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FRENCH & QUINEBAUG RIVER WATERSHED
2004 BENTHIC MACROINVERTEBRATE BIOASSESSMENT

CN 178.3

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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 (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's (MassDEP/DWM) 2004 watershed assessments, the DWM Monitoring Program was charged with increasing, both temporally and spatially, the percent coverage of assessed surface waters in the Commonwealth. Specifically, emphasis was placed on monitoring waters currently "unassessed" (i.e., there are no historical MassDEP data) or "not assessed" (i.e., historical data exist but are greater than five years old). Monitoring activities focused on aquatic benthic macroinvertebrate sampling and habitat assessments to evaluate the biological health of various portions of the French & Quinebaug River watershed. To support the biological data, DWM collected water quality data at all biomonitoring stations. Water quality surveys included measuring *in situ* parameters (dissolved oxygen, temperature, pH, specific conductance, and total dissolved solids) and collecting grab samples for bacteria analysis. These water quality data are presented in a separate technical memorandum (MassDEP 2006). Additionally, the water quality data may be discussed in this report, particularly for those instances where they may help in the interpretation of the biological data. Sampling locations, along with station identification numbers and sampling dates, are noted in Table 1. Sampling locations are also shown in Figure 1.

To provide information necessary for making basin-wide aquatic life use-support determinations required by Section 305(b) of the Clean Water Act, all French & Quinebaug River watershed 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 (NPS) pollution originating from multiple and/or unknown sources in a watershed (Hughes 1989). A single regional reference station was used for all sites during the 2004 French & Quinebaug River bioassessments—BR01, located in Browns Brook in the Quinebaug River subwatershed. Browns Brook historically has been used as a reference stream by MassDEP/DWM as part of an ongoing study in numeric biocriteria development (Lotic, Inc. 1999; Tetra Tech, Inc. 1999). BR01 was situated upstream from all known point sources of water pollution, and was also assumed (based on MassDEP water quality data, topographic map examinations, and field reconnaissance) to be minimally impacted (relative to other portions of the watershed) by nonpoint sources. In addition, a second reference station (LB01 in Lebanon Brook) was used for comparisons to those biomonitoring stations (FR04-1; LR01; W1197) in larger streams with a more comparable watershed drainage area. LB01 received the highest habitat evaluation in the entire 2004 survey (Table A5). Like BR01, LB01 was located within an undeveloped and sparsely populated subwatershed and was considered minimally impacted by NPS pollution and other perturbations. Anthropogenic impacts precluded the designation of an additional reference station in the French River subwatershed.

During "year 1" of its "5-Year Basin Cycle", problem areas, potential problem areas, and areas lacking historical data within the French & Quinebaug River watershed were better defined through such processes as coordination with appropriate groups (MassDEP, EPA, watershed associations, USGS), examining historical data (data >5 years old, i.e., from waters currently "not assessed"), identifying "unassessed" (i.e., waters never before assessed by MassDEP) waters, conducting site visits, examining GIS datalayers (land-use information), reviewing the Massachusetts Stream Classification Program Inventory of Rivers and Streams, and reviewing NPDES and water withdrawal permits. Following these activities, the 2004 biomonitoring plan was more closely focused and the study objectives better defined.

The main objectives of biomonitoring in the French & Quinebaug River watershed were: (a) to determine the biological health of "unassessed" and "not assessed" rivers/streams within the watershed by conducting assessments based on biological (aquatic macroinvertebrates) communities; and (b) to identify problem stream segments so that efforts can be focused on developing or modifying NPDES and Water Management Act permits, stormwater management, and control of other nonpoint source pollution. Specific tasks were:

1. Conduct benthic macroinvertebrate sampling and habitat assessments at locations throughout the French & Quinebaug River watershed;

2. Based upon the macroinvertebrate data, identify river segments within the watershed with 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 and/or water quantity 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 2004 French & Quinebaug River watershed survey, including station identification number, upstream drainage, station description, and sampling date. Stations are listed hydrologically (from upstream-most drainage in the watershed to downstream-most).

Station ID	Upstream Drainage Area (mi^2)	French & Quinebaug River Watershed Station Description	Sampling Date
MO01	1.35	Mountain Brook, 100 m downstream from Rt. 20, Brimfield	25 Aug 2004
WS01	1.34	West Brook, 140 m upstream from confluence with Mill Brook, Brimfield	25 Aug 2004
W1183	5.92	Unnamed tributary to Mill Brook (locally known as "East Brook"), 5 m upstream from Rt. 20, Brimfield	25 Aug 2004
BR01	5.52	Browns Brook, 230 m upstream from May Brook Road, Holland	24 Aug 2004
ST01	4.32	Stevens Brook, 200 m upstream from Mashapaug Road, Holland	24 Aug 2004
LE01	2.47	Leadmine Brook, 600 m upstream from Rt. 84, near vacant Rt. 15 rest area, Sturbridge	24 Aug 2004
HA01	2.54	Hamant Brook, 100 m downstream from sandpit access road off Shattuck Road, Sturbridge	24 Aug 2004
HC01	3.58	Hatchet Brook, 100 m upstream from South Street, Southbridge	25 Aug 2004
MK01	8.11	McKinstry Brook, 140 m upstream from Pleasant Street, Southbridge	25 Aug 2004
CO01	4.09	Cohasse Brook, 175 m upstream from Cisco Street, Southbridge	26 Aug 2004
LB01	9.73	Lebanon Brook, 550 m upstream from Ashland Avenue, Southbridge	26 Aug 2004
W1186	8.07	Unnamed tributary to Quinebaug River (locally known as "Keenan Brook"), 550 m upstream from confluence with Quinebaug River, Southbridge	26 Aug 2004
TU01	2.40	Tufts Branch, 30 m upstream from Rt. 197, Dudley	26 Aug 2004
RB01	4.58	Rocky Brook, 100 m downstream from Midstate Trail footpath, off High Street, Douglas	27 Aug 2004
BU01	3.82	Burncoat Brook, 350 m upstream from confluence with Town Meadow Brook, Leicester	3 Sept 2004
GR01	2.82	Grindstone Brook, 170 m downstream from Rt. 56, Leicester	27 Aug 2004
FR04-1	15.67	French River, 300 m downstream from Clara Barton Road, Oxford	30 Aug 2004
LR01	10.43	Little River, 20 m upstream from Turner Road, Charlton	30 Aug 2004
W1197	13.89	Unnamed tributary to South Fork (locally known as "Potters Brook"), 150 m downstream from Potter Village Road, Charlton	26 Aug 2004
SU01	2.46	Sucker Brook, 100 m downstream from Kingsbury Road, Webster	27 Aug 2004
MI01	1.03	Mine Brook, 140 m downstream from Mine Brook Road, Webster	27 Aug 2004
BW01	1.20	Browns Brook, 130 m upstream from Gore Road, Webster	29 Aug 2004

2004 FRENCH & QUINEBAUG RIVER WATERSHED BIOMONITORING STATIONS

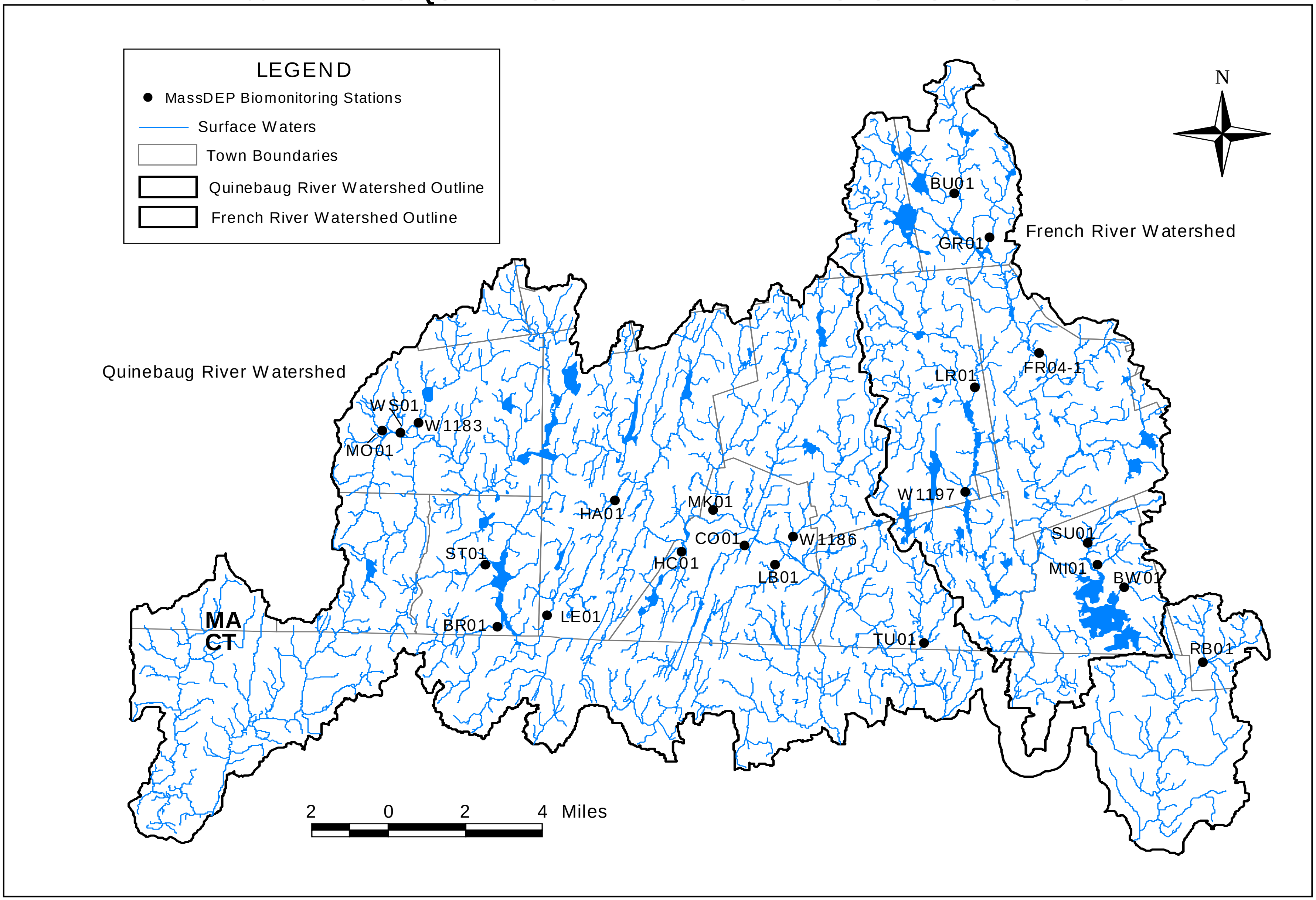

Figure 1. Location of MassDEP/DWM biomonitoring stations for the 2004 French & Quinebaug River watershed survey.

WATERSHED DESCRIPTION

The Quinebaug River subwatershed covers 744 square miles in south central Massachusetts, eastern Connecticut, and northwestern Rhode Island. The Quinebaug River flows 76 miles from its source in Mashapaug Pond in Union, Connecticut to its confluence with the Shetucket River in Norwich, Connecticut, forming the Thames River. Of the Quinebaug's 76 miles, 28 lie in Massachusetts and drain an area of 148 square miles. Major tributaries are Cady Brook in Massachusetts and the French, Five Mile, Moosup, and Pachaug rivers in Connecticut. Of these, the French River is the largest, extending 26 miles from its source in Greenville Pond, Leicester, Massachusetts to the confluence with the Quinebaug River in Thompson, Connecticut.

From its source in Mashapaug Pond, the Quinebaug River flows a short distance to Hamilton Reservoir, which lies on the Connecticut-Massachusetts state line. Leaving this reservoir in Holland, Massachusetts, the river flows north to Sturbridge, where it passes through Old Sturbridge Village. Upon leaving Sturbridge, the river turns southeast towards Southbridge, where it is joined by Cady Brook, Dresser Hill Brook, and Lebanon Brook, and flows on through Dudley to recross the state line. After the French River enters in Thompson, Connecticut, the Quinebaug flows generally south through Putnam, Danielson, and Plainfield to its confluence with the Shetucket River in Norwich. This confluence forms the Thames River which continues south to Long Island Sound.

The Sturbridge and Southbridge wastewater treatment plants discharge their effluent to the Quinebaug River in Massachusetts. Additional wastes are discharged to Cady Brook in Charlton by the town's wastewater treatment plant. The U.S. Geological Survey maintains three streamflow gaging stations on the Quinebaug River, two of which are located just downstream from the East Brimfield and Westville dams. The East Brimfield gage receives flow from an area 67.5 square miles, while the Westville gage measures a drainage area of 99.1 square miles.

The French River subwatershed totals 132 square miles, 93 of which lie within the Commonwealth. The French River is a major tributary of the Quinebaug River and extends 26 miles from its source in Greenville Pond, Leicester, to its confluence with the Quinebaug River in Thompson, Connecticut. From its headwater stream of Town Meadow Brook, the French River flows generally south throughout its length through Oxford, Dudley, and Webster to Thompson, Connecticut. Webster Lake, one of the largest natural lakes in the state, drains to the French River via Mill Brook in Webster. Other tributaries discharging to the French River are generally small and include Burncoat, Bartons, and Grindstone brooks in Leicester; the Little River in Oxford; Potash Brook in Webster; and Backwater and Sunset Hill brooks in Thompson, Connecticut.

The Leicester, Oxford-Rochdale, and Webster-Dudley wastewater treatment plants discharge their treated effluent to the French River. The U.S. Geological Survey maintains two streamflow gaging stations on the French River. One gage, located in downtown Webster, measures flow from an area of 85.3 square miles. A second gage, located at the Hodges Village Army Corps Dam, records drainage from an area of 31.0 square miles.

METHODS

Macroinvertebrate Sampling

The macroinvertebrate sampling procedures employed during the 2004 French & Quinebaug River watershed biomonitoring survey 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 (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 2004). 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 2004 French & Quinebaug River watershed biomonitoring samples are described in the standard operating procedures (Nuzzo 2003) and were conducted in accordance with the Quality Assurance Project Plan (QAPP) for benthic macroinvertebrate biomonitoring (MassDEP 2004). 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 2004 French & Quinebaug 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 a 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 matter (FPOM) levels are high.

7. Community Similarity (Reference Site Affinity)—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 French & Quinebaug 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 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 2004 French & Quinebaug River watershed biosurveys, habitat qualities were assessed and 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 2004). 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 2003).

RESULTS AND DISCUSSION

The biological and habitat data collected at each sampling station during the 2004 biomonitoring survey are attached as an Appendix (Tables A1 – A5). 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.

Summary tables of the macroinvertebrate data analysis, including biological metric calculations, metric scores, and impairment designations, are also included in the Appendix. Table A2 summarizes all Quinebaug River subwatershed biomonitoring station comparisons to the watershed reference station in Browns Brook (BR01). Table A3 is the summary table for all stations in the French River subwatershed when compared to BR01. Table A4 shows comparisons of large-stream biomonitoring stations to LB01, which drains a considerably larger area than BR01. Habitat assessment scores for each station are also included in the summary tables, while a more detailed summary of habitat parameters is shown in Table A5.

According to USGS stream discharge data, surface water runoff for the majority of south-central Massachusetts, and including the French & Quinebaug River watershed, was within normal monthly ranges for May through August 2004 (USGS 2006). The exception was a small portion of the watershed encompassing parts of northeastern Brimfield (none of the biomonitoring stations were located within this portion of the watershed) that experienced below normal surface water runoff in May. Surface water runoff was above normal throughout the watershed for the month of September.

DWM's 2004 biological sampling targeted tributaries of the French & Quinebaug River watershed, as MassDEP has historically focused its monitoring efforts on mainstem stations. The 2004 biomonitoring data generally indicate various degrees of nonpoint source-related problems in many of the streams examined. Urban runoff, habitat degradation, and other forms of NPS pollution compromise water quality and biological integrity throughout the watershed—most notably in portions of East, Cohasse, Rocky, Burncoat, Sucker, Mine, and Browns (Webster) brooks, as well as in the Little River. That said, several tributaries examined in the French & Quinebaug River watershed 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 in these unimpaired waterbodies.

