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Macroinvertebrate Diversity and Sediment Composition in the Conewago Creek

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ABSTRACT

The Conewago Creek is one of three USDA Chesapeake Bay Showcase Watersheds. Over 40 miles of the Conewago are impaired due to sediment and nutrient loading from agriculture. For more than a decade, a variety of projects have been employed throughout the watershed to improve the Conewago and its tributaries. This research assesses the current state of the Hershey Meadows, a recently restored portion of the Creek outside Elizabethtown, PA. At Hershey Meadows, more than 15 acres of wetlands and one mile of stream channel were restored. For this study, three sites sampled three times during the fall of 2015 using the PA DEP's Instream Comprehensive Stream Evaluation Protocol (PA DEP, 2009). Habitat assessment, pebble counts and the Index of Biotic Integrity were determined at each site. The habitat assessment indicated poor conditions throughout, with increasing uniformity in fine particle sediments downstream. The pebble count indicated a shift in frequency from sand and gravel to silt along that axis and the IBI results show that macroinvertebrate diversity decreased with distance as well. The uppermost site showed improved sediment and macroinvertebrate conditions from prior monitoring, and while still impaired, had fewer fine particles and greater diversity. The two downstream sites have yet to show changes in the bottom sediments and macroinvertebrate habitat, reflecting either the slow migration of fines being removed from the streambed upstream and/or the impact of an impaired tributary.

INTRODUCTION

The Conewago Creek and its tributaries drain 53 square miles of residential, forested, and agricultural land uses (Figure 1). Between the headwaters in Mount Gretna and the mouth in the Susquehanna River, the Conewago passes through Dauphin, Lancaster, and Lebanon Counties. Nearly 40 miles of its waters are listed as impaired waters under Section 303(d) of the Clean Water Act (Tri-County Conewago Creek Association, 2013).

The Conewago Creek is one of the three US Department of Agriculture's "Showcase Watersheds" in the Chesapeake Bay Drainage area along with Smith Creek in Virginia and the Upper Chester River in Maryland. This classification as a watershed of particular interest, along with its impaired status, has made the Conewago Creek the focus of many restoration projects aimed at reducing pollution, specifically phosphorus, nitrogen and sediment, and restoring habitat (Tri-County Conewago Creek Association, 2013). One of those projects is located at Hershey Meadows, outside of Elizabethtown, PA. The Hershey Meadows site is a US Fish and Wildlife restoration project that established 15 acres of wetland, planted a riparian buffer along the creek and one tributary (Gallagher Run) and installed log vanes and mud sills to reduce stream bank erosion and create fish habitat. This research assessed the current state of the Conewago Creek at the Hershey Meadows restoration project using a qualitative habitat assessment, macroinvertebrate sampling and a pebble count analysis at three sites (Figure 2).

Several anthropogenic activities contribute to excess erosion of banks and increased sedimentation in streams including, but not limited to, the construction and later breaching of dams and the removal of vegetation surrounding stream banks to be replaced with agricultural fields (Kaufmann *et al*., 2009). The building of dams causes the buildup of legacy sediments while their breaching contributes to the erosion of stream back and the release of those legacy sediments to be carried downstream. As a result, these activities are among the leading causes of impairment in aquatic habitats and water quality throughout the United States (Walter & Merritts, 2008). Accumulation of sediments consisting of fine particles less than two millimeters in diameter fill crevices created by coarse bed materials. This ultimately reduces the habitat space and oxygen availability necessary for the survival of macroinvertebrates (Kaufmann *et al*., 2009). According to Brasil *et al.* (2014), declines in environmental quality, in this case increased sedimentation, result in habitats becoming more homogeneous, which may cause a loss of species richness, changes in species composition, and shifts in abundance patterns. Homogeneous diversity in an ecosystem occurs when there is a greater population of generalist species to specialist species (Brasil *et al.,* 2014). Biological parameters integrate information over longer periods of time and better represent the responses of aquatic habitats, making biotic monitoring indices excellent tools for the sustainable management of water resources. For this reason, macroinvertebrate taxa can serve as biological indicators of environmental conditions and are extensively used for monitoring aquatic ecosystems (Uherek & Gouveia, 2014). Determining the frequency of individual macroinvertebrate groups, however, is not enough to predict overall water quality. The sensitivity of the macroinvertebrate species to pollutants must be considered in order to fully understand the overall health of a stream which is why most have been assigned a pollution tolerance value (Bouchard, 2004).

