Technical Memorandum TM 92-7

IPSWICH RIVER WATERSHED
2005 BENTHIC MACROINVERTEBRATE BIOASSESSMENT

CN 228.3

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Worcester, MA

November 2011

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INTRODUCTION

Biological monitoring is a useful means of detecting anthropogenic impacts to the aquatic community. Resident biota (e.g., benthic macroinvertebrates, fish, periphyton) in a water body are natural monitors of environmental quality and can reveal the effects of episodic and cumulative pollution and habitat alteration (Plafkin et al. 1989, Barbour et al. 1995). 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) 2005 Ipswich River watershed assessments, aquatic benthic macroinvertebrate biomonitoring was conducted to evaluate the biological health of various streams within the watershed. A total of seven biomonitoring stations were sampled to investigate the effects of various nonpoint and point source stressors—both historical and current—on the aquatic communities of the watershed. All stations sampled during the 2005 biomonitoring survey had been previously assessed by MassDEP (Fiorentino 1997; Fiorentino 2003). The 2005 biomonitoring data, then, will be used to determine if water quality and habitat conditions have improved or worsened over time. To minimize the effects of temporal (seasonal and year-to-year) variability, sampling was conducted at approximately the same time of the month as previous biosurveys. Sampling locations, along with station identification numbers and sampling dates, are presented in Table 1.

To provide additional information necessary for making basin-wide aquatic life use-support determinations required by Section 305(b) of the Clean Water Act, all Ipswich River watershed macroinvertebrate biomonitoring stations were compared to a regional reference station most representative of "least disturbed" conditions in the watershed. Use of a regional reference station is particularly useful in assessing nonpoint source pollution and nutrient/BOD loadings originating from multiple and/or unknown sources in a watershed, as well as nonpoint source (NPS) pollution impacts (e.g., physical habitat degradation) at sites suspected as chemically-impacted from known point source stressors (Hughes 1989). The regional reference station was established in Fish Brook (FB00). It was situated upstream from all known point sources of water pollution, and was also assumed (based on MassDEP water quality and benthos data, topographic map examinations, and field reconnaissance) to be minimally impacted (relative to other portions of the watershed) by nonpoint sources.

During "year 1" of its "5-year basin cycle", problem areas within the Ipswich River watershed were better defined through such processes as coordination with appropriate groups (Ipswich River Watershed Association, MassDEP/DWM, MassDEP/NERO), assessing existing data, conducting site visits, and reviewing NPDES and water withdrawal permits. Following these activities, the 2005 biomonitoring plan was formulated and included well defined study objectives. Table 2 includes a summary of the perceived problems/issues addressed during the 2005 Ipswich River watershed biomonitoring survey.

The main objectives of biomonitoring in the Ipswich River watershed were: (a) to determine the biological health of 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/or 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 Ipswich 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 2005 Ipswich River watershed survey, including station identification number, drainage area, station description, and sampling date. Stations are listed hydrologically (from upstream-most drainage in the watershed to downstream-most). Previous sampling events are also noted.

Station ID	Drainage area (mi^2)	Ipswich River Watershed Site description	Sampling Date
MB02A[1,2]	13.15	Martins Brook, 50 m downstream from Park Street, North Reading, MA	27 July 2005
IP06[1,2]	43.84	Ipswich River, 100 m downstream from Boston Street, Middleton/Peabody, MA	27 July 2005
BB01[2]	8.07	Boston Brook, 250 m upstream from Liberty Street, Middleton, MA	28 July 2005
FB00[1,2]	12.16	Fish Brook, 350 m upstream from Middletown Road, Boxford, MA	12 August 2005
HB02[1]	10.2	Howlett Brook, 5 m upstream from Ipswich Road, Topsfield, MA	25 July 2005
GB01[2]	2.15	Gravelly Brook, 60 m upstream from Topsfield Road, Ipswich, MA	25 July 2005
MR01[2]	16.87	Miles River, 370 m downstream from Route 1A (County Road), Ipswich, MA	25 July 2005

[1] Previously sampled in 1995 (Fiorentino 1997); [2] Previously sampled in 2000 (Fiorentino 2003)

Table 2. List of perceived problems addressed during the 2005 Ipswich River watershed biomonitoring survey. Specific biomonitoring stations addressing each problem are also listed.

Ipswich River Watershed Stations	Issues/Problems
MB02A	miscellaneous NPS (habitat degradation, stormwater/road runoff)[1,2]; organic enrichment/low dissolved oxygen[1, 2, 3]; upstream impoundments[3]; water treatment plant discharge[4]; *Impaired* for aquatic life use[2]
IP06	flow alteration[3]; miscellaneous NPS (habitat degradation, stormwater/road runoff)[1, 2, 3]; industrial discharge[4]; nutrients[3]; organic enrichment/low dissolved oxygen[3]; slightly impacted benthos[2]
BB01	unknown NPS[2]; upstream impoundments[3]; *Impaired* for aquatic life use[2]
FB00	reference condition, new home construction[2]
HB02	Water withdrawal[2]; miscellaneous NPS (habitat degradation, golf course, stormwater/road runoff), upstream impoundments[1, 3]
GB01	"least-disturbed conditions"[2], new golf course[2, 5]
MR01	Agricultural/horse farm runoff, organic enrichment/low dissolved oxygen[3]; *Impaired* for aquatic life use[2]

[1](Fiorentino 1997); [2](Fiorentino 2003); [3](MassDEP 2007); [4](MassDEP 2008); [5](Mackin 2003; Pancoast 2003)

WATERSHED DESCRIPTION

The Ipswich River is formed by the confluence of Maple Meadow and Lubbers brooks near Woburn Street in Wilmington. The drainage area at the confluence is 8.6 mi^2 of which 5.6 mi^2 are drained by Maple Meadow Brook. The Ipswich widens into a "pond" as it passes by the Reading Town Forest. Bear Meadow Brook, which flows out of Cedar Swamp to the south of the Ipswich, and Martins Brook, which drains 14 mi^2 of relatively undeveloped wetlands to the north of the river are the next tributaries to flow into the Ipswich River. Below Martins Brook, the Ipswich becomes more distinctly channelized and, as a result, there is a slight increase in stream velocity. The channel then begins to widen as the river passes through the center of North Reading. The river continues eastward in a series of tight meanders and is joined by an unnamed tributary and by Wills Brook before it enters the impoundment created by the Bostik Company Dam (formerly the USM Chemical Dam) in South Middleton. The first of two flow gages maintained by the US Geological Survey (USGS) on the mainstem Ipswich River is located just downstream of this dam. Station 01101500 at South Middleton, MA has a drainage area of 44.5 mi^2 and an average annual flow of 63.2 cubic feet per second (cfs). The river has a vertical fall of approximately 30 feet between its source and the South Middleton gage. One-third of the fall occurs at the dam.

