more heavily embedded in this lowest reach than in the other three Green River reaches (Table 3, Figure 1).

The other three Green River reaches were similar in instream, bank, and riparian conditions, with total rapid habitat scores ranging between 165 and 177. Riparian zones were generally intact; however, Green River road occurs within 10-20 m of the right bank of GRM6 and a maintained field occurs within 20 m of the left bank of GRM7. Stream banks in each of these reaches were stable and well vegetated. Substrate composition was similar among the three reaches, with co-dominance of boulder and cobble substrate with relatively low embeddedness.

Habitat conditions ranged widely among Green River tributary reaches. The Roaring Brook (RBM1) reference reach and Hinesburg Brook (HGBM1) received the highest rapid habitat scores of 179 and 162, respectively (Table 4). Each was characterized as having stable, well-vegetated banks and dominance by boulder and cobble substrate. Substrate embeddedness by fine sediment was low, providing ample high-quality epibenthic habitat in both RBM1 and HGBM1 (Table 4, Figure 2). The Roaring Brook reach riparian zone was well developed and intact on each bank, whereas the Hinesburg Brook reach riparian zone was narrow on each bank, as a field occurred within 10 m of the left bank and some clearing of riparian vegetation had also occurred beyond the right bank.

Johnson Brook received a total rapid habitat score of 141. The reach flows through an intact mixed hardwood/coniferous forest. An absence of groundcover and shrub layers compromises bank stability and has likely been the cause of the elevated fine

Table 3. Habitat assessment scores of four reaches in the Green River sampled for macroinvertebrates in fall 2005. The Cold River (CRM1) occurs outside the Green River watershed and was sampled to represent reference conditions within the Deerfield River watershed. For primary parameters (first 7 in table), scores ranging from 16-20 = optimal; 11-15 = suboptimal; 6-10 = marginal; 0-5 = poor. For secondary parameters (last 3 in table), scores ranging from 9-10 = optimal; 6-8 = suboptimal; 3-5 = marginal; 0-2 = poor. Roaring Brook (RBM1) represents reference conditions.

	Site				
Variable	CRM1	GRM1a	GRM4	GRM6	GRM7
INSTREAM COVER	17	9	16	11	16
EPIFAUNAL SUBSTRATE	20	15	19	20	18
EMBEDDEDNESS	20	12	18	18	16
CHANNEL ALTERATION	20	15	19	19	18
SEDIMENT DEPOSITION	20	11	17	19	18
VELOCITY-DEPTH COMBINATIONS	19	14	17	15	15
CHANNEL FLOW STATUS	11	17	16	12	15
BANK VEGETATIVE PROTECTION	10,10	2,4	8,8	9,9	8,8
BANK STABILITY	10,10	2,4	10,9	10,6	9,9
RIPARIAN VEGETATIVE ZONE WIDTH	10,10	3,4	10,10	10,7	10,10
TOTAL SCORE	**187**	**112**	**177**	**165**	**170**

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Table 4. Habitat assessment scores of eight tributaries to the Green River sampled for macroinvertebrates in fall 2005. For primary parameters (first 7 in table), scores ranging from 16-20 = optimal; 11-15 = suboptimal; 6-10 = marginal; 0-5 = poor. For secondary parameters (last 3 in table), scores ranging from 9-10 = optimal; 6-8 = suboptimal; 3-5 = marginal; 0-2 = poor. Roaring Brook (RBM1) represents reference conditions.

	Site							
Variable	RBM1	HGBM1	HDBM1	CRBM1	JBM1	KBM1	MBM1	WBM1
INSTREAM COVER	18	12	12	11	15	12	12	12
EPIFAUNAL SUBSTRATE	20	19	18	13	18	19	11	18
EMBEDDEDNESS	18	17	5	12	11	9	4	13
CHANNEL ALTERATION	20	18	15	15	20	20	8	6
SEDIMENT DEPOSITION	19	18	3	17	10	9	8	11
VELOCITY-DEPTH COMBINATIONS	18	15	8	12	14	14	12	14
CHANNEL FLOW STATUS	15	17	11	8	13	14	18	11
BANK VEGETATIVE PROTECTION	7,7	10,10	4,4	6,6	5,5	2,2	7,7	3,2
BANK STABILITY	9,9	10,10	4,3	6,6	5,5	2,2	7,8	6,3
RIPARIAN VEGETATIVE ZONE WIDTH	9,10	2,4	5,10	10,6	10,10	10,10	10,7	2,10
TOTAL SCORE	**179**	**162**	**102**	**128**	**141**	**125**	**119**	**111**

