Muncie
SANITARY DISTRICT

Indiana Scientific Purpose License Number: 3040

Bureau of Water Quality Annual Macroinvertebrate Community Report 2020

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March 2021

Photo description (previous page): *Lampsilis cardium displaying a lure. One of the many mussel species found in the West Fork White River.*

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Acknowledgements*: Thank you to Andrew Taflinger for assistance in obtaining/processing these samples and entering in data sheets.*

PREFACE

The following report summarizes the Bureau of Water Quality's (BWQ's) macroinvertebrate and mussel biomonitoring results of the year 2020. Some data displayed will be from previous years of sampling to show trends. However, the focus of the analysis will only be for the year 2020. If more information is needed from past years, please refer to previous reports from the Bureau of Water Quality.

Zebra mussels (*Dreissena polymorpha*) were first detected in 2015 with a single individual on a sampler at Prairie Creek Reservoir, located upstream of Muncie. The reservoir is closely connected to the West Fork White River (WFWR) via Prairie Creek and in 2017, zebra mussels were found in WFWR. As of 2020, zebra mussels are well established on the WFWR from Prairie Creek to downstream of Yorktown.

Starting in 2018, a project was initiated to perform timed surveys on surface mussels in the WFWR throughout Delaware county. In 2020, the sampling for this project was completed at the southeast edge of Muncie city limits. This project will most likely take two to three more years to complete.

In 2020 there was a change in state conservation status with some of the unionid species found in the WFWR. The Slippershell Mussel (Alasmidonta viridis), Spike (Eurynia dilatata) and Rainbow (Villosa iris) were all added to the list of State Special Concerned species as of 2020 (Division of Fish and Wildlife 2020). This list already includes the Wavyrayed Lampmussel (Lampsilis fasciola). It is illegal to take or possess live mussels and mussel shells in the state of Indiana unless one obtains a scientific permit from Indiana Department of Natural Resources (INDNR) Division of Fish and Wildlife (312 IAC 9-9-3 § 3(b)(1) (2019)). All BWQ employees working with freshwater mussels are covered under permits obtained by INDNR.

In 2020, due to the COVID-19 pandemic, the Bureau of Water Quality could only hire one macroinvertebrate intern instead of two. The start date for the interns was also delayed two weeks. We were able to complete our essential goals. However, these constraints along with other COVID-19 precautions limited mussel sampling and the ability to complete some of our other tasks.

INTRODUCTION

WFWR and the Bureau of Water Quality.— The WFWR headwaters are located near Winchester, Indiana. From there it flows west through Muncie, draining approximately 384 square miles at the Madison County/Delaware County line (Hoggat 1975). Most of the land surrounding the river in Delaware County is dominated by agricultural use (corn, soybeans, and livestock), but also includes urbanized areas such as 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), currently named the Bureau of Water Quality (BWQ), was established to regulate and control the sources responsible for polluting WFWR and its tributaries in and around Muncie, Indiana. The BWQ strived to accomplish the goals set by environmental 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). 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." is one of the main goals of the BWQ.

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 WFWR 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).

The most effective way to gauge water quality of a system is through both chemical and biological monitoring. Testing for chemical composition is essential; yet by itself it can overlook combined chemical effects, erratic pulse events, and physical 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.—Studying macroinvertebrate communities is one of the more commonly used biological methods for analyzing water quality. They are very diverse, abundant, sessile, and relatively easy and inexpensive to collect making them ideal for biomonitoring (Lenat et al. 1980; Hellawell 1986; Lenat & Barbour 1993). Because of these factors, macroinvertebrates can be utilized in a variety of different analyses. They can be used to detect spatial disturbances such as point source pollution, (Tesmer & Wefring 1979; Hellawell 1986; Abel 1989) especially if the source is organic (Chutter 1972). The extended life cycles of most aquatic insects allow 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).

MUSSEL METHODS

Mussel Field Sampling.— In 2018, a project was initiated to determine the distribution of mussels throughout the WFWR from the Delaware/Randolph County line to the Delaware/ Madison county line. This was done using the Timed Search Survey method (Strayer et al. 1997). Timed Search Surveys are one of the more effective methods for efficiently covering large areas (Metcalf-Smith et al 2000), obtaining high species richness, and finding rare species (Vaughn et al 1997).

Sampling in 2020 began at the upstream city limits of Muncie and proceeded upstream. Densities were calculated using catch per unit effort.

MACROINVERTEBRATE METHODS

Macroinvertebrate Field Sampling.— Macroinvertebrate samples were collected at nineteen sites along theWFWR, thirteen sites on Buck Creek and nine from other tributaries (Figure 1 and Appendix C, Table 7). 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 twelve-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 C, Table 11) were completed, including the "Qualitative Habitat Evaluation Index" sheet (Appendix C, Table 13). Taxa sheets for each macroinvertebrate site can be found in Appendix C, Table 12. QHEI sheets and tabulations can be found in Appendix C, Table 13.

Macroinvertebrate Laboratory Methods.— All organisms were identified to the lowest practical level, usually species. Non- Chironomid macroinvertebrates were identified using numerous dichotomous keys recommended in IDEM's protocol, as well as Peckarsky et al. (1990). 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).

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

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

score is assigned a specific “rank” (1, 3, or 5) with calibration 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 > 36), or “Not Supporting” of aquatic life (mIBI score <36).

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*

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 C, Table 8). 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:

xi = number of each species

ti = tolerance value for each species (Appendix. C, Table 8)

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

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.

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:

Pi = 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*

Non-metric Multidimensional Scaling (NMDS): In addition to numeric metrics, ordination techniques such as non-metric multidimensional scaling (NMDS) were used. NMDS is a technique that calculates the dissimilarities between assemblages and is often used in community analysis (Gotelli & Ellison 2013; Clarke 1993). Results are usually displayed in a scatterplot graph with observations represented by points. These points are accompanied by "stress" values, which represent the "goodness of fit", or how well the two-dimensional points represent the predicted values (Gotelli & Ellison 2013; Clarke 1993).

MUSSEL RESULTS

Timed surveys were performed upstream of Muncie city limits for continuation of a county distribution study. In 2020, twenty-one sampler hours, within a distance of approximately 0.3 miles, yielded 12,700 Unionid mussels belonging to twelve species. The most common mussels found were Actinonaias ligamentina (71.2%) and Amblema plicata (13.4%) (Figure 2 and Table 6). All sites sampled this year had zebra mussels present (which was anticipated due to the downstream proximity of sites to the zebra mussel -infected Prairie Creek Reservoir).

MACROINVERTEBRATE RESULTS

mIBI.—WFWR: WFWR mIBI scores (Figure 3 and Appendix C, Table 9) ranged from 32.0 (WHI 313.4) to 50.0 (WHI 316.8), Poor to Good. In 2020, WHI 313.4 would be considered "Not Supporting" of aquatic life by IDEM. Mean mIBI scores were Fair upstream and within Muncie, improving to Good downstream (Appendix C, Table 10). mIBI scores have increased since 2016 at WHI 328.1 ($R2 = 0.71$, $p < 0.01$), WHI 317.2 ($R2 = 0.7$, $p < 0.01$), WHI 315.8 ($R2 = 0.93$, $p < 0.01$), WHI 308.7 ($R2 = 0.71$, $p < 0.01$). No spatial trends were detected.

Buck Creek: Buck Creek mIBI scores (Figure 4 and Appendix C, Table 9) ranged from 24.0 (BUC 5.9) to 42.0 (BUC 0.5), Poor to Fair. The mean mIBI score for Buck Creek was 34.6, Fair (Appendix C, Table 10). In 2020, BUC 14.9, BUC 13.8, BUC 11.3, BUC 10.0, BUC 9.5, BUC 8.0, BUC 5.9, and BUC 4.0 would be considered "Not Supporting" of aquatic life by IDEM. mIBI scores have decreased since 2016 at BUC 8.0 ($R2 = 0.66$, $p < 0.01$). No spatial trends were detected.

Smaller Tributary Sites: mIBI scores for the smaller tributaries (Figure 4 and Appendix C, Table 9) ranged from 28 (GRE 0.6) to 40 (GRE 0.1) Poor to Fair. GRE 0.6, MUN 0.1, YPC 8.6, YPC 7.4, YPC 6.3, and YPC 2.8 would be considered “Not Supporting” of aquatic life by IDEM. No spatial or temporal trends were detected.