Quinebaug River Subwatershed

BR01—Browns Brook, 230 m upstream from May Brook Road, Holland, MA

Browns Brook is a third order stream that originates in Nipmuck State Forest in Union, Connecticut. The stream flows in a northerly direction, receiving the drainage of May Brook near the Massachusetts-Connecticut border. From its confluence with May Brook, the stream heads east before reaching Hamilton Reservoir in Holland. The majority of the Browns Brook subwatershed is heavily forested, undeveloped, and inaccessible. The total watershed drainage area upstream from the BR01 biomonitoring station is 5.52 square miles.

Habitat

The BR01 sampling reach began approximately 230 m upstream from May Brook Road near the inlet to Hamilton Reservoir. The forested nature of this portion of the watershed resulted in almost complete (90% canopy cover) shading of the reach. The stream was 10 m wide and with depths of 0.20 m in the riffle and run areas and about half a meter in the pools. A variety of rocky substrates subjected to varying flow regimes provided macroinvertebrates with excellent epifaunal habitat. Fish habitat was also considered optimal, with boulder, submerged logs and other woody debris, and deep pool areas providing ample stable cover and refugia. Channel flow status was considered slightly less than optimal, though water filled >70% of the channel and left a minimal amount of substrate exposed. Aquatic vegetation and algal coverage were minimal, comprised of instream mosses and thin-film periphyton on the rocks in both riffle and pool areas. Both streambanks were well vegetated with ferns and mosses which dominated the hemlock (*Tsuga canadensis*) understory along both sides of the channel. The hemlock forest provided a wide riparian vegetative zone along the right (south) bank, while the adjacent unpaved road near the left (north) bank reduced the riparian buffer somewhat along that side of the channel. In addition, the steepness of the streambank between the road and the left bank resulted in a few small areas of erosion that offered a potential avenue for NPS inputs (e.g., sediment inputs). Bank stability along the right bank was considered optimal due in part to the large boulders and bedrock ledge occupying the margin of the stream.

BR01 received a total habitat assessment score of 173/200 (Table A5). This was the designated watershed reference station for all biomonitoring stations in the 2004 survey by virtue of its overall excellent instream and riparian habitat quality, good water quality (MassDEP 2006), minimal nonpoint source pollution inputs, and relatively benign upstream and adjacent land-use impacts (e.g., absence of point source inputs, lack of channelization, minimal development and agricultural activity nearby, undisturbed and well vegetated riparian zone).

Benthos

Because BR01 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 Taxa Richness and EPT Index—parameters that measure components of community structure and display low inherent variability (Resh 1988)—scored well and corroborate the designation as a reference station. The Percent Dominant Taxon

(15%) metric also performed extremely well relative to other stations in the survey, indicating good overall balance in the BR01 benthic community. BR01 received a total metric score of 42 out of a possible 42 (Table A2).

MO01—Mountain Brook, 100 m downstream from Rt. 20, Brimfield, MA

A small second order stream, Mountain Brook originates in an undeveloped and densely forested portion of Brimfield. The high-gradient stream flows in a southerly direction along West Mountain before reaching the low-lying floodplain near Rt. 20 and emptying into an unnamed impoundment (along with Charles, Hollow, and West brooks) that forms the headwaters of Mill Brook. The total watershed area upstream from MO01 is 1.35 square miles. Virtually the entire drainage area is undeveloped and forested, with the exception of the Rt. 20 corridor and adjacent land occupied by the Brimfield Fairgrounds.

Habitat

MO01 began approximately 100 m downstream from Rt. 20 in a wooded area—oaks (*Quercus* spp.), maples, (*Acer* spp.) and white pine (*Pinus strobus*) completely shaded the sampling reach. The stream was small here, with a width of only about a meter and depths ranging from 0.10 m in the riffles to 0.30 m in the few isolated pools. The shallow nature of the reach—the channel was only about 75% full of water—resulted in minimal fish cover and unavailable (exposed) habitat. Riffle areas contained a good mix of rocky substrates; however, the lack of depth resulted in suboptimal epifaunal habitat for macroinvertebrates. Instream aquatic vegetation consisted of mosses and submergent macrophytes—most notably, water starwort *(Callitriche* sp.), watercress (*Nasturtium* sp.), and bur-reed (*Sparganium* sp.). Algae were not observed. Both stream- banks were well vegetated and stabilized with boulders. Shrubs (blueberry, *Vaccinium* sp.; alder, *Alnus* sp.) and ferns thrived along both banks before giving way to a dense stand of hardwoods and pine. The riparian zone was undisturbed and offered a good buffer from potential NPS inputs that might be associated with the extensive lawns of the fairgrounds. And while the upstream road crossing was a potential source of NPS pollution, instream sedimentation and other signs of runoff were absent in the MO01 reach.

MO01 received a total habitat assessment score of 156/200 (Table A5). Habitat parameters suffered mainly from low baseflow here, which appears to be naturally occurring. Flow-related habitat constraints probably impact the resident fish community more than the macroinvertebrate community in this portion of Mountain Brook.

Benthos

The MO01 benthos assemblage received a total metric score of 28, representing 67% comparability to the reference community at BR01 and resulting in an assessment of “slightly impacted” for biological condition (Table A2). Total Taxa Richness (26; score=6) was comparable to reference conditions. And while the low-scoring EPT Index indicates a reduction of some of the more pollution sensitive insect orders among the MO01 assemblage, the high scoring Biotic Index suggests that impairment here is not the result of organic pollution. Indeed, water quality data collected here by MassDEP/DWM corroborate the overall good water quality in this portion of the stream (MassDEP 2006).

Seasonal low flow conditions are probably an important determinant of benthic community composition in Mountain Brook. It is possible that flow-related habitat limitations have resulted in the displacement of EPT taxa—which are highly vulnerable to the effects (e.g., stranding; drift-induced dispersal) of decreasing stream discharge (Minshall 1984)—by a diverse group of taxa more tolerant of these instream conditions.

WS01—West Brook, 140 m upstream from the confluence with Mill Brook, Brimfield, MA

A small second order stream, West Brook originates just east of Mountain Brook’s source waters. The stream immediately crosses Warren Road in Brimfield, heading in a southerly direction that parallels the road for several kilometers. This portion of the subwatershed is relatively undeveloped and forested;

however, as the stream approaches the Mill Brook floodplain and the Rt. 20 corridor, the landscape becomes occupied with small farms and property associated with the Brimfield Fairgrounds. West Brook loses virtually all its gradient just south of a series of small impoundments and farm ponds in the vicinity of Rt. 20—the stream meanders through "wetted" forest and wetlands for the last 0.75 km of its course before making its confluence with Mill Brook. The total watershed area upstream from WS01 is 1.34 square miles.

Habitat

The WS01 sampling reach began a short distance (140 m) upstream from its mouth, in a maple forest bordered on both sides by fairground property. Trees shaded approximately 70% (i.e., 70% canopy cover) of the small 2 m wide stream. The reach was uniformly shallow (0.20 m) in the limited riffle/run areas, while pools reached depths of about 0.40 m. Gravel and pebble dominated the epifaunal substrates, and coupled with the shallow nature of the stream, offered only marginal habitat for macroinvertebrates. Fish habitat was only slightly better—snags and other woody debris provided stable cover in the deepest pool areas, but were unavailable (i.e., exposed) throughout much of the sampling reach due to the marginal (channel only about half full) channel flow status. Instream vegetation and algal cover were absent. Instream sediment deposition was fairly substantial, with moderate deposition affecting almost half the reach and resulting in shifting bars and embedded substrates. It was unclear whether sand deposits resulted from the naturally sandy floodplain soils in this portion of the subwatershed or were of anthropogenic origins (e.g., the upstream road crossing). The sandy banks along both sides of the channel showed signs of instability, with small areas of erosion observed in 30% of the reach. Both banks were well vegetated with typical floodplain vegetation, especially ferns and skunk cabbage (*Symplocarpus foetidus*). Riparian vegetation was dominated by red maple (*Acer rubrum*) and extended undisturbed from the right (west) bank, while a 15 m buffer existed between the left (east) bank and the adjacent lawns of the fairgrounds.

WS01 received a total habitat assessment score of 125/200 (Table A5). This was evaluated as the poorest habitat in the entire 2004 French & Quinebaug River watershed survey. The combination of instream sedimentation (and associated substrate embeddedness) and marginal channel flow status affected the total score most negatively.

Benthos

The macroinvertebrate community at WS01 received a total metric score of 30, representing 71% comparability to the reference station and resulting in a biological assessment of "slightly impacted" (Table A2). Affecting the total metric score most was the Percent Dominant Taxon value, a result of the hyperdominance of a single taxon among the WS01 benthos assemblage. Particularly abundant (n=41) was the net-spinning philopotamid caddisfly, *Chimarra* sp., which relies on suspended forms of fine organic particulates as a food resource. It is likely that the series of impoundments located just upstream from Rt. 20 provide an ample supply of FPOM to the downstream filter-feeding communities of West Brook. Suspended FPOM is not the only important food resource at WS01, however, as the presence of numerous (especially Elmidae) scraping taxa (Scrapers/Filterers metric score=6) in the WS01 sample indicates the presence of a periphyton-based feeding guild here as well.

While organic inputs appear to have some influence on macroinvertebrate community structure at WS01, water quality data collected here by DWM did not indicate serious organic enrichment. Dissolved oxygen levels were well within surface water quality standards during the 2004 water quality monitoring surveys, and other physicochemical parameters appeared normal (MassDEP 2006). Rather, it is most likely habitat quality—in particular, sediment deposition and/or low baseflow—that is most limiting to aquatic health in this portion of Mountain Brook.

W1183—East Brook, 5 m upstream from Rt. 20, Brimfield, MA

East Brook is a third order stream that originates near the northern end of Chamberlin Mountain in the northeastern corner of Brimfield. The stream flows in a southwesterly direction, receiving discharge contributions from Sessions Brook before flowing into Sherman Pond. Exiting the pond, the stream loses much of its gradient as it continues south and parallel to Brookfield Road. Immediately after crossing Rt. 20, the stream enters a large wetland before making its confluence with the headwaters of Mill Brook. Though technically an unnamed tributary from Sherman Pond to Mill Brook, it remains locally referred to as “East Brook” along this course. The East Brook subwatershed is largely forested and undeveloped upgradient from Sherman Pond, while numerous small farms (agriculture, livestock, and horses) and light residential development (several homes along Brookfield Road have stream-abutting lawns) begin to occupy the East Brook floodplain from Sherman Pond to Mill Brook. Total drainage area upstream from the East Brook biomonitoring station is 5.92 square miles.

Habitat

W1183 began almost immediately (about 5 m) upstream from Rt. 20 and ended at a small wooden footbridge near the center of Brimfield. The stream was run-dominated, with a few short riffles (0.20 m deep) at both the bottom and top of the reach where the majority of the “kicking” was concentrated. Though rocky substrates were numerous throughout the sampling reach, their small size coupled with the predominantly laminar flow resulted in less than optimal benthos habitat. Fish habitat was also less than desirable, due to a lack of stable cover other than a few boulders at the top of the reach and overhanging shrubs along the stream margins. Both epifaunal and fish habitat were further compromised by instream deposits of sand that affected about half the reach. Additionally, deposition of fine organic matter was noted in the slow water areas and along the stream margins. Overall stream width was approximately 3.5 m, while runs and pools—the dominant flow regimes—were uniformly deep (0.40 m), reflecting the optimal channel flow status here. Bank and riparian vegetation were dominated by shrubs and herbaceous cover—the lack of trees resulted in only about a 40% canopy cover. Instream aquatic vegetation covered approximately 5% of the reach and was comprised mainly of submergent macrophytes (bur-reed, *Sparganium* sp.; water starwort, *Callitriche* sp.; coontail, *Ceratophyllum* sp.) and some mosses. Algal coverage was quite extensive, with thin films of brown algae and green mats covering the rocky substrates in about half the reach.

Both streambanks were well vegetated and stabilized with a profusion of shrubs, vines, and herbaceous growth—most notably grasses, purple loosestrife (*Lythrum salicaria*), jewelweed (*Impatiens capensis*), riverbank grape (*Vitis riparia*), and rose (*Rosa* sp.). The riparian zone was uniformly narrow along both sides of the channel, providing only a 6 m buffer from adjacent lawns.

The W1183 sampling reach received a total habitat assessment score of 137/200 (Table A5). Fish and macroinvertebrate habitat were most notably impacted by sedimentation effects, especially the filling in of pools and substrate embeddedness caused by both inorganic and organic deposition. It is not clear where these sediment inputs originate or if they are naturally occuring; however, instream impacts from overland sources may be exacerbated by the reduced riparian buffer in this portion of the stream.

Benthos

The W1183 macroinvertebrate assemblage received a total metric score of 16, respresenting 38% comparability to the reference community and resulting in an assessment of “moderately impacted” for biological condition (Table A2). Affecting the score most notably was a sharp reduction in EPT taxa. In addition, an elevated Biotic Index (4.92—the highest in the entire French & Quinebaug biomonitoring survey) coupled with a low Scrapers/Filterers metric value (filter-feeders, especially the netspinning caddisfly Hydropsychidae, dominated the assemblage) are indicative of water quality impairment related to organic enrichment in this portion of East Brook. Indeed, low dissolved oxygen levels—often associated with organic pollution—were documented by DWM during summer water quality monitoring surveys. Both dissolved oxygen (range 3.6 – 4.4 mg/L) and percent DO saturation (range 40 – 47%) measurements consistently violated surface water quality standards here from June through September 2004 (MassDEP 2006). Consistently elevated fecal coliform bacteria levels (range 280 – 2200 cfu/100mL) measured by DWM from May through September 2004 corroborate the poor water quality documented in this portion of East Brook (MassDEP 2006).

Organic (and possibly nutrient loads) inputs that appear to shape community structure and function in the W1183 benthic community appear to originate from NPS pollution in the East Brook subwatershed. Runoff from upstream agriculture, lawns, and other unknown sources, as well as impoundment effects arising from the heavily developed Sherman Pond, all potentially contribute to the degraded water quality and impaired biota observed in this portion of the stream. In addition, habitat degradation—especially sediment deposition and substrate embeddedness—probably contributes to the biological impairment at W1183. Sand and other fine sediments drastically reduce macroinvertebrate microhabitat by filling the interstitial spaces of epifaunal substrates. Sediment deposits at W1183 may contribute to the displacement of EPT taxa—which are highly vulnerable to sedimentation (Minshall 1984)—by taxa more tolerant of these instream conditions. In addition, the filling of pools with sediment reduces fish cover and may be detrimental to fish egg incubation and survival.

ST01—Stevens Brook, 200 m upstream from Mashapaug Road, Holland, MA

Stevens Brook is a small second order stream that begins near the north slope of Burley Hill in the northeastern corner of Stafford, Connecticut. The stream flows in a northeasterly direction, running parallel to Stafford Road and through an area of wetland and dense forest. After crossing Stafford Road a final time, Stevens Brook veers east and continues for approximately a mile through extensive forest before entering Hamilton Reservoir on its western shore. The Stevens Brook subwatershed is very sparsely populated and drains an area of 4.32 square miles upstream from ST01.

Habitat

The ST01 sampling reach began in a high-gradient portion of the stream approximately 200 m upstream from its mouth and Mashapoag Road in Holland. Dense hemlock forest on both sides of the channel resulted in almost complete (93% canopy cover) shading of the sampling reach. The stream was approximately 3.5 m wide and with fast riffle/run areas of uniform depth (0.25 m); The two large pools present were slightly deeper (0.40 m). Steep gradient and an abundance of rocky substrates of varying size resulted in well developed riffle areas that offered excellent epifaunal habitat for macroinvertebrates. Instream mosses provided additional benthic microhabitat in about 40% of the reach. Fish habitat was also optimal; massive boulders, submerged logs, and other woody debris providing stable cover throughout the reach. Aquatic vegetation other than mosses was not observed and algal growth was comprised of minimal cover of thin green films on the rocky substrates of both riffle and pool areas.

Both streambanks along the ST01 sampling reach were well vegetated with herbaceous growth (mainly ferns and mosses) and boulders provided good bank stability. Riparian vegetation provided an unlimited vegetated buffer along both banks in the form of a vast hemlock forest (*Tsuga canadensis*). Understory vegetation was quite sparse as is typical among hemlocks. There were no signs of NPS pollution, and the only potential sources considered were the numerous upgradient stream crossings of Stafford Road.