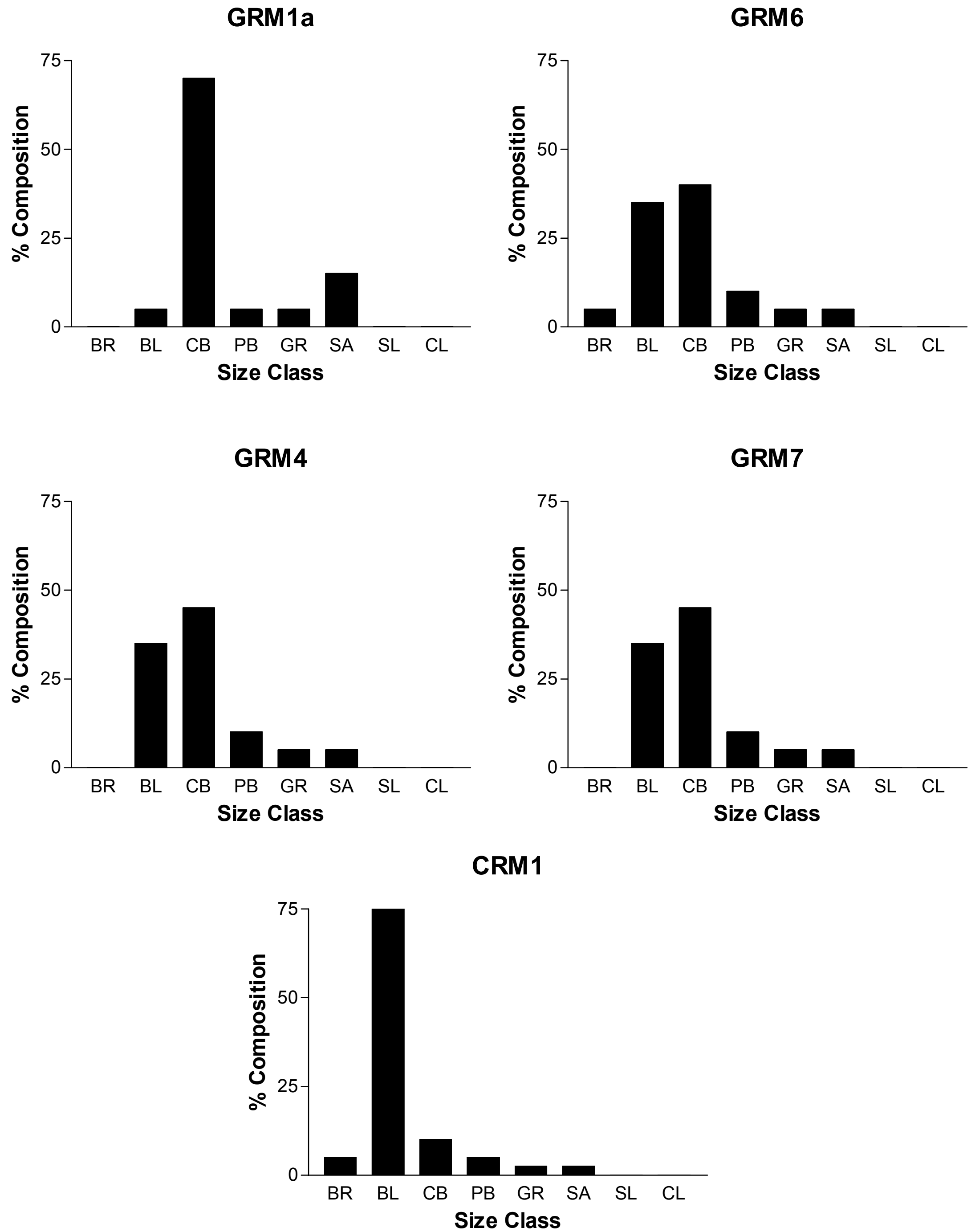

Figure 1. Visual estimates of substrate composition in four Green River reaches and the Cold River reference reach sampled for macroinvertebrates in fall 2005. BR = bedrock; BL = boulder, >256 mm, CB = cobble, 64-256 mm; PB = pebble, 16-64 mm; GR = gravel, 2-16 mm; SA = sand, 0.06-2 mm; SL = silt, 0.004-0.06 mm; CL = clay, <0.004 mm (slick).

