Muncie
SANITARY DISTRICT

Indiana Scientific Purpose License Number: 17-149

Bureau of Water Quality Annual Macroinvertebrate Community Report
2017

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March 2018

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***Acknowledgements**: Thank you to Jessica Bryzek and Zack Laughlin for their assistance in obtaining these samples, and for their countless hours of data entry, proofing, slide preparation, and general assistance in preparing this report.*

PREFACE

This paper contains results of the Bureau of Water Quality's (BWQ's) macroinvertebrate and mussel biomonitoring for the year 2076. For the purpose of displaying trends, some graphs and tables will present data from past years. However, the analysis given here is only for 2017. If further investigation of past years is needed, please refer to prior reports from this organization.

From 2013-2017 an additional Buck Creek site was sampled. This site (BUC 0.0) was sampled to observe changes in the site before and after best management practices (implemented in late 2013) were put into place.

In 2016, to provide more accuracy and adherence with the Indiana Department of Environmental Management, we obtained and implemented the use of the identification keys they use for identification of macroinvertebrates.

In 2014, one zebra mussel *Dreissena polymorpha* was found on a sampler in Prairie Creek Reservoir, upstream of Muncie. The reservoir is very near White River, connected via Prairie Creek. In 2015 zebra mussels were found on a sampler in Prairie Creek. In 2017, zebra mussels were not only found in White River, but are well established in some areas.

Due to additional studies comparing multiple sampling methods, one mussel site was sampled in 2017. However, mussel populations at other sites are always qualitatively observed and monitored.

INTRODUCTION

West Fork White River and the Bureau of Water Quality.—The headwaters of the West Fork White River (WFWR) can be found near Winchester, Indiana, moving westward through Muncie, draining approximately 384 square miles at the Madison County/Delaware County line (Hoggat 1975). The land along the river in Delaware County is primarily used for agriculture (corn, soybeans, and livestock), but also includes the urban area of Muncie. Muncie is a heavily industrialized community that has included electroplating firms, transmission assembly plants, a secondary lead smelter, foundries, heat treatment operations, galvanizing operations, and tool and die shops (ICLEI Case Study #19 1994).

In 1972, the Division of Water Quality (DWQ), now named the Bureau of Water Quality (BWQ), was established out of a need to regulate and control the sources responsible for polluting White River and its tributaries in and around Muncie, Indiana. The BWQ also wanted to attain those goals set forth by legislation of the 1970's and 1980's (The Water Pollution Act of 1972, the Clean Water Act of 1977 and the Water Quality Act of 1987). One of the ultimate goals is biological integrity, defined by Karr & Dudley (1981) as "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region."

Since the establishment of the BWQ, industries have installed millions of dollars in industrial pretreatment equipment, and corrective action is constantly being taken to prevent spills from entering the sewers and waterways. In addition, an ongoing program has reduced, and in some cases eliminated, pollution entering White River from combined sewer overflows (CSOs). Improvements have been made to the Muncie Water Pollution Control Facility (MWPCF), local sewers have been built to correct septic tank problems, and wildlife habitat has been developed along the river (Craddock 1990).

To get the best representation of the quality of a water system, both chemical and biological monitoring should be implemented. The benefits of chemical testing are vast; however, chemical monitoring can miss or underestimate combined chemical effects, sporadic events, and other factors such as habitat degradation (Karr 1981).

A benefit to using biological communities as indicators of water quality is their longevity and sensitivity to disturbances in the habitat in which they live. The observed condition of the aquatic biota, at any given time, is the result of the chemical and physical dynamics that occur in a water body over time (OEPA DWQMA 1987). Alone, neither gives a complete picture of water quality, however, the combination of biological and chemical monitoring increases the chances that degradation to the water body will be detected (Karr 1991).

Mussels as biomonitors.—Freshwater mussels are considered the most imperiled group of organisms in North America (Lydeard et al. 2004; Strayer et al. 2004), if not the world (Strayer 2008), and are declining at alarming and unprecedented rates (Neves et al 1997; Ricciardi & Rasmussen 1999; Vaughn & Taylor 1999; Strayer & Smith 2003; Poole & Downing 2004; Regnier et al. 2009). In North America alone, 72% of the native mussel fauna is either federally listed as endangered or threatened or considered to be in need of some protection (Haag 2009). At one time, 90 species of Unionid (of the family Unionidae) mussels were known to have existed in the eight Great Lake and Upper Mississippi states. Now, 33% are listed as extinct, endangered, or are candidates for that listing (Ball & Schoenung 1995). In the United States, 71 taxa are currently listed as endangered or threatened by the Endangered Species Act (USFWS 2005) and are suffering an extinction rate higher than any other North American fauna (Ricciardi & Rasmussen 1999). Contributors to this decline include commercial harvest, degradation of habitat (including channelization and dredging), toxic chemicals, and siltation. Other significant contributors include: impoundments (Vaughn & Taylor 1999; Watters 2000; Dean et al. 2002), water pollution (organic, inorganic, and thermal) (Mummert et al. 2003; Keller & Augspurger 2005; Valenti et al. 2005; 2006; Gooding et al. 2006; Bringolf et al. 2007; March et al. 2007; Wang et al. 2007; Cope et al. 2008; Besser et al. 2009), habitat alterations, and land use practices (Clarke 1981; Ball & Schoenung 1995; Biggins et al. 1995; Couch 1997; Gatenby et al. 1998; Payne et al. 1999; Watters 1999; Poole & Downing 2004). In 1990, the US EPA listed sedimentation as the top pollutant of rivers in the United States (Box & Mossa 1999). Studies have shown that silt accumulation of 0.25 to 1 inch resulted in nearly 90% mortality of mussels tested (Ellis 1936). This affects mussels by reducing interstitial flow rates, clogging mussel gills, and reducing light for photosynthesis of algae (primary forage of the mussel). Suspended particles also cause difficulty with the necessary fish and mussel interactions needed for reproduction and survival (Box & Mossa 1999). These indicate the importance of water quality as a factor in mussel survival. It is for these reasons, as well as their long life span, feeding habits, persistent shells (Strayer 1999a) and sensitive growth and reproductive rates (Burky 1983) that mussels serve well as biological indicators.

Macroinvertebrates as Biomonitors.—There are numerous reasons for using macroinvertebrates as indicators of water quality. Their ubiquitous nature, large numbers (individuals and species), and relative ease of sampling with inexpensive equipment make them ideal for bioassessments (Lenat et al. 1980; Hellawell 1986; Lenat & Barbour 1993). Macroinvertebrates are relatively sessile, allowing spatial analysis of disturbances (Tesmer & Wefring 1979; Hellawell 1986; Abel 1989). The extended life cycles of most aquatic insects allows for temporal analysis as well (Lenat et al. 1980; Hellawell 1986). Finally, macroinvertebrate species are well documented; many identification keys and forms of analysis are available, and specific responses to pollutants and stressors are well known (Hellawell 1986; Abel 1989; Rosenberg & Resh 1993). They are especially useful in situations where intermittent or mild organic enrichment is present (Chutter 1972).

MUSSEL METHODS

Mussel Field Sampling.—Sampling methods followed an adaptive cluster sampling with initial random samples without replacement, described by Strayer & Smith (2003), originated by Thompson (1992). Studies have shown a decrease in variance (Mwangi & Salim 2012) and an increase in sampling efficiency (Mwangi & Salim 2012; Smith et al. 2004) compared to conventional sampling methods. Additionally, the yield of individual mussels and rare species has been found to be increased (Smith et al.2003). Sample size was determined following Cochran (1977) and Hansen et al. (2007).

The equation is as follows:

$$n = \frac{s^2 t^2{}_{n-1}}{\delta^2}$$

Where:

n = sample size needed

s^2 = variance estimated from a pilot study

t = t-statistic defined for a given α level

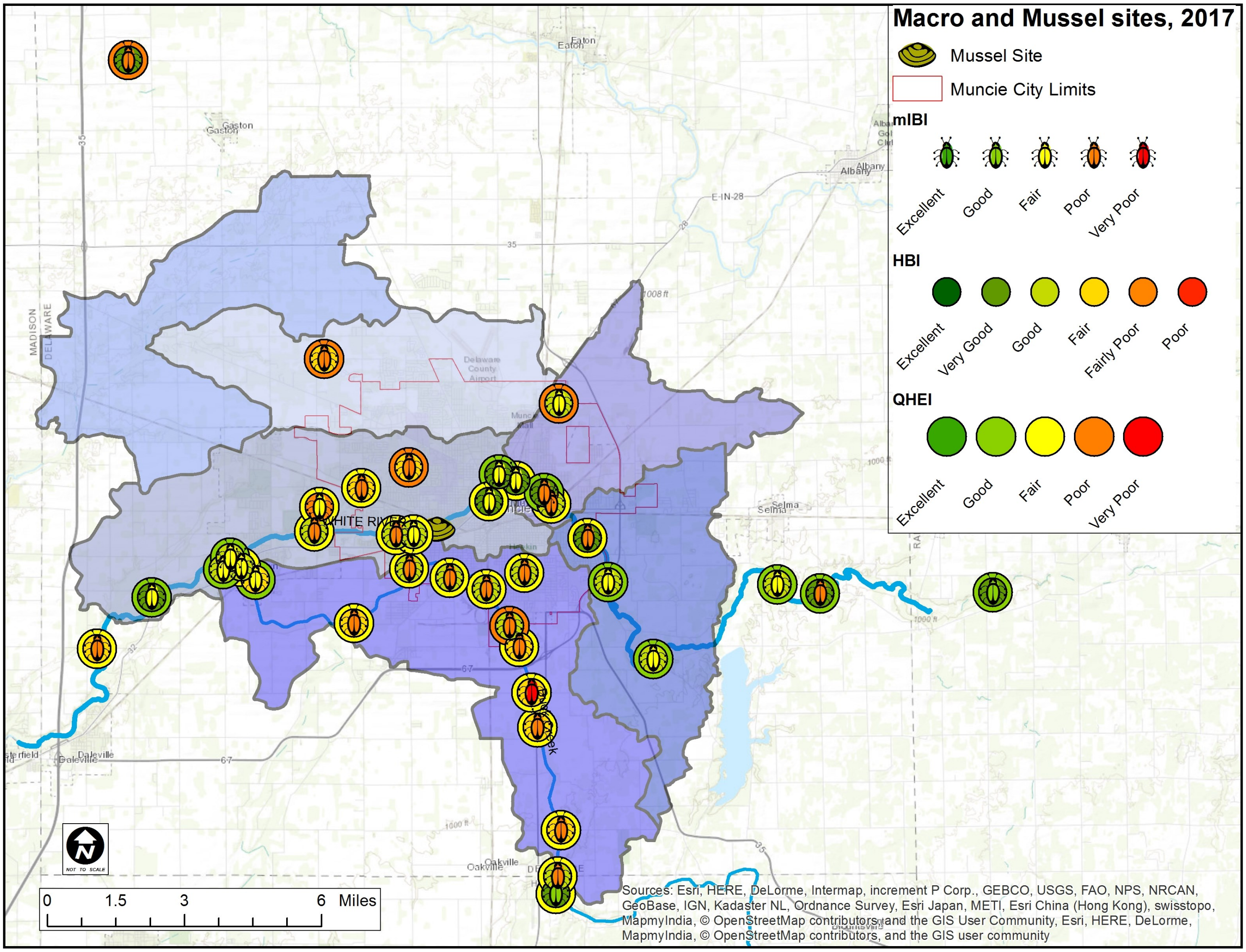
δ = precision in absolute terms

Field sheets (Appendix A, Table 8) were completed at each site (Appendix A, Table 5). A site was 100 m in river length; widths were taken at each meter along the river banks. A sampling grid was then plotted, and quadrats were then randomly chosen. Finally, a condition variable was then chosen, based on pilot studies.

Quadrats constructed with 0.25 m^2 PVC tubing were then secured in the randomly selected quadrat positions. A glass-bottom bucket was used to examine the river bottom for protruding mussels, which were removed and placed in a bucket, which was submerged and secured in the stream. Then, wearing neoprene gloves and using a garden claw, biologists began digging within the quadrat, removing all mussels and clams to a uniform depth of 10-15 cm (Dunn 1999; Smith et al. 1999). All retained mussels were identified, measured, aged (counting external annuli), and sex was recorded if the species was sexually dimorphic. Mussels were then replaced in the substrate as close to the original position as possible.

If the condition variable was not met, sampling

Figure 1.—Macroinvertebrate and mussel sites, 2017.



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community proceeded at the next randomly chosen quadrat. If the condition was met, neighboring quadrats in a cross-shaped pattern (Smith et al. 2004) were sampled. This continued until all quadrats did not meet the condition variable. The site was considered complete when all randomly chosen quadrats and their corresponding neighborhoods were sampled.