Stand Alone Indices.—HBI: WFWR: WFWR HBI scores (Figure 3 and Appendix C, Table 9) ranged from 5.62 (WHI 315.0) to 3.41 (WHI 317.2), Fair to Excellent. The mean HBI score increased within Muncie and continued to increase downstream of Muncie. Since 2016, HBI scores have decreased at WHI 326.9 ($R2 = 0.73$, $p < 0.01$), WHI 315.8 ($R2 = 0.69$, $p < 0.01$), and WHI 304.4 ($R2 = 0.71$, $p < 0.01$).

Buck Creek: Buck Creek HBI scores (Figure 4, Appendix C, Table 9) ranged from 6.33 (BUC 5.9) to 3.82 (BUC 0.5), Fair to Very Good. The mean HBI score (Appendix C, Table 10) was 5.0, Good. HBI scores decreased at BUC 4.0 ($R2 = 0.85$ $p < 0.01$) since 2016. No spatial trends were detected.

Smaller Tributary Sites: HBI scores at the smaller tributaries (Figure 4 and Appendix C, Table 9) ranged from 6.69 (GRE 0.1) to 5.25 (MUN 0.1), Fairly Poor to Good. No temporal trends were detected.

H’: WFWR: WFWR H’ scores (Figure 3 and Appendix C, Table 9) ranged from 2.79 (WHI 315.0) to 3.56 (WHI 333.4). Shannon-Wiener scores significantly increased since 2016 at WHI 333.4 ($R2 = 0.8$, $p < 0.01$), WHI 320.1 ($R2 = 0.67$, $p < 0.01$), WHI 317.4 ($R2 = 0.65$, $p < 0.01$), and WHI 306.5 ($R2 = 0.64$, $p < 0.01$). No spatial trends were detected in 2020.

Buck Creek: Buck Creek H’ scores (Figure 4 and Appendix C, Table 9) ranged from 2.43 (BUC 5.9) to 3.43 (BUC 9.2). The mean H’ score at Buck Creek sites in 2020 (Appendix C, Table 10) was 2.88. No spatial or temporal trends were detected in 2020.

Smaller Tributary Sites: H’ scores at the smaller tributaries ranged from (Figure 4 and Appendix C, Table 9) 2.09 (YPC 8.6) to 3.3 at (GRE 0.1). No spatial or temporal trends were detected in 2020.

Remaining Stand Alone Indices: WFWR: WFWR J’ scores (Appendix C, Table 9) ranged from 0.72 (WHI 315.0) to 0.92 (WHI 310.7). WFWR “Percent Dominance of Top Three Taxa” (Appendix C, Table 9) ranged from 0.26 (WHI 316.8) to 52.02 (WHI 315.0). WFWR “Percent Chironomidae” (Appendix C, Table 9) ranged from 0.0 (WHI 318.8) to 15.43 (WHI 315.8). Mean scores (Appendix C, Table 10) increased within city limits, and continued to increase downstream.

Buck Creek: Buck Creek J’ scores (Appendix C, Table 9) ranged from 0.69 (BUC 0.5) to 0.92 (BUC 9.5). The mean Buck Creek J’ score (Appendix C, Table 10) was 0.8. Buck Creek “Percent Dominance of Top Three Taxa” (Appendix C, Table 9) ranged from 30.93 (BUC 15.2) to 58.16 (BUC 0.5), with a mean of 43.6 (Appendix C, Table 10). Buck Creek “Percent Chironomidae” scores (Appendix C, Table 9) ranged from 2.94 (BUC 14.9) to 48.84 (BUC 5.9), with a mean of 21.5 (Appendix C, Table 10).

Smaller Tributary Sites: J’ scores at the smaller tributaries (Appendix C, Table 9) ranged from 0.64 (YPC 6.3) to 0.82 (GRE 0.1 and YPC 7.4). “Percent Dominance of Top Three Taxa” ranged from (Appendix C, Table 9) 31.53 (GRE 0.1) to 70.31 (YPC 6.3). “Percent Chironomidae” (Appendix C, Table 9) ranged from 2.48 (GRE 0.3) to 16.67 (YPC 7.4).

QHEI: WFWR: WFWR QHEI scores ranged from 56.5 (WHI 315.0) to 87.0 (WHI 326.9), Fair to Good (Figure 3 and Appendix C, Table 9). No spatial or temporal trends were detected in 2020.

Buck Creek: Buck Creek QHEI scores (Figure 4 and Appendix C, Table 9) ranged from 34.0 (BUC 10.0) to 76.0 (BUC 4.0), Poor to Good, with a mean score of 59.0, Fair (Appendix C, Table 10). Since 2016, QHEI scores have significantly decreased at BUC 9.2 ($R2 = 0.77$, $p < 0.01$). No spatial trends were detected in 2020.

Smaller Tributary Sites: QHEI scores at the smaller tributaries ranged from (Figure 4 and Appendix C, Table 9) 35.0 (YPC 6.3) to 57.5 (YPC 7.4), Poor to Fair. Since 2016, QHEI scores have significantly decreased at YOR 8.6 ($R2 = 0.84$, $p < 0.01$). No spatial trends were detected in 2020.

Community Similarities (NMDS): Sites clustered roughly into three groups. Buck and Muncie Creek being one, Greenfarm Ditch and York Prairie Creek the second, and WFWR the third (Figure 5). Stress was 0.14208.

DISCUSSION

Mussels.—Mussel sampling results continue to indicate good water quality upstream of Muncie city limits, despite multiple impacts including agricultural runoff. This is especially apparent when looking at this year’s high abundance and diversity of mussels sampled. In addition to this, among the species sampled were three State Special Concern Species; Spike (Eurynia dilatata), Rainbow (Villosa iris) and Wavyrayed Lampmussel (Lampsilis fasciola) (Table 6).

It has been noted that one mussel species, the White Heelsplitter, Lasmigona complanata, has not been found in WFWR 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 WFWR 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 previous five impoundments (now two) 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). With all this being said, removal of the two dams in 2019 may expand the range of the White Heelsplitter and other mussel species throughout theWFWR. Future efforts will continue to monitor for the presence of this species.

In late summer 2017, zebra mussels were found in WFWR downstream of Prairie Creek Reservoir (where they were first observed in 2015). Within weeks, zebra mussels were identified on dead mussel shell in the WHI-313.4 site. In 2020, random quadrat sampling at each macroinvertebrate site yielded densities of 0-32/m2 at sites between WHI 322.2-WHI 304.4.

Timed search surveys will continue in 2021, likely farther upstream of Muncie, and will continue until all of the WFWRin Delaware County has been assessed.

Macroinvertebrates.—mIBI scores in 2020 generally increased when compared to previous years. This is most apparent at WFWR sites, which had higher mIBI scores when compared to its tributaries. Generally, the sites that had lower mIBI scores also had lower diversity and abundance, and higher HBI scores.

Lower (Poor) mIBI scores at some sites may be attributed to a lack of quality habitat, indicated by a Poor QHEI score. BUC 11.3, BUC 10, BUC 8.0, GRE 0.6, YPC 8.6, and YPC 6.3 all had both Poor mIBI and QHEI scores. The combination of Poor mIBI scores and low abundance at these sites suggests that the lack of habitat limits the macroinvertebrates that populate these sites.

Organic impairment may be a stressor at one site. GRE 0.1 is the only site that has a Fairly Poor HBI score. One would think GRE 0.3 and GRE 0.6 would be similarly impacted since they are so close upstream. However, the combination of low abundance and lack of suitable habitat at these sites likely makes it difficult to detect related trends.

A few sites have Poor mIBI scores that cannot be attributed to organic impairment or lack of suitable habitat. The majority of these sites have low abundance and/or diversity which can exaggerate effects on these samples, which can then be reflected in other population metrics. These sites include BUC 14.9, BUC 9.5, BUC 5.9, BUC 4.0, MUN 0.1 and WHI 313.4.

YPC 7.4 and YPC 2.8 had Poor mIBI scores but did not have unusually low abundance or Poor HBI scores. These sites were dominated by moderately tolerant to tolerant macroinvertebrate taxa which affected multiple indices. Taxa primarily included members of the taxonomic groups Decapoda, Gastropoda and Isopoda which include many moderately tolerant species.