Stream flow, which has followed an easterly course since the confluence with Martin's Brook, turns abruptly to the north approximately 1.4 river miles below the gage. As the Ipswich meanders northward through Middleton, it is joined by Norris Brook, the outlet of Middleton Pond, and Emerson Brook. Again, much of the Ipswich's slowly flowing course is through wetland areas. As it is joined by Boston Brook, the overall direction of flow turns to the east as the stream meanders through Topsfield. Nichols Brook and Fish Brook join the Ipswich prior to its entrance into the northern portion of Wenham Swamp, which is the basin's largest freshwater wetland (3 mi^2). As the meandering journey of the Ipswich again turns north, the rate of flow is so slow and the surface of the stream is so level with the surrounding wetlands that several rather large backwater ponds are formed adjacent to the main "channel".

As the Ipswich flows northward, it is joined by several tributaries including Mile, Idlewild, an unnamed tributary, Howlett, and Gravelly brooks. The stream channel widens considerably and the Ipswich River begins to flow at a higher velocity in the northeasterly direction that will carry it into Ipswich Bay. The channel widens further as the river enters the impoundment created by the Willowdale "Dam", which is actually a series of small dams. The second USGS flow gage on the mainstem Ipswich, station 01102000 near Ipswich, MA, has a drainage area of 125 mi^2 and an average annual discharge of 187 cfs. Below the Willowdale Dam, the Ipswich is joined by Black Brook and the Miles River. The most noticeable vertical fall in the Ipswich River occurs in the stretch between the Willowdale Dam and the Miles River, where there are riffles in the stream. The river slows as it enters the impoundment created by the Sylvania Dam, located in the central village of Ipswich. The Ipswich Estuary begins just downstream of the dam, and the stream flows through extensive saltwater marshlands to its mouth at Ipswich Bay delineated between Little Neck and Crane Beach. There are several estuarine tributaries, but the only stream of any significance is known locally as Greenwood Creek, which receives the treated effluent of the Ipswich Wastewater Treatment Facility.

METHODS

Macroinvertebrate Sampling - RBPIII

Macroinvertebrate sampling during the 2005 Ipswich River watershed survey was conducted in accordance with the Quality Assurance Project Plan (QAPP) for benthic macroinvertebrate biomonitoring (MassDEP 2004a). The sampling procedures are described in the standard operating procedures *Water Quality Monitoring in Streams Using Aquatic Macroinvertebrates* (Nuzzo 2003), and are based on US EPA Rapid Bioassessment Protocols (RBPs) for wadeable streams and rivers (Plafkin et al. 1989). The macroinvertebrate collection procedure utilized kick-sampling, a method of sampling benthic organisms by kicking or disturbing bottom sediments and catching the dislodged organisms in a net as the current carries them downstream (Figure 1). Sampling was conducted 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.

