Mill Creek and Blue River are tributaries of the Ohio River in southern Indiana. Blue River is recognized in Indiana water quality standards as an "Outstanding State Resource" waterbody supporting many threatened and endangered aquatic animals. Although the Blue River watershed is relatively pristine, agricultural, urban, and commercial development is occurring rapidly and local environmental groups want to preserve Blue River's quality. Contaminants of concern in the watershed are E. coli, sediment, and nutrients. Potential sources of contaminants identified in the watershed include confined feeding operations, failing septic systems, and soil erosion from agriculture and construction. Lake Salinda, which is the drinking water source for the city of Salem, exhibits eutrophic conditions leading to taste and odor problems.

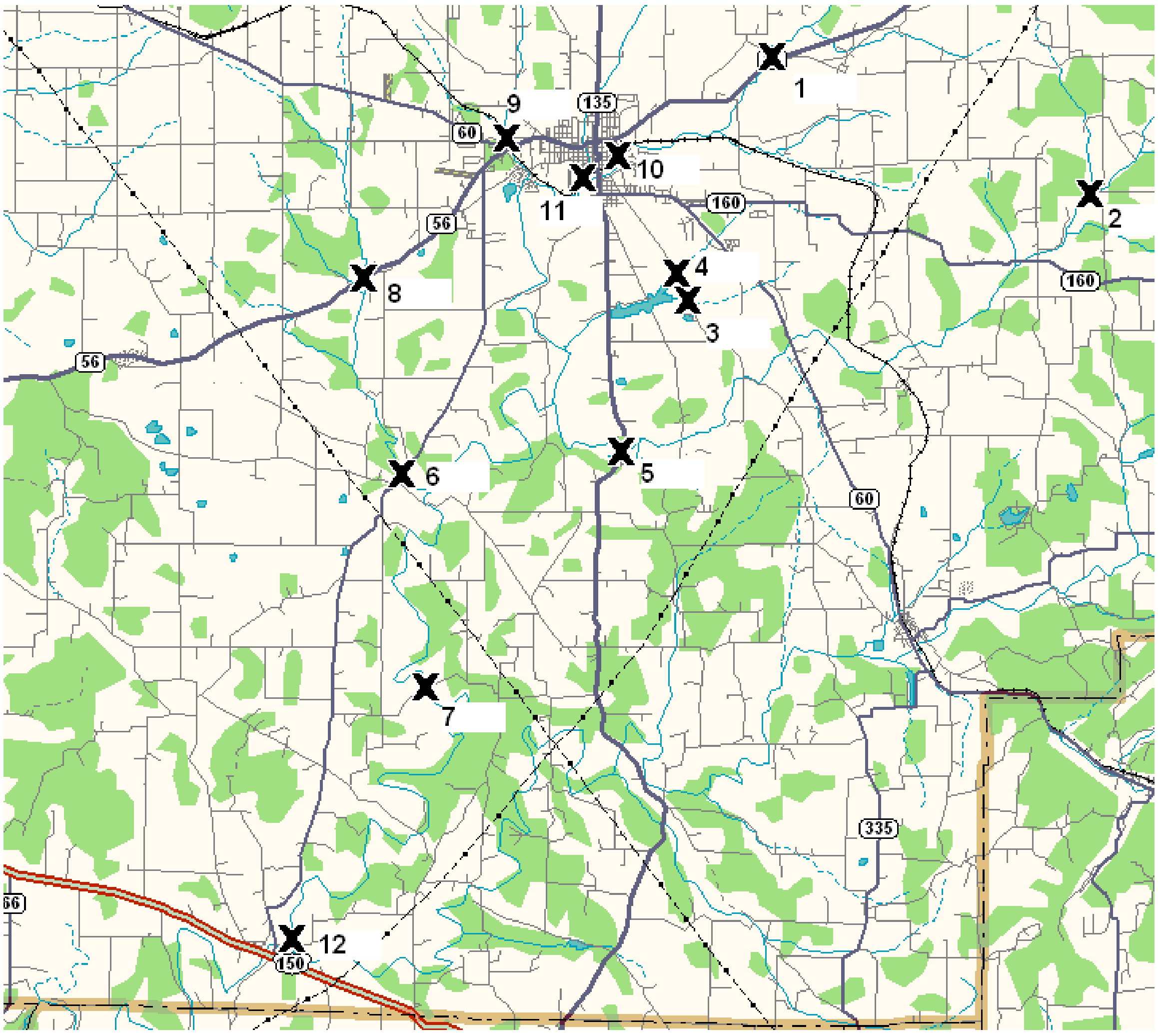
A grant was awarded to the Washington County Soil and Water Conservation District by Indiana Department of Environmental Management to prepare watershed management plan. One of the tasks in the project is to monitor water quality using biological and chemical methods to diagnose problems and propose solutions.

