IPSWICH RIVER
WATERSHED ASSOCIATION
The Voice of the River

Aquatic Macroinvertebrate Volunteer Water Quality Monitoring Program

The Ipswich River Watershed Association (IRWA) is the voice of the Ipswich River. IRWA works to protect nature and make sure that there is enough clean water for people, fish and wildlife, today and for our children and theirs.

2018-2019 Results Report

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Introduction

The Ipswich River watershed is 155 square miles and includes all or part of 21 communities in northeastern Massachusetts. The river begins at the headwaters in the towns of Burlington and Wilmington Massachusetts and the river flows a meandering 40 miles northeastward emptying into Ipswich Bay near the south end of Plum Island Sound. This river system supplies water to more than 330,000 people and thousands of businesses, providing all or part of the water supply for 14 communities: Beverly, Danvers, Hamilton, Ipswich, Lynn, Lynnfield, Middleton, North Reading, Peabody, Salem, Topsfield, Wenham, and Wilmington.

Water supply withdrawals have been linked to low flow episodes in the summer, particularly in the upper watershed (Zarriello and Reis 2000). The Ipswich River and many tributaries are listed as impaired under section 303(d) of the Clean Water Act (MassDEP, 2016). In addition to repeated, exaggerated low flow episodes, these impairments include: low dissolved oxygen levels, excessive nutrient, fecal coliform loadings, and others. Water quality assessments have identified 53% of named river miles throughout the watershed as impaired for supporting healthy populations of aquatic life (Mass DEP, 2000).

The survey of macroinvertebrates was chosen as an effective and relatively simple way to assess water and habitat quality of the Ipswich River. Macroinvertebrates can be used as an indicator of water quality based on their preferences and tolerances. For example, certain macroinvertebrates, such as mayfly larvae or caddisfly larvae, can only thrive in waters with relatively high dissolved oxygen. Other macroinvertebrates, such as the damselfly larvae, water boatmen and leeches, can tolerate lower dissolved oxygen concentrations. By recording where the majority of these macroinvertebrates live, we can reinforce the water quality testing with information about how the ecology of the river is affected by areas of low dissolved oxygen resulting from low flow and sections that have become pooled and stagnant. Furthermore, by monitoring the number, richness and diversity of macroinvertebrates present at different locations in the watershed, it is possible to establish trends, which indicate the vitality of the Ipswich River's habitat.

The Ipswich River Watershed Association began surveys of benthic macroinvertebrates in 1997 with the following objectives:

1. Determine impacts to aquatic life from low-flow / no-flow episodes and identify degraded sites and less impacted reference sites.
2. Establish and maintain a long-term macroinvertebrate sampling program to document temporal changes in water and habitat quality.
3. Provide high quality data on the health of the Ipswich River and tributaries in order to make informed decisions about water management practices and monitor ongoing restoration efforts.
4. Provide sampling and identification training to volunteers and partner organizations with an interest in aquatic ecology and assessing water quality in their region through benthic aquatic macroinvertebrate monitoring.

This report provides the findings of macroinvertebrate sampling from 2018 and 2019 as well as documentation of the site selection and methods.

Acknowledgements

The Ipswich River Watershed Association would like to thank the following volunteers and groups for their dedication and support of the macroinvertebrate monitoring program.

2018 Volunteers:
Triton Regional High School AP Environmental Science class:
Anna Behringer
Lilly Fulford
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Claire Hilsinger
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Morgan Wealti

Partner Organizations:

Parker River Clean Water Association: George Comisky and Ann Witzig
Chebacco Lake and Watershed Association: Sue McLaughlin and Russ Camp

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Methods

Site Selection

A total of 9 sites with wadeable riffles where sampling could take place had been identified in the Ipswich River watershed. Sites were selected based on accessibility, distribution across the watershed and the presence of a known riffle location on selected major tributaries and the mainstem of the Ipswich River (figure 1 and table 1). There are four sites on the mainstem of the Ipswich River and five on major tributaries. Sites on the mainstem are distributed for representativeness of the upper, middle and lower watershed. Beginning in 2019, four additional sites were identified in the Parker and Essex River watersheds in consultation with the Parker River Clean Water Association (PRCWA) and the Chebacco Lake and Watershed Association (CLWA) (figure 1 and table 1)

Figure 1. Ipswich River Watershed macroinvertebrate sampling sites.

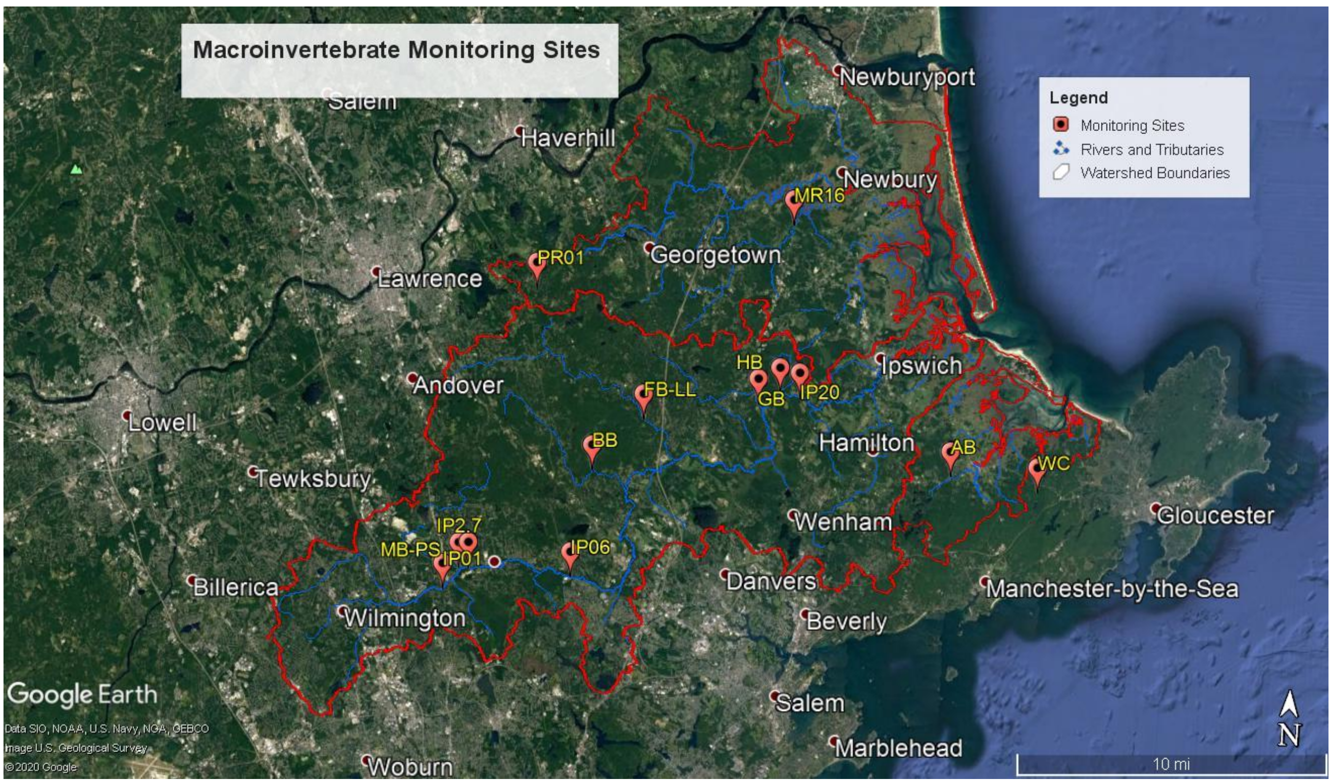

Table 1. Sampling sites and descriptions for the 2018-2019 macroinvertebrate surveys.