The significant decrease in mIBI scores from 2016-2020 could imply water quality issues at BUC 8.0. The significant increase in mIBI scores from 2016-2020 at sites WHI 328.1, WHI 317.2, WHI 315.8 and WHI 308.7, however, could indicate an improvement in water quality.

The significant decreases in HBI scores from 2016-2020 at sites BUC 4.0, WHI 326.9, WHI 315.8 and WHI 304.4 may also indicate improvement in water quality, particularly the decrease of organic pollutants, at these sites.

The significant increases in H’ from 2016-2020 suggest an increase in diversity in macroinvertebrate communities at WHI 333.4, WHI 320.1, WHI 317.4 and WHI 306.5. This could suggest that there is a decrease in stressors at these sites.

The significant decrease in QHEI scores from 2016-2020 at BUC 9.2 and YOR 8.6 indicates decreased habitat availability for these sites. However, it is unclear to what extent this has on the macroinvertebrate communities because none of the population indices significantly changed at these sites. These sites will continue to be monitored for any changes in the future.

It should be noted, however, that multiple negative mIBI scores at tributary sites may reflect impacts that appear more evident due to their smaller size. Additionally, diversity and/or abundance may be limited by the colder temperatures found in spring-fed Buck Creek (Conrad & Warrner 2005; Vannote & Sweeney 1980; Ward 1976).

When comparing macroinvertebrate assemblage structure, the streams sampled this year were markedly different. The sites on WFWR were distinctly different from the other streams, probably due to its size and/or its consistently high indices scores (Figure 3 and Table 9). Greenfarm Ditch and York Prairie Creek were comparable in assemblage possibly because they are similar in size and have comparable physical features. Buck Creek’s distinction in assemblage from some of the other streams is more than likely since it is a colder, springfed stream for reasons mentioned earlier (Conrad & Warrner 2005; Vannote & Sweeney 1980; Ward 1976). It is unclear, however, why Muncie Creek was found to be similar to Buck Creek and not to York Prairie Creek/Greenfarm Ditch since it shares some of the latter’s characteristics. This may be due to the low abundance and diversity seen at Muncie Creek sites, which may overstate Muncie Creek’s similarity to Buck Creek.

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.

An emerging global concern has also been considered for the recent drop in scores, particularly in abundance and diversity. A growing body of evidence has supported what is being called an “Insect Apocalypse”, indicating an alarming drop in insect abundance and diversity worldwide. A study in Germany’s protected areas found a 76% seasonal decline in insect biomass of over 27 years (Hallmann et al. 2017), finding no significant correlation with land use, habitat, or climate change. A study in Puerto Rico showed a 2.2-2.7% annual loss in ground-dwelling and canopy-dwelling arthropods (Lister & Garcia 2018), indicating “climate warming” as the likely cause. Similar declines in flying insects have been seen in areas all around the globe (Thomas et al. 2004; Shortall et al. 2009; Sanchez-Bayo & Wyckhuys 2019).

Since a large portion of flying insects spend part of their life cycle as aquatic insects, it stands to reason that a similar trend would be seen at an aquatic level. Declines in abundance and diversity and increases in homogeneity and/or replacement from tolerant and generalist species has been seen in the Odonata (Hickling et al. 2005; McKinney 2006; Kadoya et al. 2009; Kalkman et al. 2010), Ephemeroptera (Zahradkova et al. 2009; Zedkova et al. 2015), and Trichoptera orders (Karatayev et al. 2009; Houghton & Holzenthal 2010; Jenderedjian et al. 2012). In addition to all of this, it has been found that commonly used neonicotinoid pesticides could negatively impact aquatic invertebrate communities in some areas (Pisa et al. 2015; Yamamuro et al. 2019). Future work at the BWQ will be looking at long-term trends in our macroinvertebrate data to determine if sites in this area are experiencing similar trends. 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 WFWR, 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, improved 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 surface waters 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.—Maps of sampling sites for mussels and macroinvertebrates, 2020.

Figure 1.—Macroinvertebrate and mussel sites, 2020.

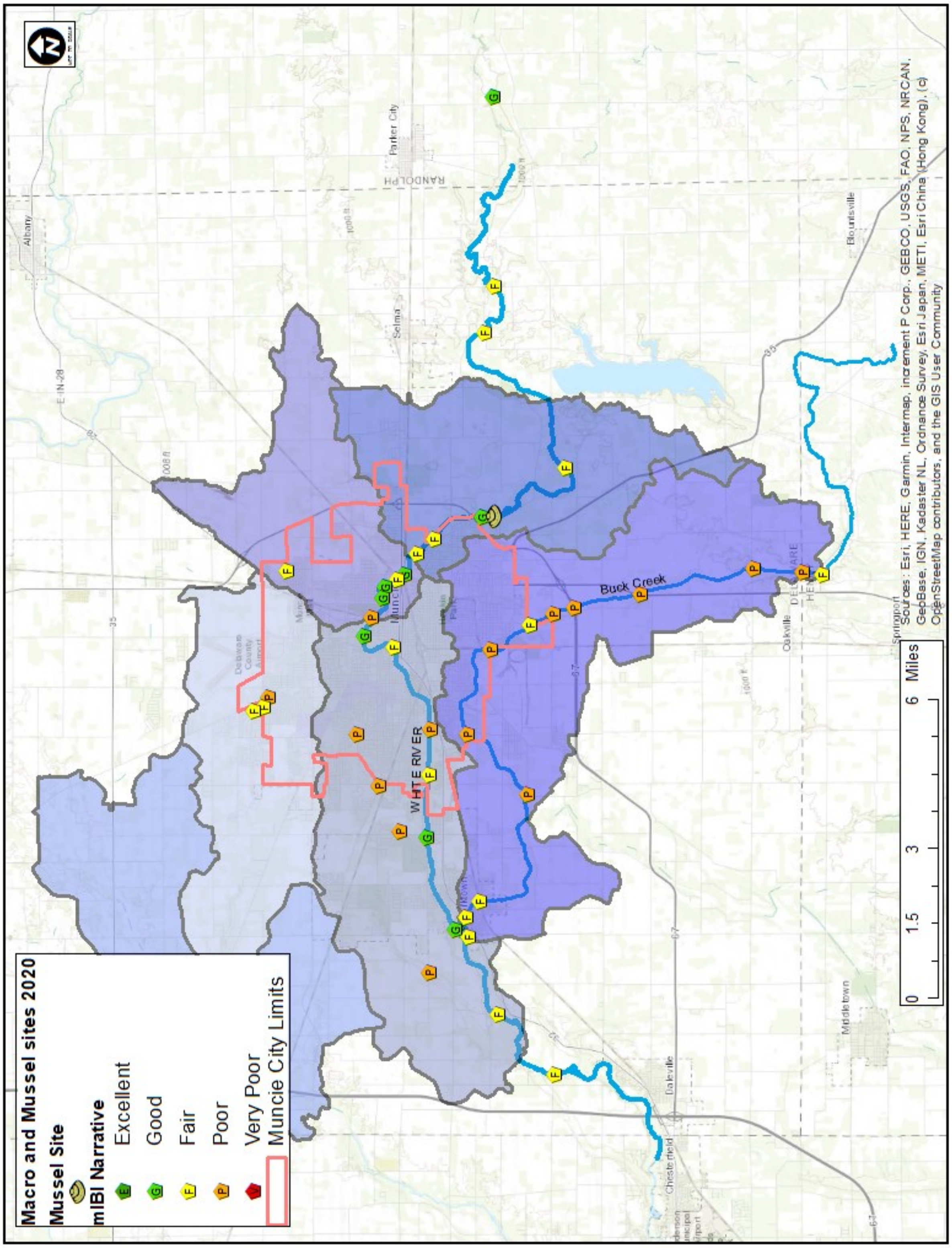


Figure 1.—Macroinvertebrate and mussel sites, 2020 (con't).