Asian clam, *Corbicula fluminea,* were also recorded. The largely fluctuating populations of this invasive species can greatly affect native mussel populations. Occasional rapid die-offs of Asian clam can occur after reproduction and sudden drops in dissolved oxygen (D.O.) (usually during the warm summer months). This can result in high levels of ammonia, detrimental to the entire aquatic ecosystem (Schiller 1997; Cherry et al. 2005; Cooper et al. 2005). It was determined that calculations of Asian clam means cannot be accurately determined from this type of sampling; the condition variable is set with the focus on Unionid density determinations. Future considerations will include an accurate way to include calculations of Asian clam and fingernailclam, *Sphaerium* spp..

Mussel Data Tabulation.—The Horvitz-Thompson (Thompson 1990) population estimator has been determined to be the superior choice for determining total population (per m^2) when utilizing the adaptive cluster method (Salehi 1999, 2003; Salehi & Smith 2005; Su & Quinn 2003). This complex calculation was determined using Philippi's (2005) code in SAS (2008). Significance was determined by $P < 0.05$ unless otherwise noted.

Table 1.—mIBI submetrics and stand alone indices and their response to disturbance

mIBI Sub-Metrics and Stand-Alone Indices	Response to Disturbance
Total Number of Taxa	Decrease
Total Abundance of Individuals	Decrease
Number of EPT taxa	Decrease
% Orthocladiinae & Tanytarsini	Increase
% Non-Insects (-Crayfish)	Increase
Number of Dipteran Taxa	Increase
% Intolerant Taxa (Score 0-3)	Decrease
% Tolerant Taxa	Decrease
% Predators	Decrease
% Shredders & Scrapers	Decrease
% Collectors/Filterers	Increase
% Sprawlers	Decrease
Hilsenhoff Biotic Index	Increase
Shannon-Wiener Diversity Index (H')	Decrease
Shannon Evenness Index (J')	Decrease
% Dominance of Top Three Taxa	Increase
% Chironomidae	Increase

MACROINVERTEBRATE METHODS

Macroinvertebrate Field Sampling.— Macroinvertebrate samples were taken at 14 sites on White River, and five sites along Buck Creek (Figure 1 and Appendix B, Table 9). Sampling followed the current IDEM Multi-habitat Macroinvertebrate Collection Procedure (MHAB) (IDEM 2010). This methodology includes a composite of a one minute riffle or mid-stream kick (if there is no riffle present) and an approximately 12-minute, 50-m riparian bank sample. The contents were elutriated six times and poured through a #30 USGS sieve. The remaining content in the sieve was then subsampled for 15 minutes. Organisms were placed in a vial with 99.5% isopropyl alcohol and returned to the lab for later identification.

Field sheets (Appendix B, Table 14) were completed, including the "Qualitative Habitat Evaluation Index" sheet (Appendix B, Table 18). Taxa sheets for each macroinvertebrate site can be found in Appendix B, Table 15. QHEI sheets and tabulations can be found in Appendix B, Table 18.

Macroinvertebrate Laboratory Methods.— All organisms were identified to the lowest practical level, usually genus. Non- Chironomid macroinvertebrates were identified using dichotomous keys by Peckarsky et al. (1990), Thorp & Covich (1991), Merritt & Cummins (1996), Wiggins (1996), and Smith (2001). Chironomids (with heads removed) were mounted on slides in a high viscosity mountant. Chironomids were then identified using Peckarsky et al. (1990), Mason (1998), and Epler (2001).

Table 2.—mIBI scores and corresponding ratings.

Total Score	Narrative Rating
54-60	Excellent
44-53	Good
35-43	Fair
23-34	Poor
0-22	Very Poor

Macroinvertebrate Data Tabulation.— Macroinvertebrate calculations were based on IDEM's Macroinvertebrate Index of Biotic Integrity (mIBI), the Hilsenhoff Biotic Index (HBI), Shannon-Wiener Diversity Index (H'), Shannon Evenness Index (J'), Percent Dominance of Top Three Taxa, and Percent Chironomidae.

IDEM's Macroinvertebrate Index of Biotic Integrity (mIBI): The mIBI is a multimetric index (Table 1) that has been calibrated using statewide data . After calculating each metric, the resulting score is assigned a specific "rank" (1, 3, or 5) based on the drainage area of the site. The sum of all metrics is then used to determine the final score. This final score is assigned a narrative rating (Table 2). IDEM ratings also include a designation of "Fully Supporting" of aquatic life (mIBI score $\geq$ 36), or "Not Supporting" of aquatic life (mIBI score <36).

Table 3.—HBI values and corresponding ratings.

HBI Score	Water Quality	Degree of Organic Pollution
0.00-3.50	Excellent	No apparent organic pollution.
3.51-4.50	Very Good	Possible slight organic pollution.
4.51-5.50	Good	Some organic pollution.
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution.
7.51-8.50	Poor	Very significant organic pollution.
8.51-10.00	Very Poor	Severe organic pollution.

Hilsenhoff Biotic Index (HBI): The HBI (Hilsenhoff 1987) is a biotic index that incorporates a weighted relative abundance of each taxon in order to determine a score for the community (Rosenberg & Resh 1993). Organisms are assigned a value between 0 and 10, according to their tolerance of organic and nutrient pollution

(Appendix B, Table 10). The number of each organism is multiplied by the tolerance value. The sum of these results is then averaged to get the resulting HBI value for the site. Modified descriptive ratings can be found below in Table 3.

The Hilsenhoff Biotic Index is calculated as follows:

$$HBI = \sum \frac{x_i t_i}{N}$$

Where:

X_i = number of each species

T_i = tolerance value for each species (Appendix. B, Table 10)

N = total number of arthropods in the sample with tolerance ratings

Shannon-Wiener Diversity Index (H'): The Shannon-Wiener Diversity Index is based on the premise that species diversity decreases with decreasing water quality (Wilhm 1967; Rosenberg & Resh 1993) in an effectively infinite community (Kaesler et al. 1978). This index incorporates both species richness as well as evenness (Ludwig & Reynolds 1988). Higher H' scores indicate increased species diversity (Vandermeer 1981; Gerritsen et al. 1998). The Shannon Wiener Index is calculated as follows:

$$H' = \sum p_i \ln p_i$$

Where:

p_i = relative abundance of each species calculated as a proportion of individuals of a given species to the total number of individuals in the community.

Shannon Evenness Index (J'): Shannon Evenness Index (Pielou 1966) is calculated from the Shannon-Wiener Diversity Index and is a ratio of observed diversity to maximum diversity in order to measure evenness of the community. Higher J' scores indicate increased community evenness.

The Shannon Evenness Index is calculated as follows:

$$J' = \frac{H'}{\ln s}$$

Where:

s = number of species

Percent Dominance of Top Three Taxa: A well balanced community is indicative of a healthy community. Predominance of only a few macroinvertebrate species can be indicative of stressors in the system (Plafkin et al. 1989; Klemm et al. 1990).

Percent Chironomidae: Chironomidae are generally considered to be pollution tolerant. An overabundance of these organisms can be indicative of stressors in the system (Plafkin et al. 1989; Barbour et al. 1994).

Qualitative Habitat Evaluation Index (QHEI): The QHEI was assessed to better determine the effect of habitat quality on the resulting scores. The QHEI (Rankin 1989) is an index that evaluates macro-habitat quality that has been found to be essential for fish communities as well as other aquatic life. QHEI metrics include substrate, instream cover, channel morphology, riparian condition, pool and riffle quality, and gradient. Each metric in the habitat assessment was scored, with the final sum of these scores reflecting available habitat (higher scores reflect better habitat). Narrative ratings for QHEI scores can be found in Table 4.

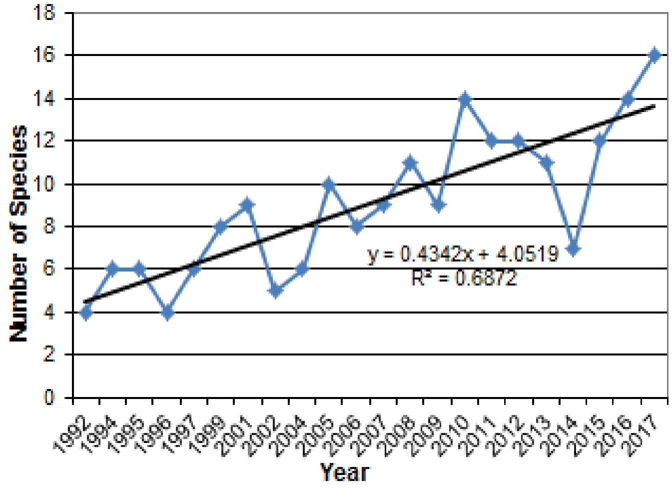
Table 4.—QHEI scores and corresponding ratings.

QHEI score	Narrative Rating
90-100	Excellent
71-89.9	Good
52-70.9	Fair
27-51.9	Poor
0-26	Very Poor

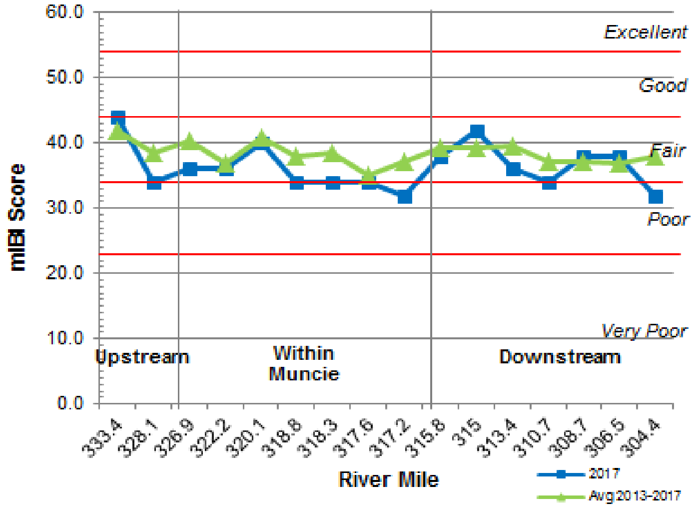
MUSSEL RESULTS

WR 313.4.—Due to an excessively large neighborhood, it was not logistically possible to complete mussel sampling at WR 313.4 in 2017, and therefore, statistical analysis was not completed. However, mussel found are reported in this report. Mussels were collected at 13 initial quadrats, with one unfinished. The condition variable for adaptive sampling was set at ≥ 2 mussels per 0.25 m^2 quadrat, based on prior sampling efforts. Mussels collected at WR 313.4 in 2017 are reported in Appendix A, Table 6. Fifteen Unionid species were sampled at this site.

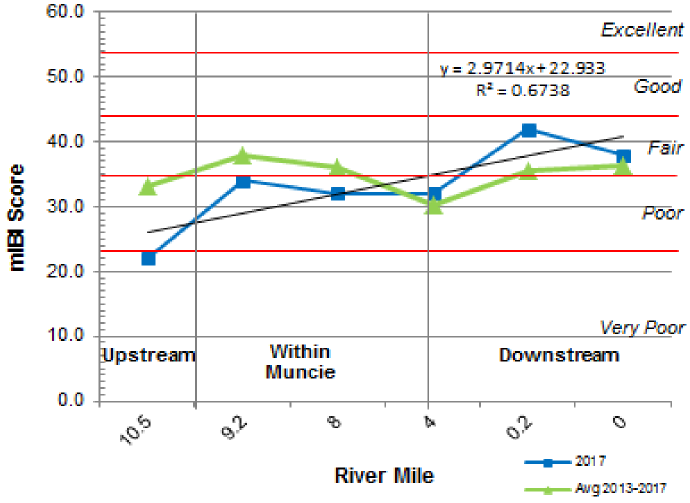
Graph 1.—Species diversity at WR 313.4, 1992-2017.



Graph 2.—White River mIBI scores, 2017.



Graph 3.—Buck Creek mIBI scores, 2017.



Species diversity has increased ($R^2 = 0.69, P < 0.001$) (Graph 1) since mussel sampling began in 1992. This is the highest density ever seen during our sampling efforts. A total number of 3089 mussels were sampled. Relative abundance (Appendix A, Graph 14) of all mussels sampled indicated that Asian clam comprised 87.3% of the sample, and Sphaeriidae comprised 0.03% of the sample. The three most abundant Unionid species at WR 313.4 were flutedshell *Lasmigona costata,* mucket *Actinonaias ligamentina,*, and elktoe *Alasmidonta marginata*.