Sampling locations	**Latitude**	**Longitude**	**Description**
Fish Brook (FB-LL)	42.64513	-70.989161	This site is located on Fish Brook on Lockwood Lane in Boxford, MA approximately 30 feet upstream of the Lockwood Lane bridge.
Howlett Brook (HB)	42.655014	-70.917065	The Howlett Brook site was sampled approximately 60 feet upstream from the Topsfield Road Bridge in Ipswich. This site is immediately downstream of a large dam and experiences high velocities.
Martins Brook (MB)	42.571439	-71.101273	The Martin's Brook site is located immediately downstream of Park Street in North Reading.
Boston Brook (BB)	42.620342	-71.020317	Boston Brook is located on Liberty St. in Middleton. Sampling occurred 50 yds. upstream of the Liberty St. bridge.
Gravelly Brook (GB)	42.661961	-70.903467	Gravelly Brook is located in the Willowdale State Forest in Ipswich. Sampling occurred 100 yds. upstream of Topsfield Rd.
IP01	42.561170	-71.110670	Site IP01 is located on the Ipswich River at Mill St, between Reading and North Reading, former site of the historic Lobs Pound Mill. Sampling occurred immediately downstream of the bridge. (Ipswich River mile 1)
IP2.7	42.571869	-71.094953	This site is located off of Route 62 at Parish Park in North Reading. (Ipswich River mile 2.7)
IP06	42.569978	-71.029225	Site IP06 is approximately 100 feet downstream of the Boston Street crossing of the Ipswich River in Middleton. (Ipswich River mile 6.)
IP20	42.658860	-70.890635	IP20 is located approximately 150 feet upstream of the Winthrop Street Bridge in Ipswich. Access is from north bank of river. (Ipswich River mile 20.)
PR01	42.703855	-71.061195	PR01 is located upstream of the culvert under Main St. in Boxford.
MR16	42.739247	-70.900459	MR16 is located at the base of the Jewell Mill Dam off of Glen Rd. in Rowley
AB	42.625742	-70.793219	AB is located on Alewife Brook just upstream of the bridge at Apple St., off of Western Ave. in Essex
WC	42.620284	-70.737728	WC is located on Walker Creek adjacent to Forest Ln., Gloucester. Sampling takes place approximately 200 feet upstream of where an access gate is located on the road.

Macroinvertebrate Sampling

Macroinvertebrate sampling is performed in wadeable riffle areas using a kick-net with a 0.5 mm mesh, according to the methods of Dates and Byrne (1997). In 2018, sampling occurred at 5 out of 9 sites in the Ipswich River watershed between October 20 and November 1. Sampling could only be completed at the tributary sites, due to high flows preventing sampling at sites on the mainstem of the river (sites denoted by IP) where flows are higher. In 2019, sampling occurred at 7 out of 9 sites for the Ipswich River watershed sites plus the two new sites in the Parker River watershed (PR01, MR16) and two new sites in the Essex River Watershed (AB, WC) between October 5 and November 21. Two sites on the mainstem of the River (IP01 and IP2.7) became inaccessible due to elevated flows and persisted through the remainder of the sampling period. Trained volunteers collect samples consisting of a composite of four sampling locations in a 50 ft. section of riffle; two from fast flowing areas and two from slow flowing areas within the riffle area of the river. Using this method approximately 0.55 square meters of the stream bottom are sampled. The sample is placed in a ziplock bag, double bagged, labeled and preserved with 90% denatured alcohol. A habitat assessment is also completed by volunteers after sampling for macroinvertebrates.

Sampling was often performed with the assistance of volunteers, including members of the Parker River Clean Water Association and Chebacco Lake and Watershed Association. Students from Triton Regional High School provided extensive assistance as well as community volunteers interested in the science and field work aspects of the program.

Following sample collection a habitat assessments was performed according to the methods of Dates and Byrne (1997). Visual assessments of primary and secondary habitat characteristics were performed. Primary characteristics have the most significance and include; river bottom composition, percent embeddedness, and current velocity. Secondary habitat characteristics affect the community, but are not as critical and include: velocity/depth regimes, channel alteration, sediment deposits in pools, riffle characteristics, percent of bottom exposed, condition of banks, bank vegetative protection, riparian vegetative zone width and overhead canopy. A list of characteristics and the assessment range is outlined in table 2. Habitat assessments for each site are calculated as the sum of primary and secondary habitat characteristic scores. The maximum possible score is 150 points.

Table 2. Primary and secondary habitat characteristics and scoring ranges assessed at macroinvertebrate sampling sites. Primary habitat scores are worth a maximum of 20 points each and secondary scores are worth a maximum of 10 points. Scores for both primary and secondary habitat characteristics are added to calculate a final score. The maximum possible score is 150 points.

Primary Habitat Characteristics	**Excellent**	**Good**	**Fair**	**Poor**
Score	**20>16**	**15>11**	**10>6**	**5>0**
% Cobble	>50%	35-49%	20-34%	<20%
Velocity	1.5-2.0 fps	1.0-1.4 fps or 2.0-2.5 fps	0.5-0.9 fps or 2.5-3.0 fps	<0.5 fps or >3.0 fps
Embeddedness	0-25%	26-50%	51-75%	>75%
Secondary Habitat Characteristics	**Excellent**	**Good**	**Fair**	**Poor**
Score	**10>8**	**7>5**	**4>2**	**1>0**
Velocity/Depth Regimes (slow/shallow, slow/deep, fast/shallow, fast/deep)	all 4 present	3 of 4 present fast-shallow predominant	2 of 4 present fast-shallow present, but not dominant	1 of 4 present slow-shallow predominant
Bank/Channel Alteration	none or minimal	10-40%	40-80%	>80%
Sediment Deposition	<5%	5-30%	30-50%	>50%
Riffle Characteristics	>60% of segment is riffle, riffle is as wide as stream and its length is at least 2X stream width	40-60% of segment is riffle, riffle is as wide as stream, but its length is <2X stream width	10-40% of segment is riffle, riffle not as wide as stream and its length is <2X stream width	no riffle present
% Bottom Exposed	<10%	11-25%	26-75%	>75%
Conditions of Banks (% Eroding)	none	<10%, mostly healed	11-60%	61-100%
Bank Vegetation	>90%	70-90%	50-69%	<50%
Riparian Vegetation Zone	>50 ft.	35-50 ft.	20-34 ft.	<20 ft.
Overhead Canopy	>75%	50-75%	25-50%	<25%

Sampling is performed in compliance with a Quality Assurance Project Plan. In addition to volunteer training, one duplicate sample (collected as a composite sample in the same manner as the volunteer samples) is collected from a sample site randomly selected by the monitoring coordinator each year.

Samples were processed to remove a minimum 100 organism sub-sample from the field sample. The preservative is poured through a #30 sieve for removal and all material is spread out in a sampling tray marked with 12 evenly sized and numbered squares and suspended in ¼" of water. Trained volunteers perform a sub-sample by first removing leaves and other large debris material. A minimum of 100 organisms are picked from 3, randomly selected squares. Specimens are picked with forceps through repeated visual inspection until macroinvertebrates have been removed and preserved in 70% denatured alcohol. Specimens are sorted into similar groups and the number or organisms are recorded during the sub-sampling and preserved in 70% denatured alcohol. Macroinvertebrates were subsequently identified to Family level by volunteers using a dichotomous key according to Pekarsky (1990) and by using the online resource: Atlas of Freshwater Macroinvertebrates of Eastern North America: https://www.macroinvertebrates.org/.

Data Analysis

Sub-sample counts were summarized according to metrics known to be responsive to water pollution and/or habitat degradation. These metrics included organism density per sample, mayfly richness, major group biotic index, modified family biotic index, percent model affinity and functional feeding group composition. The metrics and interpretation ranges (where applicable) are defined as follows. Calculations were performed according to Dates and Byrne (1997).

Organism Density per Sample: An estimate of the total number of individuals in the sample. Density can vary from site to site. Generally density will increase with the increase of organic matter and/or improvements in habitat conditions. Density will decrease with increases in siltation, low pH or the input of toxic substances.

EPT Family Richness: The number of mayfly (**E**phemeroptera), stonefly (**P**lecoptera) and caddisfly (**T**richoptera) families present. The orders of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) have taxa that are sensitive to water quality changes, so generally, the more of these families, the better water quality or the habitat. Some pristine headwater streams can be low in richness naturally, due to lack of food.

