MUNCIE SANITARY DISTRICT'S BUREAU OF WATER QUALITY

ANNUAL MACROINVERTEBRATE AND MUSSEL REPORT 2010

Prepared by:
Laura Bowley, Aquatic Biologist
March 2011

BUREAU OF WATER QUALITY

LOCAL WATER POLLUTION CONTROL

"WE HAVE ONLY ONE EARTH, LET'S ALL WORK FOR ITS PROTECTION"
- John M. Craddock

5150 W. Kilgore Avenue
Muncie, Indiana 47304-4710

RICK C. CONRAD
DIRECTOR

TEL. (765) 747-4896 FAX (765) 213-6444

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***Acknowledgements**: Thank you to Nick Abbott for his assistance in obtaining these samples, and for the countless hours of data entry, proofing, and general assistance in preparing this report. Thank you also to Jason Doll for his invaluable assistance in running statistical analyses in SAS and for help with interpretation of the results.*

PREFACE

This paper contains the results of the Bureau of Water Quality's (BWQ's) macroinvertebrate and mussel biomonitoring for the year 2010. For the purpose of displaying trends, some graphs and tables will present data from past years. However, the analysis given here is only for 2010. If further investigation of past years is needed, please refer to past reports from this organization.

Due to excessive rainfall early in the sampling season and large networks at WR 313.4, only the mussel site at WR 313.4 was completed, and WR 320.1 was only partially completed (10 of 24 quadrats were sampled) The incomplete site was assessed as if it was completed. The site at WR 320.1 was sampled at the end of the season (August-September); sites are usually sampled at the beginning (May-July). Further research into sampling methods, including two-stage sampling and stopping rules will be conducted, and it is anticipated that this will be applied in the future to avoid these issues.

In 2010, additional macroinvertebrate attributes were incorporated into our calculations, to more accurately determine the mIBI and stand alone indices (Todd Davis, IDEM, personal communication). All attributes utilized are reported in Appendix B, Table 13.

Due to sampler error, it was necessary to resample multiple sites. Baseline sites included WHI 328.1, WHI 315.0, WHI 313.4, WHI 310.7, WHI 304.4, and BUC 10.5. 319 Watershed Study sites included KIL 20.1, MUN 0.1, and TRU 0.8. These sites were originally sampled between 7/23 and 8/3, then were resampled between 9/15 and 9/29. Although within set sampling requirements (May-October), later dates may have affected scoring at these sites. Differences necessary to consider at resampled sites include an extended drought between samples, falling autumn temperatures, and increased nutrient input from falling leaves.

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.—Mussels are in a rapid state of decline (Ricciardi & Rasmussen 1999; Vaughn & Taylor 1999; Strayer & Smith 2003; Lydeard et al. 2004; Poole & Downing 2004; Strayer et al. 2004). 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 (USFW 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). 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 1999) 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 a 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

Mussels- Field Sampling.—Sampling methods were based on the adaptive cluster sampling with initial random samples without replacement, described by Strayer & Smith (2003), originated by Thompson (1992). While precision of density estimates may not be increased with this method, sampling efficiency is increased (Smith et al. 2004), and yield of individual mussels and rare species has been found to be increased (Smith 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 11) were completed at each site (Appendix A, Table 6). 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. 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 submerged in the stream. Then, wearing leather 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 replaced in the substrate as close to the original position as possible.

If the condition variable was not met, sampling 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 Corbicula 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.

Mussels- Data Tabulation.—The Horvitz-Thompson (Thompson 1990) population estimator has been determined to be the superior choice for determining total population when utilizing the adaptive cluster method (Salehi 1999, 2003). This complex calculation was determined using Philippi's (2005) code in SAS (2008).

MACROINVERTEBRATE METHODS-BASELINE

Baseline Field Sampling.—Baseline macroinvertebrate samples were taken at 14 sites on White River, and 5 sites along Buck Creek (Figure 1 and Appendix B, Table 12). 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. The organisms were placed in a vial with 99.5% isopropyl alcohol and returned to the lab for later identification.

Field sheets (Appendix B, Table 18) were completed, including the "Qualitative Habitat Evaluation Index" sheet (Appendix B, Table 19). Taxa identified from all macroinvertebrate sites are recorded in Appendix B, Table 14. Taxa sheets for each Baseline site can be found in Appendix B, Table 20. The reported QHEI score is recorded from the aquatic biologist, however, scores calculated from all samplers are presented in Appendix B, Table 21.

Baseline 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 (1990), Mason (1998), and Epler (2001).

Baseline Data Tabulation.—Baseline macroinvertebrate calculations were based on IDEM's Macroinvertebrate Index of Biotic Integrity (mIBI), the Hilsenhoff Biotic Index (HBI), Shannon-Wiener Diversity Index (H'),

Table 1.—mIBI Submetrics and their response to disturbance

Sub-Metric	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 (Scores 8-10)	Increase
% Predators	Decrease
% Shredders & Scrapers	Decrease
% Collectors/Filterers	Increase
% Sprawlers	Decrease

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*

Table 3.—HBI values and corresponding ratings.

Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.5	*Excellent*	No apparent organic pollution.
3.51-4.5	*Very Good*	Possible slight organic pollution.
4.51-5.5	*Good*	Some organic pollution.
5.51-6.5	*Fair*	Fairly significant organic pollution.
6.51-7.5	*Fairly Poor*	Significant organic pollution.