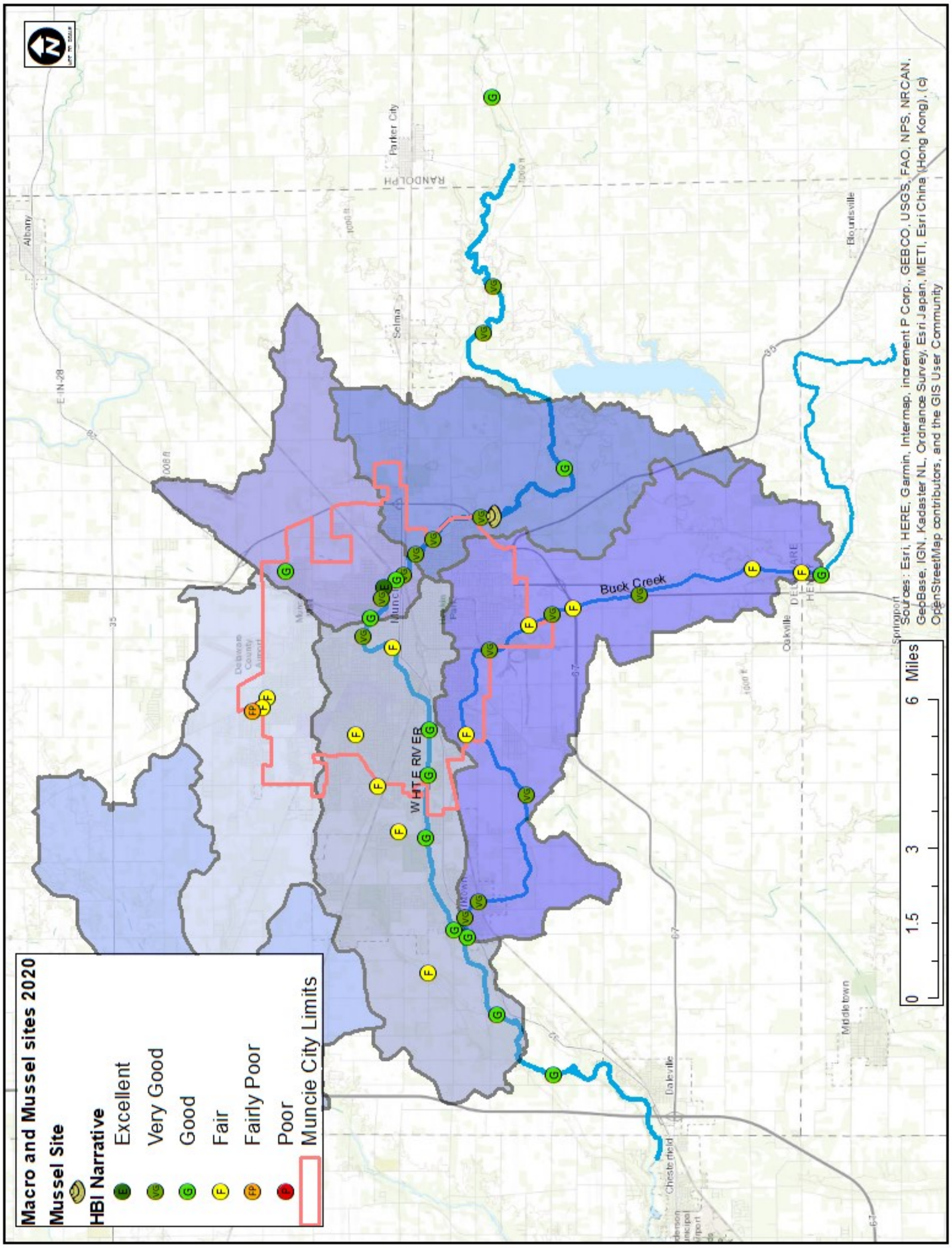
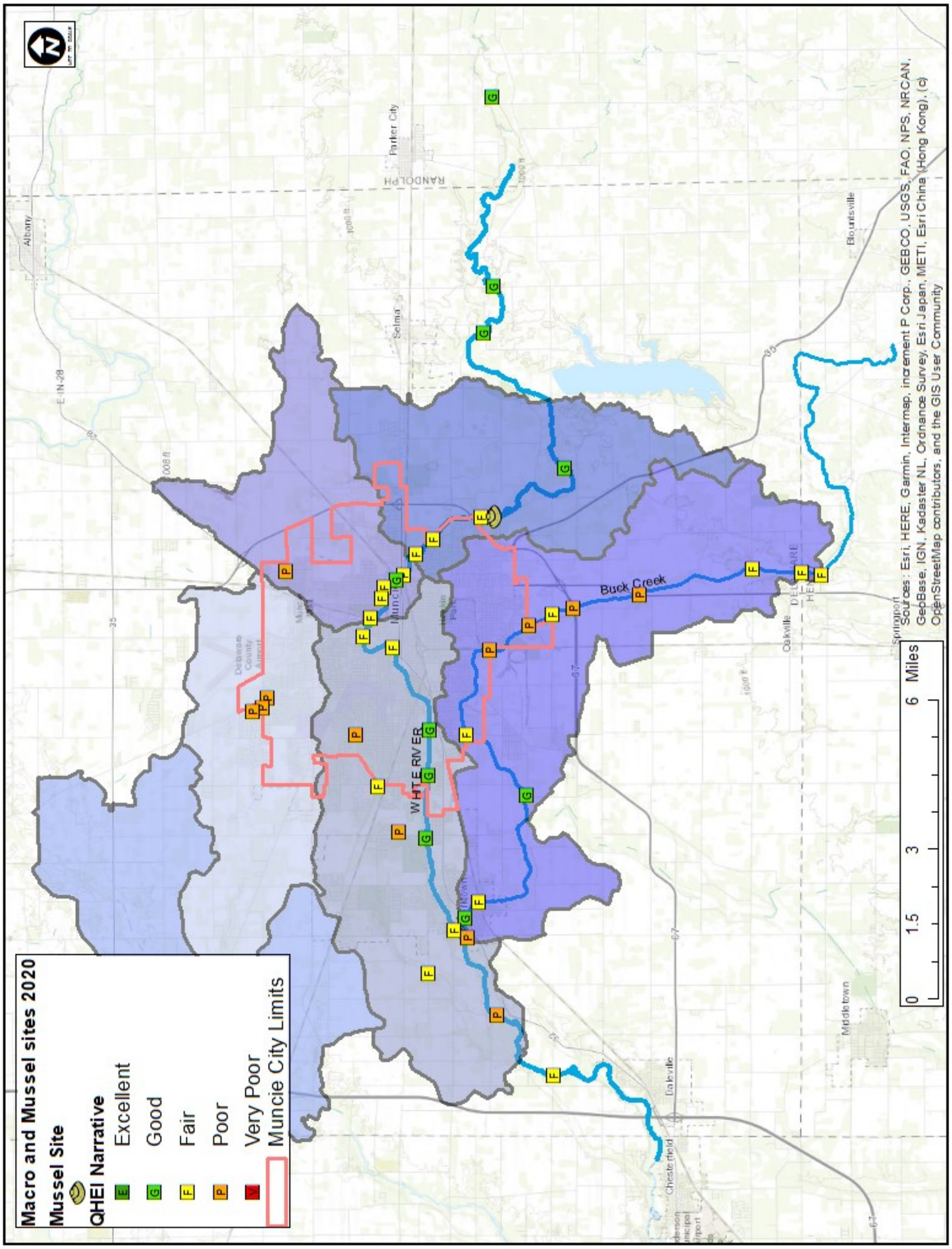


Figure 1.—Macroinvertebrate and mussel sites, 2020 (con't).



Appendix B.—Mussel assemblages and relative abundance found within city limits, 2020.

Table 5.—Mussel assemblage upstream of Muncie city limits, 2020.

Species	Common Name	Amount
Strophitus undulatus	Creeper	15
Alasmidonta marginata	Elktoe	11
Lampsilis siliquoidea	Fatmucket	199
Lasmigona compressa	Creek Heelsplitter	3
Lasmigona costata	Flutedshell	679
Actinonaias ligamentina	Mucket	9043
Lampsilis cardium	Plain Pocketbook	48
Villosa iris	Rainbow*	93
Pleurobema sintoxia	Round Pigtoe	156
Eurynia dilatata	Spike*	318
Amblema plicata	Threeridge	1697
Fusconcaia flava	Wabash Pigtoe	434
Lampsilis fasciola	Wavyrayed Lampmussel*	4
*State Special Concerned species	**Total**	**12700**

Figure 2.—Abundance for Unionid mussels sampled upstream of Muncie city limits, 2020.