With this in mind, it was hypothesized that sample sites on the Hershey Meadow restoration project which are downstream of Gallagher Run (Figure 2) would have increased sedimentation, and therefore a lowered macroinvertebrate diversity as measured by the Index of Biotic Integrity (IBI).

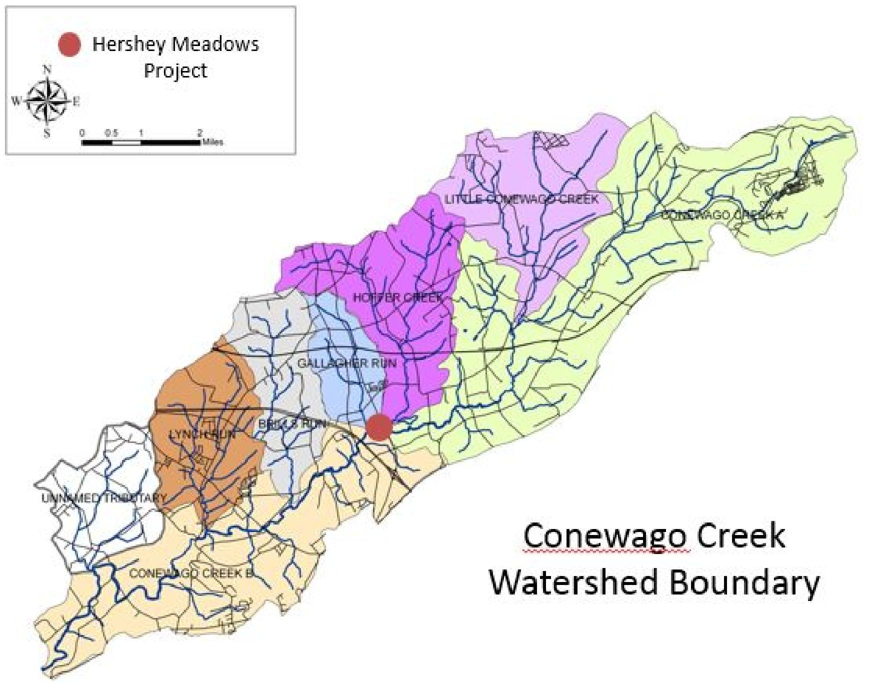

Figure 1: Conewago Creek Watershed. The main stem of the Conewago is divided into upper and lower regions (A and B above) and is fed by six tributaries. The Hershey Meadows site (dot above) is in an impaired portion of the main stem below Hoffer Creek and includes the inflow of Gallagher Run.

Figure 2: Site map of Hershey Meadows on the Conewago Creek.Gallagher Run enters between Sites 1 and 2.

MATERIALS AND METHODS

Habitat Assessment, macroinvertebrate sampling,and a pebble count analysis were conducted at three sites in the Hershey Meadows restoration project during the Fall of 2015. Site 1 was most upstream of the three sites and was located just west of the Rt. 743 bridge (Figure 2). Sites 2 and 3 were both located downstream of Site 1 and below Gallagher Run (Figure 2).

A habitat assessment (PA DEP, 2009) was performed at each of the three sites. That assessment evaluated stream habitat with twelve variables including stream bank conditions, availability of suitable wood/rocks for macroinvertebrates, stream bed quality and the condition of the riparian zone. Each of twelve variables was scored, and a total habitat score was then determined on a 240 point scale. The habitat assessment provided a quick visual tool for predicting what the macroinvertebrate analysis and pebble count would show quantitatively.