ST01 received a total habitat assessment score of 184/200, which was the third highest score in the entire 2004 French & Quinebaug River watershed biomonitoring survey (Table A5). The only habitat parameter to score outside the optimal category was channel flow status, which was considered suboptimal. Nevertheless, water filled greater than 75% of the available channel and left only minimal amounts of exposed substrates, mainly along the margins of the stream.

Benthos

The ST01 benthos received a total metric score of 38, representing 90% comparability to the reference community at BR01 and resulting in a bioassessment of “non-impacted” (Table A2). With the exception of the reference station, this was the highest scoring suite of metrics received by a benthic community during the 2004 biosurveys. Several metrics—including Taxa Richness, EPT Index, Biotic Index, and Scrapers/Filterers—outperformed not only the reference station, but also all other biomonitoring stations in the 2004 survey (Table A2). These metric values all point towards a diverse and healthy macroinvertebrate community dominated by highly sensitive taxa occupying numerous feeding guilds. In terms of community composition, ST01 displayed the highest affinity (i.e., most similar) to the reference assemblage of all the biomonitoring stations in the 2004 survey, as evidenced by a Reference Affinity metric value of 87%.

LE01—Leadmine Brook, 600 m upstream from Rt. 84, Sturbridge, MA

Leadmine Brook originates near Leadmine Mountain in Sturbridge. The small second order stream flows in a southwesterly direction into Leadmine Pond. Upon leaving the pond the stream continues south, running parallel to Interstate 84 and receiving the discharge of a small, unnamed tributary and associated wetlands. Immediately after crossing the highway and the Massachusetts-Connecticut border, Leadmine Brook flows into a small impoundment that drains into Hamilton Reservoir near the village of Mashapaug, Connecticut. Total drainage contributions upstream from the LE01 biomonitoring station are 2.47 square miles.

Habitat

The LE01 sampling reach began approximately 600 m upstream from Interstate 84, and was accessed via an abandoned rest area (vacant paved lot) located along the southbound lane of Rt. 15 in Sturbridge. The reach was of fairly high gradient in a dense hemlock forest that provided a mostly closed (90% shaded) canopy over LE01. The stream was approximately 3 – 4 m wide and with depths ranging from 0.2 m in the riffle/runs to about half a meter in the pool areas. Cobble was the dominant epifaunal substrate, though there was a good variety of other rocky types as well, providing optimal benthic habitat for macroinvertebrates in the numerous riffle areas. Fish habitat was excellent, with large boulders, several submerged trees, and snag areas in deep pools offering ample stable cover. Channel flow status was optimal, with water easily reaching the base of both banks and leaving virtually no exposed substrates. There was an absence of aquatic vegetation with the exception of a few patches of mosses, while a thin film of green algae (periphyton) covered rocky substrates on about 5 – 10% of the stream bottom.

Streambank and riparian habitat parameters were all considered optimal. Both banks were stabilized with boulder, and ferns and mosses provided good vegetative protection along both sides of the channel. The riparian zone was wide and undisturbed along both banks. Riparian vegetation was dominated by hemlocks (*Tsuga canadensis*) and an occasional birch (*Betula* sp.), with an understory of ferns and mountain laurel (*Kalmia latifolia*). There were no indications of active NPS pollution; however, some trash associated with the vacant parking area was observed near the left (east) bank, though it appeared to be well buffered from the stream.

The LE01 biomonitoring station received a total habitat assessment score of 183/200 (Table A5). This was the fourth best habitat evaluation during the 2004 biosurveys, with all but one habitat parameter (Velocity-Depth Combinations—there were no deep riffles) rated as optimal.

Benthos

The LE01 macroinvertebrate community received a total metric score of 26, representing 62% comparability to the reference community and resulting in an assessment of “slightly impacted” for biological condition (Table A2). Most notable was a reduction in total Taxa Richness (score=2), including EPT taxa (EPT Index score=0), as well as an elevated Percent Dominant Taxon metric value (score=2). Interestingly, the genus responsible for the low scoring Percent Dominant Taxon metric was the scraper *Maccaffertium* sp. (n=31), a fairly pollution-sensitive (TV=3) mayfly that grazes on periphyton. As was noted above, thin film algae (i.e., periphyton) was indeed observed in the LE01 sampling reach and appears to be an important food resource for the LE01 biota, further corroborated by the high scoring Scrapers/Filterers metric value.

It is not clear why slight impairment was detected in the LE01 benthos assemblage. Habitat quality was excellent relative to other biomonitoring stations in the 2004 survey, and while this suggests water quality limits biological integrity in this portion of Leadmine Brook, physicochemical data collected by DWM appeared normal (MassDEP 2006). It is possible that extensive upstream wetlands, or Leadmine Pond, may influence water quality in ways not detected by DWM monitoring efforts at LE01.

HA01—Hamant Brook, 100 m downstream from access road to sand/gravel pit off Shattuck Road, Sturbridge, MA

Hamant Brook begins as a series of impoundments in the southeast corner of Sturbridge. The second order stream flows in a northeasterly direction, paralleling and crossing I-84 along its course towards the impounded portion of the Quinebaug River known as Westville Lake. The Hamant Brook subwatershed lacks residential and commercial development; however, numerous sand/gravel operations are located along the stream's course. Additionally, Hamant Brook never veers more than half a kilometer from the highway. Total watershed area upstream from HA01 is 2.54 square miles.

Habitat

HA01 began approximately 100 m downstream from a semi-paved sandpit access road located just off Shattuck Road in Sturbridge. The sampling reach was in a forested portion of the watershed immediately upstream from a small, unnamed impoundment. The dense, maple dominated forest provided a mostly closed (95% shaded) canopy above the stream, which was approximately 3 m wide and ranged in depth from 0.20 – 0.30 m in the riffle/runs to about half a meter in the deepest pools. The reach contained a variety (shallow and deep pools/riffles) of flow regimes containing a mix of rocky substrates that provided optimal epifaunal habitat for macroinvertebrates. Fish habitat was also excellent due to large boulders, submerged logs and other woody debris, and good pool depth throughout the sampling reach. Instream vegetation was limited to aquatic mosses, while algal cover was considered minimal. Channel flow status was optimal, with water reaching the base of both banks. The adjacent sand pit was a potential source of NPS pollution, and while instream sediment deposition (and embeddedness) was minimal, moderate turbidity (the highest degree of turbidity observed during the 2004 biomonitoring survey) observed in the water column appeared to be the result of suspended, "whitish" particulates.

Both streambanks were well vegetated with ferns and common greenbrier (*Smilax rotundifolia*) but were moderately unstable, especially in the lower half of the reach where steep, eroding streambanks were noted. Riparian vegetation consisted mainly of maples (*Acer* sp.) and some hemlock (*Tsuga canadensis*), while a fern understory extended undisturbed from both banks.

HA01 received a total habitat assessment score of 174/200 (Table A5). Bank instability, which was confined to the bottom of the reach and was especially noticeable along the left (west) bank, was the only habitat parameter that scored less than optimal. Habitat rated slightly higher here than at the watershed reference station.

Benthos

Despite habitat highly comparable to the reference station, the HA01 benthos assemblage received a total metric score of only 22, which represented 52% comparability to the reference and placed the macroinvertebrate community in the "slightly impacted" assessment category (Table A2). The reduction of EPT taxa, as well as a virtual absence of scraping taxa, affected the total metric score most negatively. The lack of scrapers in the HA01 assemblage may be of particular significance, as these are generally considered intolerant taxa whose removal suggests an absence of periphyton as a food resource in this segment of Hamant Brook. While the shaded nature of this portion of the stream may hinder the growth of thin-film algae (i.e., periphyton) favored by scraping taxa, it is possible that suppression of periphyton growth (and associated grazers) is exacerbated by the high levels of instream turbidity—and subsequently reduced sunlight penetration—observed during the 2004 biosurvey here. Indeed, not only was turbidity observed here during both the DWM biosurvey and summer water quality surveys, physicochemical measurements taken by DWM during multiple water quality surveys consistently documented high conductance and high levels of total dissolved solids (MassDEP 2006). Specific sources of water quality degradation at HA01 are unknown; however, inorganic particulate loads associated with runoff from minimally buffered upstream sand/gravel pits and/or I-84 should receive strong consideration.

HC01—Hatchet Brook, 100 m upstream from South Street, Southbridge, MA

Hatchet Brook originates in Hatchet Pond just south of the Connecticut border. From the outlet of Hatchet Pond, the small second order stream flows in a northeasterly direction and soon enters Massachusetts. It continues north, entering the first of a series of public water supplies (No. 5, No. 4, and No. 3 reservoirs), before receiving the discharge contributions of a small unnamed tributary. From this confluence, Hatchet Brook continues northward for approximately 1 km before joining the Quinebaug River in Southbridge. The majority of the Hatchet Brook subwatershed is comprised of undeveloped forest surrounding the public water supplies, with some light residential development confined to the Westville section of Southbridge in the lower portion of the watershed. The total drainage area contributing to HC01 is approximately 3.58 square miles.

Habitat

The HC01 sampling reach began approximately 100 m upstream from South Street and immediately upstream from the ruins of an old stone wall/dam that had been breached. A dense forest dominated by maples shaded the majority (90% canopy cover) of the stream. The 3 m wide reach was of very high gradient, and as a result was completely riffle dominated ("plunge" pools were located immediately above and below the reach). Despite uniformly shallow (0.20 – 0.30 m) water and only marginal (75% of channel full) channel flow status throughout the reach, boulder and large cobbles subjected to the swift current velocity provided excellent epifaunal habitat for macroinvertebrates. Fish habitat was also optimal, with boulders and submerged logs offering stable cover.

Both streambanks were well vegetated with shrubs (alder, *Alnus* sp.) and herbaceous growth (ferns and grasses). Stability was provided by large boulders along both banks, although small areas of bank erosion were observed in approximately 20% of the reach. The riparian zone along both sides of the stream channel was wide and undisturbed as a result of the dense surrounding maple (*Acer rubrum*) forest. There were no indications of localized NPS pollution, nor were potential sources noted. The HC01 biomonitoring station received a total habitat assessment score of 166/200 (Table A5). Habitat was most compromised by the reduced baseflow, which resulted in a lack of deep water and some areas of exposed streambed along the margins of the channel.

Benthos

The HC01 benthos assemblage received a total metric score of 36, representing 86% comparability to the reference community and resulting in a biological assessment of "non-impacted" (Table A2). The community was well-balanced and dominated by intolerant organisms, especially EPT taxa. The abundance of sensitive taxa contributed to the second lowest Biotic Index (2.86) in the entire survey. Only the Scrapers/Filterers metric scored poorly (score=2), the result of numerous (n=21) filter-feeding hydropsychid caddisflies (Table A1). Individual hydropsychid densities were not high enough to negatively affect the Percent Dominant Taxon metric, however, as it received the highest possible score. It appears, then, that upstream impoundments may provide a source of FPOM for filter-feeders at HC01, but not at levels high enough to skew their abundance towards hyperdominance or indicate organic enrichment.

MK01—McKinstry Brook, 140 m upstream from Pleasant Street, Southbridge, MA

McKinstry Brook is formed at the merger of two small tributaries that originate at the base of Wheelock and Doane hills in Charlton. From here, the second order stream flows southward through vast areas of undeveloped forest and wetland before crossing Interstate 90. Just south of I-90, McKinstry Brook receives discharge contributions from tributaries draining the Massachusetts Turnpike-Charlton rest area and Heritage Country Club golf course, respectively. As the stream continues in a southerly direction, land-use becomes increasingly developed. Southbridge Municipal Airport and downtown Southbridge occupy much of the drainage area in the lower portion of the McKinstry Brook subwatershed. McKinstry Brook makes its confluence with the Quinebaug River in an area of dense residential, industrial, and commercial development on the north side of Southbridge center. MK01 receives 8.11 square miles of upstream drainage contributions.

Habitat

The MK01 sampling reach began approximately 140 m upstream from Pleasant Street in a residential area near downtown Southbridge. The reach was severely channelized, with old stone walls along both banks. The stream was somewhat run/pool dominated, with short riffles interspersed along its length before ending immediately downstream from a large beaver dam and pond. Canopy cover to the reach was about 70% and mainly provided by trees in a dense forest along the right (west) bank. Stream width was approximately 3 m and depth ranged from 0.20 m in the riffles to 0.50 m in the deepest run/pool areas. Boulders and submerged trees provided fish with optimal instream cover, while epifaunal habitat was slightly less than optimal due to the short length of most riffles. Dense beds of mosses covered about 40% of the stream bottom, which was dominated by pebble, cobble, and boulder substrates. Brown-colored algal film, which was prolific throughout the reach and was estimated at 70% coverage, grew on rocks, submerged wood, and mosses in both riffle and pool areas. Channel flow status was considered suboptimal—water filled >75% of the channel and left only minimal amounts of substrates exposed. The water column was observed to be slightly turbid.

Both streambanks were well vegetated with vines (riverbank grape, *Vitis riparia*) and herbaceous growth (especially stinging nettles, *Urtica dioica*), and stability was optimal due to the stone walls. The riparian zone was dominated by various deciduous trees (white ash, *Fraxinus americana*; maple, *Acer* sp.; cherry, *Prunus* sp.) and extended undisturbed along the left (west) bank. Riparian vegetative zone width was reduced along the right (east) bank due to encroaching lawns, gardens, and yard waste associated with several adjacent homes. In addition to potential NPS pollution inputs originating from these poorly buffered residences, some trash—including an abandoned snowmobile—was observed near the top of the MK01 sampling reach. MK01 received a total habitat assessment score of 150/200 (Table A5). The severely altered stream channel affected the habitat score most negatively.

Benthos

The MK01 macroinvertebrate community received a total metric score of 26, representing 62% comparability to the reference community and resulting in a bioassessment of “slightly impacted” (Table A2). Scrapers/Filterers and Percent Dominant Taxon metrics performed particularly poorly (scorer=0) for the MK01 benthos assemblage, the result of a hyperdominance of filter-feeding taxa—most notably the net-spinning caddisfly *Chimarra obscura*, which comprised nearly half the sample (Table A1).

Water quality impacts related to organic enrichment appear to influence benthic community composition and trophic structure at MK01. Water quality data collected by DWM documented consistently elevated fecal coliform bacteria levels, high conductance, and high TDS levels, which further corroborate water quality degradation in this portion of McKinstry Brook (MassDEP 2006). While extensive wetlands in the upper reaches of the McKinstry Brook subwatershed may offer organic inputs in the form of allochthonous materials, the beaver pond immediately upstream from the MK01 sampling reach should be considered as a potential source of organic loads as well. Beaver activity may also potentially contribute nutrient and bacteria loads to MK01 as evidenced by the luxuriant algal community and elevated fecal coliform levels documented here. Other sources of localized (adjacent lawns and roads) and/or upstream (golf course, I-90, municipal airport) NPS pollution runoff may influence water quality and biological integrity at MK01 as well.

CO01—Cohasse Brook, 175 m upstream from Cisco Street, Southbridge, MA

Cohasse Brook is a first order stream that originates in a large wetland in Woodstock, Connecticut. Flowing in a northerly direction, the stream becomes impounded to form Cohasse Reservoir—a public water supply—just north of the Connecticut-Massachusetts border. Leaving the reservoir, the stream continues north towards Wells Pond and downtown Southbridge. Cohasse Brook is culverted underground for a short distance in the vicinity of Route 198 before finally emerging immediately upstream from Oak Ridge Cemetery. From here, the stream continues in a northeasterly direction through downtown Southbridge before making its confluence with the Quinebaug River just opposite the now-defunct American Optical Corporation. The total watershed area upstream from station CO01 is approximately 4.09 square miles.