Simpson Index of Diversity (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 (Todd Davis, IDEM, personal communication). 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 ≥ 36), or "Not Supporting" (mIBI score ≤ 36).

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 (App. B, Table 13). 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 (App. B, Table 13)

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).

Table 4.—QHEI scores and corresponding ratings.

Headwaters	Larger Streams	Narrative Rating
≤20 sq. miles	>20 sq. miles	
>70	>75	*Excellent*
55 to 69	60 to 74	*Good*
43 to 54	45 to 59	*Fair*
30 to 42	30 to 44	*Poor*
<30	<30	*Very Poor*

Qualitative Habitat Evaluation Index (QHEI):

The Qualitative Habitat Evaluation Index 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 and bank condition, pool and riffle quality, and gradient. Each metric in the habitat assessment was scored, with the final sum of these scores reflecting the available habitat (higher scores reflect better habitat). Narrative ratings for QHEI scores can be found above (Table 4). Because this is only the second year that this metric has been included, further assessment will be needed to analyze temporal trends.

Additional Statistical Analyses: Spatial variability (at sites located upstream, in, and downstream of Muncie city limits) was analyzed using a mixed linear model to independently evaluate H' and HBI scores from 2002-2010. This statistical tool accounts for autocorrelation with the assumption that the results from each year are dependent, and correlated, to the previous year. Differences between adjusted means were evaluated with Tukey-Kramer adjusted pair-wise differences. All models were fit using PROC MIXED (SAS 9.2).

MACROINVERTEBRATE METHODS– 319 WATERSHED GRANT

Macroinvertebrate sampling for the fulfillment of our 319 Watershed Grant was completed at six stations in 2010 (Figure 3 and Appendix C, Table 22). Sampling, laboratory method, and data tabulation followed IDEM's current mIBI protocol.

319 Watershed Grant Field Sampling: Field sheets (Appendix B, Table 18) were completed, including the "Qualitative Habitat Evaluation Index" sheet (Appendix B, Table 19). Taxa identified from all macroinvertebrates sites are recorded in Appendix B, Table 14. Taxa sheets for each 319 site can be found in Appendix C, Table 24. The reported QHEI score is recorded from the aquatic biologist, however, scores calculated from all samplers are presented in Appendix C, Table 25. Sampling follows the IDEM mIBI protocol described for Baseline sampling.

319 Watershed Grant Laboratory Methods: Laboratory methods follow the IDEM mIBI protocol described for Baseline sampling.

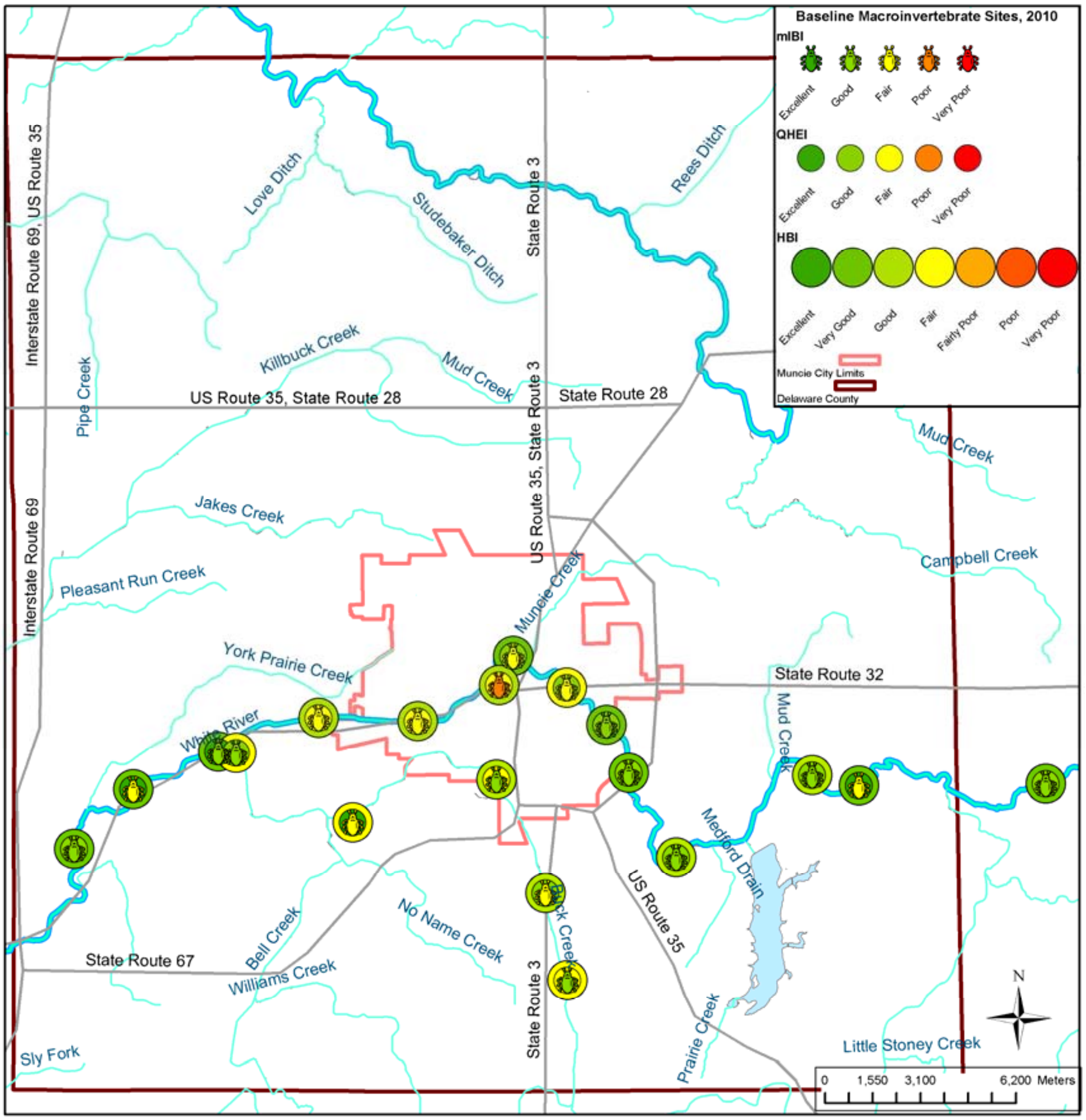
319 Watershed Grant Data Tabulation: Data tabulation follows the IDEM mIBI protocol described for Baseline sampling.