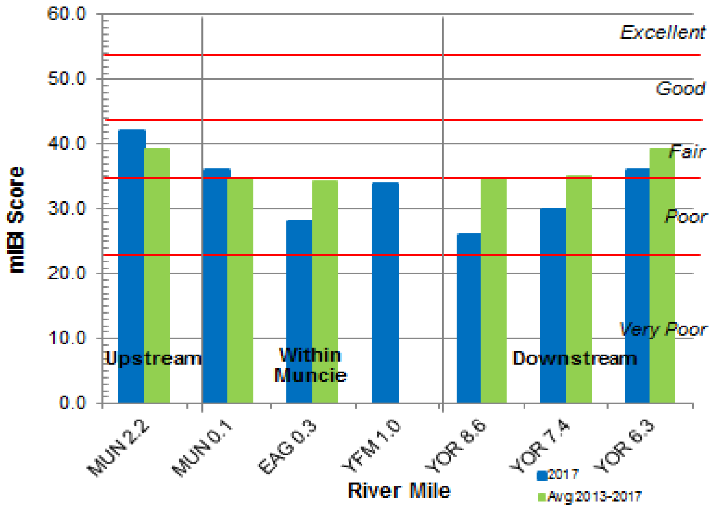
MACROINVERTEBRATE RESULTS

mIBI.—White River: White River mIBI scores (Graph 2 and Appendix B, Table 10) ranged from 32.0 (WHI 304.4 and WHI 317.2) to 44 (WHI 333.4), *Poor* to *Good*. In 2017, WHI 328.1, WHI 318.8, WHI 318.3, WHI 317.6, WHI 317.2, WHI 310.7, and WHI 304.4 would be considered "Not Supporting" of aquatic life by IDEM. Mean mIBI scores (Appendix B, Table 11) upstream, within, and downstream of Muncie were all *Fair*. Since 2013, mIBI scores have significantly decreased at WHI 328.1 ($R^2 = 0.90, p < 0.05$), WHI 317.2 ($R^2 = 0.95, p < 0.01$), and WHI 313.4 ($R^2 = 0.93, p < 0.01$). No spatial trends were detected in 2017.

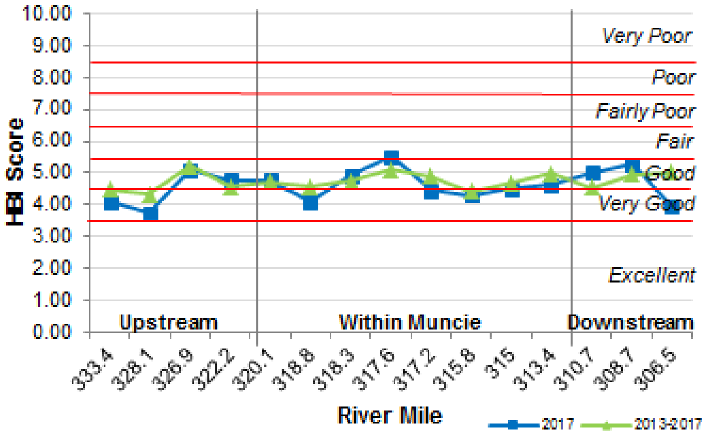
mIBI submetrics indicated additional trends at White River sites. The "Percent Intolerant" submetric at WHI 304.4 has significantly decreased ($R^2 = 0.84, p < 0.05$) since 2015. "Percent non-insects" has been consistently high at this site from 2014-2017. At WHI 320.1, The "Percent Tolerant" submetric has significantly decreased from 2013-2017 ($R^2 = 0.85, p < 0.05$).

Buck Creek: Buck Creek mIBI scores (Graph 3 and Appendix B, Table 10) ranged from 22.0 (BUC 10.5) to 44.0 (BUC 15.2), *Very Poor* to *Good*. The mean mIBI score for Buck Creek was 33.2, *Poor*. (Appendix B, Table 11) In 2017, BUC 14.9, BUC 13.8, BUC 11.3, BUC 10.5, BUC 10.0, BUC 9.5, BUC 9.2, BUC 8.0, BUC 7.1, BUC 5.9, and BUC 4.0 would be considered "Not

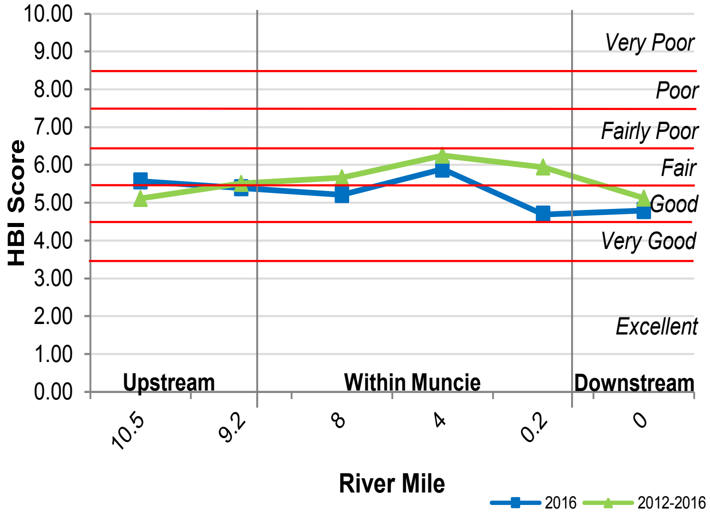
Graph 4.—Tributary mIBI scores, 2017.



Graph 5.—White River HBI scores, 2017.



Graph 6.—Buck Creek HBI scores, 2017.



Supporting” of aquatic life by IDEM. No spatial or temporal trends were detected.

mIBI submetrics indicated additional trends at Buck Creek sites. Uncharacteristic for Buck Creek sites, BUC 10.5 has had very low Percent Collectors/Filterers from 2014-2017.

In addition to the temporal trends detected from 2013-2017, a few observations should be noted. On White River, there have only been two Poor mIBI scores upstream of Muncie since 2009. Scores appear to fluctuate on White River from year to year, especially dramatic in recent years. Negative mIBI scores appear to be fairly common among tributary sites.

Smaller Tributary Sites: mIBI scores at the smaller tributaries (Graph 4 and Appendix B, Table 10) ranged from 26 (YOR 8.6) to 42 (MUN 2.2) *Poor* to *Fair*. EAG 0.3, YFM 1.0, YOR 8.6 , and YOR 7.4 would be considered “Not Supporting” of aquatic life by IDEM. Since 2013, mIBI scores have significantly decreased ($R^2 = 0.93, p < 0.01$) at YOR 8.6.

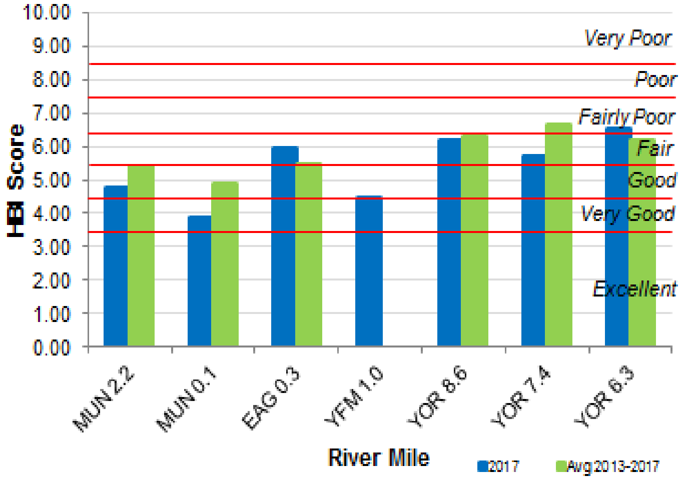
Stand Alone Indices.—

HBI: **White River:** White River HBI scores (Graph 5 and Appendix B, Table 10) ranged from 5.88 (WHI 304.4) to 3.74 (WHI 328.1), *Fair* to *Very Good*. Mean HBI scores (Appendix B, Table 11) dropped slightly from *Very Good* to *Good* within Muncie, and improved slightly below Muncie city limits. Since 2013, HBI scores have decreased at WHI 317.2 ($R^2 = 0.88, p < 0.05$). No spatial or temporal trends were detected.

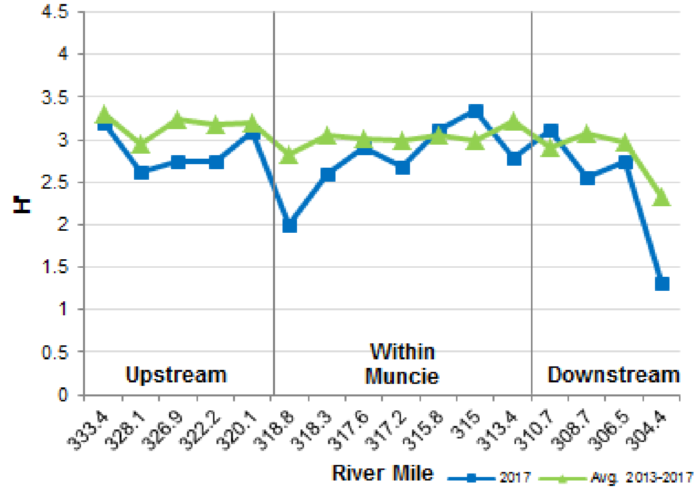
Buck Creek: Buck Creek HBI scores (Graph 6, Appendix B, Table 10) ranged from 6.39 (BUC 13.8) to 4.46 (BUC 15.2), *Fair* to *Very Good*. The mean HBI score (Appendix B, Table 11) was 5.4, *Good*. Since 2013, HBI scores have significantly decreased at BUC 8.0 ($R^2 = 0.94, p < 0.01$). No spatial trends were detected.

Smaller Tributary Sites: York Prairie Creek HBI scores (Graph 7 and Appendix B, Table 10) ranged from 6.54 (YOR 6.3) to 5.72 (YOR 7.4), *Fairly Poor* to *Fair*.

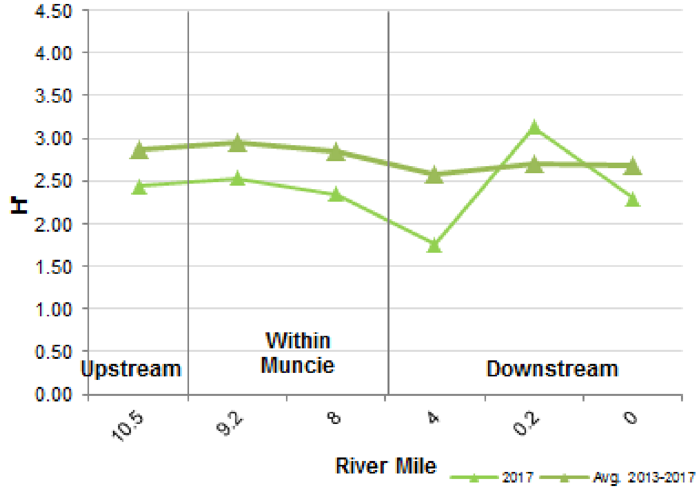
Graph 7.—Tributary HBI scores, 2017.



Graph 8.—White River H’ scores, 2017.



Graph 9.—Buck Creek H’ scores, 2017.



H’: **White River:** White River H’ scores (Graph 8 and Appendix B, Table 10) ranged from 1.31 (WHI 304.4) to 3.34 (WHI 315.0). Mean H’ scores (Appendix B, Table 11) dropped as White River progressed downstream. No spatial or temporal trends were detected ().

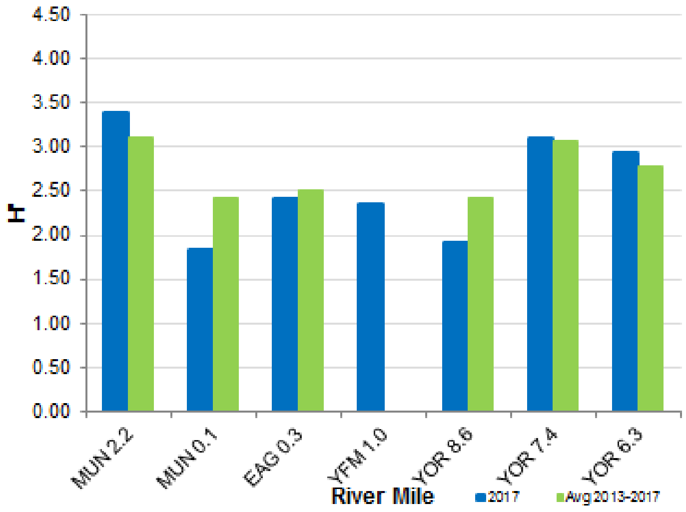
Buck Creek: Buck Creek H’ scores (Graph 9 and Appendix B, Table 10) ranged from 1.76 (BUC 4.0) to 3.17 (BUC 15.2). The mean H’ score (Appendix B, Table 11) was 2.64. Since 2013, H’ scores decreased at BUC 8.0 ($R^2 = 0.78, p < 0.05$), and BUC 4.0 ($R^2 = 0.82$, $p < 0.05$). No spatial trends were detected in 2017.