Major Group Biotic Index: This is considered a rough estimate of pollution tolerance. When organisms with higher pollution tolerance are more prevalent, groups with lower tolerance may disappear and the biotic index will increase as a result. The interpretation range is based on the following scale:

0-3.75 = No impairment
3.76-6.50 = Moderate Impairment
> 6.5 = Severe Impairment

Percent Model Affinity (Bode, 1991): This is a measure of the similarity of the sample to a model "non-impacted community" based on the Percent Composition of selected major groups. This metric compares the sites to a sample model community from Connecticut based on historical data collected by the Connecticut Department of Environmental Protection (1992) and described in Dates and Byrne (1997). The model community consists of the following groups.

38% *Ephemeroptera* (Mayflies)
5% *Plecoptera* (Stoneflies)
31% *Trichoptera* (Caddisflies)
10% *Coleoptera* (Beetles)
8% *Chironomidae* (Midges)
1% *Oligochaeta* (Worms)
7% other

The following guidelines for % model affinity were used to assess the impacts of pollution on the benthic macroinvertebrate community.

> 64% (non-impacted)
50-64% (slightly impacted)
35-49% (moderately impacted)
< 35% (severely impacted)

Percent Composition of Functional Feeding Groups: Types of food resources in the river are affected by human activities and this can be assessed from the functional feeding groups identified. Ideally, there will be a diversity of food resources and all functional feeding groups will be well represented: scrapers, filtering collectors, gathering collectors, predators and shredders. An abundance of a certain group could indicate an impact that is altering the food web.

Results and Discussion

Habitat Assessments

Data from habitat assessments and macroinvertebrate samples were collected and evaluated to determine the suitability of sites to support a macroinvertebrate community and the health of the community itself. In 2018, 5 out of 9 sites were assessed in the Ipswich River watershed. The sampled sites included the tributary sites: MB-PS, BB, FB-LL, HB and GB. High flows prevented access to the sites on the mainstem of the River at sites: IP01, IP2.7, IP06 and IP20. In 2019, 7 of 9 sites were sampled in the Ipswich River watershed. Flows had increased into the sampling period, preventing access at sites IP01 and IP2.7, while sites IP06 and IP20 were sampled while flows were still relatively safe for wading. Four additional sites were included in 2019; two from the Parker River watershed (PR01 and MR16) and two from the Essex River watershed (AB, WC). Complete habitat assessments and composite samples were collected for sites that were sampled.

Habitat quality was evaluated through a habitat assessment on the same day and following macroinvertebrate sample collection. Primary habitat characteristics include: % cobble (rocks 2-10" across), % embeddedness (the extent cobble size rocks are buried in the stream bottom) and water velocity. These characteristics have a direct impact on the specific habitat where macroinvertebrates can be found and are scored on a maximum of 20 points each. Secondary habitat characteristics include: velocity/depth regimes, bank/channel alteration, sediment deposition in pools, riffle characteristics, % bottom exposed, and conditions of banks eroding (%), bank vegetation, riparian vegetation zone and overhead canopy cover. These are related to the conditions found in and around the stream, but are less directly related to the specific preferences of the macroinvertebrate community and are scored on a maximum of 10 points each. A total habitat assessment score was calculated by combining primary and secondary habitat characteristic scores, with the maximum possible points equal to 150.

Habitat assessment scores are shaped by the natural conditions of the stream as well as the degree of impact from surrounding land use patterns. In 2018, habitat assessment scores ranged from 72 at Martins Brook (MB-PS) to 100 at Gravelly Brook (GB), with an average score of 89 (table 3A). The lowest scoring site was at MB-PS which scored in the poor range for the most categories including two primary and one secondary habitat characteristic. Martins Brook is a major tributary of the Ipswich River, located in the more developed headwaters region and frequently experiences severe low flows in summer months, partly due to more extensive water withdrawals. The stream banks are healthy, but low flows and poor primary characteristics at the sampling site reduce the habitat quality for aquatic macroinvertebrates. Gravelly Brook (GB) is located entirely within Willowdale State Forest in Ipswich, where good habitat quality is consistently present. Velocity depth regime scored poorly at GB, due to the shallow nature of the sampling and assessment area. Boston Brook (site BB), Fish Brook (site FB-LL) and Howlett Brook (site HB) are each major tributaries located in roughly the middle of the Ipswich River watershed. This region is less densely developed than the headwaters where there is less impact from water withdrawals as well as more protected lands surrounding the streams. The presence of boulders decreased the primary habitat scores for BB and FB-LL.

Similar patterns in habitat scores were observed in 2019 for those sites that were also sampled in 2018. Site IP06 is located downstream of the Bostik Dam, and the river at this location contains more boulder sized material. Site IP20 is located in Ipswich, in an area with relatively good habitat and water quality conditions supported by surrounding state forests and the Great Wenham Swamp, 2 mile upstream. In the Parker River watershed, site PR01, located near the headwaters of the Parker River had good habitat characteristics and the Mill River site (MR16) had similar features to IP06, also being located downstream of a dam. In the Essex River watershed, Alewife Brook (AB) had habitat quality impairments from low vegetation along the stream bank and low amounts of cobble in the stream. In 2019, habitat assessment scores ranged from 75 at MB-PS to 105.5 at IP20 with an average score of 91 (table 3B).

Tables 3A, 3B. Summary and interpretation range of primary and secondary habitat assessment scores of riffle areas sampled in the Ipswich River Watershed, 2018 (3A) and 2019 (3B).

	Poor	Fair	Good	Excellent
Primary Habitat Characteristics	0-5	6-10	11-15	16-20
Secondary Habitat Characteristics	0-1	2-4	5-7	8-10

3A.

	Description	MB-PS	IP01	IP 2.7	IP06	BB	FB-LL	HB	GB	IP20
Primary Habitat Characte	% Cobble Score	1				7	5	18	15	
	% Embededness Score	17				15	19	20	13	
	VelocityScore	5				15	14	5	13	
Secondary Habitat Characteristics	Velocity/Depth Regimes Score	2				1	3	2	1	
	Average Bank Alteration Score	10				10	3.5	9	10	
	Percent Sediment Deposits Score	2				NA	NA	NA	NA	
	Riffle Characteristics Score	1				5	4	2	7	
	% River Bottom Exposed Score	10				10	9	10	7	
	% of bank eroding score	7				7	7	10	10	
	% banks covered by vegetation Score	10				10	7	7	4	
	Average Riparian Vegetation Zone Score	5				8	8	5	10	
	% Stream width covered by overhanging vegetation Score	2				8	8	2	10	
	Habitat Assessment Score (maximum =150)	72				96	87.5	90	100	

	Poor	Fair	Good	Excellent
Primary Habitat Characteristics	0-5	6-10	11-15	16-20
Secondary Habitat Characteristics	0-1	2-4	5-7	8-10

3B.

	Description	IP01	MB-PS	IP 2.7	IP06	BB	FB-LL	HB	GB	IP20	PR01	MR16	AB	WC
Primary Habitat Characte	% Cobble Score		2		5	7	7	19	12	19	20	2	1	4
	% Embededness Score		17		13	15	15	17	16	18	15	20	19	18
	VelocityScore		8		13	11	7	13	14	7	11	11	18	11
Secondary Habitat Characteristics	Velocity/Depth Regimes Score		1		9	10	3	3	4	1	3	4	3	3
	Average Bank Alteration Score		10		2	10	4	8.5	10	9.5	4	4	2	10
	Percent Sediment Deposits Score		2		1	7	10	NA	NA	9	9	NA	NA	10
	Riffle Characteristics Score		1		7	5	5	8	7	2	3	9	NA	1
	% River Bottom Exposed Score		10		10	10	10	7	4	5	10	6	10	9
	% of bank eroding score		7		3	7	7	10	3	10	10	4	10	6
	% banks covered by vegetation Score		10		5	7	3	10	10	9	10	10	6	7
	Average Riparian Vegetation Zone Score		5		6	8	9	5	10	9	5	8	1	8
	% Stream width covered by overhanging vegetation Score		2		7	8	9	1	9	7	3	2	1	9
	Habitat Assessment Score (maximum =150)		75		81	105	89	101.5	99	105.5	103	80	71	96

Water Quality Metrics

Water quality metrics were calculated based on the type and abundance of specimens found in the sub-sample collected from each site. Macroinvertebrates were sorted by order (e.g. mayfly, caddisfly, etc.) and identified to the family level (e.g. order: caddisfly, family: hydropsychidae). The final taxa lists for 2018 and 2019 showing the number of specimens belonging to each group can be found in the appendix. A summary of macroinvertebrate metrics, including habitat assessments for 2018 and 2019 can be seen on pages 19 and 20, tables 4A and 4B, respectively. The individual metrics are discussed and illustrated by graphs with interpretation ranges where available.