Study Sites

Twelve sites were chosen for study.

	Latitude	Longitude
Site 1. West Fork of Blue River at Hwy 56	38.37.62	86.03.17
Site 2. Middle Fork of Blue River	38.35.87	85.57.71
Site 3. Tributary into Lake Salinda	38.34.52	86.04.64
Site 4. Tributary into Lake Salinda	38.34.82	86.04.69
Site 5. Blue River south of Salem	38.32.60	86.05.63
Site 6. Mill Creek at Becks Mill	38.32.22	86.09.27
Site 7. Blue River on Fredricksburg Rd.	38.26.15	86.11.71
Site 8. Mill Creek at Hwy 60	38.34.75	86.09.89
Site 9. Highland Creek at Old Hwy 60	38.36.56	86.07.52
Site 10. West Fork of Blue River at the fairgrounds	38.36.37	86.05.69
Site 11. Brock Creek at Confluence with Blue River	38.36.01	86.06.28
Site 12. Blue River at Grandview Road	38.29.47	86.08.87

Study sites in the Mill Creek, Blue River watershed



Methods

Water Chemistry

The following parameters were measured once each month for 12 months at each of the twelve sampling sites. All results are included in the Appendix.

Parameter	Method	Detection Limit	Type
Nitrate	SM 4500 NO3	0.5 mg/l	Lab
Total P	SM 4500 P F	0.03 mg/l	Lab
TSS	SM 2540 B	1.0 mg/l	Lab
pH	SM 4500 H+	0.1 SU	Field
Temp.	Thermocouple	0.1 degree	Field
Cond.	SM 2510 A	I uS	Lab
Turbidity	SM 2130 B	1 NTU	Lab
D.O.	SM 4500 O G	0.1 mg/l	Field
Flow	Velocity meter	N/A	Field
E.coli	SM 9223 B	1 MPN/100 ml	Lab

Habitat Analysis

Habitat analysis was conducted according to Ohio EPA methods (Ohio EPA, 1987). In this technique, various characteristics of a stream and its watershed are assigned numeric values. All assigned values are added together to obtain a Qualitative Habitat Evaluation Index (QHEI). The highest value possible with this habitat assessment technique is 100, with higher values indicating better habitat.

Macroinvertebrates

Because they are considered to be more sensitive to local conditions and respond relatively rapidly to environmental change (Hynes, 1970), benthic (bottom-dwelling) organisms were also used to document the biological condition of each stream. The U.S. Environmental Protection Agency (EPA) has developed a rapid bioassessment protocol (Plafkin et al., 1989) which has been shown to produce highly reproducible results that accurately reflect changes in water quality. We used the most recent Indiana Department of Environmental Management procedure (IDEM, 2010) to conduct this study. This method requires a standardized multi-habitat collection technique, a standardized subsampling technique, and identification of at least 100 animals from each site to the genus or species level. Collections were made on August 8,10,11, and 24, 2011.

Following identification of the animals in the sample, twelve "metrics" are calculated for each site. These metrics are based on knowledge about the sensitivity of each species to changes in environmental conditions and how the benthic communities of unimpacted ("reference") streams are usually organized. For example, mayflies and caddisflies are aquatic insects that are known to be more sensitive than most other benthic animals to degradation of environmental conditions. A larger proportion of these animals in a sample receives a higher score. The sum of all twelve metrics provides an individual "biotic score" for each site.