Smaller Tributary Sites: H’ scores at the smaller tributaries ranged from (Graph 10 and Appendix B, Table 10) 1.84 (MUN 0.1) to 3.40 at MUN 2.2.

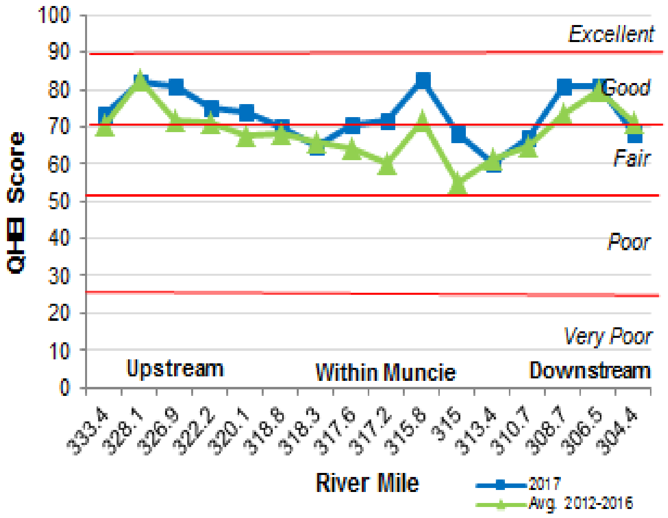
Remaining Stand Alone Indices: **White River:** White River J’ scores (Appendix B, Table 10) ranged from 0.42 (WHI 304.4) to 0.87 (WHI 315.0 and WHI 313.4). Mean J’ scores (Appendix B, Table 11) worsened downstream of the city limits. White River “Percent Dominance of Top Three Taxa” (Appendix B, Table 10) ranged from 0.27 (WHI 315.0) to 0.82 (WHI 304.4). Mean scores (Appendix B, Table 11) improved slightly within city limits, then worsened as White River progressed downstream of Muncie. White River “Percent Chironomidae” (Appendix B, Table 10) ranged from 0.04 (WHI 318.3) to 0.51 (WHI 313.4). Mean scores (Appendix B, Table 11) worsened within city limits, then improved as White River progressed downstream.

Buck Creek: Buck Creek J’ scores (Appendix B, Table 10) ranged from 0.60 (BUC 4.0) to 0.93 (BUC 10.5). The mean Buck Creek J’ score (Appendix B, Table 11) was 0.80. Buck Creek “Percent Dominance of Top Three Taxa” (Appendix B, Table 10) ranged from 0.74 (BUC 4.0) to 0.35 (BUC 15.2), with a mean of 0.50 (Appendix B, Table 11). Buck Creek “Percent Chironomidae” scores (Appendix B, Table 10) ranged from 0.48 (BUC 5.9 and BUC 0.0) to 0.09 (BUC 13.8), with a mean of 0.30 (Appendix B, Table 11).

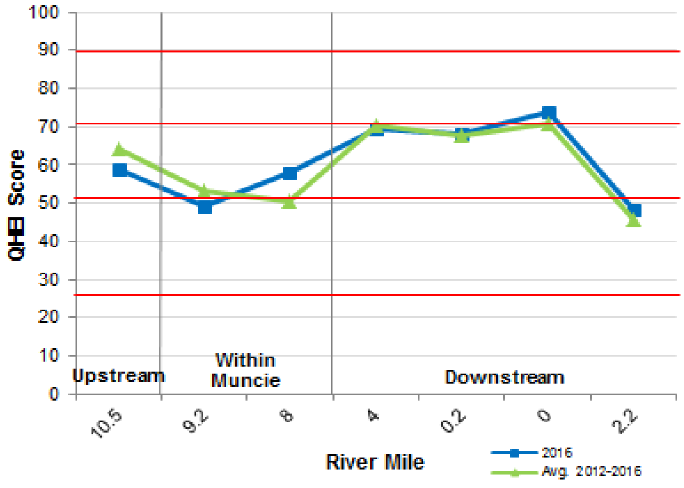
Graph 10.—Tributary H’ scores, 2017.



Graph 11.—White River QHEI scores, 2017.



Graph 12.—Buck Creek QHEI scores, 2017.



Smaller Tributary Sites: J’ scores at the smaller tributaries ranged from (Appendix B, Table 10) ranged from 0.66 (YOR 8.6) to 0.87 (YOR 7.4). “Percent Dominance of Top Three Taxa” ranged from (Appendix B, Table 10) 0.69 (YOR 8.6) to 0.32 (MUN 2.2). “Percent Chironomidae” (Appendix B, Table 10) ranged from 0.52 (MUN 0.1) to 0.10 (YFM 1.0).

QHEI: **White River:** White River QHEI scores ranged from 60.0 (WHI 313.4) to 82.8 (WHI 315.8), *Fair* to *Good* (Graph 11 and Appendix B, Table 10). Mean scores worsened within Muncie city limits, but recovered downstream (Appendix B, Table 11). A significant increase in scores was seen from 2013-2017 at WHI 317.6 ($R^2 = 0.86, P < 0.05$). Since 2013, QHEI scores have significantly increased at WHI 317.6 ($R^2 = 0.86, p < 0.05$). No spatial trends were detected in 2017.

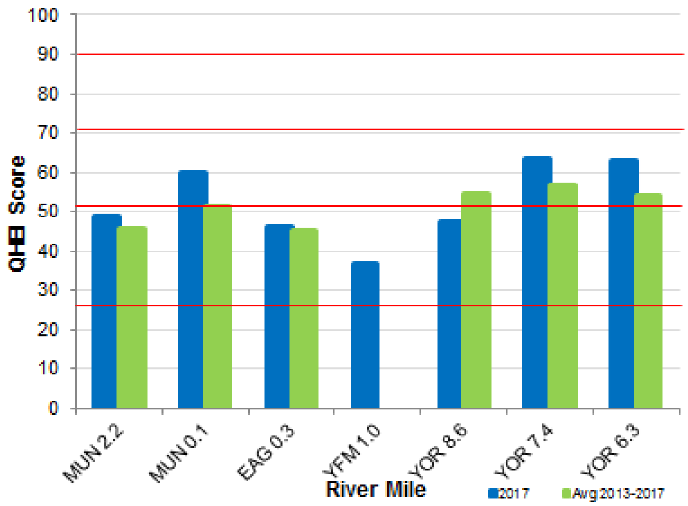
Buck Creek: Buck Creek QHEI scores (Graph 12 and Appendix B, Table 10) ranged from 49.0 (BUC 9.2) to 77.75 (BUC 0.9), *Poor* to *Good*, with a mean score of 64.27, *Fair* (Appendix B, Table 11). A significant increase in scores was seen from 2013-2017 at BUC 0.0 ($R^2 = 0.89, P < 0.05$). Since 2013, QHEI scores significantly increased at BUC 0.0 ($R^2 = 0.89, p < 0.05$). No spatial trends were detected in 2017.

Smaller Tributary Sites: QHEI scores at the smaller tributaries ranged from (Graph 13 and Appendix B, Table 10) 36.5 (YFM 1.0) to 63.5 (YOR 7.4), *Poor* to *Fair*. No spatial trends were detected in 2017.

DISCUSSION

Mussels.—Sampling results at WR 313.4 continue to indicate good water quality in this stretch of White River, impressive considering the urban location of this site. The significant increase in Unionid diversity suggests that populations at this site are thriving. The apparent fluctuation in diversity and density through the years is likely a product of random sampling, Therefore, further sampling and examination of

Graph 13.—Smaller tributary QHEI scores, 2017.



sampling design will be necessary to determine if there is a decline in native populations, and if this sampling method remains to be the most accurate and efficient method.

One of the three most abundant mussels found at this site, the elktoe, is considered to be characteristic of streams with good water quality, and intolerant of impoundment (Watters 1995; Parmalee & Bogan 1998). In apparent contrast, this mussel species has been found throughout White River within the City of Muncie, which has many impoundments. However, it is usually found in firm substrate, not the softer substrates directly upstream and downstream of the impoundments.

Corbicula spp. density has also fluctuated at this site, appearing to increase in 2017. This is characteristic of invasive species. *Corbicula* spp. populations grow rapidly and are then susceptible to sudden die-offs; generally after reproduction, sudden changes in water temperature, and low dissolved oxygen (Strayer 1999b). This was observed during our 2017 sampling. *Corbicula* spp. will continue to be monitored in order to establish trends in population numbers and correlations with Unionid populations.

It has been noted that one mussel species, the white heelsplitter *Lasmigona complanata*, has not been found in White River upstream of Muncie. This species' opportunistic nature, and its ability to tolerate silt, habitat disturbance, and impoundments (Grabarkiewicz & Davis 2008), appear to make it an ideal species to inhabit White River within city limits. However, it is possible that this species is unable to expand its range upstream due to the inability of its host species to navigate the five impoundments within Muncie city limits. Dams are well documented as obstacles to mussel population abundance and expansion (Vaughn & Taylor 1999; Watters 2000; Dean et al. 2002). Habitats are altered upstream and downstream of the impoundment, resulting in an increase of pollutants, siltation, stagnation, thermal changes, and anoxic conditions (Watters 1999), causing additional complications for mussel populations (Watters 1996; Dean et al. 2002; Lessard & Hayes 2003; Tienmann et al. 2004; Poff et al. 2007; Maloney et al. 2008).

Dams have been implicated as one of the leading causes of current-day decline in freshwater mussel populations in North America (Parmalee & Bogan 1998; Haag 2009). They have been cited as being responsible for the "local extirpation of 30-60% of the native freshwater mussel species in many United States rivers" (NRCS 2009). Studies have shown that the impacts of impoundments have resulted in reduced abundance, diversity, and species richness of mussel fauna (Dean et al. 2002; Baldigo et al. 2004; Tiemann et al. 2004; Santucci et al. 2005; Galbraith & Vaughn 2011: Tiemann et al. 2016).

In late summer 2017, zebra mussels were found in White River downstream of Prairie Creek Reservoir (where they were first observed in 2015). Within weeks, zebra mussels were identified on dead mussel shell in the WR 313.4 site. Upon further investigation, they were found to be established as far downstream as CR 575W. Now that they are established in White River, considerations will need to be taken for sampling design, monitoring, and protection for our native mussels and for uninfected streams. This will be given much thought and will be an ongoing effort.

Additional future considerations for mussel sampling at the BWQ include initial sample size, condition variable, and final sample size determination at BWQ mussel sites. Condition variables used in adaptive cluster sampling fluctuate among studies from 5-30% of the highest typical number found during a preliminary survey

(Strayer and Smith 2003). Trial and error will likely be the best way to determine the optimum condition variable for each site. Through research of the newest methods and possibly trial and error, the best approximation of the condition variable will be attained. Research will also be focused on the introduction of a stopping rule, to prevent the nearly infinite sampling of a site. Investigation into statistical methods that will accurately determine population numbers for individual species when using adaptive cluster sampling will also be re-examined. This will enable us to further investigate the possible effects of water or habitat quality on a species level.

There is also continued concern about wide confidence intervals at mussel sites. It has been found that estimates of mussel population density tend to be skewed (Philippi 2005), making the usual approach to confidence intervals inaccurate. It appears that generally, these are found when populations are highly variable, common in *Corbicula* spp. populations. These limitations will be considered when contemplating further sampling and analytical strategies.

Macroinvertebrates—Many sites had lower mIBI scores in 2017. Most of these sites also had unusually low abundance and/or diversity.

Poor mIBI scores at some sites may be attributed to a lack of suitable habitat for macroinvertebrates, quantified by *Poor* QHEI scores. Sites at BUC 9.2, EAG 0.3, YFM 1.0, and YOR 8.6 all had *Poor* QHEI scores, indicating that a lack of habitat may limit the macroinvertebrates that can inhabit these sites.

Organic impairment appears to be a likely stressor at one site. YOR 6.3 is the only site in 2017 to have a *Fairly Poor* HBI score. Despite this, the mIBI score was *Fair*.

Many remaining sites with *Poor* mIBI scores do not suggest organic impairment or habitat limitations. Most of these sites have very low abundance and/or diversity, exaggerating any effects on this sample and carrying over into multiple metrics. These include BUC 14.9, BUC 13.8, BUC 11.3, BUC 10..5, BUC 10.0, BUC 9.5, BUC 8.0, BUC 7.1, BUC 5.9, BUC 4.0, WHI 328.1, WHI 318.8, WHI 318.3, WHI 317.6, WHI 317.2, WHI 310.7, WHI 304.4, and YOR 7.4.