RESULTS

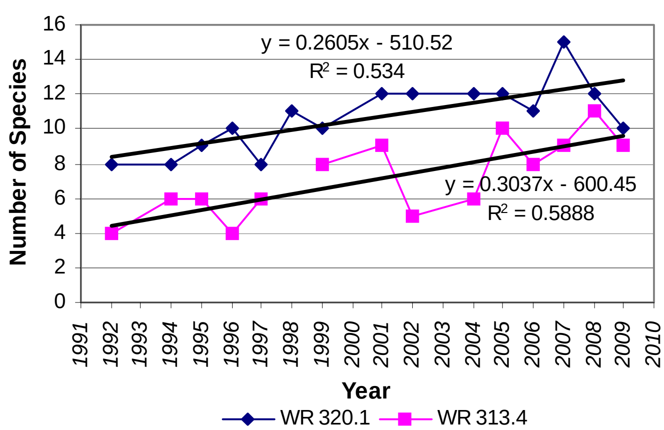
Mussels.—

WR 320.1: Mussels were collected at 10 of the 24 quadrats anticipated to be sampled at WR 320.1. Overabundant neighborhoods encountered during sampling at WR 313.4, excessive wet weather, and cold temperatures made it impractical to complete all quadrats during our sampling season. The condition variable for adaptive sampling was set at ≥ 2 mussels per 0.25m^2 quadrat, based on prior sampling efforts. Mussels collected at WR 320.1 are reported in Appendix A, Table 7. Species diversity increased

Figure 1.—Baseline macroinvertebrate sites, 2010.



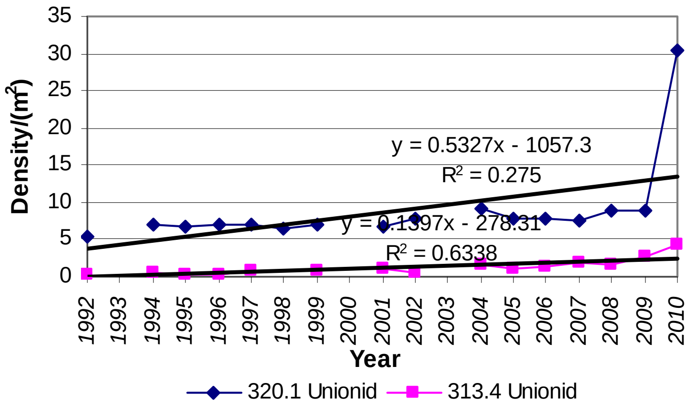
Graph 1.—Species diversity at WR 320.1 and WR 313.4, 1992-2010.



significantly ($R^2 = 0.53$, $P < 0.01$) since 1992 (Graph 1). Relative abundance (Appendix A, Graph 9) of all mussels indicated that Asian clam comprised 47% of the sample. Fingernailclam (*Sphaerium* spp.) comprised 44% of the sample. The three most abundant Unionid species at WR 320.1 were mucket (*Actinonaias ligamentina),* Wabash pigtoe (*Fusconaia flava*), and flutedshell (*Lasmigona costata*).

Unionid density (95% C.I.) at WR 320.1 was calculated to be an obviously erroneous 30.44 $\pm$ 23.6/m^2 (Appendix A, Table 9). Linear regression still shows a significant

Graph 2.—Unionid density at WR 320.1 and WR 313.4, 1992-2010.



increase (Graph 2) in density since 1992 (R^2=0.28, P < 0.05), but showed a stronger significance in 2009 (R^2=0.69, P < 0.01), prior to this anomalous finding.

WR 313.4: Mussels were collected at all 52 quadrats at WR 313.4. The condition variable for adaptive sampling was set at ≥ 1 mussel per 0.25m^2 quadrat, based on prior sampling efforts. Mussels collected at WR 313.4 are reported in Appendix A, Table 8.

Species diversity increased significantly (R^2 = 0.59, P < 0.001) since 1992 (Graph 1 and Appendix A, Table 8). Relative abundance (Appendix A, Graph 10) of all mussels indicated that Asian clam comprised 95% of the sample, and fingernail clam comprised 2% of the sample. The three most abundant Unionid species at WR 313.4 were flutedshell, elktoe (*Alasmidonta marginata*), and mucket.