The metrics used in this study were proposed by the Indiana Department of Environmental Management (2010).

Scoring Values for Metrics

	5 points	3 points	1 point
Total Taxa	>41	21-41	<21
Total Individuals	>258	129-258	<129
# EPT Taxa	Dependent on stream drainage area		
% Orthoclads & Tanytarsids	<24	24-47	>47
% Non-insects	<18	18-35	>35
# Diptera Taxa	>14	7-14	<7
% Intolerant Species	>32	16-32	<16
% Tolerant Species	<13	13-25	>25
% Predators	>36	18-36	<18
% Shredders & Scrapers	>20	10-20	<10
% Collector/Filterers	<10	10-20	>20
% Sprawlers	<3	3-6	>6

The scores for each metric (1 to 5) were added (12 metrics) to calculate an mIBI score for each site (a range of scores from 12 to 60).

Results

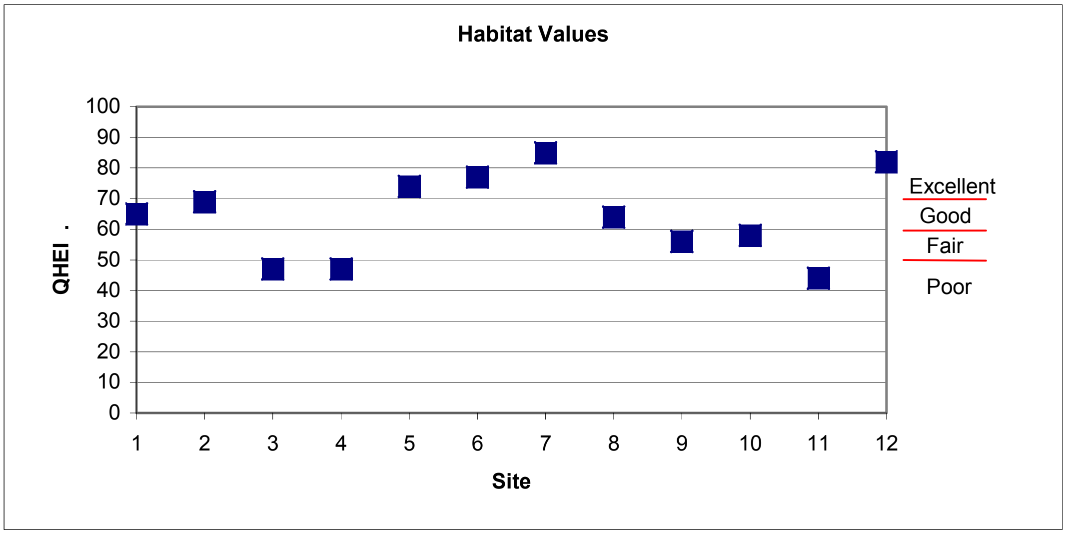
Chemistry

At most sites, water clarity was high and total phosphorus levels were quite low. Dissolved oxygen, conductivity, and pH levels fell within normal ranges during most sampling periods. The measured parameters which were often higher than Indiana water quality standards or draft guidelines included nitrate and E.coli. Average nitrate exceeded the draft nutrient criteria of 4 mg/l at sites 6 and 11. Average E.coli counts exceeded the Indiana water quality standard for “whole body recreation” (235 cfu/100 ml) seven of the twelve sites (3, 4, 6, 8, 9, 10, and 11). Sites 9, 10, and 11 were exceeded the standard by a factor of 2.

Habitat

Figure x. shows the habitat values for the study sites. The highest score was 85 (Site 7), while the lowest was 44 (Site 11). Four sites had “excellent” habitat, three had “good” habitat, two had “fair” habitat, and three had “poor” habitat. The component scores that were summed to obtain the QHEI values for each site are listed in the appendix.

Figure x. Qualitative Habitat Evaluation Index (QHEI) values for study sites.