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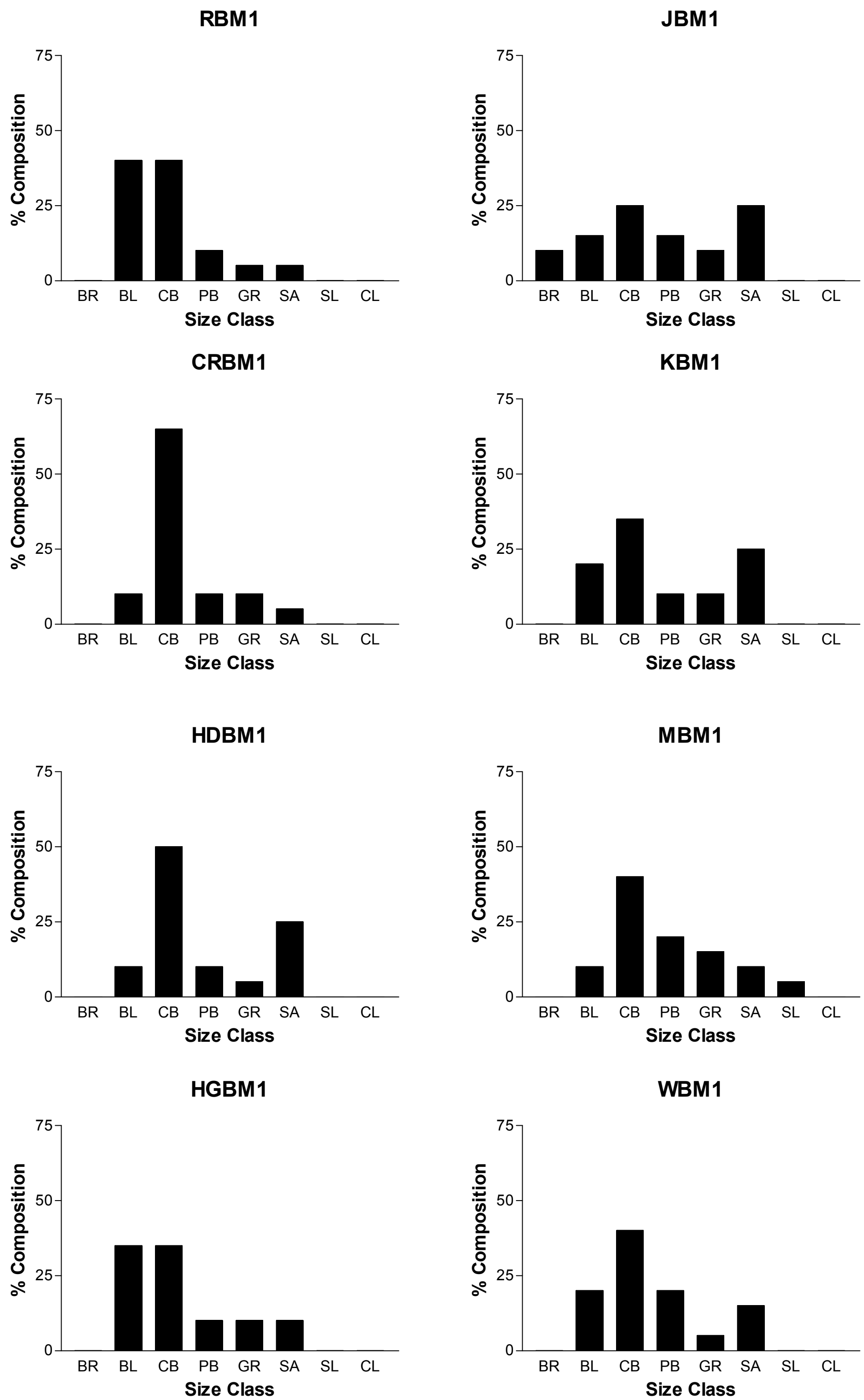

Figure 2. Visual estimates of substrate composition in eight Green River tributary reaches sampled for macroinvertebrates in fall 2005. BR = bedrock; BL = boulder, >256 mm, CB = cobble, 64-256 mm; PB = pebble, 16-64 mm; GR = gravel, 2-16 mm; SA = sand, 0.06-2 mm; SL = silt, 0.004-0.06 mm; CL = clay, <0.004 mm (slick).

sediment concentrations in this reach (Table 4). The reach, otherwise, is among the least disturbed in this study. Similarly, Katley Brook flows through a primarily forested drainage with an intact riparian zone bordering much of its length, but sparse ground cover and unstable banks contribute to the elevated sediment observed on the stream bottom. As a result, Katley Brook habitat conditions scored 125/200.

Hinsdale and Wheeler brooks, two tributaries that enter the Green River in or near the town of Greenfield, are paralleled by roads for much of their lengths. Consequently, riparian-zone and streambank conditions have been compromised and result in rapid habitat assessment scores of 125 and 111, respectively. The extent of sediment deposition in Hinsdale Brook was particularly noteworthy, as depositional areas were completely covered and some even filled in with recently deposited fine sediment. A subsequent drive-by survey of upper Hinsdale Brook along Brook Road revealed areas of significant bank erosion and hillslope failures that are delivering large quantities of sediment to Hinsdale Brook (Figure 3).

Figure 3. Sediment deposition occurring in lower Hinsdale Brook (HDBM1) and severe upstream bank erosion and hillslope failures in fall 2005.

Cherry Rum Brook and Mill Brook, the two tributaries flowing through the north end of Greenfield, received the 1st and 3rd-lowest rapid habitat scores. Mill Brook flows through rural residential and agricultural land north of Greenfield, whereas Cherry Rum Brook, a small tributary to Mill Brook, flows primarily through residential development. Each was sampled in reaches with relatively intact riparian zones. Cherry Rum Brook substrates were low in embeddedness and heavily dominated in steeper erosional areas by cobble substrate (Figure 2). Largely responsible for the low rapid habitat scores, both bank stability and channel flows were low in Cherry Rum Brook, suggesting flashy hydrology within this drainage. Mill Brook's substrate, dominated by cobble, was heavily embedded. Although an intact riparian zone occurred on both banks along most of the reach, residential clearing of the riparian zone on the right bank occurred almost to the stream channel at the upper end of the reach.

MACROINVERTEBRATE COMMUNITIES

Green River Mainstem Reaches

Macroinvertebrate communities sampled from the four Green River sample sites ranged from slightly impacted at GRM1 to non-impacted at the other three Green River sites relative to the Cold River reference reach (Table 5). Multimetric scores ranged from 34 at GRM1 to 42 at the other three Green River sites. The lower score at the lowest Green River site, GRM1, is largely attributable to the lower EPT taxonomic richness sampled from this reach, as 17 EPT taxa were sampled compared to 26 from the Cold River reference reach (Table 6).