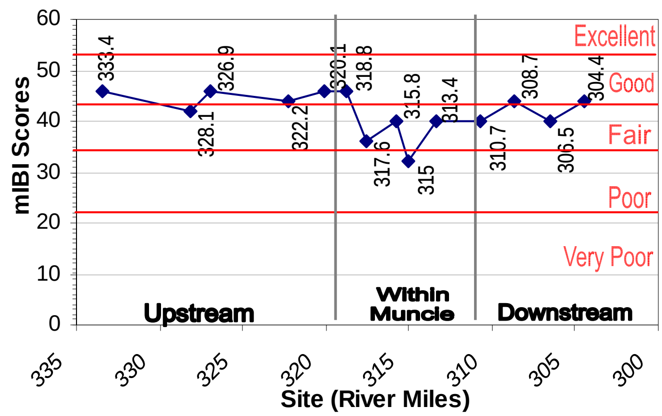
Unionid density (95% C.I.) at WR 313.4 was 4.24 ± 2.12/m^2 (Appendix A, Table 9), and has increased significantly (R^2 = 0.63, P < 0.001) since 1992 (Graph 2).

MACROINVERTEBRATES- BASELINE

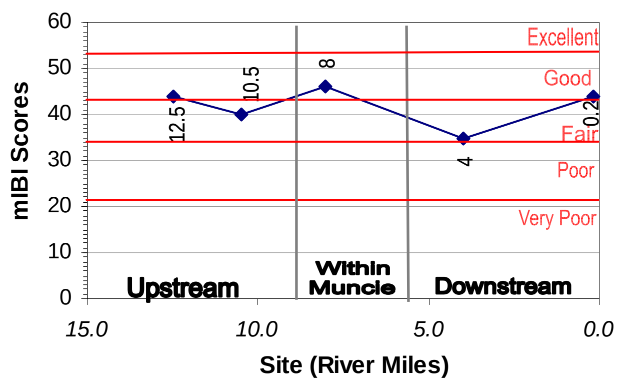
mIBI.—Organisms identified in 2010 are presented in Appendix B, Table 14. White River mIBI scores (Graph 3 and Appendix B, Table 15) ranged from 32 (WHI 315.0) to 46 (WHI 333.4, WHI 326.9, WHI 320.1, and WHI 318.8), *Poor* to *Good*. The site at WHI 315.0 was the only site that would be considered "Not Supporting" by IDEM, indicating impairment to the biological community. Mean mIBI scores (Appendix B, Table 17) worsened as White River progressed through the City of Muncie, with ratings of *Good* to *Fair*, although some improvement was seen downstream.

Buck Creek mIBI scores (Graph 6 and Appendix B, Table 16) ranged from 35 (at BUC 4.0) to 46 (BUC 8.0), *Fair* to *Good*. The site at BUC 4.0 was the only Buck Creek baseline site that would be considered "Not Supporting" by IDEM, indicating impairment to the biological community. The mean mIBI score (Appendix B, Table 17) on Buck Creek was 41.8, *Fair*.

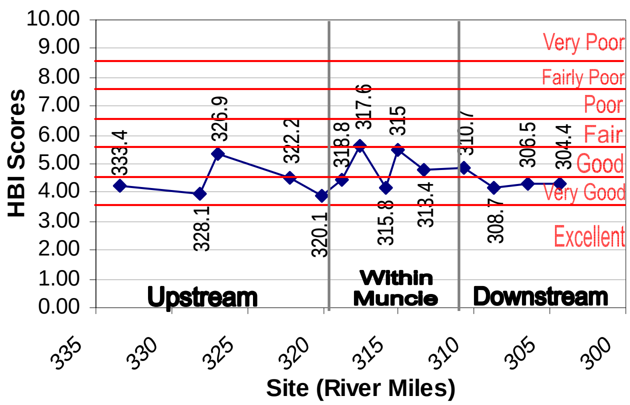
Graph 3.—White River mIBI scores, 2010.



Graph 4.—Buck Creek mIBI scores, 2010.



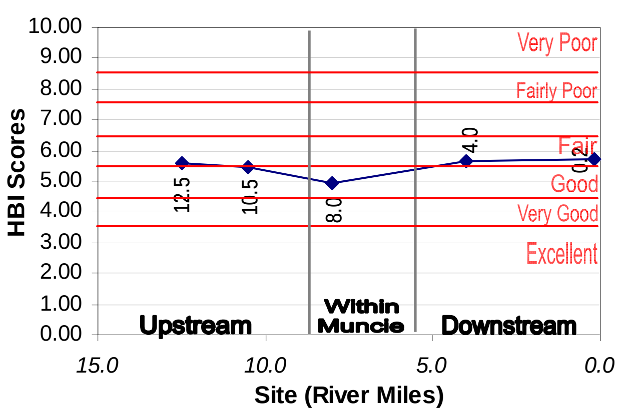
Graph 5.—White River HBI scores, 2010.



Stand Alone Indices.—

HBI: White River HBI scores (Graph 4, Appendix B, Table 15) ranged from 5.65 (WHI 317.6) to 3.90 (WHI 320.1), *Fair* to *Very Good*. Mean HBI scores (Appendix B, Table 17) worsened as White River progressed into the City of Muncie, then recovered once downstream of the city limits. HBI scores from 2002-2010 were not found to be significantly affected by the influence of the City of Muncie at the $P < 0.05$ level, but were significant at the $P < 0.10$ level ($P = 0.722$). Further pair-wise testing revealed a significant difference between HBI scores at sites upstream and sites within Muncie city limits (t(11) = 2.4, $P = 0.035$), indicating a slight negative effect of organic pollution introduced by this urban area on the macroinvertebrate community that does not improve downstream.