Macroinvertebrate sampling was completed using a D-frame kick net with six kicks per sample (PA DEP, 2009). We performed a total of three macroinvertebrate samples on each of the three sites during the months of September, October, and November. A minimum of 200 macroinvertebrates were captured each time. Samples were preserved in ethyl alcohol until identification was complete. Preserved macroinvertebrates were identified to order, genus, and species using the *Guide To Aquatic Macroinvertebrates of the Upper Midwest* (Bouchard, 2004), along with other sources. Pollution Tolerance Values were then found for all taxa (PA DEP, 2009). The macroinvertebrate sampling was used to ultimately calculate the Index of Biotic Integrity (IBI) value; a multimetric approach which combines the Beck's Index, EPT (Ephemeroptera, Plecoptera, Trichoptera) Taxa, Total Taxa Richness, Shannon Diversity Index, Hilsenhoff Biotic Index, and Percent Intolerant Individuals results to create more comprehensive metric (PA DEP, 2009).

Sediment composition was determined using the Wolman Pebble Count (Wolman, 1954). The pebble count analysis was performed once at each of the three sites. One hundred pebbles were randomly extracted from the creek bottom, measured, then replaced while walking in a zig-zag pattern across the stream from bank to bank. The sediment composition of each site was determined by analyzing the results of the pebble count. Particles were classified as sand, gravel, cobble, or boulder based on their measured length and width. Data obtained from the pebble count analysis and macroinvertebrate samples were analyzed using a combination of linear regressions to evaluate the relationship between particle size and macroinvertebrate diversity. ANOVAs were run to examine the variation of each index between sites.

RESULTS

Habitat assessments were completed for Sites 1, 2, and 3 with cumulative totals of 176, 152, and 136 respectively, with the highest possible score of 240 reflecting greatest habitat quality and the lowest possible score of 12 reflecting a habitat of poor quality. Scores between 192-240 are representative of good optimal habitat while scores ranking below 60 represent poor habitat. All three sites were suboptimal in the visual assessment.

The IBI values were determined by combining the individual Beck's Index, EPT, Total Taxa Richness, Shannon Diversity Index, Hilsenhoff, and Percent Intolerant indexes and normalizing them according to PA DEP (2009). IBI values were calculated to be 45, 45, and 32 for Sites 1, 2, and 3 respectively. Particle sizes obtained from the Wolman Pebble Count were plotted to determine the most prevalent pebble sizes of each site (Figures 3, 4, & 5).