Only BUC 11.3, BUC 9.5, and WHI 304.4 had *Poor* mIBIs, but did not have low abundance. BUC 11.3 was dominated by non-insects (39.8%) and tolerant organisms (37.8%) , with the tolerant non-insect *Lirceus* spp. dominating 34.5% of the sample. The dominance by this organisms suggests the presence of slower, pooled areas, which were found at this site. BUC 9.5 was dominated by *Lirceus* spp. and *Hyallela azteca*, tolerant non-insects, again negatively affecting multiple submetrics of the mIBI. This site no longer has a riffle, and the habitat consists of mud, clay, and slower, pooled areas. WHI 304.4 was highly dominated (73.5%) by a moderately tolerant non-insect, *Goniobasis livascens*, negatively affecting multiple submetrics of the mIBI as well as diversity and evenness. This snail has become very prevalent at this site, perhaps suggesting increased algae due to nutrient enrichment.

Significant decreases in mIBI scores from 2013-2017 indicate potential water quality issues at some sites. These sites include WHI 328.1 (falling from *Good* to *Fair*), WHI 317.2 (*Fair* to *Poor*), WHI 313.4 (*Good* to *Fair*), and YOR 8.6 (*Good* to *Poor*).

Significant decreases in HBI scores from 2013-2017 suggest improved water quality, specifically decreased organic enrichment, at some sites. These sites include WHI 317.2 (*Fair* to *Very Good*), and BUC 8.0 (*Fair* to *Good*).

Significant decreases in H' scores from 2013-2017 show decreased diversity in macroinvertebrate populations at some sites, potentially indicating stressors at these sites. These sites include BUC 8.0 (3.18-2.35), and BUC 4.0 (3.11 to 1.76).

Significant increases in QHEI scores from 2013-2017 indicate increased habitat availability at some sites. These sites include WHI 317.6 (*Fair* to the upper end of the *Fair* range), and BUC 0.0 (*Fair* to *Good*).

Observed trends give us some indication of negative impacts on sample sites. *Poor* mIBI scores generally are not seen on White River upstream of Muncie city limits, likely indicating a negative impact from the anthropogenic sources of an urbanized area (ie– storm water, impervious surface, CSOs, impoundments, etc.). Multiple negative mIBI scores at tributary sites likely reflect impacts that are more apparent due to their smaller size. Additionally, diversity and/or abundance may be limited by the colder temperatures found in spring-fed Buck Creek (Vannote & Sweeney 1980; Ward 1976).

Climatological fluctuations and extremes have been considered as factors in years with unusually low mIBI scores (Bowley 2012; Bowley 2015; Bowley 2016). Other stressors may need to be considered including the effects of multiple stressors. These may include ecological, morphological, hydrological, biological, chemical or climatological effects. To complicate an already challenging situation, most aquatic macroinvertebrates have complex life cycles that include multiple stages, some being terrestrial. Research and analysis, as well as continued monitoring, will be conducted in an attempt to determine all stressors affecting macroinvertebrate communities.

Dramatic improvements have been seen since the inception of our macroinvertebrate and mussel sampling programs. Point source pollutants have been controlled through the utilization of local permits regulated by the Bureau of Water Quality. Improvements have been and continue to be made to our Water Pollution Control Facility. Whereas most analyses historically have focused on White River, studying the tributaries and nonpoint source pollution impacting them has become critical. These impacts on water quality include hydromodifications (channelization, impoundments, dredging, and removal of riparian zones), urban storm water (sources include CSOs, SSOs, and impervious surfaces), and sedimentation. In 1990, the US EPA listed sedimentation as the top pollutant of rivers in the United States (Box & Mossa 1999), and it has been determined that reductions in water quality are detectable at > 15% impervious surface (Roy et al. 2003).

This shift in focus would benefit from public outreach, education, and cooperation to instill better management practices throughout Delaware County. These include buffer strips, rain barrels, rain gardens, better construction site practices, and the further separation of CSOs. As improved management practices are implemented, it is expected that water quality will continue to improve.

Overall, the water systems in this area appear to be in good condition, especially considering the industrial, urban, and agricultural areas through which they flow. Efforts by the citizens of Delaware County, the City of Muncie, the Muncie Sanitary District, the Bureau of Water Quality, and the industrial community are responsible for the improvements in water quality since the BWQ was established in 1972.

Appendix A.—Mussel sites, taxa identified, graphs, density, Horvitz-Thompson results, and field sheet.

Table 5.—Mussel site descriptions and locations, 2017.

West Fork White River	**West Side Park (WR 313.4)**	40.184627	-85.17339
Drainage=245 sq. miles	**HUC 14:** 05120201020060		

Land use surrounding this site is commercial. This site also borders a municipal park. The north bank is mowed to the bank, with a few trees. The south bank has a partially forested buffer, with a one residence that is mowed to the bank.

Table 6.—Mussel assemblage at WR 313.4, 2017.

Scientific Name	Common Name	# Found
Corbicula fluminea	Asian clam	2698
Lasmigona costata	flutedshell	136
Actinonaias ligamentina	mucket	87
Alasmidonta marginata	Elktoe	81
Fusconaia flava	Wabash pigtoe	31
Strophitus undulates	Creeper	8
Lampsilis siliquoidea	Fatmucket	9
Lasmigona complanata	White heelsplitter	9
Pleurobema coccineum	Round pigtoe	5
Lampsilis cardium	Plain pocketbook	10
Lampsilis fasciola	Wavy-rayed lampmussel	1
Villosa iris	Rainbow	6
Sphaerium spp.	Fingernailclam	1
Pyganodon grandis	Giant floater	2
Anodontoides ferussacianus	Cylindrical papershell	1
Eurynia dilatata	Spike	1
Amblema plicata	threeridge	3

Graph 14.—Relative abundance for all mussels and for all native mussels at WR 313.4, 2017.

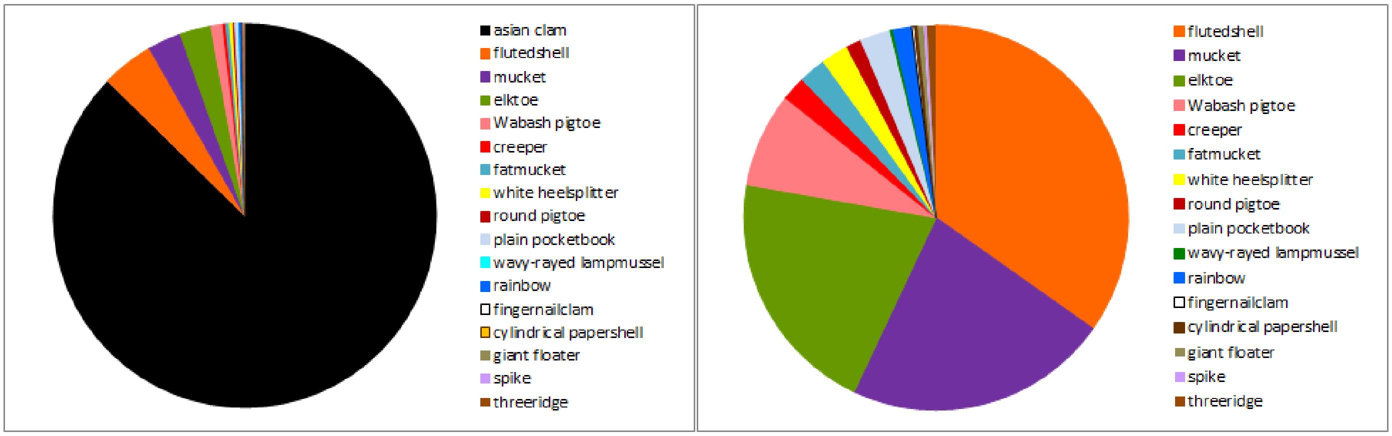


Table 7.—Mussel sampling field sheet.

BUREAU OF WATER QUALITY
MUSSEL BED SURVEY

Stream **Station** **County** **Date**

Collected by:

Collection Notes:

Width:

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Table 7.—Mussel sampling field sheet (con't).

Bureau of Water Quality Mussel Data

Stream **Station** **Date**

Transect	Collector	Species	Width	Height	Age	Count

Appendix B.—Macroinvertebrate sites, field sheets, tolerance and attributes used for calculations, taxa identified, taxa sheets, QHEI sheets, and resulting scores.

Table 8.—Macroinvertebrate site descriptions and locations, 2017.

Buck Creek	**CR 950N (BUC 15.2)**	**Lat./Long.**	40.070817	-85.363497
Drainage= 13 sq. miles	**HUC14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**CR 800S (BUC 14.9)**	**Lat./Long.**	40.076306	-85.362624
Drainage= 27 sq. miles	**HUC14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**CR 700S (BUC 13.8)**	**Lat./Long.**	40.090910	-85.361338
Drainage= 27 sq. miles	**HUC14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**SR 3 (BUC 11.3)**	**Lat./Long.**	40.123676	-85.370897
Drainage= 36 sq. miles	**HUC14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**400S (BUC 10.5)**	**Lat./Long.**	40.134629,	-85.373259
Drainage= 36 sq. miles	**HUC 14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005). Flow at this site is extremely fast. Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**ByPass (BUC 10.0)**	**Lat./Long.**	40.172703	-85.375932
Drainage= 36 sq. miles	**HUC14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**CR 300S/Fuson Rd. (BUC 9.5)**	**Lat./Long.**	40.149185	-85.378202
Drainage= 49 sq. miles	**HUC14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**Madison St. (BUC 9.2)**	**Lat./Long.**	40.155806,	-85.382286
Drainage= 49 sq. miles	**HUC 14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**23rd St. (BUC 8.0)**	**Lat./Long.**	40.16756,	-85.391803
Drainage= 49 sq. miles	**HUC 14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**Hoyt Rd. (BUC 7.1)**	**Lat./Long.**	40.171267	-85.406849
Drainage= 49 sq. miles	**HUC14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**Tillotson Ave. (BUC 5.9)**	**Lat./Long.**	40.174127	-85.423697
Drainage= 49 sq. miles	**HUC14:** 05120201020020			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**CR 325W (BUC 4.0)**	**Lat./Long.**	40.15686,	-85.446570
Drainage= 49 sq. miles	**HUC 14:** 05120201020060			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**Cornbread Rd. W. Crossing (BUC 0.9)**	**Lat./Long.**	40.170817	-85.487403
Drainage= 100 sq. miles	**HUC 14:** 05120201020060			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**SR 32 (BUC 0.2)**	**Lat./Long.**	40.174756,	-85.493202
Drainage= 100 sq. miles	**HUC 14:** 05120201020060			
Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Buck Creek	**Confluence (BUC 0.0)**	**Lat./Long.**	40.174082,	-85.500697
Drainage= 100 sq. miles	**HUC 14:** 05120201020060			
Due to severe erosion and numerous band stabilization efforts, this site underwent reconstruction in the fall of 2013. This site was sampled pre-construction in 2013, and will be sampled annually hereafter to assess water quality and habitat. During construction, banks were naturally stabilized, and large boulders and j-hooks were installed. The riffle at the j-hooks is fast, and deep. Water is much colder (4.2ºC to 6.5ºC lower than White River) due to the system being spring fed (Conrad and Warrner 2005).				
Eagle Branch Creek	**CR 350N (EAG 0.3)**	**Lat./Long.**	40.24077,	-85.458656
Drainage= 4.7 sq. miles	**HUC 14:** 05120201010130			

Table 8.—Macroinvertebrate site descriptions and locations, 2017 (con't).