Habitat

The CO01 sampling reach began approximately 100 m downstream from a small footbridge in Oak Ridge Cemetery near downtown Southbridge. A deciduous forest along the southeastern side of the stream provided 65% canopy cover over the CO01 reach. Trees were sparse along the left (west) bank due to the adjacent cemetery property. The channel was approximately 3 m wide and contained numerous shallow (0.10 m) riffles and one large pool near the top of the sampling reach. Cobble substrates provided optimal epifaunal habitat for macroinvertebrates in most of the riffle areas; however, severe sediment deposition compromised habitat quality in much of the reach. Sediment deposits appeared to be inorganic and constantly shifting, with much bar build-up in the pools and slower run areas. Sedimentation also resulted in considerable embeddedness of rock substrates—cobbles and pebbles were greater than 50% surrounded by fine sediments. Aquatic mosses covered approximately 35% of the stream bottom and provided additional microhabitat for benthos, while macrophyte and algal growth were not observed. Fish cover was suboptimal—large boulders were the primary habitat but only in about 40% of the reach. And while the pool area near the top of the reach appeared to be unstable and filling in with silt, several salmonid fish were observed during the biosurvey. Channel flow status was suboptimal—water filled slightly more than 75% of the available channel and left a few exposed cobble areas along the margins of the stream. The water column was surprisingly clear given the urbanized surroundings.

Bank and riparian parameters scored well for the right (east) bank due to a stable and undisturbed layer of streambank vegetation (jewelweed, *Impatiens capensis*; false bamboo, *Polygonum cuspidatum*; greenbrier, *Smilax rotundifolia*) that gave way to hardwood forest (oak, *Quercus* sp.; maple, *Acer* sp.). A manicured lawn provided a very narrow and poorly buffered riparian zone along the left (west) bank that appeared susceptible to bank erosion, especially where bare soil was observed. NPS pollution inputs originating from the cemetery lawn are an obvious concern here, as is the potential for runoff from the dense impervious surfaces associated with downtown Southbridge. CO01 received a total habitat assessment score of 130/200—the second worse habitat evaluation during the 2004 French & Quinebaug biomonitoring survey (Table A5). Instream sediment deposition and related substrate embeddedness, coupled with the compromised riparian habitat associated with the adjacent cemetery, were by far the major habitat constraints in this portion of the stream.

Benthos

The CO01 benthic community received a total metric score of 20, representing only 48% comparability to the reference station and resulting in an assessment of “moderately impacted” for biological condition (Table A2). The benthos assemblage here was generally dissimilar (Reference Affinity metric score=2) to the reference community, with reduced EPT richness (EPT Index metric score=2) and a hyperdominance of (n=43) filter-feeding hydropsychid caddisflies (Table A1). Based on the highly urbanized surrounding land-use, obvious habitat constraints in the CO01 sampling reach, and resident biota that appear structured in response to organic enrichment (filter-feeders comprised >60% of the sample; Scrapers/Filterers metric score=0), it is probably a combination of habitat degradation and water quality impairment associated with urban runoff that limit biological integrity in this portion of Cohasse Brook. It should be noted that DWM consistently documented the highest fecal coliform bacteria counts (range is 950 – 2200 cfu/100mL) here for the 2004 French & Quinebaug River watershed water quality monitoring surveys (MassDEP 2006).

LB01—Lebanon Brook, 550 m upstream from Ashland Avenue, Southbridge, MA

A large third order stream, Lebanon Brook is formed by two tributaries draining a vast wetland area in a remote part of Woodstock, Connecticut. The stream flows northward into Massachusetts where it soon enters an unnamed impoundment that is devoid of shoreline development. Leaving the impoundment, Lebanon Brook veers in a northeasterly direction, receiving discharge contributions from several small tributaries before crossing Route 169 in Southbridge. After flowing through a small impoundment, the stream becomes channelized and enters an area of heavy industrial and commercial use before joining the mainstem Quinebaug River in the Sandersdale section of Southbridge. The total drainage area upstream from the LB01 biomonitoring station is estimated at 9.73 square miles. With the exception of the lower portion in the vicinity of Sandersdale, the Lebanon Brook subwatershed remains relatively undeveloped, consisting of large tracts of forest and wetland, and only sparse residential land-use.

Habitat

LB01 began approximately 550 m upstream from Ashland Avenue (Route 131) and immediately upstream from a small, unnamed impoundment near the village of Sandersdale. The mostly shaded (90% canopy cover) sampling reach was located in a densely forested portion of the watershed and was accessed via a hiking trail off of Route 131. The channel was approximately 3–4 m wide and formed a highly sinuous meander. Flow regimes were dominated by riffles of varying depth (0.20 – 0.40 m) and swift current velocity, although a few large pool areas, up to a meter deep, were present as well. Rocky substrates were diverse in size, although boulder and large cobble were most common. Covered with dense beds of moss, they provided excellent epifaunal substrate for macroinvertebrates. Fish cover was optimal, with the abundance of boulder, submerged logs and snags, and ample deep-water areas resulting in ideal habitat throughout the reach. Channel flow status was also optimal, with water easily reaching the base of both banks and leaving no exposed substrates.

Boulders, coupled with a profusion of herbaceous growth (cardinal flower, *Lobelia cardinalis*; ferns; grasses), provided good stabilization to the well-vegetated streambanks along both sides of the channel. Bank vegetation gave way to a wide and undisturbed riparian zone on both sides of the stream—the dense forest was comprised mainly of hardwoods (maple, *Acer* sp.; oak, *Quercus* sp.) and occasional white pine (*Pinus strobus*). There were no NPS pollution inputs to the stream observed, nor were potential sources of pollution known.

The LB01 sampling reach received a total habitat assessment score of 193/200 (Table A5). This was the highest scoring habitat evaluation received by a biomonitoring station in the entire 2004 French & Quinebaug survey. The high-quality instream and riparian habitat observed at LB01, overall good water quality as documented by DWM during the 2004 water quality monitoring surveys conducted here, and the “least-impacted” nature of this portion of the Lebanon Brook subwatershed, warranted its use as a secondary reference station during the 2004 French & Quinebaug River watershed biosurveys. Specifically, LB01 was used as a reference for stations (i.e., FR04-1; LR01; W1197) in the larger streams in the watershed that are more comparable to Lebanon Brook than Browns Brook (BR01) in terms of watershed drainage area and stream order.

Benthos

The LB01 benthic community received a total metric score of 32, representing 76% comparability to the reference station and resulting in a “slightly impacted” bioassessment (Table A2). Metric scoring reductions for the LB01 benthos were mainly a result of reduced richness and abundance of EPT taxa, as reflected in the low scoring EPT Index and EPT/Chironomidae metrics (Table A2). It is unclear why EPTs were not more plentiful here, as both instream habitat (e.g., optimal epifaunal habitat) and physicochemical water quality parameters (e.g., high dissolved oxygen levels) appeared highly conducive to colonization by EPT taxa. Regardless, non-EPT taxa sensitive to organic pollutants (e.g., the dobsonfly, *Nigronia* sp.; the elmid beetle, *Promoresia* sp.) were well represented in the LB01 sample, and the presence of these organisms (Biotic Index metric score=6)—coupled with low numbers of filter-feeding taxa (Scrapers/Filterers metric score=6)—suggest that the effects of organic enrichment are minimal or absent in this portion of Lebanon Brook. Thus, while the overall excellent riparian and instream habitat quality at LB01 suggest that water quality limits biological potential in this portion of the stream, it is unknown what those factors might entail.

W1186—Keenan Brook, 550 m upstream from confluence with Quinebaug River, Southbridge, MA

Locally known as “Keenan Brook,” this third order tributary to the Quinebaug River originates near the Morseville section of Charleton. From its source, the stream flows in a southerly direction, closely paralleling the dense residential and commercial corridor along Route 31. It then veers southwest, receiving considerable discharge contributions from another unnamed tributary in this relatively undeveloped portion of the subwatershed. Keenan Brook closely follows Sandersdale/Dresser Hill roads as it continues its southwesterly course towards the Quinebaug River. After flowing past an active sand/gravel operation, the stream joins the mainstem Quinebaug immediately downstream from the Southbridge Wastewater Treatment Facility discharge. Total drainage area upstream from W1186 is 8.07 square miles.

Habitat

The W1186 sampling reach began just over half a kilometer upstream from its mouth, and approximately 100 m downstream from a paved road accessing an adjacent sand/gravel operation off Dresser Hill Road. A narrow band of forest on both sides of the channel provided almost complete (95% shaded) canopy cover over the stream. The high gradient reach was approximately 4 m wide and with a uniformly shallow depth of about 0.20 m. Riffle areas dominated flow regimes here, and with an abundance of cobble and boulder substrates provided optimal epifaunal habitat for macroinvertebrates. Fish habitat was only marginal due to the shallow nature of the stream, pools lacking stable cover, and exposed and unavailable habitat. Overall channel flow status was marginal, with water filling only half the channel and leaving much exposed riffle substrate and woody materials throughout the reach. Aquatic mosses were the only instream vegetation observed, covering the rocky substrates on approximately 40% of the stream bottom. The water column was strikingly clear and rocky substrates lacked algal growth of any kind.

Both streambanks were well vegetated with shrubs and herbaceous (including grasses) growth. Boulders provided excellent stability along the left (east) bank; however, the steepness of parts of the right (west) bank resulted in suboptimal stability and a few small areas of erosion. Riparian vegetation, which consisted of a mix of deciduous trees (red oak, *Quercus rubra*; yellow birch, *Betula alleghaniensis*; maple, *Acer* sp.) and conifers (white pine, *Pinus strobus*), provided a wide buffer from the adjacent road along the left bank. Riparian zone width was slightly less along the right bank, but still provided an adequate vegetative buffer from potential NPS inputs associated with the adjacent sand/gravel operation or its access road.

The W1186 sampling station received a total habitat assessment score of 149/200 (Table A5). Habitat shortcomings were mainly related to the low baseflow encountered, and its affect on fish habitat (i.e., instream cover) availability and flow regime types.

Benthos

The benthos assemblage at W1186 received a total metric score of 34, representing 81% comparability to reference conditions at BR01 and resulting in a “non-impacted” biological assessment (Table A2). The macroinvertebrate community here was well balanced and diverse, as evidenced by a low (17%) Percent Dominant Taxon metric value and a high scoring (score=6) Taxa Richness metric value. In addition, a high scoring (score=6) Biotic Index for the W1186 benthos indicates good representation by taxa sensitive to organic pollution.

TU01—Tufts Branch, 30 m upstream from Route 197, Dudley, MA

Tufts Branch is a second order stream that originates in wetlands just south of Baker Pond in Dudley. The stream flows in a generally southerly direction for much of its course, veering slightly westward after crossing into Connecticut where it soon merges with the Quinebaug River. Land-use throughout the majority of the Tufts Branch subwatershed is light residential (much of it new construction), with several small-scale farms dotting the landscape as well. There are a few sand and gravel pits in the lower portion of the basin; however, it is not known whether these remain active. Commercial development appears to be mainly confined to Dudley center along Dudley Center Road. The drainage area upstream from TU01 totals approximately 2.40 square miles.

Habitat

The TU01 biomonitoring station began 30 m upstream from Route 197 in Dudley, just over the Massachusetts-Connecticut border. The stream flowed through an area of forest and light residential development—homes near the left (east) bank were older and with expansive lawns along the stream channel, while a newly created cul-de-sac and housing subdivision was separated from the right (west) bank by a narrow band of forested area that provided shading to approximately 70% of the reach. The stream was small, with a width of about 2 m, shallow (0.15 – 0.20 m) riffle and run areas, and pools up to 0.30 m deep. Riffles dominated flow regimes in both the upper and lower portions of the sampling reach where cobble was the predominant substrate. Despite their shallowness (channel flow status was only marginal—water filled 60% of the channel), these riffles provided optimal epifaunal habitat for macroinvertebtaes. Fish habitat was also optimal, especially in the middle portion of the reach where a large pool contained a good mix of stable cover in the form of boulder, snags, and other submerged logs. Instream vegetation was absent, while a filamentous green alga was observed in the rocky riffle areas of less than 5% of the stream bottom. It should be noted that, while sediment deposition was minimal in the TU01 sampling reach, substantial deposits of sand were observed near the Route 197 crossing.

Both streambanks were well vegetated with a good mix of shrubs (elderberry, *Sambucus canadensis*), vines (riverbank grape, *Vitis riparia*), and herbaceous growth (ferns; skunk cabbage, *Symplocarpus foetidus*). Riparian vegetation along the left (east) bank consisted of only a few trees that poorly buffered both potential and obvious (grass clippings and leaf piles were observed near the top of the reach) NPS pollution inputs from the adjacent lawns. The nearby housing development along the right (west) bank was marginally buffered from the stream by a thin stand of trees (maple, *Acer* sp.; oak, *Quercus* sp.; white pine, *Pinus strobus*). Both streambanks were steep and showed signs of instability, especially the left (east) bank near the top of the reach where bank sloughing may be exacerbated by yard waste deposits. TU01 received a total habitat assessment score of 148/200 (Table A5). Scoring reductions were mainly due to marginal channel flow status and its effect on instream flow regimes (i.e., Velocity-Depth Combinations), and reduced riparian vegetative zone width.

Benthos

The TU01 macroinvertebrate community received a total metric score of 34, which was 81% comparable to the reference community and resulted in a bioassessment of "non-impacted" (Table A2). Pollution sensitive EPT taxa were well represented (EPT Index metric score=6) in the TU01 benthos assemblage, contributing to a low Biotic Index (score=6) and good overall community balance.

RB01—Rocky Brook, 100 m downstream from Midstate Trail footpath, off High Street, Douglas, MA

Rocky Brook originates in wetlands within Douglas State Forest. A second order stream, it flows through vast tracts of wetland and forest in a southwesterly direction towards the northeast corner of Connecticut. Soon after entering Connecticut, Rocky Brook joins with the Fivemile River (a Quinebaug River tributary) in East Thompson. With the exception of Thompson Road and a few residences concentrated in East Thompson, Connecticut, the Rocky Brook subwatershed is virtually undeveloped. In Massachusetts the majority of the Rocky Brook drainage area is state forest (Douglas State Forest). RB01 drains an area of 4.58 square miles.

Habitat

The RB01 sampling reach began approximately 100 m downstream from a footbridge on the Midstate Trail, a hiking and horseback riding path located off High Street in Douglas near the Massachusetts-Connecticut-Rhode Island border. A dense forest shaded the majority (95% canopy cover) of the stream, whose meanders and braids resulted in a poorly defined channel a short distance downstream from the sampling station. Baseflow was dramatically reduced downstream from RB01 as well, with virtually all water disappearing under large boulders and forest understory, and giving the streambed a "dry" appearance. Immediately upstream from the sampling reach stretched a vast wetland with obvious signs of beaver activity, offering a dramatically different type of instream habitat than the high-gradient segment just downstream. The boulder dominated reach provided macroinvertebrates with excellent epifaunal habitat, especially in the mossy riffle (0.20 m deep) areas that comprised much of the bottom half of the sampling reach. Deeper (0.40 m), pool areas occupied the upper half of the reach and provided optimal fish habitat with a variety (snags, boulders, submerged logs, root masses) of stable cover. True deep-water flow regimes were absent due to marginal channel flow status which left some (almost 25%) substrates exposed along the margins of the channel. Aquatic vegetation, consisting mainly of mosses and a few beds of bur-reed (*Sparganium* sp.), covered 60% of the reach. Algae were not observed.

Streambanks were well vegetated with herbaceous growth, especially ferns, mosses, and skunk cabbage (*Symplocarpus foetidus*). The dense layer of bank vegetation gave way to a wide and undisturbed riparian zone on both sides of the channel, with white pine (*Pinus strobus*), maple (*Acer* sp.), and birches (*Betula* sp.) the most common trees. Bank stability was good on both banks, reinforced by boulders, streamside vegetation, and a network of old stone walls. There were no signs of pollution, although the hiking trail was a potential, albeit minor, source of NPS inputs. The RB01 biomonitoring station received a total habitat assessment score of 177/200 which was slightly higher than the habitat score at the reference station (Table A5).