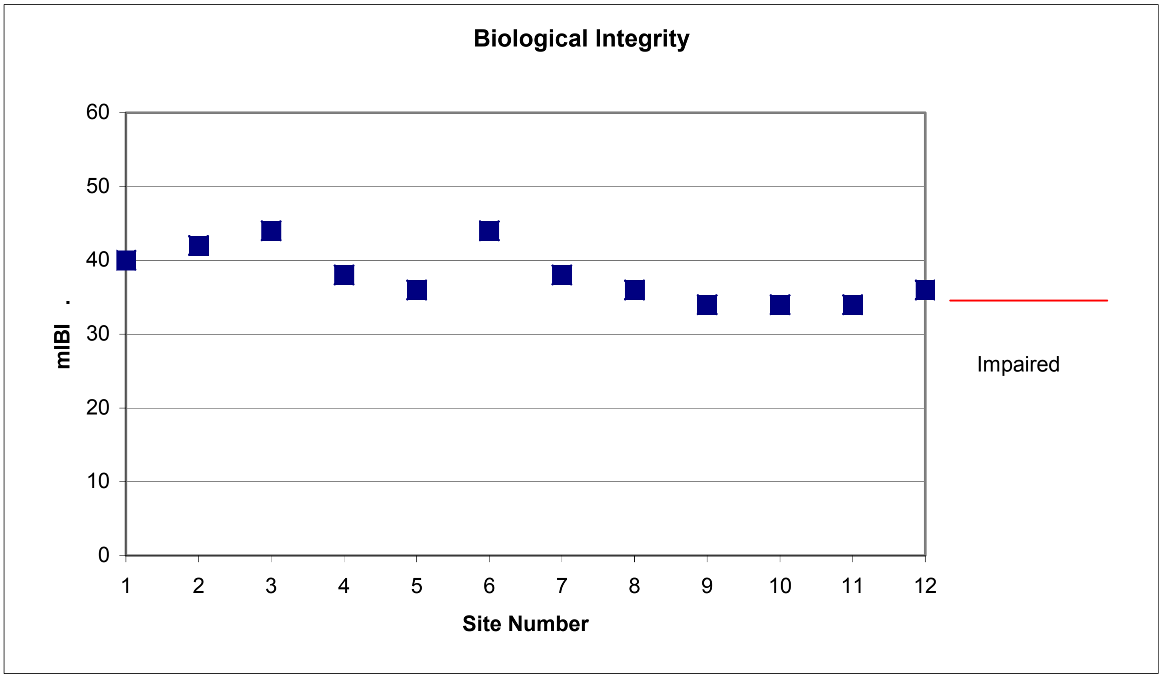


Macroinvertebrates

A total of 70 macroinvertebrate taxa were identified. Dominant forms included small minnow mayflies (*Baetis* sp.), common net-spinning caddisflies (*Cheumatopsyche* sp.), and riffle beetles (*Stenelmis* sp.).

The Indiana Department of Environmental Management defines “impaired conditions” as an mIBI of less than 35. Sites 9, 10, and 11 had scores of 34 and would be considered impaired by this definition.

Figure x. Macroinvertebrate Index of Biotic Integrity (mIBI) scores by site number. Possible range of scores is from 0 to 60; less than 35 is considered impaired.



Discussion

One of the most useful aspects of biological monitoring is that information on the way aquatic animals respond to different types of stress can be used to diagnose a problem. For example, degraded biotic integrity can often be directly related to degraded habitat. Macroinvertebrates cannot thrive where habitat is lacking. When the two values are graphed in relation to each other, they form a straight line (Plafkin et al., 1989). A measurement error of plus or minus 10% can be added to the graph to give a range in which biotic integrity degradation is explained simply by a lack of adequate habitat. When values fall outside this range, however, water quality problems are suspected. A comparison of biotic integrity to habitat is shown in Fig.x . The mIBI scores in this graph were standardized from a scale of 0-60 to a scale of 0-100 to match the QHEI scale.