Muncie Creek	**Indiana Ave. (MUN 2.2)**	**Lat./Long.**	40.226458,	-85.361522
Drainage= 10.0 sq. miles	**HUC 14:** 05120201010130			
Muncie Creek	**McCulloch Park (MUN 0.1)**	**Lat./Long.**	40.201933,	-85.379461
Drainage= 10.0 sq. miles	**HUC 14:** 05120201010130			
West Fork White River	**CR 1100W (WHI 333.4)**	**Lat./Long.**	40.165932,	-85.182243
Drainage= 120 sq. miles	**HUC 14:** 05120201010090			
West Fork White River	**CR 700E (WHI 328.1)**	**Lat./Long.**	40.165859,	-85.253616
Drainage= 184 sq. miles	**HUC 14:** 05120201010100			
West Fork White River	**Smithfield (WHI 326.9)**	**Lat./Long.**	40.168793,	-85.271332
Drainage= 184 sq. miles	**HUC 14:** 05120201010100			
West Fork White River	**Camp Red Wing (CRW) (WHI 322.2)**	**Lat./Long.**	40.145227,	-85.322876
Drainage= 213 sq. miles	**HUC 14:** 05120201010120			
West Fork White River	**Burlington (WHI 320.1)**	**Lat./Long.**	40.169697,	-85.341393
Drainage= 220 sq. miles	**HUC 14:** 05120201010120			
Large man-made boulder and cobble riffle stretches the width of the stream.				
West Fork White River	**Water Company (WHI 318.8)**	**Lat./Long.**	40.183727,	-85.349831
Drainage= 220 sq. miles	**HUC 14:** 05120201010120			
Site downstream of Water Company lowhead dam. Riffle sampled in riffle and dam for consistency to past efforts.				
West Fork White River	**River Rd. (WHI 318.3)**	**Lat./Long.**	40.184911,	-85.429108
Drainage= 220 sq. miles	**HUC 14:** 05120201010120			
West Fork White River	**E. Jackson (WHI 317.6)**	**Lat./Long.**	40.194584,	-85.364861
Drainage= 231 sq. miles	**HUC 14:** 05120201010130			
Site substrate almost exclusively bedrock.				
West Fork White River	**Bunch Blvd. (WHI 317.2)**	**Lat./Long.**	40.198117,	-85.367828
Drainage= 231 sq. miles	**HUC 14:** 05120201010130			
West Fork White River	**Elm St. (WHI 315.8)**	**Lat./Long.**	40.204031,	-85.386483
Drainage= 241 sq. miles	**HUC 14:** 05120201020060			
Substrate is dominated by bedrock.				
West Fork White River	**High St. (WHI 315.0)**	**Lat./Long.**	40.195446,	-85.390610
Drainage= 241 sq. miles	**HUC 14:** 05120201020060			
Site is downstream of large lowhead dam in downtown Muncie.				
West Fork White River	**Tillotson Ave. (WHI 313.4)**	**Lat./Long.**	40.184975,	-85.421722
Drainage= 245 sq. miles	**HUC 14:** 05120201020060			
West Fork White River	**CR 400W/Nebo Rd. (WHI 310.7)**	**Lat./Long.**	40.186045,	-85.462912
Drainage= 246 sq. miles	**HUC 14:** 05120201020060			
This is the first annual baseline site downstream of the MWPCF.				
West Fork White River	**CR 575W (WHI 308.7)**	**Lat./Long.**	40.177713,	-85.497803
Drainage= 248 sq. miles	**HUC 14:** 05120201020060			
West Fork White River	**CR 750W (WHI 306.5)**	**Lat./Long.**	40.165253,	-85.530273
Drainage= 367 sq. miles	**HUC 14:** 05120201030010			
Flow is extremely fast at this site.				
West Fork White River	**CR 300S (WHI 304.4)**	**Lat./Long.**	40.148876,	-85.552838
Drainage= 370 sq. miles	**HUC 14:** 05120201030020			
Flow is very fast at this site.				
Yaeger et al. Ditch	**CR 1000N (YFM 1.0)**	**Lat./Long.**	40.335811	-85.539662
Drainage= 10 sq. miles	**HUC 14:** 05120201050010			
York Prairie Creek	**Brook Rd./Storer Elem. (YOR 8.6)**	**Lat./Long.**	40.206286,	-85.423686
Drainage= 4.00 sq. miles	**HUC 14:** 05120201030010			
York Prairie Creek	**CR 300W (YOR 7.4)**	**Lat./Long.**	40.199781,	-85.443308
Drainage= 4.00 sq. miles	**HUC 14:** 05120201030010			
York Prairie Creek	**CR 400W (YOR 6.3)**	**Lat./Long.**	40.193758,	-85.460747
Drainage= 4.00 sq. miles	**HUC 14:** 05120201030010			

Table 9.—Tolerance values used in mIBI/HBI calculations.

Species	Tolerance Value
Ablabesmyia	5
Ablabesmyia annulata	4
Ablabesmyia janta	5
Ablabesmyia mallochi	5
Acariformes	4
Acentrella	4
Acentrella ampla	6
Acentria	5
Acerpenna	4
Acerpenna macdunnoughi	1
Acerpenna pygmaea	2
Acroneuria	1
Acroneuria abnormis	0
Acroneuria evoluta	3
Acroneuria internata	2
Acroneuria lycorias	2
AESHNIDAE	3
Agabetes	5
Agabus	5
Agapetus	0
Agnetina	2
Agnetina annulipes	2
Agnetina capitata	2
Agnetina flavescens	2
Agraylea	6
Allocapnia	3
Allocapnia vivipara	3
Alloperla	0
Ameletus	0
Ameletus lineatus	0
Ameletus ludens	0
AMNICOLA	5
Amnicola limosus	5
Amphinemura	3
Amphinemura delosa	3
Amphinemura nigritta	3
AMPHIPODA	4
ANCYLIDAE	6
Ancyronyx variegatus	4
Anthopotamus	4
Anthopotamus verticis	4
Antocha	2
Arcteonais lomondi	6
Argia	5
ASELLIDAE	8
ASTACIDAE	6
ATHERICIDAE	2
Atractides	6
Atrichopogon	5
Atrichopogon websteri	4

Species	Tolerance Value
Attenella attenuata	3
Aulodrilus	7
Aulodrilus americanus	7
Aulodrilus limnobius	7
Aulodrilus pigueti	7
Aulodrilus pluriseta	7
BAETIDAE	4
Baetis	3
Baetis brunneicolor	4
Baetis flavistriga	3
Baetis intercalaris	3
Baetis tricaudatus	4
Baetisca	4
BAETISCIDAE	3
Basiaeschna	6
Basiaeschna janata	6
Belostoma flumineum	4
Berosus	7
Berosus peregrinus	6
Berosus striatus	5
BITHYNIA	8
Bithynia tentaculata	8
BLEPHARICERIDAE	0
vejdovskyanum	7
Boyeria	2
Boyeria vinosa	4
BRACHYCENTRIDAE	1
Brachycentrus lateralis	1
Brachycentrus numerosus	1
Brachycercus	3
BRANCHIOBDELLIDAE	6
Branchiura	6
Branchiura sowerbyi	6
Brillia	5
Caecidotea	8
Caecidotea communis	8
CAENIDAE	7
Caenis	3
Callibaetis	6
Calopteryx	4
Cambarus	2
Cambarus diogenes	6
CAPNIIDAE	1
Cardiocladius	5
Cardiocladius obscurus	2
Centroptilum	3
Ceraclea	3
Ceraclea ancylus	3
Ceraclea maculata	4
CERATOPOGONIDAE	6

Table 9.—Tolerance values used in mIBI/HBI calculations (con't).

Species	Tolerance Value
Ceratopsyche alhedra	3
Ceratopsyche bronta	5
Ceratopsyche morosa	2
Ceratopsyche slossonae	2
Ceratopsyche sparna	3
Chaetogaster	7
Chaetogaster diaphanus	6
Chaetogaster diastrophus	6
Chaetogaster limnaei	6
Chaoborus	8
Chauliodes	4
Cheumatopsyche	3
Chimarra	4
Chimarra aterrima	2
Chimarra obscura	4
Chimarra socia	2
CHIRONOMIDAE(all other)	6
CHIRONOMIDAE(blood red)	8
Chironomus	8
CHLOROPERLIDAE	1
Choroterpes	4
Chrysops	5
Cincinnatia cincinnatiensis	5
Cladopelma	9
Cladotanytarsus	4
Climacia	5
Clinotanypus pinguis	8
Clioperla clio	1
Cloeon	4
Cnephia mutata	5
COENAGRIONIDAE	9
Conchapelopia	4
Corbicula fluminea	6
Cordulegaster	3
CORDULEGASTRIDAE	3
CORDULIIDAE	3
CORIXIDAE	5
CORYDALIDAE	1
Corydalus cornutus	2
Corynoneura	4
Corynoneura celeripes	2
Crangonyx	6
Crenitis	5
Cricotopus	4
Cricotopus bicinctus	7
Cryptochironomus	5
Cryptochironomus blarina	8
Cryptochironomus fulvus	8
Cryptotendipes	4
CULICIDAE	8

Species	Tolerance Value
Culicoides	10
CURCULIONIDAE	5
Cyrnellus fraternus	4
Dannella	2
Dannella lita	4
Dero	10
Dero digitata	10
Dero furcata	10
Dero nivea	10
Dero obtusa	10
Dero vaga	10
Diamesa	8
Dibusa angata	3
Dicranota	3
Dicrotendipes	6
Dicrotendipes fumidus	6
Dicrotendipes modestus	6
Dicrotendipes neomodestus	5
Dineutus	4
Dineutus assimilis	4
Dineutus horni	4
Dineutus nigrior	4
Diplocladius cultriger	8
Dixa	1
DOLICHOPODIDAE	4
Dolophilodes	0
Doncricotopus bicaudatus	5
Dreissena polymorpha	8
Dromogomphus	6
Drunella walkeri	0
DRYOPIDAE	5
Dubiraphia	5
Dubiraphia bivittata	3
Dubiraphia quadrinotata	3
Eccoptura	3
Eclipidrilus	5
Ectopria	5
Ectopria nervosa	4
Elliptio complanata	8
ELMIDAE	4
EMPIDIDAE	6
Enallagma	9
ENCHYTRAEIDAE	10
Endochironomus	6
Endochironomus nigricans	5
Epeorus	0
Ephemera	3
Ephemerella	3
Ephemerella dorothea	1
Ephemerella excrucians	1

Table 9.—Tolerance values used in mIBI/HBI calculations (con't).

Species	Tolerance Value
Ephemerella invaria	1
Ephemerella needhami	2
Ephemerella subvaria	1
EPHEMERELLIDAE	1
EPHEMERIDAE	4
Ephoron	2
Ephoron leukon	2
EPHYDRIDAE	6
Erythemis	2
Eukiefferiella claripennis	8
Eurylophella	2
Eurylophella bicolor	1
Eurylophella funeralis	2
Eurylophella temporalis	5
Ferrissia	6
Ferrissia parallelus	6
Ferrissia rivularis	6
Ferrissia walkeri	6
Fossaria	6
GAMMARIDAE	4
Gammarus	6
Gammarus fasciatus	6
Gammarus pseudolimnaeus	4
GASTROPODA	7
Glossosoma	0
GLOSSOSOMATIDAE	0
Glyptotendipes	6
Goera	3
GOMPHIDAE	1
Gomphus	5
Goniobasis	6
Goniobasis livescens	6
Gyraulus	8
Gyraulus circumstriatus	8
Gyraulus deflectus	8
Gyraulus parvus	8
Gyrinus	4
Haemonais waldvogeli	8
Hagenius brevistylus	1
Haliplus	6
Haliplus borealis	5
Haliplus connexus	6
Haliplus cribrarius	6
Haliplus immaculicollis	6
Haliplus longulus	6
Haliplus pantherinus	6
Haploperla brevis	1
HAPLOTAXIDAE	5
Harnischia	8
Harnischia curtilamellata	4

Species	Tolerance Value
Helichus	5
Helichus striatus	2
Helicopsyche borealis	3
HELICOPSYCHIDAE	3
Helisoma	6
Helisoma anceps	6
Helius	4
Helobdella	10
Helobdella stagnalis	8
Helobdella triserialis	8
Helochares	5
Helophorus	5
Heptagenia	3
Heptagenia diabasia	2
Heptagenia flavescens	4
Heptagenia pulla	4
HEPTAGENIIDAE	4
Hesperocorixa	5
Hesperocorixa interrupta	5
Hesperocorixa lucida	5
Hesperocorixa vulgaris	5
Hetaerina	3
Heterocloeon	3
Heterocloeon curiosum	2
Heterotrissocladius	0
Hexagenia	4
Hexagenia limbata	3
Hexatoma	2
HIRUDINEA	8
Hyalella azteca	8
Hydatophylax	2
Hydrobaenus	8
HYDROBIIDAE	7
Hydrobius	5
Hydrobius fuscipes	4
Hydrochara	5
Hydrochus	5
Hydroporus	4
Hydropsyche	4
Hydropsyche betteni	6
Hydropsyche bidens	3
Hydropsyche depravata	6
Hydropsyche dicantha	4
Hydropsyche frisoni	2
Hydropsyche orris	3
Hydropsyche phalerata	1
Hydropsyche scalaris	2
Hydropsyche simulans	2
Hydropsyche valanis	3
Hydropsyche venularis	3

Table 9.—Tolerance values used in mIBI/HBI calculations (con't).