Water quality metrics demonstrate that the macroinvertebrate community is shaped by the habitat characteristics, in particular primary habitat characteristics (% cobble, % embeddedness and velocity). Sites like Gravelly Brook (GB) where good habitat quality can be found will often have higher densities, but not always. Fish Brook (FB-LL) and Boston Brook (BB) have relatively good habitat quality, but with low densities (figure 2). Sites IP06, HB and MR16 are located downstream of dams and were dominated by caddisfly larvae belonging to the families Hydropsychidae and Philopotamidae. These groups feed on fine particulate organic matter that is accumulates in dam impoundments and is constantly being transported by water flowing over the dam. The macroinvertebrate community is also shaped by environmental factors over time and the recovery process can be seen from changes in organisms density at many sites following the occurrence of the historic drought of 2016 (figure 3). For sites where data are available from 2015-2019, a decline from 2015-2016 is followed by an increasing trend over the following years. Site GB shows a steadily increasing recovery trend.

Metrics based on the diversity of macroinvertebrates can identify the level of impairment of each site. The orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) should be common in streams with good habitat and water quality. According to Dates and Byrne (1997), there should be more than 10-12 estimated or identified families represented from among these groups. Using this metric, the EPT richness is low across all sampling sites (figure 4). Sites GB and FB-LL had the highest EPT richness in 2019 and these sites, along with MB-PS and BB had an increase in EPT family richness from 2018 to 2019. The EPT richness remained the same at site HB.

Major group biotic index is a rough estimate of pollution tolerance of the macroinvertebrate community. More sensitive groups will disappear due to water quality and habitat degradation and more tolerant groups will increase in abundance. In figure 5, all sites are shown to fall within the no impairment to moderate impairment range with the exception of site MB-PS in 2018. Sites MB-PS had a high proportion of amphipod crustaceans or scuds. The group as a whole has a pollution tolerance value of 7 out of 10 (less sensitive), however, the family, Gammaridae, is exclusively dominant and has a tolerance value of 4 out of 10 (more sensitive), resulting in a higher water quality interpretation. Many sites showed a shift in biotic index as a result of the 2016 drought from no to moderate impairment or moderate to severe impairment. Many of these sites also showed a recovery in biotic index in subsequent years (figure 6). When the biotic index is measured by the total number of family groups, excellent to good water quality conditions are indicated for all sites. The sensitivity levels of the families present are generally higher than each of the orders the groups belong to (figure 7). Both biotic index scores demonstrate relatively good water quality conditions across the region.

Percent model affinity is a percent similarity comparison to a model community. For this comparison, all sites fall within the slight to moderately impacted range (figure 8). Most sites were within the moderate to no impact range and this was consistent where data are available for 2018 and 2019. Based on the samples collected, site MB-PS increased from severely impacted to not impacted. One group of stoneflies and two groups of caddisflies were collected in 2019, resulting in an increased amount of diversity relative to what an unimpacted community for this region should contain.

Percent functional feeding groups were analyzed to evaluate trends and understand what conditions might be shaping the macroinvertebrate community based on the feeding behavior of the groups identified in the samples. Only the tributary sites were sampled in 2018 with sites MB-PS and BB dominated by gathering collectors, represented by amphipod crustaceans (figure 9A). Sites HB and GB had high percentages of filtering collectors, which include the caddisfly groups hydropsychidae and philopotamidae. In 2019, more sites were sampled and the trend where these groups were very prevalent at sites downstream of dams can be seen at sites IP06 and MR16 (figure 9B). Site WC also receives flow from a dam impoundment for a reservoir in Gloucester.

Recommendations

Sampling benthic aquatic macroinvertebrates provides unique insights on the state of aquatic life that is not possible through water chemistry analysis alone. Where water quality metrics were observed to be relatively good in most cases, habitat conditions can be thought to then be most strongly influential on the macroinvertebrate community. The drought of 2016 had a significant impact on the abundance of macroinvertebrates, demonstrating the need for the consistent water conservation practices on a watershed scale to reduce the impact of water withdrawals on low flows. Diversity of macroinvertebrates was preserved following the drought at sites with better primary and secondary habitat qualities. Preserving flow and protecting habitat in and around streams increases the resiliency of the system. Dams also shaped the macroinvertebrate community in unique ways. Flows below dams are often rich in oxygen, ideal for macroinvertebrates, but the habitat is not very diverse and only macroinvertebrates specially adapted to the high flows and abundant food source provided by fine organic matter, thrived at these locations. Dams may influence water quality, but the flow alterations severely limit what groups can inhabit downstream habitat. Dam removal will continue to be the best solution to restoring a more diverse and representative macroinvertebrate community.

Figure 2. Organism density per sample for riffle areas sampled in the Ipswich River Watershed in 2018 and 2019.

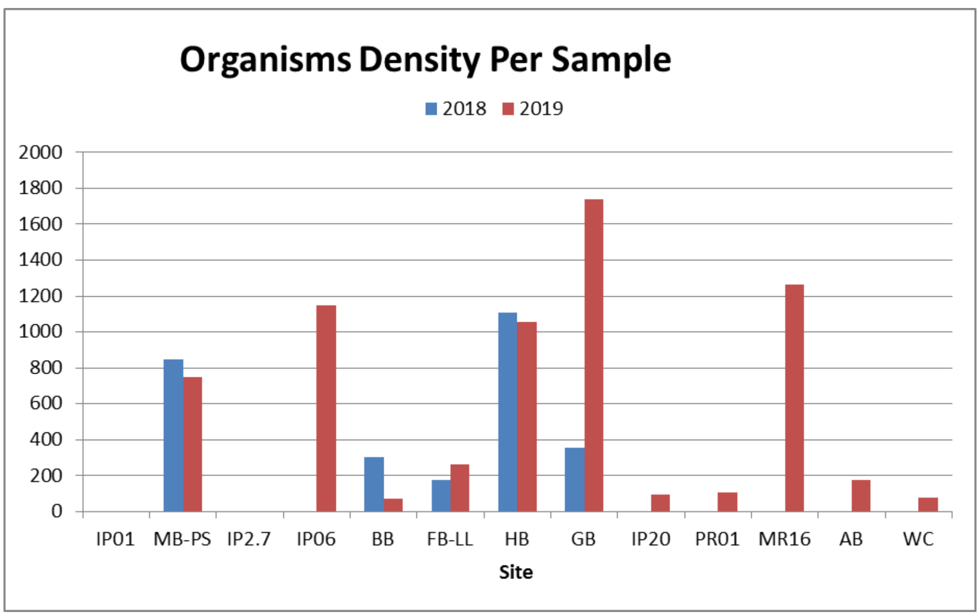

Figure 3. Trends in organism density per sample in relation to the drought of 2016.