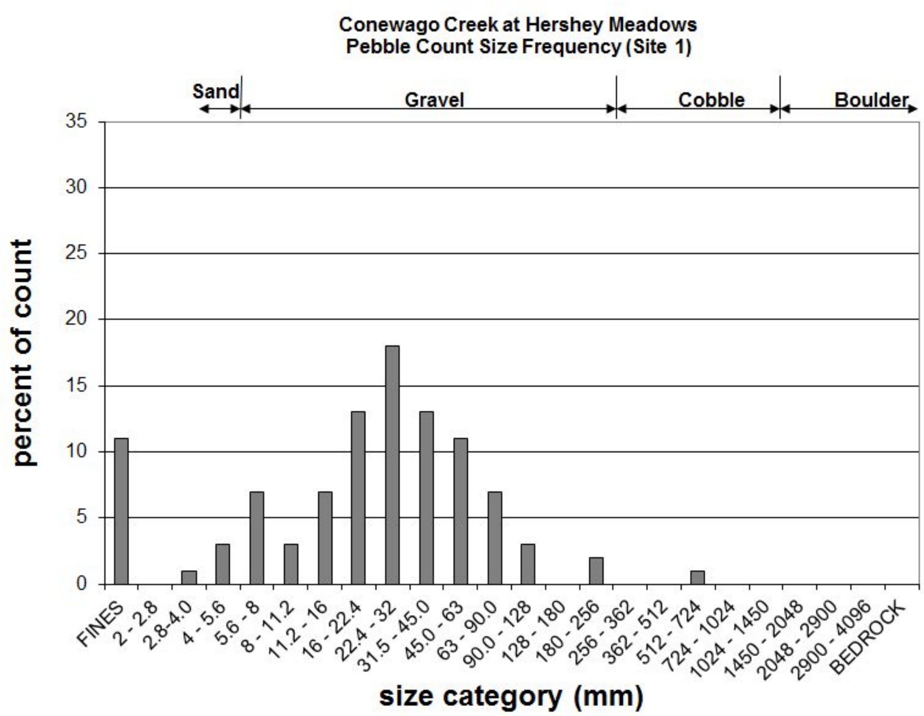

Figure 3: Pebble Count distribution for Site 1. The mean size of the particles at Site 1 was 39 mm in diameter.

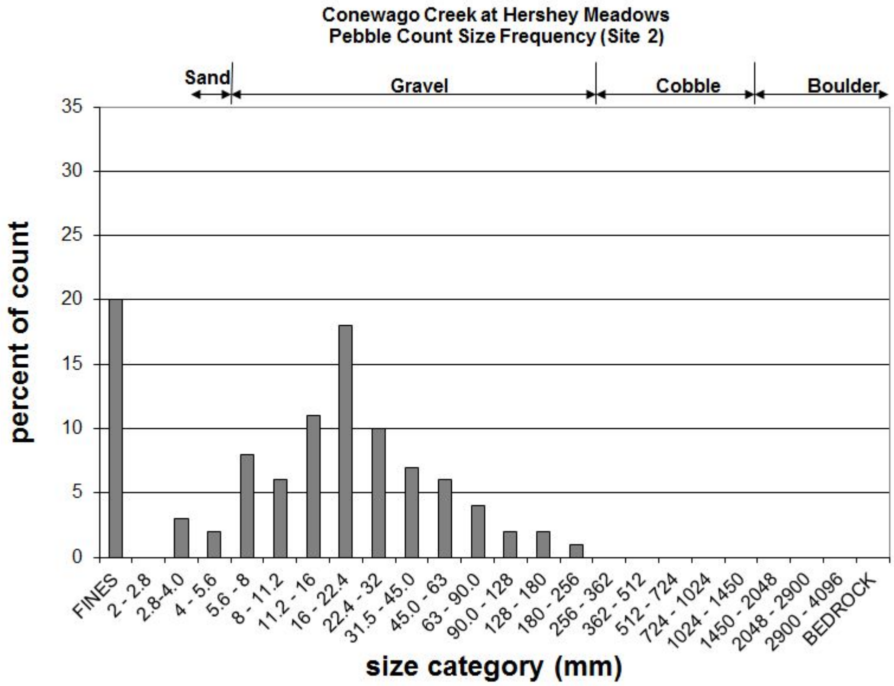

Figure 4: Pebble Count distribution for Site 2. The mean size of the particles at Site 2 was 25 mm in diameter.