Species	Tolerance Value
HYDROPSYCHIDAE	4
Hydroptila	3
Hydroptila albicornis	6
Hydroptila armata	6
Hydroptila consimilis	6
Hydroptila hamata	6
Hydroptila spatulata	6
Hydroptila waubesiana	6
HYDROPTILIDAE	4
Ilybius biguttulus	8
Ilyodrilus templetoni	10
Ischnura	9
Isochaetides freyi	8
Isonychia	2
Isonychia bicolor	2
ISONYCHIIDAE	2
Isoperla	2
Isoperla dicala	2
Isoperla frisoni	2
Isoperla namata	2
ISOPODA	8
Isotomurus	5
Labrundinia	4
Labrundinia pilosella	3
Laccobius	2
Laccobius spangleri	4
Laccophilus	8
Laccophilus maculosus	8
maculosus	8
Lampsilis radiata radiata	6
Larsia	4
Lebertia	4
Lepidostoma	1
LEPIDOSTOMATIDAE	1
LEPTOCERIDAE	4
Leptocerus americanus	4
Leptophlebia	4
LEPTOPHLEBIIDAE	2
Leucrocuta	2
Leucrocuta aphrodite	1
Leucrocuta hebe	3
Leucrocuta maculipennis	2
Leuctra	0
Leuctra ferruginea	0
Leuctra tenuis	0
LEUCTRIDAE	0
Libellula	9
LIBELLULIDAE	9
LIMNEPHILIDAE	4
Limnephilus	3

Species	Tolerance Value
Limnodrilus cervix	10
Limnodrilus claparedianus	10
Limnodrilus hoffmeisteri	10
Limnodrilus profundicola	10
Limnodrilus udekemianus	10
Limnophila	3
Limonia	6
Liodessus affinis	6
Liodessus flavicollis	6
Lirceus	8
LUMBRICULIDAE	5
Lutrochus laticeps	3
Lymnaea	6
adpressa	6
LYMNAEIDAE	6
Lype diversa	3
Maccaffertium exiguum	2
Maccaffertium luteum	4
mediopunctatum	2
integrum	3
Maccaffertium modestum	1
Maccaffertium pudicum	2
Maccaffertium pulchellum	2
Maccaffertium terminatum	2
Maccaffertium vicarium	2
Macromia	2
MACROMIIDAE	3
Macronychus glabratus	3
Macrostemum	3
Macrostemum carolina	3
Macrostemum zebratum	2
METRETOPODIDAE	2
Micrasema rusticum	2
Microcylloepus pusillus	3
Micropsectra	4
Microtendipes	7
Microtendipes caelum	3
Molanna	6
Molanna blenda	4
MOLANNIDAE	6
MUSCIDAE	6
Musculium	6
Musculium partumeium	6
Musculium transversum	6
Mystacides	4
Mystacides sepulchralis	4
NAIDIDAE	8
Nais	8
Nais barbata	8
Nais behningi	6

Table 9.—Tolerance values used in mIBI/HBI calculations (con't).

Species	Tolerance Value
Nais bretscheri	6
Nais communis	8
Nais elinguis	10
Nais pardalis	8
Nais simplex	6
Nais variabilis	10
Nanocladius	5
Nanocladius distinctus	6
Nanocladius spiniplenus	4
Natarsia	6
Natarsia baltimoreus	6
Nectopsyche	2
Nectopsyche diarina	3
Nectopsyche exquisita	3
Nectopsyche pavida	2
NEMATODA	6
Nemoura	1
NEMOURIDAE	2
Neoperla	3
Neophylax	3
Neophylax concinnus	3
Neophylax fuscus	3
Neotrichia	4
Neureclipsis	3
Neurocordulia obsoleta	0
Nigronia fasciatus	2
Nigronia serricornis	4
Nilotanypus	6
Nilotanypus fimbriatus	3
Nilothauma	3
Nixe	3
Nixe perfida	5
Nyctiophylax	3
Nyctiophylax moestus	5
Nymphula	7
Ochrotrichia	2
ODONTOCERIDAE	0
Oecetis	3
OLIGOCHAETA	8
OLIGONEURIIDAE	2
Oligostomis	2
Ophidonais serpentina	6
Ophiogomphus	1
Optioservus	4
Optioservus fastiditus	2
Optioservus trivittatus	4
Orconectes	4
Orconectes propinquus	4
Orconectes rusticus	6
Orconectes virilis	6

Species	Tolerance Value
Orthocladius	4
Orthocladius carlatus	2
Orthotrichia	6
Oulimnius	4
Oulimnius latiusculus	4
Oxyethira	5
Pagastia	1
Palmacorixa	5
Palmacorixa buenoi	4
Palmacorixa gillettei	4
Palmacorixa nana	4
Paracapnia	1
Paracapnia angulata	1
Parachironomus	4
Parachironomus carinatus	5
Parachironomus frequens	4
Paracladopelma	7
Paragnetina	2
Paragnetina media	2
Parakiefferiella	5
Paraleptophlebia	3
Paraleptophlebia guttata	1
Paraleptophlebia moerens	1
Paraleptophlebia mollis	1
Paraleuctra	0
Parametriocnemus	3
lundbeckii	5
Paranais frici	10
Paraponyx	5
Paratanytarsus	4
Paratendipes	6
Paratendipes albimanus	4
Pedicia	4
Pelocoris femoratus	4
Peltodytes	7
Peltodytes edentulus	6
Peltodytes tortulosus	6
Pentaneura	6
Pentaneura inconspicua	5
Pericoma	6
Perlesta	4
Perlesta placida	5
PERLIDAE	1
Perlinella drymo	1
PERLODIDAE	2
Petrophila	5
Phaenopsectra	7
Phaenopsectra flavipes	6
Phaenopsectra punctipes	4
PHILOPOTAMIDAE	3

Table 9.—Tolerance values used in mIBI/HBI calculations (con't).

Species	Tolerance Value
PHRYGANEIDAE	4
Phylocentropus	4
Physa	8
Physella	8
Physella gyrina	8
Physella heterostropha	8
Physella integra	8
PHYSIDAE	8
Pilaria	7
PISIDIIDAE	8
Pisidium	6
Pisidium casertanum	6
Pisidium compressum	6
Pisidium variabile	6
Placobdella montifera	8
PLANORBIDAE	6
Plathemis lydia	8
Platycentropus	4
Plauditus	4
Plauditus punctiventris	2
Pleurocera acuta	6
PLEUROCERIDAE	6
POLYCENTROPODIDAE	6
Polycentropus	3
POLYMITARCYIDAE	2
Polypedilum aviceps	2
Polypedilum convictum	4
Polypedilum illinoense	7
Polypedilum ontario	3
POTAMANTHIDAE	4
Potamothrix moldaviensis	8
Potamothrix vejdovskyi	8
Potamyia	5
Potamyia flava	3
Pristina	8
Pristina aequiseta	8
Pristina breviseta	8
Pristina leidyi	8
Pristina synclites	8
Pristinella	8
Pristinella jenkinae	8
Pristinella osborni	8
Probythinella lacustris	8
Procladius	7
Prodiamesa olivacea	3
Prostoia	2
Protoplasa	3
Protoptila	1
Psectrocladius	6
Psectrotanypus	8

Species	Tolerance Value
Psectrotanypus dyari	9
PSEPHENIDAE	4
Psephenus	4
Psephenus herricki	4
Pseudochironomus	5
Pseudocloeon	2
Pseudocloeon dardanus	2
Pseudocloeon propinquus	1
Pseudolimnophila	2
Pseudostenophylax	0
Pseudosuccinea columella	6
Psychoda	4
PSYCHODIDAE	10
Psychomyia flavida	2
PSYCHOMYIIDAE	2
PTERONARCYIDAE	0
Pteronarcys	0
Pteronarcys dorsata	0
Ptilostomis	5
Pycnopsyche	3
Pyganodon cataracta	6
PYRALIDAE	5
Quistradrilus multisetosus	10
Radix auricularia	6
Ranatra fusca	4
Ranatra nigra	4
Rheocricotopus	5
Rheocricotopus robacki	4
Rheotanytarsus	3
Rhithrogena	0
Rhyacodrilus	10
Rhyacophila	1
Rhyacophila glaberrima	1
RHYACOPHILIDAE	0
Ripistes parasita	8
Saetheria tylus	4
SCIRTIDAE	5
SERICOSTOMATIDAE	3
Serratella	1
Serratella deficiens	2
Setodes	2
Shipsa rotunda	2
SIALIDAE	4
Sialis	5
Sigara alternata	4
Sigara grossolineata	4
Sigara mathesoni	4
Sigara modesta	4
Sigara signata	4
Sigara variabilis	4

Table 9.—Tolerance values used in mIBI/HBI calculations (con't).

Species	Tolerance Value
SIMULIIDAE	6
Simulium	5
Simulium venustum	5
Simulium vittatum	7
SIPHLONURIDAE	7
Siphlonurus	4
Siphloplecton	2
Slavina appendiculata	6
Somatochlora	1
Sperchon	4
Sphaerium	6
Sphaerium striatinum	6
Spirosperma ferox	6
catascopium	6
Stagnicola elodes	6
Stempellinella	3
Stenacron	3
Stenacron carolina	2
Stenacron interpunctatum	7
Stenelmis	5
Stenelmis bicarinata	5
Stenelmis crenata	5
Stenelmis musgravei	5
Stenelmis sandersoni	5
Stenelmis vittipennis	5
Stenochironomus	4
Stenonema	3
Stenonema femoratum	3
Stictochironomus	4
Strophopteryx	3
Strophopteryx fasciata	3
Stylaria lacustris	8
Stylodrilus heringianus	5
Stylogomphus	1
Stylurus	4
Sublettea coffmani	2
Sweltsa	0
Sympetrum	10
SYRPHIDAE	10
TABANIDAE	6
Tabanus	5
TAENIOPTERYGIDAE	2
Taeniopteryx	2
Taeniopteryx burksi	2
Taeniopteryx nivalis	2
Taeniopteryx parvula	2
TALITRIDAE	8
Tanypus	9
Tanypus neopunctipennis	8
Tanytarsus	4

Species	Tolerance Value
Telopelopia okoboji	4
Thienemanniella	4
Thienemanniella similis	2
Thienemanniella xena	4
Tipula	7
Tipula abdominalis	4
TIPULIDAE	3
Tribelos	5
Trichocorixa	5
Trichocorixa calva	4
Trichocorixa kanza	4
Trichocorixa sexcincta	4
TRICORYTHIDAE	4
Tricorythodes	3
Tubifex	10
Tubifex tubifex	10
TUBIFICIDAE	10
TURBELLARIA	4
Tvetenia	5
Ulomorpha	4
UNIONIDAE	6
Valvata	8
Valvata lewisi	8
Valvata piscinalis	8
Valvata sincera	8
Valvata tricarinata	8
VALVATIDAE	8
Vejdovskyella	6
Vejdovskyella intermedia	6
VIVIPARIDAE	6
Viviparus georgianus	6
Wormaldia	2
Xenochironomus xenolabis	0
Xylotopus	2
Zavrelimyia	4

Table 10.—Scores for macroinvertebrate sites, 2017.