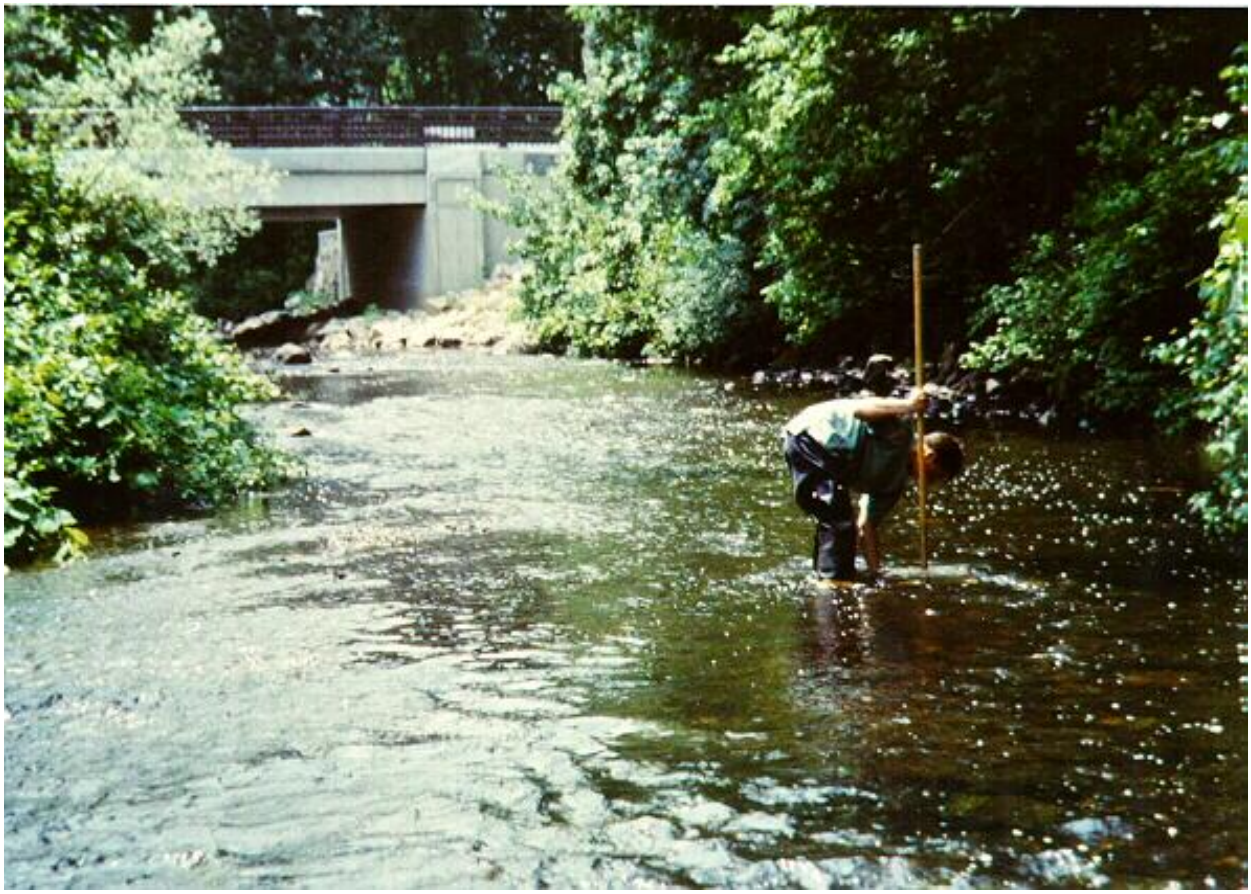

Figure 1. MA DEP/DWM biologist collecting macroinvertebrates using the "kick-sampling" technique.

Macroinvertebrate Sample Processing and Analysis

The macroinvertebrate sample processing and analysis procedures employed for the 2005 Ipswich 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 2004a). 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. 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. RBP III analysis separates sites into four categories: non-impaired, slightly impaired, moderately impaired, and severely impaired. Each impairment category corresponds to a specific aquatic life use-support determination used in

the CWA Section 305(b) water quality reporting process—non-impaired and slightly impaired communities are assessed as "support" in the 305(b) report; moderately and severely impaired communities are assessed as "non-support" A detailed description of the *Aquatic Life* use designation is outlined in the *Massachusetts Surface Water Quality Standards* (SWQS) (MassDEP 2006). 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 (Plafkin et al. 1989). Those biological metrics calculated and used in the analysis of Ipswich River watershed macroinvertebrate data are listed and defined below [For a more detailed description of metrics used to evaluate benthos data see Plafkin et al. (1989)]:

1. Taxa Richness—a measure based on the number of taxa present. Generally increases with increasing 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 DEP/DWM biologists were originally derived from Hilsenhoff and have since been revised by Bode et al. (1991). 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 numbers 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 (Plafkin et al. 1989). 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—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 Ipswich River watershed bioassessment, an index of macroinvertebrate community composition was calculated based on similarity (i.e., affinity) to the reference community, expressed as percent composition of the following organism groups: Oligochaeta, Ephemeroptera, Plecoptera, Coleoptera, Trichoptera, Chironomidae, and Other. This approach is based on a modification of the Percent Model Affinity (Novak and Bode 1992). The reference site affinity (RSA) metric is calculated as:

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

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

Habitat Assessment

An evaluation of physical and biological habitat quality is critical to any assessment of ecological integrity (Karr et al. 1986; Plafkin et al. 1989). Habitat assessment supports understanding of the relationship between physical habitat quality and biological conditions, identifies obvious constraints on the attainable potential of a site, assists in the selection of appropriate sampling stations, and provides basic information for interpreting biosurvey results (US EPA 1995). Before leaving the sample reach during the 2005 Ipswich River watershed biosurveys, habitat qualities were scored using a modification of the evaluation procedure in Plafkin et al. (1989). The matrix used to assess habitat quality is based on key physical characteristics of the water body and the immediate riverfront area. Most parameters evaluated are instream physical attributes often related to overall land use and are potential sources of limitation to the aquatic biota (Plafkin et al. 1989). The ten habitat parameters are as follows: instream cover, epifaunal substrate, embeddedness, sediment deposition, channel alteration, velocity/depth combinations, channel flow status, right and left (when facing downstream) bank vegetative protection, right and left bank stability, right and left bank riparian vegetative zone width. Habitat parameters are scored, totaled, and compared to a reference station to provide a final habitat ranking.

RESULTS AND DISCUSSION

The biological and habitat data collected at each sampling station during the 2005 biosurveys are attached as an Appendix (Tables A1 – A3). Included in the macroinvertebrate taxa list (Table A1) are total organism counts, the functional feeding group designation (FG) for each macroinvertebrate taxon, and the tolerance value (TV) of each taxon.

A summary table (Table A2) of the RBP III macroinvertebrate data analyses, including biological metric calculations, metric scores, and impairment designations, is included in the Appendix as well. 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 A3.

According to USGS stream discharge data, surface water runoff for the majority of eastern Massachusetts, and including the Ipswich River watershed, was within normal monthly ranges for May through August 2005 (USGS 2008).

The 2005 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 Martins Brook, Gravelly Brook, and the Miles River. That said, several tributaries examined in the Ipswich River watershed remain relatively unimpaired and are indicative of “least-disturbed” conditions in the watershed. It is imperative that anthropogenic perturbations be kept to a minimum in these unimpaired waterbodies.

Fish Brook

Fish Brook drains a large wetland area in North Andover. Mosquito Brook joins Fish Brook as it meanders in an easterly direction through Howes Pond in Boxford where it turns in a southeasterly direction towards its confluence with the Ipswich River. Fish Brook forms the boundary between Boxford and Topsfield as it flows into the Ipswich River.

FB00—Fish Brook, mile point 3.5, approximately 350 m upstream from Middletown Road, Boxford, MA.

Habitat

FB00 received a composite habitat score of 172/200—the second highest received by a biomonitoring station during the 2005 Ipswich River watershed survey (Table A3). This was the designated regional reference station based on its habitat evaluation, historically good water quality and healthy biota, and minimal upstream/nearstream land use impacts (i.e., absence of point source inputs, lack of channelization, minimal development or agricultural activity nearby, undisturbed and well-vegetated riparian zone, and minimal NPS inputs).

Benthos

The benthic macroinvertebrate community at FB00 was indicative of the least-impaired condition expected at this designated regional reference site. Total richness (27 taxa) and Biotic Index (4.43) values were the best encountered during the 2005 Ipswich River watershed survey and, while overall EPT taxa were not particularly well represented, this was the only sampling site supporting species populations of the pollution-intolerant stoneflies, *Acroneuria* sp. and *Leuctra* sp.