Benthos

Despite the high quality habitat available, the RB01 benthic community received a total metric score (16) that was only 38% comparable to the reference condition. Along with W1183, this was the worse bioassessment result ("moderately impacted") for a Quinebaug River tributary station in the 2004 French & Quinebaug River watershed biomonitoring survey. The RB01 assemblage was highly dissimilar (Reference Affinity metric score=0) to the reference community, with a conspicuous reduction in EPT taxa. Also notable was the displacement of scrapers (no scrapers were collected) by more tolerant filter-feeding forms, especially the net-spinning caddisfly *Hydropsyche* sp. and the codominant filter-feeding midge *Rheotanytarsus exiguus* gr. The latter's presence may be significant in that it is considered an indicator species for high levels of suspended organic particulates (Bode and Novak 1998). Indeed, the organic enrichment that appears to shape benthic community structure at RB01 is supported by the very low levels (range for DO is 4.0 – 4.5 mg/L; range for DO saturation is 42 – 48%) of dissolved oxygen documented here by DWM during the 2004 water quality surveys (MassDEP 2006). Given the undeveloped nature of most of the Rocky Brook subwatershed, it is likely that organic loads and reduced oxygen levels in this portion of the stream may be naturally occurring and mainly the result of upstream wetland contributions. Additionally, organic enrichment may be compounded by upstream beaver activity.

French River Subwatershed

BU01—Burncoat Brook, 350 m upstream from confluence with Town Meadow Brook, Leicester, MA

Burncoat Brook is a small first order stream that originates in Burncoat Pond in Leicester. From the Burncoat Pond outlet, the stream soon enters another impoundment—Cedar Meadow Pond. From Cedar Meadow Pond, the stream heads southeast into a third impoundment known as Bouchard Pond. Upon leaving Bouchard Pond the stream veers east and closely parallels Pine Street. After flowing through a small wetland and a final, unnamed impoundment, Burncoat Brook makes its confluence with Town Meadow Brook, a headwater tributary of the French River. The Burncoat Brook subwatershed is mostly forested with some light residential development and small-scale agriculture. Drainage contributions upstream from BU01 total 3.82 square miles.

Habitat

The BU01 sampling reach began immediately upstream from a small path and footbridge used by an adjacent farm for livestock (cows) crossing. The path (and station) was located off of Pine Street in Leicester, and was just downstream from a high-tension powerline crossing and approximately 350m from the mouth of Burncoat Brook. Overhanging shrubs and some trees along the stream margin provided about 50% shading to the reach. The stream was small, with a width of about 1m and displaying good meander and optimal channel flow status. Riffle areas were approximately 0.20 m deep and contained an abundance of cobble, and along with deeper (0.30 m) runs, provided macroinvertebrates with optimal epifaunal habitat. Pools were about 0.40m deep and contained adequate habitat for maintenance of fish populations. Boulders and overhanging bank vegetation were the primary types of fish cover. Macrophytes were absent from the reach, and algal cover was minimal (<5%). Aquatic mosses covered about 20% of the sampling reach. Instream sediment deposition, in the form of new bar formation and slight deposition in pools, affected approximately 20% of the reach. Deposition appeared highly localized and the result of cow access to the stream—bank erosion was severe at cow entry points along both sides of the stream, with sand deposits extended out into the channel from these erosional areas. In addition to the obvious livestock-related NPS pollution in the sampling reach, a horse paddock immediately downstream from the footbridge has resulted in numerous excrement deposits and obvious riparian zone impacts just downstream from BU01. The combination of horse and cow grazing has resulted in much denuded riparian and bank vegetation, especially along the left (north) bank near the footpath. Within the sampling reach, streambanks were fairly well vegetated with woody vines (riverbank grape, *Vitis riparia*) and herbaceous growth (greenbrier, *Smilax rotundifolia*; Joe-Pye weed, *Eupatorium maculatum*; goldenrod, *Salidago* sp.). Bank vegetative protection and stability were highly compromised midreach, however, where cow access to the stream has resulted in complete removal of vegetation. Riparian vegetation is shrub dominated with occasional deciduous trees (maple, *Acer* sp.; ash, *Fraxinus americana*; willow, *Salix* sp.) and extends for approximately 12 m before yielding to grazing areas.

BU01 received a total habitat assessment score of only 149/200 (Table A5). Habitat degradation appears mainly localized and directly related to cattle (and horses just downstream from BU01) grazing and other livestock-related activities.

Benthos

The BU01 benthos assemblage received a total metric score of 16, representing 38% comparability to the reference community and resulting in a bioassessment of "moderately impacted" (Table A3). Filter-feeders, most notably the caddisfly *Chimarra* sp. (n=38) and chironomid *Rheotanytarsus* sp. (n=25), dominated the BU01 benthos, which saw a reduction in both total Taxa Richness and EPT Index (score=2 and 0, respectively) relative to the reference station (Table A3). Biological potential at BU01 is probably compromised by a combination of habitat and water quality degradation. Occasionally elevated (as high as 1500 cfu/100mL) fecal coliform bacteria levels documented by DWM during 2004 bacteria surveys corroborate the suspect water quality in this segment of Burncoat Brook. And while livestock grazing activities here should be considered a probable source of NPS pollutant loads to this portion of the stream, additional sources of organic inputs may exist as well. Bouchard Pond, a small impoundment located approximately 1km upstream from BU01 and documented as eutrophic by DWM during a 1994 lake synoptic survey (MassDEP 2002), is probably at least partially responsible for the delivery of FPOM loads to BU01. Lentic systems can be a major source of dissolved and suspended particulate matter to downstream lotic communities—particularly when these systems are subjected to increasingly enriched conditions (Merritt et al. 1984).

GR01—Grindstone Brook, 170 m downstream from Route 56, Leicester, MA

Grindstone Brook is a small second order stream that originates in the Leicester Hill section of Leicester. The stream flows in a southwesterly direction into Henshaw Pond, a public water supply for the town of Leicester. Leaving Henchaw Pond, it soon enters a large tract of wetland known as Great Cedar Swamp. From here Grindstone Brook continues southward, receiving discharge contributions from a small tributary before finally emptying into Rochdale Pond, which is an impoundment of the French River in the Rochdale section of Leicester. The Grindstone Brook drainage area is relatively undeveloped—land-use is primarily forest and wetland areas associated with Great Cedar Swamp. Residential development is concentrated in the upper portion of the subwatershed, and mid-basin along Salem Road. The total drainage area upstream from GR01 is approximately 2.82 square miles.

Habitat

The GR01 sampling reach began approximately 170 m downstream from Route 56 in Leicester. Surrounding land-use was dense forest, and the mix of hemlock (*Tsuga canadensis*), birch (*Betula* sp.), and oak (*Quercus* sp.) provided good shading (90% canopy cover) over the reach. Long riffle areas with an abundance of cobble and boulder substrates provided optimal epifaunal habitat. Dense beds of mosses provided additional microhabitat for benthos. Fish habitat was excellent, with much submerged woody material, in addition to large boulders, providing stable cover. Pool depth (0.40 m) was good despite the marginal channel flow status that resulted in shallow (0.10 m) riffles and exposed substrates in about 25% of the sampling reach. In addition to the dense moss cover, small patches of submergent macrophytes (watercress, *Nasturtium* sp.; arrow arum*, Peltandra virginica*) were observed. Algal cover was nonexistent, possibly due to the limited light penetration through the dense overhead canopy. The upstream road crossing was a potential source of NPS pollution, and indeed, instream deposition and substrate embeddedness—though not severe—were observed in the GR01 sampling reach.

Bank and riparian habitat parameters received the maximum scores possible. Large boulders, tree roots, and herbaceous plant growth (ferns; grasses; mosses) provided optimal stability and vegetative protection along both banks. Riparian vegetation extended undisturbed through a low-lying floodplain and the dense forest along both sides of the channel.

GR01 received a total habitat assessment score of 162/200 (Table A5). The habitat score was mainly compromised by low baseflow observations and impacts (i.e., substrate embeddedness) related to instream sedimentation.

Benthos

The GR01 macroinvertebrate community received a total metric score of 26, representing 62% comparability to the reference station and placing the benthos in the “slightly impacted” biological condition category (Table A3). Scoring reductions were mainly a result of the low scoring (score=0) EPT Index. Total Taxa Richness and Biotic Index metrics scored highly (score=6), however, suggesting that other, non-EPT taxa equally sensitive to pollution (e.g., intolerant chironomids, beetles, etc.) were well represented in the GR01 assemblage. Those EPT taxa present (e.g., *Acroneuria* sp.; *Micrasema* sp.; *Dolophilodes* sp.; *Rhyacophila* sp.) at GR01 display generally very low tolerance of organic pollution.

It is unclear if habitat quality, water quality, or a combination of both limit biological integrity in this portion of Grindstone Brook. As stated earlier, substrate embeddedness—which was observed in the GR01 sampling reach—reduces epifaunal microhabitat availability for taxa such as EPTs, which are highly susceptible to the effects of instream deposition. Suspect water quality at GR01 should also receive consideration, as DWM documented elevated (range of 220 – 5800 cfu/100mL) fecal coliform levels here on four occasions during the 2004 summer water quality surveys (MassDEP 2006).

FR04-1—French River, 300 m downstream from Clara Barton Road, Oxford, MA

The uppermost segment of the French River begins at the outlet of Greenville Pond in Oxford. The river flows in a southerly direction for 4.7 miles through fairly urban and industrial portions of Leicester (in succession the villages of Greenville, Rochdale, and Cominsville). Along this course the river flows through the impoundments of Rochdale and Texas ponds, and receives the wastewater discharge of the Oxford-Rochdale Sewer District (NPDES permit no. MA0100170) before reaching Thayers Pond and North Oxford Dam which is located immediately upstream from the FR04-1 biomonitoring station. Total drainage area upstream from FR04-1 is approximately 15.67 square miles.

Habitat

The FR04-1 sampling reach began at a high-tension powerline crossing approximately 300 m downstream from Clara Barton Road and about 400 m downstream from the North Oxford Dam at the Thayers Pond outlet. The high gradient reach was wide (6 m) and meandered through a forested area providing 90% canopy cover over the river. Riffle areas were well developed and numerous, with an abundance of cobble providing optimal epifaunal habitat for resident benthos. Fish habitat was also excellent, with the majority of the stable cover provided by large boulders. Stream depth ranged from 0.30 m in the riffles to 0.40 m in the runs and pool areas. Channel flow status was optimal, with water reaching the base of both banks and leaving a minimal amount of channel substrates exposed. Instream macrophyte and algal cover were both lacking.

Both streambanks were well vegetated with a variety of shrubs (mountain laurel, *Kalmia latifolia*; dogwood, *Cornus* sp.) and herbaceous vegetation (ferns, mosses, and various Asteraceae). The left (north) bank was moderately stable, with small areas of erosion—the right bank was slightly worse. A stand of hardwoods (cottonwood, *Populus* sp.; black birch, *Betula lenta*; white oak, *Quercus alba*; red maple, *Acer rubrum*) provided a wide and undisturbed riparian zone that extended from the left bank, while the wooded (hemlock, *Tsuga canadensis*; white pine, *Pinus strobus*; cottonwood, *Populus* sp.; black birch, *Betula nigra*; white oak, *Quercus alba*; red maple, *Acer rubrum*) riparian buffer was slightly less extensive along the steeply sloped right bank due to an adjacent road. There was no evidence of NPS pollution inputs to the FR04-1 sampling reach; however, the upstream and adjacent roads were a potential source of runoff. FR04-1 received a total habitat assessment score of 176/200 (Table A5).

Benthos

The FR04-1 benthos assemblage received a total metric score of 22, representing 52% comparability to the reference community at BR01 and resulting in a bioassessment of “slightly impacted” (Table A3). A reduction in EPT taxa richness was most notable. The group was dominated by the net-spinning caddisflies *Chimarra* sp. and *Hydropsyche* sp.—both filter-feeders—whose high densities also resulted in a low scoring Scrapers/Filterers metric value (Table A3).

The FR04-1 macroinvertebrate community was also compared to the minimally impacted biological community sampled at LB01 (Lebanon Brook), which was more comparable to the French River than Browns Brook (BR01) was in terms of stream order, drainage area, and water temperature. Using LB01 as a reference station, the FR04-1 benthos received a total metric score of 28, representing 67% comparability and again resulting in an assessment of “slightly impacted” (Table A4). While the EPT Index scored better compared to LB01 than the BR01 reference station, the hyperdominance of filter-feeders—specifically *Chimarra* sp. and *Hydropsyche* sp.—at FR04-1 continued to negatively affect its total metric score, mainly due to low scoring Scrapers/Filterers (score=0) and Percent Dominant Taxon (score=2) metrics (Table A4).

Based on the overall excellent riparian and instream habitat encountered in the FR04-1 sampling reach, water quality appears to limit biological integrity in this portion of the French River. The dense filter-feeding macroinvertebrate assemblage (filter-feeders comprised 72% of the benthos sample) found at FR04-1 appears to reflect the effects of considerable organic enrichment, and is indicative of an unbalanced community responding to an overabundance of a food resource (in this case, fine particulate organic material—FPOM). Indeed, the French River segment containing FR04-1 is classified as an impaired, Category 5 Water (i.e., reported to Congress and EPA as 303(d)-listed) due to nutrients, organic enrichment, and associated low dissolved oxygen (MassDEP 2005). Potential sources of organic and nutrient inputs are numerous, and include contributions from tributaries and upstream wetlands, point source discharges (Oxford-Rochdale and Leicester WWTPs), riverfront golf courses, and miscellaneous NPS pollution associated with urban runoff. In addition, Thayers Pond, which is a eutrophic, Category 5 Water impaired by nutrients and turbidity (MassDEP 2002; MassDEP 2005), is located just upstream of the FR04-1 sample reach and is probably at least partially responsible for the delivery of FPOM loads to downstream biota in this portion of the river.

LR01—Little River, 20 m upstream from Turner Road, Charlton, MA

The Little River is a third order stream and the major tributary to the French River. Originating in Pikes Pond in Charlton, it flows in a southeasterly direction, receiving discharge contributions from large wetlands and several small tributaries before reaching Buffumville Lake. Buffumville Lake is a flood control project maintained by the Army Corps of Engineers (ACOE) New England District. The Little River exits the lake along its eastern shore and continues in an easterly direction through Buffumville Pond before joining the French River in the Hodges Village section of Oxford. Land-use in the Little River subwatershed is dominated by forest, with some light residential development and small-scale agriculture. The total drainage area upstream from LR01 is 10.43 square miles.

Habitat

The LR01 sampling reach meanders through a wooded portion of the watershed, with the adjacent forest providing a completely closed (i.e., 100% shaded) canopy over the 2 m wide stream. Gradient was good, and large boulders subjected to swift current velocity provided macroinvertebrates with excellent epifaunal habitat in the well-developed (0.30 m deep) riffle and run areas. Boulders comprised the majority of the instream cover, which would have been better with greater pool depth (only 75% of the channel was full of water) but still provided adequate stable habitat for the maintenance of fish populations. Instream vegetation and algae were not observed.

Both streambanks were well vegetated with shrubs (honeysuckle, *Lonicera* sp.; barberry, *Berberis* sp.) and herbaceous growth (ferns, grasses, and various Asteraceae). Along with massive boulders along the stream margins, bank vegetation provided optimal stability as well. Riparian vegetative zone width was slightly less than optimal due to an adjacent house and lawn along the right (north) bank and a road near the left (south) bank. Human impacts appeared minimal, though, due to a 12 – 18 m wooded (red maple, *Acer rubrum*; ash, *Fraxinus* sp.; white pine, *Pinus strobus*) buffer.

Nonpoint source pollution inputs were not observed, although the lawn of the adjacent residence was a potential source. In addition, observations made during field reconnaissance of the upper Little River subwatershed revealed a large horse farm just upstream from LR01 in the vicinity of McIntyre Road. Several small tributaries to the Little River appear to receive runoff from this farm. Also notable was a beaver dam and flooded wetland immediately upstream (approximately 60 m) from the top of the LR01 sampling reach, which may explain the moderate levels of instream turbidity observed during sampling.

LR01 received a total habitat assessment score of 167/200 (Table A5). Marginal channel flow status and the somewhat compromised riparian zone affected the total score most negatively, though most habitat parameter scores fell within the optimal range.