	BUC 15.2	BUC 14.9	BUC 13.8	BUC 11.3	BUC 10.5	BUC 10.0	BUC 9.5
mIBI Submetrics							
Total # of Taxa	5	3	3	5	1	3	5
Total Abundance	3	1	1	3	1	1	3
Number EPT Taxa	3	1	3	5	1	3	3
% Orthocladiinae & Tanytarsini	5	5	3	5	5	5	5
% Non-Insects (minus Crayfish)	5	5	3	1	3	5	1
# Diptera Taxa	3	1	3	1	1	1	3
% Intolerant Taxa (Score 0-3)	3	1	1	1	1	1	3
% Tolerant Taxa (Score 8-10)	5	5	1	1	3	3	1
% Predators	3	1	3	1	1	3	1
% Shredders & Scrapers	3	5	1	1	3	3	3
% Collector/Filterers	5	3	5	3	1	5	5
% Sprawlers	1	1	1	1	1	1	1
	44	32	28	28	22	34	34
	Good	*Poor*	*Poor*	*Poor*	*Very Poor*	*Poor*	*Poor*
Stand Alone Indices							
Hilsenhoff Index	4.46	4.92	6.39	6.08	5.57	5.30	5.80
	Very Good	*Good*	*Fair*	*Fair*	*Fair*	*Good*	*Fair*
Shannon Index of Diversity (H')	3.17	2.82	2.86	2.83	2.44	3.09	2.99
Shannon Evenness Index (J')	0.85	0.85	0.81	0.76	0.93	0.88	0.81
% Dominance of Top 3 Taxa	0.35	0.46	0.46	0.47	0.43	0.38	0.41
% Chironomidae	0.12	0.23	0.09	0.14	0.14	0.17	0.15
QHEI Scores	69.8	60.5	63.5	69.5	59	59	60.8
	Fair	*Fair*	*Fair*	*Fair*	*Fair*	*Fair*	*Fair*

	BUC 9.2	BUC 8.0	BUC 7.1	BUC 5.9	BUC 4.0	BUC 0.9	BUC 0.2
mIBI Submetrics							
Total # of Taxa	3	1	3	1	1	3	5
Total Abundance	1	1	1	1	1	1	3
Number EPT Taxa	1	1	3	1	1	1	1
% Orthocladiinae & Tanytarsini	3	5	5	5	5	5	5
% Non-Insects (minus Crayfish)	5	5	1	3	5	5	5
# Diptera Taxa	1	1	3	1	3	3	5
% Intolerant Taxa (Score 0-3)	1	1	1	1	1	1	3
% Tolerant Taxa (Score 8-10)	5	5	5	3	3	5	5
% Predators	5	3	1	3	1	3	1
% Shredders & Scrapers	1	3	3	5	5	5	5
% Collector/Filterers	5	5	3	5	5	5	3
% Sprawlers	3	1	1	1	1	1	1
	34	32	30	30	32	38	42
	Poor	*Poor*	*Poor*	*Poor*	*Poor*	*Fair*	*Fair*
Stand Alone Indices							
Hilsenhoff Index	5.39	5.21	5.15	5.25	5.89	5.60	4.69
	Good	*Good*	*Good*	*Good*	*Fair*	*Fair*	*Good*
Shannon Index of Diversity (H')	2.53	2.35	2.74	1.97	1.76	2.62	3.13
Shannon Evenness Index (J')	0.81	0.89	0.89	0.82	0.60	0.86	0.83
% Dominance of Top 3 Taxa	0.48	0.50	0.40	0.62	0.74	0.47	0.40
% Chironomidae	0.18	0.19	0.21	0.48	0.69	0.36	0.42
QHEI Scores	49.0	58	63.0	62.8	69.5	77.75	68.25
	Poor	*Fair*	*Fair*	*Fair*	*Fair*	*Good*	*Fair*

Table 10.—Scores for macroinvertebrate sites, 2017(con't).

	BUC 0.0	EAG 0.3	MUN 2.2	MUN 0.1	WHI 333.4	WHI 328.1	WHI 326.9
mIBI Submetrics							
Total # of Taxa	3	1	5	1	5	3	3
Total Abundance	1	1	3	1	3	1	1
Number EPT Taxa	1	1	3	3	5	1	1
% Orthocladiinae & Tanytarsini	5	5	5	5	3	5	5
% Non-Insects (-Crayfish)	5	3	3	5	5	5	5
# Diptera Taxa	3	1	5	1	3	1	1
% Intolerant Taxa (Score 0-3)	1	1	3	3	5	3	1
% Tolerant Taxa (Score 8-10)	5	5	5	5	5	5	5
% Predators	3	3	1	1	1	3	3
% Shredders & Scrapers	5	1	5	5	3	1	5
% Collector/Filterers	5	5	3	3	5	5	5
% Sprawlers	1	1	1	3	1	1	1
	38	28	42	36	44	34	36
	Fair	*Poor*	*Fair*	*Fair*	*Good*	*Poor*	*Fair*
Stand Alone Indices							
Hilsenhoff Index	4.79	5.93	4.76	3.89	4.09	3.74	5.11
	Good	*Fair*	*Good*	*Very Good*	*Very Good*	*Very Good*	*Good*
Shannon Index of Diversity (H')	2.29	2.41	3.40	1.84	3.19	2.61	2.75
Shannon Evenness Index (J')	0.74	0.85	0.83	0.77	0.83	0.86	0.83
% Dominance of Top 3 Taxa	0.48	0.41	0.32	0.68	0.38	0.48	0.44
% Chironomidae	0.48	0.18	0.33	0.52	0.07	0.06	0.20
QHEI Scores	73.75	46.0	48.5	60.0	73.5	82	80.8
	Good	*Poor*	*Poor*	*Fair*	*Good*	*Good*	*Good*

	WHI 322.2	WHI 320.1	WHI 318.8	WHI 318.3	WHI 317.6	WHI 317.2	WHI 315.8
mIBI Submetrics							
Total # of Taxa	3	5	1	3	3	3	5
Total Abundance	1	3	1	1	1	1	3
Number EPT Taxa	3	3	1	1	1	1	3
% Orthocladiinae & Tanytarsini	5	3	5	3	5	3	3
% Non-Insects (-Crayfish)	3	3	5	5	5	5	3
# Diptera Taxa	1	3	1	1	1	3	5
% Intolerant Taxa (Score 0-3)	3	3	1	3	1	3	5
% Tolerant Taxa (Score 8-10)	5	5	5	5	5	5	5
% Predators	1	1	5	3	3	1	1
% Shredders & Scrapers	5	5	3	3	5	5	3
% Collector/Filterers	5	5	5	5	3	1	1
% Sprawlers	1	1	1	1	1	1	1
	36	40	34	34	34	32	38
	Fair	*Fair*	*Poor*	*Poor*	*Poor*	*Poor*	*Fair*
Stand Alone Indices							
Hilsenhoff Index	4.78	4.78	4.08	4.91	5.50	4.44	4.29
	Good	*Good*	*Very Good*	*Good*	*Good*	*Very Good*	*Very Good*
Shannon Index of Diversity (H')	2.75	3.09	2.00	2.59	2.91	2.69	3.11
Shannon Evenness Index (J')	0.84	0.81	0.71	0.81	0.86	0.81	0.82
% Dominance of Top 3 Taxa	0.48	0.42	0.70	0.48	0.40	0.51	0.38
% Chironomidae	0.16	0.06	0.06	0.04	0.31	0.46	0.25
QHEI Scores	75	74	69.75	65.0	70.75	71.5	82.8
	Good	*Good*	*Fair*	*Fair*	*Fair*	*Good*	*Good*

Table 10.—Scores for macroinvertebrate sites, 2017 (con't).

	WHI 315.0	WHI 313.4	WHI 310.7	WHI 308.7	WHI 306.5	WHI 304.4	YFM 1.0
mIBI Submetrics							
Total # of Taxa	5	3	3	5	3	3	3
Total Abundance	3	1	1	5	1	3	1
Number EPT Taxa	5	1	3	3	3	1	1
% Orthocladiinae & Tanytarsini	3	5	5	5	5	5	3
% Non-Insects (-Crayfish)	3	5	1	1	5	1	5
# Diptera Taxa	3	3	1	3	1	1	1
% Intolerant Taxa (Score 0-3)	5	1	1	1	5	1	5
% Tolerant Taxa (Score 8-10)	5	5	5	5	5	5	5
% Predators	1	1	3	1	1	1	3
% Shredders & Scrapers	5	5	5	5	5	5	1
% Collector/Filterers	3	3	5	3	3	5	5
% Sprawlers	1	3	1	1	1	1	1
	42	36	34	38	38	32	34
	Fair	*Fair*	*Poor*	*Fair*	*Fair*	*Poor*	*Poor*
Stand Alone Indices							
Hilsenhoff Index	4.49	4.63	5.02	5.27	3.94	5.88	4.35
	Very Good	*Good*	*Good*	*Good*	*Very Good*	*Fair*	*Very Good*
Shannon Index of Diversity (H')	3.34	2.79	0.00	2.56	2.74	1.31	2.35
Shannon Evenness Index (J')	0.87	0.87	0.00	0.67	0.86	0.42	0.73
% Dominance of Top 3 Taxa	0.27	0.41	0.40	0.59	0.38	0.82	0.56
% Chironomidae	0.24	0.51	0.12	0.14	0.16	0.05	0.10
QHEI Scores	68.0	60.0	67.3	80.8	80.8	68.3	36.5
	Fair	*Fair*	*Fair*	*Good*	*Good*	*Fair*	*Poor*

	YOR 8.6	YOR 7.4	YOR 6.3
mIBI Submetrics			
Total # of Taxa	1	3	3
Total Abundance	1	1	1
Number EPT Taxa	1	3	1
% Orthocladiinae & Tanytarsini	3	1	5
% Non-Insects (-Crayfish)	5	5	5
# Diptera Taxa	1	3	1
% Intolerant Taxa (Score 0-3)	1	1	1
% Tolerant Taxa (Score 8-10)	5	3	5
% Predators	3	3	5
% Shredders & Scrapers	1	3	3
% Collector/Filterers	3	3	5
% Sprawlers	1	1	1
	26	30	36
	Poor	*Poor*	*Fair*
Stand Alone Indices			
Hilsenhoff Index	6.21	5.72	6.54
	Fair	*Fair*	*Fairly Poor*
Shannon Index of Diversity (H')	1.92	3.10	0.00
Shannon Evenness Index (J')	0.66	0.87	0.00
% Dominance of Top 3 Taxa	0.69	0.34	0.39
% Chironomidae	0.13	0.25	0.16
QHEI Scores	47.25	63.5	62.8
	Poor	*Fair*	*Fair*

Table 11.—Mean scores for macroinvertebrate metrics, 2017.

Mean Scores	mIBI	Rating
WFWR Upstream of Muncie	38.0	*Fair*
WFWR Within Muncie	35.7	*Fair*
WFWR Downstream of Muncie	35.5	*Fair*
Buck Creek	33.2	*Poor*

Mean Scores	% Dom
WFWR Upstream of Muncie	0.44
WFWR Within Muncie	0.41
WFWR Downstream of Muncie	0.55
Buck Creek	0.5

Mean Scores	HBI	Rating
WFWR Upstream of Muncie	4.50	*Very Good*
WFWR Within Muncie	4.62	*Good*
WFWR Downstream of Muncie	5.03	*Good*
Buck Creek	5.4	*Good*

Mean Scores	% Chiron.
WFWR Upstream of Muncie	0.11
WFWR Within Muncie	0.27
WFWR Downstream of Muncie	0.12
Buck Creek	0.3

Mean Scores	H'
WFWR Upstream of Muncie	2.88
WFWR Within Muncie	2.77
WFWR Downstream of Muncie	1.65
Buck Creek	2.64

Mean Scores	QHEI	Rating
WFWR Upstream of Muncie	77.06	*Good*
WFWR Within Muncie	69.68	*Fair*
WFWR Downstream of Muncie	74.25	*Good*
Buck Creek	64.27	*Fair*

Mean Scores	J'
WFWR Upstream of Muncie	0.83
WFWR Within Muncie	0.82
WFWR Downstream of Muncie	0.49
Buck Creek	0.8

Table 12.—Field sheet for all macroinvertebrate sampling.

Bureau of Water Quality
Macroinvertebrate Sampling Field Sheet

Name of Stream ______________________ Station ______________________
Collection Date ______________________ County ______________________
Sample ID ______________________ Method ______________________
Number of Samples ______________________
Collection Notes ____
____
____

If riffle present score it 1 then rank all other habitat present

__________ Natural Riffle
__________ Artificial Riffle (Rip/Rap)
__________ Slab/Bedrock ☐ w/ silt cover ☐ w/out silt cover
__________ Cobble ☐ w/ silt cover ☐ w/out silt cover
__________ Gravel ☐ w/ silt cover ☐ w/out silt cover
__________ Sand ☐ w/ silt cover ☐ w/out silt cover
__________ Mud/Silt
__________ Undercut Banks (Trees, roots, root wads)
__________ Riparian Vegetation (e.g. Grass)
__________ Water Willow, Root Mats
__________ Leaf Mats
__________ Logs/Woody Debris
__________ Submerged Macrophytes
__________ Filatementous Algae/Duckweed
__________ Other

Undercut?
No ☐
Slight ☐
Very ☐
Water Clarity ☐
Clear ☐
Slight Turbid ☐
Turbid ☐

Mean depth ☐
Mean width ☐
Max depth ☐
High water mark ☐

Incident Radiation ☐ %

Aesthetics
Foam ☐
Discoloration ☐
Foam/Scum ☐
Oil Sheen ☐
Trash/Litter ☐
Nuisance Odor ☐
Sludge deposits ☐
CSOs/SSOs/Outfalls ☐
Impoundment ☐
Bridge ☐

Inc. Rad.= how much shade there would be if the sun was directly overhead
summer foliage, verticle incidence, canopy cover

Date/Initials
Sample in lab ____________
Macro I.D. ____________
Chironomid I.D. ____________
Macro taxa entered ____________
Chiron taxa entered ____________
Taxa proofed ____________

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