Martins Brook

From its source, Martins Pond in North Reading, Martins Brook flows in a westerly direction towards Wilmington and turns south then easterly before joining the Ipswich River in North Reading. Martins Pond receives flow from the Skug River which drains the southeast corner of Andover.

MB02A—Martins Brook, mile point 0.10, approximately 50 m downstream from Park Street, North Reading, MA

Habitat

MB02A received a total habitat assessment score of 103/200—the poorest evaluation received by a biomonitoring station in the 2005 Ipswich River watershed survey (Table A3). Sediment deposition and associated substrate embeddedness, eroding stream banks, and riparian disruption (reduced vegetative zone, and NPS inputs from adjacent residence and road) along the right bank affected the overall assessment most negatively.

Benthos

The macroinvertebrate community at MB02A received a total metric score of 6, representing only 15% comparability to the reference site at Fish Brook, and indicative of a severely impaired biological condition – the worst, in fact, of all the 2005 Ipswich River watershed sampling locations. Only seven taxa, all of which were relatively tolerant to organic pollution, were represented in the sample from Martin's Brook. The hyperdominance (78%) of the midge, *Rheotanytarsus exiguus* gr., contributed to a severely unbalanced invertebrate community structured in response to an overabundance of fine particulate organic matter (FPOM). Habitat degradation in the form of sedimentation and substrate embeddedness further limited the capacity of this site to support a diverse and healthy macroinvertebrate community, making it difficult to distinguish water quality from habitat influences on the biological integrity of Martins Brook.

Ipswich River

Formed at the confluence of Maple Meadow and Lubbers Brooks near Woburn Street in Wilmington, the Ipswich River flows under Route 93 and forms the boundary between Reading and North Reading widening into a "pond" as it passes by the Reading Town Forest. It is joined by Bear Meadow Brook from the south and Martins Brook from the north where the river becomes more distinctly channelized and the velocity increases slightly. The channel then begins to widen as the river passes through the center of North Reading. The Ipswich flows eastward in a series of tight meanders and is joined by an unnamed tributary from the north and Wills Brook from the south before it enters the impoundment created by the Bostik Company Dam (formerly the USM Chemical Dam) in South Middleton. Bostik Findley, Inc. in Middleton, a manufacturer of industrial grade adhesives and glues, is permitted (MA0001180 issued in July 1991) to discharge contact and non-contact cooling water and stormwater runoff to the Ipswich River (MA DEP 2008). While it has followed an easterly course since its confluence with Martin's Brook, the Ipswich River is joined by Norris Brook from the south and turns abruptly to the north approximately 1.4 river miles below the USGS gage. As the Ipswich meanders northward through Middleton, it is joined by two unnamed tributaries and Boston Brook. It turns east again as it meanders through Topsfield and picks up flow from Nichols and Fish brooks prior to its entrance into the northern portion of Wenham Swamp, which is the basin's largest freshwater wetland (3 mi^2). It is here that the Salem Beverly Waterway Canal diverts Ipswich River water to supply the communities of Salem and Beverly with treated drinking water.

As the meandering journey of the Ipswich again turns north, the rate of flow is so slow and the surface of the stream so level with the surrounding wetlands that several rather large backwater ponds are formed adjacent to the main "channel". As the Ipswich flows northward, it is joined by Idlewild and Mile brooks, an unnamed tributary, Howlett Brook and Gravelly Brook. The stream channel widens considerably and the Ipswich begins to flow at a higher velocity in the northeasterly direction which will carry it into Ipswich Bay. The channel widens further as the river enters the impoundment created by the Willowdale "Dam", which is actually a series of small dams. The second USGS flow gage on the mainstem Ipswich River, station 01102000 near Ipswich, MA, has a drainage area of 125 mi^2 and an average annual discharge of 187 cfs. Below the Willowdale Dam, the Ipswich is joined by Black Brook and the Miles River. The most noticeable vertical fall in the Ipswich River occurs in the stretch between the Willowdale Dam and the Miles River, where there are riffles in the stream. The river slows as it enters the impoundment created by the Sylvania Dam, located in the central village of Ipswich.

The Ipswich River estuary begins just downstream from the Sylvania Dam and flows through extensive saltwater marshlands to its mouth at Ipswich Bay delineated between Little Neck and Crane Beach. There are several estuarine tributaries to this segment of the Ipswich River.

IP06—Ipswich River, mile point 28.6, approximately 100 m downstream from Boston Street, Middleton/Peabody, MA

Habitat

IP06 received a total habitat assessment score of 124/200 (Table A3). Low baseflow resulted in a channel only about 25% full of water. Severe instream sedimentation effects and bank erosion along the right bank also affected the total habitat score negatively. Sediment inputs appear to originate from the Boston Street/Main Street crossing and possibly the Bostik discharge. Sedimentation seriously compromised fish and macroinvertebrate habitat, causing embeddedness of instream substrates, bar formation, and deposits of fine materials in pools. Algae growth was extensive throughout the sampling reach, with thin-film periphyton covering approximately 60% of the available substrates in the slower pool areas.

Benthos

Despite substantial habitat alteration, the macroinvertebrate community at IP06 was 80% comparable to the reference condition, placing this site in the non- to slightly impaired category and indicating that the Ipswich River was supporting the A*quatic Life* use. Individual metrics, however, were illustrative of a macroinvertebrate community affected by both habitat limitations as well as an apparent imbalance in the

available food resources. Most notable were the Total Richness (16) and Percent Dominant Taxon (33%) values that deviated considerably from those of the reference condition at Fish Brook. The predominance of two net-spinning caddisflies, *Chimarra obscura* (33%) and *Hydropsyche betteni* (29%) was further indicative of an abundance of fine particulate organic matter (FPOM) suspended in the water column. It is likely that the impoundment behind the the Bostik Company Dam, situated immediately upstream from IP06 releases substantial amounts of FPOM to downstream filter-feeding communities along the Ipswich River.