Benthos

The LR01 benthic community received a total metric score of 14, representing only 33% comparability to BR01 and resulting in an assessment of “moderately impacted” (Table A3). When compared to the larger, LB01 reference station, the LR01 benthos received a similar (“moderately impacted”) bioassessment—this time based on a total metric score of 16 and 38% comparability to the reference community (Table A4). Regardless of which reference station was used, the LR01 benthos assemblage saw a large decline in numbers of both EPT taxa and total taxa, with both EPT Index and Taxa Richness metrics receiving the lowest score possible. Also performing poorly (score=0) was the Scrapers/Filterers metric, the result of a hyperdominance of filter-feeders—specifically hydropsychid and philopotamid caddisflies, which together comprised 75% of the sample (Table A1). The preponderance of filter-feeders at LR01 indicates an unbalanced community responding to an overabundance of suspended organic particulate matter. In addition, the low densities of EPT taxa, as well as a paucity of algal scrapers (3 individuals observed)—generally less tolerant than filter-feeders—suggest an oxygen-stressed community. Not surprising, DWM documented consistently low (DO ranged from 4.1 – 5.1 mg/L; DO saturation ranged from 43% - 57%) dissolved oxygen levels here during the 2004 summer water quality surveys (MassDEP 2006).

Water quality degradation related to organic enrichment appears to limit biological integrity in this portion of the Little River. While beaver activity and/or extensive wetland areas just upstream from LR01 may be responsible for observed turbidity, organic inputs, and naturally-occurring low levels of dissolved oxygen in this portion of the Little River, anthropogenic perturbations should also be considered. Agricultural areas, including the large horse farm off McIntyre Road, may be a potential source of organic and/or nutrient loads to the upper Little River. In addition, water quality degradation may be exacerbated by the presence of eutrophic impoundments (Pikes and Jones ponds) upstream from LR01 (MassDEP 2002).

W1197—Potters Brook, 150 m downstream from Potter Village Road, Charlton, MA

Though technically an unnamed tributary to the South Fork, this stream is locally known as "Potters Brook." Originating in South Charlton Reservoir, it flows in an easterly direction for a mere 2 km before joining the South Fork, which is part of the Buffumville Lake flood control system. Though Potters Brook is a small first order stream, its watershed area is considerable due to the drainages of South Charlton reservoir and associated waters (i.e., Baker and Shepherd ponds and their receiving waters). The total drainage area upstream from W1197 is approximately 13.89 square miles—much of it protected ACOE-owned land, undeveloped forest, and wetland.

Habitat

W1197 was located near the mouth of Potters Brook, beginning approximately 150 m downstream from Potter Village Road in the southeastern corner of Charlton. The stream was of high gradient and displayed good meander in this mostly forested portion of the watershed. The dense stand of hardwoods and white pine provided a mostly closed (85% shaded) canopy over the W1197 sampling reach. All major velocity-depth combinations were represented in the 3m-wide reach—long riffles of varying depths (0.25 – 0.30 m) were interspersed with deep (0.45 m) pools at each bend of the stream. Substrates comprised of an even mix of boulder and cobble provided excellent epifaunal habitat for macroinvertebrates, with aquatic mosses providing additional productive microhabitat. Other aquatic vegetation (i.e., macrophytes) was absent, while a thin film of brownish algae covered rocky substrates in 20% of the reach. Fish habitat was also optimal, with large boulders, submerged logs, and undercut banks providing ample stable cover. Channel flow status was slightly less than optimal; however, water filled well over 75% of the available channel and left only minimal amounts of substrates exposed along the margins of the stream reach.

Both streambanks were well vegetated with ferns and mosses. Stability was suboptimal along both banks as evidenced by small areas of sloughing—possibly the result of seasonal high flows that appear to cause undercutting of banks along the bends of the stream. A mix of deciduous trees (oak, *Quercus* sp.; birch, *Betula* sp.) and conifers (white pine, *Pinus strobus*) provide a wide and undisturbed riparian zone along both sides of the stream. The forest provided a good vegetative buffer from an adjacent road near the right (south) bank. There were no indications of NPS pollution, although an active sand/gravel operation was observed near the stream just upstream from Potter Village Road.

W1197 received a total habitat assessment score of 185/200 (Table A5). This was the highest rated habitat for a French River watershed biomonitoring station, and the second highest in the entire 2004 French & Quinebaug River watershed biomonitoring survey.

Benthos

The macroinvertebrate community at W1197 received a total metric score of 22, representing 52% comparability to the Browns Brook (BR01) reference station and resulting in an assessment of "slightly impacted" for biological condition (Table A3). The biota performed slightly better compared to the LB01 reference station, receiving a total metric score (28) that was 67% comparable to "least impacted" conditions (Table A4). Most notable in both reference comparisons was the highly reduced Scrapers/Filterers metric value (0.15; score=0).

While the preponderance of filter-feeding taxa in the W1197 benthos assemblage indicates an abundance of FPOM in this portion of Potters Brook, a good representation of EPTs coupled with only a slightly elevated Biotic Index, suggest organic enrichment is not excessive. Indeed, low dissolved oxygen levels normally associated with severe organic enrichment were not detected by DWM during water quality monitoring efforts here in 2004 (MassDEP 2006). Benthic community structure and function at W1197, then, suggest the large upstream impoundments (i.e., Baker Pond; South Charlton Reservoir) in the

Potters Brook subwatershed—while no doubt a contributing source of FPOM to downstream lotic communities—are probably not overly productive.

SU01—Sucker Brook, 100 m downstream from Kingsbury Road, Webster, MA

Sucker Brook emerges from Grassy Pond as an unnamed first order stream. It flows in a southwesterly direction through the completely undeveloped Douglas Woods before entering Nipmuck Pond in Webster. Leaving the pond, the stream receives the drainage of another small, unnamed tributary to become Sucker Brook. Sucker Brook continues its southwesterly course along Sutton Road, eventually emptying into Club Pond at the northernmost portion of Webster Lake near Sucker Brook Cove. The majority of the Sucker Brook subwatershed is undeveloped forest, with the exception being light residential development along Sutton Road and near the lower reaches of Sucker Brook. The total watershed area upstream from SU01 is 2.46 square miles.

Habitat

The SU01 sampling reach began 100 m downstream from Kingsbury Road near a small housing development (approximately 50 single-family homes). The stream was small here, with a width of 1 m and a maximum depth of only 0.10 m and 0.20 m in the riffle and pools, respectively. Channel flow status was marginal, as water only filled about 60% of the available channel and left much exposed substrate (both rocky and woody materials), especially near the middle and top of the reach where exposed areas of streambed gave the appearance of small islands. The shallow nature of the stream, coupled with a lack of stable cover, led to marginal fish habitat. Epifaunal habitat for macroinvertebrates remained optimal despite the low baseflow. Aquatic vegetation consisted of mosses that covered about 10% of the stream bottom, while algal cover (blue-green mats) was estimated at 10% as well. Riparian and bank vegetation along the right (west) bank has been completely replaced with the manicured lawns of adjacent residences. Additionally, some of the bank has been replaced with a brick wall—much of it collapsing into the stream. NPS pollution associated with the lawns (i.e., grass clippings, leaf piles) was obvious and minimally buffered from the sampling reach. The left (east) bank remains relatively stable and well vegetated with various shrubs (rose, *Rosa* sp.; barberry, *Berberis* sp.; bittersweet, *Celastrus* sp) and herbaceous vegetation (jewelweed, *Impatiens capensis*; Joe-Pye weed, *Eupatorium maculatum*). The riparian zone between this bank and an adjacent road is narrow but wooded, with trees (ash, *Fraxinus* sp.; red maple, *Acer rubrum*; red oak, *Quercus rubra*; white pine, *Pinus strobus*) providing a narrow vegetative buffer and shading about 75% of the sampling reach.

SU01 received a total habitat assessment score of 131/200, which was the lowest score of all French River tributary stations and the third poorest habitat evaluation in the entire 2004 biomonitoring survey (Table A5). Contributing most to habitat shortcomings were a lack of stable fish habitat due to low baseflow which may be naturally occurring (i.e., seasonal low flow), and riparian/bank disruptions associated with the adjacent lawns.

Benthos

The SU01 macroinvertebrate community received a total metric score of 10, representing only 24% comparability to the reference station and resulting in a bioassessment of “moderately impacted” (and near the low end of that category) (Table A3). This was easily the lowest total metric score received by a French & Quinebaug River watershed biomonitoring station, with all but two metrics receiving the lowest score possible.

The hyperdominance (90% of the sample) of filter-feeders in the SU01 sample was somewhat surprising and probably not solely the result of the localized NPS pollution mentioned above. There are no known sources of heavy organic loads in the Sucker Brook subwatershed, as wetland contributions are minimal, and upstream impoundments are small, undeveloped, and thought to be unproductive (MassDEP 2002). Furthermore, it is unknown if elevated (as high as 1400 cfu/100mL) levels of fecal coliform bacteria—documented by DWM during 2004 summer bacteria surveys at SU01—are associated with the organic pollution reflected in the benthic community encountered here. Runoff from the adjacent housing development—either from stormwater, or faulty septic systems if these homes are not tied into the town's sewer system—should be considered as a potential source of pollutant loadings to Sucker Brook.

While water quality factors appear to strongly limit biological potential at SU01, the effects of water quality degradation may be exacerbated by the low baseflow (i.e., reduced assimilative capacity) observed in this portion of Sucker Brook. As a major tributary to Webster Lake, Sucker Brook's potential as a source of bacteria and organic pollutants to the lake should be a concern.

MI01—Mine Brook, 140 m downstream from Mine Brook Road, Webster, MA

Mine Brook is a small second order stream that originates in Douglas Woods. The stream flows in a generally southwesterly direction through vast tracts of undisturbed forest before crossing Mine Brook Road and entering Webster Lake near Sucker Brook Cove. With the exception of a few residences near its mouth, and an apple orchard located near Rawson Road, the entire Mine Brook subwatershed is undeveloped and inaccessible. The total watershed drainage area located upstream from MI01 is approximately 1.03 square miles.

Habitat

The MI01 sampling reach began approximately 140 m downstream from Mine Brook Road in a forested portion of the watershed near the mouth of Mine Brook. The fully shaded (100% canopy cover) stream was only about 1 m wide, with an average depth of 0.10 m in the riffle dominated reach. The long riffle areas and cobble/boulder dominated substrates provided macroinvertebrates with optimal epifaunal habitat. Aquatic mosses, which covered approximately 5% of the reach, offered additional benthic microhabitat. The low baseflow—channel flow status rated at the low end of marginal and the channel was only half-full of water—resulted in marginal fish habitat due to unavailable (i.e., exposed) cover and inadequate pool depth. Algal coverage appeared to be extensive (70% coverage within reach); however, much of it appeared moribund—perhaps the result of extremely silty conditions throughout the sampling reach. Fine sediments coated most substrates in the reach, although sediment bars or heavy deposits were not observed. Instream sediment deposition, which was rated as marginal, appeared to originate from the Mine Brook Road crossing just upstream from MI01. Sedimentation was absent in the portion of Mine Brook just upstream from the Mine Brook Road crossing. Bank and riparian habitat parameters were considered optimal due to the undisturbed forest on both sides of the channel. Banks were well vegetated with ferns and mosses that gave way to a wide riparian zone comprised of oak (*Quercus* sp.), white pine (*Pinus strobus*), and maple (*Acer* sp.) with a shrubby understory (mountain laurel, *Kalmia latifolia*).

MI01 received a total habitat assessment score of 147/200 (Table A5). The low baseflow, coupled with localized sediment deposition, compromised biological potential throughout the sampling reach. The channel flow status score (7) was the lowest of all stations in the 2004 French & Quinebaug River watershed biomonitoring survey, while sediment deposition received the second lowest score (8) in the survey.

Benthos

The MI01 benthic community received a total metric score of 16, representing 38% comparability to the reference station and resulting in an assessment of "moderately impacted" for biological condition (Table A3). Community structure at MI01 appears to be influenced more by habitat constraints than water quality factors, which appeared normal according to DWM water quality surveys here in summer 2004 (MassDEP 2006). Despite scoring reductions for most metrics, the high scoring Biotic Index and Percent Dominant Taxon metrics suggest the MI01 benthos assemblage remains sensitive to organic pollution. This may be explained by the displacement of EPT taxa by other organisms intolerant of organic enrichment. Several of the more pollution intolerant Chironomidae genera were well represented in the MI01 benthic community. These include *Corynoneura* sp., *Parachaetocladius* sp., and *Polypedilum aviceps*—the latter considered a "clean water" indicator and rarely associated with impacted waters (Bode and Novak 1998). Furthermore, some of the aforementioned chironomids—most notably *Polypedilum* sp. and *Corynoneura* sp.—have been shown to thrive in silty or sandy lotic habitats (Minshall 1984), such as those encountered at MI01.

Conversely, sediment deposition may be at least partially responsible for the reduction in EPT taxa at MI01. A recent study by Zweig and Rabeni (2001) found EPT density and EPT richness to be significantly negatively correlated with deposited sediment. Indeed, metrics related to EPT density and richness (i.e., EPT/Chironomidae and EPT Index) performed poorly (score=0) in the MI01 benthos assemblage.

Resident biota at MI01 may also reflect the low baseflow conditions observed during the 2004 biosurvey there. In particular, *Orthocladius* sp. and *Polypedilum aviceps*—codominants (n=18 and 16 respectively) of the MI01 assemblage—are known to survive dry conditions or periods of reduced baseflow (Bode, NYDEC, personal communication, 1998). And while EPT richness at MI01 was notably reduced, the chloroperlid *Sweltsa* sp. was well represented. In addition to being highly sensitive to conventional organic pollution, this stonefly is able to persist within moist substrates in nonflowing areas of streams (Del Rosario and Resh 2000).

BW01—Browns Brook, 130 m upstream from Gore Road, Webster, MA

Browns Brook is a small first order stream that begins in a wetland in the Douglas Woods near the Webster-Douglas border. The stream flows in a southerly direction until it crosses Douglas Road (Route 16), then veers west to continue its course towards Webster Lake. Browns Brook enters the Reid Smith Cove portion of Webster Lake just after crossing Gore Road. The Browns Brook subwatershed is small, draining an area of 1.20 square miles upstream from BW01. Light residential development occupies the lower portion of the subwatershed and is concentrated mainly along Douglas and the Gore (Upper and Lower) roads near the eastern shore of the lake. Browns Brook, and a feeder stream entering from the east, also has historically received runoff from LKQ Used Auto Parts located on Douglas Road. The LKQ property is located immediately adjacent to both streams and contains several (more than 100) automobiles in various states of disrepair. During field reconnaissance in this portion of Browns Brook, runoff of dubious water quality (turbid and milk-colored) was observed entering both Browns Brook and the feeder stream at several entry points. DWM has since been informed by MassDEP/CERO that the property has been listed as a hazardous waste site by the Bureau of Waste Site Cleanup (Warren Kimball, MassDEP/CERO, personal communication, 2004). In addition, LKQ was fined by MassDEP in 2004 for violations of the Massachusetts Wetland Protection Act, and has since installed a state-of-the-art sediment control facility (Dignam 2006).

Habitat

The BW01 sampling reach began approximately 130 m upstream from Gore Road in a wooded area located near Douglas Road. The reach ended immediately downstream from the confluence of Browns Brook and the feeder stream where LKQ is located. The surrounding forest provided an almost complete canopy (90% shaded) over the stream, which was approximately 2 m wide, and ranged in depth from 0.20 m in the riffles to about 0.30 m in the pool areas. Substrates were rocky and large (mostly boulder with some cobble), and, subjected to swift current velocity through much of the reach they provided macroinvertebrates with excellent epifaunal habitat. Small patches of mosses on about 10% of the stream bottom provided additional benthic habitat. Macrophytes and algae were not observed. Fish habitat was suboptimal—less than half the sample area had stable habitat due to the shallowness of the stream (channel flow status was marginal, with water filling only 75% of the channel) and the exposure of potential cover. Sediment deposition affected approximately 20% of the stream bottom and consisted of very fine particulates that coated much of the substrate. The LKQ property was the suspected source of sediment inputs, as other sources of NPS pollution were not observed during sampling or reconnassaince activities farther upstream. Single-family homes on both sides of the stream appeared fairly well buffered from the channel with deciduous trees (maple, *Acer rubrum*; oak, *Quercus* sp.; ash, *Fraxinus* sp.) and evergreens (white pine, *Pinus strobus*). Both streambanks were well vegetated with herbaceous plants (ferns; jewelweed, *Impatiens capensis*; skunk cabbage, *Symplocarpus foetidus*; moss), and large boulders provided optimal stability on the left (south) bank. Small areas of erosion were observed along the right (north) bank due to sloughing along the bends of this strongly meandering stream.