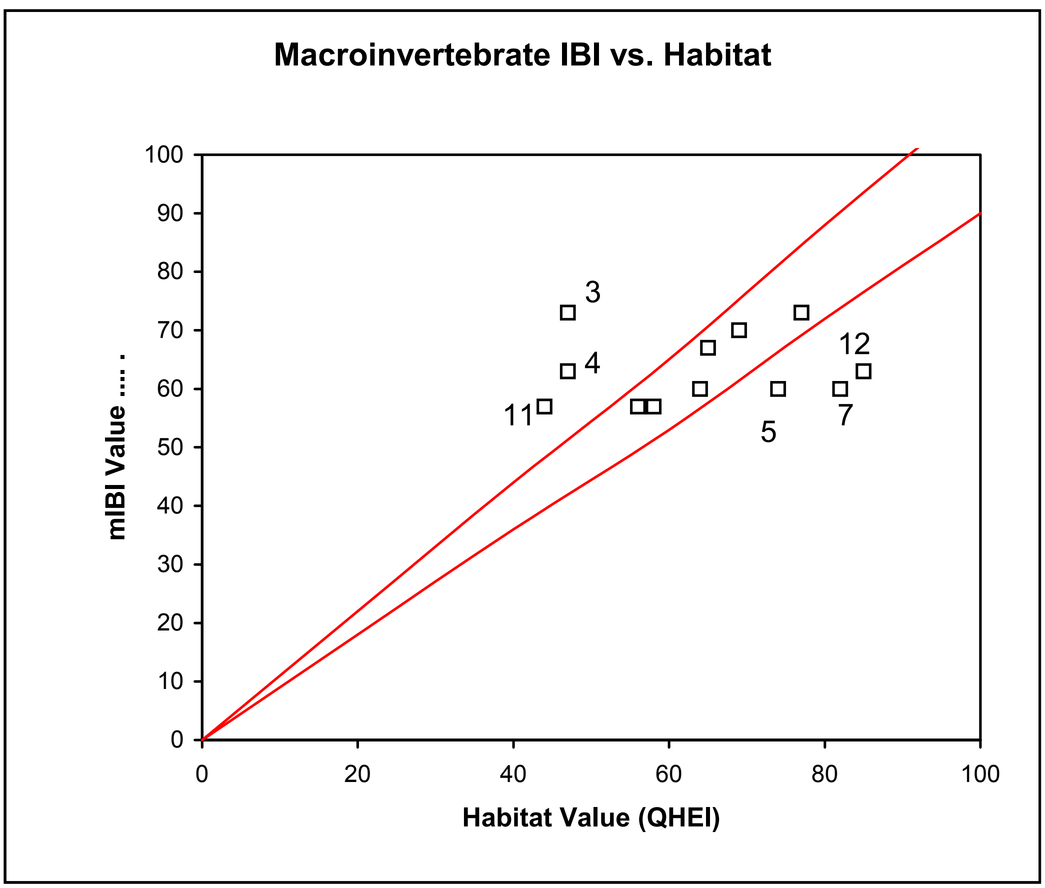
Sites 9 (Highland Creek), 10 (Blue River at Fairgrounds), and 11 (Brock Creek) all had mIBI scores less than 35, meaning they were "impaired" as defined by the Indiana Department of Environmental Management. These three sites all had low numbers of macroinvertebrate taxa that are pollution intolerant, and had the highest average E. coli counts of all the study sites. Sites 9 and 10 had "fair" habitat.

In addition to high E. coli counts, Site 11 (Brock Creek) also had elevated levels of phosphorus and nitrate, and had the lowest number of macroinvertebrate taxa of all the study sites. Its habitat was rated as “poor” and the must abundant macroinvertebrate found there was the tolerant midge *Polypedilum convictum*.

Sites 5 (Middle Fork Blue River at Hwy 135), Site 7 (Blue River at Grandview Road), and Site 12 (Blue River at Fredicksburg Road) all had “excellent” habitat but mIBI scores that were less that what would be expected based on habitat. Site 7 had the best habitat (QHEI of 85) of all the study sites, but its mIBI score was only 63% of the total possible. The most abundant animal was the relatively tolerant caddisfly *Cheumatopsyche* sp., and diversity of caddiflies and dipterans was low. The caddisfly *Cheumatopsyche* was also dominant at Site 5, comprising 47% of the organisms sampled. Site 12 had lower than expected diversity of macroinvertebrates, especially dipterans and intolerant forms.