Boston Brook

Boston Brook flows from the outlet of Towne Street Pond in North Andover along a generally southeasterly course to the confluence with the Ipswich River in Middleton. The headwater drainage area of the Boston Brook subwatershed includes drainage from Boston Hill near the Salem Turnpike in North Andover through Brook Street Pond into Towne Street Pond.

BB01—Boston Brook, mile point 1.25, approximately 250 m upstream from Liberty Street, Middleton, MA

Habitat

BB01 received a total habitat assessment score of 180/200, which was not only higher than that of the reference station in Fish Brook, but easily the highest evaluation received by any biomonitoring station during the 2005 Ipswich River watershed survey (Table A3). This was the only biomonitoring station—along with FB00—in which both instream cover for fish, and epifaunal substrates for macroinvertebrates, were considered optimal. Channel flow status was less than optimal (suboptimal); however, water filled greater than 75% of the available channel and left only a minimal amount of substrates exposed.

Benthos

The benthic invertebrate community at BB01 received a total metric score of 36, representing 90% comparability to the reference community at FB00 and resulting in a bioassessment of “non-impaired”. With the exception of the reference site, this was the highest total metric score calculated for any site assessed as part of the 2005 Ipswich River watershed survey. While Total Richness (21), Biotic Index (5.66) and Percent Dominant Taxon (24%) values compromised the total metric score, the EPT Index, and the ratios of EPT/Chironomidae Abundance and Scrapers/Filtering Collectors actually slightly outperformed those of the reference site.

Howlett Brook

From its headwaters north of Great Hill in Topsfield near the intersection of Ipswich Road and Newburyport Turnpike Howlett Brook flows in a northwesterly direction to a confluence with Pye Brook. Here the flow of Howlett Brook turns northeast and meanders to its confluence with the Ipswich River in Topsfield.

HB02—Howlett Brook, mile point 0.10, approximately 5 m upstream from Ipswich Road, Topsfield, MA

Habitat

HB02 received a total habitat assessment score of 153/200 (Table A3). Marginal channel flow status (channel only about half full of water), and its effect on velocity-depth combinations and available fish cover within the HB02 sampling reach, impacted the total habitat score most. While it is unknown whether low baseflow at HB02 is naturally occurring or the result of anthropogenic factors, it should be noted that there is one WMA permittee within this subwatershed area – the Topsfield Water Department – which withdraws from one of their two wells along the Howlett Brook (MassDEP 2004b)

Benthos

The macroinvertebrate community at HB02 was 85% comparable to the reference community, indicating that the biological condition of Howlett Brook was non-impaired. Only the HBI and Scrapers/Filtering Collectors metrics adversely affected the total metric score, and several metrics outperformed those of the reference community.

Gravelly Brook

Gravelly Brook flows through a large wetland in the Willowdale State Forest in Ipswich to its confluence with the Ipswich River in Ipswich.

GB01—Gravelly Brook, mile point 0.10, approximately 60 m upstream from Topsfield Road, Ipswich, MA

Habitat

GB01 received a total habitat assessment score of 140/200 (Table A3). Habitat quality was compromised by marginal channel flow status—only about 25% of the stream channel was full of water. Low baseflow here affected fish habitat most negatively, the result of a lack of instream cover, and constraints to fish passage (i.e., isolated pools). It is unclear whether reduced flows at GB01 are naturally occurring or the result of anthropogenic factors. It should be noted that a portion of the Turner Hill estate in the Gravelly Brook subwatershed has recently been developed into the Turner Hill Golf Course (Mackin 2003; Pancoast 2003; MassDEP 2004b).

Benthos

The total metric score (14) for the macroinvertebrate community at GB01 was only 35% comparable to that of the reference community at Fish Brook resulting in a bioassessment of “moderately impaired”. While all of the metrics were deficient, the poor performance of the EPT Index (2), Scrapers/Filter Collectors (0.03) and Percent Dominant Taxon (51%) indices were particularly noteworthy. Total richness (12 taxa) was less than half that exhibited by the reference stream, and most taxa were relatively tolerant to organic enrichment (HBI = 5.82). An analysis of the functional feeding groups represented at GB01 revealed an imbalanced community composed almost entirely of filtering (FC) or gathering (GC) collectors of fine particulate organic matter (FPOM) either suspended in the water column or deposited on the stream bottom. This preponderance of collectors is indicative of an overabundant supply of FPOM, although it is difficult to distinguish the contribution of upstream wetlands from potential anthropogenic sources.

Miles River

The Miles River flows from the outlet of Longham Reservoir in Wenham/Beverly and meanders in a northerly direction to its confluence with the Ipswich River in Ipswich. The upper subwatershed flow is generally in a southwesterly direction into Longham Reservoir. The river flows through a wetland along much of its length and forms the boundary between Hamilton and Ipswich where it is joined by Long Causeway Brook.

MR01—Miles River, mile point 0.40, approximately 370 m downstream from Route 1A (County Road), Ipswich, MA

Habitat

MR01 received a total habitat assessment score of 166/200 which was highly comparable to habitat at the reference station (Table A3). Riparian disruption caused by an adjacent residence and horse bridal trail, and the suboptimal fish habitat (due to a lack of deep pools and variety of stable cover) affected the evaluation most negatively.

Benthos

The macroinvertebrate community at MR01 was 55% comparable to the reference community placing this site at the low end of the range of comparability (54-79%) leading to an assessment of "slightly impaired". This assessment implies that the *Aquatic Life Use* was supported at the time of the biomonitoring survey. Nonethless, several individual metric scores performed poorly in the overall analysis, and any worsening of conditions in the Miles River would likely result in an *Aquatic Life Use* determination of "Non-support". For example, while the Total Richness metric was similar to that of the reference community, EPT taxa were entirely absent from the Miles River sample, and the HBI value calculated for MR01 (7.12) was the highest of all sites sampled in the 2005 Ipswich River watershed survey. Furthermore, an examination of the taxa list revealed an invertebrate community comprised, in part, of worm and midge taxa that are known to be tolerant of organic enrichment. All of this evidence points to a macroinvertebrate community structured in response to organic loadings and associated dissolved oxygen depletion. Continued monitoring of the Miles River is recommended for the future in an effort to clarify its status with respect to *Aquatic Life Use* support.