Community richness at GRM1 aside, metric values calculated from all Green River sample sites were comparable to those from the Cold River reference reach (Table 6, Figure 4)). Total taxa richness ranged from 38 to 46 across Green River sites GRM4, GRM6, and GRM7, compared to 41 at the Cold River reference site. EPT richness ranged at these three sites from 24 to 26, comparing favorably to a total of 26 EPT taxa sampled from the Cold River reference reach. Consistent with results of the 2004 Green River study (Cole 2004), a general trend in increasing EPT richness with increasing upstream distance was indicated by the data.

EPT-to-Chironomidae ratios were higher at all Green River sites than at the Cold River reference location, ranging from 4.3 to 13.0 (Table 6, Figure 4). Modified HBI scores were all relatively low, ranging from 2.7 to 4.1. Even the lowest Green River site, GRM1, received an HBI score similar to that of the Cold River reference site. Scraper-to-filterer ratios were also comparable to or better than those measured at the Cold River reference station. The highest scraper-filterer ratio, more than twice as high as measured at any other site, occurred at the lowest Green River sample site, GRM1. The high ratio resulted from an abundance of Elmidae beetles in this reach.

Percent contribution of the dominant taxon ranged from 11.1 to 15.2 among the four Green River sample sites, slightly higher than the 10% measured from the Cold River reference reach, but not high enough to affect metric scores (Table 6, Figure 4)). Hydropsychidae caddisflies were dominant or co-dominant at each of the Green River sites and the Cold River reference site.

Reference-site affinity ranged from 68 to 79-percent similarity and generally increased with upstream distance (Table 6, Figure 4). The lowest Green River site, GRM1, was least similar in taxonomic composition to the Cold River reference site. This site was uniquely dominated by the filter feeding caddisflies, *Cheumatopsyche* and *Hydropsyche sparna*, and by several Elmidae taxa. As was observed in the 2004 study, the Elmidae taxa *Optioservus* and *Stenelmis* occurred in higher relative abundance in downriver sites. Twenty seven Elmidae were subsampled from the GRM1 site sample, while only one was sampled from GRM7, the uppermost of the four Green River sites. Several other taxa showed longitudinal distribution patterns, including the sensitive mayfly genera, *Rhithrogena* and *Epeorus*, which were absent from GRM1, yet occurred at all of the upriver sites and at the Cold River reference site.

Our 2005 mainstem results are similar to those of the 2004 study and of prior DWM assessments of the Green River and differ only in the lower GRM1a score relative to 2000 DWM and 2004 DRWA metric scores. The difference between 2005 and 2004 appears to be related primarily to fewer taxa having been sampled in 2005. It is likely that the 2005 slightly impaired score more accurately characterizes this reach's condition than the 2004 score, as the reach clearly shows community composition attributes that differ from all of the other mainstem sites sampled. Despite having received the same impairment-class score last year, the 2004 report also speaks to differences observed between GRM1 and upriver reaches (Cole 2004).

Table 5. RBP III summary scores, reference comparability scores, and corresponding biological condition classifications of macroinvertebrate communities sampled from four sites in the Green River and one site from the Cold River (as a reference reach), Franklin County, Massachusetts and Windham County, Vermont in fall 2005.

	Green River Site				
Metric	**CRM1**	**GRM1a**	**GRM4**	**GRM6**	**GRM7**
Total Score	42	34	42	42	42
% Comparability to Reference	100	81	100	100	100
Biological Condition	**REF**	Slightly-impacted	Non-impacted	Non-impacted	Non-impacted

Table 6. Metric values (and standardized metric scores) derived from macroinvertebrate samples collected from the Cold River, Franklin County, Massachusetts and the Green River, Franklin County, Massachusetts and Windham County, Vermont in fall 2005.

	Site				
Metric	**CRM1**	**GRM1a**	**GRM4**	**GRM6**	**GRM7**
Richness	41 (6)	30 (4)	46 (6)	42 (6)	38 (6)
EPT Richness	26 (6)	17 (0)	24 (6)	26 (6)	25 (6)
EPT/Chironomidae	1.8 (6)	13.0 (6)	5.7 (6)	5.2 (6)	4.3 (6)
HBI modified	3.4 (6)	3.4 (6)	4.1 (6)	3.1 (6)	2.7 (6)
Scraper/Filterer Ratio	0.4 (6)	0.8 (6)	0.5 (6)	0.3 (6)	0.4 (6)
% Dominant Taxon	10.5 (6)	11.1 (6)	15.2 (6)	13.0 (6)	13.2 (6)
% Reference Affinity	100 (6)	68.0 (6)	76.6 (6)	79.5 (6)	78.1 (6)