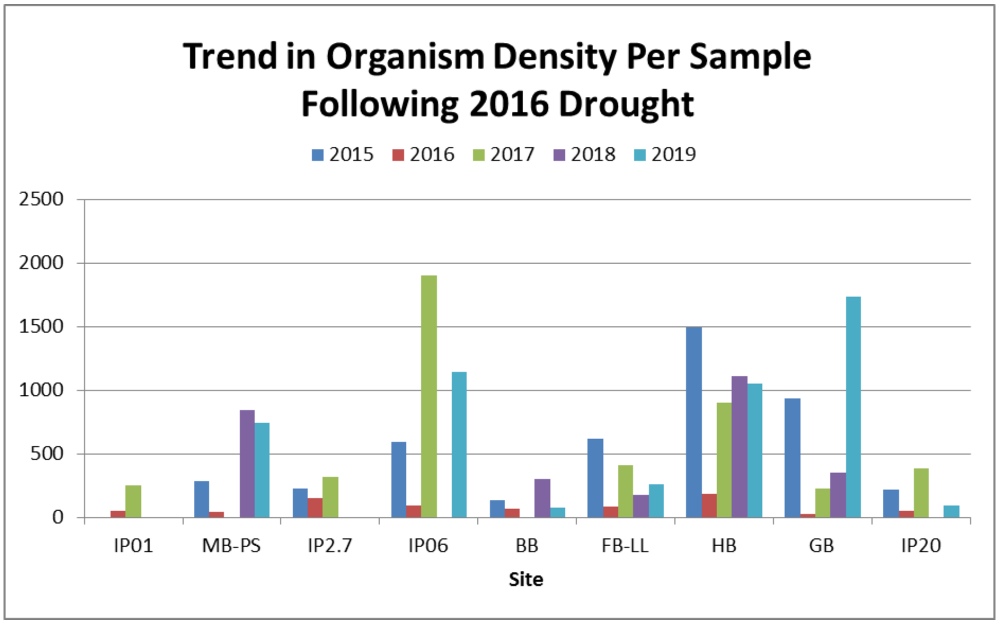

Figure 4. EPT (Ephemeroptera, Plecoptera and Trichoptera) richness for riffle areas sampled in the Ipswich River Watershed in 2018 and 2019. These three orders are the most sensitive to water quality impairments and 10-12 families of macroinvertebrates from among these orders should be present under ideal conditions.

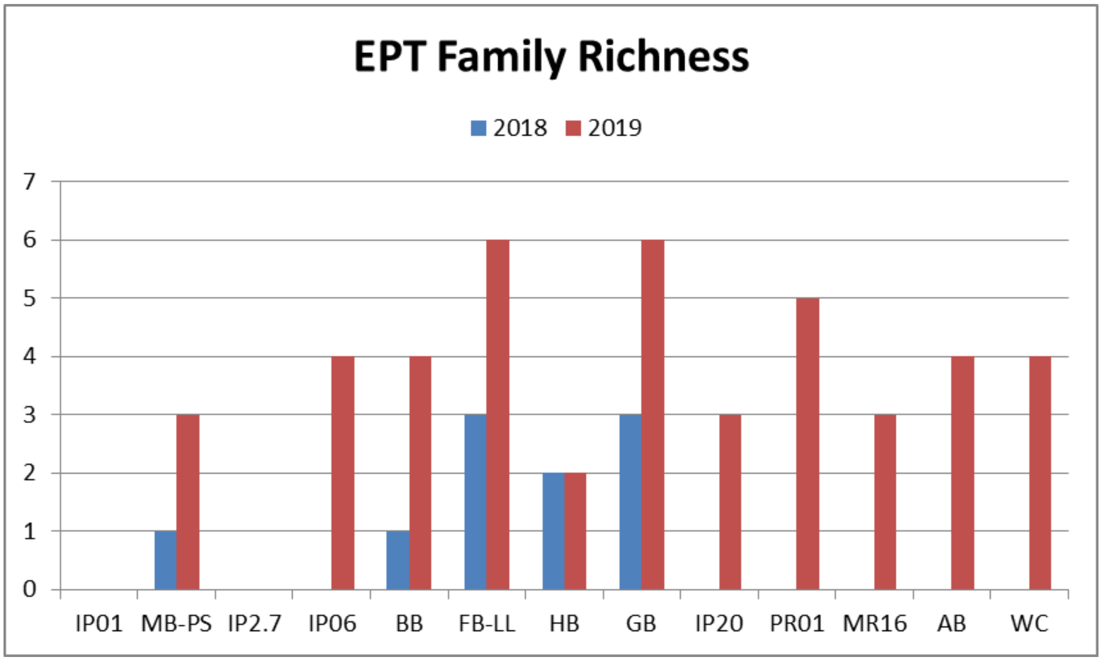

Figure 5. Major group biotic index scores and interpretation range for riffle areas sampled in the Ipswich River Watershed in 2018 and 2019.

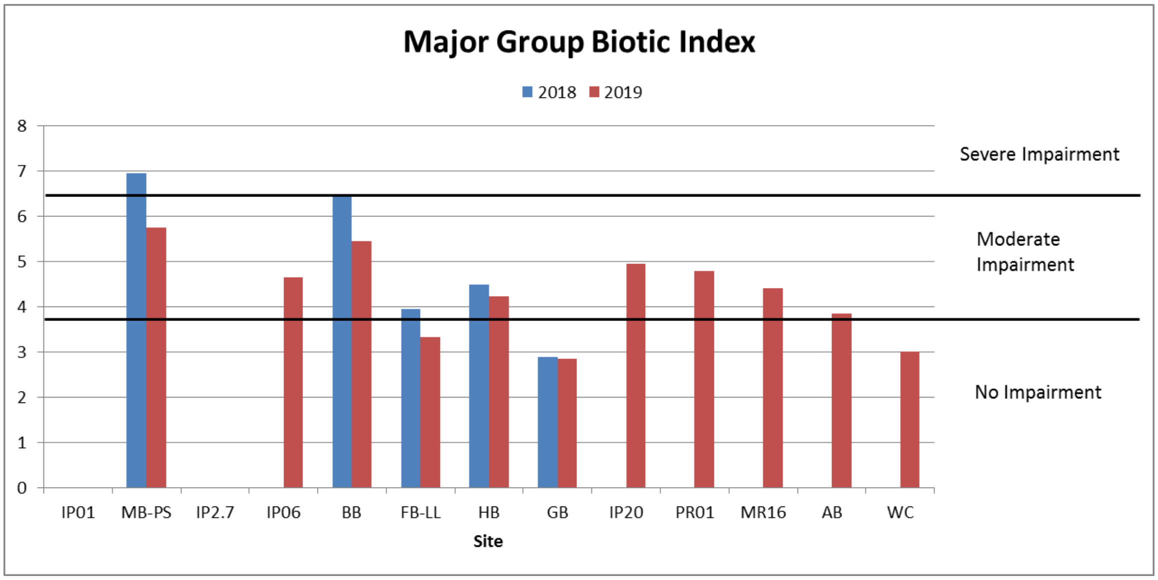

Figure 6. Trends in major group biotic index following the drought of 2016.

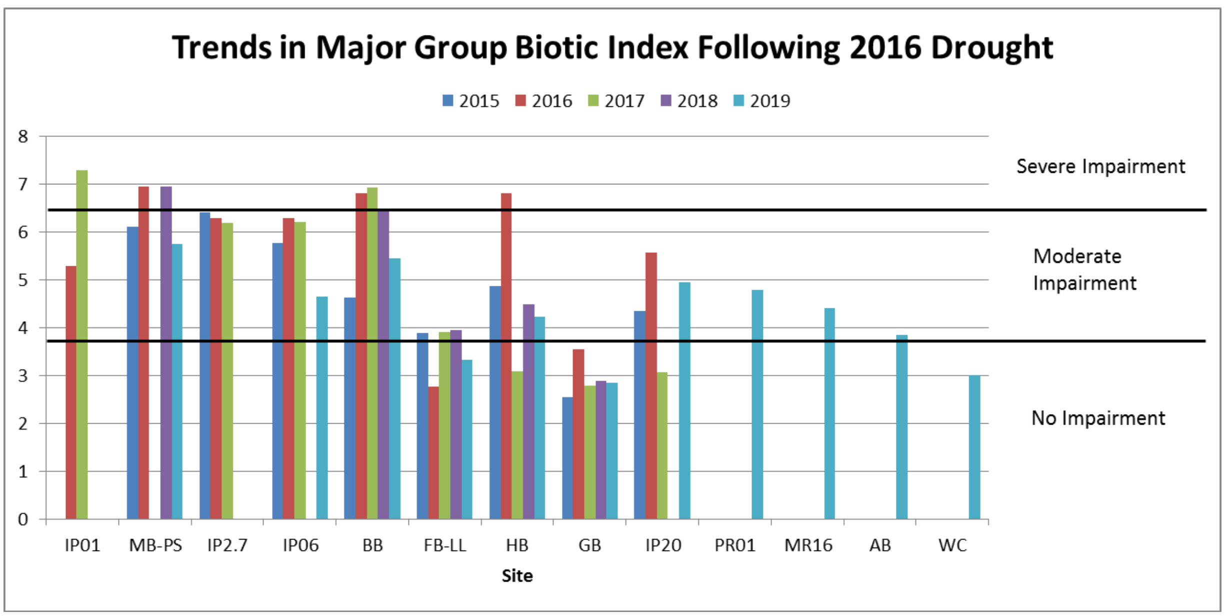

Figure 7. Biotic Index based on family level identifications of macroinvertebrates at sites sampled in 2018 and 2019. Excellent to good water quality conditions are indicated based on this metric.