SUMMARY AND RECOMMENDATIONS

As anticipated from previous studies (Fiorentino 1997; Fiorentino 2003), Fish Brook once again in 2005 exhibited reference-quality (i.e., least-disturbed) conditions for the Ipswich River Watershed. Boston and Howlett brooks also were assessed as non-impaired. The remaining biomonitoring stations investigated during the 2005 survey exhibited various degrees of impairment. Impacts to the resident biota at these sites were generally a result of habitat degradation and/or nonpoint source-related water quality impairment.

The schematic in Figure 2 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-impaired or Slightly Impaired aquatic communities—such as those encountered at FB00, BB01, HB02, and IP06—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 or Severely Impaired communities observed at GB01, MR01, and MB02A, do not support the *Aquatic Life* use and fail to meet the goals of the CWA. 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 impaired).

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. Table 3 lists the potential causes of benthic community impairment, where applicable, observed at each biomonitoring station. The table also includes recommendations addressing the various types of impairment and general conditions observed. The list is by no means exhaustive, but rather a summary of suggestions for additional monitoring efforts, BMP implementation, and other recommendations for follow-up activities.

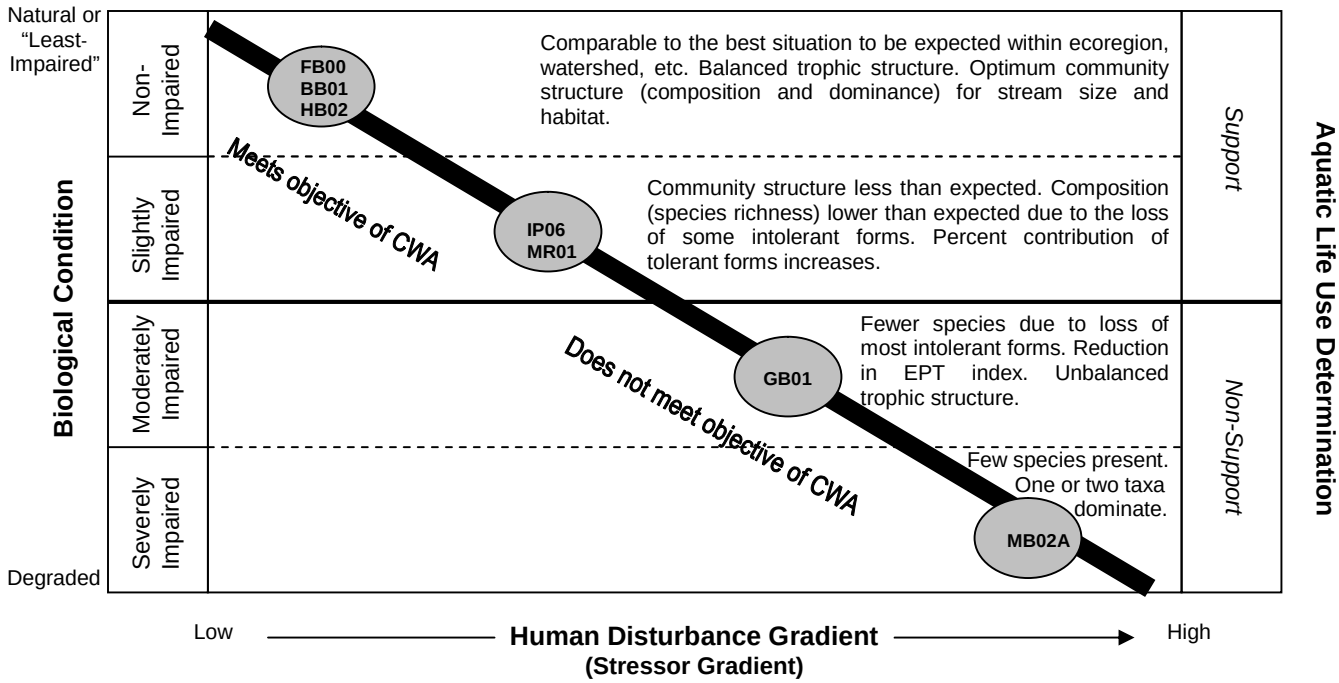

Figure 2. Results of the RBPIII analysis of the 2005 Ipswich River watershed biomonitoring stations as they relate to Tiered Aquatic Life Use.

One goal of the 2005 Ipswich River Watershed biomonitoring effort was to determine if water quality and habitat conditions have improved or worsened over time. The RBP provide an indication of the support status of the *Aquatic Life Use* at the time of sampling and are not intended to be used as a comprehensive analysis of long-term trends. They can, however, serve to identify stream segments that should be closely monitored in the future. With this in mind, the results of the 2005 biosurvey were compared with the RBP III assessments from previous investigations in 1995 and 2000 to obtain a general indication of whether biological conditions had changed (Table 4). This review revealed that the condition of the benthic invertebrate communities in Fish (FB00) and Howlett (HB02) brooks and the Ipswich River (IP06) remained essentially unchanged throughout the ten-year period bounded by MassDEP/DWM's biosurveys and these waterbodies were found to be supporting the *Aquatic Life Use*.

Discernable changes in the condition of the benthos were noted over time in the remaining streams assessed by the MassDEP/DWM. The invertebrate community in Boston Brook (BB01), which was moderately impaired in 2000, received a bioassessment of non-impaired in 2005, indicating apparent improvement in this stream. Likewise, the bioassessment of the Miles River may suggest slight improvement between 2000 and 2005, although the evidence for this is ineffectual. Conditions in Gravelly and Martins brooks, however, seem to be worsening. Martins Brook has exhibited steadily declining bioassessments beginning with the slight impairment encountered in 1995 and ending in 2005 with a finding of severe impairment. Gravelly Brook was not assessed in 1995 but was found to be non-impaired and moderately impaired in 2000 and 2005, respectively. Maietta (2006) concluded that Gravelly Brook supports a reproducing population of brook trout but is susceptible to very low flow conditions. Further investigation of both of these streams is warranted.