Sites 3 and 4 (south and north inlets to Lake Salinda) both had “poor” habitat. At these sites, the macroinvertebrate community had relatively abundant numbers of riffle beetles (*Stenelmis* sp. and *Macronychus glabratus*) and water pennies (*Psephenus herricki* and *Ectopria* sp.). These organisms feed by scraping attached algae from the substrate, and increases in their abundance may indicate nutrient enrichment leading to enhanced growth of algae.

A comparison of habitat values and normalized mIBI values (Best possible score for both is 100). Sites outside the expected range are labeled with site numbers.



References

Hynes, H.B.N. 1970. The Ecology of Running Waters. Univ. of Toronto Press, Toronto. 555 pp.

Indiana Department of Environmental Management, 2006. Indiana water quality monitoring strategy 2006-2010. M-100-OWQ-A-00-06-R03. Office of Water Quality, Indianapolis, IN.

Indiana Department of Environmental Management, 2010. Multi-habitat (MHAB) macroinvertebrate collection procedure S-001-OWQ-W-BS-10-T-R0. Office of Water Quality, Indianapolis, IN. 27 pp.

Merritt, R.W. and Cummins, K.W. 1996. An Introduction to the Aquatic Insects of North America. Third Edition. Kendall/Hunt Publishing Company, Dubuque, Iowa. 862 pp.

Ohio EPA. 1987. Biological criteria for the protection of aquatic life: Vol. II. Users manual for biological field assessment of Ohio surface waters. Div. of Water Quality Monitoring and Assessment, Columbus, Ohio.

Plafkin. J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. U.S. EPA Office of Water, Washington, D.C. EPA/444/4-89-001.

Roback, S.S. 1974. Insects (Arthropoda: Insecta). In Hart, C.W. and S.L.H. Fuller, eds., Pollution ecology of freshwater invertebrates. Academic Press, New York, 389 pp.

Schuster, G.A. and D.A. Etnier. 1978. A manual for the identification of the larvae of the caddisfly genera Hydropsyche and Symphitopsyche in Eastern and Central North America. U.S. EPA Environmental Support Laboratory, Cincinnati, OH (EPA-600/4-78-060.

Simpson K.W. and Bode. R.W. 1980. Common Larvae of Chironomidae (Diptera) from New York State Streams and Rivers. Bull.No. 439. NY State Museum, Albany NY. 105 pp.

Macroinvertebrate Data by Site Number

	SITE	**1**	**1dpl.**	**2**	**3**	**4**	**5**	**6**
Diptera	Ablabesmyia mallochi		2					
	Nilotanypus fimbriatus						1	
	Thienemanninyia spp.	11	4	16	12	13	2	5
	Coryoneura spp.				1			
	Cricotopus bicinctus	1	7					
	Eukiefferiella claripennis							
	Nanocladius spp.				1			
	Orthocladius obumbratus		2					
	Rheocricotopus robacki		2				1	
	Thienemanniella xena			3				
	Chironomus spp.							
	Cryptochironomus fulvus					1		
	Dicrotendipes nervosus	2	1					
	Endochironomus nigricans							
	Microtendipes caelum	3	2					
	Polypedilum convictum	6	4	4	1	2	14	5
	Paratanytarsus spp.							
	Rheotanytarsus exiguus		1	2				
	Tanytarsus guerlus		7	1		7	1	1
	Simulium sp.	3	1	1	2		1	
	Hemerodromia sp.		1					
	Antocha sp.							
	Hexatoma sp.			1	5			
	Ormosia sp.			1	1			
	Tipula sp.	4	5					
	Tabanidae				1			1
Ephemeroptera	Baetis flavistriga	7	1	9	28	19	8	16
	B. hageni	26	3	8	5		2	6
	Centroptilum sp.	3	1	1				
	Stenomena femoratum	9	1	21	6	6		
	S. pulchellum	1					1	7
	S. vicarium	1		2			1	3
	Stenonema spp.							
	Heptagenia sp.					1	1	1
	Isonychia sp.		4				2	6
	Caenis sp.	6	1	2		1		
	Chloroterpes sp.			1				
	Paraleptophlebia sp.							1

Macroinvertebrate Data by Site Number, cont.