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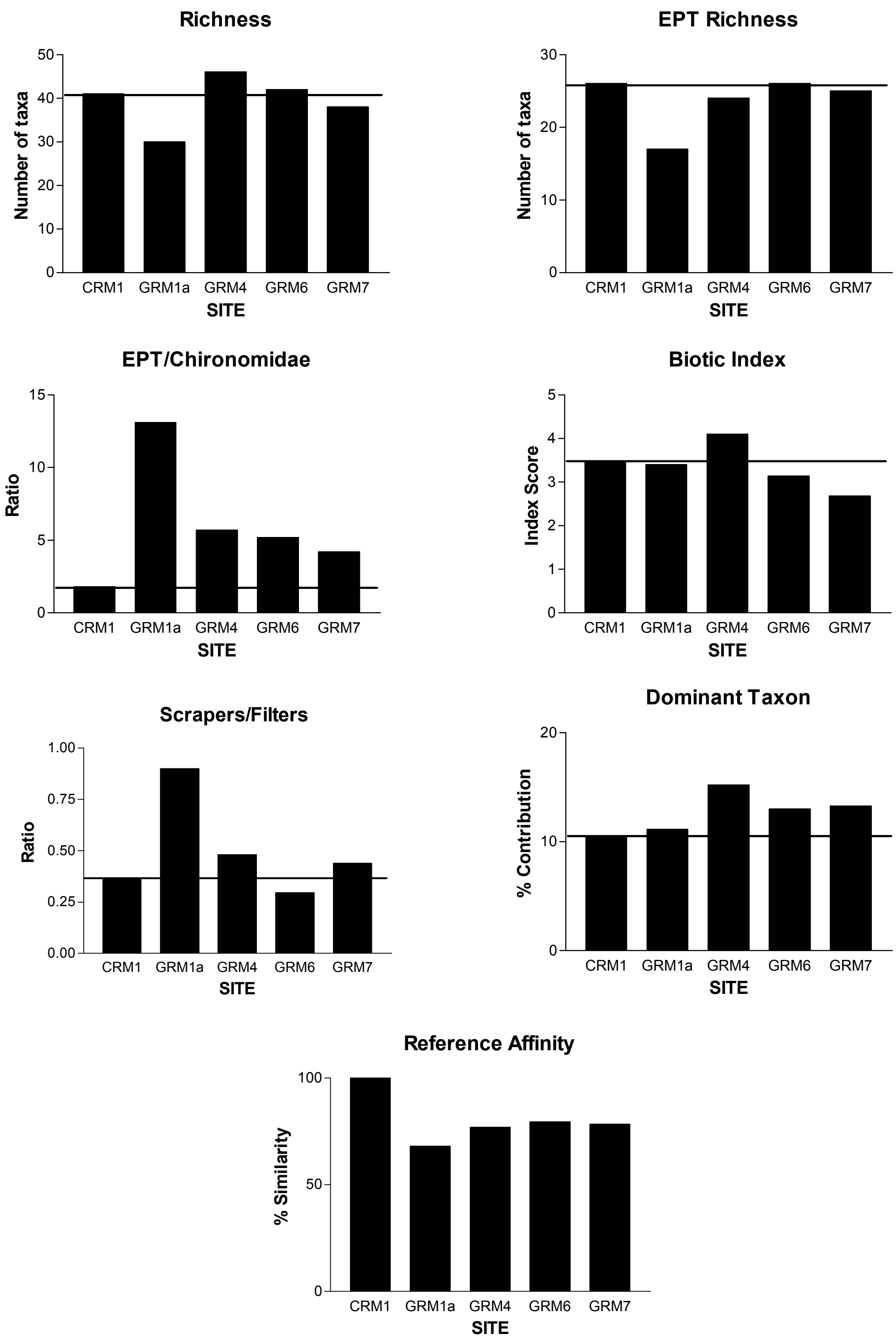

Figure 4. Metric attribute values calculated from macroinvertebrate samples collected from the Green River (GRM1a through 7), Franklin County, Massachusetts and Windham County, Vermont and from the Cold River reference site in Franklin County, Massachusetts in fall 2005. Black horizontal lines indicate value of attribute at reference site on the Cold River.

Green River Tributary Reaches

The Roaring Brook reference site supported a macroinvertebrate community with a moderately high taxonomic richness (35 taxa) and high EPT richness (23 taxa). A relatively high EPT/Chironomidae ratio suggests dominance by the more sensitive EPT taxa (Table 8, Figure 5). A low HBI score suggests that Roaring Brook supports a benthic community that is intolerant of organic-enrichment pollution. The scraper-to-filterer ratio was high, suggesting little influence of fine organic material on structuring the benthic community.

Relative to the Roaring Brook reference site, four tributary reaches scored as non-impacted, one scored as slightly impacted, and two scored as moderately impacted (Table 7). Among those scoring as non-impacted, only Hinesburg Brook scored at least 40 total metric points. Hinesburg Brook richness metrics outperformed those of the Roaring Brook reference site, as Hinesburg Brook supported the second-highest total taxa richness and EPT richness sampled from any Green River tributaries (Table 8, Figure 5). Hinesburg Brook was also characterized by a low collective tolerance to organic-enrichment pollution, with an HBI score of 2.8. Several taxa were sampled only from Hinesburg Brook in this assessment, including one individual each of the mayfly, *Ephemerella aurivilii*, and the highly sensitive stonefly family, Capniidae.

Hinsdale Brook scored an average total metric score of 38 between the duplicate samples collected from this reach (Table 7). Despite the large quantity of sediment that has recently been deposited in the reach, the metric scores suggest that the macroinvertebrate community appears to be relatively unaffected. Although metric scores suggest that this reach is non-impacted, total macroinvertebrate densities were lower in this reach than in any tributary reaches but one, indicating that recent sediment deposition may have reduced total macroinvertebrate abundance in the reach.