Graph 6.—Buck Creek HBI scores, 2010.

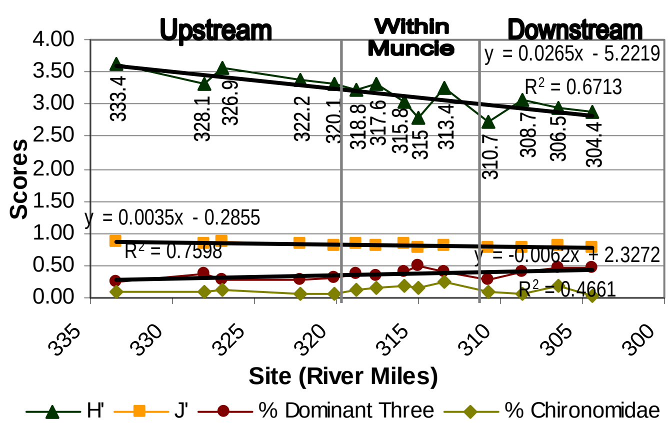


Buck Creek HBI scores (Graph 7, Appendix B, Table 16) ranged from 5.69 (BUC 0.2) to 4.96 (BUC 8.0), *Fair* to *Good*. The mean HBI score (Appendix B, Table 17) was 5.46, *Good*.

H'.— White River H' scores (Graph 5 and Appendix B, Table 15) ranged from 2.73 (WHI 310.7) to 3.61 (WHI 333.4). Mean H' scores (Appendix B, Table 17) worsened as the river progressed downstream. Linear regression revealed a significant negative trend in 2010 as scores progressed downstream ($R^2 = 0.67$).

Further analysis with the mixed linear model revealed a significant correlation between H' scores and their proximity to the city limits at the $P < 0.05$ level ($P = 0.045$). Additional pair-wise comparisons suggest that sites upstream of Muncie are significantly different than sites located downstream of Muncie city limits (t (11) = -1.61, $P = 0.017$), indicating that macroinvertebrate

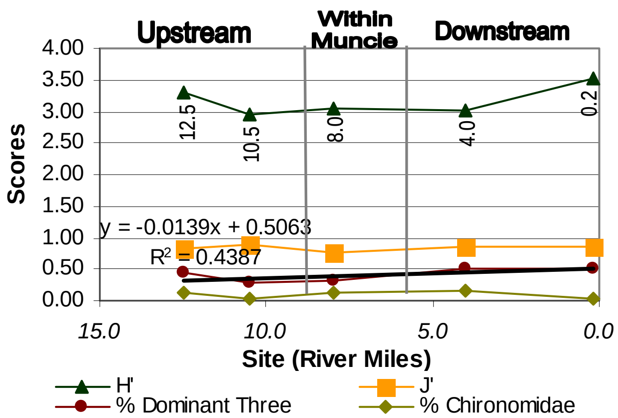
Graph 7.—White River stand-alone indices, 2010.



diversity declines downstream of Muncie city limits. Linear regression of temporal trends from 2006-2010 at WHI 310.7 indicate a significant negative trend ($R^2 = 0.88$, $P = 0.02$) in H' scores. While this is not necessarily an indication of a true decline (scores from 2002-2005 indicate a positive trend ($R^2 = 0.91$, $P = 0.05$)), it is something to note and continue to monitor.