Table 3. A summary of potential causes of benthos and habitat impairment observed at each biomonitoring station during the 2005 Ipswich River watershed survey. Where applicable, recommendations are made.

SITE	POSSIBLE CAUSES OF IMPAIRMENT	RECOMMENDATIONS
FB00	-No biological impairment observed	-Biomonitoring during next MassDEP Ipswich River watershed survey -Water quality monitoring during MassDEP Ipswich River watershed survey -Continued use as reference station for Ipswich River watershed
MB02A	-Water quality degradation--organic enrichment/low DO -Severe habitat degradation—severe instream sediment deposition, bank erosion, reduced riparian zone -NPS inputs from adjacent residence/lawn -Low baseflow (60% of channel full of water)	-Biomonitoring during next MassDEP Ipswich River watershed survey -Water quality monitoring during MassDEP Ipswich River watershed survey (attempt to isolate sources of nutrients and other pollutant loads) -Investigate possible sources (e.g., Park St. crossing) of sediment inputs—implement BMPs as needed -Outreach to address reduced vegetative buffer and yard waste along right (south) bank
IP06	-Water quality degradation—nutrient/organic enrichment -Low baseflow (25% of channel full of water) -Habitat degradation—severe instream sediment deposition, bank erosion	-Biomonitoring during next MassDEP Ipswich River watershed survey -Water quality monitoring during MassDEP Ipswich River watershed survey (attempt to isolate sources of nutrients and other pollutant loads) -Investigate possible sources (e.g., Main St. crossing, Bostik Findley Inc.) of sediment inputs—implement BMPs as needed -Review of Bostik Findley Inc. stormwater managemenr practices and discharge permit
BB01	- No biological impairment observed	-Biomonitoring during next MassDEP Ipswich River watershed survey -Water quality monitoring during MassDEP Ipswich River watershed survey
HB02	-Low baseflow (channel half full of water) (naturally occurring and/or anthropogenic)	-Biomonitoring during next MassDEP Ipswich River watershed survey -Water quality monitoring during MassDEP Ipswich River watershed survey -Investigate possible flow regulation at the outlet of upstream impoundments
GB01	-Low baseflow (25% of channel full of water) -Biological conditions have degraded since 2000 survey—biota now appears structured in response to organic enrichment	-Biomonitoring during next MassDEP Ipswich River watershed survey -Water quality monitoring during MassDEP Ipswich River watershed survey (attempt to isolate sources of nutrients and other pollutant loads) -Investigate recent land-use changes (e.g., new golf course in eastern portion of subwatershed) in Gravelly Brook subwatershed and potential impacts to baseflow, water quality, and habitat quality in Gravelly Brook
MR01	-Water quality degradation--organic enrichment/low DO	-Biomonitoring during next MassDEP Ipswich River watershed survey -Water quality monitoring during MassDEP Ipswich River watershed survey (attempt to isolate sources of nutrients and other pollutant loads) -Implement agriculture BMPs as needed -Determine to what extent organic enrichment/lowDO is related to natural conditions (wetland influence) and/or reduced baseflow resulting from water withdrawals or other nonpoint sources of pollution

Table 4. Apparent trends in the biological condition of selected streams in the Ipswich River Watershed assessed from 1995 to 2005.

Stream (Station ID)	Biological Condition			Apparent Trend
	1995	2000	2005	
Fish Brook (FB00)	Reference	Reference	Reference	↔
Martins Brook (MB02A)	Slightly Impaired	Moderately Impaired	Severely Impaired	↓
Ipswich River (IP06)	Slightly Impaired	Slightly Impaired	Slightly/Non-Impaired	↔
Boston Brook (BB01)	--	Moderately Impaired	Non-Impaired	↑
Howlett Brook (HB02)	Slightly/Non-Impaired	--	Non-Impaired	↔
Gravelly Brook (GB01)	--	Non-Impaired	Moderately Impaired	↓
Miles River (MR01)	--	Moderately Impaired	Slightly Impaired	↑

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APPENDIX

Macroinvertebrate taxa list, RBPIII benthos analysis, 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 2005 Ipswich River watershed survey between 25 July and 12 August 2005. Refer to Table 1 for a listing and description of sampling stations.

Taxon	FG[1]	TV[2]	Sampling Stations						
			MR01	GB01	HB02	MB02A	IP06	BB01	FB00[3]
Hydrobiidae	SC	8	1						
Ferrissia sp.	SC	6						1	
Planorbidae	SC	6						1	
Gyraulus parvus	SC	8		1					
Pisidiidae	FC	6		5	12		1	4	
Chaetogaster diaphanus	PR	7							
Dero nivea/obtusa	GC	10	2						
Nais sp.	GC	8							
Nais behningi	GC	6	1		1				
Nais communis/variabilis	GC	8	8					5	
Nais elinguis	GC	10	2					1	
Pristina aequiseta	GC	8	1						
Pristinella sp.	GC	10							
Pristinella osborni	GC	10							
Tubificidae IWB	GC	10	2			4			
Lumbriculidae	GC	7		3	1			4	1
Caecidotea sp.	GC	8	1	1	1				
Gammarus sp.	GC	6	8	58		8	4	5	2
Baetidae	GC	4			2				
Maccaffertium sp.	SC	3						1	
Zygoptera	PR	7			1				8
Leuctra sp.	SH	0							4
Acroneuria sp.	PR	0							7
Nigronia serricornis	PR	0		3	1		2	1	2
Cheumatopsyche sp.	FC	5		1	6	3	11	4	
Hydropsyche sp.	FC	4							21
Hydropsyche betteni	FC	6		19	16		31	14	9
Hydropsyche morosa gr.	FC	6			9			15	
Lepidostoma sp.	SH	1					2		
Ceraclea sp.	GC	3			1				
Oecetis sp.	PR	5					1		
Chimarra aterrima	FC	4			10			6	2
Chimarra obscura	FC	4			19		35		
Dolophilodes sp.	FC	0						3	
Optioservus sp.	SC	4							3
Oulimnius latiusculus	SC	4							1
Promoresia sp.	SC	2							1
Stenelmis sp.	SC	5	2		2		4	7	1
Psephenus herricki	SC	4					1		1
Chironomus sp.	GC	10	15						
Cryptochironomus sp.	PR	8							
Dicrotendipes sp.	GC	8	1						
Kiefferulus sp.	GC	10	2						
Microtendipes pedellus gr.	FC	6	1						
Microtendipes rydalensis gr.	FC	6			1				9
Polypedilum aviceps	SH	4							2
Polypedilum flavum	SH	6	3		2		3	25	
Polypedilum illinoense gr.	SH	6							1
Polypedilum tritum	SH	6	2						
Tanytarsini	FC	6							
Micropsectra sp.	GC	7							1
Paratanytarsus sp.	FC	6	10			2			
Rheotanytarsus exiguus gr.	FC	6	15	13		75		2	
Rheotanytarsus pellucidus	FC	5			2	3			2
Stempellina sp.	GC	2							1
Tanytarsus sp.	FC	6	10		5				2
Orthocladiinae	GC	5					1		
Corynoneura sp.	GC	4		1			1		