The BW01 sampling reach received a total habitat assessment score of 153/200 (Table A5). Low baseflow and its impacts (exposed habitat, limited pool depth) on fish cover, coupled with instream sediment deposition, affected the total score most negatively. It is anticipated that sediment runoff controls recently implemented at the LKQ property will result in improvements in instream habitat quality in this portion of Browns Brook.

Benthos

Despite the abundance of rocky epifaunal substrates and well developed riffle areas at BW01, the benthos received an assessment of “moderately impacted” based on a metric score that was only 33% comparable to the reference community (Table A3). This was the second lowest total metric score in the entire 2004 French & Quinebaug River watershed biomonitoring survey (Tables A2 and A3). It is difficult to determine whether biological potential here is limited by water quality, habitat quality, or both. The filter-feeding caddisfly *Hydropsyche* sp. hyperdominated the BW01 benthos assemblage; however, this taxon displays relatively low tolerance of organic pollution. Thus, suspended organic particulates—while an important food resource at BW01—may not persist at levels considered indicative of severe organic enrichment. That the Biotic Index scored fairly well compared to the reference station corroborates the lack of excessive enrichment in this portion of the stream—also supported by dissolved oxygen data collected here by DWM which appeared normal (MassDEP 2006). More telling may be the complete absence of Ephemeroptera and Plecoptera in the BW01 benthos sample, which, along with SU01, was the only sample collected during the 2004 biomonitoring survey that lacked both of these orders (Table A1). Normally abundant in high gradient, cold-water streams such as Browns Brook (average water temperature for the five water quality surveys at BW01 was 16°C), these insect orders are also the most susceptible to instream sediment loads. These fine materials can be deleterious because they can reduce light penetration (and consequently plant/algal growth), smother hard surfaces, and fill the interstitial spaces within epifaunal substrates (Wiederholm 1984). The resident EPT community at BW01, then, may be subsequently affected by obstructions to food collection or respiration caused by fine deposits of organic/inorganic matter.

SUMMARY AND RECOMMENDATIONS

With the exception of a few tributaries that displayed minimally impacted conditions, biomonitoring stations investigated during the 2004 French & Quinebaug River watershed survey indicated various degrees of impairment. Generally speaking, overall biological health appeared better in the tributaries of the Quinebaug River than at biomonitoring stations in the French River subwatershed. Of the 14 stations sampled in the Quinebaug River subwatershed, three were assessed as "moderately impacted" for biological condition, while five out of eight biomonitoring stations in the French River subwatershed received the "moderately impacted" bioassessment. Five of the fourteen Quinebaug River subwatershed stations were "non-impacted", while none of the stations in the French River subwatershed were considered "non-impacted". Impacts to resident biota were generally a result of habitat degradation and/or other nonpoint source-related water quality impairment, with suspected point source effects observed as well.

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 or Slightly Impacted aquatic communities—such as those encountered at BR01, MO01, WS01, ST01, LE01, HA01, HC01, MK01, LB01, W1186, TU01, GR01, FR04-1, and W1197—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 Impacted communities observed at W1183, CO01, RB01, BU01, LR01, SU01, MI01, and BW01 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).

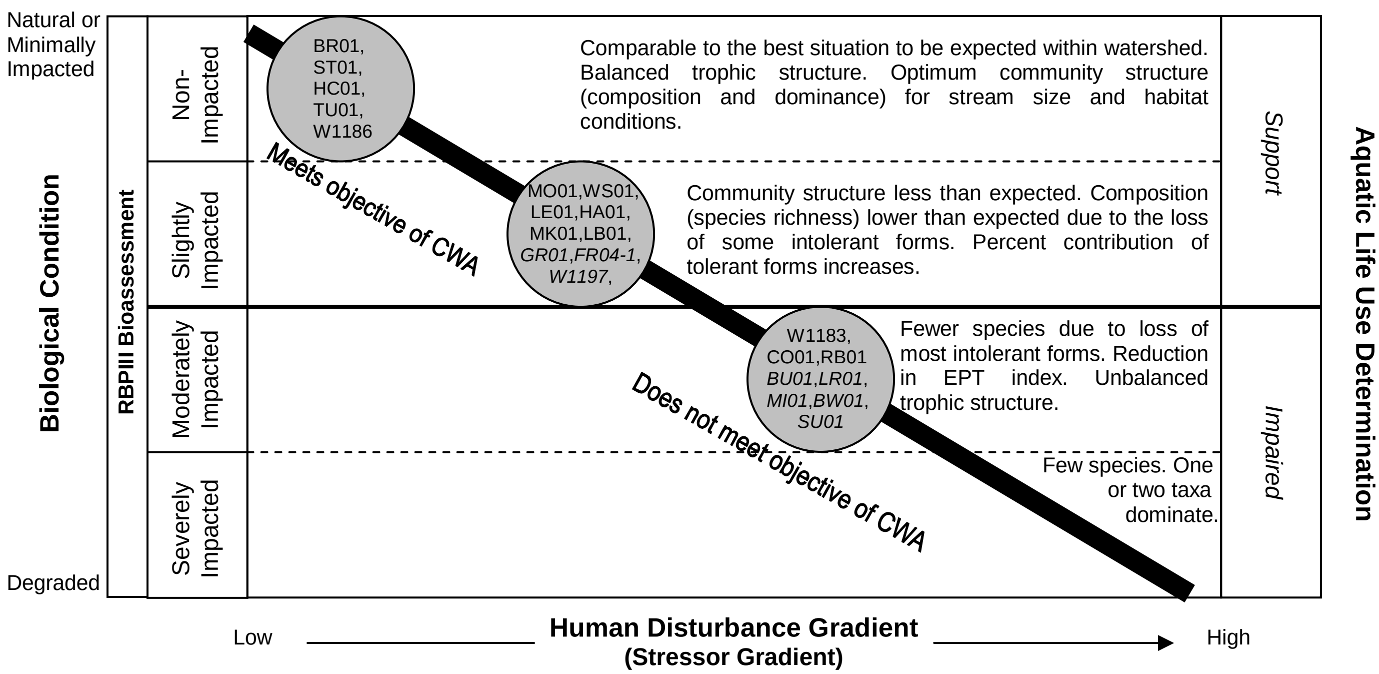

Figure 3. A schematic of results of the RBPIII analysis of the 2004 French & Quinebaug River watershed biomonitoring stations as they relate to Tiered Aquatic Life Use. To distinguish between the two subwatersheds, French River subwatershed stations are in italics.

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 2) 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" and using the resources routinely available to DWM personnel.

Table 2. A summary of potential causes of benthos and habitat impairment observed at each biomonitoring station during the 2004 French & Quinebaug River watershed survey. Where applicable, recommendations have been made.

SITE	POSSIBLE CAUSES OF IMPAIRMENT	RECOMMENDATIONS
BR01	No biological impacts observed; Sedimentation	Biomonitoring during next (2009) MassDEP French & Quinebaug River watershed survey; Water quality monitoring during 2009 MassDEP French & Quinebaug watershed survey; BMPs along May Brook Road to prevent sediment inputs to stream
MO01	Naturally-occurring low baseflow	Biomonitoring during next MassDEP French & Quinebaug River watershed survey
WS01	Naturally-occurring low baseflow; Sedimentation	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Field reconnaissance in subbasin (especially in vicinity of impoundments) to investigate land-uses that may contribute NPS inputs (organic inputs and sediments)
W1183	Organic enrichment/low DO; Sedimentation; Reduced riparian zone	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients; DO;bacteria source tracking) during next MassDEP French & Quinebaug River watershed survey; Improve vegetative buffer along both banks; Field reconnaissance in subbasin to investigate land-uses that may contribute NPS inputs; Investigate possible sources of sediment inputs—implement BMPs as needed
ST01	None observed	Biomonitoring during next MassDEP French & Quinebaug River watershed survey
LE01	Unknown; Beaver activity	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring during next MassDEP French & Quinebaug watershed survey; Field reconnaissance in subbasin to investigate land-uses that may contribute NPS inputs
HA01	Water quality degradation from sand/gravel operations	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring during MassDEP French & Quinebaug watershed survey; Investigate potential runoff from the adjacent sand/gravel operation—implement BMPs as needed
HC01	None observed	Biomonitoring during next MassDEP French & Quinebaug River watershed survey
MK01	Water quality degradation; Riparian habitat degradation; Beaver activity	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients; DO;bacteria source tracking) during next MassDEP French & Quinebaug River watershed survey; Improve vegetative buffer along west bank; Outreach to address NPS inputs (yard waste) from adjacent residences; Stream clean-up to address trash along west bank and instream; Field reconnaissance in subbasin to investigate land-uses that may contribute NPS inputs
CO01	Organic enrichment from urban runoff; Severe sedimentation; Riparian habitat degradation	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including bacteria source tracking) during next MassDEP French & Quinebaug watershed survey; Improve vegetative buffer along left bank; Investigate possible sources of sediment inputs—implement BMPs as needed

Table 2 (cont.)

LB01	Unknown water quality degradation	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients; DO; bacteria source tracking) during next MassDEP French & Quinebaug River watershed survey
W1186	No biological impacts observed; Naturally-occurring low baseflow	Biomonitoring during next MassDEP French & Quinebaug River watershed survey
TU01	Riparian habitat degradation (reduced vegetative buffer; bank erosion)	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Improve vegetative buffer along left bank; Outreach to address NPS inputs (yard waste) from adjacent residence
RB01	Naturally-occurring organic enrichment and low DO (beaver activity, wetland contributions)	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients, DO) during next MassDEP French & Quinebaug watershed survey
BU01	Agricuture-related (livestock, horses) NPS pollution—organic enrichment, sedimentation, and riparian habitat degradation	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients, DO, bacteria source tracking) during next MassDEP French & Quinebaug watershed survey; Outreach and agricultural BMPs to address livestock grazing activities, habitat destruction, etc.
GR01	Naturally-occurring low baseflow; Sedimentation; Water quality degradation	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients, DO, bacteria source tracking) during next MassDEP French & Quinebaug watershed survey; Investigate possible sources of sediment and bacteria inputs—implement BMPs as needed
FR04-1	Organic/nutrient enrichment; Other water quality degradation	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients, DO) during next MassDEP French & Quinebaug watershed survey; Field reconnaissance in subbasin to investigate land-uses that may contribute NPS inputs; NPDES permit review for Oxford-Rochdale WWTP
LR01	Organic enrichment/low DO; Water quality degradation may result from anthropogenic and natural (beaver activity) sources	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients, DO) during next MassDEP French & Quinebaug watershed survey; Field reconnaissance in subbasin to investigate land-uses that may contribute NPS inputs, especially upstream horse farm near McIntyre Road
W1197	Water quality degradation due to upstream impoundments	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients, DO) during next MassDEP French & Quinebaug watershed survey; Field reconnaissance in subbasin to investigate land-uses that may contribute NPS inputs, especially around South Charlton Pond
SU01	Organic enrichment of unknown origin; Naturally-occurring low baseflow; Riparian habitat degradation and bank modifications.	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Water quality monitoring (including nutrients, DO, bacteria source tracking) during next MassDEP French & Quinebaug watershed survey; Field reconnaissance in subbasin to investigate land-uses that may contribute NPS inputs; Outreach to address NPS inputs (yard waste) and other riparian disturbances from adjacent residences
MI01	Sedimentation; Naturally-occurring low baseflow	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; BMPs to address road runoff at Mine Brook Road
BW01	Organic enrichment; Unknown water quality degradation originating from LKQ property	Biomonitoring during next MassDEP French & Quinebaug River watershed survey; Additional BMPs to address runoff from LKQ property should be considered

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APPENDIX

Macroinvertebrate taxa list, RBPIII benthos analyses, and Habitat evaluations

CONTENTS

Table A1. Species-level taxa list and counts, functional feeding groups (FG), and tolerance values (TV) for macroinvertebrates collected from stream sites during the 2004 French & Quinebaug River watershed biomonitoring survey between 24 Agust and 3 September 2004. Refer to Table 1 for a listing and description of sampling stations.

TAXA	FG[1]	TV[2]	HA01	LE01	BR01	ST01	W1183	WS01	MO01	MK01	HC01	FR04-1	LR01	TU01	W1186	W1197	LB01	CO01	GR01	SU01	RB01	BW01	MI01	BU01
Pisidiidae	FC	6	1	5	1			2	3			1			1	5								3
Enchytraeidae	GC	10																	1					
Nais behningi	GC	6			1		2											3						
Nais communis	GC	8			1	1																		
Nais variabilis	GC	10																4	1					1
Pristinella osborni	GC	10				1																2		
Lumbriculidae	GC	7	3		7					2						5	3	1				4		
Caecidotea communis	GC	8											1								2			
Hyalella azteca	GC	8					2																	
Hydrachnidia	PR	6	1		1				1						1			2			1	1	1	1
Baetidae	GC	4						1				7				1	3	2						
Baetis (subequal terminal filament) sp.	GC	6						1																
Baetidae (short terminal filament)	GC	6														1								
Baetidae (subequal terminal filament)	GC	6								1						1								
Ephemerellidae	GC	1													1	6					1			3
Eurylophella sp.	GC	2										1											3	
Heptageniidae	SC	4					1						2			3								
Epeorus (*Iron*) sp.	SC	0			2			1																
Maccaffertium sp.	SC	3		31	9	7	1	14	6	4	3	2		3			11	1						1
Isonychia sp.	GC	2			8	5				2		1												
Leptophlebiidae	GC	2		1	16		1		2	1	15				1		5		1					
Paraleptophlebia sp.	GC	1				23																		
Boyeria vinosa	PR	2							1												3			
Calopterygidae	PR	5																			2			
Hetaerina sp.	PR	6														1								

Table A1 (cont.)

TAXA	FG[1]	TV[2]	HA01	LE01	BR01	ST01	W1183	WS01	MO01	MK01	HC01	FR04-1	LR01	TU01	W1186	W1197	LB01	CO01	GR01	SU01	RB01	BW01	MI01	BU01
Coenagrionidae	PR	9							1															
Gomphidae	PR	5																						2
Chloroperlidae	PR	1												2										
Sweltsa sp.	PR	0	8		1						2												8	
Leuctridae	SH	0			5																			
Leuctra sp.	SH	0		1	2	8				2	6			1							7			
Leuctridae/Capniidae	SH	2													1								5	1
Tallaperla sp.	SH	0				1								1										
Perlidae	PR	1							1															
Acroneuria sp.	PR	0	10								5				9	4	3		1					
Beloneuria sp.	PR	0												2										
Paragnetina sp.	PR	1			7	3				2		1	1											3
Perlodidae	PR	2						1	2	1											1			
Corydalus sp.	PR	4										1												
Nigronia sp.	PR	0			1			3					3											
Nigronia serricornis	PR	0	6	4		1			4	1	6			2	5	6	4	1	3	1	4			
Sialis sp.	PR	4				2				1							1							
Adicrophleps hitchcocki	SH	2																						
Brachycentrus sp.	FC	1					1																	
Micrasema sp.	SH	2										1							2					
Glossosoma sp.	SC	0							1							2		5						
Cheumatopsyche sp.	FC	5	16			1	15	3		11	19		8	3	18	12	4	29						
Diplectrona sp.	FC	0			1	2																4	7	
Hydropsyche sp.	FC	4	4	9	3	2	27	5	12	3	2	23	40	12	11		1	14	33	39	30	52		5
Lepidostoma sp.	SH	1				1								1										
Leptoceridae	PR	4						1																
Setodes sp.	GC	2					1																	
Apatania sp.	SC	3													1			2						
Odontoceridae	SH	0		1																				

Table A1 (cont.)