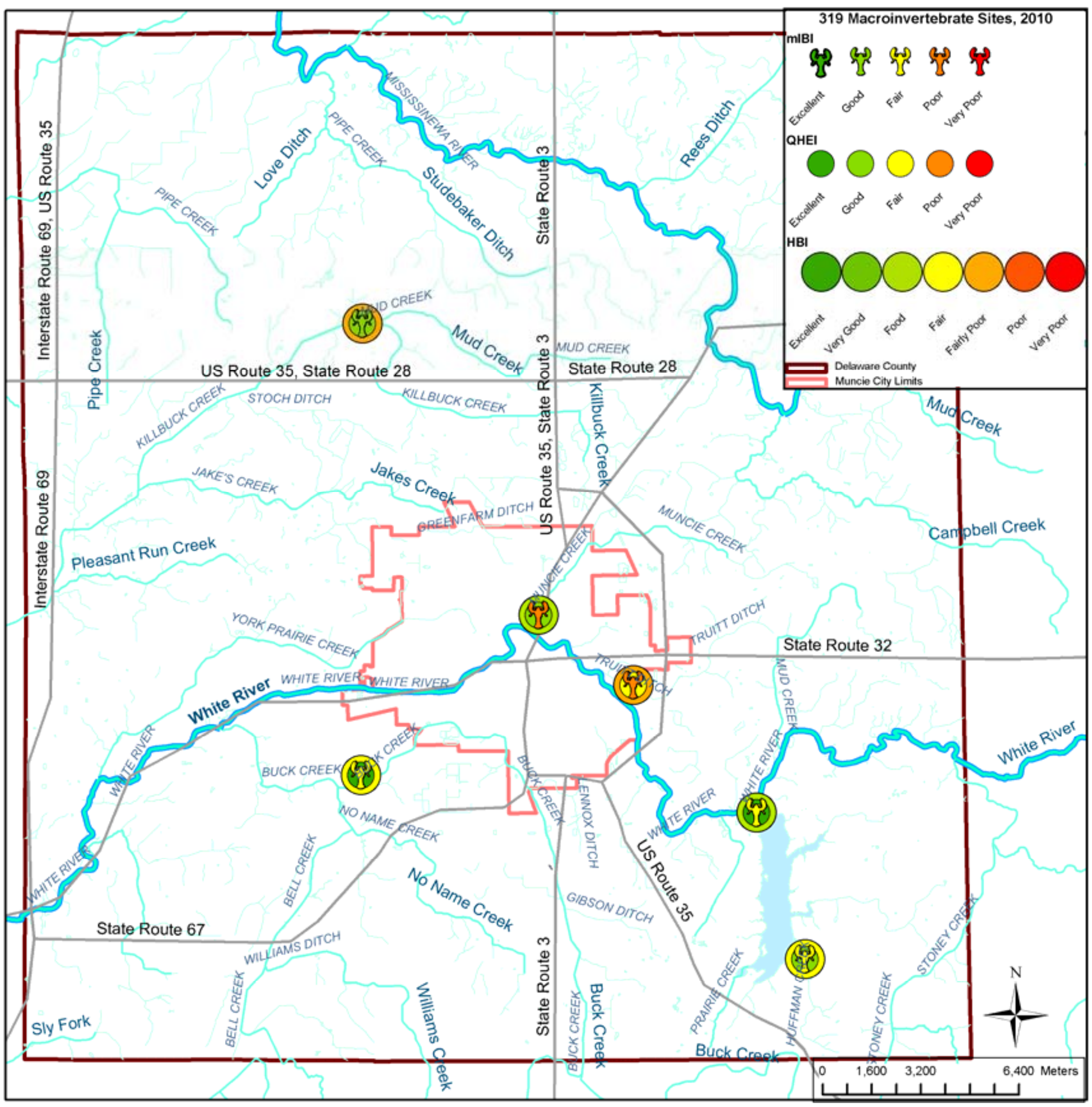
Buck Creek H' scores (Graph 8 and Appendix B, Table 16) ranged from 2.96 (BUC 10.5) to 3.54 (BUC 0.2), with a mean score of 3.18 (Appendix B, Table 17).

Graph 8.—Buck Creek stand-alone indices, 2010.



Remaining Stand Alone Indices: White River J' scores (Graph 5 and Appendix B, Table 15) ranged from 0.76 (WHI 310.7) to 0.88 (WHI 333.4), dropping significantly as White River flowed downstream (R^2 = 0.76). Mean J' scores (Appendix B, Table 17) progressively dropped as White River flowed downstream, through and beyond the City of Muncie. White River "Percent Dominance of the Top Three Taxa" scores (Graph 5, Appendix B, Table 15) ranged from 0.24 (WHI 333.4) to 0.49 (WHI 315.0), significantly rising as White River flowed downstream (R^2 = 0.47). Mean scores (Appendix B, Table 17) worsened as White River progressed downstream. White River "Percent

Figure 2.—319 macroinvertebrate sites, 2010.



Chironomidae” scores (Graph 5, Appendix B, Table 15) ranged from 0.24 (WHI 313.4) to 0.04 (WHI 304.4). Mean scores (Appendix B, Table 17) worsened within Muncie, but recovered downstream of Muncie.

Buck Creek J’ scores (Graph 8 and Appendix B, Table 16) ranged from 0.77 (BUC 8.0) to 0.89 (BUC 10.5), with a mean score of 0.84 (Appendix B, Table 17). Buck Creek “Percent Dominance of the Top Three Taxa” scores (Graph 8, Appendix B, Table 16) ranged from 0.46 (BUC 8.0) to 0.26 (BUC 0.2), and rose significantly as Buck Creek flowed downstream (R^2 = 0.44). The mean was 0.35 (Appendix B, Table 17). Mean scores worsened as Buck Creek progressed downstream. Buck Creek “Percent Chironomidae” scores (Graph 8, Appendix B, Table 16) ranged from 0.45 (BUC 8.0) to 0.16 (BUC 12.5), with a mean of 0.28 (Appendix B, Table 17).

QHEI: QHEI scores at White River baseline sites (Appendix B, Table 15) ranged from 57 (WHI 313.4) to 88 (WHI 306.5), *Fair* to *Excellent*. Mean QHEI scores (Appendix B, Table 17) reflected a decline in habitat quality within Muncie, and recovery downstream of Muncie.

QHEI scores at Buck Creek baseline sites (Appendix B, Table 16) ranged from 44.5 (BUC 8.0) to 84.5 (BUC 4.0), *Fair* to *Excellent*. The mean habitat score for Buck Creek (Appendix B, Table 17) was 64.3, *Good*.

MACROINVERTEBRATES– 319 WATERSHED GRANT

See results in Table 5.

Table 5.—319 Scores for all 319 watershed sites, 2010.