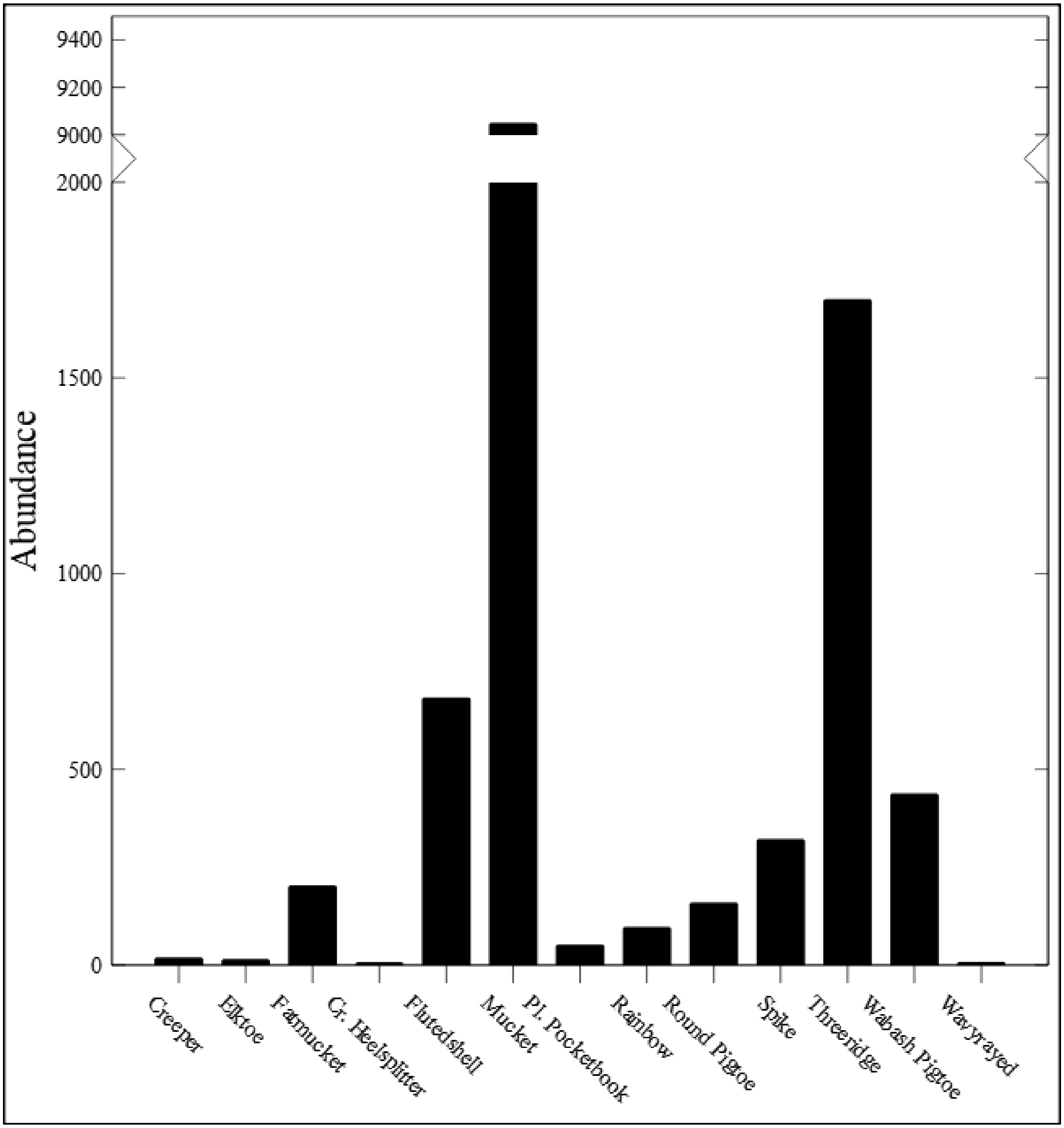


Table 6.—Mussel site field sheets, 2020.

BUREAU OF WATER QUALITY

MUSSEL BED SURVEY

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

Collected by:

Collection Notes:

Width:

1	26	51	76
2	27	52	77
3	28	53	78
4	29	54	79
5	30	55	80
6	31	56	81
7	32	57	82
8	33	58	83
9	34	59	84
10	35	60	85
11	36	61	86
12	37	62	87
13	38	63	88
14	39	64	89
15	40	65	90
16	41	66	91
17	42	67	92
18	43	68	93
19	44	69	94
20	45	70	95
21	46	71	96
22	47	72	97
23	48	73	98
24	49	74	99
25	50	75	100

Table 6.—Mussel site field sheets, 2020 (con't).

Bureau of Water Quality Mussel Data

Stream **Station** **Date**

Transect	Collector	Species	Width	Height	Age	Count

Appendix C.—Macroinvertebrate sites, field sheets, tolerance and attributes used for calculations, taxa identified, taxa sheets, QHEI sheets, resulting scores, and related statistical results.

Figure 3.—mIBI, HBI, Shannon-Wiener Diversity and QHEI scores for WFWR, 2020 and average scores from 2016-2020.

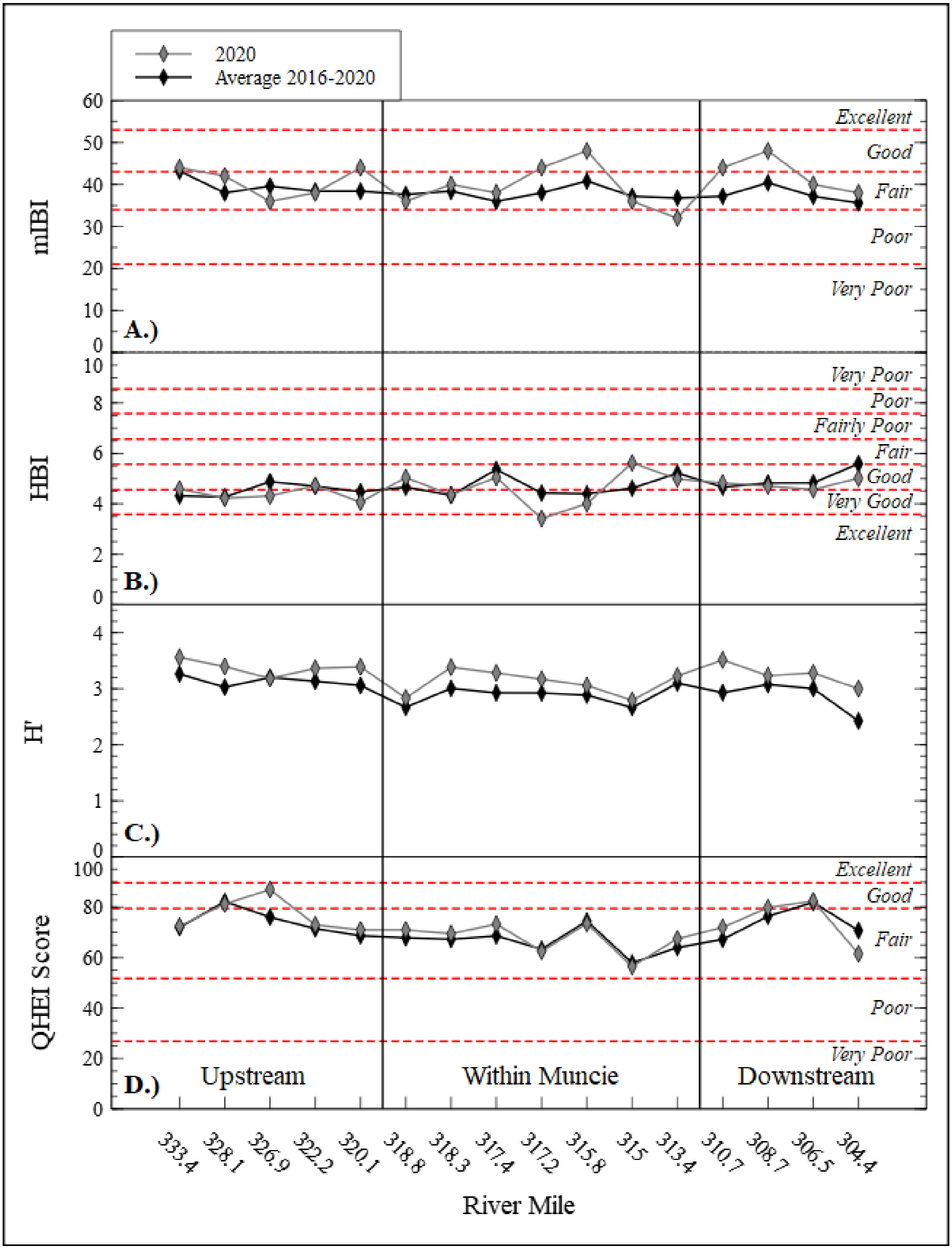


Figure 4.—mIBI, HBI, Shannon-Wiener Diversity and QHEI scores for Buck Creek, Muncie Creek, and York Prairie Creek, 2020 and average scores from 2016-2020.