Nanocladius sp.	GC	7							
Parametriocnemus sp.	GC	5	1		2				4
Rheocricotopus sp.	GC	6			1				
Rheocricotopus robacki	GC	5	2						
Tvetenia paucunca	GC	5		7	4		2	2	3
Tvetenia vitracies	GC	5					1		
Conchapelopia sp.	PR	6		2	2		1		7
Thienemannimyia gr.	PR	6						2	
Empididae	PR	6			1				
Hemerodromia sp.	PR	6						1	1
Simulium sp.	FC	5	5		1	1			2
Simulium tuberosum complex	FC	4					6	1	
Dicranota sp.	PR	3							4
Pseudolimnophila sp.	SH	3							
Total			95	114	103	96	107	105	102
HBI			7.12	5.82	5.18	6.09	4.80	5.66	4.43

[1] Functional Feeding Group (FG) lists the primary feeding habit of each species and follows the abbreviations: SH-Shredder; GC-Gathering Collector; FC-Filtering Collector; SC-Scraper; PR-Predator.

[2] Tolerance Value (TV) is an assigned value used in the calculation of the biotic index. Tolerance values range from 0 for organisms very intolerant of organic wastes to 10 for very tolerant organisms.

[3] Reference station

Table A2. Summary of RBP III data analysis for macroinvertebrate communities sampled during the Ipswich River watershed survey between 25 July and 12 August 2005. Shown are the calculated metric values, metric scores (in italics) based on comparability to the regional reference station (FB00), and the corresponding assessment designation for each biomonitoring station. Refer to Table 1 for a listing and description of sampling stations.

SAMPLING STATION	FB00		MB02A		IP06		BB01		HB02		GB01		MR01	
STREAM	Fish Brook		Martins Brook		Ipswich River		Boston Brook		Howlett Brook		Gravelly Brook		Miles River	
HABITAT SCORE	172		103		124		180		153		140		166	
TAXA RICHNESS	27	*6*	7	*0*	16	*4*	21	*4*	24	*6*	12	*2*	22	*6*
BIOTIC INDEX	4.43	*6*	6.09	*4*	4.80	*6*	5.66	*4*	5.18	*4*	5.82	*4*	7.12	*2*
EPT INDEX	5	*6*	1	*0*	5	*6*	6	*6*	7	*6*	2	*0*	0	*0*
EPT/CHIRONOMIDAE	1.34	*6*	0.04	*0*	8.89	*6*	1.39	*6*	3.32	*6*	0.87	*4*	0	*0*
SCRAPER/FILTERER	0.15	*6*	0	*0*	0.06	*4*	0.20	*6*	0.02	*0*	0.03	*0*	0.07	*4*
% DOMINANT TAXON	21%	*4*	78%	*0*	33%	*2*	24%	*4*	18%	*6*	51%	*0*	16%	*6*
REFERENCE AFFINITY	100%	*6*	45%	*2*	57%	*4*	82%	*6*	69%	*6*	59%	*4*	50%	*4*
TOTAL METRIC SCORE	*40*		*6*		*32*		*36*		*34*		*14*		*22*	
% COMPARABILITY TO REFERENCE	--		15%		80%		90%		85%		35%		55%	
BIOLOGICAL CONDITION -DEGREE IMPAIRED	**REFERENCE**		**SEVERELY IMPAIRED**		**SLIGHTLY/ NON-IMPAIRED**		**NON-IMPAIRED**		**NON-IMPAIRED**		**MODERATELY IMPAIRED**		**SLIGHTLY IMPAIRED**	

Table A3. Habitat assessment summary for biomonitoring stations sampled during the 2005 Ipswich 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	FB00*	MB02A	IP06	BB01	HB02	GB01	MR01
PRIMARY PARAMETERS (range is 0-20)	**SCORE**						
INSTREAM COVER	16	13	10	16	6	8	12
EPIFAUNAL SUBSTRATE	17	7	17	19	18	16	16
EMBEDDEDNESS	19	5	8	19	18	19	16
CHANNEL ALTERATION	20	15	15	20	16	18	20
SEDIMENT DEPOSITION	19	4	7	20	19	19	16
VELOCITY-DEPTH COMBINATIONS	14	13	12	15	10	6	15
CHANNEL FLOW STATUS	13	9	7	15	9	6	16
SECONDARY PARAMETERS (range is 0-10 for each bank)	**SCORE**						
BANK VEGETATIVE PROTECTION left	10	8	9	10	10	10	10
BANK VEGETATIVE PROTECTION right	10	7	9	10	10	10	10
BANK STABILITY left	8	5	7	10	10	5	8
BANK STABILITY right	8	4	3	9	9	5	10
RIPARIAN VEGETATIVE ZONE WIDTH left	8	10	10	9	10	10	7
RIPARIAN VEGETATIVE ZONE WIDTH right	10	3	8	8	8	8	10
TOTAL SCORE	**172**	**103**	**124**	**180**	**153**	**140**	**166**

*Reference Station