	HUF 0.20	**PRA 0.00**	**TRU 0.80**	**MUN 0.10**	**KIL 20.1**	**BUC 4.0**
mIBI Submetrics						
Total # of Taxa	3	3	1	3	5	3/3*
Total Abundance	1	1	1	1	5	1/1*
Number EPT Taxa	3	3	1	3	5	3/3*
% Orthocladinae & Tanytarsini	5	5	5	5	5	5/5*
% Non-Insects (minus Crayfish)	5	3	1	3	3	3/3*
# Diptera Taxa	1	1	1	1	1	1/1*
% Intolerant Taxa (Score 0-3)	1	3	1	1	1	1/1*
% Tolerant Taxa (Score 8-10)	5	3	1	5	3	5/3*
% Predators	3	3	3	1	5	1/1*
% Shredders & Scrapers	5	5	1	5	3	5/5*
% Collector/Filterers	3	1	3	1	5	3/3*
% Sprawlers	1	5	5	5	5	5/5*
	36	**36**	**24**	**34**	**46**	**37**
	Fair	*Fair*	*Poor*	*Poor*	*Good*	*Fair*
Stand Alone Indices						
Hilsenhoff Index	5.59	5.01	7.13	4.91	6.58	5.66
	Fair	*Good*	*Fairly Poor*	*Good*	*Fairly Poor*	*Fair*
Shannon Index of Diversity	3.13	3.09	2.70	2.77	3.43	3.03
Shannon Evenness Index	0.96	0.86	0.90	0.90	0.87	0.87
% Dominance of Top Three Taxa	0.26	0.34	0.44	0.41	0.28	0.35
% Chironomidae	0.26	0.27	0.09	0.33	0.13	0.21
QHEI Scores	68.0	74.3	46.5	54.3	54.5	84.5
	Good	*Excellent*	*Fair*	*Good*	*Good*	*Excellent*

*results (except QHEI) are an average of duplicate QAQC samples; submetrics results for both samples are shown.

DISCUSSION

Mussels.—The significant increase in Unionid diversity and density at both sites since 1992 indicates that populations are thriving. This is presumably a reflection of good water quality in the area. Increased public awareness, better stormwater management practices, the removal of impoundments, and the separation of CSOs would likely assist mussel population growth in the future.

It is difficult to make conclusions based on sampling at WR 320.1 in 2010. The inability to sample all 24 quadrats has most likely skewed results at this site. There is no indication that the mean has increased drastically in 2010. The drop in species at WR 320.1 in 2009 and 2010 also does not appear to be representative of the actual population. Species that were not accounted for during sampling were identified outside of the sampling parameters.

Sampling at WR 313.4 in 2010 indicated good water quality in this stretch of White River. A record number of Unionid juveniles were found at this site in 2010 (twenty two were age two or younger). This demonstrates active recruitment, presumably an indication of a healthy mussel community. The Unionid mussel species most abundant at WR 313.4, elktoe, is considered to be characteristic of flowing streams with good water quality, and is considered intolerant of impoundment (Watters 1995; Parmalee & Bogan 1998). In apparent contrast, this mussel has been found throughout 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 impoundments. Three species of mussels new to WR 313.4 were identified in 2010: the pea clam, giant floater (*Pyganodon grandis*) and the cylindrical papershell (*Anodontoides ferussacianus*). The two Unionid species, giant floater, and cylindrical papershell, are more typical of soft substrates and slower flowing rivers, probably inhabiting impounded sections of the river and dispersing to other reaches, including this site.

The presence of unique species differs between sites. Site locations and habitat differences such as hydro-modifications may be contributing factors. WR 320.1 is upstream of Muncie city limits; WR 313.4 is within city limits and directly downstream of one of the largest CSOs in Muncie. Between WR 320.1 and WR 313.4 are four dams, perhaps explaining the absence of certain species between sites. Dams alter habitats upstream and downstream, resulting in an increase of pollutants, siltation, stagnation, thermal changes, and anoxic conditions (Watters 1999). These factors are all detrimental to the survival of freshwater mussels (Vaughn & Taylor 1999; Watters 2000; Dean et al. 2002) . One species found at WR 313.4, but not upstream is the White Heelsplitter (*Lasmigona complanata*), noted for its opportunistic nature, and its ability to tolerate silt, habitat disturbance, and impoundment, making it an ideal species to inhabit White River within city limits (Grabarkiewicz & Davis 2008).

Since the inception of our mussel sampling program, two sensitive species have been identified that previously were only found as dead shell. A notable species found at both sites is the rainbow mussel (*Villosa iris*) , noted for its sensitivity to ammonia and copper (Augspurger et al. 2003; March et al. 2007) and its tendency to survive in only clean, well-oxygenated stream reaches (Watters 1995; Parmalee & Bogan 1998). Past occurrence of the Wavy Rayed Lampmussel (*Lampsilis fasciola*), listed in Indiana as a "Special Concern Species", at both sites is notable as well. This species is extremely sensitive to low dissolved oxygen, ammonia and copper, and only exists in hydrologically stable streams of good water quality (Strayer 1983; Watters 1995).

Future considerations include the initial sample size, condition variable, and final sample size determination at BWQ mussel sites. Sample size determinations will be reviewed to ensure that the current method is the most accurate. Condition variables will also be reviewed. The condition variables used in adaptive cluster sampling fluctuates among studies from 5-30% of the highest typical number found during a preliminary survey. Trial and error will likely be the best way to determine the optimum condition variable for each site. Research will also be focused on the introduction of a stopping rule, to prevent the nearly infinite sampling of a site. Through research of the newest methods and possibly trial and error, the best approximation of the condition variable will be attained. Research into statistics 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 a continued concern about the high confidence intervals at many sites. It has been found that estimates of mussel population density tend to be skewed and even negative (Philippi 2005), making the usual approach to confidence intervals inaccurate. All of these considerations will be researched and incorporated into 2011 sampling.