Johnson Brook also scored as non-impacted relative to the Roaring Brook reference reach with the highest total taxa richness among all tributaries sampled and the lowest HBI score (Table 8, Figure 5). Johnson Brook also supported the highest scraper-to-filterer ratio among all reaches sampled in this assessment. The reach was numerically dominated by the sensitive mayfly genus, *Epeorus*, and the sensitive caddisfly species, *Rhyacophila minor*. Wheeler Brook also scored as unimpaired, despite the sample reach occurring immediately adjacent to a road that almost eliminates the left-bank riparian zone in places. Notably, Wheeler Brook was found to support a large population of the large and disturbance-sensitive shredder stonefly, *Pteronarcys proteus*.

Among tributaries, only Katley Brook scored as slightly impaired. A low EPT richness of 13 and low scraper-to-filterer ratio of 0.4 relative to Roaring Brook reference conditions were largely responsible for the slightly impaired score (Table 8). Katley Brook currently supports a population of the caddisfly, *Hydropsyche ventura,* which was not sampled from elsewhere in the Green River watershed.

The two tributaries that flow, in part, through the north end of the town Greenfield each scored in the moderately impaired range. Mill Brook received a total of 18 metric points, only 43% of the reference site score of 42 (Table 7). Total taxa richness and EPT taxa richness were among the lowest sampled and the modified HBI score was the second highest among all sampled tributaries, each suggesting that the reach supports an impaired macroinvertebrate community (Table 8). Cherry Rum Brook scored the lowest of all of the Green River tributaries with a total metric score of only 12 which equates to

29% of the reference site condition. Only eight EPT taxa were sampled from this reach, the lowest EPT richness of any reach sampled in this assessment. Cherry Rum Brook received the highest HBI score of 5.2, indicative of a community with a high collective tolerance to organic-enrichment pollution (Table 8). Cherry Rum Brook was heavily dominated by *Hydropsyche betteni*, a caddsifly that is particularly tolerant to organic-enrichment pollution and often occurs in abundance under such conditions (Schuster & Etnier 1978).

This study is the first known to assess the biological condition of Green River tributaries. Our data suggest that tributaries occurring within developed areas in the town of Greenfield tend to support impaired macroinvertebrate communities. Those tributaries occurring further up in the watershed, where the valley walls converge and tributaries flow through steeper, forested hillslopes for their entire length to the Green River, generally support unimpaired communities. Katley Brook represents an exception to this observed pattern, as it was the only tributary outside the town of Greenfield that scored as slightly impaired or worse. It is worth noting that on June 8, 2005, the author of this report observed a milky colored plume of what appeared to be sediment-laden water flowing out of Katley Brook and into the Green River at a time when the Green River and other tributaries were running clear. The observation raises suspicions that activities are occurring somewhere in the Katley Brook drainage that are periodically creating highly elevated suspended sediment concentrations in lower Katley Brook. It is plausible that the biology in Katley Brook has responded to these disturbances, particularly in the possible reduction in numbers and richness of the more sensitive EPT taxa.

Table 7. RBP III summary scores, reference comparability scores, and corresponding biological condition classifications of macroinvertebrate communities sampled from eight tributaries to the Green River, Franklin County, Massachusetts and Windham County, Vermont in fall 2005.

	Tributary Site							
Metric	**RBM1**	**HGBM1**	**HDBM1**	**CRBM1**	**JBM1**	**KBM1**	**MBM1**	**WBM1**
Total Score	42	40	38	12	38	26	20	36
% Comparability to Reference	100	95	91	29	90	62	48	86
Biological Condition	**REF**	Non-impacted	Non-impacted	**Mod-impacted**	Non-impacted	Slightly-impacted	**Mod-impacted**	Non-impacted

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Table 8. Metric values (and standardized metric scores) derived from macroinvertebrate samples collected from Green River tributaries, Franklin County, Massachusetts and Windham County, Vermont in fall 2005.

	Site							
Metric	**RBM1**	**HGBM1**	**HDBM1**	**CRBM1**	**JBM1**	**KBM1**	**MBM1**	**WBM1**
Richness	35 (6)	39 (6)	38 (6)	26 (4)	40 (6)	24 (4)	20 (2)	29 (6)
EPT Richness	23 (6)	27 (6)	21 (6)	8 (0)	22 (6)	13 (0)	11 (0)	19 (4)
EPT/Chironomidae	4.8 (6)	8.3 (6)	4.5 (6)	2.2 (2)	8.5 (6)	4.5 (4)	14.0 (6)	11.2 (6)
HBI modified	2.6 (6)	2.8 (6)	.3.2 (4)	5.2 (0)	1.5 (6)	2.8 (6)	4.1 (2)	2.8 (6)
Scraper/Filterer Ratio	1.5 (6)	0.6 (4)	1.3 (6)	0.2 (0)	6.4 (6)	0.4 (2)	0.4 (2)	1.3 (6)
% Dominant Taxon	13.0 (6)	16.6 (6)	10.9 (6)	27.8 (4)	21.1 (2)	25.0 (4)	26.5 (4)	28.6 (4)
% Reference Affinity	100 (6)	78.9 (6)	81.1 (6)	42.6 (2)	92.9 (6)	81.1 (6)	52.6 (4)	53.1 (4)