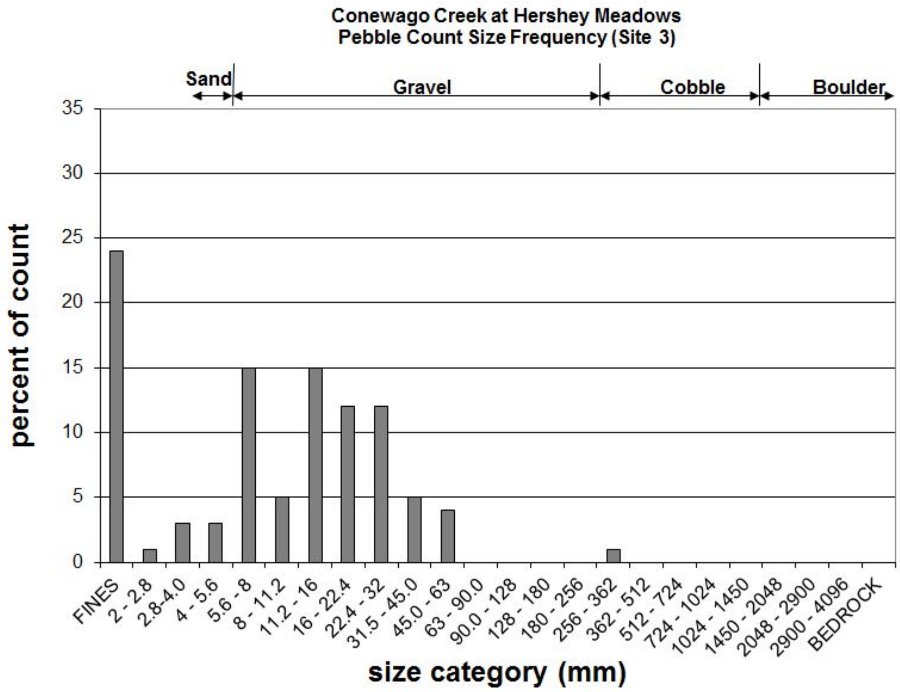

Figure 5: Pebble Count distribution for Site 3. The mean size of the particles at Site 3 was 16 mm in diameter.

Regression analyses indicated that particle size had no significant effect on each of the diversity indices. Differences between average particle sizes of each site were then analyzed using a single factor, one-way ANOVA, and were determined to be statistically different with a significance value less than p=0.05 (Table 1). Additional ANOVAs indicated significant differences between sites in both the Hilsenhoff Biotic Index and the Percent Intolerant Individuals (Table 1).

Table 1: Results of statistically significant single-factor, one-way ANOVAs.

Indices	p-values
Wolman Pebble Analysis	0.000
Hilsenhoff Biotic Index	0.031
Percent Intolerant Individuals	0.030

Tukey post hoc testing determined that Site 1 was statistically different from both Sites 2 and 3 with respect to particle size (Figure 6). Tukey post-hoc testing also determined that there was a significant difference between Site 1 and Site 3 for the Hilsenhoff Index (Figure 7) and the Percent Tolerant Individuals (Figure 8).

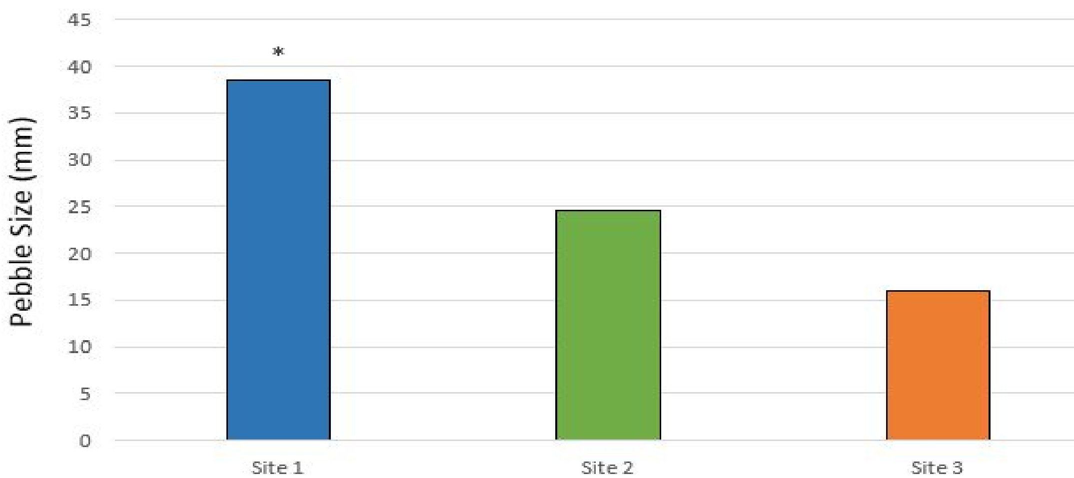

Figure 6: Average Pebble Size per Site. Tukey post hoc testing indicated that Site 1(asterisk) was significantly different than Sites 1 and 2.