	SITE	**1**	**1dpl.**	**2**	**3**	**4**	**5**	**6**
Plecoptera	Acroneuria sp.					1		4
Trichoptera	Cheumatopsyche sp.	13	41	27	6	13	47	8
	Ceratopsyche bifida							
	Hydropsyche simulans			1				
	H. betteni						2	1
	Helicopsyche borealis							1
	Chimarra obscura						6	
	Ochrotrichia sp.		1					
	Polycentropis sp.							1
Coleoptera	Stenelmis sp.	4	4		1	16	6	9
	Macronychus glabratus					1		2
	Optioservus fastiditus							
	Psephenus herricki	1	3	3	19	12	4	4
	Ectopria sp.				1			
	Hydrophilidae			1				1
	Laccobius sp.	1	1					
Hemiptera	Gerridae	1						
	Veliidae			1	1	2		1
Odonata	Argia sp.	1						
	Hetaerina sp.	7						
	Boyeria sp.							
Megaloptera	Corydalus cornutus					1	1	4
Crustacea	Lirceus sp.				4	2		
	Gammarus sp.				2	1		10
	Decapoda			1	2	2		1
Mollusca	Physidae				1			
	Pleuroceridae							1
	Valvatidae							
	Corbicula fluminea							
	Sphaeridae							
Annelida	Oligochaeta							
Platyhelminthes	Turbellaria							
Total		111	100	107	100	101	101	100

Macroinvertebrate Data by Site Number, cont.

	SITE	7	8	9	10	11	12
Diptera	Ablabesmyia mallochi						
	Nilotanypus fimbriatus						
	Thienemanninyia spp.	5	1	6	8	13	8
	Coryoneura spp.						
	Cricotopus bicinctus						1
	Eukiefferiella claripennis		1				
	Nanocladius spp.			1			
	Orthocladius obumbratus						
	Rheocricotopus robacki						
	Thienemanniella xena						
	Chironomus spp.					1	
	Cryptochironomus fulvus						
	Dicrotendipes nervosus					2	
	Endochironomus nigricans	1					
	Microtendipes caelum						
	Polypedilum convictum	13	4	6	8	27	8
	Paratanytarsus spp.		1				
	Rheotanytarsus exiguus			3			
	Tanytarsus guerlus	3		5	2	2	
	Simulium sp.		2	1			3
	Hemerodromia sp.						
	Antocha sp.		1				
	Hexatoma sp.						
	Ormosia sp.						
	Tipula sp.						
	Tabanidae				1		
Ephemeroptera	Baetis flavistriga	6	33	5	18	9	35
	B. hageni	13		10			
	Centroptilum sp.						
	Stenomena femoratum				11		
	S. pulchellum	2					1
	S. vicarium		2	2		1	1
	Stenonema spp.				1		
	Heptagenia sp.	4	3		2		4
	Isonychia sp.	4					4
	Caenis sp.	1					
	Chloroterpes sp.				1		
	Paraleptophlebia sp.						