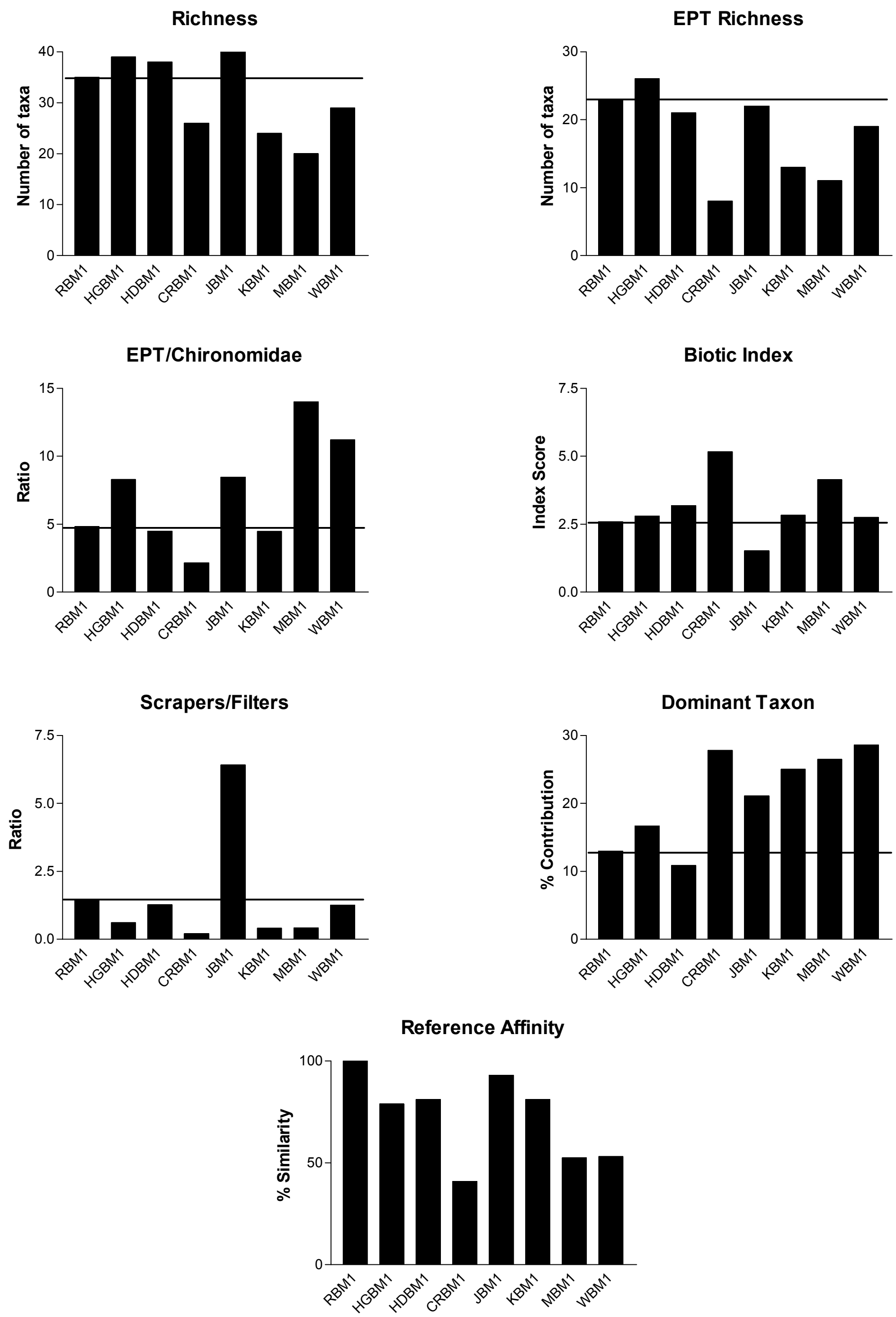

Figure 5. Metric attribute values calculated from macroinvertebrate samples collected from tributary streams to the Green River, Franklin County, Massachusetts and Windham County, Vermont in fall 2005. Black horizontal lines indicate value of attribute at reference site on Roaring Brook (RBM1).

QUALITY CONTROL RESULTS

Two samples were collected in duplicate for this study – HGBM1 and HDBM1. HGBM1 duplicate samples received identical total metric scores of 40. HDBM1 samples received total metric scores of 36 and 40, resulting in reference comparability scores 86% and 95% and each scoring as non-impacted.

Residues of two sorted samples were checked for sorting efficacy; each had been sorted at rates exceeding 95% macroinvertebrate removal (96% and 98%).

Several quality-control measures were followed to ensure quality of taxonomic data. A voucher collection of project specimens was assembled by the project taxonomist and a document was written to describe the characteristics used to identify Hydropsyche specimens to species. The document includes detailed illustrations of characters used to speciate this genus (Figure 6).

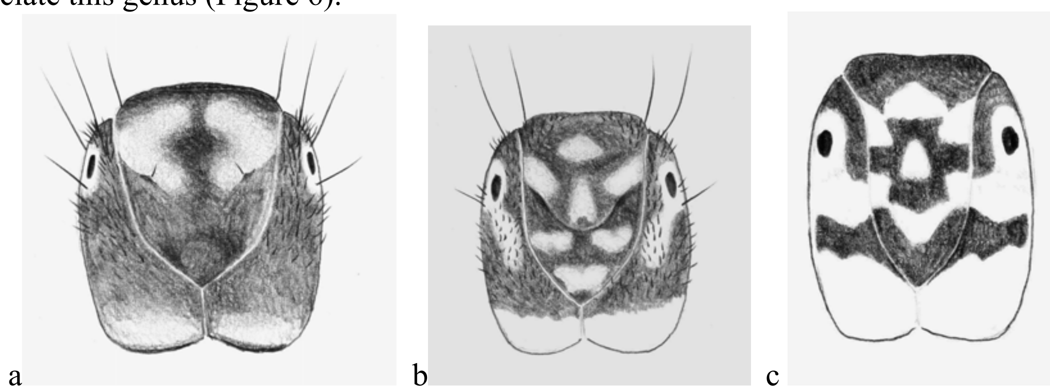

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Figure 6. Examples of illustrations of *Hydropsyche* species sampled from the Green River watershed in fall 2005. From left to right, illustrations are of a) *H. betteni*, b) *H. morosa*, and c) *H. bronta*.