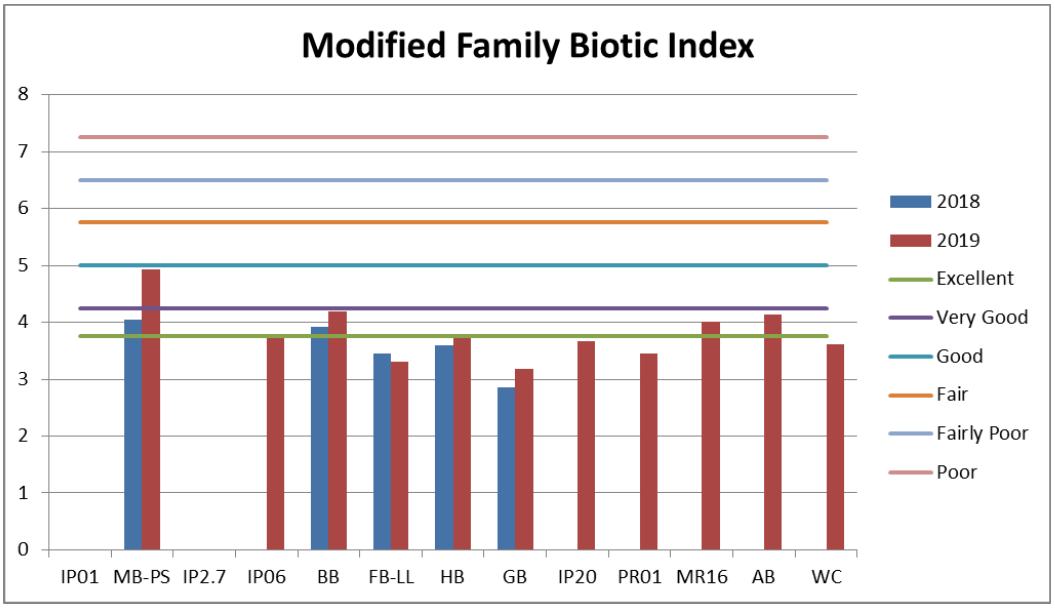

Figure 8. Percent model affinity and interpretation range based on the percent composition of selected major groups for macroinvertebrate samples from riffle areas sampled in 2018 and 2019.

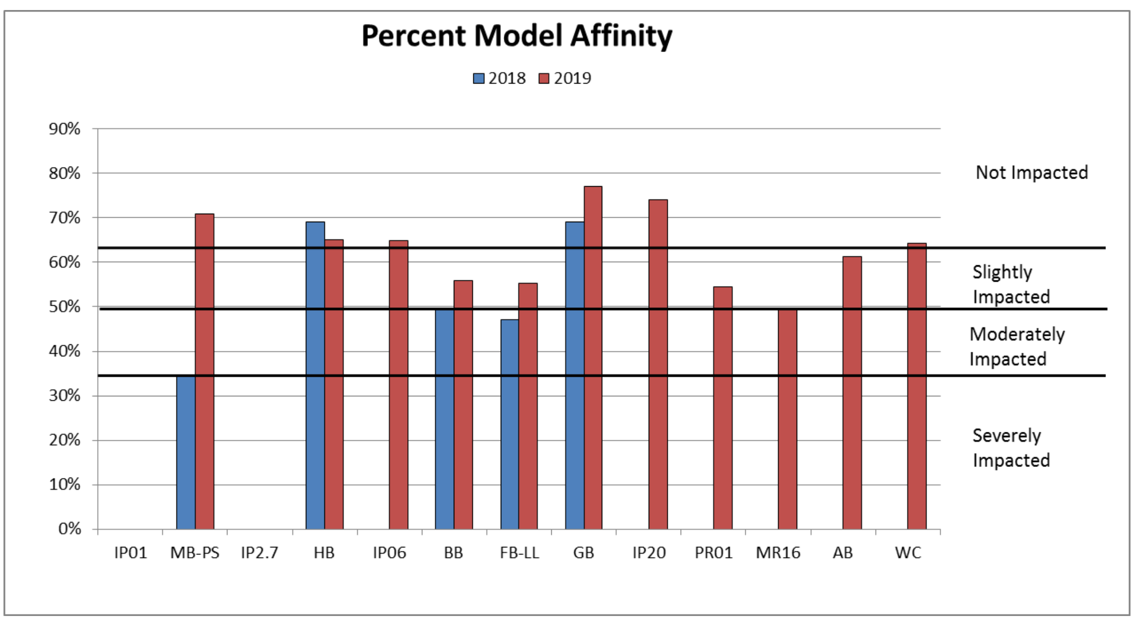

Figure 9A. Percent composition of functional feeding groups in riffle areas sampled in the Ipswich River Watershed in 2018.

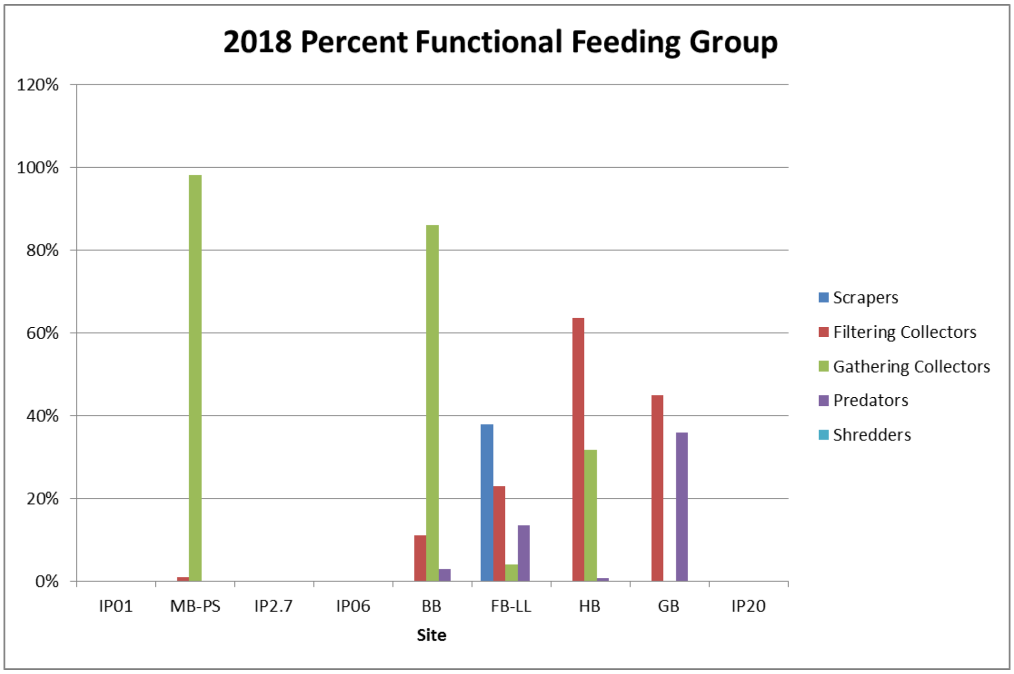

Figure 9B. Percent composition of functional feeding groups in riffle areas sampled in the Ipswich, Parker and Essex River Watersheds in 2019.