Macroinvertebrate Data by Site Number, con't

	SITE	7	8	9	10	11	12
Plecoptera	Acroneuria sp.	6					
Trichoptera	Cheumatopsyche sp.	24	17	41	35	15	15
	Ceratopsyche bifida	1					4
	Hydropsyche simulans		1	11			
	H. betteni		16	2			
	Helicopsyche borealis		3				
	Chimarra obscura	2			2		2
	Ochrotrichia sp.					1	
	Polycentropis sp.						
Coleoptera	Stenelmis sp.	22	6	12	8	23	16
	Macronychus glabratus	1	1	1			1
	Optioservus fastiditus						
	Psephenus herricki		3	1	1		1
	Ectopria sp.						
	Hydrophilidae			1			
	Laccobius sp.						
Hemiptera	Gerridae						
	Veliidae		2				
Odonata	Argia sp.					3	
	Hetaerina sp.					1	
	Boyeria sp.						
Megaloptera	Corydalus cornutus	4	7		1		4
Crustacea	Lirceus sp.					1	
	Gammarus sp.			2			
	Decapoda	1	3	1	1		
Mollusca	Physidae					1	
	Pleuroceridae	2	1				1
	Valvatidae	1					
	Corbicula fluminea	1					
	Sphaeridae				1		
Annelida	Oligochaeta	1			1		
Platyhelminthes	Turbellaria			1			
Total		118	108	112	102	100	109

Metrics Data by Site Number

	1	1dpl.	2	3	4	5	6	7	8	9	10	11	12
Total number of taxa	21	24	21	20	18	18	25	22	20	19	17	14	17
Total number of individuals	>258	>258	>258	>258	>258	>258	>258	>258	>258	>258	>258	>258	>258
# EPT taxa	8	8	9	4	6	9	12	10	7	6	7	4	8
%orthoclads & tanytarsids	1	19	6	2	7	2	1	2	2	8	2	2	1
% non-insects	0	0	0	7	3	0	11	4	1	3	2	2	1
# Diptera taxa	7	13	8	8	4	6	4	4	6	6	4	5	4
% Intolerant	1	4	1	0	2	10	23	15	9	0	4	0	10
% Tolerant	14	12	3	7	4	1	0	2	3	1	1	8	4
% Predators	19	8	18	19	17	4	17	13	9	6	10	17	11
% Shredders & Scrapers	18	13	24	28	36	13	28	27	18	14	23	25	23
% Collector filterers	14	46	27	8	13	57	15	27	33	49	37	15	26
% Sprawlers	15	8	20	14	15	3	5	5	2	6	8	13	7

Metrics Scoring by Site Number

	1	1dpl.	2	3	4	5	6	7	8	9	10	11	12
Total number of taxa	3	3	3	1	1	1	3	3	1	1	1	1	1
Total number of individuals	5	5	5	5	5	5	5	5	5	5	5	5	5
# EPT taxa	5	5	5	5	5	5	5	3	3	3	3	1	5
%orthoclads & tanytarsids	5	5	5	5	5	5	5	5	5	5	5	5	5
% non-insects	5	5	5	5	5	5	5	5	5	5	5	5	5
# Diptera taxa	3	3	3	3	1	1	1	1	1	1	1	1	1
% Intolerant	1	1	1	1	1	1	3	1	1	1	1	1	1
% Tolerant	3	5	5	5	5	5	5	5	5	5	5	5	5
% Predators	3	1	3	3	1	1	1	1	1	1	1	1	1
% Shredders & Scrapers	3	3	5	5	5	3	5	5	3	3	5	5	5
% Collector filterers	3	1	1	5	3	1	3	1	1	1	1	3	1
% Sprawlers	1	1	1	1	1	3	3	3	5	3	1	1	1
mIBI	40	38	42	44	38	36	44	38	36	34	34	34	36

Habitat (QHEI) scoring by site number. The individual components and total are listed with the maximum possible scores in parentheses.

	1	2	3	4	5	6	7	8	9	10	11	12
Substrate (20)	13	14	16	16	18	19	19	15	14	12	12	19
Cover (20)	11	11	2	2	12	10	13	11	9	11	4	11
Channel (20)	16	17	13	13	16	18	18	13	13	13	11	18
Riparian (10)	6	8	9	9	7	9	9	6	5	4	2	8
Pool/Current (12)	8	8	0	0	10	8	11	8	5	8	5	11
Riffle/Run (8)	5	5	3	3	5	5	7	5	4	4	4	7
Gradient (10)	6	6	4	4	6	8	8	6	6	6	6	8
Total (100)	65	69	47	47	74	77	85	64	56	58	44	82