TAXA	FG[1]	TV[2]	HA01	LE01	BR01	ST01	W1183	WS01	MO01	MK01	HC01	FR04-1	LR01	TU01	W1186	W1197	LB01	CO01	GR01	SU01	RB01	BW01	MI01	BU01
Psilotreta sp.	SC	0									1													
Chimarra obscura	FC	4	8	17	7		3	41	30	49		37	29	20	6	38	7	2		41	2		1	38
Dolophilodes sp.	FC	0	1			4					11			11	7	1	6	7	12			1		
Phryganeidae	SH	4																			1			
Polycentropodidae	FC	6			2																			
Polycentropus sp.	PR	6				1																		
Rhyacophila sp.	PR	1	1			1					1								4			3	3	
Neophylax sp.	SC	3						1																
Elmidae	SC	4			2	2						1												
Ancyronyx variegata	GC	5						1																
Optioservus sp.	SC	4				4		3			1	2		5	2									
Oulimnius latiusculus	SC	4	1		5	4		6			8	1		6	6		2		5			4	2	
Promoresia sp.	SC	2			2	1			11	4			1	2		5			2					
Promoresia tardella	SC	2													4		10							
Stenelmis sp.	SC	5		7	1	2	4	7	5			8	1	5	2	1	3		4	6		11		
Stenelmis crenata gr.	SC	5																						14
Ectopria sp.	SC	5													1				3					
Psephenus herricki	SC	4			1	1				2		1		3	3									2
Anchytarsus sp.	SH	4				2		2						1										
Probezzia sp.	PR	6																	2			4		
Chironominae	GC	6																			1			
Cryptochironomus sp.	PR	8					1																	
Demicryptochironomus sp.	GC	2	1																					
Dicrotendipes sp.	GC	8					2																	
Microtendipes pedellus gr.	FC	6	1		1						1						2							
Microtendipes rydalensis gr.	FC	6	7							3					1		1							
Phaenopsectra sp.	SC	7																						
Polypedilum aviceps	SH	4	3		1			6	8	1	4			9	5	1	2	6	6				16	1
Polypedilum fallax	SH	6					2																	
Polypedilum flavum	SH	6					2					1	6						1	1	3			
Polypedilum illinoense	SH	6										1				1								

Table A1 (cont.)

TAXA	FG[1]	TV[2]	HA01	LE01	BR01	ST01	W1183	WS01	MO01	MK01	HC01	FR04-1	LR01	TU01	W1186	W1197	LB01	CO01	GR01	SU01	RB01	BW01	MI01	BU01
Polypedilum tritum	SH	6				2													1					
Stenochironomus sp.	GC	5																			1			
Xenochironomus sp.	PR	0							1				3											
Micropsectra sp.	GC	7					1		1			1												
Micropsectra dives gr.	GC	7	4											1										
Micropsectra polita	GC	7		1																				
Micropsectra/Tanytarsus sp.	FC	7		1							4			1										
Rheotanytarsus exiguus gr.	FC	6	6	2			8			5	1	9				9		2	2	3	14	1		5
Rheotanytarsus pellucidus	FC	5		1								4				2		1						20
Neostempellina sp.	GC	2			1														1					
Stempellinella sp.	GC	2	2			4		1																
Tanytarsus sp.	FC	6	4		4	4	1		1	1				2							3		6	
Diamesa sp.	GC	5																				6		
Pagastia sp.	GC	1													1				1					
Brillia sp.	SH	5																1				1		
Corynoneura sp.	GC	4			1				1		1						1			1			8	
Cricotopus sp.	SH	7	1												1									
Cricotopus annulator	SH	7																				1		
Cricotopus vierriensis	SH	7																			3			
Cricotopus/Orthocladius sp.	GC	7																				3		
Diplocladius sp.	GC	8	1																			1		
Eukiefferiella sp.	GC	6									1						1	1						
Eukiefferiella claripennis gr.	GC	8																	1			1		
Eukiefferiella devonica gr.	GC	4								1														
Heleniella sp.	GC	5																					8	
Krenosmittia sp.	GC	1																					1	
Orthocladius lignicola	SH	5													1									
Parachaetocladius sp.	GC	2				4					1						3		3				4	
Parakiefferiella sp.	GC	4					1																	
Parametriocnemus sp.	GC	5	13	3	4	6			4	1	4				8		7		5			3	2	2
Paraphaenocladius sp.	GC	4			1																			

Table A1 (cont.)

TAXA	FG[1]	TV[2]	HA01	LE01	BR01	ST01	W1183	WS01	MO01	MK01	HC01	FR04-1	LR01	TU01	W1186	W1197	LB01	CO01	GR01	SU01	RB01	BW01	MI01	BU01
Nanocladius sp.	GC	7		1		1			1		1													
Orthocladius sp.	GC	6																					18	
Rheocricotopus sp.	GC	6										1									10			
Thienemanniella sp.	GC	6																						2
Tvetenia paucunca	GC	5	2			1		2	3	2	3			2	5		6	3				1		
Tvetenia vitracies gr.	GC	5								1											2			
Xylotopus par	SH	7								1														
Tanypodinae	PR	7																					1	
Conchapelopia sp.	PR	6		9	3	2				3				8	2		3		3		2	3		
Krenopelopia sp.	PR	7																					1	
Nilotanypus fimbriatus	PR	8	1			1																		
Thienemannimyia sp.	PR	6					4		1															
Trissopelopia sp.	PR	4	1																					
Zavrelimyia sp.	PR	8		1																				
Chelifera sp.	PR	6								3														
Clinocera sp.	PR	6	1						1										2					
Hemerodromia sp.	PR	6																1			4			5
Simulium sp.	FC	5	1	2	3	1	17	6	2	1		5	8	3	1	5	1	3	3	1	7			1
Tipulidae	SH	5	1																			3		
Dicranota sp.	PR	3			4	4				1	1			4	2		1		5					
Hexatoma sp.	PR	2			1																			
Tipula sp.	SH	6							1									1	1		1			
TOTAL			110	97	110	110	97	108	105	110	102	110	103	110	107	110	91	92	109	93	105	110	95	110

[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 Quinebaug River subwatershed between 24 and 27 August 2004. Shown are the calculated metric values, metric scores (in italics) based on comparability to the regional reference station (BR01), and the corresponding assessment designation for each biomonitoring station. Refer to Table 1 for a listing and description of sampling stations.

STATION	**BR01**		**MO01**		**WS01**		**W1183**		**ST01**		**LE01**		**HA01**	
STREAM	Browns Brook		Mountain Brook		West Brook		East Brook		Stevens Brook		Leadmine Brook		Hamant Brook	
HABITAT SCORE	173		156		125		137		184		183		174	
TAXA RICHNESS	32	*6*	26	*6*	20	*4*	20	*4*	34	6	17	*2*	29	*6*
BIOTIC INDEX	3.28	*6*	3.77	*6*	3.91	*4*	4.92	*2*	2.72	6	3.97	*4*	3.98	*4*
EPT INDEX	11	*6*	7	*0*	9	*4*	7	*0*	13	*6*	6	*0*	7	*0*
EPT/CHIRONOMIDAE	3.94	*6*	2.57	*4*	7.67	*6*	2.27	*4*	2.36	*4*	3.16	*6*	1.02	*2*
SCRAPERS/FILTERERS	1.00	*6*	0.48	*4*	0.56	*6*	0.08	*0*	1.50	*6*	1.03	*6*	0.02	*0*
% DOMINANT TAXON	15%	*6*	29%	*4*	38%	*2*	28%	*4*	21%	*4*	32%	*2*	15%	*6*
REFERENCE SITE AFFINITY	100%	*6*	57%	*4*	57%	*4*	46%	*2*	87%	*6*	76%	*6*	54%	*4*
TOTAL METRIC SCORE		*42*		*28*		*30*		*16*		*38*		*26*		*22*
% COMPARABILITY TO REFERENCE STATION			67%		71%		38%		90%		62%		52%	
BIOLOGICAL CONDITION (DEGREE OF IMPACT)	**REFERENCE**		**SLIGHT IMPACT**		**SLIGHT IMPACT**		**MODERATE IMPACT**		**NON-IMPACT**		**SLIGHT IMPACT**		**SLIGHT IMPACT**	

STATION	**HC01**		**MK01**		**CO01**		**LB01**		**W1186**		**TU01**		**RB01**	
STREAM	Hatchet Brook		McKinstry Brook		Cohasse Brook		Lebanon Brook		Keenan Brook		Tufts Branch		Rocky Brook	
HABITAT SCORE	166		150		130		193		149		148		177	
TAXA RICHNESS	24	*4*	28	*6*	22	*4*	25	*4*	28	*6*	24	*4*	22	*4*
BIOTIC INDEX	2.86	*6*	4.16	*4*	4.32	*4*	3.38	*6*	3.48	*6*	3.55	*6*	4.50	*4*
EPT INDEX	10	*6*	10	*6*	8	*2*	8	*2*	9	*4*	10	6	6	*0*
EPT/CHIRONOMIDAE	3.10	*6*	4.00	*6*	4.43	*6*	1.54	*2*	2.29	*4*	2.43	4	1.08	*2*
SCRAPERS/FILTERERS	0.34	*2*	0.14	*0*	0.14	*0*	1.18	*6*	0.42	*4*	0.46	4	0	*0*
% DOMINANT TAXON	19%	*6*	45%	*0*	32%	*2*	12%	*6*	17%	*6*	18%	6	29%	*4*
REFERENCE SITE AFFINITY	72%	*6*	52%	*4*	47%	*2*	72%	*6*	57%	*4*	53%	4	45%	*2*
TOTAL METRIC SCORE		*36*		*26*		*20*		*32*		*34*		*34*		*16*
% COMPARABILITY TO REFERENCE STATION	86%		62%		48%		76%		81%		81%		38%	
BIOLOGICAL CONDITION (DEGREE OF IMPACT)	**NON-IMPACT**		**SLIGHT IMPACT**		**MODERATE IMPACT**		**SLIGHT IMPACT**		**NON-IMPACT**		**NON-IMPACT**		**MODERATE IMPACT**	

Table A3. Summary of RBP III data analysis for macroinvertebrate communities sampled in the French River subwatershed between 24 and 3 September 2004. Shown are the calculated metric values, metric scores (in italics) based on comparability to the reference station (BR01), and the corresponding assessment designation for each biomonitoring station. Refer to Table 1 for a listing and description of sampling stations.

STATION	**BR01**		**BU01**		**GR01**		**FR04-1**		**LR01**		**W1197**		**SU01**		**MI01**		**BW01**	
STREAM	Browns Brook		Burncoat Brook		Grindstone Brook		French River		Little River		Potters Brook		Sucker Brook		Mine Brook		Browns Brook	
HABITAT SCORE	173		130		162		176		167		185		131		147		153	
TAXA RICHNESS	32	*6*	19	*2*	28	*6*	21	*4*	12	*0*	20	*2*	8	*0*	17	*2*	20	*2*
BIOTIC INDEX	3.28	*6*	4.51	*4*	3.57	*6*	4.32	*4*	4.04	*4*	3.92	*4*	4.12	*4*	3.68	*6*	4.53	*4*
EPT INDEX	11	*6*	6	*0*	6	*0*	8	*2*	5	*0*	9	*4*	2	*0*	6	*0*	4	*0*
EPT/CHIRONOMIDAE	3.94	*6*	1.70	*2*	2.21	*4*	4.29	*6*	8.89	*6*	5.31	*6*	16.0	*6*	0.42	*0*	2.86	*4*
SCRAPERS/FILTERERS	1.00	*6*	0.24	*2*	0.28	*2*	0.19	*0*	0.05	*0*	0.15	*0*	0.07	*0*	0.14	*0*	0.26	*2*
% DOMINANT TAXON	15%	*6*	35%	*2*	30%	*4*	34%	*2*	39%	*2*	35%	*2*	44%	*0*	19%	*6*	47%	*0*
REFERENCE SITE AFFINITY	100%	*6*	55%	*4*	50%	*4*	54%	*4*	35%	*2*	58%	*4*	26%	*0*	46%	*2*	49%	*2*
TOTAL METRIC SCORE		*42*		*16*		*26*		*22*		*14*		*22*		*10*		*16*		*14*
% COMPARABILITY TO REFERENCE STATION			38%		62%		52%		33%		52%		24%		38%		33%	
BIOLOGICAL CONDITION (DEGREE OF IMPACT)	**REFERENCE**		**MODERATE IMPACT**		**SLIGHT IMPACT**		**SLIGHT IMPACT**		**MODERATE IMPACT**		**SLIGHT IMPACT**		**MODERATE IMPACT**		**MODERATE IMPACT**		**MODERATE IMPACT**	

Table A4. Summary of RBP III data analysis for macroinvertebrate communities sampled in the largest rivers/streams of the 2004 French & Quinebaug watershed survey between 24 and 3 September 2004. Shown are the calculated metric values, metric scores (in italics) based on comparability to a reference station (LB01) of comparable drainage area, and the corresponding assessment designation for each biomonitoring station. Refer to Table 1 for a listing and description of sampling stations.

STATION	**LB01**		**FR04-1**		**LR01**		**W1197**	
STREAM	Lebanon Brook		French River		Little River		Potters Brook	
HABITAT SCORE	193		176		149		185	
TAXA RICHNESS	25	*6*	21	*6*	12	*2*	20	*4*
BIOTIC INDEX	3.38	*6*	4.32	*4*	4.04	*4*	3.92	*6*
EPT INDEX	8	*6*	8	*6*	5	*0*	9	*6*
EPT/CHIRONOMIDAE	1.54	*6*	4.29	*6*	8.89	*6*	5.31	*6*
SCRAPERS/FILTERERS	1.18	*6*	0.19	*0*	0.05	*0*	0.15	*0*
% DOMINANT TAXON	12%	*6*	34%	*2*	39%	*2*	35%	*2*
REFERENCE SITE AFFINITY	100%	*6*	64%	*4*	41%	*2*	62%	*4*
TOTAL METRIC SCORE		*42*		28		*16*		28
% COMPARABILITY TO REFERENCE STATION			67%		38%		67%	
BIOLOGICAL CONDITION (DEGREE OF IMPACT)	**REFERENCE**		**SLIGHT IMPACT**		**MODERATE IMPACT**		**SLIGHT IMPACT**	

Table A5. Habitat assessment summary for biomonitoring stations sampled during the 2004 French & Quinebaug 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	BR01	MO01	WS01	W1183	ST01	LE01	HA01	HC01	MK01	CO01	LB01	W1186	TU01	RB01	BU01	GR01	FR04-1	LR01	W1197	SU01	MI01	BW01
Primary Habitat Parameters	**Score (0-20)**																					
INSTREAM COVER	18	9	11	9	18	17	18	17	17	13	20	8	16	18	12	17	17	15	18	9	6	13
EPIFAUNAL SUBSTRATE	18	15	9	11	19	19	19	19	15	17	19	18	18	19	17	18	19	18	19	17	18	18
EMBEDDEDNESS	18	15	11	8	19	18	18	18	17	8	19	18	18	19	16	12	18	18	19	18	17	17
CHANNEL ALTERATION	19	20	18	18	20	20	20	19	4	18	20	18	16	20	19	20	20	20	20	10	20	20
SEDIMENT DEPOSITION	14	18	8	9	19	19	17	19	16	5	19	18	18	20	13	15	19	18	19	18	8	13
VELOCITY-DEPTH COMBINATIONS	18	9	10	15	18	15	17	10	14	14	19	10	11	10	10	10	15	14	19	8	11	10
CHANNEL FLOW STATUS	15	12	9	19	14	17	17	10	14	13	19	8	9	11	18	10	16	10	15	9	7	10
Secondary Habitat Parameters	**Score (0-10)**																					
BANK VEGETATIVE PROTECTION left	10	10	10	10	10	10	10	10	9	5	10	9	10	10	8	10	10	10	10	10	10	10
BANK VEGETATIVE PROTECTION right	10	10	10	10	10	10	10	10	9	9	10	9	10	10	8	10	10	10	10	5	10	10
BANK STABILITY left	8	9	6	9	9	9	3	7	10	8	9	9	7	10	8	10	8	10	8	9	10	10
BANK STABILITY right	9	9	6	9	9	9	5	7	10	8	9	7	8	10	8	10	6	10	8	8	10	7
RIPARIAN VEGETATIVE ZONE WIDTH left	6	10	7	5	9	10	10	10	5	2	10	9	2	10	6	10	10	6	10	9	10	9
RIPARIAN VEGETATIVE ZONE WIDTH right	10	10	10	5	10	10	10	10	10	10	10	8	5	10	6	10	8	8	10	1	10	6
Total Score	**173**	**156**	**125**	**137**	**184**	**183**	**174**	**166**	**150**	**130**	**193**	**149**	**148**	**177**	**149**	**162**	**176**	**167**	**185**	**131**	**147**	**153**