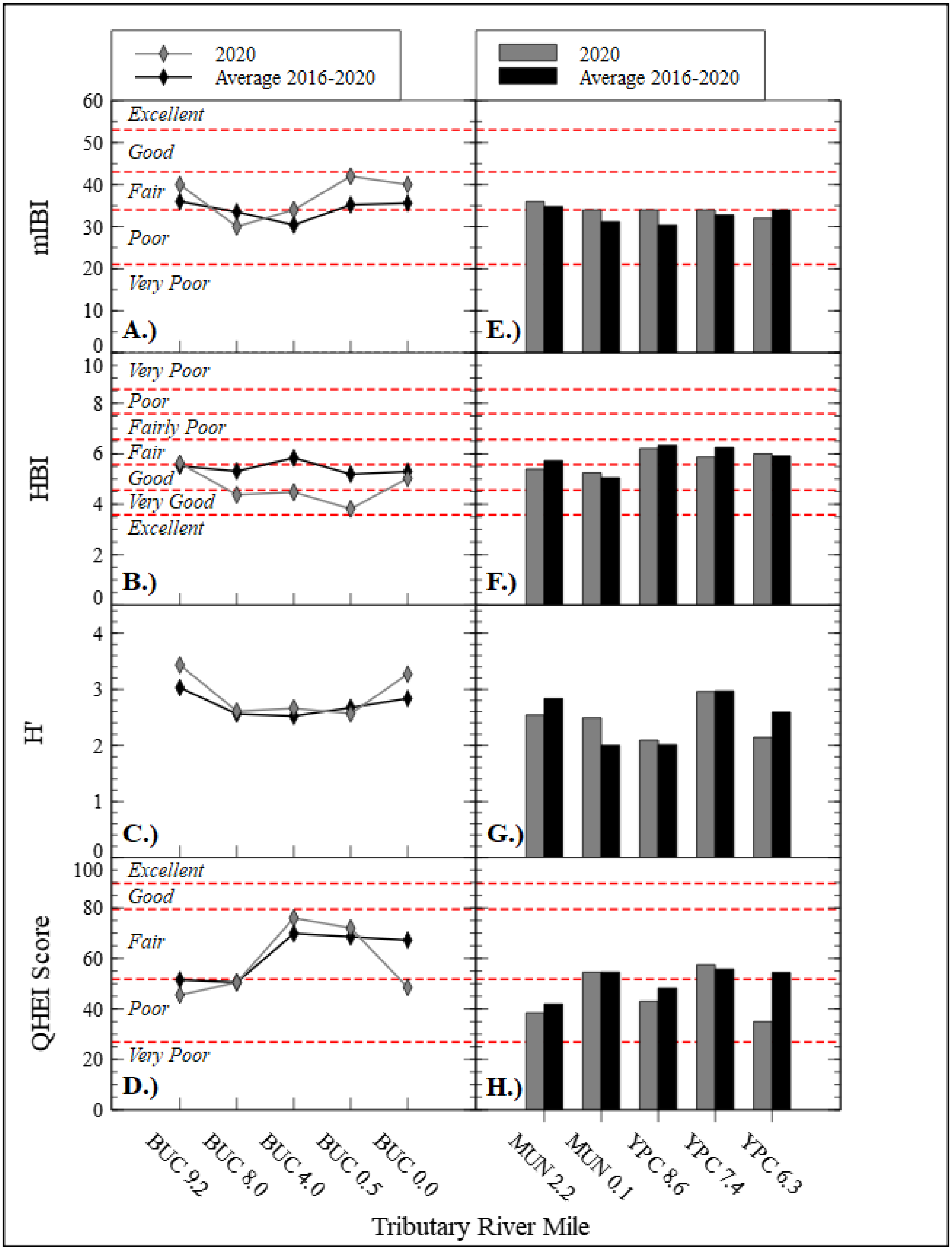


Figure 5.—NMDS graph for the WFWR and its tributaries.

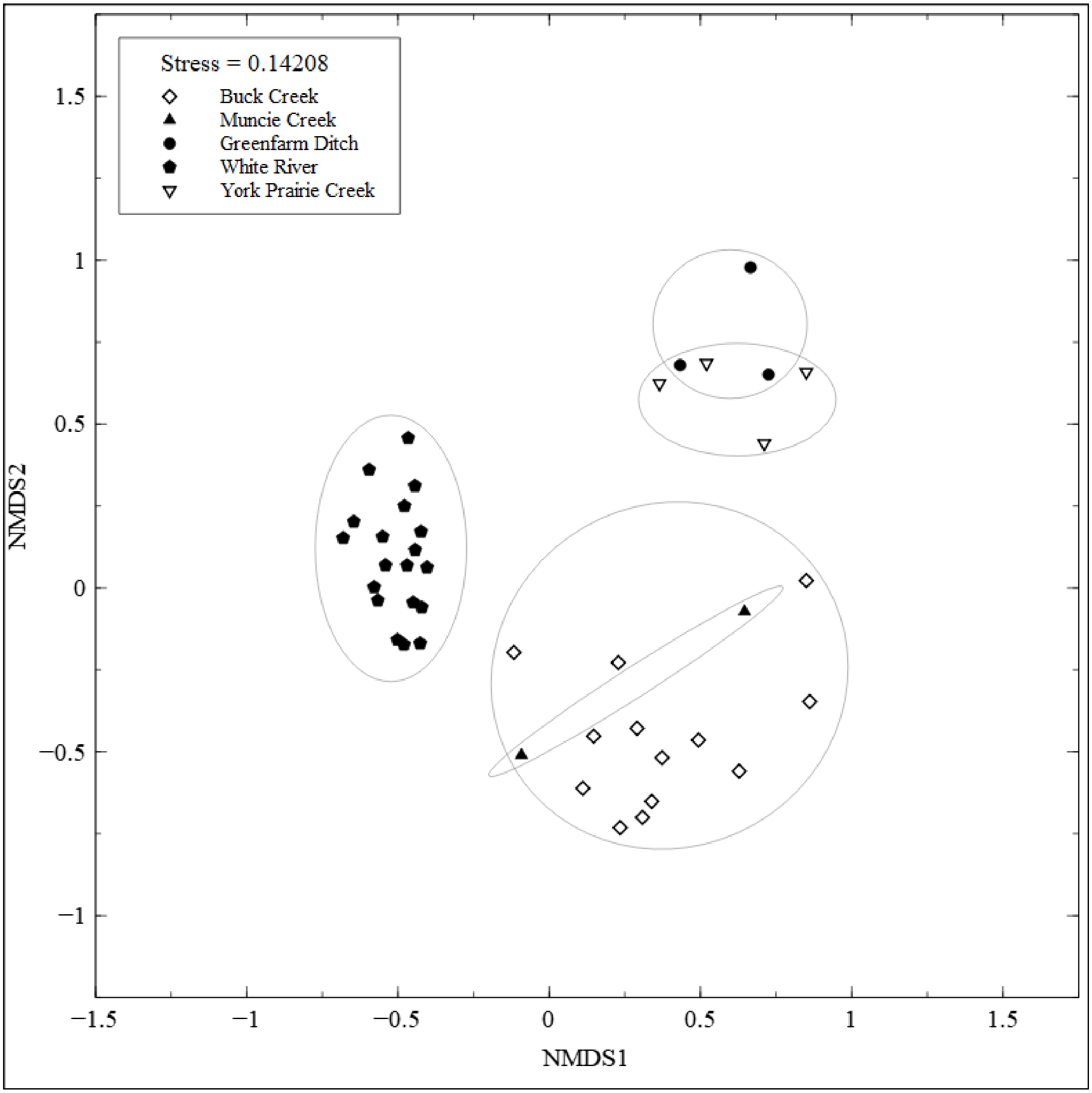


Table 7.—Macroinvertebrate site descriptions and locations, 2020.