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LITERATURE CITED

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish. Second Edition. EPA 841-B-99-002. Office of Water, US Environmental Protection Agency, Washington, DC. 151 p. + appendices

Cole, M. B. 2004. Green River Watershed Macroinvertebrate Assessment. Unpublished report prepared for the Deerfield River Watershed Association, Shelburne Falls, Massachusetts.

Cole, M.B. and M.F. Walk, 2005. Quality Assurance Project Plan for the 2005-2009 Deerfield River Watershed Volunteer Macroinvertebrate Monitoring Program. Prepared for the Massachusetts Department of Environmental Protection and the US EPA. 27 pp. + appendices.

Fiorentino, J. F., and R. Maietta. 2002. Deerfield River Watershed 2000 Biological Assessment. Technical Memorandum TM-33-3. Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA. 49 p. + appendices

Fiorentino, J. F. 1997. 1988 and 1995 Deerfield River Watershed Benthic Macroinvertebrate Biomonitoring. Technical Memorandum TM-33-1. Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA. 24 p. + appendices

MA DEP. 1989. 1988 Deerfield River Basin Survey. Department of Environmental Protection, Division of Water Pollution Control, Technical Services Branch. Westborough, MA. 70 p.

MA DEP. 1997. Draft Deerfield River Watershed 1995 Resource Assessment Report. Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA. 43 p.

MA DEP. 1999. Massachusetts Section 303(d) List of Waters – 1998. Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA. 129 p.

MA DWM 2005. SAP for 2005 DWM Monitoring in the Deerfield Watershed. MA DEP, Worcester, MA.

Merritt, R.W. and K.W. Cummins (eds.). 1996. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Co. Dubuque, IA. 862 p.

Nuzzo, R. M. 2003. Standard Operating Procedures (Working Draft): Water Quality Monitoring in Streams Using Aquatic Macroinvertebrates. Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA. 35 p.

Peckarsky, P.R. Fraissinet, M.A. Penton, and D.J. Conklin, Jr. 1990. Freshwater macroinvertebrates of northeastern North America. Comstock Publishing Assoc. Ithaca, NY. 442 p.

Schefter, P. W., and G. B. Wiggins. 1986. A Systematic Study of the Nearctic Larvae of the *Hydropsyche morosa* Group (Trichoptera: Hydropsychidae). Life Sciences Miscellaneous Publication of the Royal Ontario Museum, Toronto.

Schuster, G. A., and D. A. Etnier. 1978. A Manual for the Identification of the Larvae of the Caddisfly Genera *Hydropsyche* Pictet and *Symphitopsyche* Ulmer in Eastern and Central North America (Trichoptera: Hydropsychidae). U.S. Environmental Protection Agency publication EPA-600/4-78-060. USEPA, Cincinnati, Ohio.

Stewart K.W., and P. B. Stark. 2002. Nymphs of North American Stonefly Genera. Second Edition. The Caddis Press. Columbus, Ohio. xii+510 pp.

Wiederholm, T. (ed.). 1983. Chironomidae of the Holarctic region: Keys and diagnoses (Part 1. larvae). Ent. Scand. Suppl. 19. 457 p.

Wiggins G.B. 1996. Larvae of the North American Caddisfly Genera. Second Edition. University of Toronto Press. Toronto ON.

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APPENDIX I – SAMPLE SITE PHOTOS

CRM1 – Cold River ~1 mile upriver of Mohawk Trail State Forest campground (Berkshire County).

GRM 1a – Green River 400 m downriver of Meridian St. bridge in Greenfield.

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GRM4 – Green River ~100 m downriver of covered bridge on Eunice Williams Drive.

GRM6 - 200 m upriver of New County Road.

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GRM7 – Green River ~50 m downstream of Green River Road crossing upstream of confluence with Hinesburg Brook.

RBM1 – Roaring Brook upstream of Green River Road crossing.

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HGBM1 – Hinesburg Brook upstream of Hinesburg Road crossing.

HDBM1 – Hinsdale Brook downstream of road crossing immediately north of the Polish picnic area on Plains Road.

DRAFT

CRBM1 – Cherry Rum Brook ~75 m upstream of confluence with Mill Brook.

JBM1 – Johnson Brook upstream of Green River Road crossing.

DRAFT

KBM1 – Katley Brook ~25 m upstream of the confluence with the Green River.

MBM1 – Mill Brook ~25 m upstream of HWY 91 underpass (~100 m upstream of confluence with Cherry Rum Brook).

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WBM1 – Wheeler Brook along Shelburne Road approximately 50 m upstream of Route 2 underpass.