Macroinvertebrates- Baseline.—Most White River baseline sites range from slightly to moderately impacted, with the exception of one site that was moderately to severely impacted (WHI 315.0). Mean H' scores at sites on White River reflect a system that is affected by the obvious and expected effect of anthropogenic activities, with no recovery downstream of the urban influence. This finding is similar to studies that have found negative correlations between macroinvertebrate diversity and increasing urbanization (Stepenuck et al. 2002, Roy et al. 2003, Cuffney et al. 2005, Moore & Palmer 2005). Mean mIBI, HBI, QHEI, and % Chironomidae scores worsened within Muncie, but showed recovery downstream of Muncie. The effect of the anthropogenic activities of the City of Muncie are further supported by the marginally significant difference in HBI scores between sites upstream and within city limits (2002-2010), and the significant difference between H' scores at sites upstream and downstream of Muncie city limits (2002-2010). Urban effects include stormwater, increased impervious surfaces, CSOs, and the Muncie Water Pollution Control Facility.

The comparison of individual site results provides us with additional information about locations on the river. Our reference site, WHI 333.4 is the least impacted site on the river. The mIBI and all stand alone indices except "Percent Chironomidae" were the best of all White River baseline sites. Average duplicate scores at WHI 326.9 show that this site is also impacted very little; the mIBI and most stand alone indices scores were among the best scores found at all White River sites. The HBI score, however, was one of the lowest (but still rated *Good*). WHI 315.0 had not only the worst mIBI score, but had some of the worst scores of all stand-alone indices, as well as one of the lowest total abundances (125) of all White River sites. The *Fair* QHEI score suggests that habitat is not a factor limiting biological potential to the degree it is impacted. When this site was resampled, the riffle was almost non-existent and very little rootmat remained submerged, limiting aquatic habitat heterogeneity. WHI 317.6 had the worst HBI score and one of the worst mIBI scores, both rated *Fair*. These scores appear to be negatively affected by the high number of tolerant non-insects at this site. Again, the *Fair* QHEI score at this site suggest that it is possible that this site may have limited biological potential. Substrate is predominantly bedrock with very little cobble, most likely prohibiting the colonization of many types of macroinvertebrates.

Individual Buck Creek sites indicate possibly impaired areas. While BUC 8.0 had the best mIBI and HBI scores, it had many of the worst scores for the stand-alone indices. This site is the only Buck Creek site within Muncie, is located at a busy bridge, and the east bank is adjacent to a metal recycling business and has been clear-cut in the last five years. These factors make the mIBI and HBI results unusual, but most likely reflect the forested riparian zone upstream. Despite the best QHEI score at BUC 4.0, this site has had the worst mIBI score the past two years, *Fair*. This may be a reflection of the proximity of the site, which is downstream of all urban influences. The *Poor* HBI rating at BUC 12.5 in 2009 appears to have been anomalous, as it was rated *Good* this year. Additional data will be needed to monitor temporal trends at Buck Creek sites.

A previously unidentified exotic species was collected in 2010 macroinvertebrate samples. The first identification of the Chinese Mystery Snail (*Cipangopaludina chinensis*) in a White River baseline site will likely lead to the observance of this species at many Delaware County sites in the near future. This exotic species was introduced to North America through the Asian food market, aquarium trade, and ultimately between water systems through water/bait transfer. The introduction of the Chinese Mystery Snail may result in ecological impacts (competition with native species for food and habitat), societal impacts (clogging of water intakes by spent shells), and human impacts (vectors for transfer of human parasites) (Kipp & Benson 2008; O'Connor et al. 2008).

Macroinvertebrates- 319 Watershed Grant. —Results for sites in the 319 Watershed Grant study were highly variable. The worst site in 2010 appears to be TRU 0.8, with most indices exhibiting the worst scores of all 319 sites. This includes the worst QHEI score, which, while rated *Fair*, may limit the biological potential of this site. When this site was resampled, there was very little riparian vegetation and rootmats submerged, limiting aquatic habitats normally found at TRU 0.8. This site has been clear-cut on the south bank, and a beaver dam in 2010 changed the hydrology of the site, resulting in increased silt and possibly further inhibiting scores. PRA 0.00 continues to have one of the worst mIBI scores and HBI scores, as well as the worst J' score in 2010. This site is a non-traditional site; it is essentially a drain from the Prairie Creek Reservoir Spillway to White River, limiting its biological potential. MUN 0.1 had one of the worst mIBI scores and the worst "Percent Chironomidae," however, had the best HBI score of all 319 sites in 2010. This site was recently impacted by construction of a new bridge directly downstream. MUN 0.1 was also resampled and little rootmat remained submerged at the time of sampling. KIL 20.1 again had the best mIBI and H' scores. This site continues to be highly productive and diverse. Multiple 319 sites would be considered "Not Supporting" by IDEM (PRA 0.0, TRU 0.8, and MUN 0.1), indicating an impairment to the biological community. The further implementation of Best Management practices at these sites will likely improve the biological integrity of 319 Watershed sites.

Dramatic improvements have been seen since the inception of our macroinvertebrate and mussel sampling program. 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 have been 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 zone), stormwater (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 requires public outreach, education, and cooperation to instill better agricultural and stormwater practices throughout Delaware County. These include buffer strips, rain barrels, rain gardens, better construction site practices, and the further separation of CSOs. As better 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.

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