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	**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	**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 0.5)**	**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).				

Table 7.—Macroinvertebrate site descriptions and locations, 2020 (con't).

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).				
Greenfarm Ditch	**Wheeling Ave (GRE 0.6)**	**Lat./Long.**	40.232170,	-85.409525
Drainage= 3 sq. miles	**HUC 14:** 05120201040030			
The surroudning landuse at this site is primarily residential and commercial. Both banks are mowed to the edge.				
Greenfarm Ditch	**W. Riggin Rd. (GRE 0.3)**	**Lat./Long.**	40.233458,	-85.413325
Drainage= 3 sq. miles	**HUC 14:** 05120201040030			
The surroudning landuse at this site is primarily residential and commercial. Both banks are mowed to the edge.				
Greenfarm Ditch	**Moore Rd. (GRE 0.1)**	**Lat./Long.**	40.236342,	-85.414939
Drainage= 3 sq. miles	**HUC 14:** 05120201040030			
The surroudning landuse at this site is primarily residential and commercial. Both banks are mowed to the edge.				
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	**IS&W (WHI 317.6)**	**Lat./Long.**	40.192436,	-85.363147
Drainage= 231 sq. miles	**HUC 14:** 05120201010130			
Was upstream of the now removed Indiana Steel and Wire dam.				

Table 7.—Macroinvertebrate site descriptions and locations, 2020 (con’t).

West Fork White River	**E. Jackson (WHI 317.4)**	**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	**Ball Rd. (QL's) (WHI 316.8)**	**Lat./Long.**	40.198543,	-85.371746
Drainage= 231 sq. miles	**HUC 14:** 05120201010130			
Site substrate is mostly bedrock.				
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	**MWPCF (A) (WHI 311.7)**	**Lat./Long.**	40.185310,	-85.438843
Drainage= 245 sq. miles	**HUC 14:** 05120201020060			
Site is upstream of a modified dam and upstream of MWPCF.				
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 308.5)**	**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.				
York Prairie Creek	**Brook Rd./Storer Elem. (YPC 8.6)**	**Lat./Long.**	40.206286,	-85.423686
Drainage= 4.00 sq. miles	**HUC 14:** 05120201030010			
York Prairie Creek	**CR 300W (YPC 7.4)**	**Lat./Long.**	40.199781,	-85.443308
Drainage= 4.00 sq. miles	**HUC 14:** 05120201030010			
York Prairie Creek	**CR 400W (YPC 6.3)**	**Lat./Long.**	40.193758,	-85.460747
Drainage= 4.00 sq. miles	**HUC 14:** 05120201030010			
York Prairie Creek	**CR 50S (YPC 2.8)**	**Lat./Long.**	40.185527,	-85.514369
Drainage= 17.0 sq. miles	**HUC 14:** 05120201030010			

Table 8.—Scores for macroinvertebrate sites, 2020.

	BUC 15.2	BUC 14.9	BUC 13.8	BUC 11.3	BUC 10.0	BUC 9.5	BUC 9.2
mIBI Submetrics							
Total # of Taxa	3	3	3	3	3	3	5
Total Abundance	1	1	3	1	1	1	3
Number EPT Taxa	3	3	5	5	1	3	3
% Orthocladiinae & Tanytarsini	5	3	3	5	5	3	3
% Non-Insects (- Crayfish)	5	1	3	3	3	5	5
# Diptera Taxa	5	1	3	3	3	3	5
% Intolerant Taxa (Score 0-3)	3	1	3	5	1	5	1
% Tolerant Taxa (Score 8-10)	3	3	1	3	1	5	5
% Predators	3	1	1	1	3	1	1
% Shredders & Scrapers	1	5	1	3	5	1	1
% Collector/Filterers	5	5	5	1	5	1	5
% Sprawlers	3	1	1	1	1	3	3
	40	28	32	34	32	34	40
	Fair	*Poor*	*Poor*	*Poor*	*Poor*	*Poor*	*Fair*
Stand Alone Indices							
Hilsenhoff Index	5.14	5.66	5.55	4.49	6.09	4.40	5.63
	Good	*Fair*	*Fair*	*Very Good*	*Fair*	*Very Good*	*Fair*
Shannon Index of Diversity (H')	3.20	2.61	2.70	2.98	2.78	3.15	3.43
Shannon Evenness Index (J')	0.89	0.78	0.74	0.85	0.90	0.92	0.89
% Dominance of Top 3 Taxa	30.93	52.94	55.17	41.53	43.48	31.25	31.13
% Chironomidae	23.71	2.94	10.34	8.47	39.13	14.06	43.71
QHEI Scores	68.0	70.8	56.0	45.0	34.0	64.5	45.5
	Fair	*Fair*	*Fair*	*Poor*	*Poor*	*Fair*	*Poor*

	BUC 8.0	BUC 5.9	BUC 4.0	BUC 0.9	BUC 0.5	BUC 0.0	GRE 0.6
mIBI Submetrics							
Total # of Taxa	3	1	3	3	5	5	3
Total Abundance	1	1	1	1	5	3	1
Number EPT Taxa	3	1	5	3	5	3	1
% Orthocladiinae & Tanytarsini	5	5	5	5	5	5	5
% Non-Insects (- Crayfish)	3	3	3	5	5	5	3
# Diptera Taxa	1	3	1	3	3	5	1
% Intolerant Taxa (Score 0-3)	5	1	5	5	5	3	1
% Tolerant Taxa (Score 8-10)	3	1	3	5	5	5	3
% Predators	1	1	1	1	1	1	3
% Shredders & Scrapers	1	1	1	3	1	1	1
% Collector/Filterers	3	5	5	3	1	3	5
% Sprawlers	1	1	1	3	1	1	1
	30	24	34	40	42	40	28
	Poor	*Poor*	*Poor*	*Fair*	*Fair*	*Fair*	Poor
Stand Alone Indices							
Hilsenhoff Index	4.37	6.33	4.47	4.26	3.82	5.03	6.34
	Very Good	*Fair*	*Very Good*	*Very Good*	*Very Good*	*Good*	*Fair*
Shannon Index of Diversity (H')	2.61	2.43	2.66	3.07	2.56	3.27	2.39
Shannon Evenness Index (J')	0.79	0.90	0.77	0.84	0.69	0.87	0.77
% Dominance of Top 3 Taxa	50.91	46.51	54.72	39.39	58.16	31.25	53.66
% Chironomidae	9.09	48.84	13.21	10.10	8.87	46.53	12.20
QHEI Scores	50.5	61.8	76.0	66.0	72.0	48.5	36.3
	Poor	*Fair*	*Good*	*Fair*	*Good*	*Poor*	*Poor*

Table 8.—Scores for macroinvertebrate sites, 2020 (con't).

	GRE 0.3	GRE 0.1	MUN 2.2	MUN 0.1	WHI 333.4	WHI 328.1	WHI 326.9
mIBI Submetrics							
Total # of Taxa	3	5	3	3	5	5	3
Total Abundance	1	5	3	1	3	5	1
Number EPT Taxa	1	3	3	3	5	5	3
% Orthocladiinae & Tanytarsini	5	3	5	5	5	1	3
% Non-Insects (- Crayfish)	5	1	5	5	5	5	5
# Diptera Taxa	1	5	1	1	3	3	1
% Intolerant Taxa (Score 0-3)	1	1	1	1	3	3	3
% Tolerant Taxa (Score 8-10)	5	3	5	5	5	5	5
% Predators	3	3	3	1	1	1	1
% Shredders & Scrapers	5	5	1	3	5	3	5
% Collector/Filterers	5	5	5	5	3	5	5
% Sprawlers	1	1	1	1	1	1	1
	36	40	36	34	44	42	36
	Fair	*Fair*	*Fair*	*Poor*	*Good*	*Fair*	*Fair*
Stand Alone Indices							
Hilsenhoff Index	6.2	6.69	5.40	5.25	4.58	4.22	4.31
	Fair	*Fairly Poor*	*Good*	*Good*	*Good*	*Very Good*	*Very Good*
Shannon Index of Diversity (H')	2.41	3.30	2.54	2.49	3.56	3.40	3.18
Shannon Evenness Index (J')	0.75	0.82	0.71	0.77	0.88	0.83	0.88
% Dominance of Top 3 Taxa	61.16	31.53	56.82	53.09	26.91	31.60	34.29
% Chironomidae	2.48	11.78	7.58	9.88	3.59	5.21	2.86
QHEI Scores	49.3	55.0	38.5	54.5	72.5	81.3	87.0
	Poor	*Fair*	*Poor*	*Fair*	*Good*	*Good*	*Good*