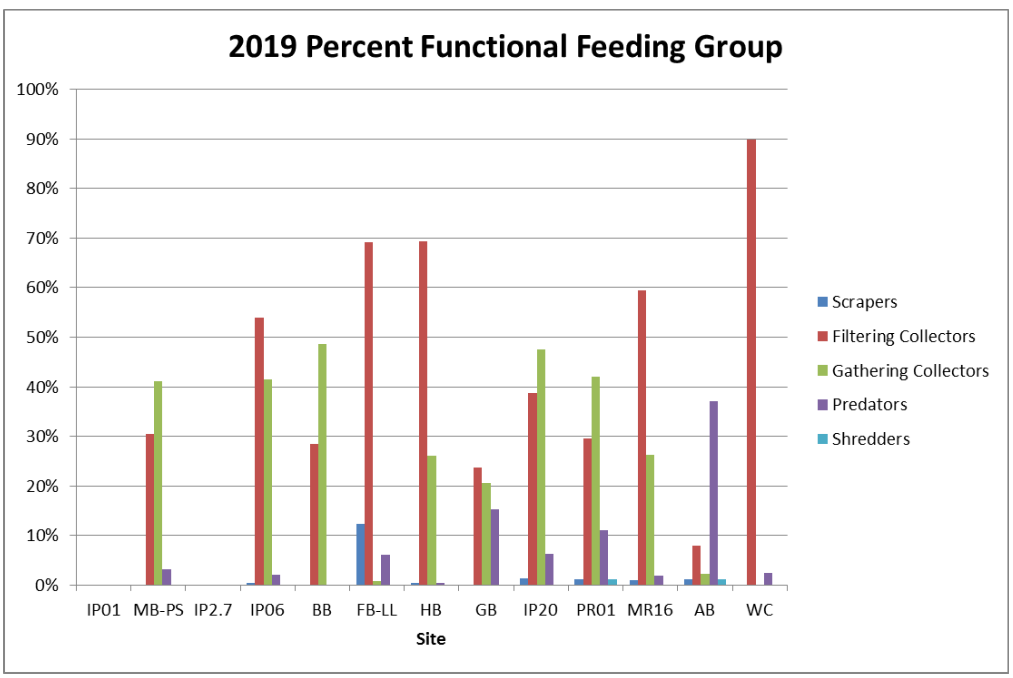

Table 4A. Summary of macroinvertebrate metrics for riffle area samples in the Ipswich River Watershed, in 2018. Refer to page 8 and 9 for metric explanations.

Metric	**IP01**	**MB-PS**	**IP2.7**	**IP06**	**BB**	**FB-LL**	**HB**	**GB**	**IP20**
Habitat Assessment Score		72			96	87.5	90	100	
EPT Family Richness		1			1	3	2	3	
Percent Model Affinity		34%			50%	47%	69%	69%	
Major Group Biotic Index		7.0			6.4	3.9	4.5	2.9	
Modified Family Biotic Index		4.0			3.9	3.5	3.6	2.9	
Organism Density Per Sample		848			300	178	1,108	356	
Total Family Richness		4			3	8	5	7	
Percent Contribution of Dominant Family		98%			85%	50%	22%	19%	
Percent Composition of Selected Major Groups									
MAYFLIES (Ephemeroptera)						1.4%		19%	
STONEFLIES (Plecoptera)						1.4%			
CADDISFLIES (Trichoptera)		0.9%			11%	23%	63.5%	45%	
MIDGES (Chironomidae, Diptera)									
BEETLES (Coleoptera)		0.5%				58%			
WORMS (Oligochaeta)		0.5%			1%				
OTHER (Odonata, Amphipoda, Isopoda, Decapoda, Hirudinea, Pelecypoda		98.1%			88%	16.2%	36.5%	36%	
Percent Composition of Functional Feeding Groups									
Scrapers						38%			
Filtering Collectors		1%			11%	23%	64%	45%	
Gathering Collectors		98%			86%	4%	32%		
Predators					3%	14%	1%	36%	
Shredders									

Table 4B. Summary of macroinvertebrate metrics for riffle areas sampled in the Ipswich, Parker and Essex River Watersheds in 2019. Refer to pages 8 and 9 for metric explanations.

Metric	IP01	MB-PS	IP2.7	IP06	BB	FB-LL	HB	GB	IP20	PR01	MR16	AB	WC
Habitat Assessment		75		81	105	89	101.5	99	105.5	103	80	71	91
EPT Family Richness		3		4	4	6	2	6	3	5	3	4	4
Percent Model Affinity		71%		65%	56%	55%	65%	77%	74%	54%	50%	61%	64%
Major Group Biotic Index		5.7		4.7	5.4	3.3	4.2	2.9	5.0	4.8	4.4	3.8	3.0
Modified Family Biotic Index		4.9		3.8	4.2	3.3	3.8	3.2	3.7	3.4	4.0	4.1	3.6
Organism Density Per Sample		748		1148	74	260	1056	1736	96	108	1264	178	79
Total Family Richness		7		7	7	10	6	15	7	11	8	10	6
Percent Contribution of Dominant Family		35%		41%	81%	68%	37%	33%	48%	42%	38%	33%	66%
Percent Composition of Selected Major Groups													
MAYFLIES (Ephemeroptera)					6.8%	0.8%		49.8%		1.2%	2.5%		
STONEFLIES (Plecoptera)		2.1%		2.1%		1.5%		0.2%	5.0%	2.5%		29.2%	5.1%
CADDISFLIES (Trichoptera)		29.9%		54.4%	28.4%	71.5%	69.3%	24.2%	37.5%	29.6%	59.5%	15.7%	91.1%
MIDGES (Chironomidae, Diptera)		19.3%			14.9%	6.9%		6.0%		3.7%			1.3%
BEETLES (Coleoptera)		3.7%		1.4%	2.7%	14.6%	1.1%	1.2%	7.5%	9.9%	2.2%	33.7%	
WORMS (Oligochaeta)		6.4%											
OTHER		38.5%		42.2%	47.3%	4.6%	29.5%	18.7%	50.0%	53.1%	35.8%	21.3%	2.5%
Percent Composition of Functional Feeding Groups													
Scrapers						12%			1%	1%	1%	1%	
Filtering Collectors		30%		54%	28%	69%	69%	24%	39%	30%	59%	8%	90%
Gathering Collectors		41%		41%	49%	1%	26%	21%	48%	42%	26%	2%	
Predators		3%		2%		6%		15%	6%	11%	2%	37%	3%
Shredders										1%		1%	

Appendix

Taxa Lists

Taxa list for macroinvertebrates sampled at sites in 2018.

SELECTED MAJOR GROUPS	IP2.7	MB-PS	IP06	BB	FB-LL	HB	GB	IP20
MAYFLIES (Ephemeroptera)								
Heptageniidae					1		17	
STONEFLIES (Plecoptera)								
Perlodidae					1			
CADDISFLIES (Trichoptera)								
Hydropsychidae		2		11		20	25	
Philipotamidae					17	156	15	
MIDGES (Chironomidae, Diptera)								
BEETLES (Coleoptera)								
Elmidae		1			15			
Psphenidae					28			
BRISTLE WORMS (Oligochaeta)		1		1				
OTHER GROUPS								
DRAGON/DAMSELFLIES (Odonata)								
Aeshnidae					3		12	
Gomphidae					6		1	
DOBSON/ALDERFLIES (Megaloptera)								
Corydalidae				3		1	18	
Sialidae							1	
SCUDS (Amphipoda)								
Gammaridae		207		85	3	88		
SOWBUGS (Isopoda)								
Asellidae		1				11		
CRAYFISH (Decapoda)								
SNAILS/LIMPETS (Gastropoda)								
CLAMS/MUSSELS (Pelycopoda)								
LEECHES (Hirudinea)						1		
MOTHS (Lepidoptera)								

Taxa list for macroinvertebrates sampled at sites in 2019.