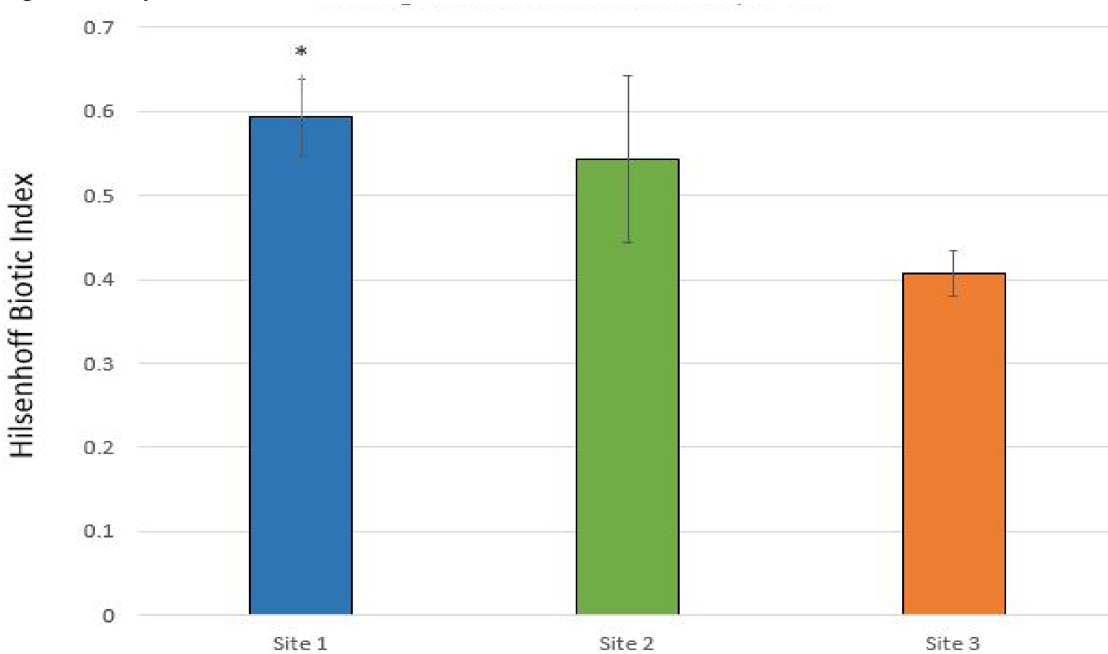

Figure 7: Average Hilsenhoff Biotic Index value per Site. Tukey post hoc testing indicated that Site 1(asterisk) was significantly different than Sites 1 and 2.