	WHI 322.2	WHI 320.1	WHI 318.8	WHI 318.3	WHI 317.6	WHI 317.4	WHI 317.2
mIBI Submetrics							
Total # of Taxa	5	5	3	5	5	5	5
Total Abundance	3	3	3	3	3	3	3
Number EPT Taxa	3	5	3	5	5	5	5
% Orthocladiinae & Tanytarsini	3	3	5	5	3	3	5
% Non-Insects (- Crayfish)	5	5	3	5	5	3	5
# Diptera Taxa	1	3	1	1	3	1	3
% Intolerant Taxa (Score 0-3)	3	5	3	3	5	3	5
% Tolerant Taxa (Score 8-10)	5	5	5	5	5	3	5
% Predators	1	1	1	1	1	1	1
% Shredders & Scrapers	3	5	3	3	5	5	3
% Collector/Filterers	5	3	5	3	3	5	3
% Sprawlers	1	1	1	1	1	1	1
	38	44	36	40	44	38	44
	Fair	*Good*	*Fair*	*Fair*	*Good*	*Fair*	*Good*
Stand Alone Indices							
Hilsenhoff Index	4.72	4.07	5.04	4.36	3.94	5.04	3.41
	Good	*Very Good*	*Good*	*Very Good*	*Very Good*	*Good*	*Excellent*
Shannon Index of Diversity (H')	3.36	3.39	2.83	3.38	3.37	3.28	3.17
Shannon Evenness Index (J')	0.88	0.88	0.82	0.88	0.85	0.85	0.84
% Dominance of Top 3 Taxa	31.25	27.78	39.86	28.66	31.67	34.56	32.06
% Chironomidae	5.56	4.44	0.00	2.55	13.57	3.69	14.83
QHEI Scores	73.0	71.0	71.0	69.5	70.5	73.3	62.5
	Good	*Good*	*Good*	*Fair*	*Fair*	*Good*	*Fair*

Table 8.—Scores for macroinvertebrate sites, 2020 (con't).

	WHI 316.8	WHI 315.8	WHI 315.0	WHI 313.4	WHI 311.7	WHI 310.7	WHI 308.7
mIBI Submetrics							
Total # of Taxa	5	5	5	3	5	5	5
Total Abundance	3	3	3	1	3	1	5
Number EPT Taxa	5	5	5	3	5	3	5
% Orthocladiinae & Tanytarsini	5	5	5	5	5	5	5
% Non-Insects (- Crayfish)	5	5	1	3	3	5	3
# Diptera Taxa	3	3	3	1	1	3	3
% Intolerant Taxa (Score 0-3)	5	5	3	3	5	3	5
% Tolerant Taxa (Score 8-10)	5	5	1	3	3	5	5
% Predators	1	1	1	1	1	3	1
% Shredders & Scrapers	5	5	3	5	5	5	5
% Collector/Filterers	5	5	5	3	5	3	5
% Sprawlers	3	1	1	1	1	3	1
	50	48	36	32	42	44	48
	Good	*Good*	*Fair*	*Poor*	*Fair*	*Good*	*Good*
Stand Alone Indices							
Hilsenhoff Index	3.90	4.01	5.62	4.99	4.82	4.83	4.70
	Very Good	*Very Good*	*Fair*	*Good*	*Good*	*Good*	*Good*
Shannon Index of Diversity (H')	3.34	3.06	2.79	3.23	3.33	3.51	3.23
Shannon Evenness Index (J')	0.89	0.82	0.72	0.90	0.87	0.92	0.81
% Dominance of Top 3 Taxa	0.26	38.27	52.02	29.59	31.85	23.33	35.64
% Chironomidae	0.21	15.43	7.62	12.24	7.41	12.50	7.61
QHEI Scores	62.5	73.5	56.5	67.5	61.8	72.0	79.8
	Fair	*Good*	*Fair*	*Fair*	*Fair*	*Good*	*Good*

	WHI 306.5	WHI 304.4	YPC 8.6	YPC 7.4	YPC 6.3	YPC 2.8
mIBI Submetrics						
Total # of Taxa	5	5	3	3	3	3
Total Abundance	3	3	1	3	1	3
Number EPT Taxa	5	5	1	3	1	1
% Orthocladiinae & Tanytarsini	5	3	5	1	5	1
% Non-Insects (- Crayfish)	3	3	5	3	1	5
# Diptera Taxa	3	1	3	3	1	1
% Intolerant Taxa (Score 0-3)	5	3	1	3	1	1
% Tolerant Taxa (Score 8-10)	3	3	5	3	5	5
% Predators	1	1	1	3	5	3
% Shredders & Scrapers	3	5	3	5	3	3
% Collector/Filterers	3	5	5	3	5	5
% Sprawlers	1	1	1	1	1	1
	40	38	34	34	32	32
	Fair	*Fair*	*Poor*	*Poor*	*Poor*	*Poor*
Stand Alone Indices						
Hilsenhoff Index	4.56	5.02	6.21	5.87	6.00	5.85
	Good	*Good*	*Fair*	*Fair*	*Fair*	*Fair*
Shannon Index of Diversity (H')	3.28	3.00	2.09	2.96	2.15	2.68
Shannon Evenness Index (J')	0.85	0.80	0.69	0.82	0.64	0.73
% Dominance of Top 3 Taxa	32.16	45.98	43.33	43.33	70.31	57.43
% Chironomidae	7.04	6.70	6.25	16.67	4.69	5.41
QHEI Scores	82.5	61.5	43.0	57.5	35.0	53.0
	Good	*Fair*	*Poor*	*Fair*	*Poor*	*Fair*

Table 9.—Mean scores for macroinvertebrate metrics, 2020.

Mean Scores	mIBI	Rating
WFWR Upstream of Muncie	40.0	*Fair*
WFWR Within Muncie	39.6	*Fair*
WFWR Downstream of Muncie	46.0	*Good*
Buck Creek	34.6	*Fair*

Mean Scores	% Dom
WFWR Upstream of Muncie	31.9
WFWR Within Muncie	34.3
WFWR Downstream of Muncie	29.5
Buck Creek	43.6

Mean Scores	HBI	Rating
WFWR Upstream of Muncie	4.5	*Very Good*
WFWR Within Muncie	4.6	*Good*
WFWR Downstream of Muncie	4.8	*Good*
Buck Creek	5.0	*Good*

Mean Scores	% Chiron.
WFWR Upstream of Muncie	3.6
WFWR Within Muncie	8.8
WFWR Downstream of Muncie	10.1
Buck Creek	21.5

Mean Scores	H'
WFWR Upstream of Muncie	3.3
WFWR Within Muncie	3.2
WFWR Downstream of Muncie	3.4
Buck Creek	2.88

Mean Scores	QHEI	Rating
WFWR Upstream of Muncie	76.0	*Good*
WFWR Within Muncie	65.9	*Fair*
WFWR Downstream of Muncie	69.8	*Fair*
Buck Creek	59.0	*Fair*

Mean Scores	J'
WFWR Upstream of Muncie	0.9
WFWR Within Muncie	0.8
WFWR Downstream of Muncie	0.9
Buck Creek	0.8

Table 10.—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 __________ Station ID ______________________
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		
_________	Filamentous Algae/Duckweed		
_________	Other		

Undercut?					**Aesthetics**	
	No	☐	Mean depth	☐ m	Foam	☐
	Slight	☐	Mean width	☐ m	Discoloration	☐
	Very	☐	Max depth	☐ m	Foam/Scum	☐
Water Clarity		☐	High water mark	☐ m	Oil Sheen	☐
	Clear	☐			Trash/Litter	☐
	Slight Turbid	☐			Nuisance Odor	☐
	Turbid	☐			Sludge deposits	☐
					CSOs/SSOs/Outfalls	☐
Incident Radiation		☐ %			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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