SELECTED MAJOR GROUPS	IP2.7	MB-PS	IP06	BB	FB	HB	GB	IP20	PR01	MR16	AB	WC
MAYFLIES (Ephemeroptera)												
Heptageniidae				4			143		1	8		
Leptophlebiidae				1	1		73					
STONEFLIES (Plecoptera)												
Capniidae									1			
Chloroperlidae									1			4
Perlidae			6		2			4				
Perlodidae		4					1				26	
CADDISFLIES (Trichoptera)												
Brachycentridae			3									
Hydropsychidae		52	103	4	2	85	57	15	23	120	7	52
Limnephilidae					2		2				6	1
Odontoceridae											1	
Philipotamidae		4	50	17	88	98	46	15	1	68		19
Polycentropodidae					1							
MIDGES (Chironomidae, Diptera)												
Chironomidae		36		11	9		25					1
Tipulidae							1		3			
BEETLES (Coleoptera)												
Elmidae		7	3	2	3	2	1	5	7	4	29	
Psphenidae			1		16	1	4	1	1	3	1	
BRISTLE WORMS (Oligochaeta)		12										
OTHER GROUPS												
DRAGON/DAMSELFLIES (Odonata)												
Aeshnidae							4					2
Calopterygidae											1	
Gomphidae							11	1	1		1	
DOBSON/ALDERFLIES (Megaloptera)												
Corydalidae					6		49		8	6		
Sialidae							1					
SCUDS (Amphipoda)												
Gammaridae		65	119	35		69	16	38	34	83	2	
SOWBUGS (Isopoda)												
Asellidae		4				8				24	10	
CRAYFISH (Decapoda)												
SNAILS/LIMPETS (Gastropoda)												
CLAMS/MUSSELS (Pelycopoda)		1	2					1				
LEECHES (Hirudinea)		2				1					5	
MOTHS (Lepidoptera)												

Site Summaries

IP 01								
Year	2013	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment		72.5						
EPT Family Richness		1		3	0			
% Model Affinity	53.50%	35%		72%	94%			Slightly to moderately impacted
Major Group Biotic Index	7	6.9		5	7			Severe impairment
Organism Density	46.8	172.5		56	254			
Total Family Richness		6		8				
% Contribution of Dominant Family		74%		70%	31%			

IP2.7											
Year	1999	2001	2002	2012	2013	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment	103	89	90			87	66					
EPT Family Richness	3	2	3	1	0	3	2	2	1			
% Model Affinity	17%	20%	20%	6%	51%	44%	54%	86%	88%			Severely to moderately impacted
Major Group Biotic Index	3.7	3.3	4.6	4.1	6.3	6.0	6.4	6.0	6.0			Moderate impairment
Organism Density	1548	180	468	257	196	271	228	151	318			
Total Family Richness	5	6	7	3	0	6	5	6	6			
% Contribution of Dominant Family	0%	56%	51%	87%		72%	85%	76%	81%			

Martins Brook	Year												
Year	1997	1998	1999	2001	2002	2012	2013	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment	75	82	86	98	71			56	56			72	75	
EPT Family Richness	4	2	2	1	2	0	0	1	2	1		1	3	
% Model Affinity	49%	26%	28%	13%	30%	16%	43%	40%	60%	98%		34%	71%	Severely impacted
Major Group Biotic Index	4.1	6.0	4.3	4.0	5.1	3.9	6.4	6.7	6.1	7.0		7.0	6.0	Moderately to severely impacted
Organism Density	784	1056	452	540	476	960	155	262	286	44		848	748	
Total Family Richness			8	6	12	2	0	5	7	4		4	7	
% Contribution of Dominant Family			8%	6%	12%	2%		86%	80%	84%		98%	35%	

IP 06													
Year	1997	1998	1999	2001	2002	2013	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment			67				79	69.5				79	
EPT Family Richness	1	4	3	5	1		3	2	2	3		4	
% Model Affinity	20%	44%	17%	27%	21%	53%	68%	56%	62%	67%		65%	Severe to slightly impacted
Major Group Biotic Index	6.5	3.7	2.3	3.9	5.3	4.0	4.4	5.8	6.0	6.0		5.0	Moderate to severe impairment
Organism Density	520	1200	1528	680	420	296	318	597	94	1908		1148	
Total Family Richness			6	16	6		6	6	9	6		7	
% Contribution of Dominant Family							50%	53%	69%	20%		41%	

Boston Brook	Year						
Year	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment		100			96	105	
EPT Family Richness	2	4	0	1	1	4	
% Model Affinity	43%	57%	96%	60%	50%	56%	Moderately impacted
Major Group Biotic Index	5.5	4.6	7.0	7.0	6.0	5.0	Moderate Impairment
Organism Density	111	138	70		300	74	
Total Family Richness	6	10	7	2	3	7	
% Contribution of Dominant Family	67%	49%	86%		85%	81%	

Fish Brook	Year											
Year	1997	1998	2001	2002	2013	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment	95	110	87	116			66			87.5	89	
EPT Family Richness	5	8	4	6	0	4	5	3	3	3	6	
% Model Affinity	45%	53%	27%	45%	77%	71%	62%	78%	76%	47%	55%	Slightly to moderately impacted
Major Group Biotic Index	4.3	5.5	3.7	4.1	4.2	4.4	3.9	3.0	4.0	4.0	3.0	Moderate Impairment
Organism Density	992	472	600	1444	225	34	616	85	408	178	260	
Total Family Richness			10	19	0	11	11	9	7	8	10	
% Contribution of Dominant Family			62%	46%		21%	5%	44%	36%	50%	68%	

Howlett Brook	Year												
Year	1997	1998	1999	2001	2002	2011	2012	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment	97	126	127	118.5	80				59			90	101.5	
EPT Family Richness	6	5	4	1	3	2	1	2	6	0	2	2	2	
% Model Affinity	48%	44%	38%	23%	21%	41%	29%	72%	47%	98%	66%	69%	65%	Moderately to severely impacted
Major Group Biotic Index	4.0	3.4	4.6	3.8	3.8	5.0	5.0	4.1	4.9	7.0	3.0	4.0	4.0	Moderate impairment
Organism Density	784	2456	600	452	1508	281	1076	498	1493	186	904	1108	1056	
Total Family Richness			11	7	11	9	11	6	12	6	4	5	6	
% Contribution of Dominant Family			35%	85%	69%	32%	42%	50%	27%	65%	27%	22%	37%	

Gravelly Brook									
Year	2011	2012	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment				107			100	99	
EPT Family Richness	3	4	4	6	2	5	3	6	
% Model Affinity	50%	27%	53%	80%	68%	91%	69%	77%	Slightly to moderately impacted
Major Group Biotic Index	4.0	4.4	3.6	2.5	4.0	3.0	3.0	3.0	Moderately Impacted
Organism Density	664	520	444	936	31	228	356	1736	
Total Family Richness	14	7	9	12	6	8	7	15	
% Contribution of Dominant Family	27%	63%	47%	44%	55%	30%	22%	33%	

IP 20														
Year	1997	1998	1999	2001	2002	2011	2012	2013	2014	2015	2016	2017	2018	2019	Assessment Range
Habitat Assessment			102	115	87					62				105.5	
EPT Family Richness	8	8	8	3	4		4	0	4	4	4	6		3	
% Model Affinity	55%	49%	22%	32%	31%	15%	35%	72%	70%	73%	80%	48%		74%	Moderately impacted
Major Group Biotic Index	4.83	3.73	2.6	3.87	3.88	3.61	4.33	4.43	4.61	4.34	6	3		5	Moderate impairment
Organism Density	756	552	232	416	1508	288	293	321.6	318	222	53	387		96	
Total Family Richness			11	11	9		11	0	6	8	7	8		7	
% Contribution of Dominant Family			0%	40%	69%		38%		20%	37%	77%	32%		48%	

PR01	Year	
Year	2019	Assessment Range
Habitat Assessment	103	
EPT Family Richness	5	
% Model Affinity	54%	Slightly impacted
Major Group Biotic Index	5.0	Moderate impairment
Organism Density	108	
Total Family Richness	11	
% Contribution of Dominant Family	42%	

MR16	Year	
Year	2019	Assessment Range
Habitat Assessment	80	
EPT Family Richness	3	
% Model Affinity	50%	Slightly impacted
Major Group Biotic Index	4.0	Moderate impairment
Organism Density	1264	
Total Family Richness	8	
% Contribution of Dominant Family	38%	

AB	Year	
Year	2019	Assessment Range
Habitat Assessment	71	
EPT Family Richness	4	
% Model Affinity	61%	Slightly impacted
Major Group Biotic Index	4.0	Moderate impairment
Organism Density	178	
Total Family Richness	10	
% Contribution of Dominant Family	33%	

WC	Year	
Year	2019	Assessment Range
Habitat Assessment	88	
EPT Family Richness	4	
% Model Affinity	64%	Slightly impacted
Major Group Biotic Index	3.0	No impairment
Organism Density	79	
Total Family Richness	6	
% Contribution of Dominant Family	66%	

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