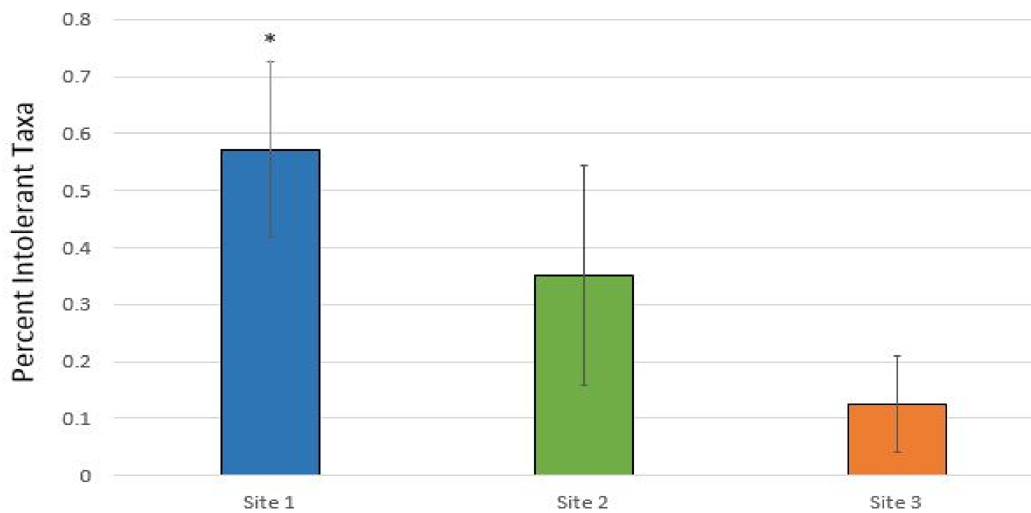

Figure 8: Average Percent Intolerant Individual value per Site. Tukey post hoc testing indicated that Site 1(asterisk) was significantly different than Sites 1 and 2.

DISCUSSION

The visual assessment of habitat was confirmed by the macroinvertebrate sampling and particle size determination. The conditions are suboptimal for macroinvertebrates at each of the three sites. When analyzing the Wolman Pebble Count, the single-factor ANOVA showed that the average pebble size differed among the three sites (Figure 6). The ANOVA Post Hoc-Tukey test determined that the particle size at Site 1 was statistically different from Sites 2 and 3. Sites 2 and 3 did not have statistically different particle sizes. Reasonably, Site 2 is significantly similar to Site 3 because both are located downstream of Gallagher Run. Gallagher Run is a deeply incised stream channel in eroding legacy sediments. A riparian buffer was recently planted along its banks, however it remains a source of fine sediments entering the Conewago.

It was anticipated that the average pebble size would affect the macroinvertebrate diversity; however, linear regressions yielded no significant relationship between the two. Although not significant, the pebble count indicated a shift in size frequency from sand and gravel to silt from Site 1 to 3 and the IBI results show that macroinvertebrate diversity decreased downstream as well. The results of the single-factor ANOVA for IBI showed no significance, which was likely caused by the large variance in each of the individual indices within the IBI metric. Single-factor ANOVAs performed on each of the individual indices resulted in significant differences between the Hilsenhoff Biotic Index and Percent Intolerant Individuals of the sites (Table 1, Figures 7, 8) Both of these indices incorporate pollution tolerance values in their calculations and as a consequence indicate that pollution tolerant species increase with distance down the Hershey Meadows site as the habitat quality decreases.

CONCLUSIONS

The success of watershed restoration efforts are measured by improvements in habitat and water quality. At the Hershey Meadows location, the most upstream site showed improved sediment and macroinvertebrate conditions from prior monitoring, and while still impaired, had fewer fine particles and greater macroinvertebrate diversity. In comparison to data collected in 2013, Site 1 saw the greatest improvement in the IBI scores. The IBI scores for Site 1 were calculated to be 34 and 37 in a 2013 study (Breza *et al*., 2014), and were calculated as a score of 45 in the current study. Although the IBI scores were higher, the scores were not yet statistically different due to extensive variation in the IBI scores collected in this research. The two downstream sites have yet to show changes in the bottom sediments and macroinvertebrate habitat, which reflects either the slow migration of fines being removed from the streambed upstream and/or the impact of the impaired tributary. Gallagher Run, like many tributaries in the watershed is heavily impacted by agriculture and continues to mine its stream banks of legacy sediments. That results in an additional source of degradation in the middle of a restoration project on the main stem. The three sites exhibited higher IBI scores than were seen in previous studies. It is anticipated that sampling in the future will provide evidence to support these positive changes in the macroinvertebrate community at the Hershey Meadows site, with enough improvement to allow for this portion of the creek to be removed from the EPA's list of impaired waters.

ACKNOWLEDGEMENTS

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